GEOLOGY AND STUDIES ON ROCK COATINGS AS A RECORD OF CLIMATE CHANGE

By

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DECLARATION

I declare that this thesis entitled “GEOLOGY AND ROCK COATING AS RECORD OF CLIMATE CHANGES OF KAMPUNG KALAI, JELI” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidate of any other degree.

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APPROVAL

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

Signature : ………………………………………………………………

Name of Supervisor : ………………………………………………………………

Date : ………………………………………………………………

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Geology and Rock Coatings as a Record of Climate Changes of Kampung Kalai, Jeli

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ABSTRACT

The research mainly focused on the geology and study on rock coatings as record of climate changes. The study area of this research is located at district of Kelantan which is small town in Jeli called Kampung Kalai. Kampung Kalai is located at 05˚ 46’ 54.12’’ N and 05˚ 44’ 5.07’’ N latitude and 101˚ 43’ 42.76’’ E and 101˚ 46’ 30.47’’ E longitude that covers about 25km^2. The lithology, geomorphology, structural geology and the geological setting of Kampung Kalai, Jeli was studied. This study aims to update geological map of Kampung Kalai in scale 1:25000, to study on rock coatings in term of petrographic analysis, microscopic image, and shape. The petrographic analysis supported with the thin section is conducted to determine the type of rock and its formation. For geochemistry analysis, the sample rock and soil was collected at 14 different places and the coordinate recorded. Soil analysis is used to analyses the composition of oxides by using X-Ray Fluorescence (XRF). There are 5 types of coatings have been identified which are case hardening, iron film, dust film, lithobiontic coating, and rock varnish. Elemental analysis and scanning electron microscopy (SEM) were used to analyse the microscopic image of rock coating with these rock coatings. SEM analysis, petrographic and XRF analysis showed evidence that rock coating can record climate change by geochemical analysis. This study provided an updated geological map and the geochemistry analysis that can give the information about the role of the rock coating as a record of climate changes.

Geologi dan Salutan Batu Sebagai Rekod Perubahan Iklim di Kampung Kalai, Jeli.

ABSTRAK

Penyelidikan terutamanya memberi tumpuan kepada geologi dan kajian mengenai '*rock coating'* sebagai rekod perubahan iklim. Kajian kawasan kajian ini terletak di daerah Kelantan yang merupakan bandar kecil di Jeli yang dipanggil Kampung Kalai. Kampung Kalai terletak pada 05˚ 46 '54.12' 'N dan 05˚ 44' 5.07 '' N latitud dan 101˚ 43 '42.76' 'E dan 101˚ 46' 30.47 '' E longitud yang meliputi kira-kira 25km^2. Litologi, geomorfologi, geologi struktur dan persekitaran geologi Kampung Kalai, Jeli telah dipelajari. Kajian ini bertujuan untuk mengemas kini peta geologi Kampung Kalai dalam skala 1: 25000, untuk mengkaji lapisan batu dari segi analisis petrografi, imej mikroskopik dan bentuk. Analisis petrografi yang disokong dengan bahagian nipis dilakukan untuk menentukan jenis batu dan pembentukannya. Untuk analisis geokimia, sampel batu dan tanah dikumpulkan di 14 tempat yang berbeza dan koordinat yang direkodkan. Analisis tanah digunakan untuk menganalisis komposisi oksida dengan menggunakan X-Ray Fluorescence (XRF). Terdapat 5 jenis lapisan yang telah dikaji iaitu pengerasan kes, filem besi, filem debu, lapisan lithobiontik, dan varnis batu. Analisis elektro dan mikroskop elektron pengimbasan (SEM) digunakan untuk menganalisis imej mikroskopik salutan batu dengan salutan batu ini. Analisis SEM, analisis petrografi dan XRF menunjukkan bukti bahawa salutan batu dapat merekod perubahan iklim dengan analisis geokimia. Kajian ini menyediakan peta geologi terkini dan analisis geokimia yang dapat memberi maklumat mengenai peranan salutan batu sebagai rekod perubahan iklim.

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LIST OF ABBREVIATIONS

SEM	Secondary Electron Microscope
EDX	Energy Dispersive X-Ray
PPL	Plane Polarize
XRF	X-Ray Fluorescence
P	Phosphorus
K_2O	Potassium Oxides
CO_2	Carbon Dioxides
CaO	Calcium Oxides
Fe_2O_3	Iron (III) oxides
Al_2O_3	Aluminium Oxides
SiO_2	Silicon Dioxides.
TiO	Titanium Oxides
MnO	manganese Oxides
Na_2O	Sodium Oxides
MgO	Magnesium Oxides
$MgCO_3$	Magnesium Carbonate
Cl	Chloride
O_2	Oxygen

LIST OF SYMBOLS

°	Degree
‘	Minutes
‘’	Second
Cm	Centimetre
mm	Millimetre
µm	Micrometre
%	Percentage
m	Meter
Km	Kilometre
GIS	Geographical Information System
g	Gram
N	North
E	East
W	West
S	South
˚C	Celcius

CHAPTER 1

INTRODUCTION

1.1. Background of Study

The research mainly focused on the geology and study on rock coatings as records of climate change. The lithology, geomorphology, structural geology and the geological setting of Kampung Kalai which is located at Jeli Kelantan created very beautiful and breath-taking natural features. The topography contributed a lot in understanding the geological setting at the study area. Petrography analysis helped in interpretation of the rock facies with identifying the mineral contents in the rock. Also, the geological data such as joint, fault were analysed by using soft wares such as GeoRose, ArcGIS and Stereo nets in interpreting geological structures. These data are crucial in term of understanding the geological history and for producing the detail geological map of the study area.

Rock coatings are described as mineral accumulations that form from materials transported to parent rock on the surfaces of the rocks (Dorn, 1998). Rock coatings can be a result from reactions between atmosphere, lithosphere, biosphere and hydrosphere that covers the rock surfaces in every terrestrial weathering environment. Also, lichen or fungi which form clay mineral or sediment transformation can be a role of the factors that contribute the record of climate change from the process of dissolution or chemical reaction from the surrounding. Dissolution may produce silicate mineral when silicon react with the abundant of mineral in the earth which are Ca, Fe, K, Mg to form silicate with help from free-living fungi and lichen. Lichen can accumulate metals such as lead, copper, and many other elements.

Geomorphology and rock coatings study is important to study because coatings play a role in case-hardening surfaces, alter weathering rates, helps in provide understanding in environmental change and can provide chronometric insight into the exposure of the underlying rock surface (Dorn, 2013). This research is concerned at Kampung Kalai which is located 24 km from University Malaysia Kelantan Kampus Jeli. The methods is started with the preliminary study to gather the information in the preparation of fieldwork, lab work and data analysis. The fieldwork is done to fulfil and gained data to make geological map and to take samples for further studies and analysis. The samples and data collection is analysed in the laboratory in University Malaysia Kelantan.

The geochemical analysis method used was scanning electron microscope (SEM) and X-ray fluorescence (XRF). The data and result was interpreted and correlated accordingly in understanding the role of rock coating in changing the rock surface as well as identifying the factors that contributes to climate change. The findings from this research are assisted in understanding the role of coatings in tracking the process of climate changes.

1.2. Problem Statement

The updated geological data at Kampung Kalai is still lacking and limited. Because the newest data on geology is on 2015 but it is very limited and may miss the details on the specific area. So it is a good chance to do a research on geology at the area that can helped in updating the geological map which comprised the types of rock, structural geology and their distributions, landform, drainage pattern, recent road connection, residential area and land use of the study area.

Besides, the study on rock coatings is never been done in Kampung Kalai. This research is filling the gaps to study about the factors that influence the rock coatings as a record of climate changes. The factors influences climate changes were useful in collecting the history of paleo-climate of the area. The data with the geochemical analysis help others in gaining information of Kampung Kalai, Jeli for additional knowledge to develop the study area or for further research.

1.3. Objectives

- To update geological map of Kampung Kalai in scale 1:25000.
- To study on rock coatings in term of petrography analysis, microscopy image, shape.

1.4. Study Area

1.4.1. Location

Study area of this research is located at Jeli, Kelantan. Kampung Kalai is a small town in Jeli which located at 05° 46’ 54.14’’ N and 05° 44’5.07” N latitude and 101° 43’ 42.76’’ E and 101° 46’ 30.47” E longitude. Area of the study is covered about 5 km x 5 km with a dimension of 25 km^2.

The research area is located near with the international border of Malaysia-Thailand. It takes about 30 minutes from the Universiti Malaysia Kelantan by local transportation. The land uses of Kampung Kalai consist of plantation area, forest, main river, settlement and many small tributaries. The topography of the area is quite hilly at the left of the study area with the highest elevation about 640 m. The study area consists of Bukit Tepoh in North West, Kampung Belimbing, Kampung Tadoh, Kampung Kalai Baharu, and in the southeast part is Jeli Reserve Forest. From the geological map shown in Figure 1.2, the lithology of district Jeli consist of intrusive rock, Triassic age rock which comprise of shale, siltstone, sandstone, limestone and Permian age rock which comprise of phyllite, slate, sandstone, limestone. The base map of the study area is shown in Figure 1.3.

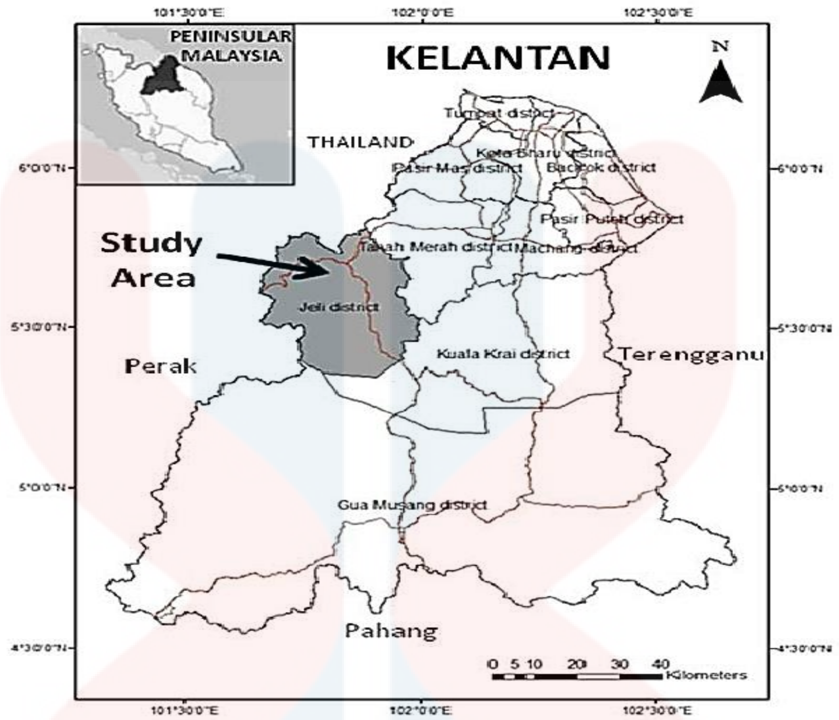


Figure 1.1: Map of Kelantan state. (Source: GeoJournal of Tourism and Geosites, ISSN 2065-0817, E-ISSN 2065-1198).

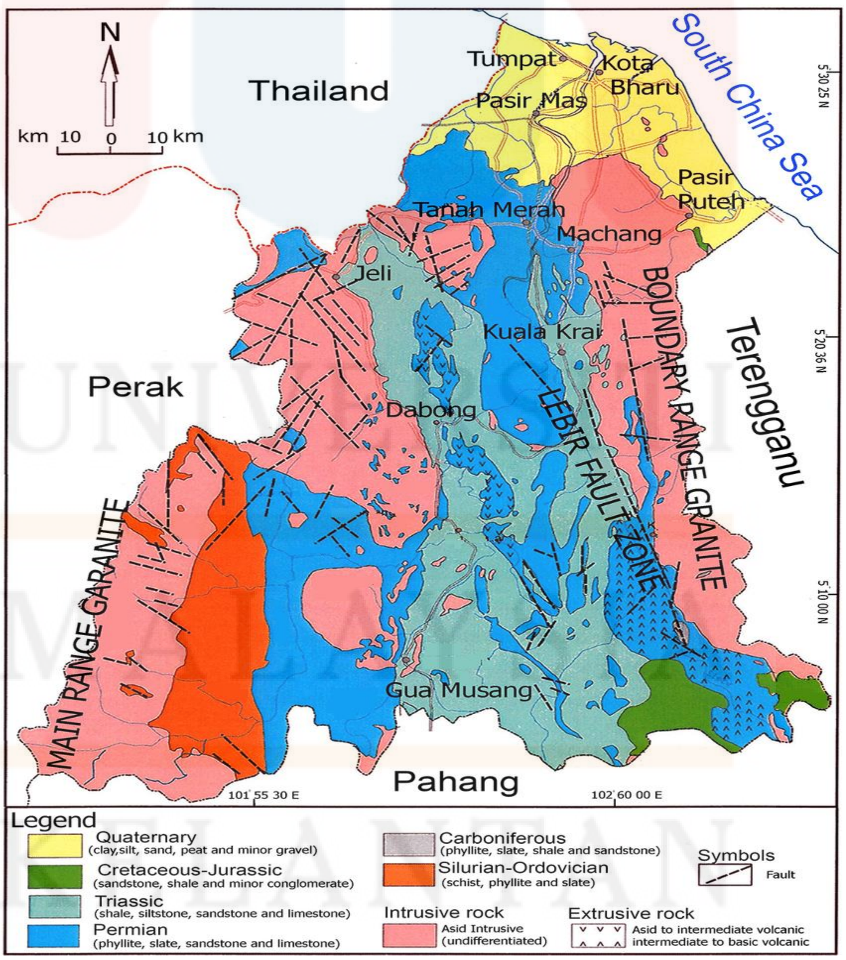


Figure 1.2: Geological map of Kelantan. (Source: Department of Minerals and Geoscience Malaysia, 2003).

