GEOLOGY AND STUDIES OF HYPERACCUMULATOR PLANT IN ULU SOKOR TANAH, MERAH

by

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A thesis submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science Geoscience with Honours

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DECLARATION

"I/we hereby declare that I/we have read this thesis and in our opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Applied Science (Geosciences) with Honors."

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Signature

Name of supervisor :

Date:

APPROVAL

I declare that this thesis entitled "Geology and Studies of Hyperaccumulator Plant in Ulu Sokor, Tanah Merah" 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 candidate of any other degree.

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Signature

Name:

Date:

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Geology and Studies of Hyperaccumulator Plant in Ulu Sokor, Tanah Merah

ABSTRACT

This research is about using hyperaccumulator plant for determination the distribution of heavy metal around Ulu Sokor, Tanah Merah. Ulu Sokor is well known with gold deposition areas and located quite close to the famous central gold belt. Hyperaccumulator plant able to grow in soil with high concentration of metal and capable to absorb or store the elements inside its body. The distribution of elements concentration could be determined using this plant around the study area in order to identify or locate the primary sources of gold. The plant species identified in this research are *Dicranopteris Linearis sp. Bambuseae sp Melastoma malabathricum sp.* and *senna alata sp*. have been selected for elemental analyses using Induced Coupled Plasma (ICP), X-Ray Fluorescence (XRF) and Atomic Absorption Spectrophotometer (AAS). The distribution of some elements such as Aluminium (Al), Arsenic (As), Iron (Fe), Lead (Pb), Silver (Ag) and Manganese (Mn) are plotted in a map based on its concentration in order to identify the anomaly. From the map it shows that the location that composed of pyrite mineral contain higher concentration of the heavy metal such as Manganese (Mn) that come from the oxidation of pyrite mineral where the concentration from the ICP analysis recording the higher among the others which is ranging in 155.58ppm. Concentration of heavy metal such Iron (Fe), Silver (Ag), Arsenic (As) and Aluminium (Al) also shown higher in the area close the mining company and for the location of highly weathered area lead to the increasing of Iron (Fe) concentration.

Kajian Geologi dan Pengkajian Pokok Hyperacumulator di Ulu Sokor, Tanah Merah

ABSTRAK

Kajian ini menggunakan tumbuhan hyperaccumulator untuk menentukan taburan logam berat di sekitar Ulu Sokor, Tanah Merah. Ulu Sokor terkenal dengan kawasan pemendapan emas kerana terletak agak dekat dengan jalur pusat emas yang terkenal. Tumbuhan hyperaccumulator mampu tumbuh di tanah dengan kepekatan logam yang tinggi dan mampu menyerap atau menyimpan unsur-unsur di dalam selnya. Kontribusi kepekatan unsur boleh ditentukan menggunakan tumbuhan ini di sekitar kawasan kajian untuk mengenal pasti atau mencari sumber utama emas. Spesies tumbuhan yang dikenal pasti dalam penyelidikan ini ialah Dicranopteris Linearis sp. Bambuseae sp Melastoma malabathricum sp. dan senna alata sp. telah dipilih untuk analisis unsur menggunakan Plated Coupled Induced (ICP), X-Ray Fluorescence (XRF) dan Spectrophotometer Atomic Absorption (AAS). Distribusi beberapa elemen seperti Aluminium (Al), Arsenik (As), Besi (Fe), Plumbum (Pb), Silver (Ag) dan Mangan (Mn) dijumpai dalam peta berdasarkan kepekatannya untuk mengenal pasti anomali. Daripada peta, ia menunjukkan bahawa lokasi yang terdiri daripada mineral pirit mengandungi kepekatan logam berat seperti Mangan (Mn) yang lebih tinggi kerana proses pengoksidaan mineral pirit di mana kepekatan dari analisis ICP merekodkan yang lebih tinggi di antara yang lain yang merangkumi dalam 155.58ppm. Kepekatan logam berat seperti Besi (Fe), Silver (Ag), Arsenik (As) dan Aluminium (Al) juga menunjukkan lebih tinggi di kawasan yang berhampiran dengan syarikat perlombongan dan lokasi kawasan yang terluluhawa menyebabkan peningkatan Besi (Fe) kepekatan

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LIST OF ABBREVIATIONS

Al	Aluminium
As	Arsenic
Fe	Iron
Pb	Lead
Ag	Silver
Mn	Manganese
Au	Gold
Hg	Mercury
Cd	Cadmium
Cr	Cgromium
Tl	Thallium
Co	Cobalt
Zn	Zinc
Cu	Copper
Ca	Calcium
Ni	Nickel
ICP	Induced Coupled Plasma
ICP-MS	Induced Coupled Plasma with mass Spectrometer
XRF	X-Ray Fluorescence
AAS	Atomic Absorption Spectrophotometer
WDXRF	Wavelength-dispersive X-Ray Fluorescence

EDXRF	Energy-dispersive X-Ray Fluorescence
wt	Weight
GDP	The Gross Domestic Product
DEM	Digital Elevation Model
ppm	Parts Per Million
ppb	Parts Per Billion
N	North
S	South
SW	South West
NW	North-West
SE	South-East
Km^2	Kilometre per square
m	metre
cm	centimeter
g	Gram
sq	square
sp.	species
mgl^{-1}	milligram per litter
μg	Micron-gram
mm	Millimetre
ml	millilitre
HCl	Hydrocloric Acid

GPS	Global Positioning System
XPL	Cross-polarized
PPL	Plane Polarized
SiO_2	Silicon dioxide
Fe_2O_3	Iron (III) oxide
K_2O	Potassium oxide
BaO	Barium Oxide
MnO	Manganese (II) oxide
V_2O_5	Vanadium oxide
TiO_2	Titanium oxide
NiO	Nickel (II) oxide
Cr_2O_3	Chromium (III) oxide
SO_3	Sulphur trioxide
Al_2O_3	Aluminium oxide

LIST OF SYMBOLS

“	Second
,	Minute
°	Degree
℃	Temperature (degree Celcius)
%	Percentage
σ	Sigma
µ	micro
>	More than
<	Less than

CHAPTER 1

INTRODUCTION

1.1 GENERAL BACKGROUND

Biogeochemistry study is one of the scientific study that include the study of chemical, biological, geological, and physical process that comprised with natural environment such as hydrosphere, lithosphere, atmosphere and biosphere. According to Hulme *et al.* (2006), the biogeochemistry method is widely applied in mineral exploration. This method using the vegetation or plant that can uptake and store the heavy element inside them. The element distribution based on plant analysis around the study area could identify the anomaly that will lead to ore finding. Countries like Canada, United States of America and Australia have been used this method for research and mineral exploration for mining company since 1960. Harry Warren from North America is known as "Father of Biogeochemistry" because his contribution in introducing the biogeochemistry method in mineral exploration (Bothe, 2011).

This research mainly focused on the "Geology and Studies of Hyperaccumulator plant in Ulu Sokor, Tanah Merah". Hyperaccumulator plant is plant that can grow in soil with high concentration of metal and hold the interest to absorb or extract metal as their nutrient. Hyperaccumulator plant is used in this biogeochemistry research. The heavy metal that associates with the ore mineral which is Gold (Au) is analysed in the soil and the plant sample. Examples of heavy metals include Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Thallium (Tl), Cobalt (Co), Zinc (Zn), Manganese (Mn), Silver (Ag) and Lead (Pb). Heavy metals are natural chemical that can be found in the Earth's crust. Gold is including as one of the heavy minerals or heavy metals. Gold is called a heavy metal because of its high density, which comes from the fact that each of its atoms is individually very heavy. In some gold exploration project, heavy mineral studies and detailed till geochemical and stratigraphy studies were used.

Ulu Sokor, Tanah Merah is selected because this area is well-known as one of area that has a potential of gold deposition. This is because Ulu Sokor, Tanah Merah is located on the Central Gold Belt which has a gold mineralisation area. According to Hutchison and Tan (2009) from the studies, in Central Gold Belt the gold is mineralisation from 150 to 350°C, with formation depth 100-700m and fluid salinity of 0.5-4.8wt%. The main event that causes the deposition of massive sulphide and gold in Ulu Sokor Tanah Merah is because it is recorded for the huge volcanic event during Permian to Triassic age. The decomposition and deposition process of volcanic event is lead to the deposition of the ore mineral in Ulu Sokor (Goh *et al.*, 2006).

In this research a geological mapping and sampling is conducted in Ulu Sokor, Tanah Merah to retrieve the information and data of the area and also the geology information. Field survey, preliminary study, observation and data analysis is conducted in order to determine the exact boundary and getting enough information of the study area. Two major views is covered include geological mapping and geochemical mapping. Geochemical mapping is a technique developed in the 1920s to give information on the spatial distribution of chemical elements and compounds at the Earth's surface (Johnson and Ander, 2008). By doing geochemical mapping, it shows the distributions of heavy mineral in study area which is Ulu Sokor, Tanah Merah..

During the fieldwork, the soil sample and selected plant is collected at several different locations. Several rocks samples also collected during the geological mapping. The samples and data collection is analysed in laboratory. The experiment is used Atomic Absorption Spectrophotometer (AAS), Induced Coupled Plasma (ICP) and X-Ray Fluorescence (XRF) to determine the concentration of heavy metals in the soil samples and also plant samples. Classes of data is collected through many processes and procedures such as mapping, sampling, and laboratory test using technologies application or software as well as referring to preliminary studies, Google earth imagery or satellites imagery and referring to the experts of this field of study.

1.2 STUDY AREA

The study area has been conducted in Ulu Sokor, Tanah Merah. Ulu Sokor is located in the southern part of Tanah Merah, where it is a territory and town in the state of Kelantan in the northern Malaysia. The main capital is Tanah Merah. It is bounded by Machang district in the East, Kuala Krai to the south east, Jeli in the southwest and Thailand in the west. Situated nearby is Sungai Kelantan. The study area is situated in the central belt of Peninsular Malaysia. The formations that form

Tanah Merah are Taku Schist formation and Telong Formation. The study area is covers about $25km^2$. The base map of the study area is produced as reference of the research. The study area is in the reserve forest name Hutan Simpan Taku which is covered by thick forest. Relatively, the topography is dominated by steep slopes and narrow valleys with difference elevation ranging above the sea level. **Figure 1.1** shows the location of Kelantan in Peninsula Malaysia and the location of Tanah Merah in Kelantan Map while **figure 1.2** shows the base map of the study area.

Figure 1.1: Location of Tanah Merah in Kelantan Map (inset Tanah Merah in Peninsula Malaysia)

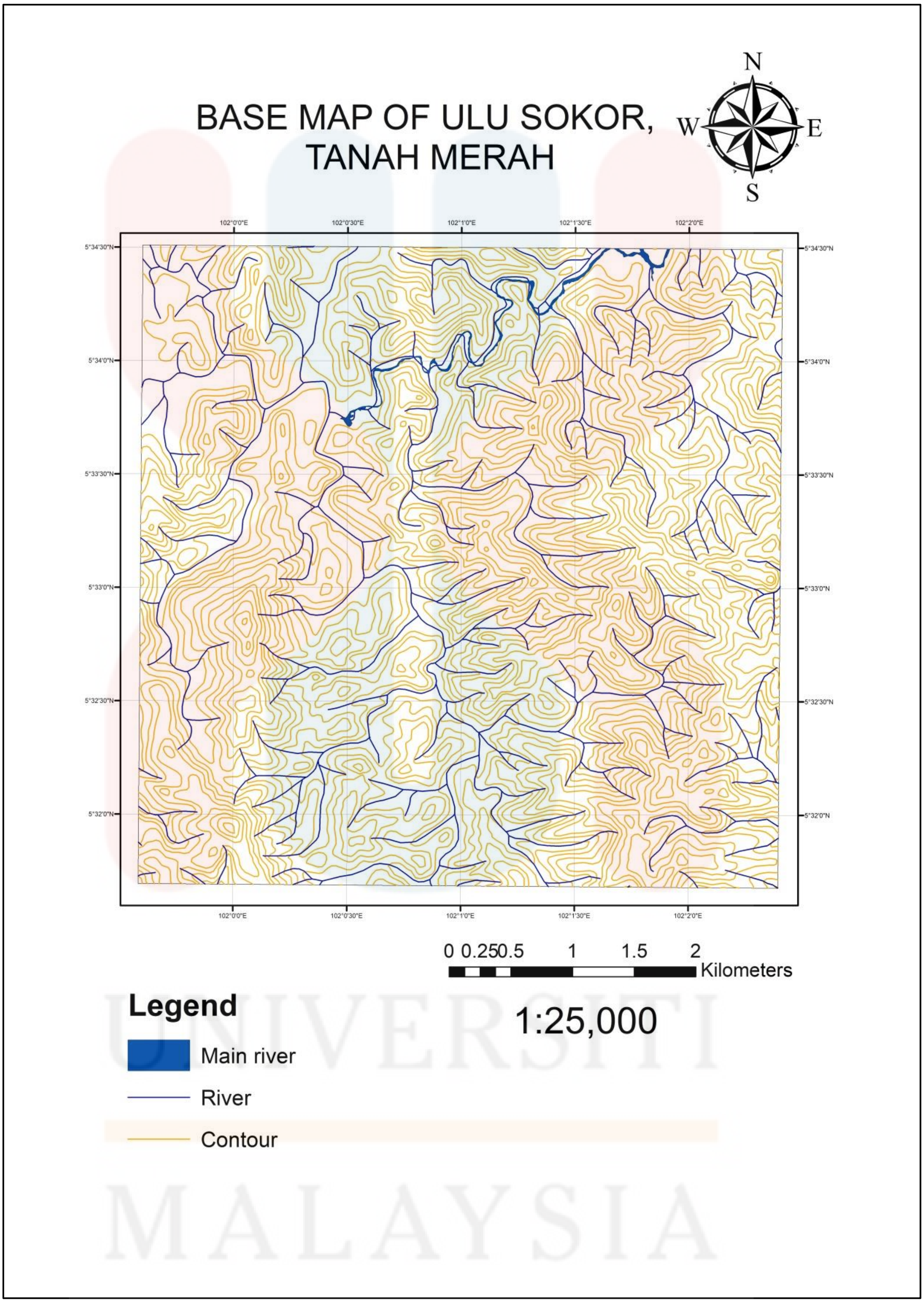


Figure 1.2: Base map of study area

1.2.1 LOCATION

Tanah Merah is a district in the state of Kelantan in northeast Malaysia. It is bordered by Pasir Mas District in the north, Machang District to the East, Kuala Krai District to the South East, Jeli District to the South West and Thailand in the West. It situated nearby Sungai Kelantan. Tanah Merah region is around 880 km^2. Bandar Tanah Merah, Batu Gajah, Bukit Bunga, Gual Ipoh, Kusial Baru, Batang Merbau, Kuala Tiga, and Bukit Panau is recorded as 8 mukim in Tanah Merah. The study area which is Sokor is located in Mukim Kuala Tiga which the nearest residence is Kampung Peralla.

1.2.2 ACESSIBILITY / ROAD CONNECTION

The location of the study area is located at the Southern-East part of Tanah Merah, which is more than 90km from UMK Jeli. To access the study area the main road Jeli-Tanah Merah is used. By turning right in T-junction of Gual Ipoh and for second T-junction at Pekan Kursial, the journey continued until entering the village name Kampung Peralla. The intersection to enter of the study area is appeared at the left side of the road. The road for entering the study area is covered by unpaved road which is suitable for motorcycle and Hilux. It took about 2 hours by driving car.

1.2.3 DEMOGRAPHY

The study area is located at the Sokor, Tanah Merah, Kelantan. 13 3400 people is recorded as population in Tanah Merah. Table 1.1 shows the total population from 2010-2014 in Kelantan. Based on **table 1.1**, it shows that total numbers of population in Tanah Merah are increasing from one year to another year. **Table 1.2** shows the population near the study area which involves Kuala Tiga and Kursial baru. It is recorded about 10, 648 in 2014. Although the area was flooded in 2014, the population in both Kuala Tiga and Kursial Baru still increasing by year.

Table 1.1: Total population of Kelantan from 2010-2014 (source: Department of Statistic Malaysia)

Daerah	Tahun				
	2010	**2011**	**2012**	**2013**	**2014**
Bachok	142,100	146,000	149,900	153,800	157,700
Kota Bharu	509,600	522,000	534,500	547,200	560,100
Machang	101,300	103,900	106,400	109,000	111,700
Pasir Mas	212,000	217,300	222,800	228,300	233,800
Pasir Puteh	134,200	137,700	141,100	144,600	148,200
Tanah Merah	133,400	136,700	140,000	143,300	146,700
Tumpat	137,200	177,700	182,200	186,800	191,400
Gua Musang	103,300	106,000	108,800	111,700	114,500
Kuala Krai	120,800	123,700	136,500	129,500	132,400
Jeli	48,000	19,300	50,600	51,900	53,200
KELANTAN	**1,641,900**	**1,690,300**	**1,772,800**	**1,806,100**	**1,849,700**

Table 1.2: Total population in the study area in2014 (source: Rancangan Struktur Negeri Kelantan)

Place	2014
Kuala Tiga	6, 623
Kursial Baru	4, 025
Total	**10, 648**

1.2.4 LANDUSE

About 45% of the land in Kelantan is under state land status, 33% is under reserve land, 21% is used as others function. In districts of Jeli, Kuala Krai and Gua Musan in southern Kelantan, the land is dominantly in 60% is covered by forest. 22% of land in Kelantan is used for agriculture and mostly in alienated land. Urban and mining land in Kelantan is not significant since it covered less than 1% from the land as urban and mining site. From the **table 1.3** the area of land use as forest reserves, agriculture, urban, mining and others can be observes.

Table 1.3: Category of Land Use in Kelantan (source: state Economic Unit Kelantan)

Category	Area (hectare)	percentage
Forest Reserve	894, 271	59.5%
Agriculture	335, 660	22.3%
Urban	4, 967	0.3%
Mining	3, 737	0.3%
Others	263, 565	17.6%
TOTAL	**1, 302, 200**	**100%**

Based on the map, soil use for Tanah Merah district study area is declared as Reserved Forest Sokor Taku, but part of it had been used for agriculture usage and mineral exploration, where there were present of estates nearer the study area which located on flood plain. This is because flood plain is abundant with mineral, that very suitable for vegetation growth. These present of a few small individual rubber plantation along the road.

1.2.5 SOCIAL ECONOMIC

Kelantan economic sector is depending on the agriculture sector and the lower level of industrialization in the State when compare to other developed states. The Gross Domestic Product (GDP) prices of Kelantan are lower that other states in Malaysia. Department of statistic Malaysia came out with the statistic of economic statistic of Kelantan as shown in the **table 1.4** and **table 1.5** show the rate of employment in Kelantan and have been divided into each gender.

Table 1.4: Gross Domestic Product (GDP) and rate of employment in Kelantan from 2013-2016 (source: department of statistic Malaysia)

Gross Domestic Product (GDP)	**2013**	**2014**	**2015**	**2016**
GDP at constant 2010 prices (RM mil.)	18,136	19,053	19,718	20,664
GDP per capita at current prices (RM)	11,284	11,751	12,087	12,812
GDP Growth (%)	3.3	5.1	3.5	4.8
Employment				
Labour Force ('000)	619.8	646.2	676.2	657.8
Employed ('000)	602.7	625.2	652.1	632.9
Unemployed ('000)	17.1	21.0	24.1	24.9
Labour Force Participation Rates, LFPR (%)				
Male	72.6	71.7	74.4	72.3
Female	46.1	48.8	49.5	45.8
Unemployment Rate (%)	2.8	3.3	3.6	3.8

The information in Table 1.5 shows the Gross Domestic Product of Kelantan state in 2010. The main contributor to the GDP is the services sub-sector followed by construction and agriculture sector. Apart from its economic contribution, the agriculture sector is important as it is the second largest employer of labour in Kelantan states. The main agriculture crops are rubber, oil palm, paddy, tobacco, fruits and vegetables. The industrial (manufacturing) sector produces mainly wood based, food based, textile, electrical and non-metallic mineral products.

Table 1.5: GDP by economc sector in 2016 (source: department of statistic Malaysia)

Sector	Growth (constant 2010 prices) %
Agriculture	2.9
Mining & quarrying	12.1
Industrial (manufacturing)	2.1
Construction	29.6
GDP percent	5.0

Based on the observation in the study area shows that almost part of the people in the study area was carried out business activities. A small stall that selling out daily necessities is open by the local people for villagers there. Some of them also open a small restaurant that selling food, drinks and some fruit for the people that passed by. Based on observation too, most of the villagers doing a rubber plantation and some of them also doing some of the logging activities.

1.3 PROBLEM STATEMENT

Based on the previous research by Geology Department of University Malaya (UM) in 2003 on my study area in Ulu Sokor, Tanah Merah, Kelantan, there are limited investigations about biogeochemical study for heavy minerals that carried out. The application of biogeochemical method is one kind of method that rarely used in Malaysia in geological research but several studies have revealed that biogeochemical prospecting is a feasible and effective mineral testimony method for disseminating Au deposition (Kim *et al.*, 2011). Previous study states that this study area has a potential of gold deposition. Hence, this research was carried out to analyse the heavy metal in the area that have high potential of gold depositional area.

In addition, the heavy minerals that were potentially found in research area gives a clue to the probable origin of the parent rocks from which the soil were formed. Thus, the parent rocks will certify the lithologies that were mapped on the geological map. Besides that, high concentration of heavy metal in soil and plant in the study area is related with gold deposition in selected area.

1.4 OBJECTIVES

The aim of this study is to apply the application of biogeochemical method in mapping process. Therefore the following are the objectives for reach the aim of this research:

a) To produce geological map of selected area in Ulu Sokor, Tanah Merah, Kelantan.
b) To analyse element concentration (As, Ag, Fe, Al, Pb, Mn) in soil and plant samples from gold potential area using biogeochemical analysis.
c) To provide the anomaly map that shows the distribution of concentration (As, Ag, Fe, Al, Pb, Mn) within the study area.

1.5 SCOPE OF STUDY

For this research, the study area is covers 5x5 km^2 in Ulu Sokor, Tanah Merah. This research project is focusing on the study of the geology which included the geomorphology, lithology, stratigraphy and structural geology of Ulu Sokor area. So that, some geological sample such as rock sample is taken from the geological mapping. Besides that, the other main focus of this research project is the analysis of heavy metal for gold potential area in the selected area. In this biogeochemical analysis some soil and plant sample is taken and conducting in the laboratory. Ulu Sokor, Tanah Merah is chosen in this research because this area has high potential of gold depositional and located in Central Gold Belt in Peninsula Malaysia.

The purpose of this study is to analyse the potential presence of heavy metals on this study area that have potential for gold deposition. Some scientific method will be follow in conducting this research to get the best result. The concentration of the heavy metals in the sample is determined by using Atomic Absorption Spectroscopy (AAS), Induced Coupled Plasma (ICP) and also X-Ray Fluorescence (XRF). From this method, the result is appear in form of concentration of heavy metal or parts per million (ppm).

1.6 SIGNIFICANCE OF STUDY

This study is important to provide knowledge and information about geology, including the lithology, geomorphology, stratigraphy and structural geology of the research area. By doing the geological mapping on the study area, it enables us to bring out an exact picture of the structure of rock formation together with detailed information such as the geographical condition of the area. Hence, this enhances the information regarding the geological development of the study area. So, this research can be a contributor to the academic sector especially in geological study. It can be a reference t another student in biogeochemistry field. From here, the biogeochemistry knowledge and geological knowledge might be improve and practically used in research.

Geochemical analyses and mapping will show the relation between heavy minerals and deposition of gold. Theoretically, the area that has gold potential deposition area has high deposition of heavy metals because gold is part of heavy metal elements. In addition, the heavy elements that found in research area give a clue of the probable of the parent rocks. Thus, the parents rocks is certified the lithologies that were mapped on the geological map. So that, the anomaly of the valuable metal can be trace by the investigator or geologist through geochemical interpretation according to the element found in plants, soil and mineral in the rocks. It is hoped that the findings from this study can be used as additional knowledge for mineral exploration, especially in mining industry sector in Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is discussed about the literature review of the previous study that had done and also the topic of studies that are related to this chapter. The purpose of the literature review is to justify methodology and collective of the research information as guidance to conduct this research. In the literature review the information is retrieve by reading and searching from books, journals, theories, internet and it is guide in generating the idea on constructing the methodology and workflows. This chapter is cover about the regional geology and tectonic setting, the stratigraphy of the study area, structural geology of the study area, historical geology of the study area and also the research specification topic which is the hypeacumulator plant.

2.2 REGIONAL GEOLOGY AND TECTONIC SETTING OF KELANTAN

According to Khoo and Tan (1983), Peninsular Malaysia is divided into three longitudinal belts, Western Belt, Central Belt and Eastern Belt. Each belt has its own distinctive characteristics and geological development. Besides, Hutchinson (2009) also mentioned that Peninsular Malaysia can be divided in four major tectonic regions which are the Western Stable Shelf, the Main Range Belt, the Central Graben and the Eastern Belt. Peninsular Malaysia is part of the Sunda plates, which is a combination of continental blocks and microcontinent of Sibumasu and Indochina. Both of the blocks continents come from the Northeast of Gondwana but different times.

Kelantan is one of the states of Malaysia and it is located at the north-eastern corner of Peninsular Malaysia (Department of Minerals and Geoscience, 2003). It is neighbouring with Thailand in the north-west. Kelantan shares it boundaries with three others states such as Perak to the west, Pahang to the south and Terengganu to the east. With the area 15,022sq km Kelantan divided it districts into ten administrative. Districts with name Tumpat, Kota Bharu, Pasir Mas, Bachok, Tanah Merah, Machang and Pasir Puteh are located in the northern part of Kelantan and the other remaining three districts of Jeli, Kuala Krai and Gua Musang located at the southern part of the state. **Figure 2.1** shows the geological map of Kelantan.

Peninsular Malaysia is a part of the Eurasian Plate and tectonically located to the north of currently active subduction zones of Sunda arc. Peninsular Malaysia is formed when the Sibumasu Plate and Indochina plate is collide in the Late Triassic age about 240 million years ago. **Figure 2.2** shows the location of Bentong Raub Suture line as accretionary complex and the formation of Central Belt of Peninsular Malaysia. Bentong Raub Suture is composed of a thin irregular strip of continental lithosphere and island arc sequence that developed in front of it. The two blocks merge together along the suture line that called Bentong Raub Suture. A collision structure overprint has generated major N-S or NW-SW trending left slip fault and dilation Riedal and subsidiary shears and numerous splays associated with these fault

(Arrifin, 2012). Bentong Raub Suture line was proposed by Hutchison (2009) as the major tectonic boundary between the western and central belt of Peninsular Malaysia.

Kelantan have four distributions of the rocks which area unconsolidated sediment, extrusive rock or volcanic rock, sedimentary or metasedimentary rock and granite rock. The rock is affected by the weathering process and it is cover approximately 15 022km^2 area of Kelantan State. The most dominant rock in Kelantan is sedimentary and metasedimentary rock that the age is in Ordovician to Cretaceous with occupying the state's north-south central position.the rock can be arrange according their age (Suntharalingam, 2015).

Ulu Sokor gold area is located within the Central Gold Belt in Peninsular Malaysia and in the middle of the state of Kelantan which about 35 km southwest of Tanah Merah. Ulu Sokor this located in the middle of Peninsular Malaysia with covering an area of nearly 70 sq km. According to Goh *et al.* (2006), it is recorded that Ulu Sokor was affected by the volcanic in Permian to Triassic period. This event is resulted the process of composion of volcanic massive sulfide deposit and gold. The gold deposite in Ulu Sokor is up until today. Gold is mainly found in the Central Gold Belt in Peninsula (Hutchison and Tan, 2009). According to Shah (2012), in the division of gold zones in Peninsular Malaysia, Ulu Sokor is in the Third Golden band. The rock lithology here is characterized by rock sequences aged Permian consisting of limestone, phylite, rhyolite and tuff which is part of the series Paleozoic volcanic sedimentary of the Central Peninsula Malaysia. Among the important rivers are involved with gold mining in this area is Sokor River, Liang River, Ketubong River, River Ketil and Sejana River.

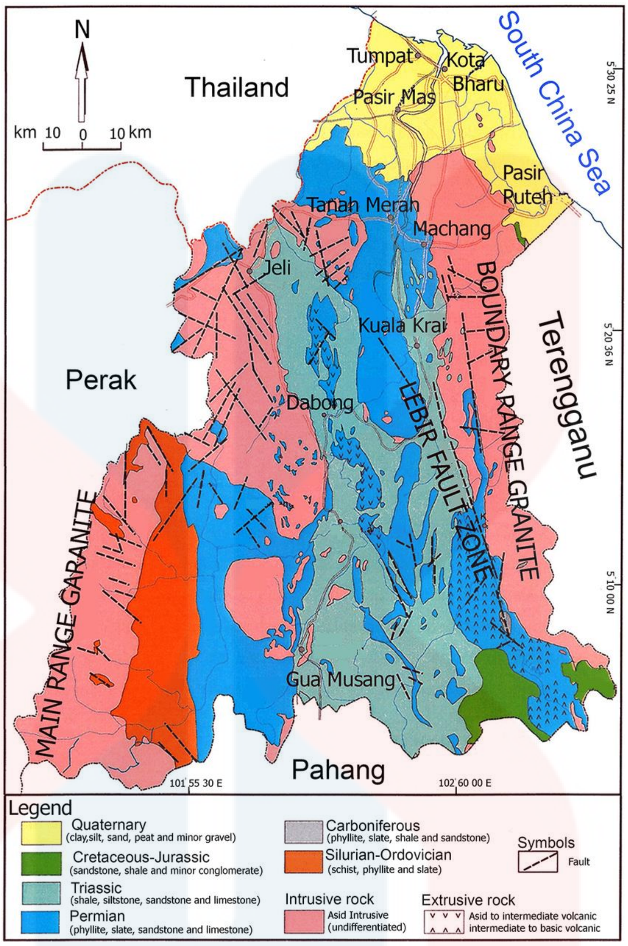


Figure 2.1: Geological Map of Kelantan (Source: Department of Mineral and Geoscience (2003)

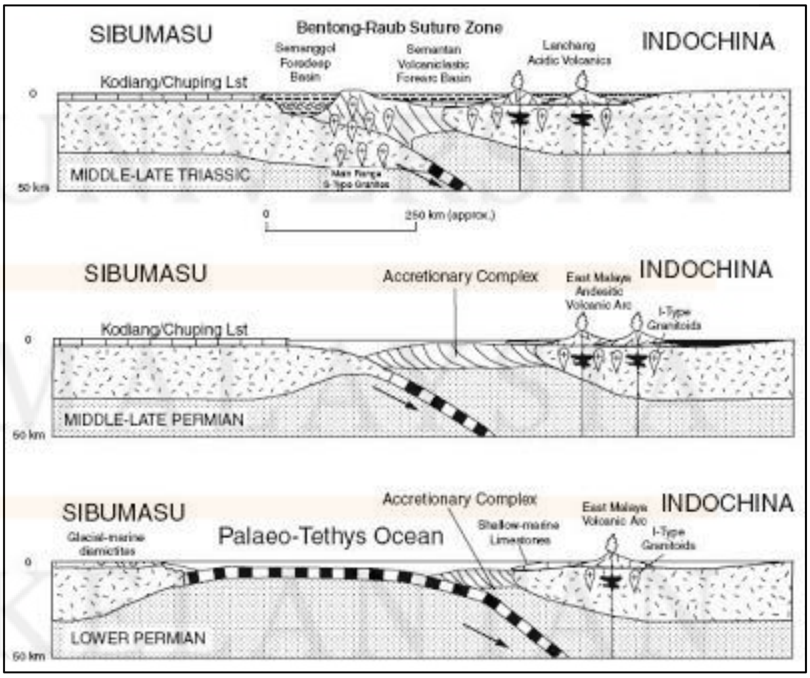


Figure 2.2: Conceptual of Sibumasu Plate and Indochina Plate collision (source: geology Malaysia blogspot, 2009)

2.3 STRATIGRAPHY

The Central Belt that known as Central Gold belts is stretches from Kelantan Johor and form a Main Range. The boundary of this belt is along the Lebir Fault and Dohol Fault. Tanah Merah is located at the central belt in Peninsular Malaysia. In the western part of Central Belt is dominated by Upper Paleozoic stratigraphy which is in Gua Musang that composed of Taku Schist Formation in east Kelantan and in the south Kelantan dominated by Aring Formation and in further south is the Raub Group. Thus, Sokor Tanah Merah is composed by two formations which is Taku Schist Formation and Telong Formation (Hutchison & Tan, 2009).

