



**GEOLOGY AND GEOCHEMISTRY OF GRANITE  
ROCKS OF KAMPUNG SUNGAI MEKONG JELI,  
KELANTAN**

by

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Report submitted in fulfillment of the requirements for the degree of  
Bachelor of applied sciences (Geosciences) with honor.

**FACULTY OF EARTH SCIENCES  
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2023

## DECLARATION

I declare that this thesis entitled “**GEOLOGY AND GEOCHEMISTRY OF GRANITE ROCKS OF KAMPUNG SUNGAI MEKONG JELI, KELANTAN**” 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.

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# **GEOLOGY AND GEOCHEMISTRY OF GRANITE ROCKS OF KAMPUNG SUNGAI MEKONG JELI, KELANTAN**

## **ABSTRACT**

Geological mapping of 25 km<sup>2</sup> with the scale of 1:25000 was conducted around Kampung Sungai Mekong, Jeli, Kelantan, Malaysia. Geographically, the area situates along the latitude of 5 °42'25"N, 101°46'13 "E. The objectives of the research are to produce an updated geological map and study the petrography and geochemistry of granite rocks in the study area. Unit lithology in the research area is dominated by granite rocks which also varies itself in terms composition and other characteristics.

There are two smaller units of sedimentary rocks limestone, and sandstone. The smaller units of limestone and sandstone are dated to be Permian-Triassic. The research area's geomorphology can be categorized into high hills, medium hills, and low relief morphology unit areas. Lineament features, joint structures, and fold structures are some of the principal geological structures in the studied region. For the investigation of granite rock, two granite samples the from the study area were analyzed using X-ray Fluorescence (XRF) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) for major and trace elements and for rare earth elements respectively. The granite that is found in the study area is classified as S-type and shows a peraluminous characteristics as the value of A/CNK is higher than 3. As conclusion, the geological mapping of the study area and the study of petrography and geochemistry of granite rocks provides important information for geological and environmental management, mineral exploration, and economic development.

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# **GEOLOGI DAN GEOKIMIA BATUAN GRANIT KAMPUNG SUNGAI MEKONG JELI, KELANTAN**

## **ABSTRAK**

Pemetaan geologi seluas 25 km<sup>2</sup> dengan skala 1:25000 telah dijalankan di sekitar Kampung Sungai Mekong, Jeli, Kelantan, Malaysia. Secara geografi, kawasan tersebut terletak pada latitud 5 ° 42'25 " N, 101 ° 46'13 " E. Tujuan kajian adalah untuk menghasilkan peta geologi terkini dan mengkaji petrografi serta geo-kimia batuan granit di kawasan kajian. Lithologi unit di kawasan kajian didominasi oleh batuan granit yang berbeza dalam komposisi dan ciri-ciri lain. Terdapat dua unit batuan sedimen kecil iaitu batu kapur dan batu pasir. Unit batuan kapur dan pasir tersebut berusia Permian-Triasik. Geomorfologi kawasan kajian boleh dikategorikan kepada ketinggian tinggi, ketinggian sederhana, dan kawasan unit kelegaan rendah. Ciri-ciri lineament, struktur bersendi, dan struktur lipatan adalah beberapa struktur geologi utama di kawasan yang dikaji. Untuk penyiasatan batuan granit, dua sampel granit dari kawasan kajian dianalisis menggunakan X-ray Fluorescence (XRF) dan Inductively Coupled Plasma Mass Spectrometry (ICP-MS) untuk unsur-unsur utama dan unsur-unsur surih serta untuk elemen tanah jarang. Granit yang terdapat di kawasan kajian diklasifikasikan sebagai jenis S dan menunjukkan ciri-ciri peraluminous kerana nilai A / CNK lebih besar dari 3. Kesimpulannya, pemetaan geologi kawasan kajian dan kajian petrografi serta geo-kimia batuan granit menyediakan maklumat penting untuk pengurusan geologi dan alam sekitar, penerokaan mineral, dan pembangunan ekonomi.

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## TABLE OF CONTENTS

<b>DECLARATION</b>	<b>i</b>
<b>APPROVAL</b>	<b>ii</b>
<b>ACKNOWLEDGEMENT</b>	<b>iii</b>
<b>ABSTRACT</b>	<b>iv</b>
<b>ABSTRAK</b>	<b>v</b>
<b>LIST OF FIGURES</b>	<b>ix</b>
<b>LIST OF TABLES</b>	<b>xi</b>
<b>CHAPTER 1 INTRODUCTION</b>	<b>1</b>
1.1 General Background	1
1.2 Study Area	2
1.2.1 Location	4
1.2.2 Road Connection	5
1.2.3 Demography	6
1.2.4 Land use	7
1.2.5 Social economy	7
1.3 Problem Statement	8
1.4 Objectives Of Study	8
1.5 Scope of Study	9
1.6 Significance of Study	10
<b>CHAPTER 2 LITERATURE REVIEW</b>	<b>11</b>
2.1 INTRODUCTION	11
2.2 Regional Geology and Tectonic settings	11
2.3 Stratigraphy	15
2.4 Structural Geology	16
2.5 Historical Geology	17
2.6 Granite Rocks Classifications	19
2.7 Rare Earth Elements (REE)	20
<b>CHAPTER 3 MATERIALS AND METHODS</b>	<b>22</b>
3.1 INTRODUCTION	22
3.2 Materials	23
3.3 Methodology	28
3.3.1 Preliminary study	28

3.3.2 Field Study	28
3.3.3 Laboratory	29
3.3.4 Petrographic Study	29
3.3.5 Geochemical Study	30
3.3.6 Data Processing	31
3.3.7 Data Analysis and Interpretation	31
<b>CHAPTER 4 GENERAL GEOLOGY</b>	<b>32</b>
4.1 Introduction	32
4.1.2 Accessibility	34
4.1.3 Vegetation	35
4.1.4 Settlement	37
4.1.5 Field Traverse and Observation	37
4.2 Geomorphology	40
4.2.1 Drainage Pattern	45
4.2.2 Weathering processes	48
4.3 Rock units	51
4.3.1 Petrographic analysis	56
4.3.2 Hand Specimen: Schist Rock	56
4.3.3 Field observation: CD 02	56
4.3.4 Thin section CD 02	57
4.3.5 Microscopic Observation: CD 02	57
4.4.1 Hand specimen: Granite rock:	59
4.4.2 Field observation CD 03	59
4.4.3 Thin section CD 03	60
4.4.4 Microscopic Observations: CD 03	60
4.5.1 Hand specimen: Quartz-rich granitoid rock	62
4.5.2 Field observation: CD 05	62
4.5.3 Thin section: CD 04B	63
4.5.4 Microscopic Observations: CD 04B	63
4.6.1 Hand specimen: Igneous rock: Diorite	65
4.6.2 Field observation: CD 06	65
4.6.3 Thin section: CD 06	66
4.6.4 Microscopic Observations: CD 06	66
4.7.1 Hand specimen: Granitic Gneiss rock	68

4.7.2 Field observation CD 08	68
4.7.3 Thin section: CD 08	69
4.7.4 Microscopic Observations: CD 08	69
4.8.1 Hand specimen: Igneous rock: granodiorite	71
4.8.2 Field observation: CD 011	71
4.8.3 Thin section: CD 011	72
4.8.4 Microscopic Observations: CD 011	72
4.9.1 Hand specimen: Igneous rock: Quartzite Granitoid	74
4.9.2 Field observation: CD 013	74
4.9.3 Thin section: CD 013	75
4.9.4 Microscopic Observations: CD 013	75
4.10.1 Hand specimen: Igneous rock: granodiorite	77
4.10.2 Field observation: CD 016	77
4.10.3 Thin section: CD 016	78
4.10.4 Microscopic Observations: CD 016	78
4.11.1 Structural Geology	80
4.11.2 Joint analysis	82
4.11.3 Folds	85
<b>CHAPTER 5 GEOCHEMISTRY OF GRANITE ROCKS</b>	<b>87</b>
5.1 Introduction	87
5.2 Major elements	89
5.3 Rare Earth Elements	96
5.3 Discussion	103
<b>CHAPTER 6 CONCLUSION AND RECOMMENDATION</b>	<b>105</b>
6.1 CONCLUSION	105
6.2 RECOMMENDATION	106
<b>REFERENCES</b>	<b>107</b>

## LIST OF FIGURES

NO		PAGES
1.1	Base map of the study area.	3
1.2	location of the study area	6
1.3	Road connection from umk to the study area.	5
1.4	The population of the study by (Department of statics Malaysia, 2020)	6
2.1	Geological map of Kelantan (Minerals and Geoscience Department Malaysia, (2003).	14
3.1	Research Flow Chart.	27
4.1	Jalan Raya Timur-Barat and small gravel road in the study area.	35
4.2	Land use map of the study area	36
4.3	Traversing map.	39
4.4	Topographic map of the study area.	42
4.5	An illustration views of the study area which represent surface features of the area.	44
4.6	Drainage pattern map of the study area.	46
4.7	Mechanically weathered granite outcrop.	49
4.8	Biologically weathered schist metamorphic outcrop.	50
4.9	Lithostratigraphic column	51
4.10	Tectonic evolution of SE Asia region (Searle et al., 2012))	54
4.11	Geologic Map of the study area	59
4.12	Photos that are taken from the outcrop	56
4.13	Flow diagram for the identification of metamorphic rocks in general (Gillen, 1982)	58
4.14	field photo representing the outcrop.	59
4.15	Outcrop photo with sampled pieces of rocks.	62
4.16	QAP diagram for showing type of granite	54

4.17	Outcrop photos of the exposure of the rock.	65
4.18	QAP diagram with plotted rock type.	67
4.19	Hand specimen photo from the exposure.	68
4.20	Flow diagram for the identification of metamorphic rocks in general (Gillen, 1982).	70
4.21	Hand specimen photo from the discovered outcrop.	71
4.22	QAP diagram with plotted rock type.	73
4.23	Hand specimen photo from the discovered outcrop.	74
4.24	QAP diagram showing the plotted type of the rock.	76
4.25	Hand specimen photo from the discovered outcrop	77
4.26	QAP diagram showing the plotted type of the rock	79
4.27	lineaments representation map showing two major lineaments and several minor lineaments.	81
4.28	Rose Diagram with joint orientation plotted.	83
4.29	joints examined site on a granite outcrop	84
4.30	heavily jointed outcrop part of the study site with (a)recumbent fold (b) anticline	85
5.1	Harker variation diagram major element with the plot of two samples.	91
5.2	K <sub>2</sub> O versus SiO <sub>2</sub> diagram (Peccerillo and Taylor 1976).	92
5.3	R1-R2 plot (De La Roche et al. 1980) diagram for the study area rock type	94
5.4	The A/NK versus A/CNK diagram (Shand, 1943).	95
5.5	Spider plot- REE chondrite (Anders and Grevesse 1989)	99
5.6	Light REE(LREE) distribution of the examined samples with data table	100
5.7	Heavy REE(HREE) distributions of the examined samples with data table	101
5.8	Sampling points with total REE distributions in each Sample	102

**LIST OF TABLES**

NO		PAGE NO
3.2	materials that were required to conduct the research in the field	23
5.1	Major Elements oxide group	89
5.2	ICP-MS result for Rare Earth Elements analysis	96
5.3	Light REE(LREE) and Heavy (HREE) distributions in the granite samples.	98

## CHAPTER 1

### INTRODUCTION

#### 1.1 General Background

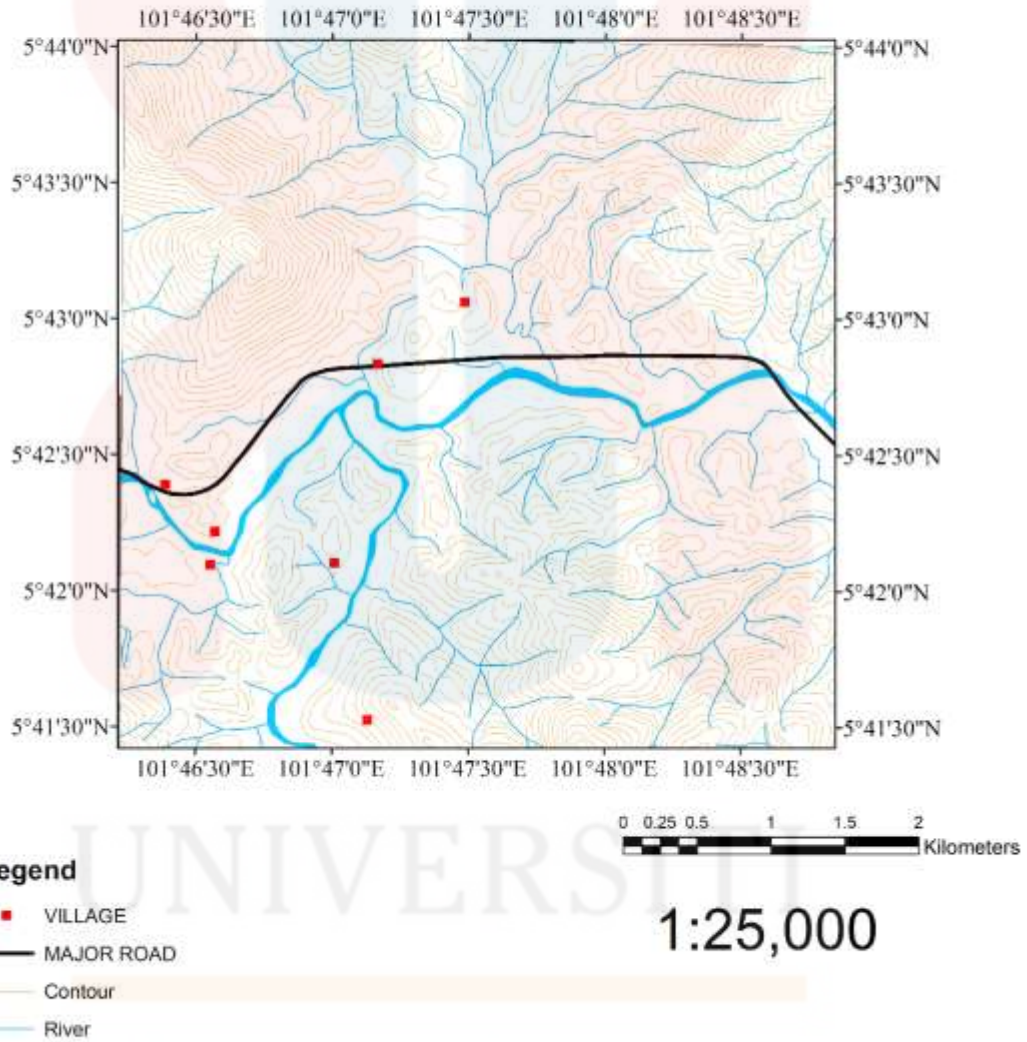
Geology is concerned with studying the Earth, the materials from which it is made, including rocks and minerals, the material's structure, and the processes that have acted upon them (Garcia et al., 2020). It includes the study of organisms that have inhabited the planet. Studying how Earth's materials, organisms, structures, and processes have changed over time is essential for geology. A mineral is a naturally occurring substance characterized by physical and chemical properties, composition, and atomic structure. In contrast, rocks can be defined as a solid collection of mineral grains that become cemented together. Rocks can be large or small. Small rocks are described as pebbles McLean et al., (2017). Each rock is composed of one or more minerals.

The geochemistry branch of geology aims to study the origin, distribution, and evolution of chemical elements contained in the rock and the products derived from the formation process (Morley et al., 2013). The primary determinant of trace minerals and other elements of a rock is usually determined through chemical analysis. Petrology is concerned with studying the origin, the structure of the rocks, classification, and composition. Studying the petrology of the igneous rock helps in understanding the tectonic and magma generations.

This study will be conducted because of the scarcity of previous studies on the granite rocks in the study location. Two methods, including the petrography and petrology analysis, will be employed to distinguish the elemental composition, origin, and rock categorization. Utilization of a polarized microscope for examination of thin sections and X-ray Fluorescence (XRF) spectrometry for the analysis of chemical compositions of rocks will be applied for this research. The geological mapping and petrology study will support a superior knowledge of the geology of the study locality. In Malaysia's Kampung Sungai Mekong-Sungai Kolok Transect area, geologists from the Minerals and Geoscience Department Malaysia carried out detailed systematic geological mapping during July and August of 2001 and examined it again in November same year. In January 2002, a further in-depth study of Quaternary Geology was conducted by (François et al., 2017).

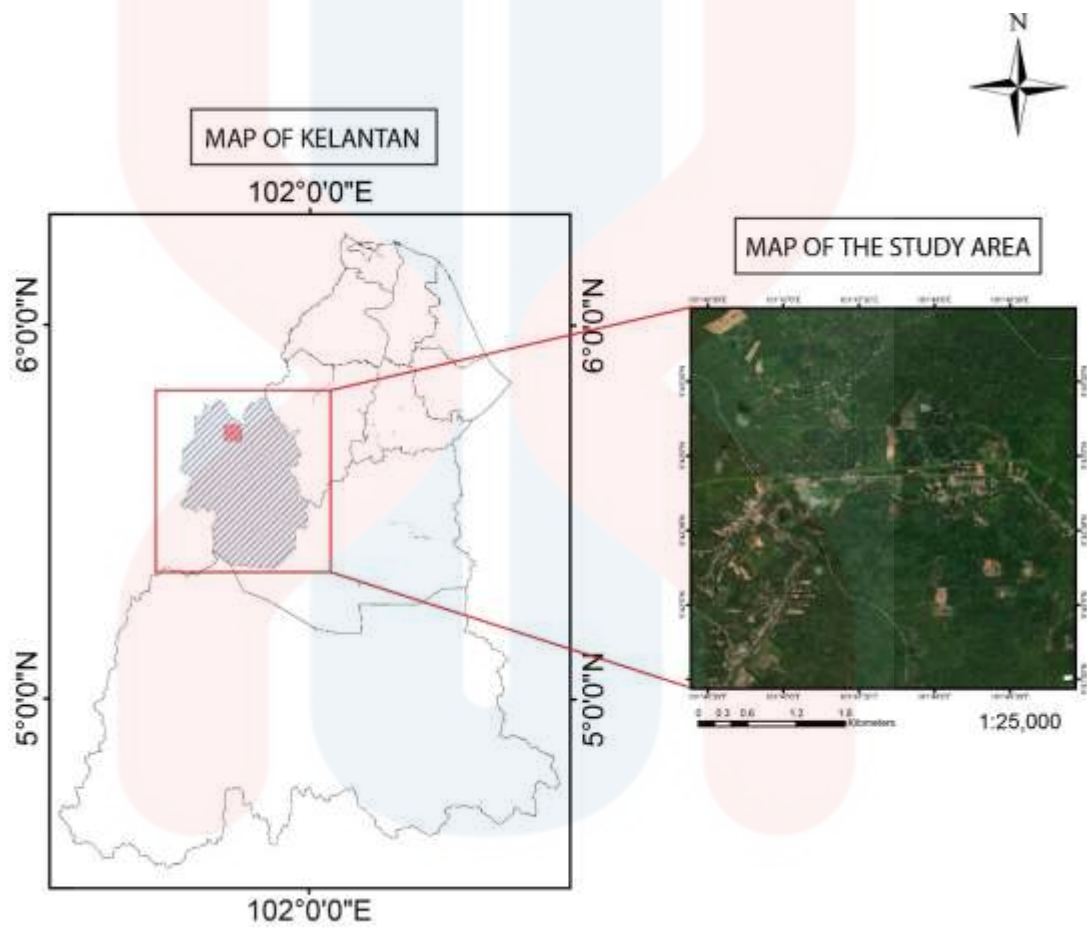
## **1.2 Study Area**

The study area is Kampung Sungai Mekong, Jeli, Kelantan, Malaysia. The area covers 25 km<sup>2</sup> and extends from a longitude of 101°58'0"E 4°54'30" N, 102°0'45"E 4°54'30" N, to a latitude of 102°0'45"E 4°52'15" N and 101°58'0"E 4°52'15" N. The landscape of the area is divided into three, including plain, mountainous, and the hilly regions. The study area has a high elevation of 600m and the lowest height of 20meters. The study area can be accessed by the main road Jalan Gerik-Pasir Puteh, and the area is also serviced by small roads some paved while some are not pav



**Figure 1.1** Base map of the study area.

### 1.2.1 LOCATION

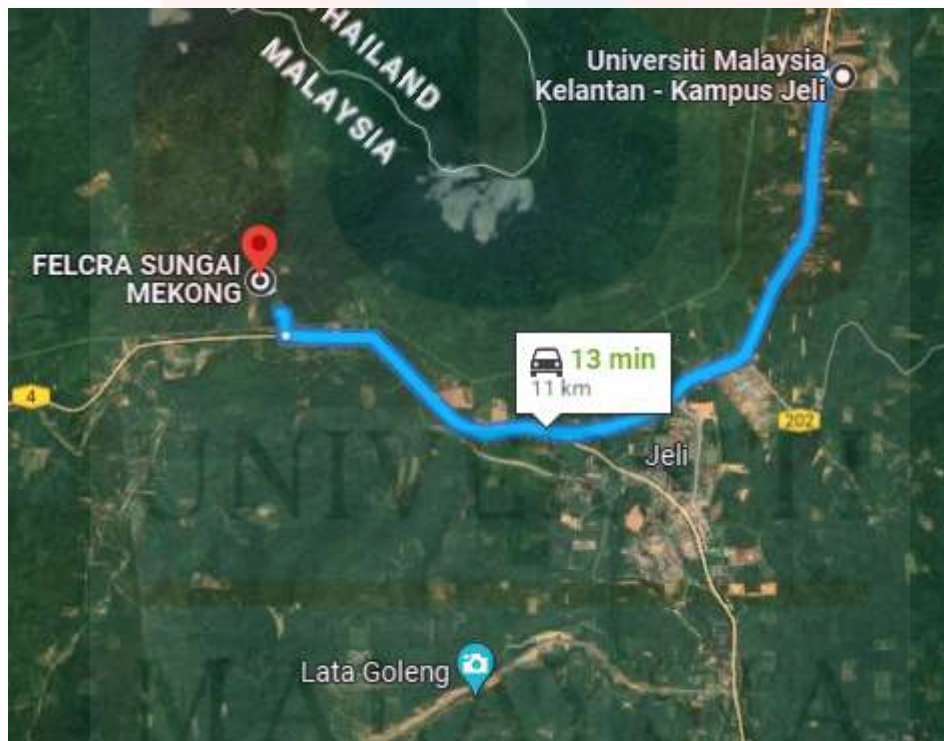


**Figure 1.2** location of the study area

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### 1.2.2 Road Connection

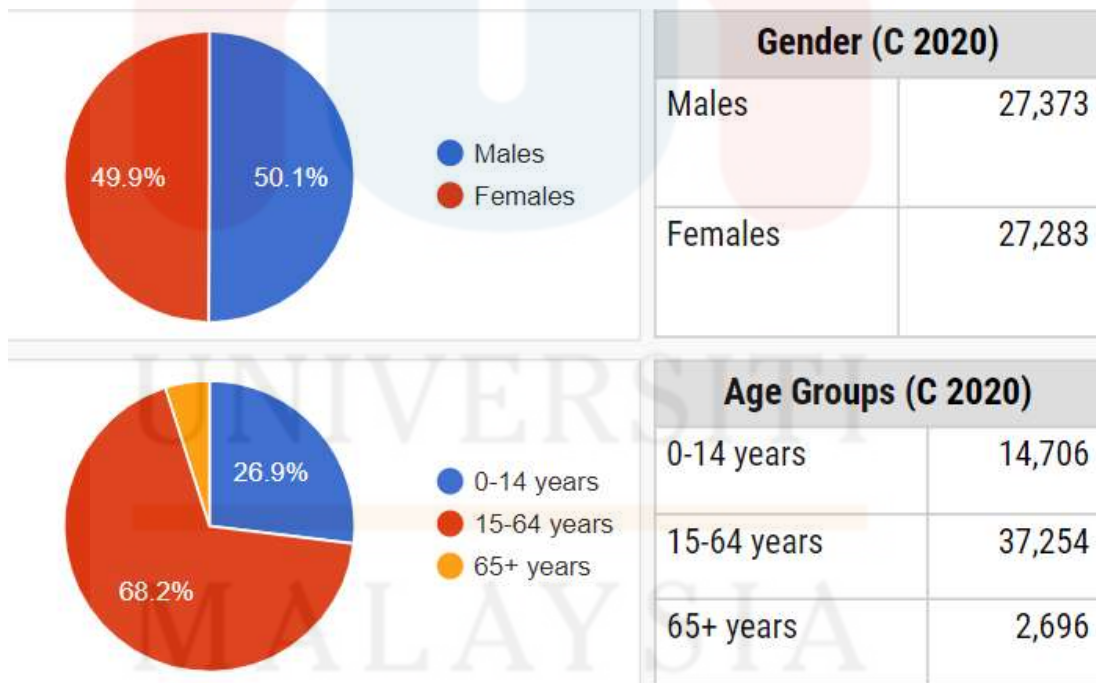
The Jalan Grik-Pasir Puteh is the primary road leading to the study area. The research area is then accessible from this major access through a short trail route that also serves as a transect between the borders of Malaysia and Thailand in (figure 3). Most of the roads are paved, however further into the countryside, where some plantations, like rubber plantations, are located, there are some gravel roads or short trails. In general, most of the study area is simple and has good access, allowing for the passage of vehicles for both social and business objectives. However, due to their elevation, several investigations were also inaccessible.



