GENERAL GEOLOGY AND GEOCHEMISTRY OF GRANITES IN KAMPUNG KALAI, BATU MELINTANG

By

SHAWN IVERSEN ANAK REBU

A report submitted in fulfilment of the requirements for the degree of

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DECLARATION

I declare that this thesis "**GENERAL GEOLOGY AND GEOCHEMISTRY OF GRANITES IN KAMPUNG KALAI, BATU MELINTANG"** is the result of my own research except those cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……………………………….

Name : ……………………………….

Date : ……………………………….

APPROVAL

I hereby declare that I have read this thesis entitled and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Applied Science (Geoscience) With Honours

Signature : ………………………………

Name of Supervisor :

Date : ………………………………

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GENERAL GEOLOGY AND GEOCHEMISTRY OF GRANITES IN KAMPUNG KALAI, BATU MELINTANG

ABSTRACT

This research is solely focused on updating the geological map of Kampung Kalai, Batu Melintang, Jeli, Kelantan. The study area covered for this research is in $25km^2$. It lies within the range from 5° 44' 2.71" N to 5° 46' 48.76" N in latitude and 101° 43' 35.27" E to 101° 46' 15.48" E in longitude. The study area is mostly covered in mountainous areas, hilly areas, and plain areas. The study area involves two formations which are Telong formation and Mangga formation. As a result, when conducting geological fieldwork, the lithology found in the study area are limestone, schist, phyllite, and granite. The minerals found within the rocks are composed of quartz, biotite, calcite, muscovite, chlorite, and garnet. All findings and data are all plotted in the geological map. The geochemical analysis is done in two granite samples which are SI 384 G and SI 10819 G. The results shows that SI 384 G has more Light Rare Earth Element (LREE) than SI 10819 G however SI 10819 G has more Heavy Rare Earth Element (HREE) than SI 384 G.

Keywords: Geological mapping, lithology, minerals, geochemical analysis.

GEOLOGI DAN GEOKIMIA GRANIT DI KAMPUNG KALAI, BATU MELINTANG

ABSTRAK

Penyelidikan ini hanya tertumpu kepada pengemaskinian peta geologi Kampung Kalai, Batu Melintang, Jeli, Kelantan. Kawasan kajian yang diliputi untuk penyelidikan ini adalah dalam 25km2. Ia terletak dalam julat dari 5° 44' 2.71" N hingga 5° 46' 48.76" N di latitud dan 101° 43' 35.27" E hingga 101° 46' 15.48" E dalam longitud. Kawasan kajian kebanyakannya meliputi kawasan pergunungan, kawasan berbukit, dan kawasan dataran. Kawasan kajian melibatkan dua formasi iaitu formasi Telong dan formasi Mangga. Hasilnya, semasa menjalankan kerja lapangan geologi, litologi yang terdapat di kawasan kajian ialah batu kapur, schist, phyllite, dan granit. Mineral yang terdapat di dalam batuan terdiri daripada kuarza, biotit, kalsit, muscovite, klorit, dan garnet. Semua penemuan dan data semuanya diplot dalam peta geologi. Analisis geokimia dilakukan dalam dua sampel granit iaitu SI 384 G dan SI 10819 G. Keputusan menunjukkan SI 384 G mempunyai Elemen Nadir Bumi Ringan (LREE) lebih banyak berbanding SI 10819 G namun SI 10819 G mempunyai lebih banyak Unsur Nadir Bumi Berat (HREE) daripada SI 384 G.

Kata kunci: Pemetaan geologi, kaedah, litologi, mineral, analisis geokimia

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LIST OF SYMBOLS

°	Degrees
‘	Minutes
“	Seconds
^{2}	Per Square
( )	Brackets
%	Percentage
wt	Weighted

LIST OF ABBREVIATION

XRF	X-Ray Fluorescence
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
LREE	Light Rare Earth Elements
HREE	Heavy Rare Earth Elements
MgO,	Magnesium Oxide
Al_2O_3,	Aluminium Oxide
SiO_2	Silicon Dioxide
K_2O	Potassium Oxide
P	Phosphorus
S	Sulphur
Ca	Calcium
Ti	Titanium
V	Vanadium
Cr	Chromium
Mn	Manganese
Fe	Iron
Ni	Nickel
Cu	Copper
Zn	Zinc
Ga	Gallium
Rb	Rubidium
Sr	Strontium
Y	Yttrium

Zr	Zirconium
Nb	Niobium
Ba	Barium
Hf	Hafnium
Pb	Lead
Th	Thorium
Bi	Bismuth
U	Uranium
Sc	Scandium
La	Lanthanum
Ce	Cerium
Pr	Praseodymium
Nd	Neodymium
Sm	Samarium
Eu	Europium
Gd	Gadolinium
Tb	Terbium
Dy	Dysprosium
Ho	Holmium
Er	Erbium
Tm	Thulium
Yb	Ytterbium
Lu	Lutetium

Qtz	Quartz
Bt	Biotite
Cal	Calcite
Chl	Chlorite
Ms	Muscovite
Gt	Garnet

CHAPTER 1

INTRODUCTION

1.1 Background of Study

This research is solely focused on the geology and geochemistry of granite rocks in Kampung Kalai, Batu Melintang. The meaning behind geology involved the study of the planet Earth and how Earth is formed. It involves dealing with and emphasising the physical surface of the Earth, the history of the Earth and the processes that act on it.

Geochemistry is the study of methods for monitoring the amount, composition, and distribution of chemical substances and isotopes in diverse geologic environments. Geochemistry is concerned with the processes and effects of element distribution in minerals and rocks in various physical and chemical settings, and so pervades all fields of geology to variable degrees. Earth science students must have a solid foundation in geochemistry. Furthermore, geochemistry is critical to our knowledge of the processes resulting in profitable mineral concentrations, whether caused by hydrothermal, magmatic, metamorphic, hydraulic (both surficial and subterranean) weathering agents or a combination of these. Geochemistry also plays an essential role in exploration.

Granite rocks are light-coloured and intrusive rocks. It is generated due to the progressive crystallisation of magma under the Earth's surface. Granite mostly consists of quartz and feldspar, with minor amounts of mica, amphiboles, and other minerals. This mineral composition gives granite a red, pink, grey, or white colour, with black mineral grains visible throughout the rock. Because the Main Range Granite is situated in the western portion of Kelantan, granite rock is widely found in Jeli, Kelantan. The Main Range Granite is Peninsular Malaysia's largest granitic batholith, and it is assumed to be entirely made of S-type granites.

1.2 Study Area

1.2.1 Location

The study area, Kampung Kalai, Batu Melintang is located at (5.7518°N, 101.7459°E) which can be found near Jeli, Kelantan. Kampung Kalai is part of the sub-district of Batu Melintang. Kampung Kalai can be found situated near the Malaysia-Thailand border. The elevation of the study area is found to be 106 m. Figure 1.1 shows the geological map of Kelantan whereas Figure 1.2 shows the base map of the study area. The study area covered for this research is 25 km^2. It lies within the range from 5° 44' 2.71" N to 5° 46' 48.76" N in latitude and 101° 43' 35.27" E to 101° 46' 15.48" E in longitude. The study area is situated close to the border of Thailand towards the north, Kuala Krai and Gua Musang district towards the south, Tanah Merah district towards the east and the state of Perak towards the west.

The base map is prepared and digitised by using ArcGIS 10.8 software. The types of landscapes found in the study area are mountainous areas, hilly areas, and plain areas. The study area is mostly covered by igneous rocks as well as the occurrence of granite intrusion in the research area.

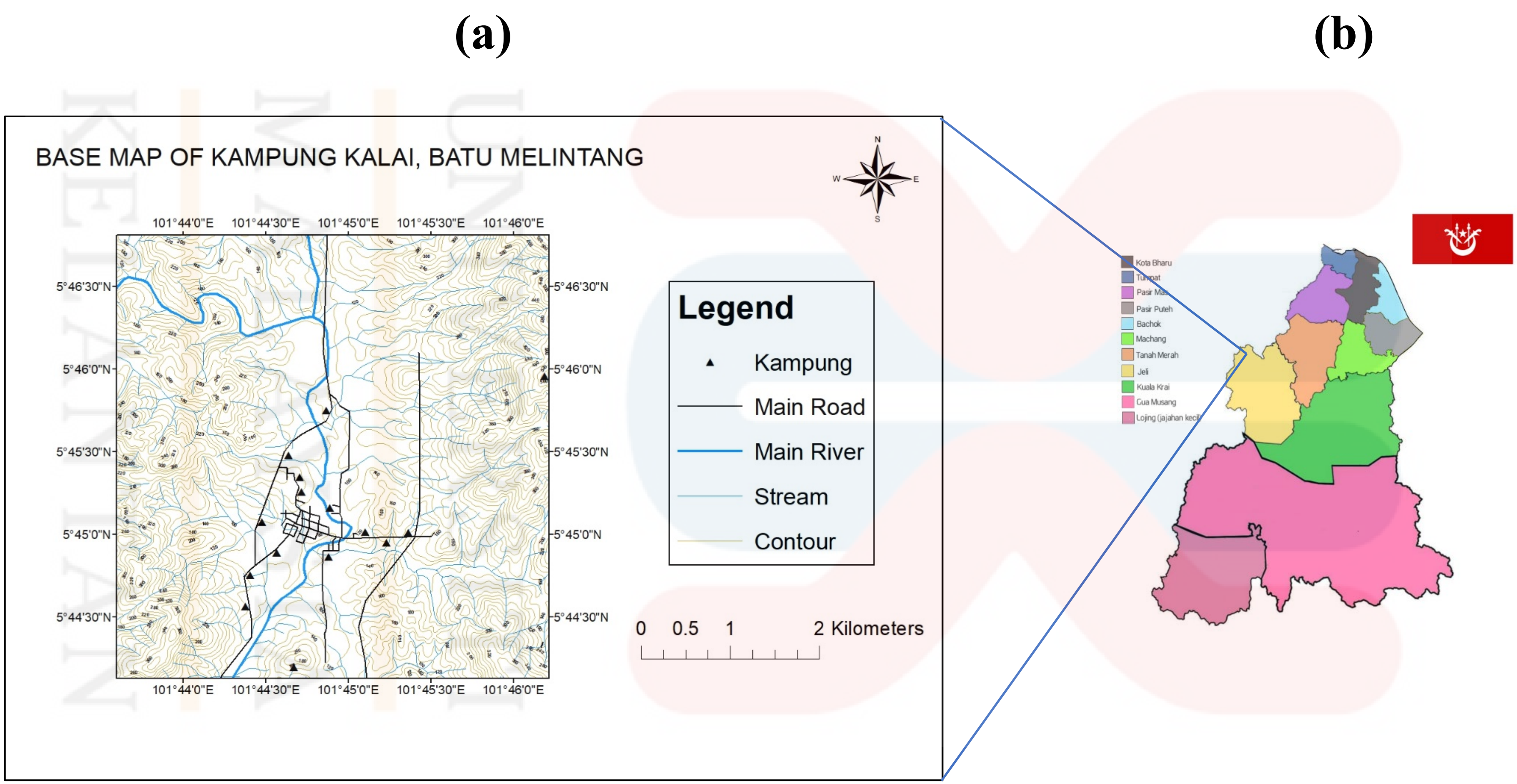


Figure 1.1 (a) Box location of the research area. (b) Map of Kelantan. (Source: Google)

1.2.2 Accessibility

The main road is located further away from the study area. Therefore, to access the study area there is a small junction where the small road leads towards Kampung Kalai. The road also transects towards the Malaysia-Thailand border as well. The roads are mostly paved but there are some unpaved roads along the way towards Kampung Kalai. Overall, most part of the study area has good road access for all kinds of vehicles from motorcycles to lorries to pass through for economic and social purposes. Though there appears to be some areas which are not reachable due to high elevation and dense forests. Figure 1.3 and 1.4 shows the destination to reach the study area from the starting point.

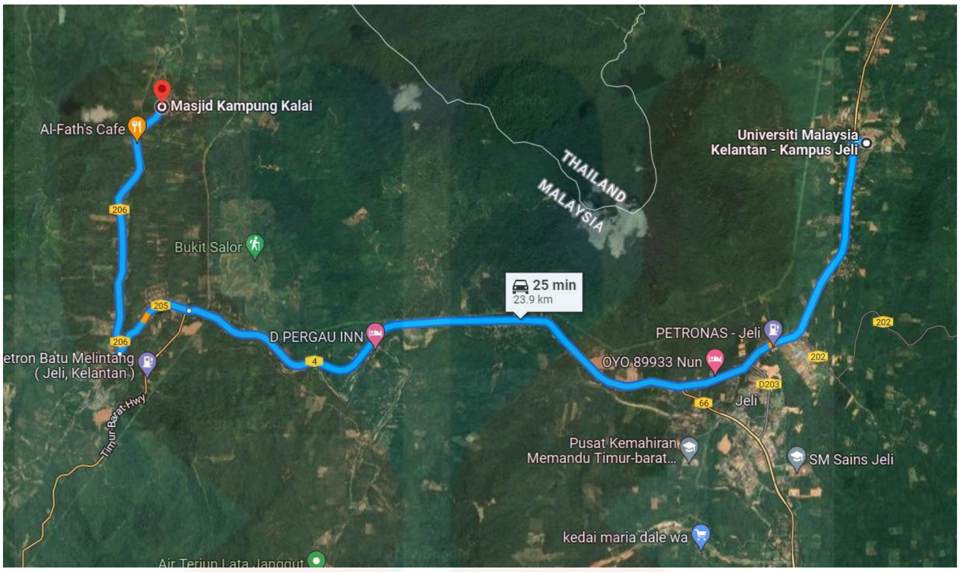


Figure 1.2 Destination to study area from Universiti Malaysia Kelantan Kampus Jeli. (Source: Google Maps)

Figure 1.3 Destination to study area from Jeli Town. (Source: Google Maps)

1.2.3 Demography

Jeli is the state of Kelantan's third biggest colony. The colony is divided into three districts: Jeli, Batu Melintang, and Kuala Balah. The colony has an area of 1,280.21 km^2. Based on the data given by Jabatan Perangkaan Negeri Kelantan in 2017, it can be observed that the total population of the three areas studied (Batu Melintang, Jeli, and Kuala Balah) has 42,872 residents. When looking at the population distribution among the three areas, Jeli has the highest population with 21,120 residents. This is followed by Kuala Balah with 12,062 residents and Batu Melintang with 9,690 residents. The data reveals that there is a significant difference in population size between the three areas, with Jeli having nearly twice the population of Batu Melintang.

Furthermore, the population in Jeli was divided into two genders: males and females. The data presented by Jabatan Perangkaan Negeri Kelantan illustrates the gender distribution of the population research. It can be inferred from the data that there is nearly equal distribution of males and females, with 21,764 males and 21,108 females. This demonstrates that the population is largely gender balanced. However, there is a slight difference in the number of males and females, with males constituting significantly more of the population. By calculating the percentage, we can see that the population under study is roughly 51% male and 49% female. Table 1.1 shows the people distribution in Jeli colony by gender while Figure 1.4 shows the percentage of people distribution in Jeli colony by gender.

In the same year, there is also an ethnic group which divides the population into their own respective race. The population is predominantly made up of Malays, with a small fraction of Orang Asli. According to the statistics, the bulk of the population is Malay (42,400 people), accounting for 99% of the entire population, followed by the Orang Asli ethnic group (472 people), accounting for 1% of the population, while data for the remaining ethnic groups is absent (Chinese, India, Lain-lain). Table 1.2 shows the people distribution in Jeli colony by ethnic groups while Figure 1.5 shows the percentage of people distribution in Jeli colony by ethnic groups.

