GEOLOGY OF TEMANGAN AND BIOGEOCHEMICAL STUDY OF PLANT AND SOIL IN MALAYSIA

by

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DECLARATION

I declare that this thesis entitled "Geology of Temangan and Biogeochemical Study of Plant and Soil in Malaysia" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

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

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Geology of Temangan and Biogeochemical Study of Plant and Soil in Malaysia

ABSTRACT

This research covered 25 km^2 of area with latitude 5°38'16.8" N to 5°41' N and longitude 102°07'30" E to 102°10'12.4" E. This research was carried out due to the limitation of geological information in the area as there are only large-scale studies had been done. Also, biogeochemical study of plant and soil in Malaysia was conducted due to less research was done on biogeochemistry in tropical region. Thus, the objective of this research is to produce a geological map of Temangan area with scale 1:25,000 and to review the existing biogeochemistry study of element concentration in plant and soil samples in selected area in Malaysia based on previous research. The general geology of study area was determined by referring to articles from internet and past year undergraduate thesis. The thematic and geological maps were produced using ArcGIS software with the help of secondary data like DEM data from USGS website. The study area comprises five lithological units: schist, sandstone, shale, andesite and ignimbrite. The formation of geological structures are influenced by Lebir Fault. For biogeochemistry study, four articles in different areas in Malaysia were choose. Four parameters were discussed involving plant species and its morphology, soil and/or sediment properties, geological condition of the area and the elemental distribution of plant and soil samples. The relationship of geology and the geochemistry of soil and the relationship of the concentration of elements in plant and soil geochemistry were determined. *Melastoma malabathricum* in Bukit Besi, Terengganu and *Antidesma montis-silam* in Mount Silam Forest Reserve, Sabah shows a very high Al and Ni element concentration in plant sample. According to Reeves, et al. (2017), those two plants are recognized as Al and Ni hyperaccumulator plant species.

Kajian Geologi di Temangan dan Biogeokimia Tumbuhan dan Tanah di Malaysia

ABSTRAK

Penyelidikan ini meliputi kawasan seluas 25 km^2 dengan garis lintang 5°38'16.8" N hingga 5°41' N dan garis bujur 102°07'30" E hingga 102°10'12.4" E. Penyelidikan ini dilakukan kerana terdapat keterbatasan maklumat geologi di kawasan tersebut kerana hanya kajian berskala besar pernah dilakukan sebelum ini. Selain itu, kajian biogeokimia tumbuhan dan tanah di Malaysia dilakukan kerana kurangnya kajian mengenai biogeokimia di wilayah tropika. Oleh itu, objektif kajian ini adalah untuk menghasilkan peta geologi kawasan Temangan dengan skala 1:25,000 dan mengulas kajian biogeokimia sedia ada mengenai kepekatan elemen dalam sampel tumbuhan dan tanah di kawasan terpilih di Malaysia berdasarkan kajian terdahulu. Geologi umum kawasan kajian ditentukan dengan merujuk kepada artikel dari internet dan tesis sarjana tahun-tahun lalu. Peta tematik dan geologi dihasilkan menggunakan perisian ArcGIS dengan bantuan data sekunder seperti data DEM dari laman web USGS. Kawasan kajian merangkumi lima unit batuan: schist, batu pasir, batu serpih, andesit dan ignimbrite. Pembentukan struktur geologi dipengaruhi oleh Sesar Lebir. Untuk kajian biogeokimia, empat artikel dipilih merangkumi kawasan yang berbeza di Malaysia. Empat parameter dibincangkan melibatkan spesis tumbuhan dan morfologi, sifat tanah dan/atau sedimen, keadaan geologi kawasan dan penyebaran unsur sampel tumbuhan dan tanah. Hubungan geologi dan geokimia tanah dan hubungan kepekatan unsur dalam geokimia tumbuhan dan geokimia tanah ditentukan. *Melastoma malabathricum* di Bukit Besi, Terengganu dan *Antidesma montis-silam* di Hutan Simpan Gunung Silam, Sabah menunjukkan kepekatan unsur Al dan Ni yang sangat tinggi dalam sampel tumbuhan. Menurut Reeves, et al. (2017), kedua-dua tumbuhan tersebut diakui sebagai spesies tumbuhan hiperakumulator Al dan Ni.

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LIST OF ABBREVIATIONS

N	North
E	East
S	South
W	West
Au	Gold
Ag	Silver
As	Arsenic
Al	Aluminium
Fe	Iron
Zn	Zinc
Pb	Lead
Mn	Manganese
Cu	Copper
O	Oxygen
Si	Silicon
K	Potassium
Ti	Titanium
Ba	Barium
Ni	Nickel
Cr	Chromium
V	Vanadium
sp.	Species
AAS	Atomic Absorption Spectrometry
XRF	X-Ray Fluorescence Spectrometry
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
GIS	Geographic Information System

LIST OF SYMBOLS

°	Degree
’	Minute
”	Second
℃	Temperature
%	Percentage
>	Greater than
<	Less than

CHAPTER 1

INTRODUCTION

1.1 General Background

Geology is the study of the earth, the materials it is made of, the composition of those materials, and the processes that operate on them. The study of how these elements change over time is an important part of geology. The fields of geology include lithology, geomorphology, petrography, structural geology, stratigraphy, historical geology, and geochemistry (Balasubramanian, 2017). Geological mapping is a method of making and recording geological observations in the field (Bahar, et al., 2019). Geological mapping is an interpretive, scientific method that for many different uses, may generate a variety of map products. Geological mapping seeks to understand the structure and composition of geological materials at the surface and depth of the earth, and to use symbols and colors to represent findings and interpretations on maps (Soller, 2004). The information that is recorded must be reliable and open-minded (Bahar, et al., 2019).

Biogeochemistry involves selection and chemical analysis of a plant, selected part of the plant and humus in soil. During chemical weathering, mobilized elements such as nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), chlorine (Cl), and zinc (Zn) diffuse and enhance the quality of a soil (Haldar, 2018). As plant flourish, roots extract these dissolved elements, together with metals, from soil. The elements drift to different parts of the plant. For example, roots, trunks, stems, and leaves. The process ends with leaves falling down the ground, enriching the metal humus. Identify and analyze using legislative selection of suitable parts of the plants may lead to anomalies suggesting buried mineralization (Haldar, 2018).

There are plants that are capable of withstanding certain quantities of heavy metals. Plants that grow in heavy metal area must have excellent adjustment and adaptation, and high tolerance towards heavy metals. This makes the presence of such plants a very good sign of heavy metal assemblages by means of chemical analysis or inspection on their morphology (Chang, 2019). To enable the identification of the existence of metal, the aggregation or population of plants living in the area should be examined, instead of focusing on one plant species only. Specific plant or plant population can also be used to assess soil types and other environmental conditions such as agriculture, groundwater and pollution.

The advantage of using biogeochemistry method is it is simple and affordable, as the vegetation sample is ubiquitous and has low impact on the environment. However, the rates of metals in plant are lower than soil, so care and cautions are required during sampling to minimize contamination. Metal elements that are commonly found in plant samples are aluminum (Al), copper (Cu), iron (Fe), zinc (Zn), lead (Pb) and arsenic (As). But, some plant samples may also pile up common pathfinder elements like silver (Ag), mercury (Hg), gold (Au) and antimony (Sb) (Chang & Ismail, 2019).

1.2 Study Area

The study area is located in Temangan, Machang. The area of interest cover 5 x 5 km in total area. Coordinate of the four corners of the 25 km^2 box in clockwise direction are 5°41' N 102°07'30" E, 5°41' N 102°10'12.4" E, 5°38'16.8" N 102°10'12.4" E and 5°38'16.8" N 102°07'30" E. The base map for the study area is shown in **Figure 1.1**.

1.2.1 Location

The study area is located in Temangan, near Kelantan River, under Machang territory. Geographically, Machang is located at the center of Kelantan Darul Naim state. It is surrounded by Kota Bharu in the north, Kuala Krai in the south, Tanah Merah in the west and Pasir Puteh in the east. **Figure 1.3** shows the location of Machang territory.

Based on **Figure 1.1**, the highest elevation in the study area is 290 m while the lowest elevation is 20 m. Few villages and plantations can be found in and near the study area. For examples, Kampung Bukit Besi, Kampung Temangan Lama, Kampung Pauh, Kampung Sungai Bedal, Bandar Temangan, Ladang Onn Chwee Lee, Ladang Sungai Bedal, Ladang Pasir Besar and Hutan Rizab Temangan.

According to the Official Portal of Machang District Council (2016), Machang Territory received their name from a village called Kampung Machang. A group of villagers from Pasir Tumboh in Kota Bharu, led by one Mr. Senik Awang Kecik, opened this village in 1880. Late in its history, the chief economic activities of the villagers here were agriculture and trade. Machang was defined as a smaller territory around 1949. Then, on 1 January 1952, Machang was given a full territory due to the accelerated pace of development and its productive economic sector. In total, Machang covers a land area of 546.26 km square. Of all this, 129 km square comes under the authority of the Machang District Council.

On the other hand, Temangan District is famous for its iron ore mining industry. According to the Official Portal of Machang District Council (2016), during the Japanese colonization in Malaya from 1941-1945, iron ore production was dominated by the Japanese government through a company called Oriental Mining Co. The mining activity was done in Bukit Besi, Temangan area. After the Second World War, production of iron ore was continued by the same company but under the control of another government, the British. Due to the short supply of iron ore in 1965, the mining operation is discontinued.

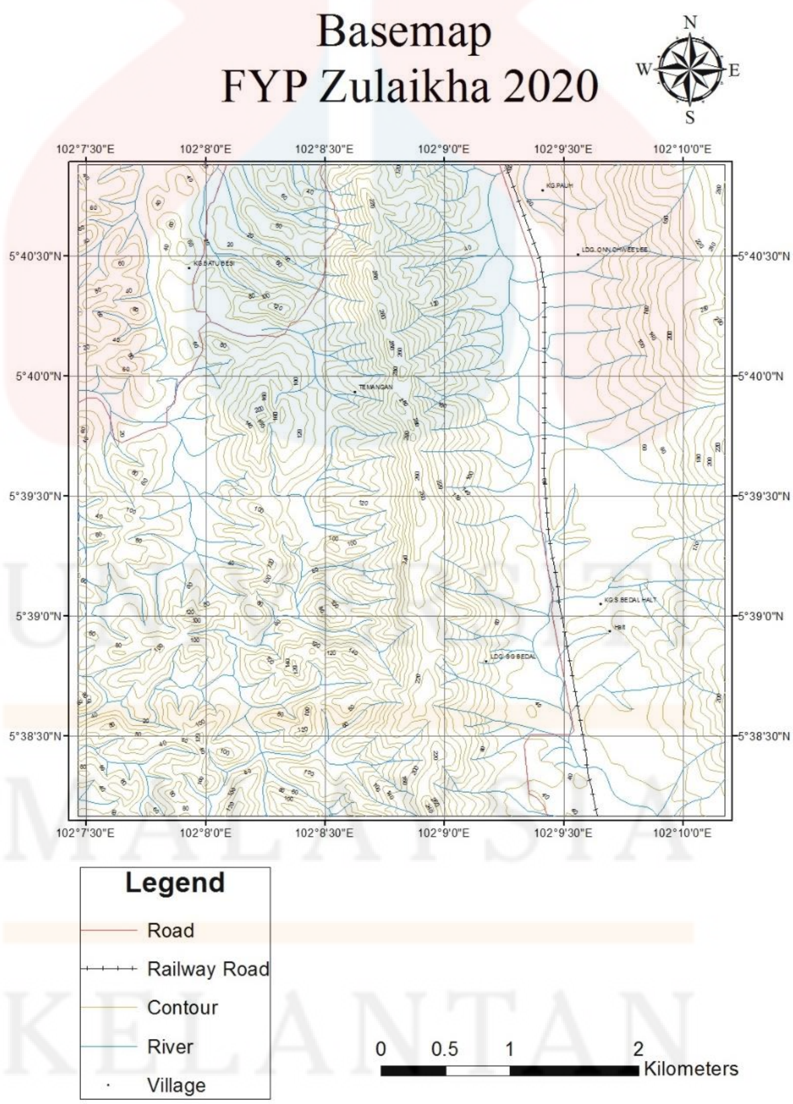

Figure 1.1: Base map of the study area in Temangan, Machang.

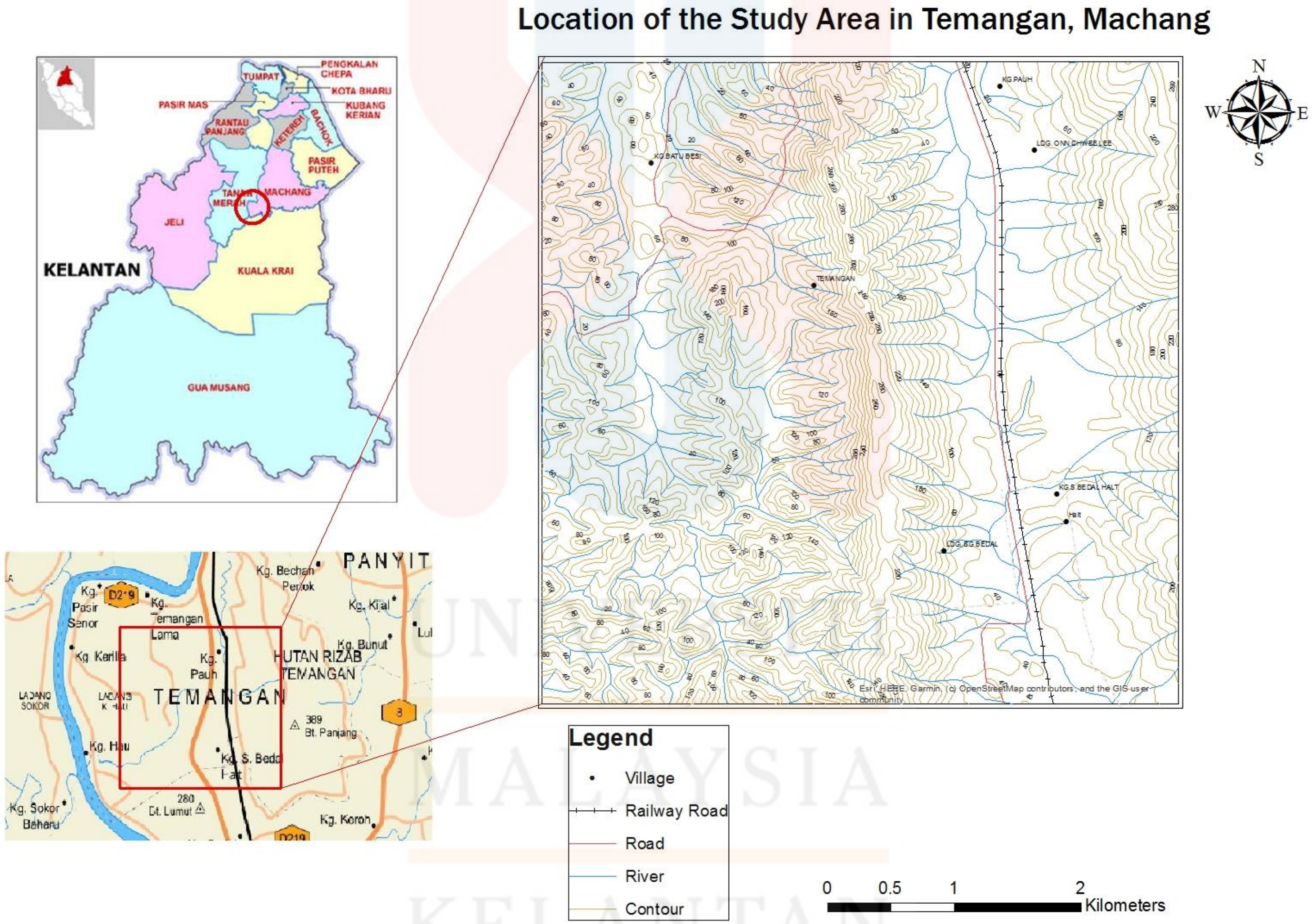

Figure 1.2: Location of the study area in Temangan, Machang.

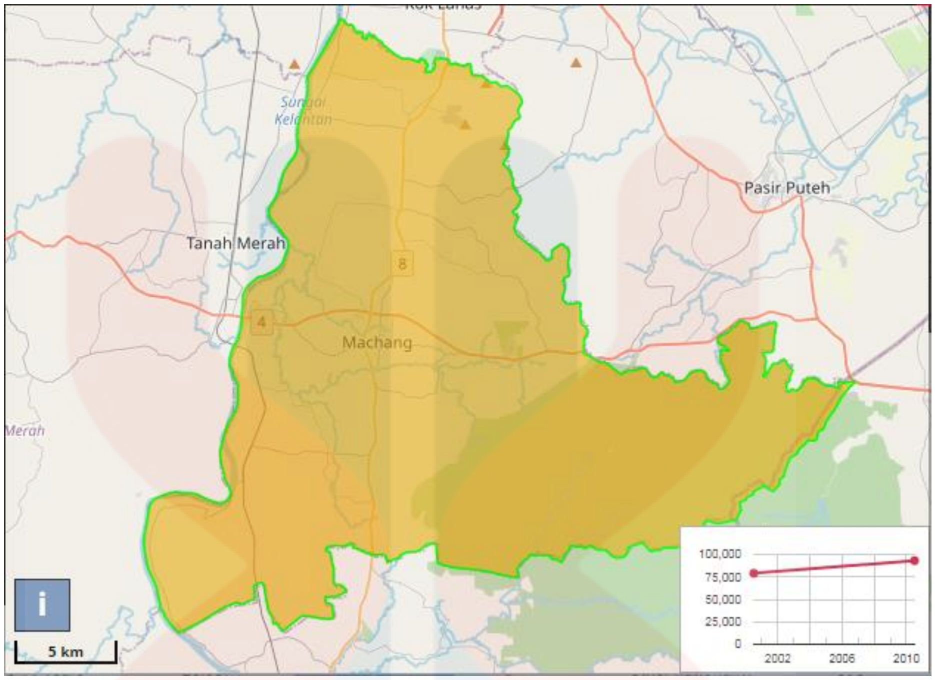

Figure 1.3: **S**treet map of Machang District bounded by the green line obtained from the Official Website of City Population (2010).

