GEOLOGY AND GRANITIC ROCK ANALYSIS IN KAMPUNG RABBANA, JELI KELANTAN

By

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

FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN

2020

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DECLARATION

I declare that this thesis entitled "Geology and Granitic Rock Analysis in Kampung Rabbana, Jeli, and Kelantan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

“I hereby declare that I have read this thesis and in our opinion, this thesis is sufficient in term of scope and quality for the award of the degree of Bachelor of Applied Science (Geoscience) with honours”

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ACKNOWLEDGEMENT

Praised to Him Allah Almighty for giving me the good health, determination and courage in fulfilling this Final Year Project and also blessed me with strength to work in completing my study.

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Geology and Granitic Rock Analysis in Kampung Rabbana, Jeli Kelantan

ABSTRACT

Granite is categorise as one of the igneous rock type. People have used granite for thousands years. It is used as a construction material such as for building, bridges, paving, monuments, countertops, tiles and many other design elements. Granite is commonly choose as a raw material due to its unique characteristics and also its strength and durability. Granite is one of the strongest stones available and it is also long-lasting as it is very resistance to weathering. This research is mainly about the geology and geochemistry analysis of granite in Rabbana Village or Kg Rabbana, Jeli, Kelantan. Geochemistry is one of the field in Earth Science that can explain the mechanisms behind major geological systems such as the Earth's crust and its oceans using the principles of chemistry. The study area covered approximately 25 km^2 bounded between latitude 5°41'37.62"N to 5°44'15.94"N and longitude 101°46'3.35"E to 101°48'48.83"E. The objectives of this study are to update geological map of Kampung Rabbana with scale of 1:25,000, to analyse major chemical composition of granitoids in the study area by using XRF method and to identify rare earth elements (REE) in granitoids using ICP-OES method. In this research, the samples that have been collected were mainly rock samples consisting of, metamorphic rock and igneous rock. The types of rock sampling used is grab sampling and chip sampling. Grab sampling is done by collecting samples randomly or by the highest degree of visible mineralization. The five samples were tested at 5 different locations that are further apart from each other and according to their differences of the grain size and colour of the granite samples. According to the result of the type of granite using XRF, only samples that are different from each other in chemical composition are tested using ICP-OES method, in order to identify the presence of REE concentration in the rock itself. The main findings of the study is the varieties of igneous rock type that presence in the study area. The igneous rocks appear to be ranging from greyish to white igneous rock were then categorized as felsic to intermediate igneous rock. From the geological findings, five main lithology such as schist, gneiss, hornfels, and granite with minor andesitic rock were identified and geological map with scale 1:25,000 was then constructed. The result produced from the XRF analysis concluded that granitoid in the study area were classified as S-type granite. XRF results were interpreted using Harker diagram to know the elemental distribution in the samples were in relations to the geological conditions of the rock. Next, two samples were selected to be selected to know the trace elements or rare earth elements (REE) using the ICP-OES method. From the analysis, it shows REE in both of the granitoids. This conforms the potential of REE in granitoid rock.

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Geologi dan Analisis Batuan Granitik di Kampung Rabbana, Jeli, Kelantan

ABSTRAK

Granit dikategorikan sebagai salah satu jenis batuan beku. Orang telah menggunakan granit selama ribuan tahun. Ia digunakan sebagai bahan binaan seperti bangunan, jambatan, jalan raya, monumen, permukaan atas meja, jubin dan banyak elemen reka bentuk lain. Granit biasanya dipilih sebagai bahan mentah kerana ciri-ciri uniknya dan juga kekuatan dan ketahanannya. Granit adalah salah satu batu terkuat yang ada dan juga tahan lama kerana ia sangat tahan terhadap cuaca. Kajian ini adalah mengenai analisis geologi dan geokimia granit di Kampung Rabbana, Jeli, Kelantan. Geokimia adalah salah satu bidang dalam Sains Bumi yang dapat menjelaskan mekanisme di sebalik sistem geologi utama seperti kerak bumi dan lautannya yang menggunakan prinsip-prinsip kimia. Kawasan kajian terletak di daerah Jeli, khususnya di kawasan Kampung Rabbana. Kawasan kajian meliputi kira-kira 25 km2 di antara latitud 5 ° 41'37.62 "N hingga 5 ° 44'15.94" N dan longitud 101 ° 46'3.35 "E hingga 101 ° 48'48.83" E. Objektif kajian ini adalah untuk memperbaharui peta geologi Batu Melintang dengan skala 1: 25,000, untuk menganalisis komposisi kimia utama granitoid di kawasan kajian dengan menggunakan kaedah XRF dan untuk mengenal pasti unsur-unsur nadir bumi (REE) dalam granitoid menggunakan kaedah ICP-OES. Dalam kajian ini, sampel yang telah dikumpulkan adalah terutamanya sampel batu yang terdiri daripada batu metamorf dan batu igneus. Jenis-jenis batuan yang digunakan ialah dengan mengambil spesimen pada bahagian permukaan. Lima spesimen telah diambil di 5 lokasi berbeza dan jauh antara satu sama lain serta mengikut perbezaan saiz butiran dan warna specimen granit. Mengikut hasil kajian granit yang menggunakan XRF, hanya sampel yang berbeza dari satu sama lain dalam komposisi kimia diuji menggunakan kaedah ICP-OES, untuk mengenalpasti kehadiran kepekatan REE dalam batuan itu sendiri. Penemuan utama kajian ini adalah jenis jenis batu igneus yang ada di kawasan kajian. Batu-batu yang terbakar muncul dari batu permata hingga batu ignna putih kemudian dikategorikan sebagai felsik kepada batuan beku pertengahan. Dari penemuan geologi, Lima lithologi utama seperti schist, gneiss, hornfels, dan granit dengan sedikit batu andesitic telah dikenal pasti dan peta geologi dengan skala 1: 25,000 kemudian dibina. Hasil yang dihasilkan dari analisis XRF dapat disimpulkan bahawa granitoid di kawasan kajian diklasifikasikan sebagai granit S-jenis. Keputusan XRF ditafsirkan menggunakan gambarajah Harker untuk mengetahui distribusi unsur dalam sampel tersebut dalam hubungan dengan keadaan geologi batu. Seterusnya, dua sampel telah dipilih untuk dipilih untuk mengetahui unsur surih atau unsur-unsur nadir bumi (REE) menggunakan kaedah ICP-OES. Daripada analisis, ia menunjukkan REE di kedua granitoid. Ini membuktikan bahawa terdapat REE dalam batu granitoid.

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LIST OF ABBREVIATION

Al_2O_3	Aluminium Oxide
ASI	Aluminium Saturation Index
Ca	Calcium
CaO	Calcium Oxide
CBFG	Coarse grained foliated biotite granite
Ce	Cerium
Er	Erbium
Fe	Iron
FeO	Iron Oxide
GM	Grey microgranite,
HBBD	Hornblende biotite basaltic dyke
HREE	Heavy Rare Earth Elements
ICP-OES	Inductively Coupled Plasma-Optical Emission Spectroscopy
K	Potassium
K_2O	Potassium Oxide
K_2O	Potassium Oxide
La	Lanthanum
LREE	Light Rare Earth Elements
MFBG	Medium grained foliated biotite granite
MgO	Magnesium Oxide
MnO	Manganese Oxide
Na	Sodium
Na_2O	Sodium Oxide
Nd	Neodymium
P_2O_5	Phosphorus Pentoxide
PPL	Plane-Polarized Microscope
Ppm	Part per million.
QAPF	Quartz, Alkali Feldspar, Plagioclase, Feldspathoid Classification
REE	Rare Earth Elements

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SiO_2	Silicon Oxide
TiO,	Titanium Dioxide
XPL	Cross-Polarized Microscope
XRF	X-ray Fluorescence Spectrometer

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LIST OF SYMBOLS

%	percentage

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Granite is categorise as one of the igneous rock type. People have used granite for thousands years. It is used as a construction material such as for building, bridges, paving, monuments, countertops, tiles and many other design elements. Granite is commonly choose as a raw material due to its unique characteristics and also its strength and durability. Granite is one of the strongest stones available and it is also long-lasting as it is very resistance to weathering.

The mining and quarrying activities in Malaysia has led to the increase of the country's economy (Department of Statistics Malaysia, 2017). This shows the demand in the mining sector in Malaysia. Suddenly in recent years, the rare earth elements (REE) have been receiving attention as critical metal due to China's domination as the main supplier in mining sector globally. REE resources have been the subject of much recent exploration as these critical metals were ought to be in demand in the future globally due to its uses especially in electronic development era. The resources exists in a wide range of settings due to the high-temperature geological processes and low temperature processes.

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This research is mainly about the geology and geochemistry analysis of granite in Rabbana Village or Kg Rabbana, Jeli, Kelantan. Geochemistry is one of the field in Earth Science that can explain the mechanisms behind major geological systems such as the Earth's crust and its oceans using the principles of chemistry. It has contributes in understanding of a number of processes including mantle convection, the formation of planets and the origins of granite and basalt. Geochemistry also plays an important role in environmental management and monitoring.

Geochemical work consists of collection of samples, chemical analysis of samples, and discussion by interpreting the analytical results. Geochemistry have been used and applied tremendously and widely in recent years especially in the field of geochemistry exploration. The geochemical process are usually focus on are the soil, weathering profile, rocks and heavy minerals. However, in this research, it only focused on the presence and distribution of trace element such as REE in every type of granite that were found.

Granite was chosen as the main material as it is highly distributed due to the tectonic movement that cause major intrusion in the study area. The degree of weathering in the study area may affect the concentration of REE. Furthermore, fresh sample of granite have higher mineral content than other rock types as it is not easily weathered and the chemical composition are not altered by metamorphism process.

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1.2 Study Area

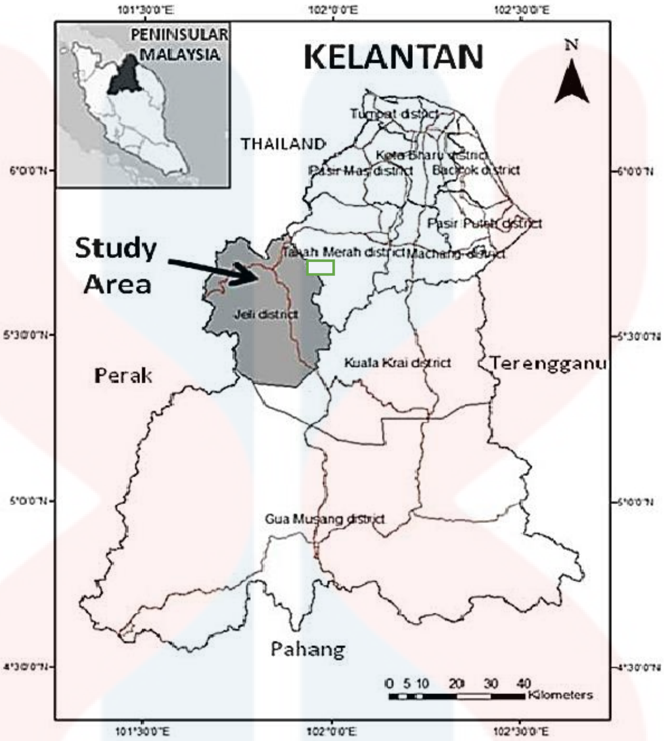

Figure 1.1: General Map of Kelantan

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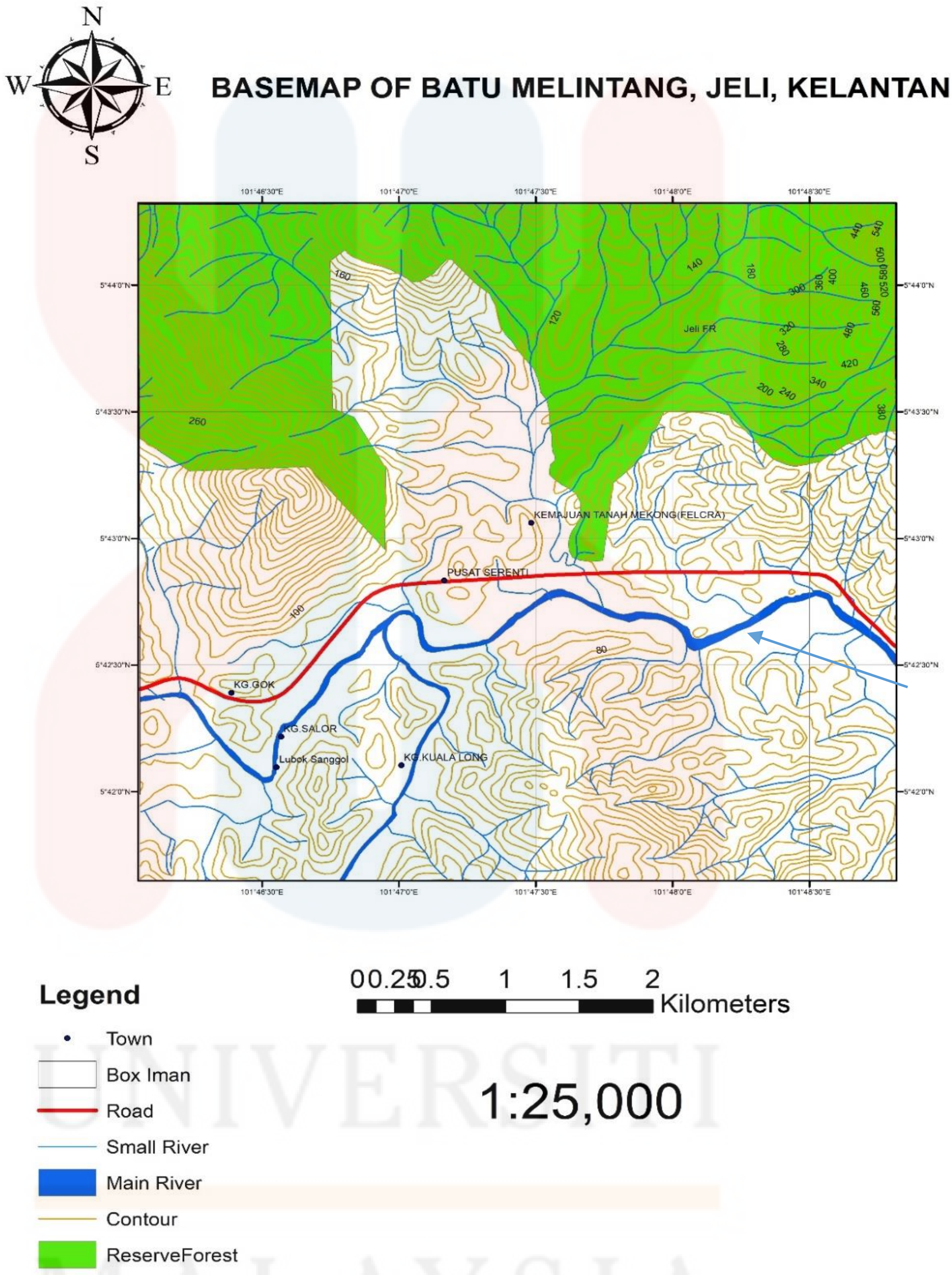

Figure 1.2: Base Map of Batu Melintang

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1.2.1 Location

The study area is located in Jeli district, specifically in Batu Melintang area. The study area covered approximately 25 km^2 bounded between latitude 5°41'37.62''N to 5°44'15.94''N and longitude 101°46'3.35''E to 101°48'48.83''E. Figure 3 shows the base map of the study area. The study can be accessed from the main road of East-West Highway. Jeli Village, Lakota Village, Gundog Village and Jeli town are the nearest urbanization to the study area.

It consists of highly vegetated area and urbanized area. The range of elevation is from 80 meters to 600 metres above the sea level. There are many small streets that connected to the main area, increasing the accessibility to the study area. The north and south region are covered by forest. The south and north region of the land is divided by the Pergau river, while west and east of the south region is divided by Long river.

1.2.2 Demography

The Jeli district divides into 3 smaller area called mukim. Mukim of Jeli district are Batu Melintang, Jeli, Kuala Balah. Batu Melintang is also known as Belimbing. Batu Melintang's total population is around 8,456 people in 2010 which are labourer in the agricultural industry, livestock farmers, informal sector workers, entrepreneurs and government worker like soldiers, teachers and police. In 2010, the total population of Batu Melintang area consists of 47.7% females and 52.3 % of males with the most age range 15-64 years old followed by 0-14 years old. Table 1.1 shows Bumiputera as

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the dominance population in Mukim Batu Melintang, Jeli and Kuala Balah. Kg Rabbana's people is included in Mukim Batu Melintang.

Table 1.1: People Distribution of Jeli District Based on Ethnic in 2010

District	**Malaysian Citizens**						**Non-Malaysian Citizens**	**Total**
	Bumiputera			Chinese	Indian	Others		
	Malay	Other Bumiputera	Total					
Jeli	18,802	530	19332	75	56	17	849	20,329

(Source: Majlis Daerah Kelantan, 2010)

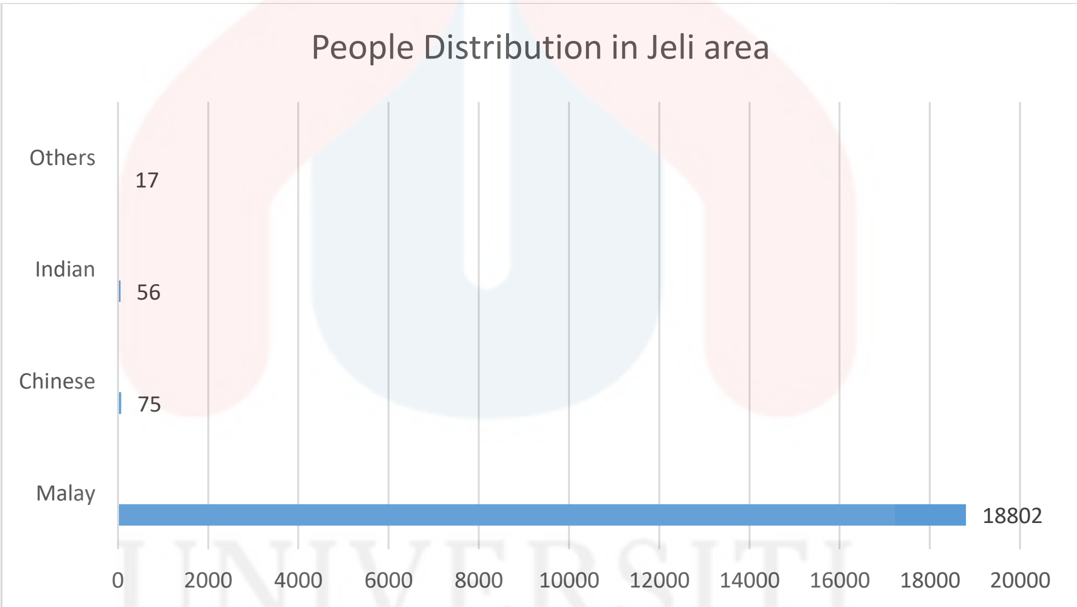

Figure 1.3: People Distribution by Ethnic in Jeli Area (Majlis Daerah Jeli, Kelantan, 2010)

1.2.3 Land Use

Total area of Jeli district are 128,020.56 hectare or 1,280.21 Km^2. Jeli district is the 3rd largest district of Kelantan state. The land use is classified into settlement such as residential area and school, forest, plantation area such as palm oil, vegetables, rubber tree, farming area, river and road. The land of Jeli district mostly used as rubber tapping or any form of plantation due to proper education system and dedicated

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teachers available in this remote area. Jeli also has good climate for agriculture with more than 6000 mm of mean rainfall annually.

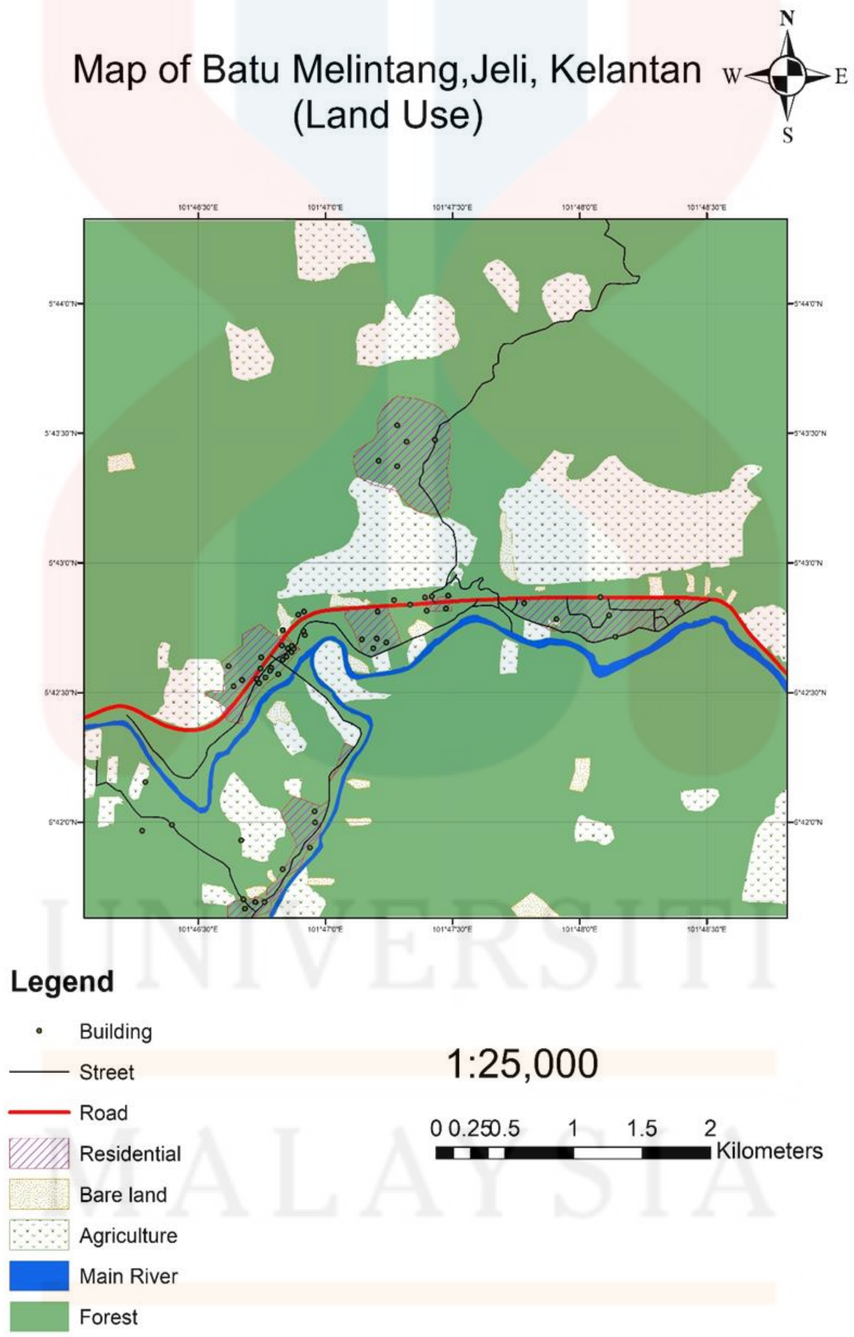

Figure 1.4: Land use Map of Study Area

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1.2.4 Road Connection/ Accessibility

Batu Melintang has a main road known as Timur Barat Highway. There are also small road connecting the small town and villages to the main road. Travel time from University Malaysia Kelantan (UMK) to study area which is located Batu Melintang is around 15 minutes. The road are busy during weekends and public holidays. There are public transport such as taxi and bus available.