Table 1.1 People distribution in Jeli by gender. (Jabatan Perangkaan Negeri Kelantan, 2017)

Gender	Population
Males	21,764
Females	21,108
Total	42,872

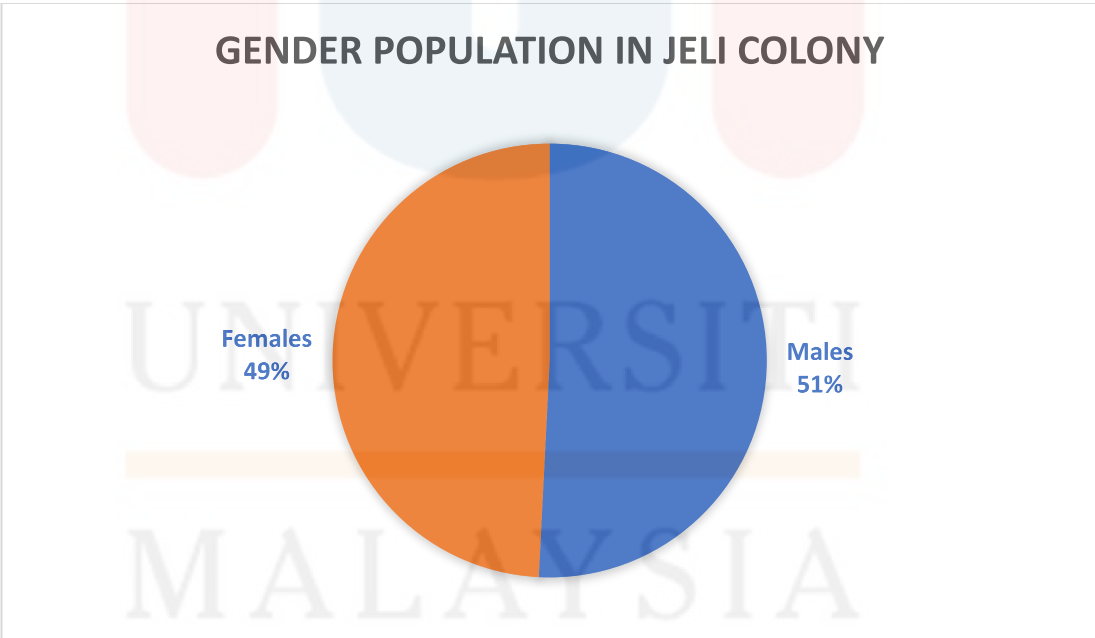


Figure 1.4 Percentage of people distribution in Jeli by gender. (Jabatan Perangkaan Negeri Kelantan, 2017)

Table 1.2 People distribution in Jeli by ethnic groups. (Jabatan Perangkaan Negeri Kelantan, 2017)

Ethnic Groups	Population
Malay	42,400
Orang Asli	472
Chinese	-
Indian	-
Others	-
Total	42,872

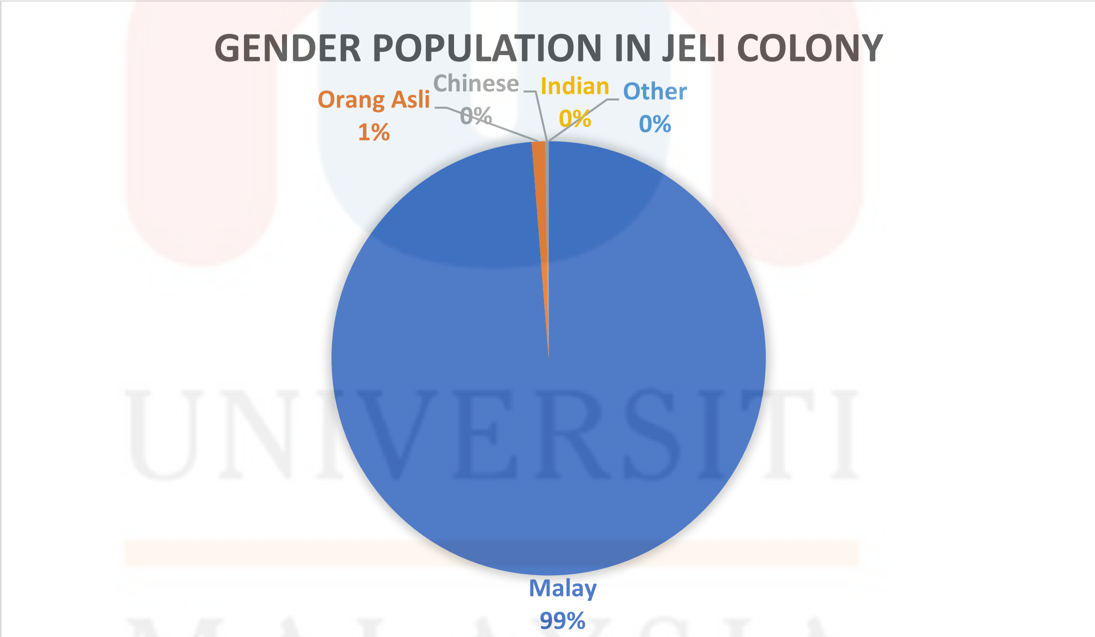


Figure 1.5 Percentage of people distribution in Jeli by ethnic groups. (Jabatan Perangkaan Negeri Kelantan, 2017)

1.2.4 Land Use

According to Abdul Rahim N. A. & Ismail R. (2020), The land use of Kampung Kalai is mostly covered by plantation area such as oil palm and rubber plantation which scattered across the area. The housing area is located within the centre of the study where the village is situated. There are several features of the land use fill in as development reasons such as local shops, clinics, mosques and schools which give amenities to the people which provide the villagers healthcare, education, and many more.

1.2.5 Social Economic

The social economy mainly depends on rubber tapping and growing oil palm for business purposes. Besides that, there are also some local shops, retail shops and car wash shop that help maintaining the social economy. The area is also famous for having a gold mining activity where there are numerous mining site located at some parts of Kampung Kalai. This way offers good fortune for the people in Kampung Kalai as it attracts people from different areas to come and carried out mining activity.

1.3 Problem Statement

The problem statement for this research is that there is a lack of discoveries known of the granite rocks and petrography research in Kampung Kalai, Batu Melintang. Petrography provides useful information regarding detailed descriptions of the rock content. By examining the rock content enables the researcher to provide information regarding the history of the research location. Whereas, geochemistry is concerned with the extraction of Earth's resources, such as metals and petroleum. With the combined petrography and geochemical analysis, we can obtain different kinds of data to identify the mineral composition and geochemistry of the granite rocks.

1.4 Objectives

The objective of this research is:

1) To produce a geological map with a scale of 1:25000 in Kampung Kalai, Batu Melintang.
2) To study the petrography and geochemistry of granite rocks in the study area.
3) To investigate the distribution of Rare Earth Elements (REE) in the study area.

1.5 Scope of Study

The scope of the study is more focused on the petrology and geochemistry of granite rocks within Kampung Kalai, Batu Melintang. The scope of the study is to identify the mineral composition and percentage of minerals in Kampung Kalai, Batu Melintang by using appropriate methods such as polarised microscope for petrography analysis, XRF (X-Ray Fluorescence) and ICP-MS (Induced Coupled Plasma - Mass Spectrometry) for geochemical analysis. The REEs (Rare Earth Element) are found in a region of the mass spectrum with few interferences and the highest sensitivity for ICP-MS. Because each REE has at least one isotope devoid of isobaric overlap, the complete group can be easily identified in most geological materials.

1.6 Significance of Study

The significance of the study is to contribute updated information regarding the petrology and geochemistry of the research area in Jeli, Kelantan. The benefit of this is to allow researchers and the community to understand the importance of petrography and geochemical analysis and its usefulness in determining the rock constituent and the history behind the granite rocks in Jeli, Kelantan. Geochemical analysis can help predict the location of commercially important minerals including REE (Rare Earth Elements).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, it will focus more on the literature review regarding the topic in detail. The purpose of literature review is to give guidance in writing up thesis. This chapter will cover literature review of regional geology and tectonic setting, stratigraphy, structural geology, historical geology, geomorphology of Jeli, Kelantan, granite rocks, rare earth elements and brief overview of equipment in geochemical analysis.

2.2 Regional Geological and Tectonic Setting

The Central Belt is mostly composed of Permo-Triassic low-grade metasediments, deep to shallow marine clastic sediments, and limestone, with significant intermediate to acid volcanics and volcaniclastics deposited in paleo-arc basins (Gobbet and Hutchison, 1973). Acid and intermediate intrusive rocks were deposited east of and parallel to the Raub-Bentong Suture. Batholiths in the Eastern Belt are smaller than those in Sibumasu, although they are more compositionally extended. The Jurassic-Late Cretaceous batholiths are of I-type affinity and include both precious and base metal mineralisation. Magmatism in the Central Belt is much less prevalent, consisting of an alkali series ranging from gabbro-diorite (157 Ma) through monzonite (163 Ma) to quartz syenite (127 Ma), as well as a later calc-alkali series of granodiorites and granites.

Peninsular Malaysia is part of the east Eurasian Plate and is tectonically positioned north of the Sunda arc's currently active subduction arc zones. Gold finding in this region is usually connected with Tertiary volcanic and hydrothermal activity and appears to be quite widely tied to tectonic limits. The Malay Peninsular is separated into two tectono-stratigraphic terranes that are part of the Sunda shelf: East Malay (Eurasian plate-Indochina) and Sibumasu (Shan-Thai). The Eurasian Terrane (Manabor block) has been viewed as a Permo-Triassic Island arc system that was never far from the Shan-Thai block. The stratigraphic, palaeontological, and palaeomagnetic data point to a potential genesis of these terranes in the Late Permian to Late Triassic rifting of the former Gondwanaland continent responsible for the development of the Central Belt and the Raub-Bentong Suture (Metcalfe, 2002).

2.4 Structural Geology

The Palaeozoic succession is characterised structurally by very tight folds, particularly in the Silurian-Devonian succession. The Triassic rock series is characterised by open folds. There were at least four tectonic events that were subjected to the land mass of Peninsular Malaysia during the Palaeozoic and Mesozoic eras, with the most notable happening during the Triassic period.

Although marine sedimentation occurred continuously throughout the Palaezoic and Early Mesozoic eras, major pauses may be seen due to the instability of the depositional basins during the Devonian-Carboniferous and Early Traissic periods. Since the previous century, numerous mineral resources have been identified and exploited, many of which are tied to granite intrusions and associated hydrothermal activity (The Malaysian and Thai Working Groups, 2006).

2.3 Stratigraphy

Faulting is pervasive and found in all rock units. The majority of the faults are typical, near vertical fractures with just small displacements. All major faults are running northwest to northeast, with the Kalai fault trending north-south along the upper half of Sungai Tadoh. This fault is linked to the gold mineralisation zone of Kalai-Tomo.

The longest fault observed going northeast-southwest along Sungai Long and a portion of Mae Nam Kolok is the Long fault. The Pergau fault runs northeast-southwest along a section of Sungai Pergau, which flows from the border between the Noring Granite and the Mangga Formation.

The Mangga Formation was described as a low-grade metamorphic sequence containing arenaceous, argillaceous, pyroclastic, hornfels, marble, and schistose rocks in the eastern section of the Belum region (Committee, 2006). The formation is called after the Mangga River, where this rock type was first surveyed and large outcrops of it were reported. The lithology is mostly composed of siliceous shale and chert, metasandstone, and metagreywacke.

2.5 Historical Geology

Historically, the transect region between Malaysia and Thailand, which is part of the Batu Melintang area, originated as a result of the collision of Sinobur Malaya to the west and East Malaysia-Indonesia blocks to the east. The Bentong Raub Suture, which can be tracked northward into Thailand and southward into the Banka and Billiton Islands, represents the collision zone. This impact, along with a large tectonic event in the Late Triassic, caused rock deformation in the Malay-Thai Peninsula (Committee, 2006).

2.6 Geomorphology of Jeli, Kelantan

In the geomorphology of the state of Kelantan, it is divided into four types of scenery, which are the mountainous regions, hilly zones, plain fields, and coastal areas according to Tanot et al. (2001). All these types of landscape exist in Jeli district except for the coastal areas which makes its appearance in the northern part of Kelantan. The mountainous regions in the state of Kelantan form in the west and north of Jeli district. The area is comprising of the Stong Migmatite Complex, the Main Range granite and schist. Some features of this landscape include mountain ridges and valleys. The hilly parts in Jeli, Kelantan are located at the base of mountain ranges. This scenery is divided into two types of hills, solitary hills and elongated hills. Gunung Reng is an example of a limestone solitary hill that is generally exposed in low-lying settings. Elongated hills have ridges; however, they are generally lower in elevation than mountain ridges (Nazaruddin, D. A. et. al., 2017). In the district's centre and east side of Jeli, Kelantan, a flat terrain develops towards the hilly areas. Tectonic activities in Peninsular Malaysia throughout the Palaeozoic and Mesozoic eras significantly impacted on the land mass, primarily through the construction of faulting and folding. Faulting and folding have been found in both regional and localised structures. Folding, jointing, and faulting are examples of localised structures in sedimentary rocks and jointing and faulting in granitic rocks. In Kelantan, the major structural pattern runs north-south to northwest-southeast. The major local buildings of the Jeli district, on the other hand, run northwest-southeast and northeast-southwest (Nazaruddin, D. A. et. al., 2017).

2.7 Granite Rocks

The granites of Peninsular Malaysia are divided into three belts, which are the Western, Central, and Eastern belts. They have been divided into two granite provinces: the Western province, which includes granites from the Western Belt and ranges in age from 200 to 230 Ma, and the Eastern province, which includes granites from both the Eastern and Central belts and ranges in age from 200 to 264 Ma (Cobbing. et. al., 1992). The Western belt granites are distinguished by huge batholiths or complicated plutons with a limited compositional range, which includes a suite of tin-bearing S-type granite. It constitutes a massive mountain range that stretches from Malacca in the south to Thailand in the north, covering an area of more than 15000 km^2. The Western Belt Granite has two distinct batholith masses. These are the Main Range batholith on the eastern edge and the neighbouring Bintang batholith to the west. Small invasive centres can be found further west. These are known as the Bukit Mertajam Kulim, Penang, and Langkawi complexes. Individual plutons comprise each granitic batholith and complex (Liew, 1983). The primary rock type is a coarse to extremely coarse-grained megacrystic biotite muscovite granite. However, two-phase versions appeared practically everywhere and may be volumetrically significant (Cobbing et al., 1992). The second category corresponds to the amphibole-bearing granite found in various granitic formations in the northern half of the Western belt granite. Peraluminous granites can be formed by partial melting of metasedimentary rocks (S-type) or metaigneous rocks (I-type) (Gao et. al., 2016). S-type granites are peraluminous because they always contain more Al than is required to form feldspar given the rock's Na, K, and Ca contents (Chappell et. al., 2012). The extra Al is held in Al-rich biotite, which is usually associated by other Al-rich minerals like cordierite or muscovite. As the compositions of S-type granite suites become more felsic, they become less peraluminous (Chappell et al., 2012). Many I-type granites, particularly the more felsic ones, are mildly peraluminous. Given that all of these I-type granites are assumed to have been generated from metaluminous parent rocks, the issue of how those peraluminous granites were derived from such materials emerges (Chappell et al., 2012).

2.8 Rare Earth Elements (REE)

Rare Earth Elements (REEs) are a group of elements with very similar chemical characteristics. This is due to their similar ionic radii and electronic configuration. REEs play an important role in geochemical studies, since their distribution in the earth crust and mantle contributes to elucidate evolutionary processes of geological cycles, providing information on derivation and dating of igneous rocks (El-Taher, 2007). The REEs are a group of chemically coherent elements ranging from lanthanum (La) to lutetium (Lu), all of which reside in a trivalent oxidation state with the exception of cerium (Ce) and europium (Eu), which are redox sensitive and can assume different valence states depending on the oxygen fugacity (Meinhold et. al., 2022). Due to the low concentrations of these elements, research on REEs in the environment requires sensitive analytical methods. Even more so for elements like Lu, which frequently exist at ng/kg quantities, contemporary analytical methods like ICP/MS may necessitate a preconcentration step. A careful verification of analytical values must be carried out, and quality control must be the rule of the day, to ensure the data's dependability. Application of the analytical process to approved reference materials often serves to verify the correctness of the analytical results (El-Taher, 2007).

2.9 Brief Overview of Equipment in Geochemical Analyses

2.9.1 Overview of XRF (X-ray fluorescence)

X-ray fluorescence analysis is a procedure for determining major and trace elements of geological materials (Potts & Webb, 1992) It is an analytical method used to assess the constituent composition of materials. XRF analysers assess the chemistry of a sample by measuring the fluorescence (or secondary) X-ray generated by a sample when stimulated by a prime X-ray source. Each element in a sample generates its own spectrum of fluorescent X-rays. XRF equipment is applied in a wide range of fields, such as cement manufacture, metallurgy, mining, petroleum, polymers, paints, and chemicals, forensic investigations, and environmental studies. Due to its affordable price of sample preparation, stability, and convenience of use of x-ray spectrometers makes this features the most extensively used methods for analysing major and trace elements in rocks, minerals, and silt. Though there are some limitations towards the usefulness of XRF, either way, XRF laboratory analysis will continue to be the benchmark for producing high-quality geochemical data analyses in the exploration of earth elements composition (Oyedotun, 2018). During laboratory analysis, XRF enables us to identify single or multiple mineral structures and able to solve the crystal structure. It allows for texture analysis and recalibrate the quantity of known minerals that exist within the samples.

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

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is widely used for elemental analysis for more than 70 elements (Houk et. al., 1980). Most ICP-MS instruments use a quadrupole mass spectrometer that rapidly, sequentially measures different masses. A single quadrupole ICP-MS has six essential compartments: the sample introduction system, inductively coupled plasma (ICP), interface, ion optics, mass analyser, and detector. Liquid samples are first nebulised in the sample introduction system, producing a fine aerosol that is then delivered to the argon plasma. The high-temperature plasma atomises and ionises the sample, creating ions that are subsequently extracted via the interface area and into a series of electrostatic lenses known as the ion optics. The ion optics concentrates and directs the ion beam into the quadrupole mass analyser. The mass analyser separates ions based on their mass-charge ratio (m/z), which are detected at the detector.

2.10 Harker Diagram

The Harker diagram is a graphical tool in geochemistry that is widely used to represent the compositions of different rock types on a ternary diagram. Harker's variation diagrams (Harker 1909) and diagrams that are similar to these (e.g., Fenner 1921) are binary plots that were created specifically for the study of the development of igneous rocks. They are plotted and displayed in a weight basis unit, but without closing the portions (i.e., without bringing the two plotted parts to 100%). (Cortés, 2009). The Harker variation graphs for major and chosen trace elements for basic to intermediate volcanic rocks from the West Nain region. Distinct symbols are used to designate different series depending on their trace elemental patterns (Yeganehfar, et. al., 2012).

CHAPTER 3

MATERIALS AND METHODOLOGIES

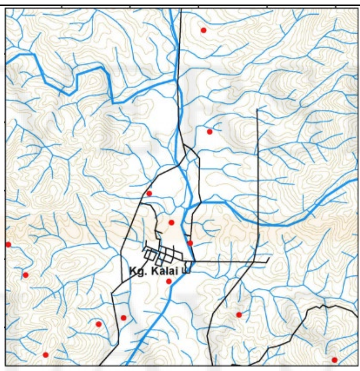
3.1 Introduction

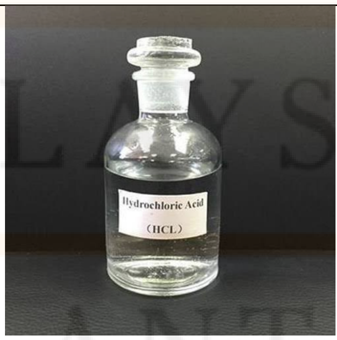
There are several materials used in order to collect data samples from the research area. Thus, it is advisable to use these requested materials to fulfil this research project's objective. The figure below shows the appropriate materials use for conducting the research in the given study area. Figure 3.1 shows the flow chart for this research.

