



Universiti Malaysia
KELANTAN

FYP FSB

**GEOLOGY AND DISTRIBUTION OF RARE
EARTH ELEMENTS (REE) IN SELECTED SOIL
PROFILES IN, JELI, KELANTAN**

by

SITI SHAFILA BINTI IBRAHIM

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

**FACULTY OF EARTH SCIENCE
UNIVERSITY MALAYSIA KELANTAN**

2023

DECLARATION

I declare that this thesis entitled “**GEOLOGY AND DISTRIBUTION OF RARE EARTH ELEMENTS (REE) IN SELECTED SOIL PROFILE IN, JELI, KELANTAN**” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any degree.

Signature :

Name : **SITI SHAFILA BINTI IBRAHIM**

Date :

UNIVERSITI
MALAYSIA
KELANTAN

APPROVAL

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

Signature :

Name of Supervisor : **DR. RONIZA BINTI ISMAIL**

Date :

UNIVERSITI
MALAYSIA
KELANTAN

ACKNOWLEDGEMENT

First and foremost, praises to ALLAH S.W.T for his blessing, kindness, and permission for me to complete my thesis with the title Geology and Distribution of Rare Earth Elements (REE) In Selected Soil Profile in Jeli, Kelantan.

I would like to express my sincere gratitude to my supervisor, Dr. Roniza Binti Ismail who contributed a lot through the process of completing my research study. Through her guidance, motivation, and knowledge I was able to learn new and valuable information. Without her help, I cannot complete this research and her vision, sincerity, and dynamism inspired me.

Finally, I would like to express my thanks to my parents and siblings for their support, motivation, and inspiration during my study. I also want to thank my friend for their help and cooperation during fieldwork and thesis writing. I also want to grant my gratitude to senior, Afikah Fendy for her help, and knowledge during fieldwork.

UNIVERSITI
MALAYSIA
KELANTAN

Geology and Distribution of Rare Earth Elements in Selected Soil Profile in Jeli, Kelantan

ABSTRACT

The study about geology and distribution of REE in the selected soil profile was conducted in the Jeli area that covered 25 km². The coordinate of the study area is 5° 44'30" to 5° 47'0" N and 101° 51' 45" to 101°54'40" E. The objectives of this study are to update the geological map of the Kg. Gemang and Kg. Ayer Lanang area in scale 1:25000 and to analyse the distribution of rare earth elements (REE) in the selected soil profile in Jeli, Kelantan. The study area consists of granite, slate, and quaternary alluvial deposits. The geomorphological features that can be observed in this area are plains area, low land, low hill, and hill area. The highest elevation is 280 m, and the lowest elevation is 40 m. The petrography analysis of the rock samples show quartz is the dominant mineral in the granite rock. The concentration of REE in the soil sample was determined using ICP-MS analysis. XRD and XRF analyses were also conducted to know the mineralogy and element composition of the sample. The result of ICP-MS analysis shows the soil sample inside UMK (JL9) consists of higher REE concentration with a total concentration of 213.5 ppm. This is because the soil sample consists of apatite (accessory mineral) that can carry REE and made the pattern of the REE in soil sample JL9 slightly different from another sample. XRD analysis shows the peak of the mineral in the sample where the sample from JL6 shows the highest peak of quartz mineral compared to another sample and XRF analysis shows the major and trace element composition in the sample. In conclusion, JL9 (213.5 ppm) show the higher REE concentration followed by JL10 (86.3 ppm) and JL16 (70.4 ppm) in Batu Melintang. However, the distribution of the REE in the Jeli area is quite low because the limited accessory minerals found in those samples.

UNIVERSITI
MALAYSIA
KELANTAN

Kajian Geologi dan Taburan Unsur Nadir Bumi Dalam Profil Terpilih di Jeli, Kelantan

ABSTRAK

Kajian geologi dan taburan REE dalam profil tanah terpilih telah dijalankan di kawasan Jeli seluas 25 km². Koordinat kawasan kajian ialah 5° 44'30" hingga 5° 47'0" N dan 101° 51' 45" hingga 101°54'40" E. Objektif kajian ini adalah untuk mengemaskini peta geologi kawasan Kg. Gemang dan Kg. Ayer Lanas dalam skala 1 :25000 dan menganalisis taburan unsur nadir bumi (REE) dalam profil tanah terpilih di Jeli, Kelantan. Kawasan kajian terdiri daripada granit, batu sabak, dan mendapan aluvium kuaterner. Ciri geomorfologi yang dapat diperhatikan di kawasan ini ialah kawasan dataran, tanah rendah, bukit rendah, dan kawasan bukit. Ketinggian tertinggi ialah 280 m, dan ketinggian terendah ialah 40m. Analisis petrografi sampel batu menunjukkan kuarza adalah mineral yang dominan dalam batuan granit. Kepekatan REE dalam sampel tanah ditentukan menggunakan analisis ICP-MS. Analisis XRD dan XRF juga dijalankan untuk mengetahui mineralogi dan komposisi unsur sampel. Hasil analisis ICP-MS menunjukkan sampel tanah di dalam UMK (JL9) terdiri daripada pengayaan REE dengan jumlah kepekatan 213.5 ppm. Ini kerana sampel tanah terdiri daripada apatit (mineral aksesori) yang boleh membawa REE dan menjadikan corak REE dalam sampel tanah JL9 sedikit berbeza daripada sampel lain. Analisis XRD menunjukkan puncak mineral dalam sampel di mana sampel dari JL6 menunjukkan puncak tertinggi mineral kuarza berbanding sampel lain dan analisis XRF menunjukkan komposisi unsur utama dan surih dalam sampel. Kesimpulannya, JL9 (213.5 ppm) menunjukkan kepekatan REE yang lebih tinggi diikuti oleh JL10 (86.3 ppm) dan JL16 (70.4 ppm) di Batu Melintang. Namun begitu, taburan REE di kawasan Jeli agak rendah kerana mineral aksesori yang terhad yang terdapat dalam sampel tersebut.

UNIVERSITI
MALAYSIA
KELANTAN

TABLE OF CONTENTS

DECLARATION	i
APPROVAL	ii
ACKNOWLEDGEMENT	iii
ABSTRACT	iv
ABSTRAK	v
TABLE OF CONTENTS	vi
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF SYMBOLS	xv
LIST OF ABBREVIATIONS	xvi
 CHAPTER 1 INTRODUCTION	
1.1 General Background	1
1.2 Study Area	2
a. Location	4
b. Accessibility	4
c. Demography	4
d. Land Use	5
e. Social Economic	6
1.3 Problem Statement	6
1.4 Research Objective	6
1.5 Scope of The Study	7

1.6	Research Importance	7
CHAPTER 2 LITERATURE REVIEW		
2.1	Introduction	8
2.2	Regional Geology and Tectonic Setting	8
2.3	Stratigraphy of Jeli	10
2.4	Structural Geology	11
2.5	Historical Geology	11
2.6	Soil Profile	12
2.7	Introduction of Rare Earth Elements	14
2.8	Properties of Rare Earth Elements	16
2.9	REE Bearing Mineral	17
2.10	Chondrite-Normalize	20
2.11	Application of Rare Earth Elements	25
2.12	Rare Earth Elements Industry in Malaysia	26
CHAPTER 3 MATERIAL AND METHODOLOGY		
3.1	Introduction	29
3.2	Materials	31
3.3	Methodology	33
3.3.1	Preliminary Studies	33
3.3.2	Data Collection	33
3.3.2.1	Geological Mapping	33

3.3.2.2	Soil Sampling	33
3.3.3	Laboratory Work	34
3.3.3.1	Thin section preparation	34
3.3.3.2	Soil sample preparation	35
3.3.3.3	Petrographic Analysis	37
3.3.3.4	Geochemical Analysis	37
3.3.4	Data Processing	38
3.3.5	Data Analysis and Interpretation	38
CHAPTER 4 GENERAL GEOLOGY OF KG. GEMANG AND KG. AYER LANAS, JELI, KELANTAN		
4.1	Introduction	40
4.1.1	Accessibility	40
4.1.2	Landuse	42
4.1.3	Settlement	43
4.1.4	Traverse and observation	43
4.2	Geomorphology	45
4.2.1	Geomorphologic Classification/Topography	45
4.2.2	Weathering	48
4.2.3	Drainage Pattern	50
4.3	Stratigraphy	52
4.3.1	Litho-Stratigraphy Unit	52
4.3.2	Petrography Analysis	54

4.4	Structural Geology	66
4.4.1	Lineament Analysis	66
4.4.2	Vein	68
4.4.3	Joint	69
4.5	Historical Geology	71
CHAPTER 5 DISTRIBUTION OF RARE EARTH ELEMENTS IN SELECTED SOIL PROFILE IN JELI, KELANTAN		
5.1	Introduction	74
5.2	Sample Description	74
5.3	Result & Discussion	79
5.3.1	Result from X-ray Fluorescence (XRF)	79
5.3.2	Result from X-ray Diffraction (XRD)	82
5.3.3	Result from Inductively Coupled Plasma Mass Spectrometry (ICP-MS)	84
5.3.4	Petrography Analysis of Accessory Mineral	88
5.4	Discussion	93
CHAPTER 6 CONCLUSION AND RECOMMENDATIONS		
6.1	Conclusion	94
6.2	Recommendations	95
REFERENCES		96
APPENDICES		98

LIST OF TABLES

No.	Title	Page
Table 1.1	Population by gender in Jeli district.	5
Table 1.2	Population by age in Jeli district.	5
Table 2.1	Concentration value of REEs (McDonough and Sun, 1995).	21
Table 2.2	Type of REE and application in industry	25
Table 4.1	Geomorphologic classification of Study Area	46
Table 4.2	Stratigraphic Column of the study area	53
Table 4.3	Description of petrography analysis JL1	58
Table 4.4	Description of petrography analysis JL7	60
Table 4.5	Description of petrography analysis JL9	62
Table 4.6	Description of petrography analysis JL13	64
Table 4.7	Joints Data of outcrop JL9	70
Table 5.1	Sample description from the study area (Figure of the rock and soil sample can refer to Appendix B).	75
Table 5.2	Composition of oxide elements in a rock sample	80
Table 5.3	Composition of trace elements in a rock sample	81
Table 5.4	The concentration of REE elements from ICP-MS analysis for all samples.	84

LIST OF FIGURES

No.	Title	Page
Figure 1.1	Basemap of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan	3
Figure 1.2	Pie chart of the population by gender in Jeli district	5
Figure 1.3	Pie chart of the population by age in Jeli district	5
Figure 2.1	Regional Geology of Kelantan (Source: Patah et al., 2021)	10
Figure 2.2	Soil composition	12
Figure 2.3	Schematic soil profile	14
Figure 2.4	Soil profile and sample from a) Lumut and b) Telok Murok. (Note: LU: Lumut site, TM: Telok Murok site).	22
Figure 2.5	Chondrite-normalized REE diagram of the weathered crust of granite and related parent rock from LU site (Lumut) that follow chondrite values from McDonough and Sun (1995). (Note: RED color is Horizon B; DARK BLUE is Horizon C and GREEN color is Horizon D). (Source: Yaraghi et al., 2020)	23
Figure 2.6	Chondrite-normalized REE of the weathered crust of granite and related parent rock from TM site (Telok Murok) that follow chondrite values from McDonough and Sun (1995). (Note: Horizon A sample indicated by ORANGE color, Horizon B with RED color, Horizon C with DARK BLUE, and Horizon D with GREEN (Source: Yaraghi et al., 2020).	24
Figure 2.7	Application of REE in the automotive industry	26
Figure 3.1	Flowchart for the methodology of this research	30
Figure 3.2	Materials for fieldwork and laboratory	32
Figure 4.1	Accessibility map of Kg Gemang and Kg. Ayer Lanas, Jeli, Kelantan	41

Figure 4.2	Landuse Map of Kg Gemang and Kg. Ayer Lanas, Jeli, Kelantan	42
Figure 4.3	Traverse and sampling point of Study Area	44
Figure 4.4	Hilly Landform in UMK Area	46
Figure 4.5	Sungai Lanas within study area.	47
Figure 4.6	Topography map of Kg Gemang and Kg. Ayer Lanas, Jeli, Kelantan	47
Figure 4.7	Physical weathering of root wedging in JL7	49
Figure 4.8	Biological weathering show lichen group in JL12	49
Figure 4.9	Drainage Map of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan	51
Figure 4.10	(A) Outcrop of Slate at JL11 (B) Hand Specimen of Slate at JL11	54
Figure 4.11	(A) Outcrop of weathered granite at JL2 (B) Hand Specimen of Weathered Granite at JL2	55
Figure 4.12	(A) Outcrop of granite at JL1(B) Hand specimen of the megacrysts granite porphyry at JL1	56
Figure 4.13	Hand Specimen of granite at JL1	57
Figure 4.14	Thin section of granite at JL1	57
Figure 4.15	Hand Specimen of granite at JL7	59
Figure 4.16	Thin section of granite at JL7	59
Figure 4.17	Hand Specimen of granite at JL9	61
Figure 4.18	Thin section of granite at JL9	61
Figure 4.19	Hand Specimen of granite at JL13	63
Figure 4.20	Thin section of granite at JL13	63

Figure 4.21	Hand specimen of hornfels rock at JL12	65
Figure 4.22	Lineament Map of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan	67
Figure 4.23	Rose Diagram from Lineament Data	67
Figure 4.24	Quartz Vein at JL 11	68
Figure 4.25	Quartz Vein at JL 9	68
Figure 4.26	Conjugate joint on the JL7.	69
Figure 4.27	Rose diagram from data joint	71
Figure 4.28	The tectonic-stratigraphic plot of the Taku Schist and the surrounding units (Kemahang Granite, Stong Complex, and Tiang Schist)	72
Figure 4.29	Geological map and Lithology Map of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan	73
Figure 5.1	Sampling point of Kg. Gemang and Kg. Ayer Lanas area.	78
Figure 5.2	Result of XRD analysis of Soil Sample in Jeli area. (Qtz: Quartz, Kln: Kaolinite, Msc: Muscovite, Gbb: Gibbsite; Note: the intensity scale is a comparison and can be ignored because the XRD results are combined)	82
Figure 5.3	The chondrite-Normalized pattern of Soil Sample from Selected Soil Profile in the Jeli area. (The pattern of this graph has been plotted using data of REE concentration that was covert to chondrite normalize and it can be referred to Appendix A).	85
Figure 5.4	Soil samples from JL6, JL15 and JL9	87
Figure 5.5	Thin section of the sample JL1	88
Figure 5.6	Thin section of the sample JL7	89

Figure 5.7	Thin section of sample JL9	90
Figure 5.8	Thin section of sample JL13	91
Figure 5.9	Thin section of sample JL13. (Chl: chlorite, Qtz: quartz, Plg: plagioclase)	91

LIST OF SYMBOLS

%	Percentage
°C	Degree Celsius
>	Greater than



UNIVERSITI
MALAYSIA
KELANTAN

LIST OF ABBREVIATIONS

Al ₂ O ₃	Aluminium oxide
Au	Aurum/Gold
Ce	Cerium
Dy	Dysprosium
Er	Erbium
Eu	Europium
Fe	Ferum/Iron
Gd	Gadolinium
GPS	Global Positioning System
Ho	Holmium
HREE	Heavy Rare Earth Elements
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
La	Lanthanum
LREE	Light Rare Earth Elements
Lu	Lutetium
MgO	Magnesium oxide
Mn	Manganese
Nd	Neodymium
Pm	Promethium
PPL	Plane Polarized Light
Pr	Praseodymium
Rb	Rubidium
REE	Rare Earth Elements

Sc	Scandium
SEM	Scanning Electron Microscopy
SiO ₂	Silicon dioxide
Sm	Samarium
Tb	Terbium
Ti	Titanium
Tm	Thulium
Th	Thorium
U	Uranium
XPL	Cross Polarized Light
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence
Y	Yttrium
Yb	Ytterbium
Zn	Zink

CHAPTER 1

INTRODUCTION

1.1 General Background

Research about the distribution of Rare Earth Elements (REE) in the selected soil profile and geological mapping has been conducted in Jeli, Kelantan. Kelantan state is located in the north-eastern part of Peninsular Malaysia. It is bordered on the north by the Narathiwat Province of Thailand, on the south-east by Terengganu state, on the west by Perak state, and the south by the Pahang state. This study explains the distribution of REE in the soil profile, including their composition and properties. REE is a rich metal component that occurs in the Earth's crust and consisting of seventeen elements that have similarities in geochemical processes. REE has been separated into two, light rare earth elements (LREE) and heavy rare earth elements (HREE) based on their atomic numbers. LREE is rich in carbonate and phosphate and HREE rich in titanite, tantalite, and phosphate. The occurrences of the REE are influenced by the source of the parents' substance and the type of soil. Usually, REE can be found in certain minerals such as monazite, allanite, bastnaesite, euxenite, and xenotime. China is a country that has large ore deposits and the common REE in China can be found in bastnaesite minerals.

The geological map of the study area has been updated based on fieldwork. The rock and soil samples have been collected during fieldwork and samples were sent to the laboratory for further analysis. A geochemical analysis such as ICP-MS, XRF,

XRD, and petrography analysis was conducted to know the distribution of REE in the soil profile, trace and major elements in a rock, and the mineralogy of the rock.

1.2 Study Area

Jeli is located in the western part of Kelantan, and it consists of three sub-districts which are Jeli, Kuala Balah, and Batu Melintang. The population in the Jeli area is approximately 54,656 people with 27,373 males and 27,283 females. The area of this district is 1,330 km² (Department of Statistics Malaysia, 2010). Jeli is an area of tropical rainforest climate that receives approximately 151.87 millimeters of precipitation and has 229.41 rainy days a year. The annual hot temperature in this area is around 29.78 °C while the annual low temperature is around 25.36 °C (The Global Historical Weather and Climate Data).

The preferred study area is located in Kg Gemang and Kg. Ayer Lanas Jeli, Kelantan. The coordinate of this area is 5° 44' 30" N to 5° 47' 0" N and 101° 51' 45" E to 101° 54' 40" E. This area consists of two landscapes, hilly areas, low land, and plains areas. **Figure 1.1** shows the basemap of Kg. Gemang and Kg. Ayer Lanas, Jeli Kelantan which covers about 25km².

UNIVERSITI
MALAYSIA
KELANTAN

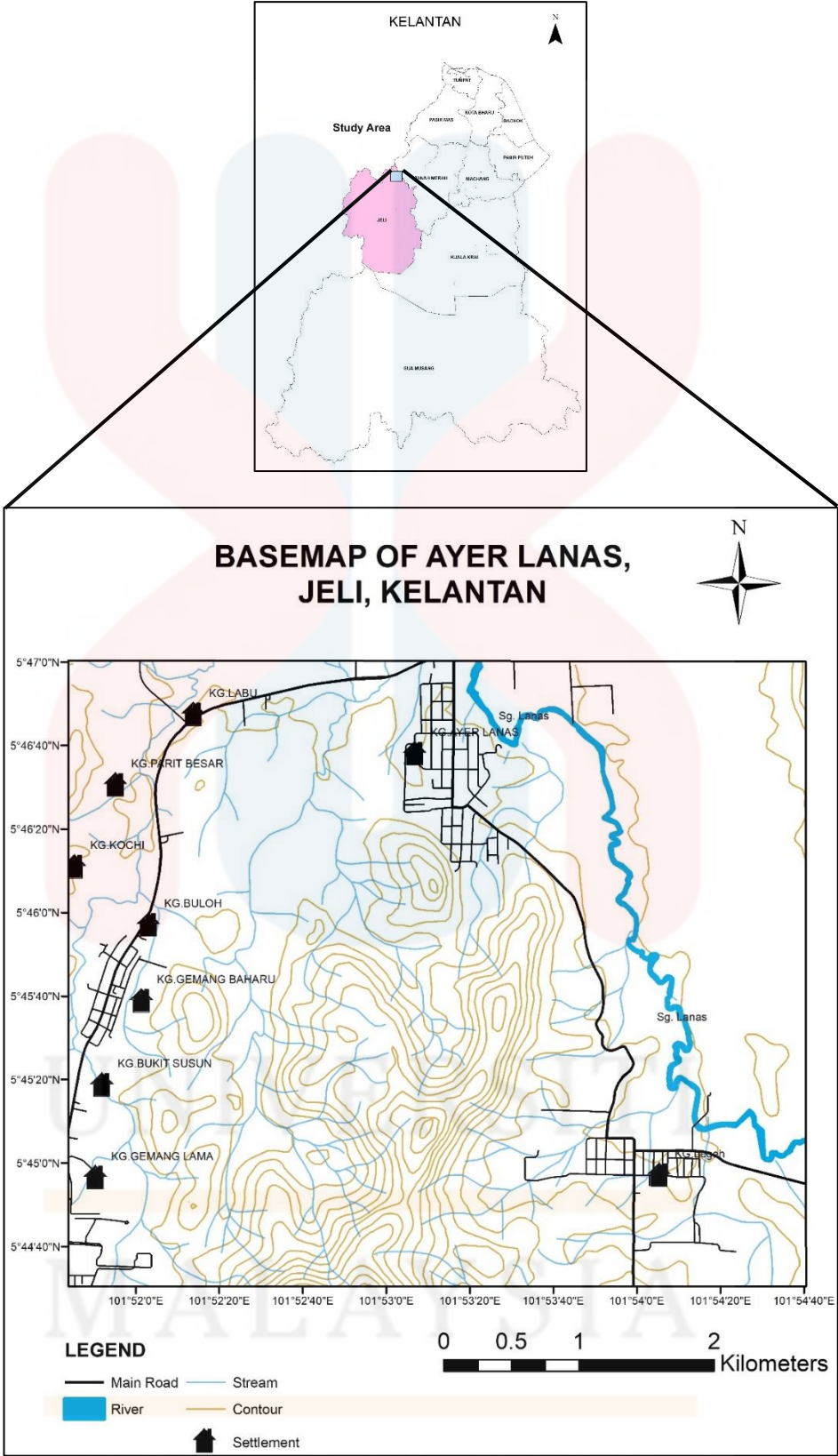


Figure 1.1: Basemap of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan

a. **Location**

The study area is consisting of nine villages which is Kg. Ayer Lanas, Kg. Legeh, Kg. Labu, Kg. Parit Besar, Kg. Kochi, Kg. Buloh, Kg Gemang Bharu, Kg Bukit Susun, and Kg. Gemang Lama. This area is mostly covered by hilly areas and plains areas with a maximum elevation are 280 m, and the lowest elevation is 40 m. The main river of this area is Sungai Lanas, and this area also consists of a few streams such as sg. Buloh, sg. Bukit Susun, sg. Legeh and sg. Gemang.

b. **Accessibility**

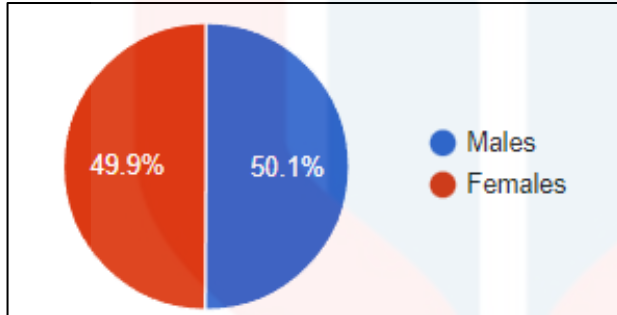
The accessibility to the Ayer Lanas area is by the main road. The Timur-Barat highway is the main road in Ayer Lanas that connect this area to Jeli and Tanah Merah tow. The accessibility study area can be accessed using a car and other transportation, but some areas cannot be accessed due to the high elevation and restricted area. The road connection of the study area can be referred in **Figure 1.2**. The distance from the study area to Jeli town is around 14 km which took 12 minutes by driving a car and 36 km from the study area to Tanah Merah district and which took 35 minutes by driving a car.

c. **Demography**

Jeli is one of the districts in Kelantan and the demography of this area is 54,656 people it can be separated into genders which are male and female. The population of males in this area is 50.1% (274,373 people) and females 49.9% (27,283 people) as shown in **Figure 1.2** and **Table 1**. The age of the people in this area can be divided into three groups, 0-14 years old (26.9%), 15-64 years old (68.2%), and >65 years old (4.9%). **Figure 1.3** shows the pie chart of the population by age in the Jeli district and **Table 1.2** shows the amount of population by age in the Jeli district. The ethnic in this

area consists of three which are Malay, Chinese, and Indian (Department of Statistics Malaysia, 2010). Malay people are the dominant ethnic in Jeli, Kelantan.

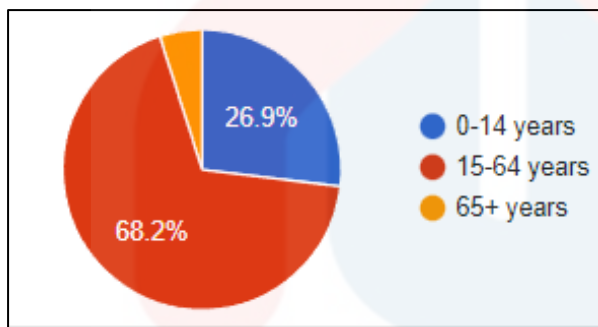
Table 1.1: Population by gender in Jeli district.



Population by Gender	
Male	27,373
Female	27,283

Figure 1.2: Pie chart of the population by gender in Jeli district (Source: Department of Statistics Malaysia, 2010).

Table 1.2: Population by age in Jeli district.



Population by age	
0-14 years	14,706
15-64 years	37,254
65+ years	2,696

Figure 1.3: Pie chart of the population by age in Jeli district (Source: Department of Statistics Malaysia, 2010).

d. Land Use

Kg. Gemang and Kg. Ayer Lanas area consists of hilly areas and plain areas, hilly area has been covered by vegetation and some area has been used for plantation such as rubber, and oil palm. The plain areas, it is consisting of a village and a few developments such as a school, clinic, shops, and government buildings.

e. **Social Economic**

The social-economic in Kg. Gemang and Kg. Ayer Lanas area is focused on plantations such as rubber, oil palm, and fruits as well as livestock breeding. Locals in study area not only focus on the plantation but also businesses such as shops and markets. Some of the locals also work as teachers, doctors, nurses, and officials in the government or private sector.