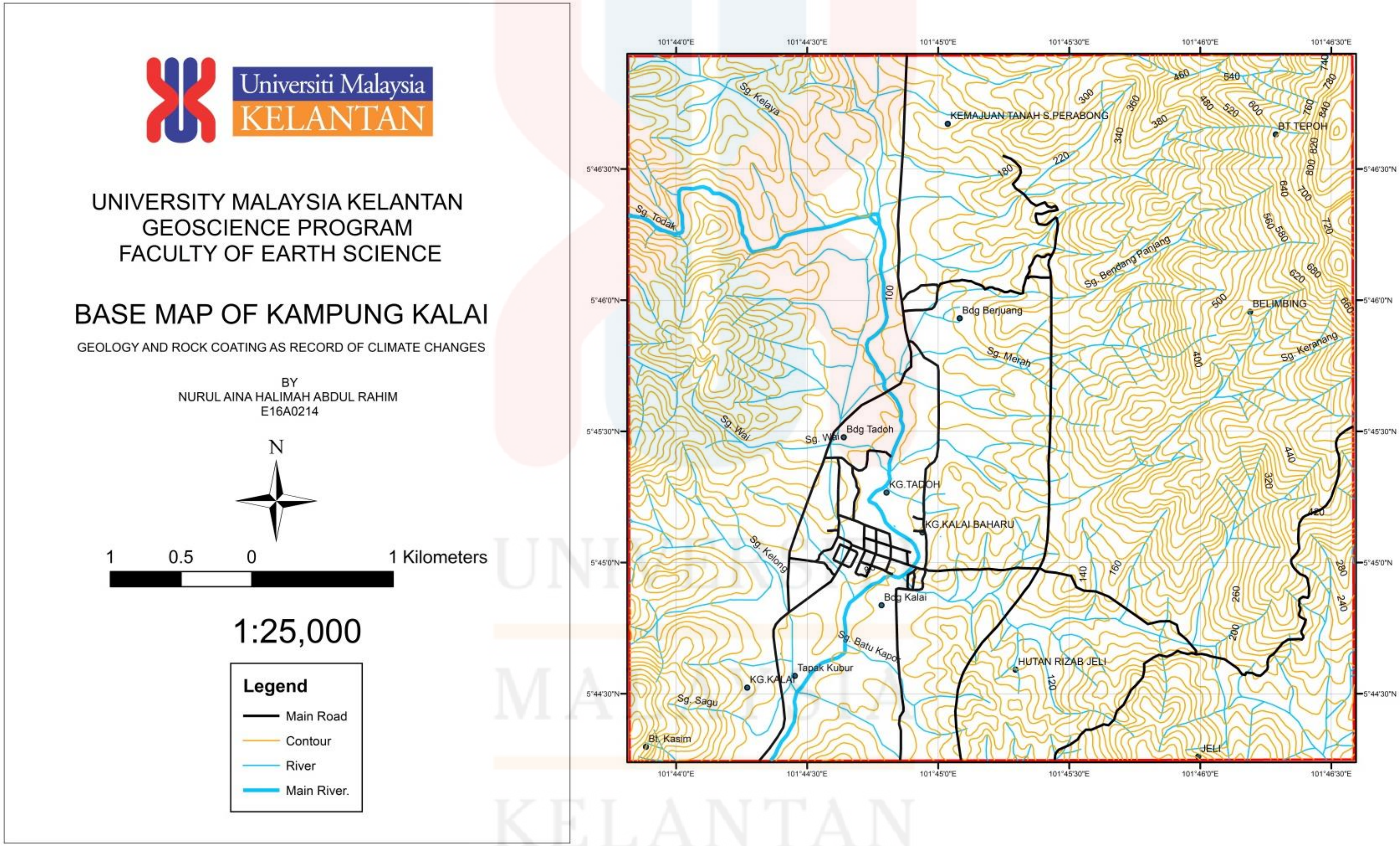


Figure 1.3: Base map of Kampung Kalai, Jeli.

1.4.2 Demography

Until year 2018, the estimation population at Kelantan is about 1856.8(‘000) including all sex, ethnic group and age. The population in Malaysia basically consist of dominantly Bumiputera, Chinese, others ethnic and the lesser one is Indian (based on the data from department of statistic, Malaysia). Same as Kelantan, the population is mainly Bumiputera which Malay followed by Chinese, Indian and others. Also, from the data the most amount of population is between age 20-24 years old while the lowest amount of population at Jeli is between ages 70-85 years old.

Table 1.1: Estimation of population in Kelantan in 2018.

Kelantan Population ('000) : 1,856.8

Umur *Age*	Jumlah *Total*	Bumiputera	Chinese	India	Others	*Non-Malaysian Citizens*
			Total			
Total	1,856.80	1,730.40	55.8	4.9	11.5	54.2
0 – 4	195.9	189.6	2.6	0.2	1.1	2.4
5 – 9	187.4	180.9	3.3	0.3	1.4	1.5
10 – 14	174	167.3	3.7	0.5	1.4	1.1
15 – 19	190.6	181.4	4.2	0.5	1.1	3.4
20 – 24	203.8	190.4	5.1	0.4	0.8	7
25 – 29	173.7	157.6	4.9	0.6	0.9	9.6
30 – 34	114.5	101.9	4	0.6	0.8	7.3
35 – 39	99.6	88.7	3.8	0.3	0.7	6.1
40 – 44	86.4	77.8	2.9	0.3	0.5	4.9
45 – 49	86.1	78.5	3.2	0.2	0.5	3.6
50 – 54	85.2	77.9	3.8	0.3	0.5	2.7
55 – 59	79	72.6	3.8	0.3	0.5	1.9
60 – 64	62.4	57.2	3.5	0.2	0.4	1.1
65 – 69	47.4	43.7	2.7	0.1	0.3	0.6
70 – 74	32.7	30.1	1.9	0.1	0.2	0.4
75 – 79	19.5	18	1.1	0.1	0.1	0.1
80 – 84	10.1	9.1	0.7	0	0.1	0.1
85+	8.4	7.7	0.5	0.1	0	0.2

Source: (Department of Statistics, Malaysia)

Notes 1. The added total may differ due to rounding.

1.4.3 Rainfall Distribution.

Jeli district has a tropical climate which is hot and humid throughout the year. There are no 4 seasons in Malaysia because it is located near the equator. Jeli has a significant amount of rainfall and the average rainfall distribution every year is about 256.2 mm of precipitation. The average annual temperature in Kampung Jeli is 26.7 ˚C but the highland tends to be colder than low land. From the Table 1.2 the most amount of rainfall in on month January since it is in Northeast Monsoon. The driest month which is getting the least amount of rainfall is in month October.

Table 1.2: Rain distribution in monthly in Kelantan 2017.

Laporan Purata Taburan Hujan Bulanan Mengikut Tahun 2017														
			Purata Taburan Hujan (mm)											
ID Stesen	Nama Stesen	Jajahan	Januari	Februari	Mac	April	Mei	Jun	Julai	Ogos	September	Oktober	November	Disember
4726001	Gunung Gagau	Gua Musang	31.7	10.8	6.6	7.8	18.8	13.4	10.9	16.8	8.8	8.2	18.8	24.0
4614002	Lojing	Gua Musang	17.0	11.4	9.1	7.6	11.9	3.9	1.9	7.3	10.5	7.2	10.3	11.2
4819027	Gua Musang	Gua Musang	12.1	2.9	2.5	2.2	13.9	7.2	4.9	11.0	7.6	13	11.47	9.5
4923001	Kg. Aring	Gua Musang	23.1	6.0	1.8	2.6	14.5	8.8	5.8	6.6	7.2	6.9	13.3	7.3
5320038	Dabong	Kuala Krai	20.4	3.8	4.1	4.6	6.2	6.0	4.8	6.6	10.1	12.8	16.4	7.4
5322044	Kg. Lakloh	Kuala Krai	21.4	3.7	3.8	2.2	7.1	4.2	6.9	10.5	14.3	7.2	15.8	6.1
5522047	SM. Teknik Kuala Krai	Kuala Krai	26.9	3.1	1.4	6	7.5	8.2	7.1	10.2	6.7	6.1	21.1	9.3
5722057	JPS Machang	Machang	40.8	5.3	3.4	4.3	10	6.8	4.4	10.9	6.5	3.8	37.4	12.3
5820005	Pertanian Batang Merbau	Tanah Merah	34.2	6.9	3.4	7.3	12.9	7.0	14.1	8.7	9.2	7.4	35.9	11.9
6122064	Wisma JPS	Kota Bharu	22.5	2.1	2.5	4.6	3.6	3.8	9.9	3.8	4.5	5.6	30.9	12.7
6120014	Kuala Jambu	Tumpat	41.3	3.1	4.4	6.8	4.3	5.8	5.7	12.5	6.5	8.2	30.3	10.4
5718033	Kg. Jeli	Jeli	32.7	7.5	6.8	7.2	6.3	6.6	6.6	8.1	12.8	5.7	25.5	9.2
5923081	Bkt Gedombak	Pasir Puteh	42.1	4.2	5.1	4.9	10	9	4.9	13.3	5.3	6.9	35.9	13.2
6019004	Rantau Panjang	Pasir Mas	14.6	1.1	2.4	2.8	12.2	6.9	10.7	14.7	5.7	7.3	31.3	13
6024074	Bachok	Bachok	21.3	3.4	8	8.8	7.6	4	6.7	5.81	7.6	7.9	27.9	12.2

Source:(http://www.data.gov.my/data/ms_MY/dataset/5ed59533f1f14efeb8ed0f9612838fb8/resource/402ae480-a98a-4314-9d0e-943a379cd10f/download/taburan-hujan2017.xlsx)(climate-data.org)

1.4.4 Land Use

Kampung Kalai has small town that still developing as the human population is increasing. The land use at Kampung Kalai was classified into mining site, building sector in small town, vegetation and plantations area, residential area, farm, and forest. Agriculture and plantation covers lots from the study area in estimate about 70% of the area. There are many roads to access Kampung Kalai as it is used by the residents and unpaved road used for agriculture. Also, there are lots of ex-mining site that can be found in Kg. Kalai, Jeli as it is well known as gold mining site in many years before. There are many manmade lakes from late mining activities as shown in Figure 1.4.

Figure 1.4: Manmade lake cause by late mining activities.

Oil palm plantation and rubber plantation are the dominant types of plantation and other than that is the orchard that full with the local fruit such as Rambutan, Durian and many more. The villagers also used the area as the farming area for raising many animals such as chicken, goats, and cows. 20% of the land used is covered by small town which comprised many culture such as school, houses, clinic, mosques and more. 5% of the study area is covered by the reserved forest.

1.4.5 Social Economic

The popular economic sectors at Kampung Kalai are mining and plantation sector since there are mining site, tourism and many plantation that found there. The examples of plantation in Kampung Kalai are oil palm and rubber plantation covers many part of the study area. The job population at Kampung Kalai, Jeli are entrepreneurs, soldier, rubber tappers, police, farmers, and teachers.

1.4.6 Road Connection/Accessibility

The roads at Kampung Kalai are located mostly at the centre and west of the study area because there is small town also because of the mining and plantation activity. Other than that, at the west of the study area the topography is low land while at the east of the study area is high land with high elevation and some covers by the Jeli reserved forest. Basically there are few main roads that cross at the east of the box of the study area so the area is accessible to go. The road is less busy at weekday or weekend because of the less population there. There is also some paved road that used by the heavy vehicles that transport the materials from the mining site and vegetation. But the entire roads can be accessed by using motorcycles, cars and heavy vehicles. Kampung Kalai can be assessed from the north and south of the study area since there are main roads there. There are roads at north and south part of the study area to make is accessible.

1.5. Scope of Study

The scope of study of this research is focussed on the geology part which included geomorphology, lithology, stratigraphy and structural geology of Kampung Kalai, Jeli. Other than that, for the specification of this research, it focussed on petrography and geochemical analysis to study about the factors that contribute rock coatings as a record of climate changes.

The specific study area of Kampung Kalai is located at district of Jeli, Kelantan with coordinate of 05° 46' 54.14'' N and 05° 44'5.07" N latitude and 101° 43' 42.76'' E and 101° 46' 30.47" E longitude. The methods used are preliminary study, fieldwork, data analysis, data interpretation (tabulation, graph) and followed by writing and submission. For the laboratory work, the geochemical instruments that used are XRF, and SEM. The soft wares that used were ArcGIS 10.2, GeoRose, and Google Earth Pro. These soft wares used by using laptop, networks, printers, plotters and digitizers. Besides, the data from the other department needed such as data from Jabatan Mineral Geosains (JMG), department of statistical and department of meteorology as the evidence for the statements.

1.6. Significant of Study

The significance study of this research is it can provide information and knowledge regarding rock coatings or geochemical sediment as a record of climate changes. The knowledge also include the recent development of the area with the geomorphology, lithology, structural geology which can be useful information for the others especially for the researcher or educational institutes and maybe geological entrepreneur. For the geology, its helps in gaining more details information in geology part in which more focused on box of the study area. As a result the geological maps produced helps in future researchers.

Other than that, this study can give the information about the role of rock coatings in identifying the factors which contribute in the process of climate change. Rock coatings are important in geomorphology as it can stabilize landform surfaces through case hardening. From the composition of element oxides from the XRF analysis and the correlation with the images from SEM and petrographic analysis the types of rock coatings can identified. Some types of rock coatings, such as silica glaze, can slow the rate of chemical weathering (Gordon and Dorn, 2005). The data gained is important for the other geology based company to extract the rock coating element as a good material for the building construction. Also, it is good for the gaining new knowledge about rock coatings and to understand more about the environmental changes as the earth is getting older day by day.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review is basically all about reviewing the journal, articles, from the previous study to help in understanding the thesis which including substantive findings both in methodological and theoretical. Literature review gives many contributions to this thesis in geological review, rock coatings and also on geochemical analysis, petrography analysis from journals in past few years.

2.2 Geological Setting

Peninsular Malaysia consists of three major belt which are western belt, eastern belt and central belt (Ghani, 2000). During early carboniferous and late Triassic, there was a collision of Indochina and Sibumasu terranes which resulting the formation of Bentong-Raub suture zone and the emplacement of the granitoids in the western, central and eastern belts in the Malay Peninsula. After that, in the late carboniferous, the Sibumasu terrane drifted away from the Gondwana across the Paleo-tethys Ocean and resulted in the production of accretionary wedges which is sedimentary materials above the subduction zone (Metcalfe, 2011). Jeli district located at the central belt which is located at the east of the Bentong-Raub Suture zone and it is comprised of Permo-Triassic metamorphic rocks and deep to shallow marine sedimentary rocks. (Kobayashi and Tamura, 1968; Makoundi, 2004). Kampung Kalai is located at the near at the International border between Malaysia and Thailand. Kampung Kalai is a small town which located at district of Jeli Kelantan. Jeli district is granted with attractive geological landform with precious earth material and unique geological phenomena such as caves, rivers, waterfalls, gold deposits and hills.