3.2 Materials

The materials use below are employed for the purpose of this geological fieldwork. Table 3.1 below shows the materials use for geological fieldwork and the function of each material use.

Table 3.1 Lists of materials use for geological fieldwork and its functions.

Materials	Figures	Function
Base map		To provide information regarding the study location.
Hammer		To collect rock samples by swinging on the outcrop to crack open it.

Brunton Compass		It uses the Earth's magnetic field to provide directional degree measurements (azimuth). Looking down into the mirror while holding the compass at waist height, the user aligns up the target, needle, and guideline on the mirror.
Geological Measuring Tape		It is use as a surveying device to determine the distance of the outcrop and measure the relative elevation.
Global Positioning System (GPS)		It is used to decode and compute the precise location of the location back to the user.
Hydrochloric Acid (HCL)		To determine whether the rock has calcite elements.

Hand Lens		Used as a portable magnifying glass to take a closer look at the rock physical content.
Field Notebook		To record the data gathered during fieldwork.
Sample Bag		Use to collect and gather data samples from the fieldwork
Stationery		Stationery such as pen, pencils, ruler and so on to write down data during fieldwork.

3.3 Methodology

Methods used for this research is distributed into preliminary study, field study, laboratory work, data processing, data analysis and interpretation and thesis writing.

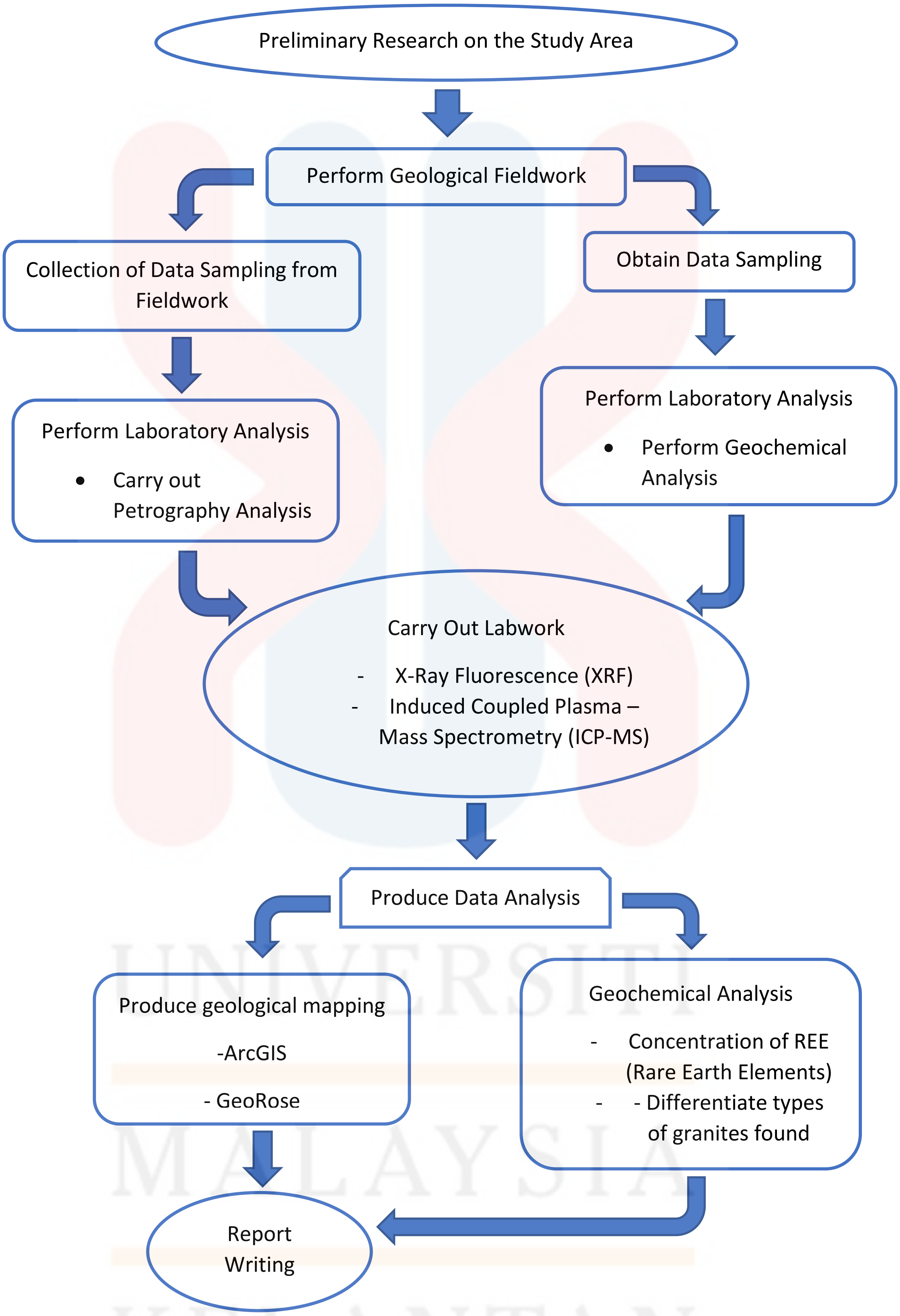


Figure 3.1 The flow chart of the research.

3.3.1 Preliminary Study

Preliminary study is an exploratory investigation focuses on the topics connected to a proposed quality assessment or evaluation. It acts as a basis to plan the experiment before starting. This study can be by observing geological map and topographic map, online reference such as online books and online journals and discussion with supervisor.

3.3.2 Field Studies

The field studies focus more on the geomorphological mapping, structural analysis, lithological analysis, and outcrop sampling of the study area. Furthermore, to construct geological map will involve traversing and observing the rocks in the area and collecting data on their physical characteristics, including their mineralogy, texture, and structure.

3.3.3 Laboratory Work

The laboratory work will be conducted through fieldwork data and petrography analysis. The method for XRF (X-Ray Fluorescence) and ICP-MS (Induced Coupled Plasma - Mass Spectrometry) will be used for geochemical analysis.

(A) Thin Section

Petrography analysis is a microscopic examination of chemical and physical properties of a certain rock, reservoir, or formation to understand more about the description and classification of rock in the study area. Petrology analysis is also defined as the methodical explanation of geological data, composition, and structure, in hand specimens and thin sections (Whitbread, I, K., 2017). Petrography analysis deals through synthesis of rocks in laboratory to denote the behaviour of the rock under physical and chemical conditions to how the rock formation occurs. Petrography also talks about the mineral content and textural relationship within the rock structure by obtaining thin sections from the study area then later perform petrographic analysis by using a petrographic microscope. The study of petrology is strongly dependent on mineralogy concepts and methodologies since most rocks are made up of minerals and produced under similar conditions (Metcalfe, I., 2001).

For this laboratory research, the researcher is required to obtain rock samples as data collection from the conducted research site and transform it into thin section for further study. Once the rock samples are obtained from fieldwork, the rock needs to be cut into fine pieces to be placed into thin sections. This task requires a copper coating on ceramic substrate cut with 20HC blade and grinder tools for cutting and smoothening the rock sample. Later the sample is heated onto the hot plate about an one hour until it is hot enough to be bonded to the standard glass slide using epoxy resin. From there, few procedures will be set to analyse rock specimen's composition, texture, and structure through thin section.

(B) Sample Preparation (Crush, pulverize and sieve)

Sample preparation refers to the process of readying a sample for analysis. The samples chosen for this process are from two granite rocks which code for S1 3804 G and S1 10819 G. The sample preparation for granite samples involved a multi-step process which are crush, pulverize and sieve. This is to ensure that the samples were representative of the population and compatible with the analytical methods used. Firstly, the jaw crusher was used to crush the granite samples into a size of 3mm. It is worth noting that the size of the rock samples varied before crushing, thus the jaw crusher was used to ensure a consistent particle size for further analysis. The next step involved the use of a pulveriser, which was used to heat the rock samples until they were in powder form. The powder was then sieved to obtain a particle size of 75 micrometres. This step is crucial as it makes the samples more easily analysed by the analytical methods used, such as X-ray fluorescence (XRF) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Later, the samples are left to dry for 24 hours to ensure that the samples were free of moisture. This is an important step as moisture can interfere with the analytical results. Finally, the dried powder was transferred into zip lock plastic bags for analysis. This step is important to prevent contamination and preserve the samples for future analysis if necessary.

Figure 3.2 Jaw crusher use to crush granite rock into smaller size rocks.

Figure 3.3 Pulverize use to pulverize granite samples into powder form.

(C) Sample Digestion Using Microwave Digestor

Total digestion was used for granite sample digestion. Prior to inductively coupled plasma mass spectroscopy (ICP-MS) analysis, it will employ concentrated Nitric Acid (HNO_3), Hydrochloric Acid (HCl), Hydrofluoric Acid (HF), Hydrogen Peroxide (H_2O_2) and Boric Acid (H_3BO_3) for chemical analysis of rare earth elements (REE) components in granite samples. In the first stage, 0.5 g of granite sample was weighted and used. Then, 4ml concentration of HNO_3 was added and shook well, followed by 2ml concentration of HCl, 1.5ml, 30%, H_2O_2 and 1.5ml, 48%, concentration HF. Later, the sample was digested in microwave digester for 40 minutes at 200 °C (Lambda Advanced Technology, 2022). After that, in Teflon jar, 30ml of 0.5 M, HNO_3, was added alongside the sample that has been microwaved. It will be added upon heating for more than 45 minutes at 75 °C in order to make sure the residual HF is removed and to obtain a clear solution. To avoid fluoride precipitation, boric acid (H_3BO_3) will be added to the mixture after digestion. The solution will then be diluted with 0.5 M HNO_3. The solution will then be ready to be analysed using ICP-MS (Al-Harahsheh et al., 2009).

Figure 3.4 Microwave digestor use to break down samples for elemental analysis.

(D) X-ray Fluorescence (XRF)

The use of XRF (X-ray Fluorescence) for the geochemical analysis uses x-rays to analyse solid materials non-destructively. The type of XRF instrument that was use was the handheld X-ray fluorescence type and model "S1 TITAN 800" which was prepared by lab GREAT UMK. The handheld X-ray fluorescence instruments are intended for use in the exploration of basic metals, precious metals, and speciality metals (for example, rare earth elements (REE), Ta, and Nb) and enable quick decision-making immediately in the field (Simandl et al., 2013). The handheld XRF can detect elemental range from Magnesium (Mg) to Uranium (U). The orderliness and purity of the XRF emission spectrum and its excellent, accuracy and precision make this approach a geochemical method of choice in mineralogy and analysis of the chemical composition of earth minerals. XRF can evaluate most elements heavier than oxygen down to the ppb level. While undergoing geochemical analysis with the samples collected from geological fieldwork, the high voltage from XRF drives electrons towards the metal target, resulting in a fixed wavelength x-ray beam that strikes the sample. As outer shell electrons drop to inner orbitals, inner shell electrons in the sample are expelled, and photons are released. Photons have certain energies, and elemental concentrations may be determined by comparing sample intensities to a known standard.

Figure 3.5 Handheld XRF equipment

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

ICP-MS (inductively coupled plasma-mass spectrometry) is a potent analytical method that has a wide range of applications in geochemistry (Jenner et al., 1990). It uses ionisation of components within a sample matrix to measure and identify elements. After passing through the ICP, the ions are separated by their mass-to-charge ratio, and the detector counts the number of selected ions per second, allowing the instrument to measure the concentration of each element through MS (Mass Spectrometry). With the data sample collected from geological fieldwork, the sample vapour is moved into a chamber under high vacuum using argon gas, where both the sample and the gas are heated up to 7000°C to produce a particular wavelength of light. By providing accurate analytical data, ICP-MS can facilitate in interpreting the movement of elements and chemical processes in water from various sources, sediments, soils, and rocks.

3.3.4 Data Processing

The results of the laboratory testing have been analysed and interpreted. The distribution of rare earth elements, major and trace elements was evaluated using the results of XRF and ICP-MS analyses. ArcGIS software version 10.8 is used to create geological maps and for mapping purposes in order to identify geological characteristics.

3.3.5 Data Analysis and Interpretation

The laboratory work's findings will be analysed and evaluated. The distribution of rare earth elements, major and trace elements was interpreted based on the results of XRF and ICP-MS analyses. ArcGIS software version 10.8 is used to create geological maps and for mapping purposes to identify geological characteristics.

3.3.6 Thesis Writing

After all the data has been collected, it will be recorded and summarized in all the following chapters from introduction to conclusion. The goal of this report write-up is to assist future researchers or readers in reviewing and understanding the issue in order to make future improvements and suggestions for better ways to handle research in the same area study.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

In this chapter, all occurring data that have been collected through conducting geological fieldwork. This chapter discussed the geomorphology, lithostratigraphy, geological structure and historical geology of the research area.

4.1.1 Accessibility

This part studied the study area's ability to be accessible from other areas to other sites. To reach or approach the area, it is necessary to have a road such as a main road, byroads, or a villager's footpath, as well as a transport mechanism such as a bike, four-wheel vehicle, or other transport that is appropriate for the physical and size of the road, and a telecommunication system. Because not all internet coverage is available in the study region, the telecommunications system is quite good. Only specific areas, such as forests and rural areas, have minimal coverage. The roads shown in Figure 4.1 shows good road network which is a crucial contribution to economic development and growth and deliver substantial social benefits. They are critical to the growth and development of Kampung Kalai, Batu Melintang. Furthermore, access to job, social, health, and education services makes a road network critical in the battle against poverty.

Figure 4.1 Accessibility roads to and from Kampung Kalai, Batu Melintang.

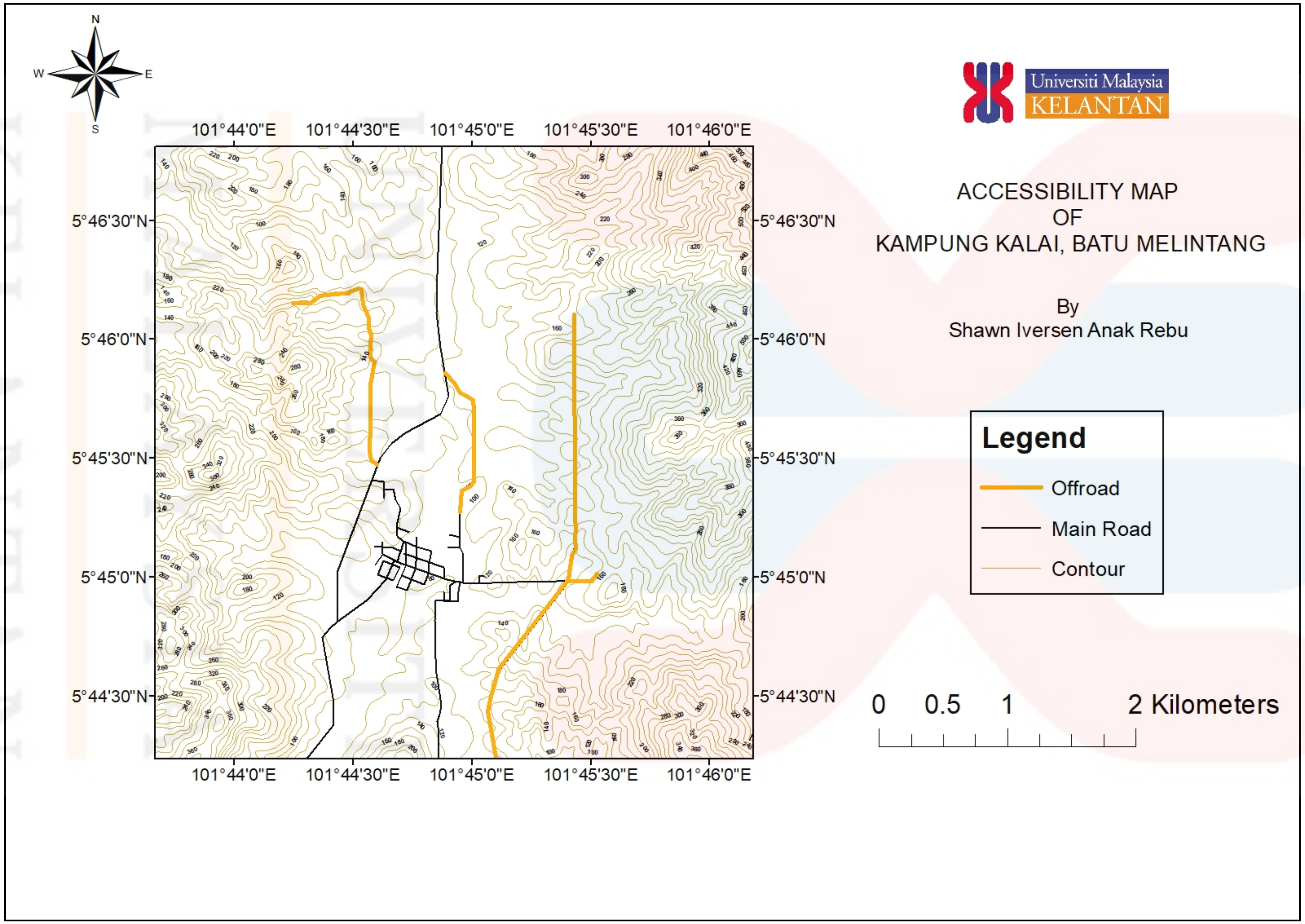


Figure 4.2 Accessibility map of research area.

4.1.2 Settlement

Settlement refers to the places and territories that have been inhabited by people who have created a community. The primary communities covered and located in the research area are Kampung Kalai, Batu Melintang. The majority of the villagers are involved in the management of rubber and palm oil plantations. The Malay race predominates in the Kalai region, with a minor number of other races such as Chinese, Indian, and others.