2.3.1 TAKU SCHIST FORMATION

Taku Schist Formation is the metamorphic rock equivalent to the Mangga formation. MacDonald is the geologist that gave the term Taku Schist to this Formation in (1967) in order to describe a sequence of metamorphic rocks cropping out in central Kelantan Malaysia. It was named after Sungai Taku which is 30 km south of Tanah Merah town where good outcrops were observed (The Malaysia-Thai Working Groups. 2006). In Malaysia, the Taku schist outcrops is in a broad belt in central north Kelantan State which is from the railway line south of Sungai Galas to Tanah Merah in the south eastern part of the Transect area. The western margin trends northward from Sungai Galas, along Sungai Kenik, passing Ulu Sungai Taku and then Sungai Sokor at Kuala Bertam to the Kemahang granite mass. It roughly follow the downstream direction in the eastern part which they follow downstream of Sungai Lebir and Sungai Kelantan.

The lithology of Taku Schist Formation is predominantly by metamorphic rocks. The main composition in Taku Schist Formation is mica schist that composed of quartz-mica schist, mica-garnet schist and quartz-mica-garnet schist. Other rock that can be found in this formation is also amphibolite schist, quartz schist, and carbonate schist. But, the carbonate schist is rarely found and from the observation, amphibolite schist and quartz schist is in the mica schist (Malaysia-Thai Working Group, 2006). According to Hutchison and Tan, (2009) hornfels are found in contact with the granitic body. MacDonald (1967) has stated that the age of Taku Schist formation is in pre-Carboniferous and it is overlain unconformably by Permian to Triassic age of Telong Formation.

2.3.2 TELONG FORMATION

Telong Formation is named after the Sungai Telong. The outcrop sequence in this formation is exposed along the Sungai Telong in Sungai Aring area in Kelantan. Telong Formation is started exposed in Kampung Lengeh and extends eastwards to the Tanah Merah. The lithology are mainly composed of low-grade metasedimentary, metavolcanic and argillite rock. From the previous research by Halim and Hamzah in earliest eighties, this formation is divided into four facies which are namely argillaceous, arenaceous, calcareous and volcanic facies. The lithologies in this formation are schist, hornfels, phyllite and greenish to reddish grey to black slate that belong to argillaceous facies and carbonaceous rock which is pyrite also abundant in this formation. From arenaceous facies it is consist of fine-grained sandstone and metasandstone. Grey marble that exposed in Gua Setir Kelantan is belongs to calcareous facies (The Malaysia-Thailand Working Group, 2006). According to Hamzah & Hamzah (1989) the lithology correlation shows that the formation of Telong Formation is believe from Late Permian to Triassic.

2.4 STRUCTURAL GEOLOGY

There are two main geological structure that recorded found in Ulu Sokor, Tanah Merah which is the fold and fault. According to Hutchison and Tan (2009), the geological structure of Ulu Sokor, Tanah Merah are fold and joint that occured in sedimentary rock. The joint and fracture also can be found on the granitic rock. Fault that dominated in Ulu Sokor, Tanah Merah is dominated by the reverse fault, oblique fault, normal fault, conjugate fault and strike slip fault. The slickenside which the evidence and indicator of the fault also can be seen. **Figure 2.3** shows the map of Ulu Sokor deposit where the structure of fold and fold can be found. These two struture is recorded in the Permian meta-sedimentary rocks. The fold and fault are occur because of the regional compression in the focal belt of Peninsular Malaysia (Li *et al.*,2011). The formation of fault struture that found in meta-sedimentary with age of Pre-Cambrian is one of the evidence of the compression tectonic that happen in Late Triassic of sedimentary rocks.

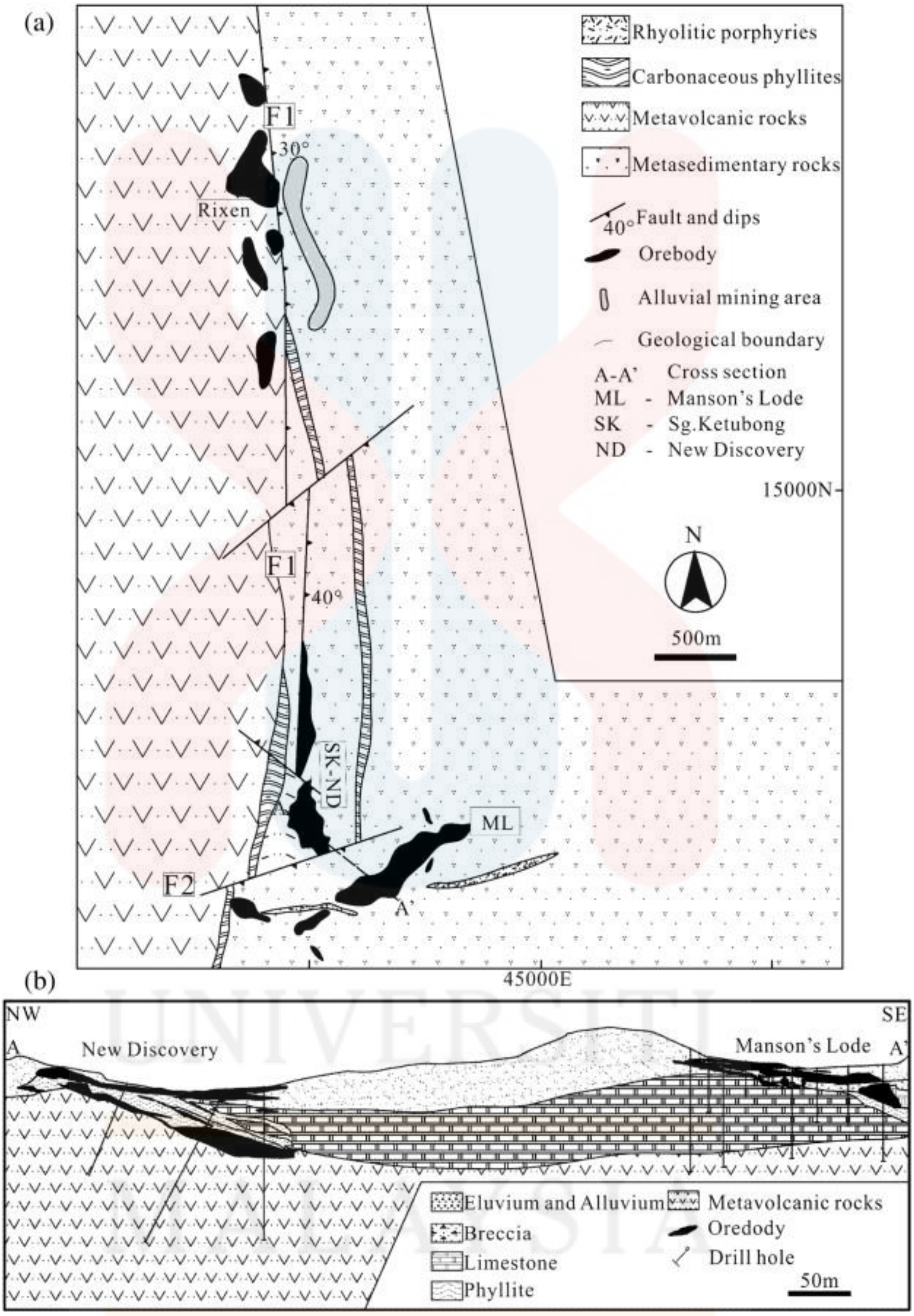


Figure 2.3: Geological map of Ulu Sokor deposit (Li *et al.,* 2014).

2.5 HISTORICAL GEOLOGY

Sibumasu plate and Indochina plate has been collide along Bentong Raub Suture Zone. It is the result from the eastward subduction of the Paleo-Tethys oceanic crust beneath the Indochina Block, which commenced in the Late Permian, evolved in the Early- to Middle Triassic and ended in the Late Triassic (Khin et al., 2014). The Paleo-arc basin is covered in the Central Belt of Peninsular Malaysia. The deposition environment is in deep to shallow marine. The stratigraphy is composed of clastic sediments and limestone, abundant intermediate to felsic volcanics and volcaniclastics that were mainly deposited during the Permian to Triassic and has undergone low-grade metamorphism (Gobbett et al., 1973).

The boundary of the collision between Sibumasu Terrane which is form the Western Belt of Peninsular Malaysia and the Indochina Terrane which form the Central Belt and Eastern Belt are represent by the Bentong Raub Suture line. The remnants of the Devonian–Permian main Paleo-Tethys ocean basin are preserved (Metcalfe, 2013). The Bentong Raub suture are composed of Devonian to Upper Permian oceanic radiolarian cherts, Carboniferous to Permian clasts of ribbon-bedded chert, limestone, sandstone, conglomerate, blocks of turbidite, volcanic and volcaniclastic rocks, and serpentinite (Metcalfe, 2000).

The Belt in Peninsular Malaysia is composed of few ore mineral, for example in Central Belt is known by the Central Gold Belt and in Eastern Belt is known as the Tin Eastern Belt. In Central Gold Belt there are many placing that already exploted. The gold in Gold Central Belt is in hard rock gold mineralization is associated with large quartz grains and parallel swarms of veins that traverse metasedimentary rocks and granite within the breccia and brittle–ductile shear zones (Yeap, 1993). The

Kelantan Gold district is associated with several felsic and intermediate intrusions that were emplaced into the Triassic and Permian meta-sedimentary rocks (MacDonald,1967).

Ulu Sokor Gold deposits are one of the gold area that famous and the largest gold deposits in Peninsular Malaysia. It is located in Central Gold Belt in Peninsular Malaysia. The orebodies deposition in Ulu Sokor is related with the NS and NE striking fractures within fault zones in Permian-Triassic meta-sedimentary and volcanic rocks of the East Malaya Block. The faulting zones is faced the mineralogy and paragenesis episodes that related with hydrothermal activity within the fractures to form the orebodies deposits. **Figure 2.4** shows the geological map of Kelantan with the gold deposits distribution in Kelantan

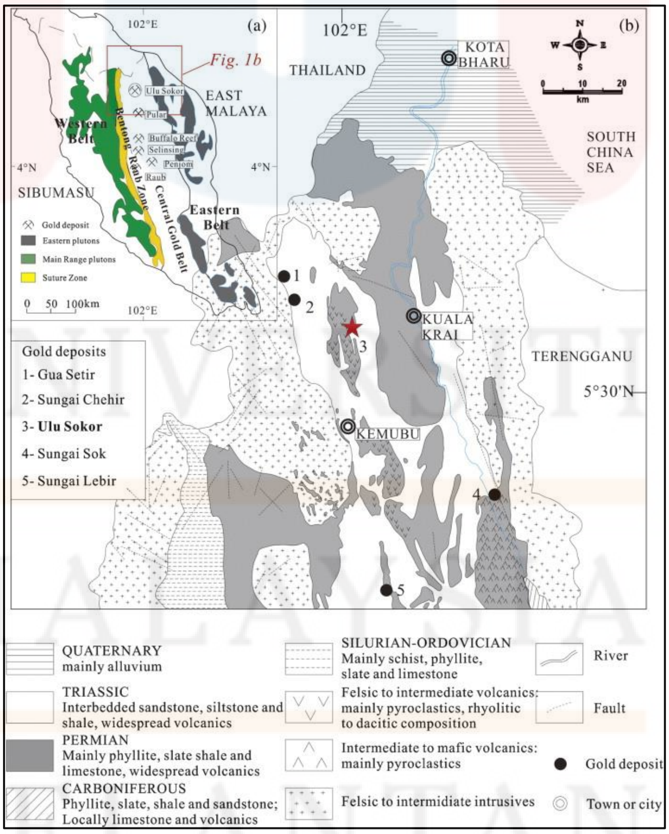


Figure 2.4: Geological map of Kelantan with the gold deposits distribution in Kelantan (source: Li *et. al*,. 2015)

2.6 RESEARCH SPECIFICATION

2.6.1 MINERAL DEPOSITION IN KELANTAN

Peninsular Malaysia is known for their formation which the event of the tectonic collision of Sibumasu plate and Indochina plate. This event is cause the formation of Bentong Raub Suture. Lebir Fault is form due to this event. In this event, Malaysia is divided into three belt which are western belt, eastern belt and central and central belt is rich with the gold deposit. Hutchinson & Tan (2009) also stated that it is probable that the volcano-sedimentary rocks of central and eastern belts in Malaysia and their extensions to the north and south into Thailand and Indonesia contain exhalation iron sulphide or iron oxide rich ores. There are indication some of these may also contain significant amounts of base and precious metals. The main factors that control the spatial variability of heavy minerals are transportation, hydraulic sorting processes, coastal erosion and the embayment morphology.

According to Goh *et. al* (2006), gold mineralization in Kelantan is mainly distributed in the central part of the state, bounded by Stong Igneous Complex and Senting Granite on the west, Kemahang Granite in the north and Boundary Range Granite in the east. Some of the gold formations in Malaysia were recorded are found in Gua Musang. It is range from Penjom area, in Kuala Lipis (Department of Minerals and Geoscience, 2003). The existence of gold derived from mineralization of pyrite, chalcopyrite, galena, arsenopyrite and sphalerite which is generally occurring in rocky zones. Gold mining activity in Malaysia is dominantly in Central

Belt of Peninsular Malaysia starting from highland of Batu Melintang, Jeli to Gunung Ledang, Johor.

In Kelantan, older and younger sedimentary rock also shows insignificant amount of gold mineralisation due to the intrusive rock such as Senting Granite, Stong Igneous Complex and Kemahang Granite that normally carry some gold mineralization in the shear zones. The quartz veins are well-developed along these shear zones and cut through the sheared granitoid. These types of deposits can be seen in Katok Batu Mine and Batu Melintang (Goh *et.al*, 2006). Six types of hydrothermal veins together with volcanogenic massive sulphides and skarn deposits are observed including mesothermal lode gold, quartz vein in shear granite zone, low and high sulphide quartz vein, quartz vein in boundary sedimentary rock and lastly is structurally controlled quartz vein in volcanic-sedimentary rock. Focused on the gold base metal zone which from volcanic exhalative, it is located in the northern part of central Kelantan, from Sungai Senor or Gua Setir gold field to Ulu Sokor gold field (Goh *et. al*, 2006). **Figure 2.5** shows the map of gold deposit in Kelantan.

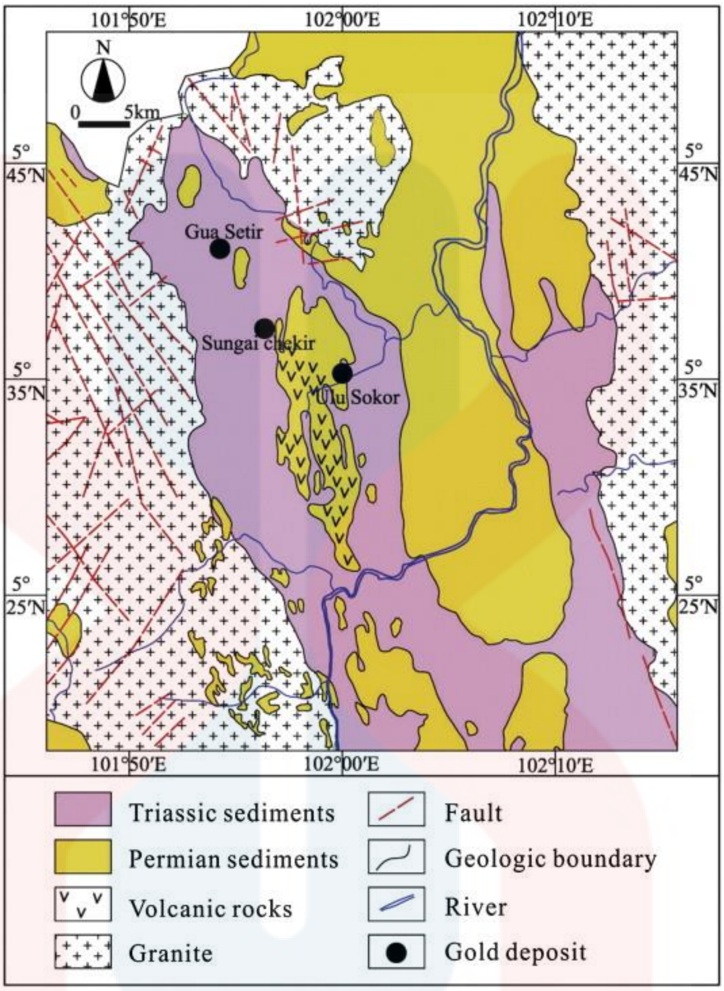


Figure 2.5: Map of gold deposit in Kelantan zone (soure:Heng *et. al*, 2006)

2.6.2 HYPERACCUMULATOR PLANT

In this research, biogeochemistry method is used in order to analyse the heavy metal concentration in the study area. The type of plant that is sampled is hyperaccumulator plant which is plant that able to grow in soil with high concentration of metal and capable to absorbs or extract metals elements as their nutrient. The metals are stored in the plant tissues. Hyperaccumulator plant also known as metallophytes. They are undergoes phythoextraction process in order to extract the heavy metals to their cells. Additionally, a plant which can gather a higher assimilation of metal from the substrate can be a marker for the biogeochemical prospect, especially in distinguishing the secured mineralization targets (McInnes *et al*., 1996).

All soils contain heavy metals. In nonheavy metal soils, the concentrations of Zn, Cu, Pb, Ni, Cd and Cr range between 0.0001 and 0.065%, whereas Mn and Fe can reach 0.002% and 10.0%, respectively (Ernst 1974). According to Kutty *et al,* (2016), one research have been conducted at mines area in Bukit Besi, Selangor and several established criteria were applied to determine the hyperaccumulator plants. The results revealed that *Melastoma malabathricum* and *Pityrogramma calomelanos* are classified as Fe and Al hyperaccumulators, while *Scirpus triqueter, Melastoma malabathricum,* and *Pityrogramma calomelanos* were undoubtedly hyperaccumulator for Cd. This study is conducted to analyse the contamination by metals element in mines area. **Figure 2.6** shows the *Melastoma malabathricum* and *Pityrogramma calomelanos* and *Scirpus triqueter* and **table 2.1** shows the result that obtained from the research in Bukit Besi. From the result it shows that *Melastoma malabathricum* is favour towards Fe and Scirpus triqueter is favour towards Pb.

Figure 2.6: a) *Melastoma malabathricum*, b) *Pityrogramma calomelanos* and c) *Scirpus triqueter,*

Table 2.1: Result from ICP-MS for Bukit Besi study

Plant	Fe (µg/g)	Al (µg/g)	Pb (µg/g)	Cd (µg/g)
Melastoma malabathricum	1388 ± 28.2	48843 ± 0.00	0.65 ± 0.01	0.07 ± 0.00
Pityrogramma calomelanos	1268 ± 40.8	527 ± 21.9	1.17 ± 0.04	0.13 ± 0.01
Scirpus triqueter,	696 ± 13.2	200 ± 3.60	3.95 ± 0.01	0.28 ± 0.00

According to Queralt, (2005) stated that medicine plants such as herbs plants also have been categories as hyperaccumulator plant. In the previous research one laboratory analysis have been conducted to *Taraxacum officinale Weber* and *Eucalyptus globulus Labill* that lives in Spain in order to analyse the concentration of metals in both plant species. The result shows the evidence that both *Taraxacum officinale Weber* and *Eucalyptus globulus Labill* contains heavy metals such as Na, Mg, Al, Ni, P, S, K, Ca and Ti that stored and accumulated in that plant tissues. The research is conducted by using wavelength-dispersive X-Ray Fluorescence (WDXRF) and energy-dispersive X-Ray Fluorescence (EDXRF) to determine the concentration of metal in the plants species and the range and the mean of the element solubility is recorded. **Figure 2.7** shows the *Taraxacum officinale Weber* and *Eucalyptus globulus Labil* and **table 2.2** shows the element concentration in both plants. From the table it shows that *Taraxacum officinale Weber* is good for extraction of Calcium (Ca).

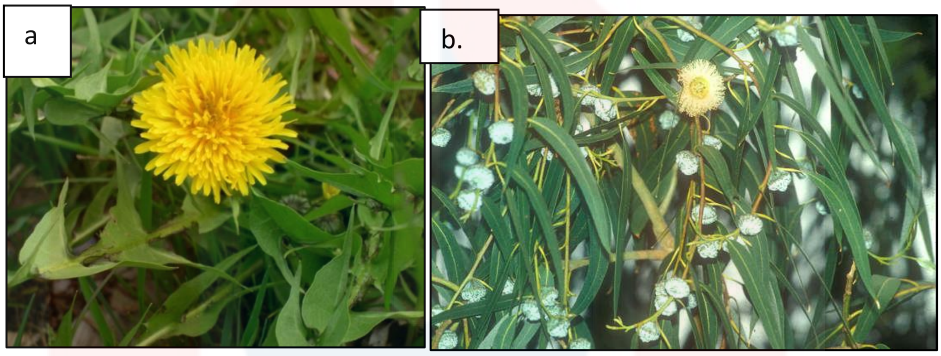


Figure 2.7: a) *Taraxacum officinale Weber* and b) *Eucalyptus globulus Labill*

Table 2.2: Concentration of elements in *Taraxacum officinale Weber* and *Eucalyptus globulus Labill*

Elements	**Na** (mgl^{-1})	**Mg** (mgl^{-1})	**Al** (mgl^{-1})	**Si** (mgl^{-1})	**P** (mgl^{-1})	**Ca** (mgl^{-1})	**Fe** (mgl^{-1})
Taraxacum officinale Weber	63	53	<0.1	3.8	56	134	0.13
Eucalyptus globulus Labill	41	27	<0.1	1.3	12	24	0.06

According to Bothe (2011) said there are four to six metallophytes or hypercumulator plant can survive in an area that contains high concentration of heavy metal in soil. In Central Europe, they can analyse that *Minuartia (Alsine)verna* can carry most of Zinc (Zn) concentration while subspecies *A. maritima ssp. Halleri* are grow on the heavy metal heap in the European plains. From Becker & Dierschke,

(2008) have list the plant that have a potential to be a hyperaccumulator species in a selection of Europe. **Figure 2.8** shows the hyperaccumulator plant that been observe in European plains and **table 2.3** shows it concentration. For zinc violet plant it divided into few colours of petals which is *Viola lutea ssp. Calaminaria* is in yellow colour, *Viola lutea ssp. westfalica* is in blue colour and *viola tricolor* that have three colours on its petal.

Table 2.3: Hyperaccumulator plant observation in Aachean, Germany (source: Ernst, 1982)

Plant species	Zn (ppm)	Pb (ppm)	Cd (ppm)
Thlaspi alpestre ssp. calaminare	159.0	8.21	4.83
Minuartia verna	151.3	6.52	0.65
Armeria maritima ssp. calaminaria	11.28	11.69	1.10
Silene cucubalus var. humilis	40.8	0.29	0.02
Lotus corniculatus	30.4	0.05	0.02
Anthyllis vulneraria	28.8	0.15	0.03
Festuca ovina	28.3	0.97	0.13
Campanula rotundifolia	24.8	4.70	0.98
Thymus serpyllum agg	22.9	3.96	0.33
Cladonia rangifera (podetium) (lichen)	21.4	8.08	0.40
Rumex acetosa	21.4	2.12	0.16
Agrostis tenuis	17.4	0.88	0.10
Achillea millefolium	14.8	1.38	0.02
Euphrasia stricta	14.3	0.94	0.10
Viola lutea ssp. calaminaria	8.9	0.19	0.02
Pimpinella saxifraga	8.2	0.26	0.03

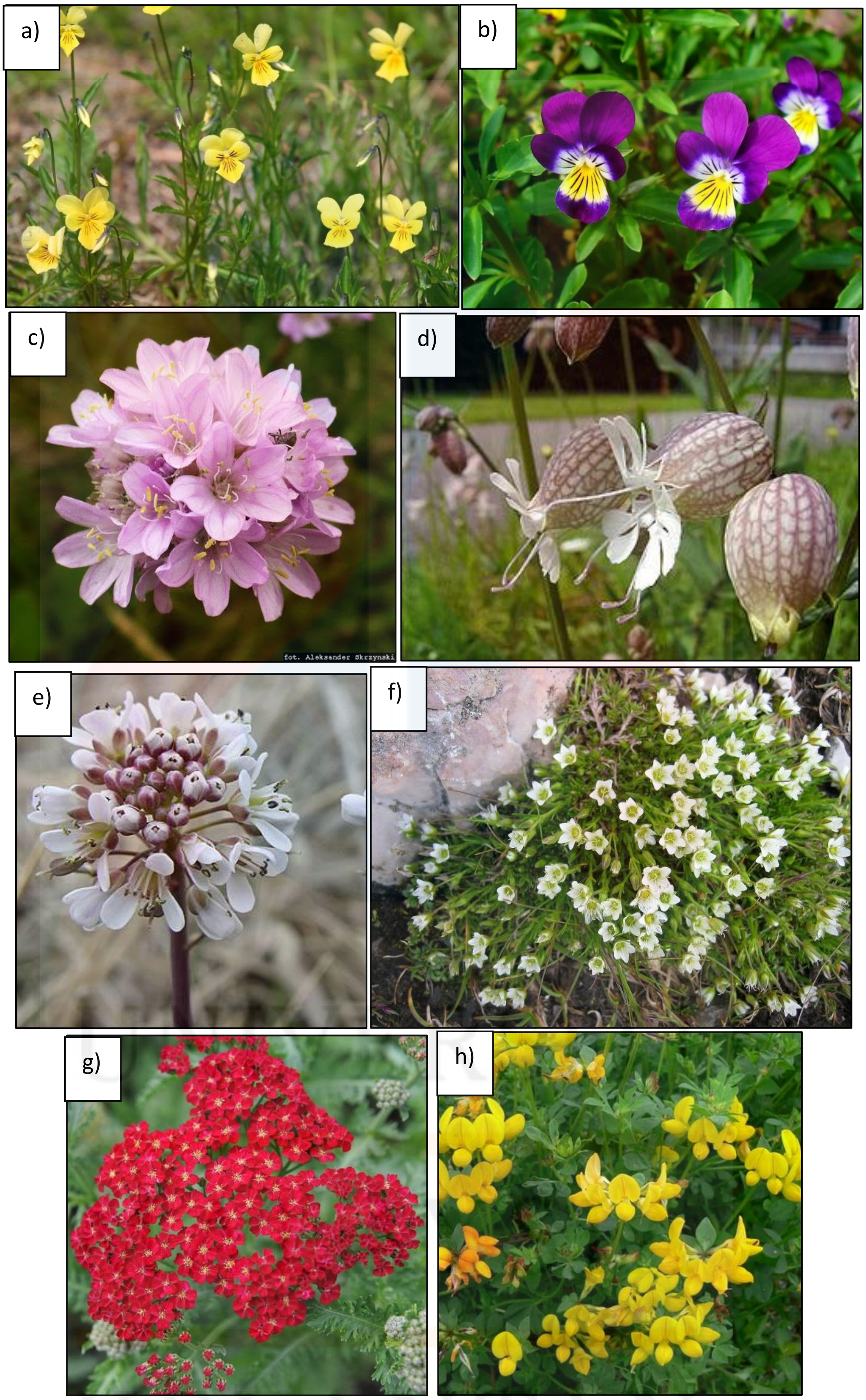


Figure 2.8: *a) Zinc violet (Viola lutea ssp. Calaminaria)* b) *Viola tricolor* c) *Armeria maritima ssp.* d) *Silene cucubalus var. humilis* e) *Thlaspi alpestre sp.* f) *Minuartia verna* g) *Achillea millefolium* h) *Lotus corniculatus*

In Asia the hyperccumulator plant studies shows that the distribution in dominantly in SE Asia, Sabah and also Indonesia. In Sabah, the biogeochemical study has been done for *Marsypopetalum pallidum sp*., *Ptyssiglottis cf.fusca*, and *hydnocarpus calophylla*. All the plant species is to study the present of ion nickel and they used XRF method to determine the concentration of Nickel (Ni). In SE Asia the research aim is to analyse the concentration of Arsenic (As) and the plant species that identified as Arsenic (As) hyperaccumulator are Pityrogramma Calomelanos, Pteris Cretia, Pteris Longifolia, Pteris Umbrossa, Microstegium Ciliatum and Dactylotenium Aegyptom. Most of the method that they used is ICP-MS and XRF method. **Figure 2.9** shows nickel accumulator species in Sabah in the recent study.