**Figure 1.3** Road connection from UMK to the study area.

### 1.2.3 Demography

In the state of Kelantan, Jeli is the third-largest settlement. Three districts make up the settlement: Jeli, Kampung Sungai Mekong, and Kuala Balah. The settlement covers 1,280.21 km<sup>2</sup> of land. Due to its remote location from Tanah Merah, the adjacent large town, the population density in Jeli town and Kampung Sungai Mekong area is notably quite high which is 54,656 persons according to administrative department in 2020. Males make up 27,373 of them, while females make up 27,283 of them. In terms of percentages male and female groups make 50.1% and 49.9% respectively. The population data also demonstrates age groups, the below pie chart shows 15-65 years old group has the number of populations.



**FIGURE 1.4** The population of the study by (Department of statics Malaysia, 2020)

#### **1.2.4 Land use**

When it comes to the land use of the study area, there are local fruit trees being grown for domestic use on small plots of land, including rambutans, durians, and bananas. In addition, several land features use to fill for development reasons, including shops, housing areas, rural health centers, and clinics that offer facilities to the public for healthcare, schools, and more. A variety of structures, including businesses, government facilities, local authorities, and city offices, can be located close to the study area, according to overviews and observations.

#### **1.2.5 Social economy**

The study area's small-scale vegetable and fruit farming and rubber tapping industries are what drive its social and economic development. Additionally, there are several stores in the study area, including a grocery store, a retail store, and a car wash. Next, the people of Kampung Sungai Mekong have access to grocery stores and wet markets that were opened by villagers who also resided in Kampung Sungai Mekong and sell fresh produce, fruits, and raw meats. The locals themselves are cultivating fresh fruits and vegetables, as well as rawmeats like chicken. The study area lacks an industrialized area and mining prospects, and local spending power and food and energy consumption are not as high as they are in the Kampung Sungai Mekong area.

### 1.3 Problem Statement

Previous research studies have focused on stratigraphy, lithology, geomorphology, and geological structure, with less research on granite rocks and chemical compositions. Little has likewise been done on the geochemistry of the granite rocks, as Kampung Sungai Mekong is growing and developing fast, the surrounding hills are being excavated. Changing the geology and geomorphology of the area; therefore, it is essential to understand the geology and geochemistry of the granite so that developments and construction can always respect the geological structure of the site. This study, therefore, intends to construct a geological map and further investigations on the chemical composition of the granite rocks specifically for quantifying in the Kampung Sungai Mekong area. The research will also be helpful in the development and updating of the geological map of the study area, which would be beneficial for future research studies.

### 1.4 Objectives Of Study

- a) To produce a Geological map of the Kampung Sungai Mekong Jeli on a scale of 1:25000.
- b) To examine the petrography and geochemistry of granite rocks of Kampung Sungai Mekong Jeli.
- c) To analyze the rare earth elements distribution in granite rocks of Kampung Sungai Mekong Jeli.

### 1.5 Scope of Study

The study area covers an area of 25 km<sup>2</sup> around Kampung Sungai Mekong. Among the activities involved in research are geological mapping and petrology of granite rocks in the study area. The examination consists of both fieldwork and laboratory work. The reason for conducting fieldwork is to observe and collect geological data on the granite to understand better their geological structure and mineralogy. The laboratory work will be needed for geochemical and petrography analysis of the rock. The geochemical analysis is vital in determining the trace elements of the granite rocks, and the information will help understand the tectonic activities under which the stones are formed. The rock sample collection is crucial in petrography analysis which will be achieved through geochemistry analysis using a microscope, so the properties and characteristics of the rock minerals can be determined. In contrast, the geochemistry of the rock is determined by using X-Ray fluorescence and the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) for measuring the concentrations of rare earth elements (REE).

## 1.6 Significance of Study

The research is substantial because it provided general geology information and granite rocks' chemical compositions in the Kampung Sungai Mekong area that is useful in contributing adding information in geology research. In addition, the research will involve a petrographic study that intends to obtain data about the compositions, textures, occurrences, and categorization of granite rocks. This will also help deliver scientific proof of granite rock in the research locality. More details about the lithology and chemistry of the granite rocks in the study area will be provided by this research to aid future researchers in their analysis of the tectonic setting and evolution of the granite.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 INTRODUCTION

Before beginning the geological mapping and geochemical investigation on the granite rocks of Kampung Sungai Mekong area, preliminary studies must carry out. Prior to performing research, preliminary investigations are techniques that involve reading and reviewing the literature on the already published past studies, such as journals, papers, and books. This aids the researchers' ability to comprehend and know more about the study area's research issue. Studies on the granite in the study area had previously been conducted, and these studies served as references for this one.

#### 2.2 Regional Geology and Tectonic settings.

Peninsular Malaysia is a fundamental portion of the Eurasian Plate and a South-East Asian piece. The formation was deposited by two North-South drift bedrock terranes placed beside one another by the end of the Permo-Triassic along the Raub-Bentong Suture. The Sunda Shelf is an eastward continuation of the main plate with a sea depth of fewer than 200 meters that can be encountered down to southern Sumatra, Natuna, and western Borneo.

The SE Asian Tin Belt granitoid, placed during subduction-related orogens, is widely distributed in the Thai-Malay Peninsula's underlain. Peninsular Malaysia's geology is dominated by granitic rocks, split into three provinces:

Western, Main Range, and Eastern. The peninsula's focal point is a North-South trending strip of Mesozoic sediment and metamorphic in the northwest. The peninsular has no Cenozoic rocks, except for the basin around the small coastal plain. (Nazaruddin et al., 2017). The North-South Palaeo Tethys in Peninsular Malaysia is represented by the BentongRaub Suture Zone, which is characterized by the imbricated complex structure of pelitic schist, serpentinite, amphibole schist, melange-olistostrome and chert of Carbonaceous age including the undated post suture reedbeds (Metcalf et al., 2013).

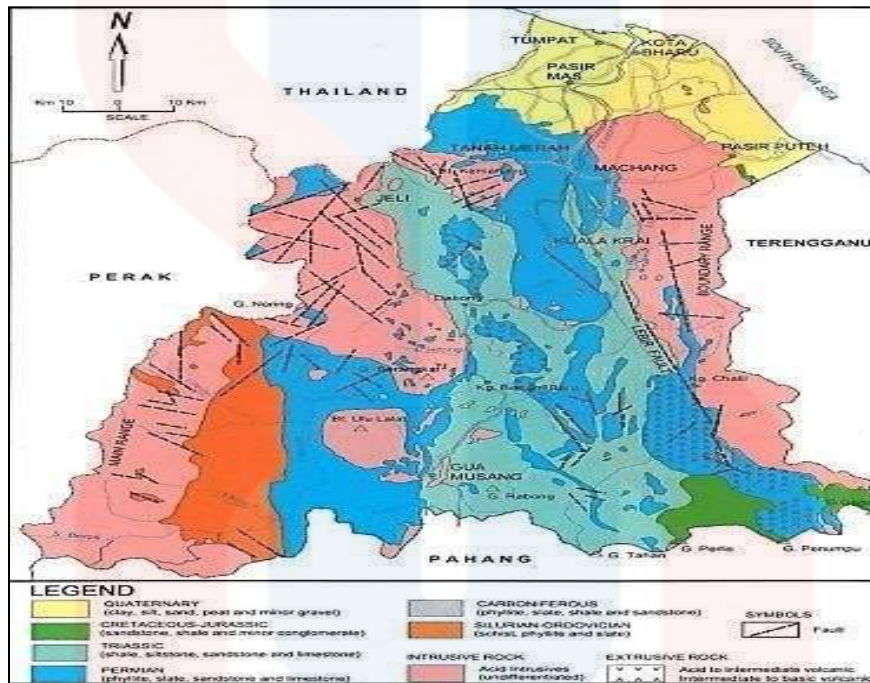
The geology of the Kelantan is mainly made up of metasedimentary rocks and sediment bordering the East Range granite and the west Main Range granites. The granite intrusive within the central location comprises of Strong Igneous Complex, Sensing batholiths, and Kemahang pluton (Sone et al., 2012). However, in Kampung Sungai Mekong, Jeli Formation stratigraphy, the stratigraphy is still incomplete. No past research had classified the Triassic and Permian successions because it is challenging to organize them based on lithological characters. Besides, the distinction of the Kampung Sungai Mekong stratigraphy depends almost entirely on fossil evidence.

Additionally, the study area was dated Paleozoic Formation ranges from Middle Permian to Upper Triassic with 650m thick that comprises crystalline limestone interbedded with thin shale beds tuff, and chert nodules, and subordinate sandstone and volcanic rocks (Mansor et al., 2014). There are two types of limestone, lightgrey calcitic limestone, and grey to black recrystallized limestone. The light grey limestone is harder, non-porous, brittle, and splintery, whereas the grey to black recrystallized limestone is composed of small amounts of carbonaceous, argillaceous, and pyroclastic impurities.

Based on (Jolivet et al., 2013), Reported that Kelantan state, specifically the studylocality Kampung Sungai Mekong is in the central belt of Peninsular Malaysia. Mesozoic granitoids of Southern Asia have heavily intruded the cellar rocks of the Malaysian peninsular. Eurasian Plate Indochina and Shan-Thai terranes are two tectonic terranes that peninsular Malaysia is divided into. Terranes originated from rifting of the North-East margins of the ancient landmass that has been associated with the formation of the central belt. According to them (Searle et al., 2012). Sedimentary or metasedimentary rocks, granitic rocks, unconsolidated sediments, and extrusive rocks are among the four major types of rocks found in the Kelantan state's north-south trend. Kelantan's geological formation can be classified into three primary chronologies: Paleozoic, Mesozoic, and Cenozoic spanning the Lower Paleozoic to the Quaternary. On the other hand, The Jeli area mostly consists of three types of rock, according to the general geology of Kelantan (Department of Minerals and Geoscience Malaysia, 2003). Shale, siltstone, sandstone, and limestone make up the Triassic sedimentary rocks (Gunung Rabong Formation), which come first. The second is phyllite, slate, sandstone, and limestone-containing Permian sedimentary rocks (Gua Musang Formation). Granitic rock is the third which is categorized as an acid intrusive.

According to geomorphology, Kelantan's landscape may be divided into four different types of landscapes: mountainous, hilly, plain, and coastal. All sorts of sceneries may be found in the Jeli district, except for the seaside region, which only exists in the northern portion of Kelantan. West and north of the district, mountainous terrain develops. Granite from the Main Range, the Migmatite Complex, and schist make up this terrain.

Hills can be divided into two categories: those that developed of the terrain and those that are isolated. For instance, Gunung Reng is a limestone isolated hill that is typically seen in low-lying areas. Ridges are long hills; however, they are often lower than mountain ridges. East and central parts of the region have plain terrain.



**Figure 2.1** Geological map of Kelantan (Minerals and Geoscience Department Malaysia, (2003).

### 2.3 Stratigraphy

The geology of the study area and whole Kelantan is characterized by a diverse range of rock types, with a significant portion of the state lying on the East Coast Zone of the Malay Peninsula, which is part of the Sibumasu Terrane. The stratigraphy of Kelantan is composed of rocks that span from the Precambrian to the Quaternary period, which is a span of around 2.5 billion years. The oldest rock formation in Kelantan is the Basement Complex, which comprises mainly granitic and gneissic rocks that are estimated to be around 550-2,500 million years old. These rocks are found in the southern part of the state and are often overlain by younger sedimentary rocks. Overlying the Basement Complex is the Bentong-Raub Group, a series of metasedimentary rocks that are between 200-550 million years old. These rocks are composed of quartzites, schists, and phyllites that have undergone significant metamorphism. They are found in the central part of Kelantan, where they are exposed in the Titiwangsa Range.

The youngest rock formations in Kelantan are the Tertiary and Quaternary sedimentary rocks that are found in the eastern part of the state. These rocks are composed of sandstones, mudstones, and conglomerates, and are often deposited in shallow marine and fluvial environments. They are also associated with the formation of coastal plains, beaches, and estuaries. Overall, the geology of Kelantan is complex and varied, with a diverse range of rock types that reflect the tectonic and depositional history of the region. The stratigraphy of Kelantan is an important aspect of the state's geology, providing insights into the geological history of the area and its evolution over time (Kasim et al., 2021).

## 2.4 Structural Geology

According to (Hutchison, 1975), the structures of the Peninsular are the result of a lengthy and intricate tectonic history that may have started as early as the Cambrian and continued all the way up to the Cenozoic. It is thought that during the upper Triassic Indosinian Orogeny, the western Gondwana portion of the Malay landmass (Sibumasu) collided with the Indochina continental block (East Malaya). The impact suturezone is defined as the Bentong-Raub line.

Peninsular Malaysia's predominant shape is NNW-SSE extended, and this shape is mostly affected by the Main Granite Range, often known as the backbone of Malaysia or the Titiwangsa Range, which has a distinct N-S lineament along its lower eastern section and is also known as the Bentong Raub Suture (Hutchison, 1983). The Lebir Fault Zone, the primary fault zone in Kelantan State, delineates the border between the central and eastern belts. Tight, divergent, and open folds, which result in the recurring and abrupt evolution in the ancient sedimentary rock, are examples of folding. Most of the bedding planes plunge eastward with various plunge angles, and the NW-SE and N-S drifting fold axes are sub-parallel to the Malay Peninsula's long axis. Everywhere in the Transect region, there are faults. Fault zones are rarely exposed at more than a few locations along their tracks, as is seen by the dense soil cover and extensive tropical weathering. Typically, rocks that are cracked, sheared, or mylonitized show differences in fault width (Committee, 2006).

## 2.5 Historical Geology

The geological history of study area is complex and has been shaped by a variety of geological events over millions of years. The rocks in Jeli district belong to the Bentong-Raub Suture Zone (BRSZ) and are part of the Main Range granite batholith. The BRSZ marks the collision of the Sibumasu terrane, a block of continental crust, with the Sundaland continental margin during the Early Permian. This collision resulted in the formation of a major tectonic boundary in the region, which created a complex mix of rocks that range in age from the Proterozoic to the Cenozoic.

The oldest rocks in Jeli are the schists and gneisses of the Setul Formation, which are part of the Western Belt of Peninsular Malaysia. These rocks are estimated to be around 1.5 billion years old and have undergone intense metamorphism and deformation, resulting in their characteristic folded and faulted appearance.

The Setul Formation is overlain by the Triassic-Jurassic aged granites of the Main Range batholith, which intruded the older rocks during the Late Triassic. The Main Range granite batholith is a large igneous province that extends from Thailand in the north to Johor in the south and is one of the largest granitic plutons in the world. The granite rocks in Jeli are known to have distinctive mineralization patterns and have been a target for mineral exploration in the past.

During the Late Cretaceous, the Main Range batholith was intruded by the younger granites of the Eastern Belt, which are estimated to be around 80 million years old. The Eastern Belt granites are part of the Stong Complex, which also includes ultramafic and gabbroic rocks. The Stong Complex is thought to be an ophiolite, a section of oceanic crust and upper mantle that was obducted onto the continental margin during the Late Cretaceous.

In the Late Eocene, the Jeli area was covered by shallow seas, which deposited the Paleogene-aged sedimentary rocks of the Kuantan Formation. The Kuantan Formation is made up of sandstones, siltstones, and shales, and is known to contain fossils of marine organisms such as foraminifera, mollusks, and corals. These rocks are also a source of oil and gas in the region. In the Quaternary period, the study area was affected by a series of tectonic events that resulted in the formation of the Malay Basin, a large sedimentary basin that extends across the Malay Peninsula. The Malay Basin is known to contain large reserves of hydrocarbons and has been the focus of extensive exploration and production activities in recent years. (Hutchison et al., (2014).

## 2.6 Granite Rocks Classifications

Granite rock is a plutonic rock with less than 90% of mafic minerals. Based on the IUGS (International Union of Geological Society) classification, granites consist of a limited range of compositions of quartz (Q), Alkali feldspar (A), and plagioclase (P) magmaseries that may include diorites, tonalites, quartz monzonites, granodiorites, and granites. The IUGS classification is used to identify the mineral and texture and for naming the rock. Thus, granitoid is used for rocks rich in quartz and feldspar. In addition, according to the percentage of felsic minerals like quartz, alkali feldspar, and plagioclase feldspar, the QAPF diagram will be used to implement the IUGS classification in mineralogical classification.

The major-element compositions are reflected by the mineralogy. The information will be plotted on a QAPF diagram based on the results gathered. Although the application of this diagram is simple and inexpensive, but it overlooks the compositional variation apart from those that affect the feldspar abundances and unable to address the minor phases which may bring important petrologic implication. Moreover, according to the past analysis, the chemical categorization of the Alumina Alteration Index, S-I-A-M classification, and tectonic setting classification may also be determined by granitoid classification. S-types, I-types, A-types, and M-types are also referred to as sedimentary, igneous, organic, and atomic sources, respectively (direct to mantle source). The X-Ray Fluorescence (XRF) equipment can be used to evaluate the entire geochemical classification.

## 2.7 Rare Earth Elements (REE)

A collection of seventeen chemical elements known as rare earth elements are found together on the periodic table. The 15 lanthanide elements lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, dysprosium, terbium, dysprosium, holmium, erbium, thulium, and ytterbium make up the group. The term "rare earth metals" is frequently used to refer to rare earth elements, which are all metals. Due to their numerous shared characteristics, these metals are frequently found together in geologic deposits. Because several of them are frequently sold as oxide compounds, they are also referred to as rare earth oxides (King et al., 2018). "Heavy Rare Earths" and "Light Rare Earths" are common categories used to categorize rare earth elements. The light rare earth includes lanthanum, cerium, praseodymium, neodymium, promethium, and samarium. The "heavy rare earth" are Yttrium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, and Lutetium. Yttrium is lighter than the light rare earth elements, but due to its chemical and physical interactions with heavy rare earth in natural deposits, it is categorized as a member of the heavy rare earth group.

Recent increases in demand for rare earth elements have been driven by their expanding use in a wide range of high-tech applications that affect many facets of contemporary life and society. Specific rare earth elements (REEs) are used separately or in combination to manufacture phosphors, substances that emit light for various kinds of ray tubes and flat panel displays, in screens ranging in size from smartphone displays to stadium scoreboards, among other things. These three elements are utilized to produce numerous light bulbs, panels, and TVs.

In addition to primary processes such as magmatic processes, hydrothermal fluid movement, and weather patterns, and secondary processes such as sedimentary concentration and weathering, enrichment of REE minerals can occur because of secondary processes that move REE minerals away from where they were originally formed. Primary (high-temperature) and subsequent (low-temperature) rare earth element formations and occurrences may be distinguished in terms of their composition. The most significant primary deposits, which are often connected with alkaline volcanic igneous rocks and carbonatites that originated in extensional intracontinental rifts, are typically associated with high grade and tonnage mineralization (Sulaiman et al., 2021).

## CHAPTER 3

### MATERIALS AND METHODS

#### 3.1 INTRODUCTION

The materials and methodology used to examine the geology and geochemistry of the granite rock in Kampung Sungai Mekong, Jeli, are introduced in this chapter. There are two categories of materials. Journals, articles, books, past research, and the internet fall under the first group. Information sources for research references can be found in this content. The second category consists of tools used in the field. Preliminary research, field research, laboratory work, data processing, data analysis, and interpretation are all parts of the methodology.


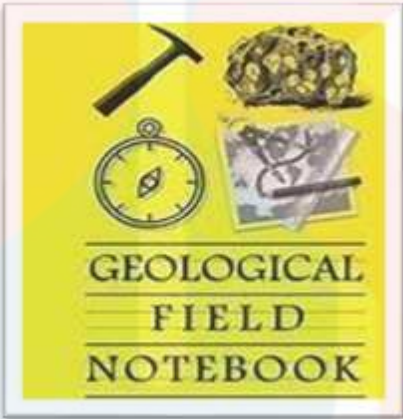

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### 3.2 Materials

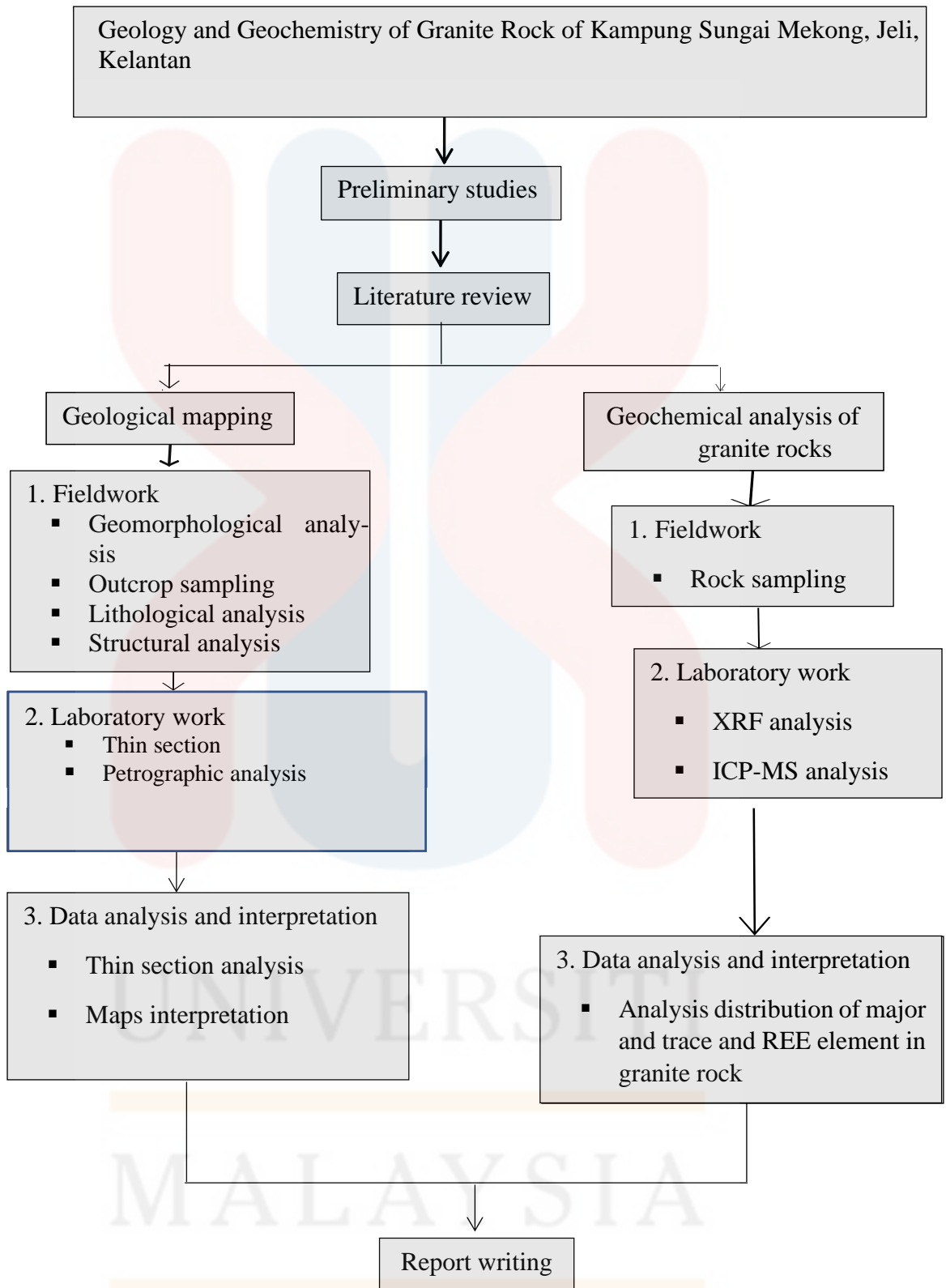
**Table 3.2** materials that were required to conduct the research in the field.

