GEOLOGY AND PRELIMINARY STUDY OF GOLD DEPOSIT USING BIOGEOCHEMISTRY IN ULU SOKOR, TANAH MERAH, KELANTAN

by

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

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APPROVAL

"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 (Geoscience) with Honors"

Signature :

Name of Supervisor :

Date :

DECLARATION

I declare that this thesis entitled "Geology And Preliminary Study Of Gold Deposit Using Biogeochemistry in Ulu Sokor, Tanah Merah, Kelantan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

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Date :

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GEOLOGY AND PRELIMINARY STUDY OF GOLD DEPOSIT USING BIOGEOCHEMISTRY IN ULU SOKOR, TANAH MERAH, KELANTAN

ABSTRACT

Malaysia is one of the country rich with valuable minerals such as gold. The exploration of gold is actively increase however, the method of biogeochemistry study using plants and soils is not widely used in Malaysia. This method is useful to identify potential of gold deposit in addition to prevent destruction to environment. This research is about geology and preliminary study of gold deposit using biogeochemistry in Ulu Sokor, Tanah Merah, Kelantan. The objective of this research is to determine the concentration of pathfinder elements which are Silver (Ag), Manganese (Mn), Copper (Cu), Iron (Fe) and Lead (Pb). Plant and soil samples were taken in 9 different locations respectively in which soil was taken at the same area with plant sample. The selected plant was taken are *Melastoma malabathricum, Mimosa pudica, Dactylis glomerate, Rhamnus frangula* and *Syzygium zeylanicum* together with the soil samples nearby the plants. The samples were analyzed using Atomic Absorption Spectrometry (AAS) and X-Ray Fluorescence (XRF). The petrography of rocks was studied accordingly using optical microscope. Based on the result, elements such as Manganese (Mn) and Lead (Pb) in 18AFDS1 are the highest concentration among others with 86.76 ppm and 3.71 ppm respectively. This can be related to its location which is closer to the new developing mine. Meanwhile for 18AFD8(5), copper (Cu) and iron (Fe) concentration also shows the higher concentration among other location, 1.606 ppm and 173.1 ppm respectively due to its location near mining and ex-mining area. As for hyperaccumulator plant, *Melastoma malabathricum* and *Rhamnus frangula* can act as hyperaccumulator plants as the value of bioaccumulation factor is more than 1. As a conclusion, the concentration of pathfinder elements in soils and plants can acts as a medium to locate the gold deposition in Sokor, Tanah Merah, Kelantan.

GEOLOGI DAN KAJIAN PERMULAAN PEMENDAPAN EMAS MENGGUNAKAN BIOGEOKIMIA DI ULU SOKOR, TANAH MERAH, KELANTAN

ABSTRAK

Malaysia adalah salah satu negara kaya dengan mineral berharga seperti emas. Eksplorasi emas secara aktif meningkat bagaimanapun, kaedah kajian biogeokimia menggunakan tanaman dan tanah tidak banyak digunakan di Malaysia. Kaedah ini berguna untuk mengenal pasti potensi deposit emas selain untuk mengelakkan pemusnahan terhadap alam sekitar. Kajian ini adalah mengenai geologi dan kajian permulaan pemendapan emas menggunakan biogeokimia di Ulu Sokor, Tanah Merah, Kelantan. Objektif penyelidikan ini adalah untuk menentukan kepekatan unsur penemang jalan yang adalah Perak (Ag), Mangan (Mn), Tembaga (Cu), Besi (Fe) dan Plumbum (Pb). Sampel tumbuhan dan tanah diambil di 9 lokasi yang berlainan di mana tanah diambil di kawasan yang sama dengan sampel tumbuhan. Tumbuhan yang dipilih ialah *Melastoma malabathricum, Mimosa pudica, Dactylis glomerate, Rhamnus frangula* dan *Syzygium zeylanicum* bersama-sama dengan sampel tanah berhampiran tanaman. Sampel dianalisis dengan menggunakan Spektrometri Penyerapan Atom (AAS) dan X-Ray Fluorescence (XRF). Petrografi batuan dikaji dengan sewajarnya menggunakan mikroskop optik. Berdasarkan hasilnya, unsur-unsur seperti kepekatan, Mangan (Mn) dan Plumbum (Pb) pada 18AFDS1 adalah yang tertinggi antara lain, masing-masing mempunyai kepekatan sebanyak 86.76 ppm dan 3.71 ppm Hal ini boleh dikaitkan dengan lokasinya yang lebih dekat pembangunan lombong baru. Sementara itu untuk 18AFD8 (5), kepekatan tembaga (Cu) dan besi (Fe) juga menunjukkan kepekatan yang lebih tinggi di antara lokasi lain, 1.606 ppm dan 173.1 ppm masing-masing kerana lokasinya berhampiran kawasan perlombongan dan bekas perlombongan. Bagi tumbuhan hiperakumulator, *Melastoma malabathricum* dan *Rhamnus frangula* boleh bertindak sebagai tumbuhan hyperaccumulator sebagai nilai faktor bioakumulasi lebih daripada 1. Sebagai kesimpulan, kepekatan unsur-unsur element penapis laluan dalam tanah dan tumbuh-tumbuhan dapat bertindak sebagai medium untuk mencari pemendapan emas di Sokor, Tanah Merah, Kelantan.

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrometry
Ag	Silver
Au	Aurum/gold
BaO	Barium Oxide
BDL	Below Detection Limit
BF	Bioaccumulation Factor
CaO	Calcium Oxide
cm	Centimetre
Cu	Copper
Fe	Iron
Fe_2O_3	Ferric Oxide
GIS	Geographical Information System
HCl	Hydrochloric acid
ICP-MS	Induced Coupled Plasma-Mass Spectrometry
km	Kilometre
K_2O	Potassium Oxide
LILE	Large Ionic Lithophile Elements
LREE	Light Rare Earth Elements
mm	Milimeter
Mn	Manganese
MnO	Manganese oxide
NiO	Nickel Oxide
Pb	Lead
ppm	Part Per Million
Sb_2O_3	Antimony(III) oxide
SiO_2	Silica
SR	Random Sampling
SUR	Uniform Random Sampling

TiO_2	Titanium(IV) oxide
UR	Uniform Random
V_2O_5	Vanadium(V) oxide
XRF	X-Ray Fluorescence
Zn	Zinc
ZnO	Zinc Oxide

CHAPTER 1

INTRODUCTION

1.1 Background Study

Malaysia is a well-known country that is rich with flora and fauna with its valuable mineral etc. This gives an insight on the importance of the valuable minerals and rock for exploitation purpose. Apart from that, the interaction of biotic and non-biotic creates a cycle, which contribute to many importance of geochemical studies. For sure, this relation open the eyes of many researcher that these cycle do contribute in giving the insight on exploring the minerals rather than using a machines. This led to a vigorous exploration activity to explore, exploit and extract the minerals especially the valuable one.

In early 90th century, a method called biogeochemistry was develop. Biogeochemistry is a process of forming of all of these types are very closely related to physical, chemical and biological processes. It is a cycle as in a way that the movement of element or compound throughout the biotic and abiotic in the biosphere. Also, during this cycle, energy are released in the form of heat in which recycling the elements occurred (Raven Peter H. et al., 2017). The term biogeochemical itself is the combination of biological, geological chemical aspects that involve in the cycles. They relate this process in how the chemical composition are cycle within the biogeochemical cycle.

The study of biogeochemical for mineral exploration are mainly use vegetation. This is because scientist believe that the chemical composition contain in the soil can be absorbed by the plant. Generally, it is an analysis of the accumulation of elements in vegetation and the upper humic layer of soils. This cycle thus helps in understanding more on the mineral exploration activities through the uptake of minerals from the underlying bedrock, which the mineralization occurs. Purposing this method for sure is a reasonable way as it cheaper compare to drilling. Besides that, according to Bradshaw and Thompson (1979), the sampling of soils lead to an accurate results compare to drilling.

All types of elements will undergo different sedimentary cycle, however the cycles are mainly consisting of solution phase (related to water) and rock phase (sediment). On the other hand, the weathered minerals will deposit as sediment and rocks and then continue to be weathered and recycled. Most studies especially in geology concerned a clear and precise morphological basis (Lastochkin, Zhirov, Boltramovich, 2018). This means that, the morphology of a certain place does play an important role on the biogeochemical cycles.

The study area located at Ulu Sokor, Tanah Merah which is well-known for gold mining. Since the earliest of time, gold had been well known for its precious properties. Gold is a renown and the most valuable minerals that had been mined since the ancient time for jewelry production but nowadays due to its physical characteristic such as ductility, high resistance towards the corrosion and conductivity leads to high demand of exploitation of this mineral. Thus, detailed study of biogeochemistry of gold between the interaction of plant and soils helps in understanding more on the location of deposition of gold in study area and the behavior of the gold dispersion in the environment. Thus, the sampling of both plant and soils and indicating of anomalies occurred at the study area can be predicted. This method, which involved the chemical analysis of vegetation, has started its ways until these modern days (Brooks, 1979). Thus, by applying this method, the finding of the presence of gold minerals and the indicator mineral of gold presence can be obtain. It is not uncommon that the biological methods had been used for more than a decade in other country, however, the method of minerals exploration using biogeochemical method is not quiet diverse in Malaysia.

This research may help in improving an innovative way in exploring the gold mineral as well as the other minerals that associated with the gold. By applying this method, it may help in reducing the cost of exploration thus lead to a productive way in exploring the gold mineral without affecting the environment. Ulu Sokor, Tanah Merah is actually located at the Central Belt Gold of Peninsular Malaysia which is known with gold deposit. Since it is known for its production of gold mineral, there are a few of mining company. One of them is a China company, China Nonferrous Metal Mining (Group) Co. Ltd (CNMC) that held about 81% of the mining industry in Ulu Sokor. In 2010, the company make a collaboration with Kelstone Sdn Bhd in purpose on producing the gold bars. Furthermore, the company not only exploiting and mining gold minerals but also silver and base metals. Approximately, the coverage area of the exploration my by the company is 10 km^2 in the Ulu Sokor area of Tanah Merah.

Determining the type of species of plants and soil characteristics before starting the mapping and sampling gives an insight on what type of plant that act as an hyperaccumulator elements for gold minerals. Sampling of indicator plants and soils and mapping the study area were conducted for the geological purpose. The geological mapping is done for geomorphology and lithology of the study area. The soil taken for sampling near surface is from 10 to 20 cm depth while for plan soils, stems, roots and leaves altogether are able to accumulate the Au. The samples of plants and soils were taken for laboratory analysis as plants sample were analyze by Atomic Absorption Spectrometry (AAS) and while soils sample were analyze by X-Ray Fluorescence and Atomic Absorption Spectrometry. The result of the data analysis were then tabulated for determining the presence of gold and the indicator minerals. This can be done by comparing the elements content in both plant and soils based on the results. Finally, map of elements distribution were constructed.

This study were conducted in order to helps in the meantime, collecting and gathering the geological information also helps in solving the geological problems. Besides that, it also as an indicator in diversify the method in exploring the potential minerals especially gold minerals and pathfinder minerals for gold in Malaysia since it is an economic way rather than drilling. The determination of the concentration pathfinder minerals may lead to the high percentage in locating the gold mineral.

1.2 Problem Statement

The study of biogeochemical was mainly focused in Ulu Sokor, Tanah Merah, Kelantan. According to Mcinnes et al in 1996, biogeochemical methods have been widely used for mineral exploration, particularly in boreal forests and semi-arid regions, but there have been fewer applications in tropical areas. In Malaysia, the exploration of gold is not widely used. The study was conducted to survey the possibilities of a biogeochemical anomaly for mineralization of gold in some areas in Ulu Sokor, Tanah Merah, Kelantan. By applying biogeochemical method, plants and soils acted as an indicator to study the presence of the type of minerals in the study area through the method of random sampling.

There were a few study were conducted for the past year about Ulu Sokor, Tanah Merah, Kelantan may not be enough for the explanation of resources in study area. This for sure helps in understanding more of the relationship between the biotic and abiotic on Earth through the study of mineralogical view. By applying the biogeochemical method, the study was conducted by taking the sample of soils and plants at the study area, in which researcher had to tested the plant and the soil at the box given for research study. Based on Havlin et al. in 2005, they said that 17 with 4 additional elements are necessary for the completion of plants' life cycle. The constituent of the soils is mainly consisting of minerals, which gives a direct or indirect influence in plants (Singh and Schulze, 2015). Thus, by studying both of minerals that exist in plants and soil, it helps in understanding the influence of the nutrient elements or minerals existed in the soils to the plants, determining the presence of indicator elements, which then lead to the discovery of gold elements in the study area.

1.3 Objectives

The objectives of this research are as follows:

i. To produce geological map at the scale of 1:25 000 for study area in Ulu Sokor, Tanah Merah, Kelantan.

ii. To determine the concentration of pathfinder elements for gold in plants and soils within the study area.

1.4 Study Area

Malaysia is blessed with attractive geological landforms/landscapes, unique geological phenomena and valuable earth materials, including of hills, caves, rivers, waterfalls, cascades, the hot spring and gold deposits. This project presents the new inventory of applying the biogeochemistry cycle in the study area for the determination of the presence of selected minerals. In this study, the specification of finding the minerals were gold minerals and the pathfinder elements of gold at Ulu Sokor, Tanah Merah, Kelantan. There is a unique and rare geological phenomenon in the district of Sokor, Tanah Merah, Kelantan.

Figure 1.1: Map of East and West Malaysia. (Retrieved 31 March 2018 from https://www.pinterest.com/)

Figure 1.2: Administrative map of Kelantan. (Retrieved 31 march 2018 from http://www.ptg.kelantan.gov.my/)

1.4.1 Location

Malaysia has 13 states including the states in Peninsular Malaysia and Sabah and Sarawak state. In this study, the research were conducted at the Kelantan state. Kelantan is located on the west Peninsular and bordered with Thailand on the north side. Tanah Merah is situated at the central part of Kelantan and approximately 35km southwest from Tanah Merah, at the coordinate 5° 35' North, 102° 0' East. This district is approximately 87,153 hectare and consists of 4 sub-districts: Kusial, Uu Kusial, Jedok, and Sokor.

1.4.2 Demography

In 2010, there are approximately 103,487 people which is 8% of Kelantan population. Table 1 shows the population by gender in Tanah Merah, Kelantan while Table 2 shows the population by race in Tanah Merah, Kelantan.

Table 1.1: Population by Gender in Tanah Merah, Kelantan.

Gender (C 2010)	
Males	58,892
Females	57,057

Sources: Jabatan Perangkaan Negeri Kelantan Anggaran, 2000.

Table 1.2: Population by Race in Tanah Merah, Kelantan

Bangsa	Bil. Orang	Peratus
Melayu	97278	94.00
Cina	4140	4.00
India	1035	1.00
Lain-lain kaum	1034	1.00
Jumlah	**103487**	**100.00**

Sources: Jabatan Perangkaan Negeri Kelantan Anggaran. 2000.

1.4.3 Rainfall

Tanah Merah, Kelantan is a district that have a tropical climate. It has the second highest percentage of number of rainfall in Kelantan. This is due to its location which is the near Jeli, Kelantan. The average temperature of this area is 26.7 °C. About 2562 mm of rainfall per year. Figure 3 shows the temperature of Tanah Merah, Kelantan per year while figure 4 below shows the rainfall of Jeli Kelantan per year.

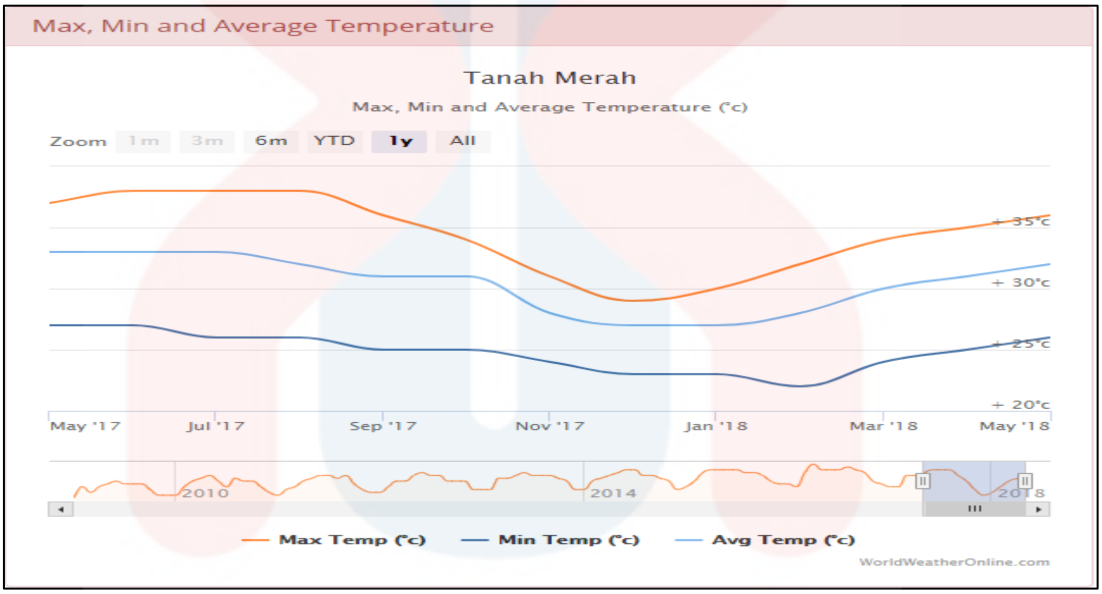


Figure 1.3: The average temperature in Tanah Merah, Kelantan.

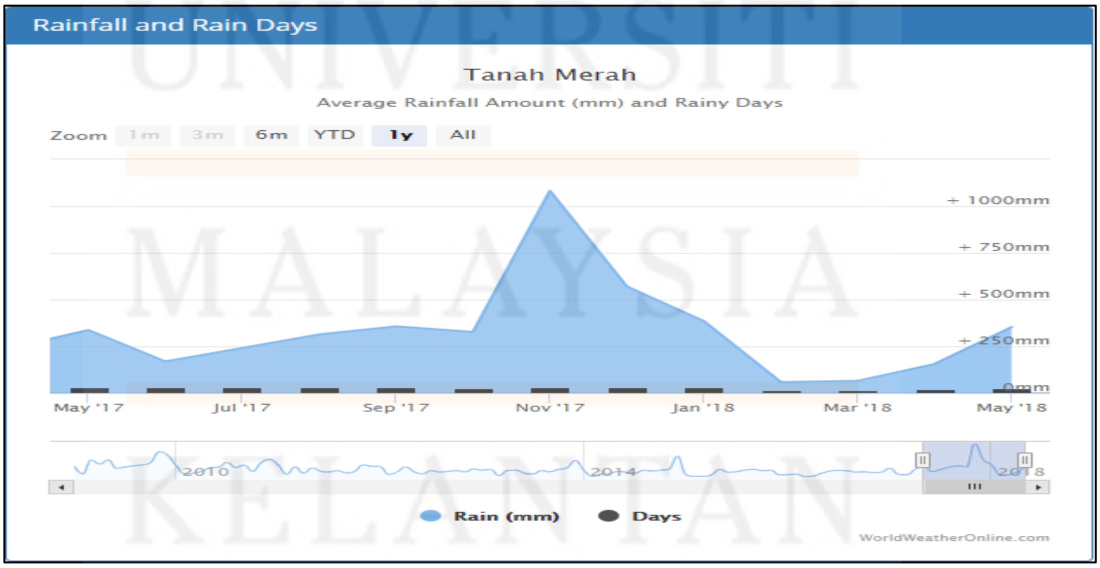


Figure 1.4: The average rainfall in Tanah Merah, Kelantan per month.

1.4.4 Landuse

Land use change pattern can be obtained via spatial analysis using Geographical Information System (GIS) and acquiring satellite imagery in remote sensing. a decrease in forest area, increase in agricultural area as well as urban development. A drastic drop in the virgin forest has also been detected as exploitation of this natural resources takes place upon development and improvement of infrastructure and utilities in Tanah Merah. The highest dropped in forest area was in 2004 with a decrease of -0.76% from the year before.

1.4.5 Social Economy

Economic activity for the Tanah Merah focused on the agricultural sector of the rubber. Basic infrastructure and social amenities provided, paled in comparison to other regions in the state. This impacted the socio-economic development here due to problems with transportation, lack of water and electricity supply, services, healthcare and education.

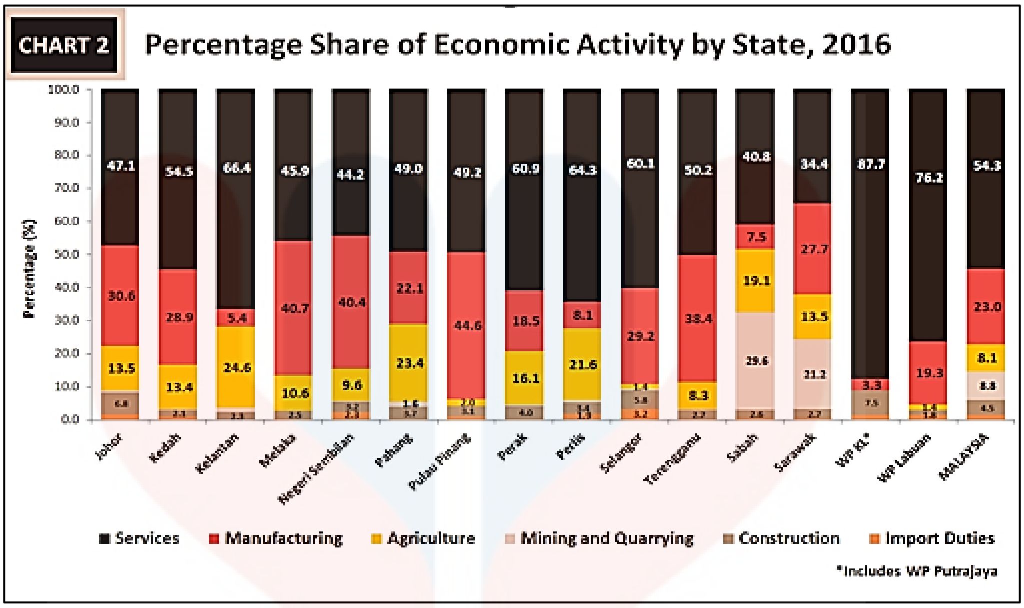


Figure 1.5: Economy of States in Malaysia. (Retrieved from https://www.citypopulation.de/php/malaysia-admin.php?adm1id=03)

Illegal immigrants from Thailand is to make a living by tapping rubber in gardens belonging to residents in Jeli and create other jobs. It's a bit much to move the economy in Tanah Merah, Kelantan. Negative impact is the entry will cause crime like theft, murder, smuggling and trafficking of drugs as a horse pill.

1.4.6 Road Connection/ Accessibility

To access the Tanah Merah district, there are three main entrance. People come from Southern part will come to the Eastern part of Malaysia. There are three entrances to reach Jeli, which are:

a) From the west via the Grik.

b) Railway from Kuala Lumpur, Gemas and Singapore.

c) From the south via Mempelam, Jelawang in Kuala Krai.

Tanah Merah can be access easily by cars or motorcycles, however in order to reach the research mapping box, four wheel drive are needed since the area is quite a remote area. Although there are a few mining located inside the Sokor, however the development in terms of population and infrastructure is still low.

1.5 Scope Of Study

This research includes several studies in geomorphological and biogeochemical of Sokor, Tanah Merah, Kelantan. It includes the geomorphology of study area, its stratigraphical characteristics and also including the structure that formed in the study area. Then, by specifying the study, using biogeochemical method plants and soils will be sampled to helps in identify and finding the mineral that may exist in the study area.

This study is conducted by using topographic maps which created and updated using base maps, Brunton compass, ArcGIS 10 software, Garmin Geographic Positioning System (GPS), geological hammer, field notebook, hand lens, measuring tapes, sample bags, Hydrochloric acid (HCL) and field camera, stationary and safety clothing. Data collected on field will be recorded and analyzed by using appropriate method. The samples are needed including rocks, soils and plants. The rocks will be used for petrographic analysis while soils and plants sample for Atomic Absorption Spectrometry and X-ray Power Diffraction will be used for identifying the minerals content in the area of study.

1.6 Research Importance

This study is being useful in updating and providing a geological map while for the specification is the study of minerals using the method of biogeochemistry. Collecting and gathering geological information of the study area could aid in solving geologic problems and provide sufficient information for researchers in the present and the future. Aim of the study is to provide the recent and improved the previous about the study area, which is Mukim Bunga Tanjung, Kuala Balah, Jeli, Kelantan. Although some area of Jeli, Kelantan had been discovered since this recent years, more geological investigation continue lead to many important discoveries. It allows both natural and features to be captured in realistic and neat way that can be understood by all the readers. The main advantage of this study is to understand more about the cycles in the study area. Since Jeli, Kelantan had a previous studies about the finding of heavy minerals especially gold minerals. Finally, the study is been conducted to in hope of further emphasizing the mineralogical evidence that exist in Kelantan.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Before starting the research project, a brief and measured preparation are really required to show the flow of work is followed as being planned. An intense and thorough study is significant to increase and enhance the knowledge of the research project. Diverse reading and searching from books, journals, theories, internet and such may help in generating the idea on constructing the methodology and workflows.

2.2 Regional Geology and Tectonic Setting Of Kelantan

During the Paleozoic until Mesozoic era, development of the land mass of Peninsular Malaysia was formed by at least four tectonic activities. This activity is vigorously happened during Triassic period as the main cause of it happened due to the compressional force that lead to faulting and folding (Source: Quarry Resource Planning for The State of Kelantan report, JMG:2013).