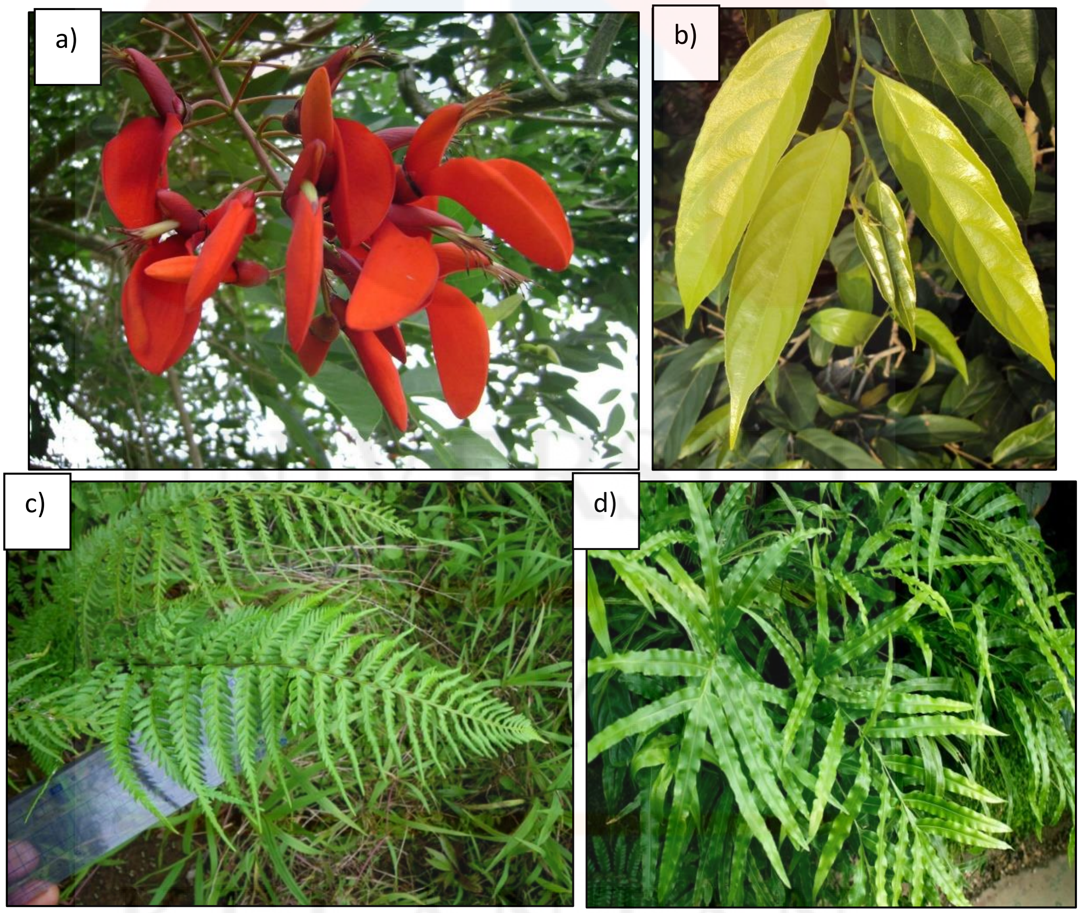


Figure 2.9: a) *Ptyssiglottis cf.fusca* b) *hydnocarpus calophylla* c) *Pityrogramma Calomelanos* d) *Pteris Cretica*

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 INTRODUCTION

This chapter is explaining the tools, materials and method that used in this research. For geological mapping, common geological tools were used such as geological hammer, hydrochloric acid, global positioning system (GPS), hand lens, compass, base map, field book, measuring tape, sample bag and ruler. **Table 3.1** shows the materials that used in this research. The data that have been collected from the field is analysed and some software were used such as Arc Map 10.2 and GeoRose is used for geological mapping. For geochemical analysis, the equipment such as Atomic Absorption Spectroscopy (AAS), Induced Coupled Plasma (ICP) and X-Ray Fluorescence (XRF) is used to analyse the heavy metal concentration in the sample. In the lab work petrographic analysis, sample preparation and sample analysis have been run to retrieve the result. **Figure 3.1** is shows the research flowchart of this research.

This research is including collective of quantitative data and also qualitative data. the quantitative method is used when enough plant sample, rock sample and also soil sample is collected while the qualitative data is collected when the fresh rock sample is collected and only the specific species is collected from the field work.

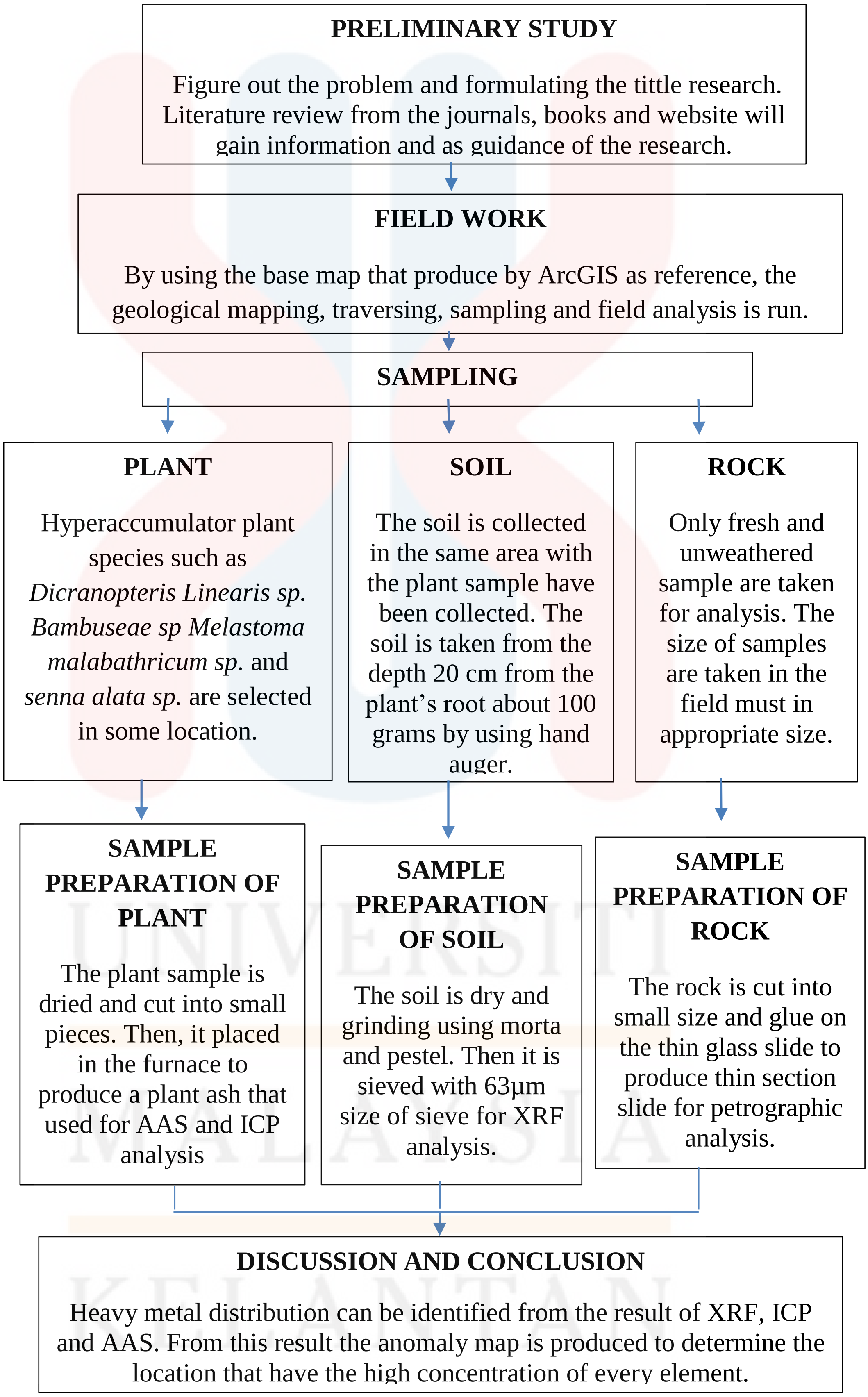
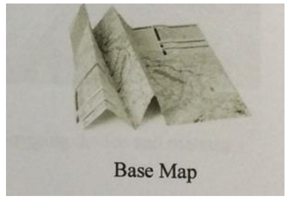


Figure 3.1: Research Flowchart

3.2 MATERIALS AND EQUIPMENTS

Table 3.1: Apparatus that used in the research

 **Geological Hammer** to break the rocks to take the rock sample	 **Compass** To take the bearing and to know direction.	 **Handlens** To observe mineral and fossils.	 **Muffle furnance** To turn plant to ash	 **Geological field book** Write down all the data and information at the field	 **base map** as a refference for geological mapping
 **Geographical Information System** To locate the location	 **Sample Bag** To store the sample.	 **Plant cutter** To cut the plant segment	 **Hand Auger** To collect the soil sample	 **Measuring tape** Measure the length and height of outcrop	 **Hydrochloric acid** To discover carbonate in rock and for stock solution of plant sample preparation

3.3 METHODOLOGY

In this research, the field study has been done in the field. The field study is about to investigate the geological information of the study area. There are two kind of investigation which is geological mapping and geochemical analysis. The steps and methodology in completing this research is recorded as follows:

3.3.1 Preliminary study

The first step that should be carried is identifying the problem. By identifying the problem we are able to construct a tittle for our research. The problem that have been identify in this research is there are lacks of investigation for heavy metal in the study area that have high potential of gold deposit. The step of preliminary study is for retrieve the information of the study area and the survey method. The information is collected by doing some literature review. Literature review can be done by using books, newspaper, journal or website. The strong literature review gives you a strong knowledge in conducting the research. It provides some general view about the study area and knowledge in conducting the biogeochemical analysis more accurate.

3.3.2 Field studies

a. Geological mapping

The precious part that has been done in this research is geological mapping. Geological mapping is one of the field assessments that apply to collect the data of the geological features in the study area. From geological study the information that needed have been gathered the entire make a geological map. Before went to the field, the base map is provided by using ArcGIS software. The base map is used in for mapping of the study area. The lithostratigraphy data, geomorphology observation and other geological features data have been collected during mapping. The important things in the geological mapping are collecting data of the rock units from outcrop and geological structures that found in the study area. Some outcrop is sampled to make some research in the laboratory. The information from the outcrop such as the lithologies, strike and dip, structures, stratigraphy, location, coordinate, picture of the outcrop and the geological features is recorded. In this mapping is also run some traverse such as river traverse and road traverse. From this field work it provides more understanding on the study area. So that, the information for produce geological map of the study area can be retrieve entirely.

Mapping tools for the geological mapping is used for the geological mapping. As the study area is a reserve forest there were a few limitations for field work such as of human, weather, geography, flora and also fauna. The weather limitation such as raining will limit the researcher fieldwork as it is very dangerous because the study area is covered by unpaved rood and also thick forest. It is also limitation from the side of geography, flora, and fauna. The steep slope and hilly area are the challenge for run the geological mapping. The thick forest that the place where the wild animal live is also the limitation for this research.

b. Sampling

Sampling is one of the vital parts in the geological mapping to gain the information or data. The samples were prepared for some laboratory analysis le. In this research the sample is included rock samples, plants samples and also soil samples. The methods of sampling are mention as follow.

- **Rock sampling**

The rock or outcrop that found in the study area is sampled by using geological hammer for igneous and metamorphic rock while for sedimentary rocks chisel hammer is used. The fresh and unweathered sample is taken for analysis. It is important to avoid taking the high weathered sample because it can give problems to gain the result.

The rock samples are a representative of certain outcrop that can give direct information of the lithologies. Hammering is also done by using goggles in order to prevent rock chip from damaging the eyes. The sampled rock is put in the plastic sample. The sampling locality data such as longitude, latitude and station number is marked on the plastic bag.

- **Soil sampling**

The soil is collected in the same area with the plant sample have been collected. The soil is taken from the depth 20 cm from the plant's root about 100 grams by using hand auger. The soil sample is put into sample bag and dries by using oven. The soil sample undergoes laboratory analysis by using XRF machine to analyse the heavy metal concentration in the samples.

- **Plant sampling**

A specific plant form hyperaccumulator plant such as *Dicranopteris Linearis sp. Bambuseae sp Melastoma malabathricum sp.* and *senna alata sp* are chosen after analyse the plant species in the study area. The plant species is sampled by using stratified sampling method. Stratified sampling method is one of random sampling method which is recommended for the research that runs in a large study area. The plants that have similar height are chosen for sampling. Paper is used to make sure that root, leaves and stems of the plant is in good condition before undergoes laboratory analysis. **Figure 3.2** shows the samples that have been taken.

Figure 3.2: a) Rock sample that has been collected b) Soil sample that have been collected c) Plant sample that have been collected.

3.3.3 Laboratory studies

a. Thin section preparation

Thin section was used for this study to gain study the lithology and the rock unit in the study area. It is a proof for the lithology of geological map and to identify the formation of the lithologies. Petrographic thin sections have been in use for more than 150 years (Vernon, 2004) and as a fundamental to the study of rock samples using the petrographic microscope. Thin section is the microscopic examination is to identify the minerals, their structural aspect such as cleavage, fracture, mineral zoning and rock textures.

The thin section step is started by cut the rock into the suitable size. Then, it is well-pollished and very thin rock slide bonded to a glass slide with epoxy. Typical thin section slides are 26x46 mm. They are sometimes covered by a cover slip attached to the rock with epoxy for protecting the rock slice (Perkins & Henke, 2003). Firstly, the rock sample is cutted into the tablet with a size 26mm wide x 46mm long x 5mm thick by using Diamond blade before grinding the tablet to remove any saw or mire cutter marks (Paulsen *et al*, 2013). Surface of interest was grinded to get smooth surface and then was cleaned using water before left on the hot plate to dry. Next, the tablets are cover by the glass slide. The epoxy solution is applied after the rock sample dried and it is left until the rock sample is well stick to the glass slide. The function of the epoxy solution is to glue the rock with the glass slide. It is important to remove trapped air inside the rock pores.

Next, section was grinded using diamond bit grinding machine to produce smooth flat surface. In this step, it is important to make sure that all the air bubbles is remove after the rock is transfer from the hot plate and cement glass slide is mount on the surface of interest. Then, cooled rock section was trimmed using lead grinder with corbonrandum powder and the specimen is ready to observe under the microscope. **Figure 3.3** shows the procedure in thin section preparation and **figure 3.4** shows the thin section slide that have been prepared.

Figure 3.3: steps for thin section preparation (source: Gale *et, al*, 2013)

Figure 3.4: Thin section slide that have been prepared

b. Plant sample preparation

The plant sample is cut into several parts and parts of interest is washed by using the tap water and also rinsed by using deionised water. Then, the plant sample is dried before weighting. The plant sample is placed in the crucible and turn into ash in 24 hours at 550°C by using muffle furnace. It then cooled to the room temperature. Next, 5ml of 20% hydrochloric acid (HCl) is mixed with the 1 gram plant sample for sample digestion and stir by using glass rod. The plant sample is filter in two times. For the second filtering 0.45-micron syringe filter is used to prevent contamination. Then, the root samples were transferred into 50 ml volumetric flask and were diluted until it reaches the calibration mark. Lastly, the sample is transfer into the falcon tube and dilute by using distilled water. Then, 15ml of the stock solution is transfer to 15ml falcon tube. Next, 1.5ml of the stock solution transfer to the 15ml falcon tube and distilled water is added until 15ml. The step is repeated until four dilution of the stock solution is ready and it is ready to analyse by using Atomic Absorption Spectrometer (AAS). **Figure 3.5** is shows the flowchart for plant sample preparation.

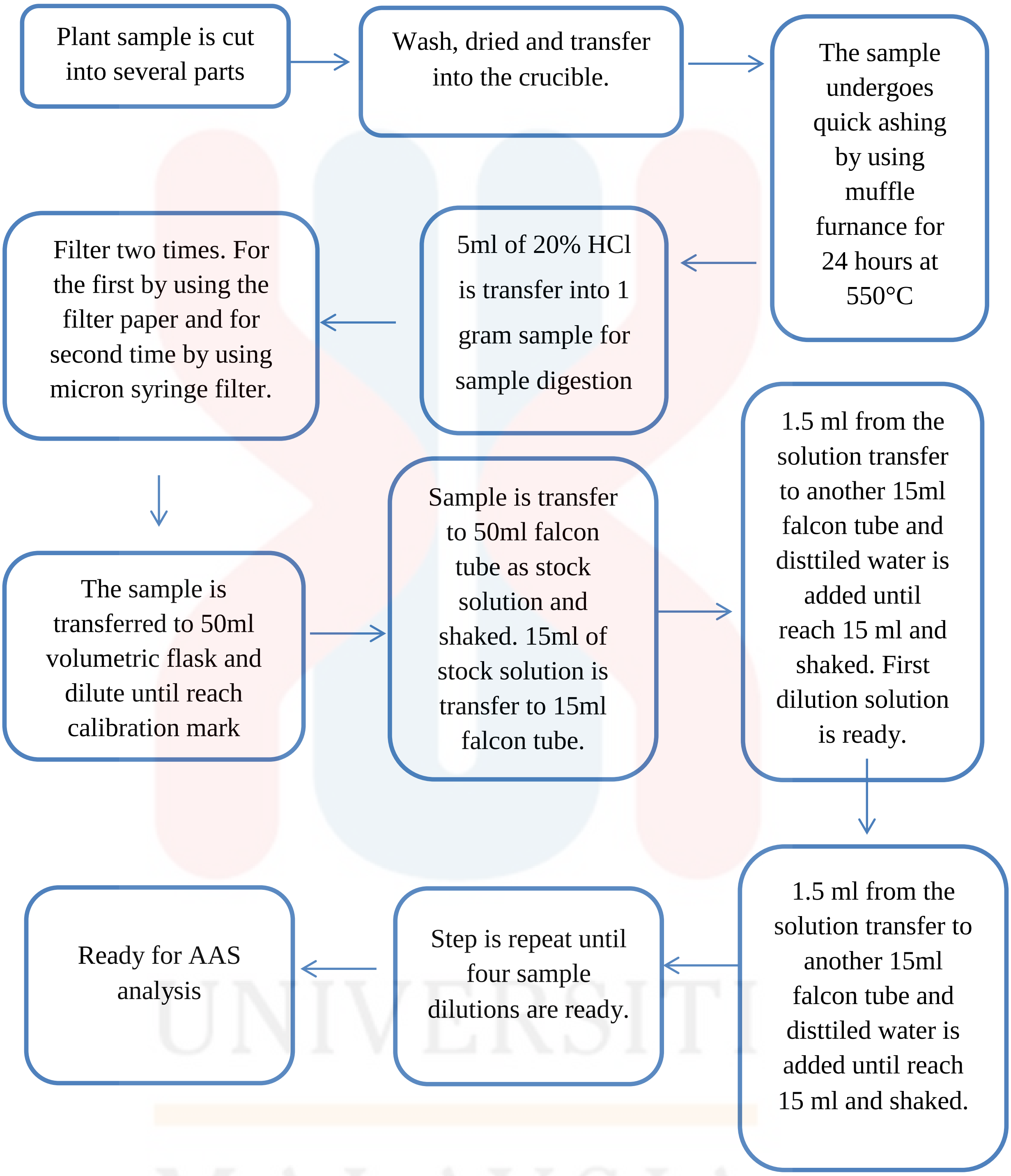


Figure 3.5: Flowchart of plant sample preparation for AAS

c. Soil sample preparation

The soil samples need to be dried in the clean place. Before grind into small aggregate, the sample is sieved through a sieve of 60 µm size and the oversize is ground again until no grains larger than 60 µm are left. Sieves made of nylon are recommended to avoid contamination by metals. A few samples should be taken from the laboratory sample for measurement, to evaluate the homogeneity, which should be better than 5% relative. Lastly, the sample was be pressed into pellet. **Figure 3.6** shows the flowchart for soil preparation. For ICP the soil sample is undergoes drying, crushing and sieving, then it sent for ICP analysis.

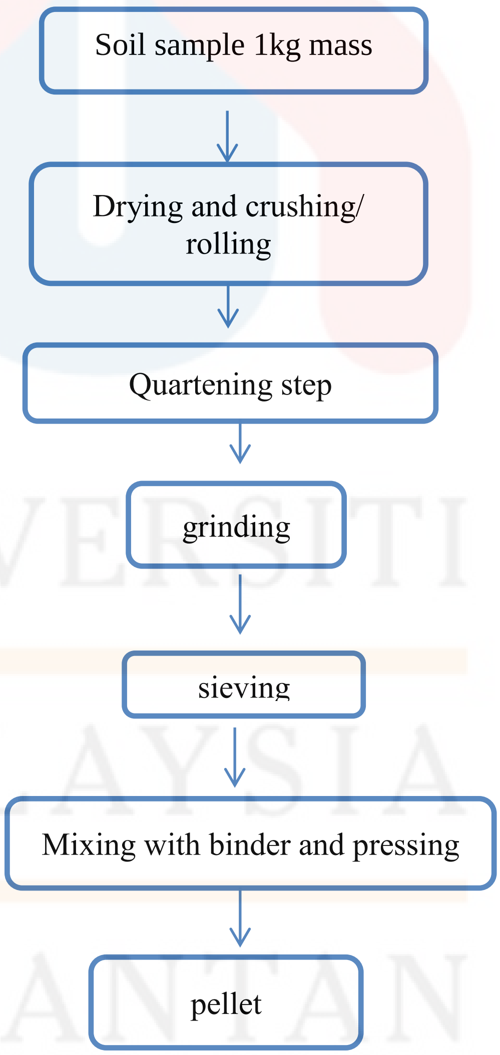


Figure 3.6: Flowchart of soil sample preparation for XRF

3.3.4 Data processing

Data processing is the step where the data is processing to gain the result. Data processing needs some software such as ArcGIS, GeoRose and Stereographic Projection

a. ArcGIS Software

Geologic Information System (ArcGIS) software was used to produce all the map such as geological map, base map, terrain map and also drainage map. Geological map is produce as a reference for the other researcher and for the residence. Base map generally shows the study area consisting road, contour, river, lake and other geomorphology including town or village distribution. The base map is used as a reference for the geological mapping. Geologic map then produced to show the lithology, different types of rock on the study area.

b. GeoRose software

GeoRose software is software that used to analyse the joint data. From thus software we can determine the direction of major force of the area that have applied to the rock units or outcrop. Before used this software the joint data is collected in the field. The joint is measure until hundred frequencies.

c. Stereographic projection

Stereographic projection can be used in software or in online. Stereographic projection used to analyse the geological structure in field such as bedding, fault and folding. From the stereographic projection we can determine the direction tilting of bedding, the type of fold and the direction of the major force that applied to the unit rock or outcrop. Stereographic projection can give the visual in 2-Dimension and 3-Dimension figure on how the geological structure in the real world.

3.3.5 Data Analysis and Interpretation

After the sample is collected in the field, it will be analysed and it is including field data analysis and laboratory analysis. The interpretation of data was done according to the sampling location within the selected study area.

a. Geochemical analysis

For geochemical analysis, the analysis is used Atomic Absorption Spectroscopy (AAS) and X-Ray Fluorescence (XRF). AAS analysis is used in order to identify the concentration of heavy metal presence in the soil sample and XRF is used to determine the concentration of heavy metal in plant. In order to calculate the concentration of the element in parts per million (ppm), the mean result from AAS and XRF is recorded. **Figure 3.7** the Atomic Absorption Spectroscopy (AAS) machine, **figure 3.8** shows X-Ray Fluorescence (XRF) machine and **figure 3.9** shows the Induced Coupled Plasma (ICP).

- **AAS Analysis of plant sample**

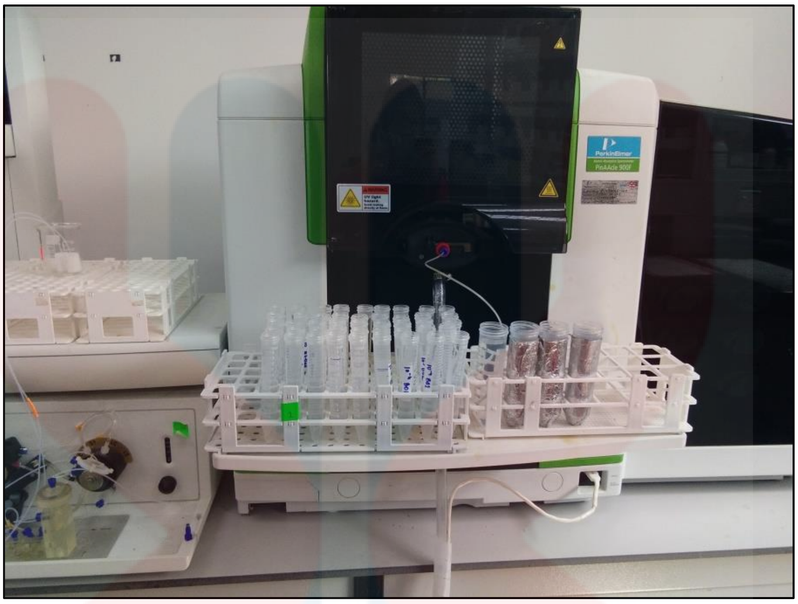


Figure 3.7: Atomic Absorption Spectroscopy (AAS)

Atomic Absorption Spectrometry (AAS) is a technique for measuring quantities of chemical elements present in environmental samples by measuring the absorbed radiation by the chemical element of interest. To analyse the soil sample, AAS method is applied. The reading of the spectra is come out when the sample is excited by the radiation. The ultraviolet or visible light is absorbed by the atoms and transition to the high energy level. A detector measures the wavelengths of light transmitted by the sample, and compares them to the wavelengths which originally passed through the sample. AAS can be used to analyse the concentration of over 62 different metals in a solution

- **XRF analysis of soil sample**

Figure 3.8: X-Ray Fluorescence (XRF)

X-ray fluorescence (XRF) spectrometer is an x-ray instrument used for routine, relatively non-destructive chemical analyses of rocks, minerals, sediments and fluids. The mechanism of XRF is the same with AAS method but the different is the emition of XRF energy is by using X-Ray wavelength radiation. The atoms in the sample absorb X-ray energy by ionizing, ejecting electrons from the lower (usually K and L) energy levels. The ejected electrons are replaced by electrons from an outer, higher energy orbital.

- ICP-MS analysis of plant sample

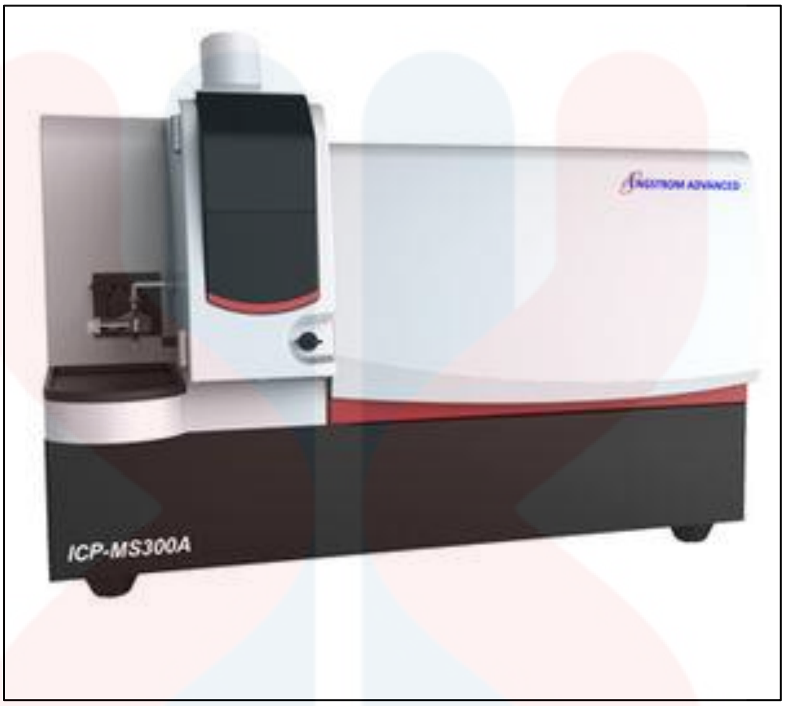


Figure 3.9: Induced Coupled Plasma with mass Spectrometer (ICP-MS)

ICP-MS is being named because of the combination of the high pressure of the ICP source with mass spectrometer. ICP could convert the sample that has been prepared into ions form. The ion will be separated and detected by the spectrometer. The ICP convert the sample to the ions with the help of the argon gas flows inside the ICP and also radio-frequency load coil that could produce the radio-frequency. The mechanism of ICP starts when the electron will strike the argon atoms and form the argon ions. The ion is oscillated in one field and collides with argon atoms and forms argon discharge or plasma. Then, the spectrometer will take over to determine the concentration of the element in the sample.

CHAPTER 4

GENERAL GEOLOGY

4.1 INTRODUCTION

In this chapter, the geology of the study area is discussed. The other aspects of geology which are geomorphology, lithostratigraphy, structural geology and the historical geology of the study area are discussed. Generally all the findings from the field or geological mapping will be explain briefly in order to increase the understanding about the geology of the study area. All the geological information is gathered in order to produce the geological map of the study area. Thus, the structural geology and the historical geology will be interpreted accordingly.

4.1.1 Accessibility

The location of the study area is located at the Southern-East part of Tanah Merah, which is more than 90km from UMK Jeli. To access the study area the main road Jeli-Tanah Merah is used. By turning right in T-junction of Gual Ipoh and for second T-junction at Pekan Kursial, the journey continued until entering the village name Kampung Peralla. The intersection to enter of the study area is appeared at the left side of the road. The road for entering the study area is covered by unpaved road. Unpaved road is also being used by logging, mining and agriculture activity around this area. Hilux is the only good and suitable transportation that have been used to cover up this study area because the unpaved road is too extreme and along the way to cover up the study area there are fully covered with nature of flora. It took about 2 hours by driving car to reach the study area. **Figure 4.1** shows the accessibility of the study area.