4.1.3 Forestry

Palm oil plantation, rubber plantation, and forestry are the three primary forms of vegetation that can be found in Kampung Kalai, Batu Melintang. Palm oil plantation occupied approximately at 80% of the research area, rubber plantation at 10%, and forestry at 10%. Plantations such as palm oil and rubber plantations are major contributors to the creation of work possibilities for Kampung Kalai residents in order to improve their economy and living standards as shown in Figure 4.2 and Figure 4.3.

Figure 4.3 Rubber plantation build by villagers in Kampung Kalai, Batu Melintang.

Figure 4.4 Oil palm plantation build by villagers for economy stability.

4.1.4 Traverses and Observation

Mapping activities are carried out by travelling and observing in order to acquire data and rock samples. This travels and observation approach is accomplished by entering the study area along the road or by river. The river is being travelled frequently as there is possibility of new exposed outcrop or highly exposed outcrop which are generally found. Before entering the site, the route of the destination is planned and determined to ensure steady flow while conducting fieldwork. When traveling and examining, distinct contour patterns on a topographic map are investigated first to identify the lithology in that area. The traverse path and observation point are recorded in GPS and displayed on the map, as illustrated in Figure 4.5. The description included details such as coordinates, elevation, lithology, strike and dip, weathering level and rock colour. Based on Figure 4.5, about 70% of the research area is covered while certain parts of the research area are not accessible due to high slopes and thick vegetation.

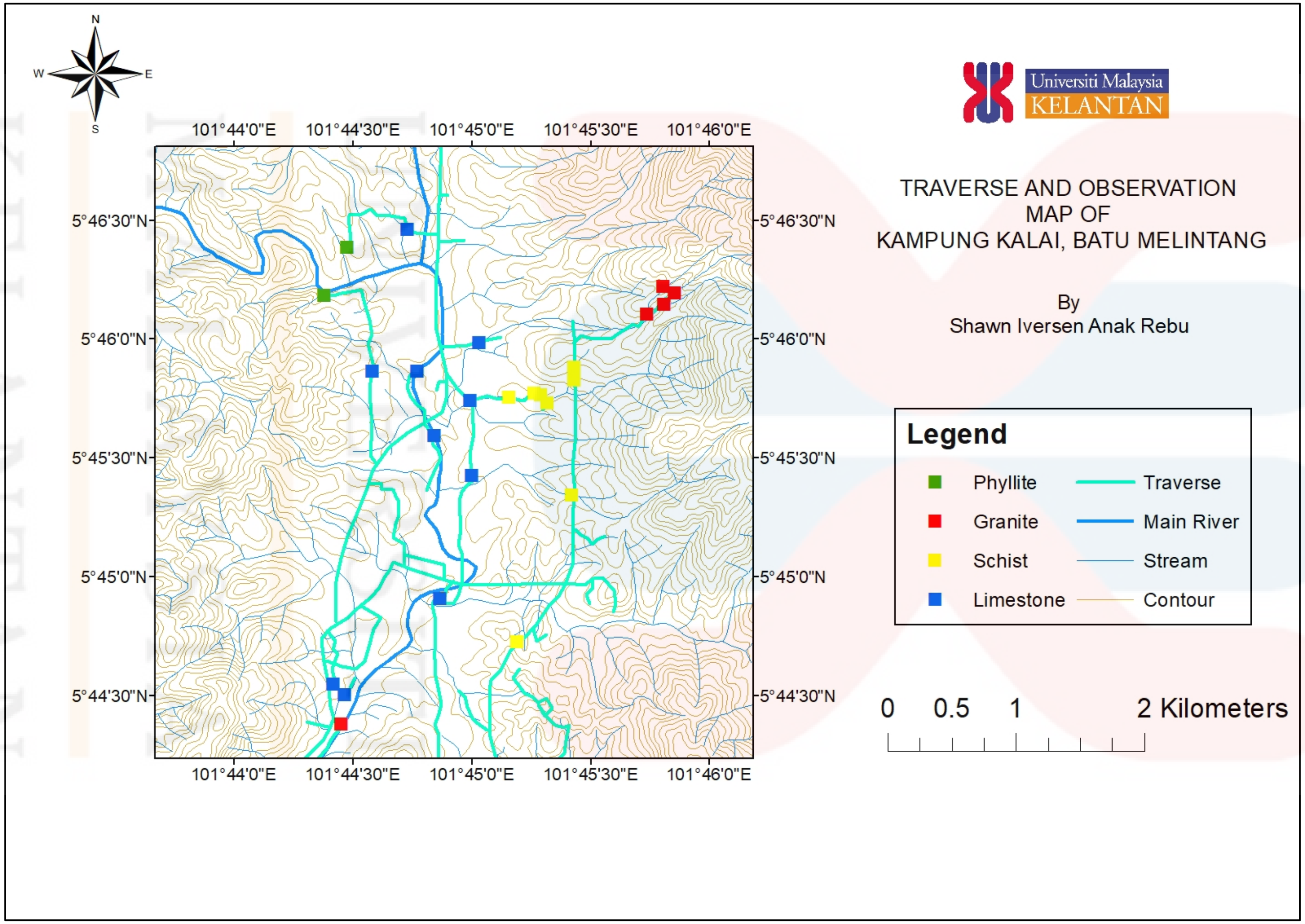


Figure 4.5 Traverse and location of outcrop in research area.

4.2 Geomorphology

Geomorphology is concerned with the structure, origin, and development of the topographical features of the earth's surface. This section is mainly discussed on the topography classification, weathering processes and drainage pattern in the research area. It also discusses the topographic classification, weathering process, and drainage pattern of the research area. Observing and studying geomorphology for an area may assist the observer in identifying various types of landscape and landform features, detecting physical changes in earth landforms, and providing a suggestion about potential hazards that may occur naturally or environmentally. Figure 4.6 shows the geomorphological view of Kampung Kalai, Batu Melintang. It is shown that the Kampung Kalai is mostly surrounded by mountains and hills.

Figure 4.6 Geomorphology of Kampung Kalai, Batu Melintang.

4.2.1 Geomorphologic classification

The geomorphologic classification is solely focused on the topography of the landscape. The topography of the research area is divided into two types: hilly areas and mountainous areas.

Based on the 3D model of geomorphological map in Figure 4.7, the landform is mostly dominated by hills and mountains with the mean elevation above the sea level range from 120m to 600m. The highest elevation is located at the northeast of Kampung Kalai with elevation 450-600m which is regarded as mountains that formed in that area. As for hills, it covers mostly the whole area of the Kampung Kalai from the west side and the east side. The elevation for hilly areas ranges from 120-450m. The hill in that area is divided into 2 types, sloping hills which are the light green in colour and steep hills which shows yellow in colour. Sloping hills are hills with a slope or inclination, as opposed to flat or level hills. They might be gently sloping or steep and rough. Steep hills are hills with an extremely steep inclination or slope. They can be difficult to climb or descend, particularly if they are rough or feature loose or slippery terrain. The lowest elevations found in the geomorphological map is the plains with 20-120m. Plains are broad, flat regions of terrain with little variation in height. They are generally found in situations where the earth has been eroded over time, such as around the margins of mountains or on extremely mild slopes. This area is mostly habitat by the villagers of Kampung Kalai. The plains are located at the centre stretching from north to south of the map.

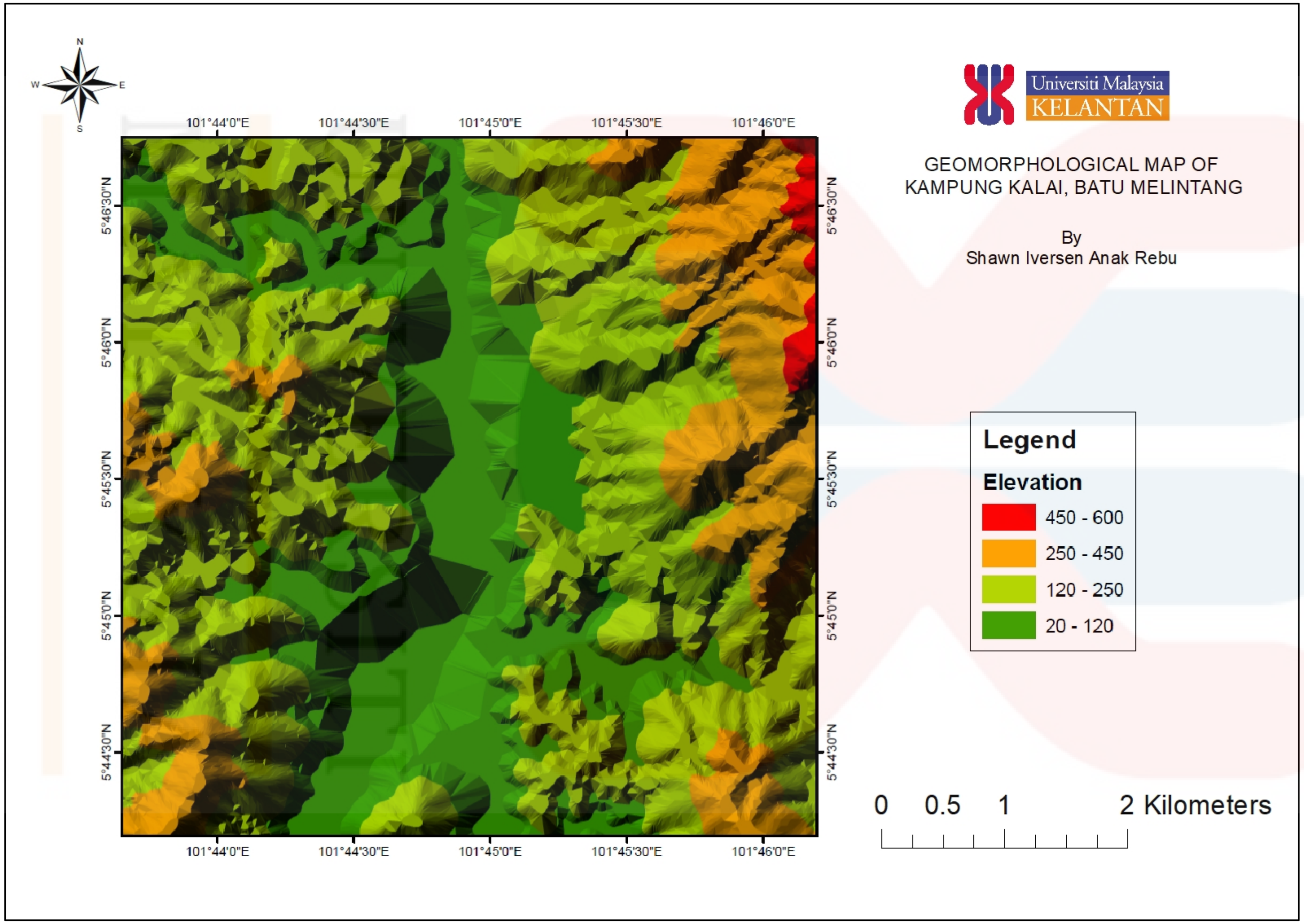


Figure 4.7 3D geomorphological map of the research area.

4.2.2 Weathering Process

There are three types of weathering processes found in the research area, chemical weathering, biological weathering, and physical/mechanical weathering. The occurrence of rocks that has been exposed to weathering will be weathered down into soil or broken-down rocks.

Physical weathering, often known as mechanical weathering, is the process through which rocks, minerals, and soils disintegrate without undergoing chemical change. Abrasion is the basic process in physical weathering (the process by which clasts and other particles are reduced in size). Temperature, pressure, frost, root movement, and burrowing animals can all cause physical deterioration. Physical weathering will increase the surface area exposed to chemical activity, accelerating the pace of disintegration.

Figure 4.8 Physical weathering occur on schist outcrop.

Figure 4.9 Joints on the granite outcrop due to physical weathering.

Chemical weathering is the interaction of rock with mineral solutions (chemicals) to modify the composition of rocks. Water interacts with minerals in this process, causing a variety of chemical reactions and transforming the rocks. Chemical weathering is a slow and continuing process in which the mineralogy of the rock adapts to the near-surface environment.

Figure 4.10 Chemical weathering due to rainwater which reacted towards the limestone outcrop.

Figure 4.11 Heavily weathered schist outcrop due to chemical weathering.

Biological weathering is the degradation and disintegration of rock which is caused by plants, animals, and bacteria. Microbial activity degrades rock minerals by changing the chemical makeup of the rock, making it more prone to weathering.

Figure 4.12 Lichen grows on the surface of the granite boulder.

Figure 4.13 Moss grows on the surface of the limestone outcrop.

4.2.3 Drainage Pattern

In this section, there are two types of drainage pattern found in the research area, which are dendritic pattern and parallel pattern.

Dendritic drainage pattern is a type of river system in which the river channels resemble the branches of a tree. It is the most common type of drainage pattern found on Earth and is typically seen in areas with homogenous rock and a moderate to high amount of precipitation. Based on the drainage pattern map in Figure 4.12, the dendritic pattern main river channel divides into smaller tributaries, which then branch out into even smaller tributaries, creating a tree-like network of channels.

Parallel drainage pattern is a type of river system in which the river channels flow parallel to each other. It is typically seen in areas with long, narrow valleys and steep slopes. Based on the drainage pattern map in Figure 4.14, the parallel drainage pattern, the rivers flow in the same direction as the slope of the land, following the contours of the valley. The channels are usually separated by a relatively short distance, and they may join together at the mouth of the valley.

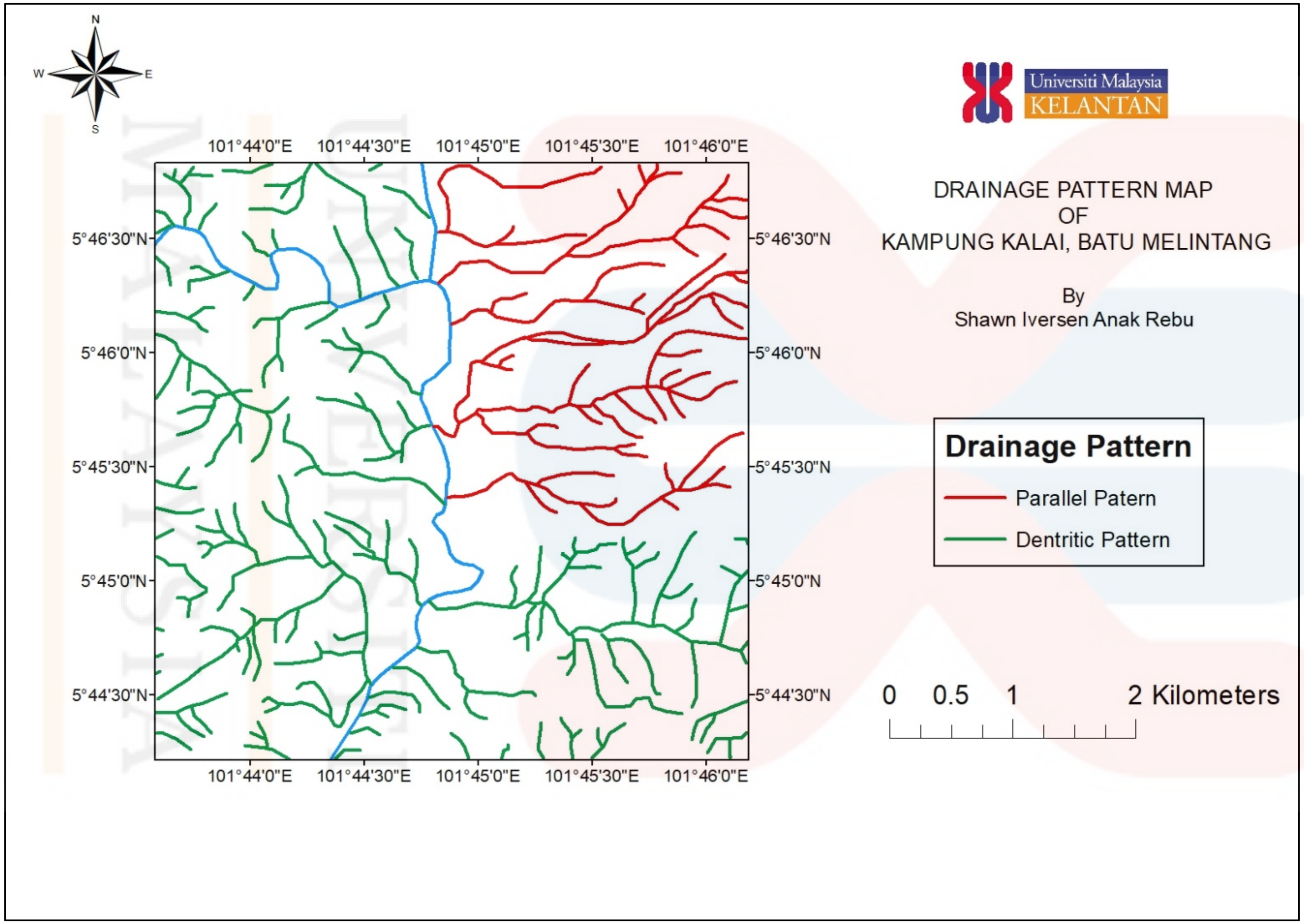


Figure 4.14 Drainage pattern map of the research area.

4.3 Lithostratigraphy

Lithostratigraphy is the study of rock layers and the relationships between them. It is a subfield of stratigraphy, which is the study of rock layers and their distribution in time and space.

In lithostratigraphy, rock layers are classified and described based on their physical characteristics, such as composition, texture, and structure. These characteristics are used to identify and distinguish different rock units, which are then grouped into formations. Formations are mappable rock units that are characterised by a set of distinctive rock types and are distinguishable from other formations.