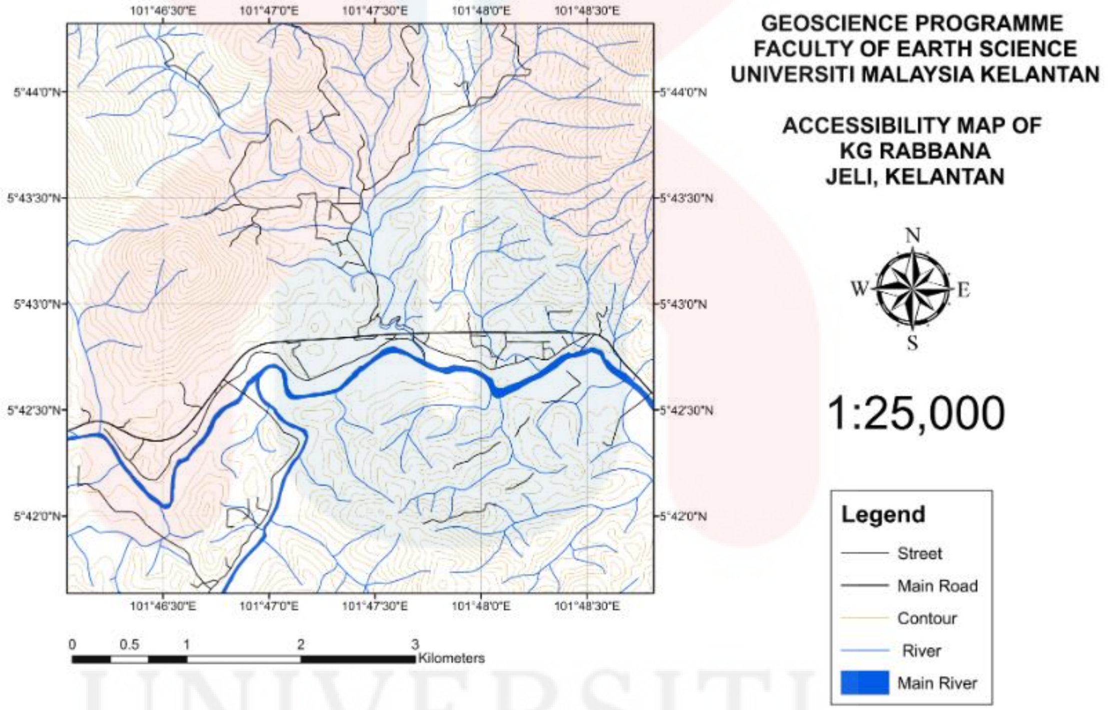

Figure 1.5: Traverse Map

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1.2.5 Rainfall Distribution

Table 1.2: Rain Distribution in Jeli from January to December 2017

Month	Jan	Feb	Mac	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Precipitation (mm)	32.7	7.5	6.8	7.2	6.3	6.6	6.6	8.1	12.8	5.7	25.5	9.2

Source: (Jabatan Pengairan dan Saliran Negeri Kelantan, 2018)

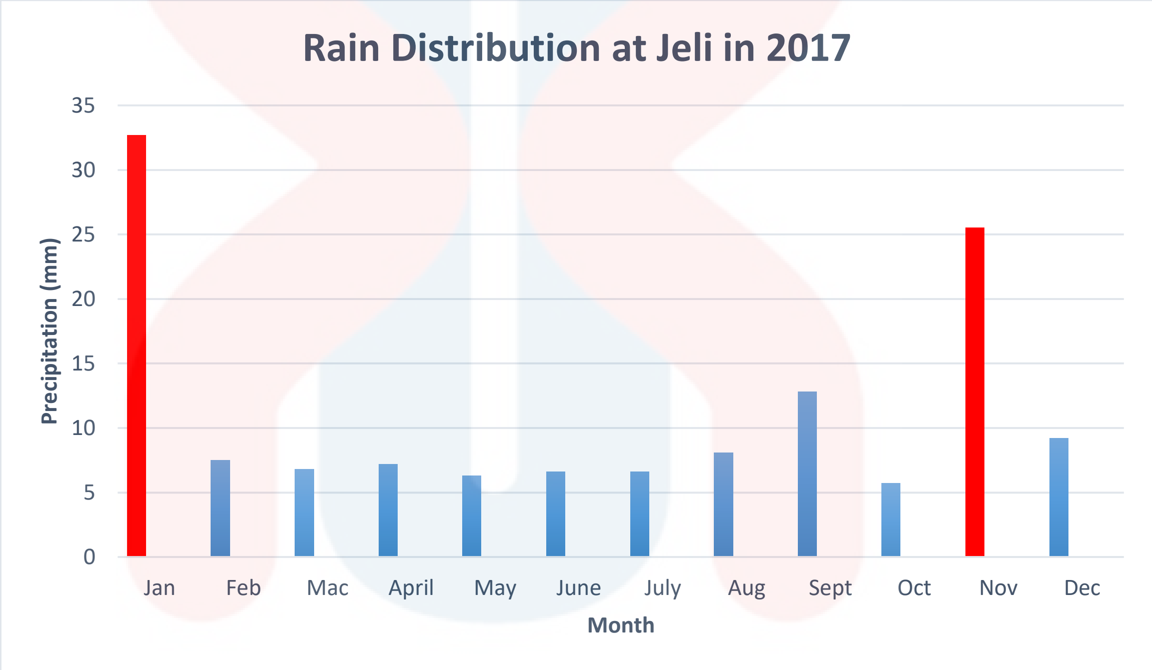

Figure 1.6: Rainfall Distribution at Jeli in 2017

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1.3 Problem Statement

Geological study of Batu Melintang have been done in large scale with the cooperation of two country which are between the Mineral and Geoscience Department Malaysia and the Department of Mineral Resources, Thailand. Geoscientist from both Malaysia and Thailand have produced the geological map with scale 1:250,000, covering 1,350 square kilometres along the border in Batu Melintang and Sungai Kolok areas (Malaysian, T., & Groups, W, 2006). Therefore, this research is conducted to update the most recent geological components such as structural geology, lithology units, geomorphology in the study area in more detail at the scale of 1:25,000.

Recent study of the igneous rock near the study area has been made by Siti Nur Arifah (2016) and Aman Shah et al, (2000) , only study about the of petrology and petrochemistry of all type of igneous rock that presence in the area. Thus, this research can be focused on one type of igneous rock which is granite. So, this research study on one type igneous rock which is granite using mixture of geochemical and petrological approach in the study area.

Research on rare earth elements (REE) was not widely done in Malaysia as this is still a new discovery in the mining sector. In Malaysia, there are few research being done for REE exploration. However, many of them focus on REE deposit in mineral like bauxite and monazite. This is because Malaysian rare earth ore especially monazite, is rich with LREEs compared to HREEs (Che Nor Aniza et al, 2015). Research on REE content in some granitic rocks of Peninsular Malaysia by Fuad et al, (1998) shows that there are potential of REE in granitic rocks.

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1.4 Objectives

i. To update geological map of Kampung Desa Rabbana in Jeli District with scale of 1:25,000.

ii. To analyse major chemical composition of granitoid in the study area by using XRF method.

iii. To identify rare earth elements (REE) in granitoid using ICP-OES method.

1.5 Scope of Study

Scope of study for this research are geological mapping, geomorphological mapping and analysis of samples with application of geochemistry in the laboratory and the field. Geological map was produced by collecting geological data via geological mapping. While geomorphological mapping is done to identify the geomorphological features, topography, drainage pattern and climatic condition of the study area that may affect the presence of REE in the area. Classification of granite is done by using geochemical method such as XRF for analysing major chemical composition of granites and detecting the concentration of REE in the area using ICP-OES method.

1.6 Significance of study

The purpose of the study is firstly to update geological map in Kg. Rabbana area with a scale of 1: 25,000. The geological map was made using the latest digital

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software consisting of updated lithology unit, geomorphological features any basic and new geological information were found when the doing the geological mapping.

This study provides confirmation of the distribution of rocks and formation in the study area. Next, the type of granite or granitoid presence in the study area are determined using geochemical and petrographic classification. Lastly, specification of the research is to identify potential resources such as rare earth elements deposit in the granite itself. All the geological information obtained during the geological surveys will be useful for future research especially in mineral exploration in the country. The geological information collected are to be disseminated to be used by other state agencies, by consultants, industry, developers, and the public as critical input in local and regional economic development plans, that can result in an economic advantage to the state.

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CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

The purpose of the literature review is to support this research by analysing previous knowledge and research that related to the research. The previous research paper also gives suggestion to further research. It also helps in writing the report by summarizing past studies made by the previous researchers.

2.2 Regional Geology

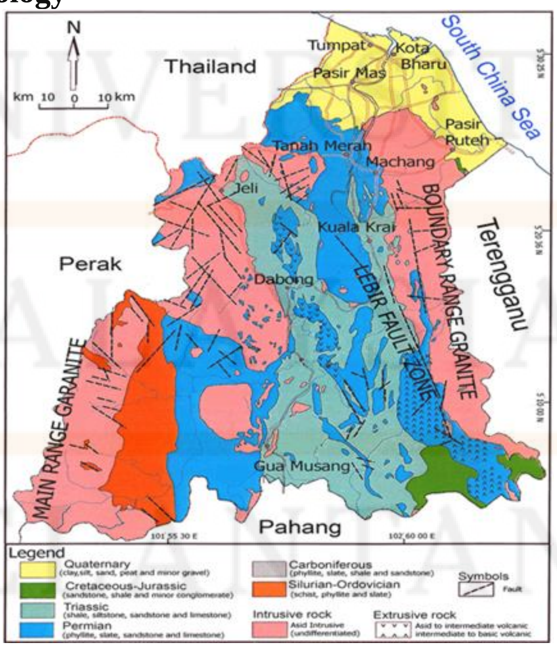

Figure 2.1: General Geological Map of Kelantan (Teoh et al., 1897)

The regional geology of Kelantan consists of a central zone of sedimentary and meta-sedimentary rocks bordered on the west and east by granites of the Main Range and Boundary Range respectively. Within the central zone, there are windows of granitic intrusive, the more prominent of these being the UIu Lalat (Senting) batholith, the Stong Igneous Complex and the Kemahang pluton. These belts of granite and country rocks have a north-south trend and are essentially the northern continuation of the regional geology of north Pahang. In west and central Kelantan, the belts continue northward into south Thailand but in the east the Boundary Range granite is overlain by the coastal alluvial flat of Sungai Kelantan (Heng et al, 2006).

Stong Igneous Complex is located at the northern part of the central belt, in the state of Kelantan, Peninsular Malaysia. It occupies an area of almost 300 km^2, from Jeli in the north to Kemubu in the south, forming a mountainous region centered on Gunung Stong and Gunung Berangkat at the south. The Stong Complex consists of three lithodemic unit, which are Berangkat Tonalite, Noring Granite and Kenerong Leucogranite.

All units have a good correlation on major- and minor-element distribution, suggesting that they are co-magmatic. The classification based on geochemistry shows the complex from shoshonite series into high-K calc-alkaline series field with metalumionous and peraluminous rock type. All rocks can be classified as “I’ type, implying that the source rocks are of mafic to intermediate igneous composition or of infracrustal derivation (Umor & Ghani, 2015).

Jeli district is situated in the western part of Kelantan state. The study area which is Batu Melintang is one of the sub-district in Jeli district. It is located more specifically near the Kelantan- Perak state boarder and Malaysia- Thailand

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international boarder. Jeli district is located at the foot of Main Range, the backbone of Peninsular Malaysia.

The range consists mostly of granitic rocks with several enclaves of sedimentary/metasedimentary rocks. Based on Figure 2.1, Jeli district is generally composed of three rock types which are Triassic sedimentary rocks (Gunung Rabong Formation) which consists of shale, siltstone , sandstone and limestone, Permian sedimentary rocks (Gua Musang Formation) which consists of phyllite, slate, sandstone and limestone and lastly granitic rocks (acid intrusives) (Department of Minerals and Geoscience Malaysia, 2003).

Distribution of igneous rock that could be found in the Jeli Igneous Complex, which is located about 1 km north of Jeli town Kelantan are coarse-grained foliated biotite granite, grey microgranite, medium-grained foliated biotite granite and hornblende biotite basaltic dyke (Aman S.O. et al, 2000). Based on Figure 2.1, there are many distribution of acid intrusive or granite (in pink colour) in state of Kelantan.

The geomorphology of whole Kelantan state can be divided into four types of landform which are mountains, hills, plain areas and coastal areas (Unjah et al, 2001). All the types of landform can be found throughout Jeli district except coastal areas. There are many structures such as folding, faulting, joint that could be found in sedimentary rocks and jointing and faulting in the granitic rocks. This is due to tremendous stress or pressure that being exerted to the land mass from the tectonic activities in Peninsular Malaysia during Palaeozoic and Mesozoic eras (Department of Minerals and Geoscience Malaysia, 2003).

The Mangga formation is well exposed in the upper reaches of Sungai Aching extending southwards to Kampung Gunung in the Batu Melintang area (Malaysia). It

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is represented by a low grade metamorphic sequence that can be subdivided into 4 facies: argillaceous facies, arenaceous facies, pyroclastic facies and calcareous facies.

Various mineral resources have been discovered and exploited since the last century and a large number of them is related to granite intrusions and subsequent hydrothermal activities. North-South trending quartz dykes and some igneous stocks intruded the country rocks, especially in the Kalai area (close to the Malaysian-Thai border). Contact metamorphism derived from igneous intrusion and its association with late stage mineralisation can be observed in the country rocks.

2.3 Stratigraphy

The Jeli Igenous Complex is located about I km north of Jeli town, Kelantan which is part of the Jeli granite. Four main rock types occur in the area namely (in decreasing age) coarse grained foliated biotite granite (CFBG), grey microgranite (GM), medium grained foliated biotite granite (MFBG), and hornblende biotite basaltic dyke (HBBD).

The CFBG, MFBG and GM consists of typical granitic mineral that is quartz, plagioclase, K-feldspar, biotite, zircon, apatite, sphene, allanite and opaque phase whereas the HBBD contains hornblende, quartz, plagioclase, biotite, apatite, sphene and opaque phases. Petrographic study shows that the rocks in the area have

The area of Batu Melintang, Jeli is covered by mostly metamorphic and igneous rocks with some occurrences of late phase intrusions such as dykes, which are mainly quartz and quarzo-feldsphatic dykes. The factors affect the metamorphism grade that occurs to the specific region, such as the temperature and the pressure.

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2.4 Structural Geology

Peninsular Malaysia was formed as a result of collision between Sinoburmalaya to the west and Eastmal-Indosinia blocks to the east. The collision zone is represented by the Bentong-Raub Suture in Figure 2.2 which can be traced northward into Thailand and southward into the Banka and Billiton Islands. This collision accompanied by the major tectonic event during Late Triassic has resulted in rock deformation in the Malay-Thai Peninsula. Pre-orogeny sedimentary successions in the Transect area are generally folded into a series of synclines and anticlines.

Folding is characterised by tight, asymmetric and open folds, which cause the repeated and overturn sequence in the older sedimentary rock. The NW-SE and N-S trending fold axes are sub-parallel to the long axis of the Malay Peninsula and most of the bedding planes dip towards the east with various dip angles. Faulting is widespread throughout the Transect area. Owing to the thick soil cover and deep tropical weathering, fault zones are seldom exposed at more than a few places along their traces.

Faults are generally varies in width characterised by fractured, sheared or mylonitised rocks. There are several faults, which are mainly of strike-slip and normal faults, trending N-S, NW-SE and NE-SW. Of these, the NE-SW trending fault is the main fault of the Transect area. The major faults are Long-Kolok fault (NE-SW), Pergau fault (NE-SW), Kalai-To Mo fault (N-S) and Ka To-Bu Yong fault.

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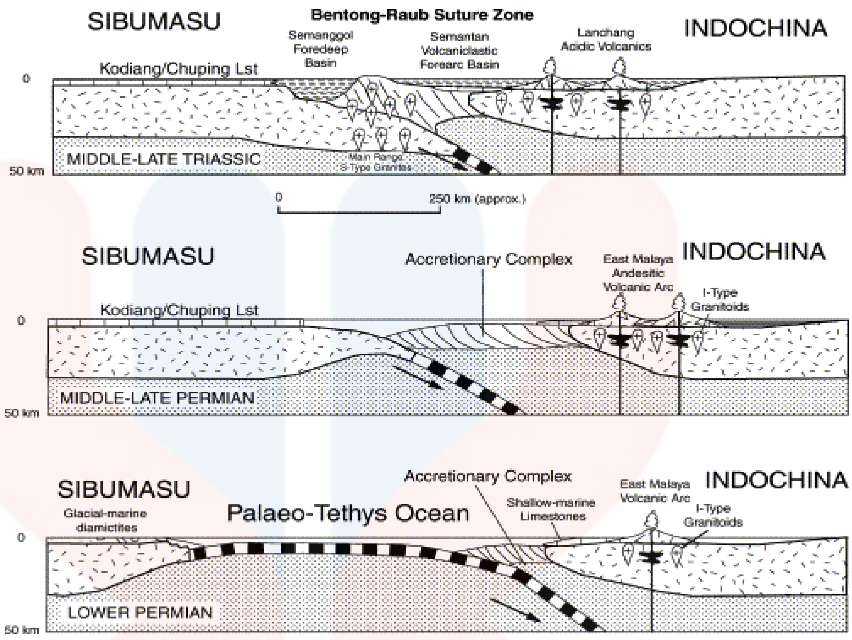

Figure 2.2: Tectonic Setting of Bentong-Raub Suture Zone

Exposures of igneous rocks are widely distributed in the Batu Melintang-Sungai Kolok Transect area. The volcanic rocks occur as flow and pyroclastics in the sedimentary succession, whereas the plutonic rocks occur as batholiths and small stocks. In Malaysia, Hutchison (1977) divided the granites into three belts based on lithology and petrochemistry of the granite: Main Range Belt, Central Belt and Eastern Belt as shown in Figure 2.3.

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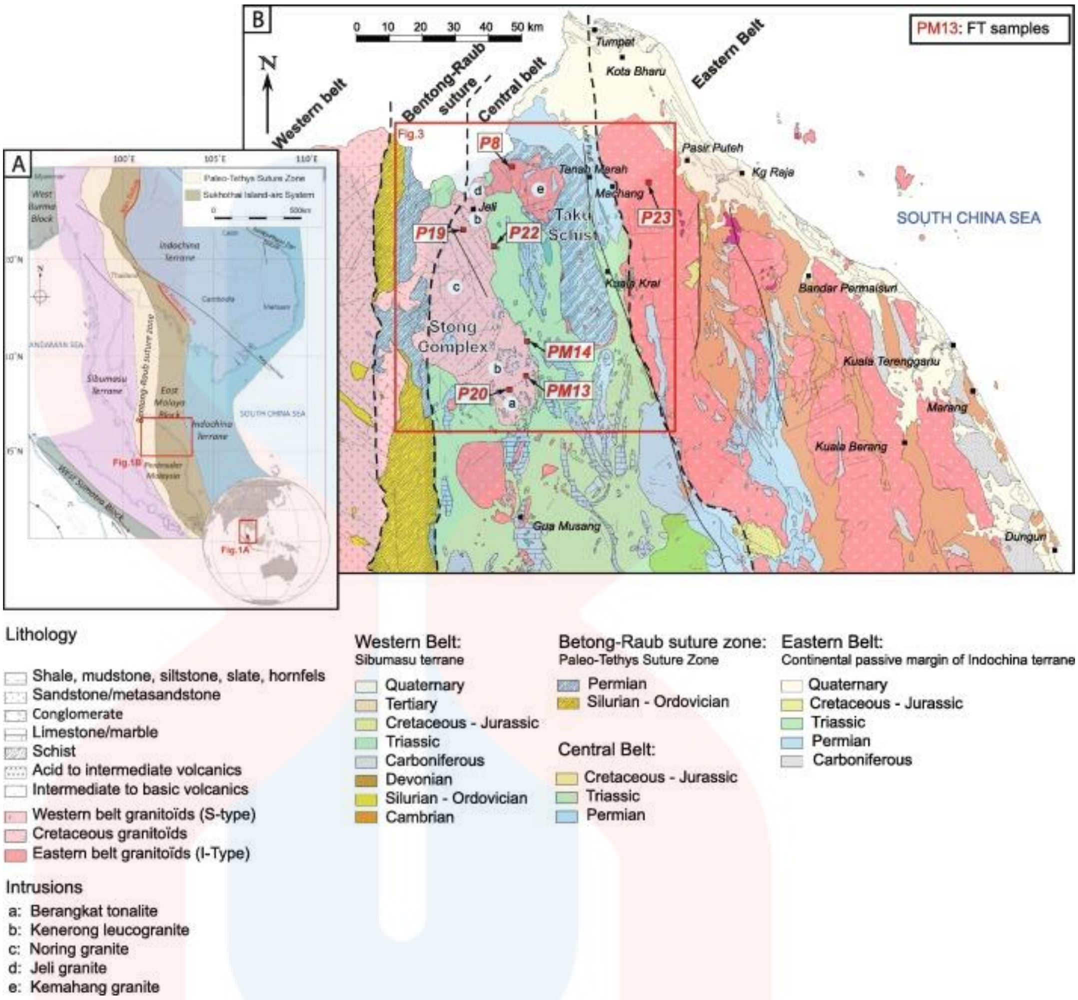

Figure 2.3: Exposures of Igneous Rocks Distributed in Batu Melintang-Sungai Kolok Transect Area

The Main Range granite is composed of S-type, ilmenite series granitoids which intruded into Paleozoic host rocks during the Permo-Triassic period. The Central Belt granite is composed mainly of S-type, ilmenite series granitoids of Triassic age with minor intrusion of Cretaceous I-type, magnetite series granitoids. The Eastern Belt granite consists mainly of I-type, magnetite series granitoids and intruded into Paleozoic host rocks during the Permo-Triassic period. Later, Cobbing et al. (1986) divided the granite into two provinces: Main Range granite and Eastern granite, with assumption that the Central and Eastern Belts are similar.

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The Main Range granite has been regarded to be constituted exclusively of S-type granites of mainly Triassic age (Bignell and Snelling, 1977; Hutchison, 1977; Cobbing et al., 1986; Hutchison, 1996). In contrast, the Eastern province granite is dominated by I-type with subordinate compositional overlap S-type granites of Permo-Triassic age. Small I-type plutons of Cretaceous age are present in the central part of the Peninsular Malaysia (Bignell and Snelling, 1977; Hutchison, 1977).

2.5 Geochemistry of Granite

Granite is an example of intrusive igneous rock. Igneous rock can be classified based on the chemical composition of magma or type of magma. There are four main groups of igneous rock based on chemical composition which are acidic, intermediate, basic and ultrabasic. Rocks that are acidic are rich in SiO_2 and K_2O and produced from magmas that have between 66 and 77.5% weight SiO_2. Acidic rocks tend to be felsic, light in colour and rich in quartz and feldspar. Granite is an example of an acidic rock and acidic magmas are known as granitic. Granite can be identified using mineralogical and geochemical classification.

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2.5.1 Classification of Granite

I. Mineralogical classification (QAP classification – IUGS classification)

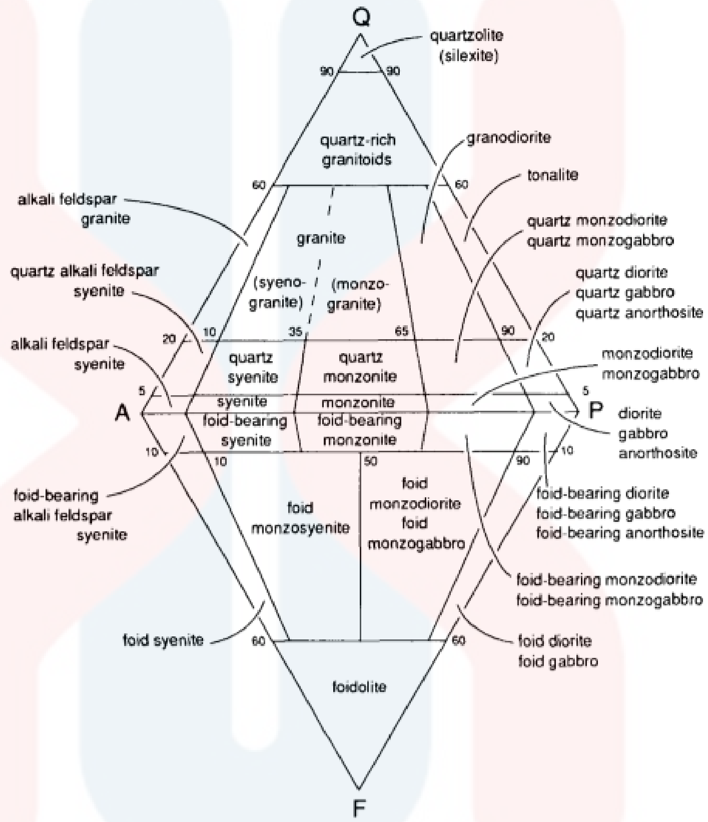

Figure 2.4: Classification And Nomenclature Of Plutonic Igneous Rocks According To Their Felsic Modal Contents When Mafic Mineral Content Is Less Than 90%. Q, Quartz;A Alkali Feldspar; P, Plagioclase; F, Feldspathoid (Foid). (Sources from http://www.atlas-hornin.sk)

Volcanic rocks that contain light, felsic minerals such as plagioclase, quartz, alkali feldspar, muscovite and foid as in Figure 2.4. While, volcanic rocks that contain dark, mafic minerals such as dark mica, amphibole, pyroxene and olivine. Example of felsic rock composed predominantly of felsic minerals are like granite and rhyolite, while mafic rocks are gabbro and basalt.

