GEOLOGY AND GEOCHEMISTRY OF GRANITOID ROCK OF PANGGONG LALAT, GUA MUSANG

By

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

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DECLARATION

I declare that this thesis entitled Geology and Geochemistry of Granitoid Rocks of Panggong Lalat, Gua Musang, Kelantan is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

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

Signature : ________________________________

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Date : ________________________________

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GEOLOGY AND GEOCHEMISTRY OF GRANITOID ROCKS IN PANGGONG LALAT, GUA MUSANG, KELANTAN

ABSTRACT

This research focussed on the geology and geochemistry of granitoid rocks in Panggong Lalat , Gua Musang Kelantan. The objectives of the research are to produce the geological map of 1:25000 scales of the study area, determined the petrography and geochemistry analysis of granitoid rock in Panggong Lalat and to investigate the distribution of Rare Earth Elements (REE) with different granite types in Panggong Lalat area. To achieve the objectives, few method have been applied such as the geological mapping, petrography and geochemical analysis using XRF analysis and ICP-MS analysis.The lithology of the study area was granite, well-bedded limestone and metamorphic rocks of slate and they are included in the Permian toTriassic age. For the specification of the research study, petrography and geochemistry analysis of granitoid rocks were also studied as there were lacks of information regarding geochemistry analysis of granitoid rock in the study area. From the major and trace elements from XRF analysis, granitoid classification of the study area was identify. Based on the result, the study area are composed of I-type and A-type granite with IUGS classification of Phaneritic Quartz Monzonitete for pink granite and Phaneritic Quartz Syenite for grey granite. The tectoning settings for both pink and grey granite were determined from their trace elements and their granite types as A-type granite was found in batholith zone while I-types granite's tectonic setting was in subduction zone. Panggong Lalat area show the highest distribution of Rare Earth Elements in Gua Musang based on ICP-MS analysis as Light REE of La, Ce and Nd and Heavy REE distributions of Gd and Y were highly obtained in the research area.

GEOLOGI DAN GEOKIMIA ANALISIS KEATAS BATUAN GRANITOID DI PANGGONG LALAT,GUA MUSANG

ABSTRAK

Kajian inifokus kepada geologi dan geokimia batu granitoid di kawasan Panggong Lalat, Gua Musang Kelantan. Objektif penyelidikan adalah untuk menghasilkan peta geologi berskala 1:25,000 di kawasan kajian, menentukan petrografi dan analisis geokimia batu granitoid Panggong Lalat dan menyiasat pengagihan Rare Earth Element (REE) dengan jenis batu granit yang berbeza di kawasan Panggong Lalat. Untuk mencapai matlamat ini, beberapa kaedah telah digunakan seperti pemetaan geologi, petrografi dan analisis XRF dan analisis ICP-MS. Litologi di kawasan kajian terdiri daripada batuan granit, batuan sedimen batu kapur yang terikat dengan baik dan batuan metamorfik batu slate dan mereka semua termasuk dalam usia Permian hingga Triassic. Untuk spesifikasi kajian penyelidikan, petrografi dan analisis geokimia batu granitoid turut dipelajari di kawasan kajian kerana terdapat kekurangan maklumat mengenai analisis geokimia batu granitoid di kawasan kajian. Dari elemen major, elemen trace dan elemen Rare Earth klasifikasi granitod bagi kwasan kajian dapat dikenalpasti. Berdasarkan keputusan analisa sample, kawasan kajian terdiri daripada granit jenis I dan granite jenis A dengan klasifikasi IUGS, batu kasar Quarza Monzonit bagi granite jenis merah jambu dan batu kasar Quarza Syenit bagi granite jenis kelabu. Penetapan tektonik bagi granite merah jambu dan granite kelabu dinilai dari jumlah taburan elemen trace dan jenis klasifikasi granit bagi batuan granit tersebut dimana bagi granit jenis A ia selalu dijumpai di kawasan batholith dan bagi granit jenis I, penetapan tektoniknya adalah zon subduksi. Kawasan Panggong Lalat menunjukkan kadar taburan REE yang paling tinggi di Gua Musang di mana REE ringan, La, Ce dan Nd dan bagi REE berat, Gd dan Y banyak dijumpai di kawasan kajian.

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LIST OF ABBREVIATION

A	Alkali felspar
Al_2O_3	Aluminium oxide
Ag	Silver
As	Arsenic
Au	Gold
Ba	Barium
BaO	Barium oxide
Be	Beryllium
Bi	Bismuth
$CaAl_2Si_2O_8$	Calcium aluminosilicate
CaO	Calcium oxide
Ce	Cerium
Cr	Chromium
Cs	Caesium
Cu	Copper
Dy	Dysprosium
Eu	Europium
Er	Erbium
F	Feldpar
Fe_2O_3	Iron(III) oxide
Gd	Gadolinium
GIS	Geographic Information System

GPS	Global Positioning System
HCL	Hydrochloric acid
Hf	Hydrofluoric acid
HFSE	High Field Strength Elements
HREE	Heavy rare-earth elements
ICP-MS	Inductive Coupled Plasme-Mass Spectometry
IUGS	The International Union of Geological Sciences
JUPEM	The Department of Survey and Mapping Malaysia
K2O	Potassium oxide
$KalSiO_3O_8$	Potassium feldspar orthoclase
La	Lanthanium
Li	Lithium
LILE	Large Ion Lithophile Element
LREE	Light rare-earth elements
MgO	Magnesium oxide
Mo	Molybdenum
MnO	Manganese(II) oxide
Na2O	Sodium oxide
$NaAlSi_3O_8$	Sodium feldspar albite
Nb	Niobium
Nd	Neodymium
Ni	Nickel
P_2O_5	Phosphorus pentoxide

P	Plagioclase
Pb	Lead
Pr	Praseodyium
Q	Quartz
REE	Rare Earth Elements
Rb	Rubidium
Sdn. Bhd.	Sendirian Berhad
SiO_2	Silicon dioxide
Sm	Samarium
Sn	Tin
SO3	Sulfur trioxide
Sr	Strontinium
SrO	Strontium oxide
Ta	Tantalum
TiO2	Titanium dioxide
Th	Thorium
U	Uranium
W	Tungsten
XRF	X-Ray Fluorescence
Y	Yttrium
Zn	Zinc
Zr	Zircon
ZrO2	Zirconium dioxide

LIST OF SYMBOLS

°	Degree
DI	Distilled water
E	East
km	Kilometre
L	Litre
m	Metre
′	Minute
mL	Mililitre
mm	Milimetre
µm	Micrometre
×	Multiply
N	North
%	Percentage
ppm	Part per million
ppb	Part per billion
”	Second
Ơ	Sigma
S	South
W	West

CHAPTER 1

INTRODUCTION

1.1 General background of the study

This research study mainly located at the southern part of Kelantan in Gua Musang and geologically consist of Gua Musang Formation and Gunung Rabong Formation. Central Belt of Peninsular Malaysia is extended from Kelantan to Johor with the Western part of the Central Belt are the upper Paleozoic rocks of the Gua Musang and Aring Formation in south Kelantan state and some Taku Schist at the east of Kelantan. These upper Palaeozoic rocks are predominantly composed argillaceous strata and volcanic rocks with subordinate arenaceous and calcareous sediments deposited in the shallow-marine environment, with intermittent submarine volcanism starting from Upper Carboniferous and peaking through Permian and Triassic (Hutchinson & Tan, 2009, p. 57).

Gua Musang Formation itself is part of Palaeozoic rocks that compose of the calcerous facies, arenaceous facies, argillaceous facies, tuffaceous and metamorphic facies and Gua Musang dominantly composed of massive carbonate rock, limestone that aged from Middle Permian to Upper Triassic (Hutchinson & Tan, 2009, p. 81). Gua Musang area contained the history of the plate tectonic development after undergoing the collision between Sibumasu and Indochina plate. There are several formations that can be found in Gua Musang which are Gua Musang Formation, Aring Formation, Taku Schist Formation, Gunung Rabong Formation and Telong Formation and Gua Musang is identified as a potential geosite for geological activities because of its unique formations and also its distributions of rocks.

For the selected study area, this valuable research study is conducted in Panggong Lalat which located in the west part of Gua Musang. The study area are very rich in biodiversity and the people there came from various races and cultures. For this research, general geology identification of the study area is done and that data obtained from the geological mapping at the field is to produce a complete geological mapping in the scale of 1:25,000. The data on lithologies, geological structures and geomorphology are also collected during the geological mapping process. For this research, outcrops are used as an indicator for geological studies. Rock samples from the research area can identify the type of rock, stratigraphy and possibly finding fossils in it.

For the specification of the research study, petrography and geochemistry of granitoid rocks were studied in the study area as there are lacks of information regarding geochemistry analysis of granitoid rock in the study area. Petrography is the discipline where minerals that embedded in the rocks can be identified. The science of petrography is based on the study of the appearance of thin, transparent sections of rocks in a microscope fitted with polarizers (Britannica, 2018). Based on petrology studies, information on lithology of the study area can be identified and descript. Other than that, a description like texture, mineral and chemical composition also can be obtained via petrology studies thus this would give a better understanding of the type and formation of rocks in the study area. Minerals can easily be identified through the thin-section of the samples and by using specialized microscopes.

In this research, geochemical analysis is used to describe and analyze the elements contained in the target rock as for this research granitoids rock are used as the target rock to examine its elements contents. Elements in the rock are determined to an intermediate level of accuracy. For the geochemistry of granitoid rocks, trace elements and major elements analysis is conducted using X-Ray Fluorescene (XRF) and ICP-MS. Each instrument used for geochemical analysis has their own advantages. The XRF is used to analyze the major and trace elements in geological materials which involve bulk chemical analyses of major elements for examples like SiO_2, TiO_2 and MgO in rock and sediment. Other than that, it also used to analyze trace elements like Ba, Cr, Cu, Nb, Ni, Rb, Zn and others in rock and sediment that more >1 ppm (Center, 2018).

While for ICP-MS, Inductively coupled plasma mass spectrometry (ICP-MS) has been used successfully for the direct determination of trace elements in granites and thus it required sample preparation methods that result with the total dissolution of the sample. The use of hydrofluoric and nitric acids for the digestion of silicate samples is established and has been applied to the dissolution of granite, basalts, soil and other rocks. Using this approach for the analysis of granites is problematic since Zr and Hf do not always go into solution. Granite often contains accessory minerals such as zircon, which are very difficult to dissolve.

1.2 Study area

The area of research is at Kampung Panggong Lalat that located at the southern part of Kelantan which is in Gua Musang district (jajahan). Figure 1.1 by Yoyok (2018) show the geological map of Kelantan that show the rock distribution of the study area in Gua Musang, Kelantan. Kampung Panggong Lalat is located in the western part of Gua Musang along Jalan Gua Musang – Kampung Kuala Betis. The size of the research area is 25km² approximately. The coordinates that cover the research area are from 4°54'49.656"N, 101°51'0.9888" E to 4°54'49.569"N, 101°53'45.022"E. The contour elevation ranges within 120 m to 540 m in the study area. The topography of the study area is mostly covered with low lying plain which is flat with a few low hill surfaces which are not too high but on the North- West side of the research area, the topography elevates up to 540 m.

Most of the lands in the study area are used for plantation purposes like palm oil plantation and rubber plant plantation as it was the main economic contribution for the villagers. The main road of this research area is either through the main road of Jalan Gua Musang – Kampung Kuala Betis, the small street along Kampung Panggong Lalat housing area or using the unpaved road in palm tree plantation and in the forest on the North-West side of the study area. Figure 1.2 shows the map of the study area which is Kampung Panggong Lalat, Gua Musang. The study area is occupied with various type of rocks like sedimentary rocks and igneous rocks. The study area also have main river which are Sungai Seting and Sungai Kundur. There is only one village that located in the study area which is Kampung Panggong Lalat and most of the peoples that live there are the Kelantanese, natives people and estates workers.

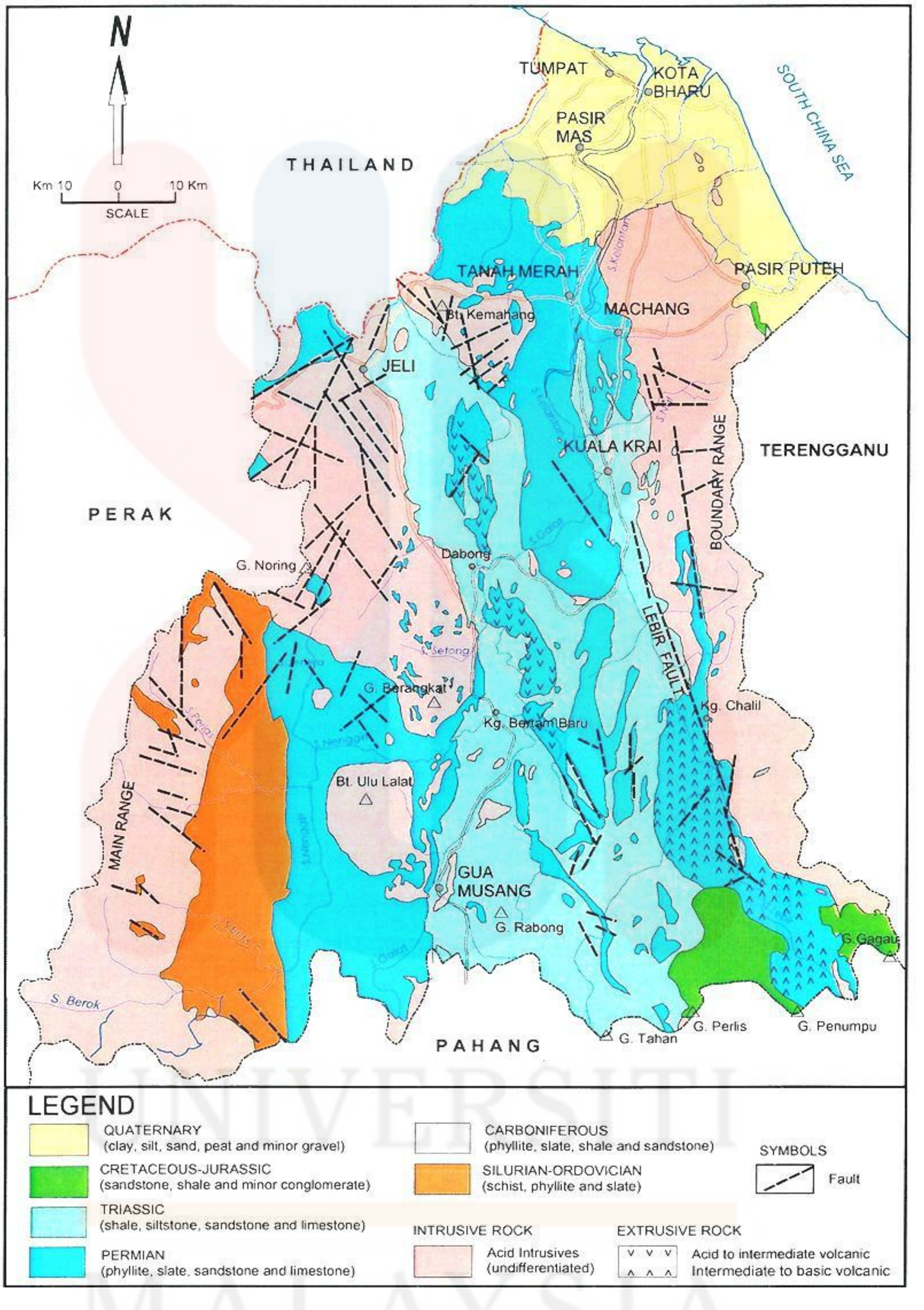


Figure 1.1: Geological map of Kelantan (Gua Musang). Modified by Yoyok, 2018

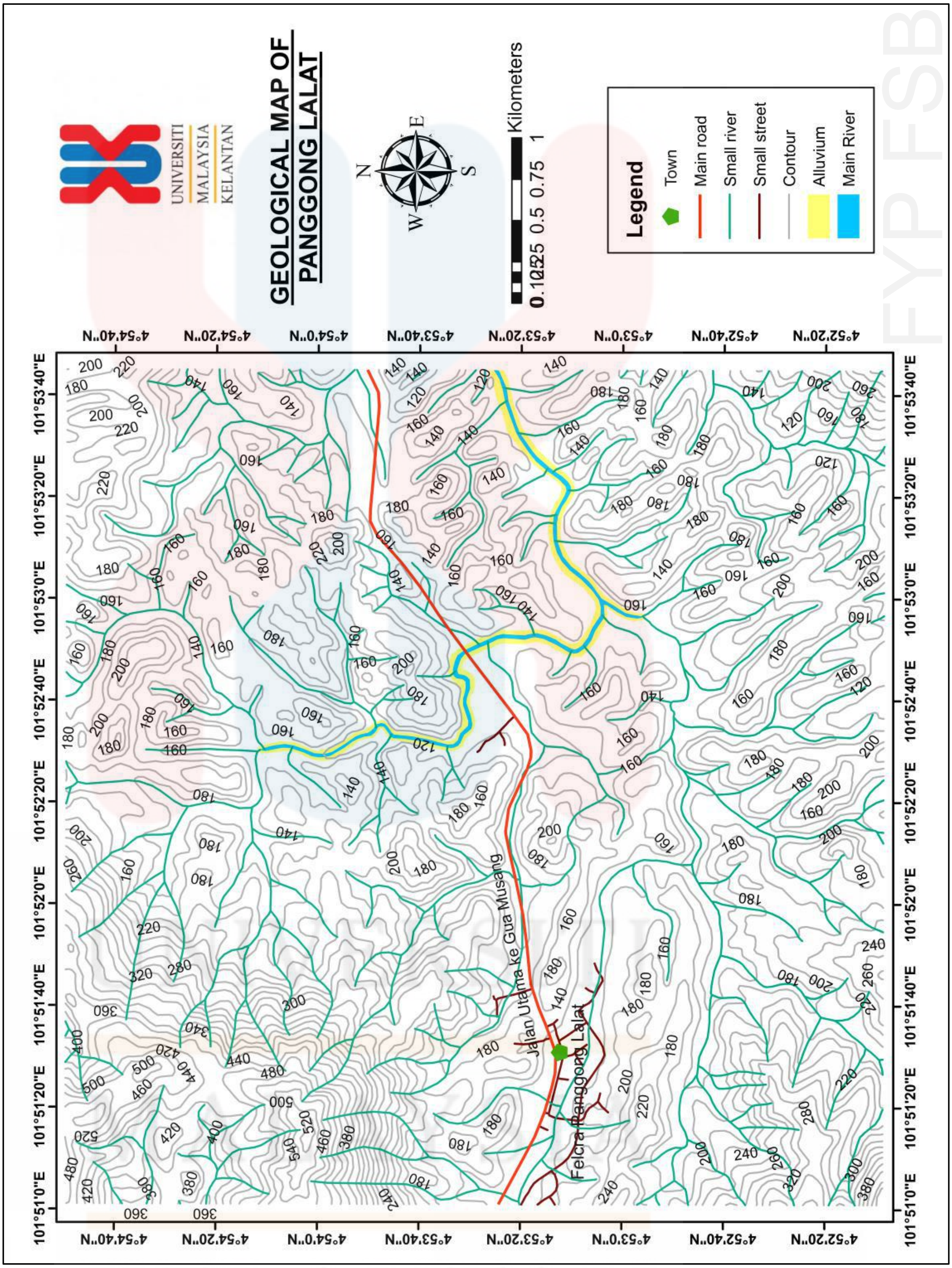


Figure 1.2: Base map of study area, Panggong Lalat

1.2.1 Demography

Kelantan is the second biggest state in Malaysia after Pahang. Based on Table 1.1 below, it shows the updated data of area by the district of Kelantan by the year of 2016. These statistics was published by the JUPEM on the year of 2018. From the table below we can clearly see that the biggest district in Kelantan is Gua Musang with 817,595 hectares (48.54%) out of 1, 684, 323 area of whole Kelantan. Although Gua Musang is the biggest district in Kelantan, its population was quite lower compared Kelantan's main state which is Kota Bharu. This is due to its undeveloping progress compared to Kota Bharu. For the population in Gua Musang, based on Table 1.2 it shows that the population of Gua Musang district in 2010 are 90,057 out of 1,539,601 people in Kelantan. Generally, based on table below we can see that the number of population in Gua Musang district keep increasing from time to time. People distribution in Gua Musang mostly came from Malay, Chinese, Indians and other Bumiputera. To be exact based on the Table 1.3, Malay ethnic show the highest population of 76,823 followed by Chinese ethnic with 3,870, then Indian ethnic with population of 350 and the least are other groups of 161 population. There are also people from other nationality like Indonesians, Vietnamese and Bangladesh that live there for working purpose.

Table 1.1: Area by District of Kelantan (Department of Survey and Mapping Malaysia, 2016)

DISTRICT	AREA (HECTARE)	PERCENTAGE (%)
Kota Bharu	40,144	2.38
Pasir Mas	56,707	3.36
Tumpat	17,725	1.06
Pasir Putih	42,302	2.52
Bachok	27,825	1.65
Kuala Krai	227,670	13.52
Machang	52,791	3.14
Tanah Merah	87,948	5.22
Jeli	131,916	7.83
Gua Musang	**817,595**	**48.54**
Lojing	181,700	10.78
JUMLAH / Total	**1,684,323**	**100%**

Source: (JUPEM, Januari 2018)

Table 1.2: Population of Gua Musang in 2010 (Department of Statistics Malaysia, 2010)

No	District	Total
1.	Bachok	133,152
2.	Kota Bharu	491,237
3.	Machang	93,087
4.	Pasir Mas	189,292
5.	Pasir Puteh	117,383
6.	Tanah Merah	121,319
7.	Tumpat	153,976
8.	Gua Musang	90,057
9.	Kuala Krai	109,461
10.	Jeli	40,637
Kelantan		1,539,601

Source:Department of Statistics Malaysia, 2010

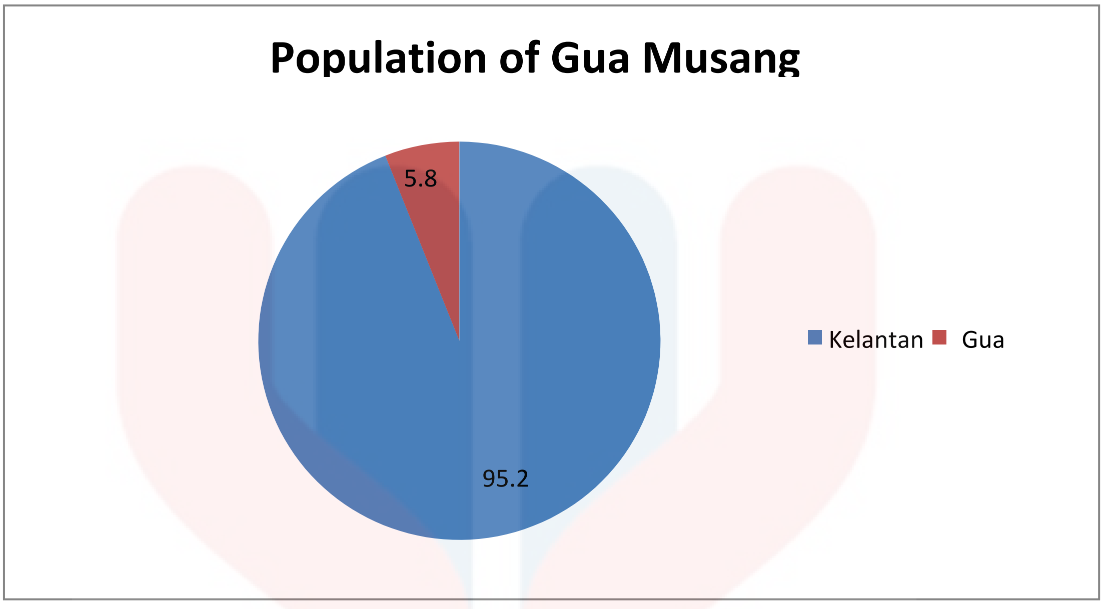


Figure 1.3: Percentage of Gua Musang Population

Table 1.3: Ethnic Group Of Gua Musang (Malaysia, 2010)

Ethnic Group (2010)	
Malay & other indigenous (Bumiputera)	76,823
Chinese	3,870
Indian	350
Other groups	161

Source: Department of Statistics

1.2.2 Rain distribution

Gua Musang has a tropical climate. Generally, the location of Kelantan in the East Coast of Malaysia makes it generally receives a considerable measure for precipitation during the Northeast Monsoon period. However, during the Southwest Monsoon and inter-monsoon, Kelantan still receives rainfall rates which are relatively high. The Northeast Monsoon from November until March is highly devastating compared to the Southwest Monsoon as it results in enormous tides in the ocean which could endanger the people and sometimes bring disaster. Meanwhile, the Southwest Monsoon from the late May until September normally signifies relatively drier weather (Suhaila, 2010).

Based on Table 1.4, the average rainfall that being recorded for Gua Musang district shown that the average rainfall pattern increase from the early to the end of the year. February recorded the least average amount of rainfall with 52.5 mm of precipitation reading and only 16 days for average rainfall days. The highest amount of average rainfall is on October with 467.5 mm of precipitation reading and 23 days for average rainfall days. This pattern might be gradually changed for the year after 2015.

Table 1.4:Table of rainfall distribution in Gua Musang for 2015. Modified by Jabatan Ukur dan Pemetaan Kelantan

Rainfall Distribution at Gua Musang region, Kelantan District Year 2015 (mm)										
Day	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct
1	0	0	0	13	1.5	0.4	0	28.8	16.5	14.4
2	2.6	0.5	0	15	22.5	0	0	3.2	0	39.6
3	0.4	2.5	0	0	28	0	16.1	9	21.9	22.5
4	0	15.3	0	0	1.9	1	15.4	0.5	88.6	4
5	4.5	10.1	0	0.4	11.1	1.5	0	2.5	1	0
6	26.5	1.6	0	11	48	3	3.5	5	6	22.5
7	16.1	0.5	0	0	0.4	0.5	12.5	2	18	0
8	25.1	2.5	5.5	0	27.1	22.9	5	6.5	0	11.5
9	6.9	1.5	59.2	0	45	0.6	34	0.5	0.5	42.6
10	16.4	1.1	1.3	5	15.5	2.9	0.5	4.5	0	3.9
11	8.4	0.9	0	9.9	0	27.6	0	19.5	9.8	3.2
12	10.5	0.6	0	12	23	2.5	0	5.6	15.4	3.3
13	0.5	0	0	4.8	0.5	2.3	0.4	13.7	4.3	39.1
14	0.6	0	0	1.3	18.5	2.2	12.4	1	0	22.9
15	0	2	0	2.7	19.5	13.5	0.1	2.1	0	1
16	0	0	0	8	1.5	0	0	0	0	31.6
17	0	0	0	0	0	0	6	16.8	0	13.7
18	0	0.6	0	12	14.8	0	24.3	32.9	0	23.2
19	1	8.9	0	16	16.7	0	6.7	0.8	1.5	0
20	0	0	0	8.3	26.8	0	3.5	0	0.4	0
21	0.6	0	2.5	1.5	2.7	0	3.5	0	9.1	0
22	0.4	3.5	0	0	18.6	0	0	0	24.9	0
23	0	0.5	0	0.5	0.4	0	21	8.5	1.6	0
24	1	0	0	0	2	0	0.5	7.5	0	14.6
25	0	0	1	0	0.4	0	25	0	0	33.7
26	0	0	3.5	1.5	0.6	0	5.5	7	0	4.4
27	0	0	1.8	5.5	3.5	0.5	28.5	0.5	0.5	16.8
28	0	0	2.7	4.1	21.5	6	40	1.8	1	36.9
29	2.7	0	2.1	5.9	18.5	0	0	0.2	32	33.5
30	0.7	0	5.4	15	0	0	5.5	10.5	44	28.5
31	0.1	0	19		27.5		19.5	2.5	0	0
Total	125	52.5	122	151	418	87.4	289.5	193.5	297	467.5

1.2.3 Road connection

There are many road connections that can be used to reach Gua Musang district. From Jeli to Gua Musang it takes about 115 km and 2 hours driving using Jalan Jeli-Jelawang-Gua Musang. Other alternative way to reach Gua Musang is via Jalan Jeli-Dabong-Gua Musang but the road takes longer time to reach Gua Musang compared to Jalan Jeli-Jelawang-Gua Musang as it takes about 3 to 4 hours to reach there.

For the road connection in Kampung Panggong Lalat area, the road in the study area is accessible as there was the main road across the study area. The main road in the study area is Jalan Gua Musang – Kampung Kuala Betis (Figure 1.4) that connected Bandar Gua Musang with the study area, Kampung Panggong Lalat. Other paved road that can be used in the study area is the small street the usually used by the villagers in Kampung Panggong Lalat area (Figure 1.5). The paved road along study area can be accessed either by car, motorcycles and other transports as the roads are located in the residential area.

The unpaved road connection are widely spread across the study area as the study area are rich with plantation site likes rubber tree plantation and palm oil plantation. However, the unpaved road seems to be quite difficult to be accessed with normal transport like cars as the topography of the area are uneven and the elevation of the plantation site like palm tree plantation was quite high. Even it have a high elevation, the unpaved road still can be accessed either by motorcycles, lorry, or Hilux as to make the geological mapping process more faster and easy.