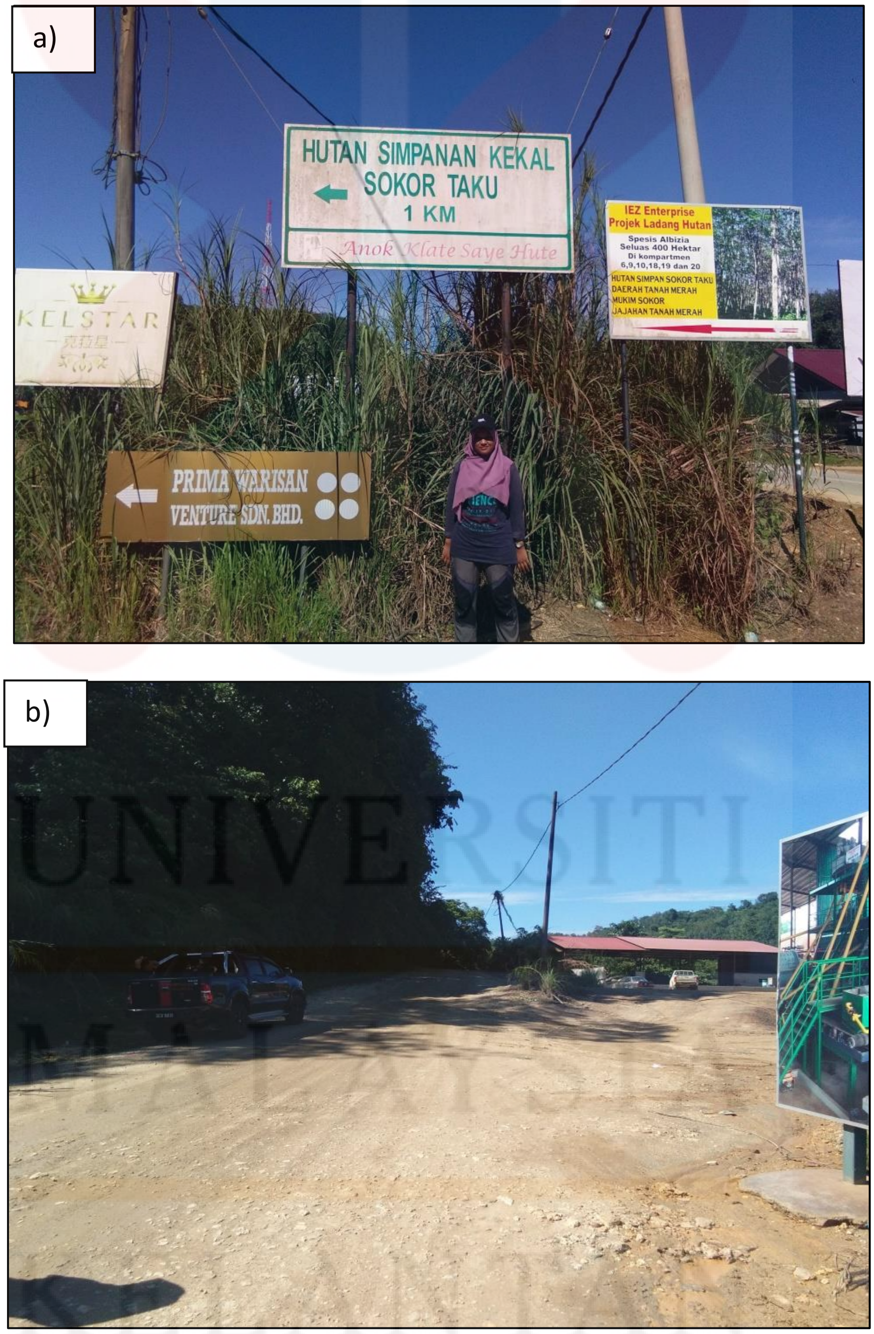


Figure 4.1: a) Entrance road to study area b) Unpaved road of the study area

4.1.2 Settlement

Settlement is the placement of the residence in the study area. Kampung Peralla and Kampung Kuala Tiga are the village that nearby the study area. From the observation in the study area, most of the resident in this area is live in own land and have agriculture occupation. Most of them are a rubber tapper on their own rubber plantation. Some of them also work in mining area in considering that the area is higher on gold deposit. This area of the study area is quite isolated. The entrance of the study area from the junction is covered by the rubber scrub. In addition, most of the area is also covered by full of forest, valuable trees for logging activity and the forest is suitable for habitats such as elephants

4.1.3 Forestry

As a reserve forest, Sokor is 80% is covered by forest. This forest has been authorized as reserved forest by the government due to the flora and fauna, ecological and geomorphological value. Because of the thick forest, some area has been created as a logging area. Some of the area should be run the logging process to open a mining area. 10% of the forest also covered by the bamboo there and this area is the area that has the large population of elephant. Another 10% of the area is a logging and mining area. In the study area, the logging and mining area is take place in western part of the study area. **Figure 4.2** shows the vegetation map of the study area.

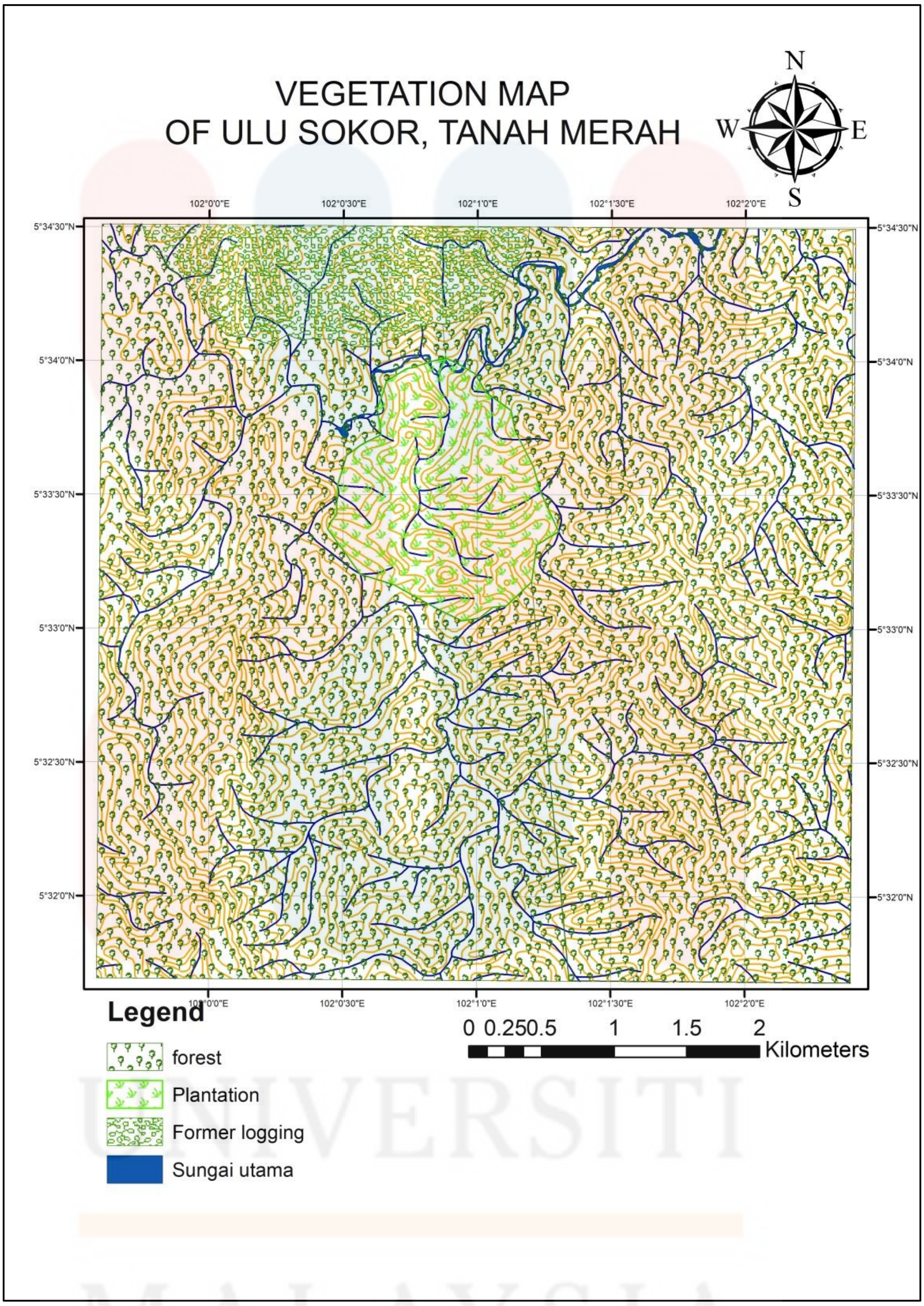


Figure 4.2: Vegetation map of study area

4.1.4 Traverse and observation

In order to fulfil the objective of the research, mapping and field observation have been conducted. The mapping and field observation is one of the requirement that should be run in this study in order to study the lithology, geomorphology, and the landform of the study area.

In this traversing, some station or checkpoint have been recorded to collect the data. Some of the outcrop samples have been sampling in order to identify the lithology and the mineral content of the study area accurately. The data from the field also have been recorded such as the data of the strike and dip, the structure of the outcrop and the geological condition of the study area.

The outcrop that have been taken from the field will be run the laboratory analysis such as a thin section to analyse the mineral content and also the microscopic structure that cannot be analysed by naked eye. By identifying the mineral content from microscopic analysis the type of rock can be identified exactly and the study about the formation and also the history of the study area can be related to the discovery. **Figure 4.3** shows the traverse map and the station or location of the sampling.

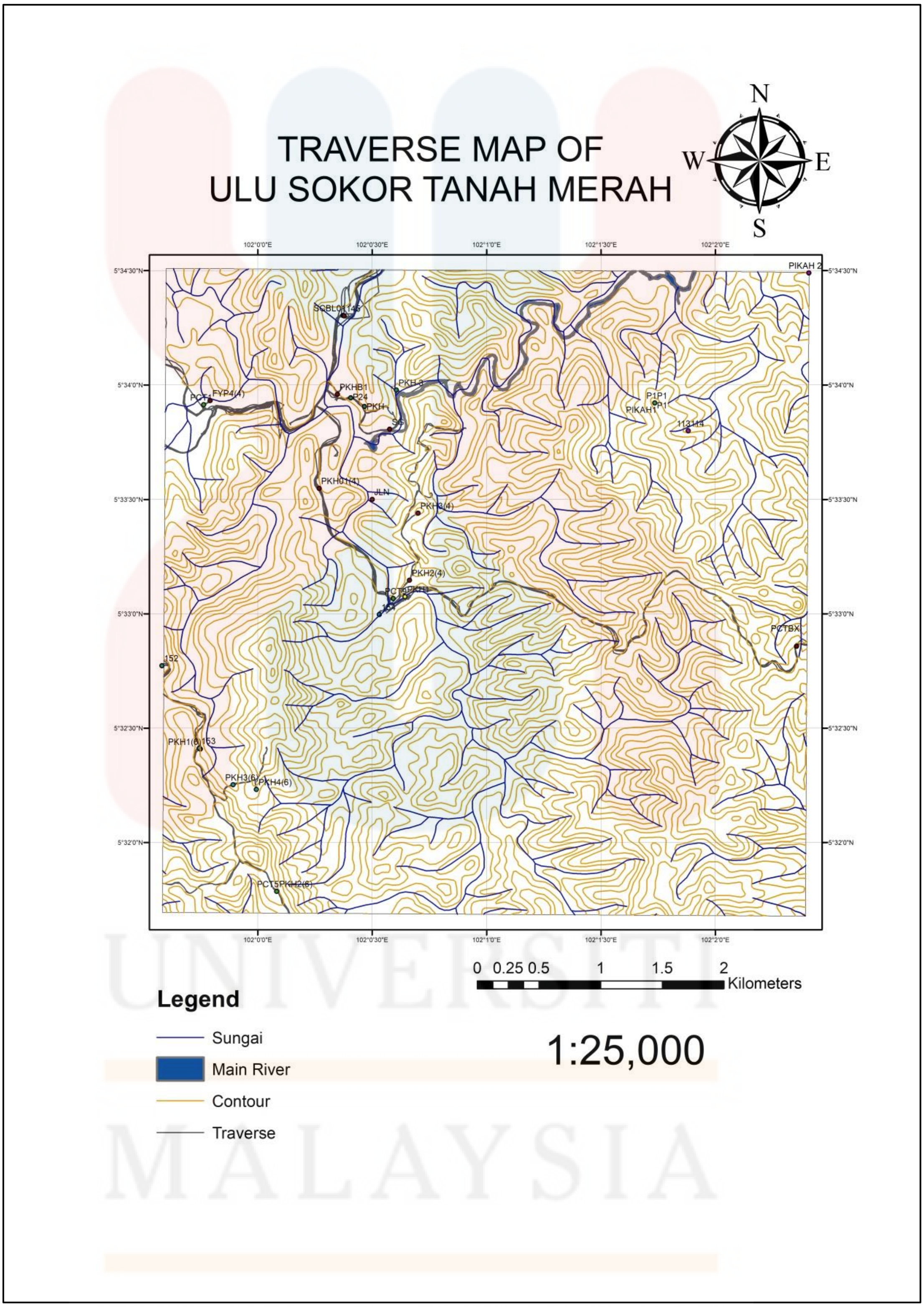


Figure 4.3: Traverse Map of The study area

4.2 Geomorphology

Geomorphology is the one of the geological aspect. In the geomorphology it is about to study the characteristics, origin, and evolution of landforms. It also includes the processes that create the landform. In this sub-topic it is discuss the topography, drainage pattern, and weathering. All of this three aspect giving the influence in land forming process. From the study of geomorphology during the fieldwork it shows that from the type of landform we can be identified and understand the geomorphologic processes that formed the earth surface from the past event.

4.2.1 Geomorphologic classification

Geomorphic features from the field can be describes in two term which are from the topography and also the landform of the study area. The landform is generally related with the topographic features. This is because both features are depends on the elevation of the area. Digital Elevation Model (DEM) is used and it is important to representing the landform with the position and elevation of its natural and manmade features on a map such as contour lines. The contour line values on the map represent the exact elevation of the area. Higher the value of the contour line in means that the stepper the area in the real world.

Hutchison and Tan (2009) stated that topographic classification can be divided into five units namely low lying, rolling, undulating, hilly and mountainous based on the mean elevation. From the contour line pattern and elevation of the area the type of topographic can be identified. **Table 4.1** shows the topographic unit classification and the mean elevation from the study area.

Table 4.1: Topographic unit classification (sources; Hutchison and Tan, 2009)

Class	**Topographic Units**	**Mean Elevation (above sea level)**
1.	Low Lying	<15
2.	Rolling	16-30
3.	Undulating	31-75
4.	Hilly	76-300
5.	Mountainous	>300

Based on the base map of the study area, it shows that the study area is dominated by hilly topographic. Some of the area in South-East area is contained by mountains topographic which is the highest elevation is 360m. The lowest elevation is in northern part which is the elevation is 60m.

Landform is also one of the features that can control the geomorphology of the area. Landform can be defined as a universal feature that formed the solid surface of the earth. The landform is created through processes by faulting that cause by the movement of the tectonic plates. When faulting happen, the tectonic that involve will go slightly upward and cause the erosion. **Figure 4.4** shows the landform of the study area and **figure 4.5** shows topographic map of the study area.

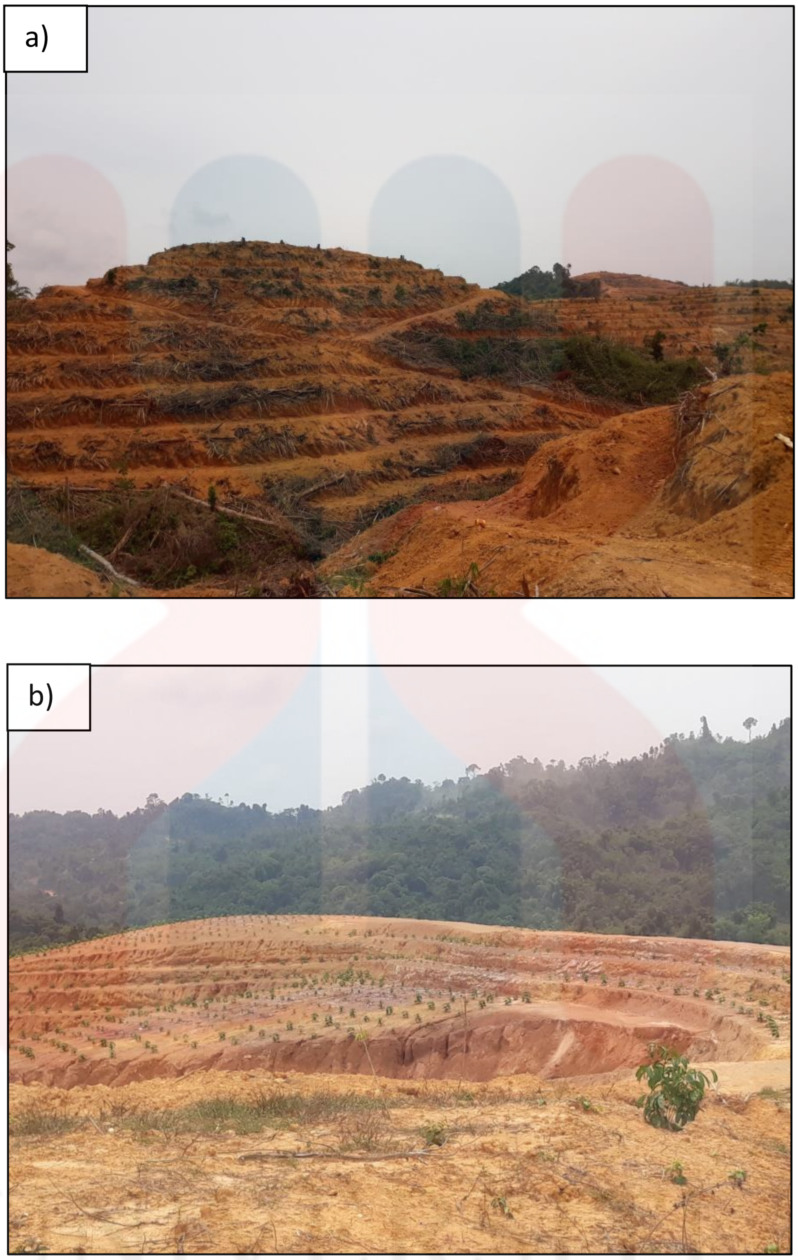


Figure 4.4: a) hilly topography in NW area (logging area)

b) hilly topography in centre area (plantation area)

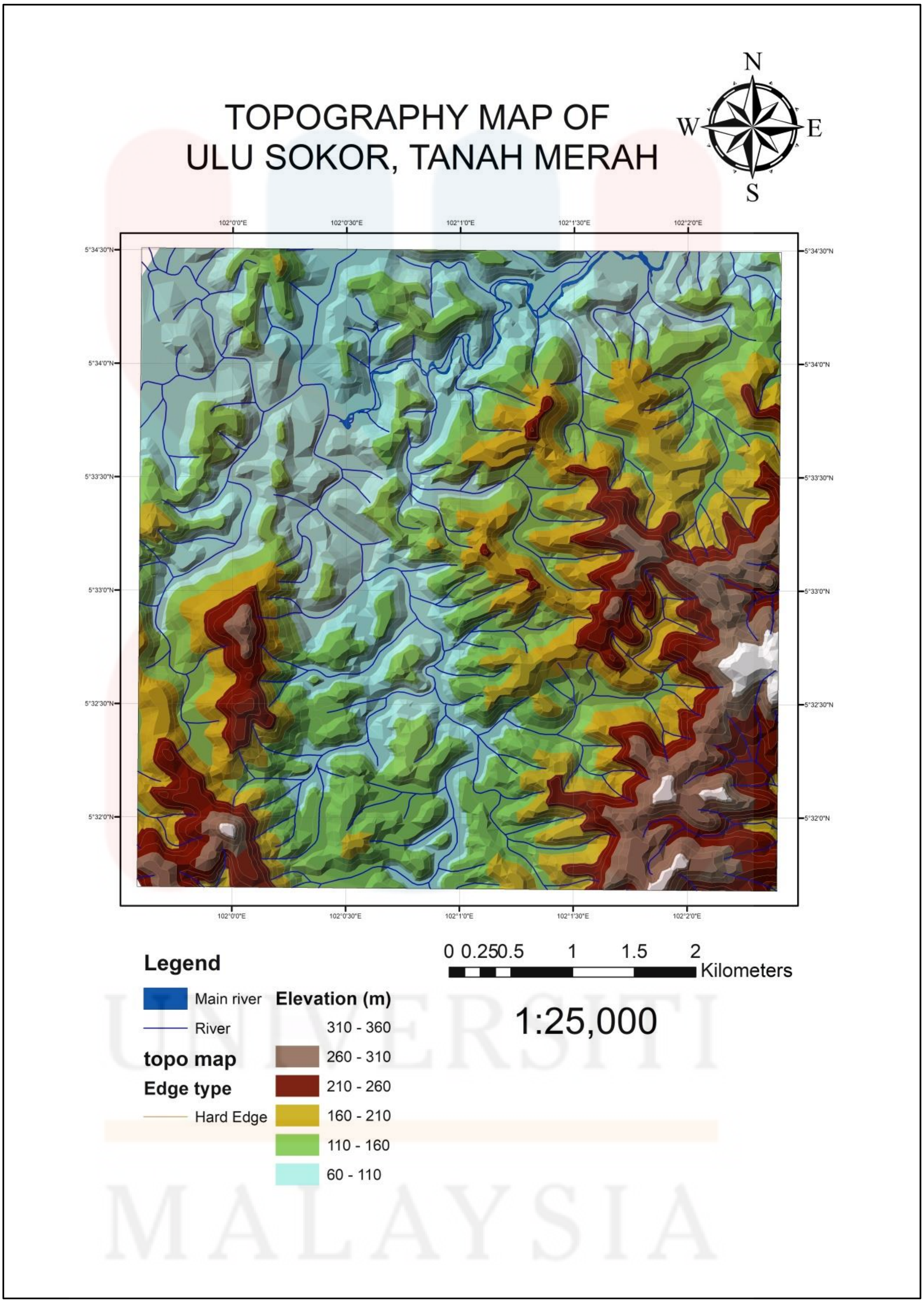


Figure 4.5: topography map of study area

4.2.2 Weathering

Weathering is the proses of disintegration of rock, soil and mineral. Weathering process has the relationship between atmosphere, hydrosphere, lithosphere and also biosphere. The rock that have low resistance can easily weathered which is the process come from the erosion and transportation of the losses particle from the rock after being weathered. The transportation process needs the agents which area water, wind and ice. Time, climate, exposure area, particle properties and mineral composition are the factors that can affect the rate of weathering.

Weathering is one of the factors that lead to the changes of the landforms and it is relating with the geomorphology of the study area. The weathering process and erosion is the process that is in the circle of the rock cycle that could give the natural and origin of the landform. This process is undergoes during geomorphology event.

In Ulu Sokor, due to the logging activities, the rock body is highly exposed and increase the rate of the weathering. Other factor that contributes the weathering process in the study area is the climate which is the climate in Peninsular Malaysia is in tropical climate. It is one factor that could boost the weathering process due to the amount of rainfall, humidity and temperature. From the observation in the field work, the physical weathering and biological weathering could be seen in the study area.

Physical weathering is the process of breakdown of the rock particle without any changes in the chemical characteristics. In physical process, the process could be happened in the way of pressure release, abrasion, frost wedging, hydraulic action and thermal expansion. The weathering agents such as moisture or frost, temperature and pressure play as important factors that contribute for physical weathering. **Figure 4.6** shows physical erosion caused by water flow. Strong erosion also can cause a landslide. The rate of erosion will increase of the rate of weathering is increase. So, from the weathering process, mass movement or landslides might be happen due to the physical erosion. **Figure 4.7** shows the mass movement that happen due to the erosion and weathering.

Figure 4.6: Physical erosion caused by water flow

For biological weathering, it is caused because of the process from the living things such as vegetation and animal. The example of biological weathering is including the burrowing animals, root wedging and also production of organic that contain in animals. Plant roots can grow into the rock joints and when it is grow thicker, the cracks is push open and become wider and deeper. Some biological weathering also involves the chemical alteration. For the example, the animal respiration process or organic decay can give the changes of the moisture content in the soil. **Figure 4.8** is shows the penetration of root through the joint or cracks in the rocks body and undergoes biological weathering.

Figure 4.7: Mass movement from physical weathering

Figure 4.8: Roots penetration in rocks in biological weathering

4.2.3 Drainage pattern

Drainage pattern is also one of the geomorphology features. Drainage pattern is the pattern of the water flow and associated with the landform features and topography. The drainage is including the stream, river and lakes in particular drainage basin. Rivers and stream can be classified into few channel patterns such as meandering, braided and straight. The water flow direction for the drainage is flow from the highest elevation to the lowest elevation. The water can flow through the slope, surface of topology and through the hardness and resistivity of the rock. The lowest elevation can be the recharge area.

There are few types of drainage patterns such as dendritic, parallel, trellis, rectangular, angular and contorted. The type of the drainage patterns is shown on the **figure 4.9** above. From the interpretation of the drainage pattern, the lithology, type of rock, recharge area and condition of the study area can be identified. The main river of the study area is Sungai Sokor and the small rivers are Sungai Taba, Sungai Jelitek, Sungai Amang, Sungai Pindak, Sungai Manek, Sungai Lesong, Sungai Ulat Bulu, Sungai Taku and Sungai Kapas.

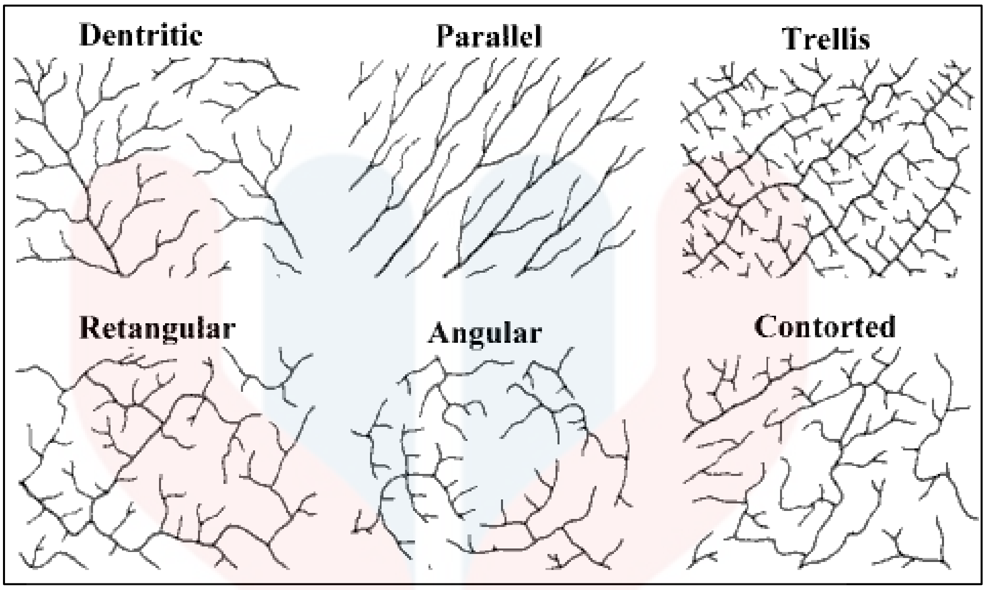


Figure 4.9: Drainage Pattern (source: Ling and Eric, 2013)

In the study area, the type of the drainage pattern is consisting of trellis and dendritic pattern. Dendritic drainage pattern is look like the tree branches and it is the common form that can be seen in this world. It has the irregular branching that connected to the main river. This pattern originated in terrains that covered with uniform rocks types, such as sedimentary rocks, massive igneous or metamorphic rocks. Sungai Taku and Sungai Kapas have the dendritic pattern in the study area.

Then, trellis drainage pattern look similar to their namesake, the common garden trellis. Trellis drainage develops in folded topography. The tributaries in trellis drainage pattern is join with the main river in right angle and eroding the soft rock in the body of rock that consisting alternating hard and soft rock. Trellis drainage pattern usually happen in the place that have the regional slopes and well adjust geological structures. It also developed in a place that have a simple fold which characterised by the alternating of anticline ridges and syncline valleys. **Figure 4.10** is shows the map of the distribution of drainage pattern.

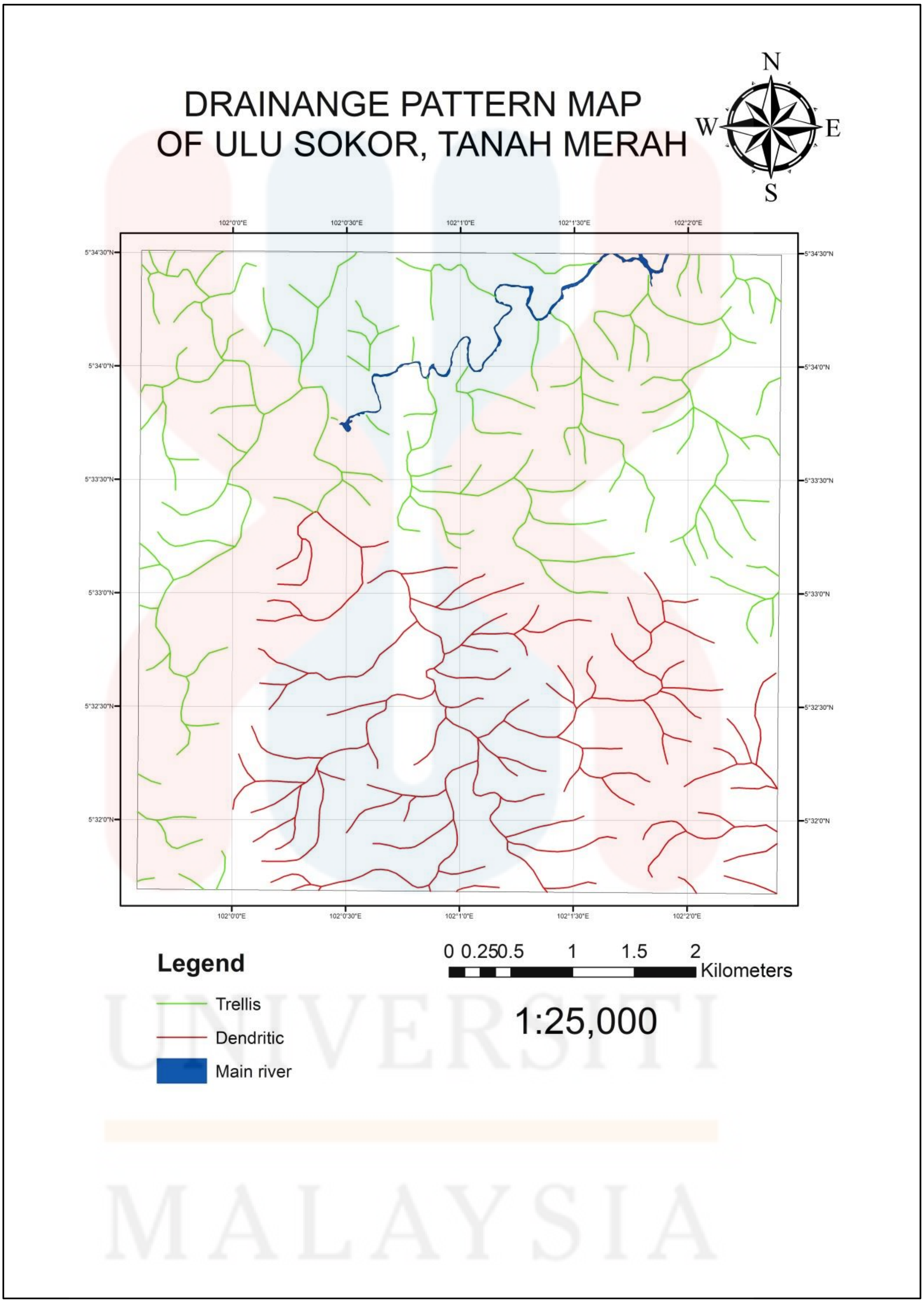


Figure 4.10: Drainage Pattern Map

4.3 Lithostratigraphy

Lithostratigraphy is a sub-discipline of stratigraphy, the geological science associated with the study of strata or rock layers. This specific study is related with the description of rock and their interpretation in terms of a general time scale. The rock unit is being described in this sub topic. It is also be analysed under microscope to identified that name of the rock units. The rock units are identified by its characteristics such as colour, mineral composition, colour, grain size texture, hardness and other information that related. The rocks unit or lithologies that have been recognized in the study area is from Telong Formation which consists of limestone units, slate units and also phyllite units. **Figure 4.11** shows the lithology map of the study area.