Lithostratigraphy is used to understand the geology of an area and to interpret the history of the Earth's surface. It is a valuable tool for geologists, geographers, and other scientists who study the Earth and its resources.

4.3.1 Stratigraphic position

Stratigraphic unit definitions comprise outlining the features and known distribution of stratigraphic units so that they may be properly recognised and identified in the field by other geologists. A type of section or locality must be discovered and specified to generate a formal definition of a new unit. For the stratigraphy unit, there seem to be 4 main rock units that appears in the map while conducting geological fieldwork. Those 4 rock units are phyllite, limestone, schist and granite.

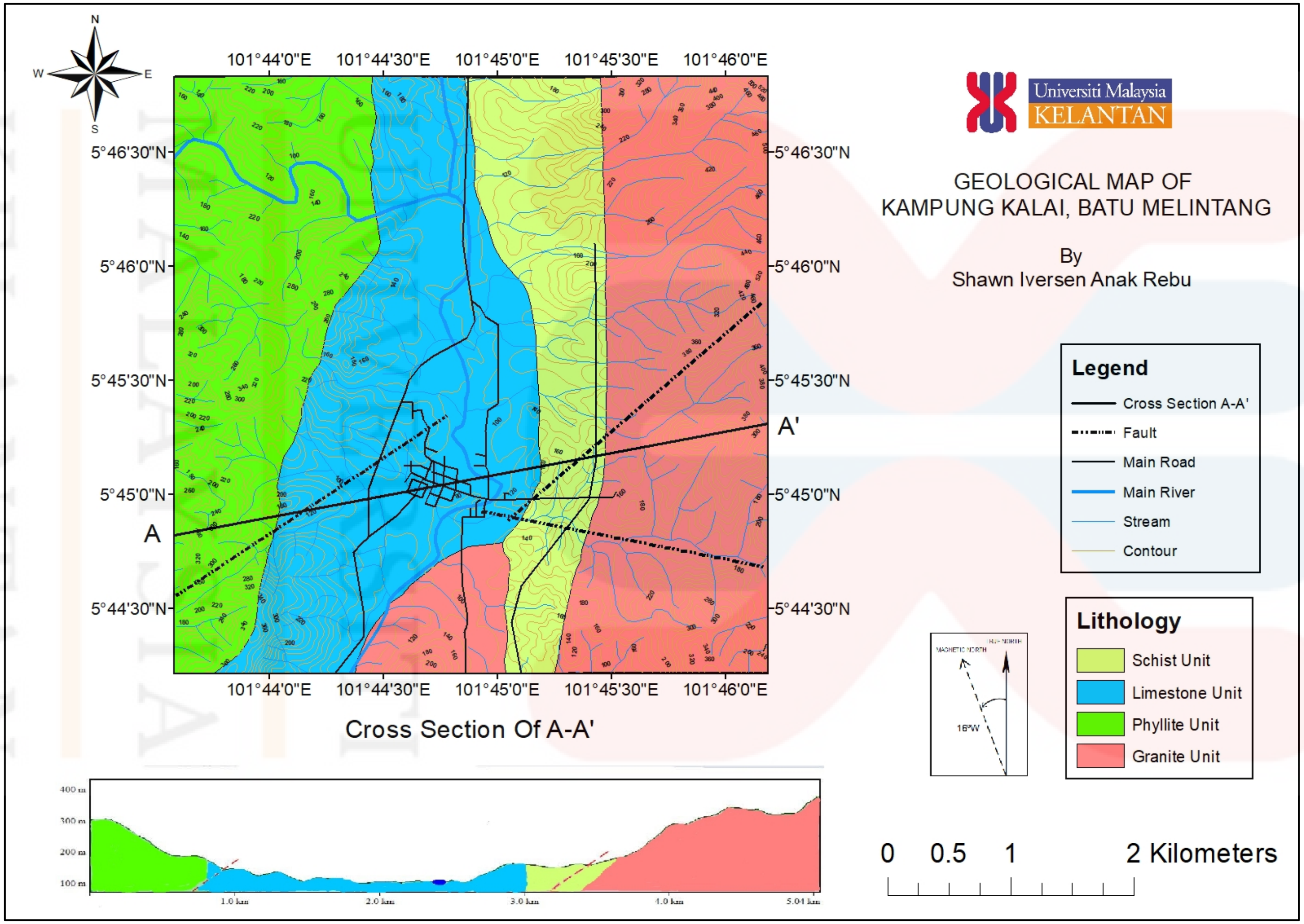


Figure 4.15 Geological map of Kampung Kalai, Batu Melintang.

Table 4.1 Lithology Unit of research area

Lithology	Era	Age	Unit	Description
	Cenozoic Era	Tertiary	Granite	- Consists of granite gneiss and granodiorite.
	Mesozoic Era	Triassic	Limestone /Marble	- Composed of limestone, metamorphosed limestone, and marble.
	Paleozoic Era	Permian	Schist	- Mainly consists of schist, slate, and shale.
		Permian	Phyllite	- Mainly consists of phyllite, slate and shale.

4.3.2 Unit Explanation

This subtopic will focus more on the petrography analysis of the rock specimens. This part plays a vital role in understanding the lithology starting from the oldest rock to the youngest rock unit.

Phyllite Unit

Figure 4.16 shows the 36th rock sample code for "SI 29836" which was collected during geological fieldwork. Based on field observation, the lithology of rock is found to be a phyllite rock. The outcrop is located at the west side of the base map right close to Kalai river. Based on the physical characteristics in Figure 4.17, the rock appears to be in greyish in colour with some part of the rock to be brown in colour due to weathering.

Figure 4.16 Phyllite outcrop.

(a) (b)

Figure 4.17 Phyllite rock samples (a) and (b).

Based on the petrographic analysis in Figure 4.18, the mineral composition that exists within the thin section are microcrystalline quartz and micas. Foliation is present when seen through plane polarised light (PPL).

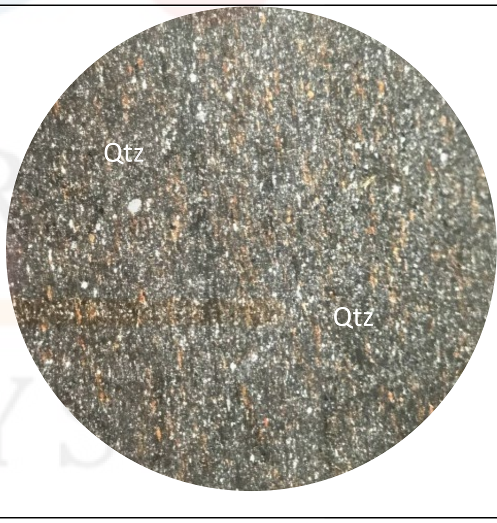
Code: SI 29836	
	
PPL	XPL
Magnification: 4x10 power	Magnification: 4x10 power

Figure 4.18 Phyllite thin section.

Limestone unit

Figure 4.19 shows the limestone outcrop where the 1st rock sample which code for “SI 381” was collected during geological fieldwork. Based on field observation, the lithology of the rock appears to be of limestone rock. The outcrop is located at the centre of the base map alongside Kalai river. Based on the physical characteristics of the rock in Figure 4.20, the rock appears to be in white colour. While doing the hydrochloric acid test (HCL), the rock fizzes, indicating that the rock has calcite minerals that react towards HCL. Thus, proving the rock is a limestone outcrop. There is some physical weathering occurred on the outcrop.

Figure 4.19 Limestone outcrop.

(a) (b)

Figure 4.20 Limestone rock samples (a) and (b).

Based on the petrographic analysis in Figure 4.21, the mineral composition found within the thin section is mostly composed of calcite with little quartz minerals.

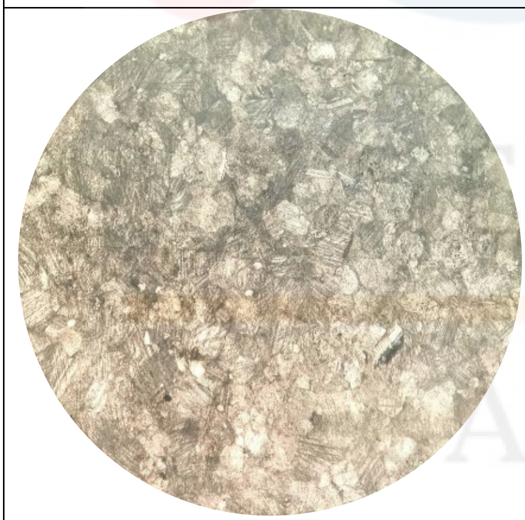
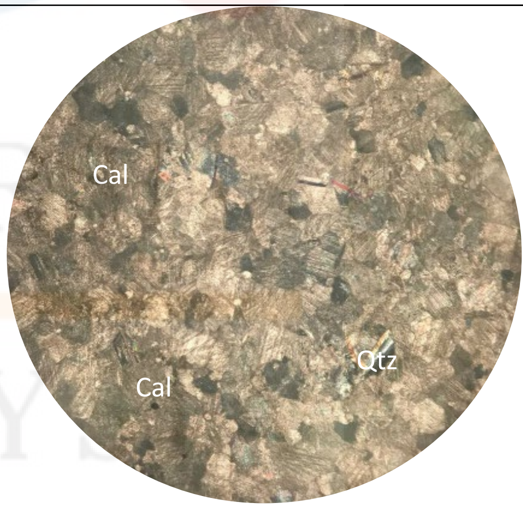
Code: SI 381	
	
PPL	XPL
Magnification: 4x10 power	Magnification: 4x10 power

Figure 4.21 Limestone thin section.

Schist Unit

Figure 4.22 shows the schist outcrop where the 29th rock sample which code for “SI 9829” was collected during geological fieldwork. Based on field observations, the lithology of rock is found to be a schist rock. The outcrop is located at the top northeast side of the base map. Based on the physical characteristics of the rock in Figure 4.23, the rock appears to be in greyish in colour with some areas shows dark brown in colour due to weathering.

Figure 4.22 Schist outcrop.

(a) (b)

Figure 4.23 Schist rock samples (a) and (b).

Based on the petrographic analysis in Figure 4.24, the mineral composition that exists within the thin section consists of microcrystalline quartz, biotite and garnet minerals. Foliation is present when seen through plane polarised light (PPL).

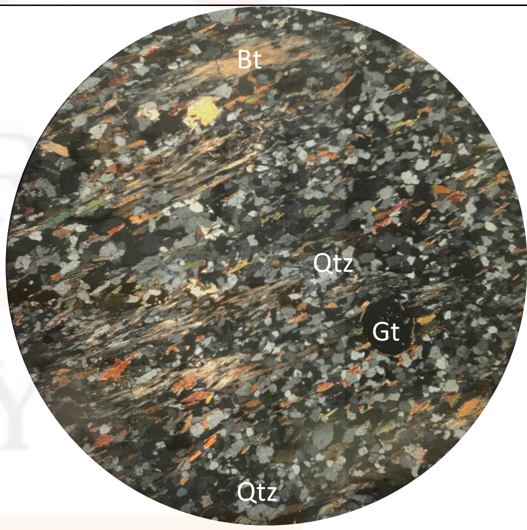
Code: SI 9829	
	
PPL	XPL
Magnification: 4x10 power	Magnification: 4x10 power

Figure 4.24 Schist thin section.

Granite Unit

Figure 4.25 shows the granite outcrop where the 4th rock sample which code for “SI 384 G” was collected during geological fieldwork. Based on field observation, the lithology of rock is found to be made of granite gneiss. The outcrop is located at the south side of the base map. Based on the physical characteristics of the rocks in Figure 4.26, the rock appears to be in greyish colour with some area brown in colour. Weathering is visibly seen on the outcrop due to chemical weathering.

Figure 4.25 Granite outcrop of “SI 384 G”.

	
(a)	(b)

Figure 4.26 Granite rock samples of "SI 384 G" (a) and (b).

Based on the petrographic analysis of Figure 4.27, the mineral composition mostly composed of biotite and quartz minerals with varying sizes.

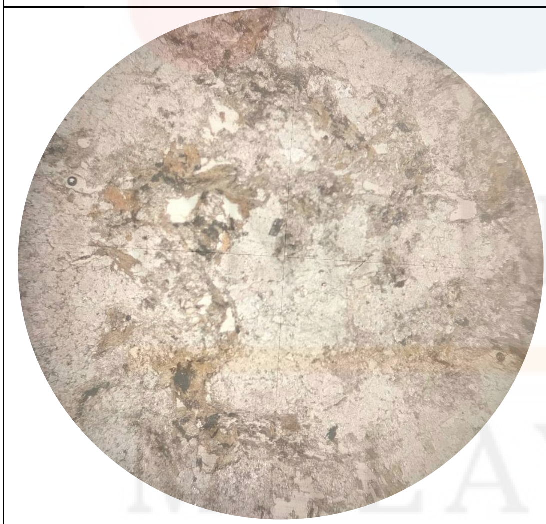
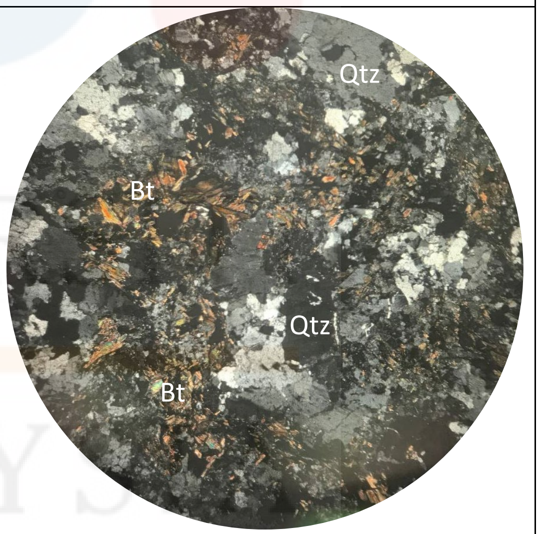
Code: SI 384 G	
	
PPL	XPL
Magnification: 4x10 power	Magnification: 4x10 power

Figure 4.27 Granite thin section of "SI 384 G".

Figure 4.28 shows the granite outcrop where the 19th rock sample which code for "SI 10819 G" was collected during geological fieldwork. Based on field observation, the lithology of rock is found to be made from granite. The outcrop is located at the top east side of the base map. Based on the physical characteristics of the rock in Figure 4.29, the rock sample appears to be in greyish white in colour with shiny appearances due to present of muscovite minerals. Weathering is visibly seen on the outcrop due to physical weathering where some areas are caused by chemical weathering. Biological weathering is also present due to moss growing on the outcrop.

Figure 4.28 Granite outcrop of "SI 10819 G".

(a) (b)

Figure 4.29 Granite rock samples of “SI 10819 G” (a) and (b).

Based on the petrographic analysis in Figure 4.30, the mineral composition of rock sample “SI 10819 G” consists of quartz, weathered biotite and muscovite. There is also presence of chlorite, but it has also been weathered.

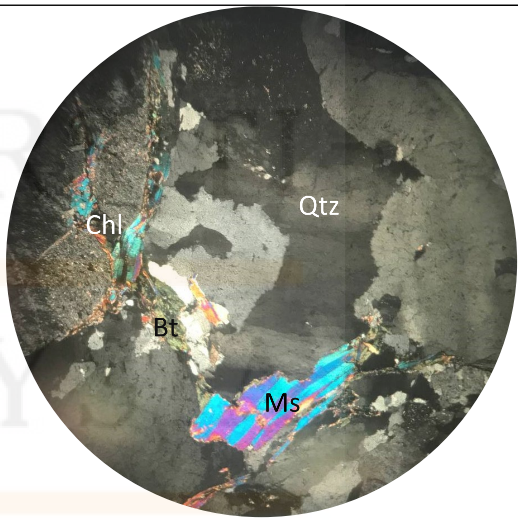
Code: SI 10819 G	
	
PPL	XPL
Magnification: 4x10 power	Magnification: 4x10 power

Figure 4.30 Granite thin section of “SI 10819 G”.

4.4 Structural Geology

Structural geology studies the three-dimensional distribution of rocks and minerals within the Earth's crust, and the processes that have shaped them. It involves the analysis of the deformations that rocks have undergone, and the interpretation of the structures that these deformations have produced.

Structural geology is an important field of study because it helps us to understand the tectonic forces that have shaped the Earth's crust and continue to do so today. It also has practical applications, such as in the exploration and extraction of natural resources, designing structures like bridges and buildings, and assessing natural hazards like earthquakes.

4.4.1 Contact

Contact metamorphism occurs when rock is exposed to high temperatures and pressures because of close contact with an igneous intrusion. An igneous intrusion is a mass of magma that has intruded and hardened into the Earth's crust, generating an intrusion such as a batholith or dike. The rock close to the intrusion is subjected to high temperatures and pressures during contact metamorphism, which can trigger chemical and physical changes. These modifications might vary depending on the rock's composition and the environment it is subjected to.

Contact metamorphism is most common in rocks near the surface, such as sedimentary or volcanic rocks. It is often distinguished by the presence of metamorphic minerals created by high temperatures and pressures, such as hornfels, marble, and quartzite. In Figure 4.18, we can see that there is an intrusion between an igneous outcrop and metamorphic outcrop which results in the formation of hornfels in between.

Figure 4.31 The formation of hornfels through sharp contact metamorphism

4.4.2 Joint

A joint is a break in rock layers that does not show any evidence of movement. Joints can form due to stresses in the Earth's crust. Joints can be of many forms and sizes, straight or curved. They can also run parallel or intersect. Joints are frequently created as a result of tensions in the Earth's crust, such as those induced by tectonic forces, or as a result of cooling and contraction in rocks subjected to high temperatures. Weathering and erosion can also cause joint formation. For example, joints in rock strata may emerge as a result of the rock's expansion and contraction owing to variations in temperature and moisture content. They can also occur because of the physical disintegration of rock caused by wind, water, and other natural processes. In Figure 4.19 shows joint structures on the granite outcrop.