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Common mineral that could be identify under the polarizing microscope for igneous rocks are olivine, pyroxene, plagioclase, amphibole and biotite. These minerals are uncommon or rarely found in sedimentary rocks because when igneous rocks are exposed to weathering, many of their common minerals completely dissolve or partially dissolve and convert into clay minerals. As a result, only quartz, K-feldspar, and muscovite are commonly seen in sedimentary rocks.

These minerals are joined in sedimentary rocks by clay minerals, calcite, dolomite, gypsum, and halite. The clay minerals form during mineral weathering. The other four minerals are salts that precipitate as water evaporates. The elemental constituents of these salts are ultimately also derived from mineral weathering. While, for metamorphic rocks, the common minerals could be from either igneous rocks or sedimentary rocks.

This happens when the host or parent rocks like sedimentary and sedimentary rocks undergone metamorphism process that result to the minerals having distinctly dissolved or disintegrate into smaller grain size. Metamorphic rocks often have foliation texture due to high temperature and pressure on the parent's rock (Atlas of Magmatic Rocks, n.d).

II. Chemical classification (Aluminium Saturation Index, S-I-A-M classification)

The traditional classification of granitoids is using IUGS classification. However, many petrologist used additional schemes to further classify the granitoids. Classification of granite are called as three-tiered classification scheme which uses chemical element as a parameter (Petro *et al.*, 1979; Maniar & Piccoli, 1989; Barbarin, 1990, 1999).

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Table 2.1 is combination of plutonic and volcanic igneous rock's chemical composition (after Le Maitre, 1976 and Tour, T. E. L. A, 1989)

Table 2.1: Combination of Plutonic and Volcanic Igneous Rock's Chemical Composition

	Granite	Granodiorite	Monzonite	Tonalite	Nepheline Syenite	Diorite	Gabbro
SiO_2	71.30	66.09	62.60	61.52	54.99	57.48	50.14
TiO_2	0.31	0.54	0.78	0.73	0.60	0.95	1.12
Al_2O_3	14.32	15.73	15.67	16.48	20.96	16.67	15.48
Fe_2O_3	1.21	1.38	1.92	1.83	2.25	2.50	3.01
FeO	1.64	2.73	3.08	3.82	2.05	4.92	7.62
MnO	0.05	0.08	0.10	0.08	0.15	0.12	0.12
MgO	0.71	1.74	2.02	2.80	0.77	3.71	7.59
CaO	1.84	3.83	4.17	5.42	2.31	6.58	9.58
Na_2O	3.68	3.75	3.73	3.63	8.23	3.54	2.39
K_2O	4.07	2.73	4.06	2.07	5.58	1.76	0.93
P_2O_5	0.12	0.18	0.25	0.25	0.13	0.29	0.24

	Andesite	Basalt	Peridotite
SiO_2	59.61	54.53	42.10
TiO_2	1.06	2.26	0.01
Al_2O_3	17.19	13.72	0.732
Fe_2O_3	4.56	3.48	2.54
FeO	2.03	8.96	5.17
MnO	0.10	0.18	0.12
MgO	1.52	3.48	43.50
CaO	4.94	6.97	0.55
Na_2O	4.32	3.30	0.01
K_2O	2.92	1.70	0.00
P_2O_5	0.51	0.36	0.01

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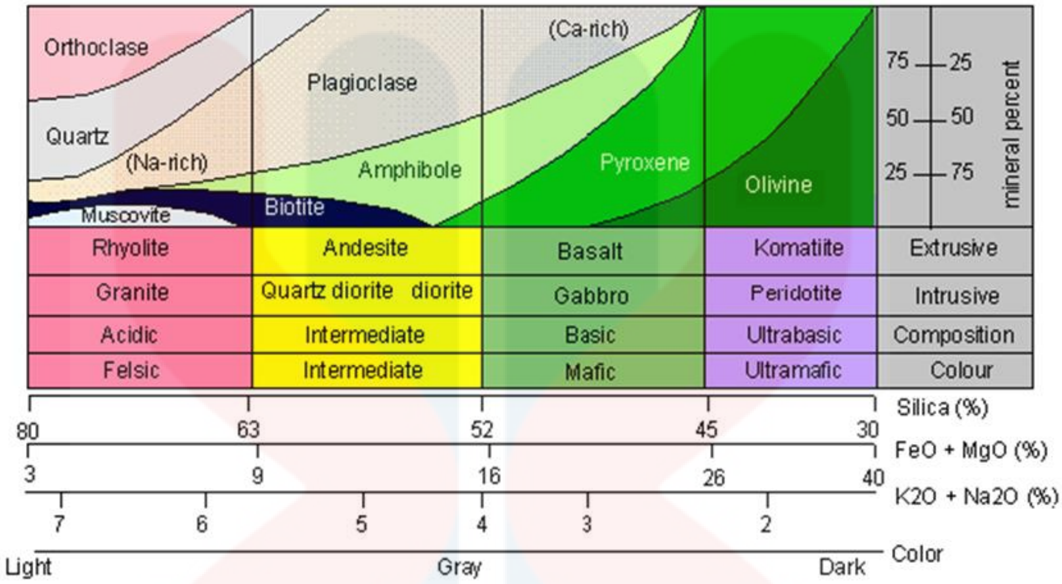

Figure 2.5: Classification of Igneous rock

a) Based on Aluminium Saturation Index (ASI) by Frost and Frost, 2008.

A geochemical classification for feldspathic igneous rock as Figure 2.5 (Frost, B.R. and Frost, C.D., 2008). This able to separate peraluminous, metaluminious and peralkaline rocks. This is expressed in the micas and minor minerals in the rock, which is related to the magma sources and the conditions of melting as in Figure 2.6 below.

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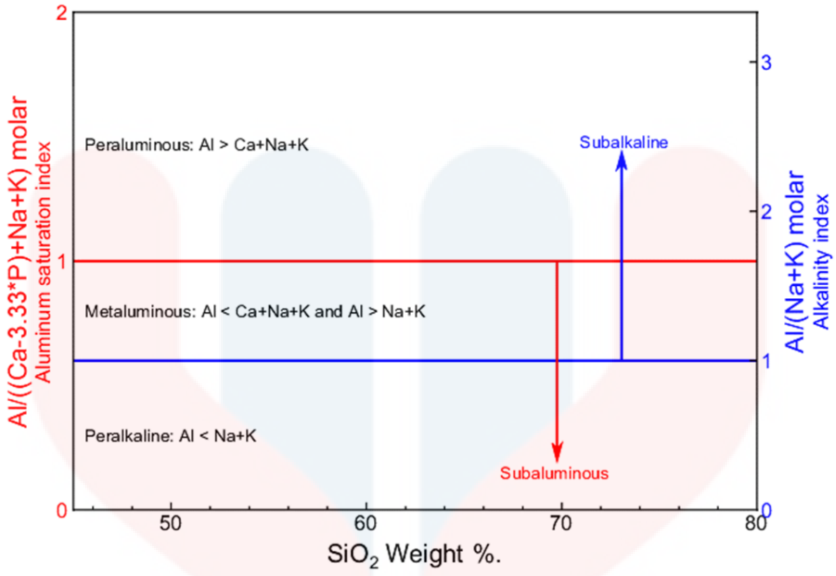

Figure 2.6: Geochemical Classification for Feldspathic Igneous Rock

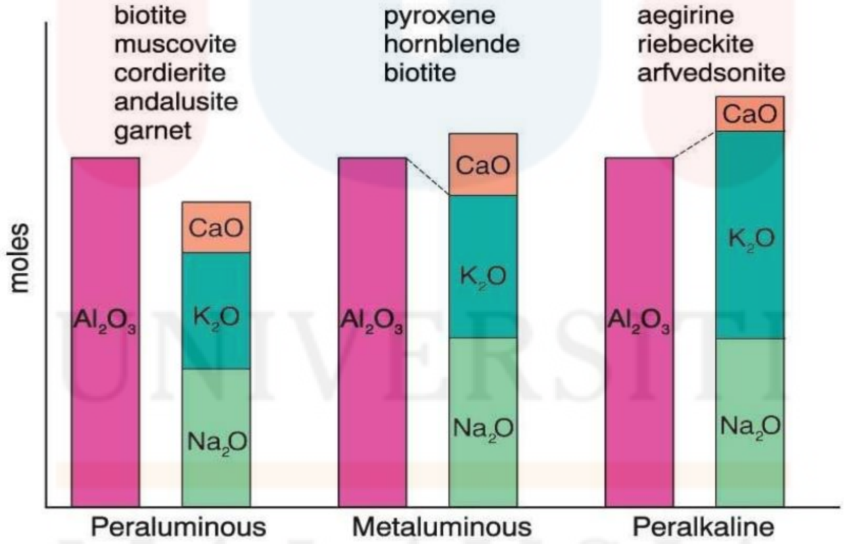

Figure 2.7: Alumina Saturation Classes based on Molar Proportions of Al_2O_3/ ($CaO+Na_2O+K_2O$) ("A/CNK")

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b) Based on alphabetic (S-I-A-M) classification by Chappell and White (1874), and Loisee and Wones (1979).

Type	SiO_2	K_2O/Na_2O	Ca, Sr	A/(C+N+K)*	Fe^{3+}/Fe^{2+}	Cr, Ni	$\delta^{18}O$	$^{87}Sr/^{86}Sr$	Misc	Petrogenesis
M	46-70%	low	high	low	low	low	< 9‰	< 0.705	Low Rb, Th, U Low LIL and HFS	Subduction zone or ocean-intraplate Mantle-derived
I	53-76%	low	high in mafic rocks	low: metal-uminous to peraluminous	moderate	low	< 9‰	< 0.705	high LIL/HFS med. Rb, Th, U hornblende magnetite	Subduction zone Infracrustal Mafic to intermed. igneous source
S	65-74%	high	low	high peraluminous	low	high	> 9‰	> 0.707	variable LIL/HFS high Rb, Th, U biotite, cordierite Als, Grt, Ilmenite	Subduction zone Supracrustal sedimentary source
A	high → 77%	Na_2O high	low	var peralkaline	var	low	var	var	low LIL/HFS high Fe/Mg high Ga/Al High REE, Zr High F, Cl	Anorogenic Stable craton Rift zone

* molar $Al_2O_3/(CaO+Na_2O+K_2O)$ Data from White and Chappell (1983), Clarke (1992), Whalen (1985)

Figure 2.8: S-I-A-M Classification

c) Based on Modified Alkali-lime index (MALI) by Peacock

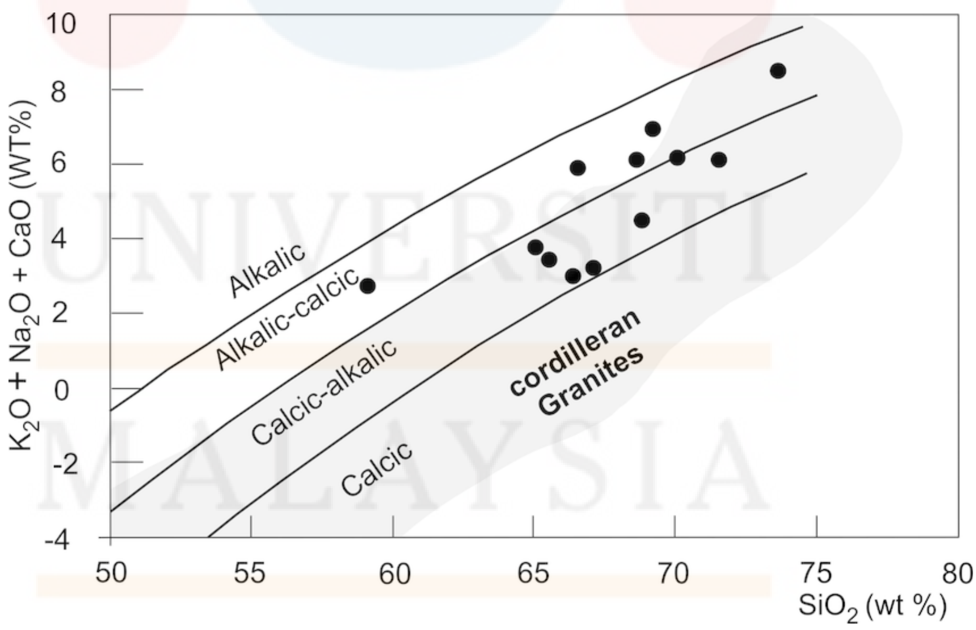

Figure 2.9: Modified Alkali-Lime Index (MALI)

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I. Tectonic classification

Table 2.2: Classification of Granitoid Rocks Based on Tectonic Setting

	Orogenic			Transitional	Anorogenic	
	Oceanic Island Arc	Continental Arc	Continental Collision	Post-Orogenic Uplift/Collapse	Continental Rifting, Hot Spot	Mid-Ocean Ridge, Ocean Islands
Geochemistry	Calc- alkaline >thol M-type &I-M hybrid Metaluminous	Calc-alkaline I-type > S-type Metaluminous to peraluminous	Calc-alkaline S-type Peraluminous	Calc-alkaline I-type S-type (A-type) Metaluminous to peraluminous	Alkaline A-type Peralkaline	Thoelitic M-type Metalluminous
Associated Volcanism	Island-arc basalt to andesite	Andesite and dacite in great volume	Often lacking	Basalt and rhyolite	Alkali lavas, tuffs, and caldera infill	MORB and ocean island basalt.
Rock types	Quartz-diorite in mature arcs	Tonalite & Granodiorite >granite or gabbro	Migmatites & leucogranite	Bimodal granodiorite + diorite-gabbro	Granite, syenite + diorite-gabbro	Plagiogranite
Origin	Partial melting of mantle-derived mafic underplate	PM of mantle-derived mafic undeplate + crustal contribution	Partial melting of recycled crustal material	Partial melting of lower crust + mantle and mid-crust contribution	Partial melting of lower crust + mantle and mid-crust contribution.	Partial melting of mantle and/or lower crust (anhydrous)
Melting Mechanism	Subduction energy: transfer of fluids and dissolved species from slab to wedge. Melting of wedge, transfer of heat upward		Tectonic thickening plus radiogenic crustal heat	Crustal heat plus mantle heat (rising asthen. + magmas)	Hotspot and/or adiabatic mantle rise	

Source: Pitcher (1983, 1993) and Barbarian (1990, 1999)

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Origin	Granitoid types	Type	ASI	MgO/ TiO_2	Tectonic setting	
Crustal	Intrusive Two-mica Leucogranites	C_{ST}	ASI >1.1	3 ± 0.2	Collision or	
	Peraluminous Autochtonous Granitoids	C_{CA}				
Peraluminous rocks	Peraluminous Intrusive Granitoids	C_{CI}				
Mixed origin (Crust+Mantle)	K Calc-Alkaline Granitoids (High K-Low Ca)	H_{LO}	ASI = 1 MgO= 3.7%	4 ± 0.2	Post- collision zones	Orogenic Granitoids
Metaluminous or Calc-alkaline	Calc-Alkaline Granitoids (Low K-High Ca)	H_{CA}	ASI=1 MgO = 1.9%	2 ± 0.4	subduction zones	
Mantle origin	Island Arc tholeiitic Granitoids	T_{IA}				
Tholeiitic Alkaline Peralkaline	Mid-ocean Ridge Tholeiitic Granitoids	T_{OR}	ASI = 1 MgO = 0.8%	1 ± 0.5	Rifting or doming Zones	Anorogenic Granitoids
	Alkaline and Peralkaline Granitoids	A				

Figure 2.10: Summary of Result ASI, MgO/TiO2 and Geodynamic Environments

(Source: Bilal, E. 1997)

2.5.2 Rare Earth Elements (REE)

The past and most common methods to extract rare earth elements from ores have been proven to create pollution. However, recent research team led by David Reed at Idaho National Laboratory have discover more clean method in extracting six rare earth elements which are yttrium, cerium, neodymium, samarium, europium and ytterbium by using mineral and organic acids, including bio-acid mixture produced by bacteria. The results suggest that the bio-acid did a better job extracting rare earth elements than pure gluconic acid at the same pH (2.1), or degree of acidity. (Nield and Staff, 2019)

There are many uses of rare earth elements. For instance, Rare earth metals and alloys that contain them are used in many devices that people use every day such as computer memory, DVDs, rechargeable batteries, cell phones, catalytic converters, magnets, fluorescent lighting and much more. Rare earth elements are not that rare, and in fact it can be found abundantly in the crust, nearly 200 times greater than gold.

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However, they are called rare as finding these metals in high concentration is unusual, making them difficult to mine for economical extraction.

REE mainly be found in silicates in form of carbonates, fluorides, phosphates, oxides or silicates in rare earth ore concentrate. They need to be transformed first into compounds that are soluble in water or mineral acid before extraction of REE takes place. This process is called concentrate decomposition. Acid, alkaline and chlorinated decomposition are the concentrate decomposition method. Commonly there are three kinds of extraction technologies which are the fractional step method, ion exchange method and solvent extraction method. Solvent extraction method has gradually become the main method of separating large amount of rare earth elements due to great improvements of the new extractant.

Spectroscopic method with combination of X-ray fluorescence or XRF can be used to determine the chemical compositions of rocks. The method is fast, accurate, not destructive and usually requires minimum of sample preparation (Jamaluddin, 2018). This means that the same sample can be used again for another analysis. However, this technique is very sensitive as samples must be free of contamination (Okunade, 1999). While, the method to detect the presence of REE using ICP-OES has been widely used. ICP-OES or inductively coupled plasma optical emission spectrometer is an analytical technique used for elemental determination. Although the method is costly, it can detect very small fraction of element.

The finding of REEs are not that hard as gold deposits and in fact they are abundant in the Earth's crust. They are called as rare because of the low concentration that could be found and the cost of production to extract them. Most REEs are can be found from placer deposits, bedrock, or clay formations (Orris, 2002). REE-rich

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minerals are generally found in either carbonatites or peralkaline granites and associated pegmatite. Concentration of REE is much lower in clay deposits. Although they are very pricey, the demand for REE is still increasing, making exploration for them increase as they have no other substitutes. About 95% of REE deposits are being retrieved from China that being used for electronic, military and environmental applications.

The primary REE-bearing minerals are monazite $(REE)PO_4$, bastnasite $(REE)CO_3F$ and xenotime $(REE)PO_4$ (Beauford, 2010). In Malaysia, monazite and xenotime are minerals phosphates that are present as by-product of tin mining processing. In facts, Malaysia has about 30, 000 tonnes of rare earths based on the finding in the residual tin deposits. Monazite contains more LREEs compared to HREEs that are associated together with NORM (Thorium and Uranium) in significant concentration. In recent studies, high grade REEs can be obtained by selective precipitation from monazite leach solution up to 96.05 – 99.10% (Aniza et al., 2015).

The geochemical behaviour of REE is influenced by nearly all important hydrothermal ore formation processes including fluid-rock interactions, fluid precipitations, absorption and scavenging onto particles, and changes in fluid temperature, pressure, pH, alkalinity and ligand concentration. Alteration assemblages of intrusive related mineralisations may exhibit a wide range of REE distributions and REE fractionation trends. The REE distribution within these hydrothermally altered lithologies will depend on the REE concentration in the rock and the fluid, the partitioning behaviour of the REE between the rock phases and the fluid, and the types of alteration reactions which take place.

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2.5.3 XRF and ICP-OES

ICP-OES is used for the determination of REEs because of its inherent capability for rapid simultaneous multi-element detection over a wide range of concentration. Although XRF techniques also can be used to detect trace elements like REE, the instruments is not very accurate for detecting very minor elements. The main advantages of the ICP-OES is regarded as suitable for the detection of most elements, with the exception of radioactive elements requiring analysis by gamma-ray spectroscopy, the halogen group, and trace contaminants found in the argon gas mixture that is used in the ICP-OES testing procedure. Among the trace elements, the lanthanides, also commonly known as Rare Earth Elements (REE), are recognised for their utility in investigating a broad range of geochemical and geological process. However, a typical sample fit for testing by ICP-OES analysis is a solid sample consisting of a metal, trace minerals, food substances, or other dissolved compound for which metals analysis is required. The reported values and ICP-OES analysed values were always be represented as chondrite normalized REE plots (Rajamanickam M. & Balakrishnan S., 2013).

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CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

In order to complete this research, there are some materials and methods that have been used. Materials are items that are essential when collecting the samples and for sample preparation before analysis takes place. While, instruments are machine and tools that were used to obtain data and information needed for this research. Methods are the steps and procedures that must be followed in order to produce good results or final output for the sake of this research.

The components of the methodologies for this research includes preliminary research, materials, field study, sampling, laboratory work, data collection, and data analysis and data interpretation. These components for research methodologies have also include flow charts for better understanding of the research.

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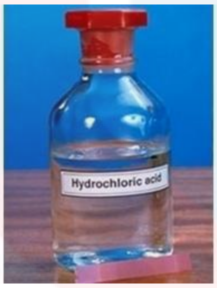
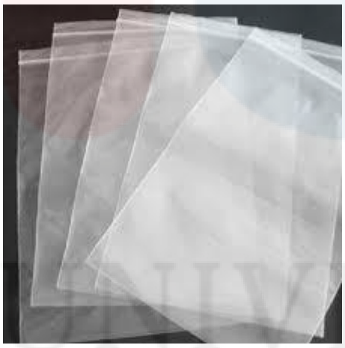
3.2 Materials & Instruments

3.2.1 Materials

i. HCL (Hydrochloric Acid) 	0.1 m of hydrochloric acid are usually taken in a small size of bottle because it only use a few drop of hydrochloric acid in testing the presence of calcite in the rocks.
ii. Chemicals used for XRF	There is no chemical needed for XRF sample as it can analyse the dry, loose solid material.
iii. Sample bags or container 	Use to seal the sample and protect the sample from surrounding contamination. In the form of plastic bags and container.
iv. Pallets 	Use as a container for the sample to be compacted in before analysing it under XRF machine.

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3.2.2 Instruments

i. Hammer 	Rock sample that needed for identification must be fresh and less weathered. Geological hammer will be used to break the rock from outcrop.
ii. Compass 	Compass are used to determine the bearing of the outcrop and measure the reading of strike and dip. In determine the position of the North, compass also will be used.
iii. Handlense 	Hand lens is a small magnifying glass that use to take a closer look at rocks in the field. By using hand lens we can identify tiny minerals and fossils in the rocks. Minerals that usually being identify by hand lens are minerals in igneous rocks.
iv. **Polarized Light Microscope**	This type of microscope is used to investigate the optical properties of various specimen. In this research, it is mainly be used in detecting

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	minerals distribution in the prepared thin section of rock by analysing their physical characters under plane-polarized lens (PPL) and cross-polarized lens (XPL).
v. GPS (Global Positioning System) 	GPS is used to identify the location of certain area in the field. Certain position that take as observation point will be mark in the GPS.
vi. **Camera** 	As a proof of the structure and lithological unit presence in the study area. As a reference when documentation of the research with real life scale of the outcrop. Using the camera from phone is enough due to easy and lightweight factor.
vii. XRF (X-ray Fluorescence) 	An X-ray fluorescence (XRF) spectrometer is an x-ray instrument, relatively non-destructive chemical analyses of rocks, minerals, sediments and fluids. It is widely

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	used methods for analysis of major and trace elements in rocks, minerals and sediment.
viii. ICP-OES 	ICP-OES or Inductively Coupled Plasma Optical Emission Spectroscopy is an elemental analysis technique that uses the emission spectra of a sample to identify and quantity the elements present.

3.3 Methodology

3.3.1 Preliminary Study

Preliminary study was the first and essential step in making of decision of the research topic or point of interest of the research study using sources like articles, journals, books, websites and any inventory that related to the interest of study can be used as a reference. From this pre-study, the topic for research has been narrowed down and have become more specific.

Once the topic and location has been decided, preliminary study about the geomorphology of the study area is done. From the base map produced, it is easier to study the type of landforms based on the elevation and identifies the drainage pattern, watershed and lineament.