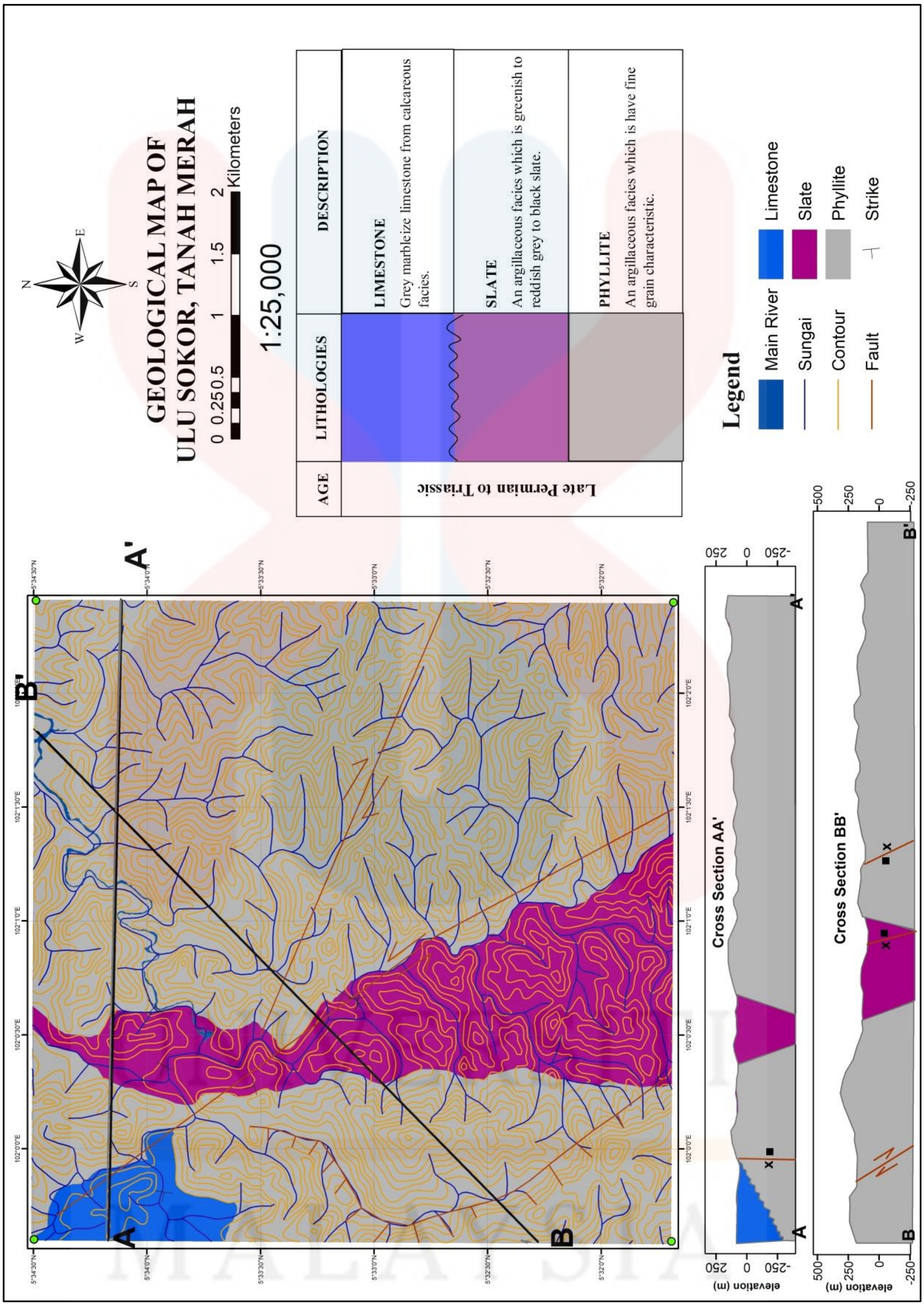


Figure 4.11: Geological Map of Ulu Sokor Tanah Merah

4.3.1 Stratigraphic Position

In the study area it is composed of lithologies that is from Telong Formation, Telong Formation is in the age from Permian to Triassic in Mesozoic era. The lithology that composed under Telong Formation in the study area is Limestone units, slate units and also phyllite units. From the construction of the cross section that shows in the map **figure 4.11**, the arrangement of the stratigraphy or the age of the lithologies can be identify. From the cross section and study in the study area it canc be observe that the youngest lithologies is the limestone units and the older is the phyllite unit. **Table 4.**2 shows the arrangement of the lithologies, the age and the detail description of the lithologies in the study area.

Table 4.2: Stratigraphic column of the study area

AGE	LITHOLOGIES	DESCRIPTION
Late Permian to Triassic		**LIMESTONE** Grey marbleize limestone from calcareous facies.
		SLATE An argillaceous facies which is greenish to reddish grey to black slate.
		PHYLLITE An argillaceous facies which is have fine grain characteristic.

4.3.2 Unit Explanation

a) Phyllite unit

Phyllite is the oldest unit in the study area. This phyllite has cover as the largest unit. It is cover over 70 percent of the box by phyllite unit. Phyllite in the study area is under Telong Formation. It is composed of argillaceous facies which is the texture of phyllite is fine grain size. For the argillaceous characteristics, this phyllite unit composed of some clay mineral as a composition of the rock. Phyllite is one of metamorphic rock and it is form due to the high pressure and temperature that applied.

In the study area, there are two type of phyllite has been found which is the green, grey and red phyllite. Both phyllite has different in colour because of the composition and mineral content in the rock unit. The red colour phyllite is formed due to the weathering process. Weather and climate are causing the weathering process of phyllite. The phyllite undergoes oxidation process and makes them change in colour to red. For the phyllite that has green colour is because of the composition mineral in the rock. For grey phyllite it because of the outcrop not highly exposed and the weathering process is medium. That did not cause the oxidation process to happen. Both grey and red phyllite has been sampled in both location N05°33’58.8’’, E102°00’36.5’’ and N05°33’32.9’’, E102°00’16.1’’. **Figure 4.12, figure 4.13** and **figure 4.14** shows the outcrop and hand specimen of phyllite.

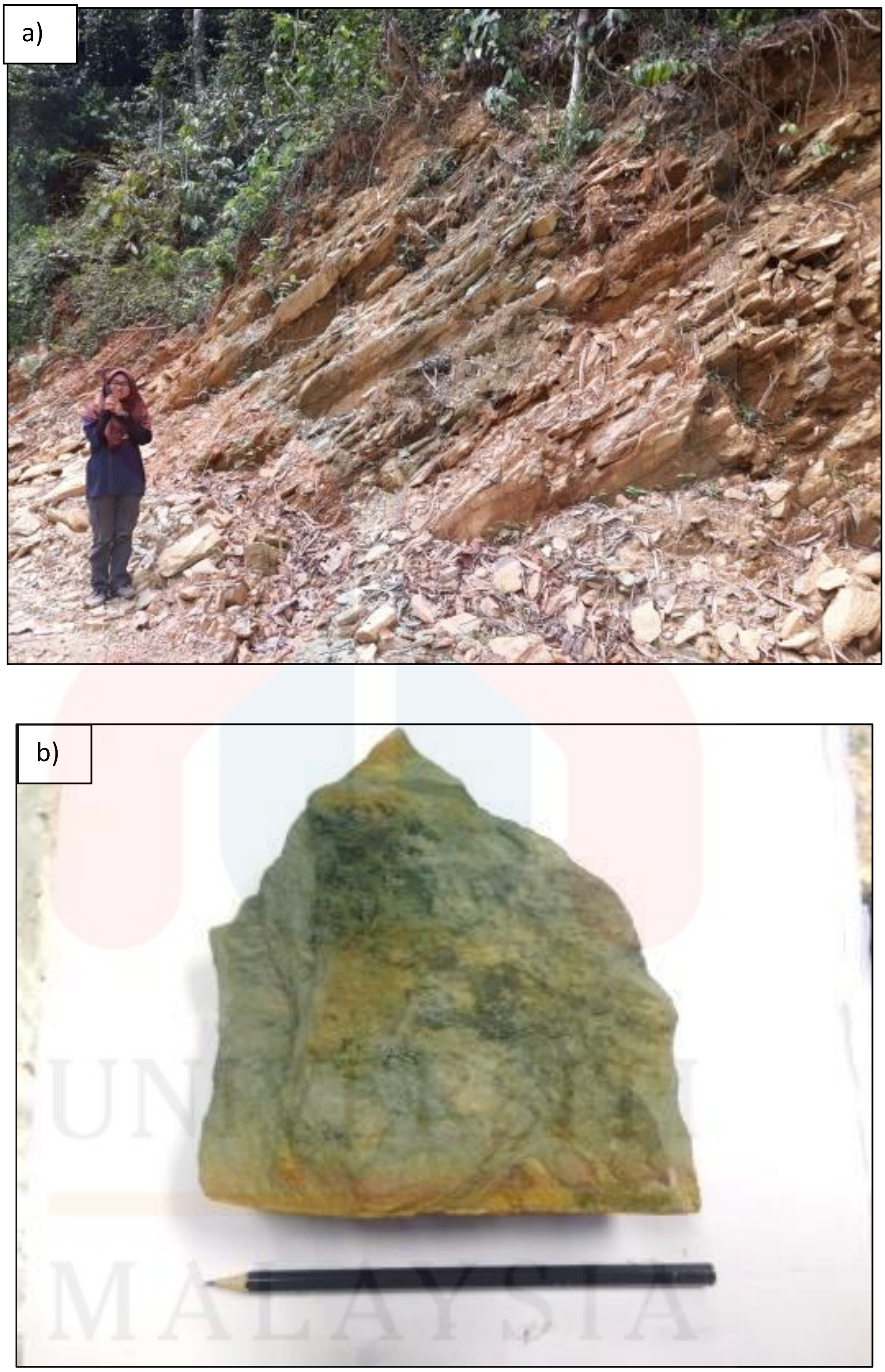


Figure 4.12: a) outcrop of green phyllite b) hand specimen of green phyllite

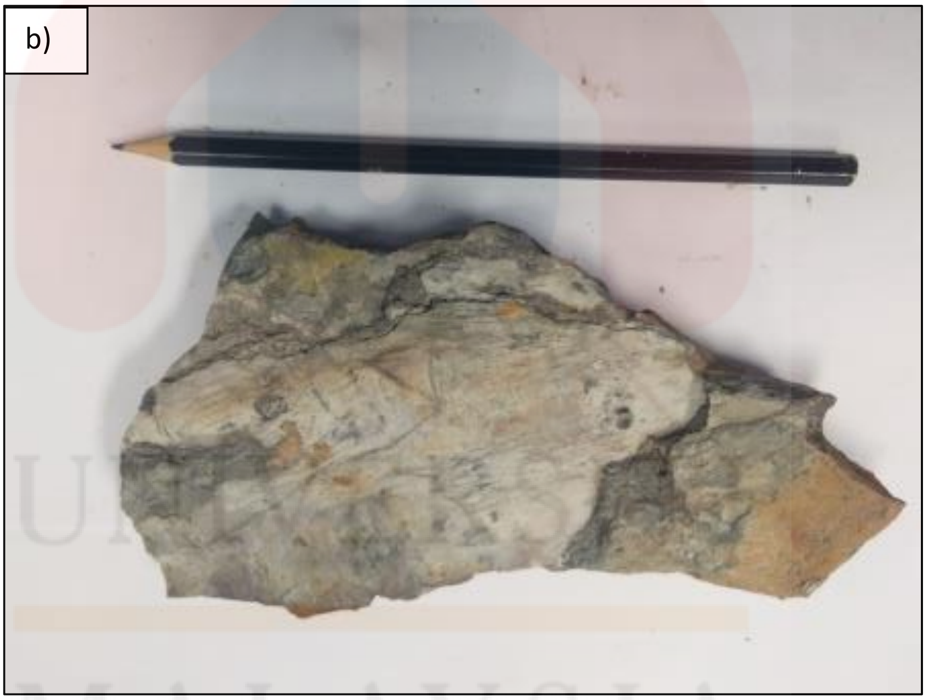


Figure 4.13: a) outcrop of grey phyllite b) hand specimen of grey phyllite

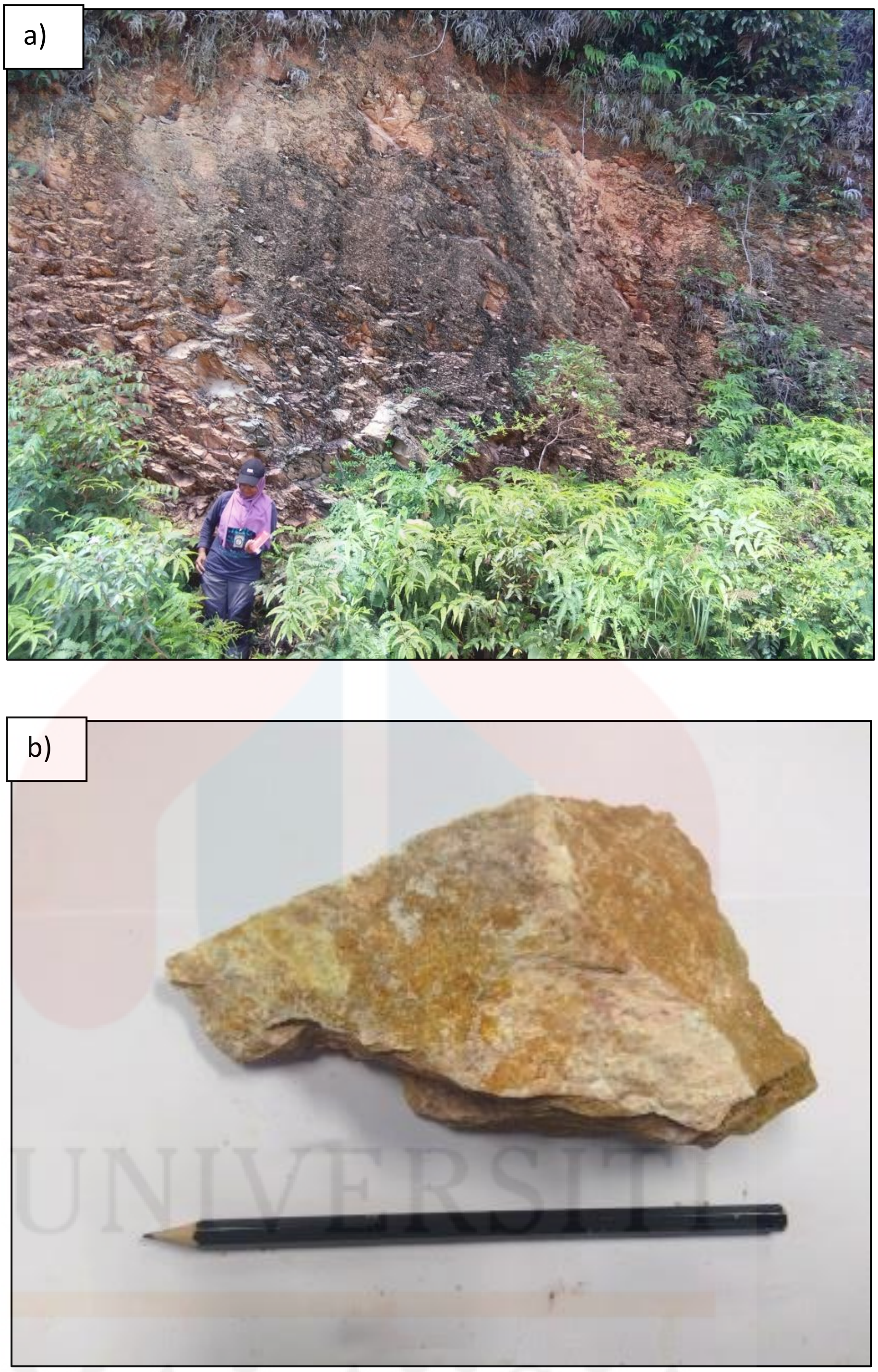


Figure 4.14: a) outcrop of the red phyllite b) hand specimen of red phyllite

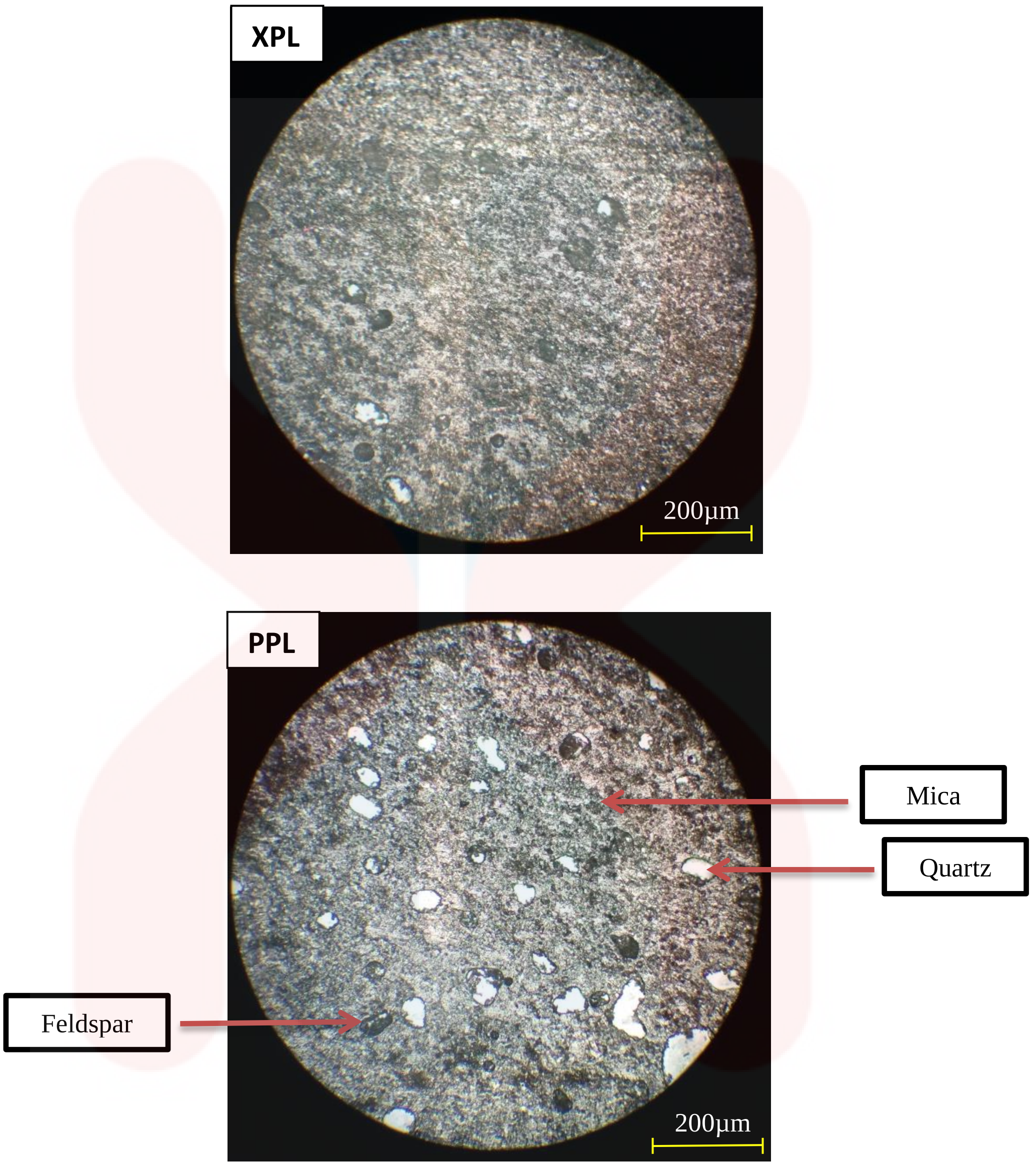


Figure 4.15: Petrographic analysis of green phyllite

Figure 4.15 shows the petrographic image of green phylite. This analysis is under 10x10 magnifications. In this petrographic image, the mineral that can be analysing are mica, quartz, and feldspar. From this analysis the quartz mineral can be recognize because the colour is grey under plane polarized and has no colour change on cross polarized. The mica has the greenish colour on cross section and it is an euhedral mineral. Feldspar is the mineral that have a twinning in both cross and plane polarized.

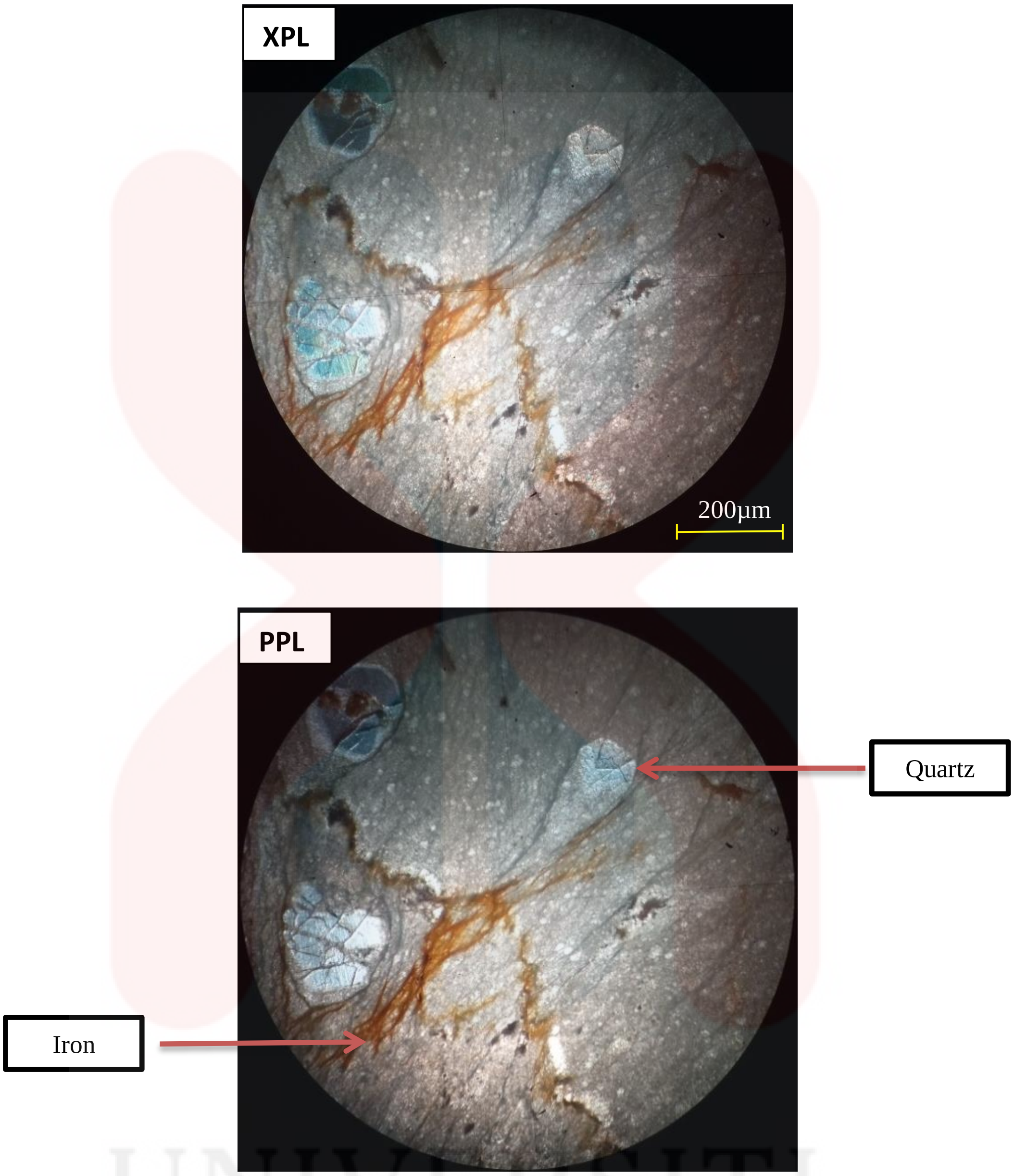


Figure 4.16: Petrographic analysis of red phyllite

Figure 4.16 shows the petrographic of the red phyllite this image is under 10x10 magnification. Mineral that can be recognizing in this this section is only the quartz and the iron. The colour of quartz minerals is grey and it has euhedral shape is representing the quartz. While under the plain polarized light, the quartz shows colourless. It h is low relief mineral. This rock sample is slightly weathered. It can be seen under microscope when the iron is form. It can be consider that the red colour of the phyllite is because of the weathering.

b) Slate unit

In the stratigraphic column, slate is overlying above the phyllite unit. It can be discussed that slate is much younger than phyllite. This slate unit is also under Telong Formation. Slate is one of metamorphic rock with low grade metamorphism. In the study area slate unit is composed of argillaceous unit which the colour is greenish reddish to black slate. Argillaceous facies of slate is shows that this unit have a fine grain size texture and composed of clay mineral. Slate is cover about 20 percent in the study area. The slate outcrop has been samples for the analysis at coordinate N05°33’4.0’’, E102°00’35.5’’. **Figure 4.17** shows the outcrop and hand specimen of slate unit.