Figure 4.32 shows a granite outcrop with joint structures.

4.4.3 Fault

A fault is a break or fracture in the Earth's crust caused by movement. Faults can be thrust faults (where the rock on one side of the fault is forced up and over the rock on the other side) or strike-slip faults (where the rock on either side of the fault moves horizontally past each other). Faults are frequently generated as a result of tectonic processes such as plate movement on Earth. Faults are frequently distinguished by the existence of fault planes, which are the surfaces along which the movement has occurred, and fault lines, which are the lines drawn by the fault planes on the Earth's surface.

4.4.4 Fold

A fold is a bend in rock strata created by Earth's crust deformation. Folds can be symmetrical (meaning that the layers on both sides of the fold are equally curled) or asymmetrical (where the layers on one side are more curved than those on the other). Folds are often generated by tectonic processes such as plate movement on Earth. Folds are frequently distinguished by the presence of a fold axis, which is the line traced by the fold's crest, and by fold hinges, which are the spots at which the rock strata are most heavily curved.

4.4.5 Mechanism of structure

Joint analysis is a structural geology approach for studying the patterns, orientations, and distribution of joints in rocks. Joints are natural fractures or cracks in rocks that can have a substantial influence on the stability and behaviour of rock masses. Joint analysis is used to determine the mechanical characteristics of a rock mass and to detect possible dangers such as rockfalls or landslides. Joint analysis is commonly performed by mapping the joints in a rock mass, measuring their orientations, and then analysing the data to discover patterns and trends. Visual observations or the use of tools such as a compass can be used to collect data in the field. The joint analysis is necessary to understand how the structure operates on the rock that led them to deform. The joint analysis aids in determining the predominant primary stress.

Coordinate: N 05º 45’44.22” E 101º 45’ 19.11”

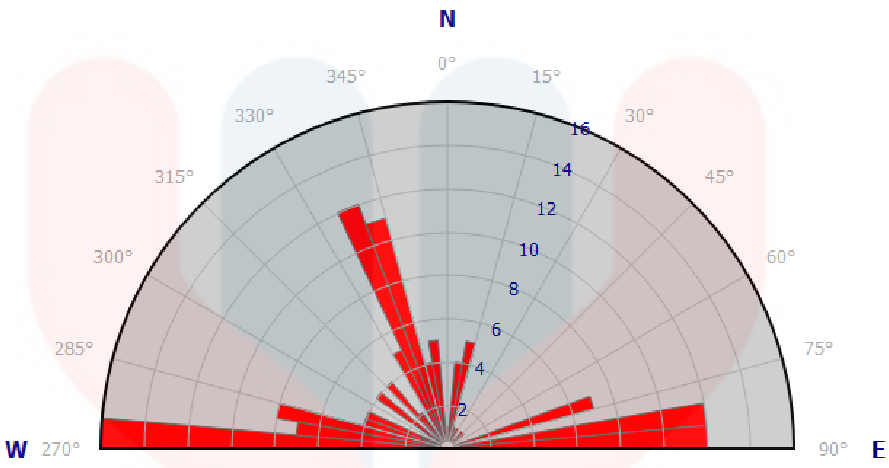


Figure 4.33 Rose diagram of granite outcrop “SI 10819 G”.

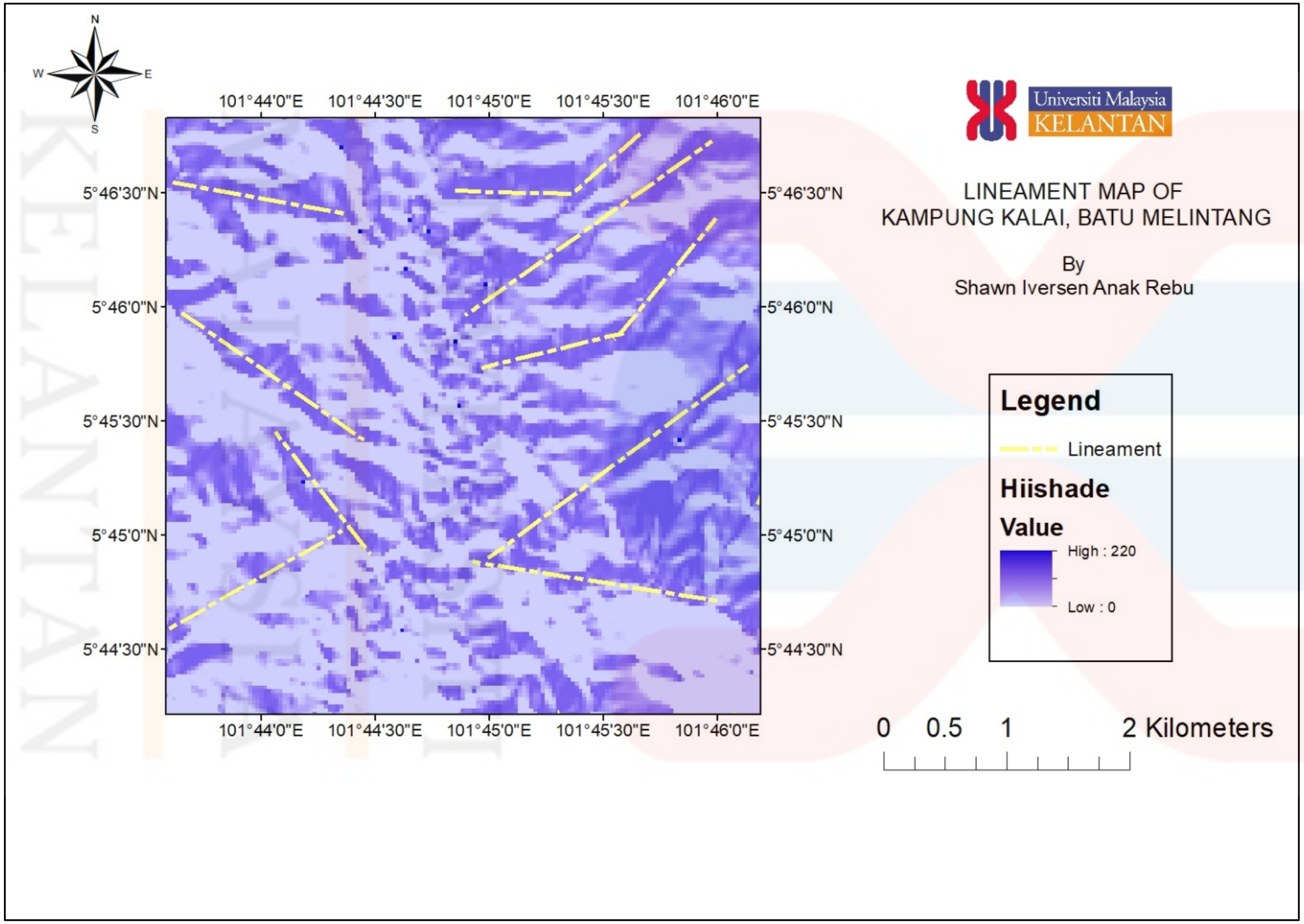


Figure 4.34 Lineament map of research area.

4.5 Historical Geology

During the Permian period, there are two formations occur in this area which are, Telong formation and Mangga formation. Kampung Kalai is underlain by metasedimentary rocks, which are close to the granite intrusion. The metasediments are composed of interbedded Mangga formation metargillites and metarenites, Tiang schist, and Telong formation hornfelsic rocks (The Malaysian and Thai Working Groups, 2006).

The Triassic period is known for the formation of limestone and marble, which are types of sedimentary rocks. Limestone is composed mainly of calcite, which is a form of calcium carbonate, while marble is a metamorphic rock that forms from the recrystallization of limestone under high pressure and temperature. The limestone and marble formed during the Triassic period are composed of limestone, metamorphosed limestone, and marble.

The Tertiary period is known for the formation of acid intrusive. The most common are granite intrusion, which is a type of igneous rock that is composed mainly of quartz, feldspar, and mica. The granite that was formed during the Tertiary period consists of granite gneiss and granodiorite.

CHAPTER 5

GEOCHEMISTRY OF GRANITE ROCKS

5.1 Introduction

In this chapter, the study solely focuses on the data analysis and interpretation of two types of granite rocks, granite gneiss and mica schist granite through geochemistry methods. The two methods of geochemistry analysis used are X-Ray Fluorescence (XRF) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The importance of conducting the geochemistry method is to identify the major elements, trace elements and distribution of rare earth elements (REE) in the granite rocks.

5.2 Major Elements

The granite samples were measured by using a handheld X-Ray Fluorescence (XRF). Table 5.1 shows the result of major elements in two granite rock samples, designated as SI 384 G and S1 10819 G. There are only four major elements present from the result of XRF analysis: MgO, Al_2O_3, SiO_2 and K_2O. All these four major elements are being normalised into 100 wt% before proceeding to plotting the geochemistry analysis graph. Figure 5.1 shows the Harker diagram used to plot three major elements in weight percentage (wt%) versus SiO_2 major element wt %. Table 5.1 shows that both samples are primarily composed of silicon dioxide (SiO_2), with concentrations of 76.49% and 81.035% for SI 384 G and S1 10819 G respectively. Aluminium oxide (Al_2O_3) was also present in both samples, at concentrations of 15.04% and 14.528%, respectively. The remaining elements, magnesium oxide (MgO) and potassium oxide (K_2O), were present in smaller quantities, with concentrations of

3.406% and 5.064% for MgO in SI 384 G and 0.626% and 3.811% for MgO in S1 10819 G, respectively. The higher concentration of SiO_2 in S1 10819 G may indicate a greater degree of felsic composition, while the higher concentration of MgO in SI 384 G may suggest a more mafic character.

Table 5.1 Major elements in granite rocks.

Granite Rocks	Major elements normalised to 100% (wt%)				Total (wt%)
	MgO	Al_2O_3	SiO_2	K_2O	
G1 (SI 384 G)	3.406	15.04	76.49	5.064	100
G2 (S1 10819 G)	0.626	14.528	81.035	3.811	100

Based on Figure 5.1, the Harker diagram shows the linear trends reflecting the fractionation trends of all the major elements. The results shows that all major elements fractionation trend decreases as SiO_2 increases. The results show that the concentration wt% of SiO2 ranges from 76.49 wt% to 81.035 wt% reflecting that the rocks are felsic. The element MgO has the lowest concentration among other elements which range from 0.626 wt% to 3.406 wt%. The content of Al_2O_3 and K_2O are range from 14.528 wt% to 15.04 wt% and 3.811 wt% to 5.064 wt% respectively.

Multiple Plot of SiO_2 vs. MgO, Al_2O_3, K_2O

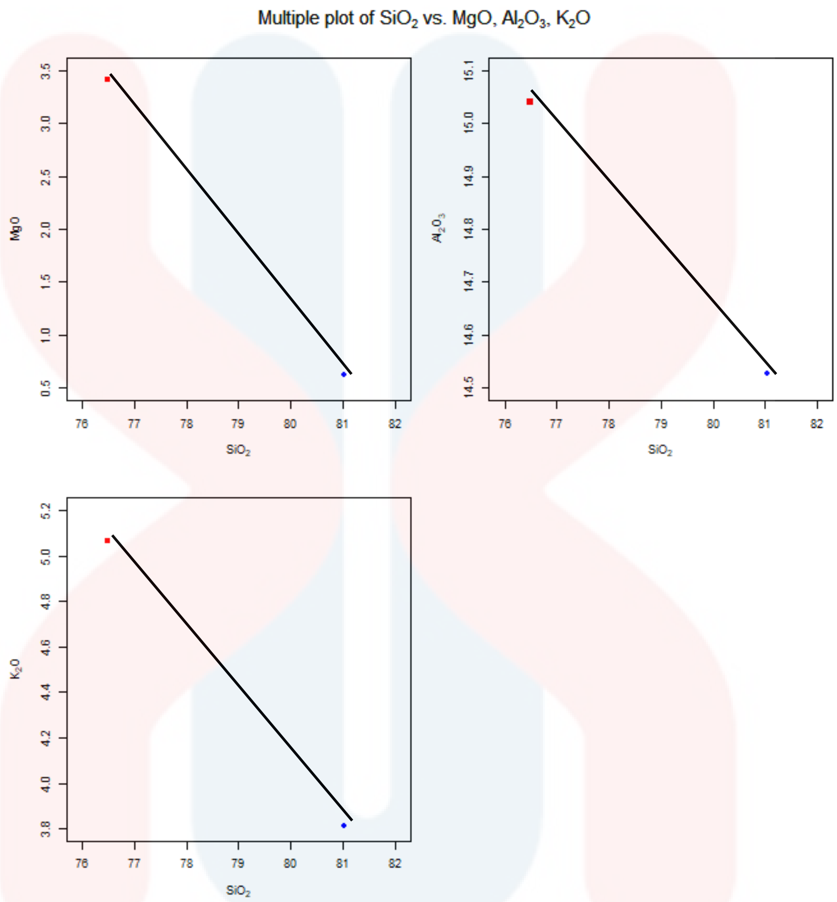


Figure 5.1 Harker diagram of major elements.

Figure 5.2 shows the diagram proposed by Peccerillo & Taylor (1976) to distinguish various series of tholeiitic, calc-alkaline and shoshonitic rocks. Sample SI 384 G belongs to the high-K calc-alkaline series whereas sample SI 10819 G belongs to the calc-alkaline series. This shows that sample SI 384 G are distinguished by high levels of potassium (K) and silica (SiO_2), and intermediate to high levels of calcium (Ca) and aluminium (Al) whereas sample SI 10819 G is characterised by intermediate to high levels of potassium (K) and silica (SiO_2), and intermediate to low levels of calcium (Ca) and aluminium (Al).

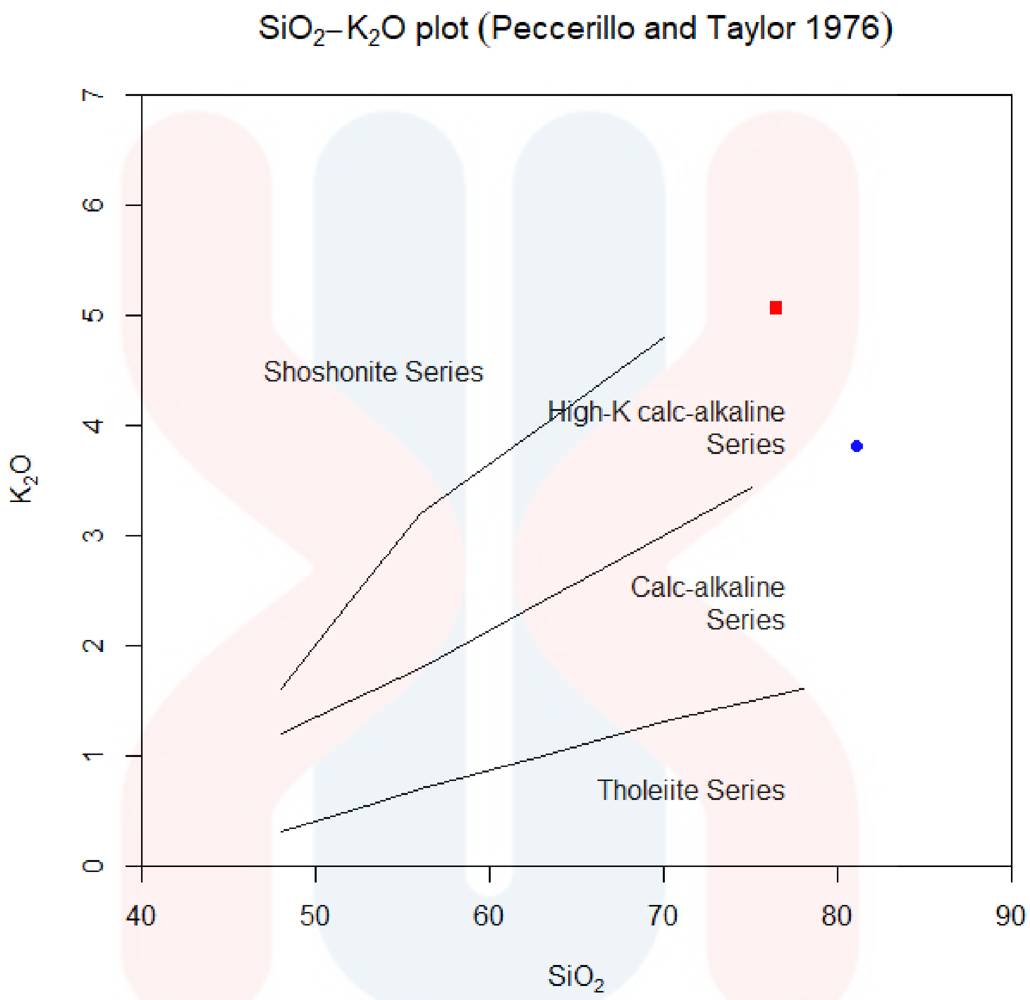


Figure 5.2 SiO2 - K2O (Peccerillo + Taylor 1976)

Figure 5.3 shows the Classic A/CNK vs A/NK plot of Shand (1943) discriminating metaluminous, peraluminous, and peralkaline compositions. This classifies granite rocks as peraluminous when A/CNK is over 1.0 and metaluminous when A/CNK is less than 1.0, depending on alumina saturation. It is reported that the two granites samples are characterised as peraluminous with A/CNK values more than 1.0.