1.3 **Problem Statement**

Rare Earth Elements (REE) is a metal element that has the potential to be used in any field such as in the petroleum field and industrial fields. Nowadays, the demand for REE minerals is increasing because it gives many benefits to the industry sector and economy of the country. The development of REE exploration in Malaysia is still in an early stage because of the less research and not much intensive study about REE in this country. Therefore, the study of REE is important because it can help in giving information about the distribution or occurrence of REE in Malaysia. REE study also can help the government and private sector in the development of REE industry. Besides that, the geological map of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan is not updated, and this issue can give problems for the sector such as land-use planners, engineering, and geology students especially during unexpected events happen. That is why geological mapping is needed in this area.

1.4 **Research Objective**

The objective of this study is:

1. To produce the geological map of Kg. Gemang and Kg. Ayer Lanas area in scale 1:25000.

2. To analyse the distribution of rare earth elements (REE) in the selected soil profile in Jeli, Kelantan.

1.5 Scope of The Study

The study of Rare Earth Elements (REE) distribution and geological mapping has been conducted in Kg. Gemang and Kg. Ayer Lanas, Jeli, and approximately 300 g of soil was collected in the selected soil profile around that area. All the detail about the soil sample and soil profile were recorded and further studies were continued in the laboratory. The inductively coupled plasma mass spectrometry (ICP-MS) technique has been used to measure the content of REE in the soil profile. All the materials such as hammer, GPS, and sample bag were used when doing the fieldwork. Rock samples were collected for petrography and SEM analysis to know the mineralogy of the rock sample. XRD and XRF analysis were performed to identify the mineralogy and major as well as trace elements in soil samples from the study area.

1.6 Research Importance

The research on the distribution of Rare Earth Elements (REE) has been conducted in Kg. Gemang and Kg. Ayer Lanas, Jeli because this area has a potential for the distribution of REE. According to Patah et al. (2021), Jeli Granite Formation has a high potential for distribution of REE compared to the other location and the lithology of the study area consists of Jeli and slate units. The significance of the Rare Earth Elements (REE) study is to give benefit the researcher, students, and other sectors because it discusses the distribution of REE in Jeli, Kelantan. This study may help in the exploration of REE in Jeli, Kelantan. The study of geology is needed to give information to the locals about geology in their area and to give benefit the other researcher during their studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses and delivers information regarding the regional geology and tectonic setting of the Kelantan area as well as the study area in Jeli, Kelantan. The specification study of Rare Earth Elements (REE) in the selected soil profile in Jeli, Kelantan is also discussed here. The information in this chapter is based on previous studies that have been gathered from journals, research papers, books, and articles.

2.2 Regional Geology and Tectonic Setting

Malaysia's peninsular can be split into three belts which are Western Belt, Central Belt, and Eastern Belts. These belts have been split based on their differences in geology, stratigraphy, structure, and distribution of rock. The Western Belt is part of Sibumasu Terrane that originates from the NW Australian margin of Gondwana in the age of late Early Permian. The Sukhothai Arc (Late carboniferous to Early Permian) is represented by the Central belt and Eastern belt on the edge of the Indochina Block. The boundary between Western Belt and the central and eastern belts is formed due to the Bentong-Raub suture zone (Metcalf, 2012). The effect of the movement of the plate tectonic to peninsular Malaysia is a major fault, granitoid intrusion, and re-setting of palaeomagnetic signatures. The Western Belt consists of Perak, Selangor, Negeri Sembilan and Malacca. The Central Belt is consisting of Kelantan, Pahang, and Johor. It stretches from Kelantan to Johor between the eastern foothills of the Main Range. While the Eastern Belt is distributed from east Kelantan

through Terengganu and east Pahang into east Johor in the south (Hutchison & Tan, 2009).

Kelantan is a state located in the north-eastern of peninsular Malaysia. It contains eleven districts which are Gua Musang district, Kuala Krai district, Tanah Merah district, Machang district, Pasir Mas district, Tumpat district, Kota Bharu district, Pasir Putih district, Rantau Panjang district, Bachok district, and Jeli district. As stated by Patah et al. (2021), Kelantan is a state that consists of a central zone of sedimentary and metasedimentary rock that is bounded by Main Range granite in the west and Boundary Range granite in the east. The rock in the Kelantan state can be classified into granitic rock, metasedimentary rock, extrusive rock, and unconsolidated sediment (Beiranvand & Hashim, 2017). **Figure 2.1** show the regional geology of Kelantan.

The research area for the specification study is in the Jeli district. The area of this district is approximately 1,330 km². It is consisting of three subdistricts which are Jeli, Batu Melintang, and Kuala Balah. Usually, the type of rock in Jeli Kelantan is shale, siltstone, sandstone, and limestone which can be categorized as Triassic sedimentary rock. Phyllite, slate, sandstone, and limestone are in Permian sedimentary rock and the last type is granitic rock which is acid intrusive. Jeli district is located at the foot main range of the backbone is Peninsular Malaysia and this range consists of granitic rock and sedimentary rock as well as metasedimentary rock. The granite unit is distributed along the western part at the border of Perak and Pahang.

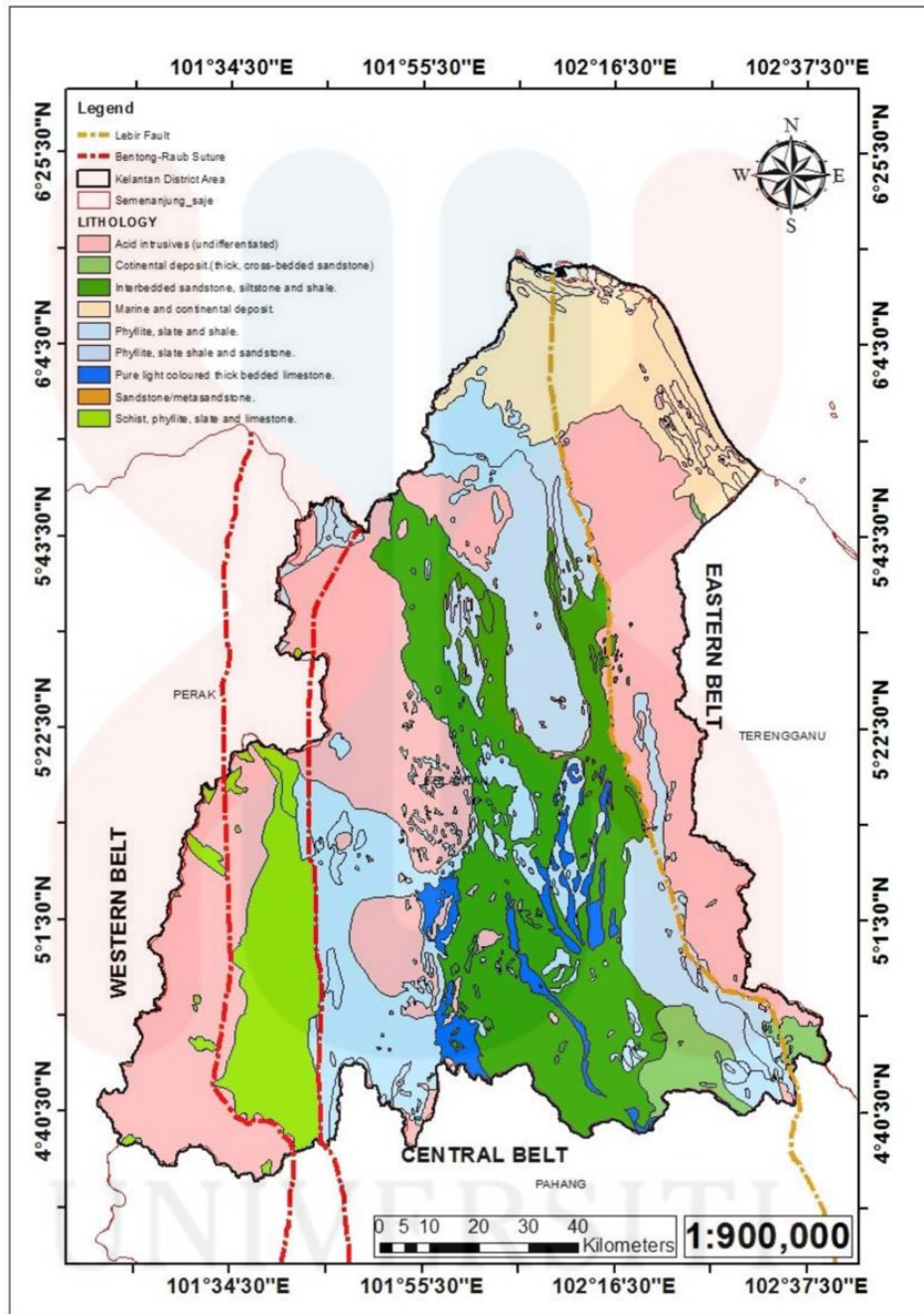


Figure 2.1: Regional Geology of Kelantan (Source: Patah et al., 2021)

2.3 Stratigraphy of Jeli

Jeli area consists of Tiang Schist (oldest formation), Mangga Formation, Taku schist, Telong formation, and granitic bodies such as Kemahang Granite and Noring Granite. The age of the Tiang Schist is Silurian to Devonian age. The well-exposed formation in the upper reaches of Sungai Machang expanding southwards to the Batu Melintang area is called as Mangga Formation. A preserved brachiopod and gastropod

fossil can be found in the Mangga Formation in the Batu Melintang area and this fossil becomes an indicator of this area in the Carboniferous to Permian age. The age of the Taku Schist is in the Permian period and the age of the Telong formation is in the Permian to Triassic. The Mangga formation and Telong formation consist of metamorphic sequences of arenaceous, argillaceous, pyroclastic, calcareous, and schistose rocks. Kemahang Granite forms the mountains range east-west of Jeli town part that spread into the Sukhirin range in Thailand. In Malaysia, it stretched to Bukit Jeli, Bukit Kemahang, Bukit Kusial, and smaller hills surrounding.

2.4 Structural Geology

Jeli area is part of the Central Belt, and it was located within the Bentong-Raub Suture Zone. Lebir fault zone is the main fault zone in Kelantan state, this fault zone is marked as a boundary between the Central and Eastern Belt. The fault line can be found in the Jeli area. Besides that, the granite intrusion that happened during Triassic and Cretaceous caused the gentle folded and slight to steep dipping in the Mangga Formation. The landscape of the Jeli district can be divided into three types, mountain areas, plain areas, and hilly areas. Based on the Malaysia-Thailand Border (2006) there are three types of sedimentary which are composed of volcanic rock and unconsolidated sediment. The unconsolidated sediments are composed of coarse gravel, and a mixture of both materials and are exposed in the rural area.

2.5 Historical Geology

Jeli is located at foot of the Main Range and normally it contains a granitic rock. The Main Range granite is positioned in the western part of Kelantan stretching along the western of Perak and Pahang (Sulaiman et al., 2020). The formation of Jeli is a marine deposition in the age of Palaeozoic to Early Mesozoic era. Kemahang granite is the youngest formation compared to other formations in Jeli, Kelantan. It is

consisting of mountains ranging from east-west to Jeli town and spread into the Sukhirin range in Thailand.

2.6 Soil Profile

Soil is a mixture of inorganic matter and organic matter that is formed from the interaction between the earth's crust and atmosphere also under biological influences. The composition of the soil is 45% minerals, 25 % water, 25% air, and 5% organic matter as shown in **Figure 2.2**. The texture of the soil depends on the percentage of its particles which are sand, silt, and clay particles. The color of the soil has been influenced by soil mineralogy. This color becomes an indicator to know the types and composition of the soil. The orange-brown to yellowish-brown color represents high iron soil and the dark brown or black color is for soil that has a high quantity of organic matter. Balasubramanian (2017) mentioned that soils are formed in parent materials over decades or centuries which is mean, the process of the soil is slow. Normally, the parent materials (rock) will undergo chemical and physical weathering to form soil.

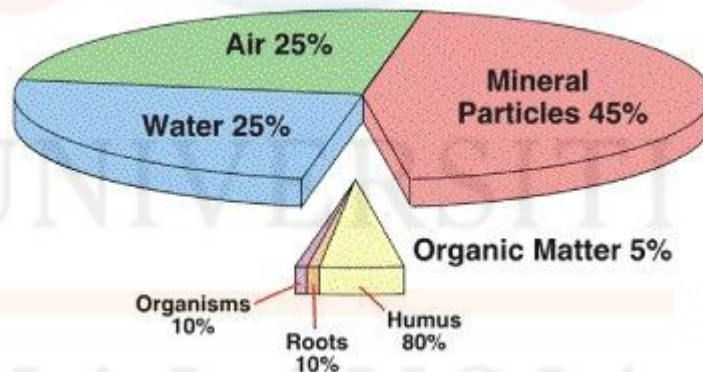


Figure 2.2: Soil composition (Source: Patricia, 2010).

The chemical composition of the soil is phosphorus, nitrogen, sulphur, carbon, hydrogen, oxygen, potassium, calcium, iron, magnesium, boron, manganese, copper, zinc, molybdenum, and chlorine. Phosphorus element can be found in clay and in soil that has high concentrations of aluminium, iron, and calcium because it has a retention

capacity. Phosphorus comes from the mineralization of organic matter, so the rate of phosphorus will be affected by temperature, moisture, and soil aeration. The optimum concentration of phosphorus in soil is 30 to 50 mg-P/kg-soil. Nitrogen elements in soil occur in the form of organic and inorganic. Calcium, magnesium, and potassium are major cations in soil that affect its properties of the soil. Molybdenum, copper, boron, manganese, iron, and zinc is a trace metal in the soil that comes from the mineral of the rock. The chemical composition of the soil is different in each layer and depth of the soil.

The soil develops in the form of a layer known as a horizon. Each layer in soil horizons has its characteristics in terms of composition, color, texture, and chemical properties. The soil profile is a cross-sectional view of the soil horizons, and it shows the various layers of soil horizons in the soil profile. The view of the soil profile is shown in **Figure 2.3**. Soil profile consists of five major horizons which are O horizon that contains 20% organic matter. The A horizon is also known as the topsoil or root zone. This layer consists of sand, silt, and clay. The B horizon is dominated by minerals, it contains a high concentration of silicate clay, iron, aluminum, and carbonates (Balasubramanian, 2017). This horizon is also known as a subsoil. The C horizon is known as a saprolite. This layer contains varied sizes of rock fragments and weathering, and chemical reactions also occur in this layer. Based on **Figure 2.3** the accumulation of rare earth elements (REE) can be seen in the saprolite layer. The R horizon is a bedrock layer, it contains compacted and cemented material.

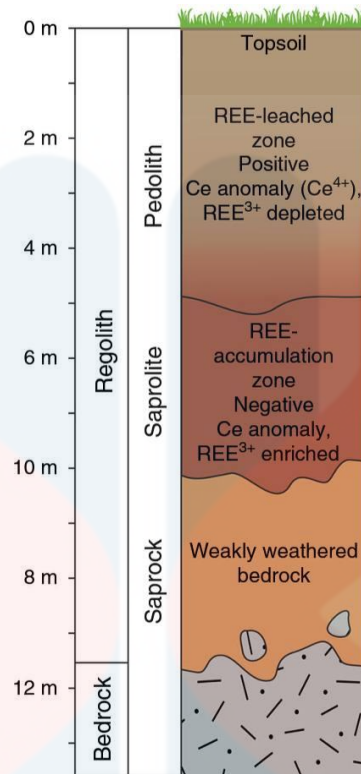


Figure 2.3: Schematic soil profile (Source: Borst et al, 2020).

The distribution of the rare earth elements (REE) in the soil profile is increase with the depth of the soil in the soil profile. Wang, Lingqing & Liang, (2015), found that the total concentration of the REE in the soil profile increased with the depth, which from the surface to 9 cm depth, dropped from 10 cm to 30 cm, and then increased slightly below the depth of 30 cm. This shows that the distribution of the REE in soil depends on the depth of the soil profile, properties of the soil, and type of mineral in the soil.

2.7 Introduction of Rare Earth Elements

Rare earth elements (REE) consist of scandium (Sc), yttrium (Y), and 15 lanthanides, lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and

lutetium (Lu) are naturally present in soils and the contents of this element depend on the parent material and soil properties. REE is a metal element that has a similar property and can be found together in geological deposits.

REE can be divided into two which are the lanthanum group and the terbium group. The lanthanum group or light rare earth elements (LREE) has 57 to 61 atomic numbers and the terbium group or heavy rare earth elements (HREE) that has >62 atomic numbers. LREE consists of seven elements which are La, Ce, Pr, Nd, Pm, Sm, and Eu while HREE consists of eight elements, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu. LREE is dominated by carbonate rock and phosphate while HREE is dominated by oxide forms such as titanite, tantalite, and phosphate. Cerium (Ce) is the most abundant element in the earth's crust while promethium (Pm) is the least abundant element in the earth's crust. The distribution of the LREE in the earth's crust is more than the distribution of HREE.

The occurrence of the REE can be found around the world, but the availability of those elements is sometimes limited in a certain area. The most abundant REE distribution can be found in China, the United States, Australia, and Russia. It also can be found in other countries such as Canada, India, South Africa, and Southeast Asia. According to Drobniak and Mastalerz (2022), REE market has been dominated by China since 1990 because they have a large REE ore deposit located at Bayan Obo and the smallest deposit is in the Sichuan area. Commonly REE mining in China comes from bastnasite deposits. The occurrence of REE can be found in certain minerals such as monazite, allanite, bastnaesite, euxenite, and xenotime. This mineral is known as a rare earth mineral (REM) and a major REE mineral. Drobniak and Mastalerz (2022) found that more than 250 minerals that can contain REE are found in carbonatites, alkaline igneous systems, ion-absorption clay deposits, and monazite-xenotime

deposits. Monazite is a phosphate that is widely distributed in India, Brazil, Malaysia, the United States, Thailand, Sri Lanka, South Korea, and South Africa. The common REE can found in monazite is LREE. Bastnaesite is a carbonate mineral with fluoride. As stated by Gupta and Krishnamurthy (2005), bastnaesite is a widespread mineral that occurs in a variety of igneous such as carbonatites, vein deposits, contact metamorphic rock, and pegmatites. The common REE that can be found in this mineral are Ce, La, Pr, Nd, and Y. Xenotime is a phosphate mineral that becomes a major source of HREE. This mineral is an accessory mineral in pegmatites igneous rock and is common in metamorphic rock.

2.8 Properties of Rare Earth Elements

REE is an element that has the same properties in terms of physical and chemical properties. That is why the occurrence of the REE can be found together in minerals at the same geological formation. The lanthanides group is a special group that has a different atomic structure from other elements. The atomic number for the lanthanides group is from 57 (lanthanum) to 71(lutetium) and this element has similarities in physical properties and chemical properties. The general properties of rare earth elements (REE) are that metals have a silver, silvery-white, or grey color, have high luster but are readily in air and it also has high electrical conductivity.

The REE is divided into light rare earth elements (LREE) and heavy rare earth elements (HREE) based on the electron configuration of each element. LREE is also known as a lanthanum group while HREE is known as a terbium group. Yttrium (39) has been included in HREE because it has similarities in its ionic radius and chemical properties (Voncken, 2016). The abundance of the REE decreases with increasing atomic number, which means LREE is the most abundant than HREE.

As mentioned by Gupta and Krishnamurthy (2005), the melting point of the REE depends on the quantities of oxygen, carbon, and nitrogen present in the sample. La, Ce, Pr, Y, and Lu have the highest boiling points. Radioactivity and isotopes of each rare earth element are different, for example, La elements have a stable isotope (^{139}La) and a radioactive isotope (^{138}La). The stable isotope of La is the most abundant and the most stable for radioisotope is ^{138}La with a 102×10^9 years half-life, ^{137}La with a 60,000-year half-life, and ^{140}La with a 1.6781-day half-life. Lu has two isotopes which are ^{175}Lu and ^{176}Lu . The most stable radioisotope is ^{174}Lu with 3.31 years of half-life.

Rare earth elements are very electropositive, and they have strong chemical bonding. REE can form oxides, halides, carbonates, phosphate, and silicates when reacting with other elements such as air, oxygen, nitrogen, hydrogen, carbon, and silicon.

2.9 REE Bearing Mineral

Rare earth element (REE) bearing mineral is a mineral associated with the rare earth element in their deposit. REE deposits are divided based on their mineralogy and origins which are primary deposits related to igneous and hydrothermal events and secondary deposits collected through sedimentary processes and weathering. Each deposit consists of different bearing minerals associated with REE. According to Castor and Hendrick (2006), REE-bearing mineral of igneous rock is apatite, allanite, monazite, titanite, and xenotime which occur in the lower mantle during magmatic differentiation. The types of secondary deposits are placer deposits and ion-adsorption clay deposits. Based on Hu et al. (2017) more than 80% of middle and heavy REEs are found in ion-adsorption clay deposits. Regolith-hosted REEs is formed by the weathering process of plutonic or volcanic rock with high REE content that causes the

accumulation of REEs in igneous weathering profile (Hoshino et al., 2016). As stated by Meldrum (1998), the weathered crusts of granite form in temperate and tropical regions when bedrock mineral change into secondary minerals such as clay minerals and are affected by weak acidic surface conditions as well as metamictization phenomena. Metamictization phenomena is a damaging process in a radioactive mineral that destroys the mineral texture and changes the mineral from full crystallization to complete metamictization. The high concentration of radioactive elements such as Uranium (U) and Thorium (Th) in REE-bearing minerals partially destroy the texture of host minerals such as micas and feldspars to facilitate the transformation of some rock-forming minerals into clay minerals.

The common REE-bearing mineral that can be found in Malaysia is xenotime, monazite, zircon, ilmenite, and struverite. This mineral was produced as the by-product of tin mining in Malaysia for several decades. The extraction of REE from monazite and other heavy mineral were obstructed by the strong occurrence of Th and U in the minerals. In Malaysia, the high potential of REE can be found together with weathered granite parallel to the Bentong-Raub suture zone in Taiping, Lumut, Bukit Tinggi, Tamping, and Baling areas (Yaraghi et al., 2016).

Deposition of REE can occur in diverse and uncommon geological settings. The types of REE deposits are carbonatites, peralkaline igneous systems, magmatic magnetite-hematite bodies, iron oxide-copper-gold (IOCG) deposits, xenotime-monazite accumulations in mafic gneiss, ion-absorption clay deposits, and monazite-xenotime-bearing placer deposits.

Carbonatite is the main source of LREE in the world since 1960 and it has been produced from large carbonatite bodies mined in China in 2016. The carbonatite

intrusions occur in many forms such as stocks, tabular bodies, dikes, irregular-shaped masses, and veins. In these deposits, the primary REE ore minerals are bastnaesite, parasite, synchysite, ancylite, and monazite. The larger REE deposit can be found in Bayan Obo iron-carbonatite deposits in Neil Mongol Autonomous Regions, China. The REE-bearing minerals are formed by late-phase hydrothermal processes and the other types of REE enrichment in the carbonatite system are in the supergene process that involves deep weathering of a carbonatite in a tropical environment that forms REE-enriched laterite deposits.

The peralkaline igneous system is inherently enriched in REE in some instances hosting high-grade deposits and this system contains high HREE. Their enriched REEs come in a variety of forms such as complexes exhibiting vertical and lateral zonation, complexes exhibiting layering, dikes and veins associated with peralkaline igneous complex and plutons, stocks, plugs, and peralkaline intrusions.

Magmatic magnetite-hematite bodies contain REE-bearing minerals with the potential to recover the REE as a by-product during iron mining. The type of REE-bearing minerals in the breccia pipes are monazite, xenotime, bastnaesite, and britholite.

Iron oxide-copper-gold (IOCG) deposits are magmatic-hydrothermal iron deposits that host economic concentrations of copper and gold. At Olympic Dam, IOCG deposits can host REE mineralization and occur in iron oxides and small carbonatites within the intrusive complex.

Xenotime-monazite accumulation in mafic gneiss is enriched in the HREE. These deposits occur in the Music Valley area of the northern part of Joshua Tree

National Park in California, and it consists of quartz, biotite, and feldspar mineral as well as accessory mineral such as sericite, apatite, magnetite, zircon, etc (Evans, 1964).

Ion-adsorption clay deposits are the primary sources of the HREE in southern China. These deposits form in tropical regions with medium to high rainfall following a general process such as:

- a) The REE are leached by groundwater from bedrock (granites),
- b) Thick zones of laterite soil develop above the granites which are intensely weathered zone that contains an abundance of clays, and
- c) The mobilized REE become weakly fixed onto the clays such as kaolinite and halloysite in the soils.

Monazite-xenotime-bearing placer deposits can be extracted from coastal sands in Brazil and India. It can be deposited in fluvial deposits and coastal and nearshore deposits of sand and silt. The occurrence of REE in fluvial placer deposits depends on the presence of monazite and xenotime in the bedrock sources from upstream.

2.10 Chondrite-Normalize

Chondrites-normalize is a geochemistry practice to normalize the REE pattern by dividing REE concentration to the REE value of the sample. The concentration value for REE as mentioned by McDonough and Sun (1995) as following (**Table 2.1**):

Table 2.1: Concentration value of REEs.

Rare Earth Elements (REEs)	REE value
Y	1.57
La	0.237
Ce	0.613
Pr	0.093
Nd	0.457
Sm	0.148
Eu	0.056
Gd	0.199
Tb	0.036
Dy	0.246
Ho	0.055
Er	0.16
Tm	0.025
Yb	0.161
Lu	0.0246

(Source: McDonough and Sun, 1995)

Based on Yaraghi et al. (2020) the characterization research was conducted in two sites which is Lumut (LU) and Telok Murok (TM) located in the granite Western belt. Both sites consist of quartz, potassium feldspar, and mica group as well as REE-bearing minerals such as apatite, allanite, monazite, xenotime, and zircon. The sample of this research has been collected from cut slopes of granitic profiles in the LU site and TM site. **Figure 2.4** show the soil profile and sample at the LU site and TM site. The rock, soil, and saprolite sample was taken by following the depth of the cut slope.

At LU and TM site the samples point was divided into four horizons which is horizon A, B, C, and D. The result of REE analyses was obtained from ICP–MS, and **Figure 2.5** and **Figure 2.6** shows two patterns of chondrite-normalized REE in LU site and TM site.