<p>Global Positioning System (GPS)</p>		<p>GPs was used to take record coordinates and to determine the outcrop location in the research area.</p>
<p>A Compass</p>		<p>A compass which is a directional method has been used to assesses directions in relation to an earthly point of reference that is fixed. The four cardinal directions north, south, east, and west are identified.</p>
<p>Hammer</p>		<p>For field work, geological hammers are essential. they are used to extract samples for additional</p>

		<p>study or to uncover new rock surfaces.</p>
<p>Measuring tape</p>		<p>To measure the distance to the ground, it employed a tape as a scale. Additionally, it is crucial for getting precise measurements of the lithology and structures.</p>
<p>Hydrochloric acid (HCL)</p>		<p>HCL was used to determine the reaction of the rock's specimen towards HCL solution and usually used for carbonate rock like limestone and dolomite.</p>
<p>Hand Lens</p>		<p>To observe and determine the tiny particles in the rock that cannot</p>

		<p>see by the naked eye. It is used to examine the sediment, rocks, soils, mineral, sand and other materials with tiny figures.</p>
<p>A Field notebook</p>		<p>The field notebook serves as the primary store for the information you collect there. It should specifically include details on the locations where the data were gathered.</p>
<p>Sample bag</p>		<p>Sample bags have been used to keep the hand specimens that will be collected in the field site during the mapping process.</p>

Arcgis-Softwares	 The ArcGIS logo features a stylized globe icon above the text "ArcGIS" in a bold, sans-serif font.	<p>The GIS files for the research region are displayed and explored in ArcMap, it is also where you may also assign symbols and design map layouts for printing or publication.</p>
Microscope	 A photograph of a white and black compound light microscope with a stage, objective lenses, and eyepieces.	<p>A microscope will be employed to observe and identify minerals of the rocks by examine the thin sections of the rock samples under PPL and XPL.</p>



**Figure 3.1** Research Flow Chart

### **3.3 Methodology**

#### **3.3.1 Preliminary study**

A preliminary study was done so that the researcher had been equipped with the information needed to conduct and complete the research process successfully. Therefore, to gain an understanding of the main rock types and other significant geological characteristics of the research locality prior geological map of the area will carefully be studied. As a guide, a few earlier studies had been examined such as Journals, books, theses, and the internet sources. Overall, the conceptual parts were examined first.

#### **3.3.2 Field Study**

Data collection was done correctly and using the right approach for this study to be completed. The results were then be generated by interpreting these data. Geological fieldmapping, field measurements, traversing, and rock sampling are all examples of field research. The geological field mapping was generally be involved in identifying all the geological aspects of the area with the purpose of preparing a detailed geological report and a map to summarize the report. A geological ma was thus shown the various rock types of the locality, the structures, geological formations, age relationships, distributionof minerals and fossils. and all these features may be super imposed over a topographic map or a base map. Field measurements is a primary which has been focused on making careful observations of rock types, textures, structures, measurement of orientation of structures and contacts.

In essence, traversing is a means of thoroughly covering a given area. Making a traverse involves travelling a roughly specified path from one spot on the map to another while charting the local geology. There are various methods for conducting field measurements, all of which must be analyzed and documented in the field. Fundamental to geological mapping are measurements of strike and dip and investigations of structures such as cleavage, foliation, and jointing. Photographs, sketches, and text descriptions will be used to document all the information that are accessible, including changes in the rock type or structural details of the outcrop that could be seen.

### **3.3.3 Laboratory**

The activities were included.

### **3.3.4 Petrographic Study**

Bulk sectioning is necessary to produce a section that is around 3 mm thick for thin section preparation. The samples must be free of debris, pneumatically to plug any pores, and mechanically supported by the specimen materials. The surface of concern had been grounded so that it was also be a smooth surface. The specimen must be dry and spotless. The specimen's top surface was mounted, and the air bubbles must be expelled. The grinding procedure employed carborundum powder to produce the necessary thickness. In addition, a decent polish has been achieved for petrography examination by polishing the samples on a machine. The thin section of rock samples collected were prepared and examined under the plane-polarized light (PPL) and cross-polarized light (XPL). The optical mineralogy of the rock compositions such as color, cleavage, texture, twinning, and other distinguishing mineral properties has been studied throughout this examination. QAP diagram has then been employed to observe the proportion of minerals present in the rocks sampled.

### 3.3.5 Geochemical Study

X-ray Fluorescence XRF spectrometry, a non-destructive chemical analysis that works on wavelength-dispersive spectroscopic principles has been used. XRF method is applicable for analyzing the bulk chemical analyses of major and trace elements (Wirth and Barth, 2018). The Great laboratory UMK Jeli campus has been to facilitate the XRF analysis. To be representative of the target rock mass, the sample must be ready to display the origin and general content of the entire material. Information on the sample's origin and history is needed to prevent compositional changes during transport and storage. To reduce the likelihood of contamination, the sample must first be kept clean and dry. The rock samples will be crushed and grounded into a powder with an optimal grain size of 60m using a rock crusher. To create a uniform sample particle, the mixture has been squeezed to less than 20 kpa using a press pellet compressor and a binding assist.

ICP-MS Inductively coupled plasma mass spectrometry (ICP-MS) was employed for the direct detection of trace elements in granites and must thus be prepared using techniques that completely dissolve the sample. Analytes must be entirely mixed for solution ICP-MS to analyze solutions correctly. While preventing sample loss or contamination, digestion's objectives are to dilute analytes and break down materials. Without digesting the samples, undissolved analytes cannot be analyzed precisely. Drying and homogenizing the rock sample is necessary. To prevent gas explosions and to let gases escape, loosen the tube's cap will take into consideration.

### **3.3.6 Data Processing**

The geological map has been constructed by using ArcMap software. The track recorded in GPS along the field study area has been transferred and digested into ArcMap. The strike and dip analysis has also been performed using the Stereo Net software. Joint measurement has been done utilizing GeoRose software to determine the main force that distorted the rock.

### **3.3.7 Data Analysis and Interpretation**

Data collection has been achieved through mapping operation, stratigraphy and structural analysis were carried out, and interpretation has been performed using associated software and self-interpretation to reflect the overall geological features and the needed information of the study region. Geochemical analyses have been adapted along with petrographically examinations in terms of rock names and classifications and evaluate tectonic settings. At the same time, it has been examined where REE is distributed.

## CHAPTER 4

### GENERAL GEOLOGY

#### 4.1 Introduction

This chapter emphasized more on overall geology of the research area, which is around Kampung Sungai Mekong in Jeli district, Kelantan. This study provides an overview of the general geology of the studied area and cover its key geological features, including geomorphology, lithostratigraphy, structural geology, and historical geology. Prior to conducting the field mapping, a plan and workflow have been developed, this phase of work was mostly carried out in the campus although a short reconnaissance field trip has been included. Once a field has been identified for mapping, it was only rational to learn everything in its regard to make a workable field study.

Compilation of all available and relevant data has been implemented, to avoid duplication of work and most importantly simplify the field study. The number of days spent during the geological mapping phase varied based on the target of each day, the equipment required and the availability of transportation. A budget for the transportation had been prepared and the lecturers that would be involved in mapping. It has also been noted to involve the local community when tracking to avoid any distraction whether it is loss in the jungle or guidance specially in protected areas as they understand their environment better than anyone else and thus be quick to pinpoint areas that maybe of interest.

Data collection and field assessment phase after planning, this step is crucial to any geological field mapping and is only completed in the field to gather information. It is possible to get information through physical samples, measurements, notes, and photos. Therefore, to take note not only geological features but also of everything around them, one must be completely prepared with all the required tools, mentally and physically. Before the start of the field tracking, direction has been determined based on the base map that has been generated during planning phase, it was also daily routine to decide daily track before entering the study area which made it possible to produce traverse map that is one the several maps that has been developed during throughout the project.

There are two kinds of filed tracking, open polygon, and close polygon. Open polygon which is to start track mapping from the first point > second point > until the finish point is not the first point in one day third point has been employed during field study, this method of tracking is like a rally track, the start point is not the finish point. The goal of this procedure of jungle tracking was to locate an outcrop where samples could be taken and structural measures recorded, as well as to locate a new outcrop where the data would be more accurate. The abundance of outcrop can be impacted by topographic conditions. It was simpler to locate an outcrop in an exposed place than one that is not. Because of study area's tropical environment, the erosion is severe.

Finding soil and highly weathered rocks was simpler than finding fresh rocks. To do that, there must be seeking out indirect evidence, such as colors of the soil, marking the location of the original rocks, or taking from cliffs, animal burrows, or man-made holes. Some bedrocks can be seen through vegetation. For instance, juniper or beech trees sign with limestone appearance. Visit the river and inspect the banks. It will be more effective because every riverbank has undoubtedly deteriorated, exposing the

bedrock. Visit the structural geology section to see whether any elevated or unstable rocks are present. Another parameter that has been taken into consideration was identifying boundaries and contacts, this need to be aware of the dipping to identify lithology boundaries. According to the law of superposition, "the youngest rocks are deposited beneath the oldest layers, unless structural controls were in place. Crossing the dips and going perpendicularly to find the youngest rocks which was the most challenging has been done in many areas of the study area.

#### **4.1.2 Accessibility**

Accessibility in project planning relates to a gauge of how simple it is to reach geographically dispersed sites or undertakings. within a city Accessibility is typically linked to a location of origin. A location with great accessibility is one from which many destinations can be reached, or destinations can be reached very quickly. Low accessibility means that fewer places can be reached for a given amount of time, effort, or money, or that leaving from that location to reach elsewhere is more challenging or expensive.

With that respect, The Jalanraya Timur-Barat is the primary road that connects the study area. The research area is then accessible from this major access through a short trail route that also crucial for farmers and villagers. Most of the roads are paved, however further into the countryside, where some plantations, like rubber plantations, are located, there are some gravel roads or short trails. In general, most of the study area is simple and has good access, allowing for the passage of vehicles for both social and business objectives. However, due to high elevation and the thick forests several places of the study area were inaccessible in the northeastern part which is part of Bukit Jeli.



**Figure 4.1** Jalan Raya Timur-Barat and small gravel road in the study area.

### 4.1.3 Vegetation

In the studied area, vegetation is pervasive, often covering up to 90% of the land at length scales below 1 m. The predominate vegetation is a lush, evergreen rainforest. Due to the research area having some notable settlements and agricultural activity primarily restricted from southwest northwestern areas are examples of anthropogenic influences on the landscape in area. In addition, the study region was mostly made up of locally owned rubber tree plantations and palm tree plantations.

According to land cover map (figure 4.2), which is shown below, more than 60% of the study region is made up of rubber tree plantations. As a result, most of the people there rely heavily on the rubber plantations as their main source of income. A palm tree plantation land of smaller coverage was found in the research area's northernmost region, as shown on the map below. palm tree plantations also serve as a source of income.

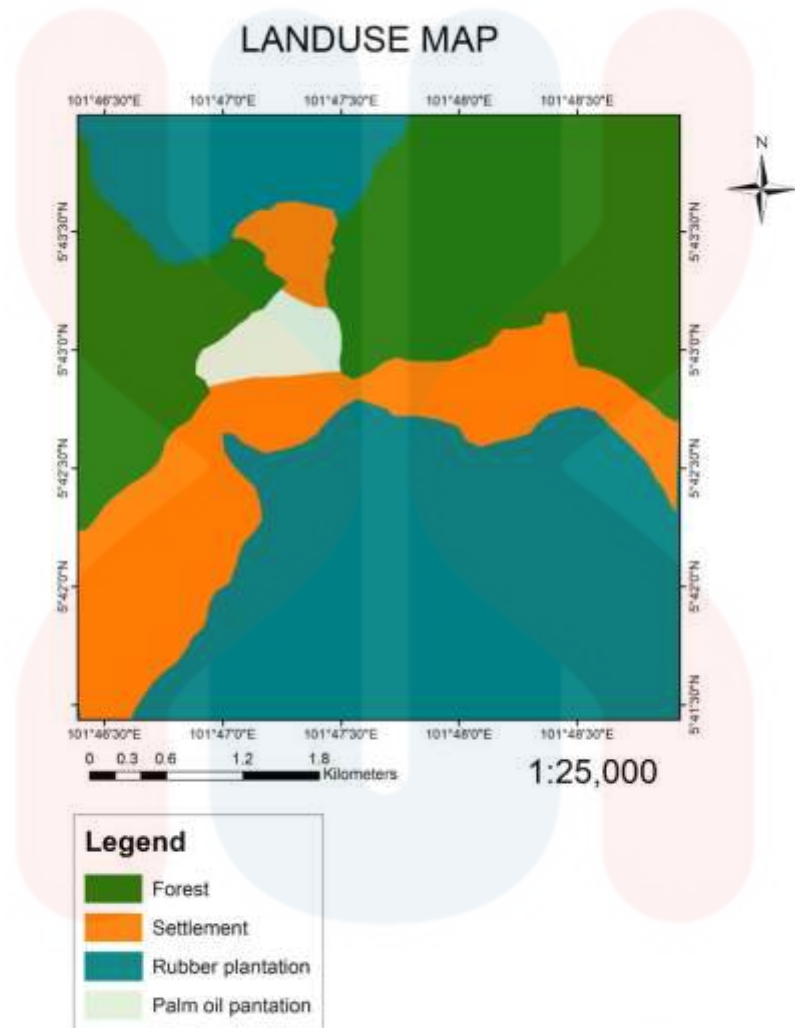


Figure 4.2 Land use map of the study area.

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#### **4.1.4 Settlement**

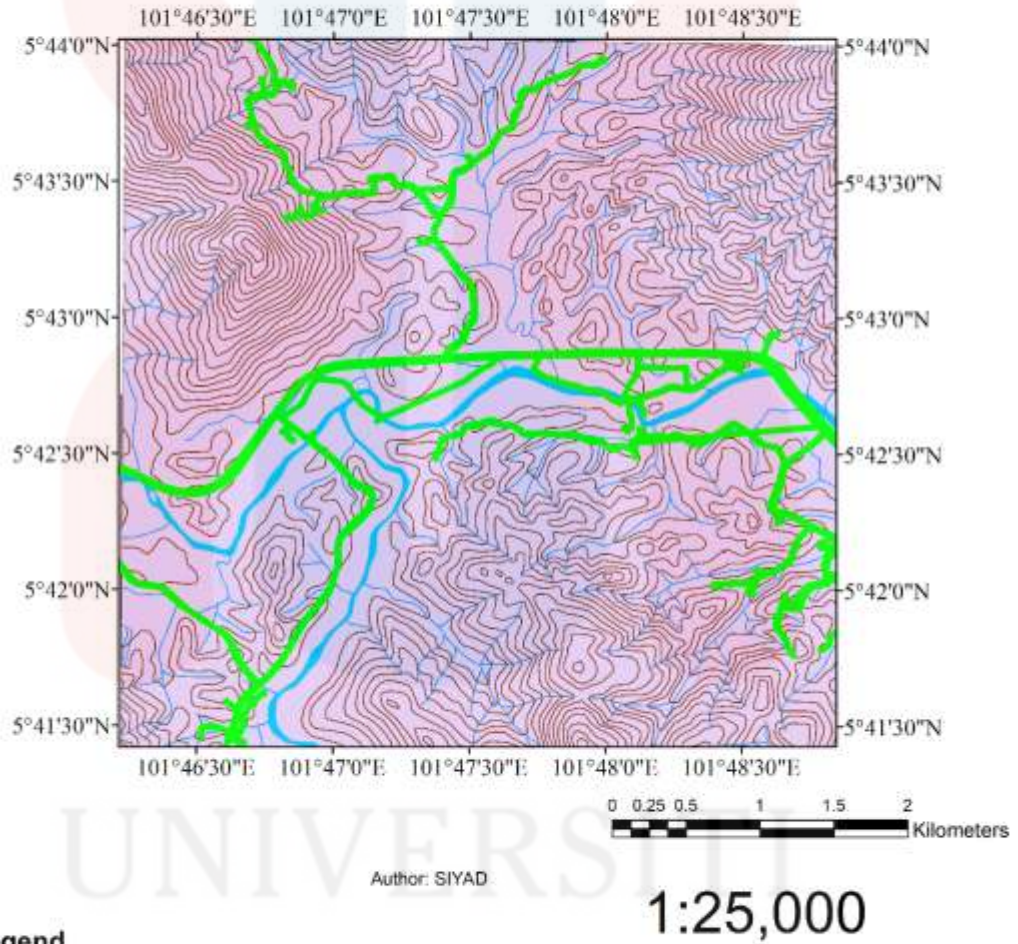
Settlement includes the places and areas that are settled by people that formed a community. The main villages that covered and located in the study area is Kampung Sungai Mekong that located at the northwest of Jeli district. Most of the community in the village works in managing rubber and palm oil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

#### **4.1.5 Field Traverse and Observation**

During the field mapping phase, traversing, which is essentially a way of managing the progress within the study region, was used. The traverse was carried out by following planned paths from one location on the map to the next while recording the general geology. A great technique to manage the density of your observations is with traverses. In the areas with exposed rocks, particularly where several exposures are approximately close, traversing was mostly utilized to map the terrain in depth. Traversals were spaced tightly in these situations and undoubtedly, GPS was useful when travelling because was used for marking locations and track record as shown in (figure 4.3). It was easily possible to locate exposures by walking traverse in some areas with offsets from one map feature to another on the terrain with good visibility and a suitable base map, even with more precise mapping.

Observations were made while crossing by keeping an eye out for any changes from the lithological and geological formations' set patterns. A field notebook was used to record every observation, and a GPS device was used to track the traverse path. After that, the traverse pathway was displayed on the map in the map below.

It took seven days of traversing to accomplish the desired data and reached all target destinations, some of parts of the study area is completely inaccessible such as north-eastern part of the study region with 650 m elevation and thicket forests. Lastly, throughout the field traverse several rocks samples have been collected from the discovered exposures then sent to laboratory for further analysis.



**Legend**

-  Tracks
-  MAIN ROAD
-  Contour
-  River

**Figure 4.3** Traversing map.

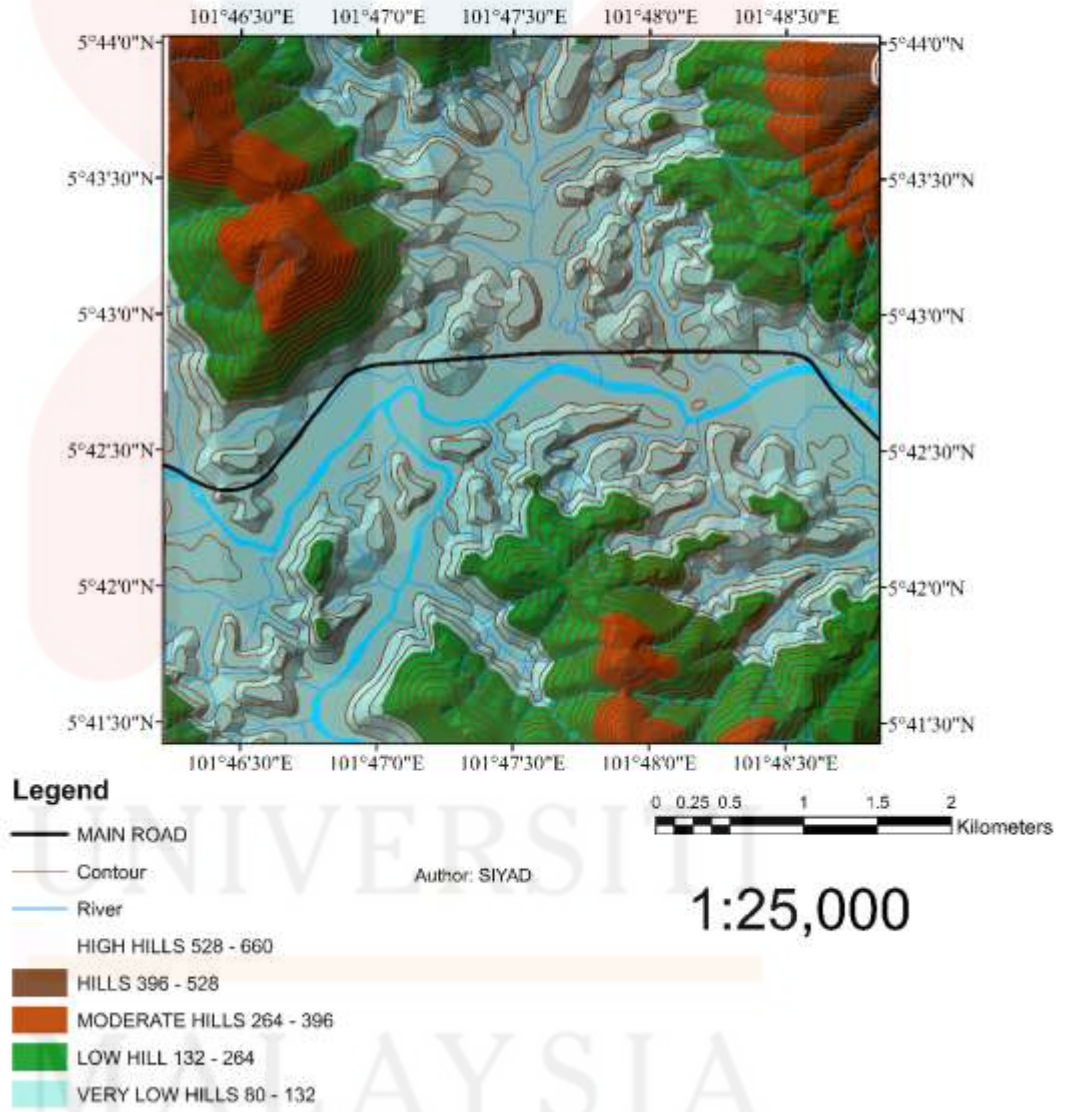
## 4.2 Geomorphology

Studies on the geomorphology of mountainous regions have mostly concentrated on high mountain systems in warm climates where mechanical weathering and frequently glacial erosion have been significant contributors to the development of the landscape. Tropical mountain systems with a lower elevation have received less study. The humid tropics are frequently described as an environment where mechanical weathering is subordinate to chemical weathering processes. Quaternary climate variations are now being shown to have had a significant impact on the development of the landscape in the study area and humid tropics globally. The Bukit Jeli, the tallest mountain in the research region, rises from the southern Titiwangsa ranges, which have an elevation of 2000–2500 m.