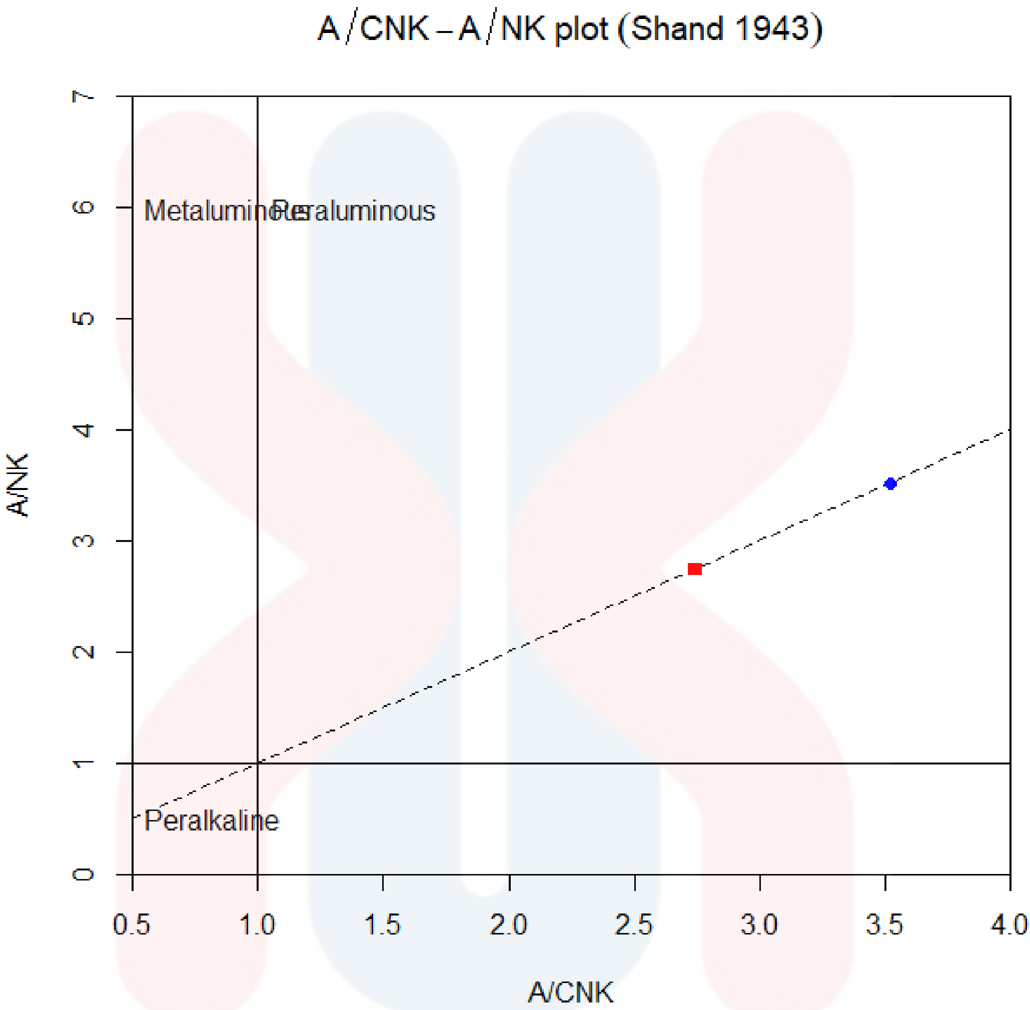


Figure 5.3 A/CNK - A/NK (Shand 1943) plot of granite rocks.

5.3 Trace Elements

Trace elements are chemical elements that are present in small amounts in rocks and minerals and can provide important information about the geochemistry of a sample. Based on the data shown in Table 5.2, both SI 384 G and S1 10819 G contain a range of trace elements in varying concentrations. The wt% results of all trace elements are normalised into ppb units. The elements La, Sc and Yb are absent in this research. In both samples, calcium (Ca), iron (Fe), and titanium (Ti) are present in relatively high concentrations, while other elements such as sulphur (S), bismuth (Bi), vanadium (V), nickel (Ni), hafnium (Hf) and thallium (Th) are either not detected or present in very small amounts. It is interesting to note that the two samples have some differences in their trace element compositions. For example, SI 384 G has higher concentrations of phosphorus (P) and chromium (Cr), while S1 10819 G has higher concentrations of sulphur (S) and manganese (Mn). Figure 5.4 depicts the trace element Harker diagram, whereas Figure 5.5 displays the trace element normalised to chondrites.

Table 5.2 Trace elements in granite rocks.

Trace elements normalised to 100% (wt%)		
Trace Elements	SI 384 G	SI 10819 G
P	1.32937	1.1807
S	n.d	9.13758
Ca	27.14286	16.22177
Ti	7.32143	1.23203
V	0.2381	n.d

Cr	0.13889	0.25667
Mn	0.93254	2.72074
Fe	58.43254	66.06776
Ni	0.15873	n.d
Cu	0.05952	0.154
Zn	0.11905	0.05133
Ga	0.01984	0.05133
Rb	0.41667	1.38604
Sr	0.39683	0.25667
Y	0.05952	0.10267
Zr	0.65476	0.154
Nb	0.03968	0.05133
Ba	2.30159	0.71869
Hf	0	n.d
Pb	0.13889	0.10267
Th	0.07936	n.d
Bi	n.d	0.10267
U	0.01984	0.05133

* n.d = Not detected

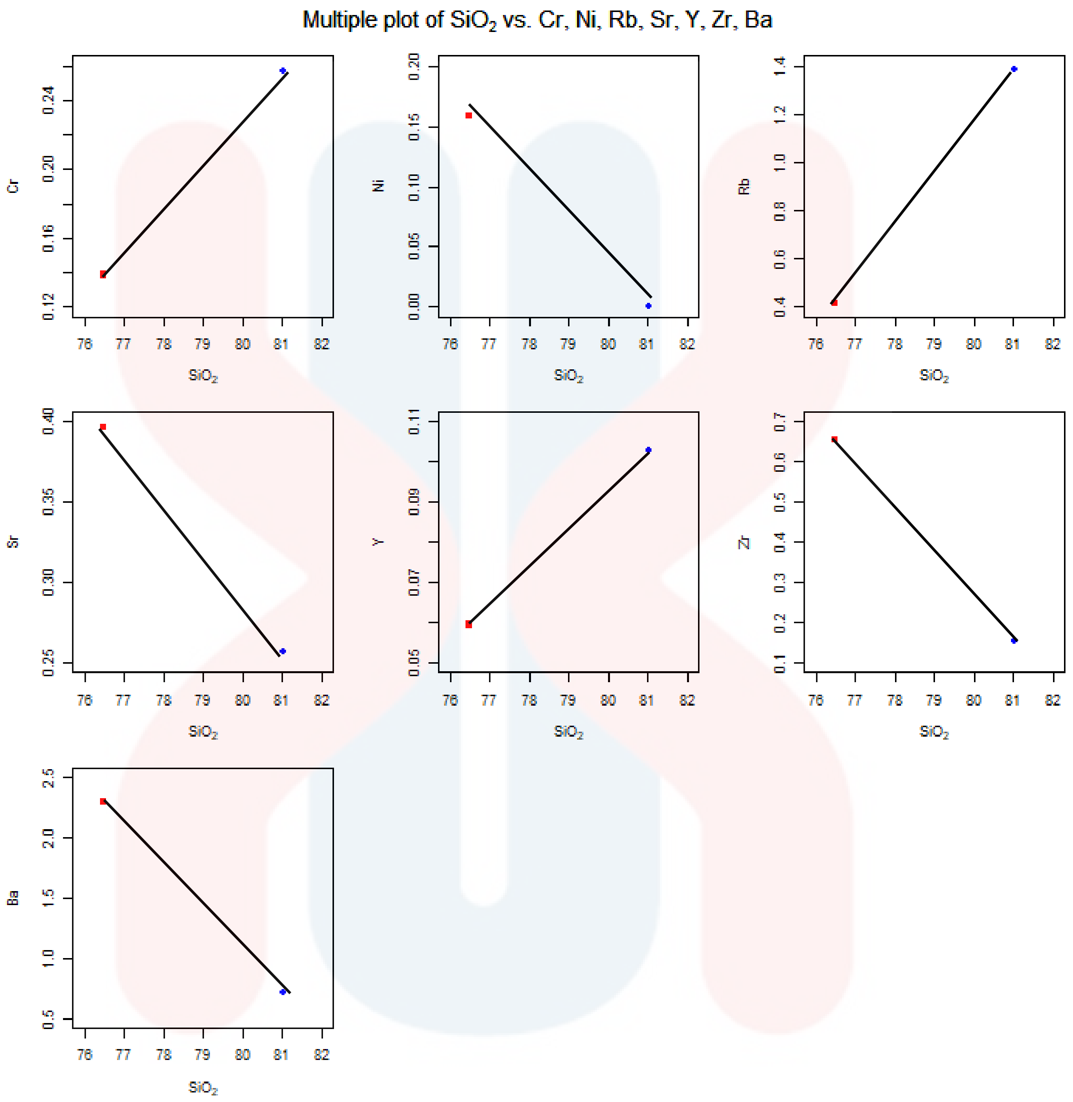


Figure 5.4 Harker diagram for trace elements (Cr, Ni, Rb, Sr, Y, Zr and Ba vs. SiO_2)

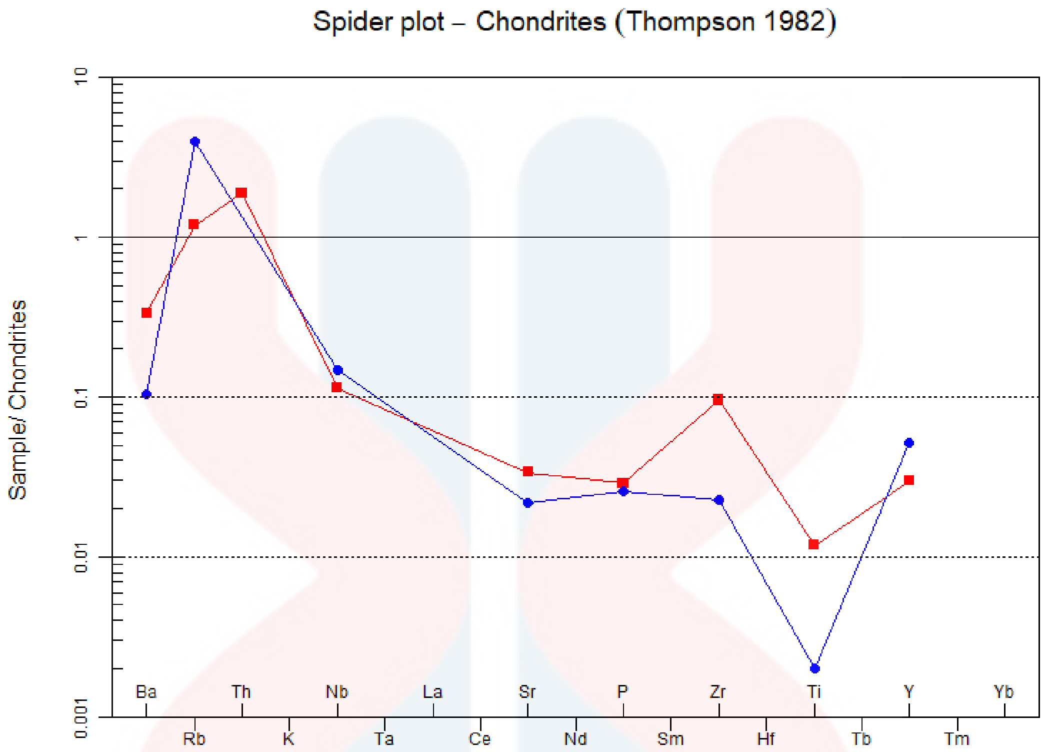


Figure 5.5 Chondrites normalised of trace elements (Thompson 1982).

5.4 REE Elements

The rare earth elements (REE) were measured using ICP-MS and were reported in ppb units. The rare earth elements are categorised into two groups which are light rare earth elements (LREE) and heavy rare earth elements (HREE). There are seven types of LREE present in the granite rocks which are Scandium (Sc), Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Samarium (Sm) and Europium (Eu) whereas for HREE there are nine types present in granite rocks which are Yttrium (Y), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yb) and Lutetium (Lu). Table 5.3 shows both light and heavy rare earth elements present in both granite rocks. From the LREE, the data show that SI 384 G has higher concentrations of Sc, La, and Ce compared to SI 10819 G, while SI 10819 G has higher concentrations of Pr, Nd, and Sm. Both samples have similar concentrations of Eu. The LREE make up a small fraction of the total elements present in the samples, with Sc, La, and Ce being the most abundant. For the HREE, the data show that SI 384 G has higher concentrations of Y, Gd, Tb, and Lu compared to SI 10819 G, while SI 10819 G has higher concentrations of Dy, Ho, Er, Tm, Yb, and Lu. The HREE make up a small fraction of the total elements present in the samples, with element Y being the most abundant.

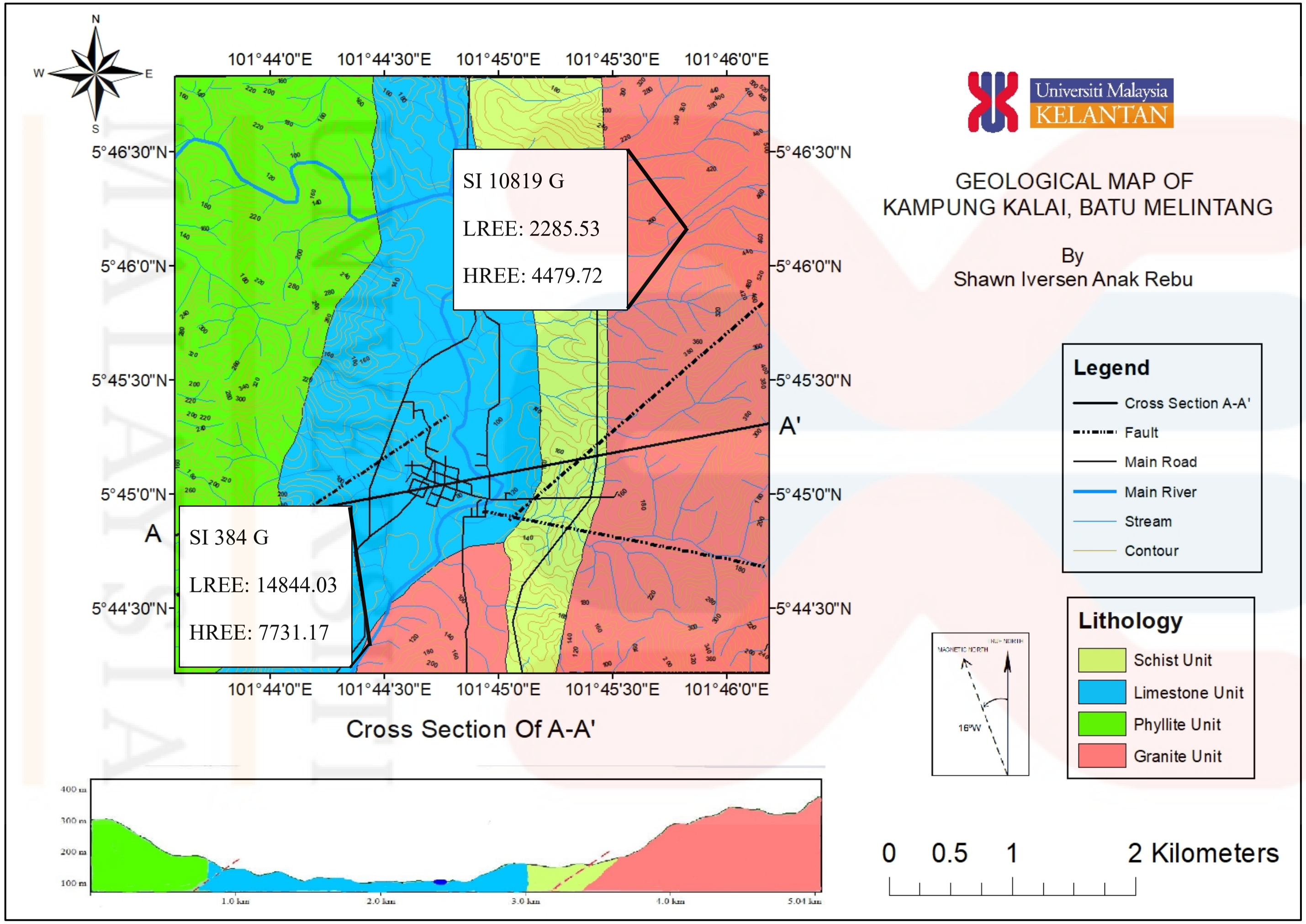


Figure 5.6 Light Rare Earth Element (LREE) and Heavy Rare Earth Element (HREE) contents in 2 specific location of granite outcrops in geological map.

Table 5.3 LREE and HREE distributions in two granite rocks, SI 384 G and S1 10819 G.

Light Rare Earth Elements (LREE)			
No.	LREE elements	SI 384 G in ppb	SI 10819 G in ppb
1.	Scandium (Sc)	652.93	620.36
2.	Lanthanum (La)	1874.82	751.84
3.	Cerium (Ce)	8478.65	401.55
4.	Praseodymium (Pr)	693.77	241.64
5.	Neodymium (Nd)	2318.7	154.92
6.	Samarium (Sm)	655.12	52.2
7.	Europium (Eu)	170.04	63.02
SUM		14844.03	2285.53
Heavy Rare Earth Elements (HREE)			
No.	HREE elements	SI 384 G in ppb	SI 10819 G in ppb
1.	Yttrium (Y)	4646.19	2422.94
2.	Gadolinium (Gd)	479.29	84.2
3.	Terbium (Tb)	456.13	411.48
4.	Dysprosium (Dy)	387.83	91.11
5.	Holmium (Ho)	251.28	215.75
6.	Erbium (Er)	221.96	82.74
7.	Thulium (Tm)	194.61	175.92
8.	Ytterbium (Yb)	599.57	512.1
9.	Lutetium (Lu)	494.31	483.48
SUM		7731.17	4479.72

Based on the bar chart in Figure 5.6, the sum of LREE and HREE concentrations is the highest in SI 384 G compared to SI 10819 G with 14844.05 ppb in LREE and 7731.17 ppb in HREE. In sample SI 384 G, the total sum of LREE concentrations is higher than the total sum of HREE concentrations at 14.845 ppb however, in sample SI 10819 G, the total sum of HREE concentrations is higher than the total sum of LREE concentrations at 4.479 ppb.