Jeli district lithology range mostly granitic rock with several enclaves of meta-sedimentary rocks and sedimentary rock which are the backbone of Peninsular Malaysia. (Nazaruddin, 2015). The Malaysia and Thai Working Groups (2006) have stated that there are North-South trending quartz dykes and some igneous stocks intruded in the country of rocks. The contact metamorphism is arising from the igneous intrusion and its association with the late stage of mineralisation that can be observed in the country of rock which occurred close to the Malaysian-Thai border especially in Kampung Kalai area. Also, it was stated that there are various mineral resources that have been discovered and exploited in last century which this have the relation with the granite intrusion and hydrothermal activities. Chu et al. (1982) carried out a geochemical sampling in the north of the study area and showed that the area has mineral potential for gold and lead. Gold is the most well-known mineral resources other than, based metal, kaolin, barite that been produced at the Thai-Kalai area for many years behind.

Based on the department of minerals and geoscience Malaysia, 2003, Jeli district is generally made up of three formation Triassic sedimentary rocks (Gunung Rabong Formation) which consist of shale, siltstone, and sandstone, Permian sedimentary rocks (Gua Musang formation) which consist of slate, limestone, phyllite, sandstone and limestone, and granitic rock (acid intrusive).

2.2.1 Stratigraphy Unit

The stratigraphy unit that present in Kampung Kalai are the Kemahang Granite, Telong Formation, Mangga formation and Tiang schist. The Malaysia orogeny is presumed by the subduction of a continental crustal plate and an oceanic crustal plate which is accompanied by the granite emplacements. The igneous rocks are widely distributed in the Batu Melintang-Sungai Kolok area. The volcanic rocks occur as flow and pyroclastic in the sedimentary rock, where the igneous rock occurs as batholiths and small stocks. Based on the Hustchison (1977), Malaysia was divided the granites into three belts based on the lithology and the petro chemistry of the granite which are Main Range Belt, Central Belt and Eastern Belt. Jeli district was occupies the eastern granite province to the east of the Bentong-Raub Suture. The exposed granite group at Jeli are Boundary Range Granite, Kemahang Granite, Lawar granite and Kenerong Granite. The irregular granite which forms the mountainous range and west of Jeli town is Kemahang granite where it covers Bukit Jeli, Bukit Kemahang, Bukit Kusial and several smaller hills.

The granite body typically forms N-S trending mountain range starting from Narathiwat Province in the eastern coast of Thai peninsula and then its continues to the Jeli town in Malaysia side. The characteristics of the granite composition in Kemahang granite consist of predominantly grey, medium to coarse-grained megacrustic biotite-hornblende granite to granodiorite. Quartz veins and lenticles are very common at some localities. The granodiorite is showing a strongly foliated. Based on, MacDonald (1967), the age of Kemahang Granite is Triassic.

Other than that, the formation is Telong formation which age about Permian-Triassic. Telong formation consists of mainly of argillite, low-grade metasedimentary rock and metavolcanic rocks and can be divided into four facies which are argillaceous, arenaceous, calcareous, and volcanic facies. Next, the formation is Mangga formation which consists of 4 main lithologies. Based on Jamaluddin (2018), Mangga Formation consists of low-grade metamorphic rock sequences of arenaceous, argillaceous, pyroclastic, hornfels, marble and schistose rocks in the eastern part of Belum area age in Carboniferous-Permian age. The lithology of Mangga Formation which is well exposed in the upper reaches of Sungai Machang extending southwards to Kampung Gunung in the Batu Melintang area which represented by low grade metamorphic sequence that can be divided by 4 facies which are arenaceous, pyroclastic, argillaceous, and calcareous facies.

Tiang schist is considered as the oldest rock unit which is in Silurian-Devonian period. The term of Tiang schist was introduced by Mohammad Hussein Jamaluddin (in manuscript) which named after the Sungai Tiang where good outcrops are observed. This formation is highly faulted and folded, forming north-south mountainous belt. The lithology comprised of quartz-mica schist and quartz garnet schist consisting quartz mica with chlorite, calcite, and pyrite as accessory mineral. The presence of quartz-mica-chiastolite schist is indicates that it might be the result of both contact and regional metamorphism. This rock unit is uncomformably overlain by Mangga formation. Figure 2.1 shows the stratigraphy column of Batu Melintang-Sungai Kolok area.

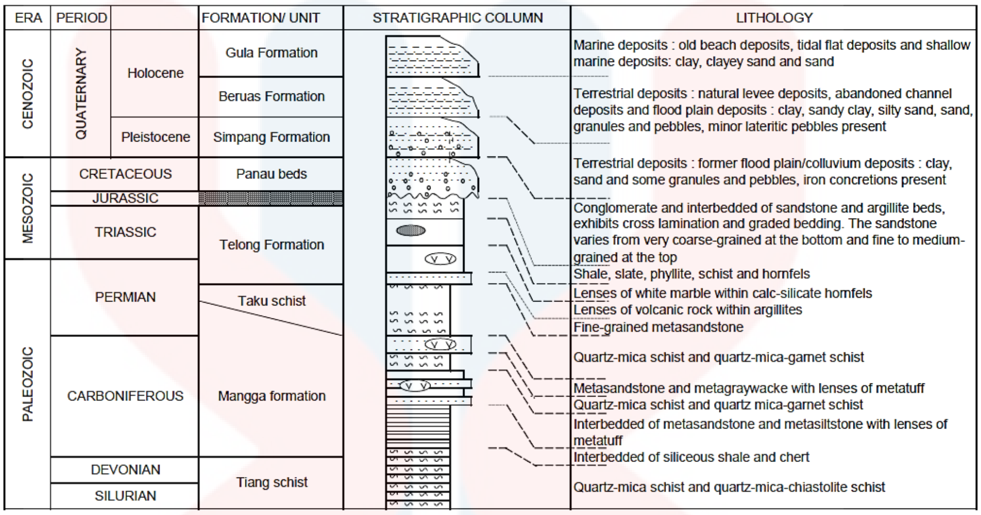


Figure 2.1: Stratigraphic column of Batu Melintang-Sungai Kolok Transect area in Malaysia.

2.2.2 Structural Geology

For structural geology, most of the faults are normal, near vertical fractures in which only minor displacement occurred. The regional structures are aligned in the north-south direction with local variations to the northwest-southeast and northeast-southwest. Faulting is widespread and present in all the rock units. Most of the faults are normal and near vertical fractures in which minor displacement occur but also contain several strike-slip fault. Kampung Kalai fault trends north-south direction along the upper part of Sungai Tadoh which is related with the gold mineralisation zone. The folding and the faulting might take place probably because during Triassic to Cretaceous due to the granite intrusion.

Kalai area is underlain by metasedimentary rocks which are close to the granite intrusion and minor intrusion especially quartz vein and micro diorite can be observed in the study area (The Malaysia and Thai Working Groups, 2006). Because of the peninsular Malaysia formed because of the result of collision between Sibumasu and Indochina, the collision cause major event during late Triassic that has resulted in rock deformation. Pre-orogeny sedimentary successions are generally folded into a series of synclines and anticlines. Folding is characterise by tight, asymmetric and open folds which cause repeated and overturn sequence in the older sedimentary rock and the bedding panes dip towards the east with various dip angles.

2.2.3 Geomorphology

Geomorphology is the characteristic of the earth's landscape and their process. The geomorphology of the state of Kelantan can be divided by four types of landscapes which are mountainous, hilly, plain area and coastal (Tanot et al., 2001). All of these landscapes are exist in Jeli except for coastal landscape because Jeli is the area of orogeny process. Mountainous landscapes forms in the west and north of the district. Hilly areas in Jeli are distributed in and elongated hills. The weathering of the outcrop also observed because weathering can refers to the various processes of physical disintegration and chemical decomposition that occur when rocks at the earth's surface are subjected to physical, chemical and biological processes. The agent of the weathering can be from wind, water, climate and others. These processes produce soil, unconsolidated rock detritus and other component that cause by the alteration of the rock. The fossil at the Kampung Kalai at this time is still cannot be found. There are few types of drainage pattern as shown in Table 2.1.

Table 2.1: Types of drainage pattern.

Drainage pattern	Explanation
Parallel 	Parallel drainage is regularly spaced and more or less parallel main streams with tributaries joining at acute angles. It develops where the strata are uniformly resistant and the regional slope is marked. Usually associated with strong structural control that exerted by a series of closely spaced faults, monoclines or isoclines.
Radial 	Radial pattern is stream flowing outwards in all directions from a central elevated tract at high point. It usually found on topographic domes, such as volcanic cones and other sorts of isolated conical hills and common at geological features which are domes and laccoliths.
Dendritic 	The dendritic pattern means that the river channel follows the slope of the terrain in shape of branches and the trunk of the tree with irregular branching of tributaries in many directions and at almost any angle. Usually occur on horizontal and uniformly resistant strata and unconsolidated sediments and on homogenous igneous rocks. Dendritic drainage associated with the very steep slopes and can erode easily in all directions.

2.3 Rock Coatings and Climate Changes

Rock coatings are geochemical sediment which deposited on the rock surface after a period of time. Coatings resulted from the wide variety of reactions and processes that occur at the interface between hydrosphere, and atmosphere, lithosphere and biosphere. Also, coatings are mineralogically, biochemically, and isotopically complex and have the ability to record changes in their immediate environment (Dorn, 2017). Components of rock coatings is vary from one locality to another locality which bottom coating are formed as the contact minerals are brought into solution and deposited onto the host rock. The sediment that deposited onto the rock for example clay cemented by hardened silica. The substance that usually found on rock surface is pollen, organic compound, and soil components. Major sources for accumulated elements may be rainfall or dust (Dragovich, 1993). The physical properties of rock varnish are difficult to characterize because the coating is so thin and discontinuous but the texture of the rock coating surface is vary of deposition material (Bierman, and Kuehner, 1992). There 14 different types of coatings which are carbonate skin, case hardening, dust film, heavy metal skins, iron films, lithobiontic coatings, nitrate crust, oxalate crust, phosphate skin, pigment, rock varnish, salt crust, silica glaze and sulphate crust as shown in Table 2.2.

Table 2.2: Types of rock coatings. (Source: Dorn, 1998).

COATING	DESCRIPTION	RELATED TERMS
Carbonate skin	Composed primarily of carbonate, usually CaCo3, but sometimes MgCO3	concrete, travertine
Case hardening	Addition of cementing agent to rock matrix material; the agent may be manganese, sulphate, carbonate, silica, iron, oxalate, organisms or anthropogenic.	Sometimes called a particular rock coating
Dust film	Light powder of clay and silt sized particles attached to rough surfaces and in rock fractures.	Clay skins, clay films, soiling
Heavy metal skins	Coatings of iron, manganese, copper, zinc, nickel, mercury, lead and other heavy metals on rock in natural and human-altered settings.	Also described by chemical composition
Iron film	Composed primarily of iron oxides or oxyhydroxides	Ferric oxide, iron staining
Lithobiontic coatings	Organisms forming rock coatings for example lichens, moss, fungi, cyanobacteria, algae.	Organic mat, biofilms, biotic

		crust.
Nitrate Crust	Potassium and calcium nitrate coatings on rocks, often in caves and rock shelters in limestone areas.	Saltpetre, nitre, icing
Oxalate crust	Mostly calcium oxalate and silica with variable concentrations of magnesium, aluminium, potassium, phosphorus, sulphur, barium and manganese. Often found forming near or with lichens.	Oxalate patina, lichen-produced crust,
Phosphate skin	Various phosphate minerals (e.g.; iron phosphate or apatite) sometimes mixed with clays and sometimes manganese.	Organophosphate films, epileptic biofilm
Pigment	Human-manufactured material placed on rock surfaces by people	Pictograph, paint, graffiti
Rock varnish	Clay minerals, Mn-Fe oxides, and minor and trace elements; colour ranges from orange to black in colour produced by variables concentrations of different manganese and iron oxides.	Desert varnish, patina, Wustenlack.
Salt crust	Chloride precipitates formed on rock surfaces.	Halite crust, efflorescence
Silica glaze	Usually clear white to orange shiny luster but can be darker in appearance, composed primarily of amorphous silica and aluminium but often with iron.	Desert glaze, turtle-skin patina, siliceous crust, silica-alumina coating, silica skins
Sulphate Crust	Sulphates (eg: barite, gypsum) on rocks not gypsum crust that are sedimentary deposits.	Sulphate skin

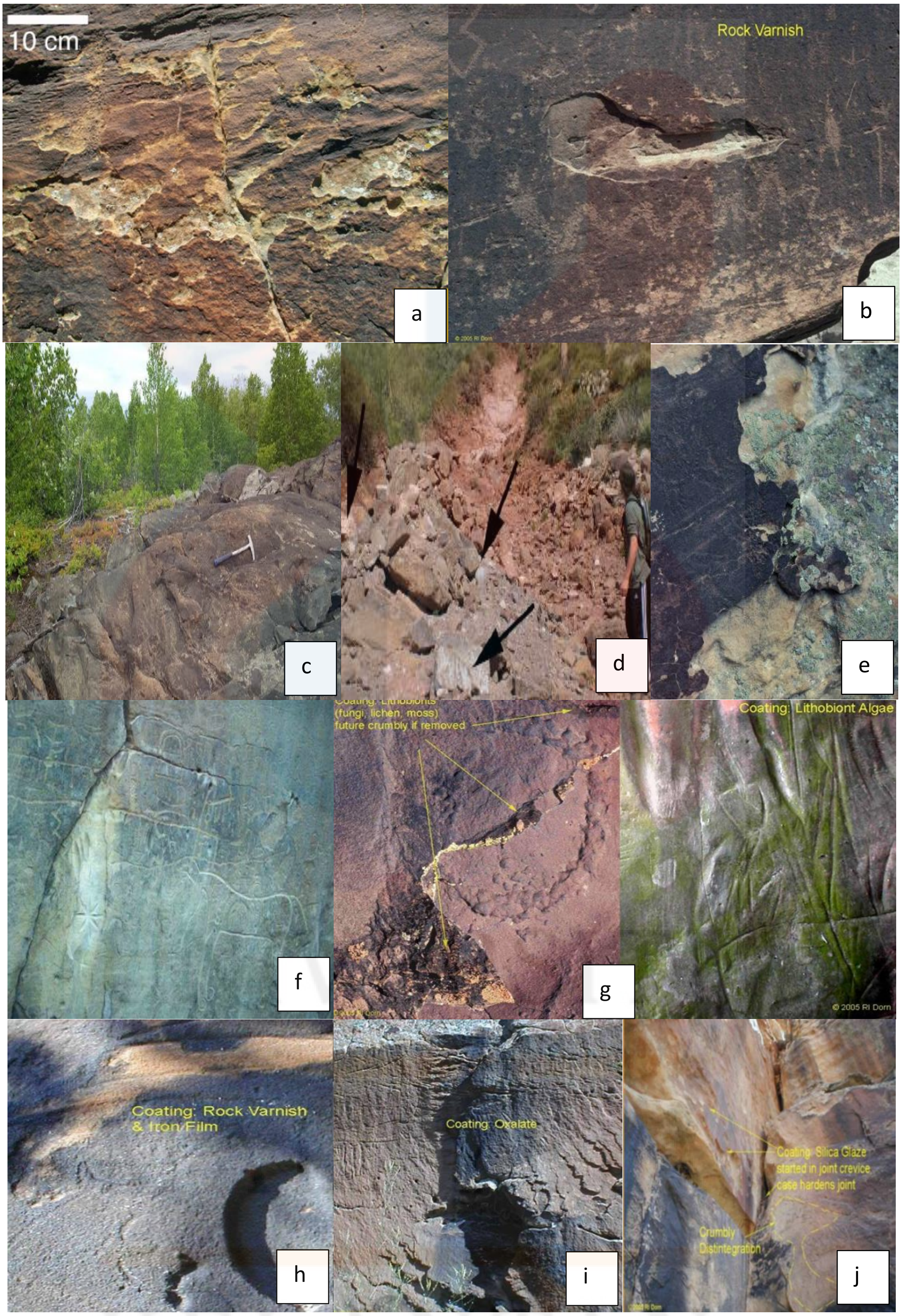


Figure 2.2: Types of coatings. (a)Case hardening (Dorn, 2017) (b) Rock Varnish (Dorn, 2017), (c) Rock coating on igneous rock (Leverington, 2018). (d) Carbonate Case (e) Dark coloured of heavy metal case. (f) Dust Film (g) Lichens coating (h) Rock Varnish and Iron Film. (I) Oxalate crust (j) Silica glaze (Dorn, 2005).