Figure 1.4: Small street of residential area of Panggong Lalat. Source, Google Pro

Figure 1.5 : Main road of Jalan Gua Musang-Kampung Kuala Betis. Source, Google Pro

1.2.4 Land use

In the study area, the land is mainly used for plantation purposes. The main plantations in the study area are rubber tree plantation and palm oil tree plantation. The activities are widely spread around Kampung Panggong Lalat area and also extended to all part of Gua Musang district due to its richness in natural resources. The villagers are very dependent on plantations and agricultures as their source of incomes. Figure 1.6 shows the land use map in Kampung Panggong Lalat area (Rafiq, 2017) and most of the land in the study area are use for plantation purposed as agricultures and vegetation show the highest land use in the map. Another type of land used is the residential area where the villagers live. Other than that, public facilities are also part of land use in the study area as mosque, Felcra office, stall, restaurants and public toilets can be found in Kampung Panggong Lalat.

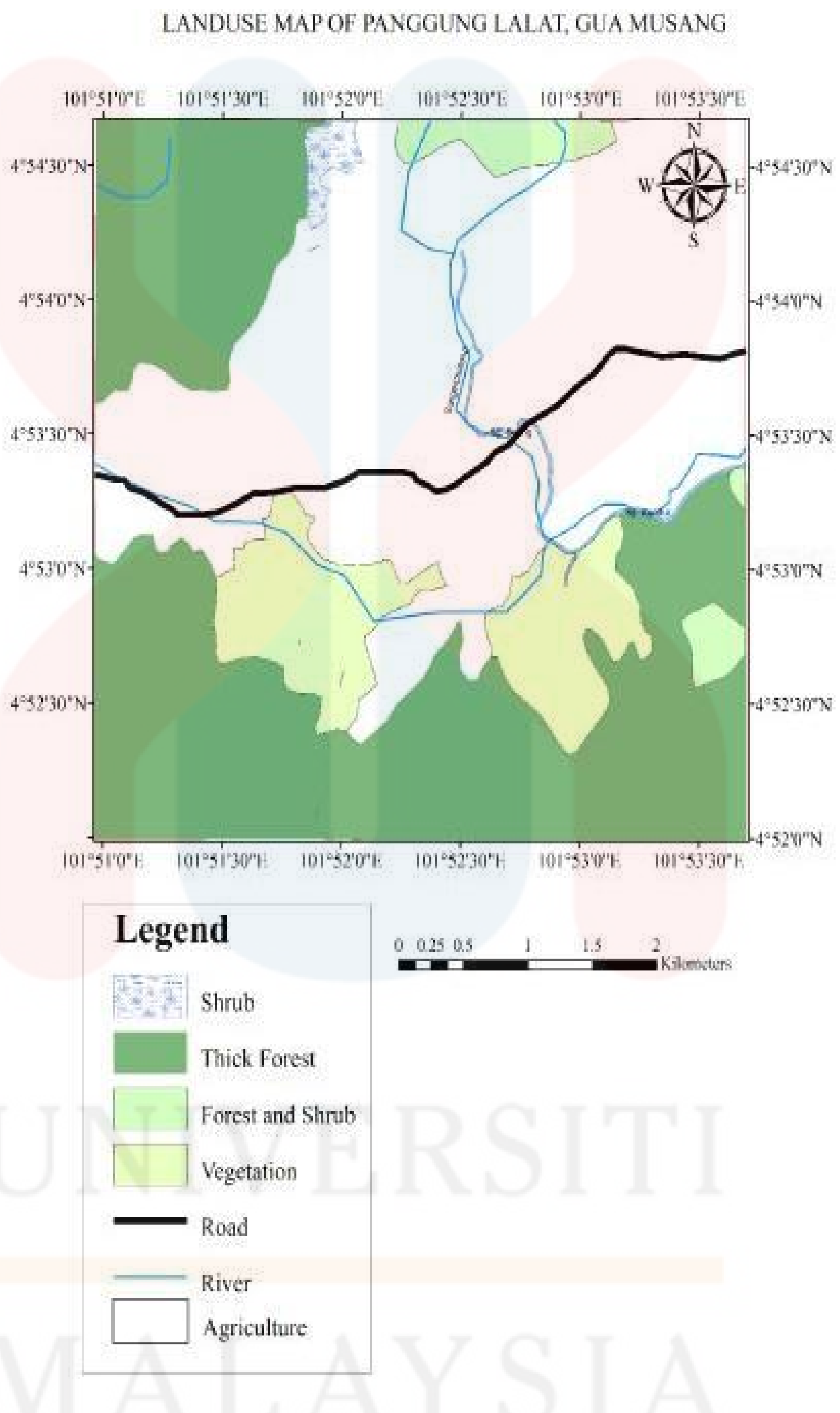


Figure 1.6: Land use map in Kampung Panggong Lalat, Gua Musang by Rafiq (2017)

1.2.5 Social economic

In Gua Musang, most of the economic industry was based on agricultures and plantation. There are abundances of plantation farm that can be found in Gua Musang district. The most popular plantations in Gua Musang are rubber tree plantation and palm tree plantation as these plantations can be easily found across Gua Musang. Other than that, people of Gua Musang also tend to increase their economic rate through quarrying as Gua Musang really rich in natural resources and composed of various type of rocks. There a lot of quarry that can be found in Gua Musang for example like Kuari Dinar Sdn Bhd (Figure 1.7) that located in Kampung Star,Gua Musang. Food industries play as the major part of economic contribution to the local beside from agricultures. Restaurants and food stalls can be found anywhere around this district as it is the main income for the Kelantanese since a long time ago.

Focusing on the study area, social economics of people in Kampung Panggong Lalat are mainly plantation and agricultures. This is because most of the study area are mainly composed rubber tree plantation and palm tree plantation. Therefore, people depending on the plantation as their main source of income and due to the demanding market for the palm oil and rubbers, people tend to open more plantations to increase the production. In addition, food industries are really famous among the locals in the study area. There are a lot of restaurants and food stall that can be found at the study area.

Figure 1.7 : Kuari Dinar Sdn. Bhd. (Seri Barat Mixed Sdn.Bhd)

1.3 Problem statement

The previous geological map of the study area that been provided has less and undetailed informations. Based on the previous topographic map by Department of Survey and Mapping Malaysia, the map released was in 1996.This show that the map was not being updated after that year until now and there might be a huge changes within the year especially the geomorphology of the study area as the gap year of the map was really long. As for the research related with petrography and geochemical analysis, so far there were no updated and latest research regarding the petrography and geochemistry analysis of granitoid rocks in the study area.

The previous undergraduate study by Rafiq (2017) only focused on the petrography of the general igneous rocks in the Panggong Lalat area but not focusing on the granitoid rocks of the study area. In addition, the researcher only focused on identifying the trace and major elemnts from XRF analysis and not identifying Rare Earth Elements from ICP-MS analysis. For granitoid research study, ICP-MS analysis is really important as ICP- MS provide more accurate data compared to

XRF analysis. So in order to obtained more accurate data regarding the study of granitoid rocks in Panggong Lalat, both analysis should be used. There were also a research by Kouame Yao et al (2017) entitled “Identification of Rocks and Their Quartz Content in Gua Musang Goldfield Using Advanced Spaceborne Thermal Emission and Reflection Radiometer Imagery” that study about the quartz contain in rocks of Gua Musang area and one of the rocks that they studied are granitoid rocks.

However in the research, the researchers only focus on the quartz contains in the granitoid rocks and not on the geochemistry analysis of the rocks. Other than that, there were only a few research regarding geochemistry of granitoid rocks that have been done at particular part of the Gua Musang district especially at Kampung Panggong Lalat area, so the informations of the geochemistry of granitoids rocks are quite lacking. In addition, granitoid rocks in Panggong Lalat area are very uniqe due to its colour, textures and its characteristics.

1.4 Objectives

i. To produce the geological map of 1:25000 scales of the study area.

ii. To determine petrography and geochemistry analysis of granitoid rock in Panggong Lalat.

iii. To investigate the distribution of Rare Earth Elements (REE) with different granite rock types in Panggong Lalat area.

1.5 Scope of study

Detailed geology of the study area are determine by the geological mapping processes that includes geomorphology. Updated geological map will help other researchers to carry out their own research at the study area in the future. Petrology studies will provide informations of the history and lithology the of the study area. Other description like texture, mineral and chemical composition gives better understanding about the formation of rocks of the study area.For the geochemistry of the granitoid rocks, trace elements, major elements and REE(Rare Earth Element) are identify and analyze by using XRF and ICP-MS respectively.

Investigations involving the petrography and geochemistry of rocks have continued to increase within the past years. The area around Panggong Lalat are really popular with the existence of numerous Senting granite outcrops that can be seen easily just a few metres from settlements. This study is focusing on the geochemistry method that had been applied onto the granite rocks found in the study area. In addition, this research provided an updated road connection of the study area. In order to prove the research activity, traversing the road was done using a GPS (Global Positioning System) and map of the study area are updated and produced using Arc Gis application.

1.6 Significance of study

The signifance of study the general geology of the study area are to produce and update latest geological map with scale of 1:25000 of the study area. The specification of the research are to determine the petrography and geochemistry analysis of the granitoid rocks of Kampung Panggong Lalat. Petrography analysis ofgranitoid rock enables the researcher to know the textures, minerals contents and physical and chemical properties of granitoid rocks of the study area. Geochemical analysis will result to the of percentages of trace,major elements and REE in the rock. Thus elements from granitoid rocks will provide information and results regarding the classification of granitoid rock in term of IUGS classification, chemical classification of S-I-A-M classification, tectonic setting of granitoid rocks and distributions of REE in granitoid rocks in the study area.

CHAPTER 2L

ITERATURE REVIEW

2.1 Introduction

Preliminary studies are done before conducting the geological mapping and the specification research regarding the geochemistry of the granitoid rocks of Panggong Lalat. Preliminary studies are methods where literature review on the existing past studies like journals, articles and books are referred and reviewed before conducting a research. This are really helpful in increasing the understanding and knowledge of the researchers regarding the research topic of the study area. There were some studies that have been done on the granite around the study area and also have been used as references in this study.

2.2 Regional geology and tectonic setting

Kelantan is a northern province of Peninsular Malaysia. The boundary of this state toward the north is Thailand, eastern part is Terengganu, southern part is Pahang and westhern part with Perak and Kedah. Geologicaly Negeri Kelantan are includes west Kelantan Olistostrom, Taku Schist and Gua Musang Formation. Igneus rock in Negeri Kelantan are granite, diorite porphire, andesite, ignimbrite dan dolerite. Structuraly Negeri Kelantan are boundared by olistostrom in the west and Lebir Fault Zone in the east. Gua Musang Formation is primarily separate in Negeri

Kelantan. Principle overlay of Gua Musang Formation in the center part towards north-south up to north-northwest – south-southeast. In the northern part of this primary fold terned by granite intrusion and pophiritic diorite towards NE-SW. The primary of fault in the Gua Musang Arrangement are dextral fault with strike N30-45E and diping 60-70° to SE of sinistral fault with strike N330-340E and diping 60-80° to ENE-WSW. In the zone boundared by igneus granite intrusion and close than main fault, Gua Musang Formation formed a compact and strongly folding. Intrusion of porphyritic diorite towards NE-SW need to terned the main fold of Gua Musang Formation to take after this intrusion (Warta Geologi, 2010).

Central Belt extends from Kelantan to Johor, the eastern foothills of the Main Range limited on its west and Lebir Fault framed its eastern limit in the north, down toward the west of the Dohol formation in the south (Hutchinson and Tan, 2009). Central belt was deciphered to represent an aborted rift based on the prove that the granitoid bodies of the Eastern Belt were a piece of the Titiwangsa granitoid complex that were isolated more than a hundred kilometers by the rifting (Tjia & Almashoor, 1996).

2.3 Stratigraphy

The Gua Musang development in South Kelantan – North Pahang was mapped by Yin (1965) to portray Middle Permian to Late Triassic argillite, carbonate, and pyroclastic /volcanic facies inside Gua Musang region. Presently, the term has been approximately utilized for almost all Permo-Triassic carbonate- argillite-volcanic groupings in the northern part of Central Belt Peninsular Malaysia (Mohamed, Joeharry et al. 2016). Far reaching dispersion of argillite-carbonate-volcanic crosswise over northern Central Belt has activated issue with respect to current names assigned. For instance, comparative lithologies of Gua Musang Formation in Felda Aring is named as Aring Formation, while those in Sungai Telong is called Telong Formation (Aw, 1990). Mohamed and Leman (1994) and later Mohamed (1995) clarified that these horizontal facies changes could be accumulated inside an indistinguishable gathering from long as these sediments were deposited in shallow marine environment of the Gua Musang platform amid the Permo-Triassic period.

The significance grouping these formations lies behind the nearby affiliations saw among these formations as far as sedimentological and paleontological viewpoints. Kamal (2016) then discover the need to reasses the utilization of informal 'Gua Musang formation' for future rank rise, formalization and clearer understanding on the geology of the northern Central Belt, especially concerning deposition of different lithostratigraphic units inside the Gua Musang. Gua Musang Group includes Gua Musang formation, Aring Formation, Telong formation, and Nilam marble. Gunung Ayam Conglomerate which was named as the basal conglomerate of the Gua Musang formation (Aw, 1974) is now regarded as the Bentong Raub Suture Zone (Tjia & Almashoor, 1996) and thus need to be excluded.

The correlation of those formations are presented in Figure 2.1 that being modified by (Metcalfe & Hussin, 1995). While Table 2.1 shows the descriptions of formations that included in Gua Musang group which modified by Lee (2004).

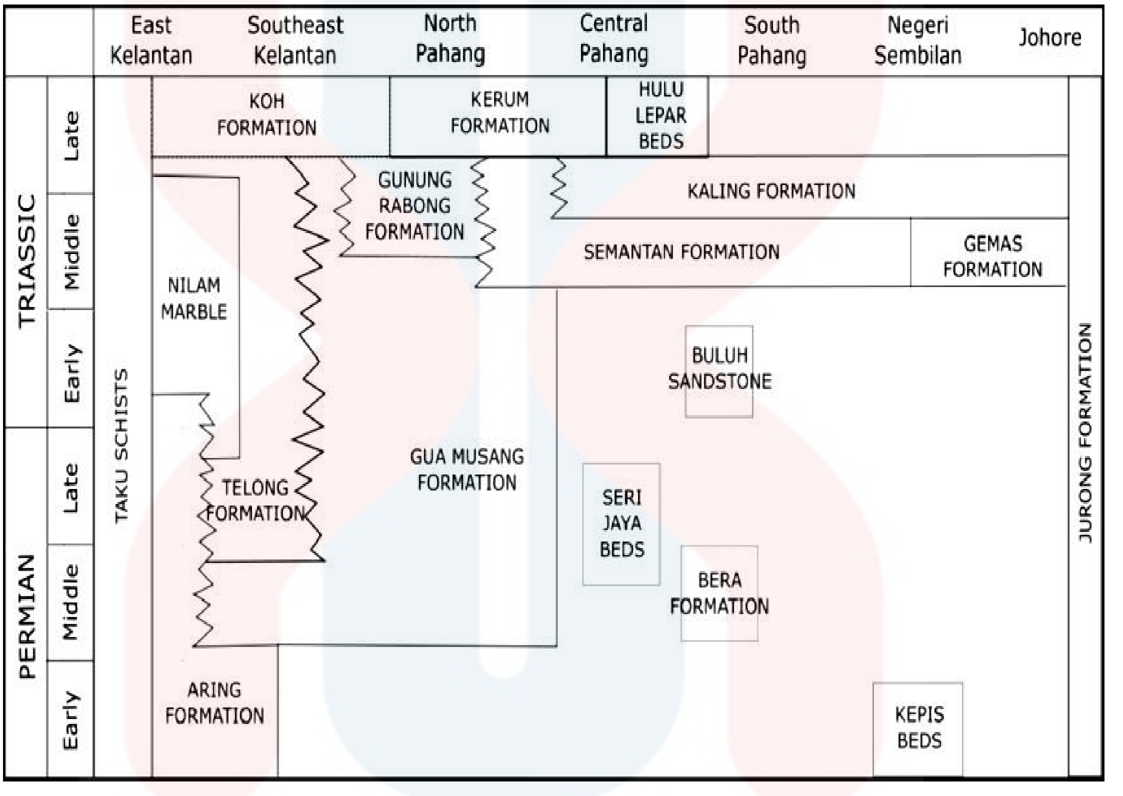


Figure 2.1: Permo-Triassic stratigraphic correlation chart of Central Belt Peninsular Malaysia. Modified from Metcalfe & Hussin (1995)

Table 2.1 : Formations descriptions that included in Gua Musang group. Modified by Lee (2004)

Name	Gua Musang formation	Telong formation	Nilam marble	Aring Formation
Origin of Name	Gua Musang, South Kelantan	Sungai Telong, South Kelantan	Sungai Nilam (of Sungai Chiku)	Sungai Aring, south Kelantan
Age	Middle Permian to Late Triassic	?Permian to Late Triassic	?Permian to Late Triassic	Carboniferous to EarlyTriassic
Boundary	Unknown lower boundary; Upper boundary overlain by Koh Formation	Lower boundary overlie Gua Musang formation; top boundary overlain by Koh Formation	Unexposed bottom and top boundary	Lower boundary unexposed. Tectonized upper contact with Telong formation and Koh Formation.
Correlation	Upper part of Gua Musang formation interfingers with Semantan Formation, Telong formation, and Gunung Rabong formation	Lateral equivalent to Gunung Rabung formation and Semantan Formation	Lower part coeval with Aring Formation, upper part coeval with Telong formation	Lateral equivalent to Gua Musang formation in Kelantan, metasediments in SE Pahang, Volcanic Series in NW Pahang
Lithology	Argillaceous and calcareous rocks interbedded with volcanic. Minor presecne of arenaceous rocks	Sequence of predominantly argillite associated with some tuff; turbidites	Calcitic marble interbedded with tuff and argillites	Basal dolomite marble, tuff, calcareous argillite, pyritiferous tuffs, subordinate lavas, argillo-tuffaceous limestone
Type Area	Gua Musang area (extended to north Kelantan and Pahang)	Sungai Telong, the upper reaches of Sungai Aring in south Kelantan	Upper reaches of Sungai Nilam	Sungai Aring, south Kelantan
Depositional Setting	Shallow marine shelf deposit, with active volcanic activity	Shallow marine environment with occasional pyroclastic	Open marine for growth of shelly fauna	Neritic with volcanic input

Specifically for Gua Musang area, previous study by Surtono (2018) has classified wholly about Gua Musang 's stratigraphy. Table 2.2 below shows the stratigraphy of Gua Musang area that have been modified by Surona (2018). Based on the stratigraphy, metasediments rock is the oldest unit in Gua Musang region with Pre-Mesozoic age, it is unconformbly overlain by the Gua Musang Group. The youngest rocks unit in Gua Musang came from Gunung Rabong Formation and based on the previous study as Gua Musang located in the central belt area, there were major granite intrusion that occur in Gua Musang . As a result all of the units are intruded by granitoid rocks with Cretaceous age. Geological structures are dominated by South of south east – North of North West directions of faults. These are cut by East – West faults.

LITHO.	LITHOLOGICAL UNITS	DESCRIPTION	AGE
	RABONG FORMATION	Conglomerate with sandstone and siltstone intercalations	?Creta-ceous
	GRANITOID ROCKS	Gray granite and pink granite	?Cretaceous
	THICK BEDDED LIMESTONE	Thick-bedded of lime-mudstone, recrystalline limestone, and ?rudstone	Late Triassic
	WELL-BEDDED LIMESTONE	Well-bedded of lime-mudstone, grainstone, and wackstone	Middle Triassic
	FINE-GRAINED SEDIMENTS	Mostly well-bedded of mudstone, siltstone and sandstone	Middle Triassic
	VOLCANIC ROCKS	Bedded tuff and lapilli tuf, inter-cated by fine-grained clastic sediments	?Early Triassic
	META-SEDIMENTS	Metamudstone, metasandstone, phylite, metalimestone, and siltstone	?Pre-Mesozoic

Table 2.2: Stratigraphy of Gua Musang (Surono, 2018)

2.4 Structural geology

Detailed studies of structural geology showed at Bentong-Raub Suture Zone, western boundary of Central Belt was form along eastern foothills of Main Range. At the east side of this lies a marine Permo-Triassic Zone where narrow N-S trending line of plutons and Jurassic-Cretaceous continental sediments located to the east (Hutchinson and Tan 2009).For geology detailed, Kelantan is located in the northern part of Peninsular Malaysia. Kelantan boundary at the northern part is Thailand, in eastern part is Terengganu, in the southern part is Pahang and in the western part are Perak and Kedah. Geological Society of Malaysia (2010) in Warta Geologi book state that geologically, Kelantan involved west Kelantan Olistostrom, Taku Schist and Gua Musang Formation. Diorite porphire, andesite, ignimbrite dan dolerite are examples of Kelantan's igneous rock.

Negeri Kelantan structurely are boundared by olistostrom in the west and Lebir Fault Zone in the east. The study is definite estimation along the street and river. Main fold of Gua Musang Formation can be found in the middle part towards north south up to north-northwest – south-southeast. The main fold actually terned by granite intrusion in the northern part and diorite pophire towards NE-SW. The main of fault in the Gua Musang Formation are dextral fault with strike N30-45°E and diping 60-70° to SE and sinistral fault with strike N330-340°E and diping 60-80° to ENE-WSW. Gua Musang Formation formed the compact and strongly folding in the area boundared by igneous granite intrusion and near than main fault and the intrusion of diorite pophire towards NE-SW have terned the main fold of Gua Musang Formatin to follow this intrusion. The main compression formed the folding and faulting of the Gua Musang Formation towards between WNW-ESE up to ENE-WSW (Geological Society, 2010).

2.5 Historical setting

Hutchinson (1977) clearly subdivided Peninsular Malaysia into four zones which are characterised by different tectonic histories. One of them is the Eastern Belt which is characterised by numerous elongate granitic plutons intruded through gently deformed, predominantly Permo-Carboniferous sedimentary formations with associated pyroclastic and volcanic rocks of acid to intermediate composition. The Eastern Belt granites have not been significantly uplifted since their crystallization in the same way that the Main Range Belt granites have which concludes that a greater tectonic stability for the Eastern Belt than for the Main Range (Hutchison, 1977).

Hutchison (1977) concludes that the major part of the granitic intrusive activity in both the Main Range and the Eastern Belts was in the Permian to Triassic as Bignell & Snelling (1977) indicated that the Late Carboniferous dates should now be reinterpreted as Permian based on the radiometric data of Bignell (1972). Bignell (1972) suggested that the Eastern Belt granites were derived from a more oceanic type of basement whereas the Main Range granites were derived from a well-established sialic acid basement. The granites were emplaced throughout the Permian and Triassic in a high-level environment so that fairly rapid loss of water did not allow the alkali feldspar to attain a stable structural state (Hutchison, 1977).

2.6 Granitoid rocks distribution in Peninsular Malaysia

Figure 2.2 shows the Peninsular Malaysia map of two divided into blocks by a suture which are western block and eastern block. Stauffer (1974) named these blocks the East and West Malaya Blocks and Hamilton (1979) used Western and Eastern Peninsular Blocks. Peninsular Malaysia forms part of the Sunda Shelf. Cenozoic deposits are all superficial and relatively thin except at the costal margin. The origin of rocks in Peninsular Malaysia shows significant continuation in their deposition. The pre-Triassic rocks are characteristically marine meanwhile, Triassic rock are made up of both marine and non-marine deposit. Furthermore, all post-Triassic rocks are non-marine in origin (Gan, 1980). Almost half of the total surface area of Peninsular Malaysia is covered by granitoids. There are at least four major episodes of granitic emplacements shown by radiometric dating, ranging from Upper Carboniferous to Lower Tertiary (Rajah and Yin 1980). The emplacement peaks are during the Permian and Triassic periods (Bignell, 1972; Hutchison, 1973), and contemporaneous submarine extrusive activities from the Upper Cambrian to the Middle Triassic characterized the geological history of Peninsular Malaysia.

The quartz-alkali feldspar-plagioclase plot, of modal proportions, discriminates three characteristics series among the large variety of granitic rocks associated in intrusions. The series are Calc-alkaline and its variants, Tholeiitic and Alkaline. Each of the series has its own chemical characteristics and some originate from different source material as shown by Bowden et al. (1984). In general, the Eastern Belt Granites belong to the calc-alkaline granodioritic series (Azman A. Ghani, 2009). Some of the granite complexes however show a trend similar to the alkali series. The SiO2 content of the Eastern Belt granite and associated mafic and intermediate rocks ranges from 50% to 78%. There are two distinct plutonic associations can be recognized in the Eastern Belt which are the dominant granitic rocks and a mafic association. The granitic rocks are dominated by I-type and minor S-types (Liew, 1983). The major I-type plutons of the Eastern Belt are believed to be derived from partial melting of mafic to intermediate lower crust, which may, in part, comprise juvenile underplated material. This mode of origin is implied by the absence of rocks of intermediate composition.

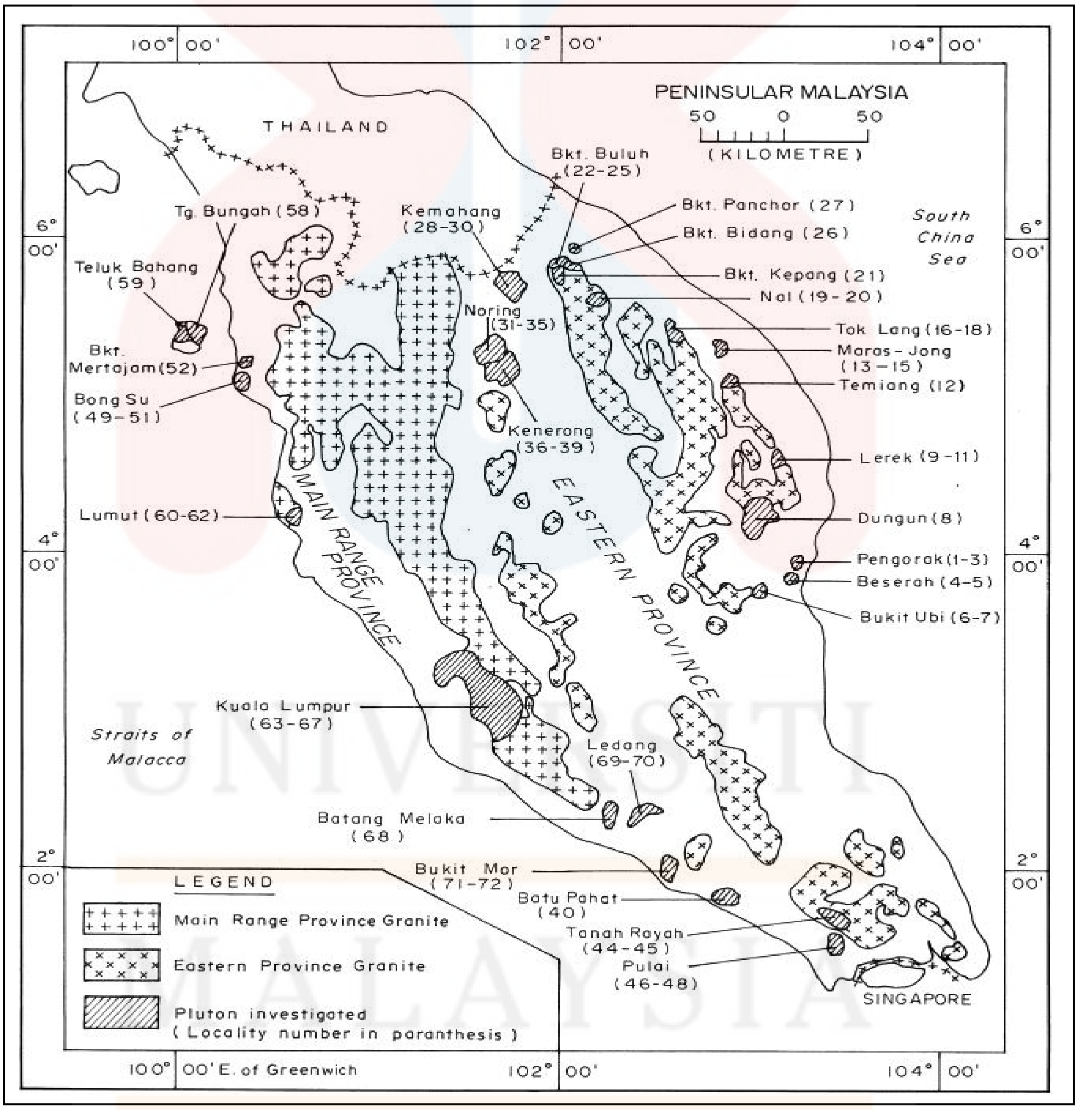


Figure 2.2: Map of Granitic Distribution in Peninsular Malaysia.Modified by Heng et al (1997)

2.7 Petrography of igneous rock

The classification of rocks are based on the information acquired during the petrographic analysis. Petrographic descriptions start with the field notes of the outcrop and include macroscopic description of hand specimens. Nevertheless, the most significant tool for the petrography discipline is the microscope. The detailed analysis of minerals by optical mineralogy in thin section and the micro-texture and structure are critical to understand the basis of the rock. Granite is classified according to QAPF diagram in Figure 2.3 and named according to the percentage of quartz, alkali feldspar, plagioclase feldspar and mafic minerals. The mineralogical composition and physical classification granite was analysed using thin sections.