Igneous and small exposures metamorphic rocks dominate the study area's hilly terrain, the southern part of the study area is mostly covered by soil making that area ideal for agricultural use. As a result, the villagers there discovered and cultivated the majority of the hilly part as a plantation area with rubber. The higher elevation region, which is a mountainous location, was heavily forested and primarily exposed granite unit. Deforestation is the primary activity being investigated in the mountainous region, and some of the areas have also been developed as plantation sites, such as rubber tree plantations. The elevation map illustrates the types of landforms with the altitude representation numbers which also indicates area has diverse landforms from low-lying areas to mountain peaks.

The cumulative impact of geomorphic, geological, hydrological, biological, and soil producing processes that have acted on the Earth's surface over time has resulted in these landforms. Therefore, landforms are commonly acknowledged as natural features that divide the Earth's surface into basic spatial entities. The properties of landform entities vary from one another, including shape, size, orientation, relief, and contextual position. Additionally, they differ in terms of the physical processes that contributed to their origin and are still in effect today within them (Etzelmüller and Sulebak, 2000).

Landforms establish the parameters within which processes in the disciplines of geomorphology, hydrology, ecology, pedology, and others operate. Size and shape of a landform are taken to be clear markers of the processes that are thought to have created it. clearly showed that the size and spacing of landforms clustered around distinctive scales or limits related to either process thresholds or available space. Landforms' surface shapes have long been used to understand or infer the geomorphic processes that shape hillslopes, such as alluvial, aeolian, or glacial deposition. These processes include erosion, denudation, accumulation, and deposition. Therefore, the land of the study area has several governance factors that has shaped and still operating today.



**Figure 4.4** Topographic map of the study area.

The above elevation map (figure 4.4) represents the topographic profile of the study area which shows several landforms and elements of those landform, the most notable landform illustrated in the map is the low-lying area which covers more than 70% of the study area, The erosive action of streams and rivers is known to have generated those landforms in the low-lying area. The most frequent characteristics are valleys, gullies, washes, and gorges, which are all created by the stream flows. The contour reentrant, or portion of the contour that curves or bends toward and away from the drainage channel, is the typical contour feature of stream courses seen in low-lying areas. Reentrants illustrate the courses of streams that are too small in a sequence of contours that surround a hill, and this type of characteristic may be found in the southern half of the research region.

In general, the basic interpretation of local surface and regional measurements of topographic context is to infer mechanisms that regulate the spatial distribution and redistribution of materials and energy in the landscape of the area. To draw additional conclusions about projected outcomes, inferences based on process formed linkages are frequently used. Site characteristics in terms of surface and subsurface moisture regimes, types, textures, and stabilities of unconsolidated materials are taken into consideration during the geomorphic survey.



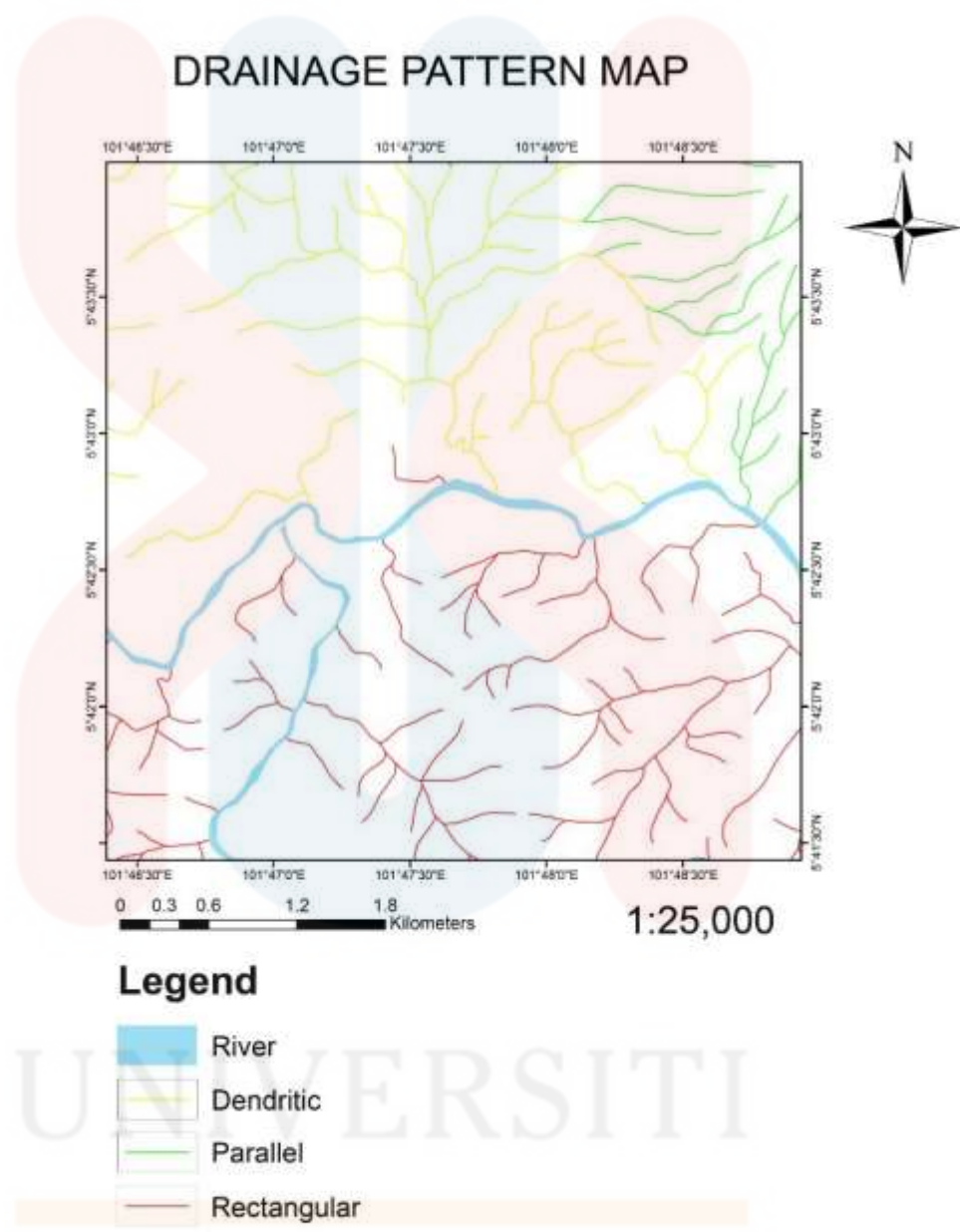
**Figure 4.5** An illustration views of the study area which represent surface features of the area.

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#### 4.2.1 Drainage Pattern

Tectonic activity can actively direct drainage pattern to take a specific channel or it can adjust passively to the fluctuating resistance of geologic materials. Drainage in the study area has been impacted by one major fault and lineaments. A great variety of structural and tectonic influences are visible in streams that originate from mountain facets and flow onto the adjacent lowlands. Mountain fronts that are subject to erosion due to a complex interaction of geomorphic factors may become plant-covered surrounding surfaces known as pediments. Alluvial fans and knickpoints are produced by deposition at the mountain front due to the enormous increase in width as a stream emerges from a mountain range specifically in the northern section of the study area. Nearly all the research regions have the ability to passively adjust to structure. However, drainage pattern situations when streams traverse structural zones might be the most fascinating ones. Some streams seem to navigate fold belts in the most challenging ways possible.

Based on the drainage pattern map, the study area accommodates three types of drainage system that has been classified according to their distinctive features coupled with the standard classification of the drainage patterns supported by field observation, the pattern is dendritic pattern, parallel pattern and rectangular. In figure 4.6 Colored representation map with the three different types of categorized drainage pattern.



**Figure 4.6** Drainage pattern map of the study area.

The map's dendritic drainage pattern is represented by a black line color. Dendritic drainage patterns typically take the form of tree-shaped drainage patterns and are widely distributed over the earth's surface. A dendritic drainage pattern is typically found where there is no structure in the rock and where the stream can easily erode in all directions. Typical igneous terrains or simply or where hard rocks are distributed typically experience dendritic drainage patterns. In the northern part of the research area, particularly near the Sungai Mekong area, dendritic drainage pattern drains. Parallel drain pattern also found in the north section of the study area.

The parallel drainage pattern in the study area is runs small area northeastern part of the research region the type of drainage pattern brought on by steep slopes with occasional respite. In areas with a constant slope, the tributaries run parallel to one another generally and in the study area which this type of pattern occurs is the steepest area. Rectangular drainage pattern can be discovered in areas that have experienced faulting. It forms in areas with limited topography and a network of bedding planes, fractures, or faults as it can southern section of the study area.

#### 4.2.2 Weathering processes

Weathering is the term used to describe one of the most fundamental geomorphic processes, which is the change of rock surfaces exposed to atmospheric conditions. Physical, chemical, and biological processes that cause alteration most frequently weaken the rock's surface, causing what is variously referred to as rock degradation, decay, crumbling, decomposition, rotting, disintegration, or breakdown, which results in erosion of the surface. Weathering, however, occasionally may at least momentarily harden the rock's surface layers. While such hardening can prevent erosion on a rock surface temporarily, it might also hasten the disintegration of the rock over time. For instance, a solidified crust may react to environmental pressures quite differently than the underlying rock, causing the top layer to deteriorate. Both in rural and urban settings, this happens rather frequently. (Moses, C., Robinson, D., & Barlow, et al., 2014).

Erosion processes work in conjunction with rock weathering processes to remove weathered elements and expose the new rock surface for continued interaction with the atmosphere. Monitoring and measuring the impact of these processes is essential to comprehending how weathering and erosion interact to affect rock surfaces. Thus, throughout the field assessment it has carefully been observed and studied the kinds of weathering processes that acted on the exposures and the erosion agent that happened or might happen in the future, during the observation there has been discovered that the rocks have mostly experienced mechanical and biological weathering.

Mechanical weathering involves undergoing rocks without any chemical change and this results in the degradation of rocks, minerals, and soils. Weathering can happen mechanically because of temperature, pressure, frost, root movement, and burrowing animals. For instance, physical weathering can use fissures to expose more surface area to chemical activity, speeding up the pace of deterioration. Consequently, the structure of the outcrops tends to deteriorate, become unstable, and eventually collapse into the soil as this weathering process continues. Therefore, physical deterioration may result in soil erosion and landslides. (Raj, J. K. et al., 2018).

the granite outcrop in the research area shows in below photo experience physical disintegration process and during the observation on the outcrop there has been discovered sheet-joints which is a typical joint of weathered surfaces. The outcrop is categorized to be moderately weathered (grade III) due to the discolored surface of the outcrop it shows.



**Figure 4.7** Mechanically weathered granite outcrop surface.

Biological weathering generally come under the influence of life activities of living things. The organic processes that contribute biological dissolution of rocks from bacterial activity, humic acids and bioerosion or destruction. The roots that sprout and the organisms of shells, lichens, cyanobacteria, algae, and fungi that penetrate the rocks on which they grow cause changes. A particularly important role is played by the bioerosion of carbonate rocks (limestone and dolomite) brought on by cyanobacteria, lichens, and fungus. Numerous very fine-grained carbonate detritus of limestone sludge is produced because of the extensive areas where these creatures live, thrive, and their protracted activities during the geological period, which result in the destruction of significant amounts of rock. (Sel, A., & Binal, A. et al., 2021).

The below (figure 4.8) represents schist metamorphic rocks that has greatly experienced biological weathering as it can be visualized the outcrop surface, the grade of the weathering is also described to be grade III which is classified as a slight change of the rock mainly on the surface features such as color and texture.



**Figure 4.8** Biologically weathered schist metamorphic outcrop.

### 4.3 Rock units

Era	Period	Description		Lithology
Mesozoic	Triassic	A coarse- to medium-grained composed of three minerals - feldspar, quartz, and mica. The feldspar is predominantly pink in color, which results in pink granite commonly found in many locations within the study area.	Granite	
		A medium-grained rock that contains more plagioclase feldspar than orthoclase feldspar, and it includes more than 20% quartz.	Granodiorite	
		Sandstone interbedded with siltstone, and volcanics, mainly tuffs of rhyolitic to dacitic.	Limestone	
Palaeozoic	Permian	Pure light colored thick to very thickly bedded limestone. With some characteristics of dolomitization.	Sandstone	

Figure 4.9 lithology representation

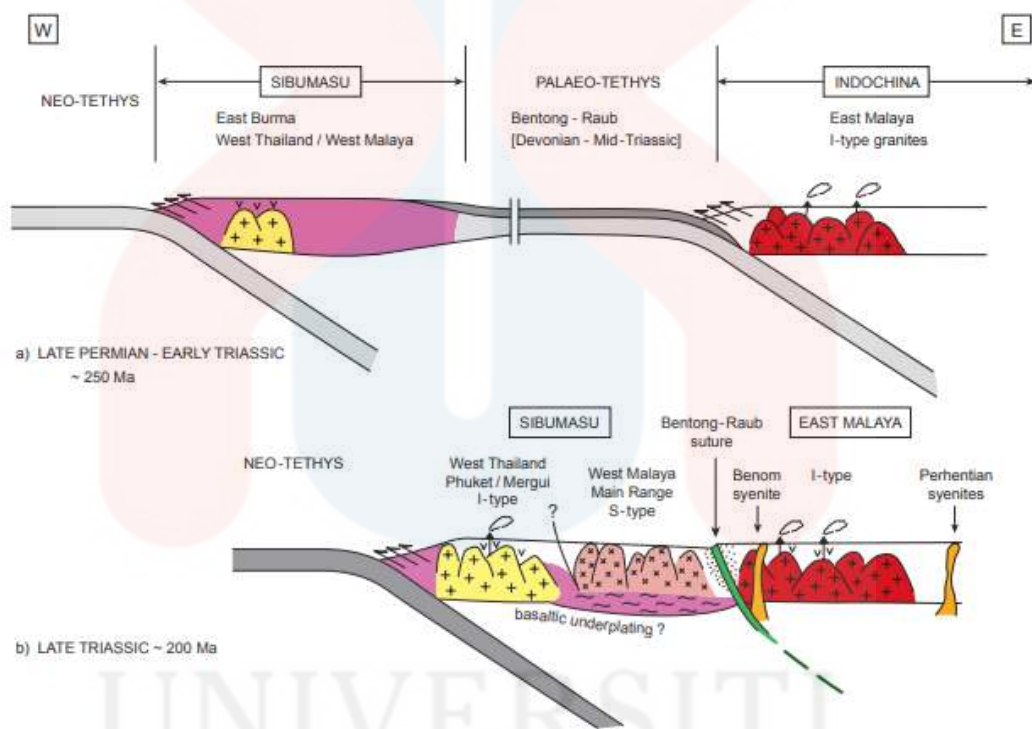
During geological data collection and mapping, rocks in the study area have carefully been observed using numerous methods exist for identifying rocks, including visually with the unaided eye or a magnifying glass. According to microscopic investigation results coupled with the field observation, four different types of lithologies have been identified in study region, granite unit which was exposed more 85% of the study, granodiorite in the middle of the study area as shown the stratigraphic column above and smaller exposures of sedimentary rocks which are limestone and sandstone. During the field observation there were various things that have taken into consideration for rock classification these include color, composition, grain size, and structure of the discovered outcrops through visual inspection.

These characteristics of rocks reflect their genesis, environment, and mineral and chemical makeup. Rocks' chemical makeup generally reflects in their color. For instance, lighter color rocks typically contain felsic minerals such as quartz and feldspar and are acidic, darker rocks contain dark mafic minerals such as pyroxene and hornblende. The field observation has involved identifying the mode occurrences of the igneous rocks in the study area by examining whether the exposures are intrusive or extrusive, petrographic investigation supported with some with characteristic of the rocks such as grain size and composition of the sampled rocks draw the conclusion of mode of occurrence of the study area as an intrusive igneous rock for instance, granite rocks. According to IUGS, granites are divided into four granite domains alkali feldspar granite, monzogranite, granodiorite, and granite monzogranite, and syenogranite. Both alkali feldspar granite and granodiorite are among the granite subtypes of the study area.

Generally, granites have been found to have formed both intraplate and at several different tectonic locations throughout the planet. They are categorized into four major groups based on their tectonic environments: ocean ridge granites (ORG), volcanic arc granites (VAG), inside plate granites (WPG), and collision granites (COLG) utilizing the trace element Y-Nb, Yb-Ta, Rb-(Y + Nb), and Rb— (Yb + Ta) diagrams. The collisional zone granites were divided into four groups by. (1) Pre-collision calc-alkaline (volcanic-arc) intrusions, which primarily result from mantle modified by a subduction component; (2) Syn-collision peraluminous intrusions (leucogranites), which may result from the hydrated bases of continental thrust sheets. (3) Late or post-collision calc-alkaline intrusions, which may have a mantle source but experience significant crustal contamination; and (4) Alkaline granites in post-orogenic continental settings that belong to the A-type or anorogenic category of granitoids. (Mokhena et al., 2016)

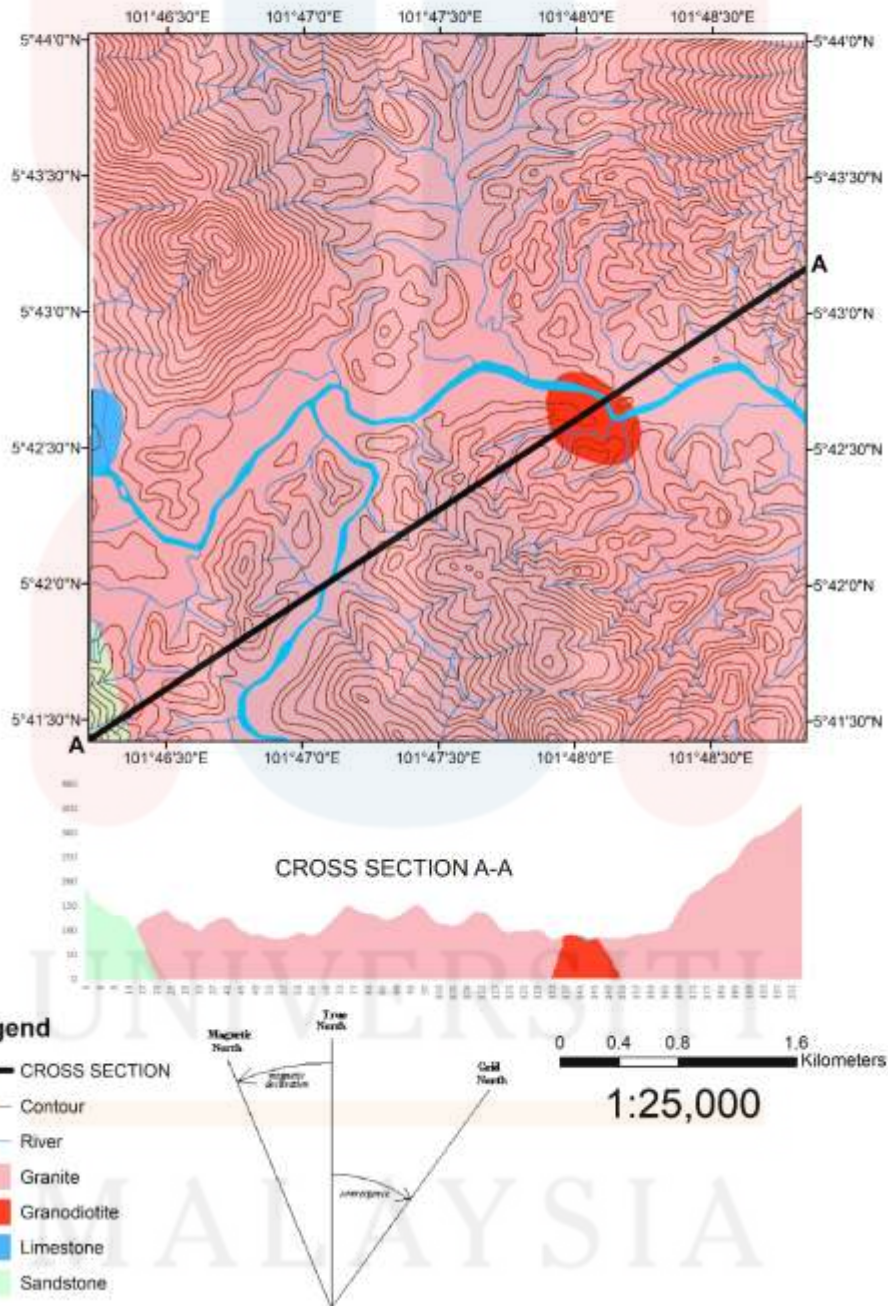
According to (Sevastjanova et al., 2011). The Malay Peninsula is divided into three geological zones (belts): the Eastern Zone, Central Zone, and Western Zone, which are delimited by significant fault zones based on stratigraphical and structural variations. The granitoids of the Main Range Province intrude the Western Zone, which is located on the Sibumasu Block. The Eastern Province granitoids intrude into the Central and Eastern Zones, which are located on the East Malaya Block. Therefore, the granites of the study area and entire Eastern Province are primarily composed of I-type and uncommon S-type Permian and Triassic granitoids, which were formed in a volcanic arc that occurred on the East Malaya Block and are thought to be subduction-related.

Granite exposures that are found in some parts specifically in the section of the study area show some characteristics such foliation or mineral alignments which is evidence of the rock has gone through heat and pressure and environmental conditions, during the field observation and data collection phase of the study all feature on out-crop has been noted and recorded for the purpose of petrographic examination and for relating with previous studies.



**Figure 4.10** Tectonic evolution of SE Asia region (Searle et al., 2012)

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**Figure 4.11** Geologic Cross-Section Map of the study area

### 4.3.1 Petrographic analysis

### 4.3.2 HAND SPECIMEN: SCHIST ROCK: SAMPLE CODE: CD 02

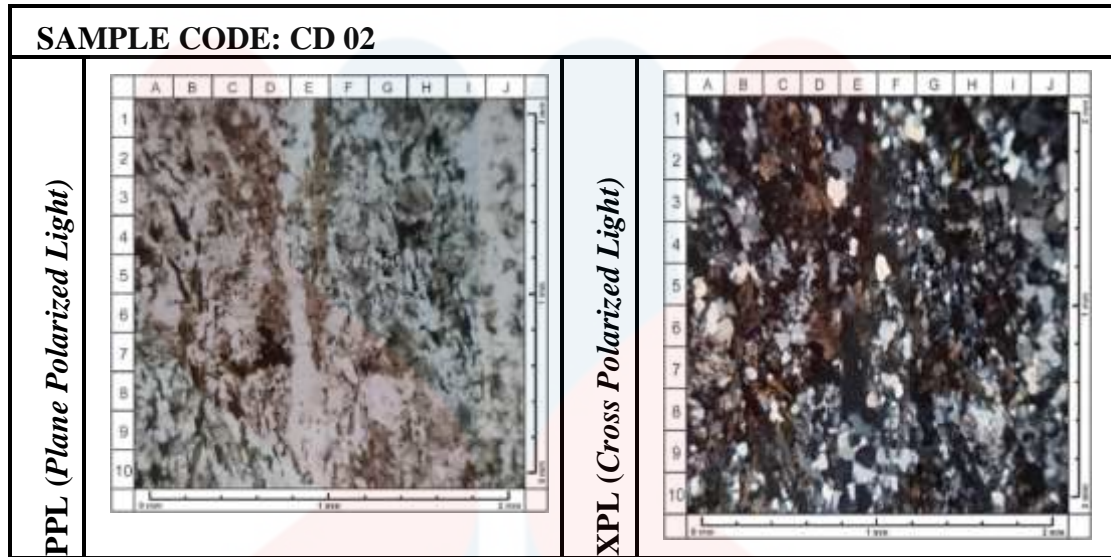


**Figure 4.12** Photos that are taken from the outcrop.

### 4.3.3 Field observation: CD 02

Based on the observation, the outcrop exposed in the middle of stream which drains in the northern section of the study. From the naked eyes observation, the outcrop was exposed to the weathering process which is biological weathering as it can be seen on the above photos. According to global standard weathering grade, the outcrop was classified with grade III that is moderately weathered. the rock has a medium grain size which is typical grain size of schist metamorphic rocks.