According to Hutchison and Tan (2009), Kelantan landmass formation can be split into three Era which were Paleozoic, Mesozoic and Cenozoic, at range of Lower Paleozoic until Quaternary period. Four microplates which are East Malay Plate, Western Malay Plate, South China Sea Plate and Natuna Ocean Plate all together create the landmass Kelantan. At Silurian period around 410 to 440 million years ago, the earliest deposition of sediment was found at the edge of Western Malay Plate, below the ocean. The changes in physical and chemical characteristic leads to the formation of mudstone (shale) graptholith, chert quartzite, intraformation conglomerate and limestone. Nowadays, these rocks are known as Bentong Formation. These sediments also deposited at Pahang, Negeri Sembilan and Melaka.

Mostly at the central of north-south portion, the rock that dominated in Kelantan are sediments and meta-sediment rock. On the other hand, based on Ghani (2013), plutonic rocks in Kelantan consist of Eastern Belt and Cretaceous plutonic rocks. This rock was being dated at the range of Permian to Triassic period with the composition of Silica (SiO_2) in between 50% to 78%. Stong Complex have the Cretaceous granites that aged around 96 to 60 Ma (Bignell and Snelling, 1997; Darbyshire,1998).

The sediments and volcanic depositional activities were ended during Carboniferous period and during Permian period, subduction zones were formed due to the movement of South China Sea block underneath the East Malaya block. These create the igneous batholith on the Western Range of eastern Kelantan. Ending of these activity at Upper Permian, expansion zone was created as the subduction activity ended leads to the formation of serpentinite and amphibolite rocks in Bentong Formation.

In Jeli, General rock composition of rock types in Jeli district are Gunong Rabong Formation Triassic sedimentary rocks, including shale, silstone, sandstone, and limestone, Gua Musang Formation Permian sedimentary rocks including phyllite, slate, sandstone and limestone and acid intrusive Granitic rocks with structural pattern of northwest- southeast and northeast-southwest (NW-SE & NE-SW) directions (Department of Minerals and Geoscience, 2003).

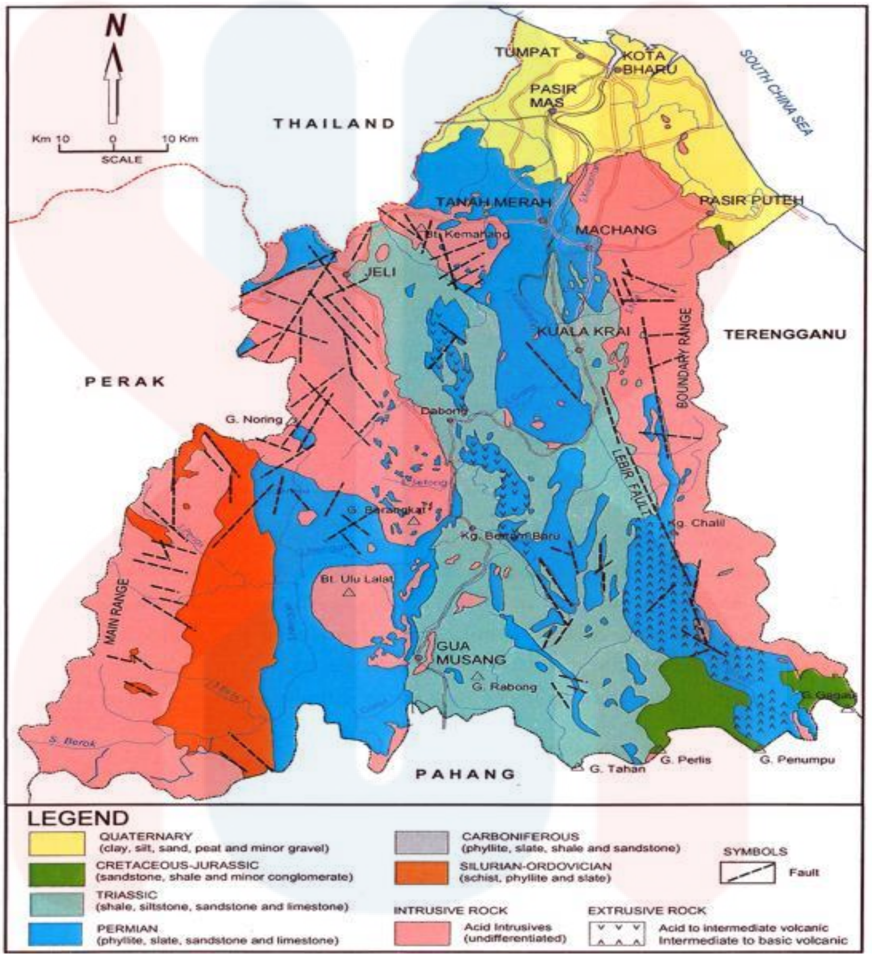


Figure 2.1: Geological Map of Kelantan, (Source: Department of Mineral and Geoscience, 2003).

2.3 Stratigraphy

Kelantan is surrounded by a few states; bordered with Pahang at south, Terengganu at east, Perak at west and different country like Thailand at north-west. From the source of Geology and Mineral Distribution in Kelantan (2000), the higher percentage of rock that distributed mainly in State that located at north-south central area are sediments and meta-sediments around the age of Ordovician to Cretaceous period. These rocks are bordered with main and boundary range granites on both east and west side. Since the north-south of Kelantan is consisting of igneous, sedimentary and metamorphic rocks, the type of rocks are typically granitic rocks, volcanic rocks, sedimentary or metasedimentary and unconsolidated rocks (Hashim, Pour and Misbari, 2017).

The stratigraphy of the study area comprises of Taku Schist Formation and Telong Formation. Taku Schist was found in the northeast of Peninsular Malaysia is an asymmetrical anticline with eastern limb has steeper dip than the western. It is believe to be in Permo-Triassic recorded by Bignell and Snelling, 1977. Mainly, the Taku Schist composed of pelitic schist of amphibole facies and predominant rock type is quartz-mica schist with subordinate quartz-mica-garnet schist and garnet-mica schist.

Telong Formation dominantly located at the Central Belt elongated from north to south beyond the international border of Thailand to Singapore. Towards the south, deeper marine turbiditic sediment is more dominant which indicate the Telong Formation.

2.4 Pattern In Gold Distribution

In Kelantan, the occurrence of gold mineralization mainly located at the central part of the state. This zone are surrounded by Stong Igneous Complex and Senting Granite on west side while on the east area are bounded by Boundary Range Granite followed by Kemahang Granite in the north. During the formation of Triassic sedimentary rocks, the gold mineralization were rapidly occurred then followed by Permian Metasedimentary rocks. In Peninsular Malaysia, the hydrothermal fluid zone is really important in contributing to the development of gold mainly in Kelantan and Pahang District. This zone formed the Central "Gold" Belt with 20 km width and it is extended from the North part until the South part. Along the North-South trend of the gold belt zone lies many main gold mining district (Richardson, 1939).

According to Jabatan Geoscience dan Mineral in 2013, due to the geological setting and tectonic movement, the mineralization of gold in Central Belt was identified as low mesothermal lode gold deposits. The Gold Belt with 20 km wide of North – South trend are Ulu Sokor – Sungai Sok – Katok Batu – Pulai for Kelantan state while for Pahang are Raub – Kuala Meding – Lipis – Merapoh. Based on Figure 5 below, it can be seen that most of the gold occurrence are located from Kelantan and Pahang state.

Figure 2.2: Central Mineral Gold Belt Of Peninsular Malaysia With Major Gold Bearing Deposits. (Retrieved from Mesothermal Lode Gold Deposit Central Belt Peninsular Malaysia. Earth Sciences, 2012)

Based on Ariffin and Hewson, typically, the mineralization of gold occurs at the skarn, system of quartz veins and volcanogenic massive sulphides. Goh et al. in

2006 claimed that the mineralization of gold could be divided into five zones based on their geological setting, geochemical data and ore deposits. They are zone of hydrothermal veins of gold mineralization, hydrothermal veins of gold-silver-mercury zone, volcanic eruption zone associated with gold-base metal vein, silver-lead-zinc zone and lastly base metal-gold zone.

In Central Belt of Malaysia, the magmatism is distinctly uncommon and consist of a series of alkali range from Gabbro-Diorite at approximately 157 Ma, Monzonite at approximately 163 Ma to Quartz Syenite at approximately 127 Ma until granodiorites and granite (calcium alkali series) (Hutchison et al, 2009).

2.5 Gold Occurence

Based on Ariffin and Hewson (2007), they stated that mineralization and gold occurrence in Malaysia are primarily from Permo-Triassic age origin from deep to shallow marine sediments. It is also a formation of acid volcanic and volcaniclastic, which range from andesite to rhyolite. In Malaysia, the stratigraphy are belong to Bentong – Raub group. In Ulu Sokor area, the gold occurrence is Rixen deposit. It is located on the Northern part of Central Belt in Peninsular Malaysia. These regional structures (Bentong – Raub Suture Zone) control the gold mineralization.

Chong and Abdul Aziz (2009) conclude that the composition of Rixen deposit is a calc-alkali series granitic rocks, a series of aluminium oversaturated volcanic rock and high in large ionic lithophile elements (LILE) and slightly of Light Rare Earth Elements (LREE)

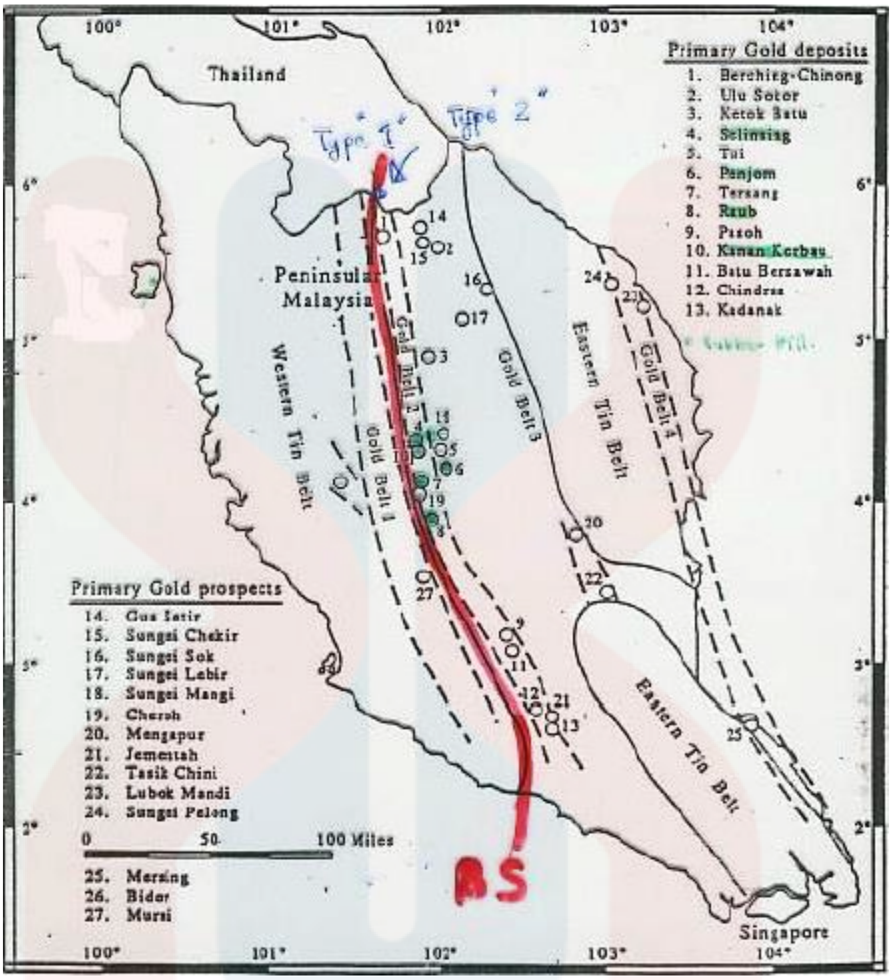


Figure 2.3: Central Belt of Peninsular Malaysia. (Retrieved at Gold-Related Sulfide Mineralization and Ore Genesis of the Penjom Gold Deposit, Pahang, Malaysia. Resource Geology, 2007).

Based on figure above, Ulu Sokor is located on the type I in Central Belt of Peninsular Malaysia consist of significant large vein traversing granite and metasediment. Gold Belt type I is known as Gold Chemical Zone. Although the zone shows the high anomalies of gold, but it also shows the highest anomalies of Aurum (Au), Lead (Pb), Copper (Cu) and Zinc (Zinc) in the stream sediments. Whereas Gold Belt type II bounded to gold disseminated within a stockwork of quartz veins affiliated with intrusive bodies and volcanogenic exhalative sulphides within a shear zone system (Shah, 2012).

2.6 Geochemistry Of Soil

Based on Lim and Samah (2004), the soil formation in Malaysia was triggered by Malaysia's temperature and climate itself. Grains or minerals that form the sediments and rocks actually gives the insights the presence and location of the type of mineralization occurs in the specific area. According to Padhy (2017), the study of the geochemistry of soil are important in the exploration of minerals such as gold, diamond, copper, etc. and is being done by the investigation sediments through geochemical test or visual inspection. Girling and Peterson in 1980 said that Arsenic, Ar acted as the mineral indicator for the presence of gold deposition in an area.

Dunn in 2010 claimed that soils are not only important in supporting the diversity of organisms in this earth, but in other perspective which involved in the cycle of main global biogeochemistry (carbon, nutrient, and water). Eash et al. (2008) claimed that even though the soil characteristic was distinguished based on its parent rock, actually, the soils is not only just a weathered rocks. They also stated that the constitution of soils formed is strongly influenced by the minerals that exist in the rocks. Simple, inorganic and ionic nutrients required by plants. Thus, mineralization process is important in changing the immobilized nutrients by microbial decomposers to simple and inorganic forms (Plaster, 2003).

Moody (2008) stated that the colour of soils as so-called black sand also gives the indication of the presence of heavy metal. Thus, soil sampling is performed to interpret the location and shape of an unknown mineralization and identify a better section within the area and this means that the results of soil sampling is much more accurate compare to drilling. Early research that had been conducted in the exploration of minerals using the application of geochemistry of soils lead to the revelation of the relationship between geochemistry of soil residue and the underlying bedrocks (Tooms and Webb, 1961; Cornwall, 1970; Ellis and McGregor, 1967; Philpot, 1975; Reedman, 1974). Mazzuchelli in 1996 said that it is very effective to make sampling near the surface of soils in an investigation area which a complete laterite profile has been preserved.

2.7 Biogeochemistry

Biogeochemical method is famous to apply in ecological modelling and was famous since 1970 (Jorgensen, 2016). It helps in controlling, furnishing, and aiding the ecosystems services (Smith et al., 2015). The biogeochemical method is important in understanding the relationship between the plant and it geological environment. Biogeochemical method can be carried out effectively on the surface expression that shows the poor mineralization (Eppinger, Closs, Meier and Motooka, 1991). Biogeochemical method is useful for the application in plants cyles and soils nutrient distribution (Jobba´gy and Jackson, 2001). Based on Raines and Canney (1980), the prospect of biogeochemistry is classified into three theoretical approaches as below:

1. The analysis of plant communities.
2. The examination of vegetation density.
3. The surveying of plant morphology.

Several plants that associated with mineral deposits have been identified (Smith et al., 2015, Dolbeare, 2014). In the assessment, three methods to identify types of elements exist in the study area through plant are as following:

1. Mapping of indicator plant
2. Physiology and appearance of plant

3. Chemical testing

Iron, manganese, zinc, phosphorus, calcium, and copper at certain concentrations can produce chlorosis in plants—a yellowing of the leaves due to hindrance of the photosynthetic process. Figure 2.4 shows the type of plants that had been use for geobotanical analysis. The entire essential nutrient, including micro and macro elements consumed by the plant for its continuous growth and reproduction. According to Girling and Peterson in 1980, the type of minerals uptake by the plants were actually determined by its species in which the plants favour to accumulate it also through soils, their rates of growing and factors that came from their surroundings.

Dunn (2010) stated that the elongated and extension of the plant's root lead to the high rate of absorption of nutrient needed by the plants for growth and reproduction. The uptake of minerals gives the insight of the sediment and groundwater and thus this gives the better representation of the geochemical environments rather than other media. Indicator plant is a species that tends to exhibit a certain type of mineralization, rock types or specific content of substrate. It can be divided into two types, local indicator; plant that can be found locally in that area and universal indicator; plant that can be used whenever it had been found (Kelepertsis and Andrulakis, 1983).

Table 2.1: Plant indicators of Aurum, Au in Central Kapuas Gold Mining Region

No	**Local names**	**Scientific names**	**Famili**	**Habitat**
1	Kapur naga	*Calophyllum hosei* Ridl	Clusiaceae	Peat soils
2	Katumbu	*Dillenia excelsa* Gilg	Dilleniaceae	Hill, with the sandy soil characteristics
3	Karuing	*Dipterocarpus crinitus Dyer*	Dipterocarpaceae	Heath forest, sandy peat soil
4	Katune	*Agrostistachys sessilifolia* (Kurz) Pax&Hoffm	Euphorbiaceae	Hills, sandy peat soil

5	Pelawan	*Tristania merguensis (Griff)*	Myrtaceae	Heath forest, sandy peat soil
6	Galam tikus	*Melaleuca soulatrii L.*	Myrtaceae	Heath forest, sandy peat soil
7	Katiau	*Shorea maxwelliana* King	Dipterocarpaceae	Little watery peat soil
8	Rangas	*Gluta renghas L.*	Anacardiaceae	peat soil
9	Kayu lalas	*Syzygium zeylanicum* (L.) DC	Myrtaceae	Hills, sandy soil
10	Tumih	*Combretocarpus rotundatus* Miq	Anisophylleaceae	sandy peat soil
11	Kayu emas	*Memecylon myrsinoides* Blume	Melastomataceae	sandy peat soil

(Sources: Sunariyati, S., 2013)

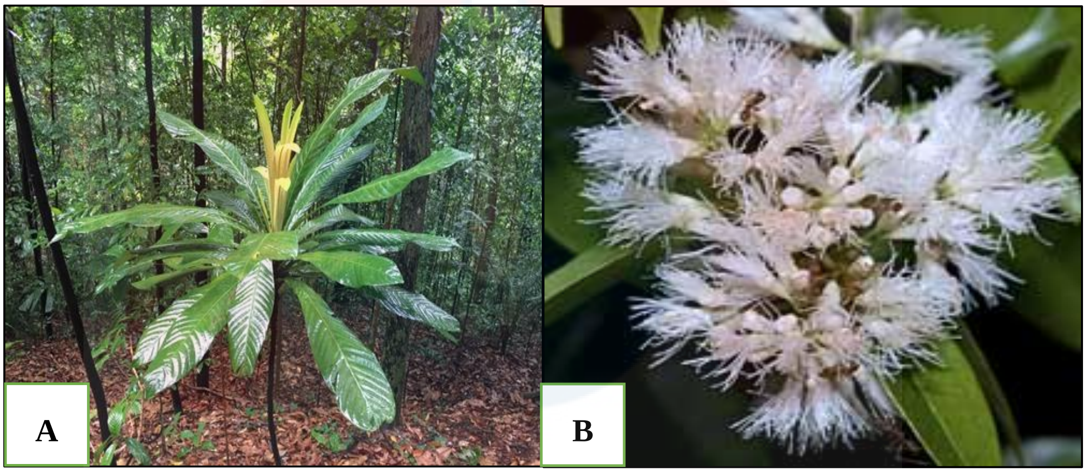


Figure 2.4: Hyperaccumulator plant based on table 2.1 (A) *Agrostistachys sessilifolia*, (B) *Syzygium zeylanicum*.

CHAPTER 3

MATERIALS AND METHODS

3.1 Methodology

Figure 3.1 illustrate the flowchart of geology and preliminary study of gold deposit using biogeochemistry in Ulu Sokor, Tanah Merah, Kelantan.

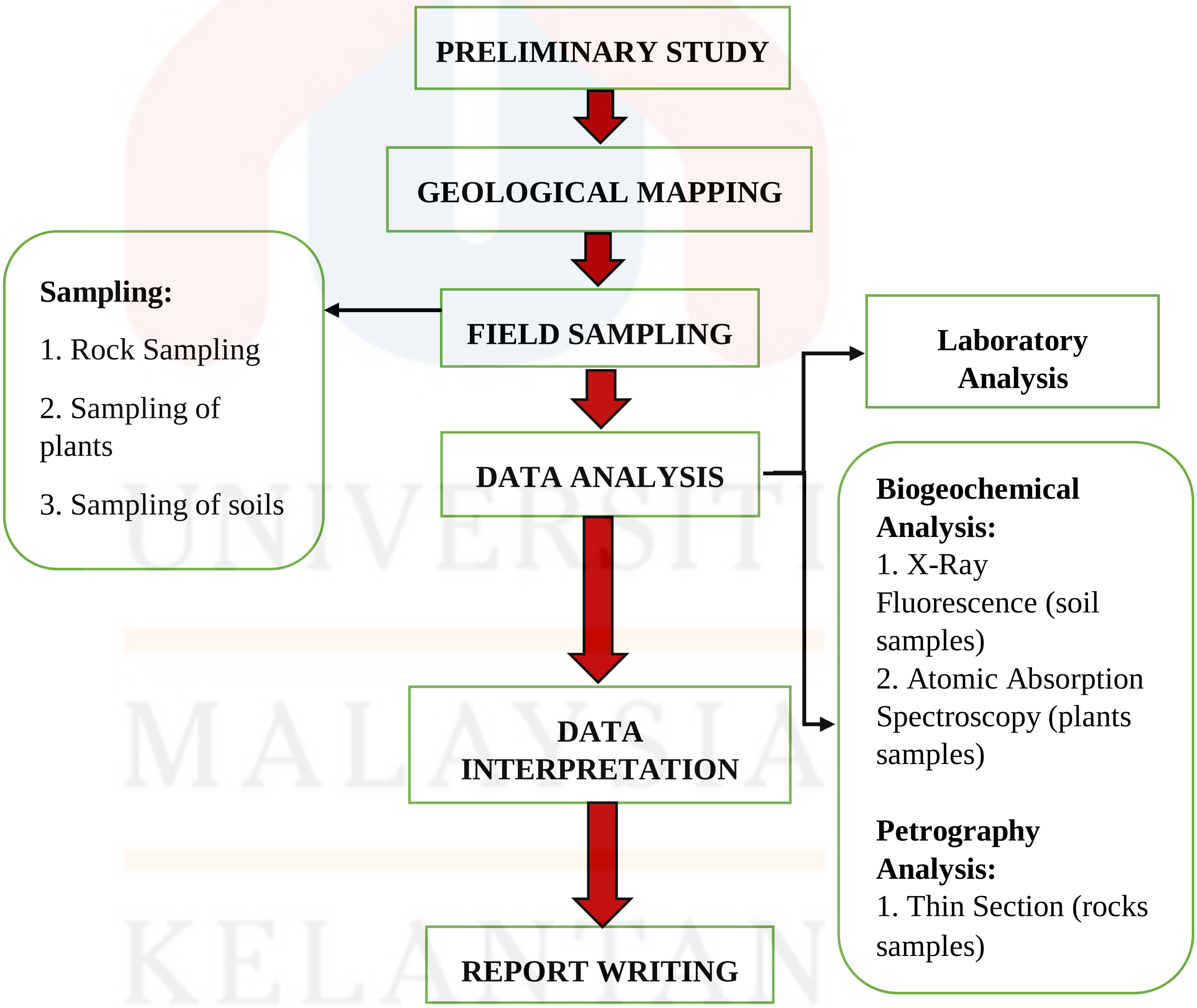


Figure 3.1: Flowchart of geology and preliminary study of gold deposit using biogeochemistry in Ulu Sokor, Tanah Merah, Kelantan.

3.1.1 Preliminary Study

Preliminary research includes primary data collection. Preliminary studies in Sokor, Tanah Merah had been done by some UMK students, Department of Mineral and Geoscience and researchers from other country. Generally, it is conducted in order to review the study area and other information for the research. Desktop study for the background of study area needs to be done using previous geological reports, journals, dissertation and books related to geology and tourism. This study is conducted to focus on biological, geological and chemical observation and the type of plants, soils and rocks especially in their gold content.

3.1.2 Geological mapping

During the mapping, the criteria that consider are the geomorphology of the study area, structural and stratigraphical evidence of the area. These data is obtained from the obtaining, marking of the samples, giving the overview of the origin of the study area, measuring, and recording the features of mapping area. This information is important for the construction of geological map. The mapping was conducted by entering the mapping box and taking the soil and plant samples for laboratory used and experiments. Materials during the mapping process include hammer, Hydrochloric acid HCl, plastic samples, compass, base map, measuring tape, hand lens and proper clothes for mapping.

<u>Constructing the Base Map using ArcGis 10.5</u>

A base map will be constructed with ArcGis for the purpose of mapping. The map was produced based on the data from the satellite previous information. Base map helps in giving a proper direction and coordinate of our location. The box area given for conducting the mapping is 5x5 kilometer and he area of study is Sokor, Tanah Merah, Kelantan.

<u>Geological Surveying</u>

Surveying and examining the geomorphology of the study area, stratigraphical evidence and geological structures that present in the study area. The aid of materials and apparatus such as GPS, compass etc., helps in constructing the geological map. The geological survey is really important in gathering the information about geomorphology, distribution of rocks, depositional environments and lithostratigraphy of the study area. These information are then will be recorded, tabulate and transfer into Arcgis for geological mapping and interpretation. Besides that, soil and plant sample also were taken for further laboratory analysis. Plants and soils sample were selected based on the station of mapping. Lastly, a final geological map, geochemical map and soil map.