1.2.2 Road Connection/Accessibility

Temangan District can be accessed by two main roads. From the north through Jalan Pasir Putih - Machang - Gerik entering Jalan Temangan - Kuala Hau and from the south through Jalan Kota Bharu - Gua Musang entering Jalan Kampong Bedal - Kuala Hau. The exact study area can be entered through few small, villages' roads and housing areas. From the satellite imagery shown in **Figure 1.4**, there are some unpaved roads connected with the small roads within the study area. These unpaved roads are located in the area of mining activity and high lands. To enter those areas, 4 x 4 wheels vehicle is required. Next, the area can also be accessed by Tumpat - Gemas railway line connected with the Temangan Railway Station, Keretapi Tanah Melayu Berhad (KTM) on the east.

Since the study area is located near the Kelantan River, motor boats and sampans are used by locals to connect them with other places via river routes.

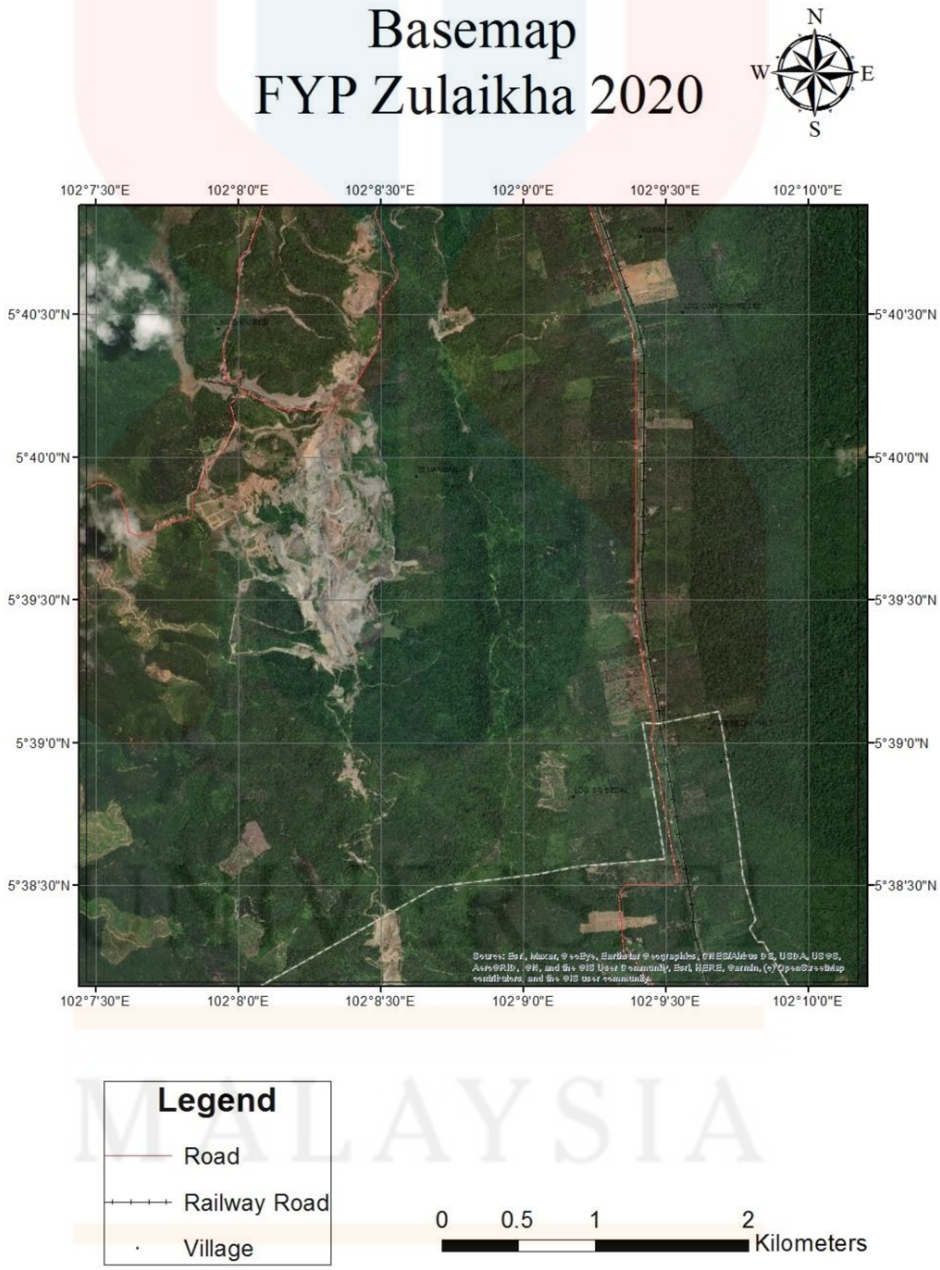

Figure 1.4: Satellite imagery of the study area in Temangan, Machang.

1.2.3 Demography

As there is limitation to obtain the current record of the study area's specific demographics, the 2010 Temangan District demographics are tabulated in this section. According to the Official Website of City Population (2010), the total population of Temangan area in year 2010 was 5786 peoples, compared to 10 years before, in 2000 was 5608. It includes people of Malaysia who are Bumiputera (Malay and others) and non-Bumiputera (Chinese, Indians and others) and non-Malaysian. Malay-Kelantanese is the local language used here.

Table 1.1: Temangan demography in ten years interval.

Year	Census 2000-07-05	Census 2010-07-06
Population	5608	5786

Source: Official Website of City Population (2010)

Table 1.2: Temangan demography according to gender.

Gender	Males	Females
Population	2896	2890

Source: Official Website of City Population (2010)

Table 1.3: Temangan demography according to age groups.

Age groups	0-14 years old	15-64 years old	More than 65 years old
Population	1766	3454	566

Source: Official Website of City Population (2010)

Table 1.4: Temangan demography according to nationality.

Nationality	Malaysian	Non-Malaysians
Population	5590	196

Source: Official Website of City Population (2010)

Table 1.5: Temangan demography according to ethnic group.

Nationality	Malay and Bumiputera	Chinese	Indians	Others
Population	4908	601	61	20

Source: Official Website of City Population (2010)

1.2.4 Landuse

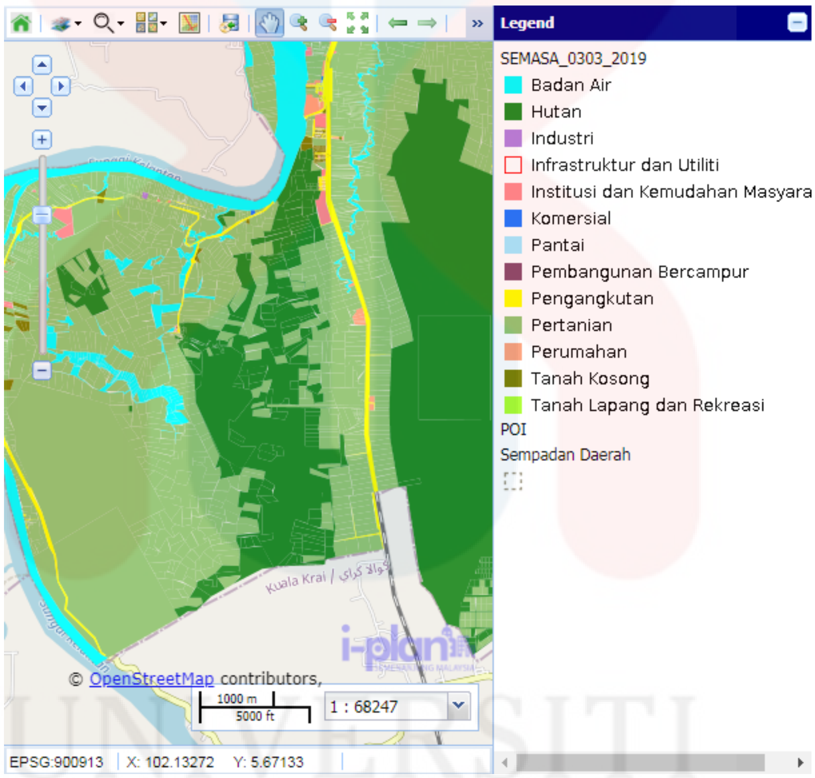

Figure 1.5: Screenshot from the Official Portal of Federal Department of Town and Country Planning, i-Plan (2019).

From the Official Portal of Federal Department of Town and Country Planning, i-Plan (2019), **Figure 1.5** shows the distribution of land use in the study area. Majority of the 25 km^2 of area is covered with two types of land use, forest and plantation. The forest extends from the north to the south of the center part of the study area and the east, consisting of Hutan Rizab Temangan. Meanwhile, plantation especially rubber plantation covers the center, left part of the area, along the railway road on the east. There are only small portion of the area is covered with village and housing area. From the satellite imagery in **Figure 1.4**, presence of unpaved road suggests activities like mining and forestry have been done there. Overall, the study area is considered as rural area, since it is located quite far from a nearby town. Malaysia's rainy tropical climate and the presence of Kelantan River near the location might be a boost factor that enhance the thick natural vegetation and other industries there.

1.2.5 Social Economic

Table 1.6 shows the Labor Force Participation Rates (%) and Unemployment Rate (%) in Kelantan from year 2015 to 2019. The Population Estimates are based on Malaysia's 2010 Adjusted Population and Housing Census. The table shows that the labor force participation in Kelantan state had undergone fluctuation along the year 2015 to 2019. However, in 2018, the numbers started to decrease. In addition with the unemployment rate, the numbers kept increasing as years pass by. Overall, the socioeconomic of Kelantan state is in worrying phase.

Table 1.6: Kelantan labor force participation rates (%) and unemployment rate (%) year 2015-2019.

Year	2015	2016	2017	2018	2019
Labor Force Participation Rates (%)	61.9	59.1	61.1	60.5	58.9
Unemployment Rate (%)	3.6	3.8	3.6	4.0	4.0

Source: Official Portal of Department of Statistics Malaysia (2019)

The Gross Domestic Product (GDP) as per sectors in Kelantan year 2018 shows that the state is developing rapidly with natural resource exploitation as shown in **Table 1.7** with a total GDP rate of 2.6%.

Table 1.7: Economic growth of Kelantan state in 2018.

Sector	Growth (%) based on constant price of 2015
Agriculture	-1.0
Mining and Quarrying	15.8
Manufacturing	0.3
Construction	-38.7
Services	5.1
Total GDP Growth (%)	2.6

Source: Official Portal of Department of Statistics Malaysia (2019)

Compared to previous year, the GDP growth of Kelantan state in 2018 had increased to 2.6% from 4.5% in 2017. The services sector grew to 5.1%, previously 4.9% in 2017, fueled by retail and wholesale commerce and sub-sectors of government services. However, due to the decline in rubber and palm oil production, the agricultural sector declined to -1.0% compared to 3.4% in 2017. In 2018, the declining trend in sub-sector of electronic, electrical, and optical had decelerated down the manufacturing sector to 0.3%, previously 9.0% in 2017 (State Socioeconomic Report 2018, 2019).

On the other hand, for the study area, since it is surrounded with plantation, mining and logging activities, the nearby villagers might probably involve themselves in these economic activities as farmers and quarry workers as well as small businesses such as small marts, retail stores and stalls to supply the workers with daily items. In addition with inspections and investigations on this area, forest rangers, surveyors, geographers and geologists might be temporary workers of this area. The nearby town of Temangan and

Kuala Krai offers basic functional services such as post offices, rural clinics, schools, police stations, markets and small-scale stores.

1.3 Problem Statement

In the geological map of Temangan, Machang, there are many constraints to geological information, as there are only large-scale studies and less information on the geomorphology, lithology and stratigraphy aspects especially in small-scale areas. Consequently, these restrictions resulted in difficulties for governments and researchers to obtain their references for any future research and development plan. Having a latest geological map of an area is important to study its geology and doing any geological-related research of that area.

In his writing of "Biogeochemistry in Mineral Exploration" in 2007, Colin E. Dunn had stated that biogeochemistry studies are currently considered to be limited, because metal biogeochemical study is mostly focused on plants in boreal and temperate forests, located in the wide belt of Eurasia and North America, primarily in Russia and Canada, and in the east of North America, central and west of Europe and northeast of Asia respectively. According to Dunn (2007), in cooler areas like boreal and temperate forests, less shrub and tree diversities are produced, and plants can accumulate wide ranges of different elements without giving any obvious signs. In humid tropical forest located near the equator such as Malaysia, the metal and mineral prospecting plants and its biogeochemistry study are less explored (Baker & Brooks, 1988).

1.4 Objectives

The objectives of this research are:

1. To produce a geological map of Temangan area with scale of 1:25 000.
2. To review the existing biogeochemistry study of element concentration in plant and soil samples in selected area in Malaysia based on previous research.

1.5 Scope of Study

5 x 5 km of study area in Temangan, Machang was selected for this research. The geology of Temangan area was studied based on the previous research done here. Due to Covid-19 pandemic occurred in our country, usual geological mapping and laboratory analysis cannot be done. Instead, preliminary study and geological interpretation based on geomorphology map, topographic map, drainage pattern map and other secondary data obtained from websites were implemented in order to understand and identify the lithology, geomorphology, structural geology and stratigraphy of the study area.

The biogeochemistry study focused on the concentration of metal elements in plant species and soil samples. The scope of study encompassed the general biogeochemistry study in Malaysia. Few articles and journals were selected and compiled, compared and analyzed their plant samples and soil samples results.

1.6 Significance of Study

This study helps in providing the latest information regarding the geology of the area. Biogeochemical study with particular species of plant could make it a very good indicator in identifying certain metals in some region. By recognizing the presence of certain plant species growing in soil with various amounts of metal elements, metal or mineral searching and prospecting through botanical approach can be developed and expanded. Other than this method is affordable, environmental friendly and time-saving, it is a hope that this research will provide a better insight towards the interaction between plants and soil.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter describes the entire geological picture in the area of research found through previous studies in terms of regional, tectonic, stratigraphic, structural and historical perspective. It also included some brief history and biogeochemistry patterns, as well as similar and related studies done.

2.2 Regional Geology and Tectonic Setting

South East Asian tectonic setting including Malaysia is widely discussed by University of Malaya's late Professor Emeritus Charles Starchan Hutchison, in his 2007 textbook, The Geological Evolution of South East Asia, released by the Malaysian Geological Society (Hutchison C. S., 2014). A review of his studies and analysis is as follows:

N-S Palaeo-Tethys Bentong-Raub suture separates the Malaysian Peninsula into a western block of Sibumasu and an eastern block of Indochina, also referred to as the East Malaya. Geographically, these blocks are referred to as the Peninsular Malaysia's West Coast and East Coast. Bentong-Raub suture is denoted by an imbricated complex showing an accretionary prism of carbonaceous pelitic schist, amphibole schist, serpentinite, chert, melange-olistostrome and redbeds. Presence of oceanic chert records that the Palaeo-Tethys history was formed during Late Devonian to Late Permian.

Figure 2.1 shows a schematic diagram showing the rifting of Indochina (East Malaya) and Sibumasu blocks from Gondwanaland. First, Palaeo-Tethys Ocean arise due to the separation of Indochina (East Malaya) from Gondwanaland. But, during Late Triassic, as Sibumasu block collided with the Indochina (East Malaya) block, the Palaeo-Tethys Ocean was then subducted. The collision between these two blocks end in the formation of Bentong-Raub Suture. During the subduction of the Palaeo-Tethys Ocean beneath the Indochina (East Malaya) block, Permian-Triassic volcanic rock and I-type granite of Sukhotai Zone arise. On the final stage of suturing, crustal thickening occurred, which gave rise to the enormous collocation of S-type tin-bearing granite, known as the Main Range.

On Indochina (East Malaya) block, Permian-aged andesitic volcanic rock can be found tremendously. Contrary, they cannot be found on Sibumasu block, due to andesitic volcanic rocks are related with subduction process. On the other hand, the volcanism of Indochina (East Malaya) due to collision with Sibumasu is characterized by rhyolitic volcanic rock and are explosive. The transition between Permian andesite to Triassic rhyolite proposed that the geological process during the formation changed from subduction to collision as the Palaeo-Tethys Ocean was abolished. In general, Sibumasu is marked by Carboniferous-Permian glacial pebbly mudstone, while Indochina (East Malaya) is marked by fusulinid limestone (Hutchison C. S., 2014).