Results were plotted on ternary diagrams QAPF diagram that containes Quartz-Alkali Feldspar-Plagioclase information (Streckeisen, 1974).In QAPF diagram the minerals are classified into five minerals groups which refers to Q (quartz), A (alkali feldspar), P (plagioclae), F (felsic) and M (mafic minerals). Q, A, P and F percentages are normalized (recalculated so that their sum is 100%) QAPF diagram is use to identify the types of plutonic igneous rocks with coarse grain texture based on plotted of dominant of minerals constituent in rocks. In addition, coarse grain textures are easy to recognize and identify whether in hand specimen or through thin section analysis identification.

Igneous rock generally ranging in colour from pink to light or dark grey and mostly consisting mostly of quartz and feldspar, accompanied by one or more dark minerals. Some dark coloured igneous rocks which are actually basalt, gabbro, dionite, diabase and anorthosite are quarried and sold as “black granite”. These stones contain little or no quartz or alkali feldspars, but, for all practical purposes, they are used interchangeably with true granites. For granitoid rocks, other than quartz and feldspars, it may also contain minerals like mica, hornblende and occasionally pyroxene. Compared to calcareous sandstones, marble and limestone, granite is not an acid soluble stone and is much more resistant to the effects of acidic solutions, rainwater or cleansing agents. In general, granite have more inert compositions that show much lower rates of deterioration, have lower water absorption, and are harder than marbles, limestones and sandstones.

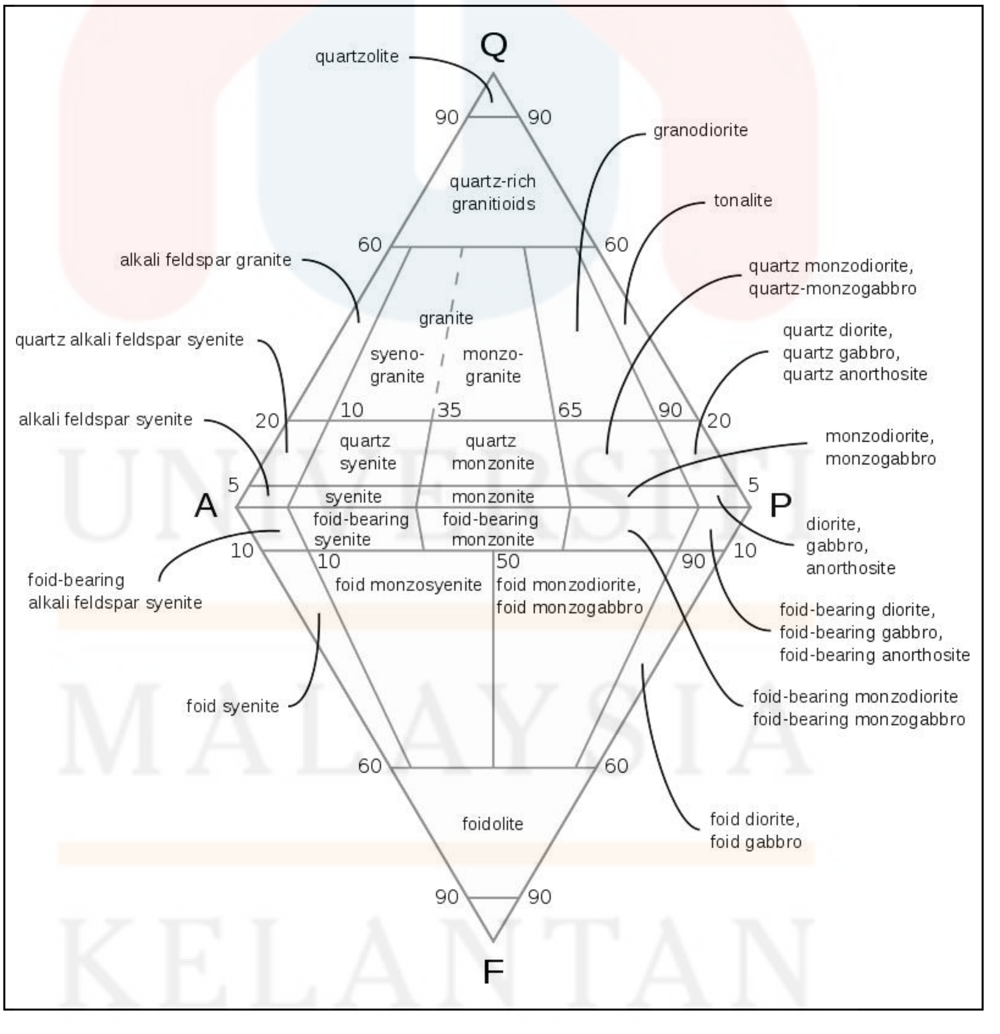


Figure 2.3: By Streckeisen (1974) ,QAPF diagram for classification of plutonic rocks.

2.8 Granitoid rock classification

The rock granite or its volcanic equivalent rhyolite has a limited range of composition that results in crystallization of equivalent amounts of quartz, plagioclase, and K-feldspar of granites only constitute a limited portion of quartz, K-feldspar and plagioclase magma series that may include tonalites, granodiorites, diorites, quartz monzonites, and granites (Figure 2.3). Therefore, the term granitoid is more general and useful as it included all rocks that are rich in quartz and plagioclase. There are three classification of granitoid rock which includes IUGS classification, chemical classification and tectonic setting classification.

2.8.1 IUGS classification

As been mentioned in petrology of igneous rocks above, IUGS classification is also a part of petrology analysis but it specifically for igneous rock. In IUGS classification of rocks, Bowen's reaction are related as it shows the series of mineral crystallization and formation as magma cooled. Temperature rate of magma in Bowen reaction series played important roles as it can determine texture of the rocks, colour of the rocks based on the minerals content, minerals contents of the rocks and types of the rocks. According to Bowen series in Figure 2.4 by Kristie (2016), the highest temperature of magma had indicated abundances of iron and magnesium in minerals which then the rocks that formed from the higher temperature then classify as mafic rocks.

Mafic rocks usually show a darker colour and aphanetic texture as the mineral had form in higher temperature. Examples of mafic rock are gabbro and basalt. Common minerals that usually contained in mafic rock are olivine, pyroxene, amphibole, plagioclase and biotite. For felsic rock, the colour usually light in colour with phaneritic texture as the minerals are formed within lower temperature compared to mafic rock. Most common minerals that formed in felsic rocks are orthoclase, muscovite and quartz and examples of felsic rocks are ryolite and granite. In granitoid rock, the most common minerals like quartz, plagioclase, alkali feldspar are usually been indicate. Other major minerals like biotite, hornblende, muscovite and tourmaline are common depending on the chemical composition of the granitoid while garnet and orthopyroxene are less common. There were also trace minerals that usually found in granitoid like zircon, apatite, sphene, oxides, allanite, monazite and xenotime.

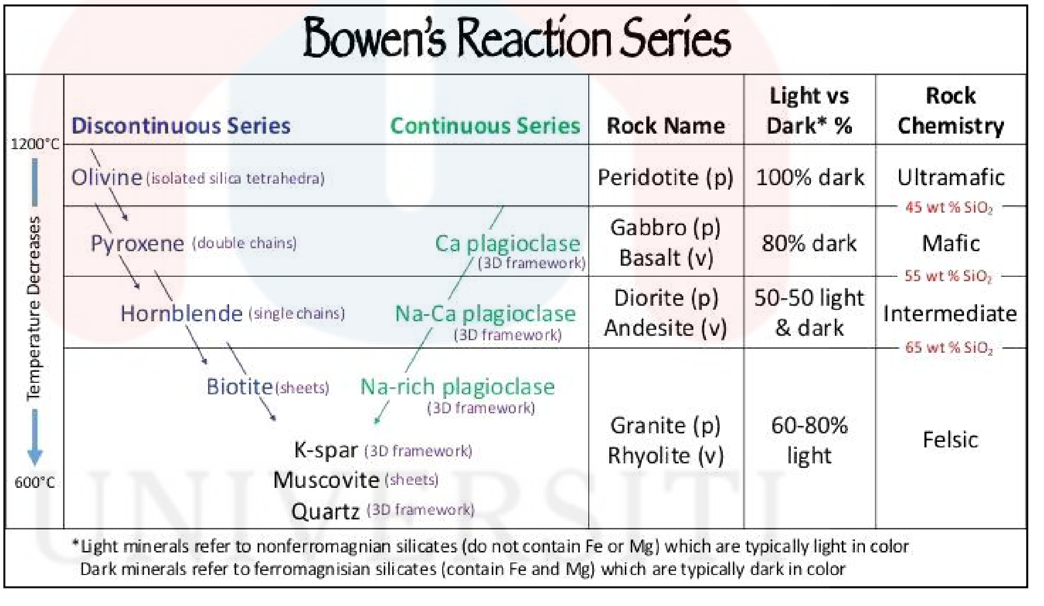


Figure 2.4: Bowen reaction series. Modified by (Kristie, 2010)

2.8.2 Geochemical classification

From previous study, granitoid classification also can indicates the chemical classification of Alumina Alteration Index , S-I-A-M classification and tectonic setting classification. S-I-A-M are known as S-types (Sedimentary source), I-types (Igneous source), A-types (anorgenic source) and M-types (direct to mantle source). All of this geochemical classification can be analyze through X-Ray Fluorescence (XRF) instrument. This classification can be analyze by major and trace elements from XRF analysis. Major elements like SiO_2, TiO_2, Al_2O_3, MnO, MgO, CaO, Na_2O, K_2O, Fe_2O_3 and P_2O_5 can be obtained from granite sample however there are detection limits for all oxides which are 0.01%. While for trace elements like Li, Cs, Rb, Cu, Pb, Bi, Ag, Th, U, Zr, Hf, Nb, Ta, Sn, W, Mo and Y there are limit for 0.1 ppm of, 1 ppm for Be, Ba, Sr, Zn, As, Ce and Cr, and 0.5 ppb for Au (Kyaw, 2014). By having these major elements and trace elements, S-I- A-M classification can be obtained as well as Alumina Alteration Index. Based on Table 2.3 below, it shows S-I-A-M classification based on the elements percentages in each granite sample (Kumar, 2014).

Table 2.3 : S-I-A-M classification of granitoids. Modified by Hartono (2017)

S-I-A- M Classification of Granitoids:

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

* molar $Al_2O_3/(CaO+Na_2O+K_2O)$

Data from White and Chappell (1983), Clarke (1992), Whalen (1985)

Alumina Saturation Index are also obtained by the geochemical analysis of major elements from XRF analysis. Major elements of $Al_2O_3/(Na_2O + K_2O + CaO)$ is plotted via graph and the ratio $Al_2O_3/(Na_2O + K_2O + CaO)$ is in terms of molar proportion. The related terminology is peraluminous if $Al_2O_3 > (Na_2O + K_2O + CaO)$ or $Al_2O_3/(Na_2O + K_2O + CaO) > 1.1$. Peraluminous rocks (including igneous rock) which excess of Al, deficiency of Na, K and Ca to form feldspar. It is indicated by the presence of Al_2O_3-rich mineral present as a modal mineral such as muscovite [$KAl_3Si_3O_{10}(OH)_2$], corundum [Al_2O_3], topaz [$Al_2SiO_4(OH,F)_2$], or an Al_2SiO_5-mineral like kyanite, andalusite, or sillimanite.

For metaluminous the graph reading $Al_2O_3 < (Na_2O + K_2O + CaO)$ but $Al_2O_3 > (Na_2O + K_2O)$ or $Al_2O_3/(Na_2O + K_2O + CaO) \approx 1.0$ as the interpretation, the rock may have hornblende . Next for subaluminous, $Al_2O_3 < (Na_2O + K_2O + CaO)$

but $Al_2O_3 = (Na_2O + K_2O)$, $Al_2O_3/(Na_2O + K_2O + CaO) < 1.0$ and rock usually have hornblende in it Lastly for peralkaline type, $Al_2O_3 < (Na_2O + K_2O)$ or $Al_2O_3/(Na_2O + K_2O + CaO) << 1.0$, rock will probably have lot of K-feldspar in the norm. Feldspar usually are very little ,if there were quartz (Kumar, 2014). Figure 2.5 show the alumina saturation classes based on the molar properties of $Al_2O_3/(Na_2O + K_2O +$ CaO.

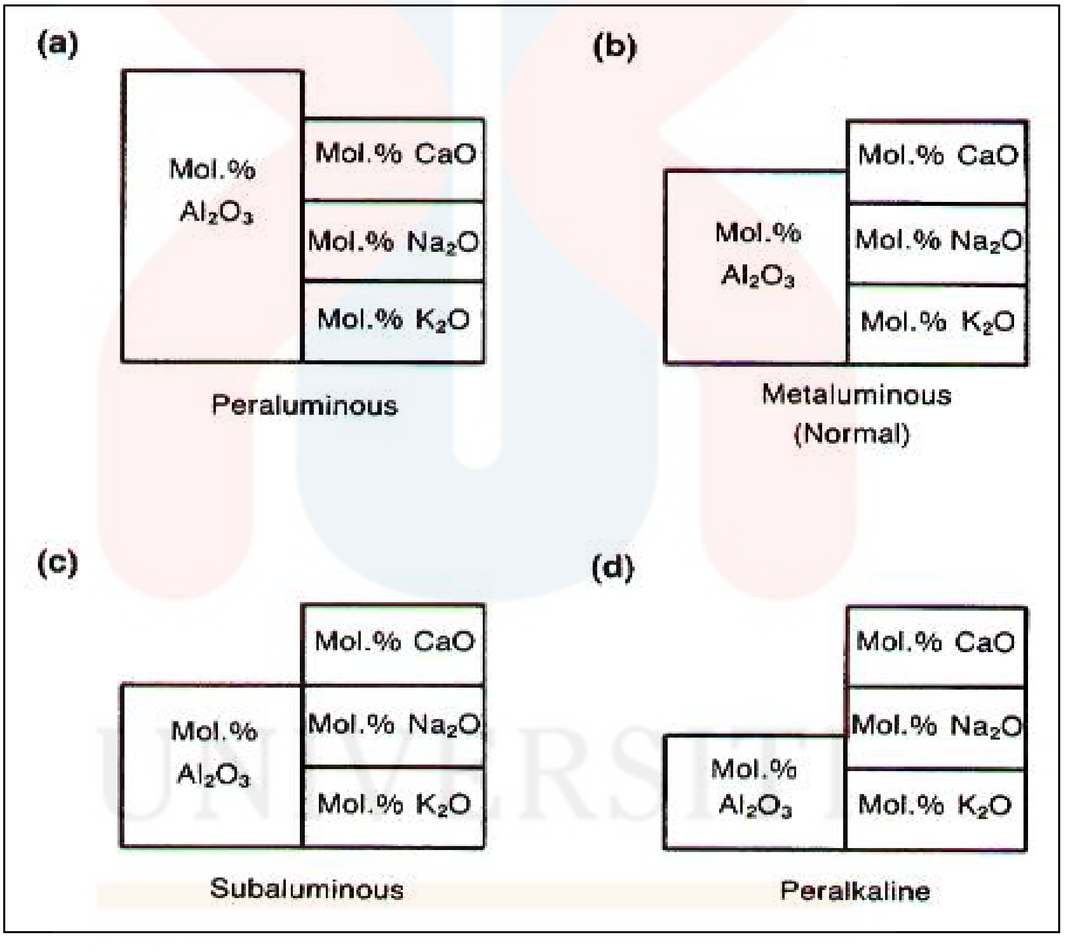


Figure 2.5: Alumina Saturation Classes based on molar properties of $Al_2O_3/(Na_2O + K_2O +$ CaO)

2.8 Rare Earth Elements (REE)

Rare earth elements are a group of seventeen chemical elements that occur together in the periodic table. The group consists of yttrium and the 15 lanthanide elements (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium). Scandium is found in most rare earth element deposits and is sometimes classified as a rare earth element. The rare earth elements are all metals, and the group is often referred to as the "rare earth metals." These metals have many similar properties, and that often causes them to be found together in geologic deposits. They are also referred to as rare earth oxides because many of them are typically sold as oxide compounds (King, 2018). The rare earth elements are often subdivided into "Heavy Rare Earths" and "Light Rare Earths". Lanthanum, cerium, praseodymium, neodymium, promethium, and samarium are the light rare earths. Yttrium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium, and Lutetium are the "heavy rare earths." Although Yttrium is lighter than the light rare earth elements, it is included in the heavy rare earth group because of its chemical and physical associations with heavy rare earths in natural deposits.

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

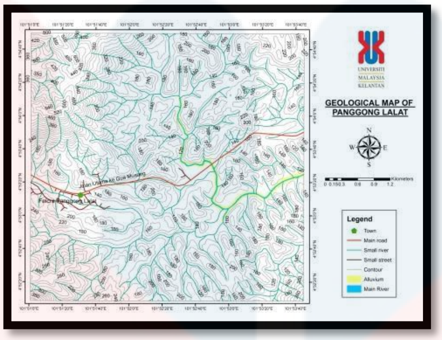
There are several methods and materials taken into account for the purposed study of geological mapping in order to achieve the objectives of the research project. Figure 3.1 is the flow chart which shows an outline of the methods that is conducted for the purpose of geological mapping in the particular study area.

3.2 Materials

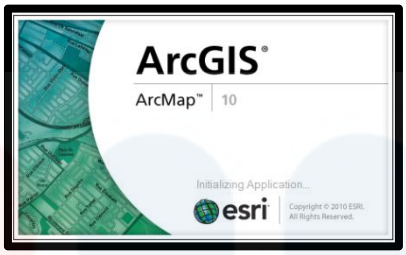
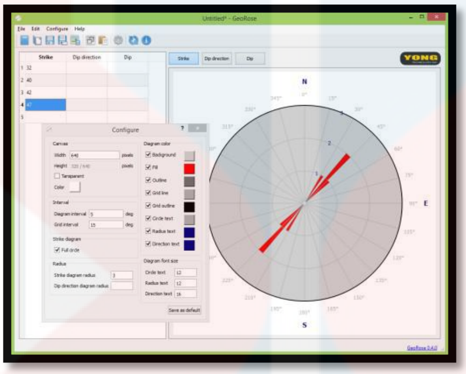
The materials that been used on the field as followed for geological mapping processes are listed in Table 3.1 below.

Table 3.1:List of materials and apparatus

Materials	Pictures	function
Hammer		Hammer is a basic tool for any geologists as it is used to collect samples. The flat end of the hammer is used for breaking the rocks and light chisel work. The pointed end is used for prying the rocks and prospecting in soil and loose rock debris. Hammer

		also can be used as a scale.
Map		Map is very important as a reference for geological fieldwork. To know the detail about the place or location. Stratigraphic contour lines may be used to illustrate the surface of a selected stratum illustrating the subsurface topographic trends of the strata.
Compass		Compass is a tool used to take the accurate bearing based on the precise directional measurements of the places.It also used to take strike and dip reading of the bedding plane of outcrop.
Measuring Tape		Tape can be used as a scale, to take the ground distance. It also important for taking actual measurements of lithology and structures.
Global Positioning System (GPS)		Gps is use to take accurate coordinate of the research area other than provides geolocation and time information to a GPS receiver anywhere.

Hydrochloric acid (HCL)		HCL was used to determine reaction of the rocks specimen towards HCL solution and usually used for carbonate rock like limestone and dolomite.
Hand Lens		To observe and determine the tiny particles in the rock that cannot see by naked eye. It is used to examine the sediment, rocks, soils, mineral, sand and other materials with tiny figures.
Field note book		Field note book is used to write all the data and information that we got from the mapping field.
Sample Bag		Sample bags are use to put hand speciment that had been taken in the field site during mapping process.
Stationary		Stationary like pen,pencil and protractor are used to jote down notes during mapping and to plot data during analysing data process.

ArcGis		A software that used to create, edit, analyze and share information to build a map.
Software		Software are used to analyse the data before and after mapping processes. The software that usually used in completing the thesis are GeoRose, Stereonet, Sedlog, Microsoft Office and Microsoft Excel.
Microscope		To observe and identify minerals of the rocks by examine the thin sections of the rock samples under PPL and XPL.

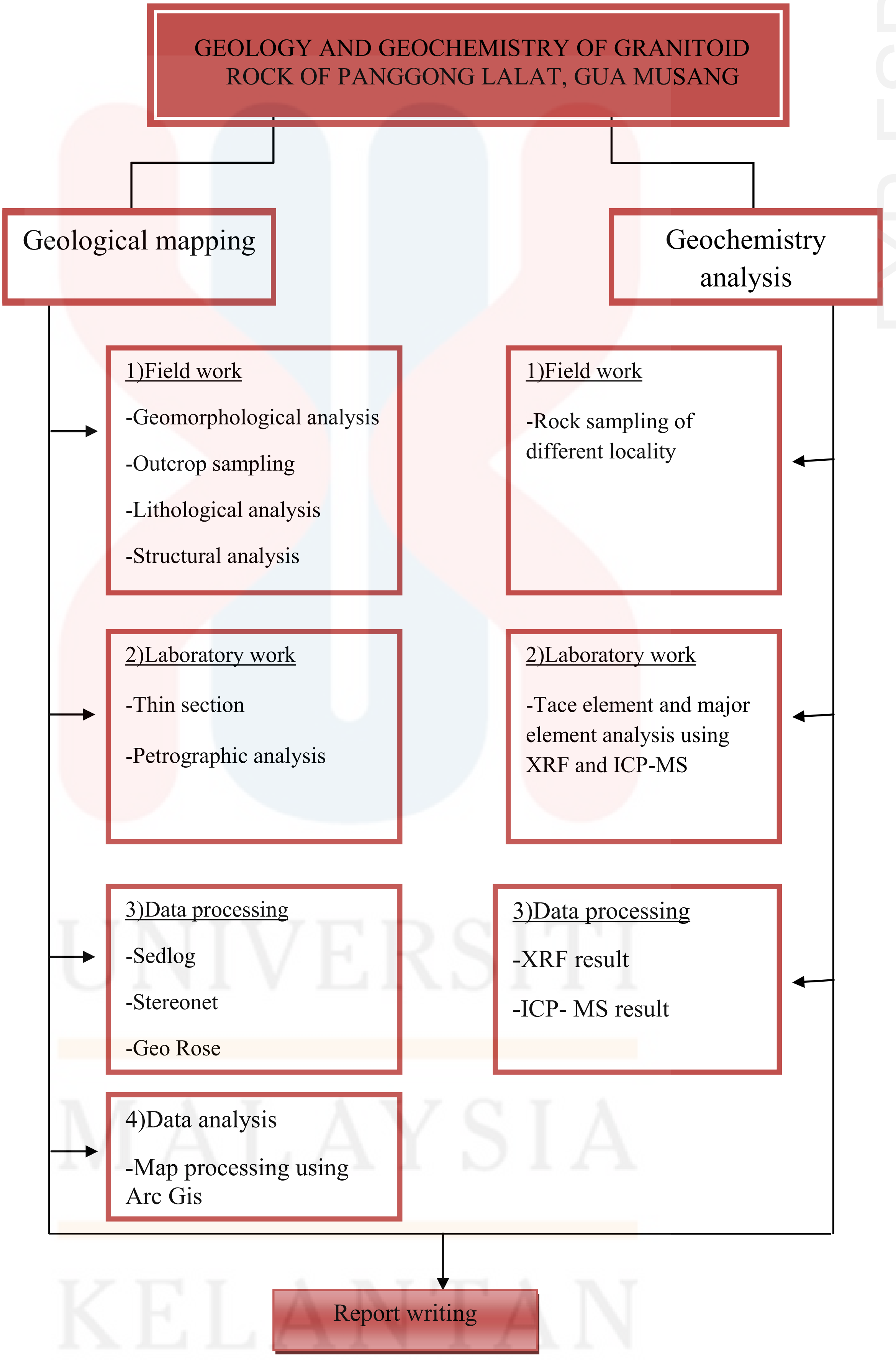


Figure 3.1: Research flow chart of the research topic

3.3 Methodologies

In this section, it covered all the methodologies that might be conducted throughout this research activity. The research is incompleted if one of the method is skipped. Figure 3.1 above shows the research flow chart of the research topic.

3.3.1 Preliminary research

Preliminary research provided the information of the study area. Preliminary research are done through desk study, and observation of topographic and geological map of the study area. Various research or studies have been conducted in area of Gua Musang. The previous research stresses out more on geological heritage, stratigraphy, sedimentology, general geology and paleo-environment rather than geomorphology in Gua Musang.

3.3.1.1 Literature review

The purpose of doing literature review is to collect the data and important information regarding the research topic. It actually will helps the researcher to get the overall ideas of the research.

3.3.2 Field studies

This research focuses on the studies of the geomorphological mapping, structural analysis and lithological analysis and outcrops sampling of the study area. These steps are needed in order to complete the geological mapping accurately.

Observation of geology in the field is part of the process of geological mapping. The observations should be recorded by traversing route in the study area and plot the geology structures along the way. The data that have been recorded will be process by using GIS software to produce geological map. Strike and dip data, lithology boundaries was taken when we doing the mapping.

This mapping involves 5km x 5km area of the study area. The outcrop samples took must in fresh condition and not altered. For taking pictures of the outcrops or sampels a needed in the outcrops pictures to clarify the outcrops reality size. For example if the sample or outcrops is smaller, smaller scale like coins or pen can be used as a scale but if the outcrops are bigger human can be used as a life scale. Geomorphological study of the study area was conducted to relate the geomorphological classifications with its processes.The stages of geomorphologic classifications were identified by making a field observation of on the geomorphologic characteristics.

3.3.2.1 Geomorphological mapping

Identification of karst formation or landforms in the field can be identify by doing a geomorphological mapping and GIS software with the aids of Google Earth and Google Maps and are used to interpret the location's data as well. The karst formation or landform that were found are plotted in the base map while traversing. Camera is the main tools to collect all the various pictures of karst formation or landform as to prove karst geomorphology in the field. Sketches and maps of landscapes and landforms have been basic methods to analyze and visualize Earth surface features .

Table 3.2: Workflow of geological mapping (Modified from Jasper Knight, 2011)

Mapping	Activity
Pre mapping	- A purpose and/ or goal of mapping should be identified. - Geological and mapping information must have been obtained. - A GIS database was design and created. - Draft map at a suitable scale for field mapping was created. - Legend system and symbols was prepared. - Gain permission for access to the mapping region.
During the field mapping	- Field mapping was conducted according to the plan. - GPS was used to mark tracks or waypoints. - Jot down the notes, take pictures and also positioned using GPS.
Post Mapping	- Create final geological and geomorphological map in the GIS software with the aids of Google Earth. - Publish the map: geological map and geomorphological map.

3.3.2.2 Structural studies

For structural studies, it is highly recommended to find a fresh outcrop in the study area as the data will be more accurate and the geochemical analysis data also would turn out well if the outcrop samples are fresh. The condition of topographic can affect the abundant of outcrops as in exposed area outcrops is easier to find compared to unexposed area. The easiest way to find the outcrops is by identifying the lineament first in the map. Finding lineaments in the map will helps the researchers to find major structures like fault as structures usually located at the lineament in the map.For strike and dip data,they should be taken and recorded on the outcrops bedding. Strike and dip data reading can be taken by using Brunton or Sunnto compass.

3.3.2.2.1Lithological analysis

Lithology analysis are distinguished by the lithology of rocks, grains size, sedimentary structures, colour of the rocks and fossil content in the rock. For accurate lithology data, the lenght of the outcrop must be measured using a measuring tape before knowing the properties of the rock. Every width and changes in colours of every rocks are measured and recorded. Grain size of every rock unit have to be considered and recorded. To get more accurate lithology result, fossil were searched around the study outcrop as fossil act as an indicator to determine the geologic time scale and geologic event of the area. All the recorded data then will be process and analyse using Sedlog software.

3.3.3 Laboratory work

This section involves all the laboratory work of the sample.It includes the thin section process and geochemical analysis which involve analysis of trace element and major element of granitoid rocks.

3.3.3.1Thin section

Thin section is done to know and to interpret the mineral composition of the rocks. There are three stages of thin section processes which are sectioning,grinding and lapping. For sectioning, a rock cutter is use to cut the rock sample to our desirable size and thickness which is suitable for thin section analysis. Next grinding is necessary after a desirable size and thickness is obtained, the rock is then grind in order to get a flat and smooth surface of the rock. Grinding process was used to remove any deformation that occurred during sectioning process.

The flat surface was then cemented to the glass slide. Lastly lapping process was done after the flat surface of the rock is cemented to the glass slide. Then, the rock chip was moved on rotary motion against the glass plate together with carborundum powder and water as shown in figure. This process is called lapping process which is done until the composition on the mineral can be seen under the microscope. This process must be done carefully, as if it overdo the minerals of the rock might be not visible even or deform (PAYAH, 2017).