#### 4.3.4 Thin section CD 02



#### 4.3.5 Microscopic Observation: CD 02

The observations were made at 10x ocular magnification and 5x objective magnification and at observation of foliation structure (schistose), including grain size  $<1/16$  –  $1/6$  mm, good sorting.

Mineral composition:

Quartz – 66% In PPL, absorption color is colorless, low relief, pleochroism is absent, anhedral crystal form, cleavage is absent. On XPL, the color of gray-white interference is order 1, the angle of darkness is wavy, there is no twin.

Biotite – 2% On PPL absorption color is brown - greenish, medium relief, strong pleochroism, subhedral - euhedral crystal form, 1-way cleavage. In XPL color interference green - orange order 3, there is no twin parallel darkening angle.

Chlorite – 30% On PPL, the absorption color is green, low relief - medium, weak - medium pleochroism, anhedral - subhedral crystal form, 1-way cleavage - none. On XPL, the interference color is gray - dark green order 1 - order 2, the darkening angle

is oblique, there is no twin.

Opaque Minerals – 2% In PPL, black absorption color, low relief, no pleochroism, euhedral - anhedral crystal form. At XPL, the black interference color of the 1st order, twinning does not exist.

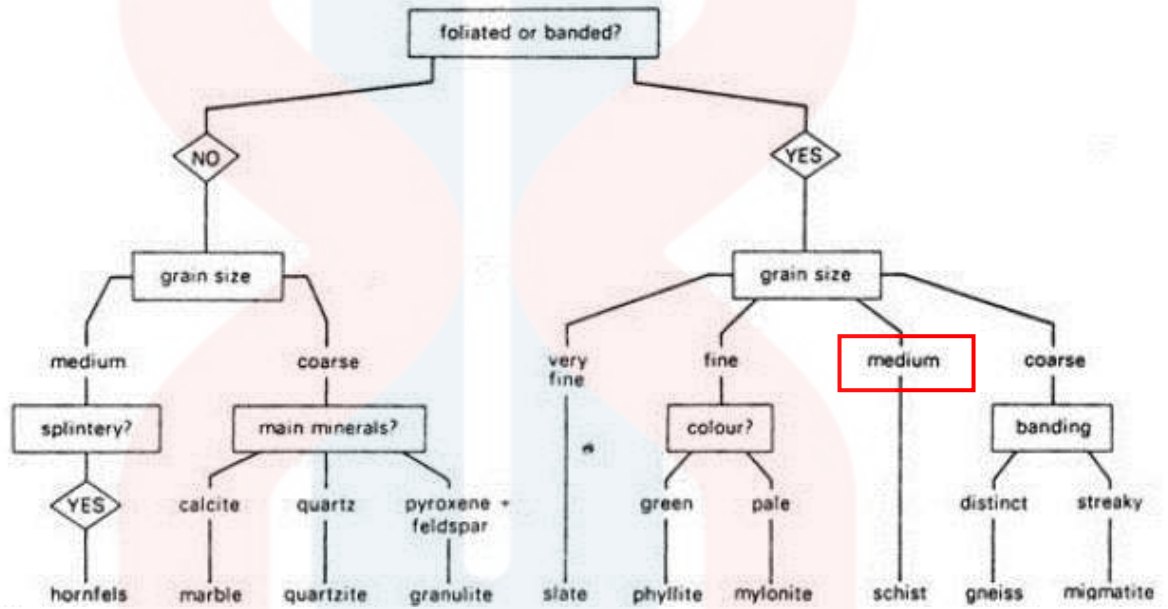


Figure 4.13 Flow diagram for the identification of metamorphic rocks in general (Gillen, 1982)

#### 4.4.1 Hand specimen: Granite rock:

SAMPLE CODE: CD 03

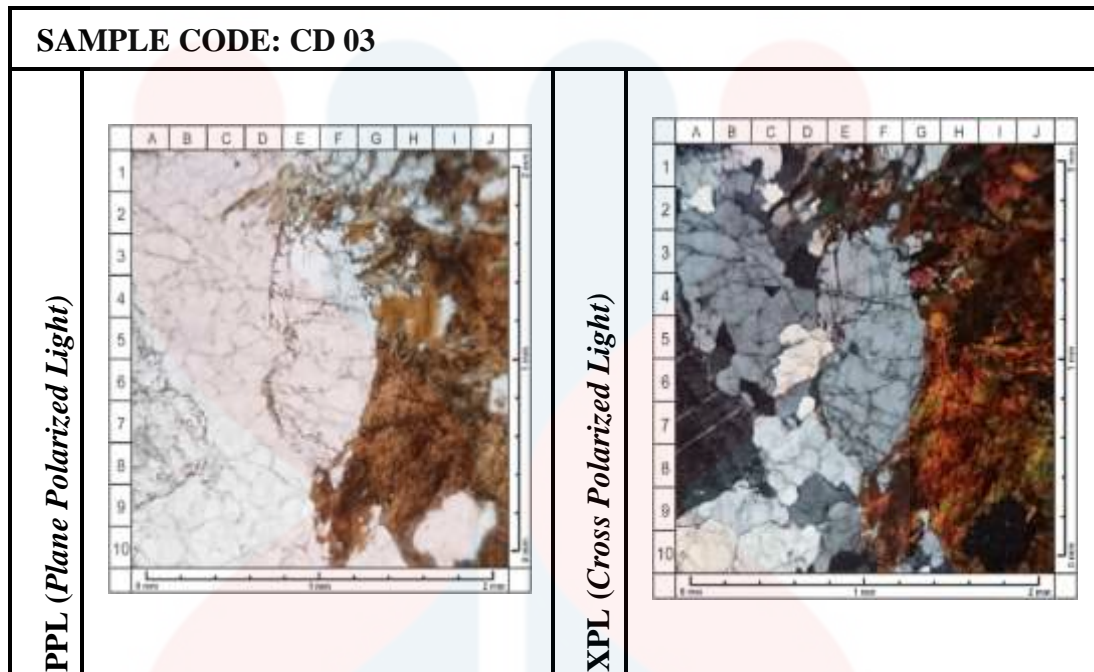


**Figure 4.14** field photo representing the outcrop.

#### 4.4.2 Field observation CD 03

From the field observation, this outcrop is quite large and well exposed near stream, the area is upland area with nearly 200 m elevation in the eastern part of the study area, the outcrop is found an excavated area for electric post and road construction and due to those activities rock show mechanical weathering which can be categorized to be grade III. The texture of is phaneritic and can easily be identified the mineral grains which reflects the cooling process of the rock that shows the rock has undergone slow cooling.

#### 4.4.3 Thin section CD 03



#### 4.4.4 Microscopic Observations: CD 03

The observations were made at 10x ocular magnification and 5x objective magnification and at observation of coarse-grained granite texture covering grain size  $<1/16 - 1.2$  mm, poor sorting.

Mineral composition:

Plagioclase – 15% In PPL, the absorption color is colorless, low relief, pleochroism is absent, euhedral - anhedral crystal form, 1-way cleavage. At XPL, the interference color is gray - white order 1, parallel darkening angle, albite twin - albite - polysynthetic.

Quartz – 49% In PPL, absorption color is colorless, low relief, pleochroism is absent, anhedral crystal form, cleavage is absent. On XPL, the color of gray-white interference is order 1, the angle of darkness is wavy, there is no twinning.

Biotite – 35% On PPL absorption color is brown - greenish, medium relief, strong pleochroism, subhedral - euhedral crystal form, 1-way cleavage. In XPL color interference green - orange order 3, there is no twin parallel darkening angle.

#### 4.5.1 Hand specimen: Quartz-rich granitoid rock

SAMPLE CODE: CD 05

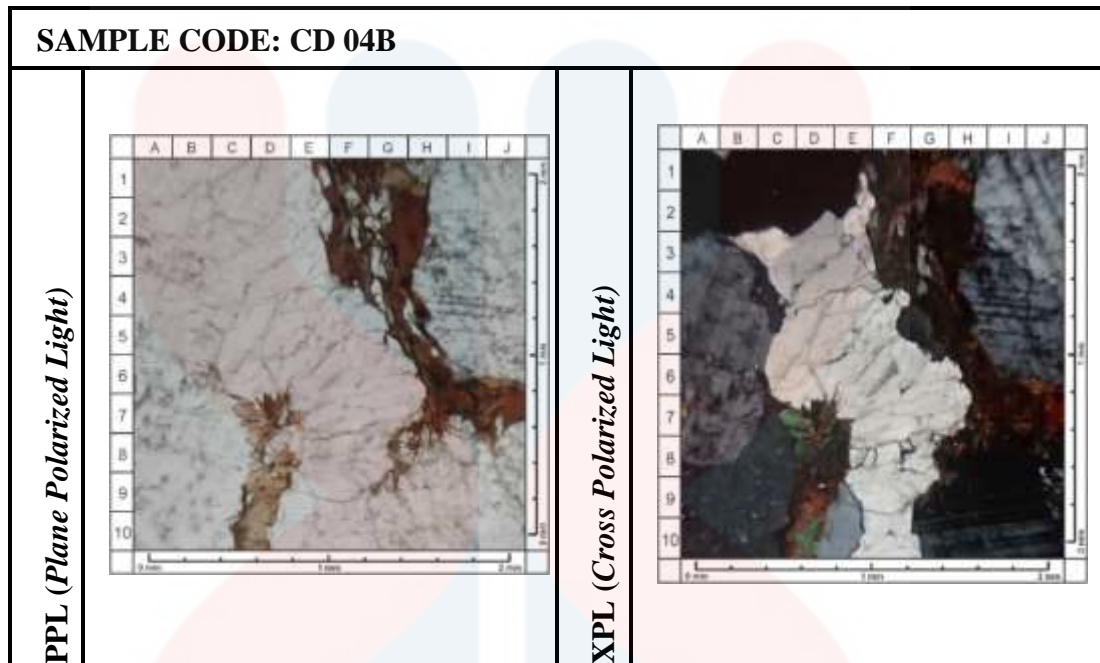


**Figure 4.15** outcrop photo with sampled pieces of rocks.

#### 4.5.2 Field observation: CD 05

According to the preliminary observation, this outcrop has distinctive characteristics of mineral features such as wavy alignments of minerals by color which can be interpreted as band, from the initial observation the rock has categorized to be gneiss but later after further microscopic examination it is concluded that the rock belongs to granite but according to some literature the rock might have through some alteration by metamorphism. This exposure was found in the of the Pergau river, it is coarse grained moderately weathered with some biological weathering and some notable structures such as dike intrusion, shear joints on the surface of the outcrop and it has also been noted diorite intrusion in some parts of the rocks.

#### 4.5.3 Thin section: CD 04B



#### 4.5.4 Microscopic Observations: CD 04B

The observations were made at 10x ocular magnification and 5x objective magnification and at observation of massive structure, phaneritic texture - weak foliation, coarse mineral size - medium. Is a meta-igneous rock, characterized by apparently parallel arrangement of mineral directions but has not yet formed a foliation structure. Mineral composition:

Quartz – 64% In PPL, absorption color is colorless, low relief, pleochroism is absent, anhedral crystal form, cleavage is absent. On XPL, the color of gray-white interference is order 1, the angle of darkness is wavy, there is no twin.

Microcline – 40% In PPL, the absorption color is colorless, low relief, pleochroism is absent, subhedral - anhedral crystal form, 1-way cleavage. At XPL, the color of the gray-white interference is order 1, the darkening angle is oblique, polysynthetic twins

Biotite – 13% On PPL absorption color is brown - greenish, medium relief, strong

pleochroism, subhedral - euhedral crystal form, 1-way cleavage. In XPL color interference green - orange order 3, there is no twin parallel darkening angle.

Opaque Mineral – 1% In PPL, black absorption color, low relief, no pleochroism, euhedral - anhedral crystal form. At XPL, the black interference color of the 1st order, twinning does not exist according to the microscopic examination.

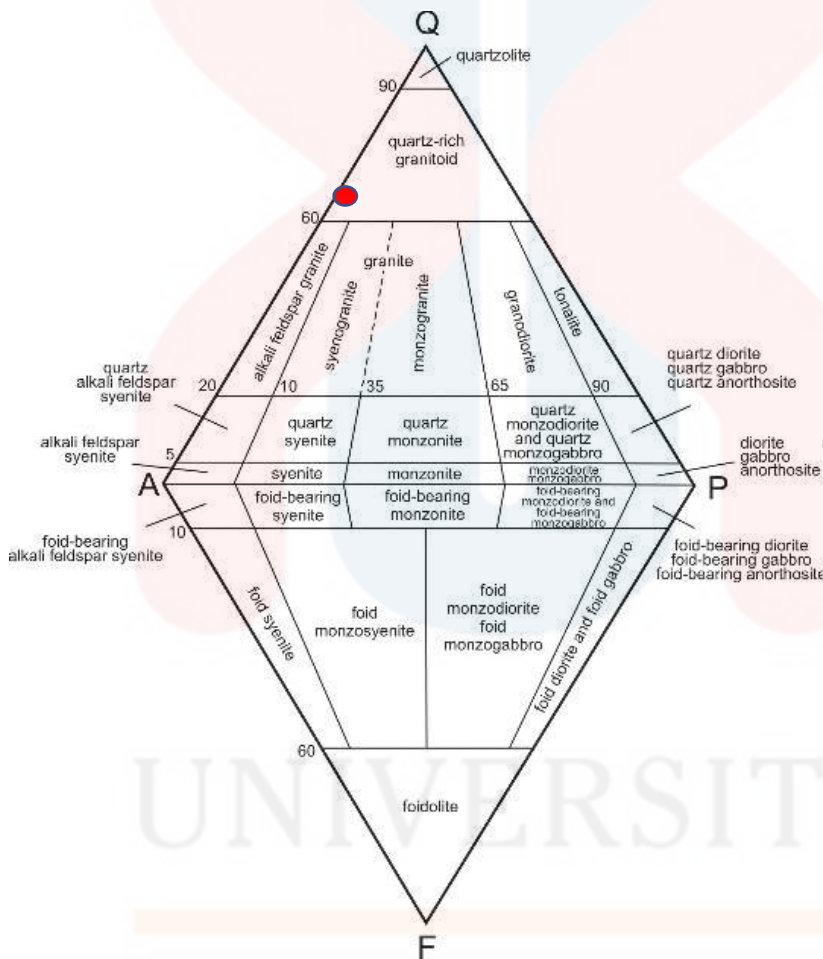


Figure 4.16 QAP diagram for showing type of granite.

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**4.6.1 Hand specimen: Igneous rock: Diorite**  
**SAMPLE CODE: CD 06**

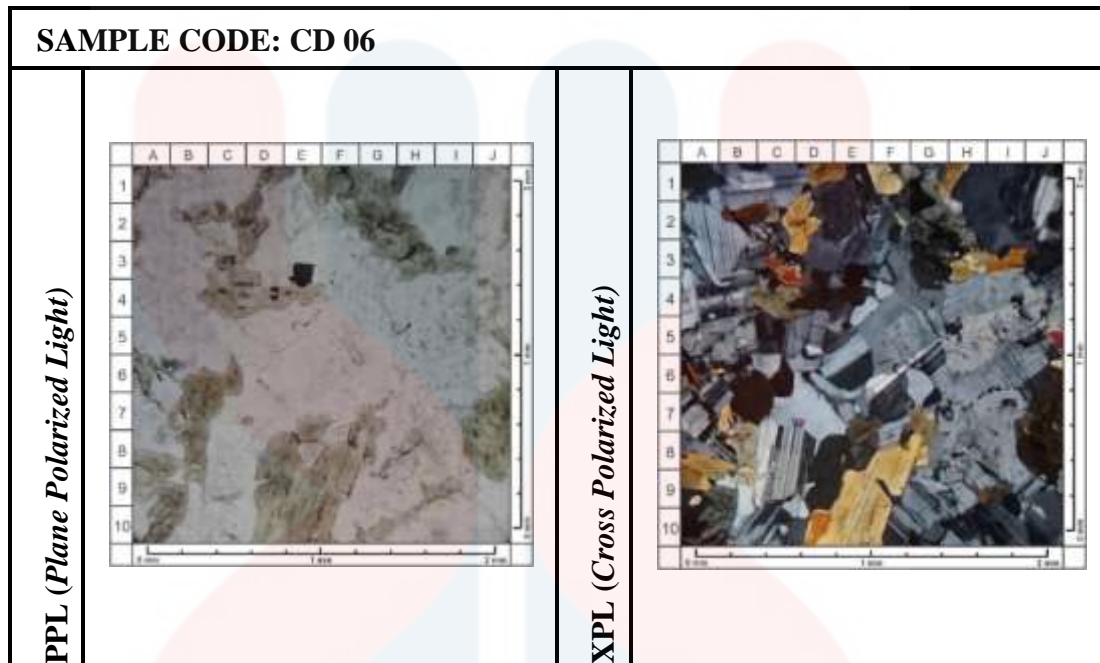


**Figure 4.17** Outcrop photos of the exposure of the rock.

**4.6.2 Field observation: CD 06**

Based on field situation the outcrop, this outcrop is exposed at the bank of river Pergau in a depositional environment where the river makes small meander not far from the sample 04B, during the observation the characteristics of the outcrop has carefully been described. Magnifying is used for mineral grain examination since the rock is medium grained at this point it is thought to be granodiorite but after microscopic investigations has been completed and made several comparisons between diorite and granodiorite the decision is made, and the rock is categorized as diorite with the evidence of mineral ratio and some physical characteristics. Overall, the outcrop seems to experience less weathering, but parts of the outcrop fractures and joints are highly exposed.

#### 4.6.3 Thin section: CD 06



#### 4.6.4 Microscopic Observations: CD 06

The observation was carried out at 10x ocular magnification and 5x objective magnification and at observation of massive structure, phaneritic texture, rough - medium mineral size.

Mineral composition:

Plagioclase – 42% In PPL, the absorption color is colorless, low relief, pleochroism is absent, euhedral - anhedral crystal form, 1-way cleavage. At XPL, the interference color is gray - white order 1, parallel darkening angle, albite - Carlsbad-albite twinning, And value 24 (oligoclase).

Quartz – 17% In PPL, absorption color is colorless, low relief, pleochroism is absent, anhedral crystal form, cleavage is absent. On XPL, the color of gray-white interference is order 1, the angle of darkness is wavy, there is no twin.

Microcline – 10% In PPL, the absorption color is colorless, low relief, pleochroism is

absent, subhedral - anhedral crystal form, 1-way cleavage. At XPL, the color of the gray-white interference is order 1, the darkening angle is oblique, polysynthetic twins.

Sanidine – 5% In PPL, the absorption color is colorless, low relief, pleochroism is absent, subhedral - anhedral crystal form, 1-way cleavage. On XPL, the interference color is gray-white order 1, parallel darkening angle, Carlsbad twinning.

Chlorite – 25% On PPL, the absorption color is green, low relief - medium, weak - medium pleochroism, anhedral - subhedral crystal form, 1-way cleavage - none. On XPL, the interference color is gray - dark green order 1 - order 2, the darkening angle is oblique, there is no twin.

Opaque Mineral – 1% In PPL, black absorption color, low relief, no pleochroism, eu-hedral - anhedral crystal form. At XPL, the black interference color of the 1st order, no twinning exists.

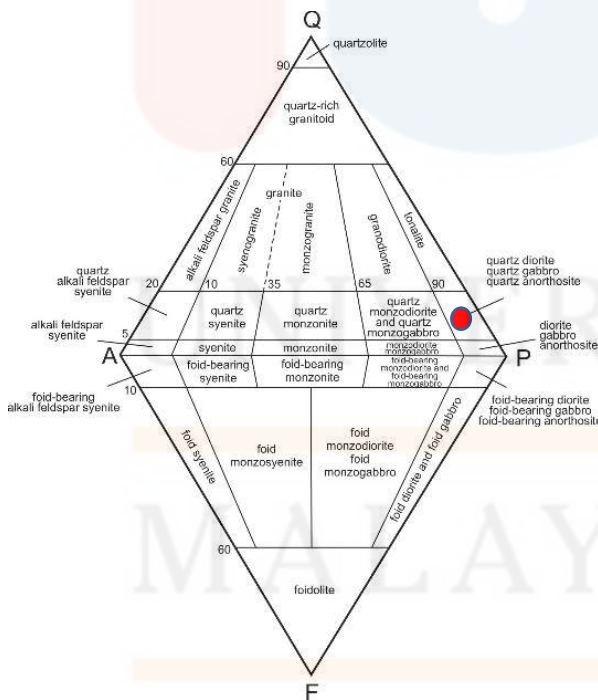


Figure 4.18 QAP diagram with plotted rock type.

#### 4.7.1 Hand specimen: Granitic Gneiss rock

SAMPLE CODE: CD 08

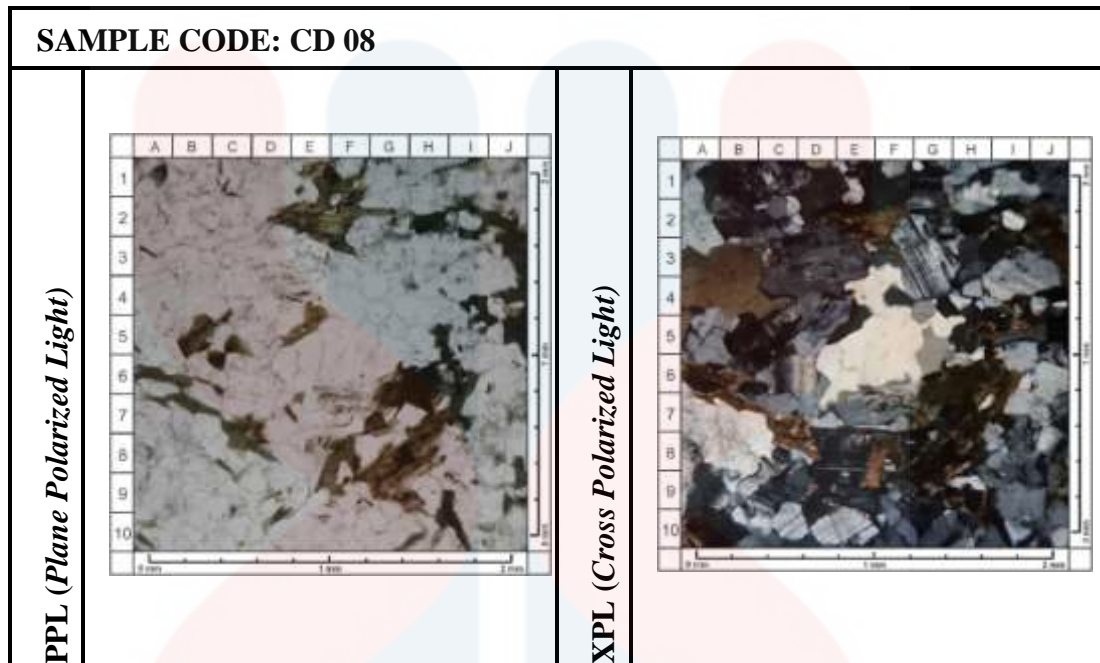


**Figure 4.19** Hand specimen photo from the exposure

#### 4.7.2 Field observation CD 08

In accordance with field with, this outcrop has found in the middle of Sungai Long which drains in southwestern part of the study area, the above figures show both exposure and samples pieces of the outcrop. This rock has distinctives features of mineral alignments as it can be seen on the right-side picture, there are dark and light bands may which formed due to the separation of mafic (dark) and felsic (light) minerals. The banding of gneiss is typically caused by the presence of different proportions of minerals in the distinct bands. Having different grain sizes in the same mineral can also result in banding. Therefore, from the microscopic examination this type of gneiss is classified to be orthogneiss with the support of mineral proportion.

#### 4.7.3 Thin section: CD 08



#### 4.7.4 Microscopic Observations: CD 08

The observations were made at 10x ocular magnification and 5x objective magnification and at observation of massive structure, phaneritic texture - weak foliation, coarse mineral size - medium is a meta-igneous rock, characterized by apparently parallel arrangement of mineral directions but has not yet formed a foliation structure.