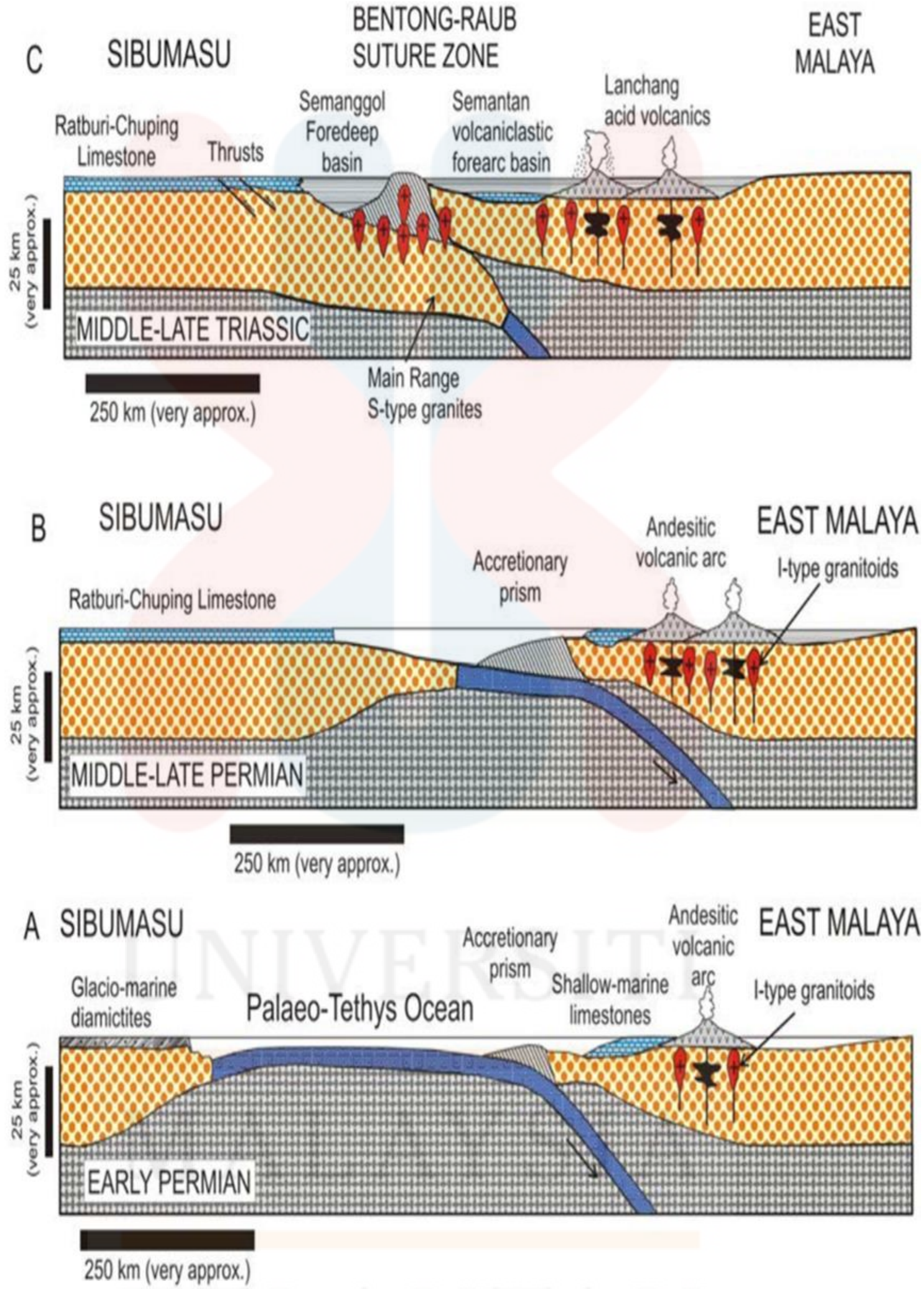

Figure 2.1: Conceptual cross-sections showing the formation of Bentong-Raub Suture due to the process of subduction of Palaeo-Tethys Ocean beneath the Indochina (East Malaya) and the collision of Sibumasu and Indochina (East Malaya) during the Indosinian Orogenic period. Modified by Metcalfe (2013).

Geologically, Kelantan state is made up of Palaeozoic, Mesozoic and Cenozoic sedimentary and metasedimentary rocks, with presence of the Main Range and Boundary Range granitic rocks and other extrusive rocks (Hutchison & Tan, 2009). The oldest rocks are of Lower Paleozoic age, consisting metapelites with minor volcanic fragments, minor occurrences of intercalation between calcerous and arenaceous units and infrequent presence of serpentinite and amphibolite rocks. They occurred in a north trend direction bordering the Main Range's foothills, extending east direction towards Sungai Neggiri. Volcanic-sedimentary Permian-aged rocks uncomformably overlie the Lower Paleozoic sequence on the eastern side of southwest Kelantan. Pre-Triassic Taku Schist Formation covers the central-north of Kelantan (Heng, Hoe, & Hassan, 2006).

In central and south of Kelantan, Triassic rocks are dominant, consisting of argillaceous and arenaceous sediments, intercalated with volcanic and limestone units. Jurassic-Cretaceous-aged rocks are the youngest, consisting of sandstone intercalated with sporadic volcanic, underlain by a conglomerate unit. This Jurassic-Cretaceous sequence overlie the Granite of Boundary Range and Triassic sediments located in Gunung Gagau area at Terengganu, Kelantan and Pahang states boundary, to the west of Gunung Pemumpu and Gunung Perlis area (Heng, Hoe, & Hassan, 2006).

In terms of Kelantan state structural geology, North-South to Northwest-Southeast (NS-NWSE) directions are Kelantan's principal structural trend. Kelantan's general geology and structural geology are clearly represented in **Figure 2.2**. Nazaruddin (2017) stated that geomorphologically, four forms of landscape are presence in Kelantan state. There are mountainous, hilly, plain and coastal areas. In the study area, two of these landscapes are present, hills and plains.

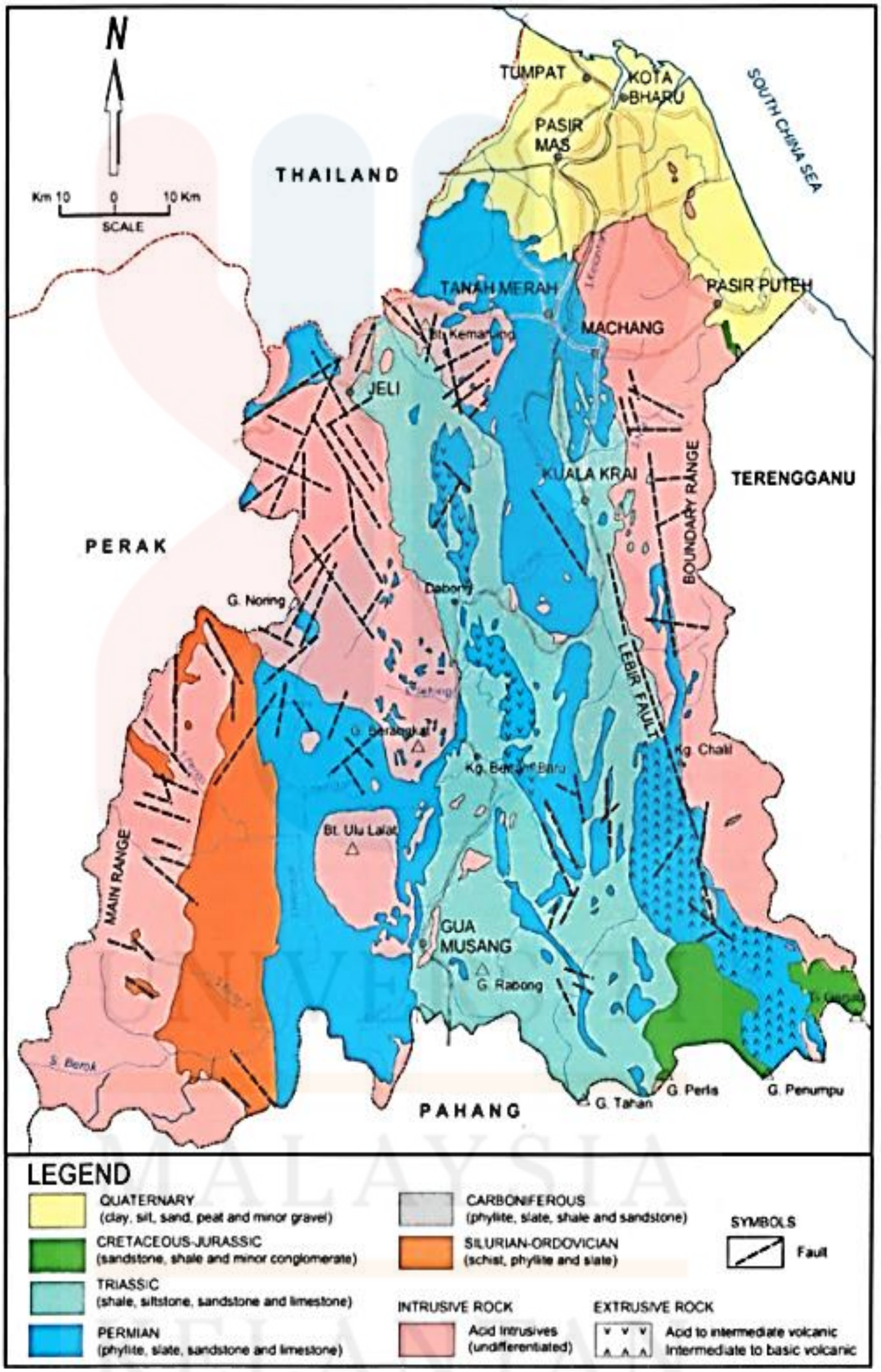

Figure 2.2: Geological map of Kelantan state. Modified from the Department of Minerals and Geoscience (2003).

2.3 Stratigraphy

Temangan is located within the Central Belt of Peninsular Malaysia. It consists of two formations. From oldest to youngest are Taku Schist Formation to Telong Formation (Department of Minerals and Geoscience, 2003). In Temangan area, Permian-Triassic rock formations are dominant, consisting of phylite, slate, sandstone and limestone units (Pour & Hashim, 2017).

Taku Schist Formation arise during Carboniferous-Permian period. In this formation, mica schist is the main rock type. It encompasses mica-garnet schists, quartz-mica schists and quartz-mica-garnet schists with narrower bands of quartz schists and amphibolite with rare talc-carbonate schists. Macdonald (1967) believed that the age of Taku Schist Formation is pre-Carboniferous. However, according to Khoo & Lim (1983) and Lee, et al. (2004), they suggested that the origin of Taku Schists formation was probably aged from Pre-Permian period while the Permian-Triassic rock occurred during the late stage of this formation was equivalent to the Gua Musang Formation due to the existence of limestone bodies. According to the Malaysian and Thai Working Groups (2006), Taku Schist Formation in Malaysia is equivalent to the Ai Ka Po Formation, Mangga Formation and Ka Lu Bi Formation in Thailand. In Malaysia Taku Schists Formation covers most of the area in Sungai Taku and its surrounding areas, near Manik Urai, in central north of Kelantan state. For the western margin, the formation starts from the south of Sungai Galas to Tanah Merah, extending northward along Sungai Kenik, passing through Ulu Sungai Taku and Sungai Sokor at Kuala Bertam until the Kemahang granite. Meanwhile, for the eastern margin, Taku Schist Formation follows roughly the downstream trajectory of Sungai Lebir and partly of Sungai Kelantan (Groups, 2006).

Next, Telong Formation arise during Late Permian to Late Triassic period (Aw P. C., 1990). It encompasses a sequence of predominantly argillite unit associated with some tuff, low grade metasedimentary rock unit and metavolcanic rock unit. According to Hamzah & Ashaari (1991), they classified the Telong Formation into four facies which are argillaceous, arenaceous, calcareous and volcanic facies. Greenish-reddish grey to black slate, phyllite, hornfels and schist made up the argillaceous facies, fine-grained sandstone and metasandstone made up the arenaceous facies, while grey marble made up the calcareous facies. Telong Formation covers the area in Sungai Telong, with the upper part reaches Sungai Aring area. Telong Formation overlain the Gua Musang Formation in its lower boundary while underlain the Koh Formation in its upper boundary. According to the Malaysian and Thai Working Groups (2006), Telong Formation in Malaysia is equivalent with the Permian-Triassic Ai Ba Lo Formation in Thailand. The depositional environment for this formation is shallow marine environment.

Other than Taku Schist Formation and Telong Formation, the formation of volcanic rock in Kelantan is also important in this study. In Kelantan state, the distribution of volcanic rocks occur in several places along Tanah Merah, Rantau Panjang and Machang areas. In volcanic rock formation, pyroclastic deposits, especially tuff are more dominant compared to lava flows, ranging from rhyolitic to andesitic in composition. Rhyolitic pyroclastic deposits are far more abundant than andesitic pyroclastic deposits. In Temangan, these pyroclastic and volcanic rhyolitic rocks are called as Temangan ignimbrite.

Temangan ignimbrite represents a prominent ridge with a dimension of 800m wide and 10km long, trending in North-South direction, separating the sandstone and shale units in Temangan area. It intrudes along the Lebir Fault Zone. Temangan ignimbrite is hard and massive in nature, with subsidiary flow structure. The ignimbrite is homogenous and porphyritic in texture and shows pink to dark brown color. But, in a slightly altered condition, it exhibits a greenish grey color. Phenocrysts of feldspar and quartz can be seen embedded within a feldsitic matrix. According to the Malaysian and Thai Working Groups (2006), the age of Temangan ignimbrite is Triassic.

2.4 Structural Geology

During Taku Schist Formation, low-grade metamorphism occurred due to local deformation in shear and contact zones had caused the original rocks in the surrounding areas to be metamorphosed into slate, phyllite, spotted slate and phyllitic shale.

Structurally, Paleozoic sequence succession is distinguished by an intense close fold, while Triassic sequence succession is distinguished by an open fold. In Kelantan, sedimentary pre-orogenic successions are folded into anticlines and synclines series. Within the older sedimentary rock formation, folding is characterized by asymmetric, tight and open folds which created a sequence of repeated and overturned series (Groups, 2006). The axes of folds trending in North-South (N-S) and Northwest-Southeast (NW-SE) directions are subparallel to the Malaysian Peninsula's long axis. With different dip angles, most of the bedding planes dip eastwards.

In Kelantan, faulting such as normal, strike-slip, thrust and reverse faults can be seen clearly and are striking in North-South (N-S), Northwest-Southeast (NW-SE) and Northeast-Southwest (NE-SW) directions. Generally, faults differ in width. They are characterized by sheared, fractured and mylonitised rocks. Due to dense soil cover and heavy tropical weathering, fault zones are rarely exposed, only visible at few places along their points (Groups, 2006).

2.5 Historical Geology

In Kelantan, marine sedimentation continuously occurred during the Paleozoic until Early Mesozoic periods. But, during Devonian-Carboniferous and Early Triassic period, a large break was detected due to the depositional basin's instability.

Historically, Temangan is famous for its iron ore producing deposit. It is located within the broad curve of Kelantan River. The mine is placed at 220m elevation along the North-South (N-S) trend. The ore body is situated between shale on the east and Taku Schist on the west. On the eastern part of this contact, a large quartz porphyry dyke can be seen. This dyke follows the striking of regional scale but defies its bedding. Towards the east of the dyke, presence of volcanic and pyroclastic rocks and interbedded shale can be observed.

Diamond drill core testing revealed the presence of veins and veinlets of siderite cutting the shale beneath the main ore body. In most places, the shale exhibits grey to greyish white color and contains bands of tuffaceous and arenaceous. Schist-tuff contact undergone shear and high alteration in apple green and white bands. They contain fuchsite, chrome mica and pyroxene carrying chromium. The ores contain limonite with subsidiary hematite and high manganese percentage (Groups, 2006).

Process of solution and redeposition from circulating water of previously existing materials bearing iron formed a secondary deposits which are the main ore bodies. A period of crustal disturbance following the consolidation of shale produced shearing and fault along the shale-schist contact. These revealed that shale had been subjected to hydrothermal activities by means of silicification, pyritisation, and siderite vein impregnation. This siderite is assumed to be the parent from whom the limonite and hematite were generated (Groups, 2006). Secondary solution and redepositioning process produced manganese, whom originally associated with the primary mineralization of carbonate. Minor crustal motions triggered some displacement of the ore bodies to fault in East-West (E-W) direction. Quartz porphyry dyke was developed by the hydrothermal solutions, east of the deposit at Temangan.

2.6 Research Specification

2.6.1 Methods Used in Plant and Soil Elemental Concentration

X-Ray Fluorescence Spectroscopy (XRF) is an analytical method used to determine the chemical composition of a wide range of sample types like liquid, solid, loose powder and slurry. It is non-destructive. A sample measured using XRF can be reused for further analysis using another analysis method. XRF measures elements from Be (beryllium) up until Am (americium) from 100% until sub-ppm (parts per million) concentration level (Kempenaers, 2020). It can be used for bulk chemical analysis of major or trace elements in sediment and rock (Wirth, 2020). Unfortunately, XRF measures the total concentration of each element in a sample. It does not differentiate different oxides. It also does not able to measures elements at lower ppb or ppt concentration levels.

With easy and quick sample preparation, XRF offers high precision and accuracy with lower cost (Wirth, 2020). As there is no need for the samples to be dissolved into a liquid or be diluted, no acids and chemicals are required (Kempenaers, 2020).