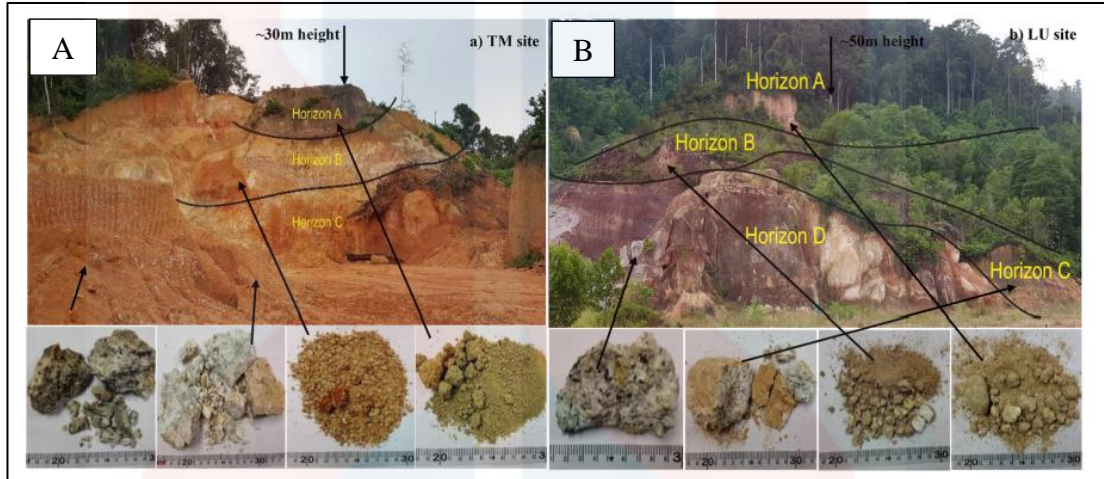


Figure 2.4: Soil profile and sample from A) Lumut and B) Teluk Murok. (Note: LU: Lumut site, TM: Telok Murok site). (Source: Yaraghi et al., 2020)

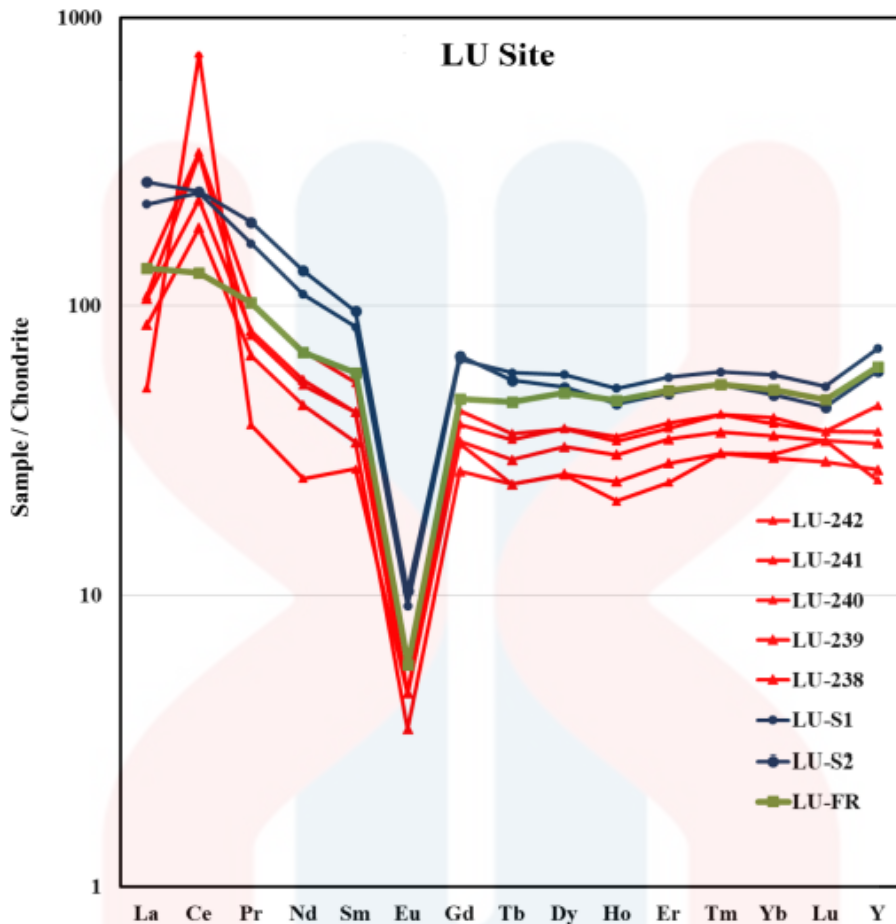


Figure 2.5: Chondrite-normalized REE diagram of the weathered crust of granite and related parent rock from LU site (Lumut) that follow chondrite values from McDonough and Sun (1995). (Note: RED color is Horizon B; DARK BLUE is Horizon C and GREEN color is Horizon D). (Source: Yaraghi et al., 2020)

Based on **Figure 2.5**, the chondrite-normalized REE patterns of the weathered crust and related syenogranite from LU showed enrichment of LREE. The REE patterns of parent granitic rock at the LU site shows more enriched in LREE than in HREE with a strong negative Eu anomaly. The strong negative Eu anomaly and high ratio of Rb/Sr (35.14) in the parent rock sample indicated that LU-FR was a highly differentiated granite related to Sn mineralization.

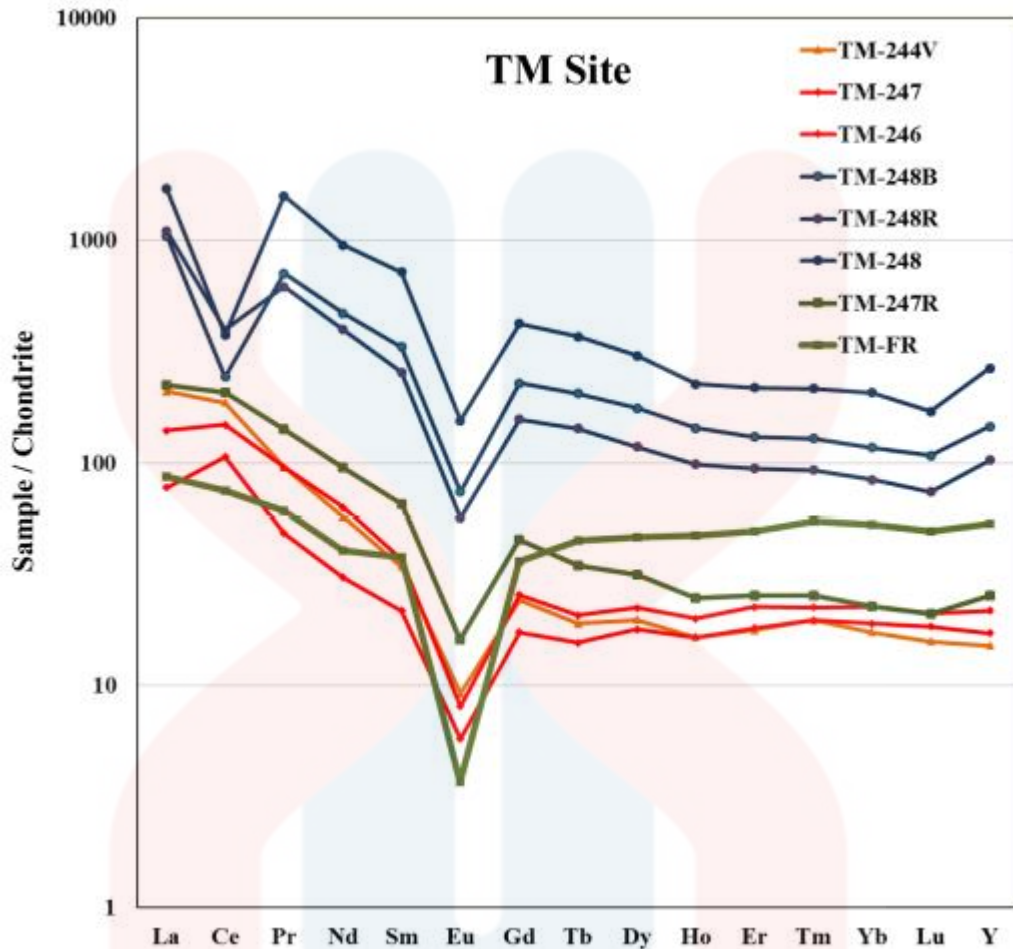


Figure 2.6: Chondrite-normalized REE of the weathered crust of granite and related parent rock from TM site (Telok Murok) that follow chondrite values from McDonough and Sun (1995). (Note: Horizon A sample indicated by ORANGE color, Horizon B with RED color, Horizon C with DARK BLUE, and Horizon D with GREEN (Source: Yaraghi et al., 2020).

Figure 2.6 illustrates the chondrite-normalized REE diagram of the weathered crust of granite and related parent rock of the TM site. The flat plot of the chondrite-normalized REE pattern of TM monzogranite proposed that the parent granite had equally abundant LREE and HREE. This plot was also consistent with the REE slope with a strong negative Ce anomaly (**Figure 2.6**). The lowest negative Ce anomaly is related to horizon C in the TM-248 site, while the lowest negative Eu anomaly is observed in horizon B at the TM-246 site. Overall, the samples from the upper part of the profile showed higher REE depletion compared with the parent rock, whereas those

from the lower part (horizon C) indicated higher REE enrichment compared with that of the parent rock (A. Yaraghi, et al., 2020).

2.11 Application of Rare Earth Elements

Rare earth elements (REE) can be used in various industries such as in automotive industry, electronic industry, oil and gas industry, green technology, and military. For example, yttrium can be used in the electronics sector for a smartphone screen. Cerium and lanthanum can be used in the automobile industry for UV cut glass and diesel fuel additives as shown in **Figure 2.7**. La, Ce, Nd, Pr, and Sc become a catalyst in the automotive industry to clean diesel and oil refining. The application of REE can support our country from depending on the other country in product supply.

Table 2.2 shows the type and application of REE in the industry.

Table 2.2: Type of REE and application in industry.

REE	Application
Nd, Pr, Sm, Dy, Tb	Lightweight magnets - In the automotive and electronics industry.
La, Ce, Nd, Pr, Sc	Catalyst - To use as an automotive catalyst - Clean diesel and oil refining
Nd, Pr, Dy, Tb, La, Nd, Ce	Hybrids vehicle - Electrics motors and generators. - Hybrid batteries
Eu, Tb, Y, Sc	Compact fluorescent lights, energy-saving lamps

Table 2.2: (Continued)

Ce, La, Pr, Sc	Polishing powder - For TV, computer LCD, plasma, lenses, and precision optical and electronic components.
Ce, Er, Gd, Tb, La, Nd, Yb, Pm, Sc	Glass additives - CRT screens stabilize glass from cathode rays, TV, and computers screen.
Dy, Er, Pr, Gd, Ho, Ce, La	Ceramics - Ceramics tile and ceramics capacitor.

(Source: Garis Panduan Eksplorasi Unsur Nadir Bumi. JMG.GP.20)

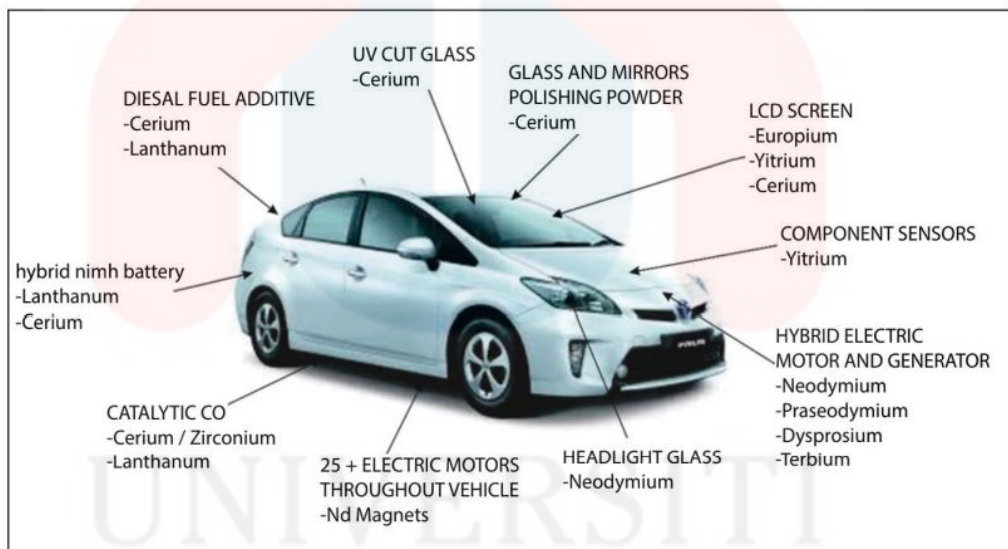


Figure 2.7: Application of REE in the automotive industry

2.12 Rare Earth Elements Industry in Malaysia

According to the US Geological Survey (USGS), the distribution of REE ores can be found in Peninsular Malaysia is approximately 30,000 to 43,000 tonnes. Based on previous research, the distribution of REE can be found in granitoid rock in Kelantan. Patah et al, (2021) found that Jeli Granite Formation has a high potential for REE distribution and the granitoid rock is widely exposed in Kelantan. The granitoid

rock is also exposed in Malaysia, so the possibility for occurrences of REE in this rock is high. The potential deposit area to find REE in Malaysia is in alluvial xenotime, monazite, and ion adsorption clay. According to the Japanese Geological Survey, they found an amount of heavy rare earth elements (HREE) in the sample collected from the Kuala Lumpur area.

In 1982, Asia Rare Earth Sdn Bhd (ARE) company caused radioactive pollution to the resident of Perak because of the yttrium extraction from monazite mineral. This pollution happens because monazite minerals are associated with radioactive elements such as thorium (Th) and uranium (U) that are dangerous to human health. These issues occur because during that time Malaysian government does not have a responsible agency to manage this matter. These issues can be prevented if during that period Malaysia has a responsible agency to manage these issues.

REE industry in Malaysia is not growing widely because the mining of the REE is not developed. Malaysia has the potential to become a supplier of REE to support the total rare earth industry supply chain. The development of the high-tech industry in Malaysia has required HREE resources. The Malaysian government has been involved in the investigation of the REE in ion adsorption clay to find suitable quantities to invite investors to determine the economic viability of the REE. JMG is a responsible agency in REE investigation, the field investigation involves soil profile sampling and determination of REE distribution pattern along the profile. The exploration of REE in ion adsorption clay in Perak involves ten million investments from the government. The involvement of JMG can attract investors because this agency can give information regarding REE investigation.

In 2022, the new project that involves a rare earth mine in Perak has been confirmed because Environment Department (DOE) has already approved to implementation of the pilot project. The state government will manage this pilot project under standard operating procedure from the ministry and this project will boost the state revenue. The local mining company, MCRE Resources Sdn Bhd is the responsible company for this project, and it's located in Kenering, Hulu Perak on land owned by the State Agriculture Department Corporation with an area of 2161 hectares. As stated by the Department of Mineral and Geoscience (JMG) this project is environmentally friendly because it involves non-radioactive rare earth element which is ionic adsorption clay that does not contain hazardous substances as well as not cause environmental harm and vegetation loss. This project will boost state revenue because estimates the market of rare earth elements will reach 9.6 billion USD by 2026 (Myn, 2022).

CHAPTER 3

MATERIAL AND METHODOLOGY

3.1 Introduction

This chapter discusses the materials and methods used during fieldwork and in the laboratory for the geological mapping and specification study. The study area is located around Kg. Gemang and Kg. Ayer Lanas area. This area has fascinating landforms such as rivers, hills, and plains area. Sg. Lanas is the main river in this study area and this area also consists of a few infrastructures such as paved roads, a school, a university, a shop, and a government building. UMK is also located in this study area.

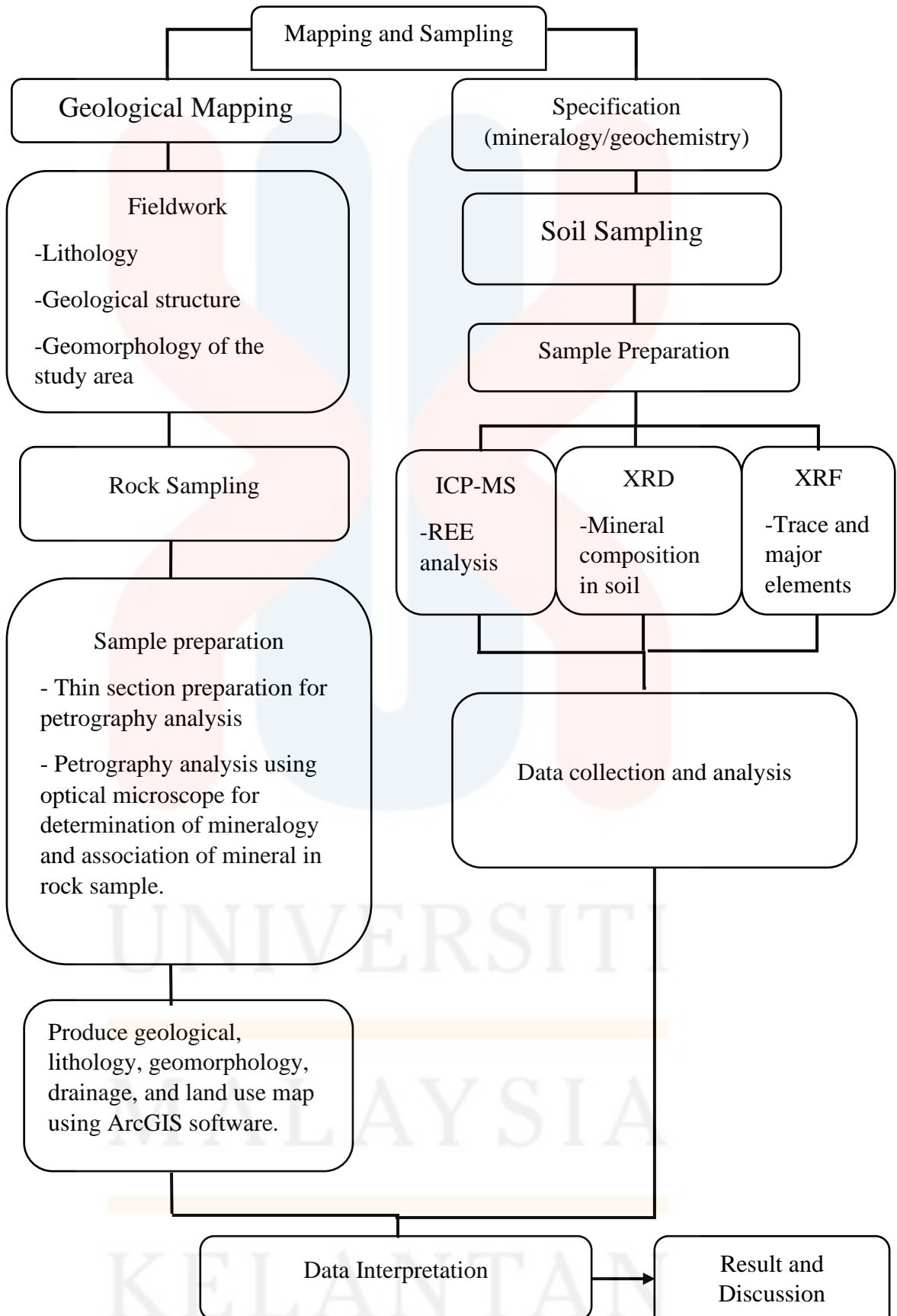


Figure 3.2: Flowchart for methodology of this research

3.2 Materials

The material used during fieldwork for geological mapping and sampling as well as for laboratory analysis are as follows:

- i. Geological map
The geological map was used as a guideline in the field.
- ii. Global positioning system (GPS)
GPS was used for navigation, tracking, and marking the location of the sample in the field.
- iii. Compass
Compass was used to measure the strike and dip.
- iv. Hammers
Hammers were used to break the rocks for sampling purposes and save them in the plastic sample.
- v. Sample bags
Sample bags were used to put rock and soil samples.
- vi. A fieldwork book and pen
A fieldwork book and pen were used to record data in the field.
- vii. Camera
A camera was used to take photos of the findings in the field.
- viii. Hydrochloric acid (HCl)
HCl was used to differentiate the types of rock (calcite and chlorite) based on their reaction.
- ix. Measuring tape
The measuring tape was used to measure the size of the outcrops and other geological structures.

- x. Inductively Coupled Plasma Mass Spectrometry (ICP-MS)
ICP-MS was used to analyse the rare earth elements (REE)
- xi. X-Ray Diffraction (XRD)
XRD was used to identify clay minerals and heavy minerals in the soil.
- xii. X-Ray Fluorescence (XRF)
XRF was used to identify the trace and major elements in the soil.
- xiii. Scanning Electron Microscopy (SEM)
SEM was used to identify the morphology of minerals in the rock sample.
- xiv. Optical Microscope
The optical microscope was used to identify the type of mineral in the rock sample.



Figure 3.2: Materials for fieldwork and laboratory

3.3 Methodology

This section explains the methodology that was used for geological mapping and specification study. The data collection, sample preparation, and laboratory analysis were explained here.

3.3.1 Preliminary Studies

Preliminary studies have been done to gather information from previous research, book, journal, and government web site to get an early picture of the research and study area. Data gathered from the preliminary studies can be used to see the difference and to make a comparison between previous research and current research.

3.3.2 Data Collection

3.3.2.1 Geological Mapping

Geological mapping or fieldwork was done to produce and update the geological map of the Kg. Gemang and Kg. Ayer Lanas area. A base map of the study area was produced by using ArcGIS 10.8 before going to the field. The sampling of the rock was conducted in the field and other data such as fault, bedding, and other geological structure were collected as well. Global Positioning System (GPS), compass, hammer, and book were used in this activity. All the sampling locations were marked in GPS and basemap. Approximately 10 to 15 rock samples were collected and stored in a plastic sample that has the detail of each rock sample.

3.3.2.2 Soil Sampling

Nine soil samples were collected from the study area during July which is during the Southwest monsoon period. Approximately 300 g of soil samples were collected from selected soil profiles in the study area using shovel and hand auger. The soil samples were collected from exposed hills that had a clear view of the soil profile

and it also depends on the height of the soil profile. The soil samples were taken at a certain horizon of the soil profile, such as in Horizon B and Horizon C but in some locations, the sampling of the soil is done according to the depth of the soil profile. The physical properties of the soil such as texture, color, and mineral content in the soil were observed and recorded for further interpretation to be correlated with geochemistry analysis as well as the geological setting of the area. The soil sample was stored in a plastic sample and further analyses were done in the laboratory. All the details about the soil profile and soil sample were recorded in the fieldwork book and the coordinates for each sample have been marked in Global Positioning System (GPS).

3.3.3 Laboratory Work

The laboratory work has been done to prepare the sample for laboratory analysis. This section explains about thin section preparation for geological mapping that consists of petrographic analysis using an optical microscope and SEM and soil sample preparation for specification study that consists of three analyses which are ICP-MS analysis, XRF analysis, and XRD analysis.

3.3.3.1 Thin section preparation

After the sampling, all the rock samples were sent to the laboratory for further analysis. A thin section has been prepared in the laboratory and an optical microscope and scanning electron microscopy (SEM) have been used in petrography analysis.

The thin section was prepared to identify the mineral of the rock sample and it shows the size, color, and shape of the mineral when observed under an optical microscope and SEM.

Step for thin section preparation

1. Prepare the glass slide.
2. Mark the rock sample.
3. Cut and clean up the slab.
4. Reduce the size of the slab by cutting it into the chip.
5. Glue the slide into the chip.
6. Polish the slide to the suitable thickness.
7. Thin section ready for petrographic analysis

3.3.3.2 Soil sample preparation

After sampling, the soil sample has been prepared in the laboratory for ICP-MS, XRD, and XRF analysis to know the chemical composition and elements contained in the sample. The sample was divided using coning and quartering sampling methods to get equal particle sizes without creating a systematic bias. ICP-MS analysis has been used to analyze REE, XRD analysis was used to identify the clay mineral and heavy mineral, and XRF analysis was used to identify the trace and major elements in the soil sample. According to Zhou et al. (2020), before further analysis, all the plant residue, roots, and stones should be removed from the sample. After that undergoes sample digestion such as the soil sample has been dry and pulverized into 63-micrometer size to get the powder sample to use in different analyses.

Step for ICP-MS analysis

1. Measure 0.5g pulverized soil samples and transfer them into the vessel
2. Add 4 ml nitric acid (HNO_3),
3. Add 2 ml hydrochloric acid (HCl),

4. Add 1.5 ml hydrogen peroxide (H_2O_2), and
5. Add 1.5 ml hydrofluoric acid into a vessel
6. Close the vessel using caps and swirl for 30 seconds for the sample and solution to react.
7. Place the vessel into microwave digestion for 1 hour.
8. After the sample dissolves, transfer it into a beaker and add 0.1 M of boric acid (H_3BO_3), and 0.5 M nitric acid (HNO_3) into the beaker.
9. Transfer the solution into a falcon tube and store it in the freezer before ICP-MS analysis.
10. The standard solution was used as a reference for the reading.

Step for XRF analysis

1. Measure 0.75 g of soil sample and 1.50 g of Somar mix
2. Mix and stir the ample using a glass rod
3. Put the mixture sample in the mold and mix with 1-2 spatula of boric acid
4. Pouring the mixture in a pressure instrument to create pressed pellets and set pressure on 17×10^4 N
5. Remove the mold that contains a sample and take the resulting pellet.
6. Sample ready for XRF analysis.

Step for XRD analysis

1. Measure 3 g of soil sample
2. Grinding the soil until less than $3 \mu\text{m}$ and put it in a ceramic plate
3. Put 3-4 drops of 10% MgCl_2 and dry.
4. Put 3-4 drops of distilled water and dry
5. Put 3-4 drops of glycerol concentrated solution and dry.

6. Sample ready for XRD analysis

3.3.3.3 Petrographic Analysis

The thin section has been observed using an Optical microscope and SEM to determine the type of minerals and the presence of heavy or dark minerals and morphological minerals as well as for the naming of rocks. This analysis gives information about mineral properties in the sample such as the texture, framework grain composition, authigenic mineral, and color.

3.3.3.4 Geochemical Analysis

a) Inductively Coupled Plasma Mass Spectrometry (ICP-MS) Analysis

ICP-MS analysis has been done to determine the concentration of Rare Earth Elements (REE) in a soil sample by using ICP-MS PerkinElmer's NexION 2000 at Gold Rare Earth and Material Technopreneurship Centre at University Malaysia Kelantan (UMK). This technique is a sensitive detection analytical technique in determining a wide range of extremely low detection limits of atomic elements (Patah et al., 2021). This technique is suitable for trace element analysis because of the sensitive detection and accurate detection limit. It is also one of the high-speed techniques in laboratory analysis.

b) X-Ray Diffraction (XRD) Analysis

XRD analysis has been done using Bruker Benchtop XDR D2 Phaser at FBKT University Malaysia Kelantan. XRD has been used to identify the composition of the mineral in the sample. This technique was determining the crystalline orientation, and structural properties, and measuring the thickness of thin films and multi-layers. This technique works by exposing a material with incident X-rays and then measuring the amounts and scattering angles of the X-ray that leave the material.

c) X-Ray Fluorescence (XRF) Analysis

The portable XRF S1 TITAN model 800 has been used to identify traces and major elements of the soil. SiO_2 , Al_2O_3 , Fe_2O_3 , TiO_2 , CaO , MgO , K_2O , Na_2O , and P_2O_5 are the elements that can be identified using this technique. This technique was determining the chemical composition of the sample by measuring the fluorescent X-ray emitted from it when excited by a primary X-ray source.