3.1.3 Field Sampling

A uniform random (UR) sampling is a procedure in picking out a sample that have an equal probability to choose. It can be carry out through Simple Random Sampling (SR) and Systematic Random Sampling (SUR). In this research, a stratified cluster sampling, which is one of the variation of random sampling.

It is easy to apply the cluster sampling when sampling a large or complex populations. This can be performing by dividing the population into a measurable sample or clusters. While for stratified sampling, the population is divided into subsets or strata that is not overlapping and the layer or stratum will be interpret differently for sampling purpose. Each of the stratum will represent different sample which can be its morphology, biogeographical areas soil horizons, soil properties, vegetation indices and etc (Basso et al., 2001; Bramley and Hamilton, 2004; Bramley, 2005; Taylor, 2004). Below shows on how the combination of sampling for both stratified and cluster. w

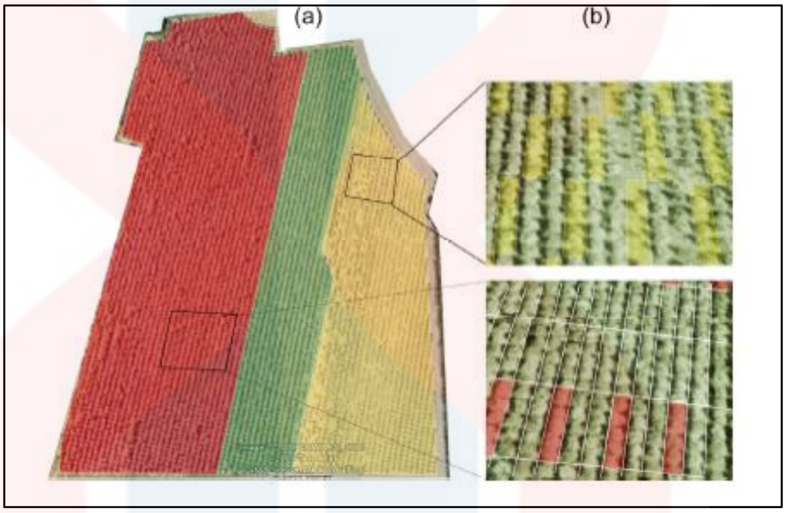


Figure 3.2: (a) Stratified sampling and (b) cluster sampling.

3.1.4 Laboratory Analysis

After completing the samples that had been taken from the field, the next stage will be the laboratory analysis of the samples. The application of biogeochemical method in determining the elements that exist in the study area will be continue by using the special instruments. The samples, which are rocks, plants and soils are then handled for different type of detector.

3.1.4.1 Petrography

In petrography and optical mineralogy, the rocks, minerals, soils, metals etc. samples will undergo the laboratory preparation, which called thin section. This is important for the analysis of petrography and mineralogy of the samples by using polarizing petrographic microscope, electron microscope and electron microprobe. In this case, the optical microscope to see the optical properties of minerals. In addition, the type of minerals can be identified and determined for petrography analysis. The rock samples will be needed to undergo thin section process so that it can be analyzed under microscope.

Thin Section Preparation

The rock sample will prepared by cutting the rock into small pieces with cutting machine. The cutted rock is then treated with polishing powder to polish the rocks. The rock is then thinned by specific method of thin section and treated for slide preparation.

Observation under Microscope

The samples that had been thinned were observed under microscope. The rock is observed in cross-polarized and plane polarized. This helps in the identification of minerals in the rocks. In addition, it is also important to study the morphology, mineralogy and physical characteristics of the rocks.

3.1.4.2 Atomic Absorption Spectrometry (AAS)

For plant samples and soil sample, Atomic Absorption Spectrometry is really suitable for performing on the samples since it is sensitive enough to analyze many types of elements in other geological materials (Belt, 1976). In order to analyze using Atomic Absorption Spectrometry, the samples must be in solution state. Digestion, extraction and preparation of the analytes are really important in sample preparation before the analysis, thus this step is time limiting.

Sample Preparation for Plant

There are three principles objectives of sample preparation, which are dissolution of analytes in suitable solvent, isolation of analytes and pre-concentration. Thus, firstly the plant samples will be dried with the temperature of 80^0C for 24 hours. Then, samples then crushed into pieces and put in the furnace in 550^0C for 9 hours. The plant that had been burned into ashes were undergo dissolution for the use of Atomic Absorption Spectrometry (AAS). About 5 mL of hydrochloric acid (HCl) required to dissolve 1g of plant ashes into conical flask then stir thoroughly for 10 minutes. The solution was then filtered using filter funnel. The filtered solution was poured into a 50 mL Falcon tube and add distilled water until it reached 50 mL and labelled as a stock solution. From stock solution, using glass dropper, 1.5 mL were then put into 15mL falcon tube and labelled as 10^{-1}. Then, take 1.5mL from 10^{-1} solution using dropper and put into another 15 mL falcon tube and labelled as 10^{-2}. The process continued until the solution was 10^{-4}. The solutions were ready for the analysis of Atomic Absorption Spectrometry (AAS).

Sample Preparation for Soil

Soil sample were dried in the oven at 100^0C for 24 hours. The dried soil samples were sieved by suing 75 micron siever. Then, the samples were ready for the sample preparation of Atomic Absorption Spectrometry. Soil samples were diluted using a double acid method. The acid preparation include 31.7% of HCl and 100% of H_2S0_4. Concentrated hydrochloric acid, HCl and concentrated sulphuric acid, H_2S0_4 were poured into 1mL volumetric flask filed with some distilled water to prevent any vigorous chemical reaction occurred. Then, add distilled water until it reached the calibration mark and shake thoroughly to mix the solution. The digestion process was continued by taking 15g of soil sample into conical flask and add 60 ml of acid solution. Stir the solution thoroughly for 10 minutes. Then, the solution was filtered using filter funnel and let the solution filtered. The filtered solution was poured into 50 mL falcon tube and labelled it as stock solution. Take 1.5 mL of stock solution using glass dropper and put into 15 mL falcon tube. Add distilled water until it reached 15mL and labelled it as 10^{-1} solution. The steps was repeated until it reaches the 10^{-4} solution of 15 mL falcon tube. The sample were then ready for the analysis of Atomic Absorption Spectrometry.

3.1.4.3 X-Ray Fluorescence (XRF)

The soil samples were analyzed by using X-Ray Fluorescence, XRF. In order to analyze the soil samples, the suitable instrument was by using the X-ray Fluorescence (XRF). This is because X-ray fluorescence (XRF) is necessary in order to provide the complete information about the major, minor, and trace element thus helps for determining the chemical composition. Since soils, which is a solid sample, is not homogeneous, it requires to prepare the sample properly in order to obtain the best data.

<u>Sample Preparation</u>

The soil samples were dried in oven at 100^0C for 24 hours. Dried soil was grind using pestle and mortar then sieved using 65 micron siever. After that, the powdered soils were placed in the sample cup and then compress it until the powdered samples is packed. By that, it can then be analyze by X-ray Fluorescence (XRF).

3.2 Materials And Apparatus

Table 4 shows the materials and apparatus that will be need during geological mapping:

Table 3.1: Materials and apparatus

Tools/ Materials/ Softwares					
a.	Base maps	h.	Acid bottles	o.	Sulphuric acid
b.	Brunton compass	i.	Field notebook	p.	Filter funnel
c.	Garmin GPS	j.	Field camera	q.	Conical flask
d.	Geological Hammer or chisel	k.	Stationary and safety clothing	r.	Volumetric flask
e.	Hand lens	l.	ArcGIS 10	s.	Plastic tube
f.	Measuring tapes	m	Trace Metal Grade Nitric acid	t.	Falcon tube
g.	Samples bags	n.	Hydrochloric acid	u.	Beaker

3.3 Data Analysis

Analysis of the data will be perform in the form of graph and table through Microsoft Excel 2007. Geological map will be produced by using Arc-GIS 10.3 with the data that obtained from the geological mapping of the study area and the results from Atomic Absorption Spectrometry (AAS) will be present in bar chart and geochemistry map and X-Ray Fluorescence (XRF) will be tabulate and the differentiate based on their location. Thus by comparing the results of plant and soil from data given by Atomic Absorption Spectrometry and X-ray Fluorescence, we will examine whether the minerals content are the same or not.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter will briefly discussed about the General Geology in the study area. These includes the geomorphology, lithostratigraphy, and the structural geology that occurred in Sokor, Tanah Merah, Kelantan. These information are needed to create a one informative geological map and thus helps to interpret the geological history that happened in the study area.

4.1.1 Accessibility

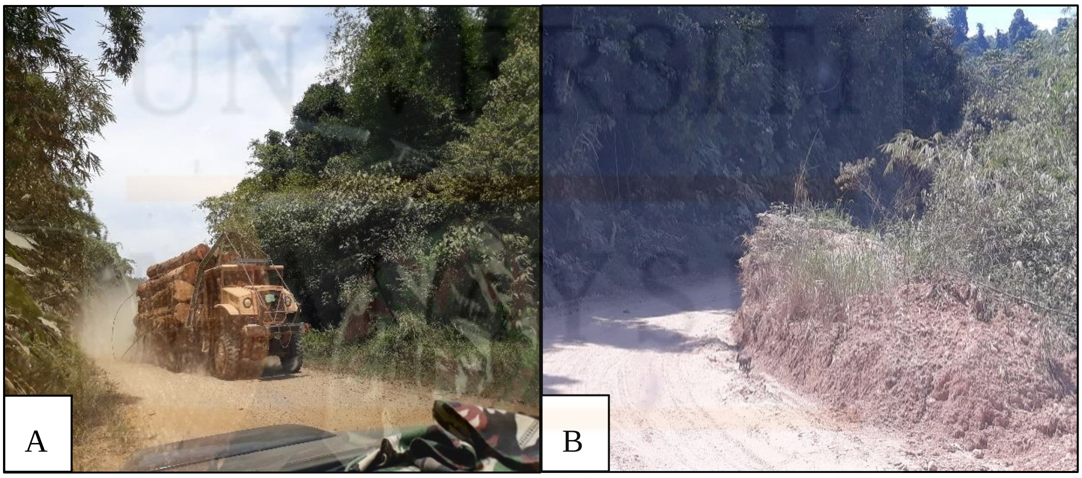


Figure 4.1: (A) The area of dominantly have logging activity (B) Unpaved road with the direction of north to south of the study area.

4.1.2 Settlement

Sokor reserve forest are mainly located in Tanah Merah District. Sokor belong to Mukim Kepala Riga and it is the nearest village with the study area. Since Sokor was well known for its gold belt deposition, the main activity that occurred inside the Sokor is mining. This include the gold mining and iron ore mining. As increased in demand of opening the mining area, this will lead to the logging activities. This either for the clearance of the area of mining or illegal logging which cutting the timber for other purpose. Thus, this cause that 20% of Sokor land is now exposed. In addition, the agriculture and fertilizer company settled inside Sokor and the study area as they planted timbers and such for future watershed and for their own purpose. Basically, the distance between the nearest human settlement with the study area is about 5 km. Therefore, mostly the workers that work inside the reserve forest are villagers.

4.1.3 Vegetation

Based on the map shown below, the study area are majorly covered by thick forest and bushes which is 75% and about 10% contain the valuable timber for logging. Then, another 10% dominated by bamboo whereas, 5% represent the other species of plant such as Melastoma, Mimosa, Syzygium and such in which it located in a certain area. These 10% of plant were used as the indicator plant for the presence of gold and pathfinder elements in the study area. Since the location of the study area is located at the industrial development such as mining and deforestation occurs vigorously, the landscape of the area is changes through time. This lead to the cycle of ecosystem disturbed. For example, increase in exposing an area in which the clearance of plantation such as bamboo will affect the food chain especially for the elephants. Besides, this also lead to the natural disaster such as mass wasting and mudflow.

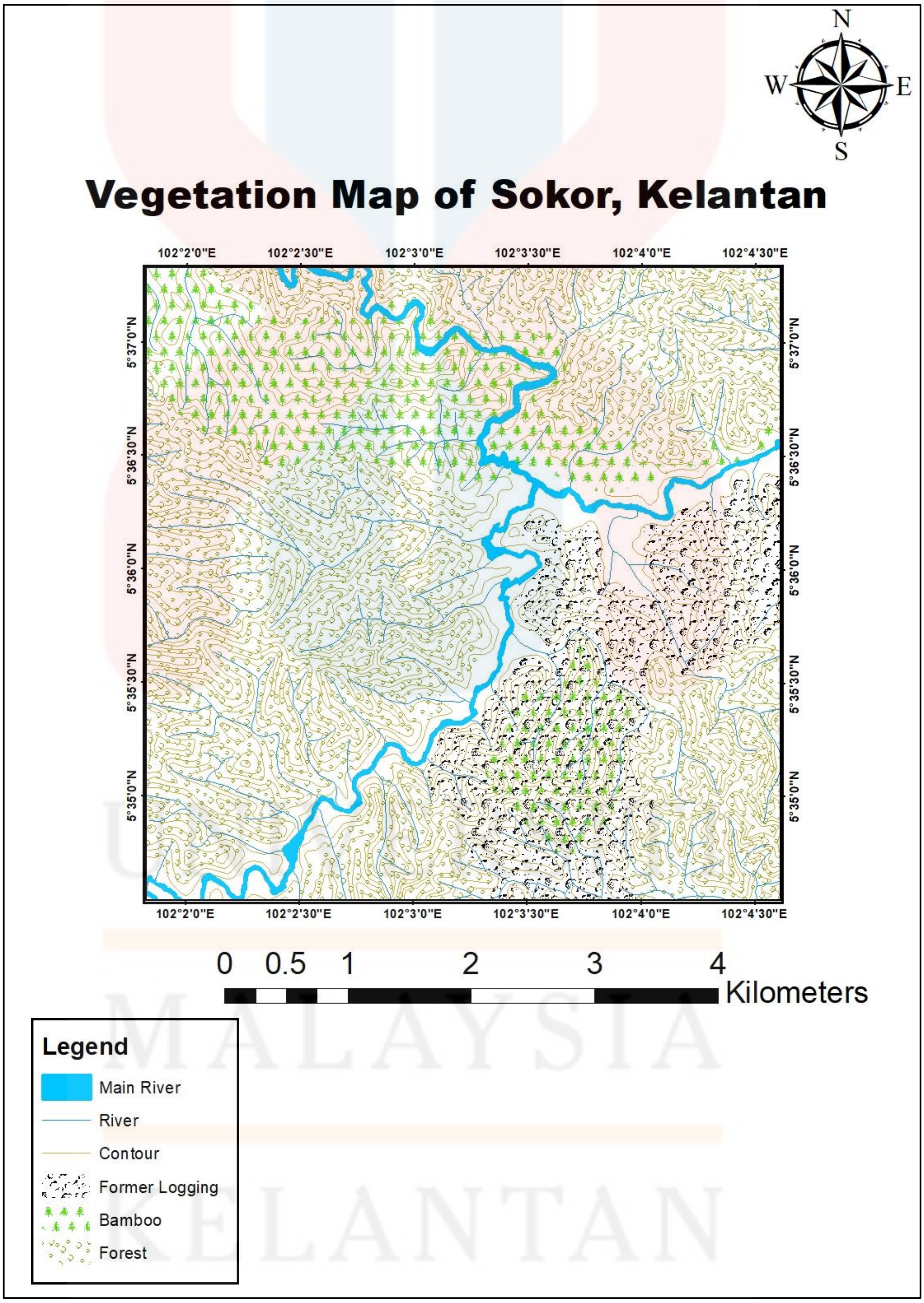


Figure 4.2: Vegetation map (bamboo and forest).

4.1.4 Traverse and Observation

Making a geological traverse is important in collecting the information of the geological occurrence the study area. Since the study area is remoted and isolated from the reach of road, the only way in reaching the mapping box is by walking, driving the four wheel drive or by lorry as the road is unpaved. Referring to the map below, it was divided into 2 parts in which the part were classified based on the accessibility, vegetation, structure that occurred and happen in the area and the plants and soil sample that were taken for the specification requirements.

In part A, this is where the only main entrance of the study area can be reached as it is the only road that can be accessed on the north-west of the mapping box. Based on the map below, mostly the upper part of the mapping box are covered. The only pathway that can be reached is the unpaved road that had been open by the loggers to carry the timbers. The final result of traversing that can be gather is that the common plant that can be observe are bushes, including bamboo. This indicate that the area are elephant habitat as passing through the way, elephant faeces can be found everywhere. Besides, the agriculture activity also occurs in the south part of the mapping box. Also, Bertam River and Sokor Rivr are intersect in the center of the study area. Based on the map, the lithology of part A is the interbedded of Schist, Phyllite and Red Tuff. Schist comes from the Taku Schist Formation while Phyllite and Red Tuff are Telong Formation. Basically, the area are covered with regolith weathered soil and rocks as the rate of weathering is high. In addition, towards the center of the study area, there is a new Gold Mining operated and an ex mining. The small pond, lakes and tailings can be found in the ex mining and majority of the rocks are slate to phyllite.

In part B or the lower part of the study area, it can be reached from the new mining area and it can reach the south west and south east part of the study area. The only main river is Sokor River in which it flows towards the south west of the mapping box. The vegetation that can be found are also resembles with the upper part of study area. However, the more towards downwards the more thicker the forest and bushes. The plants as if Melastoma, Mimosa, Ferns Bamboo and such are also abundant indicating the area are the habitat of wild animals. This pathway are merely for the transport of timbers from the logging activity due to the back and forth of the timber's lorry through the road. Towards the lithology of the rocks, they are mainly interbedded of slate to phyllite, red tuff, mudstone to shale and schist. This gives the hint of the metamorphism occurrence in the study area are vigorous.

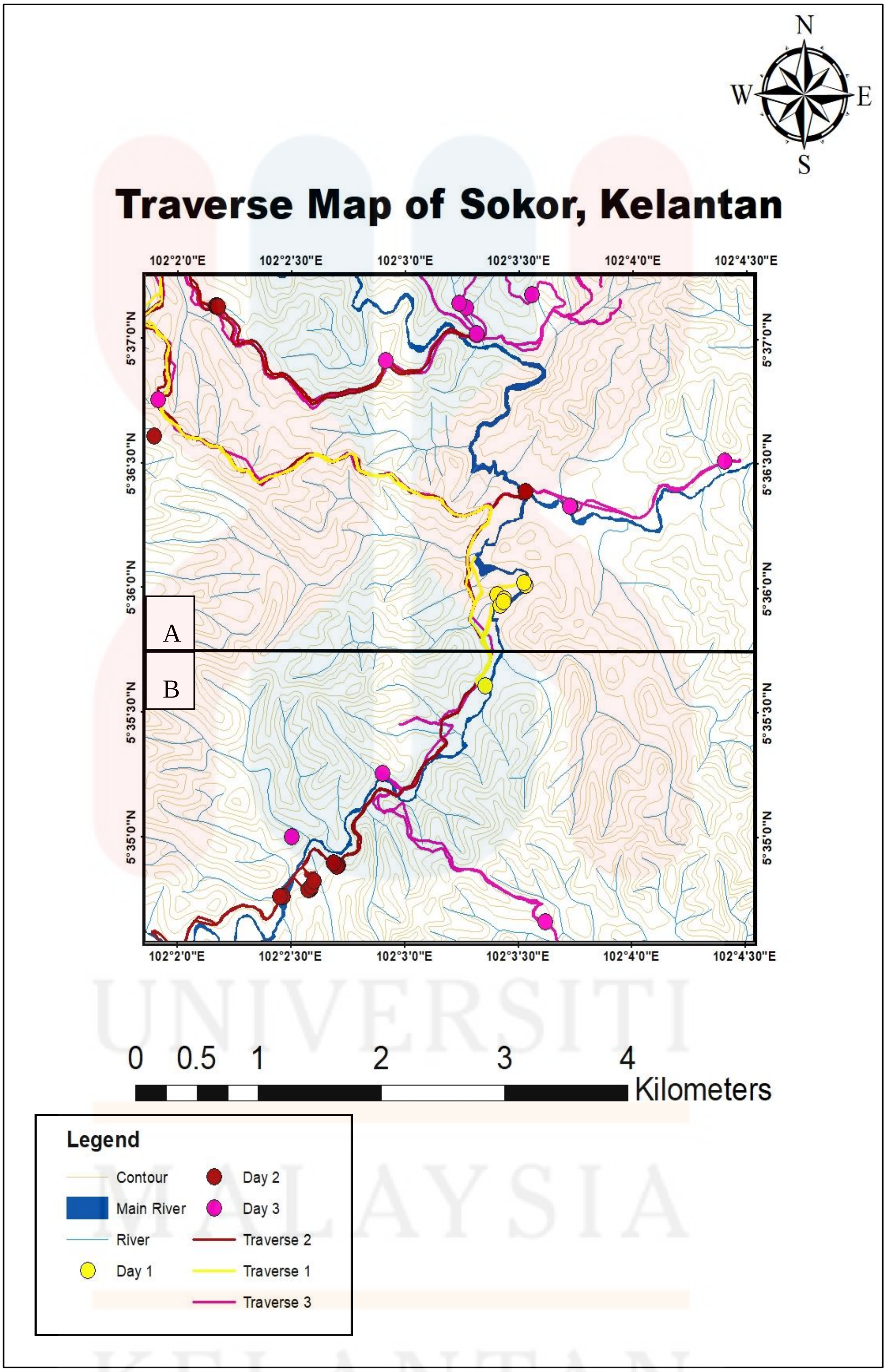


Figure 4.3: Traverse map of study area which located at Sokor in two section, A and B.

4.2 Geomorphology

Geomorphology is the study of the landform that exist in the study area, including the process on how the landform was formed, form and sediments at the surface of the Earth. The observation and study about geomorphology gives the information about physical and structural geology that happen in the study area. the discussion about geomorphology including the geomorphic classification, weathering and drainage pattern.

4.2.1 Geomorphic Classification

Based on the observation and analysis of the study area, the conclusion can be made that Sokor, Tanah Merah mostly have flat to hilly terrain. The geomorphology of the study area mostly covered by thick bushes and few ha been cleared for industrial purpose in which this also effect the shape of the landform.

The range of elevation made through the process of geological mapping, below shows the topographic unit that had been tabulate based on its range of elevation below.

Description	**Elevation (m)**
Flat and low lying	<30
Rolling	31-75
Undulating	76-125

Hilly	126-300
Mountainous	>301

Table 4.1: Topographic unit and its elevation range.

Topographic map shown below gives the view that the study area majorly have rolling and undulating morphology. Then, the second major morphology is flat and low lying area. This is because of the presence of main river. Whereas for the minor topography is hilly with the range of 10% from the study area.

Referring to Figure 4.4, the topographic map show the difference in elevation by the colour represents it. The elevation with 0 to 50 meter indicate the area is flat, low lying and rolling with green in colour. The area has the lowest elevation and sediments are mostly deposited in this area. This is because the area near to the hydrology sources; river. Thus, erosional and deposition vigorously occurred in this range. In addition, this is mainly because transportation through water agent is high thus many sediments that transported from one to another place followed by depositional process is often.

Light to dark yellow shown in the map below indicate that the morphology is rolling and undulating. Most of the landform have gentle slope and thus giving the information of the strength of the soils and rocks. Meanwhile for hilly topography, the colour shown in the map is white. The elevation of the hill is not as high as mountain as the average elevation in the study area is 220m.

Based on Figure 4.4, all of the slope have low relief shows that the topography have gentle slope. The gentle slope means the type of rock is actually sedimentary rocks, the rocks and soil mechanic are low. The mechanical strength of sedimentary rock is low because it easily absorb water, this will lead to the future mass wasting, and indeed, there are few of landslides happen in certain area.

Human activity also contribute in changing the morphology of the study area. For example, ex mining that had been left without special treatment creates an artificial ponds and lakes. Since the exploration of gold mining is digging soils and rocks and stripping the hill, this activity will decrease the strength of the rocks and soils.