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is used for multiple element-trace analysis and ultra-trace analysis. It is a versatile form of chemical analysis that can be adapted to fulfil the requirements of a wide range of industries (Niessen, 1999). A variety of materials, from super alloys to high-purity materials, can be tested in ICP-MS. The most significant benefit of ICP-MS is its multi-element capability, which enables the simultaneous measurement of multiple elements in a single analysis (Wilschefski & Baxter, 2019). ICP-MS is capable of measuring elements up to the detection limit of ppt (parts per trillion) level, which is higher than other ICP techniques (Mudalige, et al., 2019). In geological and soil science studies, where low level determination is often needed for a large number of samples, this method is useful. ICP-MS is, sadly, extremely sensitive. It requires high level of expertise and high equipment and operational costs.

Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) is another form of ICP analysis. It uses a sample introduction mechanism similar to that used in ICP-MS, but focuses on the detection of atoms and ions emitting electromagnetic radiation (Mudalige, et al., 2019). ICP-AES can detect most periodic table elements. It involves the analysis of trace to major element concentration. ICP-AES is often referred to as ICP Optical Emission Spectroscopy (ICP-OES). ICP-AES is able to measures 70 elements with detection limit up to ppb (parts per billion) range (LTI, n.d.). ICP-AES, excluding halogens and inert gases, is suitable for almost any element and is particularly useful for refractory elements, such as silicon, aluminium, barium and others (Shimadzu, n.d.). This method is relatively easy. Most laboratory staff can easily run samples once a method is set up. Disadvantages of ICP-AES are lack of sensitivity to some elements and physical and spectral interference (Wilschefski & Baxter, 2019).

2.6.2 Biogeochemistry

As stated by Browne (1944) , the history of biogeochemistry subject dates back to Greek notion. But, its development hastened rapidly during the seventeenth century with the rise of modern science. Major aspects of biogeochemical production connects to early, complex studies of photosynthesis and respiration, organic decomposition, nitrogen and sulphur metabolism, inorganic plant nutritions and weathering of soils and rocks. According to Kovalevsky (1987), biogeochemical search for mineral deposit started during 1920s in the Union of Soviet Socialist Republics (USSR), when S.P. Aleksandrov found extremely large amounts of vanadium, radium and uranium in ashes from plants grown on uranium and vanadium deposits.

Dunn (2007) in his book entitled 'Biogeochemistry in Mineral Exploration' tried to differentiate between biogeochemistry and geobotany. According to him, biogeochemical approach in mineral exploration comprises chemical examination and analysis of plant tissues to assess the presence of existing underlying mineralization, bedrock composition, structures (joints, folds or faults) and the chemistry between soil, surface sediments and adjacent groundwater. On the other hand, geobotanical exploration is focused on the identification of the presence of plant species, or populations of plants, with underlying mineralization and groundwater. In simple words, biogeochemistry represents the chemical approach, meanwhile geobotany represents the visual approach.

In biogeochemistry, samples of one or few targeted plant species are collected around a shrub or tree about the same age and the same height for sampling purpose. The area of sampling should be far from any anthropogenic sources. Plants having higher chances of being deeply rooted are better (Hulme, Dunn, & Hill, 2006). Uniform plant tissues such as seeds, flowers, barks, foliage and twigs are chose for analysis. According to Holdsworth (n.d.), plant's bark and foliage offer the strongest geochemical fingerprint. The optimal size for plant analysis range from 20g to 100-300g. Chemical analysis of plant samples can be done by using analytical methods such as Atomic Absorption Spectrophotometry (AAS), Inductively-Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), Inductively-Coupled Plasma Mass Spectrometry (ICP-MS) and Nondestructive X-Ray fluorescence (XRF) (Reeves, et al., 2017).

2.6.3 Hyperaccumulator Plants

Plants that store metals and metalloid elements in their living biomass to extremely high concentrations than what is common for most plants are called as hyperaccumulators (Ent, Mak, Jonge, & Harris, 2018). In another terms, they are called metallocoles or metallophytes (Chang & Ismail, 2019). Hyperaccumulator plants can be found in large parts of the continents except Antarctica, and in tropical and temperate environments. A large number of these plants can be found in Cuba, New Caledonia and the Mediterranean regions (Lange, et al., 2016). According to Kramer (2010), hyperaccumulators can be used in fundamental science to understand the regulation of metal including the physiology of metal absorption, distribution and sequestration, along with the adaptation and evolution of plants in extreme environments. In applied biotechnology, hyperaccumulator plants are utilized in continuous research of phytoremediation and phytomining (Ent, et al., 2015) and empirical practices of biofortification (Clemens, 2016).

According to Reeves (2003), nickel-hyperaccumulator plants are the most reported hyperaccumulators, occurred on ultramafic soil rich in nickel, cobalt and manganese. The distribution of nickel-hyperaccumulator plants includes species of genus *Alyssum* (Brassicaceae) found in Mediterranean region and species of genus *Phyllanthus* (Phyllanthaceae) found in tropical ultramafic locations in Cuba, Brazil, Southeast Asia and New Caledonia (Reeves, 2003). Next, copper- and cobalt-hyperaccumulator comes next after nickel, found in copper-cobalt enriched soils in Central Africa, followed by zinc- and cadmium-hyperaccumulator, found in metalliferous soils in China and Europe (Reeves, et al., 2017).

In 2017, Reeves, et al. had launched a new global database for hyperaccumulator plants. This latest database collects information in a standardized format for all known species of metals and metalloids hyperaccumulator plants. This is to ensure that the newest database can provides background information and knowledge to any researcher who intends to investigate specific species of hyperaccumulators. The new database produced by Reeves, et al. (2017) includes information on the taxonomy, ecology, distribution, records of collection, analytical data and references to other studies of the species.

Table 2.1 shows the latest database for plant hyperaccumulators as proposed by Reeves, et al. (2017). As of September 2017, the database had recorded a number of 721 species of hyperaccumulators in total. 523 being nickel, 53 being copper, 42 being both cobalt and manganese, 41 being selenium, 20 being zinc, 8 being lead, 7 being cadmium, 5 being arsenic, 2 being rare earth elements (REEs), 2 being thallium and only one being chromium. Some plant species may exhibits two or more hyperaccumulation (Reeves, et al., 2017). In order to obtain the status of hyperaccumulator plant species, the plant's foliar tissue dry weight must show more than 100μg g^{-1} of cadmium, selenium or thallium, more than 300μg g^{-1} of cobalt, chromium or copper, more than 1000μg g^{-1} nickel, lead, arsenic, or rare earth elements (REEs), more than 3000μg g^{-1} zinc, and more than 10000μg g^{-1} for manganese (Reeves, et al., 2017).

Out of all hyperaccumulator plant species in **Table 2.1**, the largest contributor comes from nickel-bearing plant hyperaccumulation, with total of 532 species from 52 different families and 130 different genera. As for nickel hyperaccumulators, 83 species from Brassicaceae family and 59 species from Phyllanthaceae family are the most heavily known. According to Reeves, et al. (2017), the distribution of nickel hyperaccumulators are as follows: 128 in Cuba, 65 in New Caledonia, 59 in Turkey, 30 in Brazil and 24 in Sabah, Malaysia. According to Ent, et al. (2015) and Ent, et al. (2016), Southeast Asia has begun to emerge as a global hub of plant diversity for hyperaccumulators. **Table 2.2** shows the most significant genera and families of each element, along with their distributions around the world.

Table 2.1: Global database for hyperaccumulator plant species until September 2017.

Element	Threshold ($\mu g\ g^{-1}$)	Family	Genera	Species	Global Data
Cadmium (Cd)	> $100\mu g\ g^{-1}$	6	7	7	*Arabidopsis halleri* (0.36%)
Selenium (Se)	> $100\mu g\ g^{-1}$	7	15	41	*Astragalus bisulcatus* (1.5%)
Thallium (Tl)	> $100\mu g\ g^{-1}$	1	2	2	*Biscutella laevigata* (1.9%)
Cobalt (Co)	> $300\mu g\ g^{-1}$	18	34	42	*Haumaniastrum robertii* (1%)
Copper (Cu)	> $300\mu g\ g^{-1}$	20	43	53	*Aeolanthus biformifolius* (1.4%)
Nickel (Ni)	> $1000\mu g\ g^{-1}$	52	130	532	*Berkheya coddii* (7.6%)
Lead (Pb)	> $1000\mu g\ g^{-1}$	6	8	8	*Noccaea rotondifolia* subsp. cepaeifolia (0.8%)
Arsenic (As)	> $1000\mu g\ g^{-1}$	1	2	5	*Pteris vittata* (2.3%)
Rare Earth Elements (REEs)	> $1000\mu g\ g^{-1}$	2	2	2	*Dicranopteris linearis* (0.7%)
Zinc (Zn)	> $3000\mu g\ g^{-1}$	9	12	20	*Noccaea caerulescens* (5.4%)
Manganese (Mn)	> $10\,000\mu g\ g^{-1}$	16	24	42	*Virotia neurophylla* (5.5%)

Source: After Reeves, et al. (2017)

Table 2.2: Distributions of the significant genera and families of each element, along with their occurrences.

Element	Main families	Main genera	Occurrences
Cadmium (Cd)	Crassulaceae, Brassicaceae	*Sedum, Noccaea*	China, Europe
Selenium (Se)	Fabaceae	*Stanleya, Astragalus*	USA
Thallium (Tl)	Brassicaceae	*Iberis, Biscutella*	Europe
Cobalt (Co)	Lamiaceae, Asteraceae, Linderniaceae, Phyllanthaceae, Orobanchaceae	*Crepidorhopalon, Anisopappus, Phyllanthus, Glochidion, Persicaria*	New Caledonia, DR Congo
Copper (Cu)	Commelinaceae, Asteraceae, Lamiaceae, Fabaceae, Malvaceae, Linderniaceae, Polygonaceae, Orobanchaceae	*Commelina, Anisopappus, Haumaniastrum, Crepidorhopalon*	DR Congo
Nickel (Ni)	Asteraceae, Buxaceae, Brassicaceae, Phyllanthaceae, Cunoniaceae, Violaceae, Salicaceae	*Buxus, Alyssum, Glochidion, Berkheya, Homalium, Geissois, Hybanthus, Leucocroton, Phyllanthus, Xylosma, Senecio,*	Cuba, Brazil, Turkey, Mediterranean, Southeast Asia, New Caledonia
Lead (Pb)	Brassicaceae	*Noccaea*	Europe
Arsenic (As)	Pteridaceae	*Pityrogramma, Pteris*	Southeast Asia, China
Rare Earth Elements (REEs)	Gleicheniaceae	*Dicranopteris*	China
Zinc (Zn)	Crassulaceae, Brassicaceae	*Arabidopsis, Sedum, Noccaea*	China, Europe
Manganese (Mn)	Myrtaceae, Proteaceae, Celastraceae	*Denhamia, Gossia, Virotia*	New Caledonia, Australia

Source: After Reeves, et al. (2017)

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

This chapter discuss the materials and methodologies involved while conducting this research. Clear explanations regarding the materials and methods used are important to understand how this research are conducted from zero to end. Due to Covid-19 pandemic occurred across the world, usual geological mapping and laboratory analysis cannot be done. Instead, preliminary study, data collection, data processing and data interpretation based on journals and articles and other secondary data were carried out.

3.2 Materials/Equipment

3.2.1 Secondary Data

While conducting this research, journal articles were the main source of secondary data. Journal is an academic publication which contains articles written by scholars, teachers and other professionals. Journals concentrate on a specific subject, or research field. They are not intended for general audiences, instead, they focused on technical or academic audiences. Next, the second source of secondary data was from website. Such example is Digital Elevation Model (DEM) data from USGS Earth Explorer website. A DEM data is a digital elevation image of the surface of the earth without any objects such as buildings or plants on it. Extraction of terrain parameters from DEM data was used in geomorphology research, to simulate slope, hillshade, water flow direction, water accumulation, surface runoff, stream orders and others.

3.2.2 Software

In this research, two main software were used, Google Earth and ArcGIS software. Google Earth, known as geobrowser, accesses online aerial and satellite imagery, showing ocean bathymetry, topography and other geographic data to reflect the Earth as a 3D globe. Meanwhile, ArcGIS software is a GIS-based platform created for the creation, management, analysis and sharing of spatial data. ArcGIS consists four main software components, a geographic information interface for modeling real world aspects, components for storage and management of geographic information in data files, a selection of out of the box applications to build, edit, manipulate, map, analyze and disseminate geospatial data, and a set of web services delivering content and functionality to users.

3.3 Methodology

In this research, four main steps were carried out, involving preliminary studies, map preparation and data compilation, data processing, and data interpretation and discussion. The flowchart of the research methodologies are shown in **Figure 3.1**.

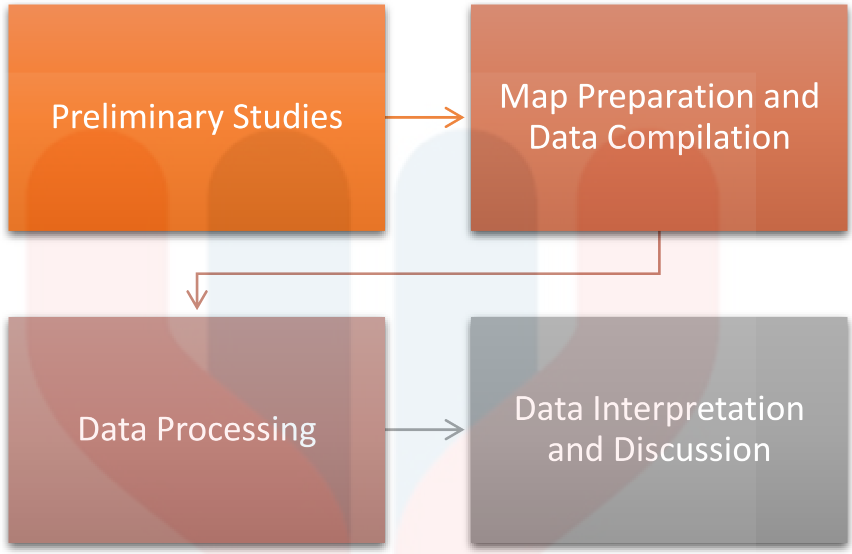

Figure 3.1: Research flow chart.

3.3.1 Preliminary Studies

Preliminary study was done as preparation before going to field. Researcher did some literature reviews from primary data like books and secondary data like articles in journals and websites, reading and collecting past references to understand and get a knowledge about their research. Articles were searched in the internet and past year undergraduate students' thesis was accessed from Universiti Malaysia Kelantan (UMK) Jeli Campus Library.

3.3.2 Map Preparation and Data Compilation

In map preparation, ArcGIS software was used to digitize thematic maps. Based on articles and past references from Aw (1967), Salwisol (2017), Shahman (2017) and The Malaysian and Thai Working Groups (2006), along with secondary data Digital Elevation Model (DEM) in Shuttle Radar Topography Mission (SRTM) format with resolution 1 arc second, dated 23.09.2014 from USGS Earth Explorer website (**Figure 3.2**), base map, geomorphology map, drainage pattern map and lineament map were digitized.

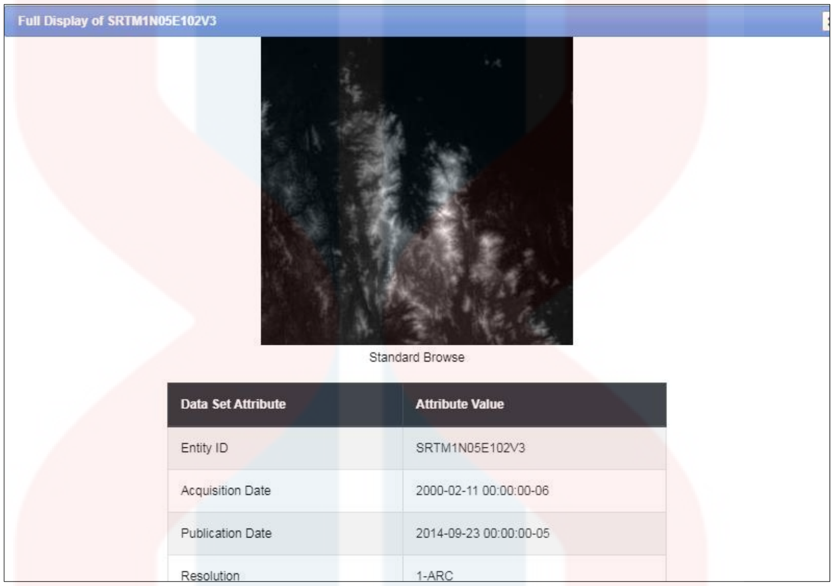

Figure 3.2: DEM data obtained from USGS Earth Explorer website.

a) Base Map

Base map was digitized by adding contour and river shapefile in vector format with projected coordinate system Kertau_RSO_Malaya_Meters. New shapefiles were added to digitize the railway, road and village.

b) Geomorphology Map

Contour data in vector format was changed into raster format, with coordinate system Kertau_RSO_Malaya_Meters. Then, the geomorphological unit was classified based on Van Zuidam (1986) topographic unit classification. Next, the raster data was converted back into polygon.

c) Drainage Pattern Map

River shapefile with projected coordinate system Kertau_RSO_Malaya_Meters was added. Drainage patterns were classified based on Howard (1967).

d) Lineament Analysis Map

Digital Elevation Model (DEM) data with resolution 1 arc second from USGS Earth Explorer website was used to create multiple hillshade layers. Lines representing positive lineaments and negative lineaments were drew on the layer. Azimuth were extracted from the lines and added into GeoRose software to create rose diagram.