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3.3.2 Fieldwork or Field Study

Geological mapping is an important steps in obtaining and collecting field data. Although there are many other ways in gaining data without going to the study area such as remote sensing, there are still data that need to be retrieved manually. Field data can cover all the aspects in the scope study which is geomorphology, stratigraphy, geological structures, sedimentology and petrology. During fieldwork, there are several methods that must followed in order to gain the best field data.

a) Traversing

Traversing is the method that have been used to establish control network or path that taken by the researcher during the fieldwork. It helps researcher to allocate the current location on the map by marking in the GPS. Traversing can be easily done with the lineament analysis of the topographic map of the study area as a guide in the field. All the observation points and sampling points were marked in the GPS along with the daily track of fieldwork.

b) Observation / Data Collection

Field observation data is very important especially in the making of geological map. The data have been collected as much as possible, covering the study area. The data collected by observation such as rate of weathering, vegetation, size of outcrop, features of geological structures, strike and dip, geomorphology and rock distribution. All the observation during the fieldwork have been recorded manually in the notebook or documenting in any digital application.

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c) Sampling

In this research, the samples that have been collected were mainly rock samples consisting of, metamorphic rock and igneous rock. The types of rock sampling used is grab sampling and chip sampling. Grab sampling is done by collecting samples randomly or by the highest degree of visible mineralization. While, chip sampling is done by chipping fragments of rock continuously along a width of exposed rock. The amount of samples collected depends on the different type of rock distribution around Kg. Rabbana area.

The samples were collected directly being taken from the outcrop using hammer and each of the location were marked in the GPS. These samples were then analysed using polarizing microscope to update the geological map, specifically the lithology unit in the area. Next, for the geochemistry part of the research, the same samples were used to be analyse using XRF technique.

Maximum of five samples were tested at 5 different locations that are further apart from each other and according to their differences of the grain size and colour of the granite samples. According to the result of the type of granite using XRF, only samples that are different from each other in chemical composition are tested using ICP-OES method, in order to identify the presence of REE concentration in the rock itself.

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3.3.3 Laboratory Work

Laboratory work such as petrographic analysis and XRF analyses for this research were done at laboratory at University Malaysia Kelantan (UMK) and for ICP-OES analyses were done at a local university in Malaysia.

a) Sample Preparation for:

I. Petrographic Analysis

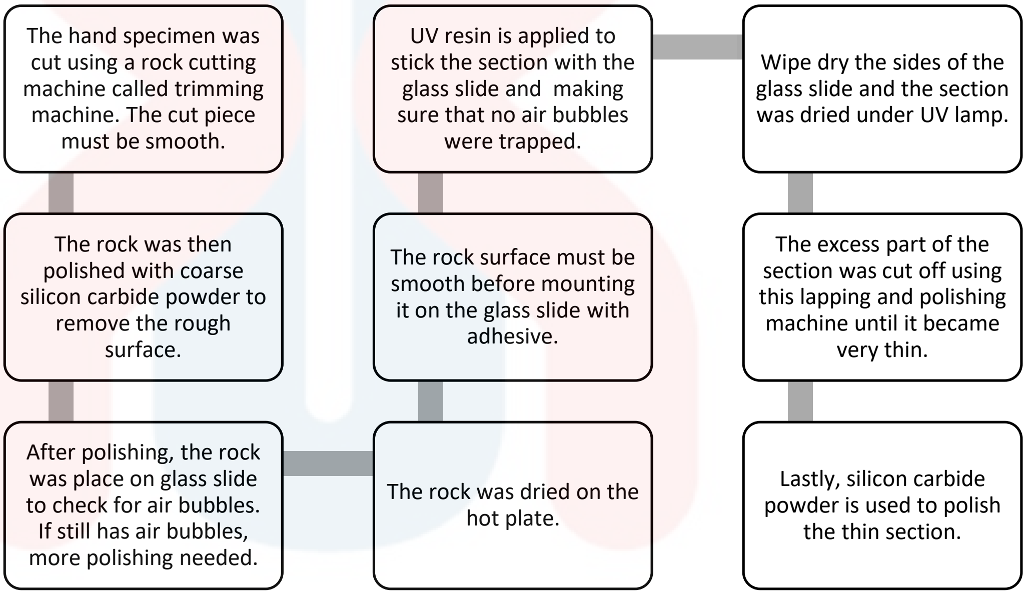

Figure 3.1: Flowchart for Sample Preparation

II. XRF sample

Different rock samples with moderate size were crushed with grinding machine into smaller pieces. The steps on how to handle XRF sample can be seen in Figure 3.2 until Figure 3.7 below. The selection of rock sample to be grind are based on the differences of colour and grain size. The rock was crushed until it produced approximately 100 g of sample each.

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The samples were then pulverized to a powder, at least fine enough to pass through a 200 mesh screen. The powdered samples will be put in a sealed container before XRF analysis takes place to minimize the risk of contamination from the surrounding. The samples were only open when doing the analysis. The finely ground rock powder was mixed with a small amount polyvinyl alcohol dissolved in water. Then, the powdered samples were compacted into a pellet using hydraulic press.

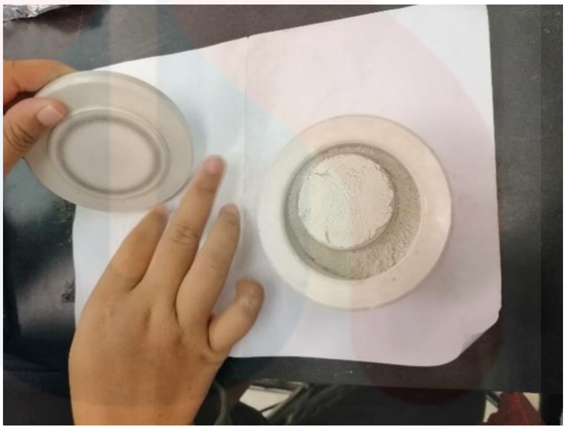

Figure 3.2: Powdered Samples Compacted Into Pallet

Figure 3.3: Grinding Machine in FBKT Laboratory

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Figure 3.4: Samples Used in Research Project

Figure 3.5: Sieve the Samples After Crushing Before Using XRF

Figure 3.6: Hydraulic

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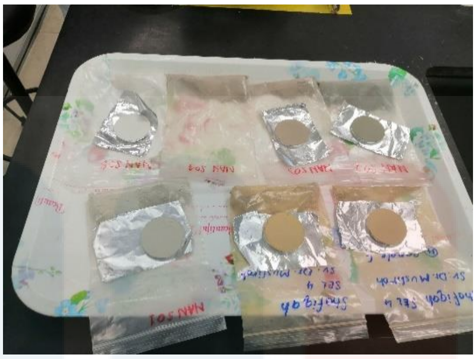

Figure 3.7: Samples in Form of Pallette

III. ICP-OES sample

Before the samples being analysed, acid dissolution is usually performed with mixtures of either HNO_3 or $HClO_4$ and HF. The samples are suggested to be digested in a pressure container. Only after digestion process, the REE determination in silicate rocks can take place. Referring to XRF results, the potential samples are selected. The samples were analysed using the standard REE chemical composition by ICP-OES to determine concentration of REE in the samples

3.3.4 Data Processing

All the geological components that have been observed during geological mapping such as lithology units, strike and dip, geomorphology were processed to produce updated geological map in the scale of 1:25,000. The processing of geological data is done by using ArcGIS software to produce a map. Strike and dip data in the study area are further processed using Geo-rose application for structural analysis and joint analysis, producing Rose diagram. This is done to analyse the direction of the maximum force that causes the joint and fracture. Structural analysis and joint analysis

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is important to study the structural geology of the study area. The geochemical data were then plotted in diagrams such as Harker Diagram and analysed using GCDkit software.

3.3.5 Data Analysis and Interpretation

The samples were analyses under the polarizing microscope for petrographic analysis, while for geochemical analysis, the samples were analyses using XRF and ICP-OES machine. Result from these analysis will be collected to be further interpreted.

a) Petrographic Analysis

Thin section of the all rocks sample were prepared. Petrographic analysis was conducted by analysing thin section of the rock samples using polarizing microscope. Under cross-polarized light, physical properties of the minerals such as twinning, birefringence and extinction that were focused on, while under plane-polarized light, physical properties of minerals that were focused on are colour, pleochroism, cleavage, relief, grain size and shape.

Petrographic analysis have been used to identify the type of rocks whether they are sedimentary rock, metamorphic rock and igneous rock that present in the study area by using the polarizing microscope based on the common mineral associated with each type of rock. The direct analysis of the mineral that composed the rock in the thin section are used in determining the type of igneous rock. The classification of igneous rock can used the general classification of igneous rock which are the QAPF diagram.

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b) Geochemical Analysis

In this study, two geochemical methods have been used which is XRF and ICP-OES. XRF is used for determination of the major chemical composition of the rock. All the igneous rock from the samples were categorize into its type based on their major chemical composition using XRF analysis. Using the same result from the XRF analysis, the sample of granite were classified based on its major chemical composition, the proposed geochemical classification that have been reviewed and summarize by B. Ronald Frost et al, (2001) which are:

I. Based on Aluminium Saturation Index by Shand (1934).
II. Based on alphabetic (S-I-A-M) classification by Chappell and White (1874), and Loisee and Wones (1979).
III. Based on Modified Alkali-lime index (MALI) by Peacock (1931).

Next, for the ICP-OES analyses, the same samples are used. However the amount of samples differ from the original amount of samples tested in XRF as only granite samples will be tested for REE concentration. All of the rare earth elements were tested on the different type of granite. From the result of ICP-OES, it showed the concentration of REE in every granite type present in the study area. The highest concentration of REE in granite was proposed to be the potential resources in the area. Moreover, the presence of REE in geological materials provide important information about the formation and the geochemical process undergone by the rock.

Preparation sample for XRF is rather simple as there is no digestion or any chemical process needed. The sample only need to be grind into powdered texture before being pressed into pellets. XRF method is used to determine concentration of major elements (SiO_2, Al_2O_3, TiO, FeO, MgO, CaO, MnO, Na_2O, K_2O, and P_2O_5).

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ICP-OES method can be used to determine major elements, minor elements, trace elements and isotope quantification. The detection limit varies from ppm to ppt. ICP-OES method can be applied especially in determining rare earth elements (REE) concentration. Preparation sample of ICP-OES is through acid leaching. Trace elements composition is usually is used to check the existence of subduction in the area, study the tectonic environment and MORB pattern.

Figure 3.8 shows the flow chart of the research. It starts from geological mapping until conclusion and recommendation.

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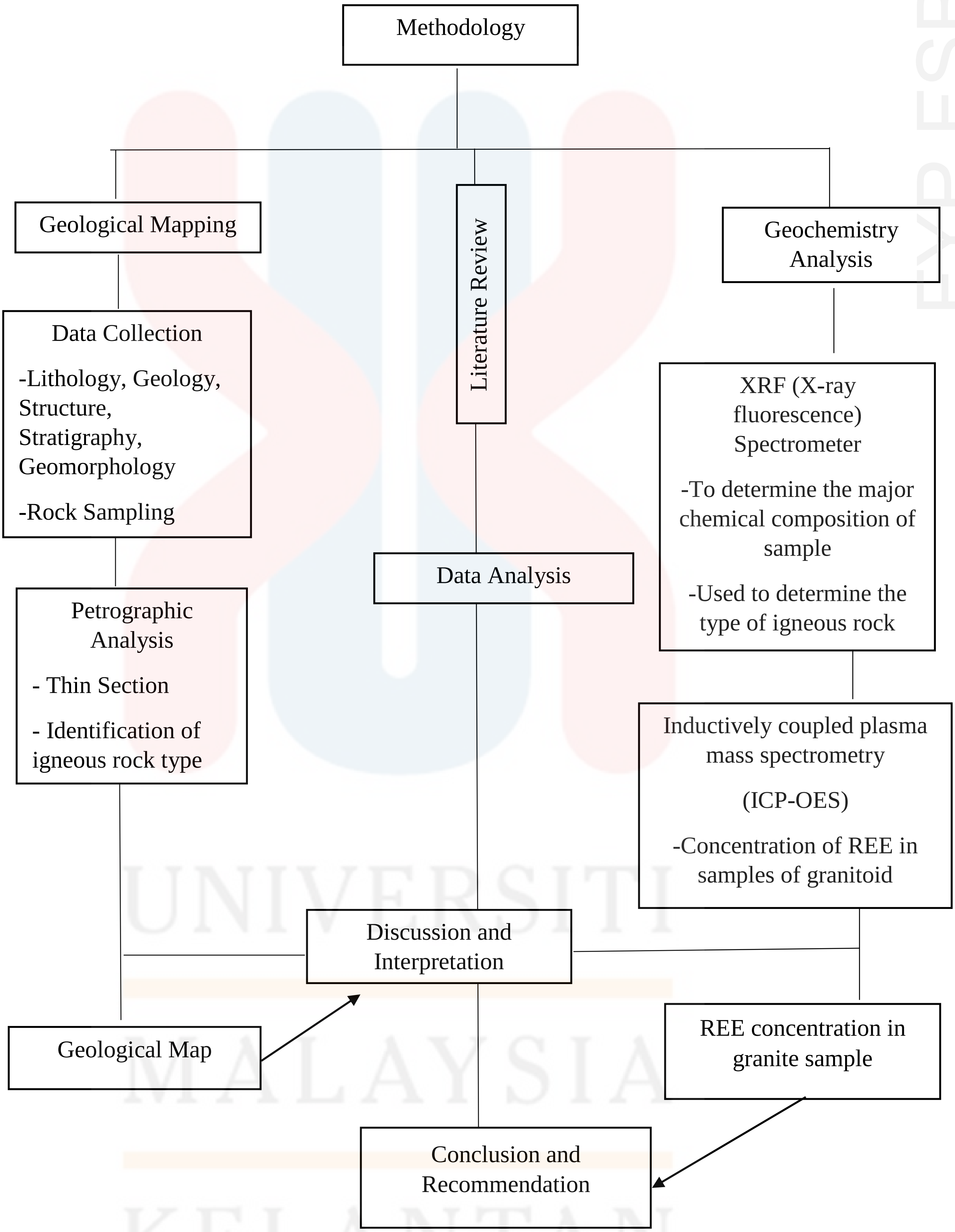

Figure 3.8: Research Flowchart

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CHAPTER 4

GEOLOGY

4.1 Introduction

This chapter will discuss more about the geological aspects such as geomorphology, lithology, petrography analysis, stratigraphy unit, geological structure and the historical geology of the study area. All the data or information that have been collected and retrieved from the mapping activities are discussed. The traverse and observation map, geomorphology map and drainage map were provided in this chapter for further understanding of the landform and the characteristics of the study area. All the data and information were also used to produce the geological map of Kampung Rabbana at Jeli District as shown in Appendix 1. This chapter is essential for geologist or person of interest such as developer to find out the past event that had been occurred in the study area.

4.1.1 Accessibility

The area of access for vehicles in study area is really limited due to the thick t and wet condition of the forest. Motors can reach quite far as there is access of small narrow road made by the farmer as almost 75% of the area is an agriculture area. The main road or tar road that suitable for cars is concentrated in the middle of the study area which is along the East-West Highway. Almost all the byroads or villagers pathway is connected by the main road. The telecommunication

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system in the study is fortunately good though especially within the thick forest. The accessibility of the area is quite good due to the presence of mosque, plantations, shop, restaurant and residential area. Presence of bridge that connects area that have been separated by the Long and Pergau River makes the study area more accessible. Hence, the mapping activities can be done effectively.

4.1.2 Settlement

The northern and the southern part of the study area is dominated with plantation areas of a mixture of palm oil and rubber tree plantation. There is also vegetation area for vegetables that being planted by the owner of the land itself. Meanwhile, the northern area also has a part of reserve forest called as Jeli Forest. The residential area is focused on the main road and a few in the area near the forest. There is no tourist’s spot in the study area as it focused on the agriculture sector and small business like restaurants, workshop and many more.

4.1.3 Forestry

Jeli district is known by its agriculture activities. The booming activities of agriculture in the area are due to humid and wet climate and the soils from weathered granite that are good and suitable for the plants growth. Various crops have been planted in the study area such as rambutan, durian, duku and other vegetables. Figure 4.1 shows the rubber plantation that even reach the peak of the hill. Rubber tree is the dominant plantation along with palm oil plantation. The palm oil area are near to the rubber plantation which is within the same hill. Palm oil area can be found from the top of the hill to the foothills like in Figure 4.2. Figure 4.3 show the entrance of Jeli Forest Reserve. The forest is very thick with the presence of wildlife.

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Figure 4.1: Rubber plantation at the peak of the hill of weathered granite.

Figure 4.2: Palm oil estate at a hill

Figure 4.3: Jeli Forest Reserve.

4.2 Geomorphology

Geomorphology refer as study of landforms, their processes or evolution that took place in its formation. Studying the landforms can provide better interpretation in order to understand more of its origin or occurrence in the past. The formation and the alteration of the Earth's surface are directly related and resulted from geomorphologic process. Human can develop and plan for their socioeconomic in the safest way and efficiently by understanding the geomorphology of the area.

Geomorphological processes are divided into two main processes. The topography of the study area consist mainly of mountainous area, hilly and floodplain area. According to Department of Minerals and Geoscience Malaysia, (2003), the land mass are effected by the tectonic activities during the Paleozoic and Mesozoic eras shown by the faulting, jointing in granitic rocks and sedimentary rocks. The fault and joint structures present due to the igneous rock intrusion. Weathering process can progress rapidly due to hot and humid climate of the area that happen all year around.

The landforms are characterized by characteristic physical attributes such as elevation, slope, orientation, stratification, and rock exposure and soil type. The highest elevation in the study area is around 600 m and the lowest is 80 m. The geomorphology of the study area can be observed at the most clearest view at 600 m hill at the northeast part.

The mountainous and hilly landform dominates the northern and the southern part of the research area. While, the plain areas dominate the centre, separating the northern and southern part. The plain areas are situated at the most ground level which are predominantly the area of deposition of alluvium consisting pebble, granule and sand. This area occupied with residential area and also used for vegetation due to near

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the water and the lower elevation. Description of the geomorphology are made based on the data obtain during observation in the field, in order to explain the conditions of the study area. Figure 4.4 shows the geomorphological landform of the research area.

Figure 4.4: Geomorphological landform of the study area.

4.2.1 Geomorphological Classification

Topography is study of surface features on the Earth's surface. The features are usually shown in a topographic map, characterized by using contour lines. Surface features such as mountains, valleys, plains and water bodies can be identified and classed using topography map. The common classification of surface features are based on the elevation and slopes.

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Table 4.1: Classification of Topographic units based on elevation (Van Zuidam R., 1985)

Topographic Unit	**Main Elevation Above Sea Level (m)**
Lowlands	< 50
Low hills	50-200
Hills	200-500
High hills	500-1000
Mountains	>1000

As shown in Figure 4.8, the study area is generally hilly and floodplain area which ranges 80-700 m above the sea level. This is according to the classification in Table 4.1.

a.) Flood plain landform

The flat area is referred as floodplain or the fluvial plain consisting of flat land that varies due by erosional and sedimentation process of the river.

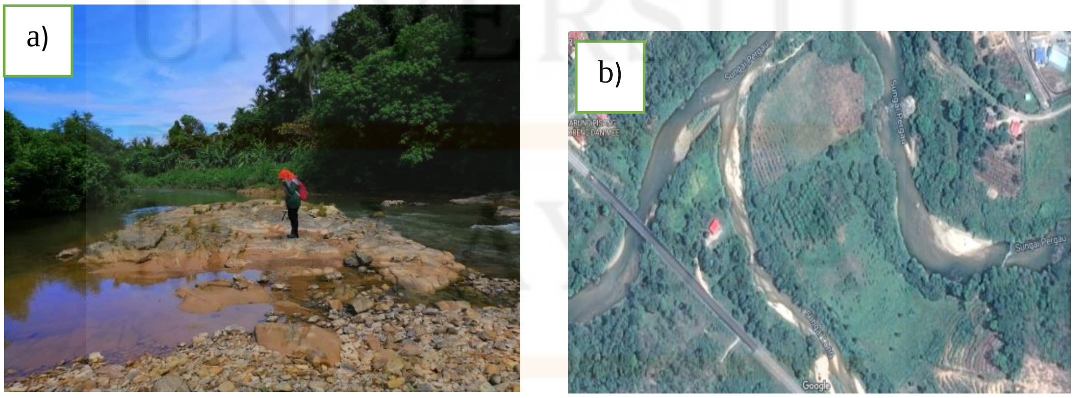

Figure 4.5: a) Floodplain areas., b) Meandering river.

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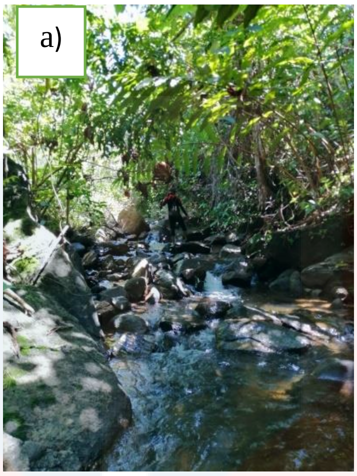

Figure 4.6: Steep fluvial areas or streams at the foothill of the hill.

The highest elevation is around 700 m in the north-eastern part. The study area are mainly vegetation area and reserved forest. From the contour pattern, concentric circle of contour indicates the hills. The close-spacing indicate steep slope while the wide spacing indicate gentle slopes. The V-shaped contour lines represent streams and valleys. Below are some topographic view that shows geomorphology features in the study area:

b) Hill landform

There is no mountain in the area as it does not achieve the qualified height. The highest peak in the area is only up to 700 metres. Hence, it is classified as a high hill. Hill is a very wide class that has been categorized according to their altitude, slope steepness and relief intensity. All of the three subclasses can be found in study area.

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a) First subclass

Defined by a series of ranges with rough profile. The elevation ranges from about 500 to 1000 m. Slopes are straight with steepness ranging from moderate to steep. Sharp crests and narrow V-shaped valleys are frequent.

b) Second subclass

Hills with large variety of slope steepness, length, shape and lithology. Elevation is moderate, around 500 m or more. Slope gradient is variable, ranging from moderate steep to sloping. Slopes were generally straight with rounded crests but the relief shape change very often according to the lithology. Sedimentary hills tend to be smooth relief rather than sharp crests shown by hills on the metamorphic and plutonic formation.

c) Last subclass

Hills are very smooth and gentle topography. Slope gradient (between 8-15%) and have low altitude. Shape and form is irregular, can be considered as undulating topography. The hills show broad rounded crests.