3.3.3.2Geochemistry analysis

a) X-Ray Fluorescene

X-ray florescence study (XRF) are used for determining the contents of major and trace elements in rocks by whole-rock and selective analyses (Fairchild et.al, 1988). Samples were crushed to a fine powder in the laboratory. The whole-rock compositions were also determined. Major elements were determined by X-ray fluorescence (XRF) using a Philips PW 1404/10 X-ray spectrometer by fusing with lithium tetraborate and casting into glass discs. The trace element Zr was also measured by X-ray fluorescence using pellets of pressed rock powder. X-ray counts were converted into concentrations by a computer program base on the fundamental parameters method of de Jongh (1973). Precision was of 2-5% for major elements, except Mn and P (5-10%), and 2- 5% for Zr (Kyaw, 2014).

b) ICP-MS

Inductively coupled plasma mass spectrometry (ICP-MS) has been used successfully for the direct determination of trace elements in granites and thus is required to use sample preparation methods that result in the total dissolution of the sample. For solution ICP-MS, analytes must be completely dissolved for accurate analysis of solutions ICP-MS. The goal of digestion is to dissolve the analytes and to decompose solids while avoiding loss or contamination of the sample. Undissolved analytes will not be accurately measured if the samples are not digested. The rock sample should be dried and homogenized. Weigh 0.25 g of sample into a pre-cleaned 50 mL plastic tube. Add 5 mL of nitric acid. Loosely cap the tube to allow gasses to escape without exploding the tube. Let the sample react at room temperature for a minimum of 1 hour.

Heat samples at 90°C for 30 minutes. Allow the sample to cool, add an additional 5 mL of nitric acid and heat for another 30 minutes, repeat until no brown fumes are emitted from the sample. Heat the sample (still loosely capped) until all but 5 mL have evaporated. Add 2 mL of DI water and 3 mL of trace-metal grade hydrogen peroxide. Heat until effervescence subsides. With the tube still capped, heat the sample until 5 mL remains. Dilute to a final acid concentration of 2-5%. Process 2 blank samples followed the same procedure as the samples and submit as a method blank. Process 2 certified reference materials (of similar composition to your sample) following the same procedure as the samples and submit. (http://cais.uga.edu).

3.3.4 Analysis, result and discussion

In this part, the data that been collected from the mapping and experiment are analysed.For producing 1:25,000 geological map,all data that being obtained during mapping will be analysed using ArcGis and GPS.For petrography analysis,the data interpretation of granitoid mineral content was refered and QAPF diagram areplotted.For geochemistry analysis,the data obtained will be interpreted to determine the characteristics of the granitoid rocks through XRF and ICP-MS result.

3.3.5 Conclusion

In this section, conclusion are made based on the result and the discussion.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

4.1.1 Contents

In this chapter, only mapping activities and informations regarding the general geology of the study area, Panggong Lalat were discussed and provided in order to complete this research report, the specification study was later discussed in Chapter 5 of the research report. For general geology informations, it comprise the geomorphology, drainage pattern classifications, lithostratigraphy, structural geology and the historical geology of the study area which is Panggong Lalat, Gua Musang. So in order to accomplish all the general geology data, geological mapping was done in the specific research area of a researcher. However before entering the site for geological mapping, a preliminary study of the research area was done via previous research, books, online journals and informations and others. Other than that, petrography studies are also briefly explained in this chapter. Further elaborations and analysis will be continued in chapter 5 as research specifications.

This chapter will make readers comprehend the general geology of study area. For your information, geological mapping was done in about a month in order to complete the general geology aspects based on the guidelines that have been given by the faculty. All researchers were given different study area around Gua Musang with 25km^2 each and the study area were given according to its compatibility with the specification research of the student that they had chose before. The main purpose of doing the geological mapping was to update, observe and measure the latest geological data and map in the study area as by mapping, geological data structures like bedding informations (through strike and dip readings) can be obtained. Other than bedding informations rock types of the study area, outcrop sampling, geology structures like fault, joint and others, geomorphology, stratigraphy and history of the study area can also be obtained.

The purpose of collecting all the geological data was to achive the first objective of the research study which is to update and produce the geological map of 1:25000 scales of the study area. Based on the geological data obtained, it was found that the study area, Panggong Lalat composed of three rock unit which are granite the youngest one, limestone and metasediment (slate mostly) as the oldest rock unit in the study area. Based on geomorphology prespectives, the contour elevation ranges of the research area are within 120 m to 540 m. The topography map of the study area in Figure 4.3 showed that the study area are mostly covered with hilly landform surfaces which are not too high but on the North-West side of the research area the topography elevates up to 540 m.

The outcrops of the study area were mostly found and discovered in the forest, estate, rubber tree plantation and housing area (Figure 4.1). The condition of outcrops were quite weathered as the weather and the environment in the research area are quite harsh. Geological structures like fault was really hard to find and there are some area in the research area that cannot be accessed. Granite can be considered as one of the industrial mineral that important for sources of construction, almost 30% of granite rock were found in the study area. Figure 4.2 shows one granite outcrop that was found in the foot hill of rubber tree plantation.

Figure 4.1: Limestone outcrop at Kampung Panggong Lalat housing area.

Figure 4.2: Granite outcrope along the offroad road in the forest area.

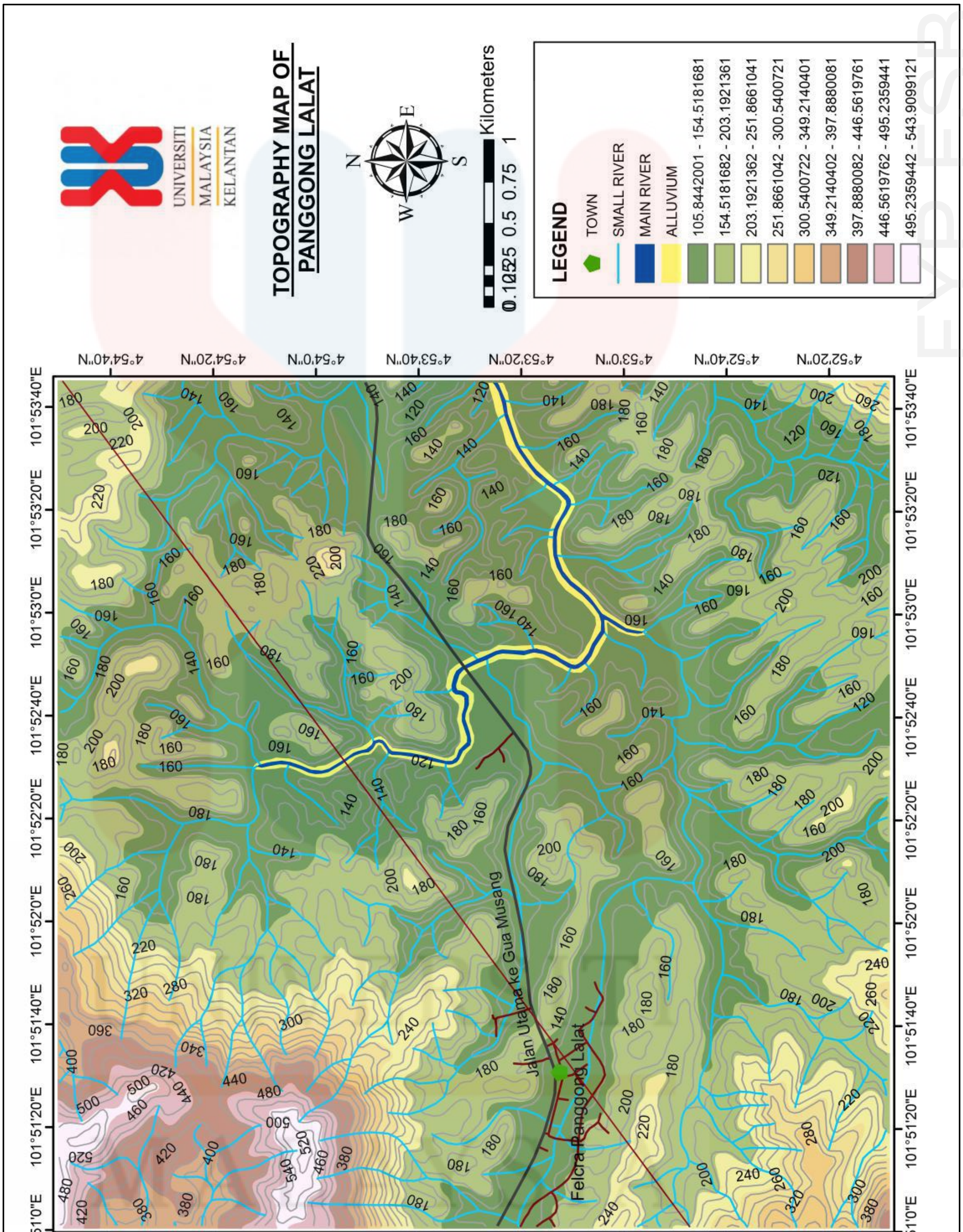


Figure 4.3: Topography map of Panggong Lalat

4.1.2 Accessibility

The accessibility of the research area, Panggong Lalat is quite smooth as it is strategically located at the main road of Jalan Gua Musang – Kampung Kuala Betis, however there were also limitations in accessibility as the study area is covered with high elevation and thick forest area. Figure 4.4 shows the main road of Jalan Gua Musang to Kampung Kuala Betis that connected with Bandar Gua Musang with the study area, Panggong Lalat. The main road is used by the villagers around the area as the accessibility to their main town, Bandar Gua Musang. The village area in the research area are also accessible as there are paved road that have been used by the villagers in Kampung Panggong Lalat area (Figure 4.5). The paved road along study area can be access either by car, motorcycles and other transports as the roads are located in residential area.

The unpaved road connection are widely spread across the study area as the study area are rich with plantation site like rubber tree plantation and palm oil plantation. The accessibility of the unpaved are actually referred to the landform of the area. Based on the mapping experienced in the study area before, it seems that the accessibility in plantation area like rubber tree plantation and palm oil plantation are quite smooth as the were already unpaved small street that have been made and access by the villagers around the area. However, the unpave road like the thick forest area that showed in Figure 4.6 seem to be quite difficult to be access with normal transport like car as the topography of the area are uneven and the elevation of the plantation site like palm tree plantation are quite high. Even it have high elevation, the unpaved road still can be access either by motorcycles or 4x4 vehicles as to make the geological mapping process more faster and easy.

Figure 4.4 : Main road of study area Jalan Gua Musang to Kampung Kuala Betis. Source, Google Map

Figure 4.5 : Small street along Kampung Panggong Lalat. Source, Google Map

Figure 4.6 : Unpaved road at high elevation forest area

4.1.3 Settlement

Table 4.1: Area by District of Kelantan by year 2016

DISTRICT	AREA (HECTARE)	PERCENTAGE (%)
Kota Bharu	40,144	2.38
Pasir Mas	56,707	3.36
Tumpat	17,725	1.06
Pasir Putih	42,302	2.52
Bachok	27,825	1.65
Kuala Krai	227,670	13.52
Machang	52,791	3.14
Tanah Merah	87,948	5.22
Jeli	131,916	7.83
Gua Musang	817,595	48.54
Lojing	181,700	10.78
JUMLAH / Total	**1,684,323**	**100%**

Source: JUPEM, 2018

Table 4.2: Total population by ethnic group, district/mukim and state, Malaysia, 2010

District/ Mukim	Total	Malaysian Citizens							Non-Malaysian Citizens
		Total	Bumiputera			Chinese	Indian	Other	
			Total	Malay	Other				
Gua Musang	**86,189**	**81,2004**	**76,823**	**64,253**	**12,570**	**3,870**	**350**	**161**	**4,985**
Galas	36,955	35,312	31,084	30,981	103	3,808	329	91	1,643
Bandar Gua Musang	20,047	19,369	15,944	15,848	96	3,100	287	38	678
Batu Papan	1,834	1, 706	1,687	1,687	-	9	-	10	128
Gua Musang	163	160	160	160	-	-	-	-	3
Ketil	1, 818	1, 660	1, 617	1,617	-	14	25	4	158
Pulai	2,203	2, 069	1,422	1,418	4	617	16	14	134
Renok	10,890	10, 348	10,254	10,251	3	68	1	25	542
Kelantan	**1,470,696**	**1,439,640**	**1,378,352**	**1,362,830**	**15,522**	**48,787**	**3,658**	**8,843**	**31,056**

Source: Majlis Daerah Tumpat ,2011

Gua Musang is the largest district in Kelantan (Table 4.1), however due to its undeveloping process, Gua Musang population was quite low compared to Kelantan's main capital state,Kota Bharu that its district area was twenty times smaller tan Gua Musang. Due to its undeveloping process by government, Gua Musang area was really beautiful with its geographical features of limestones. Gua Musang area was statistically divided into three Mukim which are Mukim Galas, Mukim Relai and Mukim Chiku. According to JUPEM,2018, the reasearch area,Panggong Lalat was included in Mukim Galas region. Based on Table 4.2, it shows that Mukim Galas hold total of 36, 955 population out of 86,189 population of whole Gua Musang and based on the table also we can see each of region population based on Mukim Galas population statistics.

In Panggong Lalat area, there was Felcra Panggong Lalat. Figure 4.7 and Figure 4.8 below showed the Felcra Panggong Lalat's office and Felca Panggong Lalat staff's housing area in study area respectively. Felcra Panggong Lalat is one of the Felcra Malaysia government- owned company that established on 1966. Their goal is to develop the rural sector by helping their residents participate in the economic activities of Malaysia and further enhance their living standards and values (Felcra Berhad, 2018). As the area were developed by Felcra Malaysia so most of the residents there were involved in agriculture sectors like rubber tree plantation and palam oil tree plantation. Most of their main source of income come from that sectors, while there were also some residents that involved themselves in business sectors as there were many small shops like workshops,grocery shops and small eatery places along the study area's roadside.

Figure 4.7: Felcra Panggong Lalat office.

Figure 4.8: Felcra Panggong Lalat staff's housing area.

4.1.4 Vegetation

As the study area was mainly owned by Felcra Berhad, so most of the land in the study area were developed into plantation area like rubber tree plantation and palm oil tree plantation. However, not all land in the study area owned by Felcra Berhad, there were also some land that owned by the villagers as the results many orchards can be found around the study area. There were also undeveloped area like thick forest that located at the North- West and South- West in the box's map of Panggong Lalat area (Figure 4.12). As the results most of this area were discovered and explored by the logging company for logging purposes. Recently,most of the hill were explored and most of them were nearly bald due to excessive logging. Based on Figure 4.9, the picture shows the products of logging that were left near the unpaved road in the hilly area of Panggong Lalat. Futhermore, most of the residents of Panggong Lalat area were self-employed and most of the them tend to involve themselves in agriculture sectors like rubber tree plantation, palm tree plantation and others.

Dominantly, Panggong Lalat area were mainly composed of rubber tree plantation (Figure 4.10) and palm tree plantation (Figure 4.11) that owned by Felcra Berhad. Based on figure 4.10 below, we can clearly see that almost half of the study area composed of rubber tree plantation in the study area, as the result most of the villagers there really depend on the rubber plantation as their main source of income. Palm tree plantation was located at centre part of study area, this can be seen in the map of figure 4.12 below. In addition, palm tree plantation also play as the source of incomes for the people in the research area, Panggong Lalat. Despite its as sources of income to the villagers, the palm tree plantation in the study area however was not organized well as most of the unpaved road in the plantation area cannot be access via transport and only by walking due to its thick bushes around the area. Agriculture sectors in the study area were not only involved by the villagers, there were also foreign workers like Indonesians, Vietnamese and Bangladesh that worked in that sectors in the study area.

Figure 4.9: Left trees due to logging.

Figure 4.10: Rubber tree plantation along the road side of the study area

Figure 4.11: The palm tree plantation in the study area

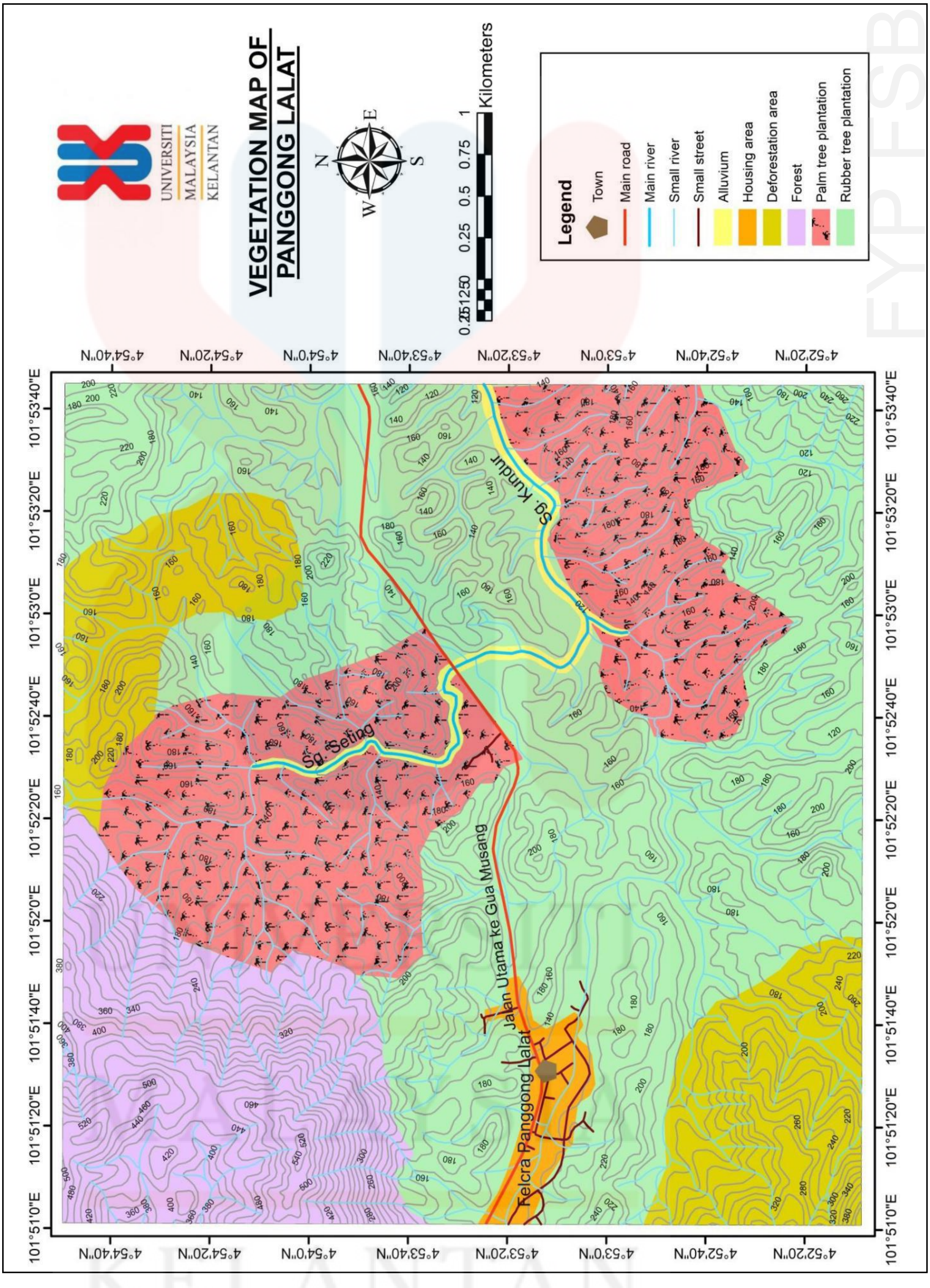


Figure 4.12: Vegetation map of Panggong Lalat

4.1.5 Traverse and observation

Figure 4.13 showed traverse and rock sample map of the research area, Panggong Lalat. Based on the map, the traverse route are mostly covered the paved road of the study area. This is because the paved roads, Jalan Gua Musang – Kampung Kuala Betis is the main road that connect the whole study area. Other than that, there where also paved roads in the housing area that are easy to access in the study area. In addition referring to the geomorphology map in Figure 4.14 , we can see that the topographic units of the study area are hilly to mountainous with mean elevation of 76 - 300 m to > 301 m respectively. So based on the topography of the study area, there were many unpaved roads found in the higher elevation area especially in rubber tree plantation, palm tree plantation and in forest area. Based on the map below, all the traverse route in higher elevation area are unpaved road and most of the unpaved road cannot be access by normal transport like car, it just can be access via hilux or 4x4 transport as the routes are quite extreme and slippery. Most of the routes in study area are access by walking as geological mapping need a further observation and measurement in order to obtain accurate data.

For the observation in the study area, the observation are made based on the geomorphological analysis, outcrops sampling, lithology analysis and structural analysis. For geomorpological analysis, the study area are in form of hilly to mountainous landform with mean elevation of 76-300 m to > 301 m. Then for outcrops samplings, the sampling had done in various location according to its lithological unit as the study area composed of three lithological units of granite, sedimentary rock of limestone and metasedimentary rock of slate. Table 4.3 showed the rock samples coding with their further description. Other than that, structural analysis observation are made in the study area according to the lineament analysis.

No fossils are found in the study area since the area might have exposed to volcanic activity thus that why granite intrusion occur in the area. Depositional environment was conserved as the shallow marine environment since the area composed of dark grey carbonaceous rocks.

Table 4.3: Rock samples coding of outcrops in the study area.

SAMPLE CODING	LITHOLOGY	COORDINATES	ELEVATION (m)	DESCRIPTION
IGNEOUS ROCK				
18AZ01A *S01	Grey Granite	-101°53'44.336"E -04°54'4.03" N	-145 m	-Slightly weathered - Outcrop in the small river in rubber tree plantation
18AZ02A *S02	Pink Granite	-101°52'25.8"E -04°53'51.3"N	-142 m	-Slightly weathered -Outcrop located in the small waterfall area in palm tree plantation
18AZ03A *S03	Grey Granite	-101°51'46.183"E -04°53'27.392"N	-160 m	-Moderately weathered -Outcrop located at the valley of rubber tree plantation’s hill
18AZ04A *S04	Andesite dike	- 101°52'12.4"E -0 4°54'09.6"N	-163 m	-Highly weathered -Outcrop located on the unpaved road area of palm tree plantation, intruded the pink granite outcrop.
SEDIMENTARY ROCK				
18AZ06B *S05	Crystallize limestone	-101°53'16.002"E -04°53'45.308"N	-219 m	-Moderately weathered. -Outcrop was located in

				the rubber tree Plantation.
				-Outcrop were taken from karst landform which is Gua Berlian.
18AZ07B *S06	Limestone	-101°51'36.929"E -04°53'7.132"N	-139 m	-Slightly weathered eventhough it is exposed. -Outcrop was located in the housing area which is Felcra Panggong Lalat area.
METASEDIMENT				
18AZ08C *S07	Slate	-101°53'21.098"E -04°53'18.597"N	-147 m	-Highly weathered as almost half of the outcrop's material was decomposed or disintegrated to soil. -Located in the palm tree plantation. -Slatey cleavage were obviously seen -The slate was in greyish black colour.
18AZ09C *S08	Slate	- 101°52'23.65"E -04°52'41.941"N	-137 m	-Moderately weathered as the outcrops were found in the small river. -Located in the rubber tree plantation area. -Slatey cleavage were found on the outcrop and the outcrop colour is reddish brown.
18AZ10C	Slate	-101°51'0.976"E	-161 m	-Highly weathered as

*S09		-04°53'10.843"N		almost half the outcrop's materials wasdecomposed and disintegrated to soil. -Outcrop was found in the village area
18AZ11C *S10	-Slate	-101°53'13.284"E -04°54'1.746"N	-192 m	-Completely weathered as the rock material is decomposed and disintegrated to soil. -Outcrops located in the deforestation area around. -Slatey cleavage form and outcrops are in red brownish colour.
18AZ12C *S11	-Slate	-101°51'14.023"E -04°52'19.327"N	-323 m	-Highly weathered as almost half the outcrop's materials was decomposed and disintegrated to soil. -Outcrop located on the hill side of deforestation area -Slatey cleavage form and the rock sample is yellowish brown in colour.

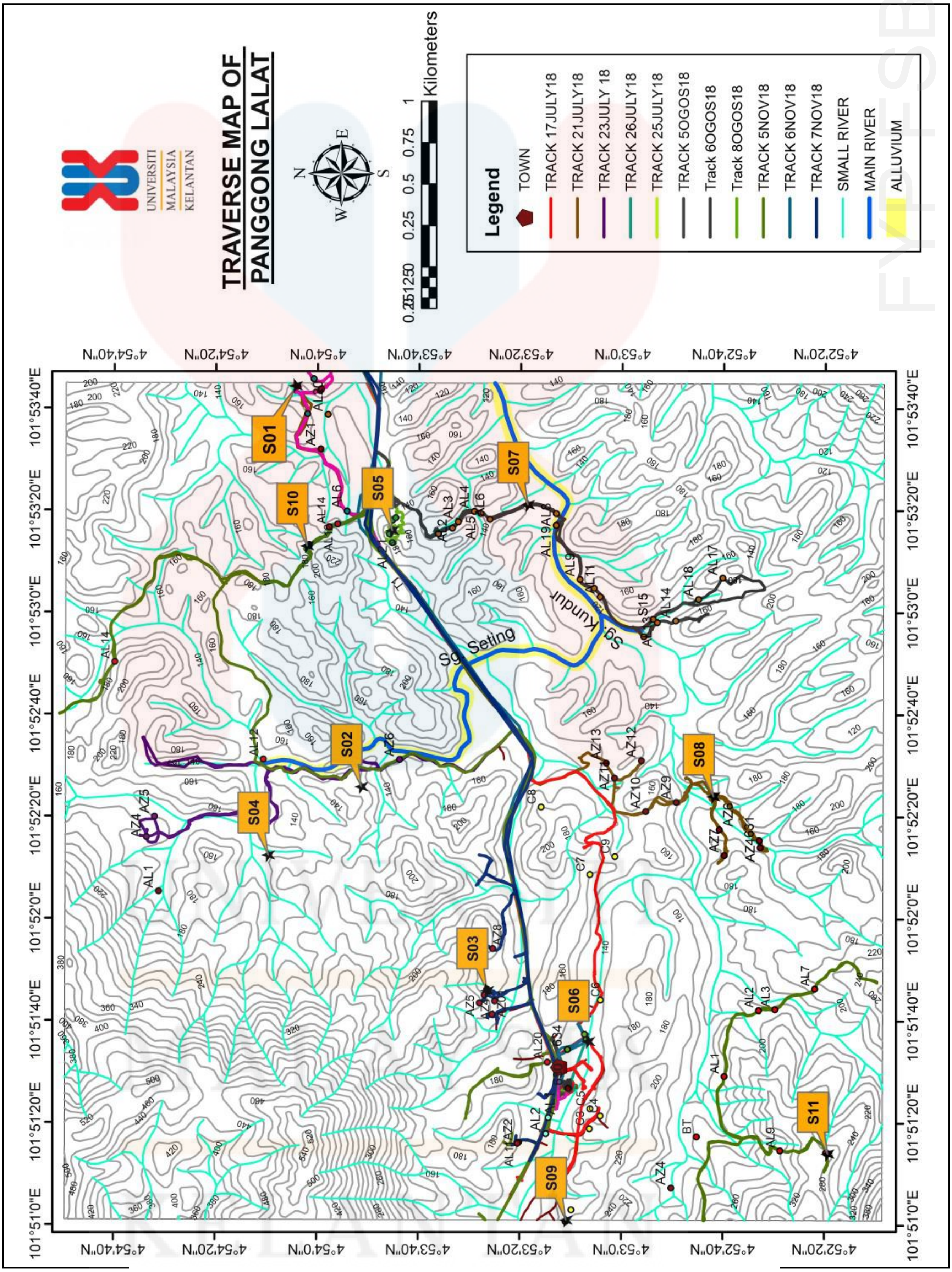


Figure 4.13: Traverse map of Panggong Lalat.

4.2 Geomorphology

4.2.1 Topography

Based on the geological mapping process, geomorphological analysis is one of the major part in completing the fieldwork analysis. Based on the topographic features of the study area that are seen in the map of Figure 4.14 below, the study area composed of two topographic unit which are hilly and mountainous with 76 – 300 m and > 301 m of mean elevation above sea level reading respectively. Other than that, three dimensional (3-D) map (Figure 4.17) of the study area Panggong Lalat was produced in order to show the geomorphology landform of the study area in three dimensional. The research area are mostly covered with the plantation as the Panggong Lalat was owned by Felcra Berhad.

The hilly part of the study area are mainly composed of metasediment rocks and soils which suitable for agricultures activities. So as the result, most of the hilly part were discovered and developed as the plantation area of rubber tree,palm tree and orchards by the villagers there. The higher elevation area which is mountainous region, was covered by thick forest and mainly exposed of granite unit. The main activity that being explored in the mountainous area was deforestation and some of the area were also developed as the plantation area like rubber tree plantation. Table 4.4 below showed topographic units with mean elevation above sea level (m) reading:

Table 4.4: Topographic units classification (Raj, 2009)

No.	Topographic unit	Mean Elevation Above Sea Level (m)
1.	76-300	Hilly
2.	>301	Mountainous

Source: Geology of Peninsular Malaysia

Figure 4.15 shows the geomorphology landform that had been taken from the mountainous area of elevation of 390 m with bearing of 084°. From the picture, hilly landform and karst landform are clearly seen from the picture, while Figure 4.16 also show the picture of the landform but taken via panorama style that taken from the same location of 101°50’ 57.9” E, 04°52’ 06.9” N.