For the specification part which is biogeochemical study in Malaysia, four articles related with the existing biogeochemistry study and elemental distribution in plant and soil samples in Malaysia were chose, compiled and screened to understand their objectives and findings. Those articles are from Chang & Ismail (2019), Kutty & Al-Mahaqeri (2016), Ent, et al., (2018) and Nkrumah, et al., (2018). The articles were chose carefully to avoid any misinformation and unnecessary data.

3.3.3 Data Processing

ArcGIS software was used to digitize the geological map of study area. Lithology and structural geology data collected from previous researches were used to produce the geological map. The data were imported into ArcGIS and analyzed in the software. The cross-section of the study area were built using CorelDraw. Dip points, fault lines, and other geological information required to complete a geological map were labelled together. After adding the cross section in the geological map in ArcGIS, a complete geological map of study area was generated.

3.3.4 Data Interpretation and Discussion

After preparing all maps, the geology of the study area was interpreted based on articles like Aw (1967) and The Malaysian and Thai Working Groups (2006), past year undergraduate students' thesis like Salwisol (2017), Shahman (2017) and Anoar (2017), and from each of the thematic maps itself. For example, structures and features on land like ridges, hills, plains, and valleys can be determined in topographic map. By examining the map, one may define the existence of a given region's surface processes including landsliding areas, erosion sites and deposition sites. Not only that, details regarding the study areas structural geology and historical geology can also be determined. Upon analyzing and interpreting all the maps, correlation was done between each map to classify the area's lithology, stratigraphy and structural geology.

For the specification part, based on the articles referred, four parameters were discussed, the types of plant species involved and its morphology, the soil types at which the plant species were collected, the geological condition of the area and the elemental distribution in plant and soil samples. These parameters are important to achieve the second objective of this research. Data discussed were explained in detail and tabulated.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

The geology of the study area were addressed in this chapter. The general geology were discussed based on the interpretation of data collected after thematic map digitization and reference from other secondary data such as websites, articles and past references. Geomorphology, lithostratigraphy, structural geology, and historical geology aspects were included in this chapter.

4.1.1 Brief Content of Chapter 4

The general state of the study area is defined on the basis of its accessibility, which is the ease of access to the study area using different types of transportation, the settlement which includes the area where the residents live and the forestry and vegetation which includes the management and conservation of forests and plant assemblages in the area. In geomorphology, geomorphologic classification was constructed and drainage pattern was discussed. Lithostratigraphy includes the description of each stratigraphic unit and its position. Structural geology outlined the faulting, folding and mechanism of structures existed there. While historical geology were discussed based on the past references and articles referred.

4.1.2 Accessibility

The district of Temangan is accessible through two main roads. From the north to Jalan Pasir Putih - Machang - Gerik to Jalan Temangan - Kuala Hau and from the south to Jalan Kota Bharu - Gua Musang to Jalan Kampong Bedal - Kuala Hau. The exact study area can be reached via few tiny roads and housing areas of villagers. **Figure 4.1** shows the road access along the villager's house. There are several unpaved roads connected with the small roads within the study region. These unpaved roads are situated in the mining sector and in the highlands as shown in **Figure 4.2**. Vehicles with 4 x 4 wheels may be needed to access those areas. Next, Tumpat - Gemas railway line connected to Temangan railway station, Keretapi Tanah Melayu Berhad (KTM) to the east, can also be reached from the region. **Figure 4.3** shows the road located next to the railway line. Since the study area is located near the Kelantan River, locals use motor boats and sampans to connect them via river routes with other locations.

Figure 4.1: Road access along the villager's house (Street View, 2015).

Figure 4.2: Unpaved roads heading towards Kampung Bukit Besi (Street View, 2015).

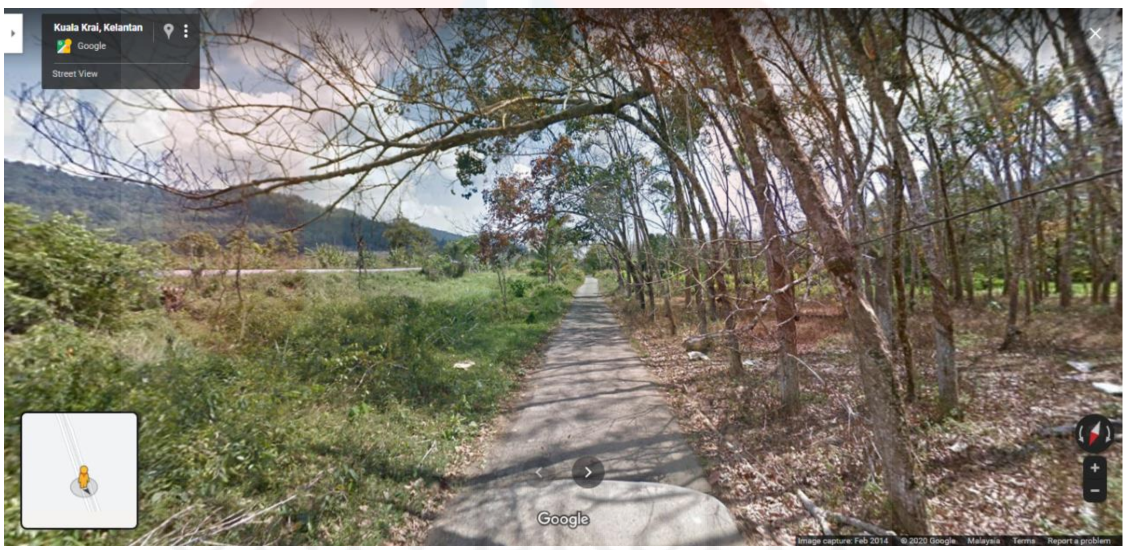

Figure 4.3: Road located next to Tumpat - Gemas railway line (Street View, 2014).

4.1.3 Settlement

Within the study area, the residents are mostly live along the street, adjacent to the rubber and oil palm plantations. Since the area is mostly covered with forestry, plantation and mining area, only few small villages are present there. **Figure 4.4** shows the houses located along the street. There are Kampung Temangan Lama, Kampung Bukit Besi and

Kampung Pauh. The settlement is more concentrated around the Temangan Town district and along Kampung Bedal - Kuala Hau road heading towards Kuala Krai district and along the Kelantan River. For examples, Kampung Kerilla, Kampung Kuala Hau and Kampung Keroh.

There is one mining area at the center of the study area. It is called Lombong Bukit Besi, Temangan (**Figure 4.5**). However, according to the Official Portal of Machang District Council (2016), the mining operation is no longer operated. But, there are still few houses, camps and dormitory buildings left in the area, which might belonged to the past workers and officers. Since there are few plantations in the area such as Ladang Onn Chwee Lee, Ladang Sungai Bedal and Ladang Pasir Besar, the farmworkers are probably the nearby villagers who oftenly come back and forth daily to this area.

Figure 4.4: Houses located along the street (Street View, 2014).

Figure 4.5: Lombong Bukit Besi, Temangan (Street View, 2015).

4.1.4 Forestry or Vegetation

Referring to **Figure 1.4,** 60% of the study area is covered with forest and hills and 20% with plantation. Other 15% is mining area while another 5% is the settlement. The forest extends from the north to the south of the center part of the study area and the east, consisting of Hutan Rizab Temangan. Meanwhile, plantation especially rubber plantation (**Figure 4.6**) and oil palm plantation (**Figure 4.7**) covers the center, left part of the area, along the railway road on the east. Based on Google Earth, the forest in the study area has an elevation between 100 m to 260 m. Some of this forest had been excavated for mining activities while others are preserved as Hutan Rizab. Rubber and oil palm plantations are more centered at the center, left part of the study area due to its location which has lower elevation, from 30 m to 60 m. Apart from the forestry and vegetation along the road in the study area, other locations are mostly relic area, covered with bushes and shrubs due to lack of development and infrastructure there.

Figure 4.6: Rubber plantation (Street View, 2014).

Figure 4.7: Oil palm plantation (Street View, 2014).

4.2 Geomorphology

Geomorphology is the study of surface landforms and its evolution. This study encompasses both descriptive as well as quantitative measures. In geomorphology study, morphology, landforms, geomorphological processes, ages and origins are all involved (Stetler, 2014). The objective of studying geomorphology is to understand the ways in which landforms are formed and to record landform evolution over time. Geomorphology of an area is the product of interplay involving three key factors, which are process, structure, and time (Aber, et al., 2019).

Surface landform is influenced by external and internal process (exogenic and endogenic process). Internal process involves forces emanating from the earth's interior, commonly related to plate tectonics. Meanwhile, external process evolves at or above the earth’s surface. Agents involved in external process are wind, ice, water, mass movement, living organisms or extra-terrestrial materials (Aber, et al., 2019). In this chapter, geomorphology study of geomorphologic classification and drainage pattern were discussed.

4.2.1 Geomorphologic Classification

Geomorphologic classification was done based on topographic unit classification from Van Zuidam (1986). The topographic unit classification is based on the difference of elevation. The lowest elevation in the study area is around 5 m while the highest is around 260 m. According to Van Zuidam (1986), the classification of topographic unit in the area can be classified into three classes. First, low-lying plain with elevation between 5 m - 100 m. Second, low hills with elevation between 100 m – 200 m. Third, hills with elevation between 200 m – 500 m.

Table 4.1: Topographic unit classification.

Absolute Altitude (m)	Topographic Unit Class
<5	Lowland
5-100	Low-Lying Plain

100-200	Low Hills
200-500	Hills
500-1500	High Hills
1500-3000	Mountains
>3000	High Mountains

Source: (Zuidam, 1986)

From geomorphology map digitized in **Figure 4.8**, low-lying plain is located on the left side and at the center, right side of the map. Based on observation from Google Earth, this area is filled with plantations such as rubber and oil palm plantation, shrubs and bushes and residential area. Next, hills is situated on the center and on the right side of the map. This area consists of mainly the mining area, the lower part of Hutan Rizab Temangan and the lower part of the forest at the center. Lastly, hills is located also on the center and on the right side of the map. This area consists of the upper part of Hutan Rizab Temangan and the upper part of the forest at the center.

By using Google Earth and the contour map of the study area, few terrain features had been observed. First, plain, which occurs as lowland along valleys. On the central, right part of the study area, a plain appears as lowland area between two hills. It is developed for road connections and plantations. The plain is surrounded with other terrain features such as ridges, spurs, gullies and valleys on the low hills area. On the left side of the study area, the valley in the low hills is predominant with mining industry. In the hills, there are presence of cliffs at the center. Since the study area is located just beside Sungai Kelantan, the lowland area on the upper left side of the map is dominant with flood plain.

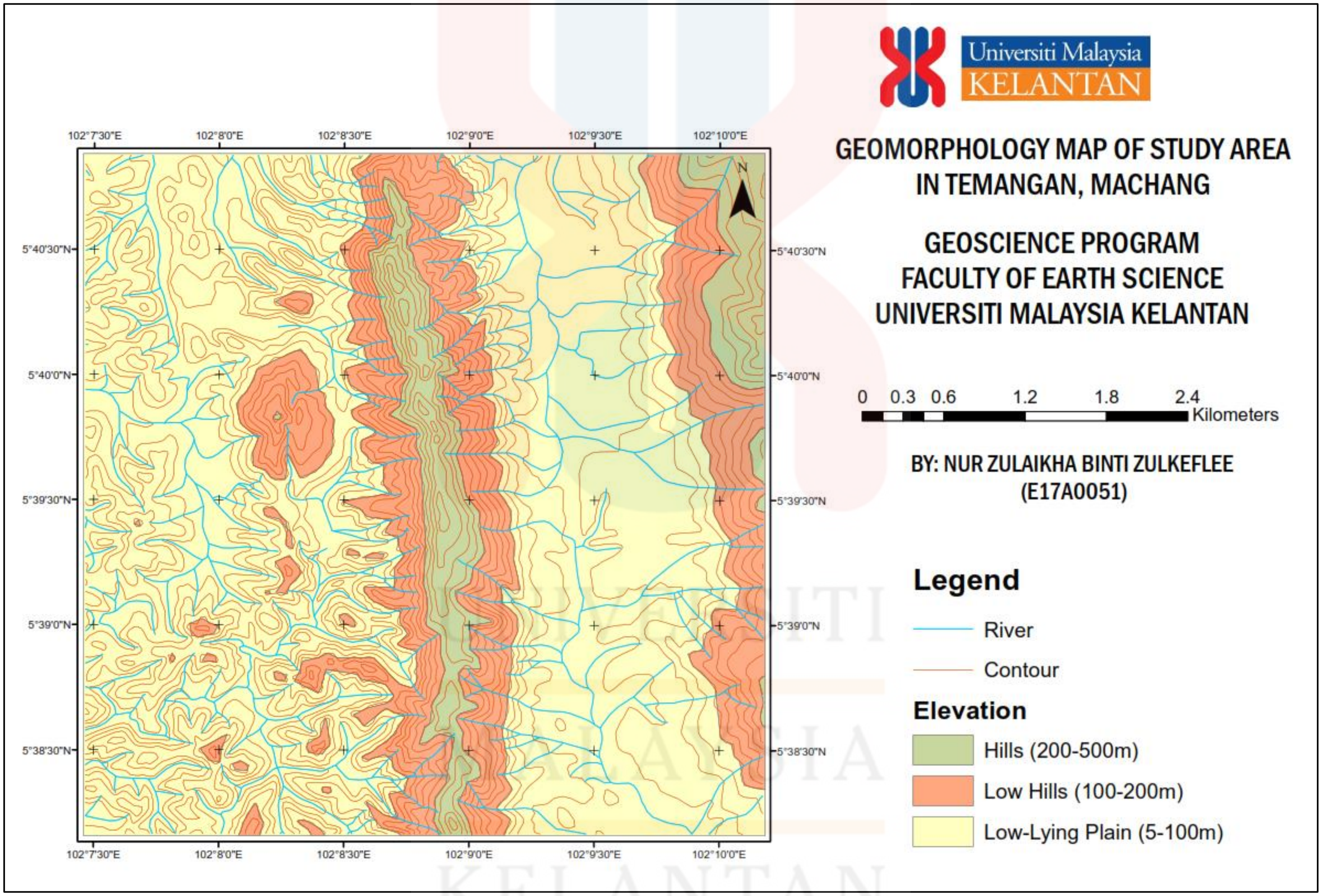

Figure 4.8: Geomorphology map of the study area.

4.2.2 Drainage Pattern

Drainage pattern or drainage system is a pattern formed in a specific drainage basin by a network of stream channels and tributaries. The underlying geology of the basin and the topography of the land plays an important factor in creating the drainage pattern (Skills, 2019). For example, whether a particular basin is dominated by hard rock or soft rock, the drainage pattern formed will be different. On topographic map, drainage pattern can be recognized by the shape or the pattern formed by the main river and its tributaries.

Based on **Figure 4.9**, four types of drainage pattern had been identified. First, rectangular pattern on the right side of the study area. Rectangular drainage pattern shows that both the main streams and its tributaries bend at right-angle. This pattern normally develops on a strongly jointed rocky terrain. Second, parallel pattern on the upper, left side of the study area. Parallel drainage pattern shows several streams flow in the same direction with tributaries joining the main streams at about the same angle. This pattern normally occurs at uniformly slope topography with gentle dipping bed.

Third, annular pattern on the central part of the study area. Annular drainage pattern shows streams flowing in concentric, circular joints around a belt of weak rock or uplifted sedimentary rock dome. The tributaries for this pattern usually flow in right angle to the main stream. Lastly, dendritic pattern on the bottom, left side of the study area. Dendritic drainage pattern shows randomly formed, tree-like shaped pattern of main streams with branching tributaries forming insequent streams. This pattern normally develops on a homogenous rock and on impervious soil.