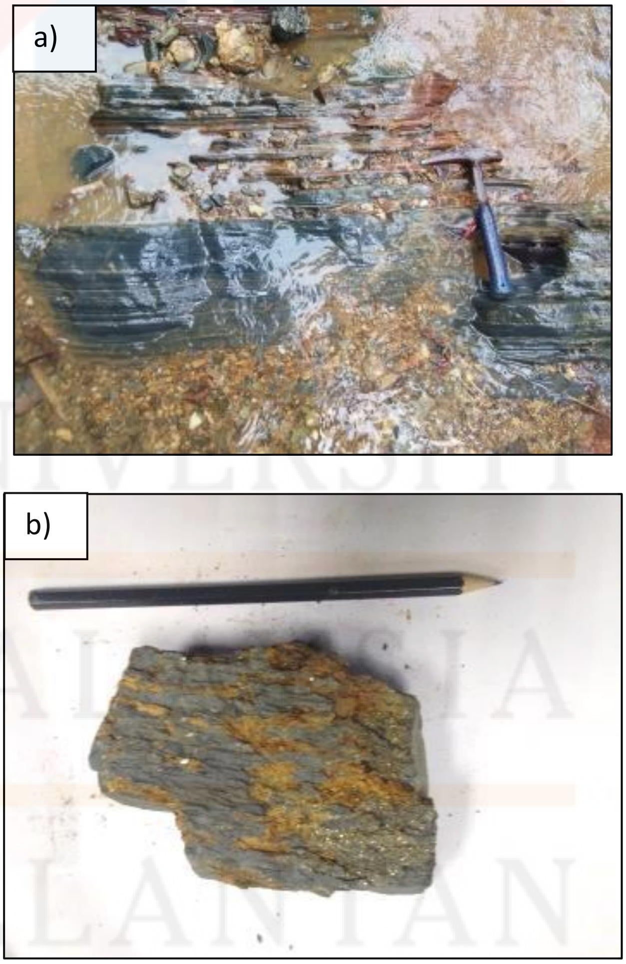


Figure 4.17: a) outcrop of the slate unit b) hand specimen of slate

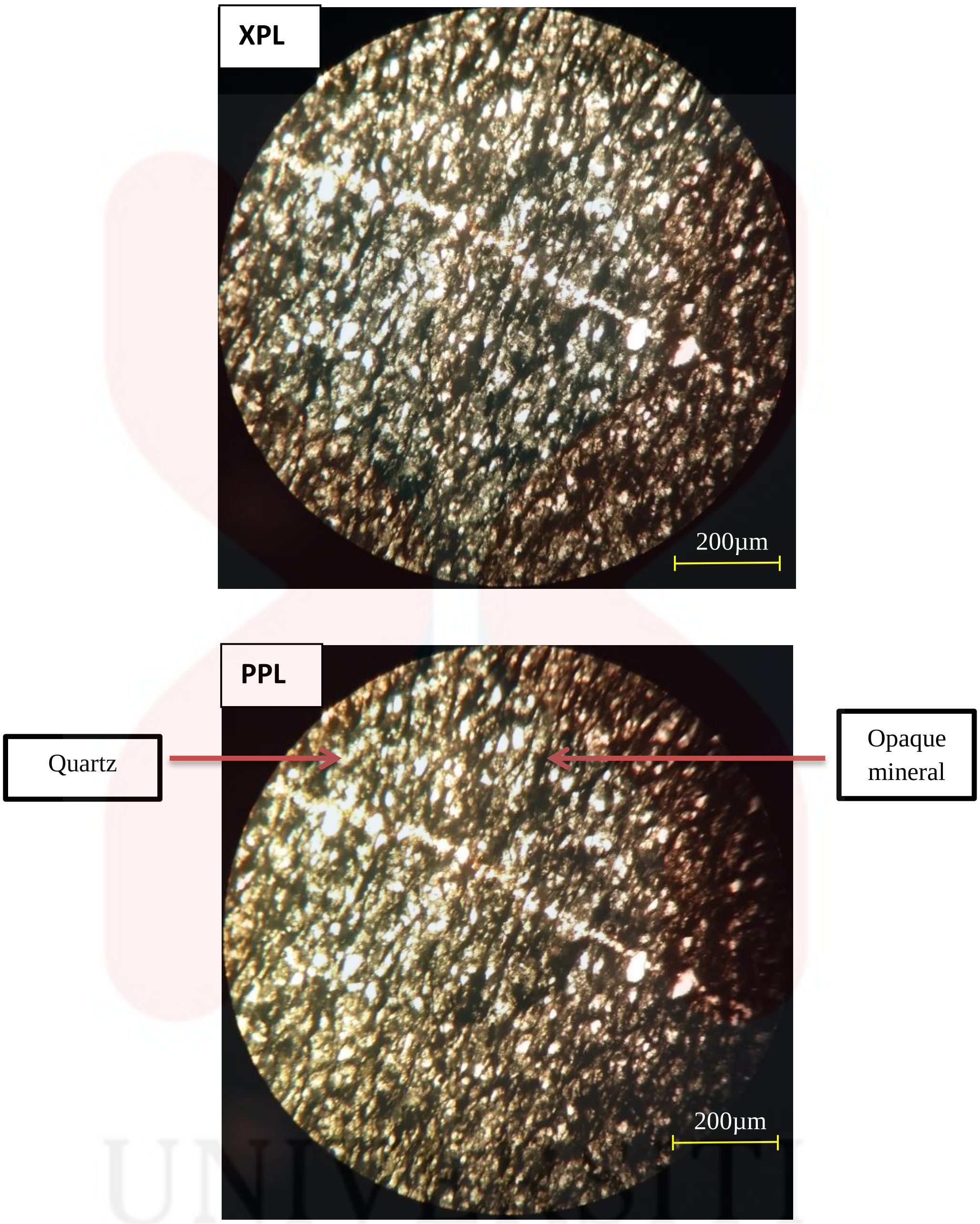


Figure 4.18: petrographic analysis of slate unit

Figure 4.18 shows the petrographic image of slate using 10x10 magnification of microscope. From the petrographic analysis, the sample consist mixture of mica and quartz with small distribution of opaque mineral. From this figure the microscopic of quartz vein can be seen clearly. The opaque mineral show the arrangement is align and shows the characteristic of metamorphic rock. The mica mineral shows the changes of colours for plane polarized which is green and colourless for cross polarized.

c) Limestone unit

Limestone unit is the youngest unit rock in the study area. It composed of the grey marbleize limestone and from calcareous facies. From the calcareous facies it describe that this rock unit composition composed of carbonate and calcite. Limestone is a clastic sedimentary rock and generally forms on the stable continental shelf environment along a passive margin. The colour of the limestone that found in the study area is in a light grey colour and has a fine grain texture. This limestone is under Telong Formation. Limestone that found in the study area is in river area which in Sungai Jelitek small stream from Sungai Sokor main stream. **Figure 4.19** shows the outcrop and hand specimen of limestone that has been sampled from the study area.

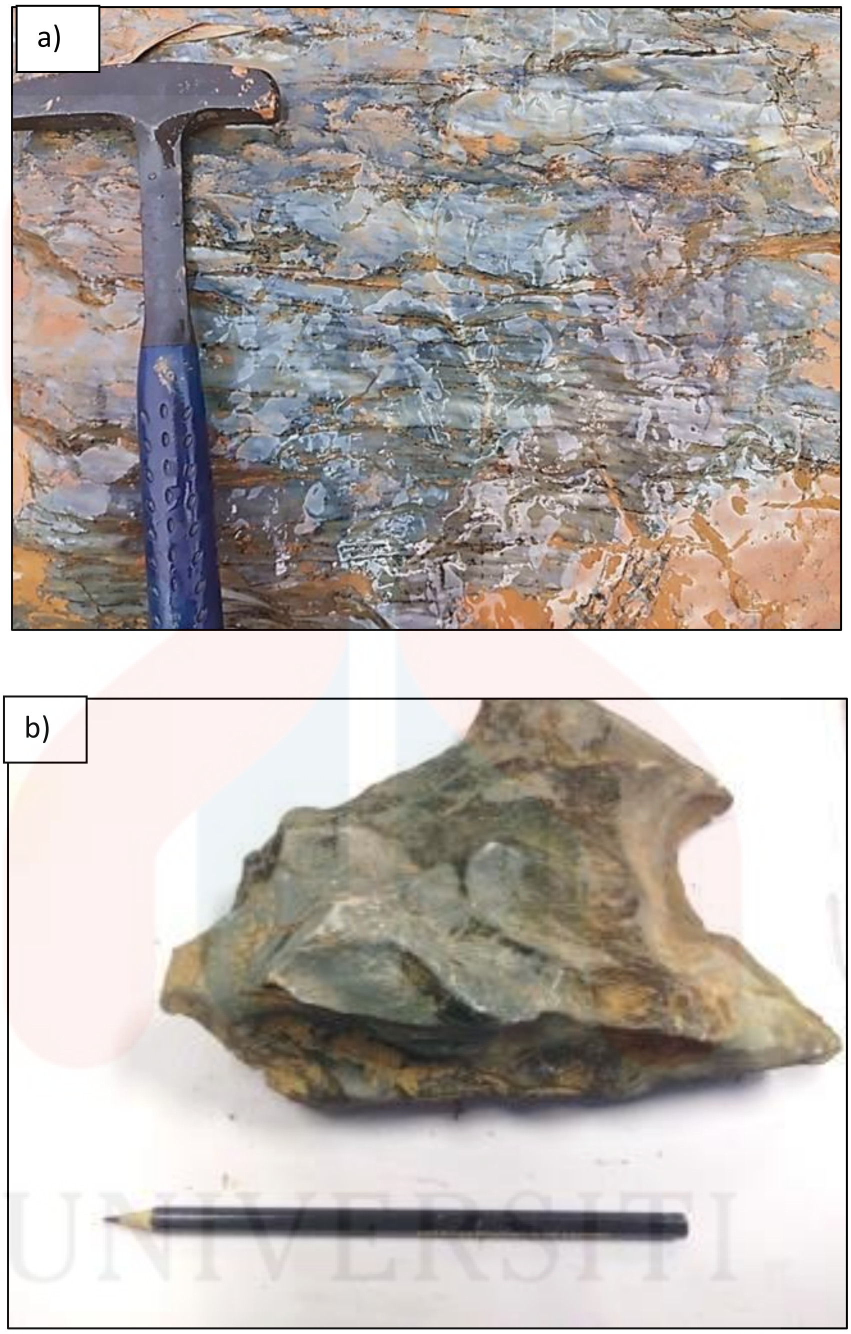


Figure 4.19: a) outcrop of limestone unit b) hand specimen of limestone unit

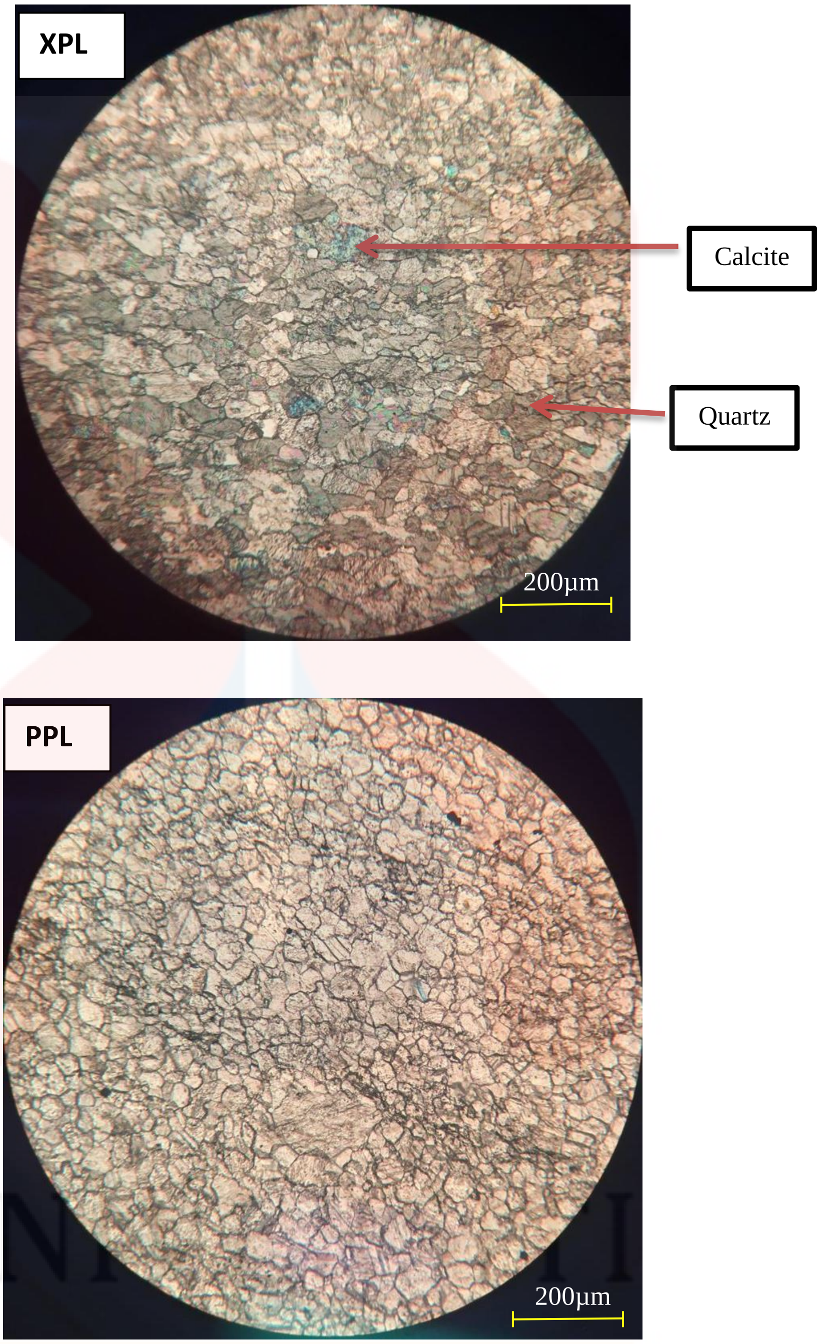


Figure 4.20: Petrographic analysis of limestone unit

Figure 4.20 shows the petrographic image of limestone under microscope with 10x10 magnification. Here the calcite mineral can be identifying. Calcite mineral shows the colour changes from green to pink in cross polarized and no colour changes under plane polarized. Calcite mineral is a basic unit of limestone.

Quartz mineral shows the grey colour in cross polarized and have twinning. In plane polarized quartz shows no colour changes.

4.4 Structural Geology

Structural geology is divided into two type which are primary structural and secondary structural. Primary structure is a structure that resulted from the deposition without alteration from the tectonic activity but secondary structural is the structural is a structural that have been resulted from the tectonic activity that include the high temperature, pressure and stress that have been applied on a body of rock. Example of the primary structure is including the sedimentary bedding, cross bedding and others but for secondary structure is including the fault, vein, fold and many more.

In this chapter the secondary structure in the study area will be describe and analyse by using few Microsoft such as GeoRose software for the joint analysis and also the strereonet Microsoft for fault, fold and bedding analysis. From the analysis the force that applied and also direction of the force can be determine and study including the field data and also laboratory data. Here, the mechanism of the tectonic activity can be seen clearly from the analysis.

4.4.1 Lineament Analysis

Lineament analysis is a primary step before started the mapping process. The lineament map has been provided in order to make a first prediction on the geological structures or geological features in the study area. Basically, a lineament is a linear feature in landscape whose part in align in a straight or slightly curving relationship to express the underlying geological structures such as ridges, joints, faults and boundaries of the stratigraphic formation.

The lineament can be analysing by using the terrain mapping. From the terrain map, the linear features such as the stream and ridges. Terrain map with the help of topographic map by using GIS method can be produce. The topographic data is a very crucial as they complement each other to make lineament interpretation to characterize the regional area. **Figure 4.21** shows the terrain map with the lineament line.

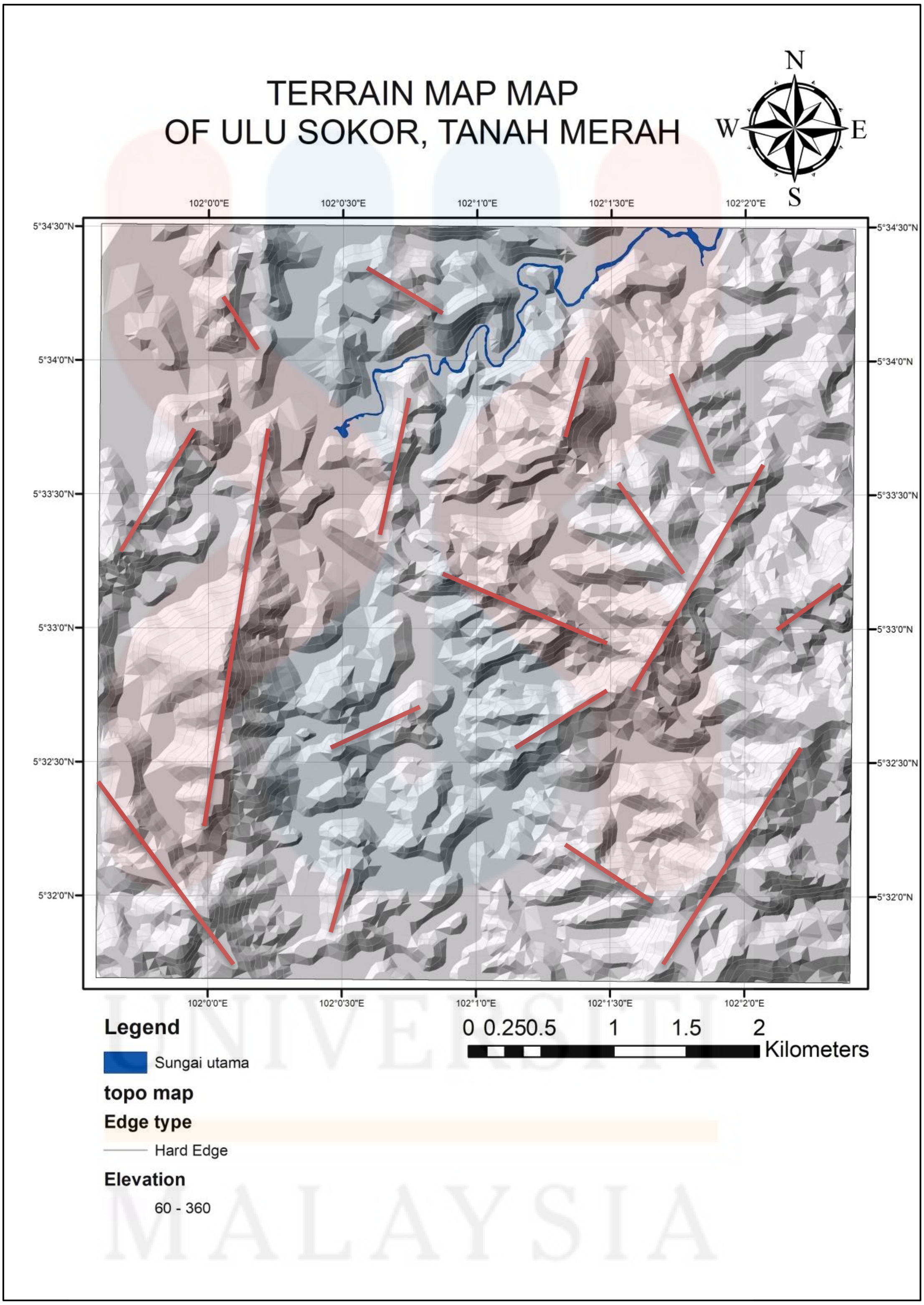


Figure 4.21: Terrain map of study area

4.4.2 Vein

A vein is a mineral mass of tabular form that deposited in the rock fracture. It formed when the mineral constituents carried by an aqueous solution within the rock, the mineral constituents that carried by aqueous solution are despite through precipitation. In this mechanism, the vein usually involved hot water flow that is due to hydrothermal circulation making a huge deal of the water being defines as supercritical.

Ulu Sokor is well-known with gold mineralization and commonly gold are found associated with quartz veins. Several quartz veins have been found in the study area shown in **figure 4.22**. Some sulphide mineral such as pyrite mineral are also identified associated together within the quartz vein.

Figure 4.22: Quartz vein

4.4.3 Joint

Joint is line or fracture that divided the rock body into two sections. Joint is caused by regional stress that applied and breaks the rock along which has no movement have occurred. The mineralization process is often concentrates along these regular or irregular planes of joints. The direction of the joints have been recorded and transfer to the GeoRose diagram in order to identified the direction of the regional force that have been applied on the body of rock in Ulu Sokor Tanah Merah. **Figure 4.34** several cross-cutting joint that could be seen on the outcrop.

Figure 4.23: Several cross-cutting joints could be seen on the outcrop

Table 4.3: Joints direction data

351	342	9	348	330
341	14	3	349	346
352	352	9	341	356
69	357	342	326	352
65	356	344	11	341
71	75	330	330	72
62	7	30	334	330
339	332	3	329	341
356	345	6	355	

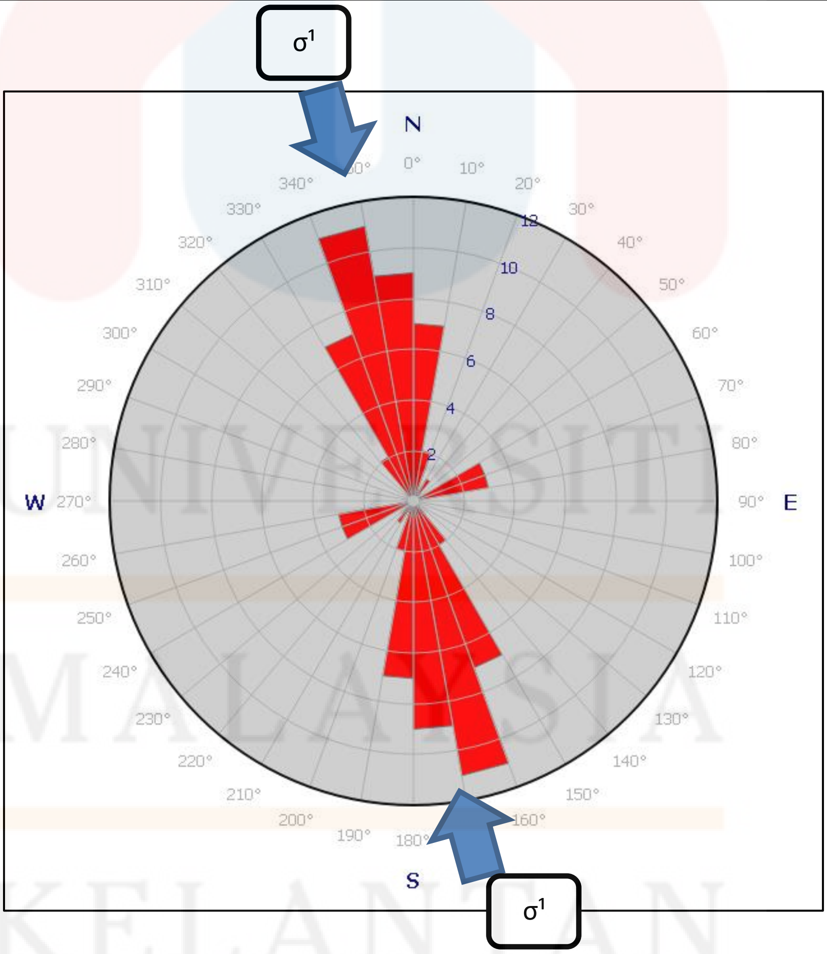


Figure 4.24: Rose diagram of the joint analysis

Figure 4.24 shows the rose diagram of the joint analysis in the study area. From the analysis the regional forces (σ^1) can be determined. From the diagram the force that applied on the rock mass from north-south direction. This maximum force is the force that tends to make the rocks slightly break or fracture. The direction of the (σ^1) is at north-west where the reading is N 350° S. Based on **figure 4.24**; it indicates that the distribution of the joint in the study area is dominant at 350° N and 170° S direction. Thus, this indicates that when the shear stress acts on the body of rocks, the maximum stress caused the rock to slide in 350°N and 170°S direction.

4.4.4 Fault

Fault is defined as joints and fractures on which have a noticeable movement. Fault zones are favourable avenue and localization of mineralization solution for movement and concentration. Generally, fault can be classified by their movement, and there are three main types of stress which are tensional forces, compressional forces and shear strength of an intact rock formation or frictional strength of a pre-existing fault.

The type of fault that is found in the study area is a reverse fault. The type of the fault can be distinguished by the position of the hanging wall and footwall. For reverse fault, the hanging wall is move upward. **Figure 4.25** shows the reverse fault that can be found in the study area.

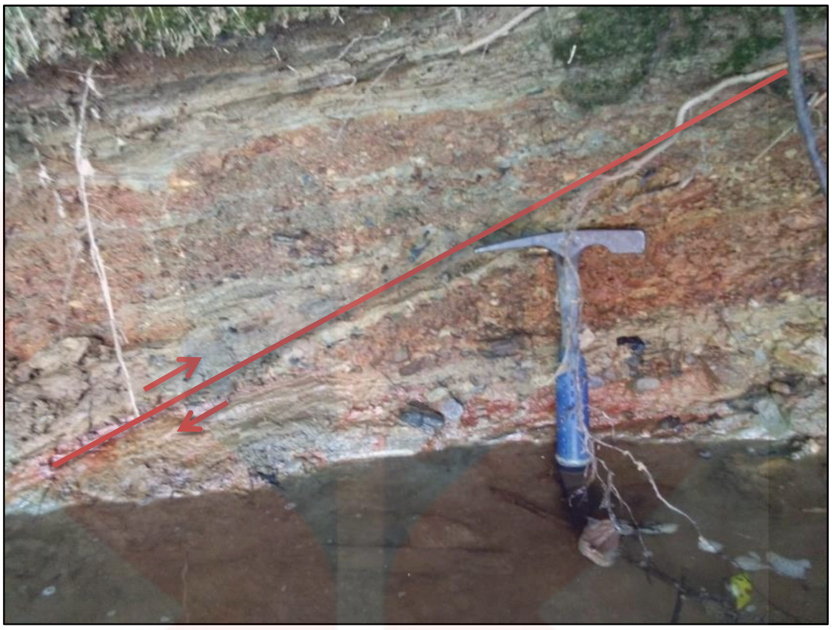


Figure 4.25: Reverse Fault

4.4.5 Fold

The fold is one type of geological structure. It is a wave-like geologic structure which forms due to the compressional stress. The bending of rocks is known as deformation process. Fold is occur on the body of rock that have a plasticity characteristics, which is has ability to bend.

In the study area, the types of fold that can be found are drag fold and also slump fold. **Figure 4.26** shows the geological fold produced in soft or thinly laminated beds lying between harder or more massive beds in the limbs of a major fold and relatively thin layers that show drag folding are usually embedded in incompetent which are soft, weak, or compliant rocks that in turn are sandwiched between thick competent beds. **Figure 4.27** shows the slump fold. Slump fold is one of irregular fold that is the indicator for the marine depositional environment. The slump fold occur during the mass wasting in the marine environment and give a slumping structure.

Figure 4.26: Drag Fold

Figure 4.27: Slump Fold

4.5 Historical Geology

After analyse the data from the field such as lithologies, stratigraphy, structure and other geological features we can observe that the history of the study area is from the shallow marine environment. This is because the lithology such as limestone is deposit in shallow marine environment. Some structural such as slump fold also one of the evidence of the shallow marine environment.

The sedimentary rock that deposit in the study area is already undergoes metamorphism process resulted from the regional metamorphism process. The metamorphism process is indicates the higher temperature, stress and pressure have been applied on the rock body of the study area. This findings can prove the previous study in Ulu Sokor Tanah Merah which is the metamorphism process occur when the regional metamorphism occur during the collision of Sibumasu Plate and Indochina Plate that can form the Peninsular Malaysia.

Previous study also state that the study area of Ulu Sokor Tanah Merah is experience of many volcanic event during Permian to Triassic age and assumes that the area was then composed of volcanic massive sulfide deposit and gold in the Ulu Sokor now is the result of decomposition or deposit of the volcanic event. This study can be prove by the findings of the quartz vein that have been undergoes the hydrothermal alteration which contain the pyrite and sulphide mineral in some location in the study area.

CHAPTER 5

BIOGEOCHEMICAL STUDY OF HYPERACCUMULATOR SPECIES

5.1 INTRODUCTION

In this chapter, the study of the biogeochemistry in hyperaccumulator plant is discussed. The result from the analysis of Induced Plasma Coupled (ICP), Atomic Absorption Spectrophometer (AAS) and X-Ray Fluorescence (XRF) will be analysed and discussed in this chapter. The distribution of the path finder elements which is Lead (Pb), Zinc (Zn), Copper (Cu), Silver (Ag), Manganese (Mn) and Iron (Fe) in the study area will be descript and the anomaly map that can be as reference of the ore body is produced. Few samples also have been analysis for the potential present of Gold (Au). The entire result from the field and laboratory analysis will be describe briefly in this chapter.

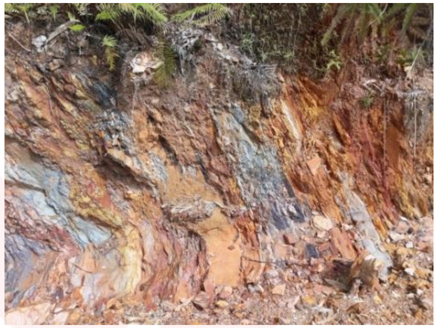
5.2 SAMPLE DESCRIPTION

The sample is composed of rocks samples, plants samples and soils samples. The plants samples that have been collected are the hyperaccumulators species which are *kratom mitragyna speciosa sp, melastoma sp. bambuseae sp* and *Pteridophyta sp.* The soil sample is collected at the same places where the plant sample collected. The rock sample that have association with gold deposition is undergoes petrographic analysis. **Table 5.1** shows the description of the sample of soil and plant that has been collected from the field.

5.2.1: SOIL AND PLANT SAMPLE

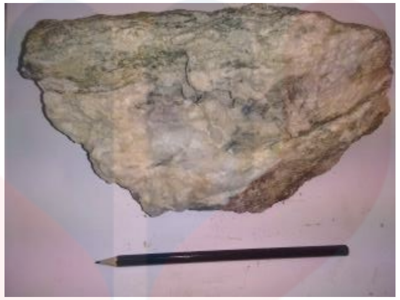
Table 5.1: Sample analysis from the field

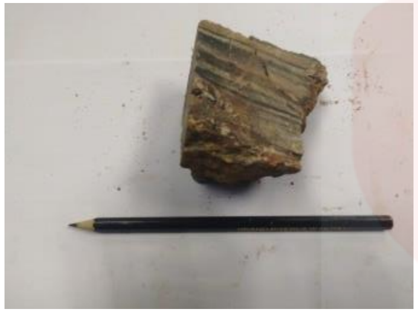
LOCATION /COORDINATE	GEOLOGICAL DESCRIPTION	STRUCTURE	PLANT AND SOIL SAMPLE
1. Location 1 N05°33'4.5'' E102°00'38.6'' E=84m	 Lithology: interbedded slate and iron (have coal body) Strike & dip : 256°/52° Texture: coarse grain, black colour	 Bedded slate and iron	 *Senna alata sp.* **Soil sample**: • Colour : dark yellow • Grain size: fine to medium grain (0.25mm-0.5mm) • Location : river

2. Location 2 N05°33’56.1’’ E102°00’20.7’ ’	 Lithology: banded iron formation (slate and iron) Strike & dip: 153°/64° Texture: banded, black and yellow, fine grain	 Banded iron formation	 *Melastoma malabathricum* (senduduk)  bambuseae sp. (buluh) **Soil sample**: • Colour : light brown • Grain size : medium grain (0.5mm-1.0mm) • Location : roadside

3. Location 3 N05°33’08.8’’ E102°00’39.8’’ E=113m	 Lithology: interbedded phyllite n slate Texture: grey, fine grain Structure: fold Strike n dip: 150°/52°	 Slump fold	 *bambuseae sp*. (buluh),  *Melastoma malabathricum* (senduduk) **Soil sample :** • Colour : reddish brown • Grain size: fine grain (0.006mm-0.12mm) • Location : roadside

4. Location 4 N05°33’26.4’’ E102°00’42.1’’	 Lithology : phyllite Texture: grey, fine grain Geomorphology : forest, hilly		 *Bambuseae sp* (buluh) **Soil sample:** • Colour : reddish brown • Grain size : coarse grain (0.25mm-0.5mm) • Location: hill

5. Location 5 N05°33’55.9’’ E101°59’47.5’’	 Lithology: marblieze limestone Texture: grey, fine grain	 Structure: quartz vein with alteration and sulphide mineral	 *Dicranopteris Linearis sp.* (fern) **Soil sample** • Colour : yellow • Grain size : fine grain (0.12mm-0.5mm) • Location: river

6. Location 6 N05°33'57.6'' E102°00'20.9''	 Banded iron formation Lithology: banded iron formation (slate) Texture: banded, grey Strike & dip : 242°/54°	 Structure: banded and have sulphide mineral	 *Dicranopteris Linearis sp.* (fern) **Soil sample** • Colour : pale red • Grain size : fine grain (0.12mm-0.5mm) • Location: hill

7. Location 7 N05°32’47.0’’ E102°00’0’’	Lithology: phyllite Texture: fine grain, brown, highly grade Strike & dip: 280°/8°	 landslide	 *Dicranopteris Linearis sp.* (fern) **Soil sample:** • Colour : light brown • Grain size : medium (0.125mm-0.0.25mm) • Location: hill

8. Location 8 N05°33’4.0’’ E102°00’35.5’’	 Lithology : slate Texture: black and have sulphide mineral Strike n dip : 180°/24°	 Minor reverse fault	 *Melastoma malabathricum* (senduduk)  *Dicranopteris Linearis sp.* (fern) **Soil sample:** • Colour: yellow • Grain size: fine to medium (0.125mm-1.0mm) • Location: river

9. Location 9 N05°32’47.6’’ E102°02’25.7’’	 Litholog: phyllite Colour: red Texture: fine grain, brown, highly grade		 *Dicranopteris Linearis sp.* (fern) **Soil sample**: • Colour: reddish • Grain size : fine grain (0.25mm-0.5mm) • Location: roadside

5.2.2 ROCK SAMPLE DESCRIPTION

Pyrite has been found in some location in the study area. The samples that have been found undergo the petrographic analysis to determine alteration that related to the ore which is gold. Pyrite is one of the mineral that associate with gold occurrence and known as fools gold. Gold and pyrite can deposited together in the same rock. **Figure 5.1 to 5.8** shows the hand specimen and petrographic analysis of the rock that composed the association of gold.