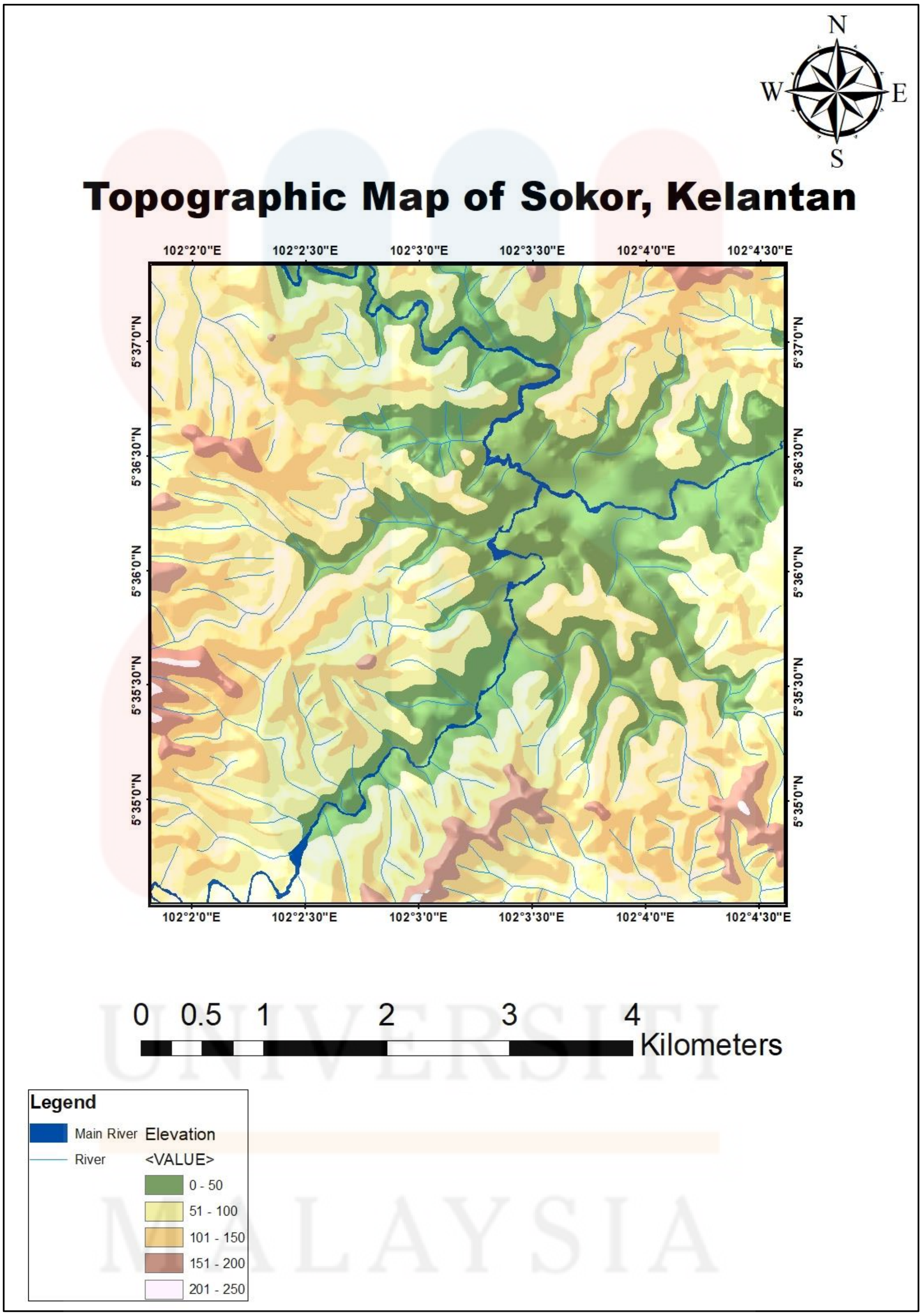


Figure 4.4: Geomorphology classification map of Ulu Sokor, Tanah Merah, Kelantan.

Figure 4.5: Geomorphology view from high elevation.

Figure 4.6: Current mining area.

4.2.2 Weathering

Generally, weathering is the process of breaking down in-situ materials into smaller pieces by the action of agents. The weathering can be distinguish into three types, physical weathering, chemical weathering and biological weathering. In the study area, the rate of weathering can be differ from low to high. Weathering is an important role in giving the view of the geomorphology of the study area as it either contributes the major or minor changer towards the landforms. The weathering process discussed in this chapter include the occurrence of changes the landform of the study area caused by the agent of atmosphere, hydrosphere and lithosphere. From here, the origin of the rocks and morphology of the study area can be describe and discussed.

The rate of weathering in the study area can be rated to low and high weathering. This is due to a several agent that catalyst the weathering process. Low rate of weathering mostly occurred in the area of thick forest. Meanwhile, for the high rate of weathering occurred in the exposed area which had been clear for either mining or due to the logging activity. In addition, the type of weathering that majorly take place in the study area are physical and biological weathering while chemical weathering is minor.

Physical weathering is the process in which the disintegration of in-situ materials into small pieces without altering the chemical composition of the materials from its parent. In addition, this mechanical weathering includes the actions on the rocks by abrasion, freeze thaw, temperature fluctuations and growth of salt crystal. This may cause due to the changes of temperature, pressure and high expose towards the wetness. Physical weathering is the common weathering in our region. Since our country located near the equator, this caused our climate is hot and humid throughout the year thus susceptible for physical weathering. On the other hand, chemical weathering is the erosion or disintegration of in-situ materials and chemical composition of the materials altered due to the chemical reaction occurs during the process. Particularly, the reaction occurs in the acidic area, carbon dioxide, oxygen and requirement of water is high. The process of chemical weathering includes the action of oxidation, hydrolysis and solution. Meanwhile for the biological weathering, this type of weathering is the process in which the disintegration of in-situ materials by the agents of plants, animals and microbes. Generally, this type of weathering can associate with physical and chemical weathering by means the crack of rocks due to physical weathering may lead to the growth of roots of plant inside the rocks.

Figure 4.7: Physical weathering of outcrops.

Figure 4.8: Physical weathering of soils that lead to a gully formation.

4.2.3 Drainage Pattern

In the study area, there are two main river intersect in the center of mapping box. They are Bertam River and Sokor River. Based on Figure 4.9, the small river also created the geomorphology of the stud intersect in the center of mapping box. They are Bertam River and Sokor River. The small river also created the geomorphology of the study area. In this part, the drainage pattern is discussed through the pattern of the rivers. Drainage pattern is created due to the erosional activity that happen through time and thus reveal the characteristic of the types of rocks and the structural geology that takes place in the landform drained by the stream. Stream will flow from the highest to lowest elevation due to the act of gravity.

The pattern of drainage in the mapping box can be divided into three part. They are Rectangular, Trellis and Parallel. The shape of the landform do influence the pattern of drainage. Based on the map below, rectangular pattern is represented by red colour. For rectangular pattern, this type can be distinguish based on its shape, rectangular-like shape. Rectangular pattern always formed on the area that have high fracture bedrocks, for example joint. It is a system of bedding planes and fractures that eventually lead to the formation of rectangular pattern and usually occurred in the area that have low topography.

Then, the other drainage pattern which is Trellis is the pattern always occurs in the sedimentary rocks, in which the sedimentary rock had undergo deformation like folding and tilting then eroded. The pattern were shown in map by green in colour. This pattern can easily formed in the area that have an alternating weak and resistant bedrock. Meanwhile, for Parallel pattern, this pattern were formed due to steep slope with slight relief. Since the slope are steep, this create the pattern of the river are straight, flow in the same direction and low tributaries. It was represent by purple colour for parallel pattern.

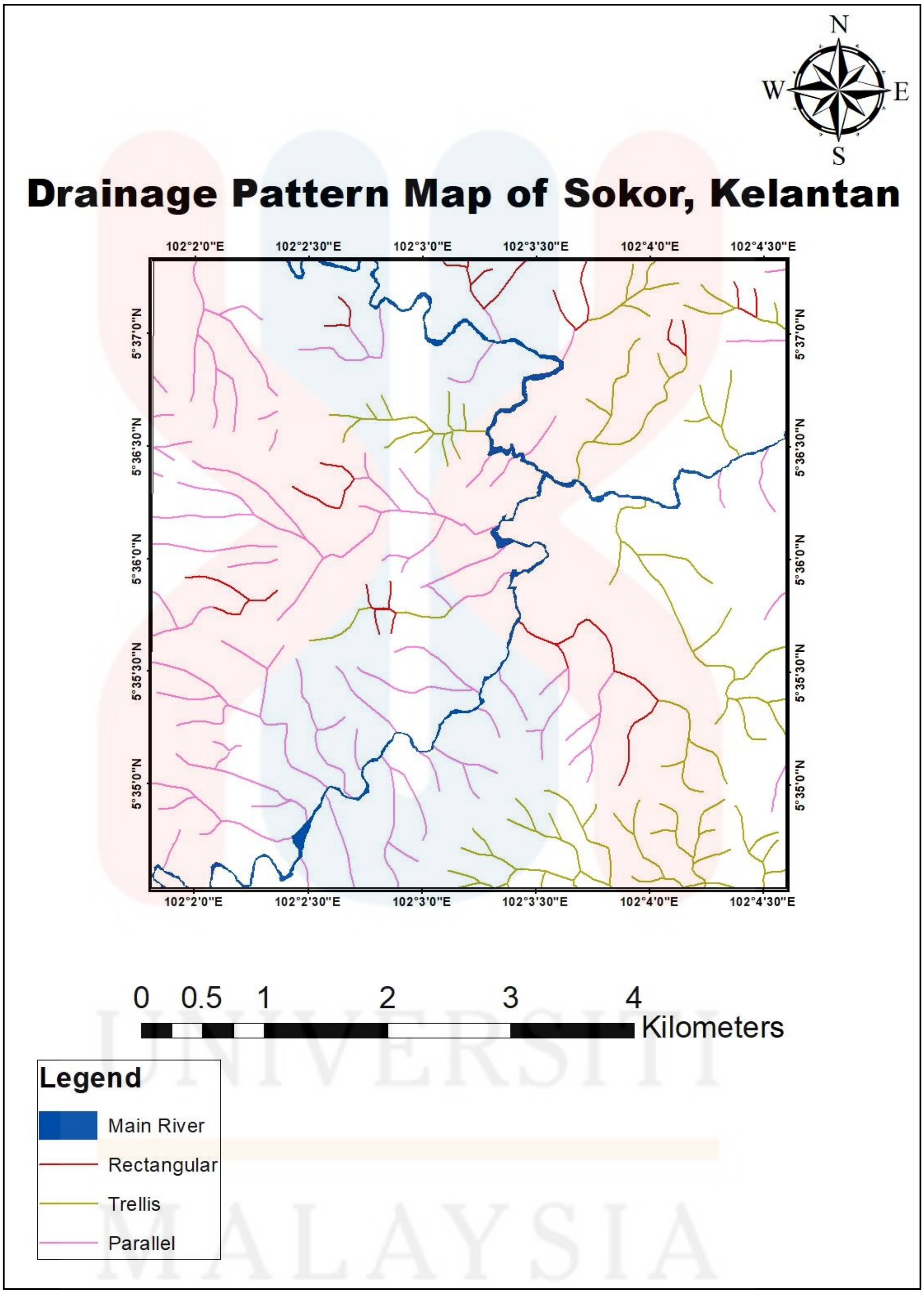


Figure 4.9: Drainage pattern map consist of rectangular, trellis, and parallel drainage system.

4.3 Lithostratigraphy

4.3.1 Geological Map

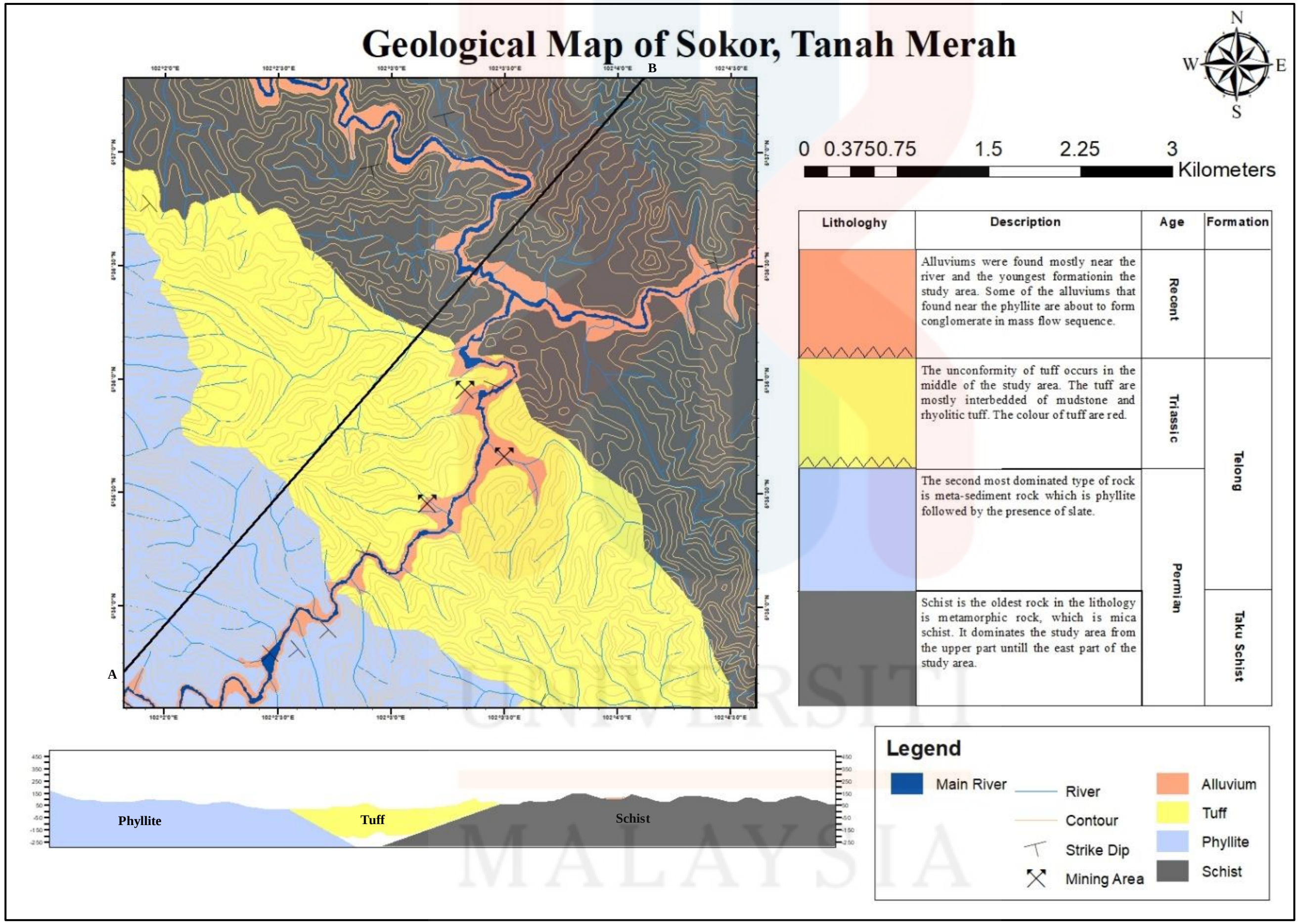


Figure 4.10: Geological Map of Ulu Sokor, Tanah Merah, Kelantan.

4.3.2 Stratigraphical Position

Lithologhy	Description	Age	Formation
	Alluviums were found mostly near the river and the youngest formationin the study area. Some of the alluviums that found near the phyllite are about to form conglomerate in mass flow sequence.	Recent	
	The unconformity of tuff occurs in the middle of the study area. The tuff are mostly interbedded of mudstone and rhyolitic tuff. The colour of tuff are red.	Triassic	Telong
	The second most dominated type of rock is meta-sediment rock which is phyllite followed by the presence of slate.	Permian	
	Schist is the oldest rock in the lithology is metamorphic rock, which is mica schist. It dominates the study area from the upper part untill the east part of the study area.		Taku Schist

Figure 4.11: Stratigraphic position of rock formation.

4.3.3 Unit Explanation

4.3.3.1 Mica Schist

The first unit of rock in the study area is mica schist. It is the domain unit that can be found mostly on the upper part of the mapping box. The physical characteristic that can be distinguish from other type of rock was as schist composed on thin layering compound of shiny component that was first identified the component as mica. Schist can be classified as a low grade metamorphic rock because it's flat sheet-like component which the minerals inside it elongated due to metamorphism effect.

Schist can be distinguish through its physical characteristics and under microscope. The physical characteristic that can be identified from schist was the colour of the rock. Basically, schist commonly can be found in green, grey, dark brown which indicating the presence of Biotite, and silver, indicating the presence of Muscovite. In the study area, most of the schist had silver to black colour giving a hint that this schist contain Muscovite. Besides, the evidence of indicating schist can be observed through its texture. Schist was generally foliated and had a platy sheet-like texture in which indicate that schist rock undergo metamorphism. Due to the pressure and temperature act on the rock, this cause the minerals inside the rock to become elongated and platy.

On the other hand, the provenance of schist is actually shale in which the compound was made up mainly from clay minerals. Basically, shale undergo metamorphism forming slate, phyllite and gneiss. However, depending on the temperature and pressure act on the shale lead to the type of rock formed. Schist was formed from shale as shale metamorphed and foliation occurs in terms of schistosity cause the schist to split into layers easily. Thus, all mica minerals can be distinguish easily through naked eyes due to the parallel arrangement of platy sheet-like mica minerals.

Schist undergo metamorphism along the convergent plate boundaries. The rock were formed and recrystallized during the process of subduction of the plate boundaries. This indicate that the occurrence of schist majorly generated from the process of regional metamorphism. Regional metamorphism is a type of metamorphism process in which the reforming and recrystallized of rocks occur on the subduction area of the convergent plate boundaries.

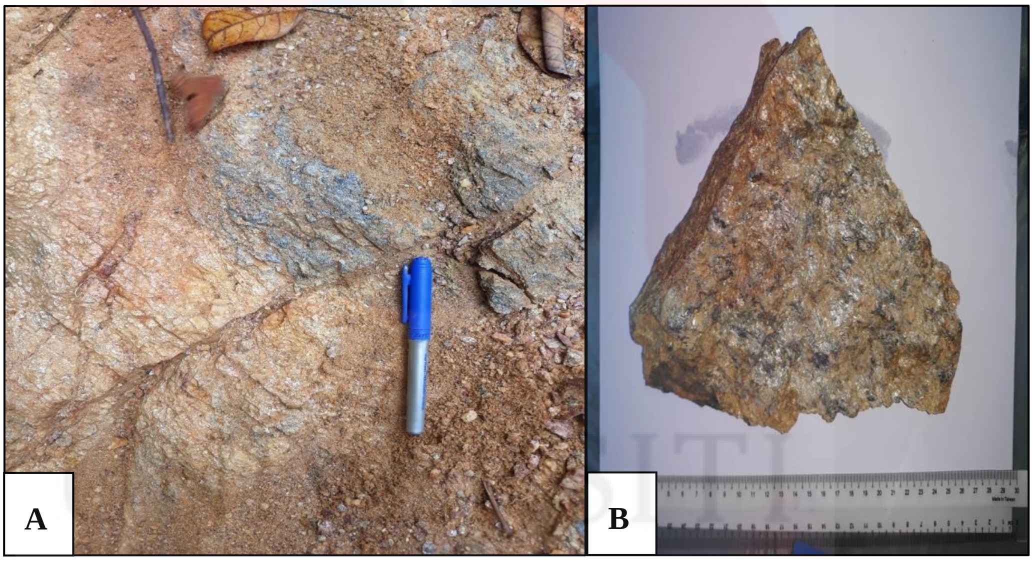


Figure 4.12: (A) Outcrop of mica schist (B) Hand specimen of mica schist.

Next, the identification of schist was by observing under microscope. After the process of thin section, the rock that prepared in slide was then put under microscope. The rock was identified by cross-polarized light and plane-polarized light.

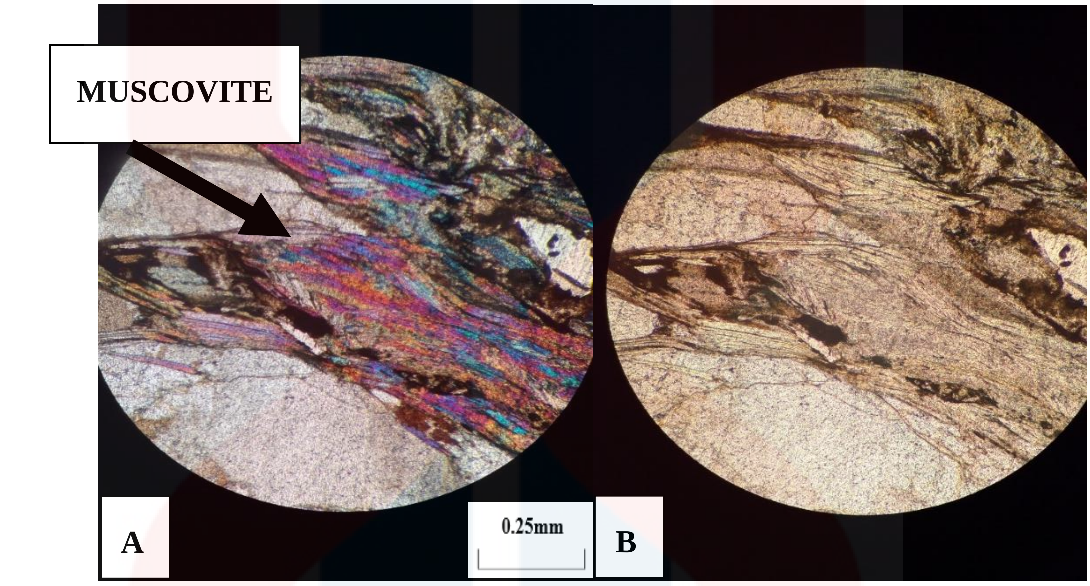


Figure 4.13: The image of mica schist under the magnification of 60x0.80. (A) Cross Polarized Image (B) Plane Polarized Image.

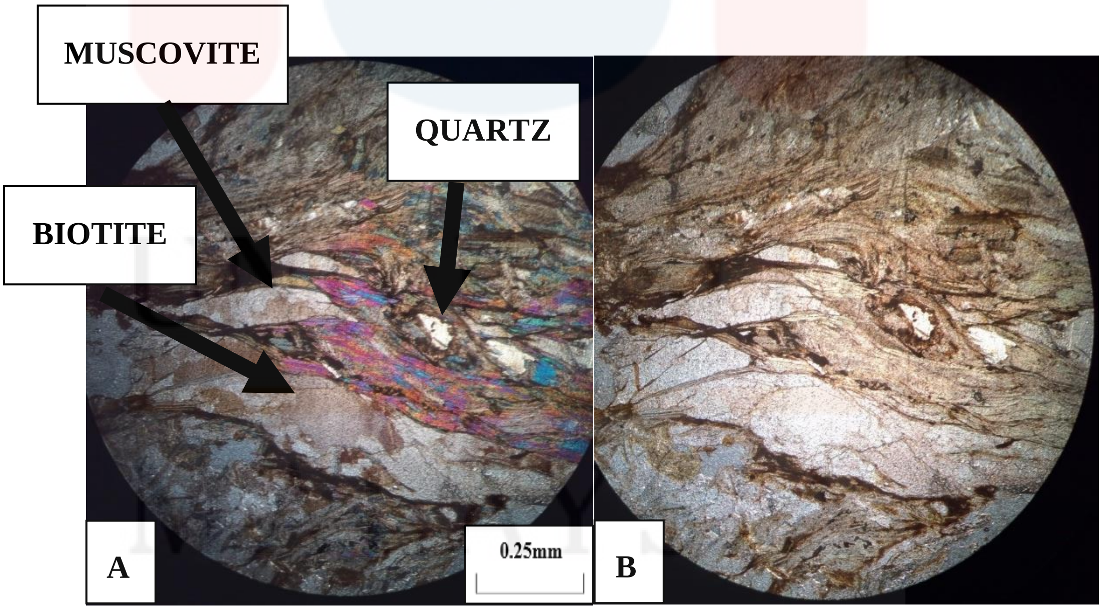


Figure 4.14: The image of mics schist under 4X0.1 magnification. (A) Cross polarized image (B) Plane polarized image.

Name of rocks: Mica Schist. Location: Hutan Simpan Ulu Sokor, Tanah Merah, Kelantan.	
Rock Type: Metamorphic rock	
Identification: Petrography	
Quartz	• Quartz mineral is colourless in Plane Polarized light. • Low pleochroism
Biotite	• High pleochroism including in plane polarized light. • Remains the same colour in both ppl and xpl, which is brown. • Has a perfect cleavage.
Muscovite	• It has low pleochroism • The foliation of mica can be see clearly. • Has perfect cleavage and bright interference colour.

4.3.3.2 Phyllite

Phyllite is a low grade of metamorphic rock. This is because it formed due to low temperature and pressure acting on the rock. This type of rock unit is the second most abundant in the study area. Generally, it composed of the a platy-flake shaped in which there is a presence of mica in it and gives the parallel alignment of the rocks. This cause the rock to easily split into pieces. Phyllite is the second most dominate rock in the study area in which it presence associated with slate and mudstone.

Phyllite usually grey in colour and sometimes reddish to light brown due to the process of weathering acting on phyllite. Also, the grain of phyllite in the study area are mostly fine grain. This is because, the metamorphism of phyllite comes from its provenance rock which are shale and mudstone. Basically, phyllite was composed mainly from clay minerals.

The sample taken from the study area, phyllite tends to have grey colour. Grey colour of phyllite means that the surrounding area of rock has low oxygen for the process of weathering. Whereas if the colour of phyllite is reddish this means that, the weathering activity is very high. The formation of phyllite occurs in regional metamorphism. The area in which the subduction of plate boundaries called as regional metamorphism occurs lead to the formation of phyllite.

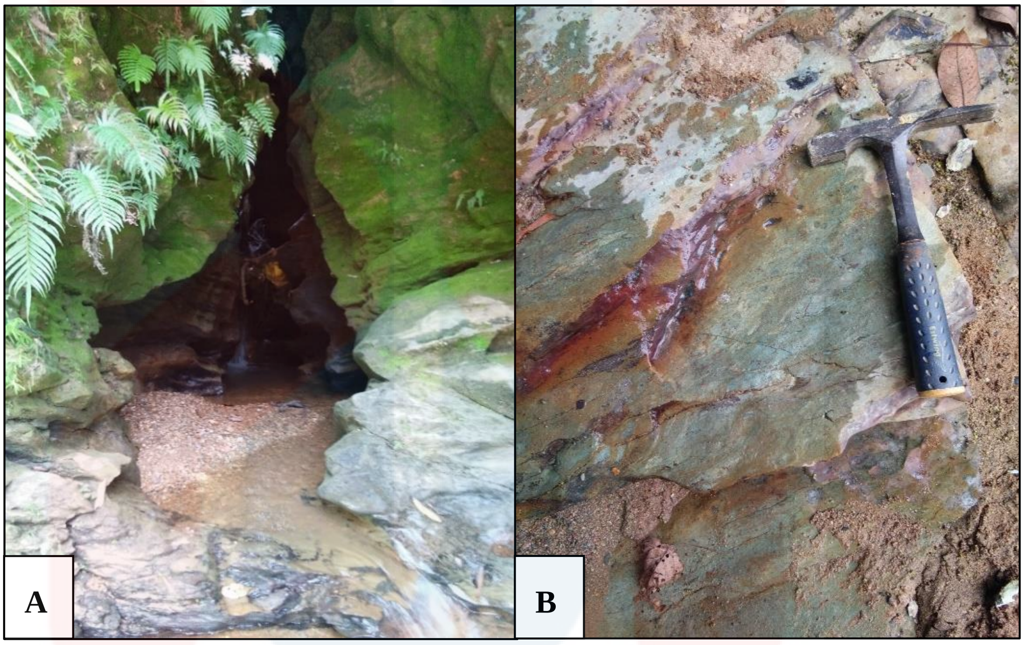


Figure 4.15: Outcrop of Phyllite in the study area (A) phyllite in the river (B) sample for petrography analysis.