Mineral composition:

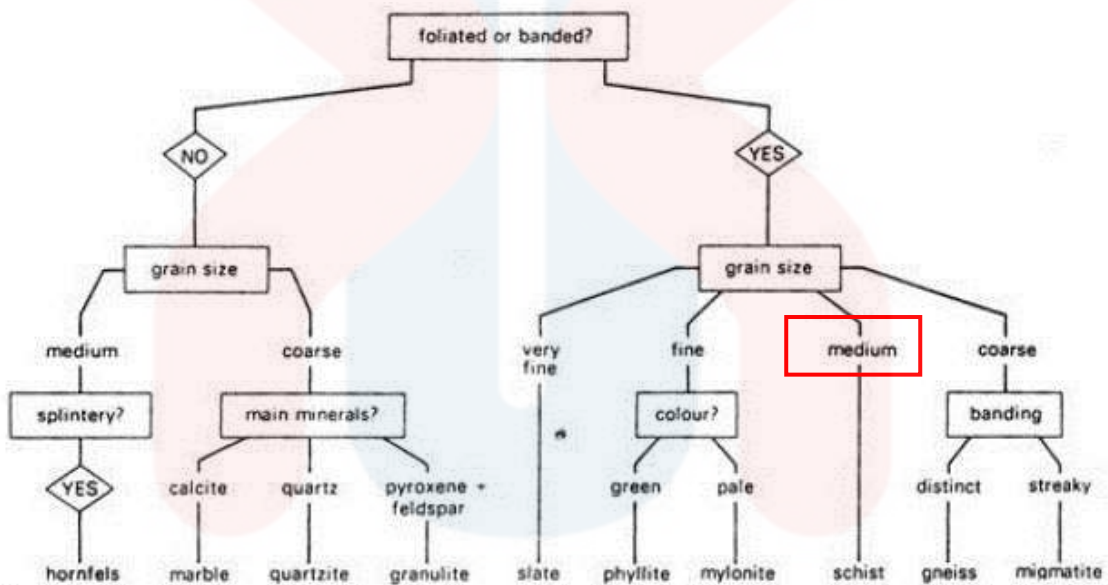
**Quartz** – 57% In PPL, absorption color is colorless, low relief, pleochroism is absent, anhedral crystal form, cleavage is absent. On XPL, the color of gray-white interference is order 1, the angle of darkness is wavy, there is no twin.

**Microcline** – 30% In PPL, the absorption color is colorless, low relief, pleochroism is absent, subhedral - anhedral crystal form, 1-way cleavage. At XPL, the color of the gray-white interference is order 1, the darkening angle is oblique, polysynthetic twins

**Chlorite** – 12% On PPL, the absorption color is green, low relief - medium, weak -

medium pleochroism, anhedral - subhedral crystal form, 1-way cleavage - none. On XPL, the interference color is gray - dark green order 1 - order 2, the darkening angle is oblique, there is no twin.

Opaque Mineral – 2% In PPL, black absorption color, low relief, no pleochroism, euhedral - anhedral crystal form. At XPL, it shows black interference color of the 1st order.



**Figure 4.20** Flow diagram for the identification of metamorphic rocks in general (Gillen, 1982)

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#### 4.8.1 Hand specimen: Igneous rock: granodiorite

SAMPLE CODE: CD 011

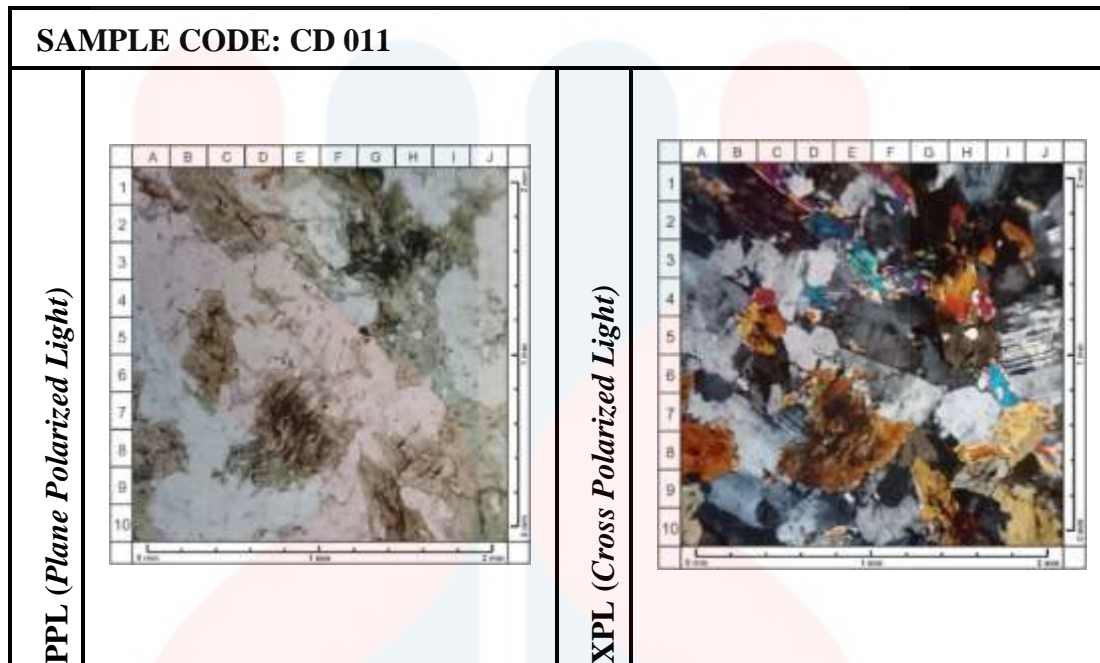


**Figure 4.21** Hand specimen photo from the discovered outcrop.

#### 4.8.2 Field observation: CD 011

From the field observation, this rock was in the middle of small stream which drains in southwestern part of the study area. The rock was categorized to be granodiorite during the initial observation, several methods were employed in the process of the rock identification including the use of the magnifying glass to examine grain size and better visualize the minerals that the rock is composed of. Hand specimen figure below shows that the rock has experienced oxidation which a type of chemical weathering that effects the color of the rocks, for instance, the sampled piece on the right-hand side photo shows the color alteration which is resulted from exposed environments of the rocks as the rock sits in a stream which also close to a waterfall nearby the area.

#### 4.8.3 Thin section: CD 011



#### 4.8.4 Microscopic Observations: CD 011

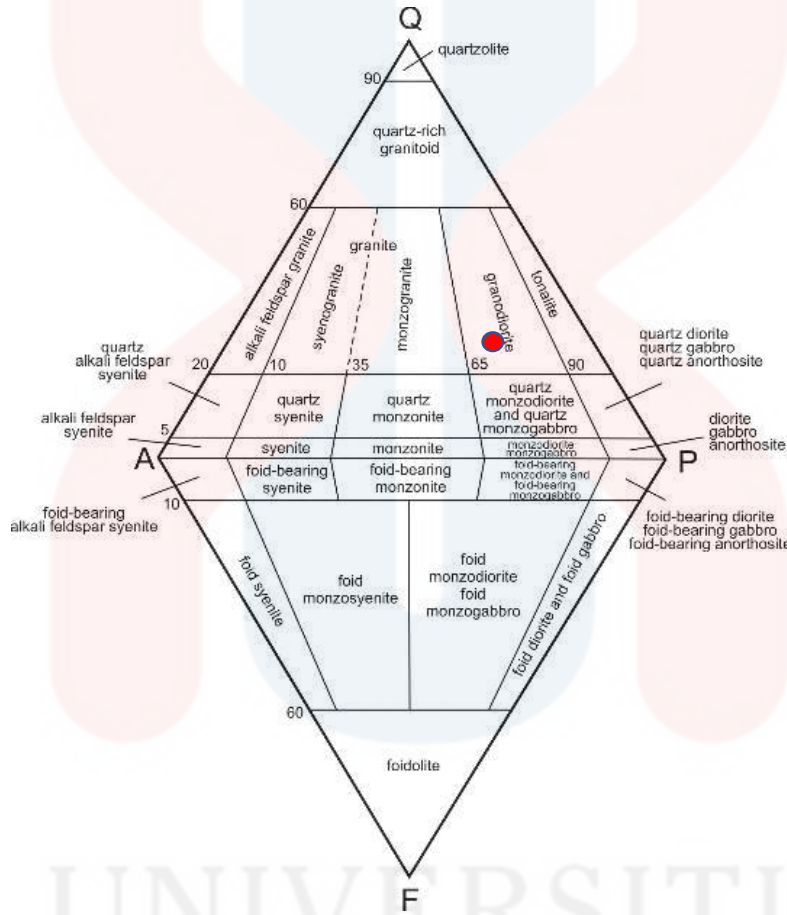
10x ocular magnification and 5x objective magnification was utilized for during the microscopic observations of massive structural and textural classification for rough - medium mineral size.

Mineral composition:

Plagioclase – 29% In PPL, the absorption color is colorless, low relief, pleochroism is absent, euhedral - anhedral crystal form, 1-way cleavage. At XPL, the interference color is gray - white, order 1, parallel darkening angle, albite - Carlsbad-albite twinning. Quartz – 25% In PPL, absorption color is colorless, low relief, pleochroism is absent, anhedral crystal form, cleavage is absent. On XPL, the color of gray-white interference is order 1, the angle of darkness is wavy.

Microcline – 15% In PPL, the absorption color is colorless, low relief, pleochroism is absent, subhedral - anhedral crystal form, 1-way cleavage. At XPL, the color of the

gray-white interference is order 1, the darkening angle is oblique, polysynthetic twins.  
 Chlorite – 40% On PPL, the absorption color is green, low relief - medium, weak - medium pleochroism, anhedral - subhedral crystal form, 1-way cleavage - none. On XPL, the interference color is gray - dark green order 1 - order 2,



**Figure 4.22** QAP diagram with plotted rock type.

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#### 4.9.1 Hand specimen: Igneous rock: Quartzite Granitoid

SAMPLE CODE: CD 013

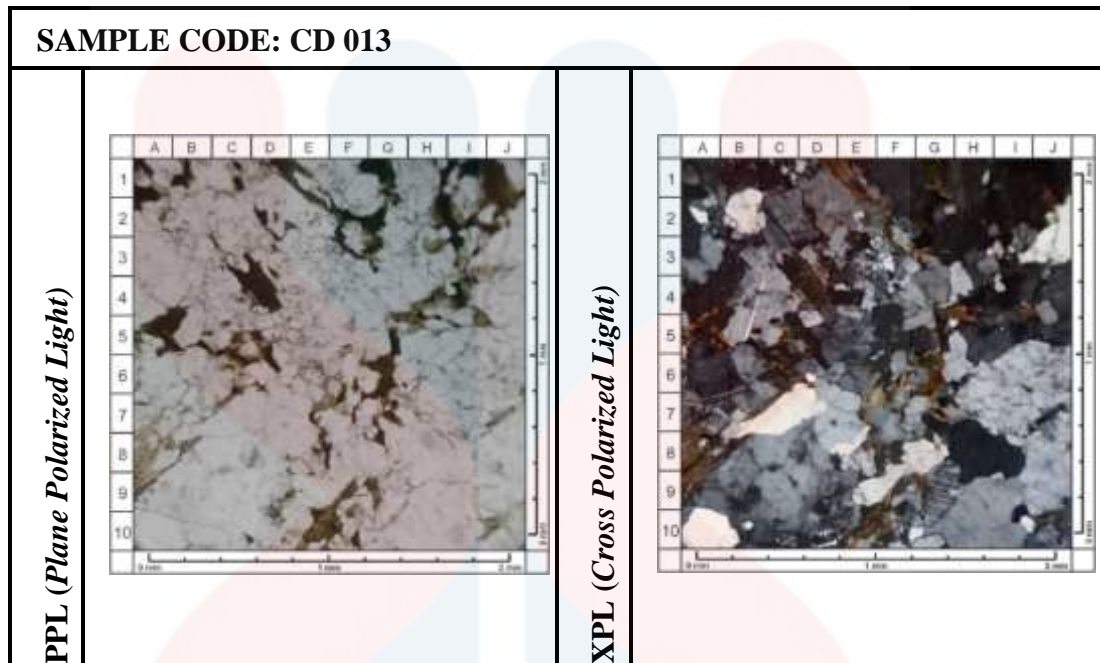


Figure 4.23 Hand specimen photo from the discovered outcrop

#### 4.9.2 Field observation: CD 013

Field observation made it possible to discover this exposure, this rock was found in the middle of unpaved road that goes to the plantation area in the north of the study area. Based on the below figures on the left side photo shows that the rock looks col-luvium materials but due to excavation process for the road construction the exposed part of the rock was graveled and mechanically broken could also act as a physical weathering as an anthropogenic activity. The observed grain size of the rock identified to be medium grain as shown on the right-hand side photo below.

#### 4.9.3 Thin section: CD 013



#### 4.9.4 Microscopic Observations: CD 013

The observations included visible structure, type of the texture with presence or absence of foliation, mineral grain size, examined with 10x ocular magnification and 5x objective magnification. It has been concluded that the rock is a meta-igneous rock with parallel mineral direction arrangements and seemingly interconnecting mineral arrangements that have not yet developed a foliation structure.

Mineral composition:

Quartz – 69% In PPL, absorption color is colorless, low relief, pleochroism is absent, anhedral crystal form, cleavage is absent. On XPL, the color of gray-white interference is order 1, the angle of darkness is wavy, there is no twin visible.

Microcline– 15% In PPL, the absorption color is colorless, low relief, pleochroism is absent, subhedral - anhedral crystal form, 1-way cleavage. At XPL, the color of the gray-white interference is order 1, the darkening angle is oblique, polysynthetic twins

Chlorite – 15% On PPL, the absorption color is green, low relief - medium, weak - medium pleochroism, anhedral - subhedral crystal form, 1-way cleavage - none. On XPL, the interference color is gray - dark green order 1 - order 2, the darkening angle is oblique, there is no twin.

Opaque Mineral – less than 1% In PPL, black absorption color, low relief, no pleochroism, euhedral - anhedral crystal form. At XPL, the black interference color of the 1st order.

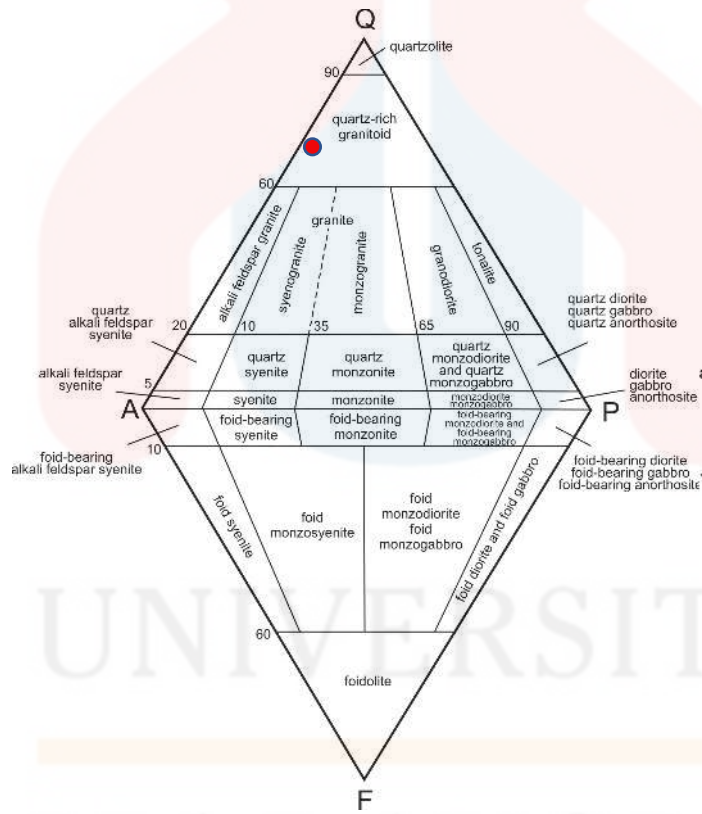


Figure 4.24 QAP diagram showing the plotted type of the rock.

#### 4.10.1 Hand specimen: Igneous rock: granodiorite

SAMPLE CODE: CD 016

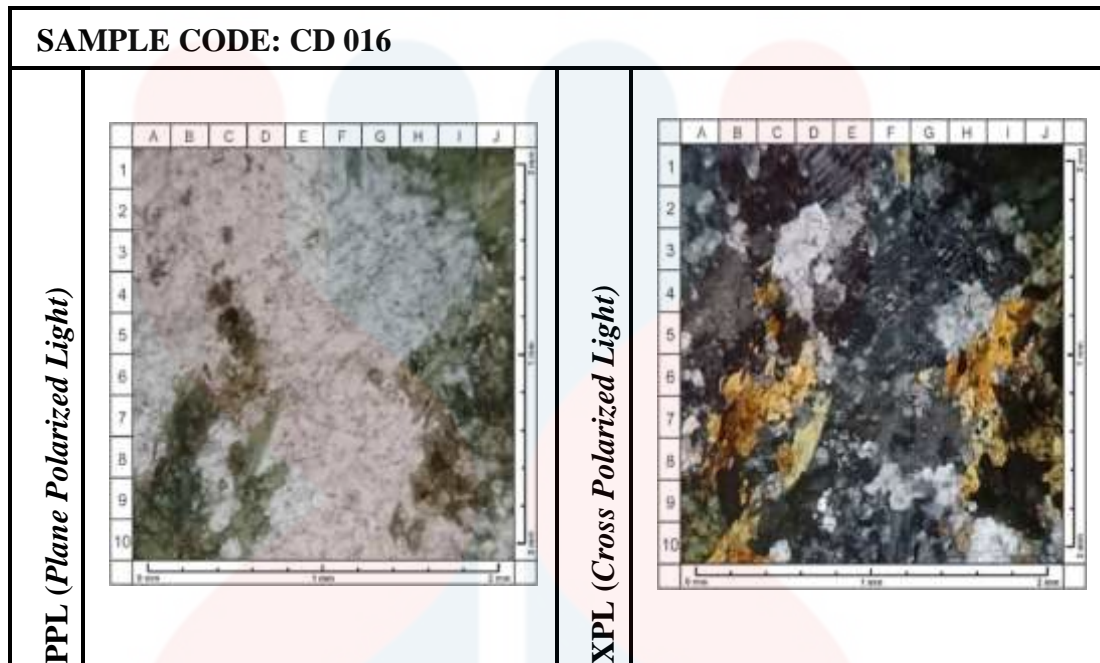


Figure 4.25 Hand specimen photo from the discovered outcrop

#### 4.10.2 Field observation: CD 016

This outcrop was deposited in small stream in the northern section of the study area, it has been found place where there are complex structures that could be associated with primary formation of the rocks in the area. For example, Pegmatites that are texturally complex igneous rocks characterized by skeletal, radial, or graphic crystal orientations, exceptionally large but varied crystal sizes, spatial mineral zonation, and strong anisotropy from the edges inward. Phenocryst is among some unique crystallization which is a larger porphyritic texture that grows under slow conditions, forming large crystals. The rock also exhibits mega-crystals form by textural coarsening.

#### 4.10.3 Thin section: CD 016



#### 4.10.4 Microscopic Observations: CD 016

The objective magnification of 10x and 5x was utilized for the observations the structures found under microscopic photos, mineral grain size, and all other observable optical properties of the minerals such as extinction, twinning, pleochroism, cleavage, interference colors etc. after careful examination of all those mentioned properties then QAP diagram was plotted to come up with definite category of the rock type. Therefore, the rock that falls the plotted area of QAP diagram becomes **Alkali felspar granite**.

Mineral composition:

Quartz – 39% In PPL, absorption color is colorless, low relief, pleochroism is absent, anhedral crystal form, cleavage is absent. On XPL, the color of gray-white interference is order 1, the angle of darkness is wavy, there is no twin found in quartz.

Microcline– 30% starting to turn into sericite. In PPL, the absorption color is colorless,

low relief, pleochroism is absent, subhedral - anhedral crystal form, 1-way cleavage. At XPL, the color of the gray-white interference is order 1, the darkening angle is oblique, twining that has been observed in rock is polysynthetic twining which occurs when two twinned planes with the same number of inhabitants repeated simultaneously.

Chlorite – 30% On PPL, the absorption color is green, low relief - medium, weak - medium pleochroism, anhedral - subhedral crystal form, 1-way cleavage - none. On XPL, the interference color is gray - dark green order 1 - order 2, the darkening angle is oblique, there is no twin.

Opaque Minerals – 1% In PPL, black absorption color, low relief, no pleochroism, euhedral - anhedral crystal form. At XPL, the black interference color of the 1st order.

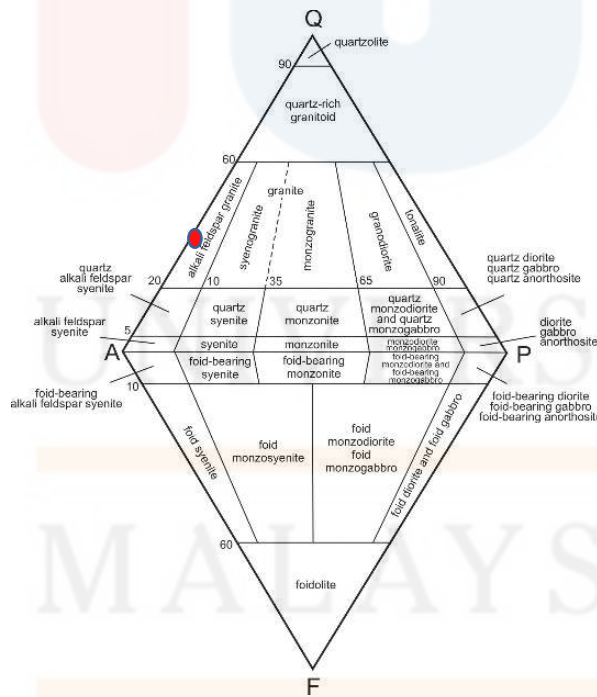
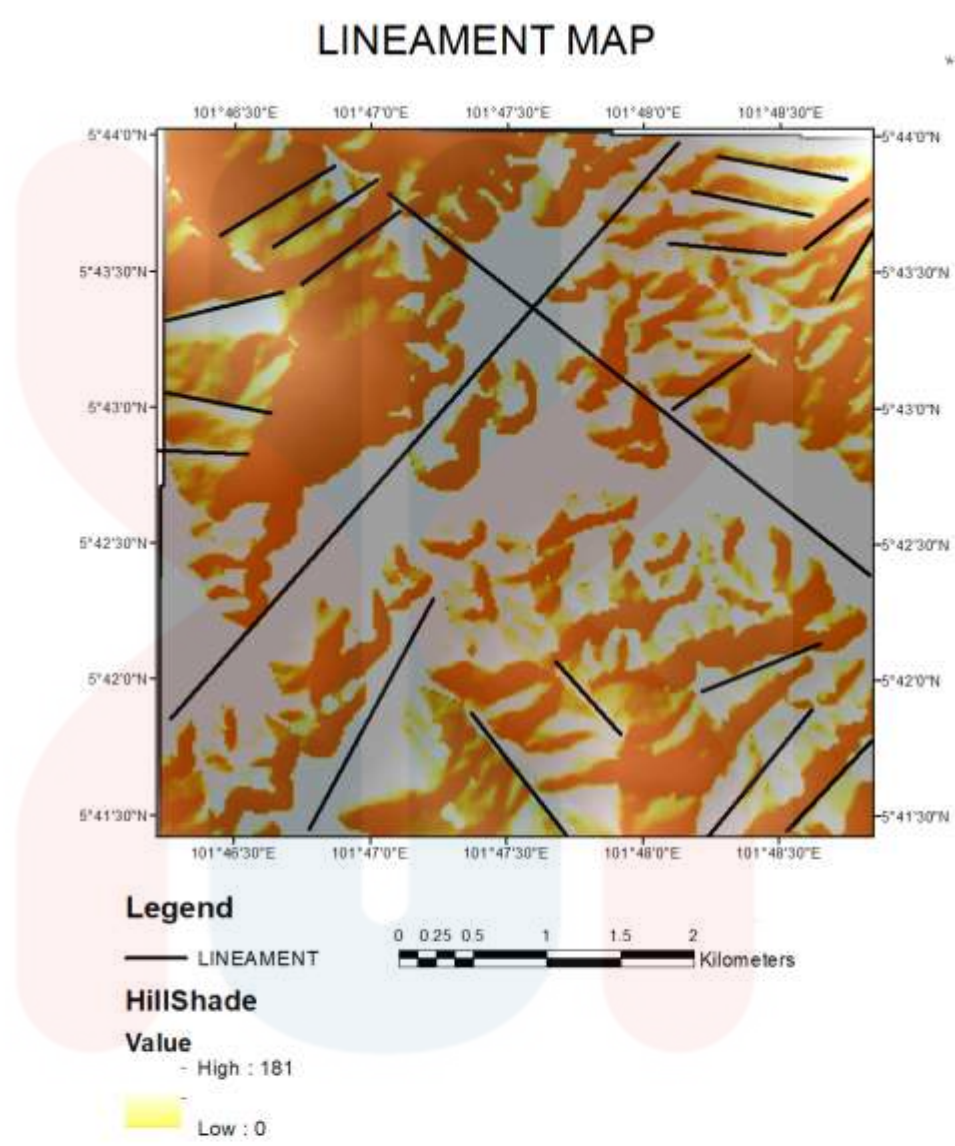


Figure 4.26 QAP diagram showing the plotted type of the rock.