Fungi and lichen is a microorganism that can be found anywhere which are important geoactive agents in the change of geochemical in the biosphere aspect. Fungi are capable to lots of transformations of metals and minerals that can alter the surface structure and chemistry of the rock and their constituent minerals. Other than that, rock coating has the potential give information to preserve evidence of past life in the form of mineralized filaments and other morphological characteristics. Also, it has unique habitat for microbes with distinct communities and later has a range of metabolic capabilities (Marnocha, & Dixon, 2013). It appears that the rate of varnish formation varies with time and location, which probably as a function of climate (Taylor-George, 1983).

Although there are lots of nutrients may be available on surface of the rock but the fungi can grow in the presence of limited nutrients. Colonization and metabolic activity can be affected by the rock porosity and geochemical heterogeneity. Besides, lichens are probably the most obvious fungal inhabitants of rock surfaces which intimately associated with elements that, besides O, account for over 99.9% of crustal rocks (i.e. Na, Mg, Fe, K, P, Ca, Al, Si, Ti, Mn). As a result of lichen bio weathering, many rock-forming minerals exhibit extensive surface alteration, bio deterioration and chemical transformation (Chen et al. 2000). Fungi also produce variety other metal oxalates when they interact with minerals that contain metals, including Ca, Zn, Pb, Cu, Co, Mg, Mn, Sr, and Ni (Gadd, 2017). Most fungi that reduce Mn (IV) oxides do so through the product ion of metabolites that can act as reductants, such as oxalate, which results in the formation of lindbergite (Mn oxalate dehydrate) (Wei et al. 2012). Many lichens and free-living fungi play a role in silicate dissolution which release important nutrients such as P, K and Fe and contribute to the genesis of clay minerals and to soil and sediment formation.

The occurrence of silica-rich matrices in the black coatings was the formation of the amorphous silica gel-type layers. The gel-type properties of the layer allowed the trapping and encapsulation of particulate matter and aerosols while dissolution of the underlying silicate minerals continued. These layers formed through the non-stoichiometric dissolution of the silicate minerals under acidic condition result of the emission of sulphuric acid and precipitation of acid rain. Continuous dissolution of the underlying rock and trapping of particulate matter combined with dissolution of particulate matter and crystallization of sulphate minerals resulted in the formation of micrometre-thick metalloid and silica-rich regions (Caplette et al. 2015).

Jamaluddin, (2018) stated that if the rock coatings have SiO_2 then concentration of calcium is due to the leaching of calcium by the solution and the subsequent re-precipitation. Change of environments indicated by the increase of SiO_2 content with the influx of terrigenous material. The presence of Fe_2O_3 and high Ca shows that the reducing environment and the deposition in closed basin. The presence of little amount of phosphate and manganese in the limestone indicates that the climate during the deposition of the carbonate sediments is warm and humid. The elements that derived from the rocks that contain elements of Fe or iron mixed and react with the elements to the oxidation process by Cl and O on the conditions of the tropical-subtropical climates.

2.4 Geochemical and Petrographic Analysis

Field mapping, sampling, and laboratory by using geochemical instrument X-Ray Fluorescence (XRF), and scanning electron microscope (SEM) are the methods for this research. SEM used for imaging and chemical analysis of the bulk material. Scanning electron microscope (SEM) the quantitative and qualitative chemical analysis can be carried out such as grain sizes, distribution of phases, surface topography, cracks or pores. (Ingemarsson and Halvarsson,2011)

The SEM method used to determine the topography and morphology of the surface of rock coating. Also, it is used to determine the thickness and the composition of layers and coatings. The method is accurate, not destructive, and fast and requires minimum of sample preparation. The use of SEM is analysis the morphology of the minerals. The presence of the high Ca content in the rock asphalt indicates that the increased of pores size of the rock which show that the rock has resistive properties. (Jamaluddin, 2018).

The other method in this research is (X-Ray Fluorescence) XRF. This method is used because the non-destructive methods and have the ability to perform simultaneous multi-elemental determination. XRF has the advantage of being a rapid and inexpensive method with a simple sample preparation. Furthermore, XRF spectrometry is an elemental technique with broad application in science and industry. XRF is based on the principle that individual atoms, when excited by an external energy source, emit X-ray photons of a characteristics energy or wavelength. The identification of elements by X-ray methods is possible due to the characteristic radiation emitted from the inner electronic shells of the atoms under certain conditions.

Petrographic analysis is the one of the method used to where it is useful in analysed the chemical and physical features of a particular rock sample. The optical microscope was used in this method to determine their mineralogy in the rock. The petrography of igneous rock in Jeli usually consists of quartz, plagioclase, K-feldspar, biotite, zircon, apatite, sphene, and opaque mineral.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Introduction

This chapter is about materials, procedures and methodology on handling in data collection for the study. The methodology involved the preliminary study, data collection, data interpretation and analysis and how to conduct the study.

3.2 Materials

Materials are very important in the data collection as its makes the work easier whether in the field mapping, laboratory work or in data analysis. Main methods are preliminary study, field work, sample preparation, data analysis and interpreting and reporting.

The materials that used at field mapping are as follow:

- Global Positioning system (GPS) for navigation. It is a system that tells the accurate latitude, longitude, altitude, velocity, time and its help us to decide where to go while mapping to avoid lost. GPS also function in marking the checkpoint of measured, sampled and observed the outcrop found at the study area.
- Tip point geological hammer for sampling. Tip point hammer gave high impact of forces to the rock to make the sampling process easier. This is

important in order to get a fresh surface of the rock to determine the nature colour, composition, mineralogy more accurately.

- Hand lens used for petrology observation. A small size of magnifying glass used to take a closer look of the rock properties. It helps to identify and to make assumption on minerals, textures, minor structures and fossils in rocks.
- Hydrochloric acid (HCL) for testing the presence of calcite in rock. HCl use to perform quick test at the field while mapping to distinguish the most common carbonate rocks, dolomite and limestone, marble. It will result in the intensity of fizzing sound on the surface of the rocks.
- Brunton compass for strike/dip, orientation, traversing, slope measurement. Brunton is used to measure the strike and dip in order to make geological map with full of geological data.
- Sample bags for sample storage. The sample bags used and wrote the details of the sample such as time, name of the area of sampling, coordinate, early interpretation and so on.
- Measuring tape used for dimension of outcrop and structure measurements. It is used in measuring the dimension of the outcrop, measure the thickness of the bedding, length of the joint and so on.
- Google search/Google earth pro for instant information.
- Camera for used for record geomorphology, outcrops, structures and many more for as evidence in report.
- Optical microscope is an instrument that uses combination of lenses and light to magnify the image. It is important in petrography analysis to identify and certify the rocks based on the mineralogy and other physical properties of rock.

- Scanning Electron Microscope JSM-IT100 that used for analysing the morphology, topography of the rock sample which result in high-resolution images of shapes of object.

Figure 3.1: Scanning Electron Microscope JSM-IT100

- X-Ray Fluorescence S2 Ranger (XRF) non-destructive analytical technique used in determining the materials element and oxide composition. The identification of elements and oxide is possible due to the characteristics radiation emitted from the inner electronic shells of the atoms under certain conditions.

Figure 3.2: X-Ray Fluorescence (XRF) S2 Ranger.

3.3 Methodology

Methodology is the systematic plan with theoretical analysis of the methods that applied in the field of study. It is important to plan what method and the procedure to get more accurate data. The methodology started with the preliminary study followed by data collection, data interpreting and analysis and reporting.

3.3.1 Preliminary Study

This is the first method before starts the research study. Preliminary study is a process for studying the previous work, books, articles and many more to get extract the beneficial information that can be useful for further step in this study. This is very important as the information that collected can be a guidance to make decisions. Also, it helps to understands more and get the ideas about the scope of study regarding the research topic. First data collection is important as it can influence the result of the study. Also, producing base map is crucial by using ArcGIS 10.2 before start traversing and mapping at the research area.

3.3.2 Data Collection

Data collection is done after the preliminary study which involved field mapping, observation; measurement and sampling for further research and get the raw data before process in the next step.

a) Field Mapping

After getting information from the preliminary study, field mapping is done at the study area. The field mapping started with traversing by using base map that have been digitize using ArcGIS 10.2 and GPS to mark the coordinate of the outcrop.

Then, the observation, description, measurements took place at the outcrop. This is very crucial as the rock itself contain lots of information. The measurements included with the measurements of strike, dip, trends, plunge and joint reading, by using GPS, measuring tape and board.

b) Sampling

The crucial part of the field mapping is the sampling. A few checkpoints were marked and do some sampling as the sample helps in data analysis in petrographic analysis and geochemical analysis. There were three types of sample needed for this study which is soil sampling for XRF analysis, rock sample for petrographic analysis and 2 mm fragmented rock coating for SEM analysis. The samplings done by using the tip point hammer to break down the outcrop into chips or grab. The factors used for taking rock samples for petrographic analysis are at the river because usually the outcrop is very fresh, visible and sampling focussed at different lithology in study area. For the rock coating sample, the distribution pattern of the most rock coatings is irregular and variable and not all the rock surfaces are available from sampling. Thus the sampling availability and factors are limited. Sampling for rock coating are done on visible rock surface away from few centimetre from joint to avoid the contamination of the elements that percolate through joints. About 8 coating samples were taken from rock surfaces that contain variable types of coating. The other type of sample which is soil was taken during mapping. The amount of soil for sampling is between 100 g to 200 g. The sample was focussed at the near the outcrop to relate or correlate the element with rock coatings. 14 soil samples was taken then prepared for XRF analysis.

c) Sample Preparation

The laboratory work started in petrography with the preparation of the thin section of the rock samples from field mapping. Thin section is important as it show the information about lithology, properties, texture, fractures, that can helps in identifying the types of rock. This step is important as it can identify the minerals in the rock and their distribution.

The sample has to be thin enough for light to pass through in a light microscope. The thin section is done by cutting the hand specimen into smaller pieces by using geological hammer. Then, the chip sample is mounted on a slide with a diamond saw. Then, the slab is labelled on one side and the other side is lapped flat and smooth first on a cast iron lap with carborundum then finished on a glass plate with grit carborundum. After that, the slide is dried on a hot plate then a glass slide is glued to the lapped face of the slab. Then, the slab is cut off close to the slide by using saw. The thickness is the reduced more by using grinder. After, required the need thickness the slide is polished and lapping the section by using glass plate and carborundum. Then, the final thin section was ready to analyse in optical microscope.

Geochemical analysis (experimental) method that used in this research is SEM and XRF. The sample used involved few procedures which are grinding, or crushed to make the sample smaller to use in the SEM instrument. For SEM analysis the samples then dried and prepared into fragment to required size which is 2 mm and observed using scanning electron microscopy (SEM) by secondary and backscattered electrons and X-ray maps in a JEOL JSM 6400 scanning electron microscope at laboratory in University Malaysia Kelantan Kampus Jeli.

The process of SEM analysis was started with put the sample into the SEM instrument and wait for few minutes for the analysed. Few points are mapped on the sample to get few different magnified pictures. The sample for SEM analysis is in solid state to get the morphology and topography of the sample. The result of SEM analysis is produced in magnified pictures in 100X, 200X and 300X then, the best images from these magnification was chosen to analysed.

Figure 3.3: SEM analysis in producing magnified images.

For the sample preparation for soil for XRF analysis, it was taken to dry by using oven in Thin Section Laboratory in UMK. The sample was put on the aluminium paper then left dried about 1 day in 60˚C. After the sample was dried, the sieving is done to remove the organic matter and then it is crushed by using grinder machine to become powder. Then powdered then pressed to make palette because XRF used powder to run the samples. Then about 1.5 g of the sample were taken into palette and analysed in a wavelength dispersive XRF S2 Ranger machine.

Figure 3.4: Soil sample is prepared to dry using oven.

Figure 3.5: Sieving at 120 micron to remove the organic matter.

Figure 3.6: The soil sample prepared to grind and make palette to make powder for XRF analysis.

3.3.3 Data Analysis and Interpretation

After the laboratory work and analysis the result processed by using software such as Rose diagram for joints and Stereo Nets for fold, faults, and fractures to support the assumption. GIS laboratory produce map using ArcGIS 10.2 – the raw data that collected from field mapping is filled in the geological map. For example, the types of rock and the structure geology, symbol of strike dip, fault and rock boundary and more are stated to produce the updated geological map. The geological map, landuse map, slope map, landform map, drainage pattern map, sampling map, lineament map is done by using ArcGIS 10.2.

The reading of joints processed by using Rose Diagram to know the direction of the forces came from. Then, the other data such as strike and dip or known as plunge and trends is processed by using Stereo Nets. The final result from geochemical analysis and petrographic analysis in form of image, graph, and tabulation were discussed to achieve the objectives of the research.