Figure 4.15: Geomorphology landform of the study area

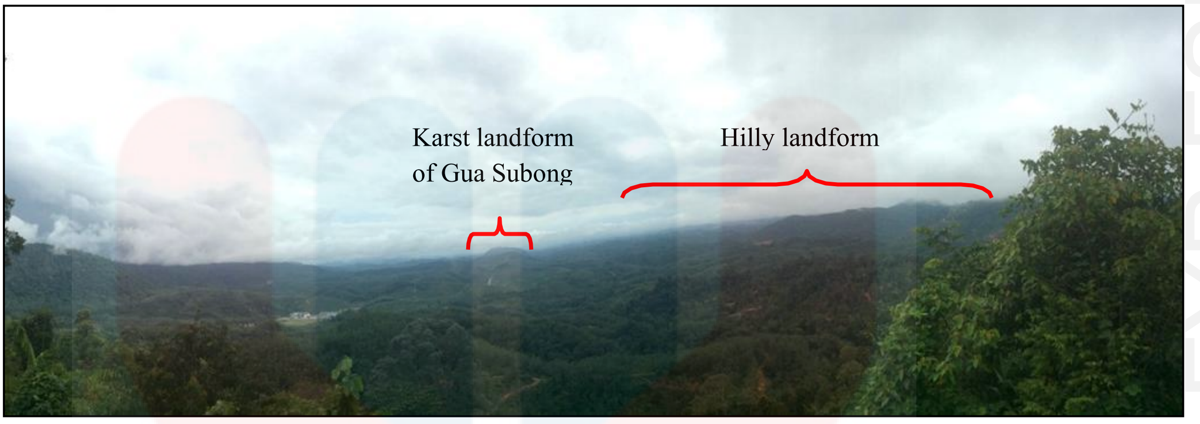


Figure 4.16 : Panoramo picture of geomorphology landform of the study area

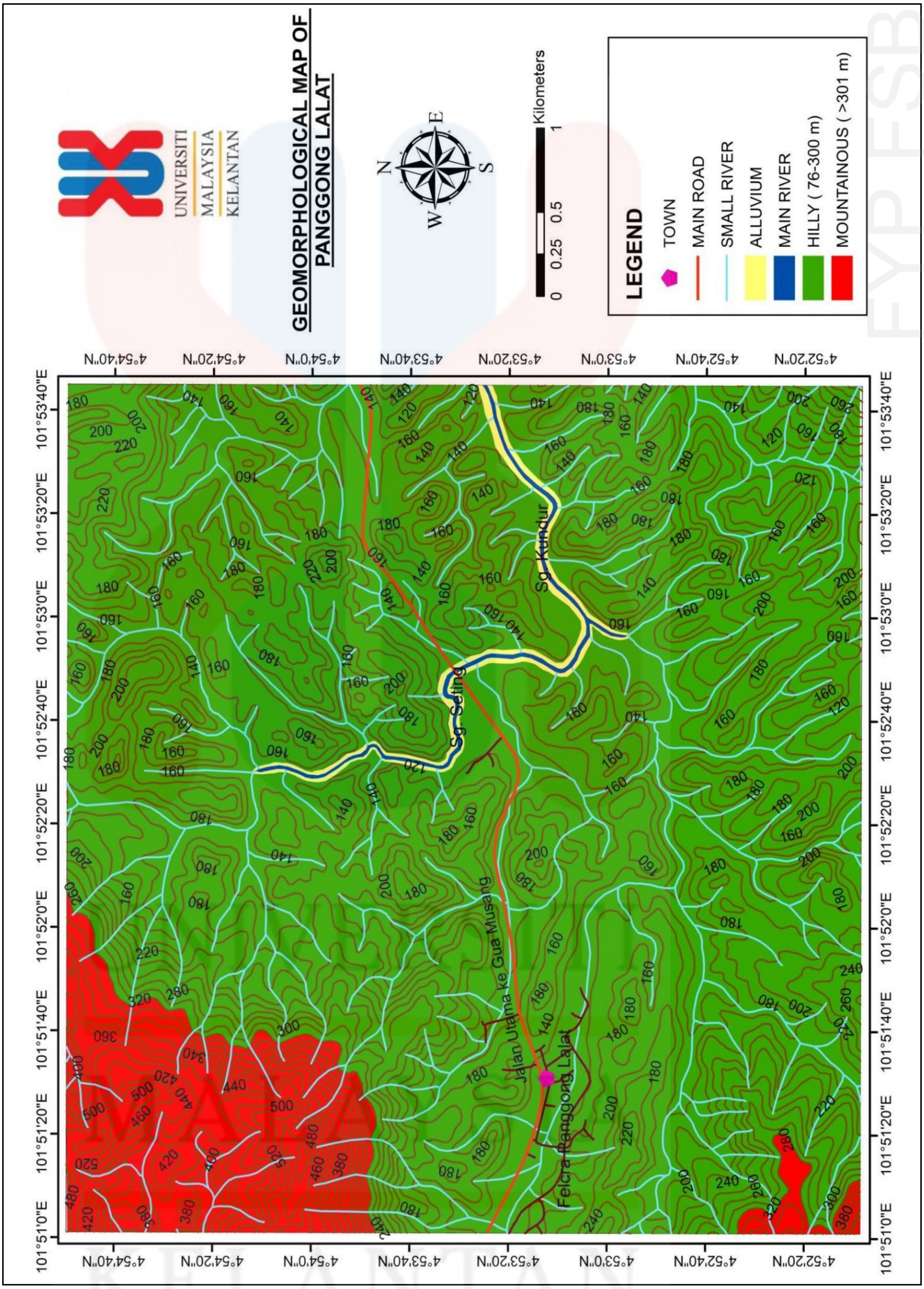


Figure 4.14: Geomorphological Map of Panggong Lalat

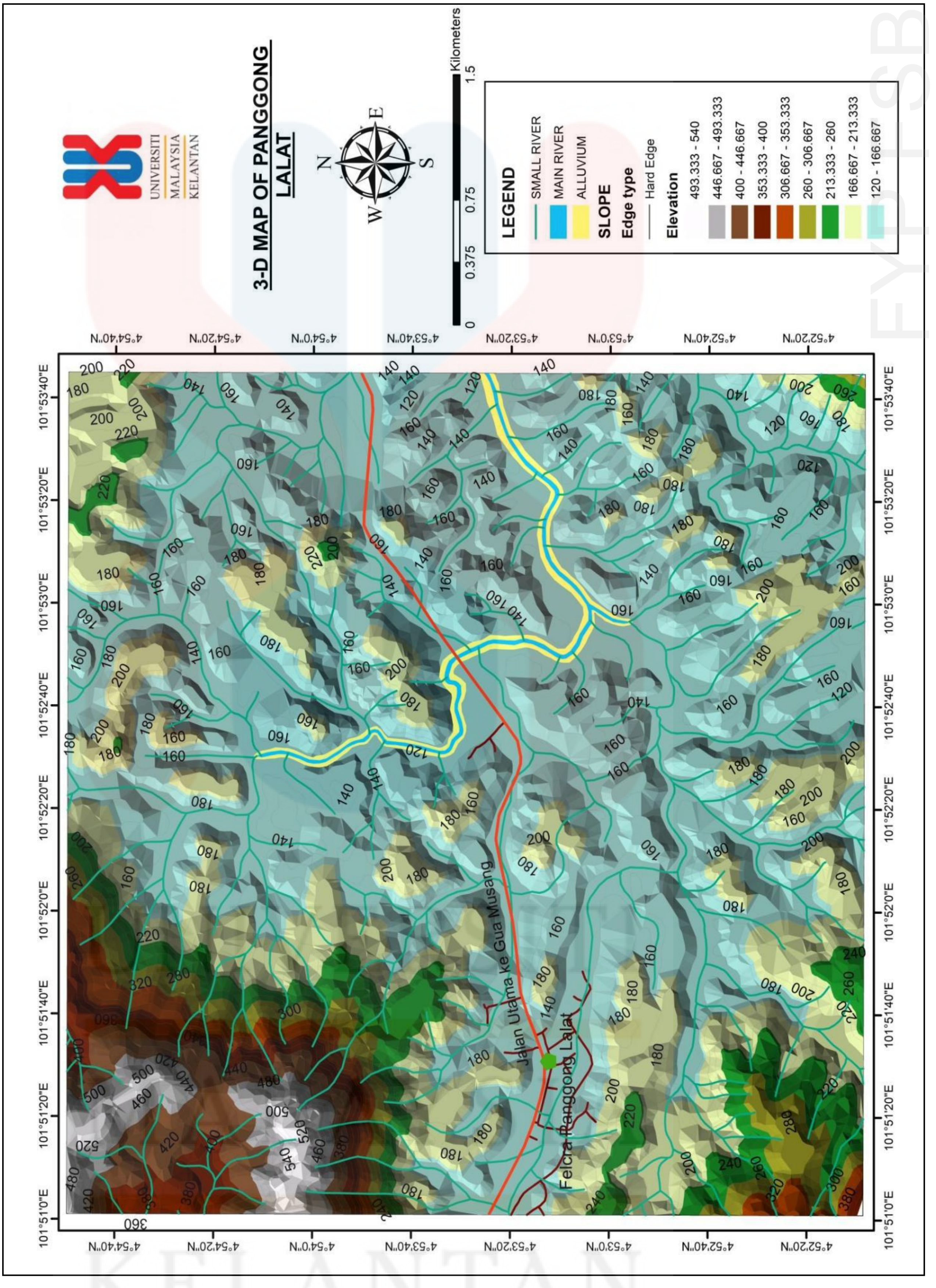


Figure 4.17: 3-D Map of Panggong Lalat

4.2.2 Weathering

Weathering is a part of rock cycle procesess that breakdown the rocks at the Earth's surface, by the physical activity like extreme temperature, chemical activity like action of rainwater and biological activity (Society, 2012). According to Eduard Gerber, 1969 the process usually occurs in- situ where most of the time, it will change the hardness of the rock from a hard state to a weaker state, that causes the rock to be eroded and deposited into another area. To explain why the rocks in Malaysia are highly weathered, this due to Malaysia's climate that is quite extreme as the activity of weathering is much more dynamic than other countries due to the amount of rainfall, humidity and temperature and many contributing factor compared to other Asia's country like Indonesia, Korea and Japan that seem to have quite cold climate due to their geological features and their variety of seasons for Japan and Korea. Other than that compared to Indonesia, the rocks in our country are much more older than the rocks in Indonesia so that why our outcrops are more prone to be weathered.

Specifically, the rocks in Panggong Lalat area much more weathered compared to other state in Malaysia as Kelantan holds the highest temperature during summer season and highest rain distribution during rainy season. According to the observation, there are three types of weathering that occur in the study area, which are physical weathering, chemical weathering and biological weathering. Physical weathering is caused by thermal stress which is the contraction and expansion effect on the rocks thus caused the rocks to disintegrates into smaller pieces or soil and it is usually caused by rains, winds,temperature, pressure and others. Rocks that undergo physical weathering can be classify by weathering grade by L.Borrelli et al. , 2007. Chemical weathering is the decay of rock forming minerals caused by water, temperature, oxygen mild acids and more. Biological weathering is caused by the presence of vegetation or the activity of animals such as root wedging and the production of organic acids (Sonia, 2018). For outcrop sampling, weathering grade usually referred as the parameter to classify the rocks weathering grade. There are six types of weathering grade that usually used by the geologist as a parameter for them to classify the weathering types of the outcrops sampling. Table 4.5 shows the weathering grade classification and description based on six classes by L.Borrelli et al, 2007.

Table 4.5: Weathering grade classification with its description.

CLASS	TERM	DESCRIPTION
VI	RESIDUAL AND COLLUVIAL SOILS	All rock material is converted to soil. The original rock structure is completely destroyed. The point of geological pick easily indents in depth. When the rock material is struck by the hammer don't emits sound.
V	COMPLETELY WEATHERED ROCK	All rock material is completely discoloured and converted to soil, but the original mass structure is still visible. The point of geological pick easily indents. When the rock material is struck by hammer emits a dull sound.
IV	HIGHLY WEATHERED ROCK	All rock material is discoloured. The original mass structure is still present and largely intact. The point of geological pick not easily indents. The rock material make a dull sound when is struck by hammer.
III	MODERATELY WEATHERED ROCK	The rock material is discoloured, but locally the original colour is present. The original mass structure is well preserved. The point of geological pick produce a scratch on the surface. The rock material make a intermediate sound when is struck by hammer.
II	SLIGTLY WEATHERED ROCK	Discolouration is present only near joint surface. The original mass structure is perfectely preserved. The point of geological pick scratch the surface with difficulty. The rock material make a ringing sound when is struck by hammer.
I	FRESH ROCK	The rock material isn't discoloured and has it's original aspect. The point of geological pick scratch the surface with many difficulty. The rock material make a ringing sound when is struck by hammer.

4.2.2.1 Physical Weathering

Physical weathering occur due thermal stress which is the contraction and expansion effect on the rocks thus caused the rocks to disintegrates into smaller pieces or soil and it is usually caused by rains, winds, temperature, pressure and others (L.Borrelli et al., 2007). As this weathering process keep occur over and over again, the outcrops structure tend to weakens, unstable and thus disintegrated to soil (National Geographic, 2018). As a result, soil erosion and landslides might happened due to physical weathering. Figure 4.18 the weathering process that occured on the granite outcrops in the study area. Based on the outcrops sampling it seem that the rock's weathering grade is grade III as moderately weathered. Other than that, Figure 4.19 shows the physical weathering process that occured on the slate outcrop in the study area. Based on the outcrop sampling, it shows that the rock was highly weathered with grade IV as more than half the rock material is decomposed and disintegrated to soil.

Figure 4.18: Physical weathering that undergo by granite outcrop

Figure 4.19: Physical weathering that undergo by slate rock with grade IV (highly weathered)

4.2.2.2 Chemical Weathering

Chemical weathering also occured in the study area. Figure 4.20 show the chemical weathering that undergo by sedimentary rock, limestone in the study area Panggong Lalat. Chemical weathering occured due to acid that produced from carbonation process of air or soil with water. This eventually prroduced weak acid called carbonic acid that can dissolve rock. This cases usually occured on limestone rocks that contain calcium carbonate. This reaction will caused the limestone rock to dissolve as carbonic acids seep through limestone rock, it can form karst landform of caves.

Figure 4.20: Limestone rock that undergo chemical weathering

4.2.2.3Biological weathering

Biological weathering occured due to breakdown and disintegration of outcrops by plants, animals and microbes. Figure 4.21 shows that the biological weathering by plant's root onto the slate outcrop in the study area. The plant's root seem to break down the intact of the outcrop by growing through cleavage and fractures of the outcrops. This outcrops is located in the rubber tree plantation so that why the outcrops are exposed more to the plant nearby. Based on the outcrop observation, the outcrops not only undergo biological weathering, it also prone to physical weathering as the sample from the outcrops was highly weathered.

Figure 4.21: Biological weathering that undergo on the slate outcrop.

4.2.3 Drainage Pattern

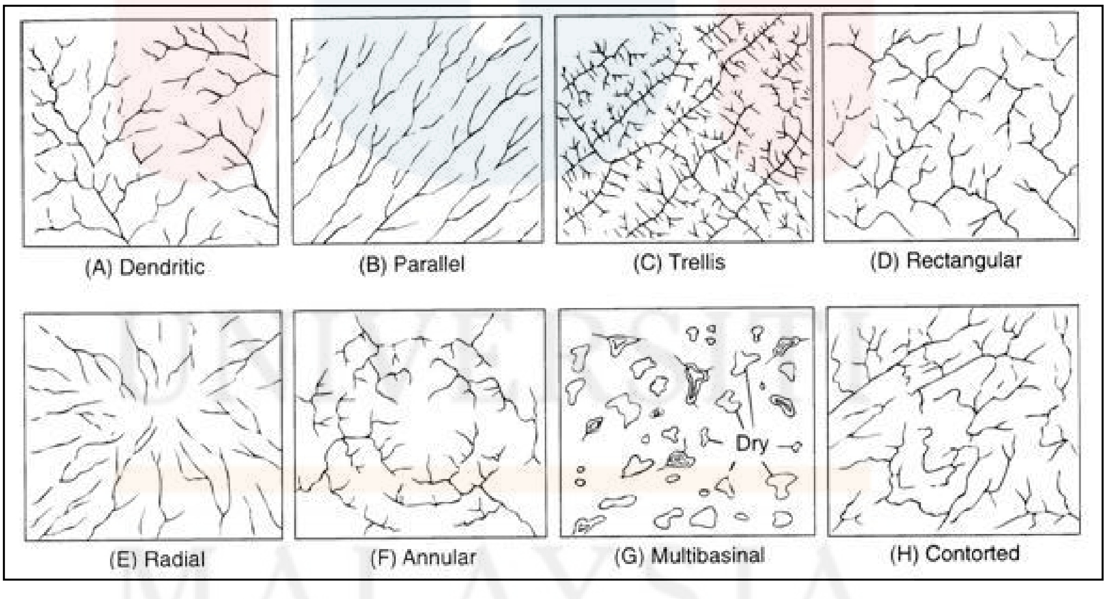


Figure 4.22: Types of drainage pattern (Lakdawalla, 2010)

Drainage pattern are created by stream erosion over time that reveals characteristics of the kind of rocks and geologic structures in a landscape region drained by streams. Drainage pattern formed by the streams, rivers, and lakes in a particular drainage basin. They are governed by the topography of the land, whether a particular region is dominated by hard or soft rocks, and the gradient of the land. Figure 4.22 shows the different types of drainage pattern and formation of drainage pattern usually formed due to earth landform. Based on drainage pattern map in Figure 4.23, it shows that Panggong Lalat area have dendritic, radial and trellis drainage pattern.

Dendritic drainage pattern in the map are shown as green line colour. Generally, dendritic drainage pattern formed as tree-shaped drainage pattern and it is commonly founded on the earth's surface widespread. Dendritic drainage pattern usually located in areas where the rock are have no particular structure and where the stream can eroded easily in all direction. Most of rock area that usually undergo dendritic drainage pattern are hard rock area like granite, gneiss, volcanic rock and sedimentary rock. Dendritic drainage pattern in the study area was located at Sungai Seting in granite landform area.

Radial drainage pattern in the map shown as yellow line colour. It has been found in the west and south part of mountainous landform in the study area. Radial drainage pattern often occured in the high elevation and steep area landform. The streams are radiates outwards from the pick of the high point. Based on the map in Figure 4.23, we can clearly see that the radial drainage pattern formed as the stream tend to radiate from the peak of the mountain. The radial drainage pattern formed in the mountainous granite landform.

Lastly, there were also trellis drainage pattern that formed in the study area. Trellis drainage pattern were shown as purple line colour and trellis drainage pattern seem to formed at the southern part of the map in the study area. Generally, trellis drainage pattern develop where sedimentary rocks have been folded or tilted and then eroded to varying degrees depending on their strength. In the study area, the trellis drainage pattern formed in the hilly topograhic unit that have elevation of 76-300 m. The lithology of the trellis drainage pattern is metasedimentary rock of slate and it formed in the plantation area of rubber tree and palm tree.

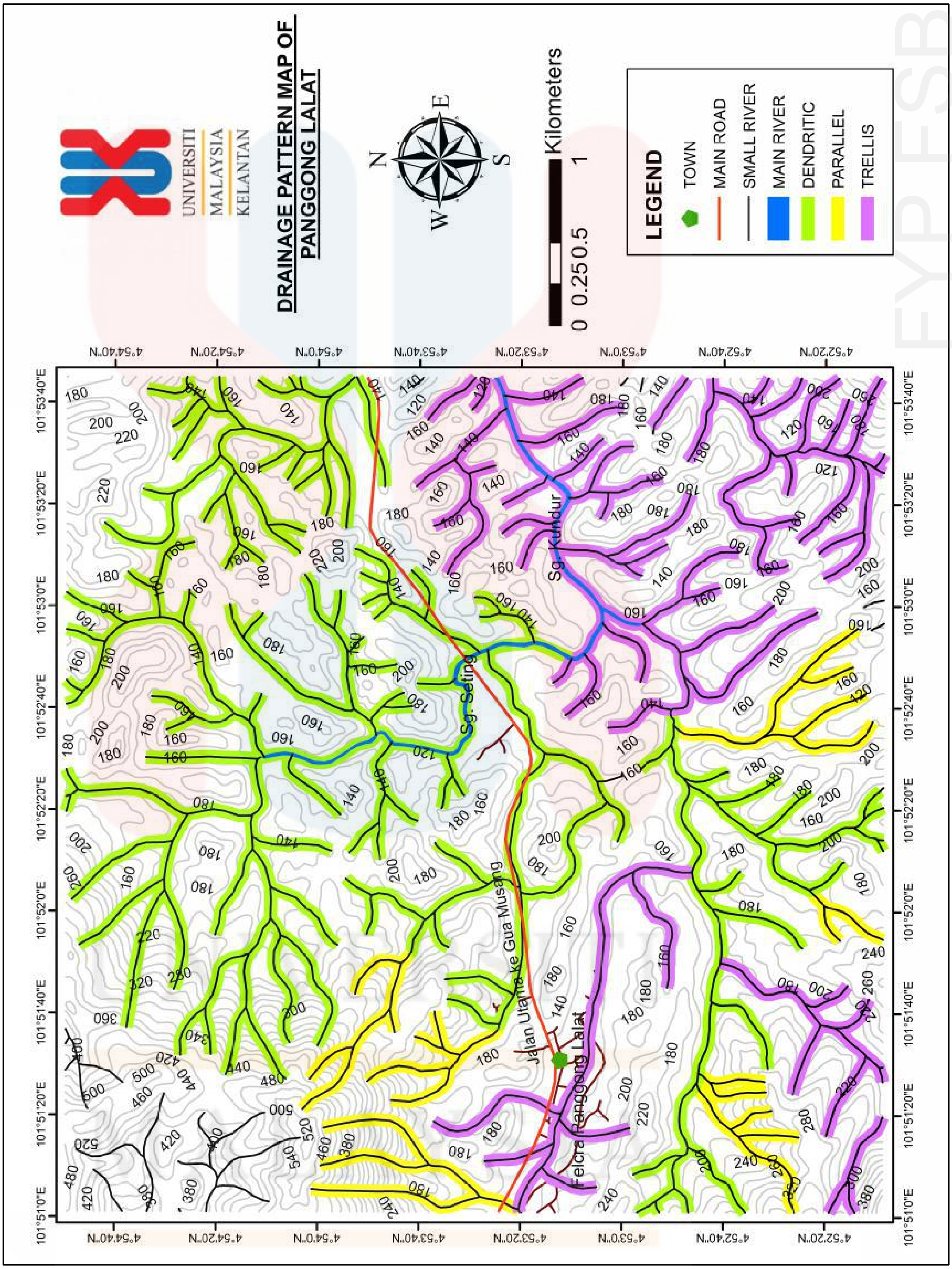


Figure 4.23 :Drainage Pattern Map of Panggong Lalat

4.3 Lithostratigraphy

During on the geological mapping process, lithological analysis was done in the study area in order to know the rock's lithological unit and its stratigraphy. Based on the mapping result, the rock unit in Panggong lalat can be classify into four lithology which are, metasedimentary rock (slate unit) , well-bedded limestone, granitoid unit and alluvium. The study area are related to Gua Musang Formation based on previous study. As according to the characteristics of Gua Musang Formation, the study area are exposed to Central Belt so that why pink and grey granite are found in the study area. For granite intrusion in the study area, previous study had proved that the granite landform are formed from the Senting intrusion. Figure 4.24 shows the cross-section map of the study area.

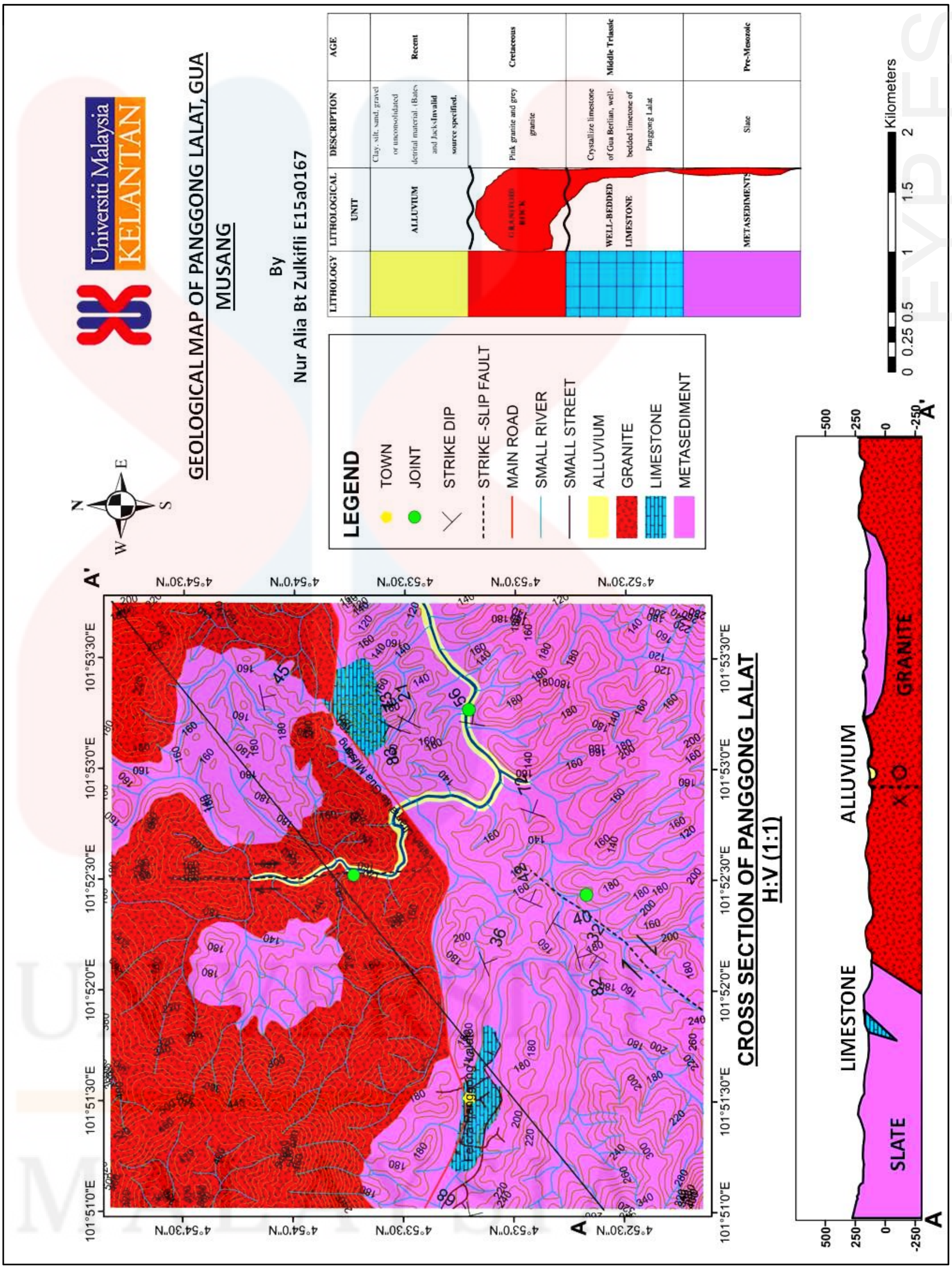


Figure 4.24: Cross-section map of Panggong Lalat

4.3.1 Lithostratigraphy of Panggong Lalat

Panggong Lalat area composed of four lithological unit which are metasediments of slate, well-bedded limestone, granitoid unit and alluvium. **Table** 4.5 shows the stratigraphy of the study area, Panggong Lalat and according the table of stratigraphy below, metasediments is the oldest lithology unit with Pre-Mesozoic age. Metasediment unit that have been found in the study area was slate. Slate unit are abundances in the hilly landform area of rubber tree and palm tree plantation and dominantly located at the south part of Panggong Lalat. For well – bedded limestone, crystallize limestone from Gua Berlian and limemudstone from Panggong Lalat area are found.Limestone outcrops are found in the West and East part of the study area. Well-bedded limestone in the study area are from Middle Triassic age.