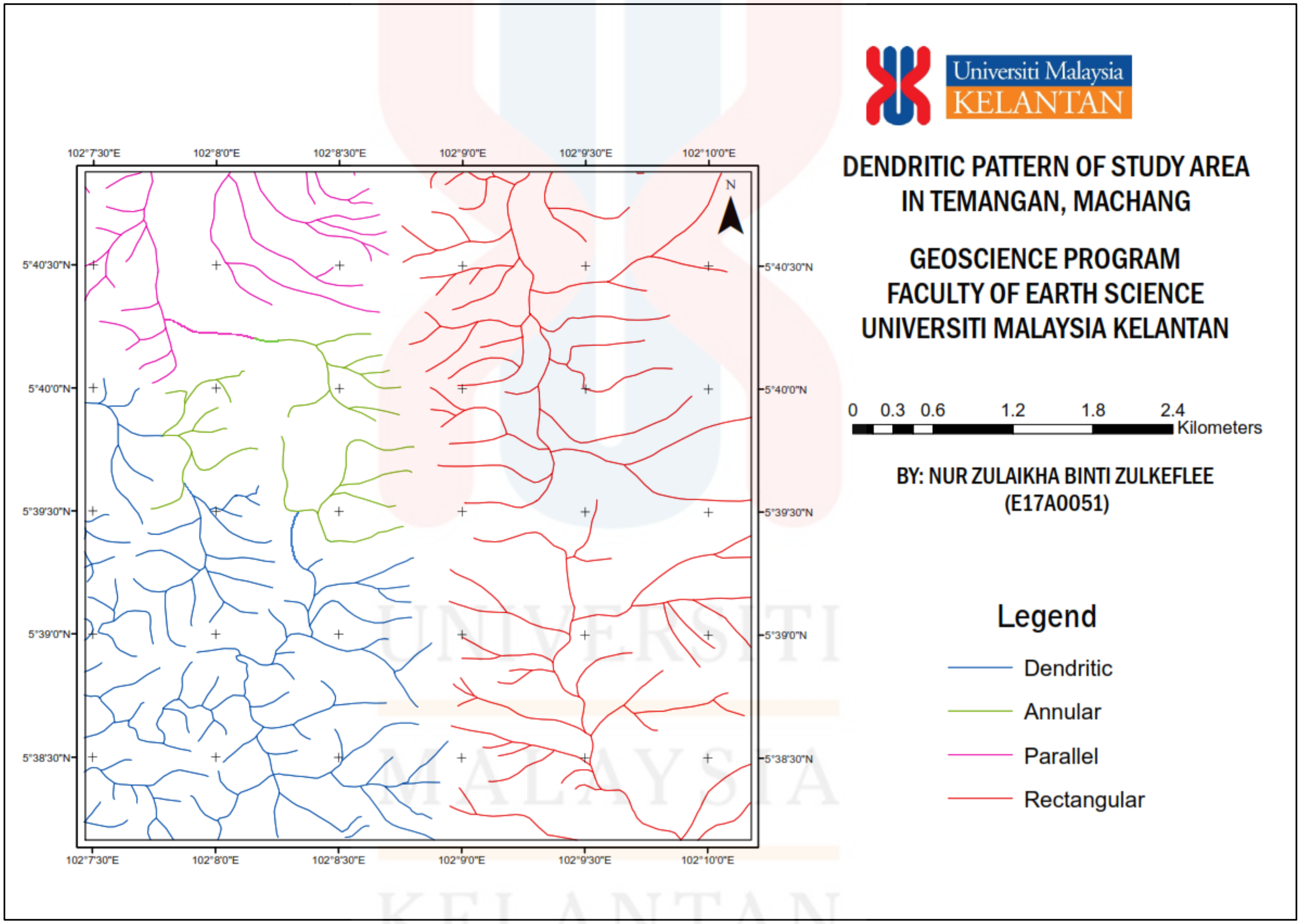

Figure 4.9: Drainage pattern map of the study area.

4.3 Lithostratigraphy

In lithostratigraphy, rock units were classified in respect of the lithological features of the strata and their respective stratigraphic positions. By analyzing the physical relationships and geometric that show which beds are older and younger, the relative stratigraphic positions of rock units were established. In this part, different formations consisting of different rock units were shown through stratigraphic column. The description of each rock units were explained. **Figure 4.19** shows the geological map of the study area.

4.3.1 Stratigraphic Position

The study area in Temangan is comprises with three different formations. The oldest being the Carboniferous-Permian Taku Schist Formation, consisting of metamorphic rock schist, is unconformably overlain by the Permian-Triassic Telong Formation. Meanwhile, Telong Formation, consisting of from the oldest to the youngest, fine-grained sandstone, followed by shale and andesite, is unconformably overlain by Temangan Ignimbrite, occurred as dyke during the Triassic period. Temangan Ignimbrite represents a prominent ridge, trending in North-South direction, separating the sandstone and shale units in Temangan area. It intrudes along the Lebir Fault Zone (Aw, 1967). **Figure 4.10** shows the stratigraphic column of the study area.

Era	Period	Lithology	Unit	Description
Mesozoic	Triassic		Temangan Ignimbrite	Occur as dyke (intrusion). Brittle and rough. Has pinkish to dark brown color. Exhibit eutaxitic texture.
	Permian-Triassic		Telong Formation	Andesite showing greyish green color. Exhibit porphyritic texture.
Paleozoic				Brownish grey, very fine-grained shale. Texture is smooth and clastic.
				Dark grey, fine-grained sandstone. Show moderate rough surface. Exhibit aphanitic texture.
	Carboniferous-Permian		Taku Schist Formation	Greyish orange schist. Exhibit foliation (schistosity). Dominated with quartz-mica-schist. Show pelitic texture.

Figure 4.10: Stratigraphic column of the study area.

4.3.2 Unit Explanation

4.3.2.1 Schist Unit

Figure 4.11: Hand specimen of schist from Shahman (2017).

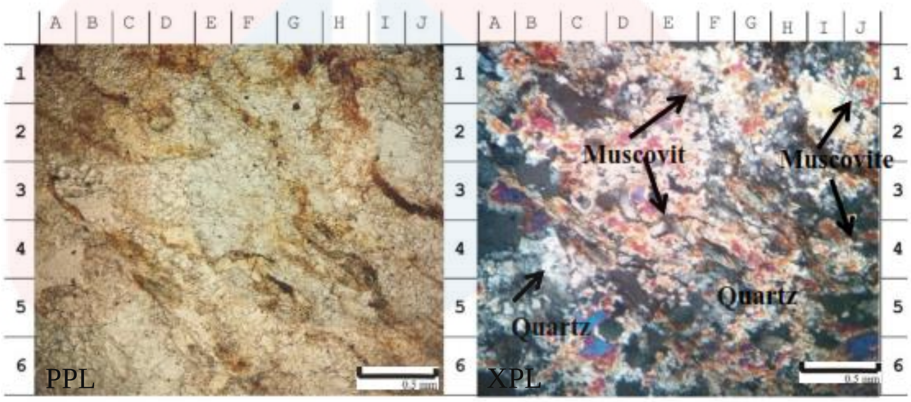

Figure 4.12: Schist specimen under microscope with magnification 4x10 (Shahman, 2017).

The hand sample of schist showing greyish orange color. It exhibits platy grains, which aligned in common orientation, making the rock to easily split into layers, following its grain orientation direction (Salwisol, 2017). Schist exhibits foliation (schistosity). The rock is course-grained, meaning the crystals are large enough to be seen under naked eyes. In thin section, the dominant mineral is quartz, followed by muscovite (Shahman, 2017). But, in hand specimen, muscovite mica crystal can be seen clearly, making the rock surface to look sparkly and shiny. The schist in the study area is identified as quartz mica schist (Shahman, 2017).

4.3.2.2 Sandstone Unit

The hand sample of sedimentary rock sandstone collected by Salwisol (2017) and Mahmood (2013) shows dark grey colour. The rock is very fine-grained, exhibit aphanitic texture. Small fragments of siltstone can be found in the study area, but only in minor amounts, which cannot be mapped on the geological map.

4.3.2.3 Shale Unit

Figure 4.13: Hand specimen of shale from Shahman (2017).

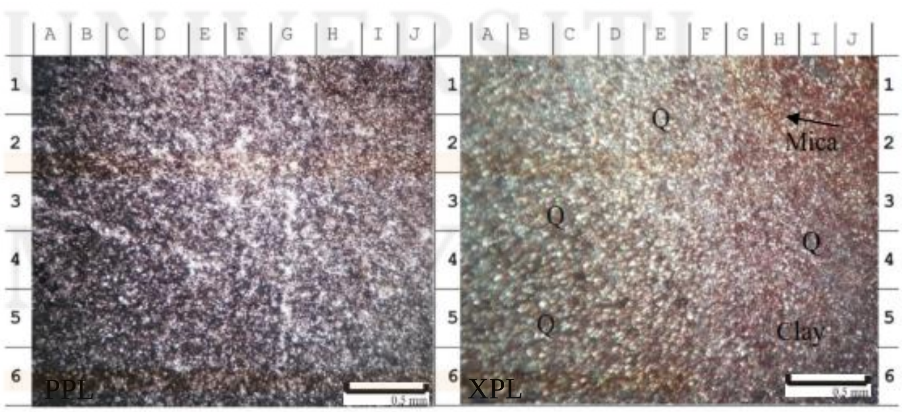

Figure 4.14: Shale specimen under microscope with magnification 4x10 (Shahman, 2017).

The hand sample of clastic sedimentary rock shale showing brownish grey color. It exhibits fine lamination structure (Shahman, 2017). The rock is highly fissile. It can be easily breaks up into sheets. The rock is very fine-grained. The texture is very smooth. In thin section, the dominant mineral is fine-size quartz and clay minerals, followed by fine mica (Shahman, 2017).

4.3.2.4 Andesite Unit

Figure 4.15: Hand specimen of andesite from Shahman (2017).

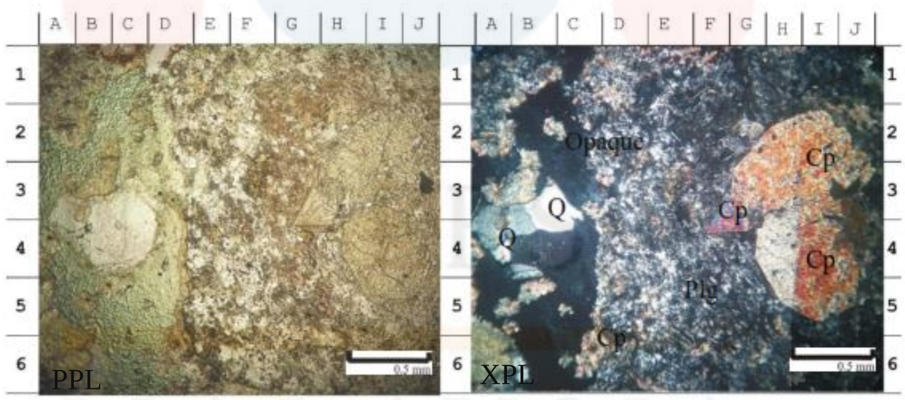

Figure 4.16: Andesite specimen under microscope with magnification 4x10 (Shahman, 2017).

The hand sample of andesite showing greyish green color. It exhibits aphanitic texture (Salwisol, 2017) (Mahmood, 2013), where the grain is very fine, it cannot be seen under simple lens. The rock also shows porphyritic texture (Shahman, 2017) (Mahmood, 2013), where the phenocryst is comprises with pyroxene, showing black color on the rock surface, while the groundmass is comprises with plagioclase, showing light green color on the rock surface. In thin section, the dominant mineral is plagioclase, followed by pyroxene, quartz and alkali feldspar (Shahman, 2017). Other minerals stated by Salwisol (2017) is biotite and calcite.

4.3.2.5 Ignimbrite Unit

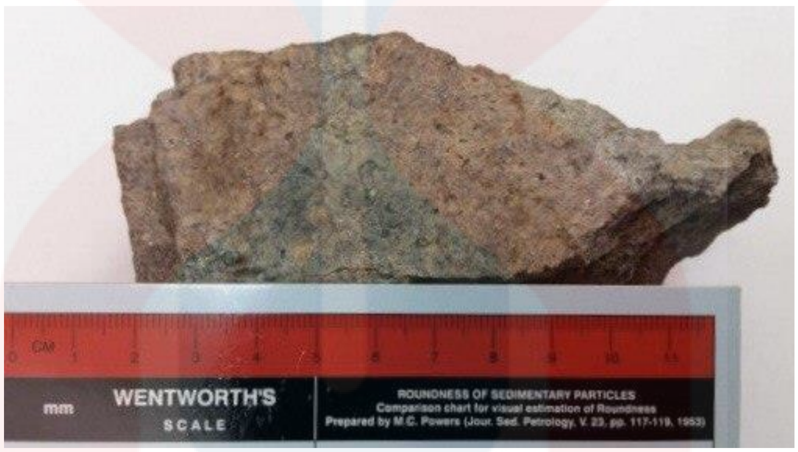

Figure 4.17: Hand specimen of ignimbrite from Shahman (2017).

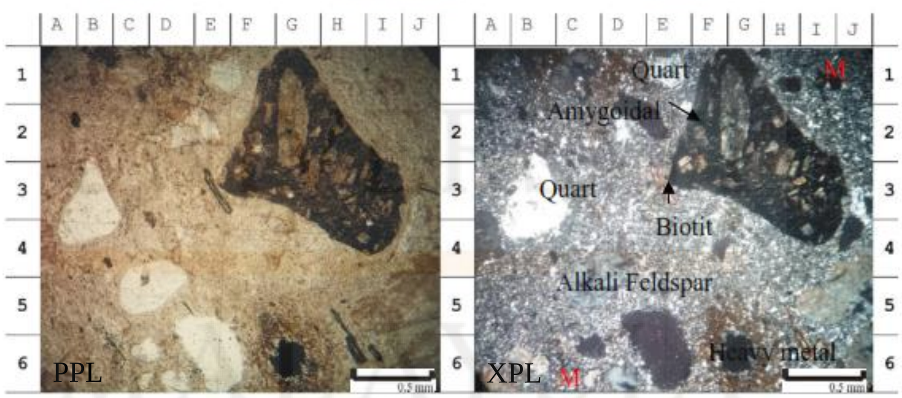

Figure 4.18: Ignimbrite specimen under microscope with magnification 4x10 (Shahman, 2017).

The hand sample of ignimbrite showing pinkish to dark brown color. The rock is brittle and it has rough surface. It displays eutaxitic texture (Shahman, 2017). It exhibits aphanitic texture (Salwisol, 2017) (Anoar, 2017), where the grain is very fine, it cannot be seen under simple lens. The rock also shows porphyritic texture, where the phenocryst is comprises with alkali feldspar and quartz, while the groundmass is comprises with alkali feldspar, quartz and biotite (Shahman, 2017). In thin section, the dominant mineral is feldspar, followed by biotite, pyroxene and quartz (Anoar, 2017). Other minerals stated by Salwisol (2017) is muscovite and lithic fragments. According to Aw (1967), the texture of Temangan ignimbrite is intermediate between rhyolite lava and tuff. The evidences collected from his research suggest that the Temangan ignimbrite is represented as a tuff flow.

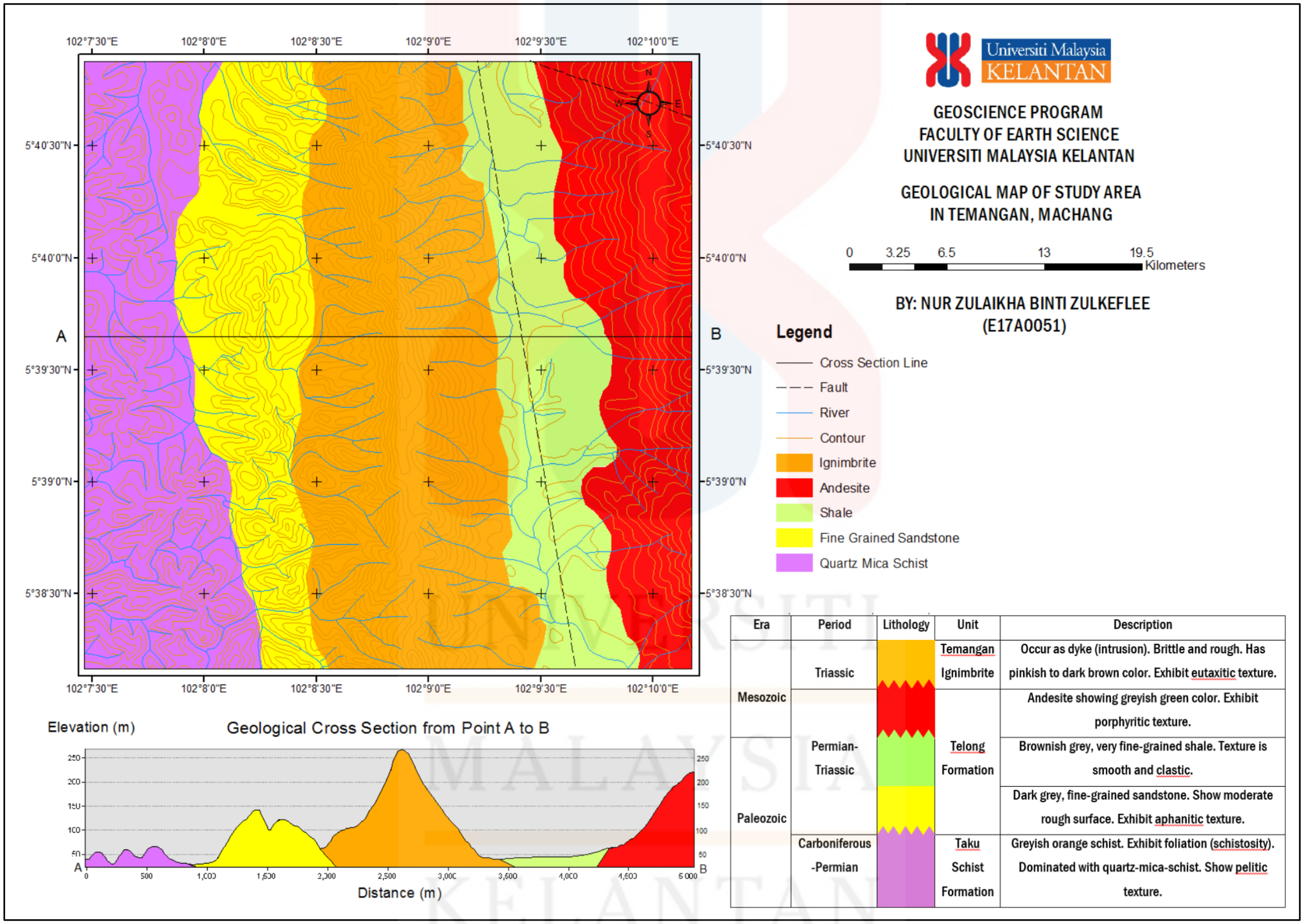

Figure 4.19: Geological map of the study area.