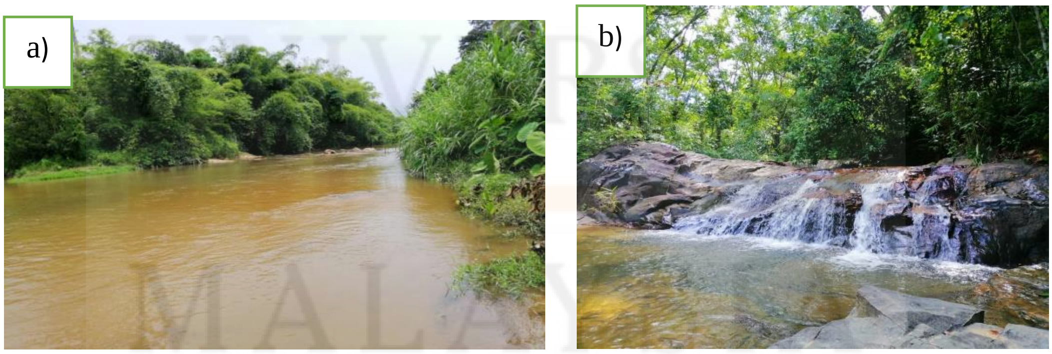

Figure 4.7: Hilly and floodplain area in study area

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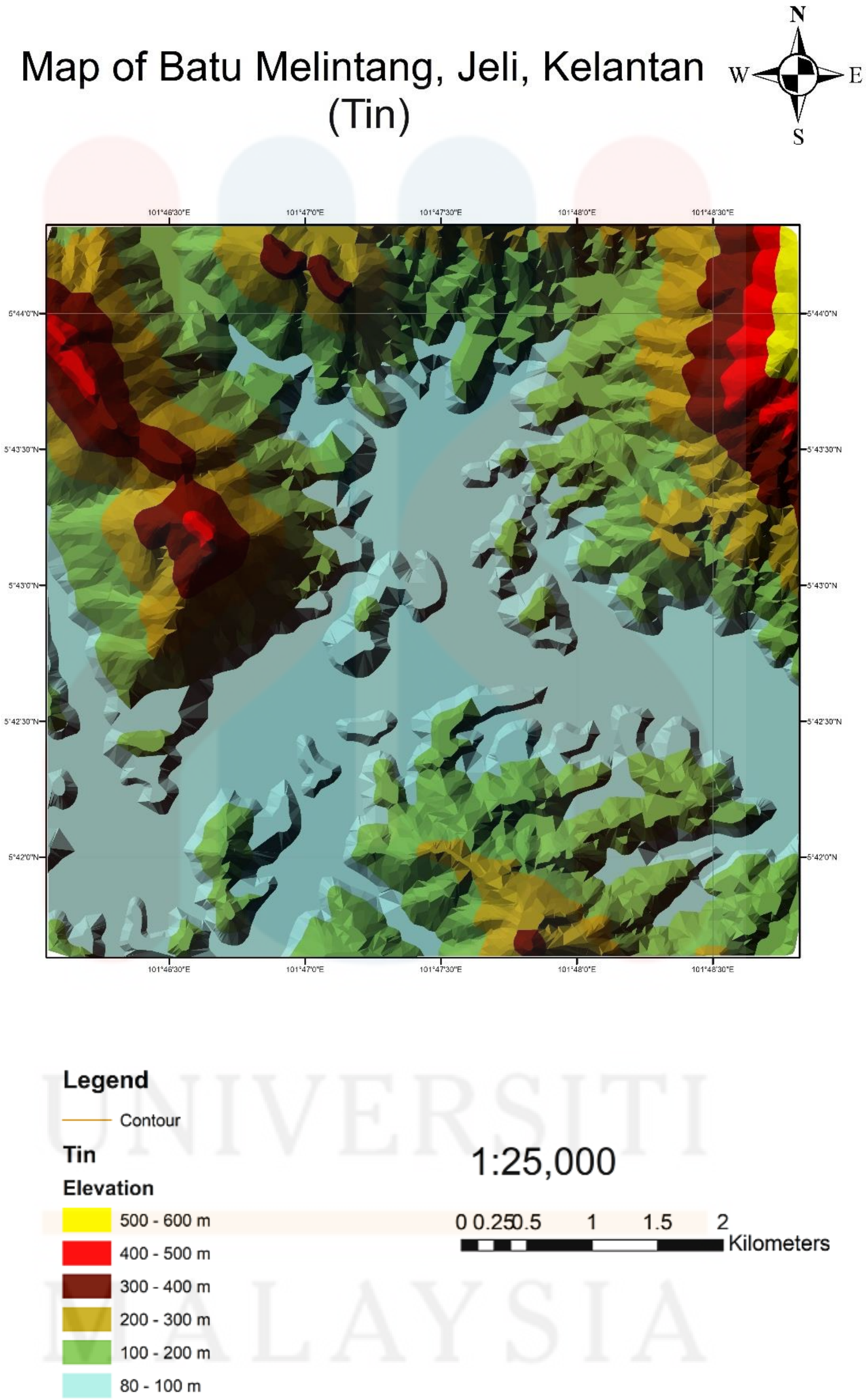

Figure 4.8: Tin map of the study area

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4.2.2 Drainage Pattern

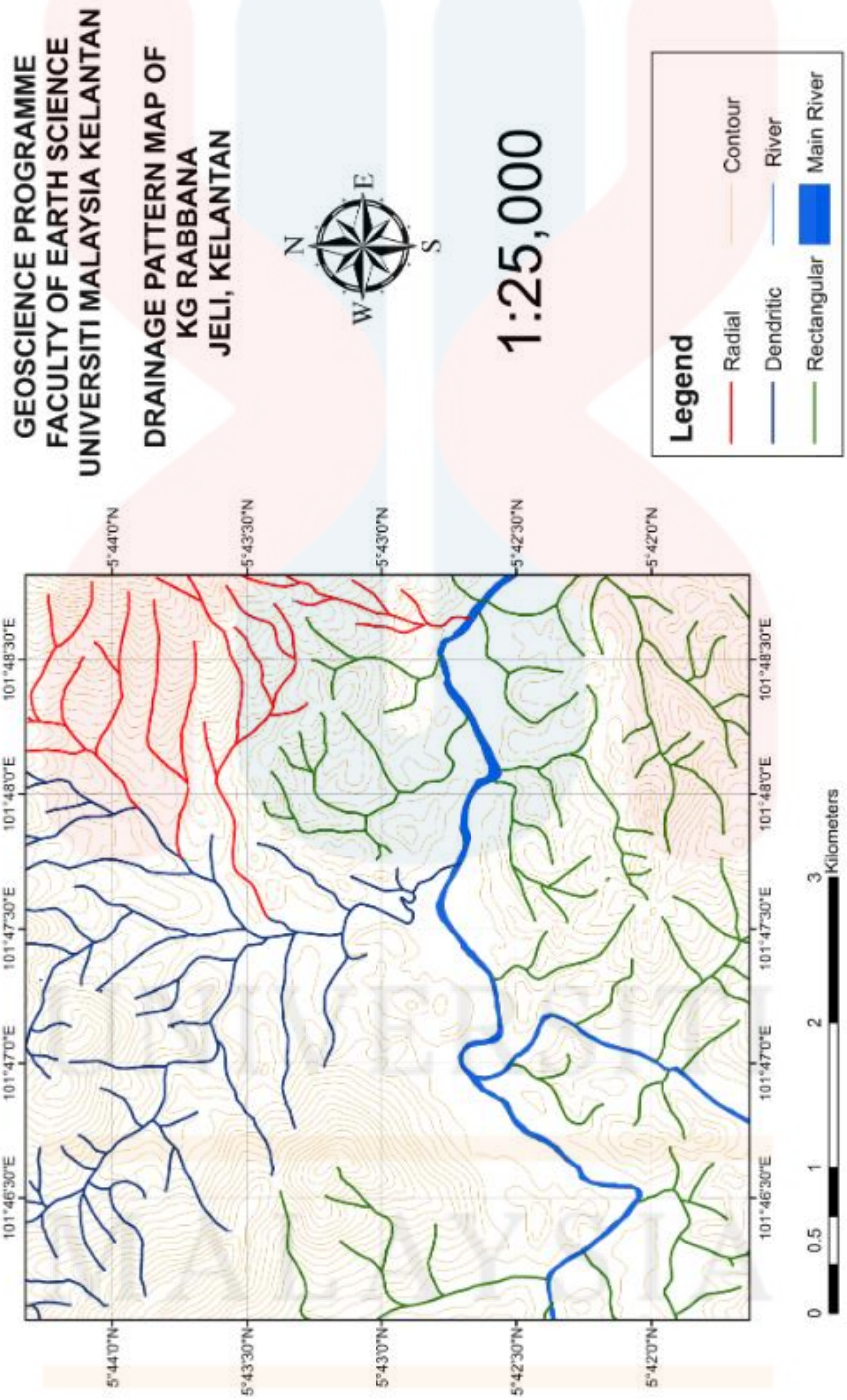

Figure 4.9: Drainage pattern of the study area

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The drainage pattern in the study area based on Figure 4.9 is a combination of dendritic, radial and rectangular. From the central peak of mountains or hills, streams radiates outwards. Once it reaches the fluvial plain, it forms branching networks (braided) of streams in a dendritic pattern before reaching the main river. Dendritic drainage pattern is usually forms in the area that consist of rock that cannot being easily eroded in all direction and it is also in the area that consist of homogenous lithology. Radial drainage pattern is usually form on the slope of mountain hill or a volcanic cone. Rectangular drainage pattern is when the main streams display right-angle bends and exhibit approximately the same length. It indicates prominent fault and joint systems that breaks the rock into rectangular blocks.

4.2.3 Weathering Process

Weathering processes and weathering rates differ from place to place. It is determine by factors like rock type, climate, topography and organisms. Climate is often the main mechanism that speeds up the rate biological, chemical and biological weathering. This is due to the presence temperature and rainfall condition. The type of climate in Malaysia according and classified its weathering patterns as allitization zone by Thomas, 1974. Allitization zone is a zone or surface area that have an intense leaching regime due to the humid tropics and is associated with tropical rainforest. This type of zone has the highest rates of weathering compared to other types of zone. Human activity also effects the weathering rates. Plantation and clearing the area for building and road.

Geomorphological agents such as water and air also contribute to the processes of weathering and erosion. These agents have ability and strength to transport Earth

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material by destruction and lead to the formation of landform in an area. Type of weathering such as chemical, mechanical and biological can be found scattered in the study area.

Physical weathering is a process where the agents such as water, wind, ice and temperature. This weathering will fasten the erosion process of a rock without changing its composition. In the study area, the main agent for physical weathering is water because most of the outcrop situated along or in the river. The movement of water in the river will erode the outcrop as the time increases. Besides, the continuous hit of water splash on the outcrop will produce joints and cracks.

Figure 4.10: Physical weathering at the research area

Chemical weathering is a process where the composition of rock alter due to chemical reactions caused by carbon dioxide, oxygen and other elements. Based on the study area, oxidation process was identified during geological mapping. This activity was formed when the iron in rock reacted with oxygen which causes rusty texture.

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Figure 4.11: Chemical weathering at the study area

Generally, biological weathering is mainly initiate by plants and animals. The roots plants can create cracks and break apart the rocks because of the pressure exerted by the roots. Animals such as microbial activity have ability to change the chemical alteration of rock and as time passes the rock will break apart. Some of the outcrop in the research area shows the indication of biological weathering because the outcrop was covered with bushes and trees.

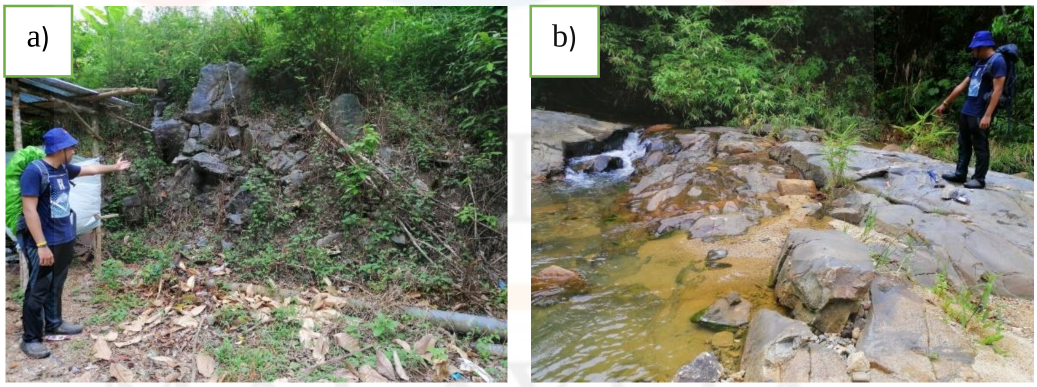

Figure 4.12: *a-b*) Weathering at the study area

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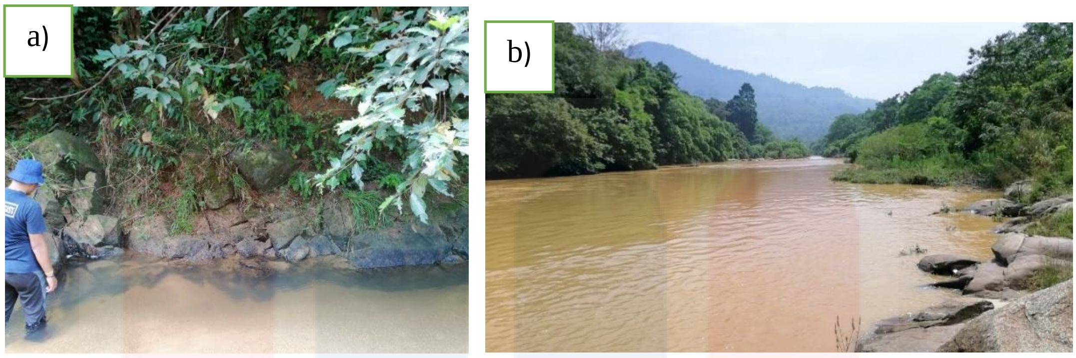

Figure 4.13: *a*) Biological and physical weathering at the study area
b) Physical, Biological and chemical weathering at the study area

Figure 4.14: Physical, Biological and chemical weathering at the study area

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4.3 Lithostratigraphy

Lithology is known as the study of the rock unit where the characteristics of the rock was elaborated by referring to the texture, colour, grain size and composition of a respective rock. Whereas, stratigraphy is the study of the rock arrangement based on the distribution, formation and chronological succession. Hence, lithostratigraphy combines both lithology and stratigraphy which means, the arrangement and relationship of the rock units were identified.

4.3.1 Lithology

There are 4 main type of rock units were determined in the study area which were schist, gneiss, amphibole and granite. The four types of rock units will be discussed further based on the petrography analysis.

a) Schist Unit

Figure 4.15: Schist a) Schist outcrop, b) Schist rock hand specimen

Table 4.1: Description of Schist

Sample Number: UI 16		**Location** : Along the river
Rock name: Schist		
Coordinate: N 5°43'55.71" E 101°47'47.53"		
Mineralogy Description		
Minerals	**Amount (%)**	**Description of Optical Mineralogy**
Quartz, Qtz	79	**PPL:** Anhedral to subhedral. Colourless, has low relief and possesses no pleochroism. Low relief without cleavage.
		XPL: Max interference is first order, colour white to grey. Have undulatory extinction and no twinning.
Feldspar, Fe	4	**PPL:** Bright colour. Has medium pleochroism.
		XPL: Colour varies from white to cloudy grey. Subhedral to euhedral. Albite Twinning.
Chlorite, Cl	6	**PPL:** Greenish-brown colour. Has medium relief and low to medium pleochroism.
		XPL: Greenish colour.
Biotite, Bi	10	**PPL:** Dark-brownish in colour, have medium to high relief and medium pleochroism.
		XPL: Colour varies from orange to brown. Have 1 cleavage. Subhedral.

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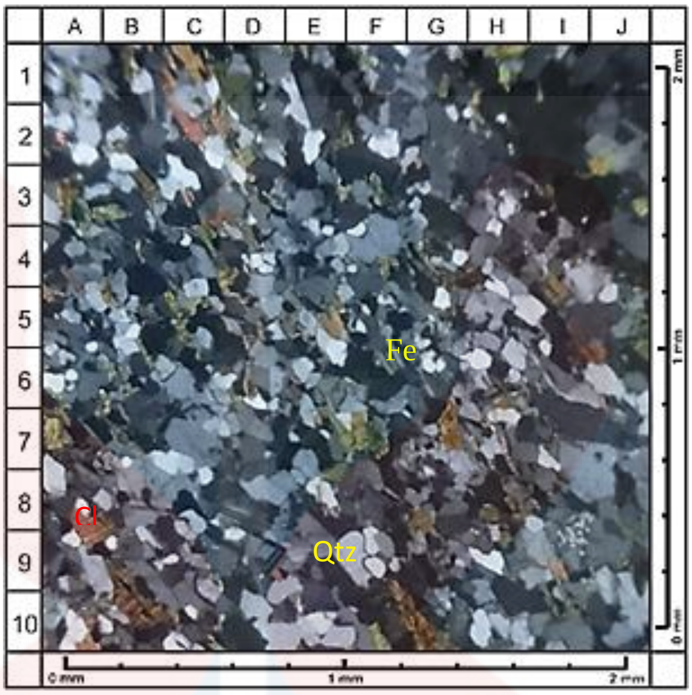

Figure 4.16 : UI 16 under XPL Microscope

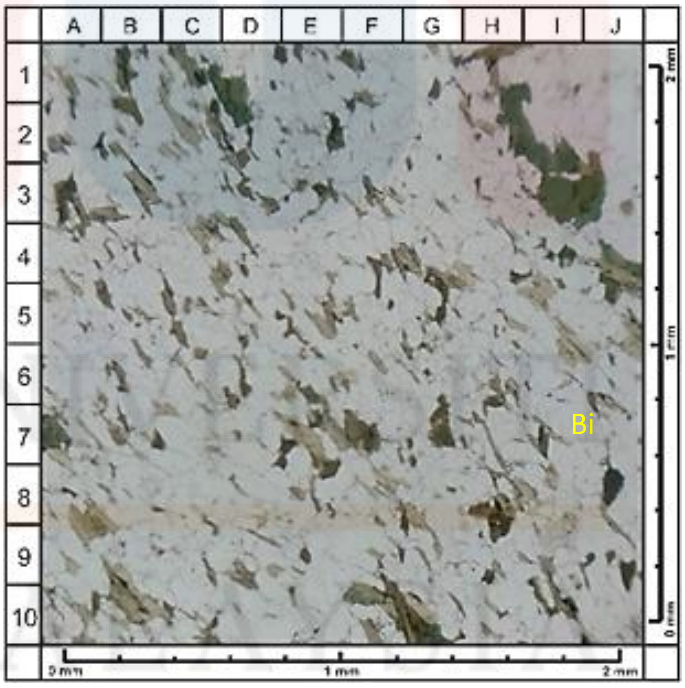

Figure 4.17 : UI 16 under PPL Microscope

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b) Gneiss Unit

Figure 4.18: Gneiss rock hand specimen

Table 4.2: Description of Gneiss

Sample Number: UI 20		**Location :** Along the river
Rock name: Gneiss		
Coordinate: N 5°42'22.16" E101°46'38.94"		
Mineralogy Description		
Minerals	**Amount (%)**	**Description of Optical Mineralogy**
Quartz, Qtz	5	**PPL:** Anhedral. White colour or colourless, has low relief and possesses no pleochroism. Low relief without cleavage.
		XPL: Max interference is first order, colour white to grey. Have undulatory extinction and no twinning.
Anorthoclase, An	48	**PPL:** Bright colour. Has medium pleochroism.
		XPL: Colour varies from pinkish to grey. Subhedral to euhedral. Albite Twinning.
Biotite, Bi	35	**PPL:** Dark brown colour. Medium to high relief. Medium pleochroism.
		XPL: Colour varies from orange to brown. Subhedral.

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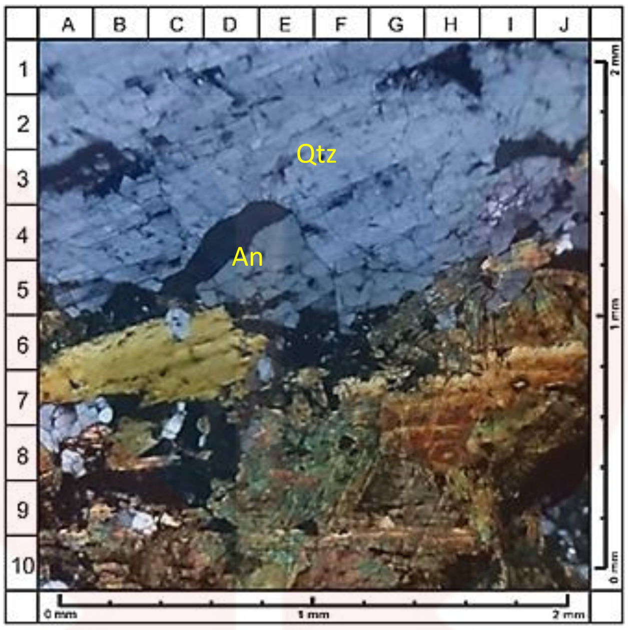

Figure 4.19 : UI 20 under XPL Microscope

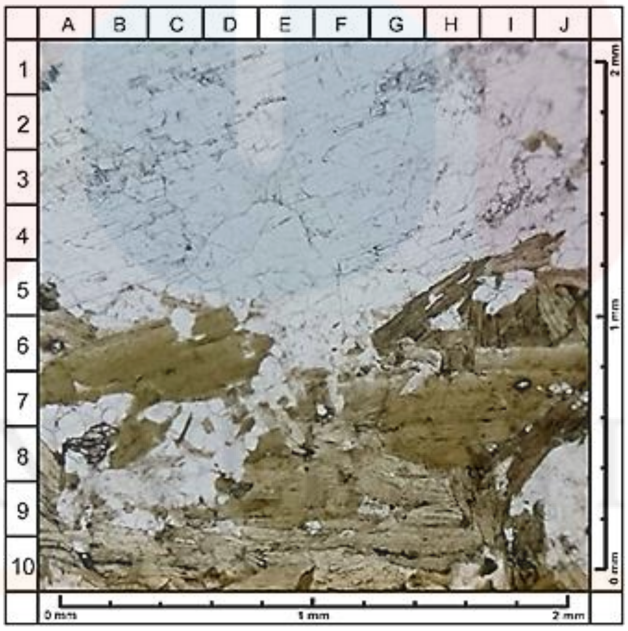

Figure 4.20 : UI 20 under PPL Microscope

C) Hornfels Unit

Figure 4.21: Hornfels rock hand specimen

Table 4.3: Description of Hornfels

Sample Number: UI 13		**Location :** Car Workshop
Rock name: Hornfels		
Coordinate: N 5°42'54.35" E 101°48'2.43"		
Mineralogy Description		
Minerals	**Amount (%)**	**Description of Optical Mineralogy**
Quartz, Qtz	76	**PPL:** Anhedral. White colour or colourless, has low relief and possesses no pleochroism. Low relief without cleavage.
		XPL: Max interference is first order, colour white to grey. Have undulatory extinction and no twinning.
Pyroxene, Py	8	**PPL:** Brighter shade of brown colour. Has good cleavage (2 direction). It has low relief and weak pleochroism.
		XPL: Colour varies from yellow, grey, brown, orange.
Chlorite, Cl	10	**PPL:** Greenish-brown colour. Has medium relief and weak to medium pleochroism.
		XPL: Greenish colour. Has 1 cleavage.

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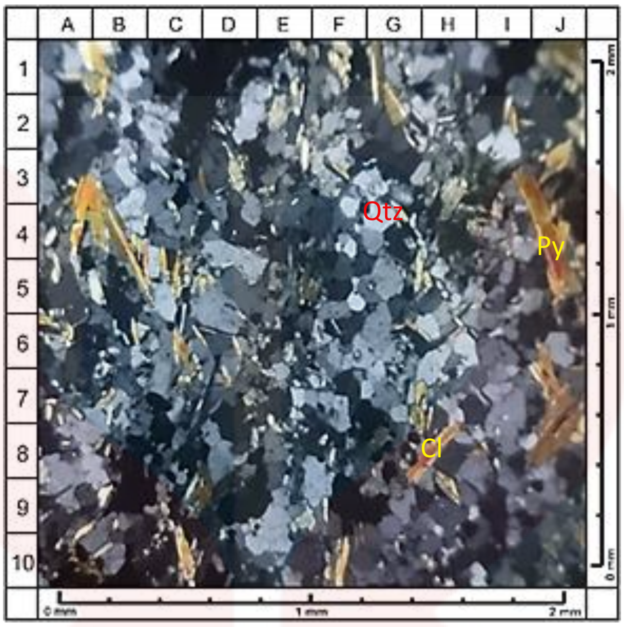

Figure 4.22: UI 13 under XPL Microscope

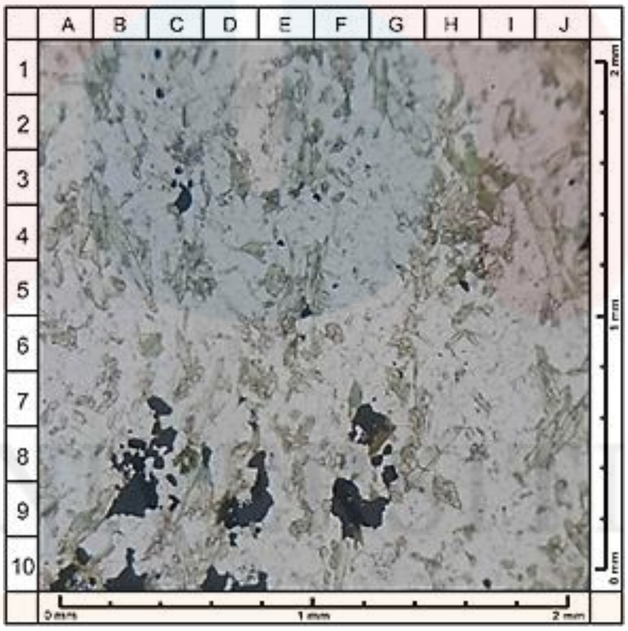

Figure 4.23: UI 13 under PPL Microscope

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d) Amphibolite/ Intermediate igneous rocks

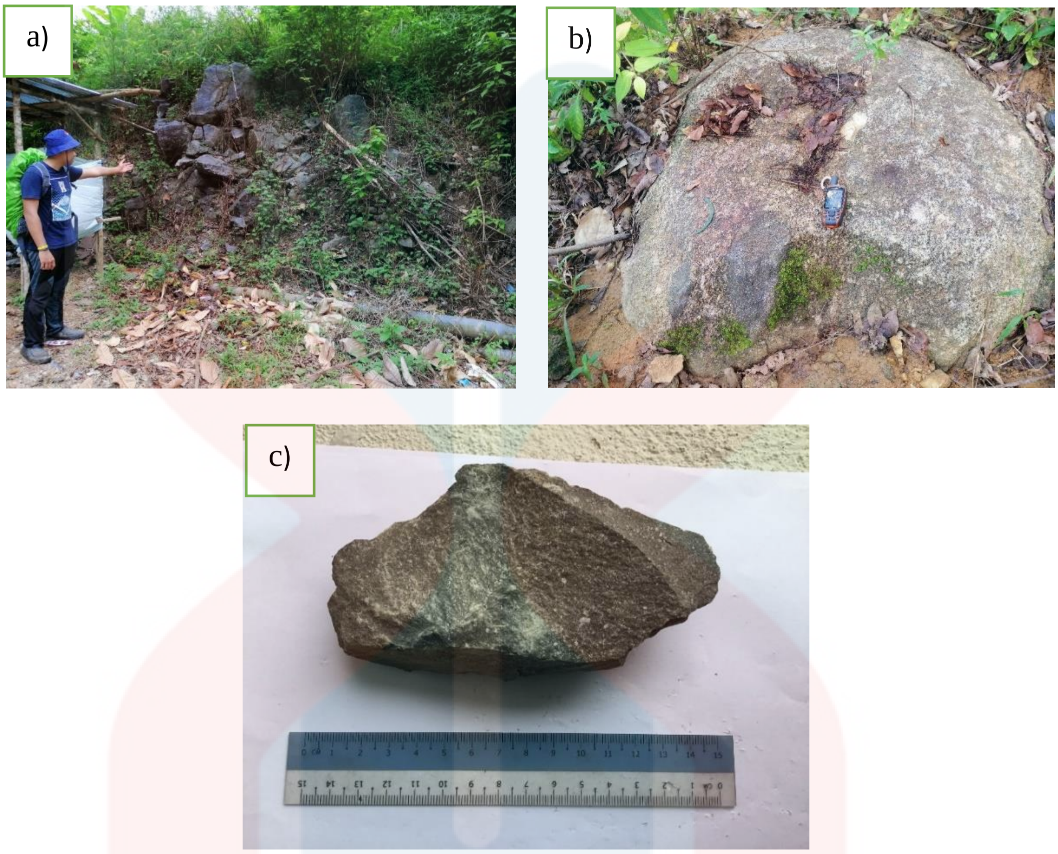

Figure 4.24: a) Amphibole outcrop b) Amphibole outcrop, c) Amphibole rock hand specimen

e) Granitoid rock Unit

1) Porphyritic granite (Coarse-grained foliated granite)

The observation of this type of rock that have been made in several localities in the study area, especially in the northern part. Large granite outcrops and boulders can be found scattered and near to each other in the mountainous area, covering up to 45 % of the study area. There is no sample being taken due to the condition of the granite itself that poorly exposed due to the deep weathering surface and dense vegetation.