Other than that, granitoid unit are also found in the study area. Granitoid rock unit in the study area can be classify into two types which are pink granite and grey granite. According to the previous research, pink granite outcrops are more older compared to grey granite. The granite unit can be classify based on its minerals content as orthoclase are abundances in pink granite while plagioclase are abundances in grey granite. The youngest lithology in the study area was alluvium with recent age. Alluvium was located in the main river of Sungai Seting and Sungai Kundur in the study area. Alluvium are usually in form of clay, silt, sand, gravel or unconsolidated detrital material. As the conclusion, the oldest lithology unit in Panggong Lalat area is metasediment of slate unit followed by well-bedded limestone, granitoid unit and the youngest lithology unit is alluvium

Table 4.6: Stratigraphy of Panggong Lalat

LITHOLOGY	LITHOLOGICAL UNIT	DESCRIPTION	AGE
	ALLUVIUM	Clay, silt, sand, gravel or unconsolidated detrital material. (Bates and Jacks (Bates, 1987)	Recent
	GRANITOID ROCK	Pink granite and grey granite	Cretaceous
	WELL-BEDDED LIMESTONE	Crystallize limestone of Gua Berlian, well-bedded limetone of Panggong Lalat	Middle Triassic
	METASEDIMENTS	Slate	Pre-Mesozoic

4.3.2 Unit explanation of rock lithology

4.3.2.1 Metasediment of slate unit

Metasediment unit are found in the formed of slate in the study area. The outcrops was located at the south part of the study area, dominantly found in the hilly landform that composed of rubber tree and palm tree plantation. Other than slate, there were also silify tuff that being found in the study area but not as abundances as slate. Silicify tuff however are not considered as lithology unit due to its less exposed in the study area. According to the stratigraphy of Gua Musang, slate rocks in Panggong Lalat are from Pre-Mesozoic age. Based on the observation of slate outcrop in the study area, the slate was determined by its slaty cleavage. Slaty cleavages are obviously formed on all slate outcrops in the study area. There were also geological structures like joints, fractures, bedding and others on the slate outcrops. Slate that are found in the study area are greyish black in colour, breddish brown and yellowish brown and most of the slate were found had undergo quite extreme weathering process as some of the outcrops already disintegrated and break down into soil.

i) 18AZ08C (*S07)

Figure 4.25: Slate outcrop in palm tree plantation

Table 4.7 : Slate outcrop's description

Sample	Slate
Location/ place:	Palm tree plantation (South-east of research area)
Coordinate:	101°53'21.098"E ,04°53'18.597"N
Elevation:	147m
Azimuth:	290°
Geomorphology:	Hilly landform
Vegetation:	Palm tree plantation
Dimension (height x length)	2.5 m x 5.5 m

Table 4.7 shows the outcrop's description. Based on the observation, the outcrop was highly exposed with hot and cold as the area was already excavated for road purpose. Based on naked eyes observation, the outcrops were exposed to the weathering process like physical weathering and biological weathering. According to weathering grade(Table 4.5), the outcrop can be classify with grade III as highly weathered.

This is due to more than 50% of the rock materials are already disintegrated and decomposed to soil. The outcrops also had undergo biological weathering as there were small plants and weeds that grow on top and within the outcrop's fractures and cracks. The outcrop also involved with secondary geological structures like fractures and small joints.

Table 4.8: Hand specimen description

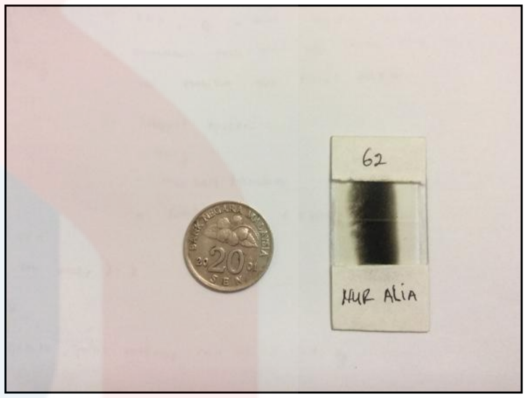
A  a) **Figure 4.26**: Slate's sample	B  b) **Figure 4.27:** Slate's thin-section slide
Colour	Greyish black
Texture	Fine grain
Grain shape	Sub angular to sub rounded
Sorting	Well sorted
Fabric	Concave- convex
Structures	Bedding, foliation
Fossil content	No
Name of rock	Slate

Table 4.9 : Thin section analysis of slate sample

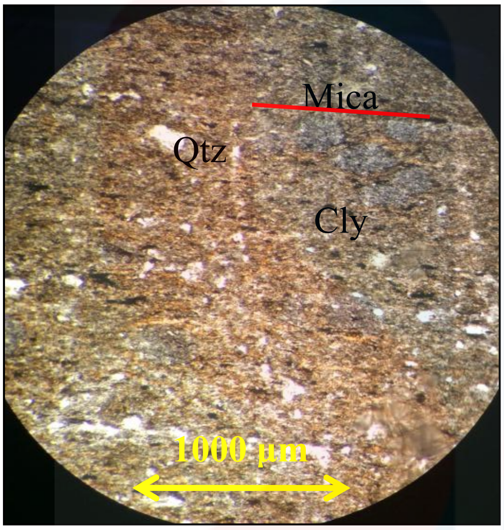


Figure 4.28:PPL of slate with magnification 10x

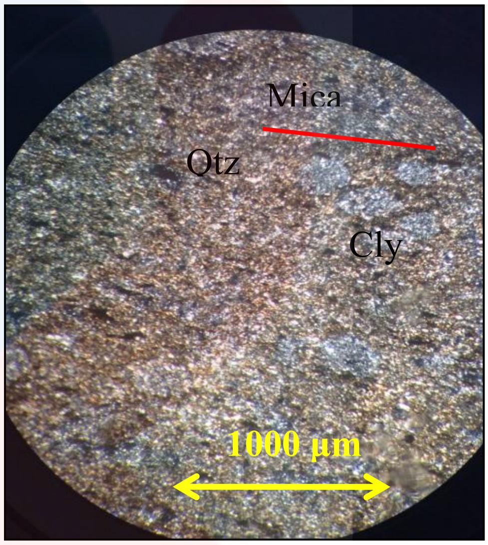


Figure 4.29: XPL of Slate with magnification 10x

Code.	**Decription of minerals in PPL**	**Code.**	**Description of minerals in XPL**
Qtz	-Quartz in PPL is colourless	Qtz	-Quartz in XPL show matte white to black colour -Form of crystal: Subhedral -Low birefringe -Low relief - Contents: >5%
Cly	-Clay minerals show brownish colour inder PPL	Cly	-Clay minerals in XPL show brownish colour -Clay mineral content: 80%
Mica	-Form a line under PPL -Dark line form	Mica	-Form line that represent slaty fabric in XPL -Dark line form -Content:10%

4.3.2.2Well-bedded limestone unit

Well-bedded limestone is one of lithological unit of Panggong Lalat area with Middle Triassic age. Limestone outcrops in Panggong Lalat was classified as well-bedded limestone due to its bedding plane that shown on the outcrops. There were two types of limestone that been found in the study area which are crystallize well-bedded limestone and well-bedded lime-mudstone. Both of these outcrops are found in different area as the well-bedded crystallize limestone are found in rubber tree plantation area and the outcrops (Figure 4.30) was taken from Gua Berlian while the lime-mudstone was found in housing area of Panggong Lalat. Both of the limestone come from same source eventhough the crystallize limestone already crystallize this due to its location that located near with granite intrusion in the study area. The geological structures that have been found on the outcrops are stylolites and calcite veins. Most of the limestone outcrops in the study area are exposed to weathering process as a result a cave is formed due to chemical process thus Gua Berlian is formed.

i) 18AZ06B (*S05)

Figure 4.30: Well-bedded crystallize limestone

Table 4.10 : Limestone outcrop's description

Sample	Crystallize limestone
Location/ place:	Rubber tree plantation (South-east of research area)
Coordinate:	101°53'16.002"E 04°53'45.308"N
Elevation:	219 m
Azimuth:	210°
Geomorphology:	Hilly landform, karst lamdform
Vegetation:	Rubber tree plantation
Dimension (height x length)	2.8 m x 7.5 m

Table 4.10 shows the outcrop's description of limestone and based on the observation, the outcrops were highly exposed to weathering processes like physical weathering, chemical weathering and biological weathering. For physical weathering, the outcrops can be grade as III of moderately weathered as less than 50% of the outcrops has disintegrated to soil (Eduard Gerber, 1969). For chemical weathering, the outcrops are highly exposed to chemical weathering as the cave already formed and there were abundances of big cracks and holes due to dissolution process onto limestone outcrops. While for biological weathering as based on Figure 4.30, there were many plants that already grow on the outcrops and thus make the outcrops to breakdown due to excessive strength onto it.

Table 4.11: Hand specimen descriptions.

A  a)**Figure 4.31**: Limestone's sample	B  b)**Figure 4.32:**Limestone's thin-section slide
Colour	Greyish black
Texture	Fine grain
Grain shape	Sub angular
Sorting	Well sorted
Fabric	Sutured contact
Structures	Bedding, stylolites
Fossil content	No
Name of rock	Well- bedded crystallize limestone

Table 4. 12: Thin section analysis of limestone sample

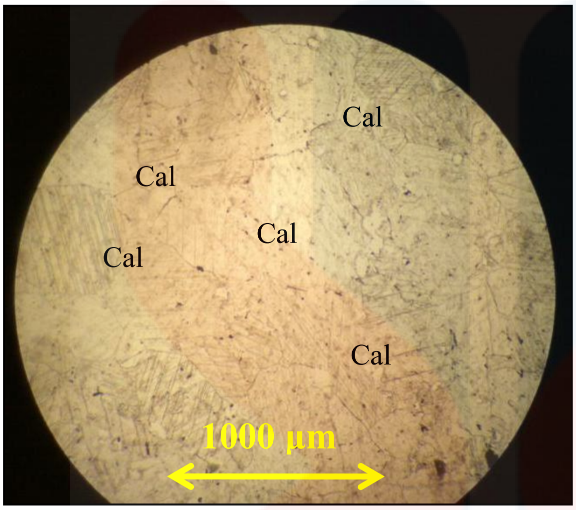


Figure 4.33:PPL of limestone with 10x magnification

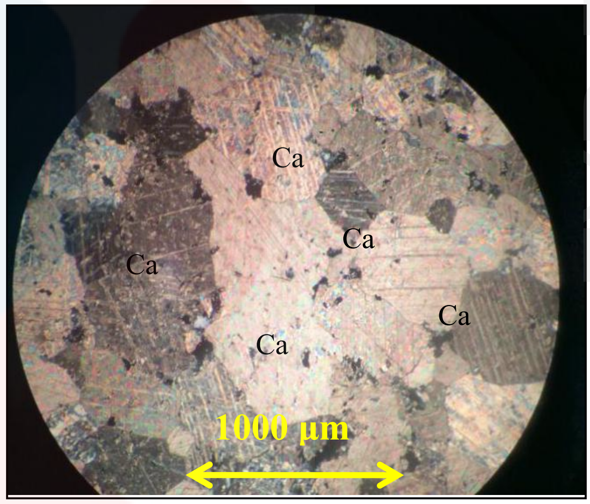


Figure 4.34:XPL of limestone uder 10x magnification

Code.	**Decription of minerals in PPL**	**Code.**	**Description of minerals in XPL**
Cal	-Calcite in PPL is colourless	Cal	-Calcite in XPL show greyish white to black colour -Form of crystal: Subhedral -Low birefringe -Relief : Extreme, pinky-buff -Have 2 cleavage of 60-120° - Contents: 100%

4.3.2.3 Granitoid Rock Unit

Based on the stratigraphy of Gua Musang that related with the Panggong Lalat area, granitoid rock is the youngest rock unit in study area with Cretaceous age. The granite are was located in the hilly to mountainous landform of study area both in rubber tree plantation and palm tree plantation. There were two types of granite that have been found in the study area which are pink and grey granite. There rock minerals of both are quite different as for grey granite it contain plagioclase while for pink granite orthoclase are found. According to previous study, pink granite seem to be much more older compared to grey granite but both of them still in Cretaceous age. The texture of the granite that have been found was phaneritic, coarse texture as huge scale of ortoclase minerals are found on pink granite outcrops.

i) 18AZ01A (*S01)

Figure 4.35 :Grey granite outcrop in small river of palm tree plantation

Table 4. 13: Granite outcrop's description

Sample	Grey granite
Location/ place:	Rubber tree plantation (East side of research area)
Coordinate:	101°53'44.361"E 4°54'4.21"N
Elevation:	145m
Azimuth:	330°
Geomorphology:	Granite Landform (Granite waterfall)
Vegetation:	Rubber tree plantation
Dimension (height x length)	6.5 m x 7 m

Table 4.13 shows the outcrop's description of granite and based on the observation, the outcrop was moderately exposed as the area was covered with the bushes and the high trees. Based on naked eyes observation, the outcrops were exposed to the weathering process like physical weathering and biological weathering. Physical weathering is caused by the effects of changing temperature on rocks, causing the rock to break apart and the process is sometimes assisted by water (The Geological Society of London, 2012). As the outcrop was located at the river area it is likely to expose more to the water. The outcrop had undergone biological weathering as there were small plants and weeds the growth on top and within the outcrops fractures and cracks. Based on the weathering grade, it can be concluded that the outcrops had undergo II grade of weathering as slightly weathered. There were several geological structures that found on the outcrops like joints, fractures and quartz vein.

Table 4.14: Hand specimen of grey granite

Figure 4.36:Sample of granite

Figure 4.37: Thin section slide of grey granite

Colour	Greyish white with black biotite
Texture	Phaneritic
Composition	Quartz, Feldspar, Plagioclase and Biotite
Degree of crystalinity	Holocrystalline
Grain size	Coarse
Form of individual crystal	Subhedral and inequigranular
Relationship between crystal	Hypidiomorphic

Table 4.15: Thin section analysis of grey granite

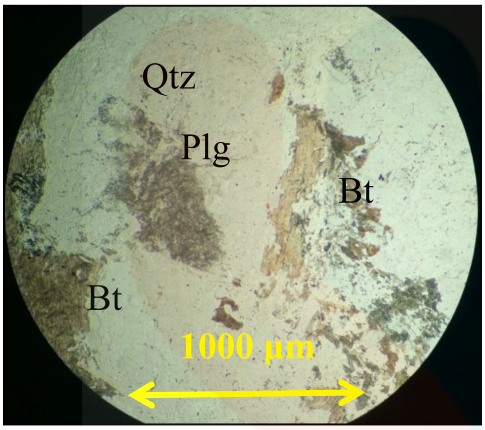


Figure 4.38: PPL of grey granite with 10x magnification

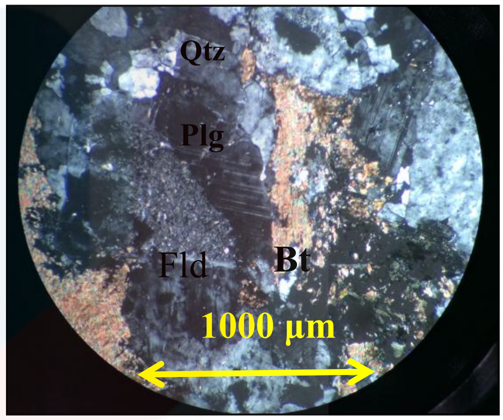


Figure 4.39: XPL of grey granite with 10x magnification

Code.	Decription of minerals in PPL	Code.	Description of minerals in XPL
Bt	- Biotite in PPL is brownish colour	Bt	-Biotite in XPL show greenish brown colour -Form of crystal: Subhedral and inequigranular -High birefringe -Holocrystalline -Extension angle: 26° - Contents: 10%
Fld	-Feldspar in PPL is colourless	Fld	-Greyish white in colour -Subhedral and inequigranular -Low birefringe -Holocrystalline -Extension angle:26° Content:45%
Qtz	-Quartz is colourless in PPL	Qtz	-White matte -Subhedral and inequigranular -Low birefringe -Holocrystalline -Extension angle:18° Content:20%
Plg	-Plagioclase in PPL is colourless	Plg	-Greyish white

			-Have albite twinning -Subhedral and inequigranular -Low birefringe -Holocrystalline -Extension angle:19° -Content:25%

ii) 18AZ02A (*S02)

Figure 4.40: Outcrop of pink granite

Table 4.16 :Pink granite outcrop descriptions

Sample	Pink granite
Location/ place:	Palm tree plantation (East side of research area)
Coordinate:	101°52'25.8"E 04°53'51.3"N
Elevation:	142 m
Azimuth:	240°
Geomorphology:	Granite Landform (Granite waterfall)
Vegetation:	Palm tree plantation
Dimension (height x length)	6.5 m x 7 m

Table 4.16 above show the outcrop's descriptions. Based on naked eyes observation, the outcrops were exposed to the weathering process like physical weathering and biological weathering. Physical weathering is caused by the effects of changing temperature on rocks, causing the rock to break apart and the process is sometimes assisted by water (The Geological Society of London, 2012) . As the outcrop was located at the river area it is likely to expose more to the water. The outcrop had undergone biological weathering as there were small plants and weeds the growth on top and within the outcrops fractures and cracks. Based on the weathering grade, it can be concluded that the outcrops had undergo II grade of weathering as slightly weathered. There were several geological structures that found on the outcrops like joints, fractures and quartz vein.

Table 4.17: Hand specimen of pink granite

 **Figure 4.41**: Sample of pink granite	 **Figure 4.42:** Thin section slide of pink granite
Colour	Pinkish white with black biotite
Texture	Phaneritic
Composition	Quartz, Feldspar, Orthoclase and Biotite
Degree of crystalinity	Holocrystalline
Grain size	Coarse
Form of individual crystal	Subhedral and inequigranular
Relationship between crystal	Hypidiomorphic

Table 4.18: Thin section analysis of pink granite

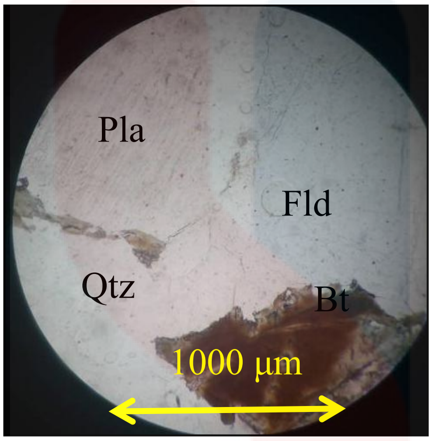


Figure 4.43: PPL of grey granite with 10x magnification

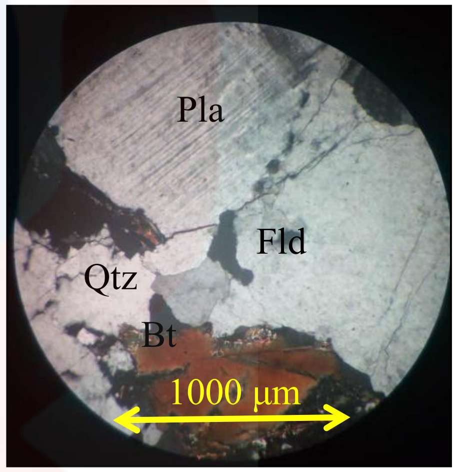


Figure 4.44: XPL of grey granite with 10x magnification

Code.	**Decription of minerals in PPL**	**Code.**	**Description of minerals in XPL**
Bt	- Biotite in PPL is brownish colour	Bt	-Biotite in XPL show greenish brown colour -Form of crystal: Subhedral and inequigranular -High birefringe -Holocrystalline -Extension angle: 28° - Contents: 15%
Fld	-Feldspar in PPL is colourless	Fld	-Greyish white in colour -Subhedral and inequigranular -Low birefringe -Holocrystalline -Extension angle:23° Content:28%
Qtz	-Quartz is colourless in PPL	Qtz	-White matte -Subhedral and inequigranular -Low birefringe -Holocrystalline -Extension angle:18°

			Content:15%
Pla	-Plagioclase in PPL is colourless	Orth	-Greyish white -Have twinning -Subhedral and inequigranular -Low birefringe -Holocrystalline -Extension angle:20° -Content:42%

4.4 Structural geology

Structural geology is one of the main part of general geology that geologist need to know as it can tell the history of the place based on its geological structure that have been exposed in the study area. Based on the geology structures of the research area, many informations of the place we can obtained like its geomorphology landform, its tectonic setting, the ages of the rocks based on its bedding and many others. Thus, geological structures are really important in general geology as it provided the geologist with hint of how the minerals, rocks and earth deformation based on their process. Structures of geology can be described based on lineament analysis on map.

Lineament is any parallel line that we have on the research map. The parallel line will indicated geological structures based on the location of the lineament lines that we have plot on the map. Based on lineament map in Figure 4.45, it shows several lineament lines that might have geological structures on the sites. But even with the of lineament analysis, geological structures are not easy to identify as for our country are exposed to hot and humid weather so weathering process in our country is really high. So proper geological mapping should be done in order to obtain the geological structures.

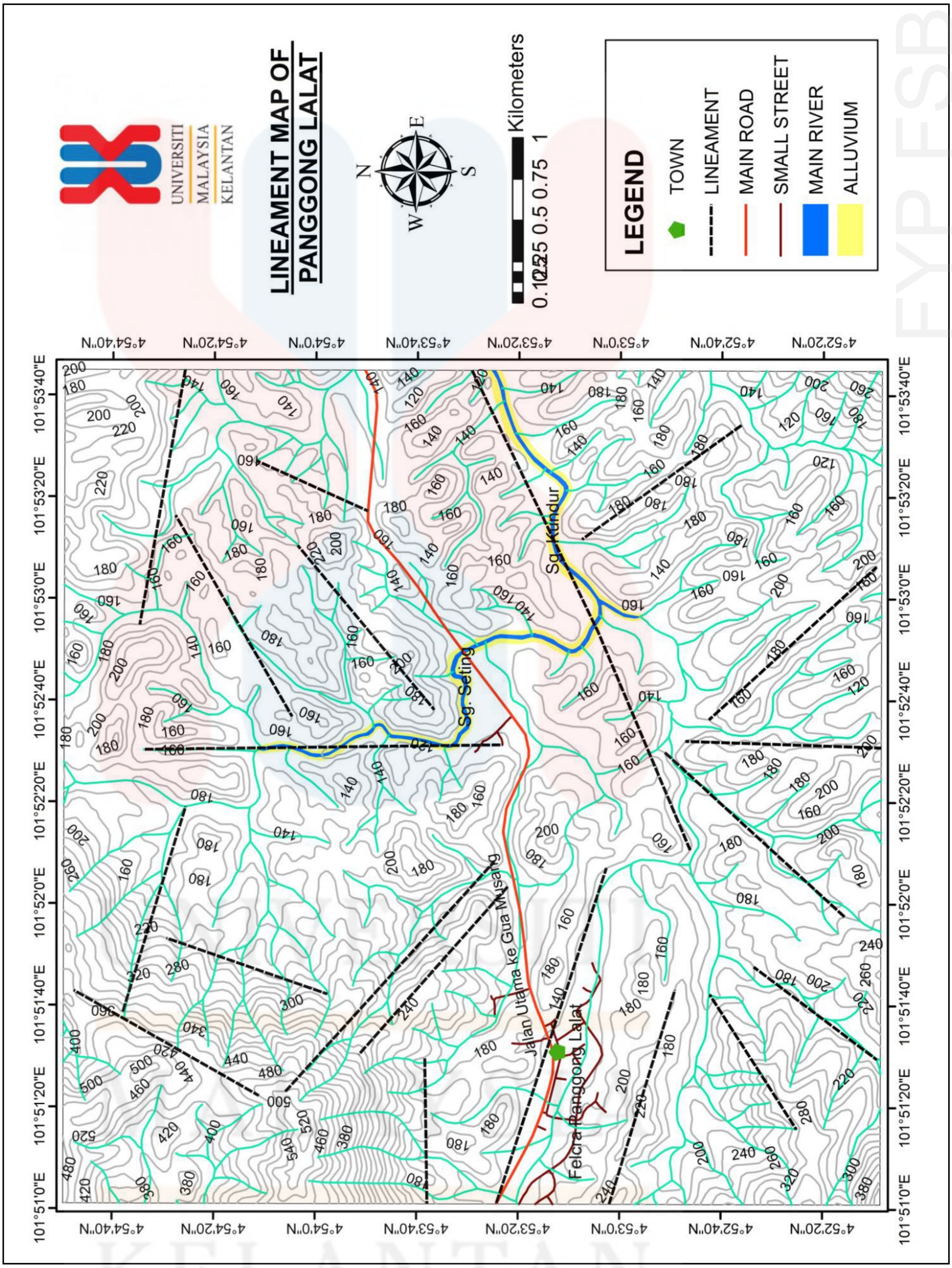


Figure 4.45: Lineament Map of Panggong Lalat

4.4.1 Strike-slip fault

Strike-slip fault occured due horizontal compression and the energy are release by rock displacement in a horizontal direction almost parallel to the compressional force. The fault plane is vertical, and the relative slip is lateral along the plane (Figure 4.46). These faults are widely spread and most of strike-slip fault are found at the boundary between obliquely converging oceanic and continental tectonic plates (Alexandra E. Hatem et al, 2017). In the research area, strike-slip fault are identify based on the geomorphology landform. This is due to the stike-slip fault cannot be found anywhere in the study area so lineament map above are used to identify the strike-slip fault. In the study area, the fault was targeted at the granite landform and in metasediment unit landform.

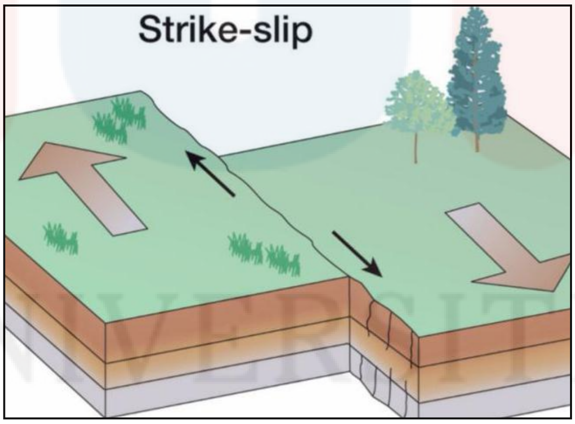


Figure 4.46: Strike-slip model. Modified by Alexandra E. Hatem et al. (2017)

4.4.2 Folding

Folding structure was found with the coordinates of in slate rock unit in Panggong Lalat area. Folding is the formation of bending or curve on the outcrop, thus resulted to permanent deformation. Folding occured when the was compressive force that acts on both side of the bedding strata and thus the layers of rock undergo plactic defomation. Even the source of the fold cannot be found as the outcrop in the fold area was highly weathered, the fold are intepreted as a syncline fold based on its dipping angle that show downward.

Figure 4.47: Folding structure in the study area

4.4.3 Joint

Joint structures are spreadly found in the study area. Based on the joints that obtained from the fieldwork, joint analysis had been done via GeoRose in two different places at coordinates of N 04 53 11.9 E 101 53 11.7 in Panggong Lalat waterfall area and in N 04 53 51.3 E 101 52 12.4 of the South side of the study area. Figure 4.46 and Figure 4.47 show the joint analysis of the study area and their direction of Ơ1 and Ơ3 (stress).

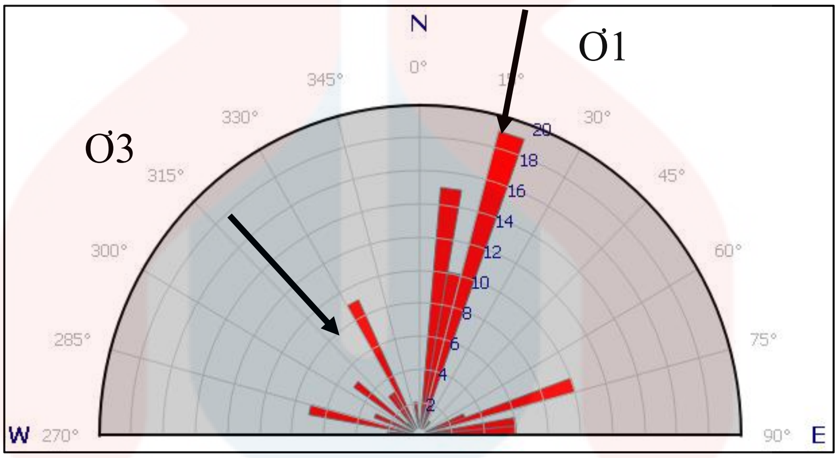


Figure 4.48: Joint analysis of granite landform waterfall in coordinates of N 04 53 11.9 E 101 53 11.7

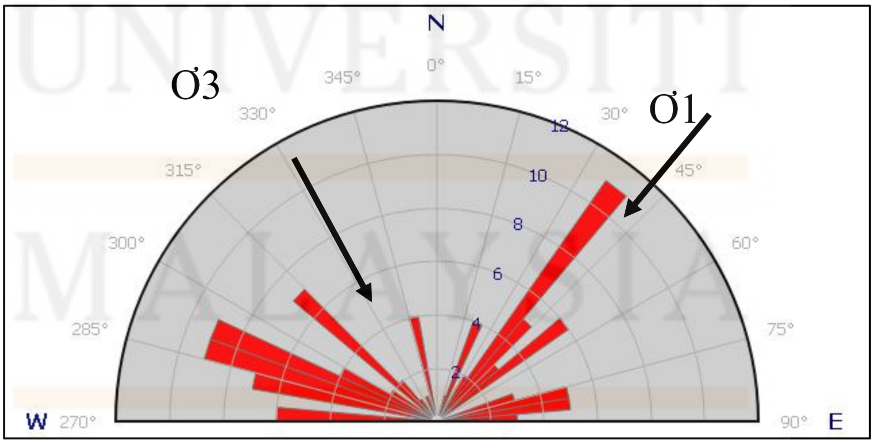


Figure 4.49: Joint analysis of slate outcrops in coordinates of N 04 53 51.3 E 101 52 12.4

Based on the joint analysis above we can see that both joint analysis have almost same Ơ1 and Ơ3 direction, thus we can concluded that Panggong Lalat area had undergo major stress from Ơ1 direction and minor stress from Ơ3 direction. From the stress direction we also can predicted other structures formation like fault formation. Figure 4.05 shows the joint structures in the study area. Joints are really importants in the natural resources development, safe design of structures and safety of environment. Joints have a huge control on weathering process and erosion of rock in the study area so as a result, they exert a strong control on how topography and morphology of landscapes develop (Davis, 2012).