4.4 Structural Geology

In this section, the geological structures fault and fold were discussed based on the past references and the mechanism of structure was interpreted based on the lineament analysis done in rose diagram.

4.4.1 Fault

In the study area, from Shahman (2017), there is a presence of normal fault with principle force coming from N-S trending. Unfortunately, the normal fault only exists as a minor fault. Presence of slickenside in the area is an indicator for the presence of faulting.

Figure 4.20: Normal fault in the study area (Shahman, 2017).

4.4.2 Fold

From Salwisol (2017), monocline folding is present in the study area.

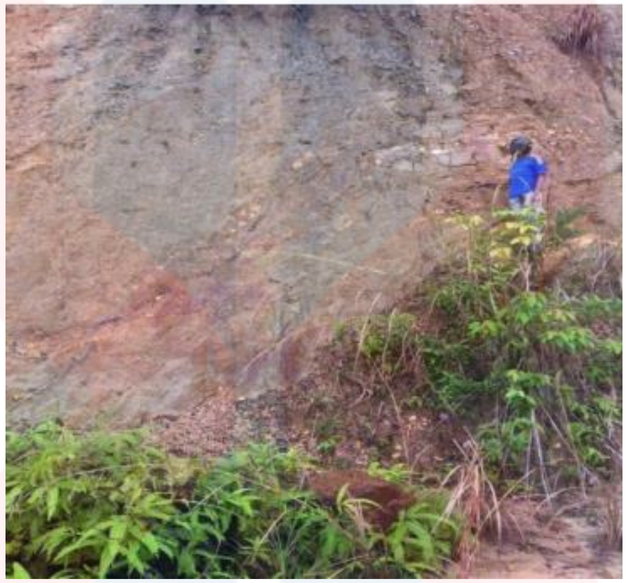

Figure 4.21: Monocline fold in the study area (Salwisol, 2017).

4.4.3 Mechanism of Structure

Mechanism of structure was done based on the lineament analysis. Lineament is oftenly used to point out any linear geological features that can be identified in aerial photographs and satellite imageries. Linear patterns of topographic feature are incredibly useful for structural geology purpose, as they represent and enable geological structures to be interpreted. Linear trend of high topography, known as positive lineament and linear trend of low topography, known as negative lineament are two types of linear patterns of topographic feature. **Figure 4.22** shows the lineament analysis map of the study area.

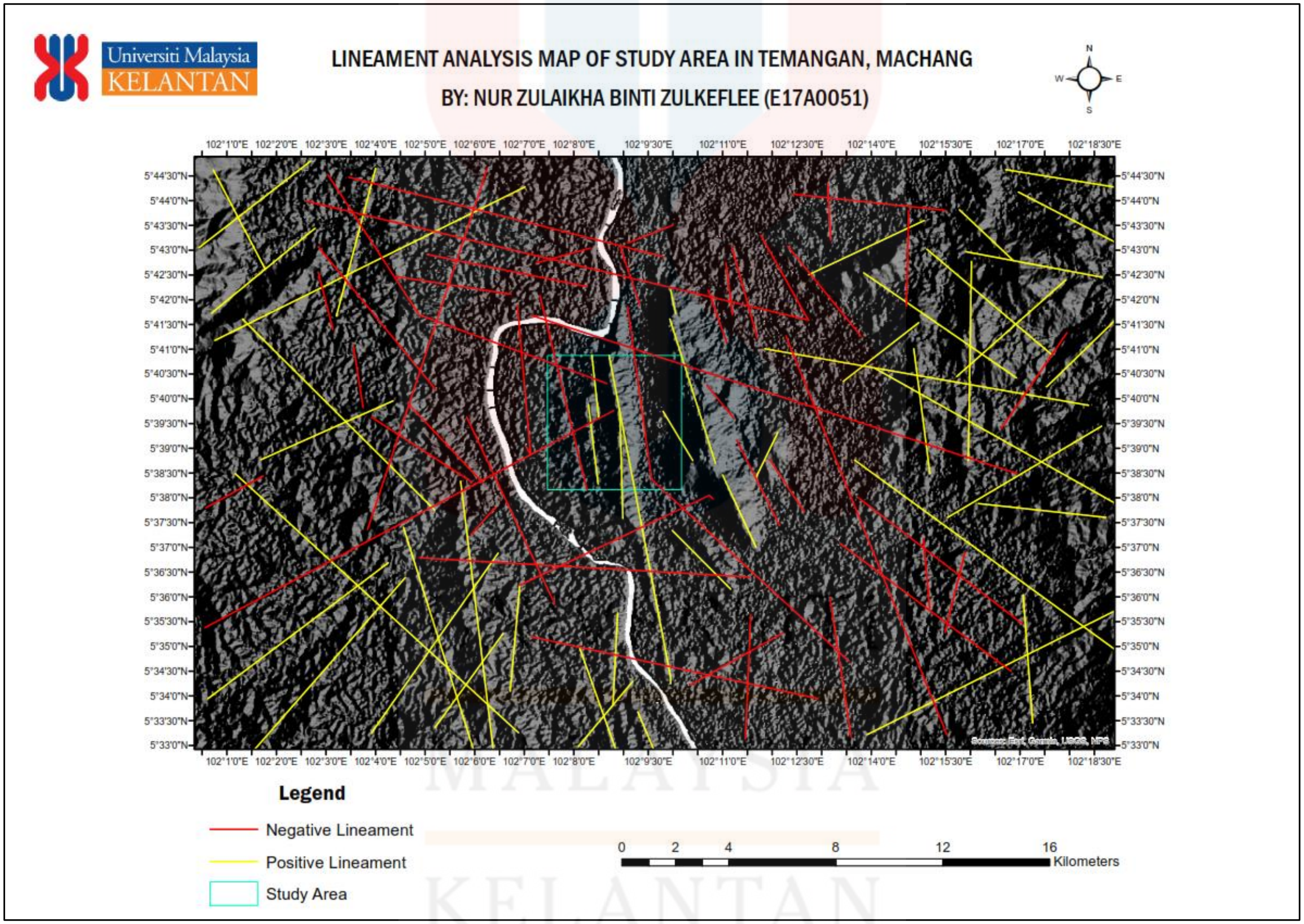

Figure 4.22: Lineament analysis map of the study area.

Positive lineament normally defines the presence of resistant rock units like dykes and ridges, while negative lineament normally defines the presence of non-resistant rock units like straight valleys, or the rock planes or zones of weakness exposure in rocks like fault and joint. **Figure 4.23** shows the rose diagram for the analysis of positive lineaments on the map while **Figure 4.24** shows the rose diagram for the analysis of negative lineaments on the map.

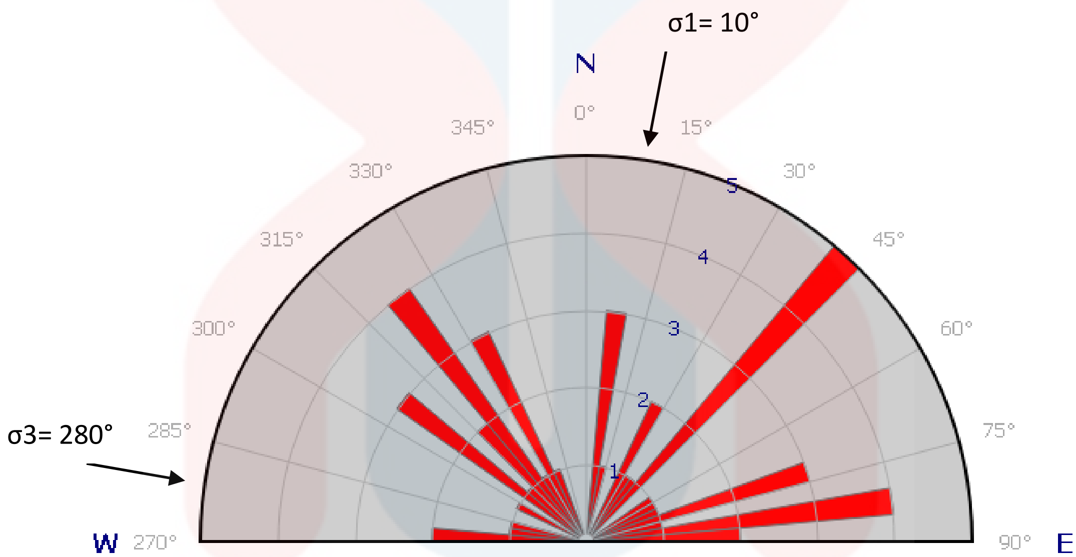

Figure 4.23: Analysis of the positive lineaments on the study area.

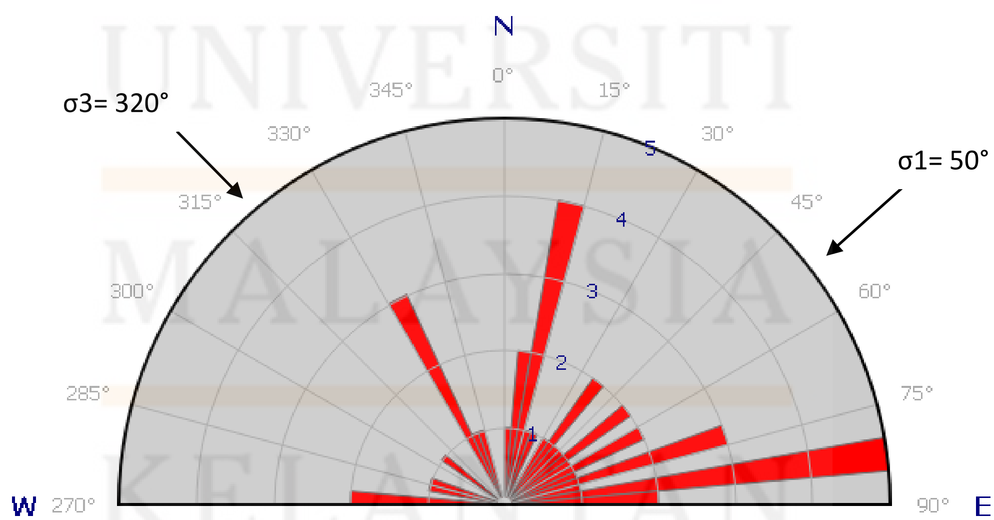

Figure 4.24: Analysis of the negative lineaments on the study area.

Based on **Figure 4.23**, for positive lineament analysis, the principal stress comes from N-S trend with angle of 10°. The principal force had come from the right side, causing faulting facing the left. The fault is called as sinistral strike-slip fault. Meanwhile, based on **Figure 4.24** for negative lineament analysis, the principal stress comes from NE-SW trend with angle of 50°. The principal force also had come from the right side, causing faulting facing the left. The fault is also called as sinistral strike-slip fault.

The occurrences of these lineaments are connected with the N-S trending of Lebir Fault Zone. The N-S trending and NE-SW trending strike-slip fault from both positive and negative lineament analysis move sinistrally in the Lebir Fault Zone. These sinistral movements are responsible for the formation of other geological structures in the surrounding area.

4.5 Historical Geology

The sedimentary rocks were deposited during Permian-Triassic period. Then, during Triassic, an active tectonic setting activities had happened, causing the Taku Shist to be metamorphosed into medium grade metamorphic rocks. During Triassic period, Temangan ignimbrite had come out as a thick dyke. It plugs an old feeding fissure. Temangan ignimbrite represents a prominent ridge, separating the sandstone and shale units in Temangan area. It intrudes along the Lebir Fault Zone (Aw, 1967).

Temangan was located in the northwest part of the Kelantan state. The research study is underlain by metamorphic rock comprises of the Taku Shist and the Telong Formation, as well as extrusive rock of Temangan ignimbrite. Based on Aw (1967), the

Temangan ignimbrite rock is predominantly displays porphyritic texture, with presence of quartz phenocryst and feldspar in feldsitic matrix. The sedimentary rocks were deposited during the Permian to Triassic period. The Carboniferous-Permian Taku Shist is uncorformably overlain by the Triassic Telong formation. The Taku Shist has been metamorphosed into medium grade metamorphic rock due to the Triassic tectonic setting activities and the Late Cretaceous granitic intrusion. The rock unit is dominated by schist, consists predominantly of quartz-mica shist. In the eastern part of the state of Kelantan, one of the main lineament in Peninsular Malaysia and is considered to be post-Cretaceous and a sinister strike-slip fault, the Lebir Fault Zone is located (Tjia, 1989) (Harun, 2002).

CHAPTER 5

BIOGEOCHEMICAL STUDY OF PLANT AND SOIL IN MALAYSIA

5.1 Introduction

In this research, a review on biogeochemistry study of element concentration in plant and soil samples in selected area in Malaysia based on previous research was conducted. Literature review, compilation of journal articles and discussion of the articles collected had been done to obtain the data needed for this research. In total, four articles in different selected area in Malaysia were collected to be discussed and reviewed. Four parameters were discussed upon completing this review. Plant species and its morphology, soil and/or sediment properties, geological condition of the area and the elemental distribution of plant and soil samples. A relationship on geology and the geochemistry of soil as well as relationship on the concentration of elements in plant and the soil geochemistry are discussed further at the end of this chapter.

For the elemental distribution of soil sample, three different methods were used in analyzing the element concentration. X- Ray Fluorescence (XRF) in Sokor, Kelantan, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) in Bukit Besi, Terengganu and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) in both research in Kinabalu Park and Mount Silam Forest Reserve in Sabah. Meanwhile, for the elemental distribution of plant sample, two different methods were used in analyzing the element concentration. Inductively Coupled Plasma Mass Spectrometry (ICP-MS) in Sokor, Kelantan and Bukit Besi, Terengganu and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) in both research in Kinabalu Park and Mount Silam Forest Reserve in Sabah.

5.2 Plant Species and Its Morphology

A total of three plant species from four different articles were described in terms of their morphology. First species, *Melastoma malabathricum* from two different sites were choose. One from an article written by Chang & Ismail (2019) in Sokor, Kelantan and two, from an article written by Kutty & Al-Mahaqeri (2016) in Bukit Besi, Terengganu. Second species, *Glochidion cf. sericeum* from an article written by Ent, et al., (2018) in the North of Kinabalu Park (near Serinsim), Sabah, and third species, *Antidesma montis-silam* from an article written by Nkrumah, et al., (2018) in the Mount Silam Forest Reserve, Sabah. Info regarding the plant species and its morphology was tabulated in **Table 5.1**.

5.3 Soil/Sediment Properties

In Sokor, Kelantan, the soil properties was identified as ultisol and oxisol. In general, the soil in the area is rich in clay minerals, quartz and iron minerals. Meanwhile, in Bukit Besi, Terengganu, the soil was identified as granitic soil with presence of kaolinite and goethite. The granitic soil has an extremely acidic pH (3.45). In Sabah, the area of north Kinabalu Park exhibits ferralsol, with pH 3.8 (acidic). Contrary, the area of Mount Silam Forest exhibits cambisol, with pH 6.18 (neutral). Both are originating from ultramafic bedrock. Detailed information regarding the soil/sediment properties was presented in **Table 5.2**.

5.4 Geological Condition of the Area

Research done by Chang & Ismail (2019) identified that the geology of the area in Sokor, Kelantan is associated with hydrothermal alteration due to weathering, causing supergene enrichment. Presence of phyllic and argillic alteration were established due to the presence of phyllite rocks and its associated mineral sericite, dickite and kaolinite. In Bukit Besi, Terengganu, granitic intrusion had caused low thermal metamorphism and folding of rocks in the contact area. Iron ore can be found tremendously in shale, with iron ore mineral haematite, magnetite and goethite are numerous (Sarman, et al., 2019).

The ultramafic bedrock in Sabah is part of the Ophiolite Complex sequence formed during the Cretaceous-Jurassic period. The sequence composed of volcanic-sedimentary rock and ultramafic-serpentinite rock. In Kinabalu Park, presence of tremolite and lherzolite- bearing peridotites are major, while wehrlite and harzburgite are minor. Low-temperature peridotite hydration and metamorphism had resulted in the formation of serpentinite rock (Ent, et al., 2018). Meanwhile, in Mount Silam, the research area consists of ultramafic rock, amphibolite, gabbro, plagiogranite, basaltic dyke, and basaltic rock of igneous and sedimentary rocks topped by red radiolarian chert (Isnain, et al., 2017). **Table 5.3** disccused the geology of the study area for all articles in detail.

5.5 Elemental Distribution of Plant and Soil Sample

5.5.1 Soil Sample

Using XRF analysis, the value of quartz dominates other oxides in Sokor by 47.89 µg/g, followed by iron oxide, potassium oxide and small amount of titanium and vanadium oxide. The atomic arrangement of silica helps it to become more resistant to chemical and physical weathering.

Next, from ICP-MS analysis on sediment in Bukit Besi, iron dominates other elements by 2459 µg/g, followed by aluminum, lead and cadmium. According to Kutty & Al-Mahaqeri (2016), the value of pH of sediment affects the concentration of the element in sediment/soil, by which smaller pH give rise to a high absorption ability of iron, aluminum, lead and cadmium in the Bukit Besi surface sediment.