3.3.4 Data Processing

Data processing is a step after collecting the data from the field for geological mapping. Data were collected and transformed into different forms such as a chart, tables, and maps by using technology such as Microsoft word, excel, ArcGIS software, GeoRose software, Stereonet software, and global mapper software. After the data processing, all the data from the observations are analyzed and interpreted to produce new data.

3.3.5 Data Analysis and Interpretation

After the laboratory analysis, all the data has been collected and organized based on their analysis for interpretation. The focus of this research is to analyze the distribution of rare earth elements (REE) in soil profiles which can be determined after the interpretation of the data from the ICP-MS analysis. The concentration and distribution of the major and trace element in the soil profile in Jeli, Kelantan can be determined after the interpretation of the data from XRF analysis. The mineralogy of the rock was determined using petrography analysis. The result obtained from the analysis has been interpreted to correlate with the geological setting or mineralogy of the study area. The map of the distribution and concentration of REE in the selected soil profile was produced using ArcGIS software. The geological map was produced

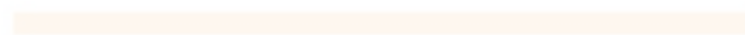
using ArcGIS software and GeoRose software was used to produce a rose diagram to know the direction and orientation of the structure. Other than that, Stereonet software was used to analyze the geological structure in the study area.



UNIVERSITI



MALAYSIA



KELANTAN

CHAPTER 4

GENERAL GEOLOGY OF KG. GEMANG AND KG. AYER LANAS, JELI, KELANTAN

4.1 Introduction

This chapter explained the geology of the study area, which is in Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan that has been conducted in August 2022. All the details about geomorphology, petrography, stratigraphy, structural, and historical geology of this area have been elaborated in this part. The geological features have been observed, measured, and obtained by geological mapping. The structural data, lithology, and geomorphology data obtained have been analysed and interpreted.

4.1.1 Accessibility

Timur-Barat highway is the main road that connects Jeli town and Tanah Merah district to the study area. The study area can be accessed using a car or motorcycle because mostly the road is paved but there was also unpaved road, especially in plantation and vegetation areas. There is a certain area that cannot be accessed due to the high elevation and dangerous to access. This study area is near Thailand's borders which is in the north part and that is why some areas are restricted.

Figure 4.1 shows the accessibility map of the study area.

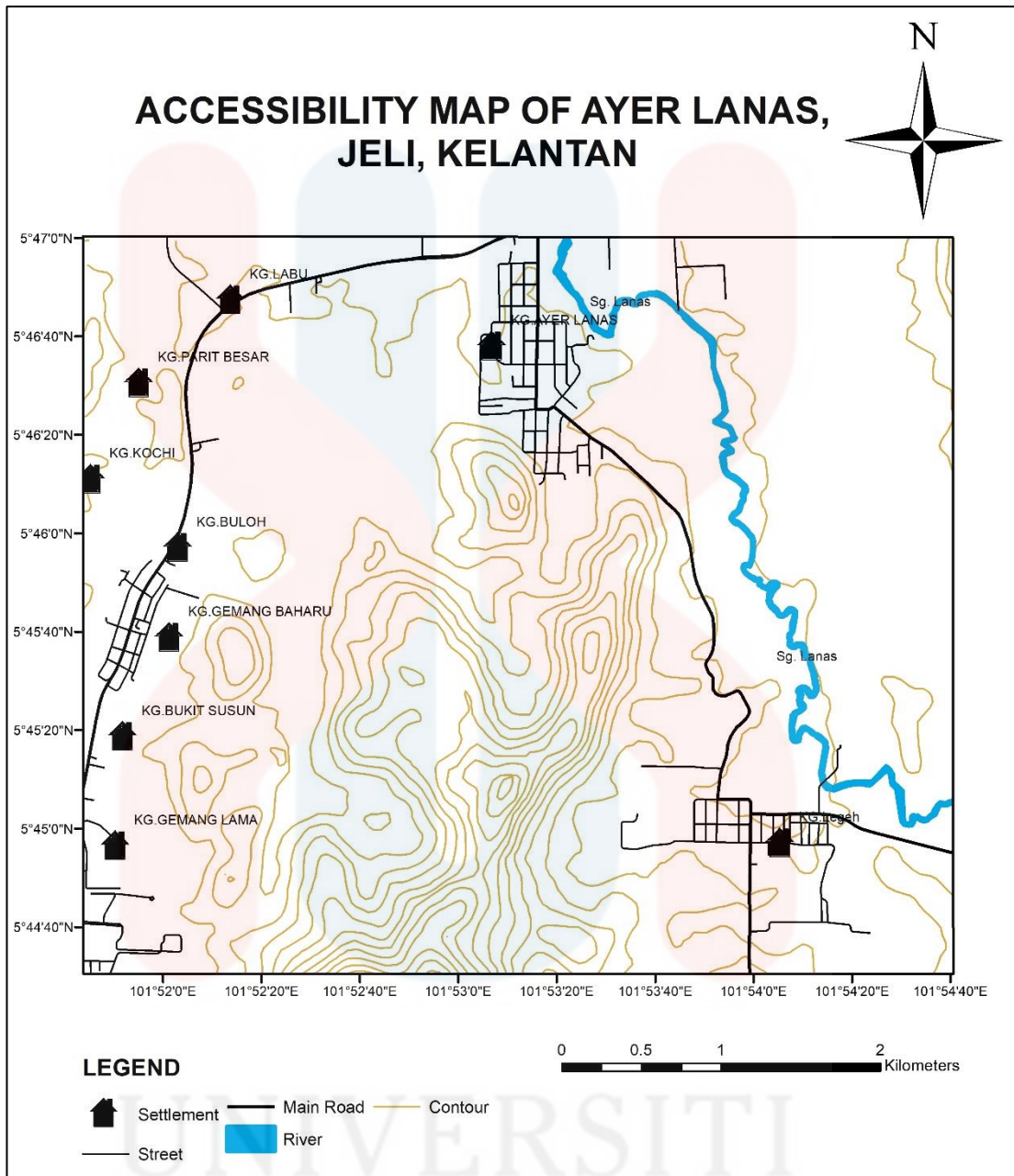


Figure 4.1: Accessibility map of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan.

UNIVERSITI
MALAYSIA
KELANTAN

4.1.2 Landuse

Mostly this study area covered plantation areas such as rubber plantations and oil palm plantations, but some areas are also covered by reserved forests that cannot be accessed. This area also has a few settlements that consist of various infrastructure such as schools, clinics, mosques, and residential for locals' people. **Figure 4.2** show the landuse map of the study area.

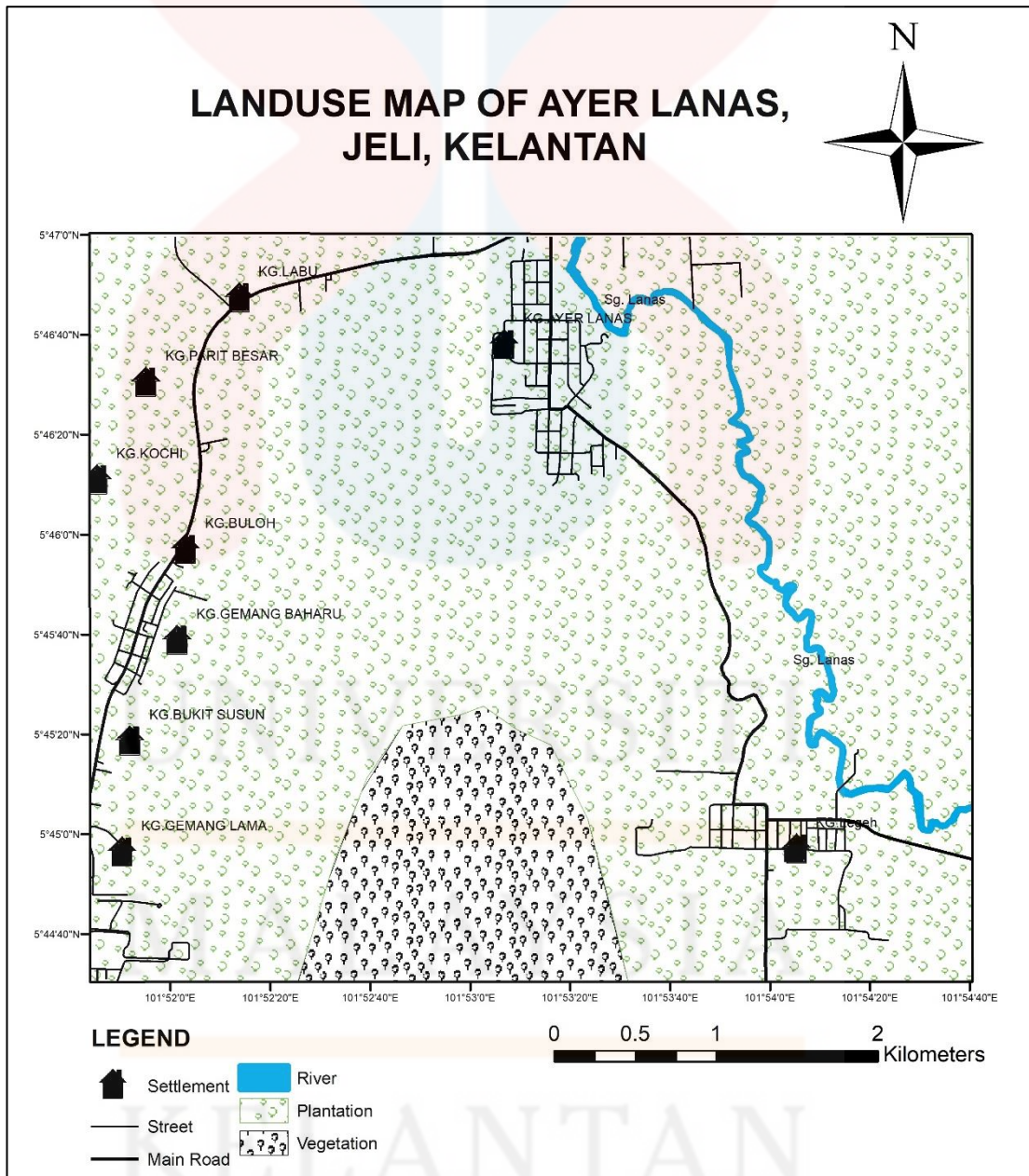


Figure 4.2: Landuse Map of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan.

4.1.3 Settlement

The settlement in this study area consists of a few villages such as Kg. Gemang, Kg. Ayer Lanas and UMK are also located in the study area. Some settlements are located in the plains area and near the river for example SMK Ayer Lanas and a few houses are located near the main river which Sg. Lanas. This area is a flooding area that always happens during monsoons.

4.1.4 Traverse and Observation

Traverse is one of the methods of geological mapping, this method has been done by traversing along the main road, unpaved road, hilly area, and along the river. This study area mostly consists of a plain area with an elevation of 40m and the highest elevation is 280 m which is a hilly area. Based on observation during traversing, this area is mostly covered by settlements, plantations, and vegetation. The local people usually do oil palm and rubber plantations. A few infrastructures such as schools, clinics, universities, mosques, and shops can be seen in this study area. The sampling of the soil and rock sample has been done at several locations and geological data was also collected during this time. All the sampling points and traverse can be seen in **Figure 4.3.**

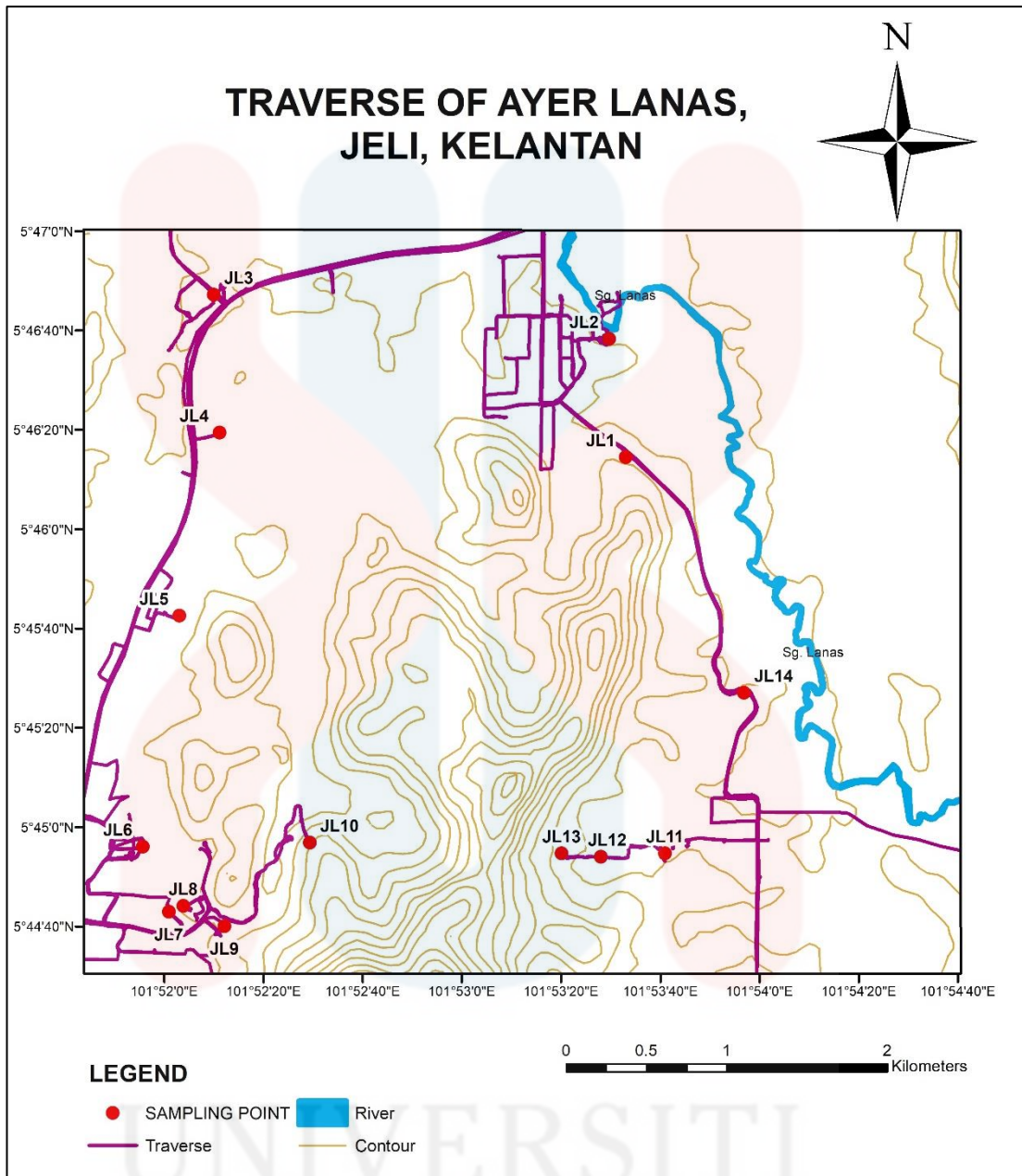


Figure 4.3: Traverse and sampling point of study area.

MALAYSIA
KELANTAN

4.2 Geomorphology

Geomorphology is the study of the characteristics, origin, and evolution of landforms and it is one of the geological aspects that need to be identified during fieldwork. Topography, weathering, and drainage pattern are discussed in this section because it is factors that influence the processes of the landform.

4.2.1 Geomorphologic Classification/Topography

Geomorphic classification is a categorization and definition of the nature, origin, and development of the landform. The landform is related to topographic features because it depends on the elevation of the area. Based on the elevation map that has been processed using Digital Elevation Model (DEM) data shows there are three types of landforms in the study area which are plains landform, low land, low hill, and hill. Each of the landforms has its elevation and the type of landform can be identified based on its elevation and contour line. **Table 4.1** shows the classification of the landform and their geomorphological unit. The types of the landform also became indicators to identify lithology units. The lowest elevation in this study area is 33 m and the highest elevation is 280 m. 33 m is the plains area and 280 m are the hilly area. The slope of the plains area is very gentle, and the hill area consists of a strong slope. The geomorphological unit of the slope has been identified based on the slope map. This study area is mostly covered by plains area because this is a settlement and plantation area. **Figure 4.4** and **Figure 4.5** show the geomorphological features of the study area. The topography map of the study area can be seen in **Figure 4.6**.

Table 4.1: Geomorphologic classification of Study Area





NO.	SYMBOL	GEOMORPHOLOGICAL UNIT	DRAINAGE PATTERN	LANDFORM	ELEVATION (m)
1.		Very gentle slope	Dendritic and parallel	Plains	33 – 60
2.		Gentle slope	Dendritic and parallel	Low land	61 – 100
3.		Moderate slope	Dendritic	Low hill	101–200
4.		Strong slope	Dendritic	Hill	200 - 500



Figure 4.4: Hilly Landform in UMK area.

KELANTAN



Figure 4.5: Sungai Lanas within study area.

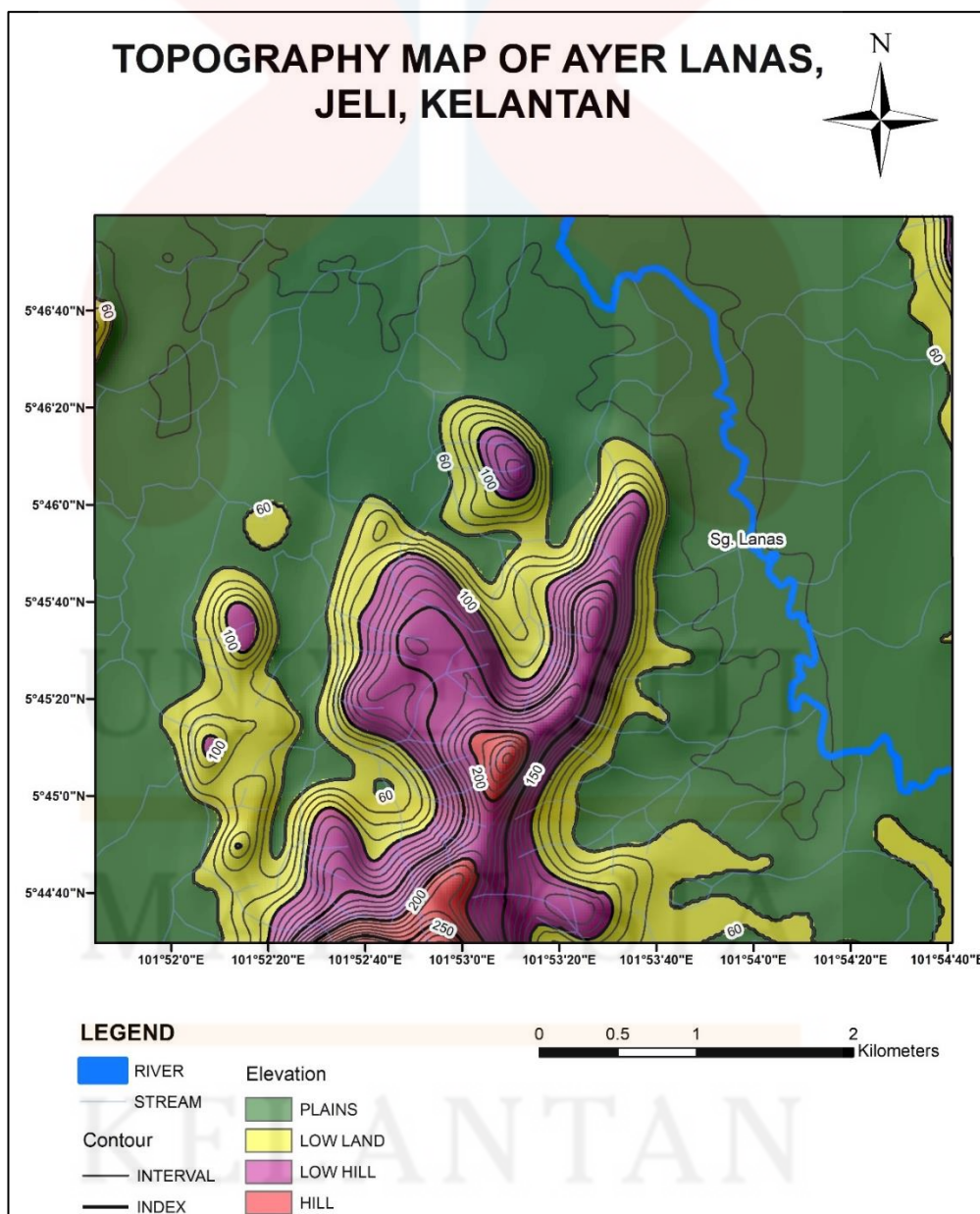


Figure 4.6: Topography map of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan.

4.2.2 Weathering

Malaysia is a country located on the equator line that has a tropical climate where it receives heavy rainfall and has a warm climate most of the time. The rate of the weathering process is influenced by several factors such as the material's properties, temperature, humidity, chemical reaction, time, and topography. Therefore, the rate of weathering in Malaysia has increased on the surface due to the weathering favours such as hot, warm, and damp weather. Weathering is the deterioration of rocks, soil, and minerals into smaller materials and there are three types of weathering which are physical weathering, chemical weathering, and biological weathering. Physical and biological also called mechanical weathering where there is no chemical change in their chemical compound.

Physical weathering is a disaggregation process of rock without changing its chemical composition or mineral content. The type of physical weathering is frost weathering, salt-crystal growth, hydraulic action, and thermal stress. This type of weathering is caused by main factors such as temperature change, wind, water, and glacial materials which happens in places that consist of limited soil and plant growth. The contraction and expansion give an effect on the rock which contributes to thermal stress due to the temperature change which reaction from heating and cooling. The uneven expansion and contraction cause the rocks to crack and break apart into smaller pieces. **Figure 4.7** shows the physical weathering of root wedging in JL7.



Figure 4.7: Physical weathering of root wedging in JL7

Biological weathering involves the weakening and subsequent disintegration of the rock by plants, animals, and microbes. The most common biological weathering occurred when the tree roots seep or grow through the cracks or joints, and the roots gradually separate the rock apart. This happened because when the plants grow, they exerted pressure on the rocks that subsequently break the bulk rock apart. The type of biological weathering is burrowing animals, root wedging, and organic material.

Figure 4.8 shows the biological weathering of lichen in JL12.



Figure 4.8: Biological weathering show lichen group in JL12

Chemical weathering is a chemical reaction that occurs in the rock when water dissolves mineral in rocks and form a new compound. Usually, chemical weathering occurs in humid tropical climates, and the type of chemical weathering are the solution, oxidation, and hydrolysis. Solution of chemical weathering occurs when the rock dissolves in a solvent and oxidation of chemical weathering happens when the rock turns into a rusty compound. The hydrolysis process happens when rock breakdown into clays mineral. This occurs when ion hydrogen reacts with ion in k-feldspar that can transform feldspar into clay mineral, potassium, and silica. Hot and wet environments can accelerate chemical weathering because they can occur in all environments, not including cold regions.

4.2.3 Drainage Pattern

The drainage pattern is a study of pattern that is formed by stream erosion over time, and it shows the types of rock and geological features in their area. It is formed by streams, rivers, and lakes in a particular drainage basin. The common types of drainage patterns are dendritic, trellis, rectangular, parallel, and radial pattern. The study area consists of a dendritic pattern and parallel pattern as shown in drainage maps (**Figure 4.9**), but this study area is dominated by a dendritic pattern. The dendritic pattern is the most common pattern of drainage, and it develops in areas where the rock and unconsolidated material below the stream has no structure and can be eroded equally in all directions. It resembles the branching pattern of tree roots. Examples of lithology that are associated with this drainage pattern are granite, gneiss, volcanic rock, and sedimentary rock that has not been folded. The parallel pattern is a pattern of rivers caused by steep slopes with some relief. It is formed where a slope exists, and the tributary stretches out in a parallel-like following the slope of the surface.

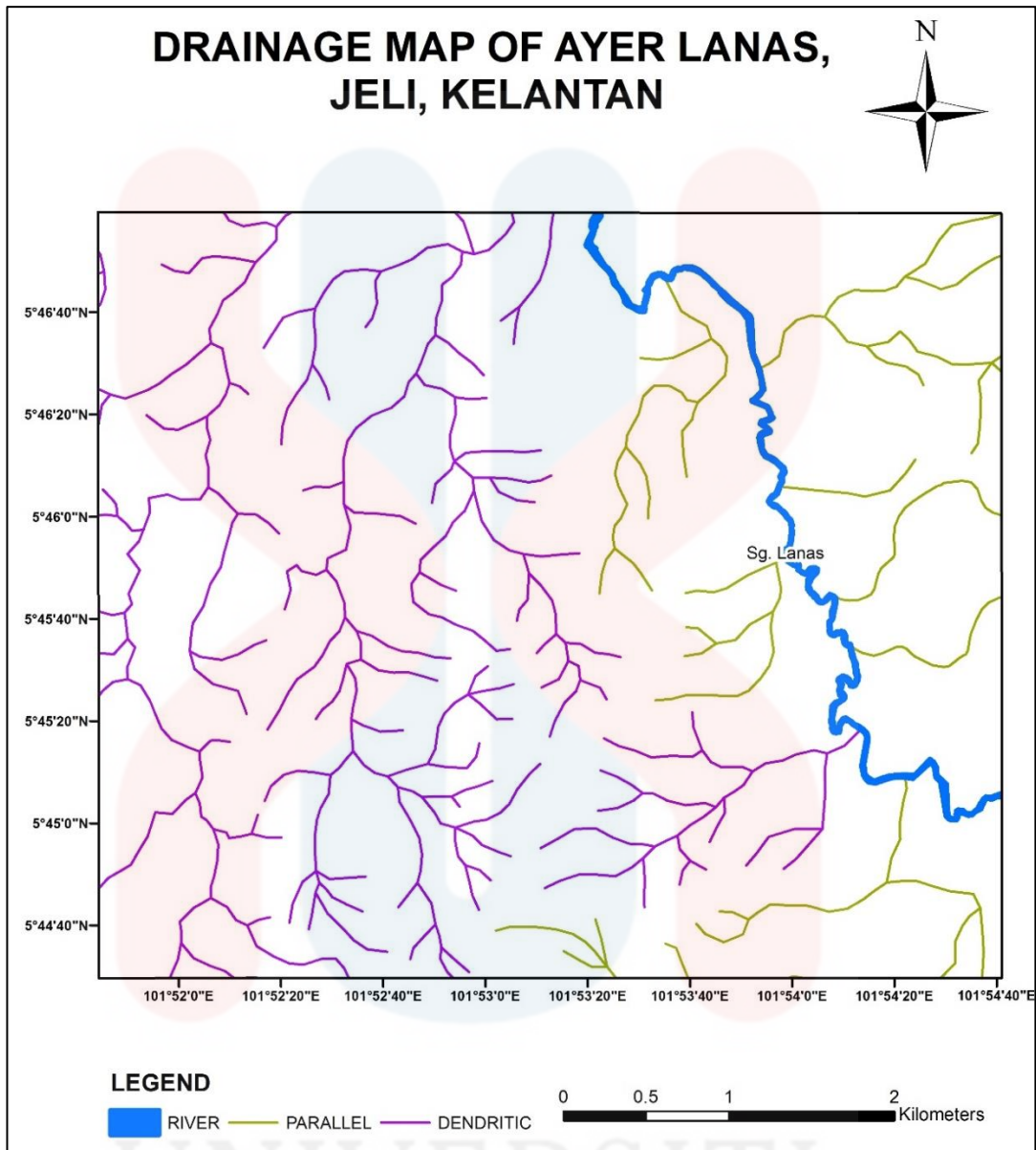


Figure 4.9: Drainage Map of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan.