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The observations that have been can be correlated with observations by the Malaysian Thai Worker. The porphyritic granite is light grey in colour and have medium to course- grained. Petrographic analysis done by the Malaysian Thai Workers shows the granite have groundmass composed of medium to coarse-grained quartz (20-35%), light grey to pale grey, euhedral to subhedral crystals, K-feldpsar (30-40%), chalky white, subhedral to euhedral plagioclase (15-20%) and dark grey to black, euhedral, biotite (15%). Meanwhile, accessory minerals that can be found are sphene, allanite, clinozoisite, monazite and apatite.

Figure 4.25 shows the large and dominant feldspar in the granite show definite orientation of N-S trending foliation especially near-ground level area or foothills area. The foliation of feldspar at the upper area or the top of the mountain is rather weak. The differences of the foliation by the granites show the lower part of the granites being the area of the major force of uplifting action or faulting mechanism due to igneous intrusion. Veins ranging in size of width from 5 to 10 cm were also commonly found in this type of rocks especially in the upper region with darker colour and finer grained compared to the porphyritic granite.

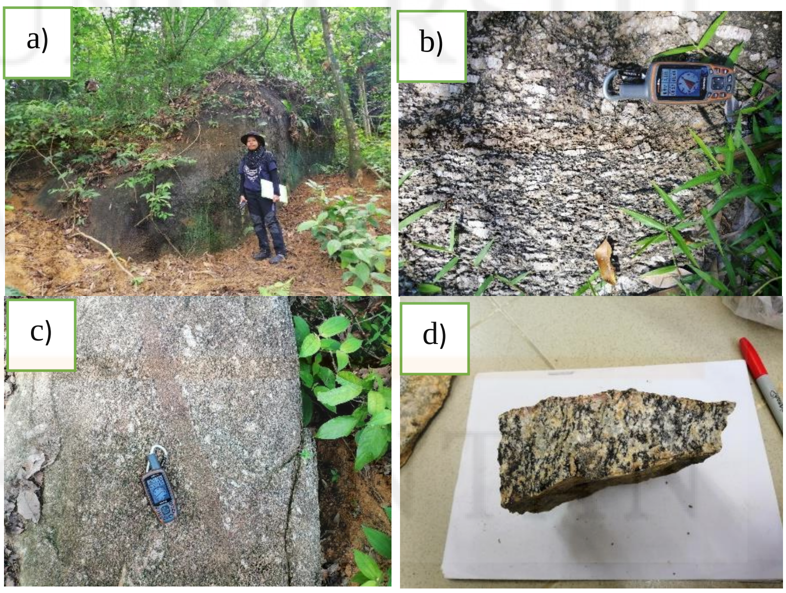

Figure 4.25: a-b) Porphyritic granite outcrop, c) Porphyritic granite outcrop, d) Porphyritic granite hand specimen

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2) Medium grained foliated granite

Figure 4.26: Granite rock hand specimen station UI15

Table 4.4: Description of UI15 granite

Sample Number: UI 15		**Location :** Kg. Rabbana, Jeli, Kelantan
Rock name: Granulite		
Coordinate: N 5°43'18.99" E101°47'25.12"		
Mineralogy Description		
Minerals	**Amount (%)**	**Description of Optical Mineralogy**
Quartz, Qtz	38	**PPL:** Anhedral. White colour or colourless, has low relief and possesses no pleochroism. Low relief without cleavage.
		XPL: Max interference is first order, colour white to grey. Have undulatory extinction and no twinning.
Feldspar, Fe	7	**PPL:** Bright colour. Has 1 direction cleavage. It has medium pleochroism. Subhedral to euhedral crystal shape.
		XPL: Colour varies from pinkish to grey. Albite twinning.
Chlorite, Cl	4	PPL: Greenish-brown colour. Has medium relief and weak to medium pleochroism.
		XPL: Greenish colour. Has 1 cleavage.
Biotite, Bi	6	**PPL:** Dark brownish colour. High relief to medium relief. Medium pleochroism. Subhedral crystal habit.
		XPL: Varies from orange to brown.

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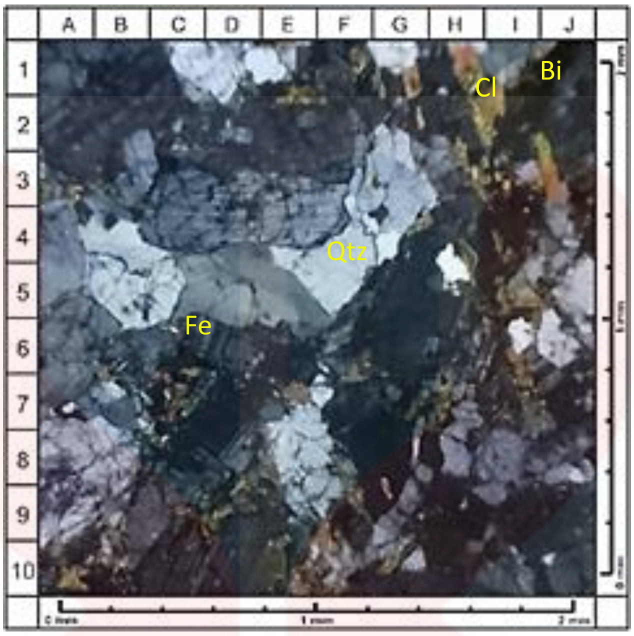

Figure 4.27: UI 15 under XPL Microscope

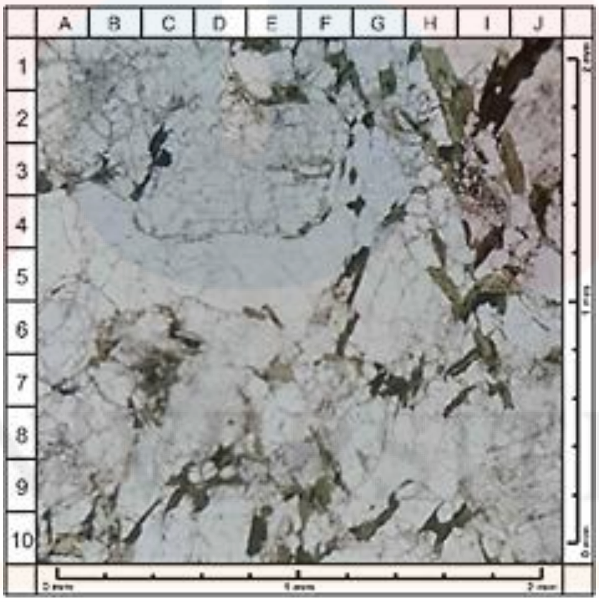

Figure 4.28: UI 15 under PPL Microscope

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3) Quartz-rich granitoid UI 12

Figure 4.29: Granite rock hand specimen station UI12

Table 4.5: Description of UI12 granite

Sample Number: UI 12		**Location :** Long River
Rock name: Quartz-rich granitoid		
Coordinate: N 5°41'39.80", E 101°46'48.08"		
Mineralogy Description		
Minerals	Amount (%)	Description of Optical Mineralogy
Quartz, Qtz	71	PPL: Anhedral. White colour or colourless, has low relief and possesses no pleochroism. Low relief without cleavage.
		XPL: Max interference is first order, colour white to grey. Have undulatory extinction and no twinning.
Orthoclase, Ort	7	PPL: Bright colour. Has l direction cleavage. It has low to medium pleochroism. Subhedral to euhedral crystal shape.
		XPL: Colour varies from pinkish to grey. It shows no twinning.
Chlorite, Cl	5	PPL: Greenish-brown colour. Has medium relief and weak to medium pleochroism.
		XPL: Greenish colour. Has 1 cleavage.

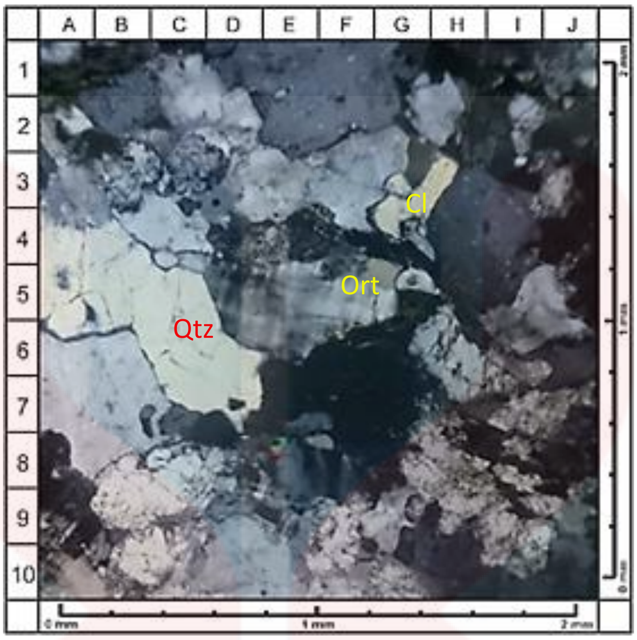

Figure 30: UI 12 under XPL Microscope

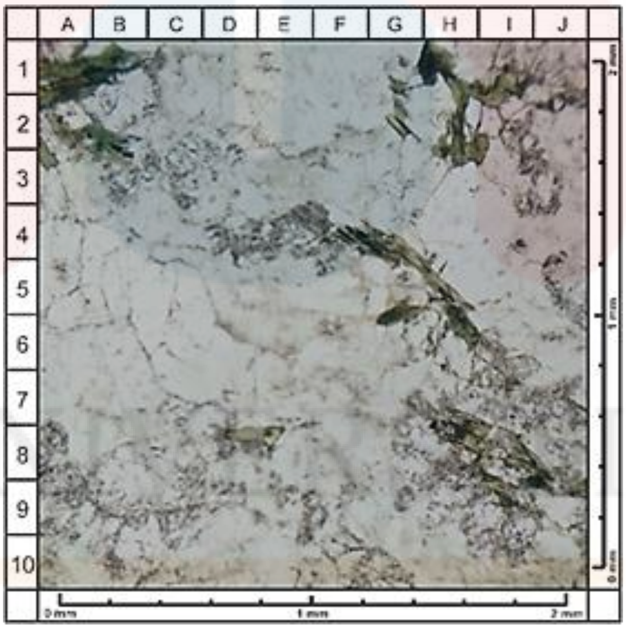

Figure 4.31: UI 12 under PPL Microscope

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4.3.2 **Stratigraphic Position**

Lithostratigraphic column of the study area is shown in Table 4.6.

Table 4.6: Lithostratigraphic column

Era	Period	Rock Unit	Description
Cenozoic	Quaternary	Alluvium	Pebble, granule, sand, silt, slay and detritus sediments in river.
Mesozoic	Triassic	Schist	Mostly found at northwest part of the study area.
		Gneiss	Exposed at the central part.
		Amphibolite	
		Granites	Dominantly can be found in the study area. Poor differentiation of granite.

Figure 4.32 shows the geological map of study area. The boundary of the igneous rock is rather difficult as the type of igneous rock was poorly differentiated. The layer of Permian rocks as limestone or other sedimentary rocks cannot be seen in the study area due to high degree of weathering and faulting event that makes the granitic rocks exposed in the surface.

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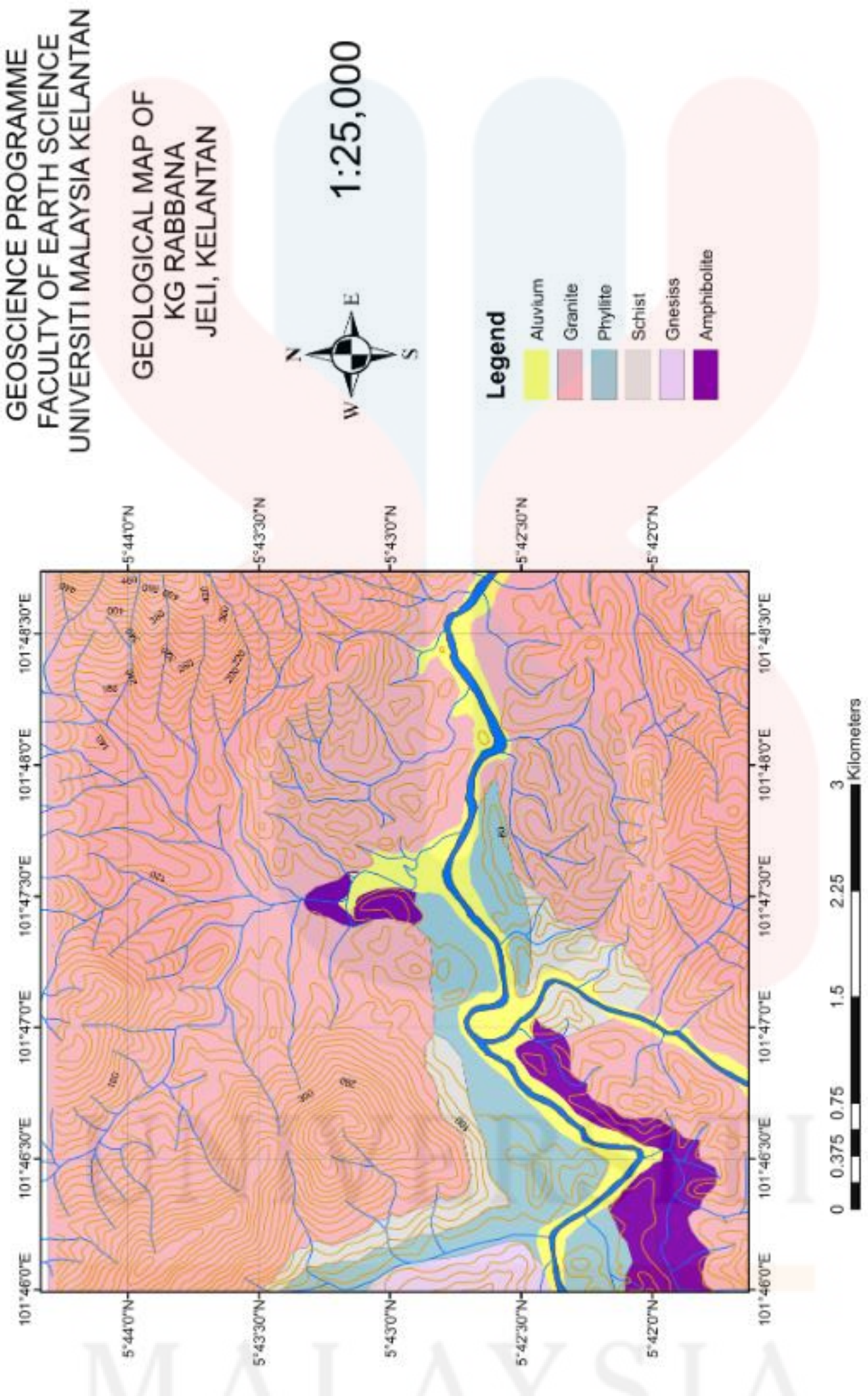

Figure 4.32: Geological Map of Kampung Rabbana, Jeli, Kelantan

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4.4 Structural Geology

4.4.1 Lineament Analysis

There are less to none sedimentary formation in the study area. This is because the formation of the sedimentary rock are already weathered leaving the more resistant type of rock which is igneous rock. The only structural features that present were joints and foliation. Joints and veins can be found in almost every type of igneous rock, while foliation can be seen by the formation of schist and gneiss.

Lineament is straight line features that can be seen clearly at large scale on the Earth's surface (Ibrahim and Juhari, 1990). The linear features can be seen clearly from the satellite imagery. Terrain map shows the ridges and valleys. Figure 4.33 shows the lineament from the terrain map from Google Earth. The line features show dominantly the direction towards N-S and NE – WS. The lineaments are due to the movement of the crust or tectonic due to the granitic intrusion.

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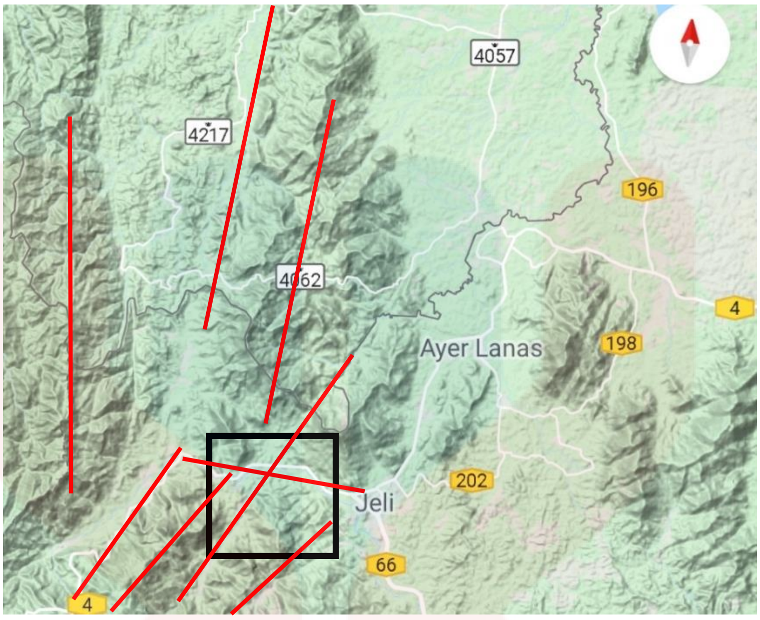

Figure 4.33: Lineament map in the study area

4.4.2 Structural geology of study area

- Principle of cross cutting

As the study area only shows magmatic deformation and formation it is impossible to see fossils. Age dating is also impossible as it is very costly. Picture shows the veins that has been displace due to tectonic.

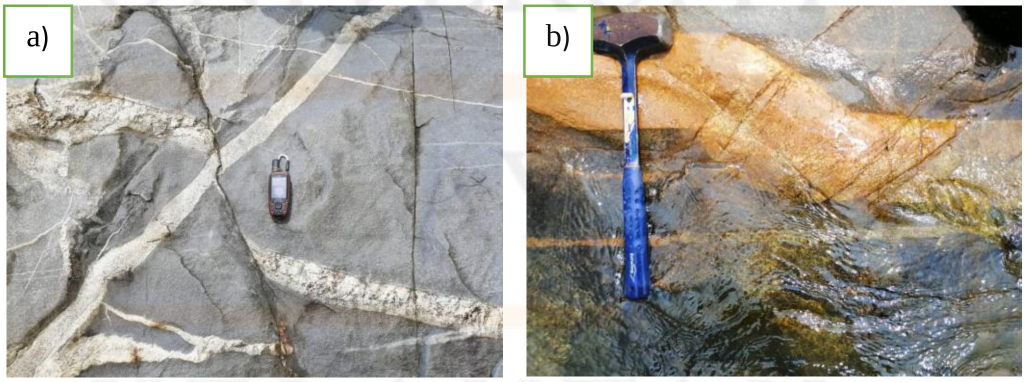

Figure 4.34: a) Vein in the study area, b) Dyke in the study area

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Vein structure in the study area shows the brittle deformation of the host rock due to tectonic force. Formation of cracks, making quartz veins deposited filling the gap. Interconnected veins are due to the repetitive faulting that took place in the area. Dyke structure shows the movement of rock due to tremendous pressure and heat, intrudes the host rock.

- Contact

Contact between medium grained foliated granite (MFBG) and grey microgranite (GM). The contact between both rocks is characterized having irregular outline, suggesting that the magmas are synplutonic. Synplutonic is mutually intrusive relations suggesting both magmas intrude coarse grained foliated biotite granite (CFBG) at about the same time. The different rocks texture indicate that the magmas intruded at different viscosity.

Figure 4.35: Contact between medium grained foliated granite (MFBG) and grey microgranite (GM) in the study area

Traditionally, tectonic (or geotectonic) forces divide into two group which are diastrophic forces and volcanic and plutonic forces. Diastrophic forces lead to the folding, faulting, uplift, and subsidence of the lithosphere. Volcanic forces lead to the extrusion of magma on to the Earth’s surface as lava and to minor intrusions (e.g.

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dykes and sills) into other rocks. Plutonic forces, which originate deep in the Earth, produce major intrusions (plutons) and associated veins.