- Sample 1

  Coordinate : N05°33'57.6'', E102°00'20.9''

  Lithology : Banded iron formation with quartz that undergoes alteration

Figure 5.1: Disseminated pyrite mineral in quartz

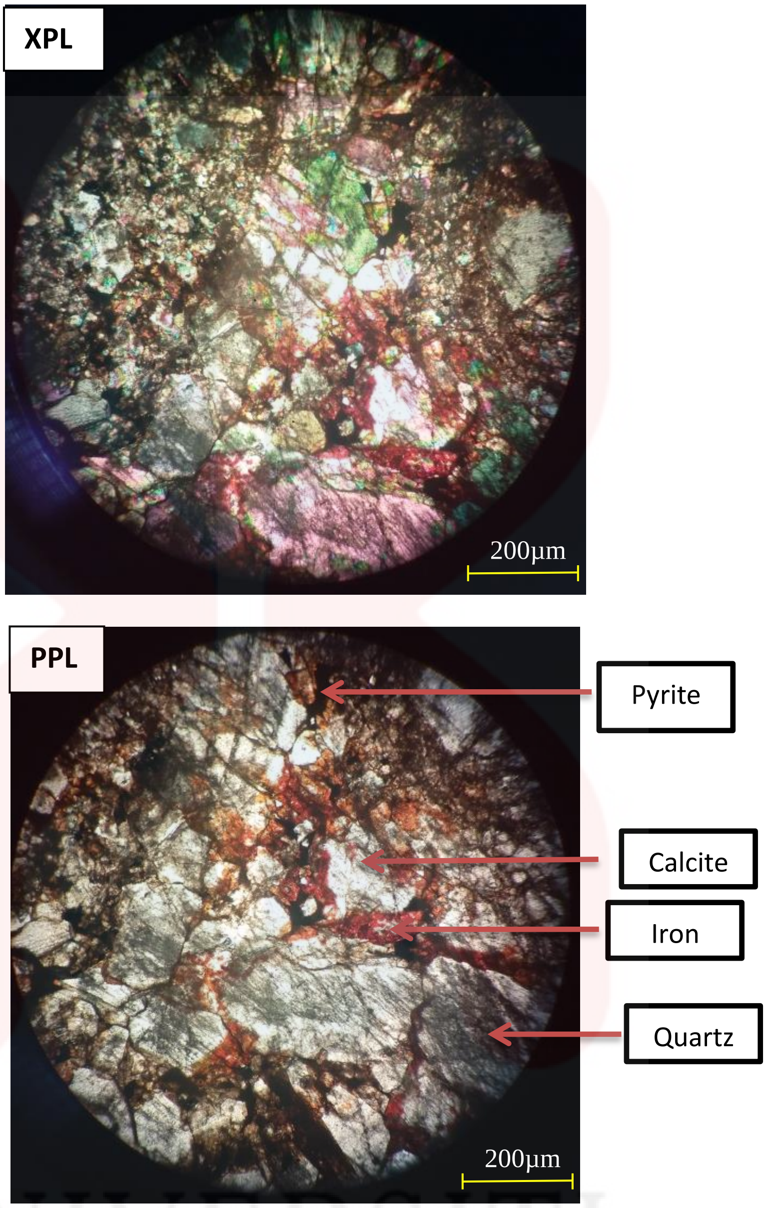


Figure 5.2: Petrographic analysis of the hand specimen

Figure 5.2 shows the petrographic image of the quartz that having the pyrite mineral. This image is under 10x10 magnifications. This sample is taken at the hilly area. The quartz is a vein at the sedimentary rocks. From this petrographic it can see the pyrite mineral which is the black colour. Pyrite is one of opaque mineral that cannot be seen the colour under microscope.

- Sample 2

Coordinate : N05°33'4.0'', E102°00'35.5''

Lithology : slate

Figure 5.3: Pyrite mineral in slate

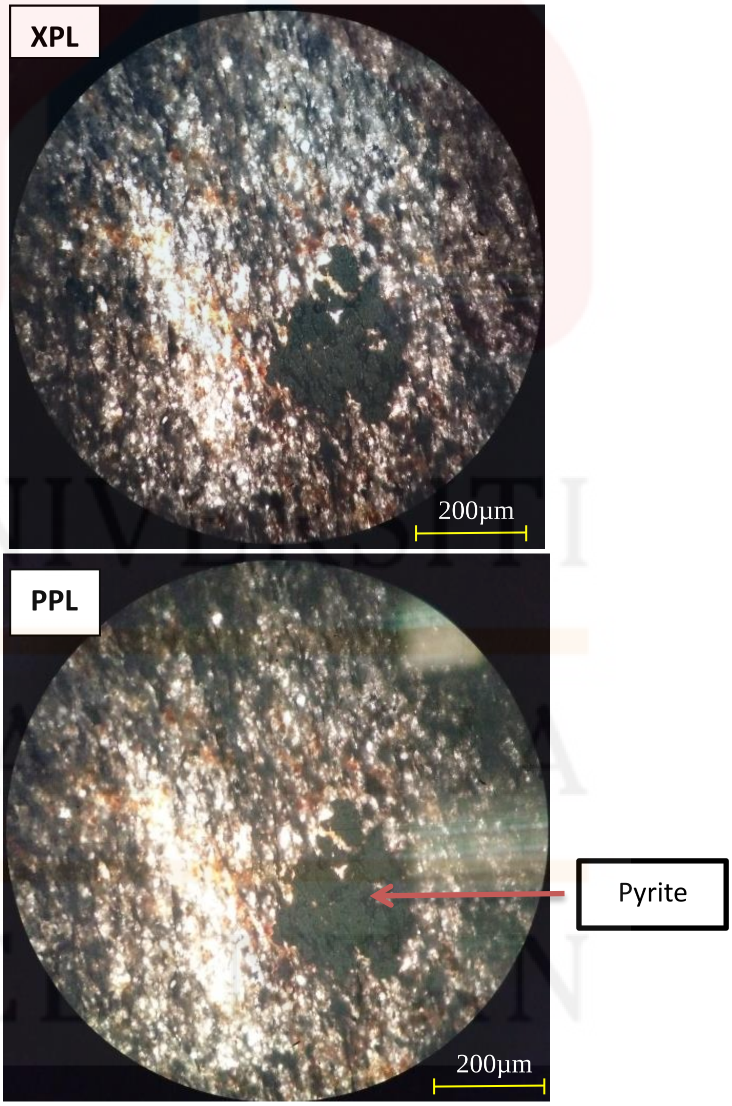


Figure 5.4: Petrographic analysis of slate specimen

Figure 5.4 shows the petrographic image of slate with magnification 10x10 magnifications. This sample has been taken on the river at the centre part of the study area. From the observation there are some residences from the nearest village extract the gold in this place by using panning method. This pyrite mineral is found at the bedding of slate. From the observation, this place can be assumed that have the deposition of the ore deposit which is gold. This river is the one of the small river that connecting to the Sokor main river.

- Sample 3

  Coordinate : N05°33’56.1’’, E102°00’20.7’

  Lithology : Banded iron formation

Figure 5.5: hand specimen of Banded iron formation

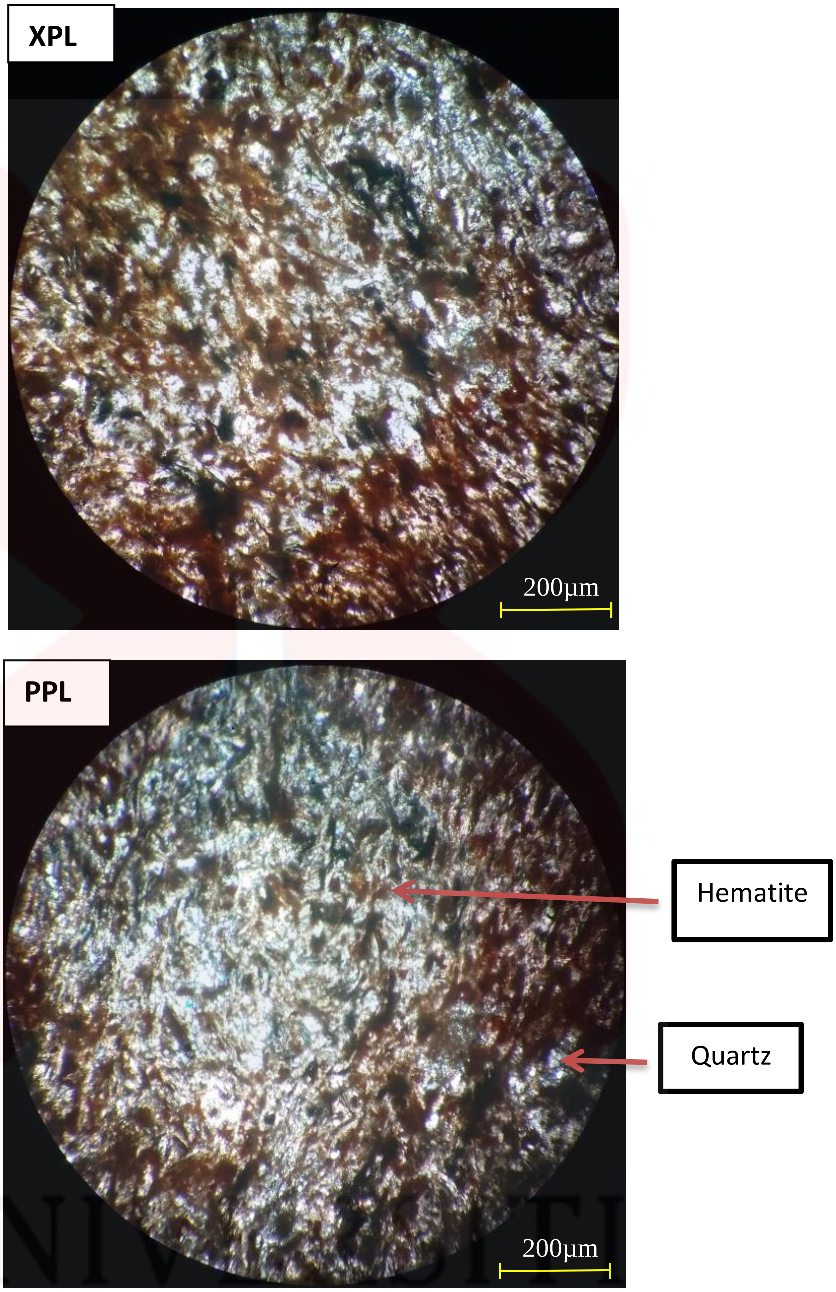


Figure 5.6: Petrographic analysis of banded iron formation

Figure 5.6 shows the petrographic image of the banded iron formation. The magnification of this image is 40x10. This sample has been collected on the North-East part of the study area. The outcrop of banded iron formation also can be seen in the study area. Banded iron formation is composed of hematite. From this petrographic analysis, the red hematite can be seen clearly and the opaque mineral cannot be identified due to opaque characteristic.

- Sample 4

Coordinate : E05°33’55.9’’, E101°59’47.5’’

Lithology : limestone with quartz that has pyrite mineral

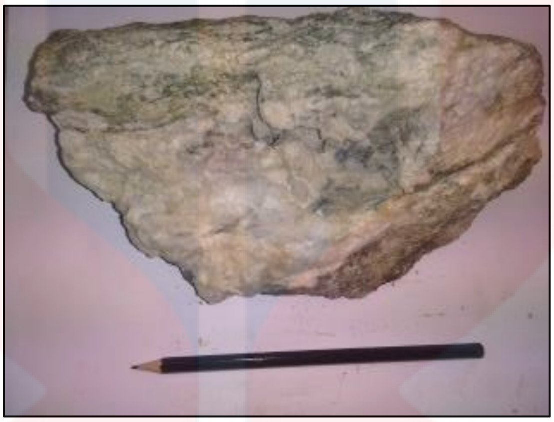


Figure 5.7: Quartz in limestone area

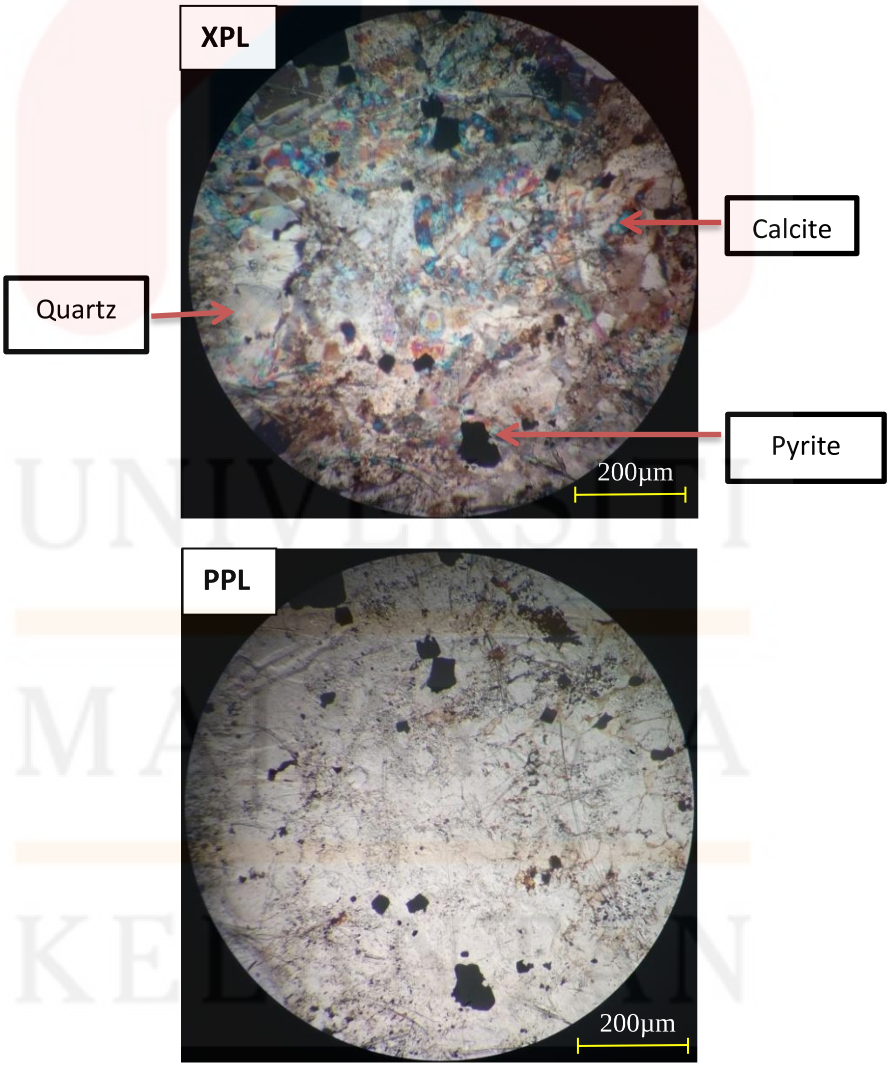


Figure 5.8: Petrographic analysis of quartz

Figure 5.8 shows the petrographic image of quartz that contains pyrite mineral. The magnification that use is 10x10 magnifications. This sample is taken on the top corner of the study area where the lithology there is limestone. It can be seen that the calcite mineral from the limestone is attached on the quartz. This sample is from the river. From the petrographic analysis we can analyse that the quartz here is undergo alteration that can drive to the deposition of pyrite.

5.3 RESULT

The result of X-Ray Fluorescence (XRF), Atomic Absorption Spectrophotometer (AAS) and Induced Plasma Coupled-Mass Spectrometer (ICP-MS) for sample analysis are shown in **table 5.2, 5.3 and 5.4.**

Table 5.2: Result of soil sample analysis from XRF

Location & Element concentration	**L5** (%)	**L6** (%)	**L7** (%)	**L9** (%)
SiO_2	68.9907	65.9506	73.9666	66.3587
Fe_2O_3	20.8576	21.3006	13.8550	21.5712
K_2O	6.3559	10.6222	10.0007	9.4203
BaO	2.8006	0.8212	BDL	1.1073
MnO	0.7645	BDL	BDL	BDL
V_2O_5	0.2308	BDL	0.0799	BDL
TiO_2	BDL	1.0577	1.7478	1.4064
NiO	BDL	0.2476	0.2584	0.1361
Cr_2O_3	BDL	BDL	0.0915	BDL

Table 5.3: Result of plant sample analysis from ICP

Location and plant species	Element Concentration (ppm)								
	Mn	Fe	Zn	As	Pb 208	Pb 206	Cu	Al	Ag (ppb)
L5 *Dicranopteris Linearis sp.*	48.90	44.31	68.86	0.05	0.24	0.42	1.99	42.71	BDL
L6 *Dicranopteris Linearis sp.*	74.12	198.44	5.00	0.46	42.61	72.37	1.72	289.88	BDL
L6 *Melastoma malabathricum sp.*	155.58	161.84	7.69	0.07	0.74	1.26	2.13	194.25	3.46
L7 *Dicranopteris Linearis sp.*	15.92	1615.69	2.14	0.73	3.75	6.37	0.75	705.88	11.0
L8 *Dicranopteris Linearis sp.*	19.88	197.32	7.03	0.08	0.20	0.34	4.13	51.18	BDL
L9 *Dicranopteris Linearis sp.*	100.60	840.64	5.28	0.33	12.59	12.63	1.83	884.46	3.94

Table 5.4: Result of plant sample analysis from AAS

Location & species	Ag (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Pb (ppm)	Zn (ppm)
L1 *senna alata sp.*	0.034	0.205	5.694	6.539	0.639	2.189
L2 *Melastoma malabathricum sp.*	0.014	0.032	1.015	44.75	0.141	0.621
L2 *Bambuseae sp*	0.052	0.448	28.16	67.92	1.848	3.025
L4 *Bambuseae sp*	BDL	0.029	1.684	1.529	0.770	0.115
L6 *Melastoma malabathricum sp*	BDL	0.045	0.528	8.688	0.227	0.205

5.4 DISCUSSION

Selected soil samples have been analysed by XRF to determine the composition as shown in **Table 5.2**. The result from XRF analysis is a evidence for the heavy metal occurrence which are Si, Fe, K, Ba, Mn, V, Ti, Ni, Cr and S in the study area. It is shows that the highest concentration element in the study area is generally Silica Oxide (SiO_2).

Plant sample is analysing using ICP and AAS as shown in **Table 5.3 and 5.4**. Plant sample that have been selected are *Dicranopteris Linearis sp. Bambuseae sp Melastoma malabathricum sp.* and *senna alata sp.* There are two plant species have been analyse in the same location which is location 6 and location 2. In location 2, *Melastoma malabathricum sp* and *Bambuseae sp*. have been analysed. From the analysis it shows that *Bambuseae sp*. have the higher reading of all element from *Melastoma malabathricum sp*. So, it shows that *Bambuseae sp*. is the good hyperaccumulator than *Melastoma malabathricum sp* For location 6, *Dicranopteris Linearis sp.* and *Melastoma malabathricum sp.* have been analysed. From the result it shows that both plant capable to absorb high Mn, Fe and Al but *Dicranopteris Linearis sp* can absorb more Fe, Al and Pb more and *Melastoma malabathricum sp* capable to absorb more manganese and silver. The graph for the heavy metal distribution is provided in **figure 5.9.**

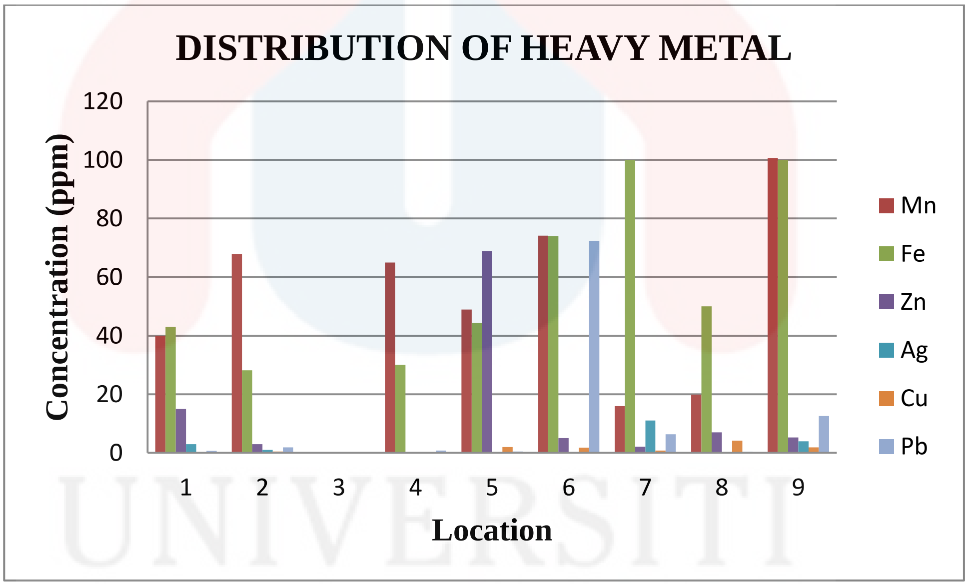


Figure 5.9: graph of heavy metal distribution

Based on the histogram in **figure 5.9** the highest concentration of Manganese (Mn) and Iron (Fe) is identified location 9. This is also supported by the finding of pyrite association in this location during mapping. Pyrite is one of the sulphides mineral that associate with gold occurrence. The occurrence probability can lead to the highest concentration of heavy metal such as Mn and Fe. Location 6 shows the highest value concentration for Lead (Pb) is highest among the other location. In this location, the value of Mn, Fe and Pb shows slightly same. This is because the lithology of this location is banded iron formation that can cause the high reading of some heavy metal. For result of AAS for soil samples in location 5 is around 0.1ppm for gold concentration. This concentration is linked to the findings of the heavy metal in this area such as Manganese (Mn), Iron (Fe) and Zinc (Zn). For further study, the anomaly map of some element such as Iron (Fe), Manganese (Mn), Aluminium (Al), Arsenic (As), Lead (Pb) and Silver (Ag) are provided in **figure 5.10** until **figure 5.15.**