UNIVERSITI
MALAYSIA
KELANTAN

4.3 Stratigraphy

The formation of this study area is Kemahang granite because the rock sample shows the characteristic of Kemahang granite which has alkali feldspar phenocryst mineral and a phaneritic texture. Granite rock consists of large and visible alkali feldspar minerals as a phenocryst with an average length is 2 cm.

4.3.1 Litho-Stratigraphy Unit

Lithostratigraphy is a study of the classification of rock bodies based on the observation of the lithological properties of strata and their stratigraphic positions. It is a basis for geological mapping and description of stratigraphic sections in outcrop. The lithology unit is described based on its characteristics such as color, texture, grain size, and mineral composition. In the study area, there are three types of lithology units which are the alluvial unit, granite unit, and slate unit. The alluvial unit is the youngest because it is from a Quaternary period in Cenozoic Era. This unconsolidated sediment is deposited in the flat and low-lying areas to the undulating area such as river areas (Sg. Lanas) and it consists of gravel, sand, silt, and clay material. The Granite unit is an acid intrusive rock, and its age is from the Triassic period in Mesozoic Era. The granite unit in this study area consists of alkali feldspar phenocryst mineral and the texture of the granite is coarse grains. The oldest rock unit in this study area is a slate from the Permian period in Paleozoic Era. **Table 4.2** shows the stratigraphy column of the study area and geological map as well as lithology map have been shown in **Figure 4.29**.

Table 4.2: Stratigraphic Column of Kg. Gemang and Kg. Ayer Lanas

LITHOLOGY	ROCK NAME	DESCRIPTION	ERA	PERIOD
	Alluvial	Alluvial consists of gravel, sand, silt, and clay. Widespread in the flat valley.	Cenozoic	Quaternary
	Granite	Acid intrusive rock	Mesozoic	Triassic
	Slate	Mainly consists of phyllite, shale, and slate	Palaeozoic	Permian

4.3.2 Petrography Analysis

a) Slate Unit

Slate in this study area is the oldest rock unit that forms during the Permian age. The coordinate of this outcrop is N 05°44'54" E 101°53'40" with an elevation of 64m. According to Adriansyah, D., et al., (2015), the Permian sedimentary rock of the Gua Musang Formation is consisting of phyllite, slate, sandstone, and limestone so the slate unit in this area is probably from Gua Musang Formation and it is a metamorphic rock with low-grade metamorphism. The color of this lithology is light grey to brown, and the texture is fine-grained. It is composed of clay minerals. **Figure 4.10** shows the outcrop and hand specimen of the slate unit at JL11.

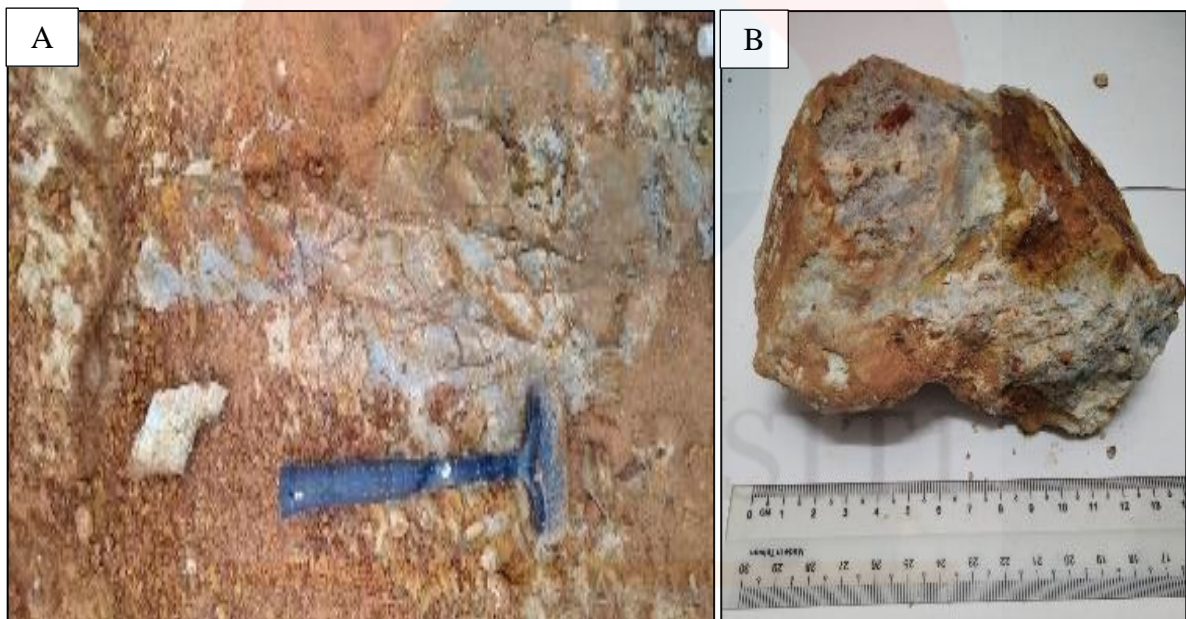


Figure 4.10: (A) Outcrop of Slate (B) Hand Specimen of Slate at JL11

MALAYSIA
KELANTAN

b) Granite Unit

A granite unit is an igneous rock that is underlain by a slate unit, which means granite is younger than slate. The age of granite in this study area is in Triassic Period in Mesozoic Era, it is part of Kemahang Granite. Granite units cover almost 50% of the study area and it is consisting of fresh granite and weathered granite. The weathered granite (dark color) has been found in the Sungai Lanas area which is the main river of the study area. The outcrop of weathered granite easily crumbles into mixtures of gravel-sized particles, sand, and silt-sized particles together with clay. **Figure 4.11** shows the outcrop and hand specimen of weathered granite. The fresh granite unit shows a grey color and has medium to coarse-grained megacrysts porphyry which contains alkali feldspar as the phenocryst. **Figure 4.12** shows the outcrop and hand specimen of granite.

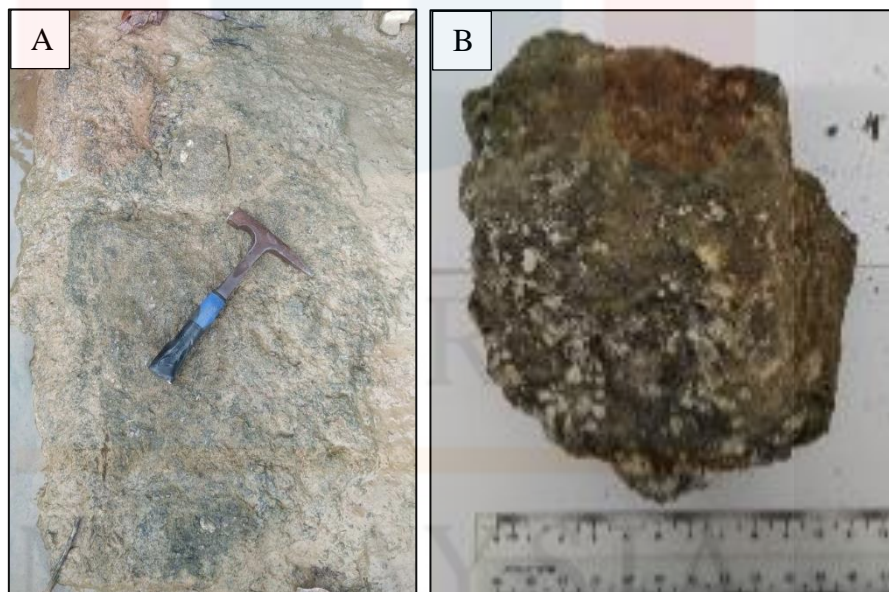


Figure 4.11: (A) Outcrop of weathered granite at JL2 (B) Hand Specimen of Weathered Granite at JL2

KELANTAN

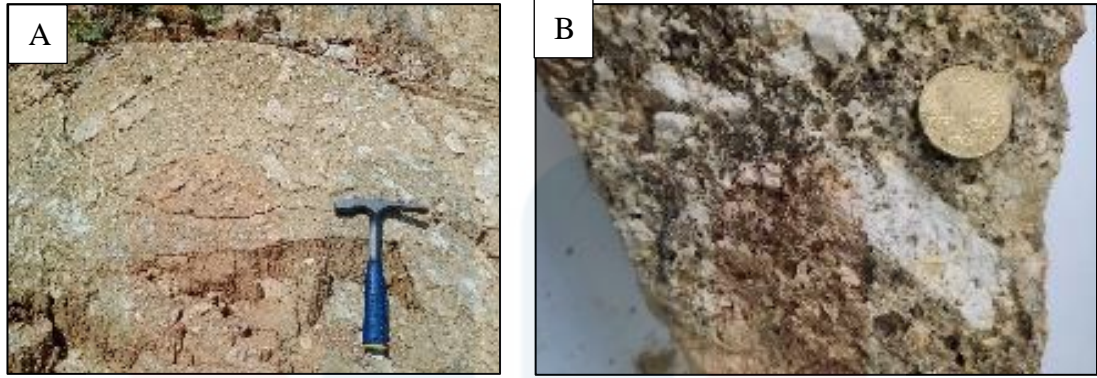


Figure 4.12: (A) Outcrop of granite at JL1 (B) Hand specimen of the megacrystic granite porphyry at JL1

JL1



Figure 4.13: Hand specimen of granite at JL1

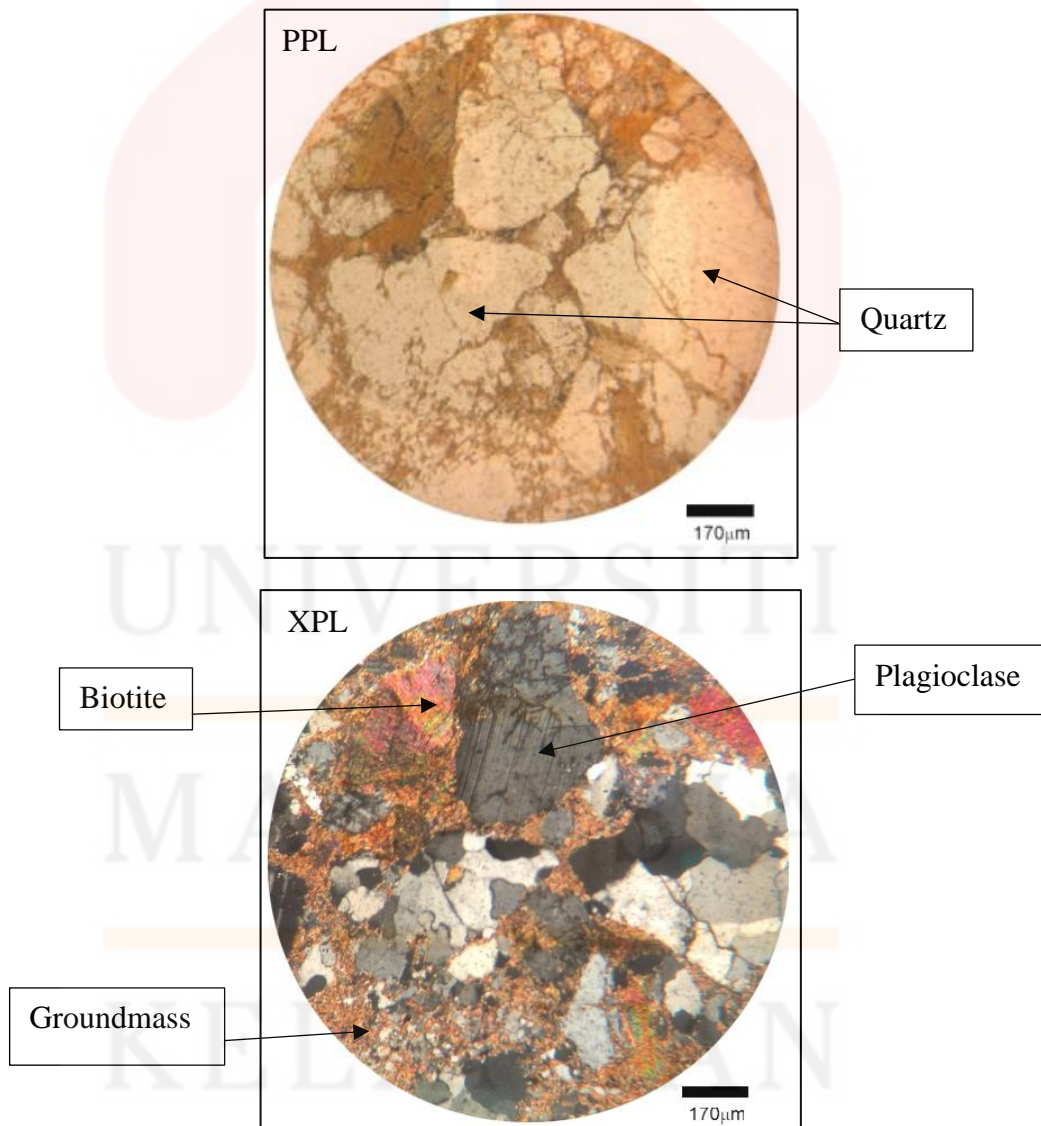


Figure 4.14: Thin section of granite at JL1

Table 4.3: Description of petrography analysis JL1

Sample : JL1		
Coordinate : N 05°46'14.5" E 101°53'33.1" Elevation : 88.7 m		
Rock Name: Biotite Granite (Igneous rock)		
Mineral Analysis		
Mineral Composition	Percentage of the mineral (%)	Description of mineral under XPL and PPL (Magnification 10X)
Quartz	60	The color of the quartz mineral under plane-polarized light (PPL) is colorless while in cross-polarized light (XPL) is grey. Quartz does not have cleavage and has low relief. Under XPL the interference color of quartz mineral is in the first order.
Biotite	15	Biotite minerals have a brown to tan color under PPL while under XPL it has darker brown. It is consisting of perfect cleavage without twinning and has moderate relief.
Plagioclase	15	The color of plagioclase mineral under PPL is colorless or cloudy with dirt while under XPL it has a grey to black color. This mineral has low to moderate relief with perfect cleavage. Plagioclase has a euhedral shape and under XPL it has a first-order interference color.
Groundmass	10	Quartz, biotite, and clay mineral.

JL7



Figure 4.15: Hand Specimen of granite at JL7

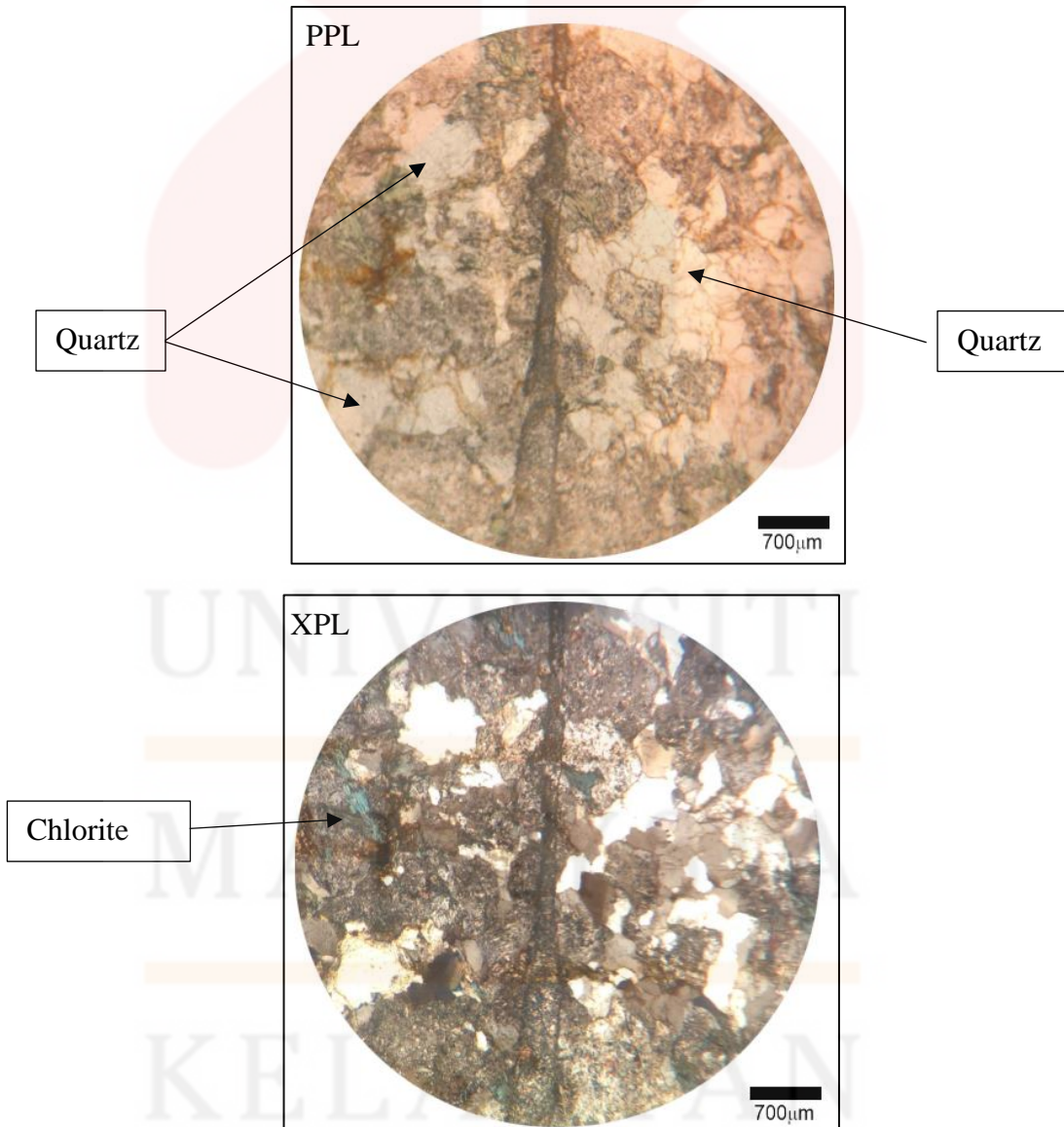


Figure 4.16: Thin section of granite at JL7

Table 4.4: Description of petrography analysis JL7

Sample : JL7		
Coordinate : N 05°44'42.9" E 101°52'01"		
Elevation : 60.0 m		
Rock Name: Granite (Igneous rock)		
Mineral Analysis		
Mineral Composition	Percentage of the mineral (%)	Description of mineral under XPL and PPL (Magnification 10X)
Quartz	70	The quartz mineral can be identified based on color in PPL and XPL. Under PPL quartz mineral is colorless while in XPL it is grey with an anhedral shape. It has low relief without cleavage.
Chlorite	30	The color of chlorite in the thin section is pale green under PPL and blue color under XPL. It has moderate pleochroism. Chlorite mineral has low relief and low birefringence distinctive. The twinning is difficult to recognize. The blue color of chlorite mineral is typical of optically negative crystals. Usually, it is found with biotite, garnet, and muscovite.

JL9



Figure 4.17: Hand specimen of granite at JL9

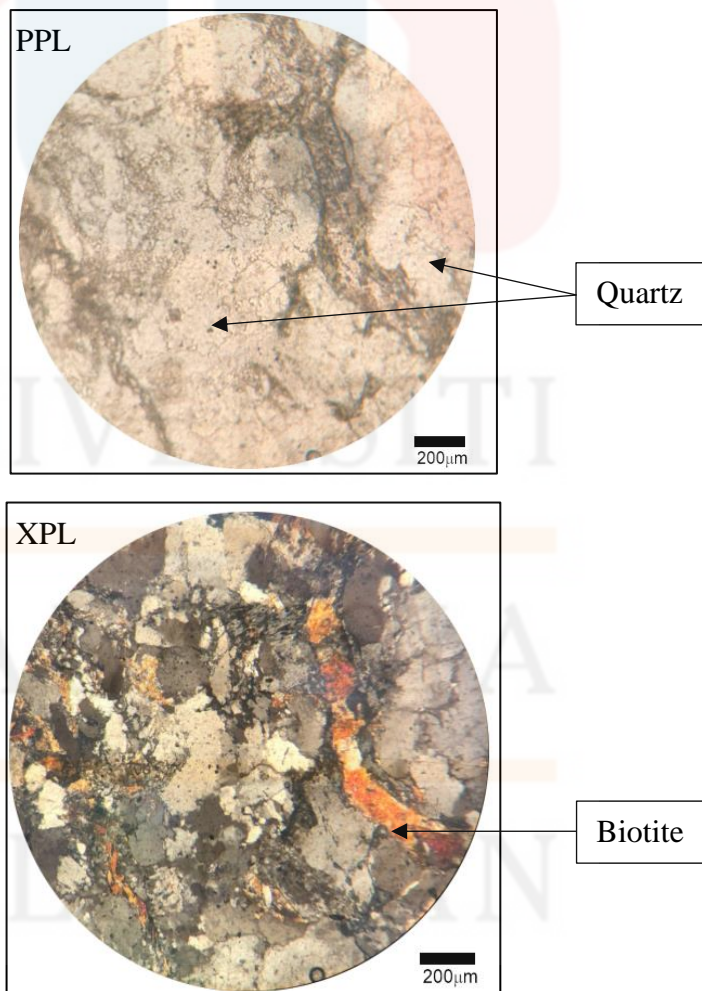


Figure 4.18: Thin section of granite at JL9

Table 4.5: Description of petrography analysis JL9

Sample : JL9		
Coordinate : N 05°44'40" E 101°52'12.1" Elevation : 76.0 m		
Rock Name: Granite (Igneous rock)		
Mineral Analysis		
Mineral Composition	Percentage of the mineral (%)	Description of mineral under XPL and PPL (Magnification 10X)
Quartz	75	The color of the quartz mineral under plane-polarized light (PPL) is colorless while in cross-polarized light (XPL) is grey. Quartz does not have cleavage and has low relief.
Biotite	25	The color of the biotite in XPL is orange to brown and it shows moderate to strong pleochroism. Relief of the biotite is moderate relief and has a cleavage. This mineral does not have twinning. This mineral is the common mineral in igneous rocks such as granites, diorites, gabbro, and peridotites.