#### 4.11.1 Structural Geology

This section discusses about structural geology of the study area which was mostly focused on Geometric analysis which encompasses the study of the geometrical properties of structures. Included the size, geometric relationship, shape, and geographic direction of the primary (first order) structure and associated smaller-scale (second order) structures. The final argument underlines how most structures are composite and manifest themselves in specific structural relationships at different scales. Kinematic analysis, which considers how rock particles have shifted during deformation. One of the features that is helpful in kinematic analysis is the deflection of layers along faults and in shear zones (Figure 1.29) as well as the striations on fault surfaces.

Another significant factor considered for artificial recharge structures is lineament a linear landscape feature that represents a fault, fracture, or other underlying geological structure, such as a joint. In the examination of remote sensing of fractures or structures, lineaments are typically used. With the use of ARCGIS and field observation, the lineaments are created and identified. Positive and negative lineaments make up the two primary categories of lineaments in the study area. These lineaments show, respectively, ridge trends and river valleys. While joints, faults, and shear zones may be represented by topographically negative straight lineaments, straight lineaments that are topographically favorable can be regarded as dykes and dyke swarms. (Ramli et al., 2010) Therefore, after completing the field traverse and noted all reachable lineaments ArcMap was utilized to digitize all some identified line features as shown in the below (figure 4.27).



**Figure 4.27** lineaments representation map showing two major lineaments and several minor lineaments.

#### 4.11.2 Joint analysis

In the study area two locations was chosen to conduct joint analysis after careful investigation of and consideration on obtainable joint and the deformation of area these two places was carried joint examination and measurements.

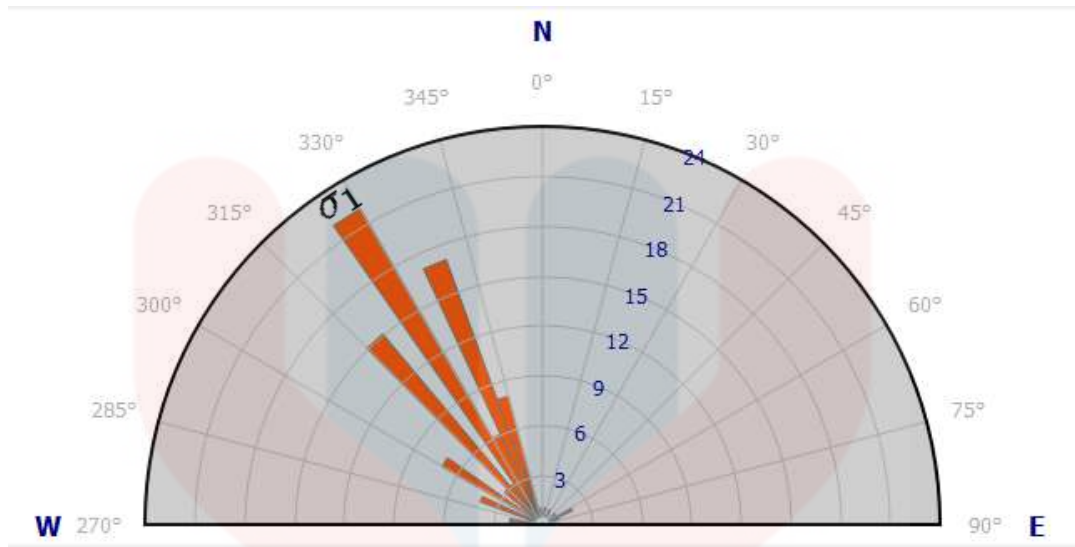
**Location 1: N05°42.35.0, E101°48.08.0**

**Outcrop: CD04B**

**Elevation: 53m**

**Date: 04/08/22**

The location was discovered in middle of Pergau river where there are complex rock formations which are hugely jointed fractured, the rocks in this area were exposed on the river floor and at the bank of the river so due high-water current in the river it was not possible to reach those rocks in the middle of river, therefore this joint measurement was carried out at the rock exposures on the bank of the river. During analysis, geologic compass was used to measure to bearings of the joints and after recorded all identifiable joint data GeoRose software was utilized to generate rose diagram which is a straightforward, understandable, and fundamental geological structure depiction method, it is frequently used to describe the level of development and dominant orientation of structural surfaces. The rose diagram is straightforward and useful for examining regional organization features also. It mainly reflects the primary joints' orientation more clearly.



**Figure 4.28** Rose Diagram with joint orientation plotted.

Based on the principal stress  $\sigma_1$  and  $\sigma_3$  determine the maximum and minimum force applied on the rock respectively. According to the rose diagrams from Outcrop 1, (Figures 4.28) the major stress, Sigma 1, is most likely to be between 315° and 345°, and Sigma 3 is at 240°. The strike readings for most joints fall between 270 and 350 degrees. It is apparent from the rose diagram that the fracture-causing compressional stress is coming from a direction of NW-SE.

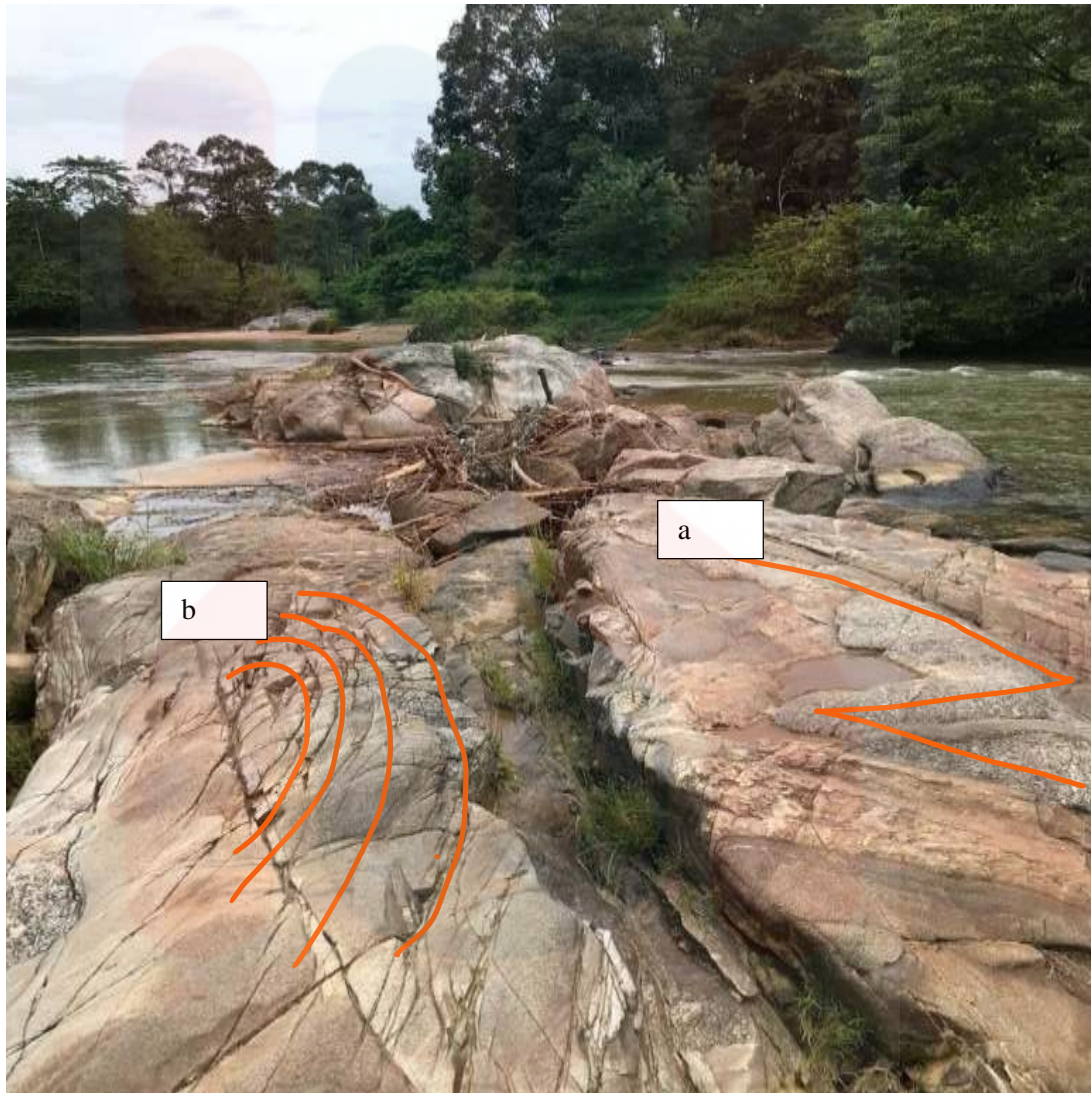
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**Figure 4.29** joints examined site on a granite outcrop.

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### 4.11.3 Folds



**Figure: 4.30** heavily jointed outcrop part of the study site with (a)recumbent fold (b) anticline

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The figure 4.30 clearly show (a) Recumbent fold which generally are isoclinal fold that have been rotated so that their limbs are almost horizontal. They can appear in a wide range of physical situations. However, under some circumstances, they are more frequent. For instance, the beginning of metamorphic reactions delineates the top limit of a soft zone inside the orogenic crust, and the development of extensive tectonic foliation and related recumbent folds is frequently linked to the formation of micas and amphiboles from sedimentary minerals. These minor recumbent folds also found in north-eastern part of study and that is defined by the presence of minor folds in quartz and folded quartz veins. Shear bands in quartz which indicate north to northeast directed movements.

(b) Anticline folds which are less common in igneous rocks than in sedimentary rocks have been identified in the area as shown in (figure 4.29), these folds can occur due to tectonic forces acting on the solidified magma or due to the cooling and contraction of the magma itself. In the case of tectonic forces, the same mechanism of compressional forces acting on a horizontal layer of rock applies, but instead of sedimentary rock, it is the solidified magma that is folded. As the magma is subjected to pressure, it may crack and deform, resulting in an anticline fold. This type of fold may be seen in areas of volcanic activity, where magma is forced to the surface by tectonic forces.

## CHAPTER 5

### GEOCHEMISTRY OF GRANITE ROCKS

#### 5.1 Introduction

This chapter focuses on geochemical investigations of granites rocks of the study area to identify any potential discrepancies in the distribution of major, trace, and rare earth elements as well as the investigation of chemical variations to get a greater comprehension according to the evolution, petrogenesis, and texture. Four samples of granite from the study area were examined for major and trace with X-Ray Fluorescence (XRF) and REE elements using Inductively Coupled Mass Spectrometry (ICP-MS).

By examining two samples from the study region, a geochemistry investigation of the granite rocks was conducted. The samples, designated CPSA03 and CPSA16, were taken from various points inside the study region; CPSA03 was taken from the northeastern section, and CPSA16 was collected from the northern section. Since it is assumed that the data are from the same source and origin, they are compared and related to one another.

Major element data are used by geochemistry in three main ways: to classify rocks, to create variation diagrams, and to compare with experimentally established rock compositions that were formed under known conditions. Additionally, to determine the tectonic context of igneous and sedimentary rocks, major elements are combined with trace elements.

The origins and crystallization history of the melt are determined by the trace element compositions of granitoids; the tectonic environment is secondary. According to the makeup of the crust that developed during orogenesis, post-collisional granitoids, for instance, can come from a variety of sources. These granitoids are also closely linked to mafic magmas, which could mix or blend with melt components coming from the crust. They plot over the given range of fields because a variety of source components have an impact on the chemical makeup of this tectonic group.

To describe the tectonic context of granitic rocks, Pearce (1984) developed a geochemical technique. The four main tectonic settings of ocean ridge granites, volcanic arc granites, within-plate granites, and collisional granites were geochemically distinguished using more than 600 analyses. Plots of Y against Ta, Y vs Nb, Y vs Rb, and Y vs Rb were the most effective discriminators. This method, which is popular and well accepted, is thought to be crucial for figuring out the tectonic setting of granitic rocks whose tectonic context has not been retained. (Pearce et al., 1984)

## 5.2 Major elements

In general, the plutonic rocks show the significant contact abundance of major elements which include  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{FeO}$ ,  $\text{CaO}$ ,  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{O}$ ,  $\text{P}_2\text{O}_5$ ,  $\text{TiO}_2$ , and  $\text{MnO}$  these group of elements are also categorized major oxide. Therefore, both examined samples show some of these major elements include  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{K}_2\text{O}$ . Table 5.1 is a list of the sample analyses that were investigated and the obtained. To minimize the loss or error of weight elements, all major elements are 100% normalized.

**Table 5.1:** Major Elements oxide group

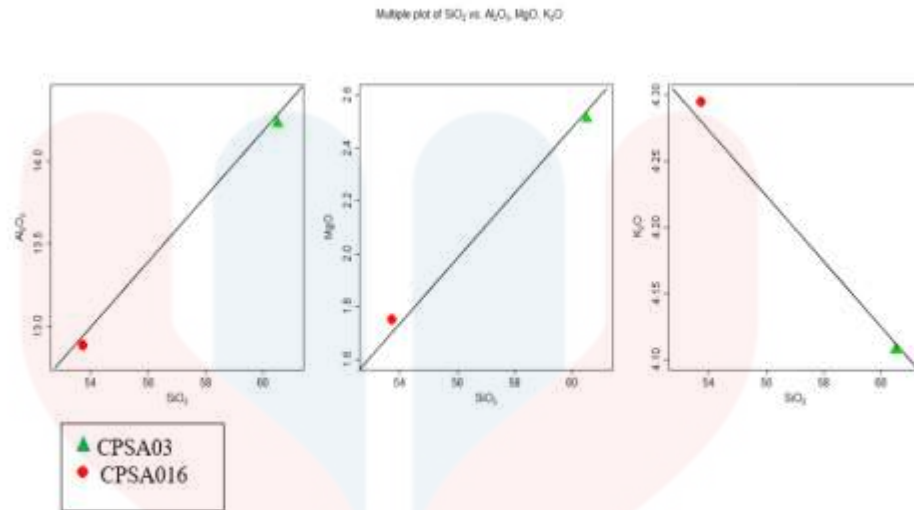
Major elements	Sample Code	Sample Code
	CPSA016(Alkali-feldspar granite)	CPSA03(Pink granite)
	Wt. (%)	Wt. (%)
$\text{SiO}_2$	53.713	60.489
$\text{Al}_2\text{O}_3$	12.885	14.231
$\text{MgO}$	1.750	2.511
$\text{K}_2\text{O}$	4.295	4.107

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Based on the table 5.1 above, four major oxide elements have been detected in the face of XRF examination. The greatest primary components found in the rock samples were  $\text{SiO}_2$  with 53.713 wt.% to 60.489 wt.%, both samples show significant amount of  $\text{SiO}_2$  which can be interpreted that the exposures of the study area are composed of more silicate minerals. On top of the CPSA016 and CPSA03 also show higher percentage of  $\text{Al}_2\text{O}_3$  which are 12.885 wt.% and 14.231 wt.% respectively, these results are essentially used to deduce the source-area rock composition, because  $\text{Al}_2\text{O}_3$  ratio increases from 3 to 8 for mafic igneous rocks, from 8 to 21 for intermediate rocks and from 21 to 70 for felsic igneous rocks.

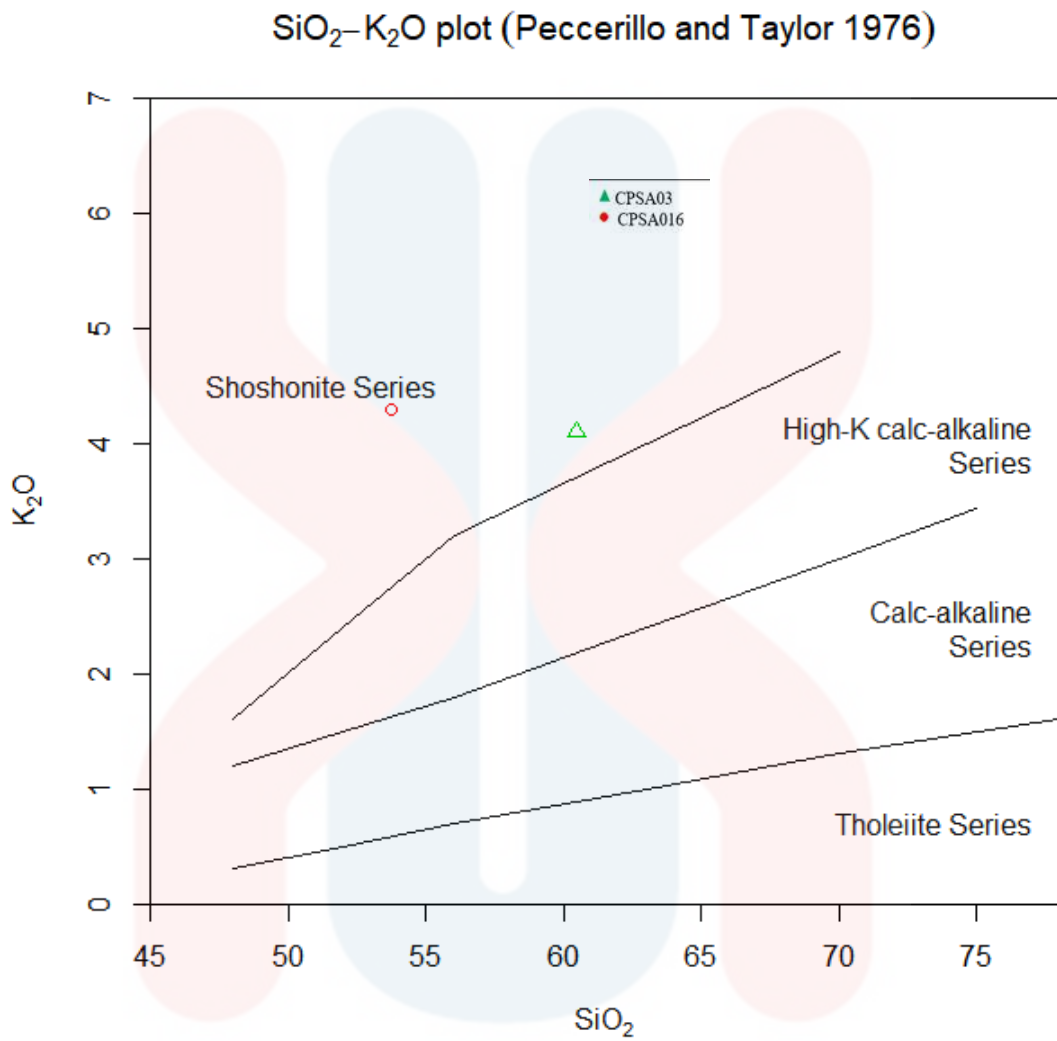
Harker variation diagrams are plots that demonstrate how the variations between each oxide component of a rock differ from one another. Most variation diagrams plot the other oxides against  $\text{SiO}_2$  as illustrated in the diagram shown (figure 5.1), even though any other oxide might be chosen for plotting on the x-axis, since  $\text{SiO}_2$  typically exhibits the greatest variation in any suite of rocks. Plots with comparatively smooth trends in the component's fluctuation hinted at the possibility of a mechanism connecting the rocks. Of addition, the magmas must have either intruded upon or have erupted within a suitable period for them to be related to one another. Precambrian and Tertiary age rocks for example plotted together may indicate smooth fluctuation, although it is doubtful that the magmas were connected to one another.



**Figure 5.1** Harker variation diagram major element with the plot of two samples.

Figure 5.1 displays the ratio of SiO<sub>2</sub> to all other major element groups for plotting these using Harker variation diagrams. Some of the plotted major elements have linear relationships, indicating that these traits are connected to their source and can be included when talking about their petrogenetic history. In general, the figures demonstrate two distinct downward trends in Al<sub>2</sub>O<sub>3</sub>, MgO, and SiO<sub>2</sub> vs. SiO<sub>2</sub> and SiO<sub>2</sub> vs. K<sub>2</sub>O content. Because of these patterns, it is possible that fractional crystallization had a significant role in the development of the granite in the study area and its surrounds.