The data from the SEM, XRF and petrographic analysis were collected and discussed to make the relationship between them to achieve the objectives of the study. The last step of this research is comprised of discussion, conclusion and final report for submission and followed by evaluation from examiners and supervisor.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

The chapter explained about the geological of the study area in term of geomorphology, petrography analysis, stratigraphy, structural geology and history geology. Geology is the study of the structure and function of the earth and its processes. These aspects of geological part were observed, measured and analysed by geological mapping. This is important for a geologist to understand the processes that happened long time ago that makes the earth features now. The data collected are such lithological data, structural data, geomorphology data, and the hand specimen. History geology concept helps geologist to interpret the earth where the present is the key to the past.

4.1.1 Road Connection (Accessibility)

There are many roads in small town in Kampung Kalai that makes the study area accessible to traverse. The area is connected with bituminous road and non-bituminous road in certain part of the area especially at the plantation area because the villagers are using the road every day to the plantation area. The traverse can be done by riding motorcycle or Hilux because there are lots of non-bituminous road that not suitable to drive car except at the small town of Kampung Kalai. From

Figure 4.1 the main entrance to the box from UMK is the main road called Timur-Barat Highway.

Figure 4.1: Main road that connected Kampung Kalai to the UMK.

Figure 4.2: Main bituminous road that used for villager in agriculture at the northern part of the study area.

Figure 4.3: Non-bituminous road that used by agriculture sector.

4.1.2 Landuse (Forestry and Vegetation)

Landuse is the section where the measuring of current conditions of what covers the land which included recreational, transport, agricultural, residential and commercial. Identification of the land cover were observed and analysed by Google map and make confirmation when traversing around the study area. It acts as guide and objectives for all activities that affect the local area either for government or private.

From the map in Figure 4.5, there are small town in the study area which called Kampung Kalai which consists of clinic, residential, school, and mosque. There are small population in Kampung Kalai where makes a small gap between each houses with one another. Moreover, about 70% of the study area was cover by the agriculture activities such as oil palm plantation, rubber plantation such as Figure 4.4 and also orchard. But the agriculture activities are one of the sources of economy to the villagers. Also, on the left side of the study area, there are small old mining site which produced and left lots of manmade lakes from mining activities. On the right side of the study area, there Jeli reserved forest which contains lots of unique flora and fauna that need to sustain for the further generation.

Figure 4.4: Common type of agriculture which is rubber plantation.

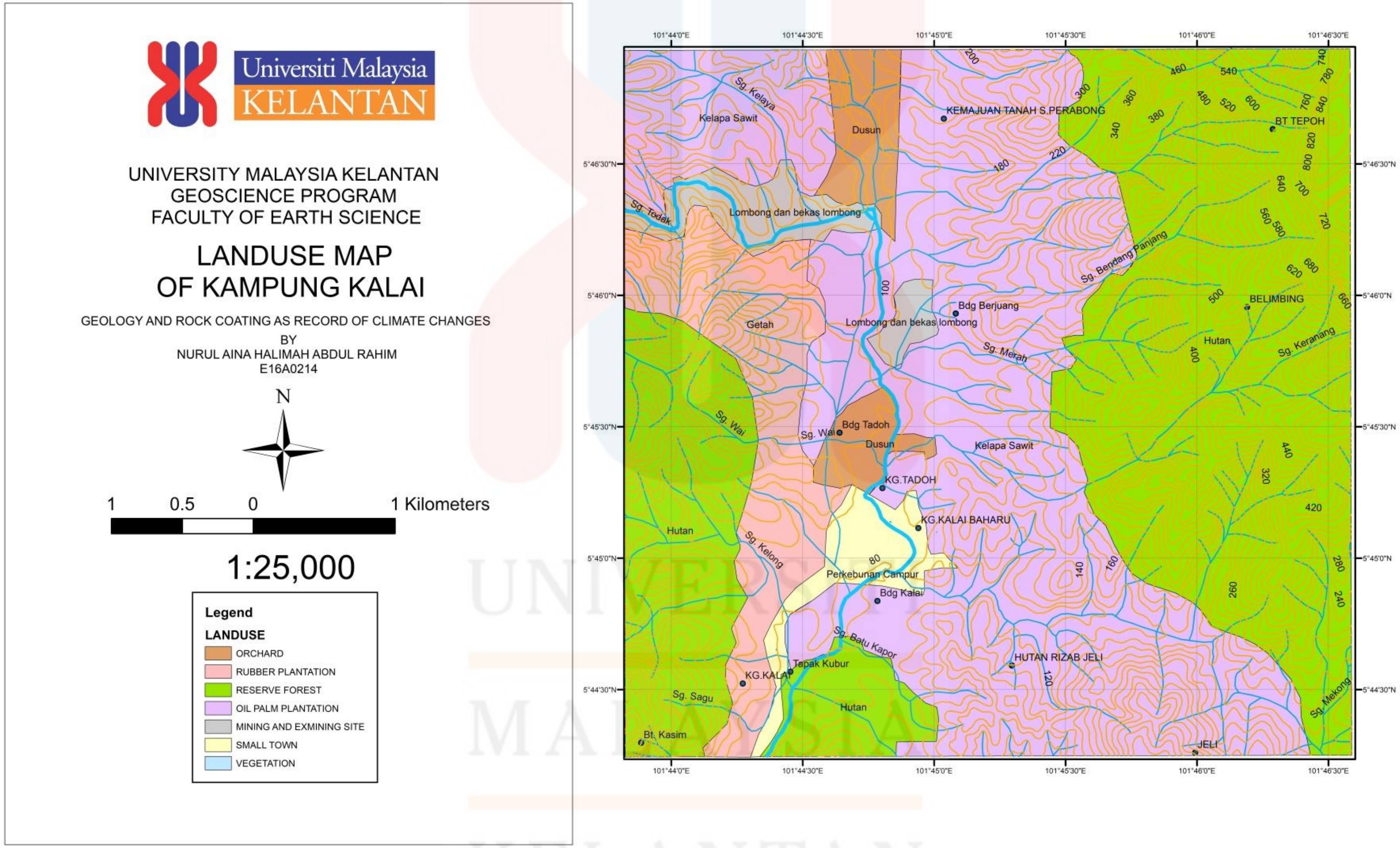


Figure 4.5: Landuse map of Kampung Kalai.

4.1.3 Traverse and Observation

Geological mapping has been conducted and 70% that comprised from 25 km^2 dimension of the study area was successfully traversed in Kampung Kalai when mapping. Another 30% of the study area was hard to access because of the steep high elevation, no road access and Jeli reserve forest. Most of the traverse was followed the pattern of the river because it is easier to find fresh outcrop at river. The traverse was done in many ways because there was a lot of unpaved road used by the farmer and the villagers. The main road at Kampung Kalai was useful to finish traverse the area. The geological data was collected during traversing and mapping. The traverse data is processed into traverse map as shown below, it basically shows all the tracks from day one until day last mapping with all the waypoints of sampling and observation points. Sampling is done to make further analysed and acted as evidences. Figure 4.6 shows traverse and observation map during mapping.

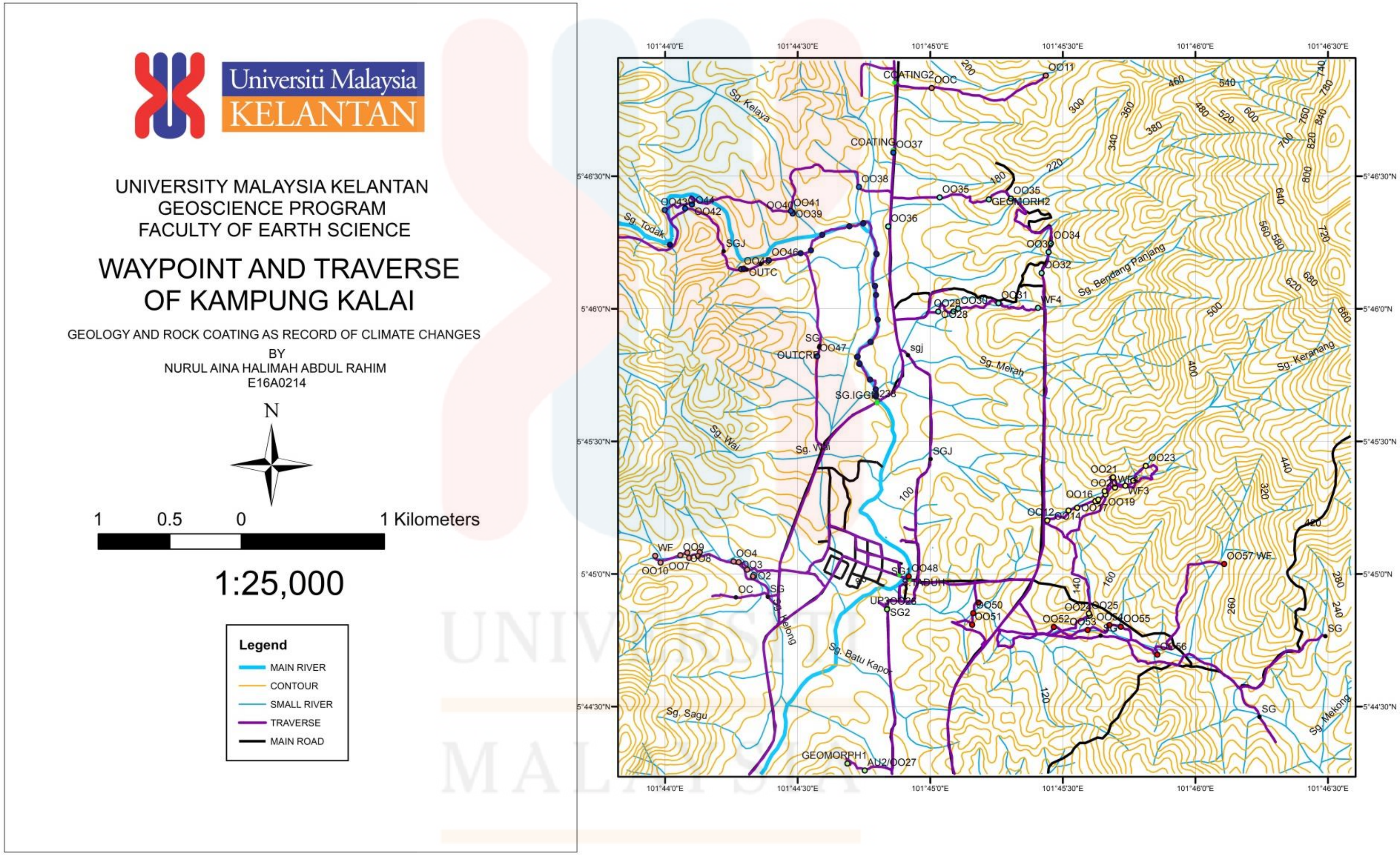


Figure 4.6: Traverse and waypoint map of Study area.

4.2 Geomorphology

Geomorphology is concerned about the description and the classification of the earth's topographic features. Other than that, geomorphology is the study of earth's physical land-surface features, its landforms, rivers, hills, plains, beaches, sand dunes and other that makes up the earth features. The form, process and the relationship between them are central to understanding the origin and development of the landform. Their process include chemical and physical characteristic to form each different landform and may drive by the geological forces from inside the earth (endogenic process) such as intrusion, tectonic, and also forces originating at or near earth's surface and in the atmosphere (exogenic process) such as wetting, evaporation by the rain. There are two locations for geomorphology station interpretation where it shows great exposure of earth landscape.

The landform that found is main river, tributaries, hilly area, flood plain and many waterfalls at the steep contour. Waterfalls usually cause by the rivers encountering some locally and highly resistant rocks whilst deepening their valleys. Waterfalls are characterised by falling water flow over bedrock that have a near-vertical drop greater than 1 m. Waterfalls vary considerably in height, form and volume of water because some of them are big and some small and narrow. There are few waterfall found in the study area with different scale and location.

Figure 4.7: Geomorphology of study area at coordinate: N 05˚ 44’ 17.1, E 101˚ 44’ 41.3’’ at bearing 050˚.

Figure 4.8: Geomorphology of study area at Coordinate: N 05˚ 46’ 01.6’’ E 101˚ 45’ 32.1’’ at bearing 292˚.

Figure 4.9: Meandering river channel.

4.2.1 Geomorphology Classification/ Topography

Topography describes the physical features of the earth. These features include natural formation such as hill, rivers, lakes, valleys. It also refers to the elevation and relief of the earth's surface. Topography also can include the artificial features such as dam, cities, parks, landmarks, buildings and more which are manmade topography. From the reading of contour in topographic map, the interpretation of height, slope and shape of the earth landform can be known. Contour lines represent the shape and the elevation of the landform.

The topography of the area is quite hilly at the left with the highest elevation is about 880m and the lowest elevation is about 80m. The eastern part of the study area is hilly terrain (30-40%) with thick forest especially near to the border of Thailand while 60-70% of the western and central parts are covered by relatively undulating terrain with rubber, oil palm plantation. The low-lying area in the eastern part is covered by quaternary deposits. There are many classification of topography but based on the Van Zuidam's elevation classification it is divided into 7 classes as shown in Table 4.1. The classes of the classification are included lowland, low-lying plain, low hill, hill, high hill, mountain and High Mountain.

Table 4.1: Topography elevation classification (Source: Van Zuidam, 1985).