Figure 4.48: Joint on outcrop in study area.

4.4.4 Vein

Most of vein structures that are found in the study area are quartz vein and calcite vein. Veins form as a long, regularly shaped of open spaces of the rocks and it usually occur during hydrothermal process. Vein is a place for the growth of crystals on the planar fractures in rocks and the crystal will fill the open spaces thus it called as vein. Figure 4.51 below showed the quartz vein that formed in the open space of metasedimentary rock of Sungai Kundur in the study area. Other vein that has been found in the sudy area is calcite vein, it being spotted on the limestone outcrop in study area.

Figure 4.51: Quartz vein in metasediment rock unit

4.4.5 Stylolite

Stylolite structure are found on the limestone outcrop in the coordinates of 101°51'35.813"E 4°53'6.486"N and the stylolites are spreadly found on the outcrop with the dimension 3.5 meters length x 1.8 meters height in the study area. Figure 4.52 below shows the stylolite structures on the limestone outcrop that located in the Felcra panggong Lalat area. Stylolites is a serrated surfaces that formed parallel to bedding, because of overburden pressure, but they can be perpendicular to bedding, as a result of tectonic activity. Due to the pressure of dissolution, the rock mass material was removed by pressure dissolution. Insoluble minerals such as clays, pyrite and oxides, as well as insoluble organic matter remain within the stylolites and make them visible (Andrews & Railsbak, 2003).

Figure 4.52: Stylolite formation in Panggong Lalat

4.5 Historical geology

Historical geology is a discipline that uses the ideologies and methods of geology to reconstruct and understand the geological history of Earth. It emphases on geologic processes that change the Earth's surface and subsurface. Stratigraphy, structural geology and palaeontology informations will tell sequence of these events. The Middle Permian to Upper Triassic Gua Musang Formation was mapped by Yin (1965) in south Kelantan. The formation was estimated to be 650 m thick, made up of crystalline limestone, interbedded with thin beds of shale,tuff, chert nodul es and subordinate sandstone and volcanics. Poorly- preserved fusulines including Verbeekina from Gua Musang give a Permian age to parts of the limestone and Lower Triassic (Scythian) ammonoids have also been described from the limestone nearby. The thin-bedded, laminated and fissile shale is usually grey in colour but is black when carbonaceous (Hutchinson & Tan, 2009). The argillaceous sandstone is fine to medium grained with angular quartz in a matrix of limonitic or carbonaceous clay. The formation is the lateral equivalent of the pyroclastic Aring Formation and is synonymous with the Telong Formation of in south Kelantan(Aw, 1974).

CHAPTER 5

PETROLOGY AND GEOCHEMISTRY OF GRANITOID ROCK

5.1 Introduction

This chapter cover the specification study of petrology and geochemistry of granitoid rocks in Panggong Lalat area. This study is important as it is one of the objective of this thesis. In addition, this study is also important as a basic knowledge to study the petrogenesis of granitoid rock. According to this research, granitoid rock that being identify are classified as pink granite and grey granite. However, the IUGS classification have not done yet. Generally IUGS classification will classify the name of the granitoid rock based on its common minerals content like Quartz, Alkali feldspar and plagioclase for felsic plutonic rock, granitoid rock.

In futher result and dicussion, IUGS classification will be made based on the rocks mineral contents. In addition the petrology, geochemistry and tectonic setting are being explained summary in this chapter. The geochemistry analysis of this thesis are focused on the elements that being produced through X-Ray Fluorescence (XRF) analysis and ICP-MS analysis for rare earth elements (REE) in the granitoid rocks of the study area. Three granite samples had been chose from different places in order to run the test. Figure 5.1 shows the map of granite sample that being labelled as NSS#001, NSS#002 and NSS#003. All of the result will be plotted and discuss futher via graph.

For XRF analysis, major and trace elements are obtained to know the classification of granitoid through S-I-A-M classification, alumina saturation standard and tectonic setting classification. While for ICP-MS analysis, REE was obtained in order to know the distribution of REE in Panggong Lalat area based on the third objective.

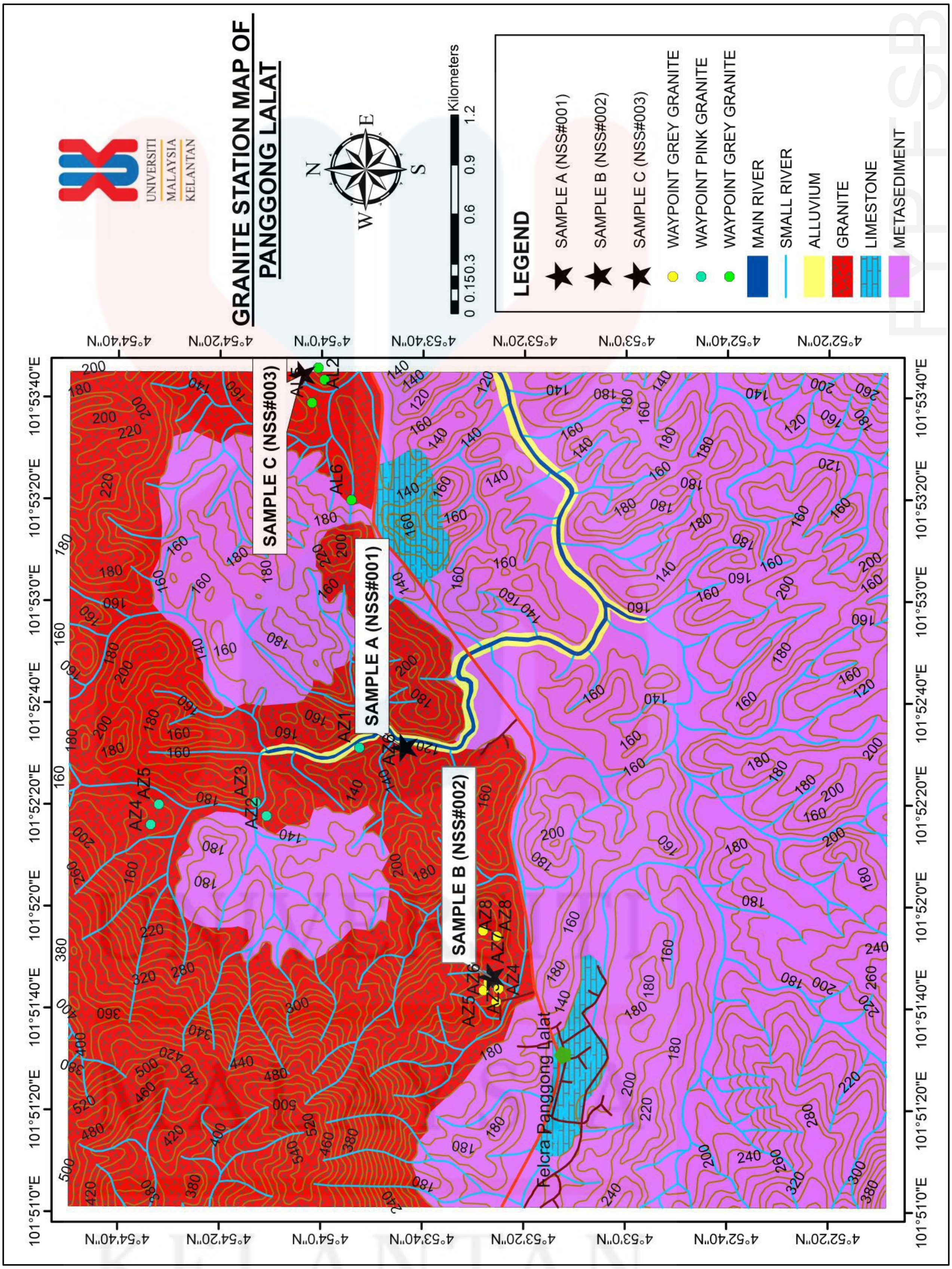


Figure 5.1: Granite rock sample map of Panggong Lalat

5.2 Petrography

Petrography study is really important in geology as it is one of the techniques to indicate the rock types followed by IUGS classification. In this research only two sample were chose for petrography analysis as the study area are composed of two types of granite which are pink granite and grey granite. IUGS minerals classification are made based on thin-section analysis in Chapter 4. The sample that have been chose for this petrography study are NSS#001 and NSS#003.

5.2.1 i) Pink granite (NSS#001)

Table 5.1: Sample description

Sample	Pink granite
Location/ place:	Palm tree plantation (East side of research area)
Coordinate:	101°52'25.8"E 04°53'51.3"N
Elevation:	142 m
Azimuth:	240°
Geomorphology:	Granite Landform (Granite waterfall)
Mineral contents:	P-Plagioclase: 42% A-Feldspar:28% Biotite:15% Q-Quartz:15%

ii) IUGS classification

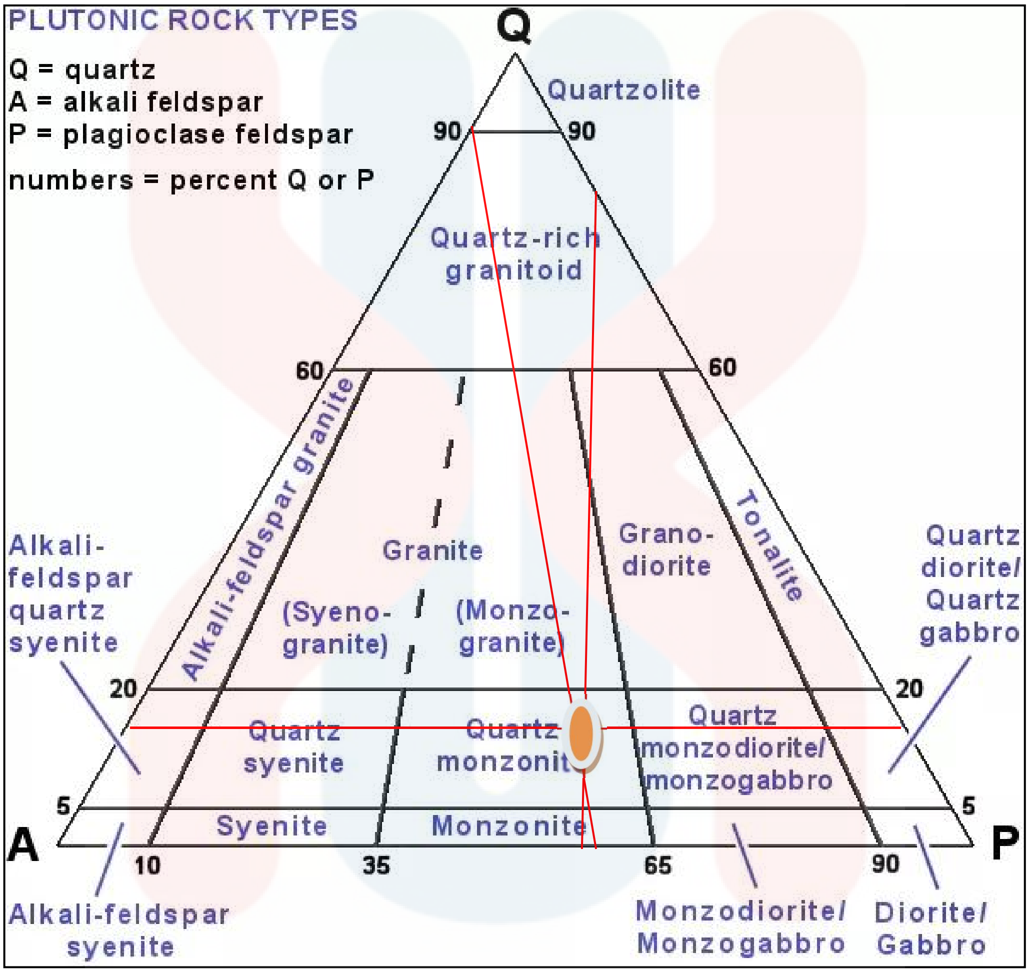


Figure 5.2:IUGS classification of NSS#001 sample.

-Q + A + P = 85%	A+P= 82
-Q= 15(100/85)= 18%	A'= 33(100/82)=40%
-A= 28(100/85)=33%	P'=60%
-P=42(100/85)=49%	

-Based on IUGS classification, the granitoid rock of NSS#001 is phaneritic Quartz-Monzonite. It is classify as phaneritic becauseQ+A+P>10%.

5.2.2 i) Grey granite (NSS#003)

Table 5.2: Sample description

Sample	Grey granite
Location/ place:	Rubber tree plantation (East side of research area)
Coordinate:	101°53'44.361"E 4°54'4.21"N
Elevation:	145m
Azimuth:	330°
Mineral content:	P-Plagioclse: 25% A-Felspar:45% Biotite:10% Q-Quartz:20%

ii) IUGS classifcation

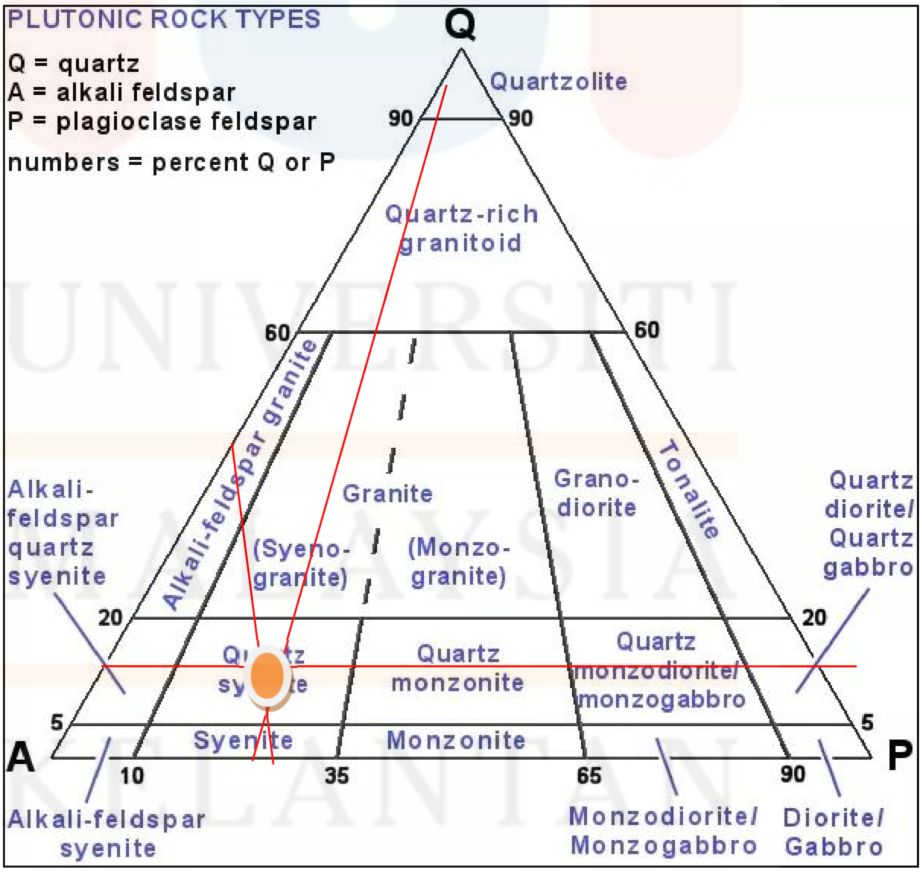


Figure 5.3: IUGS classification of NSS#003 sample

-Q + A + P = 80%	A+P= 87.5
-Q= 10(100/80)=12.5%	A'= 62.5(100/87.5)=71%
-A= 50(100/80)=62.5%	P'=29%
-P=20(100/80)=25%	

-Based on IUGS classification, the granitoid rock of NSS#003 is Phaneritic Quartz-Syenite. It is phaneritic because Q+A+P>10%

5.3 Geochemical analysis

Geochemical analysis on the granites samples was analyzed via XRF analysis and ICP- MS analysis. Based on the analysis data of major elements, trace elements and REE were obtained. However based on the results that obtained, the major elements and the trace elements that were obtained were quite lacking as some of the samples did not have the specific elements that the research need thus the result that were produced were quite lacking due to the absent of important elements like Rb and Nb in trace elements. In this analysis, three granite samples are analyse in order to identify the granitoid classification in the study area. All the samples were taken from the study area in Panggong Lalat.

5.3.1 Major elements

Table 5.3: Major elements in granitoid rocks of study area

Major Elements	Wt (%) Normalized 100%		
	NSS#001 (Pink granite)	NSS#002 (Grey granite)	NSS#003 (Grey granite)
SiO2	55.74	50.37	98.05
TiO2	6.10	1.35	1.31
Al2O3	11.40	13.00	10.70
FeO*	22.19	33.00	0.46
MnO	0.40	0.67	0.20
MgO	0	1.57	1.54
CaO	10.38	7.05	0.45
Na2O	0	6.14	6.11
K2O	5.18	8.91	1.09
P2O5	1.05	1.14	0.96

124In general, plutonic rocks contained high distributions of major elements like, SiO_2, Al203, MgO, FeO*, CaO, K_2O, Na_2O, P_2O_5, TiO_2 and MnO and for XRF analysis, all major elements are normalized 100% to reduce the loss or error of weight elements (Figure 5.3). Figure 5. 4 show the linear trends are exhibited by Harker diagram, the highest major elements that recorded in the rock samples was SiO_2 that range 50.37 % to 98.05% ,TiO_2 range between 1.31% to 6.10% and Al_2O_3 with 10.70 to 13.00. Then for FeO* the wt% range from 0.46% to 22.19%, for MnO range from 0.20% to 0.67%, MgO shows the lowest distribution in the study area with 1.57% to 1.54%, however MgO in NSS#001 sample cannot be identify, CaO elements wt% reading was range from 0.45% to 10.38%, Na_2O_2 are slightly decreased in the figure below with wt% reading range 6.14% to 6.11% without Na_2O_2 reading from NSS#001 sample, K_2O reading is decease with range from 5.18% to 1.19% and lastly P_2O_5 wt% range from 0.96% to 1.05%.

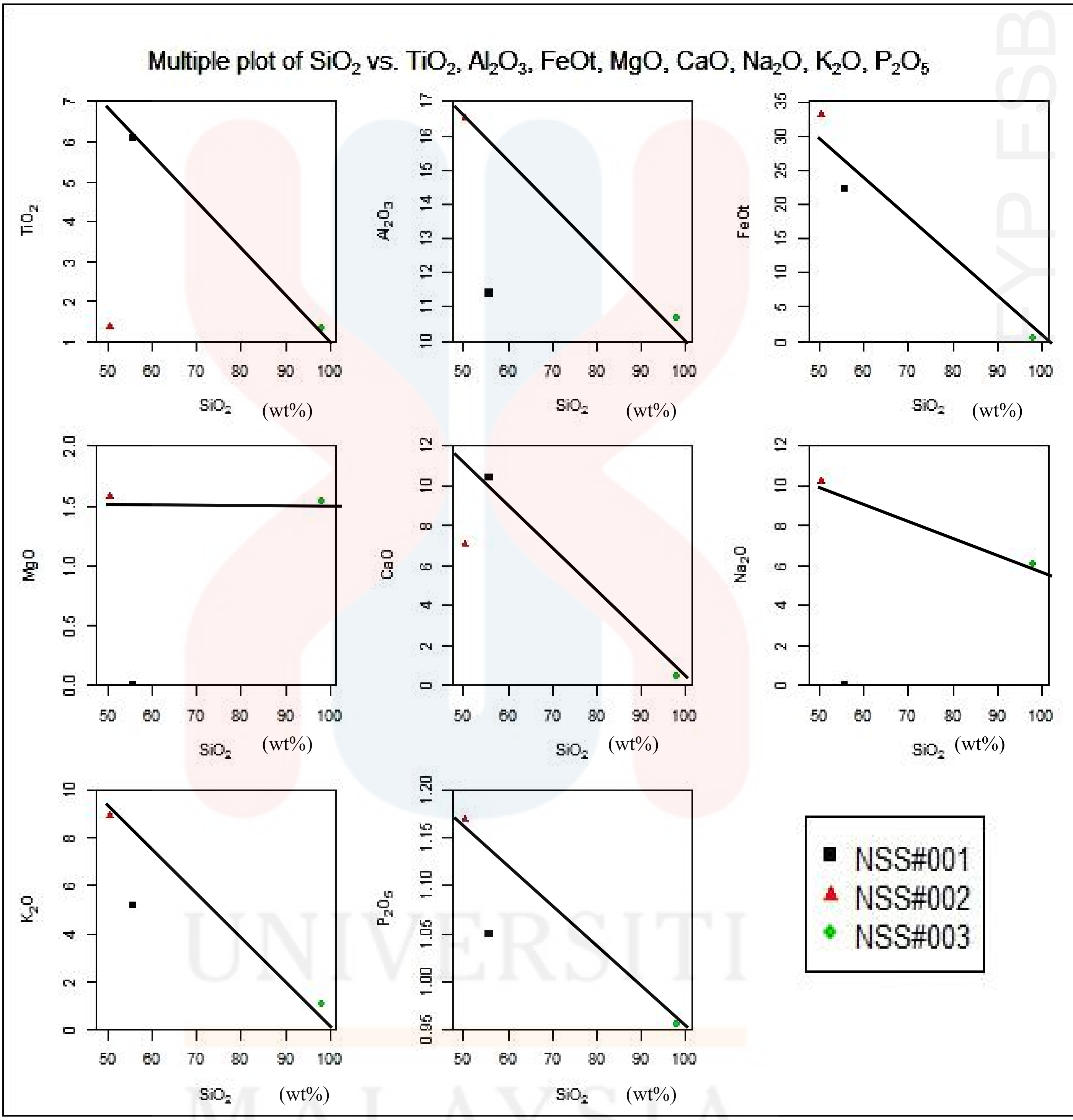


Figure 5.4: Major elements based on Harker diagram in Panggong Lalat area.

Based on Figure 5.5 of K2O against Na2O diagram, we can tell the types of granite in the study area. Based on the diagram, only two samples show their granite types, this due to NSS#001 sample that did not obtained the Na2O elements from the XRF analysis. However based on previous research by Samuel Wai-Pan Ng et al. (2015) Panggong Lalat area that located in East Province granite can be concluded as I –type granite as both of the granite samples are in I-type region.

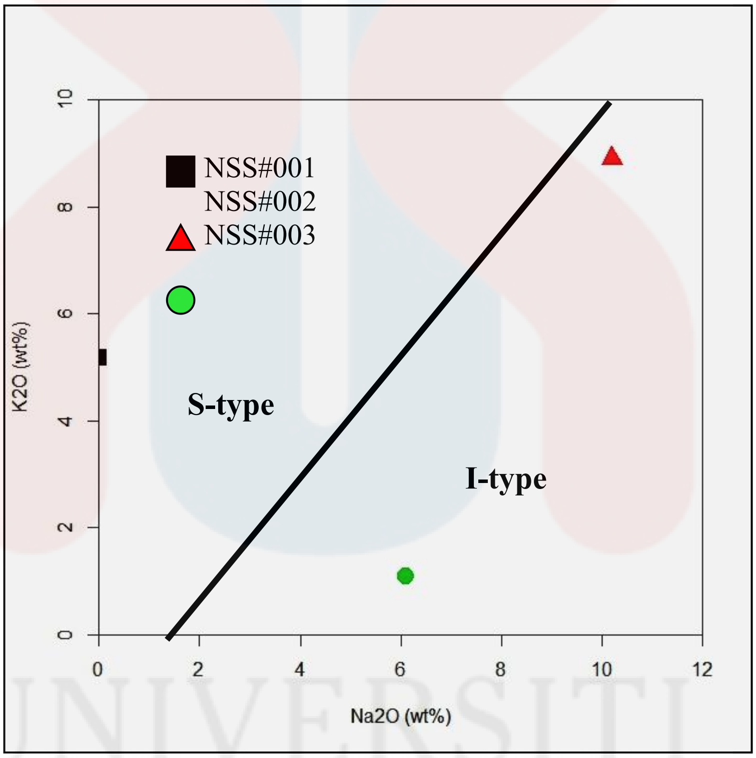


Figure 5.5:K2O(wt%) against Na2O (wt%)

Based on Figure 5.6 below, AFM diagram by Irvine and Baragar (1971) were plotted based on three granite sample in the study area. Those samples seem to have vary result as sample NSS#001 and NSS#002 show in tholeiite series while sample of NSS#003 shows in Calc-alkaline series.

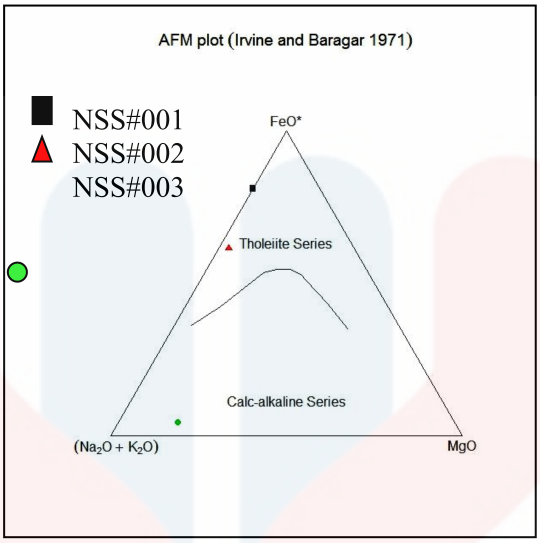


Figure 5.6: AFM diagram of granite sample in Panggong Lalat. Modified by Irvine and Baragar (1971)

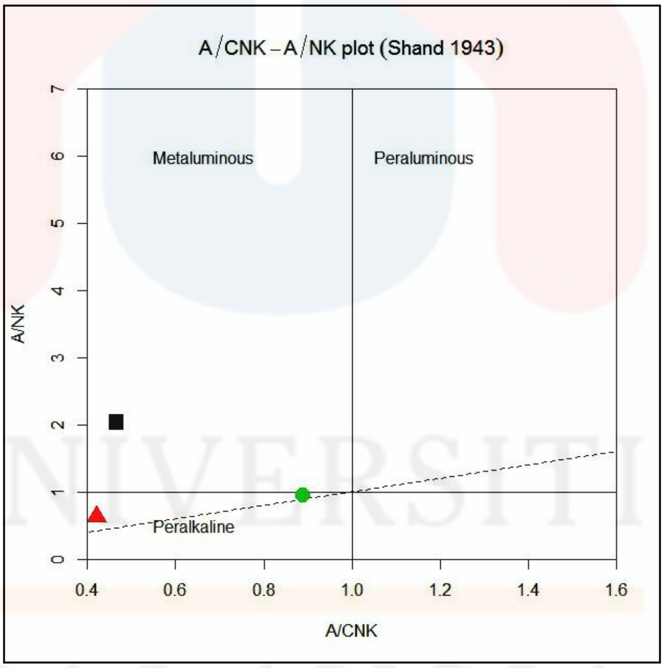


Figure 5.7: Al2O3/ Na2O+K2O against Al2O3/Cao+NaO2+K2O

Based on Figure 5.7 above, it shows the alkali saturation index of three samples that being analysed by XRF analysis. The granite seem to be as I-type but the result show that two of the sample have peralkaline composition. Futher discussion will be explained.

5.3.2 Trace Elements

Trace elements occur in low concentration of rocks reported to be less than 0.1% of parts per million (ppm) and it is calculated in form of ppm which 1% wt of an element is equal to 10000 ppm. Trace elements are divided into two groups, which are incompatible elements and compatible elements. Incompatible elements are K, Rb, Cs, Ta, Nb, U, Th, Y, Hf, Zr and Rare Earth Elements (REE) of La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er,Tm,Yb, and Lu. While compatible elements are like Ni, Cr, CO, V, and Sc that fits easily into crystallographic sites that normally accommodate Mg, and Fe since they have smaller ionic radii. Table 5.4 below shows the trace elements that being obtained by granite samples of Panggong Lalat based on geochemical analysis of XRF.