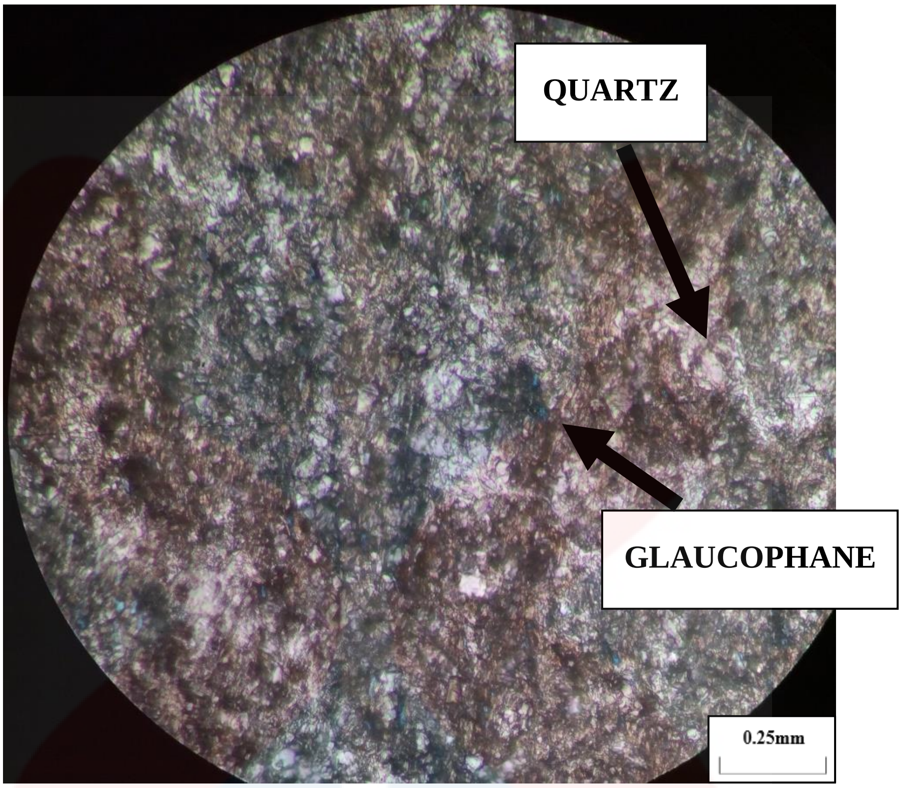


Figure 4.16: The image of a fine grain of phyllite under magnification of 60x0.80 of cross polarization.

Name of rocks: Phyllite Location: Hutan Simpan Ulu Sokor, Tanah Merah, Kelantan.	
Rock Type: Metamorphic rock	
Identification: Petrography	
Quartz	• Quartz mineral is colourless in Plane Polarized light. • Low pleochroism.
Glaucophane	• It has blue colour under cross-polarized microscope. • Due to blue pleochroism. • High birefringence.

4.3.3.3 Rhyolitic Tuff

The next lithology is tuff. Tuff is a volcanic igneous of a rock type. Based on the observation, the colour of the rhyolitic tuff is reddish brown. This is because effect from the oxidation due the weather and climate where most of the outcrop were highly exposed to weathering process. The texture of the tuff is very fine grain. Besides, it is hard and has been made of lithified pyroclastics minerals. The final product of tuff is when the pyroclastics have been thrown out and lithify under some circumstances.

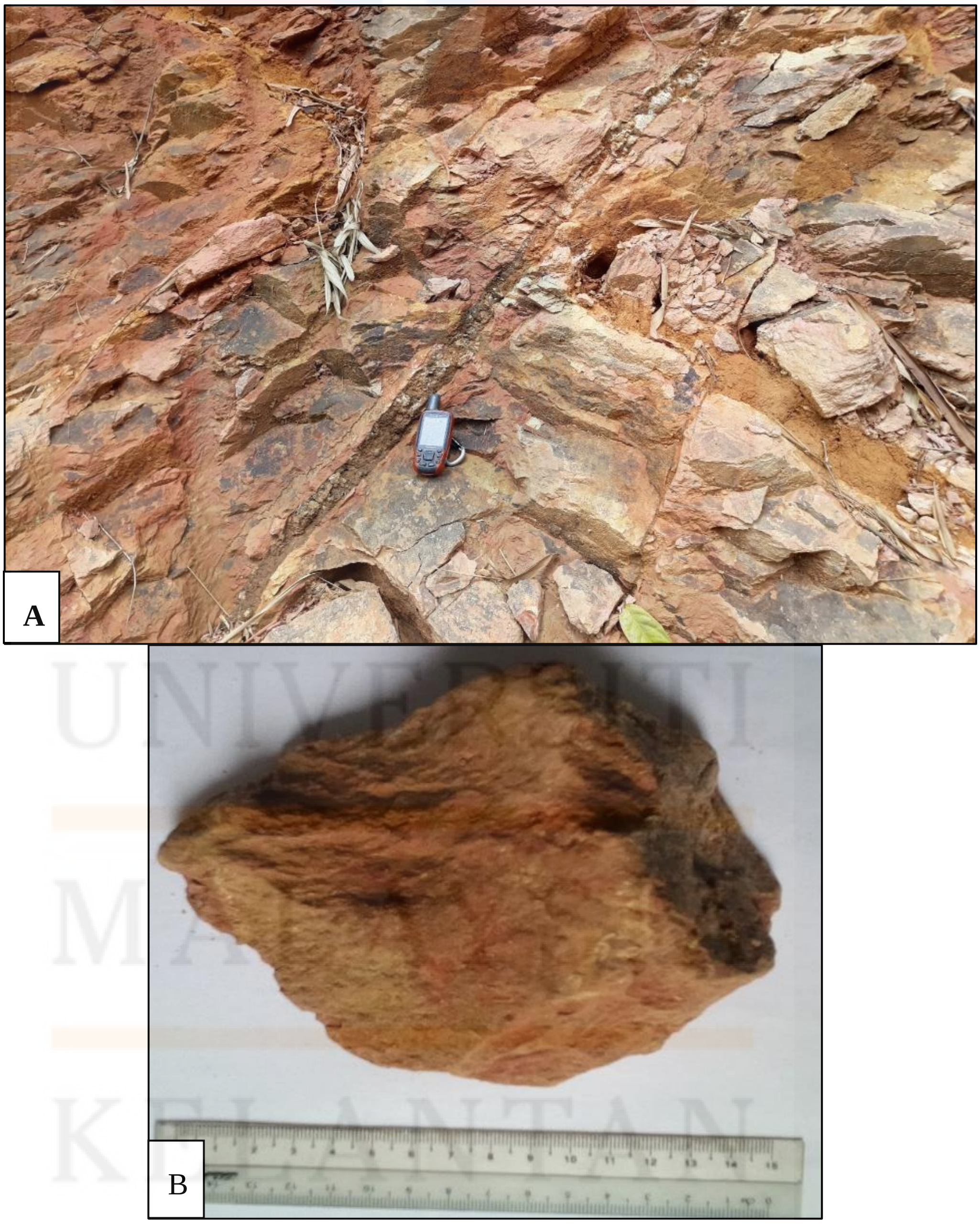


Figure 4.17: (A) Outcrop of tuff interbedded with mudstone and the presence of quartz veins (B) Sample of tuff for petrography analysis.

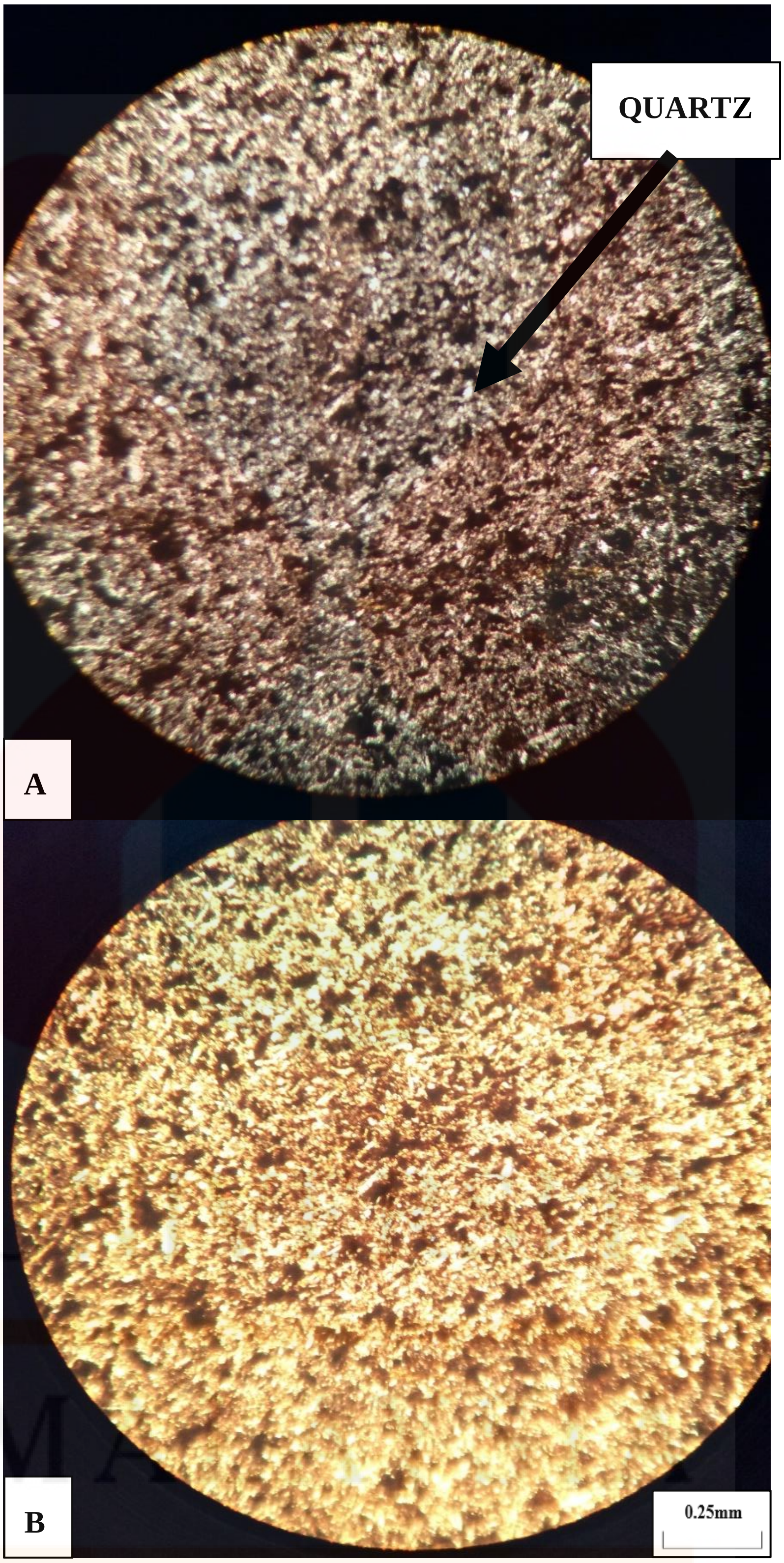


Figure 4.18: The image of a very fine grain tuff under 4X0.1 magnification. (A) Cross polarized image (B) Plane polarized image.

Name of rocks: Rhyolitic Tuff Location: Hutan Simpan Ulu Sokor, Tanah Merah, Kelantan.	
Rock Type: Igneous rock	
Identification: Petrography	
Quartz	• Quartz mineral is colourless in Plane Polarized light. • Low pleochroism

4.4 Structural Geology

4.4.1 Lineament Analysis

Lineament is the linear features based on the observation from the terrain map. Analyzing the lineament gives the overview of the geological activity and structure that exist in the study area. Typically, a lineament usually gives a hint of any fracturing activity as it indicate the presence of faulting, folding or a series of fold-faulting valley.

Figure below shows the lineament analysis from terrain map. Yellow colour of straight line is a lineament. The lineament was detected for example, when the river flow in straight. Also, the top of the hill are in linear position. The fractures may not be seen in the field as it occurred within deep of the outcrop.

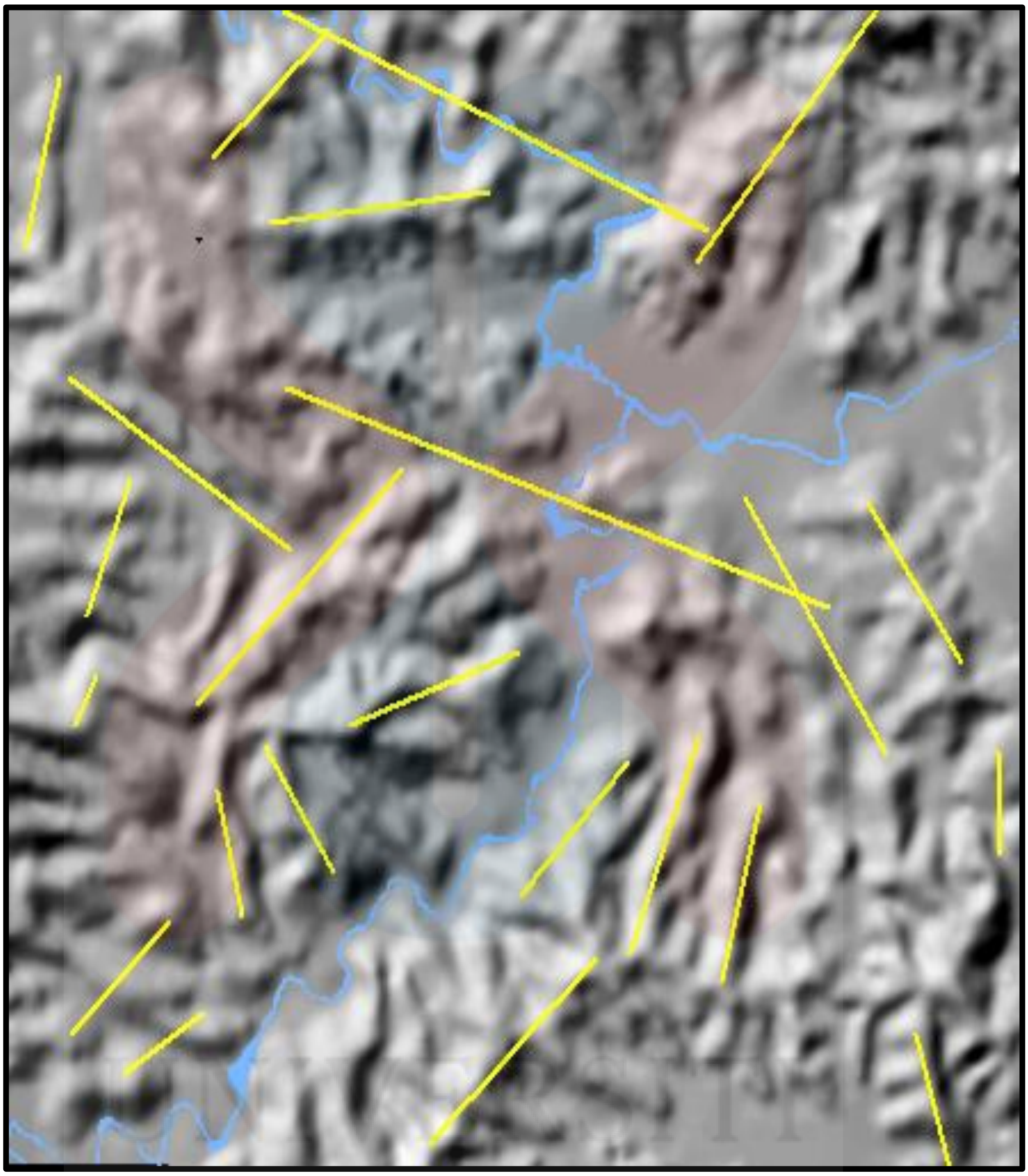


Figure 4.19: Lineament analysis of terrain map of Ulu Sokor, Tanah Merah, Kelantan**.**

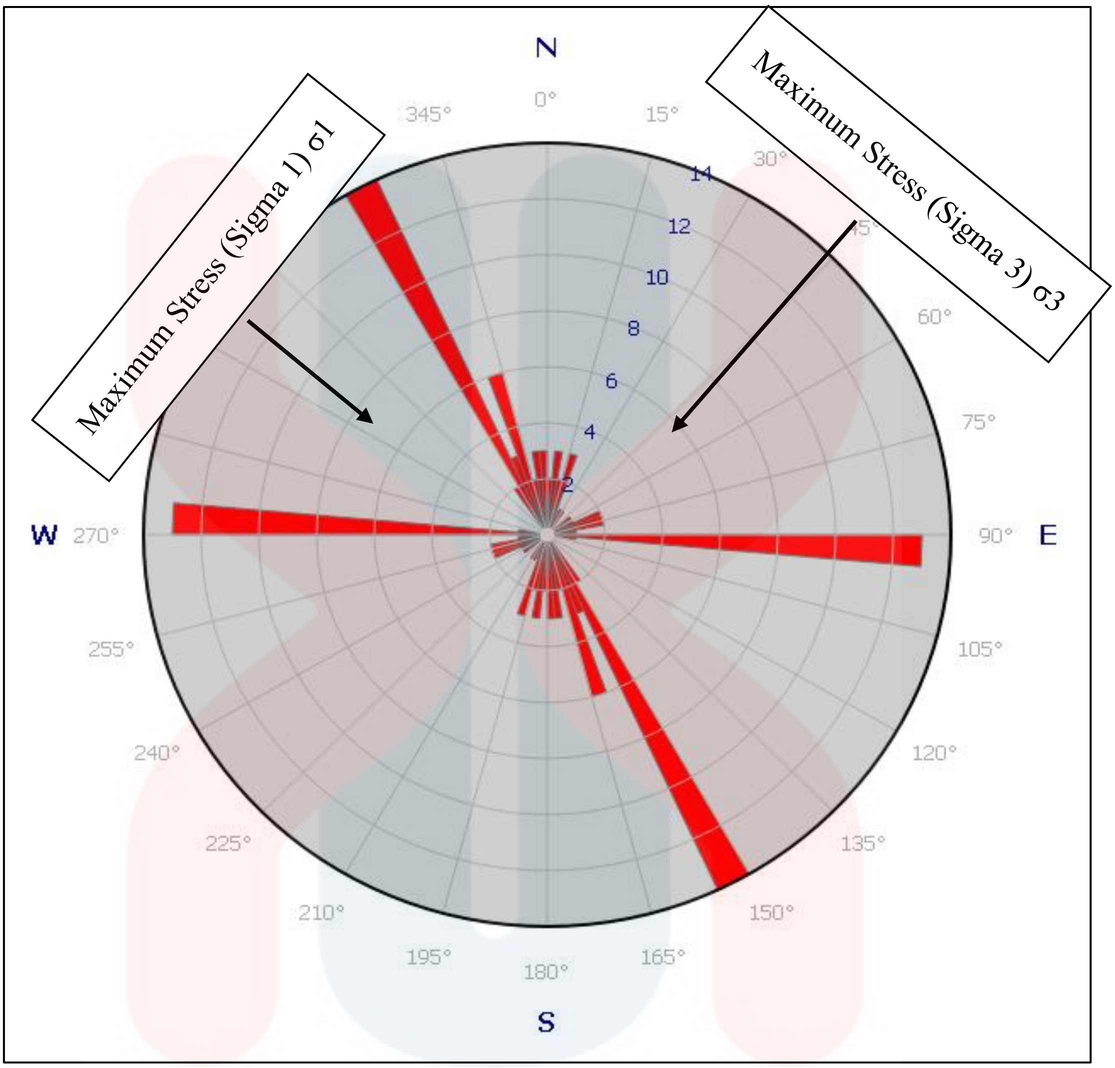


Figure 4.20: Rose diagram of lineament analysis of Ulu Sokor, Tanah Merah, Kelantan.

Table 4.2: Frequency of angle of strike for lineament analysis.

Angle of Strike	Frequency
0-10	11
11-20	6
21-30	3
61-70	8
71-80	1
241-250	2
251-260	2
271-280	10

281-290	13
301-310	1
321-330	6
331-340	11
341-350	12
351-360	9

4.4.2 Fold

In structural geology, structure as fold is commonly detected. Fold formed due to the deformation of rock strata, as the rock strata is weak and ductile. The rock undergo a great pressure of compression lead to the folding of rock strata instead fracture it. The basic type of fold are syncline and anticline. In Figure 4.21 the type of rock that undergo folding is schist with the presence of tuff and mudstone.

There are three types of mechanisms of folding, which are buckling, bending and passive folding. For the buckling mechanism, it is a fold process that can initiate when a layer is shortened parallel to the layering. Folds appear to have formed in response to layer-parallel shortening. A contrast in viscosity is required for buckling to occur, with the folding layer being more competent than the host rock (matrix). The result of buckling is rounded folds, typically parallel and with more or less sinusoidal shape.

Whereas for bending, it happens when forces act across layers at a high angle, unlike buckle folds where the main force acts parallel to a layer. This is also the case for passive folding. However, bending is something that is more directly forced upon the layers by geometries and kinematics of the bounding rock units. Several aspects of bending have been studied in great detail by engineers because of its importance in the field of construction engineering, such as in horizontal beams supported by vertical pillars.

For passive folding typical for rocks where passive flow occurs. In these cases the layering only serves as a visual expression of strain with no mechanical or competence contrast to near layers. The layers are called passive layers. Perfectly passive folds produced by simple shear are folds, and passive folds that are associated with simple shear, or atleast a significant component of simple shear, are called shear folds.

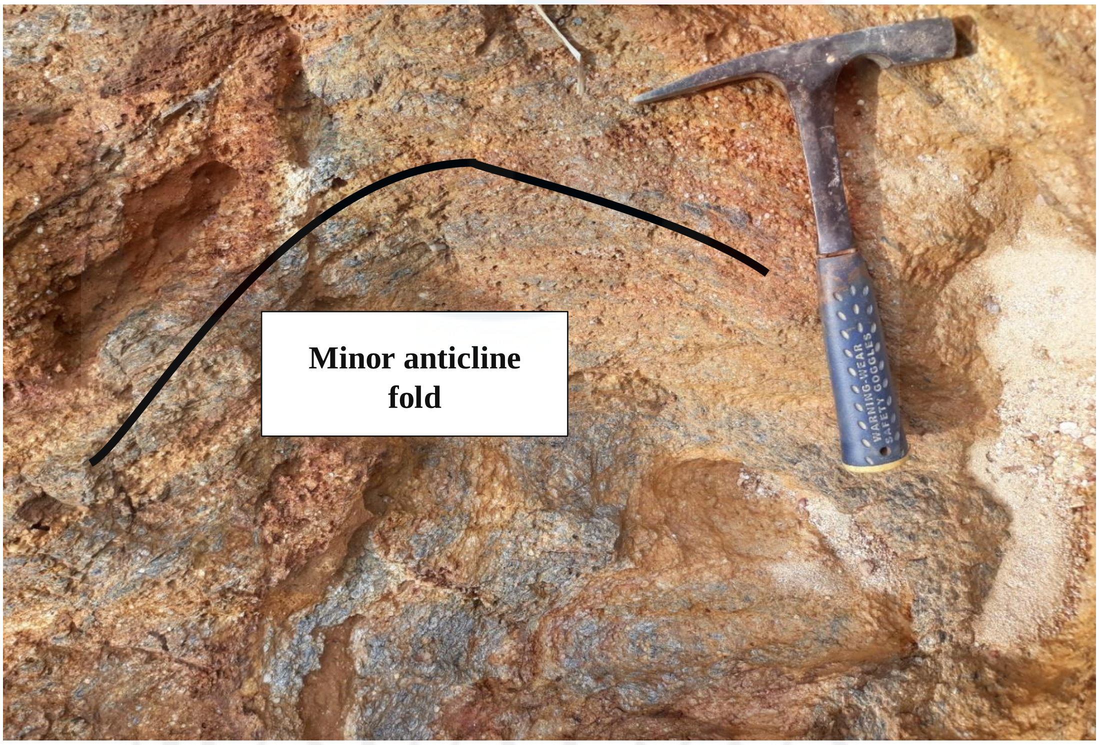


Figure 4.21: An anticline fold in meta-sediment outcrop.

Figure 4.22: A recumbent fold**.**

Based on figure 4.21 and 4.22, the type of folding that were found in the study area are anticline fold and recumbent fold. In Figure 4.21, the fold is formed in the schist rock interbedded with mudstone and tuff. Meanwhile for the recumbent fold, it can be identified when the two limbs of fold are parallel to each other.