Absolute elevation	Morphology element
<50	Lowland
50-100	Low-lying plain
100-200	Low hill
200-500	Hill
500-1500	High hill
1500-3000	Mountain
>3000	High mountain

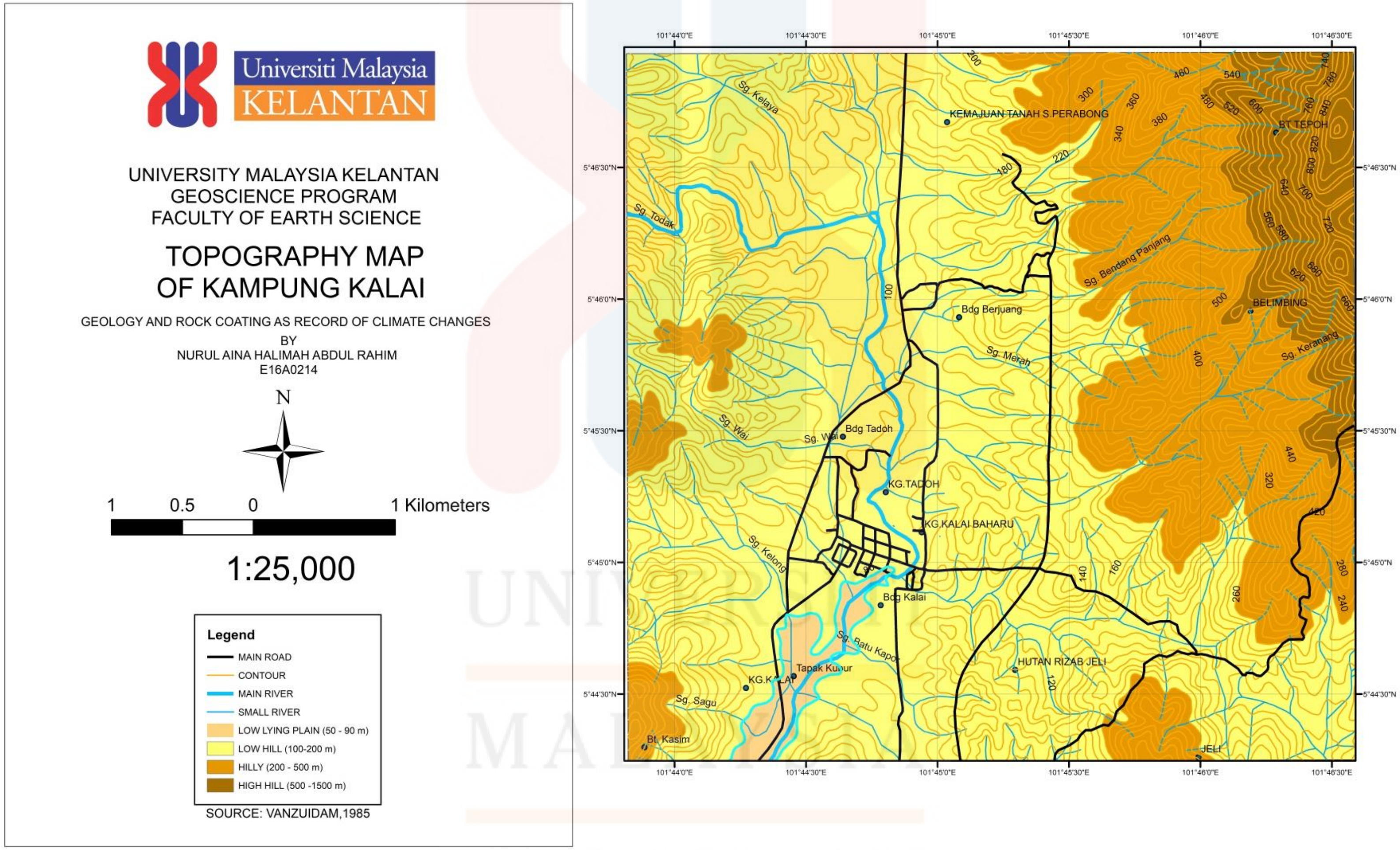


Figure 4.10: Landform of study area. (Source: Van Zuidam, 1985)

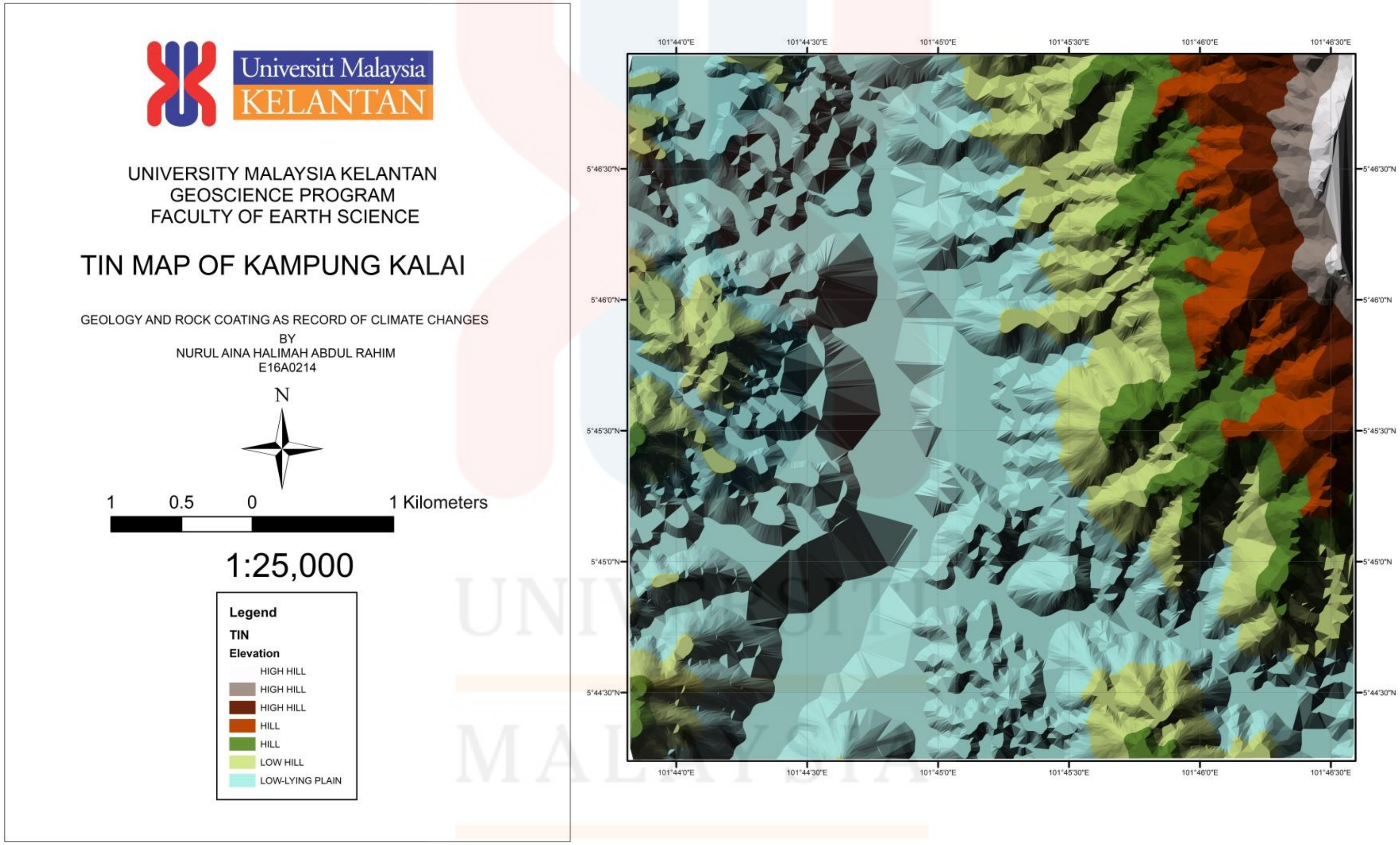


Figure 4.11: Tin Map of study area.

- Low land

It is the condition where the elevation is lower than 50 m and sometimes above sea level. Lowland habitats are warm with slow flowing rivers and the water frequently has contamination with sediment and organic matter. The activity found at this level is agriculture activity.

- Low lying plain

Low lying land is also considered as plain area with elevation higher than lowland which is ranging about 50-100 m in elevation. This topography is considered as place where the flood plain area, predicting that the sea or river level will rise and flooding many low-lying area. The land is mainly covered by the housing and settlement which it is categorised safe area for people to make shelter.

- Low hill

Low hill is the elevation with ranging 100-200 m. they are less steep and not as high. Low hill may be referring to particular section of flat terrain without a massive summit. This place is suitable for terrace types of agriculture where is can hold the stability of the slope for example oil palm plantation or rubber plantation. Low hill usually consist of alluvium and soil deposition with minor solid rock. Many settlements were built on low hills to avoid floods.

- Hill

High hill may form through the geomorphology phenomena such as faulting, erosion of larger landform such as mountain by erosion exposing solid rock which whether down into a hill. Hill is elevation of the earth’s surface that has distinct summits but lower elevation than mountains with elevation ranging from 200 -500 m. The slopes usually have steep slope or very high steep slope where landslides always occur.

Other than that, from the result of GIS processing it shows that the study area have variety of slope ranging from flat to very steep slope like shown in Figure 4.12, colour from green to red in colour which green in for flat and red is for very steep. The centre from north to south of the study area dominated by the flat to low slope with slope about 0-15 in percent and followed by the moderated slope with 15-25 in percent. At the eastern part of the study area, the colour of the map is dominated by red and orange colours which mean that it have high slope and steep slope that ranging from 25 to more than 40 in percent same goes to the western part of the study area.

The area which has high slope and steep slope are predicted to become landslide potential area because of the lithology and the structural geology characteristics of the area. From traversing, the minor landslide can be found at the location with coordinate N 05˚ 45’ 15.3’’, E 101˚ 44’ 30.1’’. The type of landslide is slump landslide as shown in Figure 4.13. This landslide also may cause by the land clearing process which is done to be used as agricultural land regardless of the characteristic aspect of the slope because this landslide is found near the agriculture zone. Land clearing on the steep slope can be a potential factor that may cause landslide and damaging human life. The landslide also can cause by the high rain intensity where the slope stability cannot restrain the load so it cause slide. From the observation, the landslide that occurs is affected by topography with steep slope, clear land activities and also affected by the heavy rain intensity.

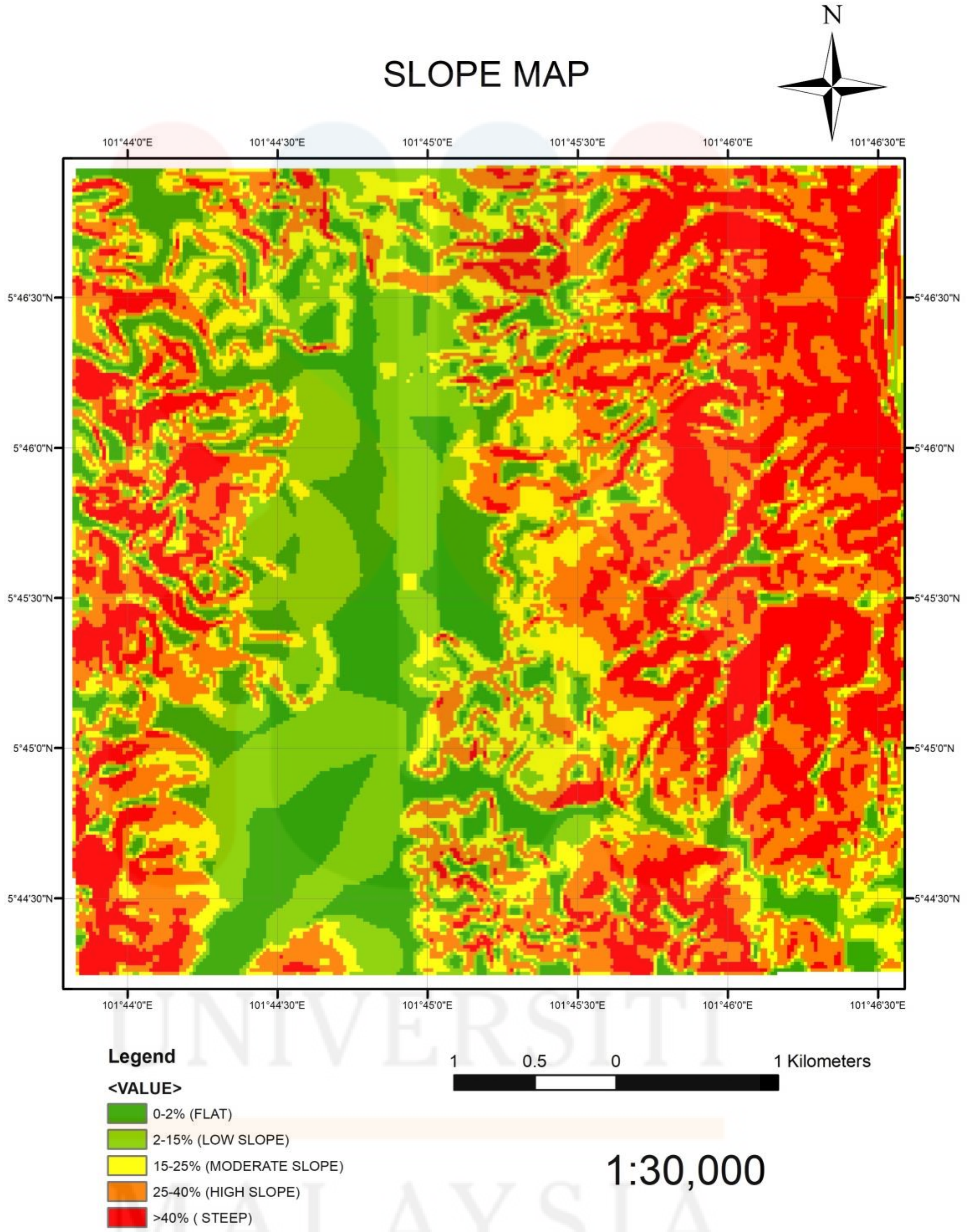


Figure 4.12: Slope map of Kampung Kalai.

Figure 4.13: Minor landslide at N 05˚ 45' 15.3'', E 101˚ 44' 30.1''.

4.2.2 Weathering

Weathering is the breakdown of rocks by mechanical disintegration and chemical decomposition. Weathering process weakens the rocks and makes them more permeable because they decay when expose to lower temperature and pressure at earth's surface and brought into contact with air, water and organisms. Living things have the influential role in weathering process by attacking the rocks and mineral through various biophysical and biochemical process. These processes produce soil, unconsolidated rock detritus and components dissolved in groundwater and runoff. Alteration is also process which involve changes in composition of rock but often caused by the hydrothermal solutions or chemical weathering.

Basically weathering changes the mineralogical composition of a rock that result in reduction of the mechanical properties of a rock. The degree of weathering is usually estimated from visual observations from mapping or hand specimen but the weathering also can be found by analysis of thin section in a microscope. There are three processes in weathering which is mechanical, organic and chemical weathering. Those types of weathering result in different types of rock behaviour and visual.

Table 4.2: Guide to rock and soil description. (Hong Kong, 1988)

Grade	Rock characteristics	Ground behaviour
Residual soil	Original rock texture completely destroyed Can crumble by hand and finger pressure into constituent grains.	Soil
Completely decomposed	Original rock texture preserved. Can be crumbled by hand and finger pressure into constituent grains Easily indented by point of geological pick Slakes when immersed in water. Completely discoloured compared with fresh rock	Soil, probably with clay properties
Highly decomposed	Can be broken by hand into smaller pieces Makes a dull sound when stuck by geological pick Does not slake when immersed in water. Completely discoloured compared with fresh rock.	Mixed ground
Moderately decomposed	Cannot usually be broken by hand, easily broken by geological hammer. Makes a dull or slight ringing sound when stuck by geological hammer. Completely stained throughout	
Slightly decomposed	Not broken easily by geological hammer. Makes a ringing sound when stuck by geological hammer Fresh rock colours generally retained but stained near joint surfaces	Rock mass
Fresh	Not broken easily by geological hammer. Makes a ringing sound when stuck by geological hammer No visible signs of decomposition (no discolouration)	

- **Mechanical Weathering**

Mechanical weathering is also known as physical weathering which mean that physical breakdown of rocks into smaller and smaller pieces. It is causes by the effects of changing temperature on rocks but sometimes assisted by water. There are two main types of physical weathering which are freeze-thaw and exfoliation. Free-thaw occur when water seeps into cracks then freezes and expands and breaking the rock apart. Foliation is occurring as cracks develop parallel to the land surface a consequence of the reduction in pressure during uplift or erosion. It occurs repeated melting and freezing of water or through expansion and contraction of the surface layer of rocks.