Table 5.4: Trace elements of granite samples

Trace Elements	ppm		
	NSS#001 (Pink granite)	NSS#002 (Grey granite)	NSS#003 (Grey granite)
Si	802800	1022000	994400
O	3364800	2359600	1221600
Ba	0	0	8000
Rb	0	0	0
Th	0	0	0
K	15250	256000	206200
Nb	0	0	0
La	28.5	145.6	41.5
Ce	62.1	125.3	82.1
Sr	0	0	0
Nd	30.3	121.9	34.2
Ti	6000	51000	62000
Y	1.8	91.9	1.8

Based on the Harker diagram in Figure 5.4 below, the Ba shows the highest ppm value of 6000 ppm in sample NSS#003 while the other two granite samples did not show any sign of Ba elements, Ti elements also show the highest range in samples NSS#002 and NSS#003 with range of 51000 ppm to 62000 ppm while sample NSS#001 shows the lowest Ti value with 6000 ppm. The result that were obtained were quite lacking as important trace elements like Rb, Th and Sr are not found during the analysis as this might related with the error or sample contamination during the geochemical analysis procedure. However there were still other elements that are obtained like K that range 15250 ppm to 256000 pmm , REE of La that range 28.5 ppm to 148.5 ppm, Ce that range from 62.1 ppm to 125.3 ppm and Nd elements that range within 30.3 ppm to 121.9 ppm.

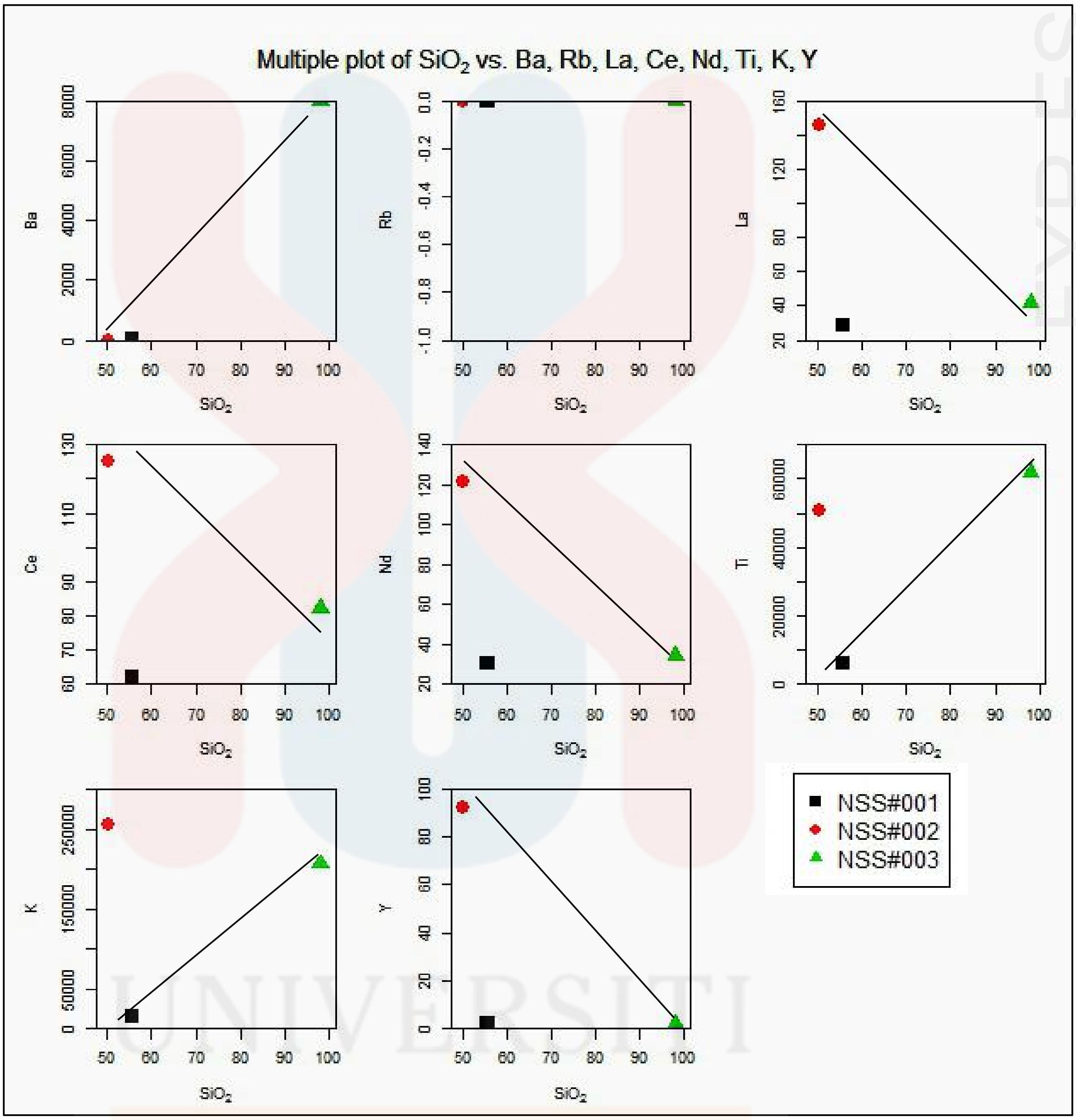


Figure 5.8: Trace elements based on Harker diagram in Panggong Lalat area.

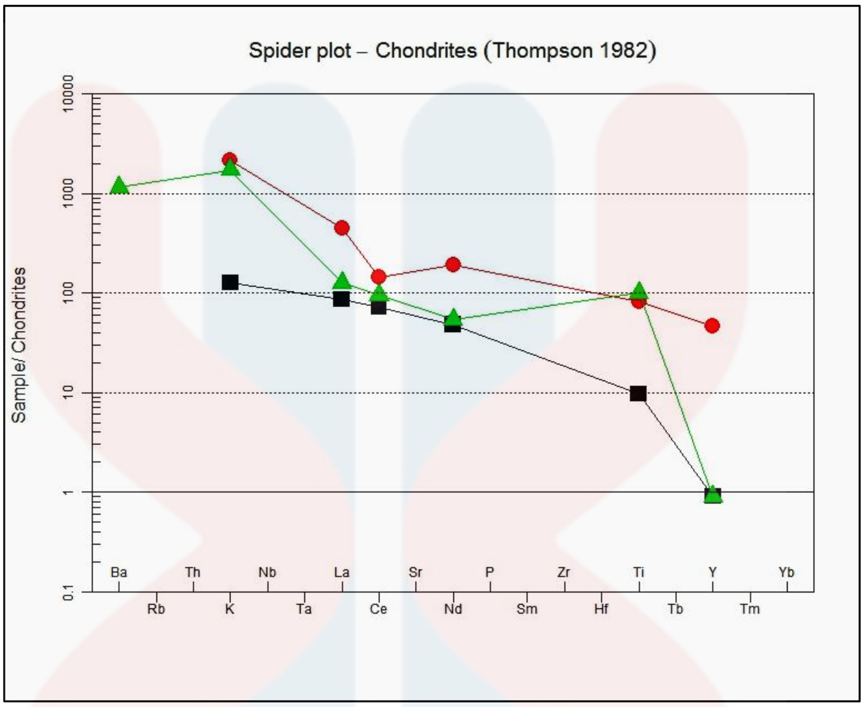


Figure 5.9: Trace element in spider plot of Thompson (1982), to detect the variation that indicates the magma source in subduction zone.

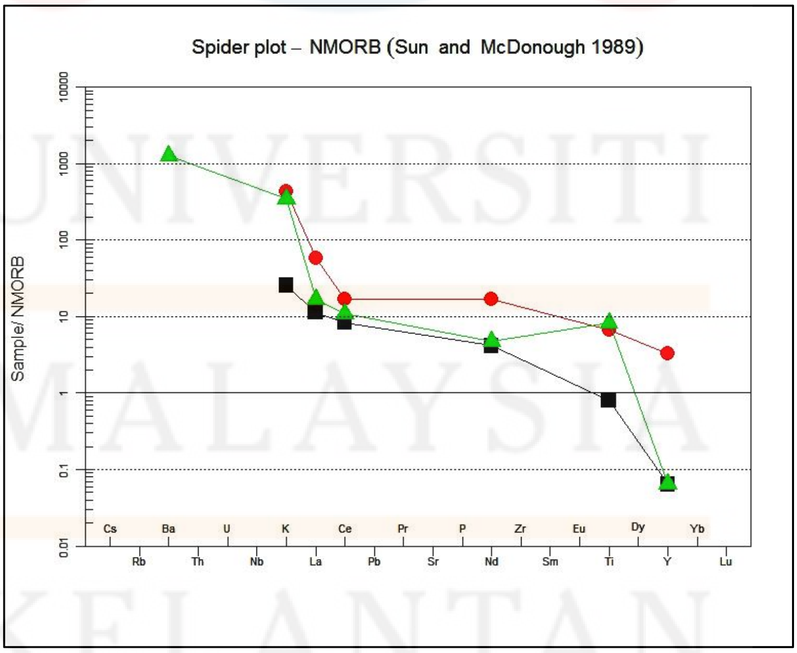


Figure 5.10: Spider plot of NMORB by Sun and McDonough 1969.

Based on spider plot above,the graph of trace elements plotted vs chondrite shows the magma characteristic of originated from magma in a subduction zone environment. Generally, the characteristics of trace elements are observed where enriched in LILE of Th, K and La, and depleted in Ti. However based on the graph, Ti elements in samples of NSS#002 and NSS#003 seem to be enriched and not depleted. This might show a A-type characteristic of the magma. Both graph in spider plot- Chondrites and spider plot- NMORB show depleted value in Y.

5.3.3 ICP-MS Analysis

Rare Earth Elements data was obtained from ICP-MS analysis and after running the analysis on three samples of granitoid rocks of NSS#001, NSS#002 and NSS#003 light REE and heavy REE was obtained. Light REE that was obtained by the ICP-MS analysis are Lanthanium (La), Cerium (Ce),Praseodyium (Pr),Neodymium (Nd) and Samarium (Sm). This shows that only 5 out of 6 light REE present in the granite of Panggong Lalat. While for heavy REE there are 10 elements that present out of 11 elements of Europium (Eu) Gadolinium (Gd) Terbium (Tb) Dysprosium (Dy) Erbium (Er) Thulium (Tm) Ytterbium (Yb) Holmium (Ho) Lutetium (Lu) and Yttrium (Y). Table 5.5 below shows the Rare Earth Elements of both light and heavy.

Table 5.5: REE distribution in Panggong Lalat

Granite type	Pink granite	Grey granite	Grey Granite
LREE	NSS#001 (ppm)	NSS#002 (ppm)	NSS#003 (ppm)
Lanthanium (La)	28.5	145.6	41.5
Cerium (Ce)	62.1	125.3	82.1
Praseodyium (Pr)	0.7605	28.8	0.933
Neodymium (Nd)	30.3	121.9	34.2
Samarium (Sm)	6	26.4	6
SUM	**127.6605**	**448**	**164.733**
HREE	NSS#001 (ppm)	NSS#002 (ppm)	NSS#003 (ppm)
Europium (Eu)	0.0793	0.3872	0.0617
Gadolinium (Gd)	5.3	29.5	5.2
Terbium (Tb)	0.0771	0.4123	0.0736
Dysprosium (Dy)	0.4006	2.1	0.3941
Holmium (Ho)	0.0767	0.3768	0.0764
Erbium (Er)	0.2035	0.8952	0.2066
Thulium Tm	0.0278	0.1116	0.0285
Ytterbium (Yb)	0.1714	0.6173	0.1733
Lutetium (Lu)	0.0244	0.0854	0.0245

Yttrium (Y)	1.8	91.9	1.8
SUM =	**8.168**	**126.3858**	**8.0387**

5.3.2.1 REE data analysis

a) Distribution of Light Rare Earth Elements in Panggong Lalat

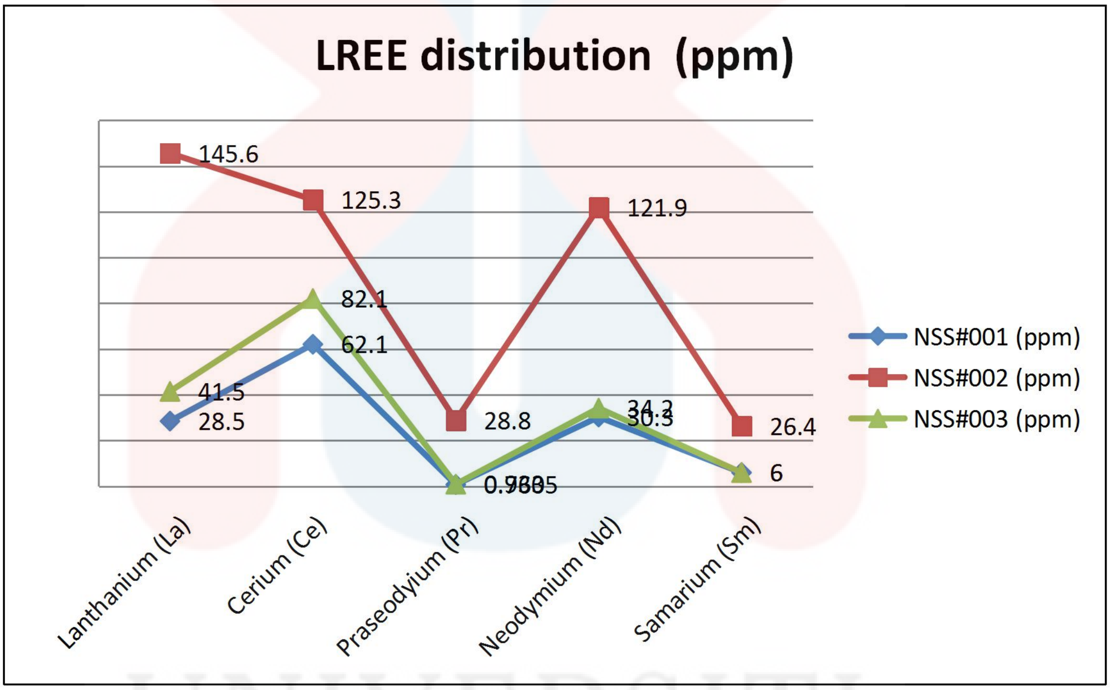


Figure 5.11: Light REE distribution in Panggong Lalat.

Based on the graph of Light REE distribution in Figure 5.11, it shows that grey granite of NSS#002 obtained the highest distribution of Lanthanium of 145.6 ppm and Neodymium with 121.9 ppm in the study area. While the lowest LREE show in granite of NSS#001 with Lanthanium(La) with 28.5ppm and Praseodyium (Pr) with 0.7605.However Cerium(Ce) and Neodymium(Nd) of the three sample show quite highest reading they show the highest reading for each rock sample.

b) Distribution of Heavy Rare Earth Elements in granite of Panggong Lalat

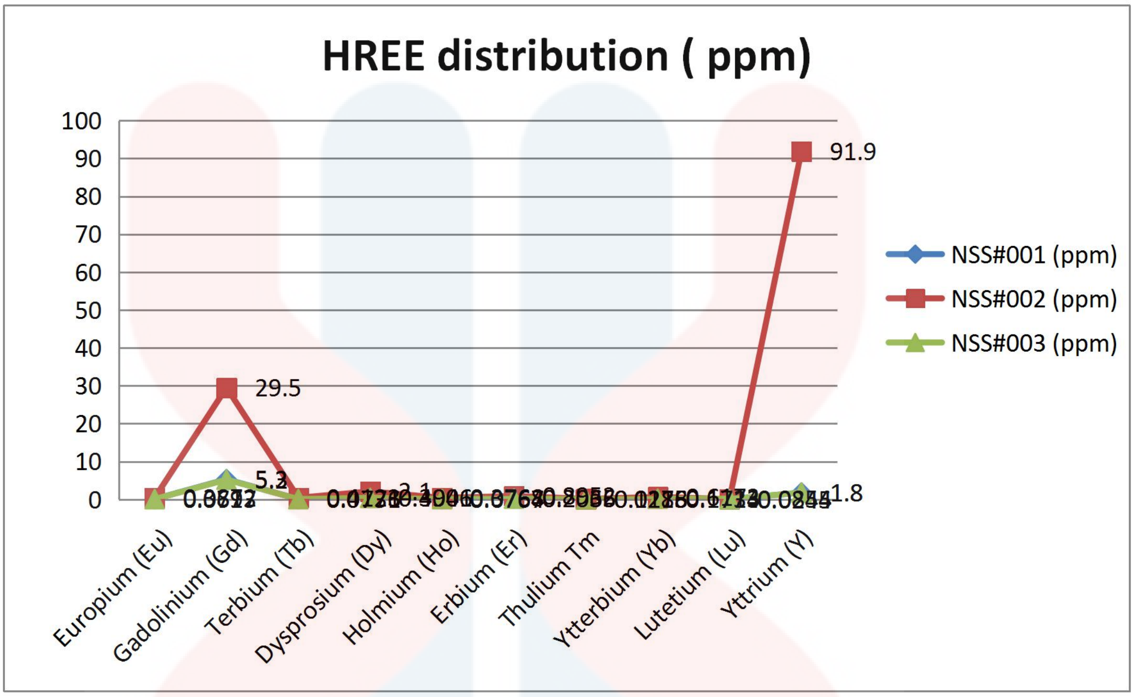


Figure 5.12: Heaby REE distribution in Panggong Lalat

For distribution of HREE, same granite sample had been analysed in order to know the their REE distribution based on different types of granites, which is pink granita and grey granite.Sample NSS#002 showed the highest reading of Yttrium(Y) distribution with 91.9 ppm, then its also show quite a higher result of Gadolinium(Gd) with 29.5 ppm. Other samples however show the same REE distribution and are considerably below than <1.00 ppm based on the Figure 5.12 above. Thulium(Tm) and Lutetium(Lu) show the lowest distribution reading as they are the two least abundances of Rare Earth Elements.

5.4 Discussion

Geochemistry analysis's research of granitoid rocks was done in Panggong Lalat area as there were lack of research study that being done in Panggong Lalat. The analysis was done in order to fulfill the second and third objectives of the research study. For geochemistry analysis, granitoid rocks were used as a research sample and based on the samples, granitoid claasification based on the rocks were made.

For IUGS classification, only two granite samples were selected as the study area are composed of pink and grey granite and both of the samples were code as NSS#001 and NSS#003 respectively. After doing some petrography analysis and IUGS classification, the granite of NSS#001 was named as Phaneritic Quartz-Monzonite. It is name as phaneritic due to its Q+A+P >10% same as texture for granite of NSS#003. Phaneritic Quartz-Monzonite contained plagioclase feldspar, orthoclase feldspar, and quartz (Britannica, 2018). So its often called as pink granite as a result the sample that was found was pink granite. It is abundant in the batholiths area and Panggong Lalat area was known to be located in batholith area of Senting intrusion. Quartz monzonite is different from granodiorite as it contained more alkali feldspar, more biotite, less hornblende, and oligoclase instead of andesine as the plagioclase mineral.

Next for granitoid sample of NSS#003, it was named as Phaneritic Quartz-Syenite after petrography and IUGS classification. Downes et al.(2005) state that Quartz-syenite are mainly composed of alkaline feldspar and little plagioclase feldspar. However, based on the research the sample are abundances of plagioclase. Most of syenite rocks are peralkaline with high proportions of alkali elements relative to aluminum, or peraluminous with a higher concentration of aluminum relative to alkali and earth-alkali elements (predominantly K, Na, Ca). Quartz-Syenite of NSS#003 shows peralkaline behavior in Alumina Saturation Index diagram in Figure 5.7.

Based on the major elements, SiO2 show the highest range from 50.37% to 98.05%, Thus Al, Ca and Na approxiamately present in fractionalization of plagioclase. AFM diagram in Figure 5.6 showed varied results from the granite samples as NSS#001 and NSS#002 are in tholeiitic series while NSS#003 sample was in Calc- Alkaline series, this actually can described about the history of the granite intrusion. Tholeiitic series formed by oceanic magma sources and Calc-alkaline formed through thesyn- collusion granite or subduction exposed. Maybe this can describe about the Senting intrusion that formed in Gua Musang, specifically Panngong Lalat area and the depositional environment of Gua Musang that known as shallow marine environment.

Based on whole geochemical analysis in the study area, the granitoid rock can be classify as I-type and A-type granite. I-type granite is prove when sample of NSS#001 seen to show low metaluminous behavior and the have the SiO2 content of 55.74 %. For I-type granite they roughly content SiO2 with range of 53% - 73% and usually occurred in subduction zone and place that have igneous source. Relate with its IUGS classification of Phaneritic Quartz- Monzonite that formed in batholiths area this is strongly prove that NSS#001 granite is I-type granite.

For NSS#002 and NSS#003 samples, they are classified as A-type granite as they show the peralkaline behavior in AFM diagram. For A-type granite, SiO2 wt% must be more than 77% and have higher alkali feldspar contents thus NSS#003 granite shows that it contained almost 93% of SiO2 and its alkali feldspar contents in the rocks is almost 45%. Relate with its IUGS classification, NSS#003 is a Phaneritic

Quartz-Syenite that usually form in anorogenic and all plutonic rocks that form in anorogenic will be classify as A-type rock. The most strong prove that shows NSS#002 is a A-type rock is its REE contents in diagram 5.8 and 5.9 that shows the highest distributions in the study area both in light REE of La, Ce and Nd and heavy REE of Gd and Y of other than its peralkaline behavior in AFM diagram.This really prove that the NSS#002 sample is a A-type based on those data that being obtained in overall research.

For tectoning setting classification, trace elements are used to observe the evolution of the magma so the graph from the spider plot - Chondrites and spider plot- NMORB are used to show the tectonic setting of the study area based on the trace elements distributions. The spider plot in Figure 5.9 shows the enrichment in LILE of Th, K, and La and the depletion of HFSE of Ti element in sample NSS#001. However in sample NSS#002 and NSS#003, Ti elements show to be enriched together with the enrichment in LILE of Th, K, and La thus this resulted to the enrichment of HFSE and LILE in granite region of NSS#002 and NSS#003. HFSE depletions occur due to LILE that partitioned into H2O rich fluids released by partial melting of slab rocks thus this usually related with the generation of fluids and melt distilled from the subducting plate.

Based on the result obtained by major elements, trace elements and rare earth elements analysis, tectonic setting of granites also can be explained based on its granite type. Based on the result, granite in Panggong Lalat area can be classify as I-types and A-types granites. I-type granites are dominant in sample of NSS#001 and I- type granite usually found in orogenic setting of subduction area. This can be related to the result of spider plot- chondrites that shows the result of subduction area in the study area. As for A-types granite, its formed in anorogenic setting of batholith area. Granite sample of NSS#002 and NSS#003 showed the high probability of having A-type granite as they contains high values of REE with high SiO2 in NSS#002 sample. According to the research Panggong Lalat area are exposed with the batholith area and Senting intrusion, so this can be related to the presence of A-type granites in the study area. Throughout the discussion, the tectonic setting can be classify as orogenic setting of subduction zone for I-type granite and anorogenic setting of batholith zone for A-type granite.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

As the conclusion, all the objectives are achieved throughout the Final Year Project (FYP) progress. Geological map of the study area was able to produced and updated with scale of 1:25,000 of the study area, Panggong Lalat. By referring to the geological map, geological mapping was doned and the data of geomorphology analysis, lithology analysis, geological structure and other geological informations was interpreted. Referring to the research title, the research are more prone to the specification research of geochemistry of granitoid rocks in the study area. Petrology analysis was done together with the geochemical analysis in order to achieve the geochemistry of granitoid rocks in the study area. Through the geochemistry analysis, the all the granite samples was classify according to their characteristic based on their granitoid classification.Thus,Panggong Lalat granitoid rocks composed of I-type classification and A-type classification.

6.2 Recommendation

Outcrops sampling is the most important things in order to complete Chapter 5 for specification part. For more accurate data, amount of samples to analyse should be at least five samples or above as this will eventually help the researcher to get the ideas and elaborate more on the specification part. Futher research also should be conducted in the study area in the future as there were lacking of informations regarding the geological informations there. Futhermore, there were many other geological structures that have not be explored by the geologist like Gua Berlian in the study area. Last but not least, the study area should be developed more in the future especially in agriculture sector as the soil fertility there was really high.

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APPENDICES A

CENLAB/F/007

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Tel No	09-9477000/2936	Fax No	-
Sample Lab No	2018/456	No of sample	12

Sample marking : 2018/456(1)
Sample description : **NSS-001**
Date of sample received : 16-11-2018
Date reported : 29-11-2018

RESULTS:

No	Parameter	Results	Unit	Test Method
1.	Yttrium (Y)	1.8	ppm	CENLAB/WI/CHEM-TM/008
2.	Lanthanium (La)	28.5	ppm	CENLAB/WI/CHEM-TM/008
3.	Cerium (Ce)	62.1	ppm	CENLAB/WI/CHEM-TM/008
4.	Praseodyium (Pr)	760.5	ppb	CENLAB/WI/CHEM-TM/008
5.	Neodymium (Nd)	30.3	ppm	CENLAB/WI/CHEM-TM/008
6.	Samarium (Sm)	6.0	ppm	CENLAB/WI/CHEM-TM/008
7.	Europium (Eu)	79.3	ppb	CENLAB/WI/CHEM-TM/008
8.	Gadolinium (Gd)	5.3	ppm	CENLAB/WI/CHEM-TM/008
9.	Terbium (Tb)	77.1	ppb	CENLAB/WI/CHEM-TM/008
10.	Dysprosium (Dy)	400.6	ppb	CENLAB/WI/CHEM-TM/008
11.	Holmium (Ho)	76.7	ppb	CENLAB/WI/CHEM-TM/008
12.	Erbium (Er)	203.5	ppb	CENLAB/WI/CHEM-TM/008
13.	Thulium (Tm)	27.8	ppb	CENLAB/WI/CHEM-TM/008
14.	Ytterbium (Yb)	171.4	ppb	CENLAB/WI/CHEM-TM/008
47.	Lutetium (Lu)	24.4	ppb	CENLAB/WI/CHEM-TM/008
48.	Thorium (Th)	1.8	ppm	CENLAB/WI/CHEM-TM/008

2018/456
Page **1** of **12**

Sample marking : 2018/456(2)
Sample description : **NSS-002**
Date of sample received : 16-11-2018
Date reported : 29-11-2018

RESULTS:

No	Parameter	Results	Unit	Test Method
1.	Yttrium (Y)	91.9	ppm	CENLAB/WI/CHEM-TM/008
2.	Lanthanium (La)	145.6	ppm	CENLAB/WI/CHEM-TM/008
3.	Cerium (Ce)	125.3	ppm	CENLAB/WI/CHEM-TM/008
4.	Praseodyium (Pr)	28.8	ppm	CENLAB/WI/CHEM-TM/008
5.	Neodymium (Nd)	121.9	ppm	CENLAB/WI/CHEM-TM/008
6.	Samarium (Sm)	26.4	ppm	CENLAB/WI/CHEM-TM/008
7.	Europium (Eu)	387.2	ppb	CENLAB/WI/CHEM-TM/008
8.	Gadolinium (Gd)	29.5	ppm	CENLAB/WI/CHEM-TM/008
9.	Terbium (Tb)	412.3	ppb	CENLAB/WI/CHEM-TM/008
10.	Dysprosium (Dy)	2.1	ppm	CENLAB/WI/CHEM-TM/008
11.	Holmium (Ho)	376.8	ppb	CENLAB/WI/CHEM-TM/008
12.	Erbium (Er)	895.2	ppb	CENLAB/WI/CHEM-TM/008
13.	Thulium (Tm)	111.6	ppb	CENLAB/WI/CHEM-TM/008
14.	Ytterbium (Yb)	617.3	ppb	CENLAB/WI/CHEM-TM/008
47.	Lutetium (Lu)	85.4	ppb	CENLAB/WI/CHEM-TM/008
48.	Thorium (Th)	37.9	ppm	CENLAB/WI/CHEM-TM/008

Sample marking : 2018/456(3)
Sample description : **NSS-003**
Date of sample received : 16-11-2018
Date reported : 29-11-2018

RESULTS:

No	Parameter	Results	Unit	Test Method
1.	Yttrium (Y)	1.8	ppm	CENLAB/WI/CHEM-TM/008
2.	Lanthanium (La)	41.5	ppm	CENLAB/WI/CHEM-TM/008
3.	Cerium (Ce)	82.1	ppm	CENLAB/WI/CHEM-TM/008
4.	Praseodyium (Pr)	933.0	ppb	CENLAB/WI/CHEM-TM/008
5.	Neodymium (Nd)	34.2	ppm	CENLAB/WI/CHEM-TM/008
6.	Samarium (Sm)	6.0	ppm	CENLAB/WI/CHEM-TM/008
7.	Europium (Eu)	61.7	ppb	CENLAB/WI/CHEM-TM/008
8.	Gadolinium (Gd)	5.2	ppm	CENLAB/WI/CHEM-TM/008
9.	Terbium (Tb)	73.6	ppb	CENLAB/WI/CHEM-TM/008
10.	Dysprosium (Dy)	394.1	ppb	CENLAB/WI/CHEM-TM/008
11.	Holmium (Ho)	76.4	ppb	CENLAB/WI/CHEM-TM/008
12.	Erbium (Er)	206.6	ppb	CENLAB/WI/CHEM-TM/008
13.	Thulium (Tm)	28.5	ppb	CENLAB/WI/CHEM-TM/008
14.	Ytterbium (Yb)	173.3	ppb	CENLAB/WI/CHEM-TM/008
47.	Lutetium (Lu)	24.5	ppb	CENLAB/WI/CHEM-TM/008
48.	Thorium (Th)	2.2	ppm	CENLAB/WI/CHEM-TM/008