CHAPTER 5

BIOGEOCHEMISTRY STUDIES OF GOLD USING PLANT AND SOIL

5.1 Introduction

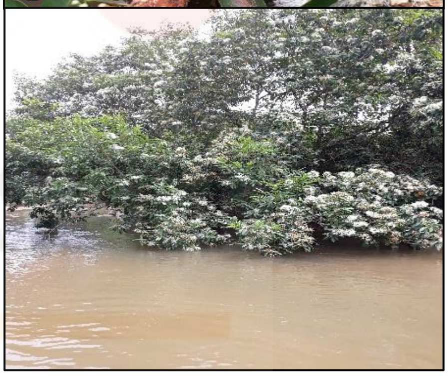
In this chapter, the biogeochemistry studies of gold is discussed as the cycle of biogeochemistry is a process of forming of all of these types are very closely related to physical, chemical and biological processes. The interaction of plants (biotic) and soil (abiotic) are being observed and examined for the purpose of finding the area in which the gold are primarily deposited. Thus, after undergoing the experiment for both plants and soils, the results obtained are giving the indication of the pathfinder elements and type of hyperaccumulator plants.

The pathfinder elements that were discussed are Iron (Fe), Copper (Cu), Manganese (Mn) Silver (Ag) and Lead (Pb). This type of elements gives an insight on the possibility presence of gold. In addition, the plant that act as hyperaccumulator plants are *Dactylis glomerate, Melastoma malabathricum, Syzygium zeylanicum, Rhamnus frangula* and *Mimosa pudica*.

5.2 Descriptions Of Samples

Table 5.1: The description and location of the samples.

Station	Description	Plant and Soil Samples
18B01 N 5°37'7.631" E 102°2'9.724"	Soil and plant samples were taken in the same place. Most of the rock were schist. The colour of soil was greyish due to the weathering of schist. The soil samples contain high amount of weathered schist. Sample plant, which was taken for laboratory analysis, was *Melastoma malabathricum*.	 
18B04 N 5°34'53.105" E 102°2'42.522"	The plant that had been taken was *Melastoma malabathricum*. There are abundant of Melastoma plant. The colour of the soil sample was yellowish brown and thick like-mud.	 

18AFDS1 N 5°35'58.502" E 102°3'24.174"	The samples taken were near the gold mining site. Plant that were taken as a sample was *Mimosa pudica* as it was abundant in the area. The soil samples taken from the gold mining were 3 with different type of colour which were brown, grey-brown and grey.	 
18B02 N 5°36'23.216" E 102°3'31.651"	The plant sample taken for analysis was *Syzygium zeylanicum* or rose apple plant. The soil sample was taken on the river. Mostly the soil sample contain high amount of weathered schist and had shiny characteristics.	 

18B07 N 5°34'45.584" E 102°2'27.042"	The soil sample in 18B07 was generally has yellowish-brown in colour and the area is dominated by phyllite. Meanwhile, *Melastoma malabathricum* was taken as a sample for laboratory analysis.	
18AFD11(5) N 5°34'39.526" E 102°3'37.037"	In this station, *Rhamnus Frangula* was taken as a sample for investigation. The soil sample has greyish brown in colour and the grain was medium coarse.	

18AFD8(5) N 5°36'30.683" E 102°4'24.283"	In this area, *Dactylis glomerate* was abundantly found. This plant was taken for analysis while for the soil nearby, the soil generally was fine grain. The colour of the soil was light-brown.	 
18AFD3(5) N 5°37'7.594" E 102°3'16.081"	*Melastoma malabathicum* was taken as a sample as it is the abundant plant that can be found in this location. The soil sample was taken from the river sediment.	 

18AFD4(5) N 5°37'10.859" E 102°3'33.221"	In this area, the soil was fine grain and yellowish-brown in colour. On the other hand, *Melastoma malabathricum* was abundant in that area thus it was taken as a sample for further analysis.	 

5.3 Results

Both samples of soil and plant from four locations have been tested using Atomic Absorption Spectrometer (AAS). The results are represented in tables respectively.

5.3.1 Result of Soil and Plant Samples Using Atomic Absorption Spectrometry (AAS)

The concentration of the metals in soil and plant samples were determined by using Atomic Absorption Spectrometer (AAS). Metal concentrations were expressed in parts-per-million (ppm) unit. Table 5.2 shows the results of Atomic Absorption Spectrometry (AAS) of plant samples.

Table 5.2: Atomic Absorption Spectrometry (AAS) results of soil and plant samples respectively.

Locations	Silver		Manganese		Copper		Iron		Lead	
	Soil	Plant	Soil	Plant	Soil	Plant	Soil	Plant	Soil	Plant
18B01	0.006	0.022	1.554	12.840	0.158	0.051	5.064	0.430	0.467	0.350
18B04	0.002	0.004	35.590	2.169	0.422	0.018	18.730	1.078	0.947	0.391
18AFDS1	0.027	0.020	86.760	45.130	1.094	0.024	49.990	0.194	3.716	BDL
18B02	0.014	0.001	53.370	0.208	0.350	0.018	27.140	0.200	0.396	0.280
18B07	0.004	0.009	26.940	2.789	0.459	0.006	25.600	0.063	1.164	0.047
18AFD11(5)	0.003	0.010	10.130	12.180	0.198	0.024	9.942	0.782	0.375	0.241
18AFD8(5)	0.007	0.012	42.360	13.740	1.606	0.011	173.100	0.063	1.861	BDL
18AFD3(5)	0.002	0.005	33.170	156.000	0.613	0.038	23.260	1.181	0.452	0.223
18AFD4(5)	BDL	BDL	0.344	1.747	0.447	0.024	18.140	0.446	2.790	0.270

5.3.2 Result of Soil and Plant Samples Using X-Ray Fluorescence (XRF)

The concentration of the metals in soil samples were determined by using X-Ray Fluorescence (XRF). Metal concentrations were expressed percentage of element oxide content in the soil sample. Table below shows the results of X-Ray Fluorescence (XRF) of soil samples.

Table 5.3: X-Ray Fluorescence (XRF) results of soil samples.

Compounds \ Station	18AFD4 (Brown)	18AFD4 (Grey-Brown)	18AFD4 (Grey)	18B07
SiO_2	65.65%	61.29%	71.98%	71.80%
Fe_20_3	20.34%	28.77%	15.13%	17.84%
K_2O	10.08%	6.24%	8.45%	7.59%
BaO	3.65%		3.67%	
V_2O_5	0.29%	0.12%	0.31%	0.08%
TiO_2		2.79%		1.80%
MnO		0.51%		0.22%
Sb_2O_3		0.30%		
NiO			0.31%	
ZnO			0.16%	
CaO				0.67%

5.4 Discussion

In this research, the sampling was done by observing and analysing the soils and plants sample. Soil sample was taken near the plant sample. For *Melastoma malabathricum*, the plant were selected as sample in 5 stations which were 18B01, 18B04, 18B07. 18AFD8(5) and 18AFD4(5). This is because it was the only dominant plant that exist in the area. Whereas for 18B02, *Syzygium zeylanicum* was taken as a sample. This plant was one of the bioaccumulator plant proposed by the previous research. On the other hand, in 18AFDS1, *Mimosa pudica* was abundant in that mining area. Meanwhile for 18AFD, *Dactylis glomerate* was picked as sample. The area was a large pond. Lastly, *Rhamnus frangula* was taken as a sample for station 18AFD11(5).

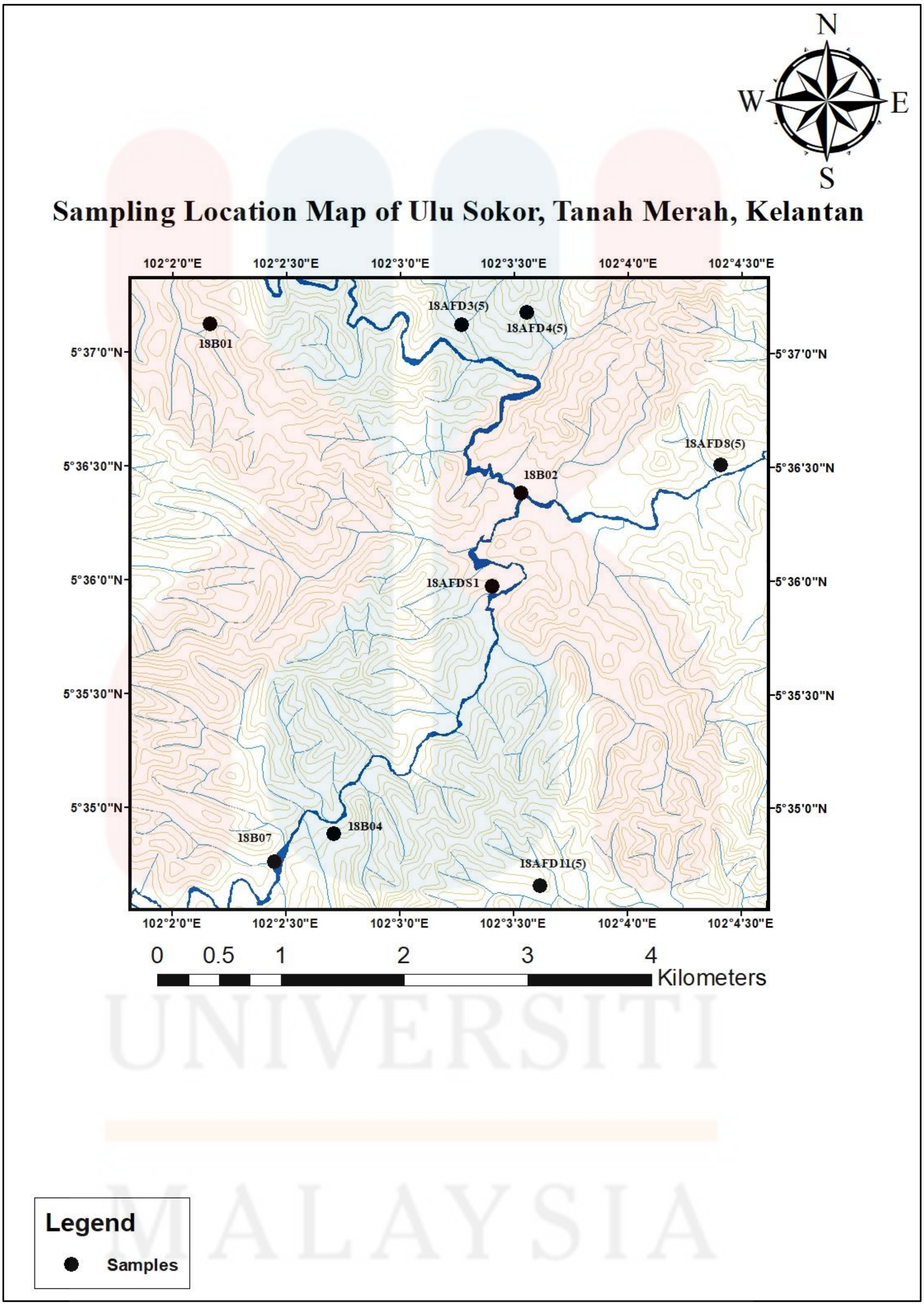


Figure 5.1: Sampling location map for plant and soil in Ulu Sokor, Tanah Merah, Kelantan.

5.4.1 Elements Distribution in Study Area

Based on the analysis of Atomic Absorption Spectrometry and X-Ray Fluorescence, determination of elements and compounds contain in plant samples and soils can be done. Two samples were analysed for XRF, in which one sample from 18B07 and 3 samples with different colours from 18AFDS1 that is located in the gold mining. On the other hand, the samples analysed for AAS had 9 samples respectively. Chart below shows the distribution of the concentration of elements based on the AAS results in every locations respectively.

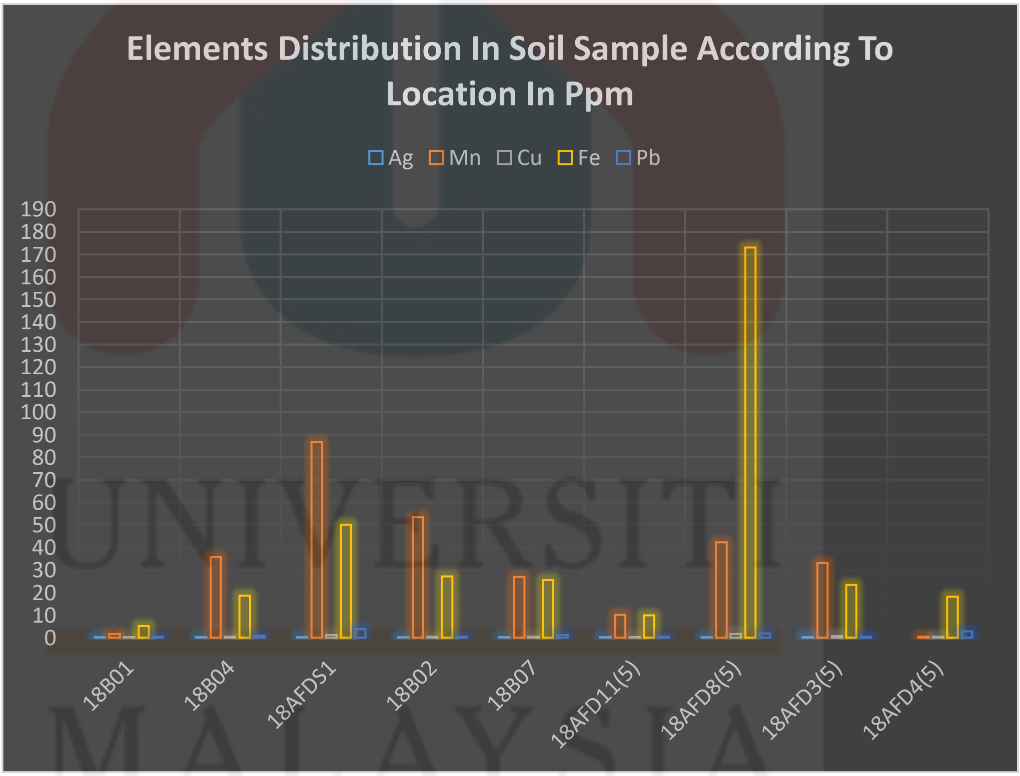


Figure 5.2: Elements distribution of soil samples based on AAS result respective to their locations.

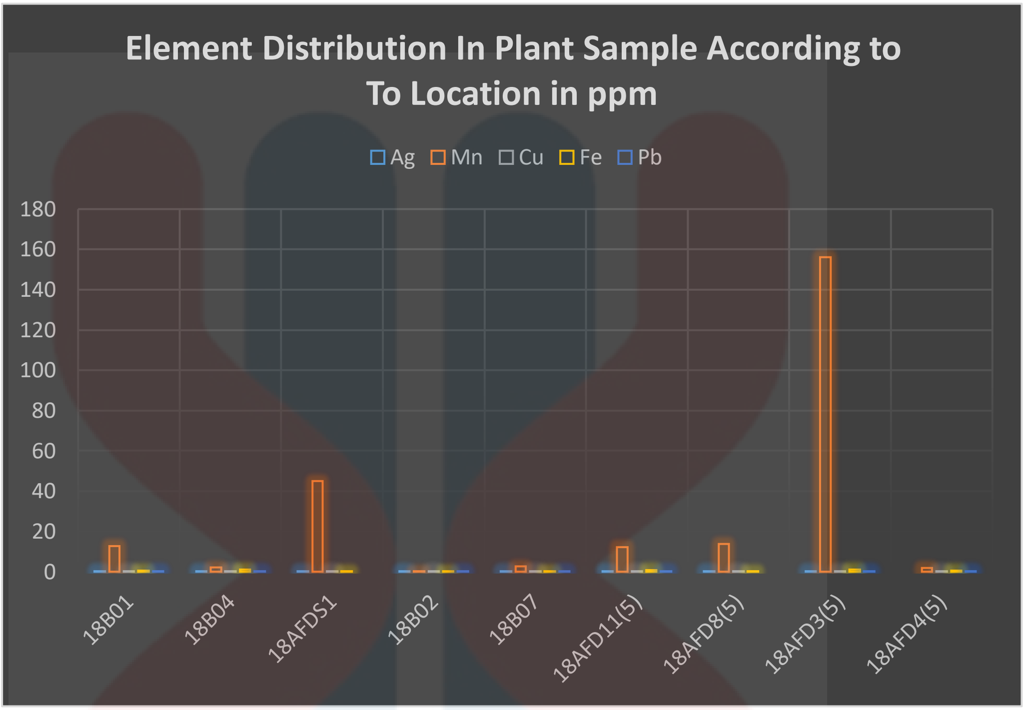


Figure 5.3: Elements distribution of plant samples based on AAS result respective to their locations.

Silver Concentration

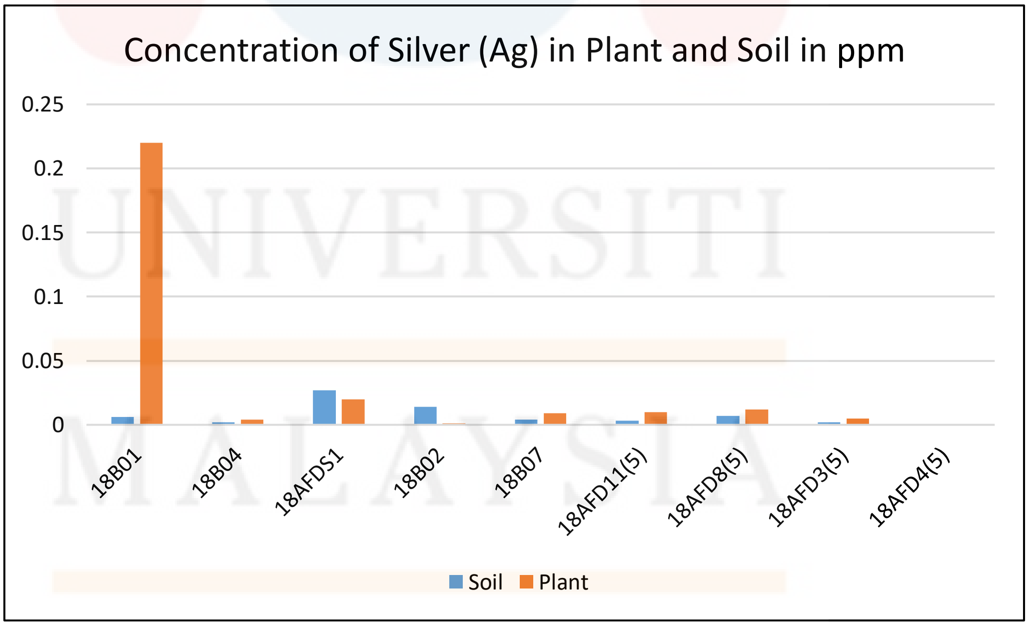


Figure 5.4: Silver (Ag) concentration for plant and soil samples.

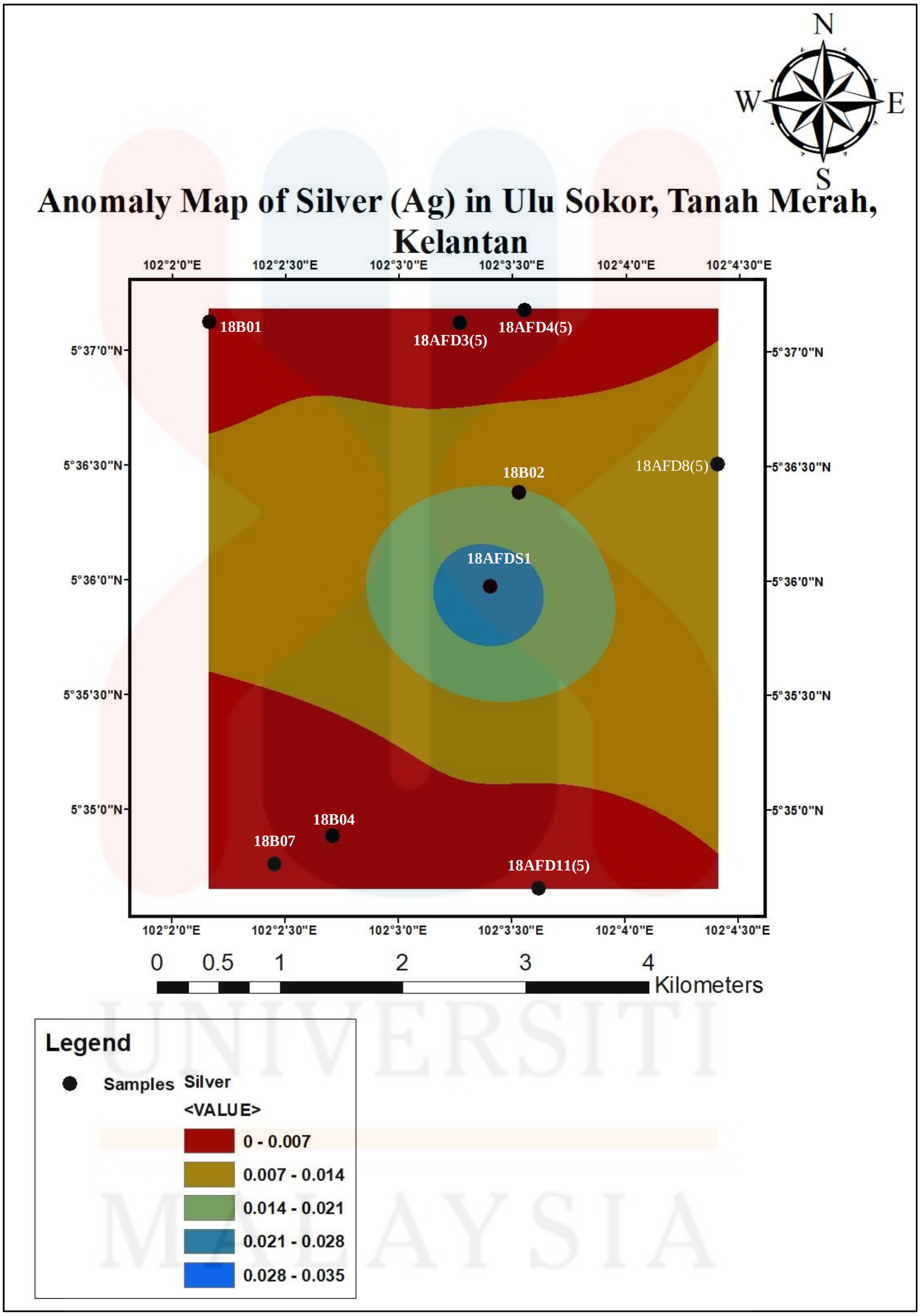


Figure 5.5: Anomaly Map of Silver (Ag) in soil in respective locations.

Based on Figure 5.4, the distribution of silver elements are varies. However, all of the value of trace silver below 1 thus the concentration of silver can be neglected. Nevertheless, the highest silver content in soil can be found in 18AFDS1 with 0.027 ppm and second highest is 18B02 with 0.014 ppm. The moderate concentration is located in 18AFD8(5) with 0.007 ppm. Meanwhile the lowest concentration for silver trace are 18AFD4(5) with Below Detection Limit and second lowest is 18AFD3(5) with 0.002 ppm.

Meanwhile for silver concentration in plant, the highest concentration is located in 18B01 (*Melastoma malabathricum*) and 18AFDS1 (*Mimosa pudica*), 0.022 ppm and 0.020 ppm respectively. For the medium concentration, it is indicated in 18AFD8(5), *Dactylis glomerate* with concentration of 0.012 ppm and the lowest concentration of silver is in 18AFD4(5), *Melastoma malabathricum* which the value is Below Detection Limit (BDL).

According to anomaly map of silver in the study area based on soil sample result, the highest distribution of silver element based on the soil analysis by Atomic Absorption (AAS) is in the centre of the study area. The map give the point in which soil samples taken in 18AFDS1 is the highest content and the second highest is 18B02 compare to other places. Towards the north-south and east-west of the study area, the silver content in soils decreases.

What can be discussed for the silver content in soil of 18AFDS1 is that the location is located nearest iron and gold mining. Silver deposition sometimes associated with lead, thus create a very toxic combination when present in the soil. The soil was taken in the area that the exploration and production of gold was taken place while for 18B02, the soil sample was taken on the riverbank. Factually, when there is the presence of silver in soil, the soil tends to have lighter colour, however, in both location the soil have darker reddish-brown colour. This gives a hint that the residual silver content in both location is very small and thus can be neglected. The soil wetness also an important indication in the presence of indicator elements. The silver contained in soil depends whether the soil is waterlogged or not. The higher the wetness of the soil, the higher the content of the silver and vice versa. In addition, the nutrient in soil will also low. This is because when the content of heavy metal such as silver is high, it gives a picture of soil that as less nutrient content for normal growth of plants and microorganisms. The toxicity of soil depends on the content of silver itself. Silver is toxic to organisms and microorganisms. Thus, increase in consumption of silver by plant cause the plant to be classified as toxic plant.

<u>Manganese Concentration</u>

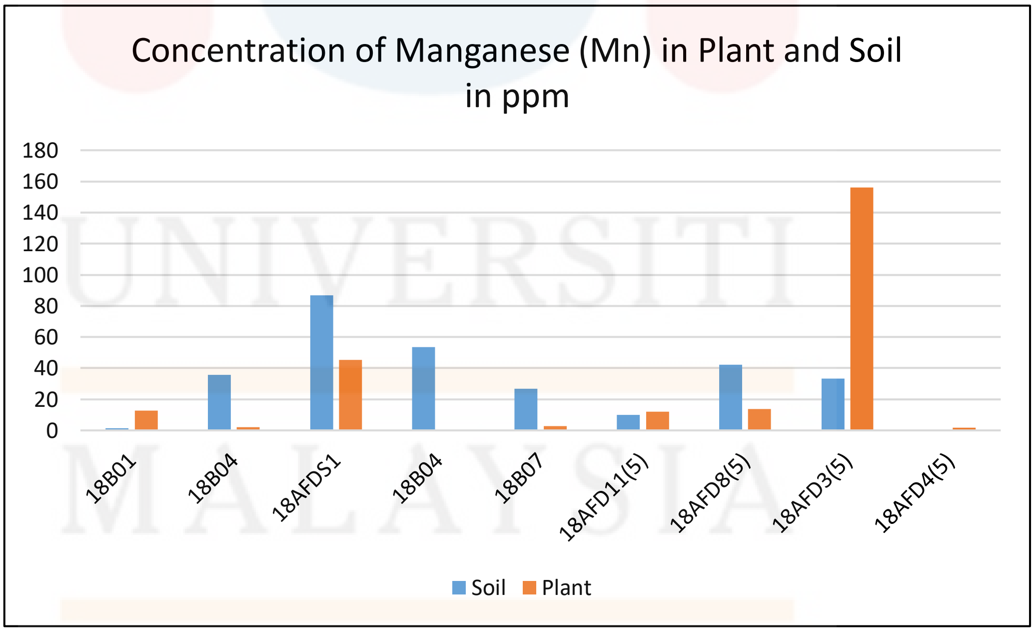


Figure 5.6: Manganese (Mn) concentration for plant and soil samples.