The results of mechanical weathering are the opening up of joints, the formation of new joints and the fracture or cleavage of individual mineral grains. It is involve the breakdown of the rock without any decay of minerals. The source of the process occur are from the thermal expansion and contraction of rock, pressure release upon rock by erosion of overlying materials, alternate freezing and thawing of water between cracks and fissures within the rock, crystal grown within rock and the growth of plants and living organism on rock.

From the Figure 4.14, the cracking of the rock is believed caused by the expansion and contraction of the rock. The pressure makes the rock become brittle and resulted in cracking. The pattern of the cracking is irregular and not in the same direction. From the observation, the fractures are filled with the fungi or lichen and many secondary mineral that got into the cracking of the rock. The weathering also resulted in many small holes that cause from the pressure. The physical weathering can be seen on marble, schist, granite which is brittle when the pressure hit them so the fractures easily to occur. It is also influenced by the temperature and the volume of water in the pore spaces present. When the temperatures are in the extreme condition, the water exerts forces outwards that cause the rock to break. The rock then resulted in decrease in size until it becomes soil.

Figure 4.14: Physical weathering that cause cracking of the rock which upper left and lower right is marble while lower left and upper right is schist.

- **Chemical Weathering**

Chemical weathering is the weakening and subsequent disintegration of rock by chemical reactions. The chemical reaction involved oxidation, hydrolysis and carbonation which either form or destroy minerals in altering the nature of rock mineral composition. It is causes by the rain water that usually acidic reacting with the mineral grains in rocks to form new minerals and soluble salts. Hydrolysis is the process of breakdown of rock by acidic water to produce clay and soluble salts. Oxidation is the process of breakdown of rock by oxygen and water, often giving iron-rich rocks a rusty-coloured weathered surface. Carbonation or also known as solution is the process of removal of rock in solution by acidic rainwater. The result from of the chemical weathering causes the discolouration of the rock, decomposition of complex silicate minerals and leaching or solution of calcite and salt minerals. From the Figure 4.15, the discoloration of the rock can be seen as resulted from chemical weathering where the minerals react with another chemical reaction or by rain water of heavy metal from the river.

Figure 4.15: Discolouration of the schist (left). Discolouration of granite (right).

From the Figure 4.16, the iron bearing minerals such as olivine and pyroxene tend to become red in colour when oxidised. The brownish red stain that can be seen at the rock is resulted of the oxidation process where rusting is occur. The oxidation tends to occur near at the cracking of the rock. The rusting of the rock makes the rock become weak and easy to break apart. From the figure below, the rusting can be seen occur in granite and schist.

Figure 4.16: Oxidation of granite (right), schist (left).

From the 4.17, the dissolution of rock is influenced by the carbon dioxide in the atmosphere also in the water such as river or rainwater. Carbon dioxide from the atmosphere and the soil seep percolated into precipitation then strikes to the surfaces of the rock. Carbon dioxide forms mild acid which slowly dissolve alkaline materials. The alkaline carbonate bedrocks units are affected by this process then neutralised the unit. The carbonate unit is dissolved in this neutralization process thus increased the size of the fracture in which water flow and makes holes cause by the process on the surface of the rock. As the process continues the size of the opening increased, solution features increased. The solution features can trap the secondary mineral and can caused accumulation of materials.

Figure 4.17: Dissolution makes hole on marble (focussed on circle).

- **Biological Weathering**

Biological weathering is the weakening and disintegration of rock by plants, animals and microbes. From the Figure 4.18, roots from plant exert stress or pressure on rock. The pressures from plant cause by the plant root grow deeper to find sources of water, applying force to push them apart. The agents of biological weathering include humans, plants, wind, water, air, and animals. Microbial activity breaks down rock minerals by altering the rock's chemical composition. For example, the lichens which are fungi and algae that living together that live on rock surface. Fungi release chemicals that break down rock minerals, then the minerals release by the rock consumed by algae. This process produced holes and gaps on rock which exposing the rock to physical and chemical weathering.

Figure 4.18: Biological weathering on marble (upper), on schist (lower).

4.2.3 Drainage Pattern

Drainage pattern is the pattern formed by the stream, rivers, and lakes in a particular drainage basin. They are influenced by the topography of land, weather a particular region is dominated by hard or soft rocks and the gradient of the land. Drainage can be either natural or artificial. Watershed are represents all of the stream tributaries that flow to some location along the stream channel. The low-lying area in the eastern part is covered by quaternary deposits.

There are few types of drainage pattern as shown in Table 2.1 in Chapter 2. The types of drainage pattern system are dendritic pattern, parallel pattern, trellis pattern, rectangular pattern, radial pattern and annular pattern. Map in Figure 4.19 shows the drainage pattern at the study area. The drainage patterns of the tributaries found at study area are dendritic, radial and parallel pattern. The dendritic pattern that contain in the study area has channel that oriented in varieties of direction that can be found at north east of the study area. About 40% of the tributaries have dendritic pattern type. Most of the landform that have dendritic pattern is associated with the steep slope and the lithology there is granite and schist which give the influences for the shape and the pattern in tributaries.

The type of drainage pattern at northwest part of the study area is parallel pattern which covers about 55% of the study area. The types of lithology dominantly schist followed by carbonate rock and minor granite. The stream found straight and flows at same direction. They also have the uniform sloping surface. Also, they associated by the structural geology which is faulting. There are lot of evidence of faulting found there such as waterfall. 5% from the drainage pattern is radial type.

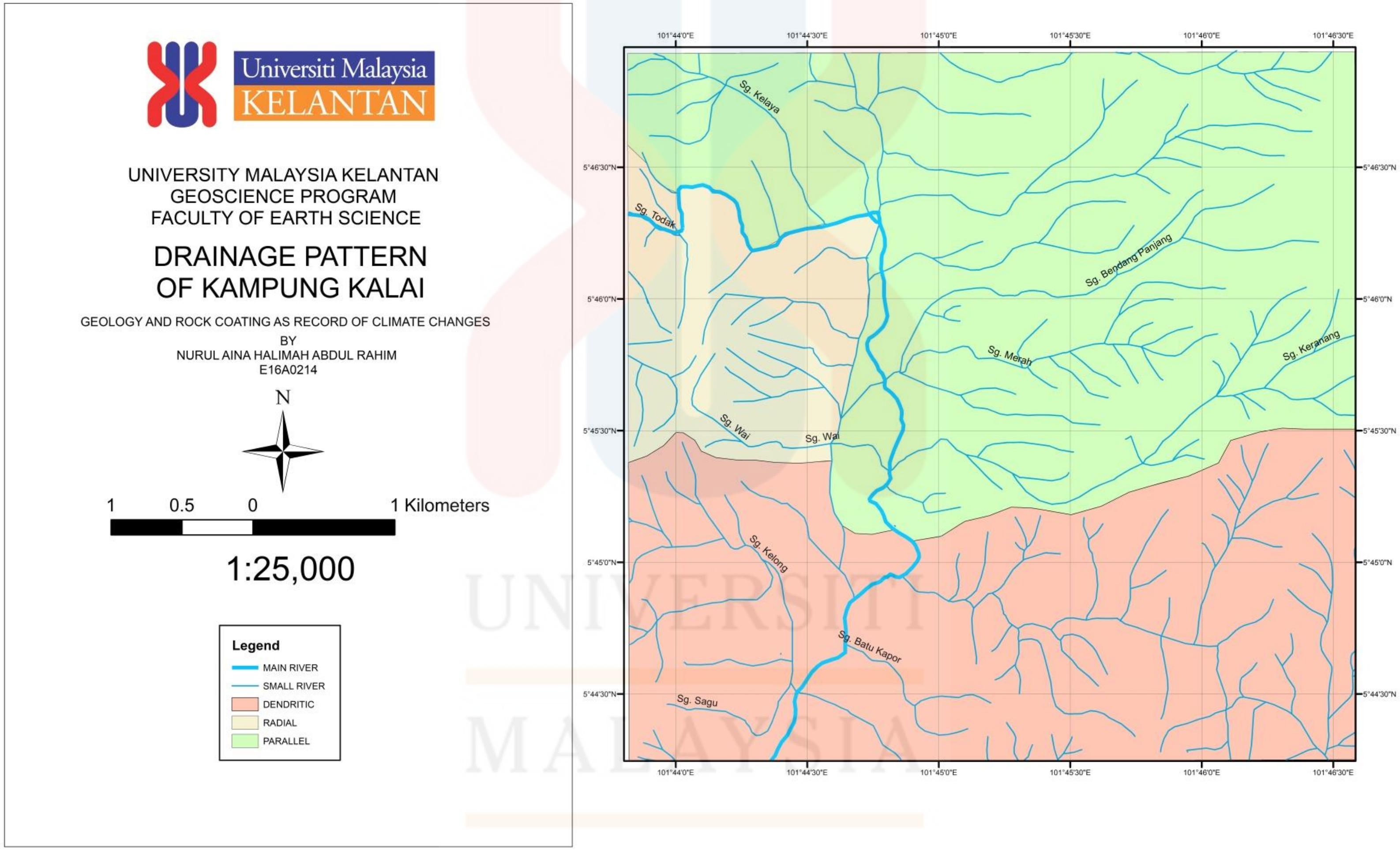


Figure 4.19: Drainage pattern within study area.

4.3 Stratigraphy

Stratigraphy is chapter geology which concerned with the order and the relative position of strata and their relationship to the geological timescale. The position of the lithology and the age helps geologist to understand the historical geology in the study area. The lithologies of district Jeli consist of intrusive rock, Triassic age rock, Permian age, Carboniferous age and followed by the quaternary alluvium. The formation that concerned at Kampung Kalai is Telong formation, Mangga formation, Tiang schist formation and Kemahang Granite which age ranging from Triassic to Silurian age.

Table 4.3: Lithostratigraphy column of Kampung Kalai.

ERA	PERIOD	UNIT/FORMATION	LITHOLOGY	LEGEND
Cenozoic	Quaternary	Alluvium	Loose, unconsolidated sediments	
Mesozoic	Triassic	Kemahang Granite	Alkali feldspar granite, quartz-rich Granitoid,	
			Foliated Diorite	
Paleozoic	Permian	Telong formation	Lenses of white marble with calc-silicate hornfels	
	Carboniferous	Mangga Formation	Quartz-mica schist and quartz mica garnet schist	
	Devonian-Silurian	Tiang Schist Formation	Quartz-mica schist	

4.3.1 Lithostratigraphy Unit.

a) Kemahang Granite

This irregular granite mass which forms the mountainous range east and west of Jeli town. From the data when mapping Kemahang granite can be seen covers at the east part of the study area. The granite is in the form of batholith is largely distributed which typically forms N-S trending mountain range. Many boulder of the granite found along near the granite area which undergo erosion and weathering and transported to the nearest area. The granite found consists of predominantly grey, medium to coarse-grained biotite-hornblende granite to diorite in composition and the feldspar phenocryst has average length of 1-2 cm and contain abundant of biotite.

Quartz vein are commonly found within study area. Granite outcrops are well exposed at the northeast of the study area. The contour lines were very close and very steep because the igneous rock contains many quartz minerals which have high ability to the resistant. But at the eastern part of the study area was hard to found good igneous outcrop because of weathering and covered by vegetation but the boulder are abundant. The xenoliths are also can be found at certain area in this granitic rock. MacDonald (1967) suggested that the age of Kemahang Granite is Triassic. Based on Malaysian and Thai working Groups Kemahang granite can be considered as I-type granite. The common granite found at the study area is alkali feldspar granite, quartz rich granitoids such in Figure 4.20 and foliated diorite.

Figure 4.20: Quartz rich granitoid at coordinate: N 05˚ 45' 13.5'', E 101˚ 45' 31.8''.

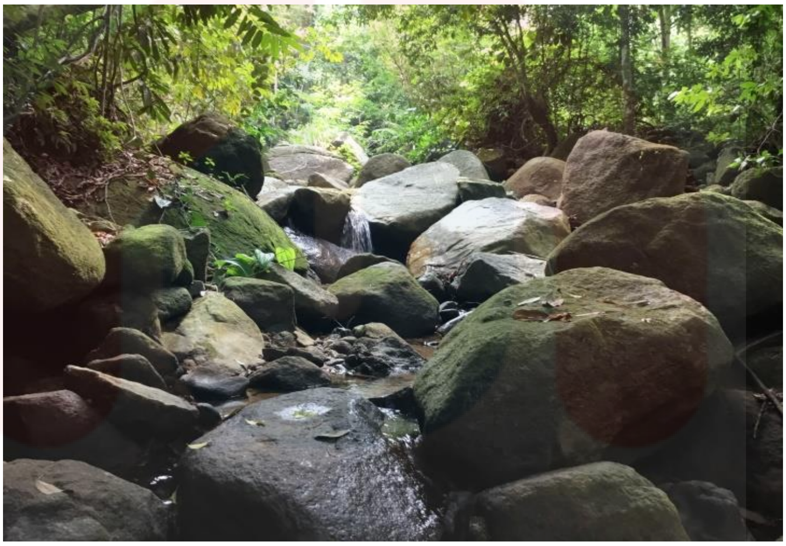


Figure 4.21: Plenty of granite boulders within study area.

Figure 4.22: Alkali Feldspar granite at coordinate N 05˚ 46' 54.1'', E 101˚ 45' 31.4''.

b) Telong Formation

Telong formation consists of argillaceous, arenaceous, calcareous, and volcanic facies. The argillaceous facies consist of greenish to reddish grey to black slate, phyllite, schist and hornfels. But the lithology that can be found at study area is lenses of white marble with calc-silicate hornfels, lenses of volcanic rock within argillite such in Figure 4.23. The distribution of the hornfels can be found at the centre to the north west of the study area. The good outcrop can be found at Sungai Tadoh where dominantly consist of marble and some clastic metamorphic rock such as hornfels, phyllite, and schist. The age of the formation is believed to range from Late Permian to Triassic. The hornfels mostly found near the calcareous facies which composed of grey marble as Figure 4.24.