Figure 4.36: Dyke identified in the study area

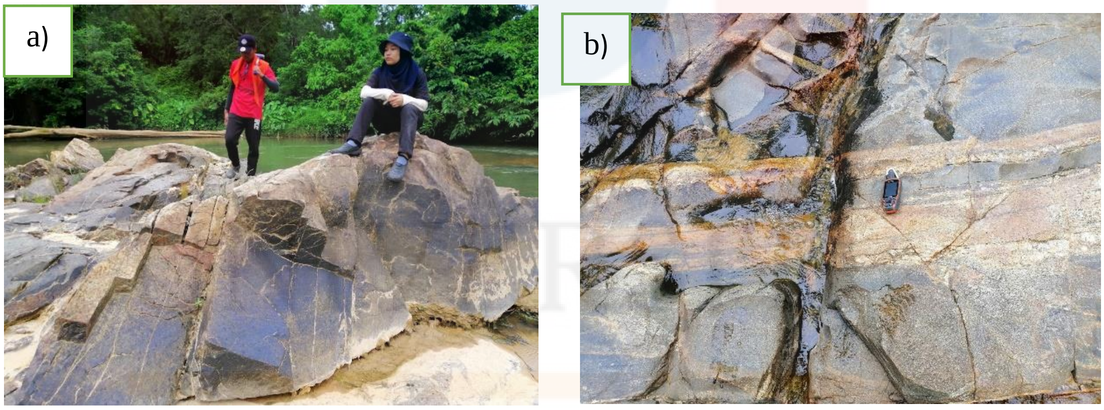

Figure 4.37: a) Dyke identified in the study area b) Dyke founded in the study area

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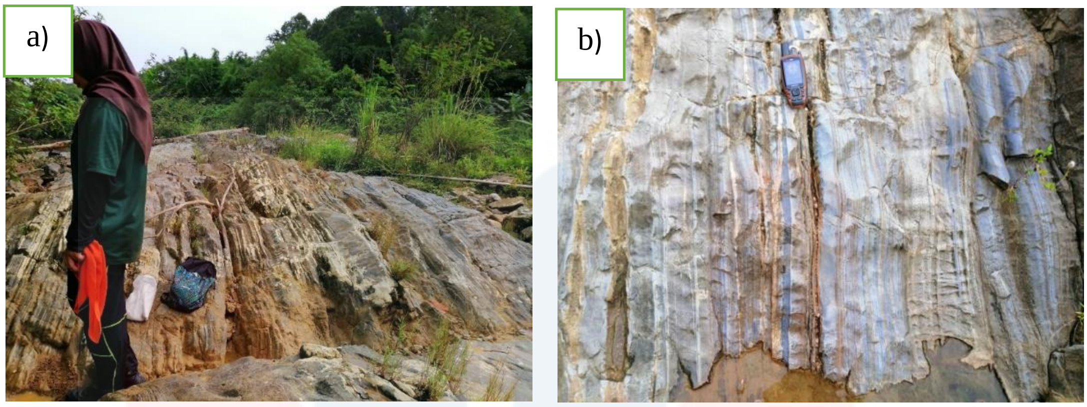

Figure 4.38: a) Phyllitic shale in the study area, b) siltstone and mudstone in the study area

4.4.3 Joint Analysis

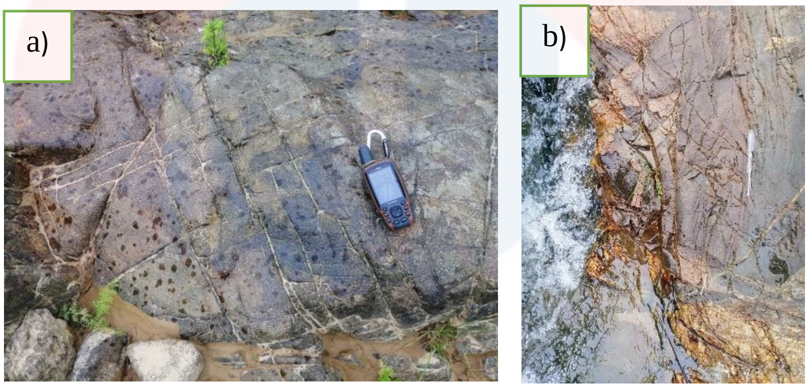

Figure 4.39: a) Systematic joints in the study area, b) Breccia in the study area

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Joint Analysis 1

Location: N 05 42 48.3E 101 45 40.9

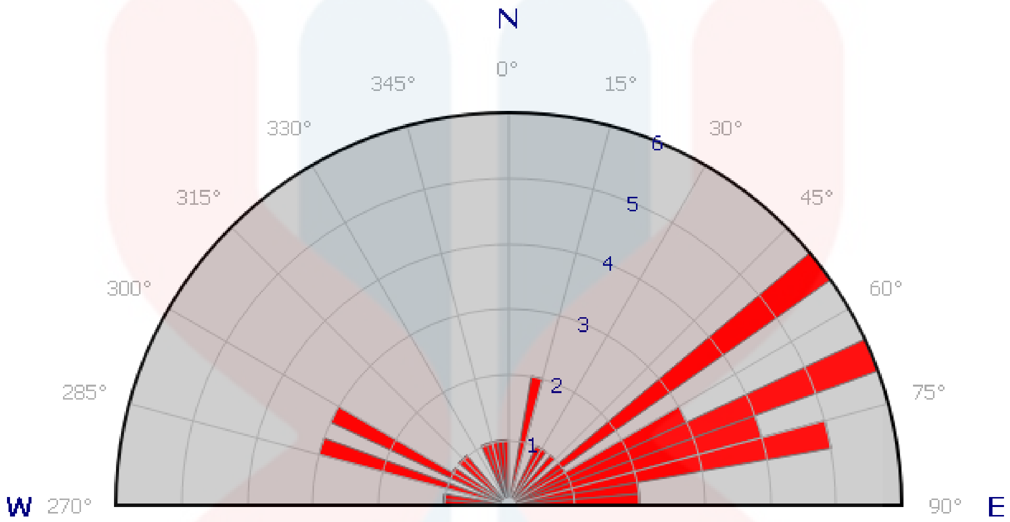

Figure 4.40: Rose diagram of joint analysis 1

Joint Analysis 2

Location: N 05° 42’ 34.8” E 101° 47’ 03.6”

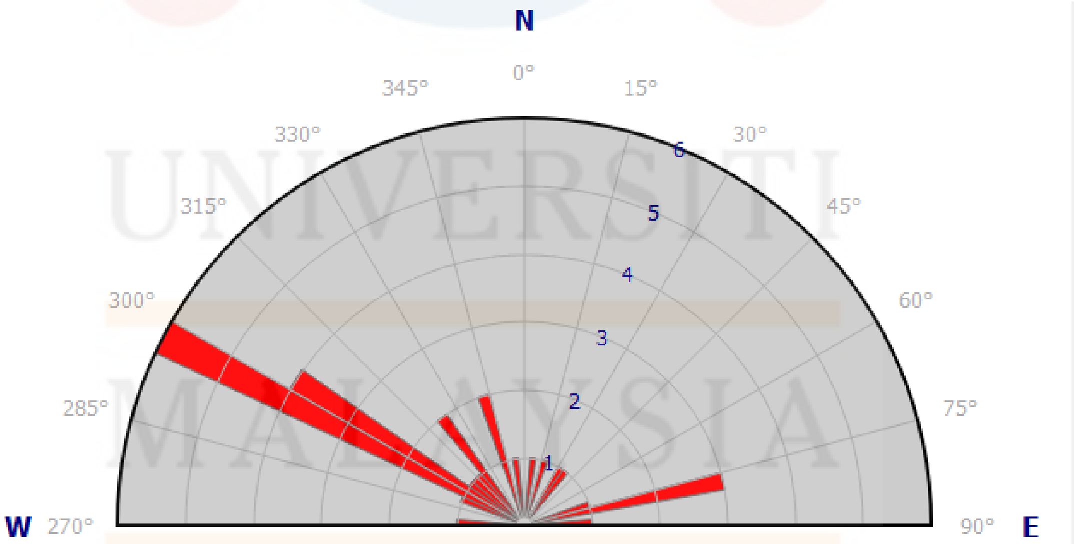

Figure 4.31: Rose diagram of joint analysis 2

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Joint Analysis 3

Location: (N 05^{0} 41' 38.5", E 101^{0} 47' 01.3")

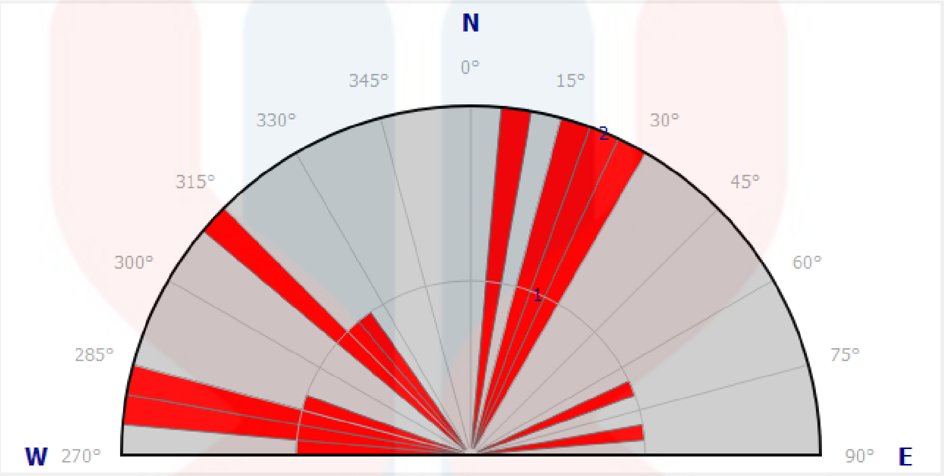

Figure 4.32: Rose diagram of joint analysis 3

Table 4.7: Dip and strike reading of Joint Analysis 1

No.	Strike/Dip
1.	$115^{0}/63^{0}$
2.	$116^{0}/69^{0}$
3.	$232^{0}/69^{0}$
4.	$72^{0}/75^{0}$
5.	$142^{0}/81^{0}$
6.	$254^{0}/80^{0}$
7.	$167^{0}/69^{0}$
8.	$271^{0}/85^{0}$
9.	$301^{0}/68^{0}$
10.	$120^{0}/58^{0}$
11.	$64^{0}/77^{0}$
12.	$51^{0}/320^{0}$
13.	$304^{0}/87^{0}$

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Table 4.8: Dip and strike reading of Joint Analysis 3

No.	Strike/ Dip
1.	278°/87°
2.	93°/59°
3.	16°/71°
4.	284°/70°
5.	281°/66°
6.	7°/73°
7.	186°/6°
8.	27°/71°
9.	278°/210°
10.	314°/25°
11.	20°/85°
12.	28°/78°
13.	130°/72°
14.	320°/88°
15.	285°/72°
16.	135°/74°
17.	80°/72°

4.5 Historical Geology Strike/Dip

More differentiated, intermediate-to-felsic magmas, on the other hand, are partly derived from the melting of continental crust by hot, mafic magmas that either pond at the crust-mantle boundary, or intrude into the overlying continents where they reside in magma chambers located at various crustal levels.

Firstly, marine sedimentation took place continuously throughout the Paleozoic and Early Mesozoic Eras. Shows by the marble (from limestones) and interbedded shales and sandstones (MT-JGSC, 2006). (Mahang Formation). Next, massive batholith or plume happens in the subsurface due to subduction by Bentong-Raub Suture. The force pushes the crust upward forming andesitic volcanic arc. Due to formation of andesitic mountains, it creates cracks and fractures allowing felsic magma to intrudes and resurface together with the andesite. This shows by synplutonic structure, magma mixing and contact between felsic and intermediate

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rocks. Shales and sandstones now have become metamorphed. Gneiss rock formed due to the contact between the sedimentary rock and heat and pressure from the extrusive igneous rock.

More subduction happens at Bentong Raub Suture, possibly may contributes different types of intrusion with different types of composition. This can be seen by the different types of igneous rock in the study area. This is cause by the partial melting, magma mixing with contact of the extrusive igneous rock. There are varieties of grain size, may due to the different cooling time as it is exposed to the surface. After andesitic surface cools, there are series of faulting events that creates gap between batholiths. This shows by the rift valley created called Sungai Kolok and Sungai Long. This mechanism called as pull apart basin or strike slip faults. This are shown by the dykes and veins intruding the intermediate rock.

During the Quaternary, unconsolidated sediments that were deposited in the valley or river, characterised by silty clay, sand and gravel (MT-JGSC, 2006). The felsic massive grained granite are exposed at the surface and can be find at almost every hills due to extreme erosion and weathering of the hills. This is because andesitic layer can no longer be seen on top of the mountains. They can only be seen at the bottom of the hills and at the valley.

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CHAPTER 5

GRANITIC ROCK ANALYSIS IN KAMPUNG RABBANA, JELI, KELANTAN

5.1 Introduction

This chapter will be discussing on the granite that present in the study area using XRF and ICP-OES analysis. X-ray Fluorescent (XRF) is the method used to interpret the distribution of element of solid samples such as rocks. Meanwhile, Inductively Coupled Plasma Atomic Emission Spectroscopic (ICP-OES) is used to determine the existence of elements in rocks. The two analysis was conducted in order to identify the chemical composition and type of granite.

5.2 Sample Description

The study area was covered mainly with granitic rock. Besides, there were also gneiss which might form because of metamorphism of granite. Presence of grain microgranite shows very fine aphinitic texture. This texture result from rapid cooling in volcanic and hypabyssal environment. The granitic rock was varied in term of grain size, colour and matrix. The differences may formed due to the formation of rock, interaction of rock and magma as well as weathering. During geological mapping, the granitic rocks was collected for sampling process. The sample were selected based on the region or location of the rock.

i. NAN S01

The coordinate of the outcrop was at N 5°41’36.9”, E 101°46’44.42”. The horizontal outcrop was found near the Long River and there was a contact of mafic igneous rock. The outcrop was black in colour meanwhile, the rock was white to grey. The differences in colour was occurred due to weathering. The rock was highly fractured because of physical weathering that caused by the river. The igneous texture of the rock is phaneritic which means the minerals can be seen via naked eye. The grain size was identified as medium grain. There were several structures found such as felsic coarse grain or quartz dyke and joint.

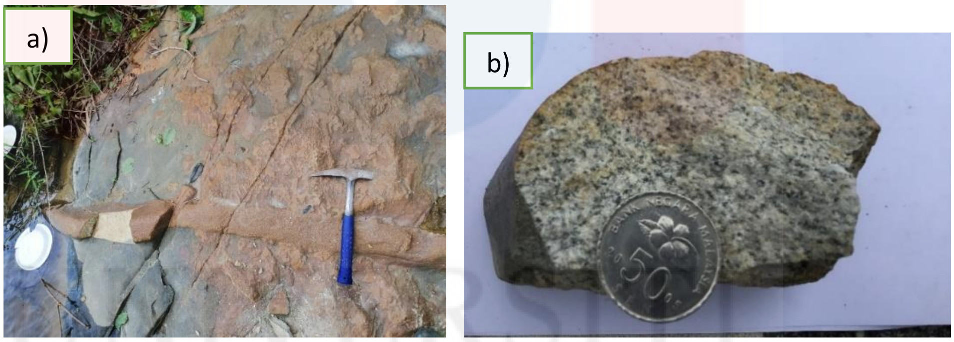

Figure 5.1: a) Outcrop of (mix of mafic and felsic granite at NAN S01
b) Sample of felsic medium-grained granite

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ii. NAN S02

The coordinate of the outcrop was at 5°43’27.82”, N101°47’4.39”E. The location was identified in the base of river. The outcrop laid laterally on the ground. The colour of the outrop is light brown to orange. There is contact between the coarse-grained and felsic igneous rock. The rock was affected by the weathering process mainly physical weathering. The sample was displayed in white and black colour in porphyritic texture. Porphyritic texture is a texture with two or more distant sizes of grain. The structure that can be seen is felsic dyke intrude the outcrop.

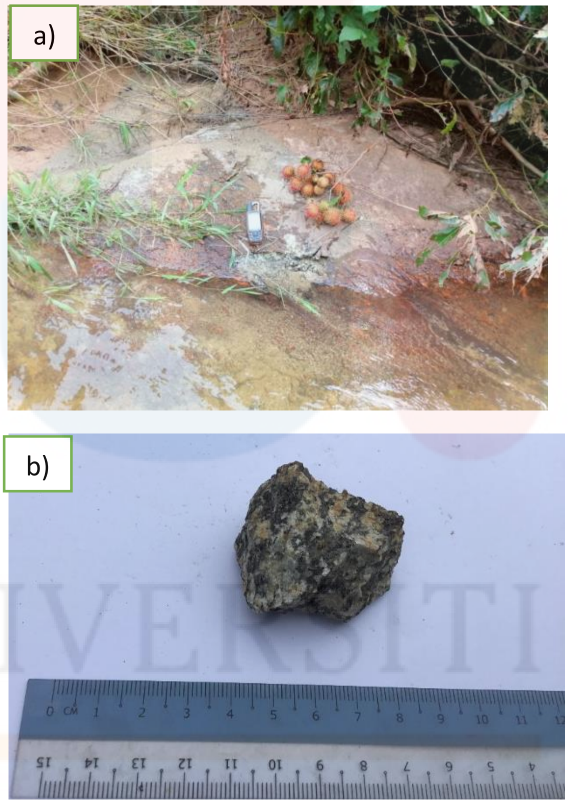

Figure 5.2: a) Outcrop of porphyritic granite at NAN S02
b) Sample of porphyritic granite

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iii. NAN S03

This outcrop was placed at the edge of the river. To be exact, the coordinate of the outcrop was at N 05°42'43.97”, E 101°48'26.89". It s a large horizontal outcrop and the dimension of the outrop was approximately 10m. Based on observation, the colour of the outcrop was grey, howevr the rock sample was light grey in colour. This happens due to weathering process and more accurately because of physical weathering. The outcrop laid laterally on the ground. There is massive quartz dyke intrude the outrcop. The sample has phaneritic texture and it is medium coarse-grained. Exfoliation joint was identified at the top layer of the structure. The structure form because of the surface parallel-fracture system.

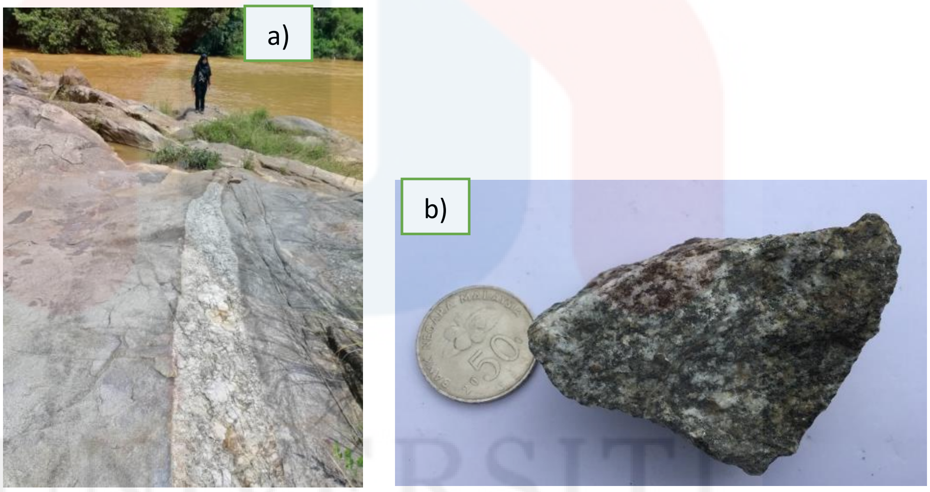

Figure 5.3: a) Outcrop of porphyritic granite at NAN S03

b) Sample of porphyritic granite

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iv. NAN S04

This outcrop was placed in the river. The coordinate of the outcrop was N 5°42'59.60" E 101°47'32.23”. Part of the outcrop is not submerged and the other part is fully submerged in water. The outcrop appear to be horizontal and the dimension of the visible outrop was approximately 5 m. . The sample has porphyritic texture and it is coarse-grained. The colour of sample is the dark grey in colour. Biotite minerals or mafic minerals appear to be dominant in the sample. Physical weathering happens sue to the present of water.

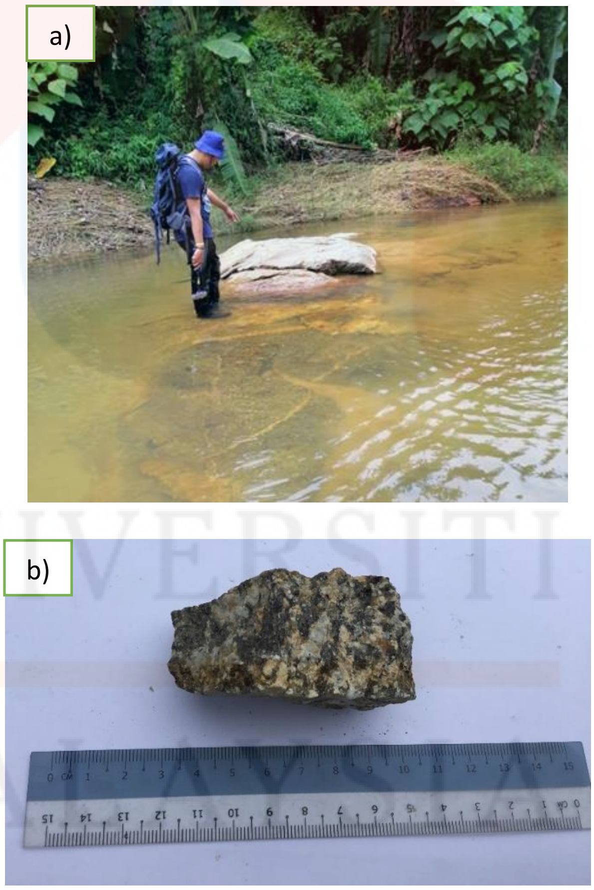

Figure 5.4: a) Outcrop of porphyritic granite at NAN S04

b) Sample of porphyritic granite

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v. NAN S05

This outcrop was placed in the river. The coordinate of the outcrop was N 5°43'2.83, E 101°48'18.7. The outcrop is exposed at one of the hill area. The outcrop undergone biological weathering and physical weathering. The outcrop appear to be was approximately 2m in height. The sample has porphyritic texture and it is coarse-grained. The colour of sample is the felsic or white in colour. Quartz minerals tend to be the deminant with minor mafic minerals.

Figure 5.5: a) Outcrop of porphyritic granite at NAN S05

b) Sample of porphyritic granite

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5.3 Major elements

Table 5.1 display the product of the major elements in five granitiod rock samples that have been collected during geological mapping. 3 of the samples which were sample 2, 3, and 4 were labelled as greyish biotite granite. Meanwhile, rock sample 2 and 5 were classified as felsic medium to coarse-grained granite. Out of 19 major elements, only five major elements was interpreted from XRF analysis. Approximately the major element were being normalized to 100%, before the geochemical analysis was plotted. The Harker diagram is constructed to produce elements with percentage (wt%) vs the Si02 major elements wt% . The reason constructing this diagram is to analyse the granitoid's fractionation of the elements strength.

Table 5.1: Major elements normalized to 100%

Granitic Rock	Major elements normalized to 100% (wt %)							Total (wt %)
	SiO_2	TiO_2	Fe_2O_3	MnO	CaO	K_2O	Na_2O	
NAN S01	71.000	0.170	1.240	0.000	1.960	12.500	1.1	100.000
NAN S02	65.800	0.670	4.730	0.180	5.310	7.180	1.12	100.000
NAN S03	62.400	1.100	5.230	0.150	4.110	10.200	1.52	100.000
NAN S04	62.400	1.120	5.740	0.190	3.690	9.860	1.42	100.000
NAN S05	71.100	0.000	0.260	0.000	0.870	15.400	0.99	100.000

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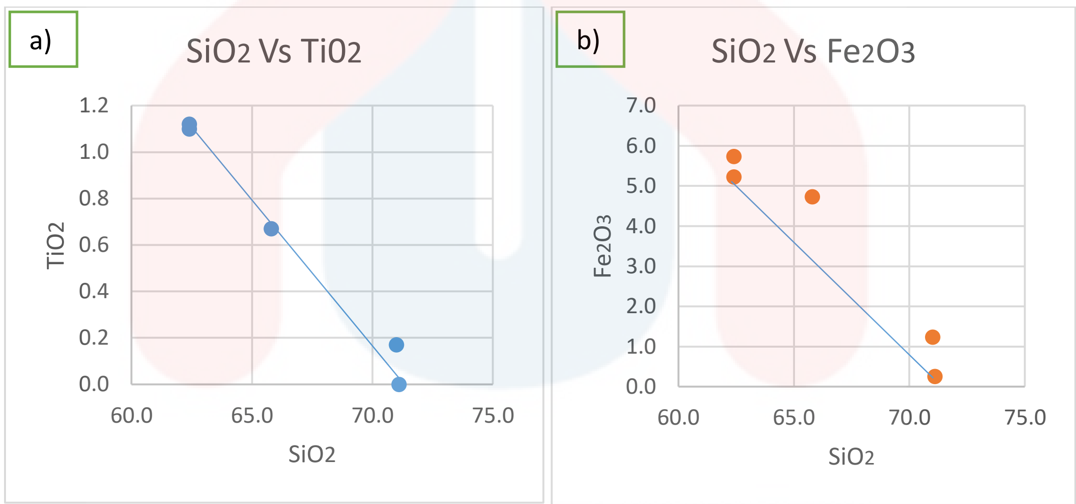
Based on the Harker Diagram in Figure 5.6, all the major elements projected the fractionation trend in the form of linear trends. The outcome that can be interpreted were the elements fractionation trend decreases as the SiO_2 increases. The rocks can be classified as felsic due to the high content of SiO_2 which range from 62.400 wt % to 71.000 wt %. The composition TiO_2 and MnO is less than 0.5 wt % in the granitic rocks sample. Fe_2O_3 and CaO were moderately high which range from 0.260 wt % to 5.740 wt % as well as CaO from 0.870 wt % to 5.310 wt %. Furthermore, K2O shows higher wt % with 15.400 in NAN S05 granitic rock. While, Na2O shows higher 1.52 wt % in NAN S03 granitic sample.