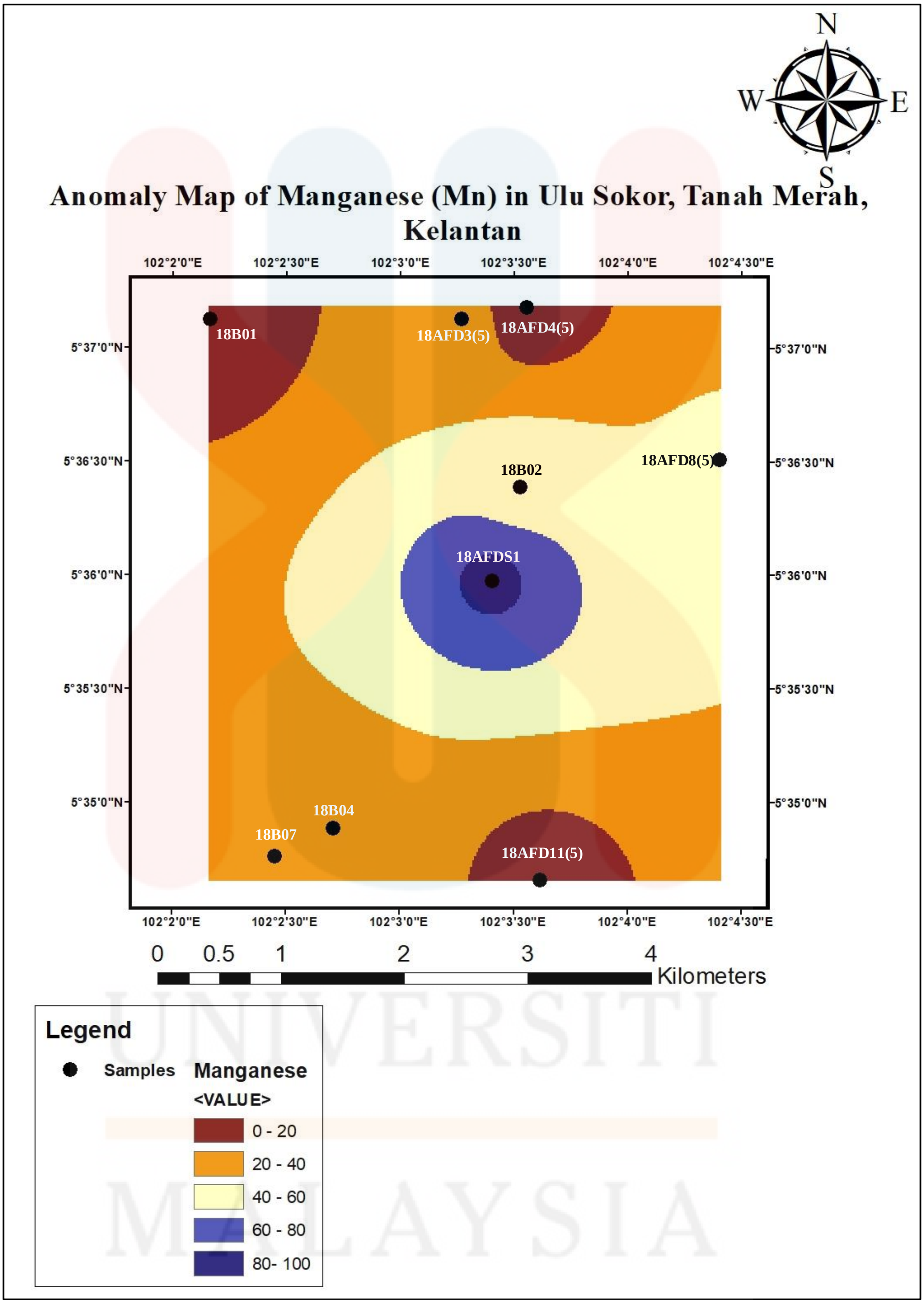


Figure 5.7: Anomaly Map of Manganese (Mn) in soil in respective locations.

In Figure 5.6, the differences between the distributions of manganese can be seen based on the value content of manganese in both plant and soils. Two location, 18AFDS1 followed by 18B02 have the highest concentration of manganese in ppm, 86.760 ppm and 53.370 ppm respectively. The moderate concentration of manganese is located in 18B04 with 35.590 ppm. Meanwhile, for the lowest concentration of manganese are located in 18AFD4(5) as the results gives 0.344ppm.

On the other hand, for the concentration of manganese in plant, the highest concentration is 156 ppm which located at 18AFD3(5) (*Melastoma malabathricum*) while the medium concentration is located at 18AFD8(5) (*Dactylis glomerate*) with 13.740 ppm. The lowest concentration has the concentration of 0.208 ppm in 18B04 (*Melastoma malabathricum*).

Also, based on Figure 5.7, the map shows the anomaly map of the distribution of manganese elements in the study area. What can be seen is the area of the mapping box show that the concentration of manganese increase towards the centre of the box. This by means that the area of 18AFDS1 and nearby contain higher concentration of manganese. Then, followed by the 18B02. Besides that, moving towards north and towards south, the concentration of manganese in soil decreases while moving towards east and south, the concentration of manganese is moderate.

As stated above, manganese can be essential element for organisms, yet however, it can become a toxic if the concentration of manganese is high. It is common that heavy metals can be detected in soils but the amount may be inadequate for the plants especially. If the plant absorbed the manganese higher that the limit of the nutrient it needs meaning that the plant is a toxic plant. As mentioned above, 18AFDS1 sample was taken in mining area so there is no doubt that the concentration of manganese is high. Whereas 18B02 sample was taken in riverbanks in which there is still no other mining and gold exploitation occurs in the area. It can be a toxic if the value is excessive and higher than the actual needed of the organisms. Manganese is a good indicator for possible gold deposits. The presence of manganese is sometimes associate with iron. This is because manganese has the same physical chemical properties but differ in hardness. On the other hand, Manganese has the ability in dissolving the gold together thus giving an indication of the highest possibility of the association of gold bearing in the study area.

Generally, the colour of soil tends to darker if there is an abundant presence of manganese in the soils. In both locations, the soil's colour are light reddish to greyish. Since the concentration of manganese is higher than 50 ppm in both samples and both of the soils has reddish to greyish in colour, this gives a hint in the possible gold deposit.

Copper Concentration

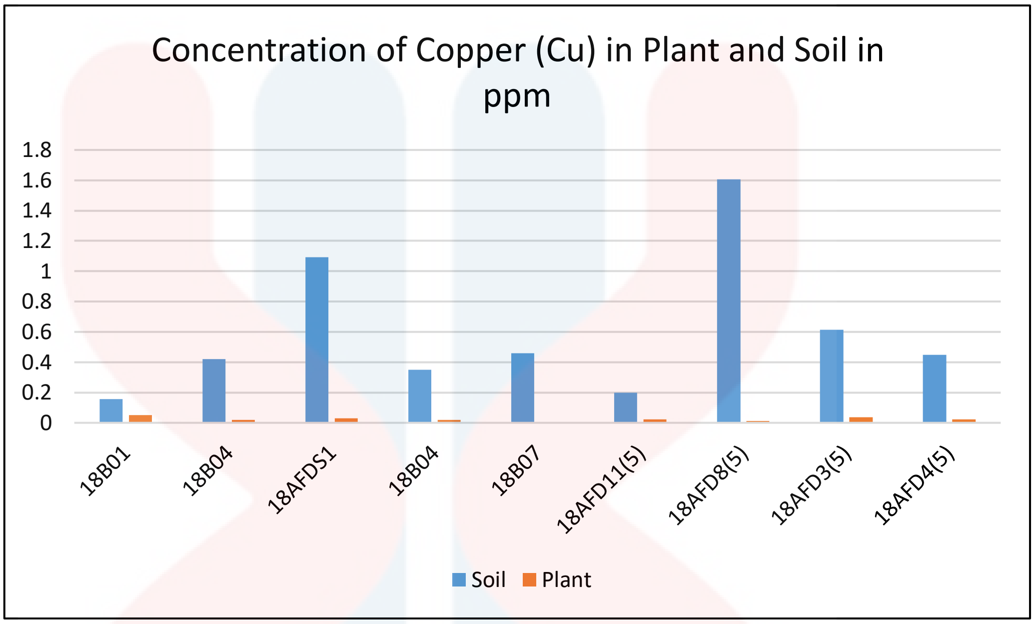


Figure 5.8: Copper (Cu) concentration for plant and soil samples.

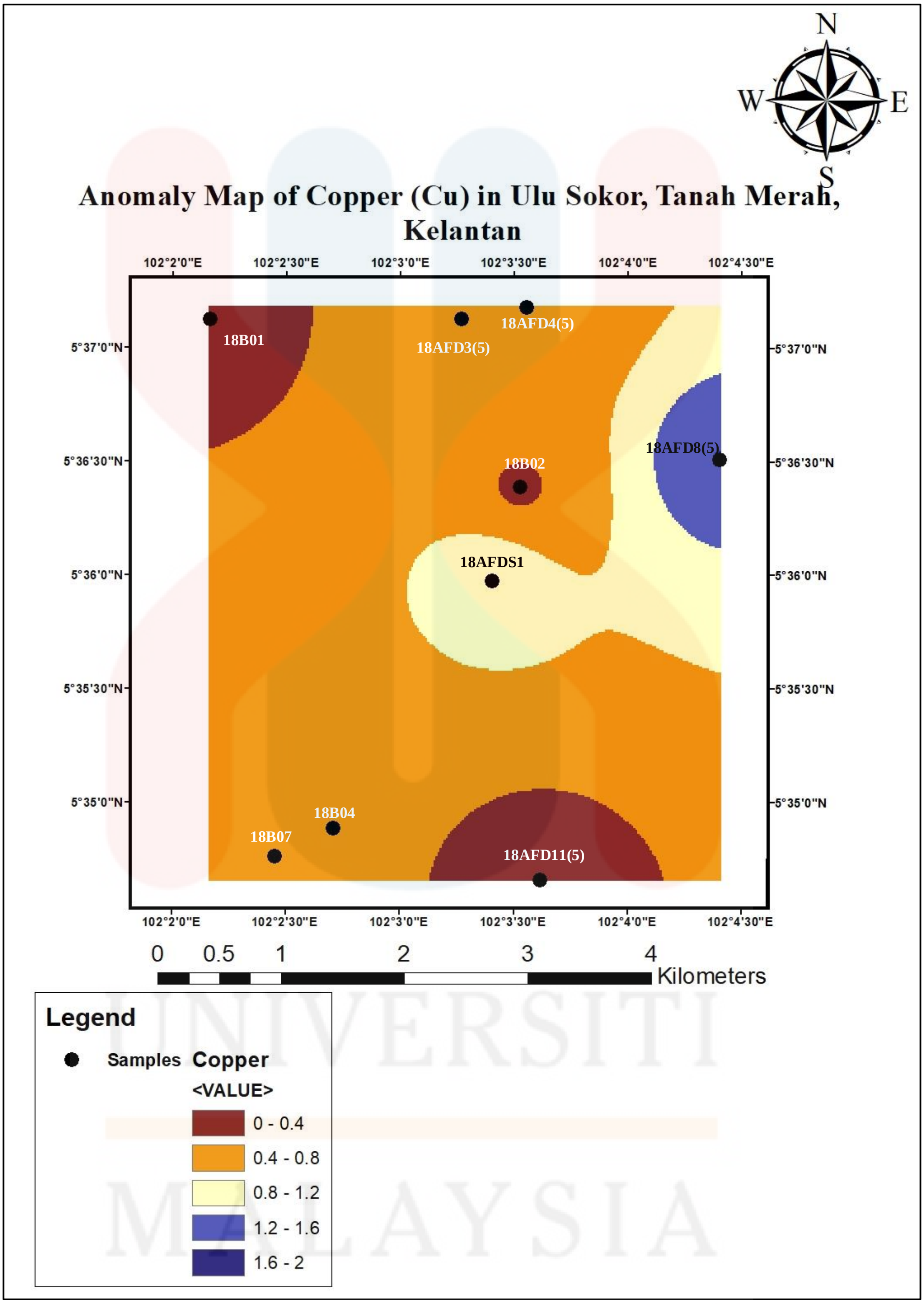


Figure 5.9: Anomaly Map of Copper (Cu) in soil in respective locations.

Based on Figure 5.8, the concentration of copper in all location are low than 2 ppm. The highest concentration recorded in the study area are in 18AFD8(5) and 18AFDS1 as both of these location have the concentration value higher than 0.1. The value of both concentration are 1.606 ppm and 1.094 ppm respectively. For the medium concentration, it is located in 18B04 with 0.422 ppm. On the other hand, the lowest concentration recorded is 18B01 with 0.158 value of copper concentration.

For the concentration of copper in plant, the highest concentration of copper recorded is 0.051 ppm, which is located 18B01 (*Melastoma malabathricum*) while the medium concentration is in 18AFD8(5) with 0.011 ppm (*Dactylis glomerate*). Whereas for the lowest concentration recorded is 18B07 (*Melastoma malabathricum*) with 0.006 ppm.

Next, examining the anomaly map constructed in Figure 5.9 above the distribution of the concentration of copper is normally distribute. This is because the concentration of copper increase when moving towards the east of the study area. The highest concentration of copper located in 18AFD8(5) located on the east of the mapping box followed by the second highest concentration which is the mining area, 18AFDS1.

Basically, copper is used in the geochemical exploration, acting as pathfinder element for gold deposits. However, higher amount of copper concentration indicate the presence of mafic rock rather that gold. The results obtained based on the analysed of soil using AAS, the amount is below 2 meaning that the concentration of copper may indicating the presence of gold in both area that had higher concentration of copper which is 18AFD8(5) and the mining area, 18AFDS1.

As copper characteristic is alkaline, it is mobile when it is in the area of acid condition especially the area is in between 5.0- 6.0 in pH values and higher alkalinity since copper is alkali element. Thus, this is why the copper concentration in soil is low and mostly copper are flowed towards downstream. Low amount of concentration of copper in all location meaning that most of the study area are acidic. Often copper associated with lead, gold, zinc and nickel.

Lastly, the higher the waterlogged inside soils also lead to the low copper concentration. Copper cannot withstand in the area in which wet since most of the soil sample that had been taken for sampling has high content of water. The waterlogged soil is most definitely has higher organic matter. In this case, higher organic matter de-elevate the concentration of copper.

Iron Concentration

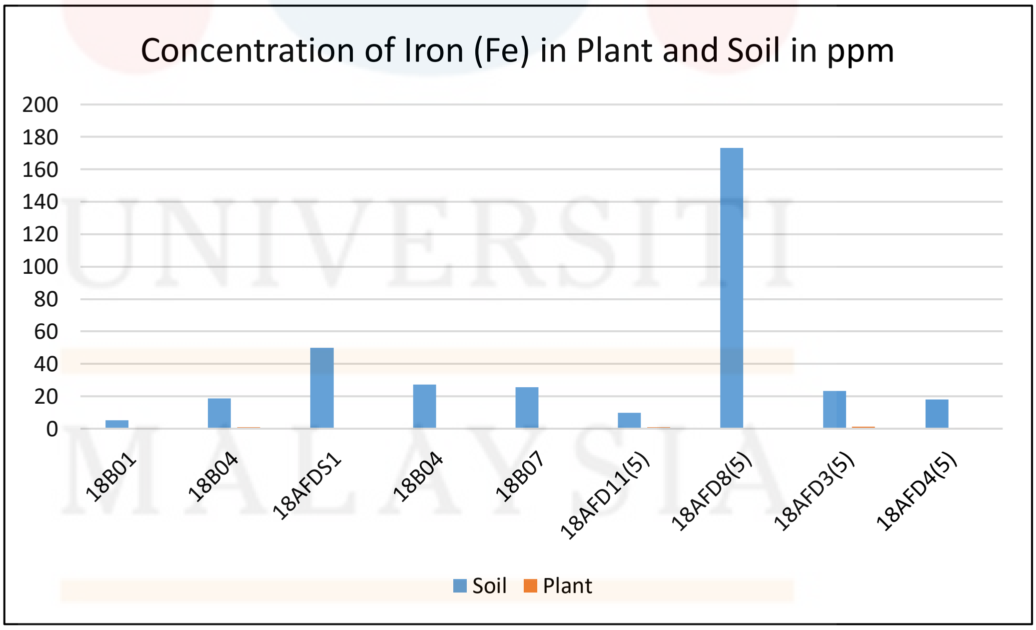


Figure 5.10: Iron (Fe) concentration for plant and soil samples.

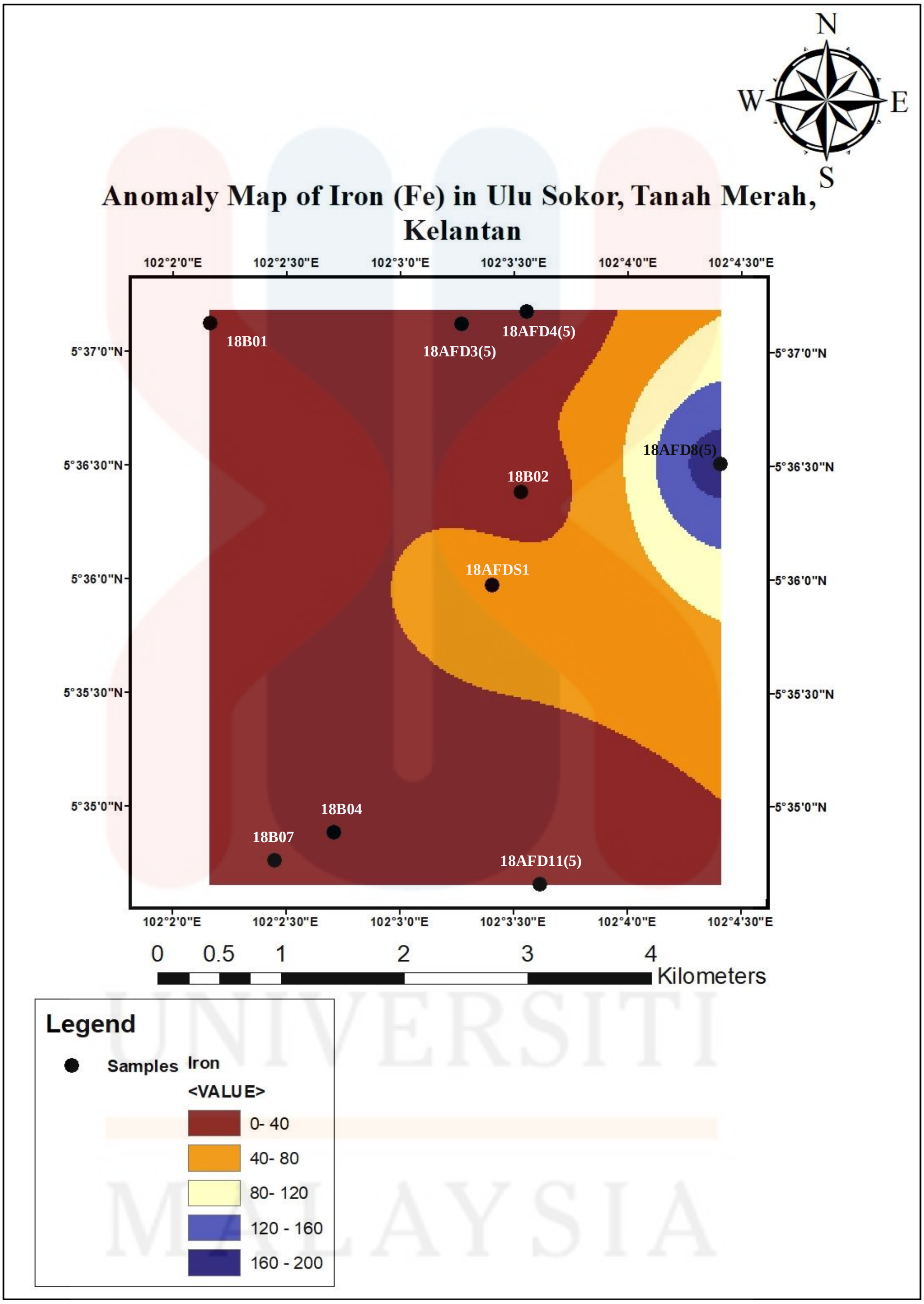


Figure 5.11: Anomaly Map of Iron (Fe) in soil in respective locations.

Figure 5.10 shows that the concentration of iron (Fe) is differ in respective locations. Iron concentration in soil is higher in both location as in 18AFD8(5) and in 18AFDS1 with the concentration are 173.100 ppm and 49.900 ppm respectively. As mention above, 18AFDS1 is located in gold mining area whereas for 18AFD8(5) is located toward east of the gold and ex gold mining area. The medium concentration for iron is recorded in18AFD3(5) with 23.260 ppm. Meanwhile, the lowest concentration of iron in study area is located in 18B01 with the value of iron concentration is 5.064 ppm.

Meanwhile for the concentration of iron in plant, the highest concentration resulted by 18AFD3(5), *Melastoma malabathricum* with the concentration 1.181 ppm. The moderate concentration resulted is 0.430 ppm located at 18B01 (*Melastoma Malabathricum*) and the lowest concentration is absorbed by (*Dactylis glomerate*) with 0.063 ppm.

According to the map construct in Figure 5.11, what can be conclude is that moving towards the east part of the map indicating the higher concentration of iron in which 18AFD8(5) sample was located. The second most highest iron concentration is in mining area in which 18AFDS1 located in the centre of the anomaly map. The lowest distribution of iron concentration in soil located towards the northwest and towards south part of the anomaly map.

The concentration of iron can be identified based in the type of soil, as the soil in the area are mostly laterite. Laterite soil is commonly contain high amount of iron and gives the colour of soil reddish to brownish. In addition, the availability of iron element in soils influenced by the waterlogged contained in the soils. The wetness of the soil affect the presence of the soil. High content of water inside the soil lead to the higher amount of iron content. Also, higher amount of organic matter in soil lead to the higher content of iron.

The soil in both location are generally acid as the presence of iron is quite high. The existence of iron can be detected when the soil are acidic. To determine the soil is acidic or no is based on its colour. Both of the soils have reddish to greyish in colour. Thus, this gives an indication of the presence of heavy elements such as iron. Besides that, the presence of iron always associated with manganese. It means that when the concentration of iron is high in certain location, the concentration of manganese also high.

Lead Concentration

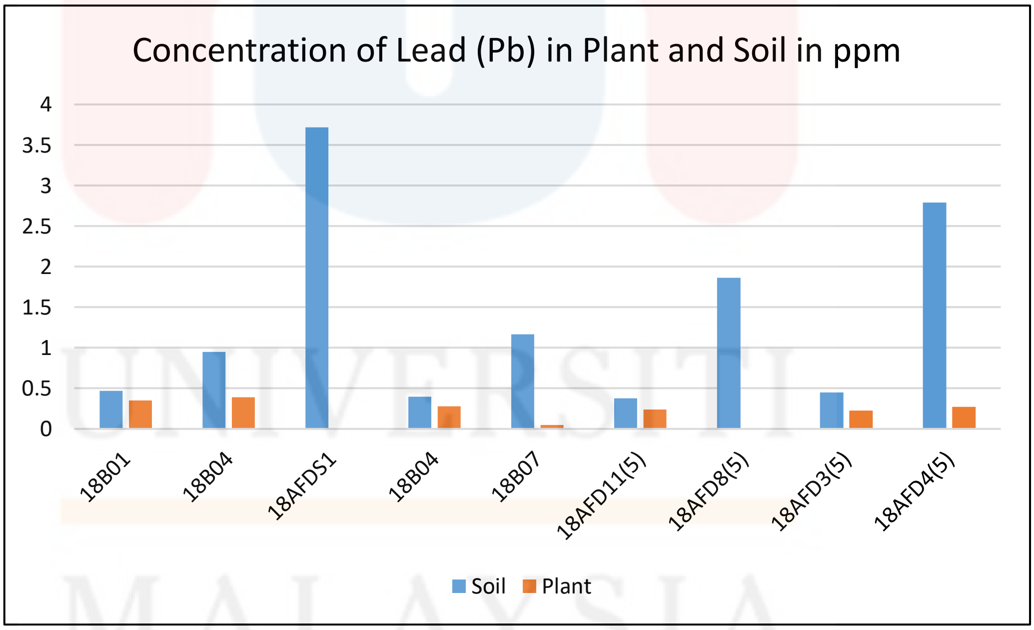


Figure 5.12: Lead (Pb) concentration for plant and soil samples.