From ICP-AES analysis of soil in Kinabalu Park, iron, aluminum and chromium dominates other elements in their total concentration (385700 µg/g, 30800 µg/g and 16300 µg/g respectively). Concentration of cobalt, nickel and manganese obtained from the analysis is considered normal for ultramafic bedrock. Meanwhile, concentration of calcium, potassium, and magnesium are fewer compared to other elements due to intensive leaching via heavy rainfall. Detailed results of the elemental distribution of soil samples in the articles' research area are shown in **Table 5.4**.

5.5.2 Plant Sample

Using ICP-MS analysis, the value of iron and aluminum concentration dominates other elements in Sokor, Kelantan by 223.09 µg/g and 95.5 µg/g respectively, followed by manganese and small amounts of zinc, lead, copper, arsenic and silver. Meanwhile, ICP-MS analysis in Bukit Besi, Terengganu shows high concentration of aluminum and iron (48843 µg/g and 1388 µg/g respectively) while concentration of lead and cadmium only minor. This value is normal as Watanabe & Osaki (2002) stated that *Melastoma malabathricum* exhibits high capacity to accumulate more than 10,000 µg/g aluminum in their leaves.

From ICP-AES analysis of plant in Kinabalu Park, magnesium, manganese and potassium dominates other elements in their total concentration (6232 µg/g, 2866 µg/g and 3453 µg/g respectively). Meanwhile, concentration of iron, zinc and chromium are smaller compared to others. Contrary, in Mount Silam Forest Reserve, ICP-AES shows total concentration of nickel, potassium and magnesium dominates the other by 18120 µg/g, 8605 µg/g and 4690 µg/g respectively. Cobalt and aluminum are relatively low. Even though both plants are located on ultramafic bedrock, the elemental concentration of both localities are quite different. Detailed results of the elemental distribution of plant samples in the articles' research area are shown in **Table 5.5**.

Table 5.1: Plant species and its morphology.

Study Area	Plant Species	Plant Morphology
Sokor, Kelantan Bukit Besi, Terengganu	*Melastoma malabathricum*	1.8-2m high (shrub, small tree)
		Purple-magenta flowers with purple petals and purple buds
		Round berry fruits with dark blue-red pulps, and orange, minute seeds
		Lanceolate-shaped, hairy and bristly, parallel veined leaves
	Figure 5.1: *Melastoma malabathricum* in its habitat.	Reddish, erect, branching stems covered with ciliate, appresed scales
Reference: (Chang & Ismail, 2019), (Kutty & Al-Mahaqeri, 2016), (International, 2019).		
North of Kinabalu Park (near Serinsim), Sabah, Malaysia	*Glochidion cf. sericeum*	5-8m high (medium-sized tree)
		Whitish flowers with occurrence of white-yellowish fascicles in nodes
		Pinkish red fruits, completely open septicidal, densely tomentose
		Smooth surface with acuminate tips, lanceolate-shaped leaves
		Red colour phloem (inner bark)
	Figure 5.2: *Glochidion cf. sericeum* in its habitat.	Phyllanthoid branching stems
Reference: (Ent, et al., 2018).		
	Antidesma montis-silam	30m high (hardwood, straight, tall tree)

<table>
<tr><td rowspan="5">Mount Silam Forest Reserve, Sabah, Malaysia</td><td rowspan="5">
Figure 5.3: Dried leaf sample of *Antidesma montis-silam.*</td><td>Light-coloured flowers with pilose to glabrous pedicals' surface and sinuses rounded sepals, raceme-typed inflorescences</td></tr>
<tr><td>Ellipsoid-shaped fruits, pilose to glabrous infructescences , green when immature, bright colours when mature</td></tr>
<tr><td>Evergreen, oblong to slightly obovate-shaped leaves with flat petioles, soft and straight hairy surface, with elliptic blades</td></tr>
<tr><td>Whtitsh, lenticelled, scaly barks</td></tr>
<tr><td>Striate, brown twigs</td></tr>
<tr><td colspan="3">**Reference:** (Nkrumah, et al., 2018), (Hoffmann, 2006).</td></tr>
</table>

Table 5.2: Soil/sediment properties.

Study Area	Plant Species	Soil / Sediment Properties	Reference
Sokor, Kelantan	*Melastoma malabathricum*	Yellowish brown colour (not rusty)	(Chang & Ismail, 2019)
		Rich in clay minerals kaolinite, dickite, halloysite and pyrohyllite, quartz and cristobalite, and iron mineral gibbsite, goethite and hematite (XRD analysis)	
		Contain minor barium, vanadium, chromium, titanium, nickel and manganese oxides. Major silicon dioxide, iron oxide and potassium oxide (XRF analysis)	
		Composed of ultisol (severely leached, clay-accumulated soil) and oxisol (totally weathered)	
		Compacted soil, having large hydrated iron minerals, hard to 'rust'	
Bukit Besi, Terengganu	*Melastoma malabathricum*	Reddish-orange coloured, granitic soil	(Kutty & Al-Mahaqeri, 2016), (Sarman, et al., 2019)
		Presence of mineral kaolinite (formed via weathering of feldspar) and secondary mineral goethite	
		pH extremely acidic (3.45-3.85)	
		Percentage of the content of organic matter (OM) low, only 1.56%	
North of Kinabalu Park		Ferralsol (deep, strongly lateralized soil) originating from ultramafic bedrock	

(near Serinsim), Sabah, Malaysia	*Glochidion cf. sericeum*	Predominantly consists of red coloured goethite and minor hematite (ferrocrete)	(Ent, et al., 2018), (Ent, et al., 2018)
		pH acidic (3.8–5.7)	
		Always undergoing strong leaching due to heavy rainfall	
		Promote efficient biological recycling of significant macro nutrients	
Mount Silam Forest Reserve, Sabah, Malaysia	*Antidesma montis-silam*	Cambisol (well-buffered hypermagnesian) originating from ultramafic bedrock	(Nkrumah, et al., 2018), (Isnain, et al., 2017)
		pH neutral (mean 6.18)	
		Very shallow cambisol formed at high altitude, a direct outcome from primary weathering of near-surface bedrock	
		Result of the breakdown of phyllosilicates and re-absorption into secondary Fe-oxides and clay	
		Alluvial deposits composed of peat and grey lateritic clay	

Table 5.3: Geology of the study area.

Study Area	Plant Species	Soil / Sediment Properties	Reference
Sokor, Kelantan	*Melastoma malabathricum*	Main rock type is phyllite	(Chang & Ismail, 2019)
		Presence of quartz veins indicate hydrothermal alteration and ore path finding	
		Hydrothermal alteration occurred due to the enrichment of supergene via weathering, by which the circular flow of meteoric water percolated the primary sulphide ore minerals and redistributed it through the reaction between primary minerals and leaching minerals, causing accumulation under enrichment zone's water table	
		Presence of phyllite rocks along with mineral sericite and quartz indicates phyllic alteration (replaced plagioclase into sericite and mafic minerals to quartz)	
		Also undergone argillic alteration (replaced amphibole and plagioclase into dickite and kaolinite at low temperature)	
Bukit Besi, Terengganu	*Melastoma malabathricum*	Main rock: shale is dominant, with minor granite, quartzite and limestone	(Kutty & Al-Mahaqeri, 2016), (Sarman, et al., 2019)
		Granitic intrusion had caused low thermal metamorphism and folding of rocks in the contact area. Sedimentary rocks changed into calc-silicate band hornfels. Minerals like hornblende and quartz can be found, with minor sericite, epidote, casiterite, garnet and magnetite	

		Iron ore can be found tremendously in shale. Haematite, magnetite and goethite are the major iron ore minerals. Also can be found in granite and limestone skarn	
		Iron mineralization occurred as results from replacement of minerals in rocks and fractures	
		Pyrometasomatisme is the mineralization process	
		Also have presence of sulphide ore mineral association (irregularly distributed), like chalcopyrite, pyrite and pyrrhotite	
North of Kinabalu Park (near Serinsim), Sabah, Malaysia	*Glochidion cf. sericeum*	The ultramafic bedrock is part of an ophiolite sequence resulting from a suture collision between the micro-continent of Kalimantan and the Sulu Arc	(Ent, et al., 2018), (Ent, et al., 2018)
		Presence of tremolite and lherzolite- bearing peridotites are major, while minor wehrlite and harzburgite	
		Low-temperature peridotite hydration and metamorphism results in the formation of serpentinite, typically along tectonic borders (such as along mid-ocean ridges) or during continental positioning at the sea floor. The assemblage of minerals are entirely modified to metamorphic analogues during serpentinization, and only chromite commonly remains unchanged	
		Peridotite minerals (pyroxene and olivine) produce secondary minerals (Fe-rich) (hematite and goethite) in well-drained soils, while Si and Mg pass	

		down the soil profile and deposited at depth, while Al, Cr and Fe are less soluble and stay higher in the profile	
		During pedogenesis, Ni is heavily leached and much of it is lost, compared to other metals such as Al	
Mount Silam Forest Reserve, Sabah, Malaysia	*Antidesma montis-silam*	Lithology: Darvel Bay Ophiolite Complex (oceanic crust ophiolitic sequence formed during Cretaceous-Jurassic period) composed of volcanic-sedimentary rock and ultramafic-serpentinite rock	(Nkrumah, et al., 2018), (Isnain, et al., 2017)
		The area consists of ultramafic rock, amphibolite, gabbro, plagiogranite, basaltic dyke, and basaltic rock of igneous and sedimentary rocks topped by red radiolarian chert	
		Crystalline basement and ultramafic rock underlie the hilly region of Mount Silam to the undulating region at the northwest	
		Formation of mélange surrounded the complex while Neogene and Quaternary sediments overlain it	
		Medium to coarse grained granite dominates, usually in porphyritic form	

Table 5.4: Elemental concentration in soil sample.

Method / Reference	**XRF** (Chang & Ismail, 2019)	**ICP-MS** (Kutty & Al-Mahaqeri, 2016)	**ICP-AES** (Ent, et al., 2018)	**ICP-AES** (Nkrumah, et al., 2018)
Element	Sokor, Kelantan (*Melastoma malabathricum*)	Bukit Besi, Terengganu (*Melastoma malabathricum*)	North of Kinabalu Park (near Serinsim), Sabah, Malaysia (*Glochidion cf. sericeum*)	Mount Silam Forest Reserve, Sabah, Malaysia (*Antidesma montis-silam*)
Si	47.89			
Fe	44.43	2459.00	385700	27800
K	5.83		83	30
Ti	1.76			
V	0.10			
Pb		0.55		
Cd		0.02		
Al		1021.00	30800	
Cr			16300	1120
Zn			270	40
Mn			2318	1660
Ca			561	310
Co			50	60
Mg			512	32,600
Ni			2452	1200
P			279	150

Table 5.5: Elemental concentration in plant sample.

Method / Reference	**ICP-MS** (Chang & Ismail, 2019)	**ICP-MS** (Kutty & Al-Mahaqeri, 2016)	**ICP-AES** (Ent, et al., 2018)	**ICP-AES** (Nkrumah, et al., 2018)
Element	Sokor, Kelantan (*Melastoma malabathricum*)	Bukit Besi, Terengganu (*Melastoma malabathricum*)	North of Kinabalu Park (near Serinsim), Sabah, Malaysia (*Glochidion cf. sericeum*)	Mount Silam Forest Reserve, Sabah, Malaysia (*Antidesma montis-silam*)
Mn	19.57		2866	75
Fe	223.09	1388.00	38	40
Al	95.50	48843.00	197	15
Pb	0.40	0.65		
Cd		0.07		
Zn	0.77		36	70
Cu	0.27			
Cr			43	
K			3453	8605
Mg			6323	4690
P			346	1465
S			1453	1865
Co			482	15
Ca			2725	6960
Ni			1602	18,120
Ag	0.11			
As	0.19			

5.6 Relationship on Geology and the Geochemistry of Soil

In Sokor, Kelantan, the accumulation of Si in soil shows the highest concentration. It is acceptable as the main mineral composition in the soil sample of the area is clay mineral like kaolinite, dickite and sericite, which were altered from plagioclase mineral. The clay minerals reflect phyllic and argillic alteration happened in the area, as explained in **Table 5.3**. Other than that, Fe also shows high concentration. This is due to the soil being compacted and have high hydrated iron minerals in it, in addition with the presence of iron sulfide mineral, pyrite.

On the other hand, Fe also shows the highest concentration in soil in Bukit Besi, Terengganu, aligned with the presence of large numbers of iron ore mineral magnetite, hematite and goethite in metamorphic rock shale. These iron minerals were formed due to the process of pyrometasomatisme, a formation at high temperatures of contact-metamorphic mineral deposits through emanation from intrusive material.

Next, in Kinabalu Park, Sabah, Fe, Al and Cr shows the highest concentration in soil. Meanwhile, in Mount Silam Forest Reserve, Sabah, Mg and Fe shows the highest concentration in soil. The concentration of Mg in Kinabalu Park, Sabah is lesser compared to Mg in Mount Silam. However, it has higher concentration of Cr than in Mount Silam. Both soils were derived from ultramafic bedrock, but, the soil type in Kinabalu Park is ferralsol while the soil type in Mount Silam is cambisol. While ferralsol is acidic, cambisol is neutral. While ferralsol is mature residual soil in lower altitude, cambisol is young in high altitude. It affects the Mg concentration in a way that in ferralsol, the Mg is open to greater leaching while in cambisol, the Cr is more prone to incipient weathering and transformation from younger soil to a mature soil.

5.7 Relationship on the Plant's Elemental Concentration and the Soil Geochemistry

In Sokor, Kelantan, the accumulation of Fe and Al in the leaves of *Melastoma malabathricum* show the highest concentration. It aligned with the high concentration of Fe availability in the soil. Unfortunately, the take up of Fe and Al from the soil to the leaves are not enough for the *Melastoma malabathricum* to be called as hyperaccumulator plant, as the value for Fe and Al concentration in plant sample are not exceeding the value of elemental concentration required for hyperaccumulator plant proposed by Reeves, et al. (2017).

On the other hand, Al in *Melastoma malabathricum* young leaves in Bukit Besi, Terengganu also show high concentration. In fact, the plant concentration value accumulated from the soil are large enough for the plant to be called as Al hyperaccumulator plant. They exceed more than 1000 µg/g Al content as introduced by Kabata-Pendias (2010).

Next, in Kinabalu Park, Sabah, Mn and Ni accumulation shows high concentration in the leaves of *Glochidion cf. sericeum*. It aligned with the high concentration of Mn and Ni availability in the soil. Unfortunately, for Mn concentration in the plant, it is not enough for the plant *Glochidion cf. sericeum* to be called as hyperaccumulator plant species. This is because according to Reeves, et al. (2017) in **Table 2.1**, to recognize Mn hyperaccumulator plant species, the weight foliar tissue must exceed more than 10,000 µg/g Mn. For Ni hyperaccumulation, the concentration value had exceeded 1000 µg/g Ni as proposed by Reeves, et al. (2017). Unfortunately, in Sabah, other Ni hyperaccumulator plant species exhibits much higher concentration value compared to *Glochidion cf. sericeum*. Thus, this makes the plant a weak Ni hyperaccumulator species.

Meanwhile, in Mount Silam Forest Reserve, Sabah, the leaves of *Antidesma montis-silam* shows a very high Ni concentration, higher than the *Glochidion cf. sericeum* in Kinabalu Park. Thus, this make *Antidesma montis-silam* a very good Ni hyperaccumulator plant species in Malaysia. Nkrumah, et al. (2018) mentioned that *Antidesma montis-silam* falls into a group of hyperaccumulator plant species called 'hypernickelophores', a species with a dry weight of shoot more than 1 Wt%, where globally only 150 species are recorded.

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

As a conclusion, all objectives for this research were established. A geological map of Temangan area with scale 1:25,000 were digitized using ArcGIS software. Five lithologies consisting schist, sandstone, shale, andesite and ignimbrite rock units were explained well. The rock distributions are made up of three different formations, Taku Schist Formation, Telong Formation and Temangan Ignimbrite Formation. Structural geology and historical geology of the area were understood well.

The biogeochemistry study of element concentration in plant and soil samples in selected area in Malaysia based on previous research was done. The relationship between the geology and the geochemistry of soil, as well as relationship between plant's elemental concentration and soil geochemistry and how they interact between each other were established. The availability of element concentration in soil or sediment affects the elemental concentration of plant. Plants that take up large amount must exceed the values proposed in order to be recognize as hyperaccumulator plant.

6.2 Suggestion

There are some limitations when conducting this research, therefore some suggestions for better future research were proposed. First, the need of secondary data.

Secondary data are important when there is lack of information during conducting the research. Hence, the initiative to find the best secondary data such as suitable and high quality spatial data and satellite imagery from official websites like USGS and Google Earth, accurate lithology and structural geology data from agencies like the Department of Mineral and Geoscience and reliable journal articles from the internet need to be taken seriously in order to get an accurate and better research result.

Biogeochemical study of plant and soil in Malaysia is still considered limited. A collaboration between multidisciplinary experts in different expertise like geology, geobotany, geochemistry and biology could be done in the future to explore more about the potential of biogeochemistry method in Malaysia. More plant and soil samples should be analyzed and drawn into a geochemical anomaly map for better representation. Deep and thorough analysis using suitable method and instrument need to be done in order to get the precise values for the element concentration in plant and soil samples. A standardized analysis could be set up for the study of plant hyperaccumulation and soil element concentration in Malaysia. Collection and management of data repository and data inventory regarding this topic should be done by responsible agencies.

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