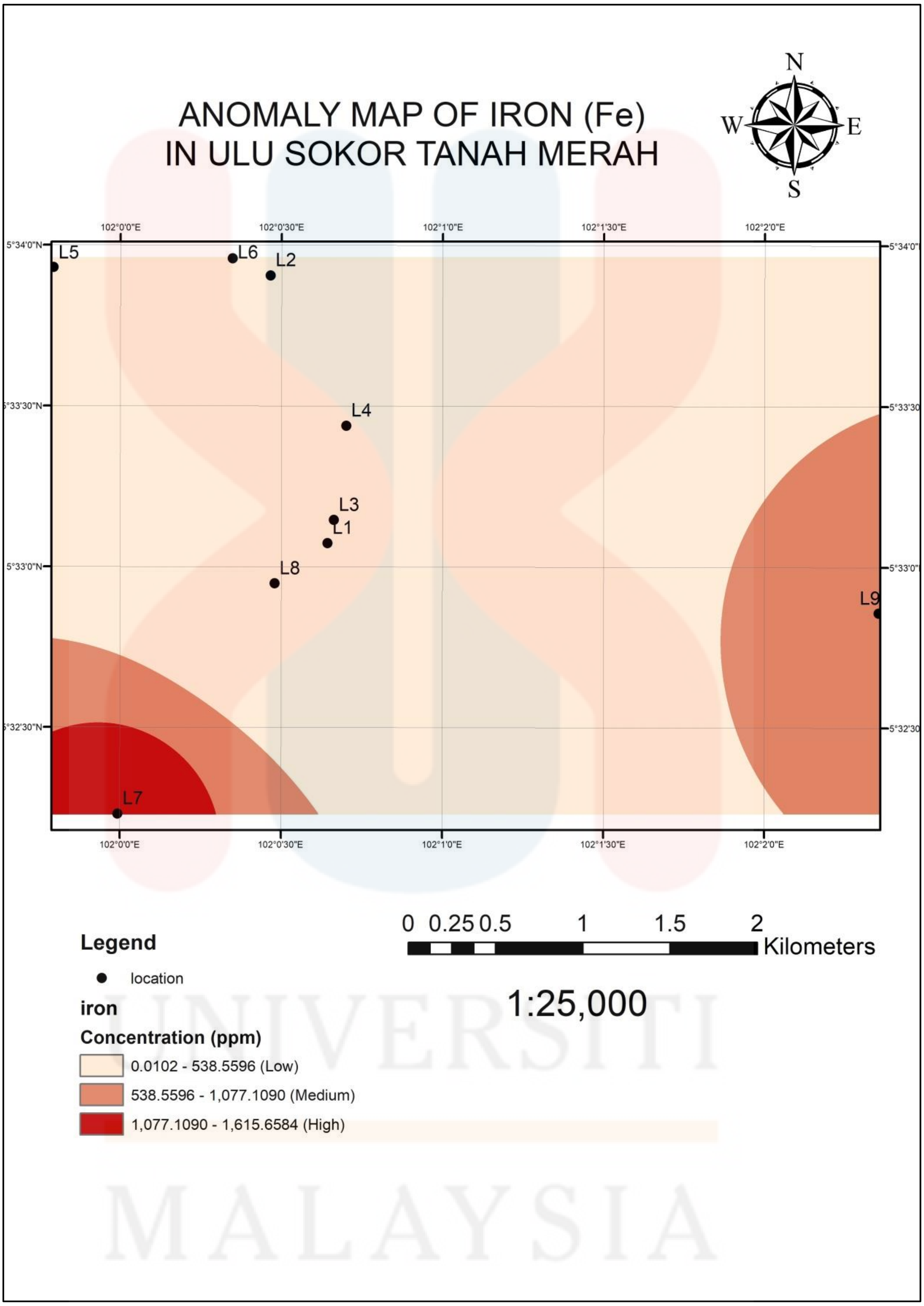


Figure 5.10: Anomaly map for iron distribution

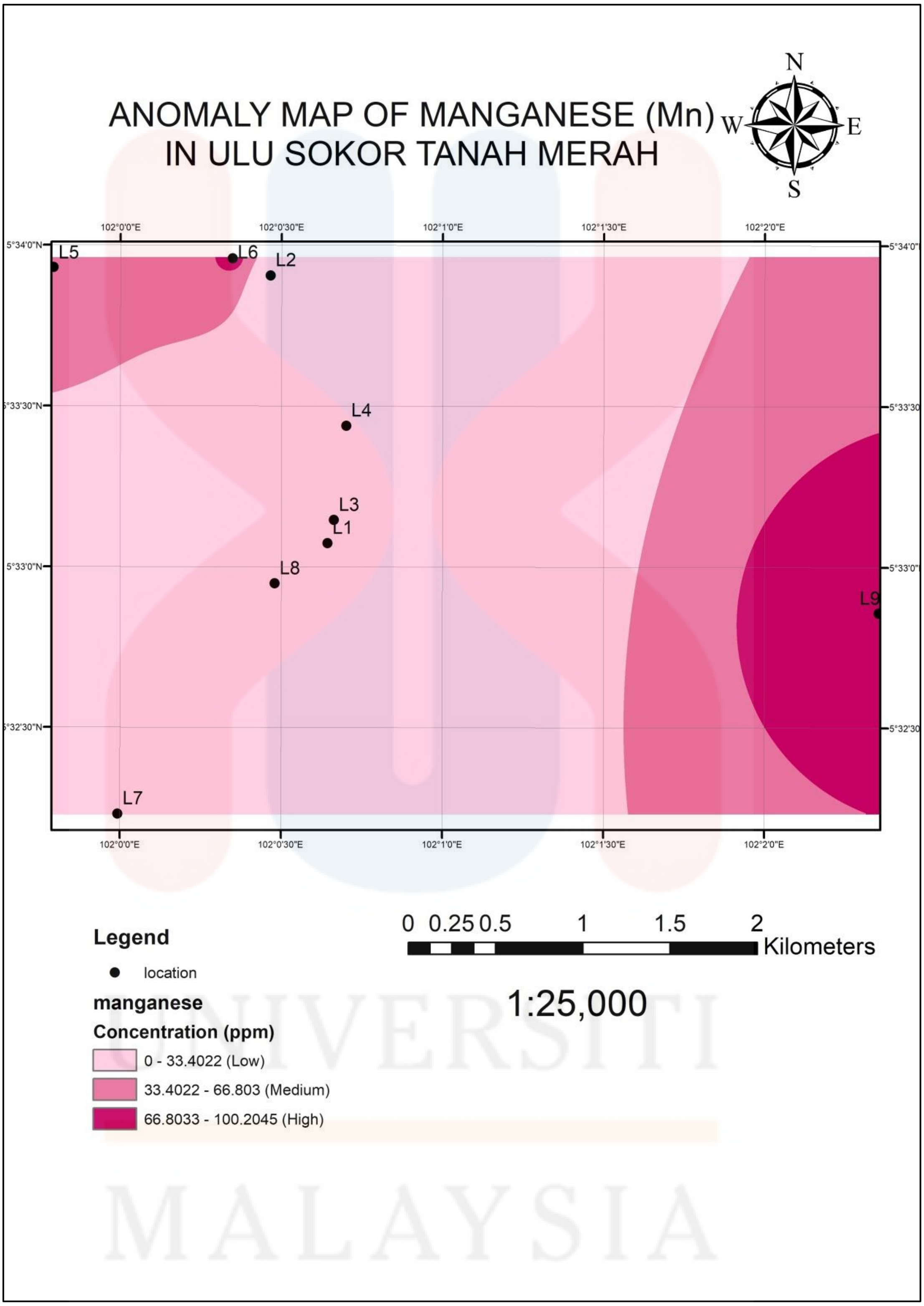


Figure 5.11: Anomaly map for manganese distribution

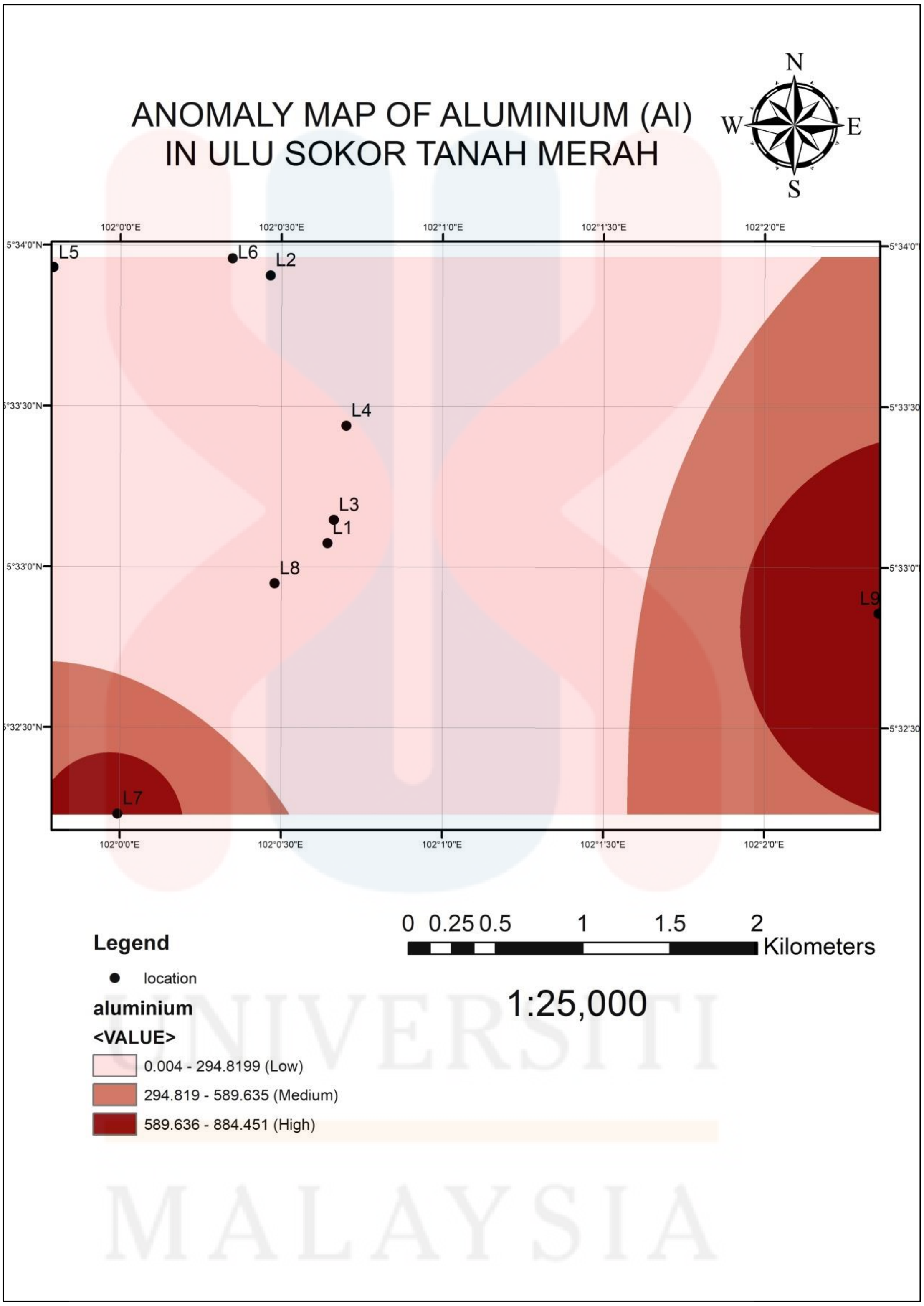


Figure 5.12: Anomaly for aluminium distribution

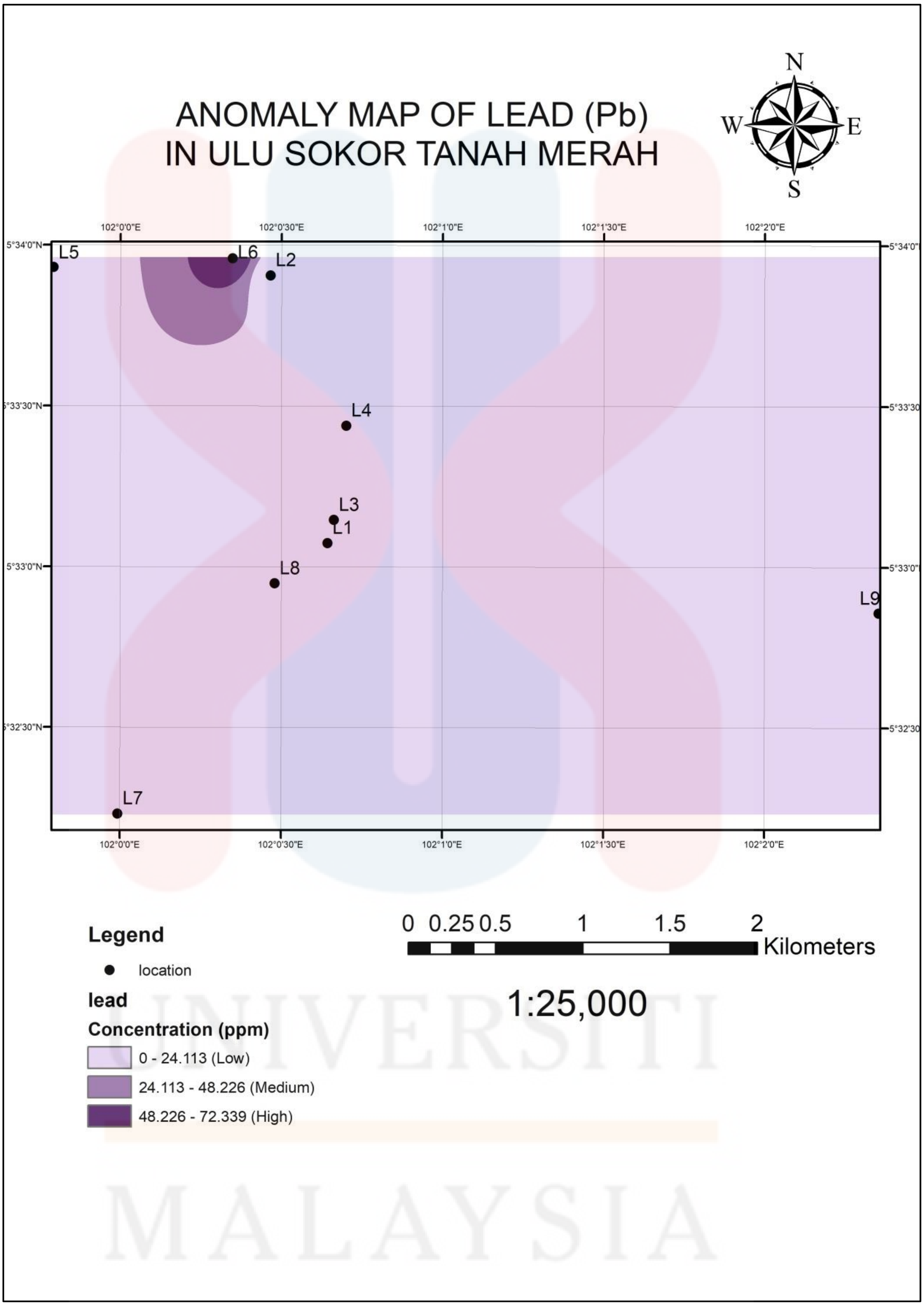


Figure 5.13: Anomaly for lead distribution

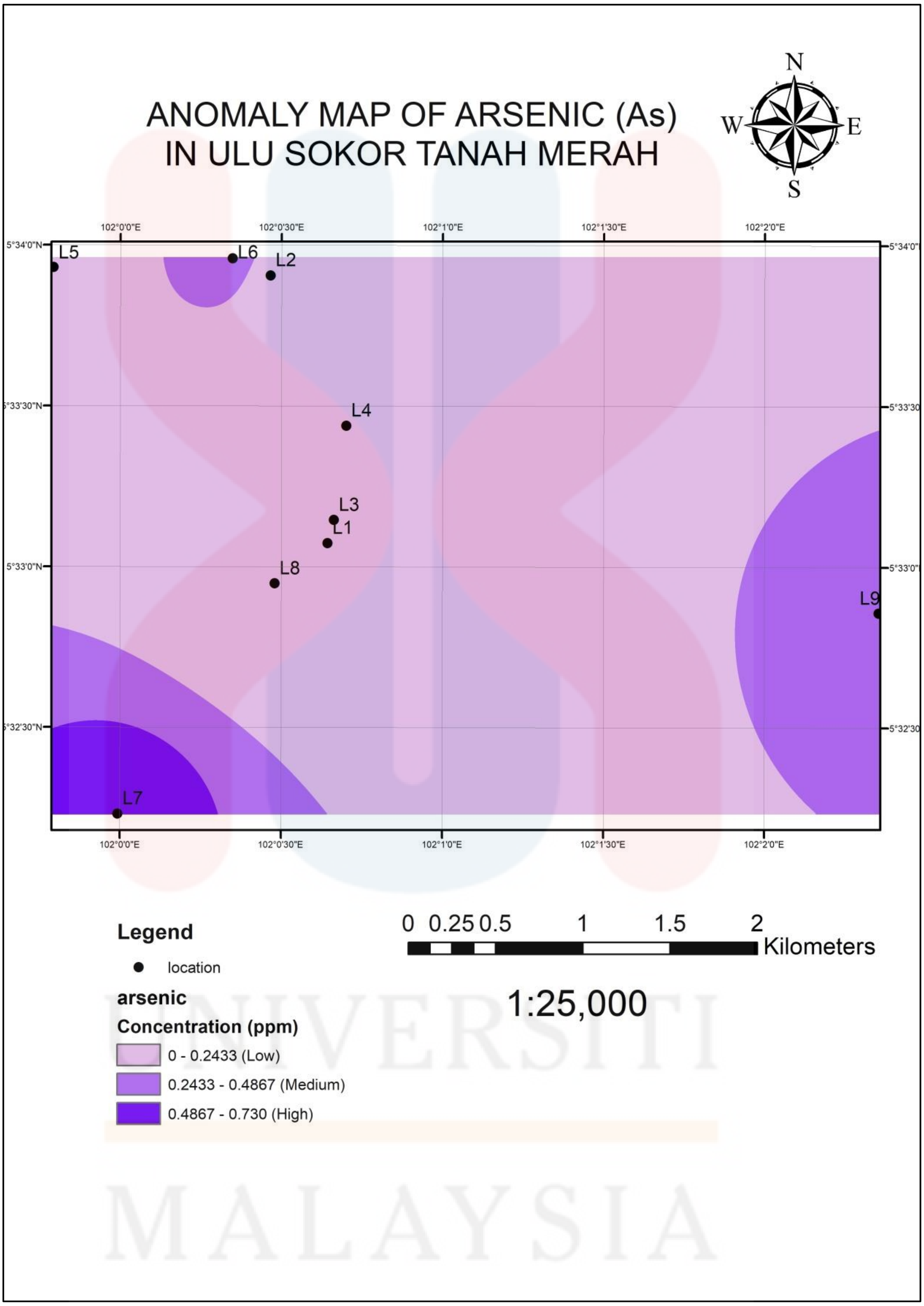


Figure 5.14: Anomaly for arsenic distribution

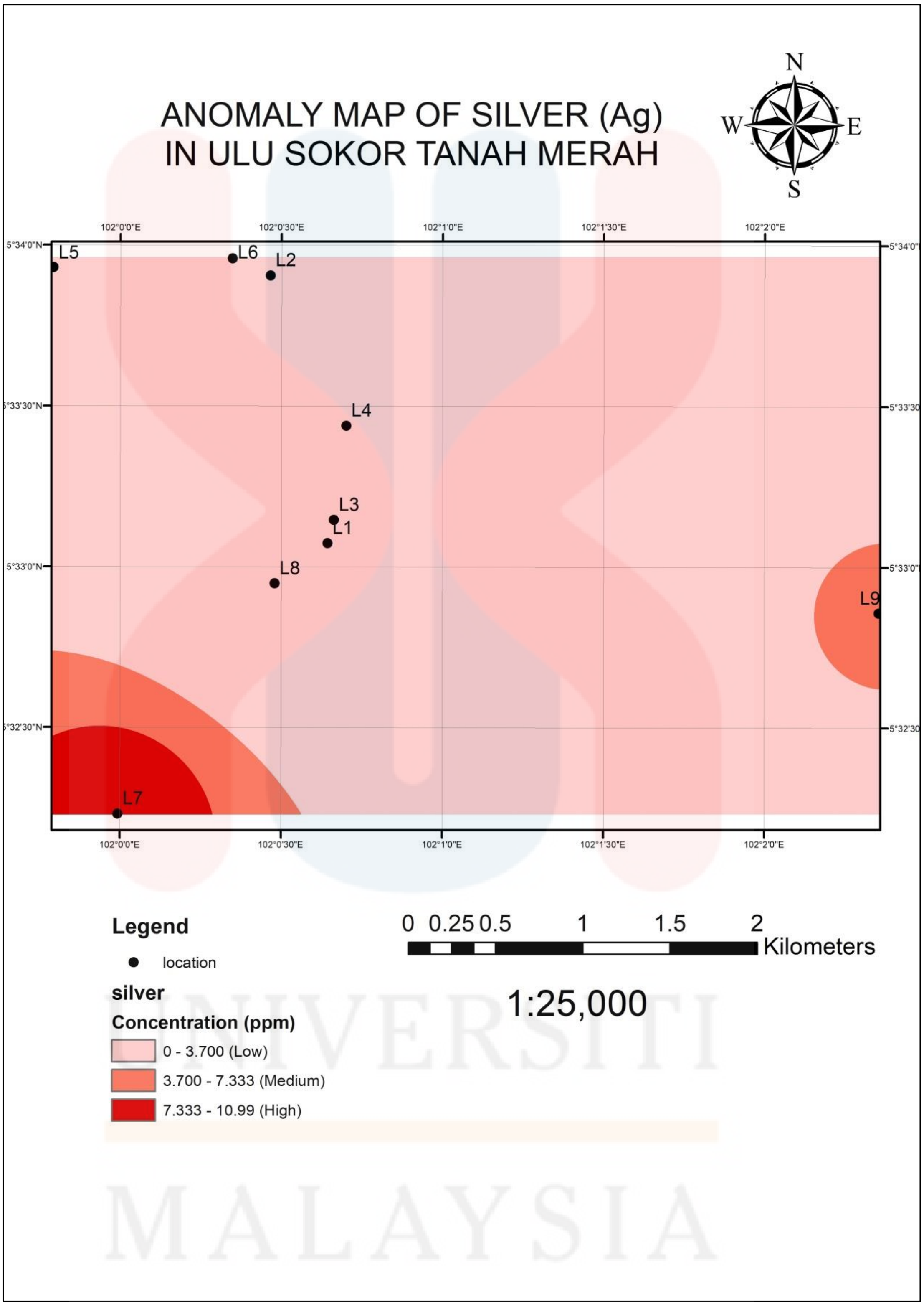


Figure 5.15: Anomaly for silver distribution

5.4.1 Iron (Fe)

Figure 5.9 shows the highest concentration range for iron is on the location 7 and location 9. Location 7 contains high concentration of iron because it is located closer to the CNMC mining company. The red phyllite in location 7 and 9 which underwent weathering process potentially contributed to the greater of the iron concentration. The others location shows the lower concentration of iron because its located quite distance from mining company and the lithology of rock such as limestone, slate and grey phyllite do not highly weathered.

5.4.2 Manganese (Mn)

From the reference of manganese distribution map form **figure 5.10** it can be identified that the highest reading for manganese is on location 6 and location 9. Location 6 shows the high reading because from the fieldwork mapping, there is some pyrite deposition on the quartz found in the location. Finding of the pyrite mineral can lead to the concentration of manganese because of the oxidation process of pyrite. Under anaerobic condition, the pyrite mineral that composed of iron disulphide (FeS_2) undergoes oxidation process and change to manganese dioxide (MnO_2). Location 9 shows the high reading of manganese because this area also contain of high reading of iron. Manganese is always found in combination of iron.

5.4.3 Aluminium (Al)

Figure 5.11 represent the map for aluminium distribution shows the highest concentration of aluminium is on location 7 and location 9. The high reading of aluminium concentration is because the soil types in both locations are laterite soil. Laterite soil is rich of iron and aluminium. From the map of iron distribution in **figure 5.9**, it shows that this both locations also contain high of iron concentration. Laterite soil is red colour soil that comes from the weathering process of parent rock. Laterite soil also composed of titanium oxide (TiO_2) and also hematite (Fe_2O_3). **Table 5.2** which results of XRF for soil shows the evidence that this area composed of TiO_2 and Fe_2O_3. Laterite soil gains the aluminium elements from the composition of gibbsite ($Al_2O_3.3H_2O$) in the laterite soil. Moreover, concentration of aluminium high in location 7 because it is near to the mining company, CNMC.

5.4.4 Lead (Pb)

Figure 5.13 shows anomaly map of lead distribution and the highest concentration of lead is located on location 6. This might related to the finding of pyrite around the area. According to Heinrichs *et. al***. (**1980), he stated that the distribution of the lead in sedimentary rocks is depends on the presence of the primary detrital minerals such as feldspar, mica, sulphides and clays mineral. Pyrite is one of the sulphides mineral and it lead to the increasing of the lead concentration in location 6. McLennan and Murray, (1999) have stated that the black colour of sedimentary rock that found is the evidence and reflecting the affinity of lead for organic matter. This statement is proven when black colour of slate found in for the location 6 that contains high concentration of lead.

5.4.5 Arsenic (As) and Silver (Ag)

Distribution map of arsenic and silver that in **figure 5.14** and **5.15** has shown that the location 7 that have the highest concentration for both elements. This is because location 7 located near with CNMC mining company. Moreover, the mining activity from the mining company also can affect the concentration of arsenic because arsenic may also be mobilised in cyanide aqueous that used for leaching of ore for mining. In gold occurrence there also have a lead-zinc-silver deposit, in which gold and silver can be recovered as by products. According to Arehart *et.al*, (1993) it stated that gold can present in arsenian pyrite that forms overgrowth rims on, and narrow veinlets in gold free pyrite.

5.5 SPATIAL DISTRIBUTION OF ELEMENT IN THE STUDY AREA

The anomaly of the six elements which is Fe, Mn, Ag, Pb, Al and As that identified in previous sections were used to represent the distribution of the heavy metal elements in the study area. It is interpolated using the IDW method (weighted by inverted distance) in the ArcGis 10.2 environment.

From the anomaly map that have been provided, the relationship between the ore mineralization and the concentration of the heavy metal has been identified. From the observation it can be concluded that the location contains pyrite mineral in location 6 and location 9 have high concentration of few heavy metal element. For the example from the anomaly geochemical pattern it shows that location 6 having high concentration of Mn, Pb and As while location 9 having high concentration on Fe, Mn, Al, Ag and As elements. From the petrographic studies, the sample of location 6 also contains pyrite minerals in disseminated morphology. Location 7 which is near CNMC mining company having high concentration of Fe, Al, As and Ag. The concentrations of these elements are related with the mineralisation of gold within the CNMC mining company.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

From this study, a geological map of Ulu Sokor, Tanah Merah has been produced. Based on mapping, the lithology of the study area consists of three lithology unit which are limestone, slate and phyllite. The entire lithology is under Telong Formation with the age in Late Permian to Triassic. After producing the geological mapping the regional fault such as normal fault and oblique fault could be determined.

Biogeochemical analysis has shown promising results as the variations of elemental concentration in samples from selected location have indicated the correlation between the data from AAS and ICPMS. The results also were supported by XRF analysis especially for determination of major composition on some soil samples in similar sampling points. Anomaly maps for elements have been plotted based on elemental concentration could be used as guidance to the distribution of the heavy metal that lead to the sources. The result shows the location that composed of pyrite mineral contain higher concentration of the heavy metal such as Manganese (Mn) where the reading from the ICP analysis and AAS shows the higher among the others which is in range of 155.58 ppm in ICP analysis and 8.688ppm for AAS analysis. Both reading are from *Melastoma malabathricum sp*

This study area is located nearest to the CNMC mining company. The location that is nearest to the company which is location 7. It shows that the reading is contains high concentration of heavy metal such Iron (Fe), Silver (Ag), Arsenic (As) and Aluminium (Al). The location that is highly weathered contains high concentration of Fe metal for example in location 9 which shows the reading of Fe is 840.64 ppm. In location 6 two plant species have been analyse and the result shows that *Dicranopteris Linearis sp.* capable to absorb high concentration than Melastoma malabathricum sp but *Melastoma malabathricum sp* can absorb more Ag than *Dicranopteris Linearis sp.* Two plant species also have been analysing for location 1 which is *senna alata sp.* and *Melastoma malabathricum sp* the result shows that *senna alata sp* is the best hyperaccumulator than *Melastoma malabathricum sp.*

6.2 RECOMMENDATION

For recommendation, the research of biogeochemistry study should be continuing for the next researcher in order to improve this research. Biogeochemical study is one of the study that least applied in Malaysia. This study is beneficial especially in exploration of ore deposit because low cost and less destruction for environment. This method has been applied greatly in Canada and Australia. So, I recommended for the mining company especially in Malaysia to used and improve the biogeochemical study and applied it in mineral exploring activity.

In conducting this research, it need a long time and it is not enough time that university provide for the final year student for this project. University should lengthen the time for this research project. I also recommended that, this research have to get the collaboration with botanist student. This is because the lack of knowledge for the geologist students about the plant studies. Furthermore, I also recommended for the university to repair and improve the machine that used for study such as AAS, XRF and also machine that used for thin section in order to support the student's research and give the accurate result for the student and research.

REFFERENCES

Arehart, G., Chryssoulis, S. and Kesler, S. (1993). Gold and arsenic in iron sulphides from sediment-hosted disseminated gold deposits; implication for depositional process. Economic Geology, 88(1), pp.171-185.

Becker T, Dierschke T (2008) Vegetation response to high concentrations of heavy metals in the Harz Mountains. Phytocoenologia 38:255–265

Bothe, H. (2011). Plants in Heavy Metal Soils. Soil Biology Detoxification of Heavy Metals, 35-57. doi:10.1007/978-3-642-21408-0_

Department of Minerals and Geoscience (2003), Bumi Kelantan Kaya Sumber Mineral

Department of Statistic Malaysia, 2018. Total Populatioj of Kelantan and Economic range of Kelantan from 2013 to 2016

Ernst WHO (1974) Schwermetallvegetation der Erde. Gustav Fischer, Stuttgart

Gale Paulsen, Kris Zcny, and Christopher B., (2013). Robotic Instrument for Grinding Rocks Into Thin Sections (GRITS). Honeybee Robotics, 398 W Washington Blvd, Suite 200, Pasadena, CA 91103, Colorado School of Mines, 1600 Illinois St., Golden, CO 80401, United States, Advanced Superabrasives Inc., 1270 N. Main Street, Mars Hill, NC 28754

Gobbett, D.J., Hutchison, C.S., Burton, C.K., (1973). Geology of the Malay Peninsula: West Malaysia and Singapore. John Wiley-Interscience, New York, pp. 1–438.

Goh, S. W., Teh, G. H., & Wan Fuad Wan Hassan. (2006). Gold Mineralization And Zonation In The State Of Kelantan. *Geology Society of Malaysia Bulletin 52*, pp 129-135.

Hamzah A.H and Hamzah M. (1989). Reconnaissance Geochemical Survey on the Tanah Merah area, (Kelantan). Geological Survey of Malaysia unpublished report, EMR No 11/1989.

Heinrichs, H., Schulz-Dobrick, B. and Wedepohl, K. (1980). Terrestrial geochemistry of Cd, Bi, Tl, Pb, Zn and Rb.

Heng, G.S.,Hoe, T.G.,Hassan, W.F.W., 2006. Gold mineralization and zonation in the state of Kelantan. Bull. Geol. Soc. Malaysia 52, 129–135.

Hulme K.A., Dunn C.E., Hill S.M., (2006). Biogeochemistry For Mineral Exploration In Canada & Australia: A Comparison Based On International Collaboration. Crc Leme, School of Earth & Environmental Sciences, University of Adelaide, SA, 5005 Consulting Geochemist, Sidney, B.C

Hutchinson, C. S., & Tan, D. N. (2009). *Geology of Peninsular Malaysia*. Kuala Lumpur: Universiti Malaya.

Johnson, C. C., and Ander, E.L. (2008). Urban geochemical mapping studies: How and why we do them. In *Environment Geochemistry and Health* (Vol. 30, pp. 551-530)

Kamal Shah Ariffin (2012). Mesothermal Lode Gold Deposit Central Belt Peninsular Malaysia, Earth Sciences, Dr.Imran Ahmad Dar (Ed.), ISBN: 978-953-307-861-8, InTech, Available from:http://www.innterchopen.com/books/earth-sciences/mesothermal-lode-gold-deposit-central-belt-peninsular-malaysia.

Khin, Z., Meffre, S., Lai, C.K., Burrett, C., Santosh, M., Graham, I., Manaka, T., Salam, A., Kamvong, T., Cromie, P., 2014. Tectonics and metallogeny of mainland Southeast Asia — a review and contribution. Gondwana Res. 26, 5–30

Khoo, T. Tan., & Lim, S. P. (1983). Nature of The Contact Between The Taku Schist and Adjacent Rocks In The Manek Urai Area Kelantan and Its Implication. Geological Society Malaysia Bulletin 16, pp 139-158.

Kim, J. N., You, Y. J., & Chon, H. T. (2011). A biogeochemical orientation survey in the Moisan gold-mineralized area, Haenam. Journal of Geochemical Exploration, pp 152-159

Kutty, A. A., & Al-Mahaqeri, S. A. (2016). An Investigation of the Levels and Distribution of Selected Heavy Metals in Sediments and Plant Species within the Vicinity of Ex-Iron Mine in Bukit Besi. *Journal of Chemistry,2016*, 1-12. doi:10.1155/2016/2096147

Li, Bin, et al. (2014) "Geology and Fluid Characteristics of the Ulu Sokor Gold Deposit, Kelantan, Malaysia: Implications for Ore Genesis and Classification of the Deposit." Ore Geology Reviews, vol. 64, 2015, pp. 400–424., doi:10.1016/j.oregeorev.2014.07.018.

Li, B., Zou, H.Y., & Yang, M. (2011). Ore-forming fluid and stable isotope research of Ulu Sokor gold deposit, (in Chinese with English abstract) pp 485-486.

Ling Zhang and Eric Guilbert, (2013). Automatic drainage pattern recognition in river networks. International Journal of Geographical Information Science 27(12):2319-2342. DOI: 10.1080/13658816.2013.802794

MacDonald. (1967). The Geology and Mineral Resource of North Kelantan and North Terengganu. Geological Survey Malaysia District Memoir 10, pp 202.

McLennan and Murray (1999). Geochemical Assessments and Distribution of Arsenic, Selenium, Tin and Antimony in the Surfacial Bottom Sediments of Brullus Lagoon and its Effects on Human Health, DOI: 10.3923/ecologia.2017.20.28.

McInnes, I. B., Dunn, E. C., Cameron, M. E., & Kameko, L. (1996). Biogeochemical exploration for gold in tropical rainforest regions of Papua New Guinea. *Journal of Geochemical Exploration*, 57(1-3), pp 227-243

Metcalfe. I (2000). The Bentong-Raub suture zone, Journal of Asian Earth Science, 18,691-712.

Metcalfe, I., 2013. Gondwana dispersion and Asian accretion: tectonic and palaeogeographic evolution of eastern Tethys. J. Asian Earth Sci. 66, 1–33.

Mushrifah, I., Ahmad, A., & Badri, M. A. (1995). Heavy metals content in sediment of Terengganu River, Malaysia. *Toxicological & Environmental Chemistry,51*(1-4), 181-190. doi:10.1080/02772249509358236

Paulsen, G., Zacny, K., Dreyer, C. B., Szucs, A., Szczesiak, M., Santoro, C., . . . Skok, J. (2013). Robotic Instrument for Grinding Rocks Into Thin Sections (GRITS). Advances in Space Research, 51(11), 2181-2193. doi:10.1016/j.asr.2013.01.001

Queralt, I., Ovejero, M., Carvalho, M. L., Marques, A. F., & Llabrés, J. M. (2005). Quantitative determination of essential and trace element content of medicinal plants and their infusions by XRF and ICP techniques. *X-Ray Spectrometry,34*(3), 213-217. doi:10.1002/xrs.795

Shah, K. (2012). Mesothermal Lode Gold Deposit Central Belt Peninsular Malaysia. Earth Sciences. doi:10.5772/26179

S.M. McLennan and S.M. Murray, G.N. H(1999). Mineralogic Controls on REE Mobility During Black-Shale Diagenesis. SEPM Journal of Sedimentay Research

Suntharalingam, T. (n.d.). Malaysia: Peninsular malaysia. Encyclopedia of Earth Science Encyclopedia of European and Asian Regional Geology, 525-530. doi:10.1007/1-4020-4495-x_64

The Malaysia-Thai Working Groups. (2006). Geology of the Batu Melintang Sungai Kolok Transect Area along the Malaysia-Thailand Border. The Malaysia-Thailand Border Joint Geological Survey Committee, pp 1-70.

Yang, S., Daněk, T., Yang, X., & Cheng, X. (2016). Distributing Characteristics of Heavy Metal Elements in A Tributary of Zhedong River in Laowangzhai Gold Deposit, Yunnan (China): An Implication to Environmentology from Sediments. *IOP Conference Series: Earth and Environmental Science,44*, 052064. doi:10.1088/1755-1315/44/5/052064

Yeap, E.B., 1993. Tin and gold mineralizations in Peninsular Malaysia and their relationships to the tectonic development. J. SE Asian Earth Sci. 8, 329–348.

Vernon, R. A (2004) Practical Guide to Rock Microstructure. Macquarie University, Sydney, ISBN:978052189133