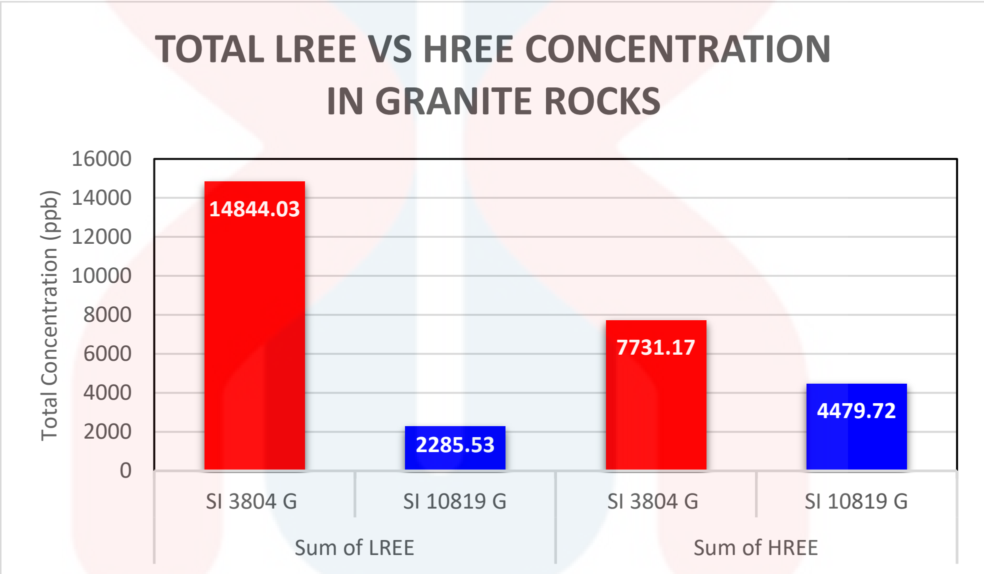


Figure 5.7 Bar chart of total LREE vs HREE concentration in granite rocks.

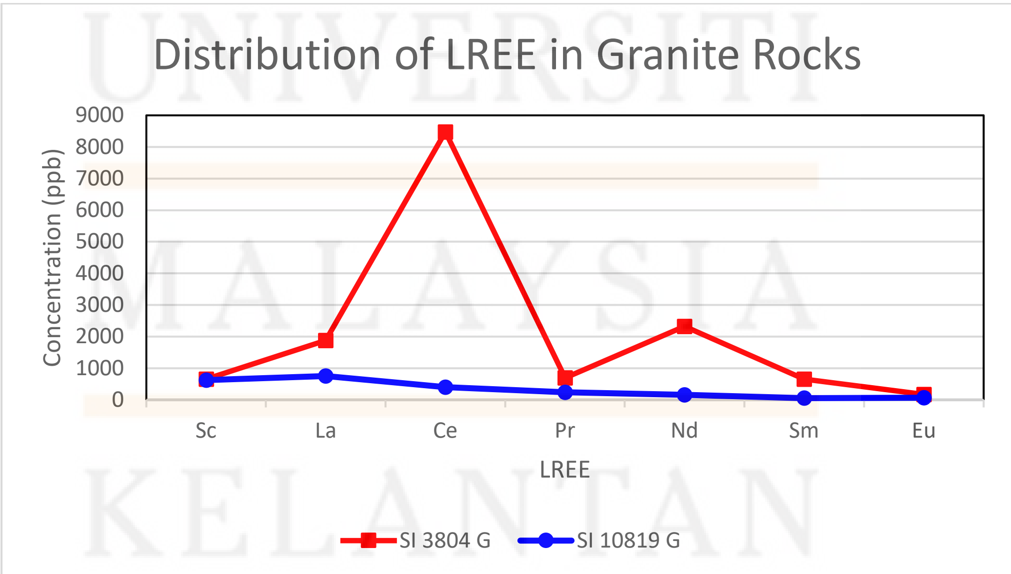


Figure 5.8 LREE distribution in granite rocks.

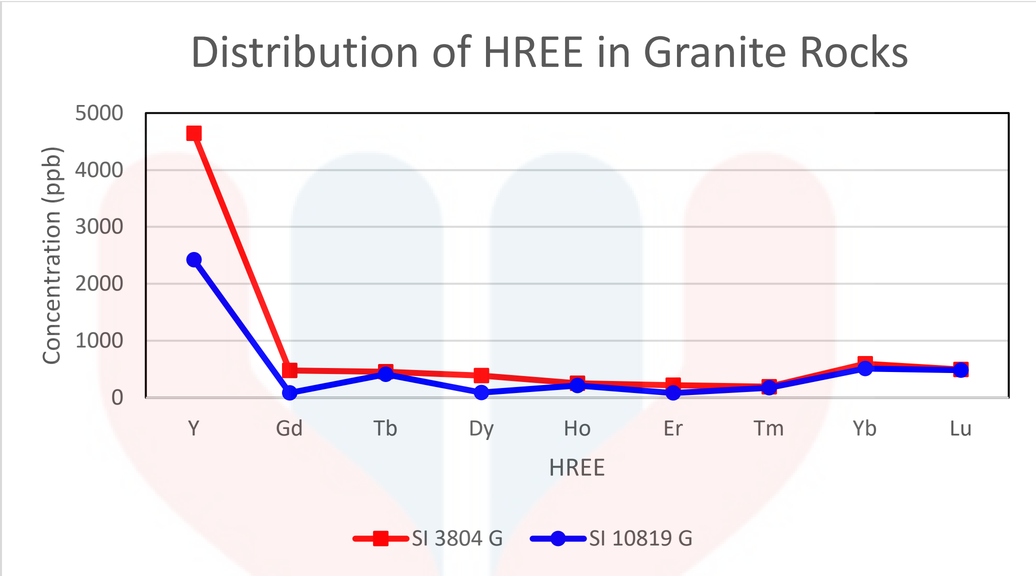


Figure 5.9 HREE distribution in granite rocks.

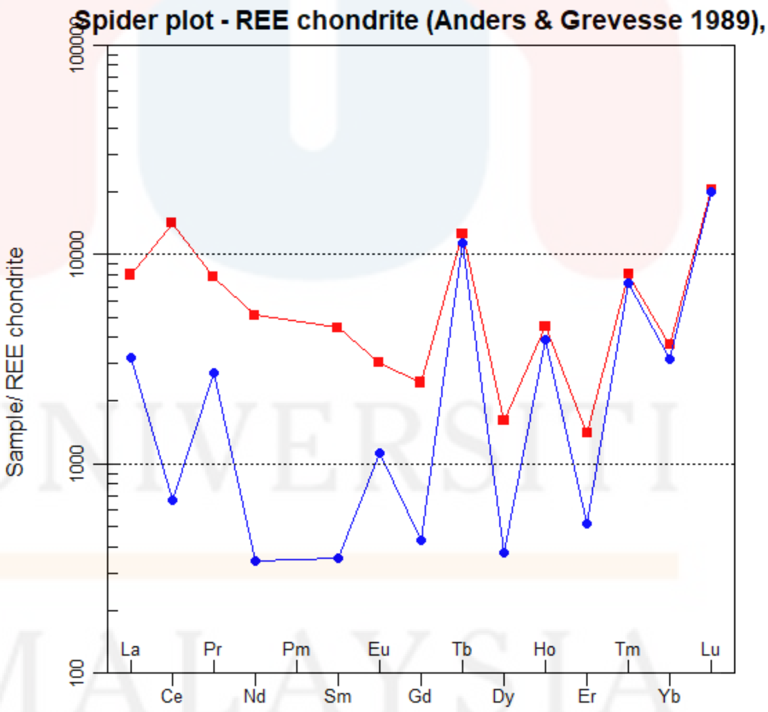


Figure 5.10 Spider plot of REE Chondrite (Anders & Grevesse 1989)

5.5 Discussion

The data presented in this study provide insight into the chemical compositions of two different samples, referred to as SI 384 G and SI 10819 G.

In the major elements section shown in Table 5.1, only four elements are present in the two granite samples from the 10 common major elements of granites. The major elements present in the samples are MgO, SiO_2, Al_2O_3 and K_2O whereas the other major elements show no sign of availability such as TiO_2, FeO. MnO, CaO and Na_2O. There is no presence of Na_2O in order to identify the S-type and I-type of granite rocks. Analysis of the major elements in the samples showed that SI 384 G has a higher concentration of MgO compared to SI 10819 G. In comparison, SI 10819 G has a higher concentration of Al2O3 compared to SI 384 G. Both samples have similar concentrations of K2O. Still, SI 10819 G has a significantly higher concentration of SiO_2 than SI 384 G. The graph shows that the MgO and K2O decreased when SiO2 increases except for Al2O3 which increases as SiO_2 increases.

In the trace elements section shown in Table 5.2, it showed that the two samples also had different concentrations of elements P, S, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, Hf, Pb, Th, Bi, and U. The analysis of trace elements in the samples showed that SI 384 G has higher concentrations of P, Ca, Ti, V, Cr, Mn, Fe, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, and Pb compared to SI 10819 G. SI 10819 G has higher concentrations of S, Fe, and Ba compared to SI 384 G. Both samples have similar concentrations of Ni, Hf, Th, Bi, and U.

As for the REE distribution as shown in Table 5.3, the analysis of the Light Rare Earth Elements (LREE) in the samples showed that SI 384 G has higher concentrations of Sc, La, and Ce compared to SI 10819 G, while SI 10819 G has higher concentrations of Pr, Nd, and Sm. Both samples have similar concentrations of Eu.

The LREE make up a small fraction of the total elements present in the samples, with Sc, La, and Ce being the most abundant. As for the analysis of the Heavy Rare Earth Elements (HREE) in the samples showed that SI 384 G has higher concentrations of Y, Gd, Tb, and Lu compared to SI 10819 G, while SI 10819 G has higher concentrations of Dy, Ho, Er, Tm, Yb, and Lu. The HREE make up a small fraction of the total elements present in the samples, with Y being the most abundant.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In conclusion, the research objectives were successfully achieved through the production of a geological map with a scale of 1:25000 for Kampung Kalai, Batu Melintang, the study of the petrography and geochemistry of granite rocks in the study area, and the investigation of the distribution of Rare Earth Elements (REE) in the study area. The geological map provides a detailed understanding of the topography and geomorphology of the area. Based on the geological map produce, we can identify many geological aspects. From the interpretation we can understand the geomorphology, geological structure, lithology, drainage pattern and others geological information found within.

Furthermore, the petrography and geochemistry of granite rocks in the study area provides insights into their origin and formation. Through the thin section petrography, we can denote that the type of granite rocks found in the research area are granodiorite and granite gneiss. As for the geochemistry of granite rocks, two analytical methods are used which are X-Ray Fluorescence (XRF) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). From the XRF method, the major elements found in both granite samples are MgO, Al_2O_3, SiO_2 and K_2O whereas for the trace elements most of it are mostly present except for elements such as sulphur (S), bismuth (Bi), vanadium (V), nickel (Ni), hafnium (Hf) and thallium (Th) which are either not detected or present in very small amounts. From the ICP-MS method, there are 16 types of rare earth elements found in the granite samples except for promethium (Pm) as there seem to be no traces of it.

Moreover, the investigation of REE distribution in the study area is achieved by using ICP-MS. The granite samples that were used to came from 2 different location further away from each other which called as SI 384 G and SI 10819 G. Based on the results provided by ICP-MS, it depicts that SI 384 G contains more LREE than SI 10819 G whereas SI 10819 G contains more HREE than SI 384 G. This shows that the two areas have different types of rare earth element levels that may corresponds to the origin of the rocks thus may provide valuable information for potential mineral exploration in the area.

6.2 Recommendation

For the recommendation to future researchers, it is best noted that there are some areas still needs to be examining the geochemistry of specific areas or environments in the research area that have not been well studied in the past. In addition, since there are high amounts of traces of heavy rare earth elements (HREE) in the research area, it is recommended to conduct research to understand the amounts of HREE since it appears less common than light rare earth elements (LREE). It is considered critical in the heavy rare earth metals group as they face low supply and increasing importance in the development of clean energy technologies. Heavy rare earths are also important in other technologies such as hybrid automobiles, fibre optics, and medical equipment.

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XRF Result

GREAT
GOLD, RARE EARTH & MATERIAL TECHNOPRENEURSHIP CENTRE

Company info: Gold, Rare Earth and Materials Technopreneurship Centre, Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan

Instrument info:

Type	S1 TITAN
Model	800
Serial number	800N10467
Last calibration check	

Measurement info:

Acquisition time	28/12/2022 3:51:48 PM	Application	GeoExploration
Calibration	Oxide3phase	Measurement time	60
Type standardization set		Operator	Supervisor
ID	SI 384 G		

Result table:

Element/Compound	%	±2σ
MgO	2.862	0.567
Al2O3	12.639	0.337
SiO2	64.279	0.595
P	0.067	0.013
K2O	4.256	0.033
Ca	1.368	0.016
Ti	0.369	0.007
V	0.012	0.008
Cr	0.007	0.005
Mn	0.047	0.004
Fe	2.945	0.022
Ni	0.008	0.001
Cu	0.003	0.001
Zn	0.006	0.001
Ga	0.001	0.001
Rb	0.021	0.001
Sr	0.020	0.001

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GOLD, RARE EARTH & MATERIAL TECHNOPRENEURSHIP CENTRE

Company info: Gold, Rare Earth and Materials Technopreneurship Centre, Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan

Element/Compound	**%**	**±2σ**
Y	0.003	0.000
Zr	0.033	0.001
Nb	0.002	0.000
Ba	0.116	0.008
Hf	0.000	0.000
Pb	0.007	0.001
Th	0.004	0.001
U	0.001	0.001

Excitation parameters:

Phase	1	2	3
Time [sec]	20	20	20
Voltage [kV]	30	50	15
Current [µA]	13.6	18.4	9.7
Filter	Blank	Blank	Blank
Collimator [mm]	8 / 8		

GOLD, RARE EARTH & MATERIAL TECHNOPRENEURSHIP CENTRE

Company info: Gold, Rare Earth and Materials Technopreneurship Centre, Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan

Instrument info:

Type	S1 TITAN
Model	800
Serial number	800N10467
Last calibration check	

Measurement info:

Acquisition time	28/12/2022 3:47:07 PM	Application	GeoExploration
Calibration	Oxide3phase	Measurement time	60
Type standardization set		Operator	Supervisor
ID	SI 10819 G		

Result table:

Element/Compound	%	±2σ
MgO	0.613	0.435
Al2O3	14.223	0.342
SiO2	79.333	0.672
P	0.023	0.010
S	0.178	0.014
K2O	3.731	0.032
Ca	0.316	0.009
Ti	0.024	0.004
Cr	0.005	0.003
Mn	0.053	0.004
Fe	1.287	0.014
Cu	0.003	0.001
Zn	0.001	0.000
Ga	0.001	0.000
Rb	0.027	0.001
Sr	0.005	0.000
Y	0.002	0.000

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GOLD, RARE EARTH & MATERIAL TECHNOPRENEURSHIP CENTRE

Company info: Gold, Rare Earth and Materials Technopreneurship Centre, Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan

Element/Compound	%	±2σ
Zr	0.003	0.000
Nb	0.001	0.000
Ba	0.014	0.005
Pb	0.002	0.001
Bi	0.002	0.001
U	0.001	0.000

Excitation parameters:

Phase	1	2	3
Time [sec]	20	20	20
Voltage [kV]	30	50	15
Current [μA]	13.6	18.4	9.7
Filter	Blank	Blank	Blank
Collimator [mm]	8 / 8		

ICP-MS Result

SI 384 G	Ce	84.79	0.50	50.00	8478.65
	Dy	3.88	0.50	50.00	387.83
	Er	2.22	0.50	50.00	221.96
	Eu	1.70	0.50	50.00	170.04
	Gd	4.79	0.50	50.00	479.29
	Ho	2.51	0.50	50.00	251.28
	La	18.75	0.50	50.00	1874.82
	Lu	4.94	0.50	50.00	494.31
	Nd	23.19	0.50	50.00	2318.70
	Pr	6.94	0.50	50.00	693.77
	Sc	6.53	0.50	50.00	652.93
	Sm	6.55	0.50	50.00	655.12
	Tb	4.56	0.50	50.00	456.13
	Th	10.80	0.50	50.00	1079.59
	Tm	1.95	0.50	50.00	194.61
	Y	46.46	0.50	50.00	4646.19
	Yb	6.00	0.50	50.00	599.57

SI 10819 G	Ce	4.02	0.50	50.00	401.55
	Dy	0.91	0.50	50.00	91.11
	Er	0.83	0.50	50.00	82.74
	Eu	0.63	0.50	50.00	63.02
	Gd	0.84	0.50	50.00	84.20
	Ho	2.16	0.50	50.00	215.75
	La	7.52	0.50	50.00	751.84
	Lu	4.83	0.50	50.00	483.48
	Nd	1.55	0.50	50.00	154.92
	Pr	2.42	0.50	50.00	241.64
	Sc	6.20	0.50	50.00	620.36
	Sm	0.52	0.50	50.00	52.20
	Tb	4.11	0.50	50.00	411.48
	Th	3.30	0.50	50.00	330.36
	Tm	1.76	0.50	50.00	175.92
	Y	24.23	0.50	50.00	2422.94
	Yb	5.12	0.50	50.00	512.10