JL13

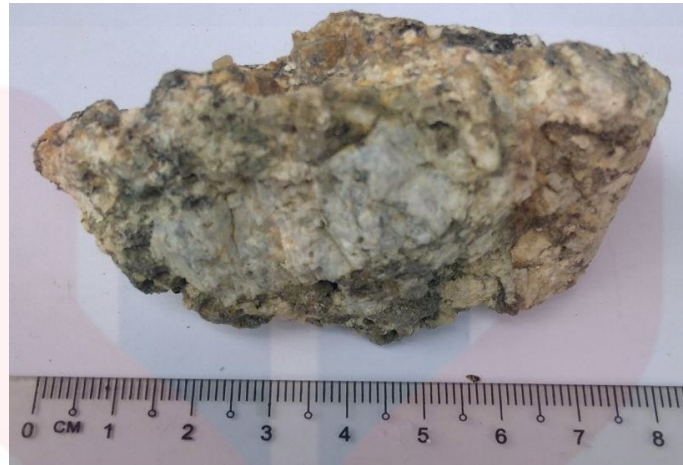


Figure 4.19: Hand Specimen of granite at JL13

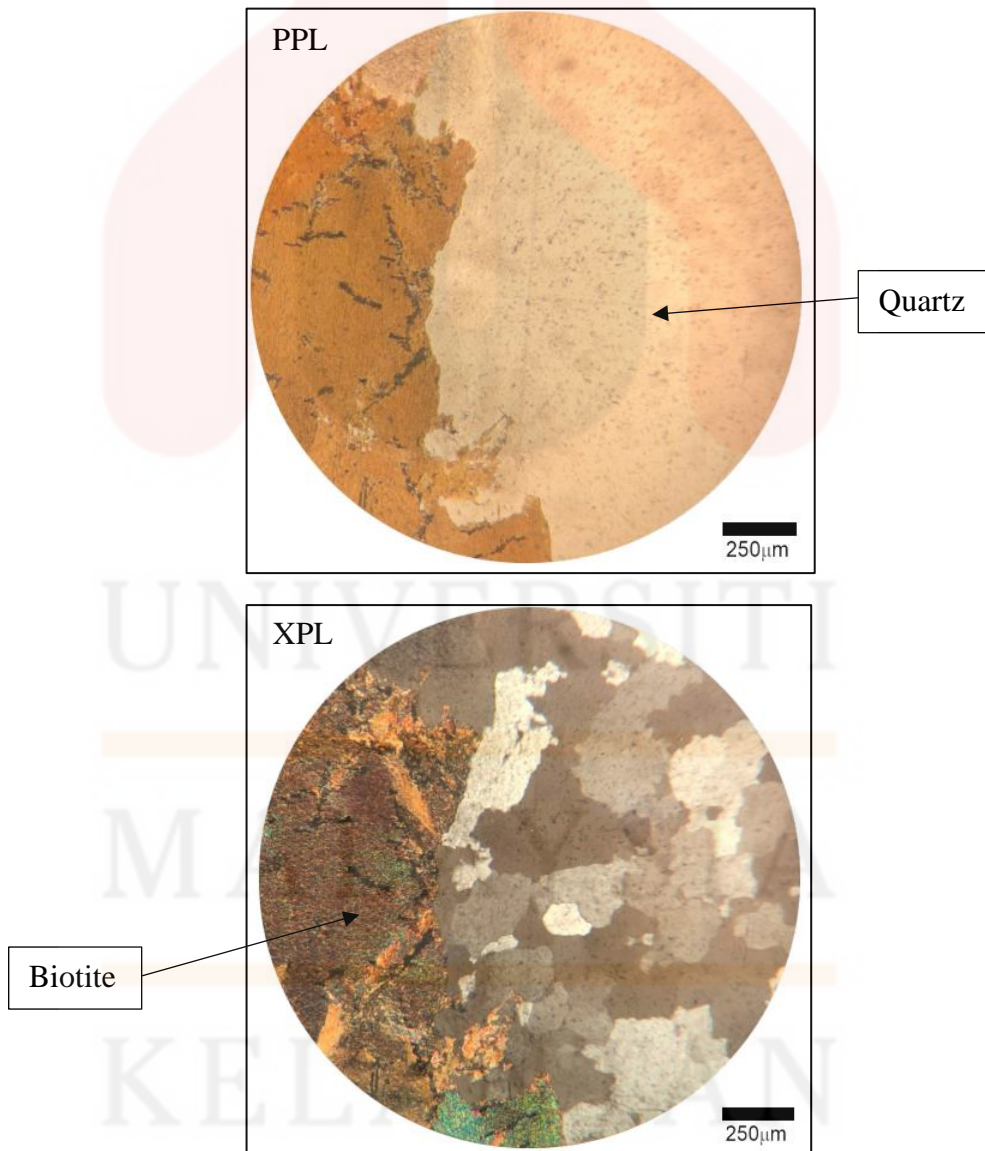


Figure 4.20: Petrography Analysis of granite at JL13

Table 4.6: Description of petrography analysis JL13

Sample : JL13		
Coordinate : N 05°44'53.9" E 101°53'21" Elevation : 64.8 m		
Rock Name: Granite (Igneous rock)		
Mineral Analysis		
Mineral Composition	Percentage of mineral (%)	Description of mineral under XPL and PPL (Magnification 10X)
Quartz	80	The color of the quartz mineral under plane-polarized light (PPL) is colorless while in cross-polarized light (XPL) is grey. Quartz does not have cleavage and has low relief. Under XPL the interference color of quartz mineral is in the first order
Biotite	20	Biotite minerals have a brown to tan color under PPL while under XPL it has darker brown. It is consisting of perfect cleavage without twinning and has moderate relief.

c) Hornfels Rock

Hornfels is a fine-grained metamorphic rock that forms at shallow depths due to the heat of contact metamorphism. The protolith of the hornfels is from igneous, sedimentary, and metamorphic rock. Hornfels rock has been collected in the river at Legeh area (JL12). Based on the hand specimen collected from the field, this rock consists of blackish color and aphanitic texture where the minerals are small and cannot be seen by the naked eye. **Figure 4.21** shows the hand specimen of the hornfels rock in the study area (JL12).



Figure 4.21: Hand specimen of hornfels rock at JL12

d) Alluvial deposit

Alluvial quaternary deposits are unconsolidated sediments that are deposited in the plains area and river areas by running water. Usually, it is dominated by silt, sand, clay, and gravel. The alluvial deposit can be observed in the main river in the study area which is Sg Lanas.

4.4 Structural Geology

Structural geology is the study of three-dimensional respect to the distribution of the rock unit, surfaces, and the composition of the interior. The structural geology that exists in the field can be found by measurement. Examples of structural geology are lineament analysis, veins, and joint analysis.

4.4.1 Lineament Analysis

Lineament analysis is a geological feature that represents geological structure or discontinuities in the rock mass such as faults and folds except for a ripple mark. **Figure 4.22** shows the lineament map of the study area. This map is a linear feature of the landscape that can be found on the topographic map, and it is formed in a regional area such as at the stream and ridges. Based on a rose diagram of lineament analysis of the study area in **Figure 4.23** it shows that the major force of the study area occurred in the NE direction.

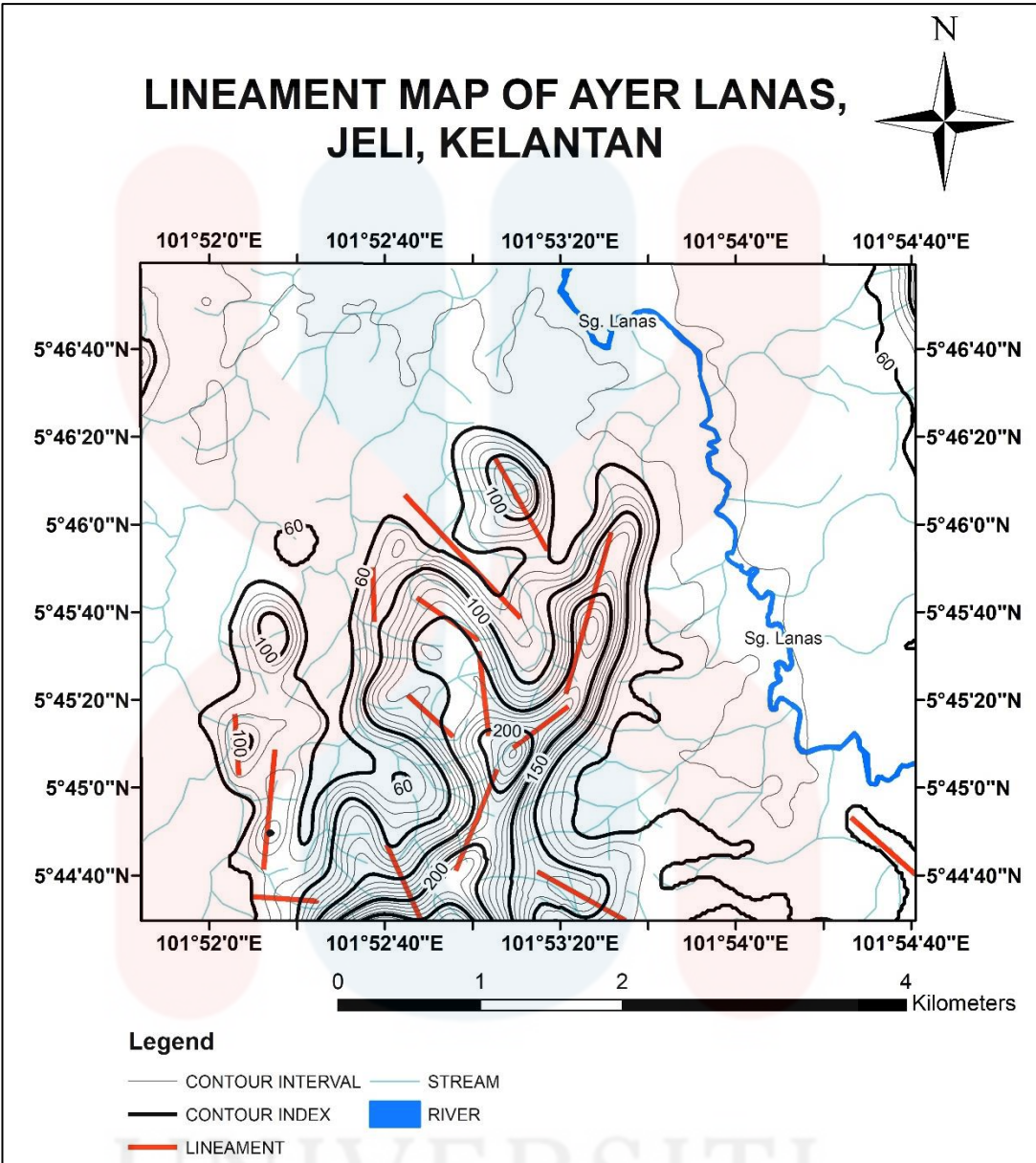


Figure 4.22: Lineament Map of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan.

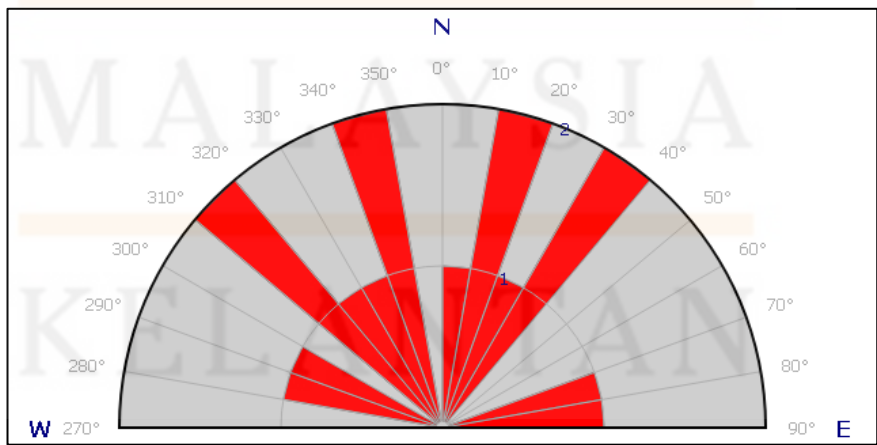


Figure 4.23: Rose Diagram from Lineament Data

4.4.2 Vein

The vein is a structure that forms when minerals are deposited in the fracture of the rock. **Figure 4.24** shows the quartz vein at JL11, and **Figure 4.25** shows the quartz vein on the outcrop at JL9. The vein is a white dull color, and it is dominated by quartz minerals and calcite that indicate fluid pressure. During fieldwork, the vein has been tested by HCl but does not react and it shows that the mineral in the vein is quartz. The quartz vein intruded granite rock and its mean vein is younger than granite rock.



Figure 4.24: Quartz Vein at JL 11



Figure 4.25: Quartz Vein at JL 9

4.4.3 Joint

A joint occurs from the brittle fracture of the rock due to tensile stress and it occurs at the surface of a rock. A Joint can extend in various directions called a set of discontinuity. Joints can be found in every lithology unit that is exposed. Joints filled by another mineral are called a vein while a joint filled by solidified magma is called a dike. **Figure 4.26** shows the conjugate joint at the outcrop JL7. The strike and dip of the joint were collected at outcrop JL9 where all the data was shown in **Table 4.7**. Rose diagrams have been produced based on the data in **Table 4.7**. Based on the rose diagram in **Figure 4.27** shows the force direction of the joint is from the NW direction.



Figure 4.26: Conjugate joint on the JL7.

MALAYSIA

KELANTAN

Table 4.7: Joints Data of outcrop JL9

No.	Strike	Dip/ Dip direction
1.	222	76 NW
2.	341	71 SE
3.	203	56 NW
4.	216	62 SW
5.	346	71 SW
6.	325	80 SW
7.	341	54 NE
8.	344	58 NW
9.	335	80 SW
10.	318	77 NW
11.	166	39 SW
12.	160	41 SW
13.	218	60 SW
14.	212	60 NW
15.	207	56 SW
16.	180	62 SW
17.	170	66 SW
18.	184	44 NW
19.	175	46 NW
20.	156	40 SW

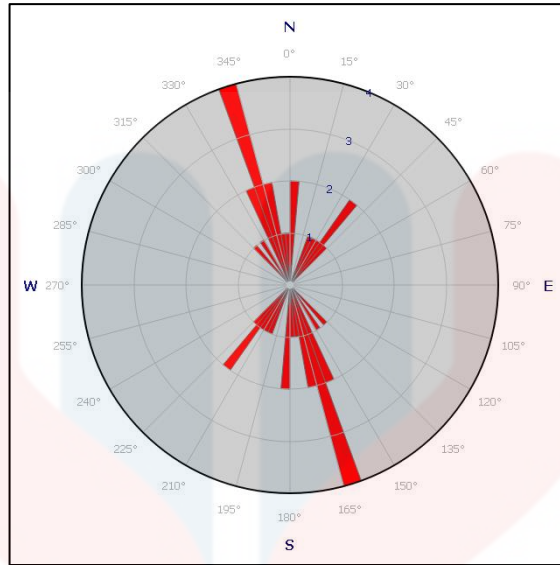


Figure 4.27: Rose diagram from data joint

4.5 Historical Geology

Kemahang Granite is located in the northernmost part of the Central Belt in Peninsular Malaysia and continues across the border into Thailand as the Sukhirin Granite Unit. It intruded into the north-western part of the Taku Schist and bordered by Gua Musang Formation and continued with Stong Complex to the west. The shear/fault zone develops after the granitic emplacement because of the presence of cataclastic granite gneisses (Khoo, 1980). This shearing is a result of movement along the NNW-SSE trending Galas Fault Zone that can be seen from steeply dipping mylonite rock indicating top to southwest shear. Kemahang Granite, Taku Schist, Stong Complex, and Tiang Schist form the footwall of the Taku detachment that was separated from the Gua Musang hanging wall by a similar top-SE shear deformation. **Figure 4.28** show the tectonic-stratigraphic plot of the Taku Schist and the surrounding units such as Kemahang Granite, Stong Complex, and Tiang Schist.

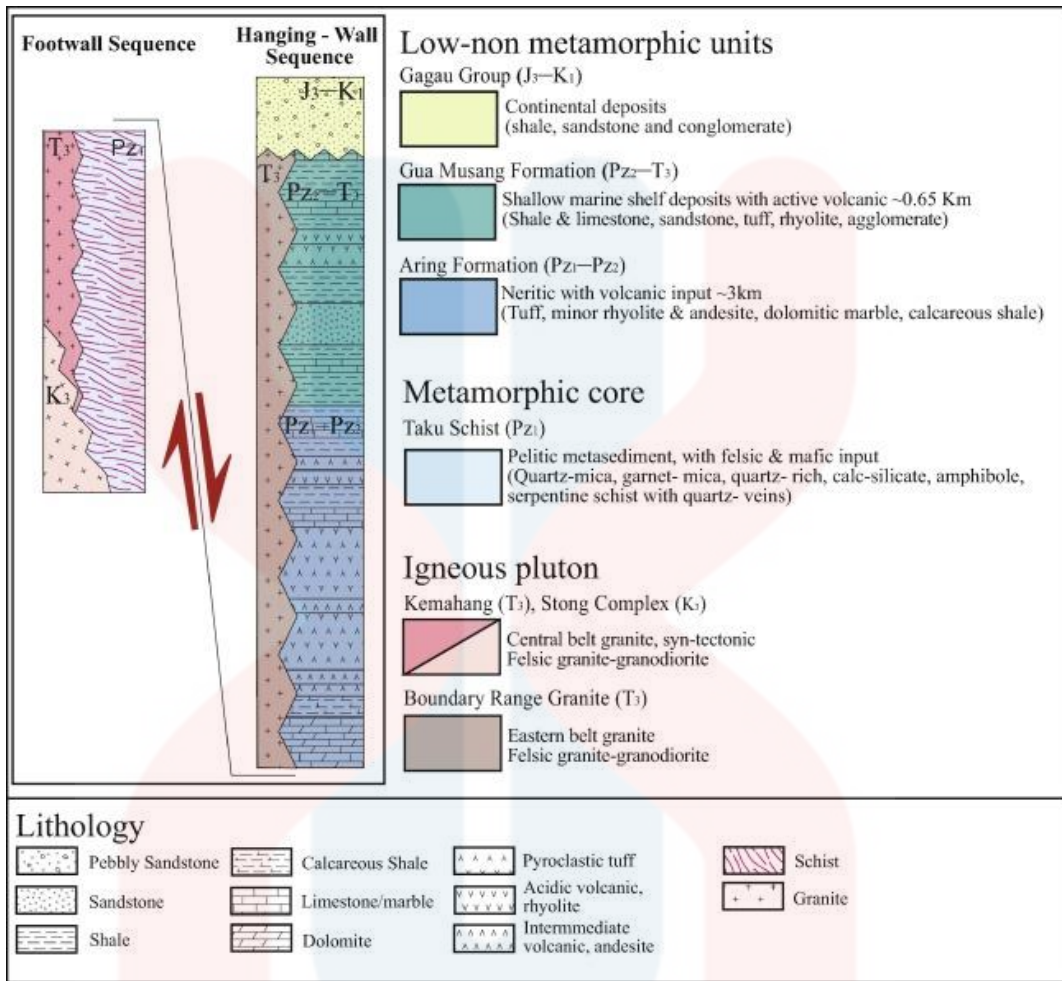


Figure 4.28: Tectonic-stratigraphic plot of the Taku Schist and the surrounding units (Kemahang Granite, Stong Complex, and Tiang Schist)

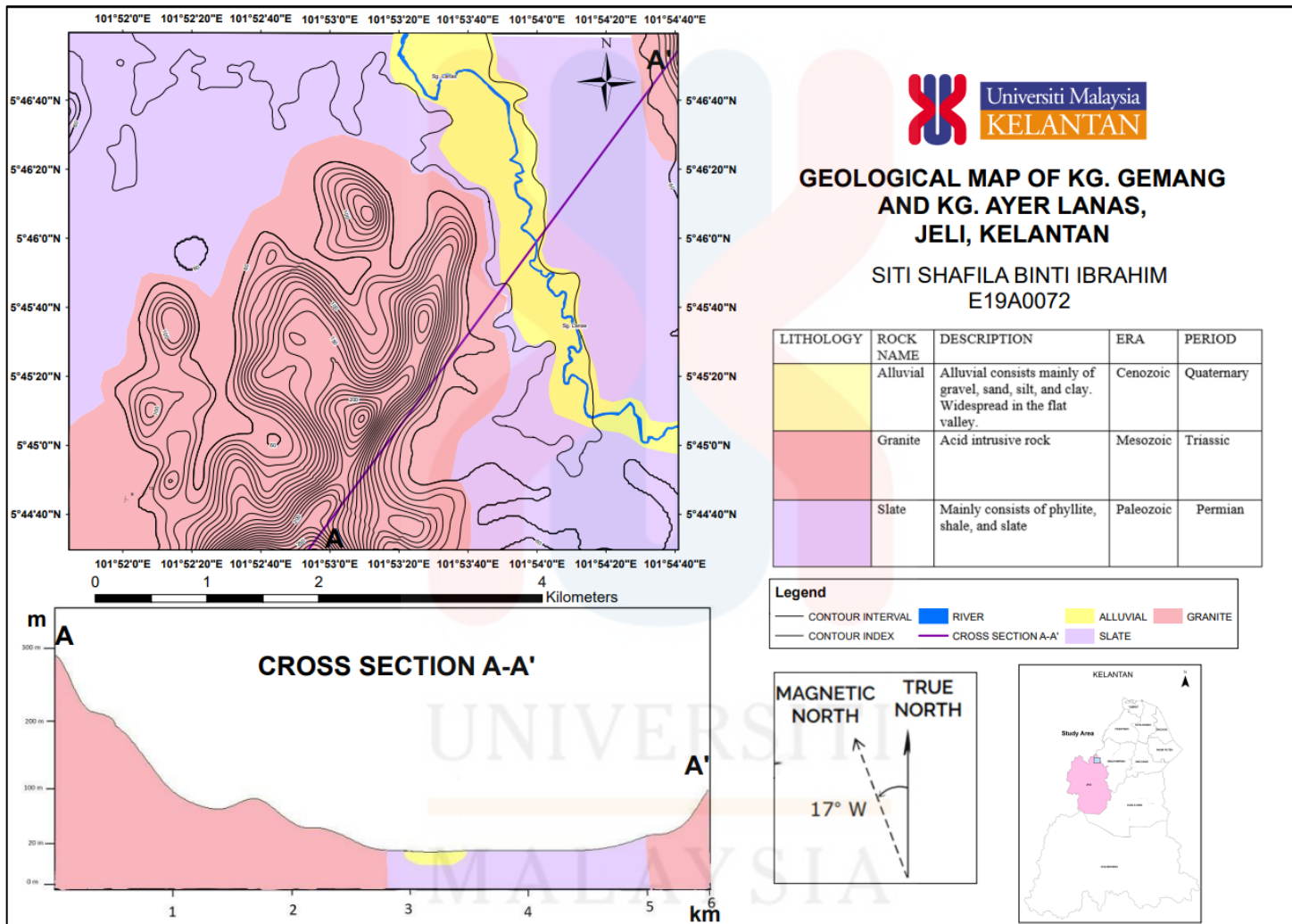


Figure 4.29: Geological Map and Lithology Map of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan.

CHAPTER 5

DISTRIBUTION OF RARE EARTH ELEMENTS IN SELECTED SOIL PROFILES IN JELI, KELANTAN

5.1 Introduction

This chapter discusses the distribution of rare earth elements (REE) in the selected soil profile in Jeli, Kelantan. The soil sample was collected around Jeli as well as in UMK Jeli, Kelantan. The soil sample that was collected during geological mapping undergoes a few analyses such as X-Ray Diffraction analysis (XRD), Inductively Coupled Plasma Mass Spectrometry (ICP-MS) analysis, and X-Ray Fluorescence (XRF) analysis. The result was displayed in the form of a graph and table and all the results from each analysis were interpreted and discussed in this chapter.

5.2 Sample Description

The sampling of the soil sample using a random-mapping method where only a selected soil profile has been chosen for soil sampling. **Table 5.1** shows the details of the sample that was collected from the field. Nine soil samples have been collected around the Jeli area and six samples were sent for ICP-MS analysis to know the concentration of REE in the samples. The picture of the sample and sampling point on the map can be referred **Figure 5.1**.

Table 5.1: Sample description from the study area (Figure of the rock and soil sample can refer to Appendix B).

SAMPLE	COORDINATE	DESCRIPTION
JL1	N 05°46'14.5" E 101°53'33.1" 88.7 m	The rock and soil sample has been collected at the roadside in the Legeh area. The hand specimen of the rock sample has a grey color, and it consists of feldspar phenocryst. The size of the rock sample is coarse grain. The color of the soil sample is orange and brown. It consists of fine to medium grain. The rock sample has been sent for petrography analysis and XRF analysis meanwhile the soil sample has been sent for XRD analysis.
JL2	N 05°46'38.3" E 101°53'29" 29.4 m	The rock sample was collected in a river area which is in Sg. Lanax. This river is the main river in this study area. The hand specimen shows a black color and the sample undergo chemical and physical weathering because it crumbles when hit with a hammer.
JL3	N 05°46'47" E 101°52'10" 51.4 m	The location of this hand specimen is near the river in the Ayer Lanax area. This rock is coarse grain and has light grey color.
JL4	N 05°46'19.5" E 101°52'11.2" 59.6 m	The location of soil sample is at the roadside in the Ayer Lanax area. The color of the sample is reddish-orange, and it consists of medium grain. The soil sample has been sent for XRD analysis.
JL5	N 05°45'42.6" E 101°52'3" 63.2 m	The location of soil sample is at the roadside in the Ayer Lanax area. The color of the sample is reddish-orange, and it consists of coarse to medium grain.
JL6	N 05°44'56" E 101°51'55" 63.5 m	The location of the soil sample is at the roadside in the UMK area. The color of the sample is brown, and it consists of fine to medium grain. The soil sample has been sent for XRD analysis and ICP-MS analysis.

Table 5.1: (Continued)

JL7	N 05°44'42.9" E 101°52'01" 60.0 m	The location of the rock sample is at the river in the UMK area. The color of the sample is grey, and it consists of medium to coarse grain. The structure in this outcrop is joint. The rock sample has been sent for petrography analysis.
JL8	N 05°44'44.1" E 101°52'03.9" 118 m	The location of the soil sample is in the FSB UMK area. The color of the sample is orange, and it consists of fine to medium grain. The soil sample has been sent for ICP-MS analysis.
JL9	N 05°44'40" E 101°52'12.1" 76.0 m	The location of the rock and soil sample is in the UMK area. The color of the rock sample is grey, and it consists of medium to coarse grain. The outcrop consists of a quartz vein. The color of the soil sample is reddish, and it has medium grain. The rock sample has been sent for petrography analysis and XRF analysis meanwhile soil sample has been sent for ICP-MS analysis.
JL10	N 05°44'56.9" E 101°52'29" 104.2 m	The location of the soil sample is at the hill in the UMK area. The color of the sample is blackish-red, and it consists of fine to medium grain. The soil sample has been sent for ICP-MS analysis and XRD analysis.
JL11	N 05°44'54" E 101°53'41" 64.2 m	The location of the rock and soil sample is in the Legeh area. The color of the rock sample is light grey, and it consists of fine grain. This area consists of a quartz vein. The color of the soil sample is orange, and the grains size is medium to coarse grain. The soil sample has been sent for XRD analysis.

Table 5.1: (Continued)

JL12	N 05°44'53.9" E 101°53'21.1" 62.4 m	The location of the rock sample is at the river in the Legeh area. The color of the sample is blackish, and it consists of fine grain. The rock sample has been sent for XRF analysis.
JL13	N 05°44'53.9" E 101°53'21" 64.8 m	The location of the rock sample is at the river in the Legeh area. The color of the sample is grey, and it consists of medium to coarse grain. This outcrop shows the phenocryst mineral which is the feldspar mineral. The rock sample has been sent for petrography analysis.
JL14	N 05°45'27" E 101°53'56.8" 48 m	The location of the soil sample is at the roadside in the Legeh area. The color of the soil sample is red to brownish, and it consists of medium grain.
JL15	N 5°40'14.64" E 101°41'58.62"	The location of the soil sample is at Lata Kashmir in Batu Melintang. The sample consists of fine grain and has a brown color. The soil sample has been sent for ICP-MS analysis.
JL16	N 5°45'20.88" E 101°44'31.62"	The location of the soil sample is at Kg Kalai in the Batu Melintang area. The color of the sample is brown and consists of medium grain. The soil sample has been sent for ICP-MS analysis.