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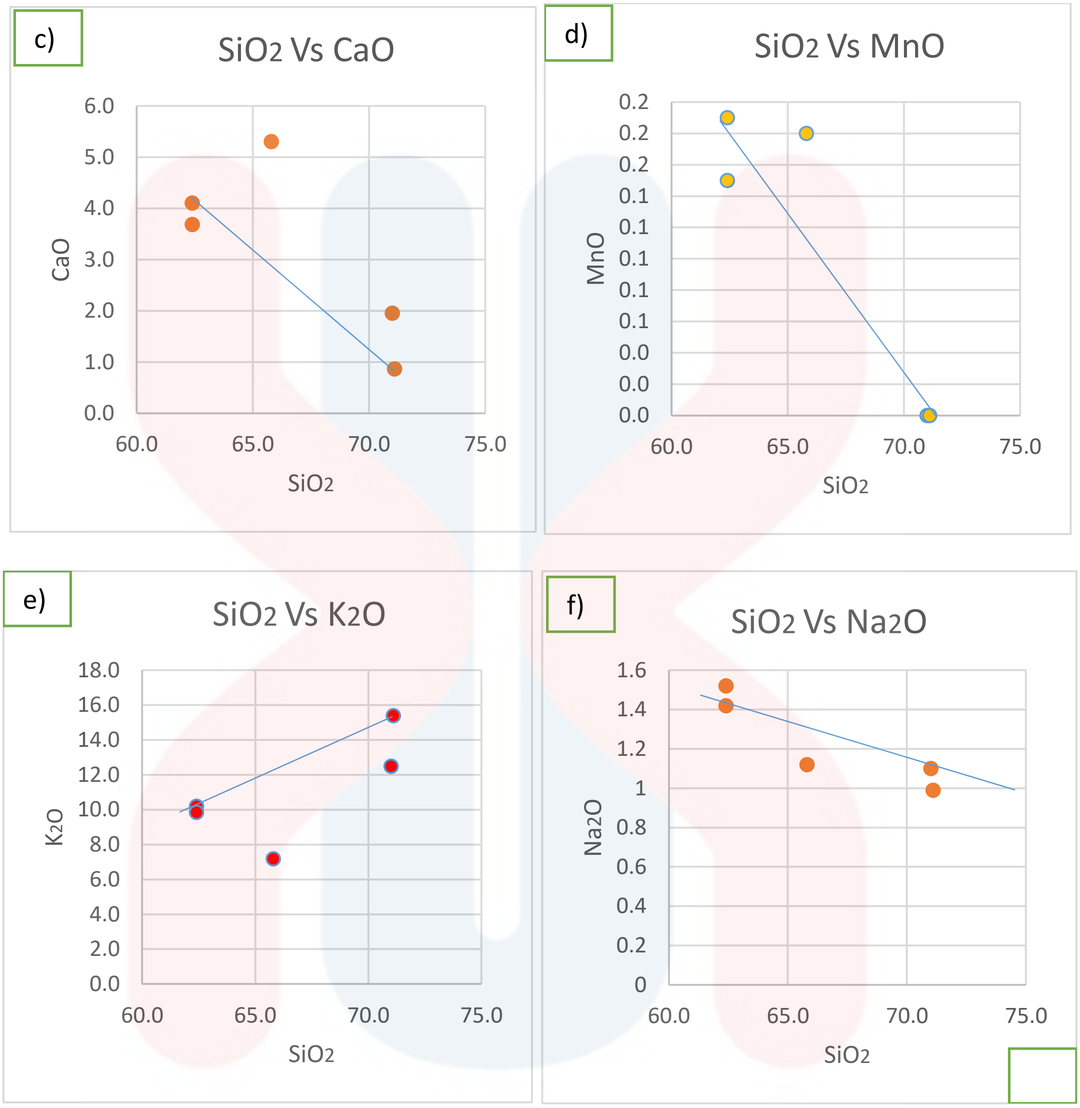

Figure 5.6: a-f) Major oxide elements used in Harker Diagram.

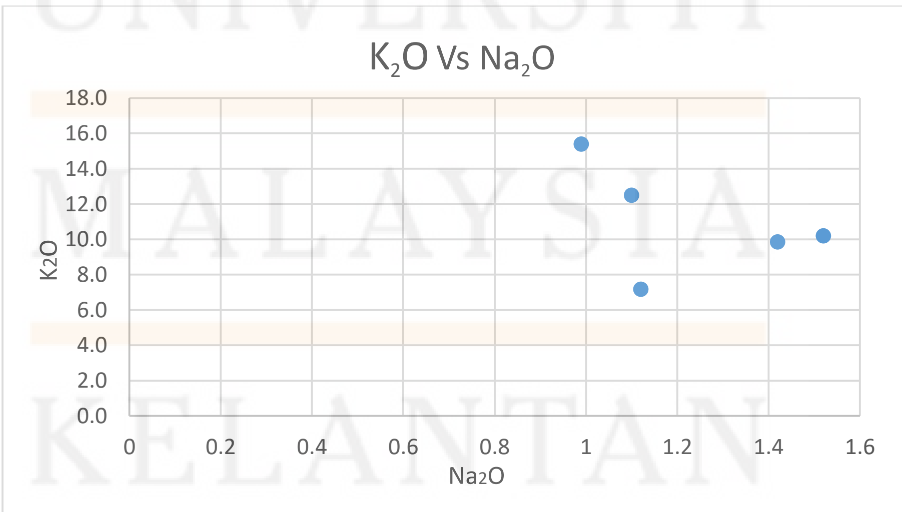

Figure 5.7: K_2O vs Na_2O graph.

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Figure 5.8 indicates the graph of K_2O vs Na_2O which mainly used to classify the I-type or S-type of the granitic rock based on distribution. The results shows the concentration of Na_2O is lower which is below 2 wt%. Hence, all the major elements is classified as S-type with the highest reading of 16 wt % of K_2O.

5.4 REE elements.

REE stands for Rare Earth Elements, which categorized into two types. Light REE (LREE) and Heavy REE (HREE). Inductively Coupled Plasma optical emission spectrometry (ICP-OES) instrument is used to test the REE elements in sample NAN S02 and sample NAN S05. Sample NAN S02 has 3 types of LREE which are Cerium (Ce) 138.36 ppm, Lanthanum (La) 157.61 ppm, Neodymium (Nd) 33.90 ppm. Erbium (Er) 5091.63 ppm is the only HREE for NAN S02. Meanwhile, sample NAN S05 has no LREE and only has one HREE which is 328.35 ppm of Erbium (Er). The geochemical analysis done by the ICP-OES had only manage to detect 4 elements out of 14 elements. The elements that have been detected are Ce, Er, La and Nd were categorized into LREE and Er was categorized in HREE.

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Table 5.2: LREE and HREE distributions in granitoids

Light Rare Earth Elements (LREE)			
No	LREE	NAN S02 (ppm)	NAN S05 (ppm)
1	Ce	138.36	0.00
2	La	157.61	0.00
3	Nd	33.90	0.00
SUM		**329.87**	**0.00**
Heavy Rare Earth Elements (HREE)			
4	Er	5091.63	328.35

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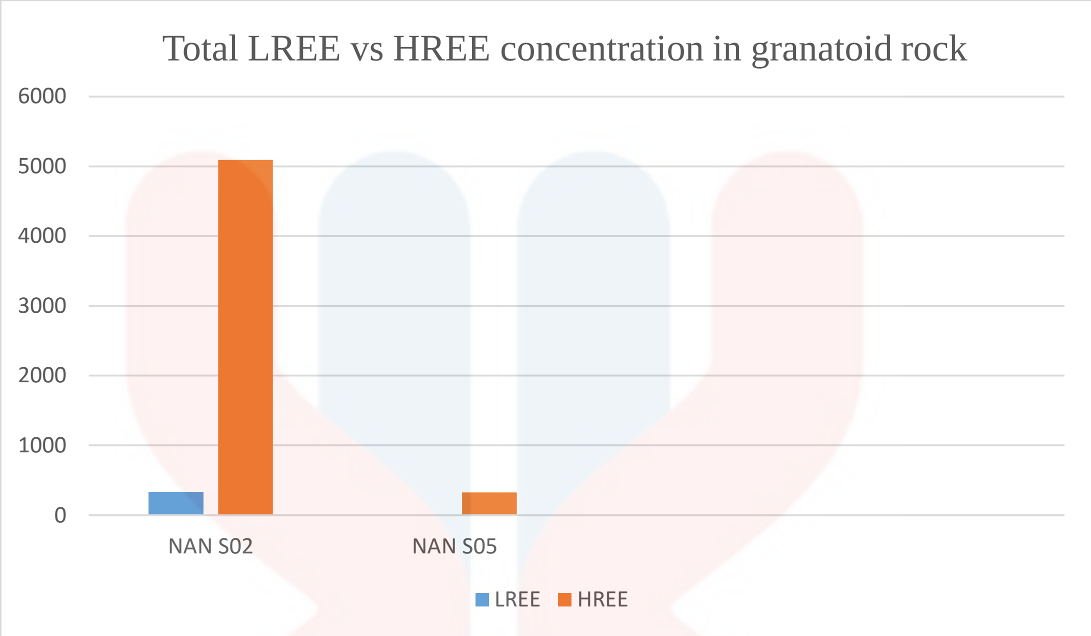

Figure 5.8: The LREE and HREE distribution in NAN S02 and NAN S05

5.5 Discussion

5.5.1 Discussion element based on XRF data

Based on the major elements in figure 5.6, there are only 8 elements are founded in granitic rock usually the granites contain 10 common major elements of granites. Referring to the Harker diagrams plotted, six elements (TiO_2, Fe_2O_3, MnO, CaO and Na_2O) are inversely proportional with SiO_2. However, element K_2O directly proportional to SiO_2.

Furthermore, some of the element's concentration (Ca, Na, K and Fe) from the Harker diagram of the 5 samples were compared using XRF analysis.

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Calcium

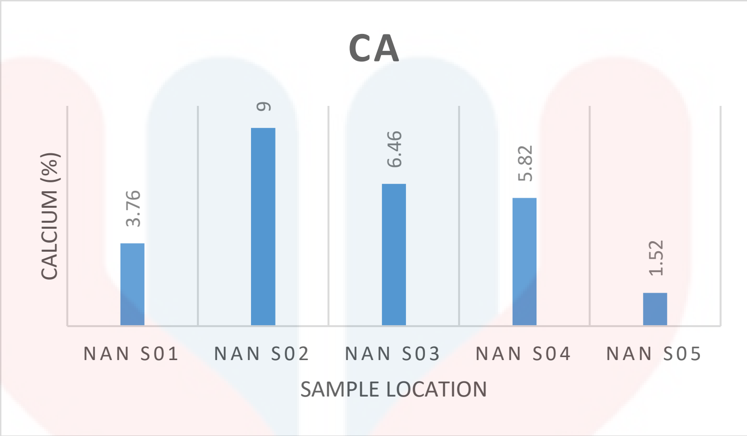

Figure 5.9: The calcium element in rock by using XRF

Figure 5.9 shows the concentration of calcium in the 5 samples collected from the study area. The concentration of calcium was high in sample NAN 502 (9%) whereas low in NAN 505 (1.52%).

Potassium

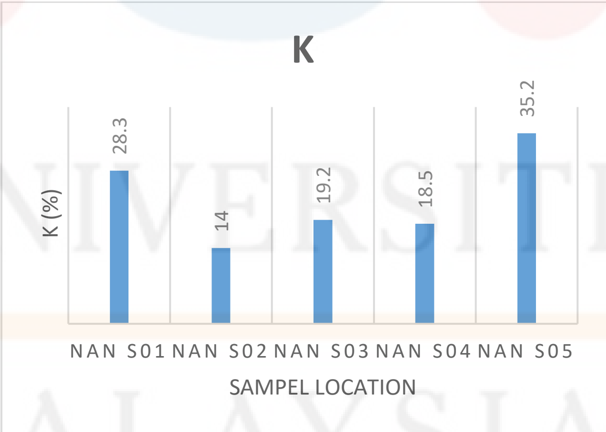

Figure 5.10: The potassium element in rock by using XRF

The concentration of potassium in NAN 505 was higher (35.2%) than other elements meanwhile NAN 502 was listed as the lowest (14%). The statement was interpreted by referring to the Figure 5.10.

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Sodium

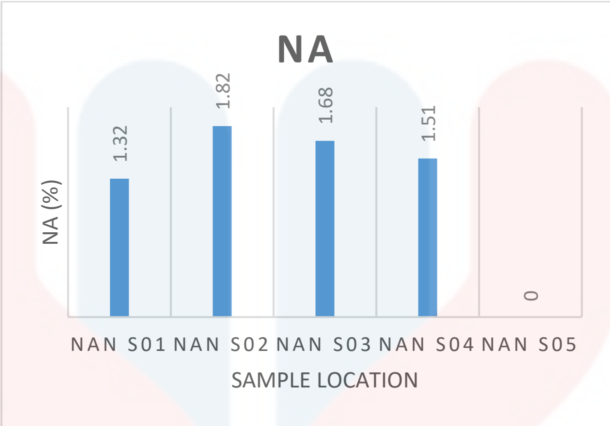

Figure 5.11: The sodium element in rock by using XRF

By referring to Figure 5.11. Concentration of sodium in NAN 502 was 1.82% which was higher than other samples. Meanwhile, sodium was zero or absent in sample NAN 505. The other sample's concentration was slightly differ from sample NAN 502 except NAN 505.

Iron

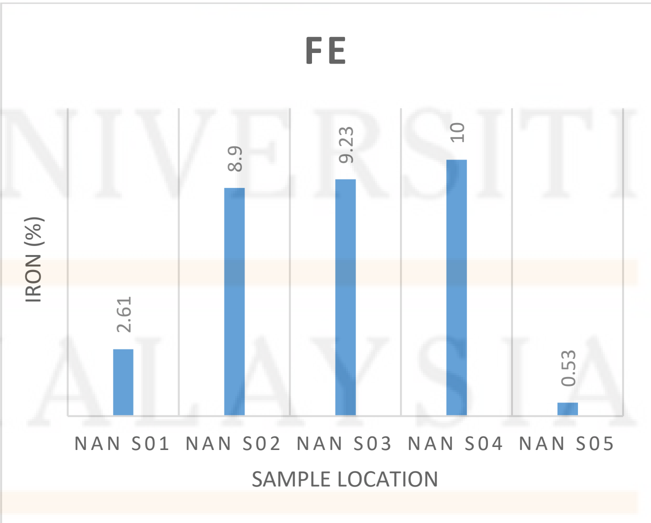

Figure 5.12: The iron element in rock by using XRF

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Distribution of element in Fe content in location NAN SO4 is the highest (10%), while NAN S05 having the lowest Fe content (0.53%).

NAN S02 appear to be mafic or dark in colour while NAN S05 appear to be white or felsic. Differences of the colours of the sample are due to the formation of the rocks. Both of the rocks are considered as plutonic rocks or granites. Igneous rocks make up the crust of the earth with minor amount of sedimentary and metamorphic rocks. The lithic crusts consist of the upper part and the lower part. The upper part has silicic composition as it derives from silicon and aluminium. While, the lower part is more mafic due to the derivation from silicon-magnesium. According to the position or the geological conditions of the granites, NAN S02 is found at near ground level, located along the river. While, NAN S05 is found at the foothills of one of the mountains. There is no contact with water and the S05 sample appear to be fresh or does not be altered greatly compared with NAN S01. From petrographic analysis, both samples have quite distinct differences from the mineral composition and the grain size. The grain size of the feldspar for NAN S02 is big in size compared giving its porphyritic texture, while the feldspar for NAN S05 cannot be identified with naked eyes and rather interconnected with other felsic minerals such as quartz.

Based on study made by Jack et al. (1988), chemical elements are divided into group of mobile and immobile elements during weathering. Elements that are immobile are such as Zr, Hf, Fe, Al, Th, Nb, Sc and the REE. While, mobile elements such as Ca, Na, P, K, Sr, Ba, Rb, Mg and Si are derived mainly from minerals such as feldspar, micas and apatites.

From the XRF analysis, the SiO_2 contents reflect the amount of quartz in the samples. Sample S05 has the highest amount of quartz mineral content, while S03 has the lowest SiO2 content. The lack of quartz or felsic minerals contents in the sample

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are replaced by the mafic mineral contents such as mica and amphibole. Based on the petrographic analysis, the S02 sample has the higher feldspar contents than S05. While from the chemical analysis, S02 samples has greater elements contents such as Ca, Na, and Mg, showing the higher content of feldspar and mica minerals compared to S05 sample. However, potassium element or K is supposed to be equivalent with the feldspar content as K is derived from the feldspar. The result show the opposite as the potassium content in S02 is lower than S05. The differences in the results may be due to the error in the analysis.

Next, the REE contents can be analysed for its weathering conditions. REE contents may differ in weathered and fresh rocks. Based on the result of XRF and ICPOES methods, it shows some major differences especially for NAN S02 and S05 samples. The cause of the differences are mainly due to different weathering level of the sample and the different mineralogical composition of the samples.

Granite is mainly composed of quartz, feldspar with minor amounts of mica, amphiboles and other minerals. This mineral composition gives granites its varieties of colour such as red, pink, grey or white colour. Sample S02 tends to be seen darker than sample S05.

According to research made by (Kenzo et al., 2009), REE was enriched in granitic rocks due to the degree of weathering shown by the LOI (loss of ignition) results. They suggest that the samples show high LOI content due to sufficient weathering, enriched in clay and hydrous mineral, which may have ion-absorption type REE mineralization. This ion-absorption type deposits absorb HREE compared to LREE. This may apply to the sample NAN S02 and S05. Observation of the hand specimen, sample S02 may undergone metamorphism shown by its strong feldspar arrangement and weathering of the sample is shown by the orange colour or

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discolouration. Meanwhile, the sample S05 is not altered, may due to morphology conditions that is not exposed to the river or direct contact with water. S05 sample show depletion in HREE compared to weathered S02 granitic rock. Moreover, the S02 granitic rock was relatively enriched LREE relative to HREE. This shows the alteration or degree of weathering do effect the REE concentration in the rock. The low degree of weathering may result to the lower LREE and HREE content. HREE is enriched by the degree of weathering and generally relative to the LREE content (Kenzo et al., 2009). However, the result of ICP-OES show that, the weathered S02 sample contain both high concentration of LREE and HREE compared to low concentration of HREE and absence of LREE content in S05 sample. Supposedly, the low degree of alteration of sample S05 will result to low HREE concentration and high LREE concentration. This may due to the detection error of the ICP-OES machine.

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CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

As a conclusion, the geology of Kampung Rabbana was analysed. The first objective of the research was achieved which the geological map of 1: 25 000 was produced. There are five main lithology unit, schist, gneiss, amphibole, hornfels and granite. The youngest rock unit is granite as the granite forms from the melting of the sedimentary rocks in study area. The principle of cross cutting, also shown by the displacement of quartz vein due to the tectonic movement. The movement may due to intrusion of igneous rock or granite. The main force in the study area is exerted at the direction of N60^{o}E. This force was the main stress that produced the geological structure at the study area such as the Long Fault at Long River. The common geological structure formed are strike-slip fault, dyke, vein and joint. The geological findings of the research area were constructed into a geological map with scale of 1: 25,000 ratio.

Next, the major chemical compositions of granitoids in the study area was analysed using XRF method. By referring to the XRF analysis the granitoid in the study area was classified as S-type granite. The second objective of the research was achieved. The Rare Earth Element (REE) in granitoids was identified using ICP-OES method. The two elements that found in the rocks which were, Light Rare Earth Element (LREE) and High Rare Earth Element (HREE). The result shows that HREE

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was higher than LREE in granitoid rock of the study area. The third objective was achieved.

6.2 Recommendation

As for recommendation, the future researcher can use other methods to determine the rare earth elements (REE) or trace elements of the sample by using ICP-MS machine. This method will give more accurate reading as the detection limit is quite low and can detect rather low concentration of elements. This method also compatible with solid and liquid samples. Using REE elements, it also can conform the type of granitic rocks in the study area using the chondrite normalized diagram.

High understanding of petrographic of igneous rock and metamorphic rock is rather essential as the presence of igneous rocks in the study area are very different from each other. The name of the specific type of igneous rock is different from the common igneous rock classification. So, petrographic and chemical analysis are both needed and essential in order in classifying the type and name of each type of rock. Moreover, there can be more study whether the differences of igneous rock can have different REE elements and can explain more on the pathogenesis of the study area.

In addition, since the study area have large quartz vein due to the intrusion of granites. Hence, in future it is recommended to do research on the gold deposition since the study area has high potential in gold deposition. The study area may have the primary deposition of gold that can be one of the potential sources for the people.

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CERTIFICATE OF ANALYSIS (COA)

To / Attn	Muhyammad Afif Aflah Bin Mohd Yusri		
Address	UMK, Kampus Jeli, Beg Berkunci 100, 17600 Ayer Lanas, Kelantan		
Tel No	017-9122950	Fax No	
Sample Lab No	2019/479	No of sample	4

Date of sample received : 20-11-2019
Date reported : 25-11-2019
Sample description : 2019/479(1)
Sample Marking : **AFIF 01**

RESULT:

No	Parameter	Result	Unit	Test Method
1.	Cerium (Ce)	166.12	ppm	In-house Method based on APHA 3010
2.	Dysprosium (Dy)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
3.	Erbium (Er)	3047.54	ppm	In-house Method based on APHA 3010
4.	Europium (Eu)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
5.	Gadolinium (Gd)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
6.	Holmium (Ho)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
7.	Lanthanum (La)	150.07	ppm	In-house Method based on APHA 3010
8.	Lutelium (Lu)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
9.	Neodymium (Nd)	52.75	ppm	In-house Method based on APHA 3010
10.	Praseodymium (Pr)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
11.	Samarium (Sm)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
12.	Terbium (Tb)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
13.	Thorium (Th)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
14.	Yitrium (Y)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010

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Date of sample received : 20-11-2019
Date reported : 25-11-2019
Sample description : 2019/479(2)
Sample Marking : **AFIF 02**

RESULT:

No	Parameter	Result	Unit	Test Method
1.	Cerium (Ce)	213.85	ppm	In-house Method based on APHA 3010
2.	Dysprosium (Dy)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
3.	Erbium (Er)	7554.11	ppm	In-house Method based on APHA 3010
4.	Europium (Eu)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
5.	Gadolinium (Gd)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
6.	Holmium (Ho)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
7.	Lanthanum (La)	168.83	ppm	In-house Method based on APHA 3010
8.	Lutelium (Lu)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
9.	Neodymium (Nd)	63.64	ppm	In-house Method based on APHA 3010
10.	Praseodymium (Pr)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
11.	Samarium (Sm)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
12.	Terbium (Tb)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
13.	Thorium (Th)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
14.	Yitrium (Y)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010

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Date of sample received : 20-11-2019
Date reported : 25-11-2019
Sample description : 2019/479(3)
Sample Marking : **NAN 02**

RESULT:

No	Parameter	Result	Unit	Test Method
1.	Cerium (Ce)	138.36	ppm	In-house Method based on APHA 3010
2.	Dysprosium (Dy)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
3.	Erbium (Er)	5091.63	ppm	In-house Method based on APHA 3010
4.	Europium (Eu)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
5.	Gadolinium (Gd)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
6.	Holmium (Ho)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
7.	Lanthanum (La)	157.61	ppm	In-house Method based on APHA 3010
8.	Lutelium (Lu)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
9.	Neodymium (Nd)	33.90	ppm	In-house Method based on APHA 3010
10.	Praseodymium (Pr)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
11.	Samarium (Sm)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
12.	Terbium (Tb)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
13.	Thorium (Th)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
14.	Yitrium (Y)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010

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Date of sample received : 20-11-2019
Date reported : 25-11-2019
Sample description : 2019/479(4)
Sample Marking : **NAN 05**

RESULT:

No	Parameter	Result	Unit	Test Method
1.	Cerium (Ce)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
2.	Dysprosium (Dy)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
3.	Erbium (Er)	328.35	ppm	In-house Method based on APHA 3010
4.	Europium (Eu)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
5.	Gadolinium (Gd)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
6.	Holmium (Ho)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
7.	Lanthanum (La)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
8.	Lutelium (Lu)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
9.	Neodymium (Nd)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
10.	Praseodymium (Pr)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
11.	Samarium (Sm)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
12.	Terbium (Tb)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
13.	Thorium (Th)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010
14.	Yitrium (Y)	Not Detected (Less than 0.1)	ppm	In-house Method based on APHA 3010

The certificate shall not be reproduced except in full without the written approval of the laboratory.
The above analysis is based on the sample submitted by the customer.

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MOHD RAFIE ROSLY
SCIENCE OFFICER

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