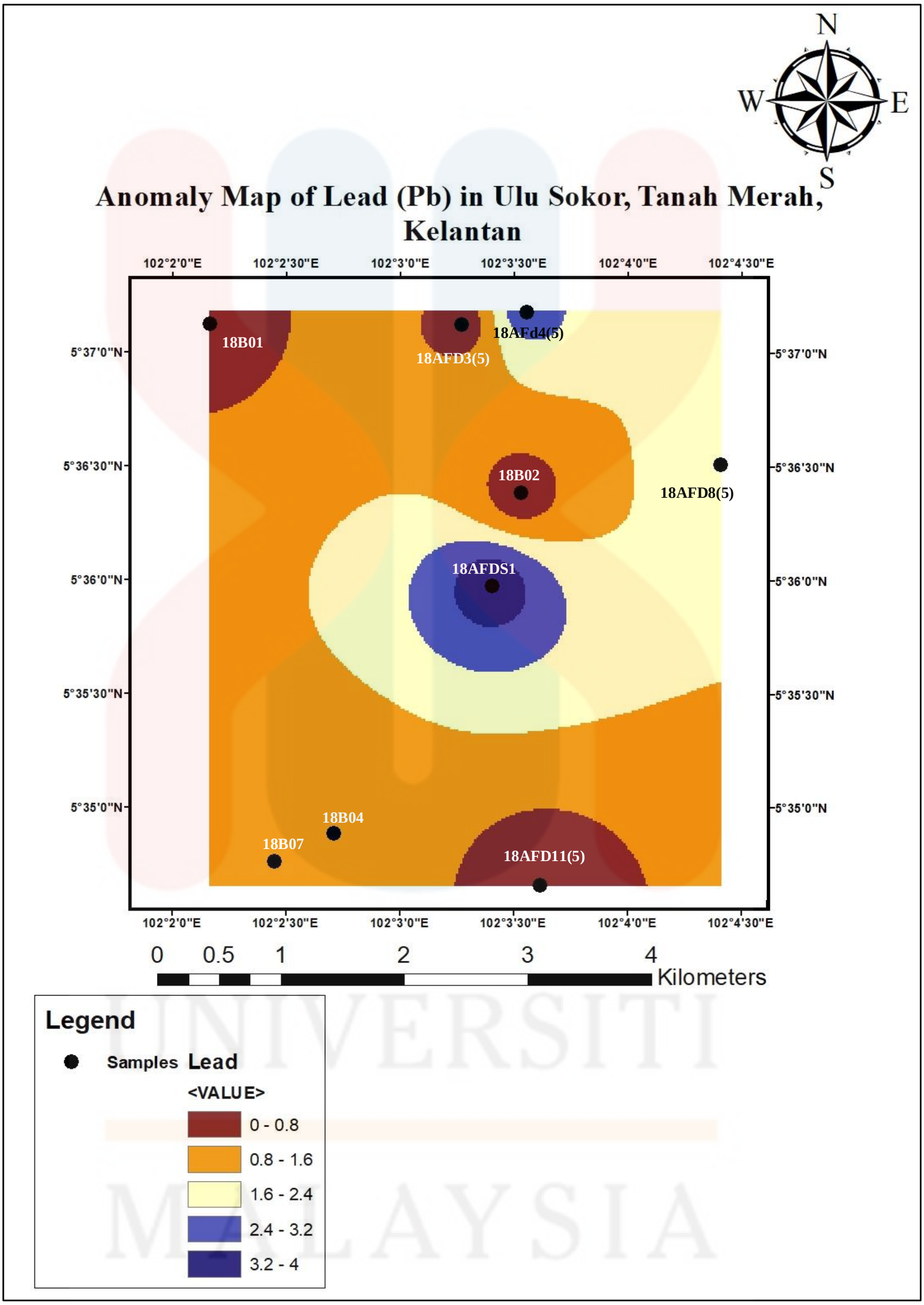


Figure 5.13: Anomaly Map of Lead (Pb) in plant and soil in respective locations.

In Figure 5.12, the distribution of lead is higher in only two place which the value of part per million (ppm) is higher than 2 ppm. This amount is quite high as lead is one of very toxic element. The most highest concentration of lead is located in mining area, 18AFDS1. The lead concentration reach up to 3.716 ppm followed by 18AFD4(5) with 2.790 ppm. 18AFD4(5) sample was taken near the big lake. The medium concentration is resulted in 18B04 with 0.947 ppm. Meanwhile, for the lowest concentration of lead located in 18AFD11(5) with the value of lead concentration is 0.375 ppm.

In terms of plan absorption for lead concentration, the highest concentration absorbed by plant is 18B04 (*Melastoma malabathricum*) with 0.391 ppm. As for the medium concentration recorded absorbed by plant is 18B02 (*Syzygium Zeylanicum*)with 0.280 ppm and the lowest is recorded in two location which are 18AFDS1 (*Melastoma malabathricum*) and 18AFD8(5) (*Dactylis glomerate*) both gives the value of Below Detection Limit, BDL.

On the other hand, referring to the anomaly map of lead in Figure 5.13, the distribution of lead are is higher on the centre part of the map in which the mining area is located. In addition, highest concentration of lead also distribute on small part of north area of anomaly map where the sample of 18AFD4(5) is located. Whereas, the distribution of lead decrease towards the south and northwest part of the anomaly map.

Sometimes, lead always associated with silver. Thus, the colour of soil when there is the presence of lead tends to have greyish to lighter grey. Since the soil in the mining area is greyish, this give a hint that the presence of lead is quite high. Thus, conclude that the soil is contaminate. Also, this gives an indication of the presence of gold. The presence of lead also influenced by the presence of higher amount of organic content.

5.5.2 Possibility of Gold Deposition According To Pathfinder Elements Distribution

Overall, the possibility of gold bearing are located in three locations which are 18AFDS1, 18AFD8(5) and 18B02. There is no doubt that in 18AFDS1 has the presence of gold as the mining activity occurred in that area. As discussed above according to the pathfinder elements distribution, 18AFDS1 has the most highest value of concentration of silver (Ag), manganese (Mn) and lead (Pb) then as second highest concentration value of copper (Cu) and iron (Fe). This evidence can be strengthen by the XRF result which gives the overview of element oxide present in the three different colour of 18AFDS1 soil. Overall, the three sample of 18AFDS1 have a few heavy metals associate with oxide. They are Vanadium (V) oxide, Titanium (IV) oxide, Antimony (III) oxide, Nickel oxide and Zinc oxide. Besides that, the concentration of silica presence in the soil also exceed the mean content of silica in soil which is 67%. Typically, the percentage of iron is 1-5% in the soil composition. However, based on the result of XRF, the soil has and exceed percentage number of iron oxide. All of the explanation above gives the evidence that the soil has the tendency in containing the heavy metals.

For samples in 18AFD8(5), it results the highest value of concentration in copper (Cu) and iron (Fe). It can be said as the possible location for the deposition of gold. The sample was taken nearby the rivers. The other pathfinder elements which are manganese (Mn) and Lead (Pb) also high. As the result shown previously, the content of above heavy metals indicate that the area is said to accumulate the possible gold deposition as gold are sometimes associate with copper, manganese and lead as gold is a native element.

On the other hand, the samples taken located in 18B02 can be said as the possible place for the existence of gold deposit. This is because the plant that was taken as a sample is one of the hyperaccumulator plant that was recorded in past research. The value of the concentration of pathfinder elements are second higher from both location mentioned above. The soil sample was taken on the riverbank. Besides that, this area was located near the ex and currently gold mining area. Thus, the possibility of the gold existence is higher compare to the other place.

5.5.3 Hyperaccumulator plants

Generally, hyperaccumulator plant model is used for phytoremediation purpose. This is because they can absorb and tolerant with heavy metals that present in the soils. These type of plant have a high tendency to absorb heavy metals and accumulate the heavy metals in its tissue. These plants are called toxic plants. Plants will always uptake the nutrients that presence in the soils. This biogeochemical cycle gives an overview that every element that contain in the soil will be absorbed by the plant for its benefit.

Thus, in order to determine the degree of metal accumulation in plant, the Bioaccumulation Factor (BF). If the value of BF is greater than 1, the plant concerned to be a hyperaccumulator plant (Wei et al, 2011). Below shows the formula calculation for Bioaccumulation Factor, BF:

$$TF = \frac{Concentration\ of\ metals\ in\ Plant}{Concentration\ of\ metals\ in\ Soil}$$

Table 5.4: Result of Bioaccumulation Factor, BF.

Elements / Locations	Silver (Ag)	Manganese (Mn)	Copper (Cu)	Iron (Fe)	Lead (Pb)
18B01 (*Melastoma malabathricum*)	0.300	8.263	0.323	0.085	0.750
18B04 (*Melastoma malabathricum*)	2.000	0.061	0.043	0.058	0.413
18AFDS1 (*Mimosa pudica*)	0.741	0.520	0.022	0.004	-
18B02 (*Syzygium zeylanicum*)	0.071	0.004	0.051	0.007	0.707
18B07 (*Melastoma malabathricum*)	2.250	0.104	0.013	0.002	0.040
18AFD11(5) (*Rhamnus frangula*)	3.333	1.202	0.121	0.079	0.463
18AFD8(5) (*Dactylis glomerate*)	0.714	0.324	0.007	-	-
18AFD3(5) (*Melastoma malabathricum*)	2.500	4.703	0.062	0.051	0.493
18AFD4(5) (*Melastoma malabathricum*)	-	5.088	1.000	0.025	0.097

The Bioaccumulation Factor (Bf), in *Melastoma malabathricum* in 18B04, 18B07 and 18AFD3(5) and *Rhamnus frangula* in 18AFD11(5), are more than 1 for silver concentration. As for manganese, the Bf value which have more than 1 are 18B01, 18AFD3(5) and 18AFD4(5) for *Melastoma malabatricum* and 18AFD11(5) for *Rhamnus frangula.* Meanwhile for copper concentration, the value of Bf is higher only in *Melastoma malabathricum* which is 1.

The results show that *Melastoma malabathricum* can accumulate silver, manganese and copper while *Rhamnus frangula* can absorb silver and manganese.

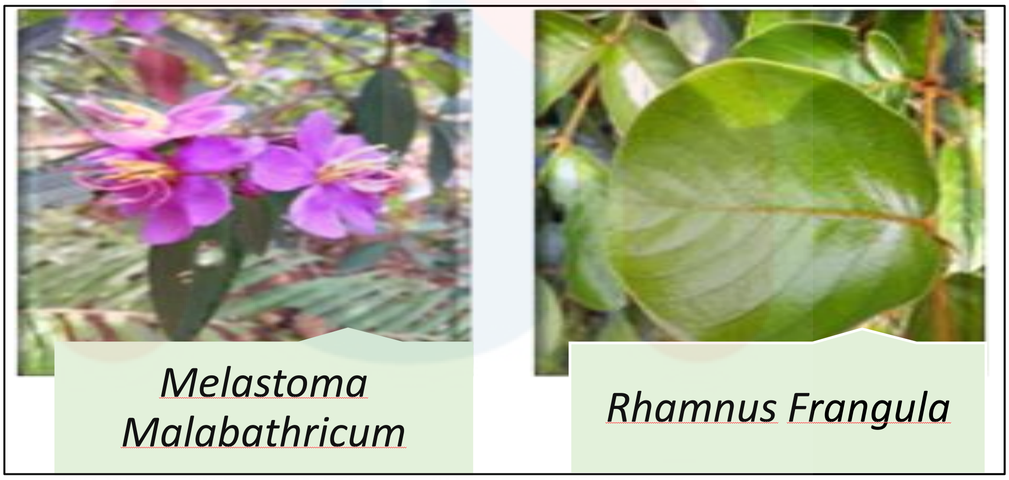


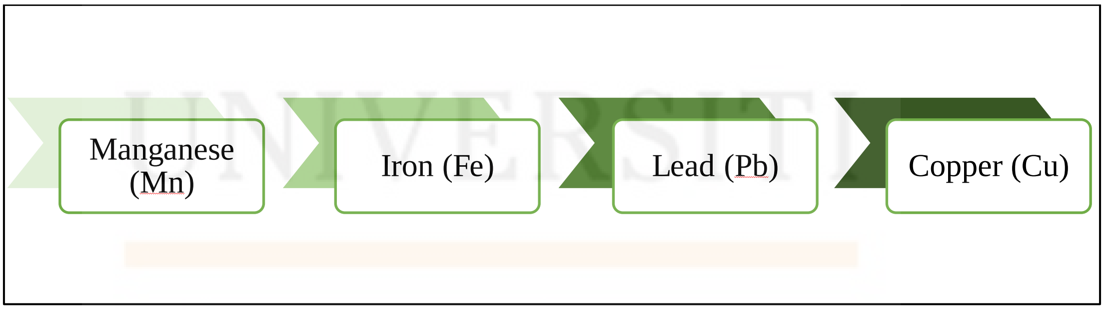
Figure 5.14: Plant species that can be consider as hyperaccumulator plant in which the value of Bioaccumulation factor is more than 1.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

Conclusion

The value of pathfinder elements are differ based on their location respectively. The pathfinder elements which are silver (Ag), manganese (Mn), copper (Cu), iron (Fe) and lead (Pb) are important in determining the possible location of the presence of gold deposit, however, the concentration value of silver can be neglected since all of the value is less than 0.05 ppm. The concentration of silver is not harmful if it is not more than 0.05 ppm, Schlich (2013). Thus, this can be conclude that the easy order of the presence of pathfinder elements can be present as followed:



Melastoma malabathricum and *Rhamnus Frangula* can act as hyperaccumulator plants because the concentration of Bf is higher than 1. *Melastoma malabathricum* can absorb silver, manganese and copper at high rate while *Rhamnus frangula* can absorb silver and manganese elements.

As a conclusion, the possible location of gold bearing in the study area are located in 18AFDS1, 18AFD8(5) and 18B02 and. This is because, the presence of pathfinder elements in these three location based on the result of AAS of soil samples indicate is quite high than the other six samples.

Recommendation

For the recommendation, for future research is that the plant samples should be taken more than one in one location for the determination of which plant is the best hyperaccumulator plant. A proper sampling also is necessary so that the coverage of anomaly elements can be constructed perfectly. Besides that, the use of instrument in UMK should works efficiently to prevent any problems in sample analysing. Also, collect a non-dominant species in order to determine the hyperaccumulator plant. Lastly, laboratory instrument in UMK should works efficiently to prevent any problems in sample analysis.

REFERENCES

Ariffin, K. S., & Hewson, N. J. (2007). Gold-Related Sulfide Mineralization and Ore Genesis of the Penjom Gold Deposit, Pahang, Malaysia. Resource Geology, 57(2), 149-169. doi:10.1111/j.1751-3928.2007.00014.x

Bader, N. R., & Zimmermann, B. (2012). Sample preparation for atomic spectroscopic analysis: An overview. Advances in Applied Science Research, 3(3), 1733-1737.

Basso B, Ritchie JT, Pierce FJ, Braga RP, Jones JW (2001) Spatial validation of crop models for precision agriculture. Agricultural Systems 68: 97–112.

Bignell, J.D. and Snelling N. J. (1977), Geochronology of Malayan Granites. Overseas Geol. Min. Resour., 47, 1-72.

Bradshaw, P. M. D., and Thomson, I., 1979, The application of soil sampling to geochemical exploration in non-glaciated regions of the world. In: Geophysics and geochemistry in the search for metallic ores; Geological Survey of Canada, Economic Geology Report 31, p. 327-338

Bramley RGV, Hamilton RP (2004) Understanding variability in winegrape production systems. 1. Within vineyard variation in yield over several vintages. Australian Journal of Grape and Wine Research 10: 32–45.

Bramley RGV (2005) Understanding variability in winegrape production systems. 2. Within vineyard variation in quality over several vintages. Australian. Journal of Grape and Wine Research 11: 33–42.

Brooks, R. R. (1979). Advances In Botanical Methods Of Prospecting For Minerals Part 2 Advances In Biogeochemical Methods Of Prospecting.

Craig A. Lockard, Z. B. A., Ooi Jin Bee, Thomas R. Leinbach (2018). Malaysia. In E. BRITANNICA (Ed.), Plant and animal life: Encyclopædia Britannica, inc.

Dana, J. D., & Hurlbut, C. S. (1971). Danas Manual of mineralogy. New York: Wiley.

Darbyshire, D.P.F., 1988. South-East Asia Granite Project- Geochronology of Thai Granites. London, Nat Environment Research Council, Isotope Geol. Centre Rept. 88/5, 46 p.

David Mann, C. L., Henry Paul Nunes, D. T Oakley. (1989). THIN SECTION PREPARATION PROCEDURE (5).

Department of Minerals and Geoscience Malaysia: Quarry Re-source Planning for the State of Kelantan, Osborne and ChappelSdn. Bhd., Kuala Lumpur, Malaysia, 2003

Dolbeare, A. (2014, November). Geobotany: Plants Associated With Mineral Deposits. Prospecting & Detecting. doi:https://www.icmj.com/magazine/article/geobotany-plants-associated-with-mineral-deposits-3156/

Dunn, C. E. (2010). New Perspectives on Biogeochemical Exploration. Advances in Prospect-Scale Geochemical Methods, 250-258.

Eash, N. S., Green, C. J., Ravzi, A., & Bennet, W. F. (2008). Soil Science Simplified, 5th Edition (5th ed.). Swaston street, Victoria: Wiley-Blackwell.

Ghani, A. A., Cottam, M. A., & Hall, R. (2013). Late Cretaceous and Cenozoic Tectonics of Malaysia Peninsula Constrained by Thermochronology. Journal of Asian Earth Science, 76, 241-257.

Geosains., M. J. M. d. (Cartographer). (2000). Peta geologi dan taburan mineral Negeri Kelantan = Geologi and mineral distribution map of Kelantan.

Girling, C. A., & Peterson, P. J. (1980). Gold in plants. Gold Bulletin, 13(4), 151-157. doi:10.1007/bf03215461

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

Hashim, M., Pour, A. B., & Misbari, S. (2017). Mapping land slide occurrence zones using Remote Sensing and GIS techniques in Kelantan state, Malaysia. Journal of Physics: Conference Series, 852, 012023. doi:10.1088/1742-6596/852/1/012023

Havlin, J., Nelson, W. L., Beaton, J. D., & Tisdale, S. L. (2016). Soil fertility and fertilizers: An introduction to nutrient management. Noida, Uttar Pradesh, India: Pearson.

Hutchison C.S and Tan D.N.K (2009). Geology of Peninsular Malaysia. Published by University Malaya and Geological Society of Malaysia.

Ito, A., & Wagai, R. (2017). Global distribution of clay-size minerals on land surface for biogeochemical and climatological studies. Scientific Data, 4, 170103. doi:10.1038/sdata.2017.103.

Jobbágy, E. G., & Jackson, R. B. (2004). The Uplift Of Soil Nutrients By Plants: Biogeochemical Consequences Across Scales. Ecology, 85(9), 2380-2389. doi:10.1890/03-0245

Jobba´gy, E. G., and R. B. Jackson. 2001. The distribution of soil nutrients with depth: global patterns and the imprint of plants. Biogeochemistry 53:51–77.

Jorgensen, S. E. (2016). Chapter 2 - Biogeochemical Models. Developments in Environmental Modelling, 28, 13-38.

Kelepertsis, A., & Andrulakis, I. (1983). Geobotany-biogeochemistry for mineral exploration of sulphide deposits in northern Greece — Heavy metal accumulation by Rumex acetosella L. and Minuartia verna (L.) Hiern. Journal of Geochemical Exploration, 18(3), 267-274. doi:10.1016/0375-6742(83)90072-9.

Kramer, S. (2018). Prepare for Accurate Analysis: Sample Preparation Guidelines for ED-XRF Analysis.

Lastochkin, A. N., Zhirov, A. I., & Boltramovich, S. F. (2018). System-morphological approach: Another look at morphology research and geomorphological mapping. Geomorphology, 303, 486-503. doi:10.1016/j.geomorph.2017.10.022

Lee, C. P. (2009). Paleozoic stratigraphy. In: Hutchison C.H., Tan D.N.K.,(eds). Geology of Peninsula Malaysia. Kuala Lumpur, Malaysia. University of Malaysia and Geological Society of Malaysia.

Lim, J. T., & Samah, A. A. (2004). Weather and climate of Malaysia: University of Malaya Press.

Malaysia, Department of Land and Territory of Kuala Krai, Kuala Krai Land and District Office. (2016). Background. Kuala Krai, Kelantan

Manske, L.L. 2012b. Improvement of cropland soil quality through restoration of ecosystem biogeochemical processes. NDSU Dickinson Research Extension Center. Summary Range Management Report DREC 12-3059. Dickinson, ND. 4p.

Map of East and West Malaysia. Retrieved 31 March 2018 https://www.pinterest.com/pin/297659856598263883/

Mazzucchelli, R. H. (1996). The application of soil geochemistry to gold exploration in the black Flag Area, Yilgarn Block, Western Australia. Journal of Geochemical Exploration, 57(1-3), 175-185. doi:10.1016/s0375-6742(96)00033-7

Mcinnes, B. I., Dunn, C. E., Cameron, E. M., & Kameko, L. (1996). Biogeochemical exploration for gold in tropical rain forest regions of Papua New Guinea. Journal of Geochemical Exploration, 57(1-3), 227-243. doi:10.1016/s0375-6742(96)00039-8

Moody, P. W. (2008). Soil Constraints and Management Package (SCAMP) guidelines for sustainable management of tropical upland soils. Canberra: ACIAR.

Padhy, S. (2017, September 04). Indicator and Pathfinder Minerals in Gold Exploration | INN. Retrieved June 6, 2018, from https://investingnews.com/daily/resource-investing/precious-metals-investing/gold-investing/indicator-minerals-pathfinder-minerals-and-gold-exploration/

Raj, J.K. (2009) Geomorphology. In: Hutchison, C.S. and Tan, D.N.K., Eds., Geology of Peninsular Malaysia, Geological Society of Malaysia, Kuala Lumpur, 5-29.

Raven, P. H., Johnson, G. B., Mason, K. A., Longos, J. B., & Singer, S. R. (2017). Biology 11th Edition (11th ed.). 2 Penn Plaza, New York: McGraw-Hill Education.

Reese, C. W., Strango, Z. I., Dell, Z. R., Tristram-Nagle, S., & Harper, P. E. (2015). Structural insights into the cubic–hexagonal phase transition kinetics of monoolein modulated by sucrose solutions. Physical Chemistry Chemical Physics, 17(14), 9194-9204. doi:10.1039/c5cp00175g

Roels J.M, Jonker P.J. (1983). Probability sampling techniques for estimating soil erosion. Soil Science Society of America Journal 47: 1224–1228.

Plaster, E. J. (2003). Soil Science & Management (Z. M. Lawrence Ed. 4th ed.). Clifton Park, NY: Thomson Learning, Inc.

Rackley, S. A. (2017). 14 – Geochemical and biogeochemical features, events, and processes. Carbon Capture and Storage (Second Edition), 365-386.

Schlich, K., Klawonn, T., Terytze, K., & Hund-Rinke, K. (2013). Hazard assessment of a silver nanoparticle in soil applied via sewage sludge. Environmental Sciences Europe, 25(1), 17. doi:10.1186/2190-4715-25-17

Scholes, M. C., & Scholes, R. J. (2013). Dust Unto Dust. Science, 565-566.

Shah, K. (2012). Mesothermal Lode Gold Deposit Central Belt Peninsular Malaysia. Earth Sciences, 322. doi:10.5772/26179

Simonsson, M., Court, M., Bergholm, J., Lemarchand, D., & Hillier, S. (2016). Mineralogy and biogeochemistry of potassium in the Skogaby experimental forest, southwest Sweden: Pools, fluxes and K/Rb ratios in soil and biomass. Biogeochemistry, 131(1-2), 77-102. doi:10.1007/s10533-016-0266-9

Singh, B., & Schulze, D. G. (2015). Soil Minerals and Plant Nutrition. Retrieved April 9, 2018, from https://www.nature.com/scitable/knowledge/library/soil-minerals-and-plant-nutrition-127881474

Smith, P., Cotrufo, M. F., Rumpel, C., Paustian, K., Kuikman, P. J., Elliott, J. A., ...Scholes, M. C. (2015). Biogeochemical cycles and biodiversity as key drivers of ecosystem services provided by soils. Soil, 1(2), 665-685. doi:10.5194/soil-1-665-2015.

Sunariyati, S. (2013). 4th International Conference on Global Resource Conservation & 10th Indonesian Society for Plant Taxonomy Congress Brawijaya University. The Ability of Plants to Accumulate Aurum (Au) in the Central Kapuas Gold Mining Region.

Taylor JA (2004) Digital terroirs and precision viticulture: Investigations into the application of information technology in Australian vineyards. PhD thesis, The University of Sydney, New South Wales, Australia.

Tuttle, M. L., Severson, R. C., Dean, W. E., & Klusman, R. W. (1986). Geochemical variability of soils and biogeochemical variability of plants in the Piceance Basin, Colorado (pp. E1-E46, Publication No. 1134). USGS.

Wei, S., Zhu, J., Zhou, Q. X., & Zhan, J. (2011). Fertilizer amendment for improving the phytoextraction of cadmium by a hyperaccumulator Rorippa globosa (Turcz.) Thell. Journal of Soils and Sediments, 11(6), 915-922. doi:10.1007/s11368-011-0389-5

Wenjuan Huang, S. J. H. (2017). Optimized high-throughput methods for quantifying iron biogeochemical dynamics in soil. Geoderma, 306, 67-72.

Woodford, C. (2018, April 07). How do electron microscopes work? Retrieved from https://www.explainthatstuff.com/electronmicroscopes.html

Wulfsohn, D. (2010). Sampling Techniques for Plants and Soil. Landbauforschung Völkenrode (340), 3-24.

APPENDICES