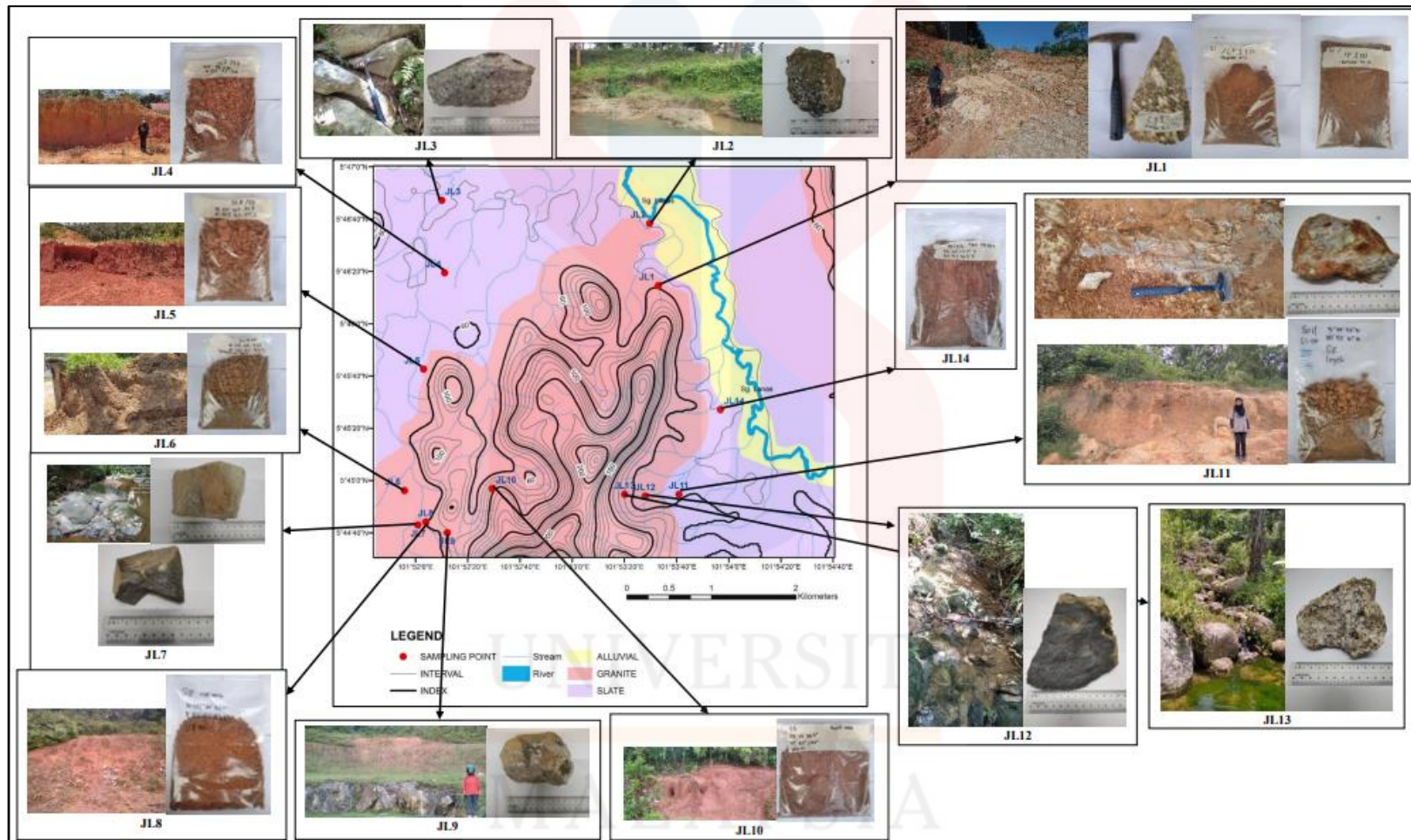


Figure 5.1: Sampling point of Kg. Gemang and Kg. Ayer Lanas, Jeli, Kelantan.

KELANTAN

5.3 Result & Discussion

The result of the XRF and ICP-MS analysis of the soil sample are shown in **Table 5.2**, **Table 5.3** and **Table 5.4** while the result of the XRD analysis is shown in **Figure 5.2**.

5.3.1 Result from X-ray Fluorescence (XRF)

The portable XRF S1 TITAN model 800 has been used to determine the major and trace elements in the rock sample. Three rock samples (JL1, JL9, and JL12) from various locations have been selected for analysis to determine the element composition in the rock as shown in **Table 5.2** and **Table 5.3**. Based on **Table 5.2**, the oxide elements such as SiO_2 , Al_2O_3 , and K_2O element are present in all samples, and MgO is only present in two samples which are JL1 and JL12 samples. Based on XRF analysis, SiO_2 is the highest percentage of the oxide composition in all samples where JL1 (78.77 %), JL9 (78.94 %), and JL12 (69.84 %) which represent the composition of quartz (SiO_2) in each sample. The percentage of the Al_2O_3 element in all samples shows the presence of corundum mineral that occurs in the soil by inheritance of the parent's rocks. Corundum minerals are usually associated with kaolinite, gibbsite, diaspore, zoisite, and sillimanite (Barak, P., and E.A. Nater., 2005). This can be supported by the result of the XRD analysis of JL1 in **Figure 5.2** where the peak of the graph shows the presence of the kaolinite and gibbsite. The highest percentage of SiO_2 in each sample indicates the presence of the quartz mineral this can be supported by petrography analysis of sample JL1 (**Figure 4.14**) and JL9 (**Figure 4.18**) where quartz mineral is the dominant mineral in each sample. Based on observation of the granite hand specimen (JL1) shows the presence of quartz mineral (**Figure 4.13**) and vein of quartz in JL9 (**figure 4.17**). Trace elements are the elements that occur in the mineral with a small amount of less than 0.1% as shown in **Table 5.3** and these

elements are not included in the chemical formula of the mineral. Based on **Table 5.3** the trace elements such as Ti, Mn Fe, Zn, Rb, Sr, Y, Sb, Ba, and Pb are present in each sample with low concentrations with ranged from 0.1 to 0.001 %. The rubidium, Rb element present in all samples which are 0.019% (JL1), 0.025% (JL9), and 0.011% (JL12), this element indicates the presence of orthoclase, a feldspar mineral in the sample because Rb is the common trace element in that mineral. The presence of the Au element only can be detected in a rock sample from JL9 with a percentage of 0.001% and the U element presence in a rock sample from JL1 (0.003%) and JL9 (0.002%). U is the radioactive element that is hazardous to the environment and humans if that element is present in high concentration.

Table 5.2: Composition of oxide elements in rock sample (JL1: Legeh area, JL9: UMK area, and JL12: Sg. Legeh area).

Element	Element Composition (%)		
	JL1	JL9	JL12
MgO	1.22	-	4.73
Al ₂ O ₃	16.65	13.92	23.27
SiO ₂	78.77	78.94	69.84
K ₂ O	3.36	7.14	2.15

Table 5.3: Composition of trace elements in rock sample (JL1: Legeh area, JL9: UMK area, and JL12: Sg. Legeh area).

Element	Element Composition (%)		
	JL1	JL9	JL12
P	0.041	-	0.052
S	-	-	0.204
Ca	1.231	0.299	8.276
Ti	0.034	0.073	0.255
V	0.019	0.009	0.019
Cr		0.006	0.013
Mn	0.014	0.015	0.067
Fe	2.279	0.991	4.796
Co	-	-	0.007
Ni	-	-	0.012
Cu	-	0.001	0.005
Zn	0.002	0.001	0.018
Ga	0.001	-	0.002
Rb	0.019	0.025	0.011
Sr	0.052	0.041	0.029
Y	0.004	0.003	0.002
Zr	0.009	0.011	-
Rh	-	0.005	-
Ag	0.002	-	-
Cd	0.001	-	-
Sn	0.007	-	-
Sb	0.003	0.005	0.003
Ba	0.263	0.262	0.012
La	0.013	-	-
Pb	0.005	0.005	0.002
Au	-	0.001	-
U	0.003	0.002	-

5.3.2 Result from X-ray Diffraction (XRD)

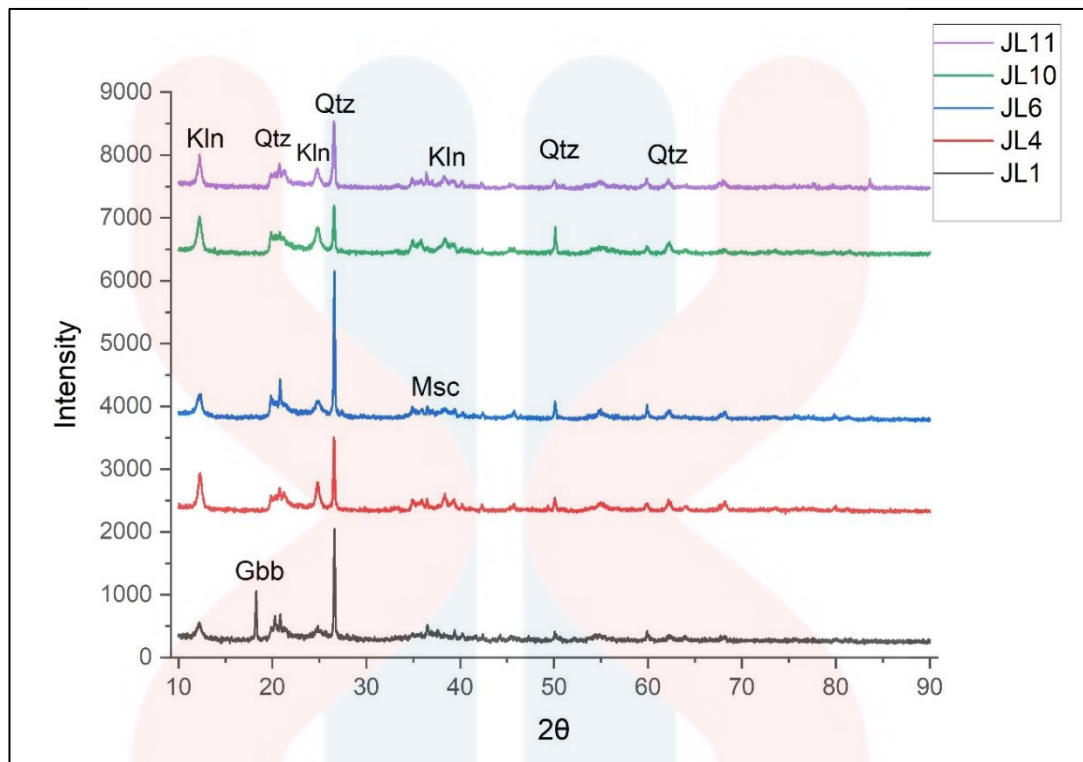


Figure 5.2: Result of XRD analysis of soil sample in Jeli area. (Qtz: Quartz, Kln: Kaolinite, Msc: Muscovite, Gbb: Gibbsite; Note: the intensity scale is a comparison and can be ignored because the XRD results are combined, JL1: Legeh area, JL4: Kg. Ayer Lanas area, JL6: Kg. Gemang area, JL10: UMK area, JL11: Sk. Legeh area).

Figure 5.2 shows the result of the XRD analysis of soil samples in the Jeli area, it shows the combination of five samples. The intensity scale can be ignored because this figure is for the comparison of the sample. Based on **Figure 5.2**, quartz mineral and kaolinite minerals are the dominant minerals in each soil sample except for JL1 because it consists of quartz and gibbsite. This also can be supported by the XRF result (**Table 5.2** and **Table 5.3**) because it shows the sample contains a higher percentage of SiO₂ and clay elements. The main mineralogical phases that can be detected in the soil sample of the selected soil profile are quartz and kaolinite. Gibbsite mineral can only be detected in sample JL1, and muscovite is detected in sample JL6. The sample JL6 was picked from the soil profile in Kg. Gemang shows the highest peak of quartz

mineral compared to the other sample because the concentration of SiO₂ composition in this sample is higher. This is also supported by petrography analysis of JL7 (**Figure 4.16**) where quartz veins can be identified in the thin section. Sample JL10 was collected in the soil profile at UMK, and the peak of the quartz mineral is lower than another sample because the composition of the SiO₂ in this sample is low. Gibbsite mineral is a secondary clay mineral and the presence of the gibbsite in sample JL1 shows that this sample is located in the tropical and subtropical environment that is usually found in lateritic formations, highly weathered soil, and clay deposits (Harrison, 1933). The presence of muscovite mineral in the JL6 sample shows that this sample consists of fine-grained sediments and the muscovite mineral is also found in the veins and pegmatite. This can be supported by the petrography analysis of JL7 (**Figure 4.16**) which shows the presence of the quartz veins in the thin section because the location of sample JL7 is close to sample JL6. The location and detail of all-sampling point can be referred Appendix B.

5.3.3 Result from Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

Table 5.4: Concentration of REE elements from ICP-MS analysis of six soil samples (JL6, JL8, JL9, and JL10: inside UMK area, JL15 and JL16: Batu Melintang).

Concentration (ppb)						
ELEMENTS	UMK Area				Batu Melintang	
	JL6	JL8	JL9	JL10	JL 15	JL 16
La	2190.9	3373.79	47542.75	8978.17	2346.55	7637.36
Ce	760.96	20668.22	54544.82	48381.1	2813.29	36788.55
Pr	664.66	983.27	12300.02	1954.79	771.03	1774.05
Nd	1417.02	3224.05	40762.94	5517.13	1644.33	5052.44
Sm	362.44	725.96	9552.91	906	580.73	994.82
Eu	22.55	54.78	1144.17	121.34	94.86	157.48
Gd	252.18	475.22	7454.07	575.96	336.19	650.29
Sc	275.79	5157.48	347.28	291.35	277.25	386.35
Y	11366.18	6490.34	21370.55	12526.16	10588.99	13855.77
Tb	330.4	350.69	1150.02	354.07	349.88	372.36
Dy	187.68	302.82	5591.69	319.51	367.17	464.99
Ho	281.03	288.3	926.31	298.17	309.07	311.91
Er	28.92	84.69	2449.89	99.06	160.87	166.59
Tm	225.64	229.49	478.5	233.38	246.45	238.6
Yb	43.48	111.55	1896.34	117.6	217.96	172.32
Lu	462.95	470.94	661.97	471.13	484.06	476.49
Th	223.55	10908.38	5320.8	5189.25	333.48	910.21
SUM of REE	19096.33	53899.97	213495.03	86334.17	21922.16	70410.58
SUM of LREE	5946.50	34662.77	173648.96	66725.84	8864.23	53441.34
SUM of HREE	12926.28	8328.82	34525.27	14419.08	12724.50	16059.00

MALAYSIA
KELANTAN

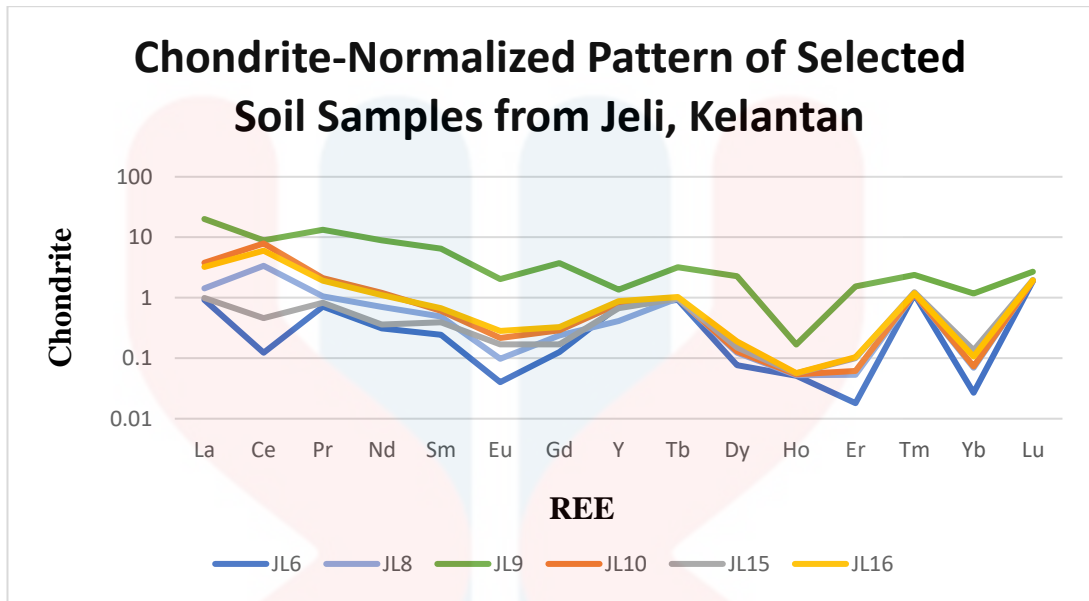


Figure 5.3: Chondrite-normalized pattern of the soil sample from selected soil profile in the Jeli area. (The pattern of this graph has been plotted using data of REE concentration that was converted to chondrite-normalization and it can be referred Appendix A).

ICP-MS analysis has been done by using ICP-MS PerkinElmer's NexION 2000 and the sample has been digested using Total Digestion Method by Microwave Digester PerkinElmer Titan MPS. The sample was diluted and measured using ICP-MS with the calibrated standards (REE elements). ICP-MS has been done to determine the concentration of REE in the selected soil profile in the Jeli area, and six soil samples from JL6, JL8, JL9, JL10, JL15, and JL16 have been selected for this analysis as shown in **Table 5.4**. The soil sample JL6, JL8, JL9 and JL10 is from the study area while soil sample JL15 and JL16 is from the Batu Melintang area. The soil sample from Batu Melintang have been analysed together with soil sample from study area is to know the difference between the REE concentration in the soil sample from the study area (Kemahang Granite formation) and Batu Melintang area (Strong Complex Formation). The concentration of REE in ppb unit can be referred to **Table 5.4** where the soil sample from JL9 shows the highest concentration of REE which is 213495.03 ppb because Ce element contributes to the highest concentration which is 54544.82

ppb and the soil sample from JL6 show the lowest concentration of REE which is 19096.33 ppb because the concentration of Ce element is lowest (760.96 ppb) compared to another sample. The highest concentration of Eu can be seen in JL9 with 1144.17 ppb while the lowest concentration of Eu can be seen in JL6 with 22.55 ppb. The concentration of each REE element contributed to the total concentration of REE in the soil sample. JL9 shows the highest enrichment of LREE with a concentration of 173648.96 ppb compared to HREE with a concentration of 34525.27 ppb because the soil sample was used for analysis. The enrichment of the Th element can be seen in JL8 which has a concentration of 10908.38 ppb while the enrichment of the Y element can be seen in JL9 which concentration of 21370.55 ppb.

The pattern of the REE concentration in **Figure 5.3** has been plotted using normalization factors from McDonough and Sun, (1995) and the table for the calculation of the chondrite-normalized can be referred to Appendix A. The pattern for all samples shows negative Ce anomaly and negative Eu anomaly. The pattern also shows that the concentration of LREE is highest than the concentration of HREE in samples this is because the LREE is more contradictory where they have bigger atomic radii and subsequently more concentration in the continental crust (Patah et al. (2021). Based on **Figure 5.3** samples JL8, JL10, and JL16 have similar patterns while JL6, JL9, and JL15 show slightly different patterns. The lowest negative Ce anomaly can be seen in JL6 where $(Ce/Ce^* \leq 1)$ and the lowest negative Eu anomaly can also be observed in JL6. The negative Ce anomaly depends on the concentration of REE in the sample and the fractionation trend of the sample is lower than the usual deposit because limited existence of accessory minerals that can carry REE together with them. The increase of REE concentration in soil or sediment depends on a few factors such as geological texture and composition of minerals in the soil. The soil that

contains high clay minerals and fine grains size has abundant REE. The sample from JL9 shows a slightly different pattern from another sample because this sample contains accessory minerals such as apatite minerals that can carry REE elements. This can be supported by petrography analysis of rock samples in JL9 as shown in **Figure 5.7**. Based on **Table 5.4** the total of LREE is high in all samples except the soil sample from JL6 and JL15. Both soil samples show the enrichment of HREE which is 12926.28 ppb (JL6) and 12724.50 ppb (JL15). The enrichment of HREE in soil samples occurs because of the mineral composition in the soil sample and this can be identified based on the color of the sample as shown in **Figure 5.4**. This figure shows both soil samples have similar color which is brown and consists of fine to medium grains. This can be compared with a soil sample from JL9 that shows the enrichment of LREE which is 173648.96 ppb, and it shows reddish color (**Figure 5.4**). The color of the soil depends on the mineralogy of the soil and the soil sample from JL9 consists of clay minerals and apatite minerals so that is why the soil sample from JL9 has a high concentration of LREE.

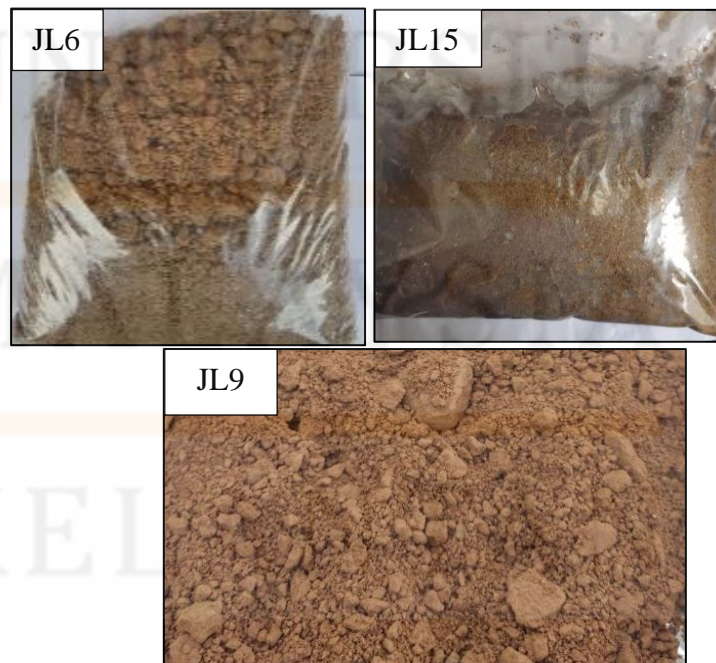


Figure 5.4: Soil sample from JL6, JL15 and JL9

5.3.4 Petrography Analysis of Accessory Mineral

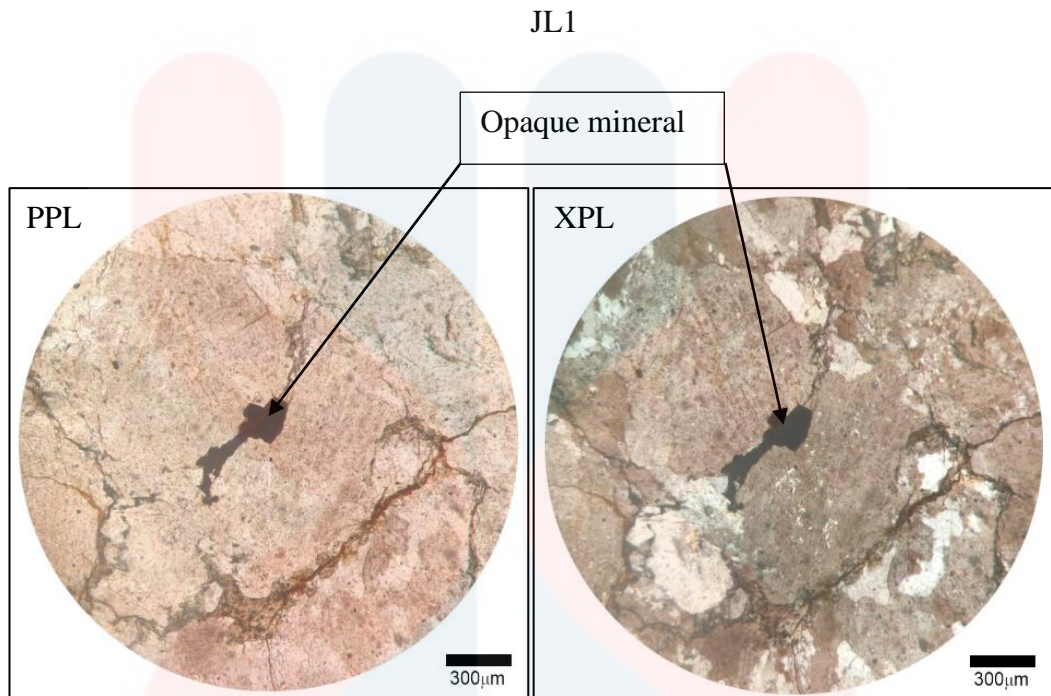


Figure 5.5: Thin section of the sample JL1

This sample has been collected at the roadside in the Legeh area. **Figure 5.5** shows the petrography image of the quartz mineral with opaque mineral in sample JL1. The magnification that uses for this image is 10x10 magnifications. Based on **Figure 5.5**, the opaque mineral shows a black color in PPL and XPL because it cannot transmit light in thin sections. This mineral is the common accessory mineral in igneous rock.

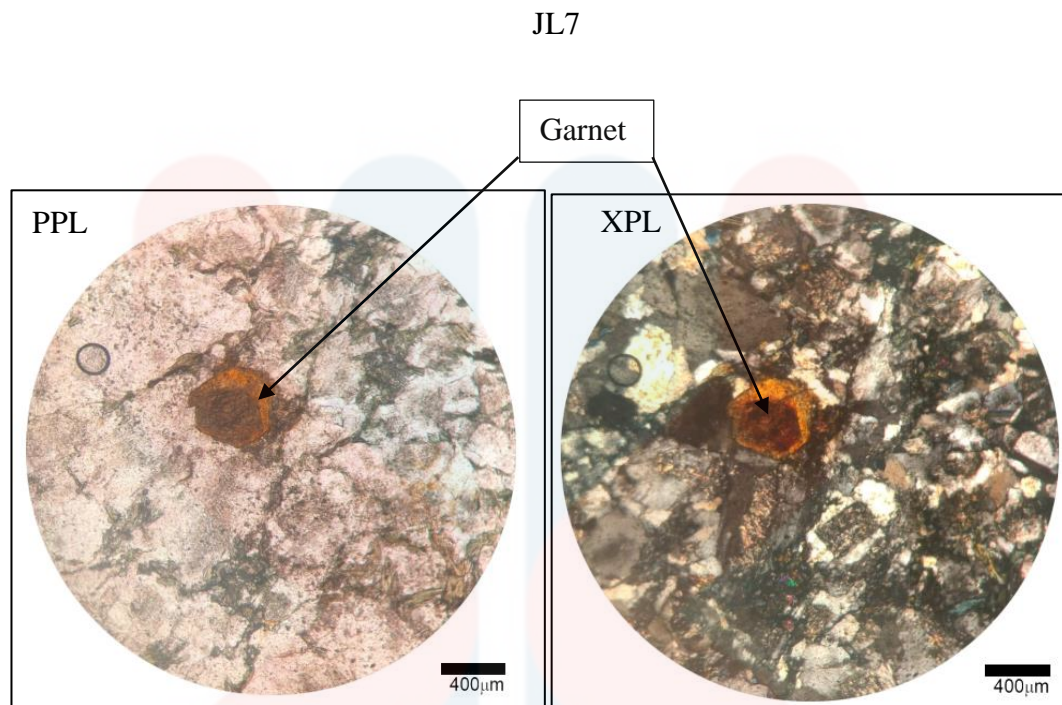


Figure 5.6: Thin section of the sample JL7

The hand specimen of JL7 has been collected in the UMK area. **Figure 5.6** show the petrography image of garnet mineral surrounded by quartz, biotite, and plagioclase mineral. The garnet mineral shows a brownish color in XPL and PPL. It also shows high relief and has a euhedral shape. This mineral does not have twinning and cleavage.