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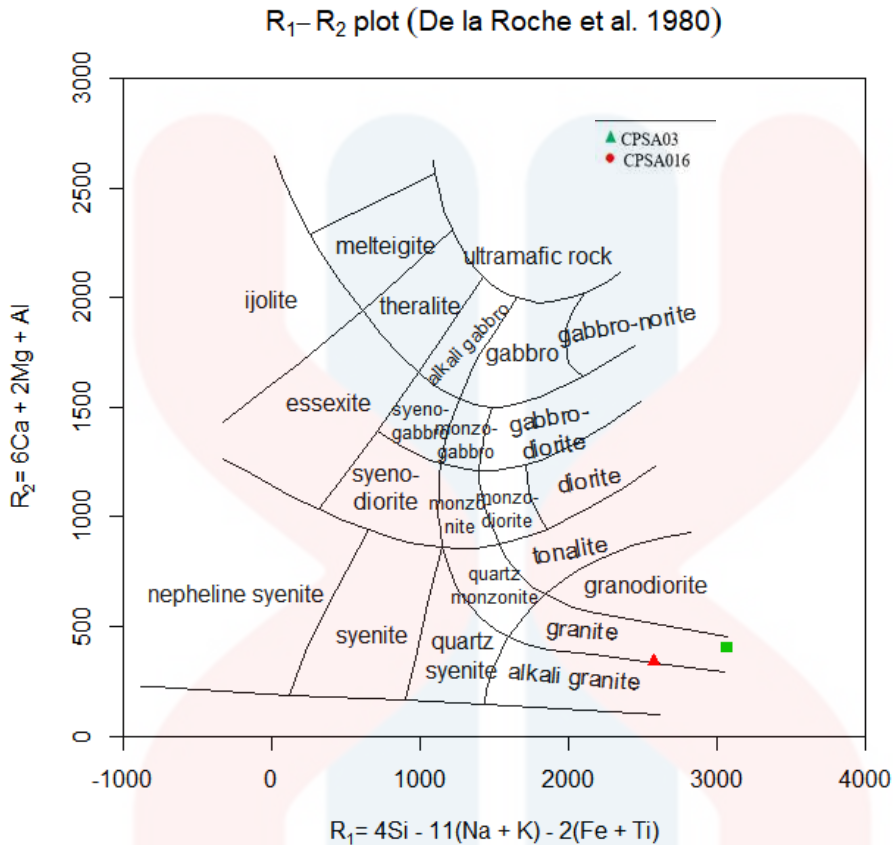


**Figure 5.2** the K<sub>2</sub>O versus SiO<sub>2</sub> diagram (Peccerillo and Taylor 1976).

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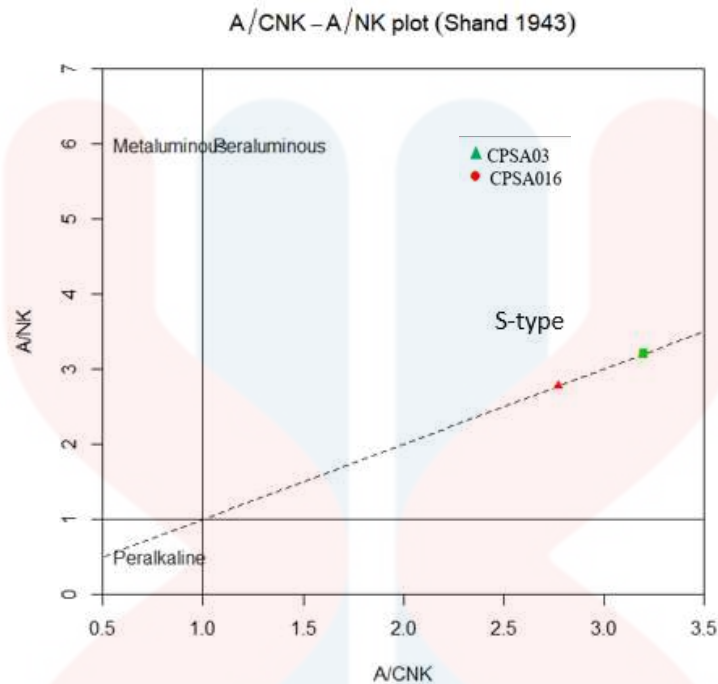
Generally, shoshonitic rocks suggests there is a group that is near-silica saturated, K-rich and has low iron enrichment that cannot be unambiguously classified as part of calc-alkaline or alkali-basalt associations. This group is here referred to as the shoshonite rock association. The shoshonite rock association is characterized by hypersthene-olivine normative basalts, low iron enrichment, high  $\text{SiO}_2 + \text{K}_2\text{O}$ , high content of light ion lithophile elements, high but variable  $\text{Al}_2\text{O}_3$ , high  $\text{Fe}_2\text{O}_3/\text{FeO}$  and low  $\text{TiO}_2$ . Mineralogical characteristics include coexisting plagioclase and sanidine in the groundmass, K-feldspar rims on plagioclase phenocrysts and low  $\text{TiO}_2$  content and lack of iron enrichment in clinopyroxene. Shoshonitic rocks on continental margins are younger, stratigraphically higher, and more distant from the oceanic trench than the high-K calc-alkaline or calc-alkaline suites, but there is a complete gradation between the suites. (Morrison, et al., 1980)

In accordance with Figure 5.2, the chosen  $\text{SiO}_2\text{-K}_2\text{O}$  plot (Pecerillo and Taylor 1976) and plot clearly show that the two samples belong to the same series but there is a slight compositional variation, which can be interpreted to mean that sample CPSA03 is plotted between the field of high-K calc-alkaline series and Shoshonite series, which can also be seen to be close to be high-K calc-alkaline series. These plotting results demonstrate the calc-alkaline nature of the granite samples, and it can be inferred from these interpretations that the granite samples primarily exhibit calc-alkaline affinity. Moreover, sample CPSA016 shows to have higher  $\text{K}_2\text{O}$  and low  $\text{SiO}_2$ . Therefore, the line series can be seen to be Steep positive slope for  $\text{K}_2\text{O}$  versus  $\text{SiO}_2$  at low  $\text{SiO}_2$ .



**Figure 5.3** R1-R2 plot (De La Roche et al. 1980) diagram for the study area rock type.

From the above figure 5.3, both samples plotted in the De la Roche *et al.* (1980) diagram and the samples are in the field of granite. However, the sample CPSA016 has previously been categorized to be alkali feldspar granite during the petrographic analysis and as it can be seen in the plotted diagram above, both results provide same result which shows that the rock is end member of granite that is rich in alkali feldspar. The rock is also belonging to felsic plutonic igneous rocks which are mostly composed of quartz 20–60% of felsic minerals and alkali feldspar > 90% of feldspars. Consequently, the other sample (CPSA03) falls same category in the field of granite, but difference is that the rock shows low composition of alkali feldspar mineral.



**Figure 5.4** The A/NK versus A/CNK diagram (Shand, 1943).

The molecular proportions of the ratio  $\text{Al}_2\text{O}_3/(\text{CaO}+\text{Na}_2\text{O}+\text{K}_2\text{O})$ , abbreviated as A/CNK, have been the most widely used metric to indicate the type of granitic magma. Depending on the alumina saturation, A/CNK classified the granite rocks into peraluminous, peralkaline, and meta luminous categories. Both samples are categorized as peraluminous as they are showing A/CNK values greater than 2.2 depending upon the alumina saturation. According to (A. Brako et al., 2020) the granites rocks that fall in the peraluminous section can be categorized to be S-type which are related to intra-crustal melting.

### 5.3 Rare Earth Elements

Rare Earth Elements data was obtained from ICP-MS analysis and after running the analysis samples of granite rocks to obtain the distribution of Light REE and Heavy REE.

**Table 5.2** ICP-MS result for Rare Earth Elements analysis

No	Sample ID	Elements	RESULTS (ppb)
1	CPSA 03	Ce	2137.04
		Dy	235.05
		Er	141.81
		Eu	124.13
		Gd	241.19
		Ho	233.14
		La	812.09
		Lu	486.99
		Nd	711.05
		Pr	344.56
		Sc	523.35
		Sm	280.06
		Tb	432.11
		Tm	186.75
Y	4999.15		

		Yb	541.79		
2	CPSA 16	Ce	22004.88		
		Dy	379.14		
		Er	182.82		
		Eu	323.66		
		Gd	652.79		
		Ho	245.51		
		La	5542.51		
		Lu	489.59		
		Nd	5401.21		
		Pr	1694.01		
		Sc	981.71		
		Sm	1245.71		
		Tb	463.78		
		Tm	196.05		
		Y	5231.23		
Yb	563.58				

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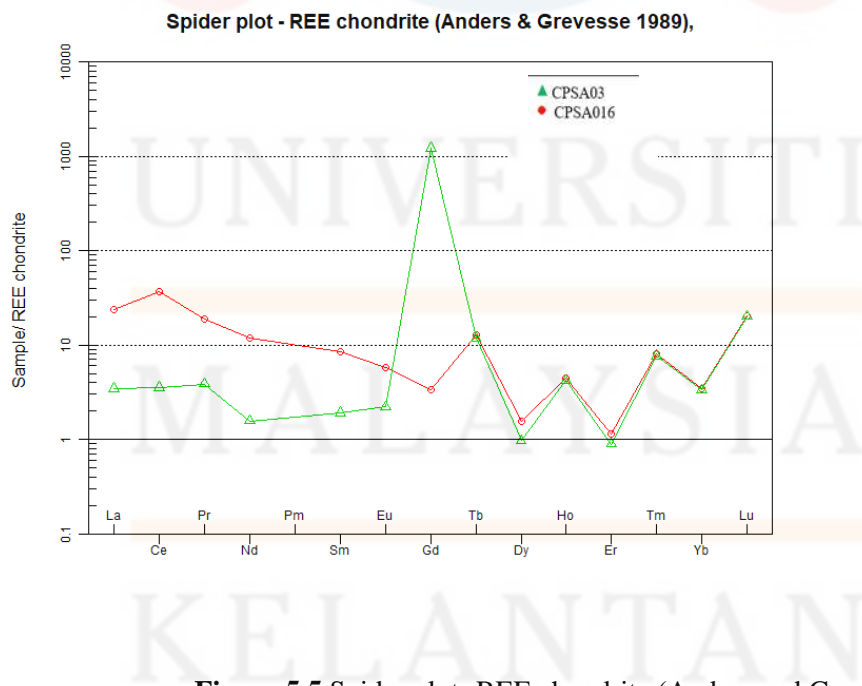
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**Table 5.3:** Light REE(LREE) and Heavy (HREE) distributions in the granite samples.

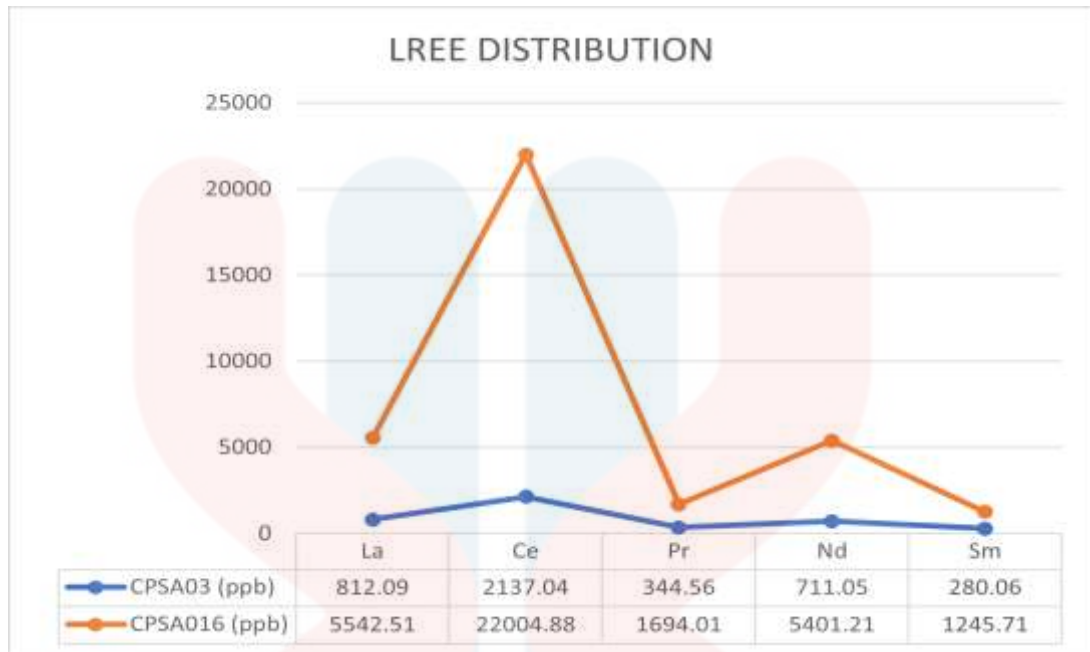
<b>Samples</b>	<b>CPSA03</b>	<b>CPSA016</b>
<b>LREE</b>	<b>(ppb)</b>	<b>(ppb)</b>
La	812.09	5542.51
Ce	2137.04	22004.88
Pr	344.56	1694.01
Nd	711.05	5401.21
Sm	280.06	1245.71
<b>Total per sample</b>	<b>4,285.61</b>	<b>35,888.32</b>
<b>Samples</b>	<b>CPSA03</b>	<b>CPSA016</b>
<b>HREE</b>	<b>(ppb)</b>	<b>(ppb)</b>
Dy	235.05	379.14
Er	141.81	182.82
Eu	124.13	323.66
Gd	241.19	652.79
Ho	233.14	245.51
Lu	486.99	489.59
Sc	523.35	981.71
Tb	432.11	463.78
Tm	186.75	196.05
Y	4999.15	5231.23
Yb	541.79	563.58
<b>Total</b>	<b>8,145.46</b>	<b>9,709.86</b>

Table 5.3 illustrates the distribution and amount of both Light REE and Heavy REE in the two selected samples of granites of the study in ppb. The data obtained from the ICP-MS analysis varies in the two sample. for instance, sample CPSA016 demonstrates to have the highest amount of distribution of both light REE and heavy. 5, for individual distribution of all the 17 examined REEs cerium found in sample CPSA016 encapsulates an elevated amount of concentration of 22004.88 ppb because cerium is the most prevalent rare earth element that makes up around 0.0046% of the earth's crust.

The chemical characteristics of rare earth elements are remarkably similar, and they are typically thought to be impervious to fractionation in supracrustal conditions. The distribution of REE can be utilized as a clue to identify the rock's originating materials. Figure 5.5 displays the proportions of rare earth elements (REEs) in these two categories of granitic rocks. Graphs depicting the light rare earth element (LREE) and heavy rare earth element (HREE) classifications of REE in general.

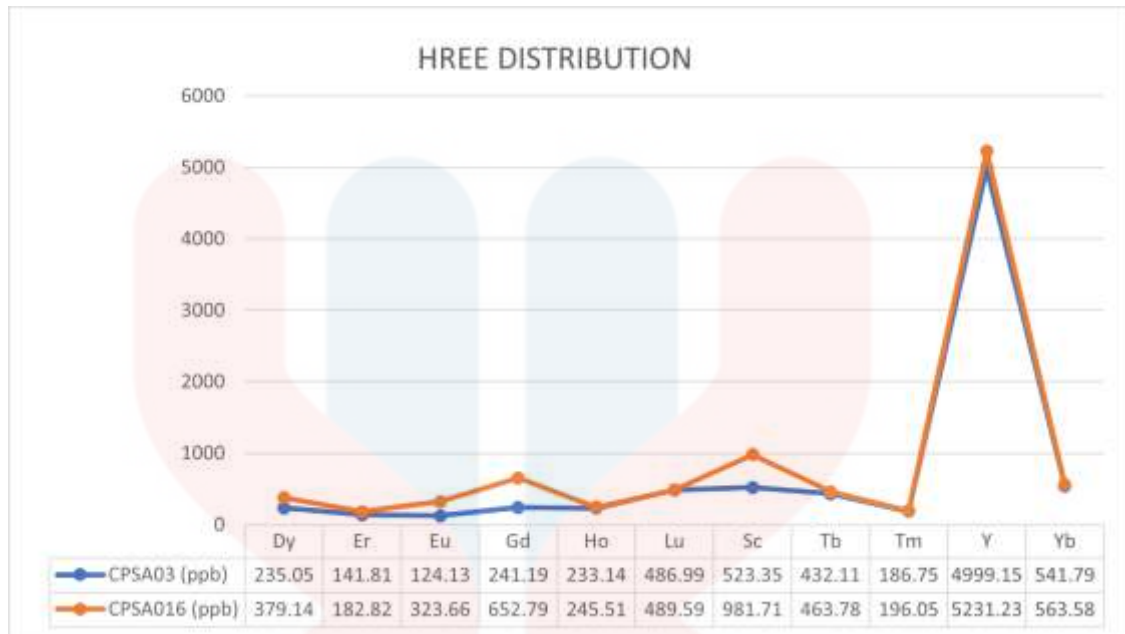


**Figure 5.5** Spider plot- REE chondrite (Anders and Grevesse 1989)



**Figure 5.6** Light REE(LREE) distribution of the examined samples with data table.

According to graph representation of LREE in Figure 5.6 showing that the distribution of light REE elements, alkali feldspar granite designated as CPSA016 demonstrates the greatest concentrations of all LREE from Ce the highest (22004.88 ppb) to Sm the lowest (1245.71 ppb). Similarly, the pink granite sample CPSA03 illustrates a steady graph line which can be interpreted that this sample contains average value as shown the data table in the graph. In the sample (CPSA03) possesses the lowest concentration of both individual and group elements for example, the concentration of Samarium detected is 280.06 ppb which is the lowest in the entire group.



**Figure 5.7** Heavy REE(HREE) distributions of the examined samples with data table.

In accordance with above graph above, heavy REE concentrations in both samples are presented, this group of HREE also shows that the sample (CPSA16) has the dominant distribution compared to other sample (CPSA03). The line graph demonstrates close range of data in both samples, from Dy to Yb but the significant figures of numbers in the data table and line graph represents the highest concentration of Yttrium (Y) in both samples.



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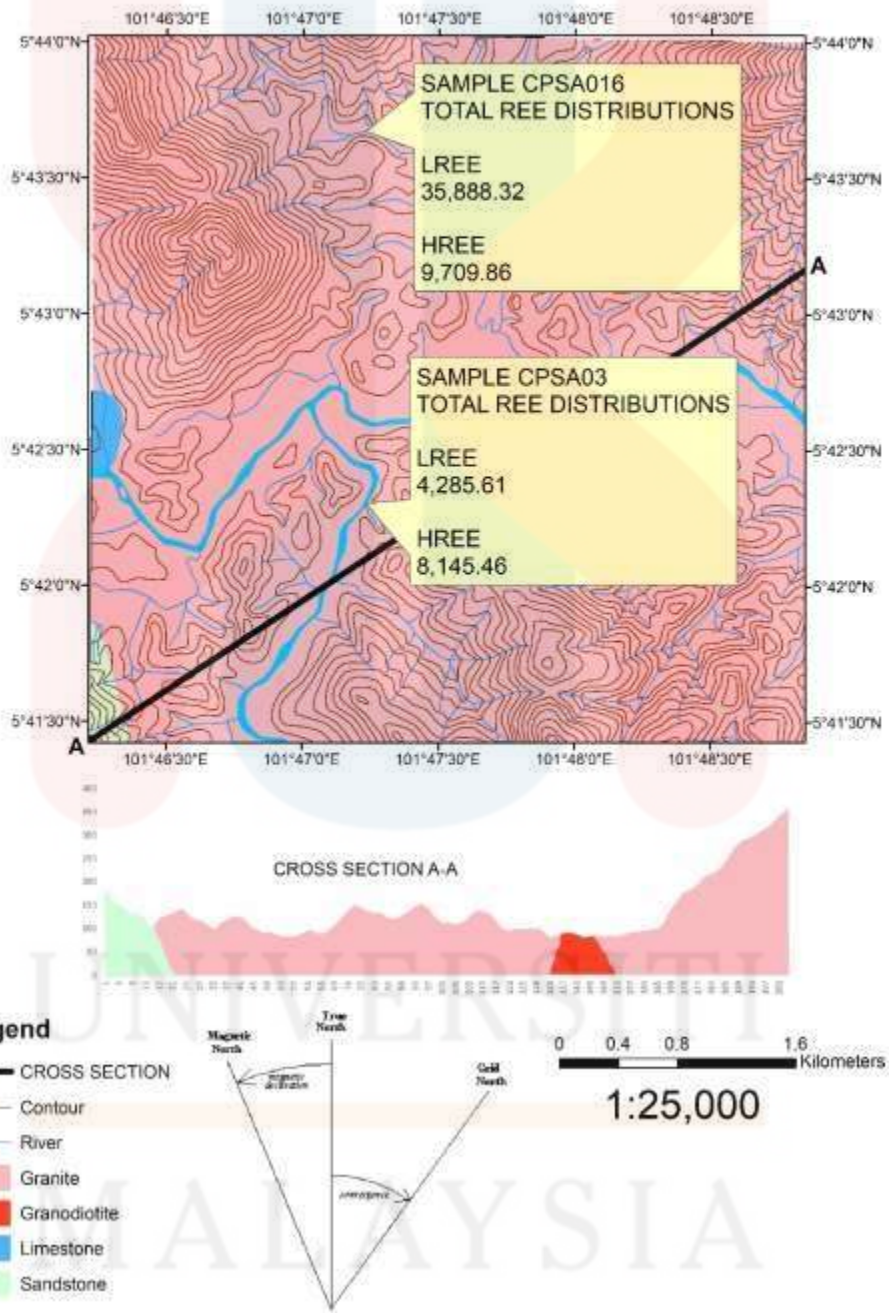


Figure 5.8 Sampling points with total REE distributions in each Sample.

### 5.3 Discussion

The chosen samples were subjected to geochemical examination at the Great Laboratory on the campus of UMK Jeli. The samples were examined for their rare earth and minor/trace elements compositions using an inductively coupled mass spectrometer (ICP-MS). The X-ray fluorescence spectrometer was used to investigate the major and trace element compositions. Rock samples that had been ground into powder were weighed, mixed for three minutes, and then formed into pellets for analysis. The diverse geochemical compositions of the granite suites in the study imply that the rocks were produced from various sources. However, the findings demonstrate that the two rock samples under examination came from a single magmatic source, as evidenced by the linear trends of the major oxides in the Harker diagrams (Figures 5.1) which shows the major elements concentrations for both samples, SiO<sub>2</sub> is dominant major elements in both rocks with ratio of 53.713 and 60.489 wt.%

According to Figure 5.2, the SiO<sub>2</sub>-K<sub>2</sub>O plot (Pecerillo and Taylor 1976) clearly demonstrate that the two samples belong to close series, despite a minor compositional variation. This can be interpreted to mean that sample CPSA03 is plotted between the field of high-K calc-alkaline series and Shoshonite series, which can be seen to be close to be high-K calc-alkaline series. Sample CPSA016 plots in the shoshonite series field on the K<sub>2</sub>O versus SiO<sub>2</sub> diagram, while the SiO<sub>2</sub> concentrations of the two samples under examination range from 50 to 60 wt.% with these.

Based on the granitic rock categories examined samples have further classified during petrographic studies in chapter four. Therefore, to further evidence the type of granite of these two samples R1-R2 plot (De La Roche et al. 1980) diagram has been utilized and plotted the samples as (figure 5.3) shown, sample CPSA016 is happens in the alkali feldspar granite meanwhile sample CPSA03 falls in the field of granite. Consequently, The A/NK versus A/CNK diagram (Shand, 1943) was plotted for Classic discriminating of metaluminous, peraluminous, and peralkaline compositions as shown in (figure 5.4), both samples have been classified to have peraluminous composition and with that respect the study area rock are said to be S-type granites which source from partial melting sedimentary rocks. Sample CPSA016 shows less value of A/CNK than CPSA03 sample that possesses greater 3 of A/CNK value.

Rare earth element distributions in the selected two samples were examined using ICP-MS machine table 5.3 illustrates the raw data extracted from the machine and next table 5.4 shows classified REE into two groups: heavy REE (HREE) and light REE(LREE). Five of the six LREE have been identified in both samples equally, but with different concentrations. The graph in (figure 5.6) exemplifies all concentration of REE in both samples with Cerium (Ce) showing the highest amount of concentration 20044.88 ppb detected in sample CPSA016.

In this group samarium (Sm) is detected to have the lowest concentration which is 280.06 ppb in sample CPSA03. Overall distribution of LREE, sample CPSA016 illustrates relatively high concentration of all elements compare to CPSA03.

Relative to figure 5.7, HREE distribution in each sample was shown in line graph and data table. Based on both line graph and data table one elements which yttrium possesses the highest concentration in terms of individual ratio which 5231.23 ppb in sample CPSA016 and close to that number also detected in CPSA03 4999.15 ppb.

## CHAPTER 6

### CONCLUSION AND RECOMMENDATION

#### 6.1 CONCLUSION

This final year project which is carried out through two semester needs a lot of research on the theory and field mapping. Before that, research on several areas done to select the best and deliverable objectives. The general geology of the study location has carefully been studied to achieve the first objective of the research. During this phase of the research several aspects have been incorporated including geomorphological and lithological study to produce the geological map of the study area. In conjunction with this, petrographic examination has been done to identify the rock types in the study region in fulfillment of second objective of the project. Therefore, geochemical examination has carried out in two granite samples designated as CPSA03 (pink granite) and CPSA016 (alkali feldspar granite), during these geochemical investigations rare earth elements has been analyzed to quantify the distribution of these elements in the rocks of the study area. To that end, both LREs and HREEs with respective amount of distribution have detected the two samples. for instance, five of the six LREE were detected in both samples with cerium as a single highest element for LREE and for both samples other notable element is yttrium which was detected the highest in the HREE group.

## 6.2 RECOMMENDATION

Hopefully, for the future project, geological study and geochemical analysis can be improved in terms of data analysis so that more powerful and exact techniques may be applied to obtain more accurate data. It is necessary to undertake a study extended and explanation. Future researchers will be required to do in-depth studies on wide areas in the field of geoscience. With the fast-growing technology, it is essential to ensure the researchers to be equipped adequate technological knowledge that would be beneficial for the processing and producing accurate and reliable result.

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