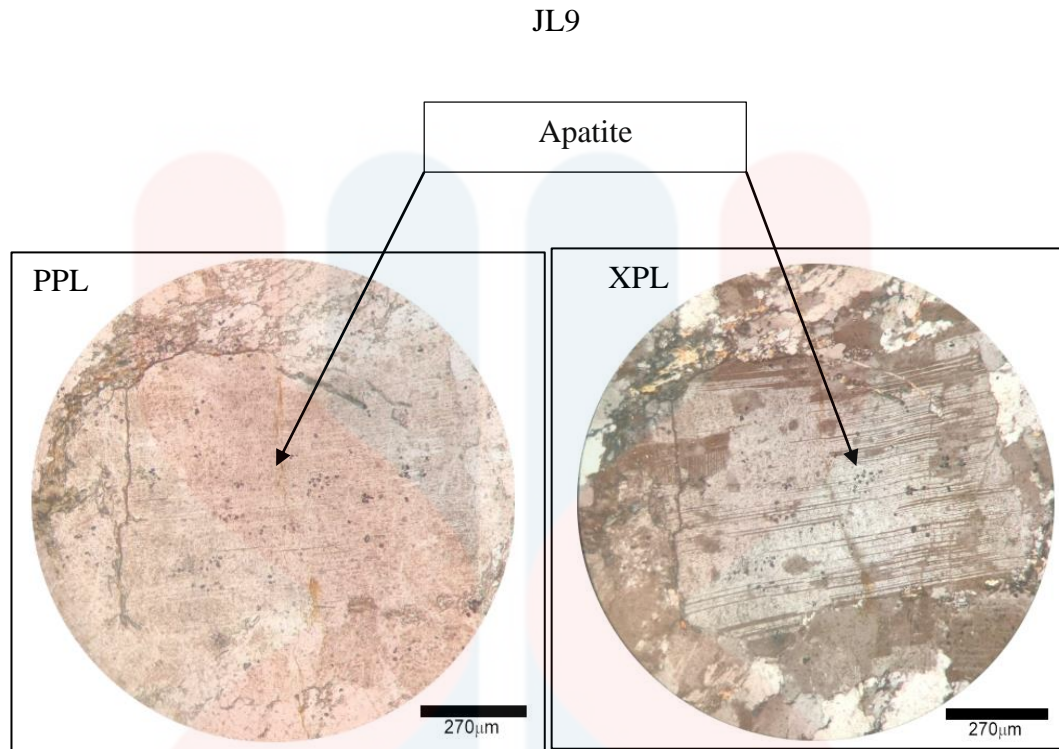


Figure 5.7: Thin section of sample JL9

This sample has been collected in the UMK area. **Figure 5.7** shows the petrography image of the apatite mineral with opaque mineral in sample JL9. The magnification that uses for this image is 10x10 magnifications. Based on **Figure 5.7**, the apatite mineral shows a pale brown color in XPL and is colorless in PPL. It shows moderate relief and has a euhedral to elongate prismatic shape. It has an imperfect cleavage that is parallel to the length of the mineral and the twinning of this mineral is rare to found.

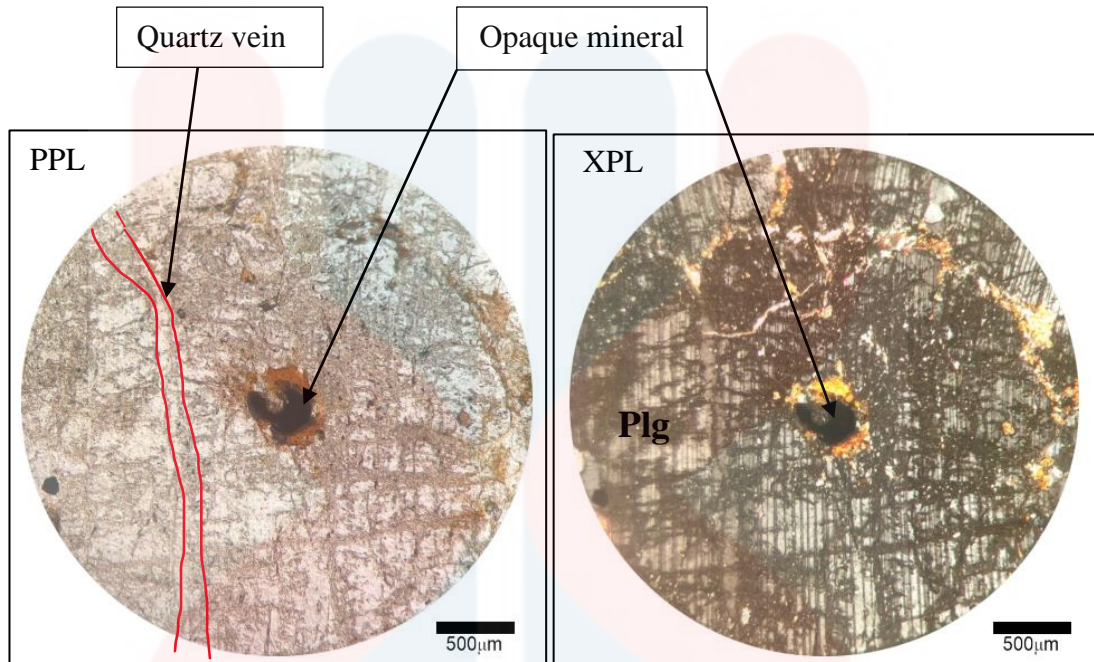


Figure 5.8: Thin section of sample JL13

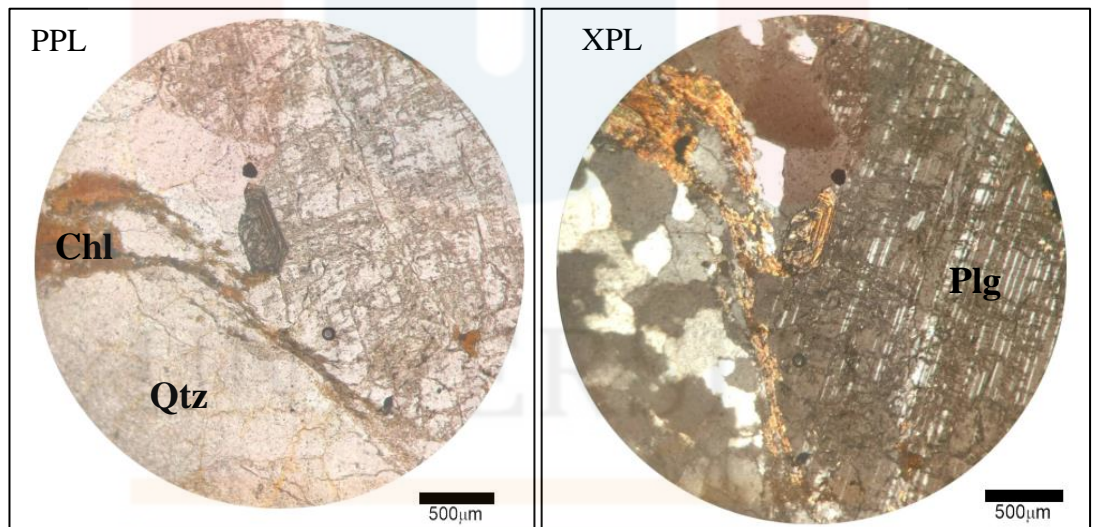


Figure 5.9: Thin section of sample JL13. (Chl: chlorite, Qtz: quartz, Plg: plagioclase)

This sample has been collected in the river at Legeh area. **Figure 5.8** shows the petrography image of the opaque mineral surrounded by plagioclase mineral in the sample JL13. The magnification that uses for this image is 10x10 magnifications. Based on **Figure 5.8**, the opaque mineral shows a black color in both PPL and XPL because it cannot transmit light in thin sections. The quartz veins (red line) also can be

seen in this thin section. **Figure 5.9** shows the quartz, biotite, and plagioclase mineral in the thin section JL13. The color of the quartz mineral is colorless in PLL and black to white in XPL. It has low relief and has anhedral to high irregular in igneous rock. Cleavage and twinning are absent in quartz minerals. Plagioclase mineral consists of low to moderate relief and occurs in euhedral and anhedral grains with tabular parallel and elongated parallel crystals. It has cleavage and lamellae twinning. Chlorite mineral consists of pale green and low to moderate relief. It also has moderate pleochroism and I to II order of interference color.

5.4 Discussion

The REE-bearing mineral such as monazite and xenotime does not present in the soil sample and that is why the concentration of REE is lower than expected. The accessory mineral such as apatite, ilmenite, and garnet in the sample only carry a limited concentration of REE. The concentration of REE in ppb units of all samples were shown in **Table 5.4**. Based on **Table 5.4** the highest enrichment of REE can be seen in the sample JL9 with a concentration of 213495.03 ppb (213.5 ppm) followed by samples JL10, JL16, JL8, JL15, and JL6 with the lowest concentration which is 19096.33 ppb (19.1 ppm). The petrography analysis of the rock sample shows the presence of accessory minerals such as apatite, ilmenite, and garnet mineral that carry REE elements in the sample. The highest concentration of Ce element in JL9 shows the enrichment of the REE in that sample. It is because the presence of apatite minerals in the JL9 (**Figure 5.7**) influences the enrichment of the REE. After all, apatite minerals can carry REE elements. XRF analysis of JL9 also shows the presence of Al_2O_3 element that indicates corundum mineral that is associated with clay minerals such as kaolinite, gibbsite, diasporite, zoisite, and sillimanite that can contribute to the enrichment of REE in the soil sample. The presence of clay minerals such as kaolinite and gibbsite in the soil sample from XRD analysis has shown that the REE was distributed in the clay deposit. Based on XRD analysis soil sample from JL10 shows the presence of the kaolinite mineral which is one of the important minerals that can carry REE. This can be supported by ICP-MS analysis (**Table 5.4**) which shows soil sample from JL10 has the second-highest concentration of REE. The presence of radioactive elements such as thorium Th in the sample also affects the concentration of REE because Th can destroy the texture of the host mineral such as micas and feldspar to transform them into clay minerals (Balan, 2001).

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In conclusion, the geological map of the Kg Gemang and Kg. Ayer Lanas area with scale 1:2500 has been updated as shown in chapter 4 (pg. 73). The distribution of the REE in the selected soil profile in Jeli Kelantan has been identified and analysed using geochemistry methods such as ICP-MS analysis, XRD analysis, and XRF analysis. The petrography analysis of the rock sample shows the presence of minerals such as quartz, plagioclase, chlorite, and biotite as well as accessory minerals such as garnet, ilmenite, and apatite in the rock sample. The rock unit in this study area consists of granite, hornfels, and slate as well as alluvial deposits. The distribution of the REE mineral in the selected soil profile is lower than expected because of the lack of REE-bearing minerals and accessory minerals that can carry rare earth elements in the soil because based on the petrography analysis of the JL1, JL7, JL9, and JL13 show the presence of accessory minerals such as garnet, ilmenite, and apatite but this mineral carries limited concentration of REE elements. XRD analysis shows the mineralogy of the soil sample such as soil sample JL1 that was collected in Legeh consists of the highest peak of quartz mineral compared to another mineral in the same sample. It is because the concentration of SiO₂ element is high which can be supported by the result of XRF analysis and petrography analysis where the presence of the quartz mineral (SiO₂) can be identified in the thin section of sample JL1.

6.2 Recommendations

For recommendations, the research on the REE distribution should be continuing with other locations around the Jeli area such as in Batu Melintang, Kuala Balah, and Jeli area to know the concentration of REE in the soil profile around Jeli. The other recommendation is to do research regarding the extraction of REEs from the ion absorption clay where the REE minerals are decomposed and ionized REEs are absorbed on clay mineral such as halloysite and kaolinite. This extraction of REEs in this deposit is easy to find and safe to extract by heap leaching. The REEs research is beneficial to the government and private sector because it contributes to their finding, and it also can help in the industry of REE mining in Malaysia as well as improve the exploration of the REE.

REFERENCES

- Adriansyah, D., Busu, I., Eva, H., & Muqtada, M. (2015). Geoheritage as the basis for geotourism development: A case study in Jeli District, Kelantan, Malaysia. *GeoJournal of Tourism and Geosites*, 15(1), 25-43.
- Balan, et al., 2001. Metamictization and chemical durability of detrital zircon. *Am. Mineral*. 86.
- Balasubramanian, A. (2017). CHARACTERISTICS OF SOIL PROFILE.
- Barak, P., and E.A. Nater. 2005. "The Virtual Museum of Minerals and Molecules: Molecular visualization in a virtual hands-on museum". *J. Nat. Resour. Life Sci. Educ.* 34:67-71.
- Beiranvand, A., & Hashim, M. (2017). Application of Landsat-8 and Alos-2 data for structural and landslide hazard mapping in Kelantan, Malaysia. *Natural Hazards and Earth System Sciences*, 17(7), 1285–1303.
- Borst, A.M., Smith, M.P., Finch, A.A., et al. (2020). Adsorption of rare earth elements in regolith-hosted clay deposits. *Nat Commun* 11, 4386.
- Brady, N. C. (2014). *Soil Physical and Chemical Properties*. The Nature and Properties of Soils | NRCS New Jersey.
- Brown, R. (2022). *Layers of soil: Definition, description with diagram (soil profile)*. Jotscroll.
- Buurman, P., & Breemen, N. V. (2002, January). *Soil Chemical Processes*
- Drobniak, A., & Mastalerz, M. (2022). Rare Earth Elements - A brief overview. *Indiana Journal of Earth Sciences*. 4. 10.14434/ijes. v4i1.33628.
- Castor, S.B., Hedrick, J.B., 2006. Rare Earth Elements. In: *Industrial Minerals*. Society for Mining, Metallurgy, and Exploration, Inc., Littleton, CO (United States), pp. 769–792.
- Evans, J.R., 1964, Xenotime mineralization in the southern Music Valley area, Riverside County, California: Sacramento, Calif., California Division of Mines and Geology Special Report 79, 24 p.
- Garis Panduan Eksplorasi Unsur Nadir Bumi. JMG.GP.20. Minerals and Geoscience Department Malaysia. Pp 17.
- Gupta, C. K., & Krishnamurthy N. (2005) Extractive metallurgy of the rare earths. CRC Press, Boca Raton, chapter 1.5, pp 22-25.
- Harrison, J.B., 1933. The Katamorphism of Igneous Rocks under Humid Tropical Conditions. Imperial Bureau of soil science, Harpenden, 79 pp.

- Hutchison, C. S., & Tan, D. N. (2009). *Geology of peninsular Malaysia* (Vol. 57). Published jointly by the University of Malaya and the Geological Society of Malaysia.
- Hu, G., Feng, Z., Dong, J., Meng, X., Xiao, Y., Liu, X., 2017. Mineral properties and leaching characteristics of volcanic weathered crust elution-deposited rare earth ore. *J. Rare Earths* 35, 906–910.
- Meldrum, et al., 1998. Radiation damage in zircon and monazite. *Geochim. Cosmochim. Acta* 62 (14).
- Metcalfe, I. (2012) Tectonic Evolution of the Malay Peninsula. *Journal of Asian Earth Sciences*.
- McDonough W. F. and Sun S.- s. (1995) " The composition of the Earth" *Chemical Geology* 120, 223–253.
- Myn, C. (2022) *Rare earth mining in Malaysia's Perak Forest raises environmental and health concerns, Eco. Eco-Business*.
- Patah, M. F., Shafiee, N. S., Ismail, R., Bahar, A. M., Khan, M. M., Eh Rak, A., & Awang, M. (2021). Distribution of light (LHREE) and heavy rare earth elements (HREE) in Kelantan granitoids rock. *IOP Conference Series: Earth and Environmental Science*, 842(1), 012038.
- Patricia, S. (2010). *Soil Composition*. University of Illinois
- Shafiee, N. S., Achmad Bahar, A. M., & Ali Khan, M. M. (2020). Potential of rare earth elements (rees) in Gua Musang Granites, Gua Musang, Kelantan. *IOP Conference Series: Earth and Environmental Science*, 549(1), 012027.
- Sulaiman, N., Sulaiman, N., Hussin, H., Achmad Bahar, A. M., & Udin, W. S. (2020). Diversification of igneous rocks and geoheritage values in Pergau, Jeli Kelantan. *IOP Conference Series: Earth and Environmental Science*, 549(1), 012020.
- Voncken, J., H., L. (2016). *The rare earth elements: An introduction*. Chapter 3 pp 53-71. Springer.
- Wang, Lingqing, & Liang, T. (2015). Geochemical fractions of rare earth elements in soil around a mine tailing in Baotou, China. *Scientific reports*. 5. 12483. 10.1038/srep12483.
- Yaraghi, A., Ariffin, K.S., Baharun, N., 2016. Geochemistry and mobility of REE associated with weathered lateritic tin-granite profile. *J. Malaysian Crit. Met.* 1, 39–45.
- Zhou, W., Han, G., Liu, M., Song, C., & Li, X. (2020). Geochemical distribution characteristics of rare earth elements in different soil profiles in Mun River basin, Northeast Thailand. *Sustainability*, 12(2), 457.

APPENDICES

Appendix A

Table 1: Result of the soil sample from ICP-MS Analysis (follow chondrite normalised by McDonough and SUN., 1995).






Concentration (ppb)						
ELEMENTS	UMK Area				Batu Melintang	
	JL6	JL8	JL9	JL10	JL15	JL16
La	9244.30	14235.40	200602.32	37882.57	9901.05	32225.15
Ce	1241.37	33716.51	88980.13	78925.12	4589.38	60013.95
Pr	7146.88	10572.80	132258.28	21019.25	8290.65	19075.81
Nd	3100.70	7054.81	89196.81	12072.49	3598.10	11055.67
Sm	2448.92	4905.14	64546.69	6121.62	3923.85	6721.76
Eu	402.68	978.21	20431.61	2166.79	1693.93	2812.14
Gd	1267.24	2388.04	37457.64	2894.27	1689.40	3267.79
Y	7239.61	4133.97	13611.82	7978.45	6744.58	8825.33
Tb	9177.78	9741.39	31945.00	9835.28	9718.89	10343.33
Dy	762.93	1230.98	22730.45	1298.82	1492.56	1890.20
Ho	510.96	524.18	1684.20	542.13	561.95	567.11
Er	180.75	529.31	15311.81	619.13	1005.44	1041.19
Tm	11282.00	11474.50	23925.00	11669.00	12322.50	11930.00
Yb	270.06	692.86	11778.51	730.43	1353.79	1070.31
Lu	18819.11	19143.90	26909.35	19151.63	19677.24	19369.51









(McDonough and SUN., 1995)





KELANTAN




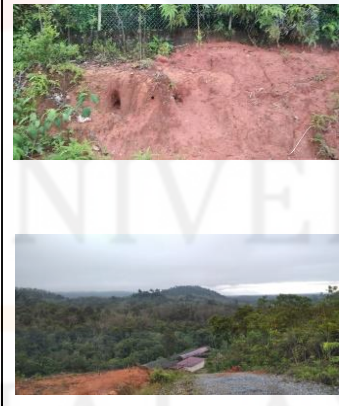

Appendix B

Table 2: Description table for sampling point.

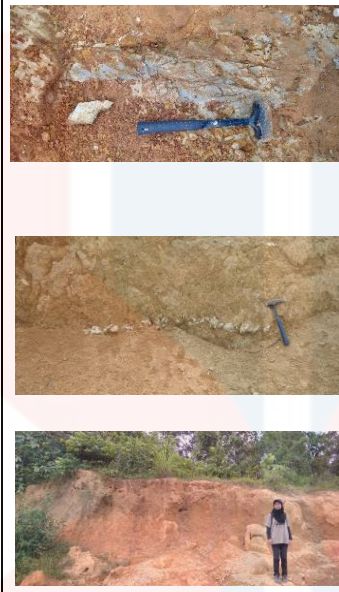






LOCATION	LITHOLOGY	TYPES OF SAMPLES	DESCRIPTION
<p style="text-align: center;">JL1</p> <p style="text-align: center;">N O5°46'14.5" E 101°53'33.1" 88.7 m</p>		<p style="text-align: center;">Rock: Granite</p>  <p style="text-align: center;">Soil</p> 	<p>The rock and soil sample has been collected at the roadside in the Legeh area. The hand specimen of the rock sample has a grey color, and it consists of feldspar phenocryst. The size of the rock sample is coarse grain. The color of the soil sample is orange and brown. It consists of fine to medium grain. The rock sample has been sent for petrography analysis and XRF analysis meanwhile the soil sample has been sent for XRD analysis.</p>
<p style="text-align: center;">JL2</p> <p style="text-align: center;">N O5°46'38.3" E 101°53'29" 29.4 m</p>		<p style="text-align: center;">Rock: Granite</p> 	<p>The rock sample was collected in a river area which is in Sg. Lanas. This river is the main river in this study area. The hand specimen shows a black color and the sample undergo chemical and physical</p>




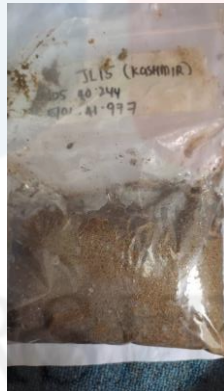


			weathering because it crumbles when hit with a hammer.
<p>JL3</p> <p>N 05°46'47" E 101°52'10" 51.4 m</p>		<p>Rock: Granite</p> 	<p>The location of this hand specimen is near the river in the Kg Gemang area. This rock is coarse grain and has light grey color.</p>
<p>JL4</p> <p>N 05°46'19.5" E 101°52'11.2" 59.6 m</p>		<p>Soil</p> 	<p>The location of soil sample is at the roadside in the Ayer Lanas area. The color of the sample is reddish-orange, and it consists of medium grain. The soil sample has been sent for XRD analysis.</p>
<p>JL5</p> <p>N 05°45'42.6" E 101°52'3" 63.2 m</p>		<p>Soil</p> 	<p>The location of soil sample is at the roadside in the Ayer Lanas area. The color of the sample is reddish-orange, and it consists of coarse to medium grain.</p>
<p>JL6</p> <p>N 05°44'56" E 101°51'55" 63.5 m</p>		<p>Soil</p> 	<p>The location of the soil sample is at the roadside in the UMK area. The color of the sample is brown, and it consists of fine to medium grain. The soil sample has been sent for XRD</p>

			analysis and ICP-MS analysis.
<p>JL7</p> <p>N O5°44'42.9" E 101°52'01" 60.0 m</p>		<p>Rock: Granite</p> 	<p>The location of the rock sample is at the river in the UMK area. The color of the sample is grey, and it consists of medium to coarse grain. The structure in this outcrop is joint. The rock sample has been sent for petrography analysis.</p>
<p>JL8</p> <p>N O5°44'44.1" E 101°52'03.9" 118 m</p>		<p>Soil</p> 	<p>The location of the soil sample is in the FSB UMK area. The color of the sample is orange, and it consists of fine to medium grain. The soil sample has been sent for ICP-MS analysis.</p>

<p>JL9</p> <p>N 05°44'40" E 101°52'12.1" 76.0 m</p>		<p>Rock: Granite</p>  <p>Soil</p> 	<p>The location of the rock and soil sample is in the UMK area. The color of the rock sample is grey, and it consists of medium to coarse grain. The outcrop consists of a quartz vein. The color of the soil sample is reddish, and it has medium grain. The rock sample has been sent for petrography analysis and XRF analysis meanwhile soil sample has been sent for ICP-MS analysis.</p>
<p>JL10</p> <p>N 05°44'56.9" E 101°52'29" 104.2 m</p>		<p>Soil</p> 	<p>The location of the soil sample is at the hill in the UMK area. The color of the sample is blackish-red, and it consists of fine to medium grain. The soil sample has been sent for ICP-MS analysis and XRD analysis.</p>

UNIVERSITY
MALAYSIA
KELANTAN

<p>JL11</p> <p>N O5°44'54" E 101°53'41" 64.2 m</p>		<p>Rock: Slate</p>  <p>Soil</p> 	<p>The location of the rock and soil sample is in the Legeh area. The color of the rock sample is light grey, and it consists of fine grain. This area consists of a quartz vein. The color of the soil sample is orange, and the grains size is medium to coarse grain. The soil sample has been sent for XRD analysis.</p>
<p>JL12</p> <p>N O5°44'53.9" E 101°53'21.1" 62.4 m</p>		<p>Rock: Hornfels</p> 	<p>The location of the rock sample is at the river in the Legeh area. The color of the sample is blackish, and it consists of fine grain. The rock sample has been sent for XRF analysis.</p>
<p>JL13</p> <p>N O5°44'53.9" E 101°53'21" 64.8 m</p>		<p>Rock: Granite</p> 	<p>The location of the rock sample is at the river in the Legeh area. The color of the sample is grey, and it consists of medium to coarse grain. This outcrop shows</p>

			the phenocryst mineral which is the feldspar mineral. The rock sample has been sent for petrography analysis.
<p>JL14</p> <p>N 05°45'27" E 101°53'56.8" 48 m</p>		<p>Soil</p> 	<p>The location of the soil sample is at the roadside in the Legeh area. The color of the soil sample is red to brownish, and it consists of medium grain.</p>
<p>JL15</p> <p>N 5°40'14.64" E 101°41'58.6"</p>		<p>Soil</p> 	<p>The location of the soil sample is at Lata Kashmir in Batu Melintang. The sample consists of fine grain and has a brown color. The soil sample has been sent for ICP-MS analysis.</p>
<p>JL16</p> <p>N 5°45'20.88" E 101°44'31.6"</p>		<p>Soil</p> 	<p>The location of the soil sample is at Kg Kalai in the Batu Melintang area. The color of the sample is brown and consists of medium grain. The soil sample has been sent for ICP-MS analysis.</p>