Figure 4.23: Argillite facies outcrop at northwest of the area.

Figure 4.24: Hornfels interbedded with marble.

c) Mangga Formation- Metagilities and Metarenites.

Mangga formation has low-grade metamorphic sequences of arenaceous, argillaceous, pyroclastic, hornfels and marble as shown in Figure 4.25. They consist of sedimentary and low grade metamorphic clastic group that occur at western part of the study area. Kampung Kalai consists of metagilities and metarenites. Metagilities consist mainly of metamorphosed siliceous shale, slate, phyllite, metasiltstone and hornfels. The colours of phyllite found are grey to dark grey. The arenaceous unit consist of minor metasiltstone and schist the schist consists of quartz-mica schist, quartz-mica-garnet schist and quartz-mica-graphite schist. The pyroclastic rock found at study area is rhyolitic tuff but in smalls scale and occur as lenses with arenaceous and argillaceous. The Mangga formation strongly deformed and metamorphosed, trends N-S and dips moderately to steeply either to west and east.

Figure 4.25: Marble found at study area. Coordinate: (a) N 05˚ 46’ 20’’, E 101˚ 44’ 55.8’’ (b) N 05˚ 46’ 00.7’’, E 101˚ 45’ 07.1’’ (c) N 05˚ 45’ 40.2’’ E 101˚ 44’ 47.8’’. (d) Minor rhyolitic tuff at N 05˚ 46’ 02.7’’, E 101˚ 45’ 21.0’’.

d) Tiang Schist

Tiang formation is the oldest formation and lithology unit in the study area which age ranging about Silurian-Devonian. The distribution found in the study area mostly focused on the central-eastern part of it. Tiang schist consists of quartz-mica chiastolite schist and quartz-mica schist. Foliation has various trends and dip steeply both eastwards and westwards resulting from folding and faulting. Tiang schist distribution is at the eastern part of the study area such as in Figure 4.26.

Figure 4.26: Schist at eastern of the study area. Coordinate: (a) N 05˚ 44’ 41.7’’ E 101˚ 45’ 51.4’’, (b) N 05˚ 45’ 19.3’’, E 101˚ 45’ 45’’.

4.3.1 Petrography Analysis

Petrographic analysis helps in determining and can act as evidence to prove the lithology by examines and evaluates the optical properties of the material. This branch of geology is important and examine by thin section using optical microscope. The petrographic analysis helps geologist to understand and relate the composition of earth’s crust. The optical and physical properties of minerals analysed and discussed the type of the rocks. The structural and the metamorphism characteristics also analysed in the thin section analysis.

There are three types of rock in the earth which are igneous rock, sedimentary rock and metamorphic rock. The characteristics and chemical composition of igneous rock tell how it formed through crystallization or may involve a different process that helps them solidifies the molten rock. The characteristics of metamorphic rock tell whether it from intrusive rock or extrusive rock. Form the metamorphic petrology, the composition and texture of the rock show the metamorphism characteristics due to the extreme pressure and temperature such as foliation or mylonite. Such rocks include marble, gneiss, slate and schist. The petrology helps in geologist to know about the historical geology of the earth surface in creating a comprehensive series of geological events as well as recognised minerals that have a high value for commercial.

1. **Quartz rich granitoids. (UI43)**

Figure 4.27: Hand Specimen and the outcrop at Coordinate**:** N 05˚ 45' 13.5'', E 101˚ 45' 31.8''.

Rock description: The colour of the rock is white, colourless, grey, and black. The mineral composition is quartz, plagioclase, and biotite. The texture is phaneritic where the mineral is coarse enough to see with naked eye.

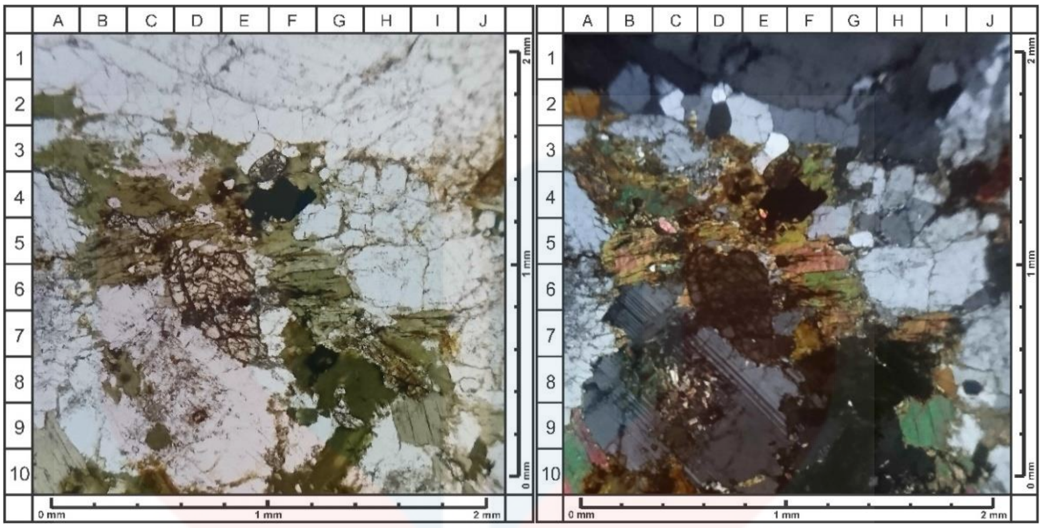


Figure 4.28: PPL (Right), XPL (left).

Microscopic observation:

The observation was done by using 10X magnification and 5X objective magnification to observe the massive structure, phaneritic textures and coarse grain.

Mineral composition:

Plagioclase (E8) - In PPL observation, the colour of the plagioclase is white, and at XPL it shows light pink-grey colour, subhedral to euhedral, Carlsbad albite twinning, value An 28 (oligoclase), medium pleochroism, and one way cleavage, present scattered in thin section as phenocryst. Contain about 10% of mineral.

Quartz (F1)-The colour in PPL observation it shows white colour, XPL shows white-grey-black, low relief without cleavage, low pleochroism, the shape of crystal is anhedral, present scattered over thin section. Contain about 60% of quartz mineral.

Opaque mineral (J1) - In PPL and XPL observation, the colour is black or opaque, present scattered in thin section. Contain about 4% of opaque mineral.

Biotite (F6) - In PPL observation the colour is brown, in XPL the colour is orange-light pink-brown. One way orientation of cleavage, medium to high relief, medium pleochroism, and subhedral, present scattered in thin section. Contain about 18% of epidote.

Chlorite (G8) - In PPL the colour is greenish brown, XPL show greenish colour with one way cleavage-no cleavage, medium relief, low-medium pleochroism, scattered in thin section. Contain about 8% of chlorite.

Rock Name: Quartz-Rich Granitoid (Streckeisen, 1976)

2. **Meta-quartz arenite, schist. (UI44)**

Figure 4.29: Hand specimen and outcrop at coordinate: "N 05˚ 45' 18.2'', E 101˚ 45' 43.3"

Rock description: The contact between schist and meta-quartz arenite can be seen. The colour is dark grey-black and white and colourless. The foliation can be seen on the dark grey coloured rock.

<u>**Microscopic observation:**</u>

The observation was done by using 10X magnification and 5X objective magnification to observe the massive structure-foliation, textures including grain size <1/256-1/4 mm, good sorting, neatly closed.

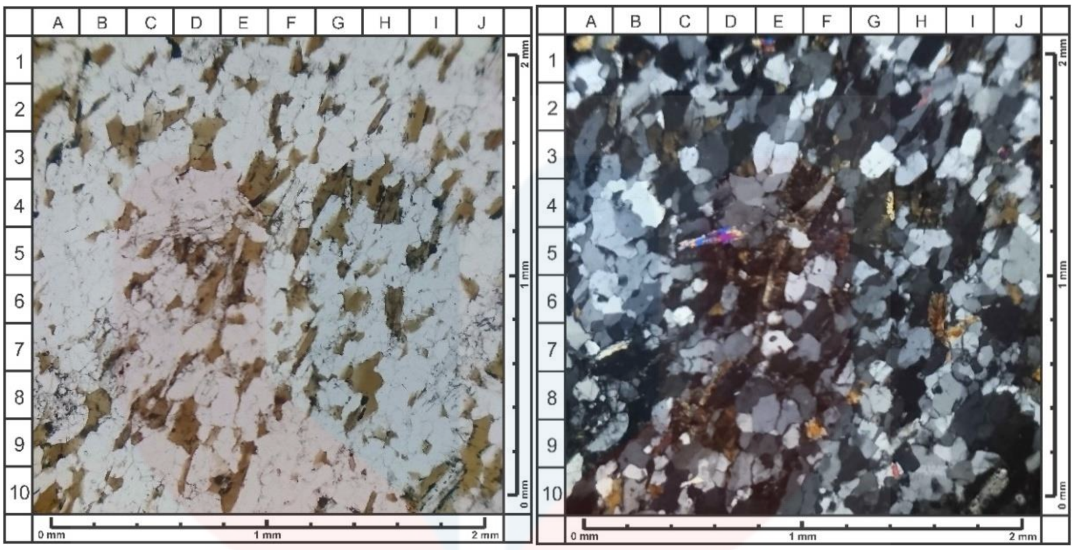


Figure 4.30: PPL (Right), XPL (left).

<u>Mineral composition:</u>

Quartz (J1) - In PPL observation, the colour of the plagioclase is light, and at XPL it shows white-grey-black colour, anhedral, low pleochroism, low relief with no cleavage, present scattered in thin section. Contain about 71% of mineral.

Epidote (D5) - The colour in PPL observation it shows brown colour, XPL shows reddish purple-orange, medium relief with two way cleavage, medium pleochroism, present scattered over thin section. Contain about 1% of epidote mineral.

Biotite (A2) - In PPL observation, dark brown while in XPL the colour shows orange-brown, high-medium relief, medium pleochroism, one way cleavage, and subhedral, present scattered in thin section. Contain about 20% of biotite.

Opaque mineral (B1) - In PPL and XPL observation, the colour is black or opaque, present scattered in thin section. Contain about 3% of opaque mineral.

Clay mineral-Silica clay (A8) - In PPL observation the colour is white-greyish, in XPL the colour is greyish black. Relief- pleochroism, cleavage and shape of crystal cannot be determined, present scattered in thin section. Contain about 5% of minerals.

Rock Name: Quartz-Rich Granitoid (Streckeisen, 1974).

3. Hornfels (UI45)

Figure 4.31: Hand specimen and the outcrop at coordinate: "N 05˚ 44’ 52.0’’, E 101˚ 45’ 41.4 "

Rock description: Massive outcrop. Pink, grey fine grain rock. Surround by rubber plantation and small river. Have many shear and extension joint.

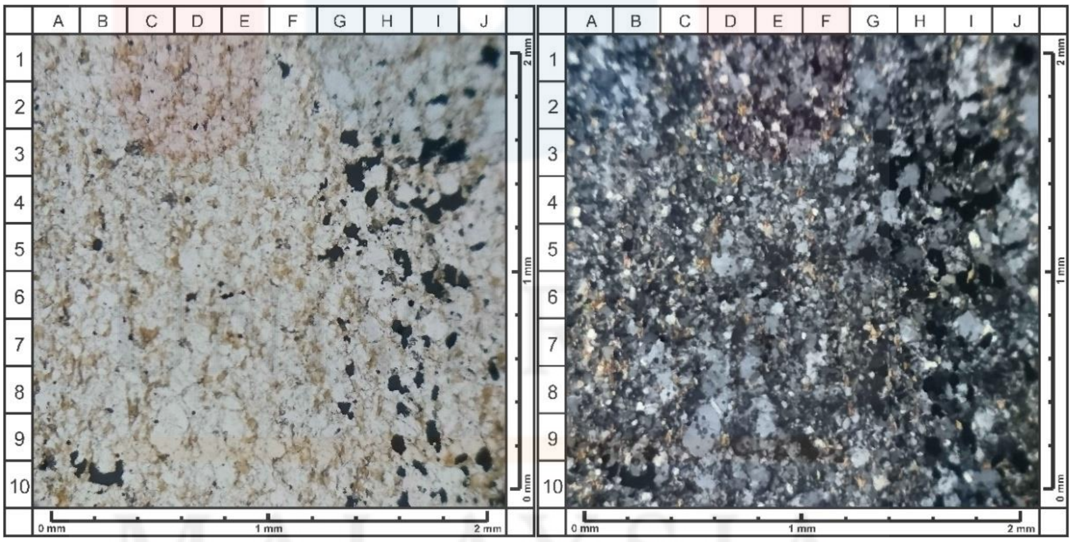


Figure 4.32: PPL (Right), XPL (left).

<u>**Microscopic observation:**</u>

The observation was done by using 10X magnification and 5X objective magnification to observe the massive structure-non foliation (granulose), Palimpest (blastopsamit) textures where the remnant texture if the parent rock found preserved in the metamorphic rock including grain size <1/256-1/5 mm, good sorting. Granulose structure is produced due to the predominance of equidimentional minerals such as quartz, feldspar, pyroxenes and calcite.

Mineral composition:

Quartz (A1) - In PPL observation, the colour of the plagioclase is white, and at XPL it shows white-greyish black colour, anhedral, low pleochroism, low relief with no cleavage, present scattered in thin section. Contain about 47% of mineral.

Biotite (A6) - In PPL observation, dark brown while in XPL the colour shows orange-brown, high-medium relief, medium pleochroism, one way cleavage, and subhedral, present scattered in thin section. Contain about 15% of biotite.

Opaque mineral (J1) - In PPL and XPL observation, the colour is black or opaque, present scattered in thin section. Contain about 8% of opaque mineral.

Clay mineral-Silica clay (E1) - In PPL observation the colour is white-greyish, in XPL the colour is greyish black. Relief- pleochroism, cleavage and shape of crystal cannot be determined, present scattered in thin section. Contain about 15% of minerals.

Clay mineral-clay oxide (A6) - In PPL the colour shows brown, while in XPL the colour is greyish brown-black, relief-pleochroism-shape crystal cannot be seen, present scattered in thin section. Contain about 15% of minerals.

Rock Name: Hornfels (Gillen, 1982).

4. Granulite (UI47)

Figure 4.33: Hand specimen and outcrop at coordinate: N 05˚ 44’ 52.5’’, E 101˚ 44’ 50’’.

Rock description: the colour of the rock is dark grey-black. The grain size is coarse grain can be seen by naked eyes. Pyroxene and quartz can be seen clearly.

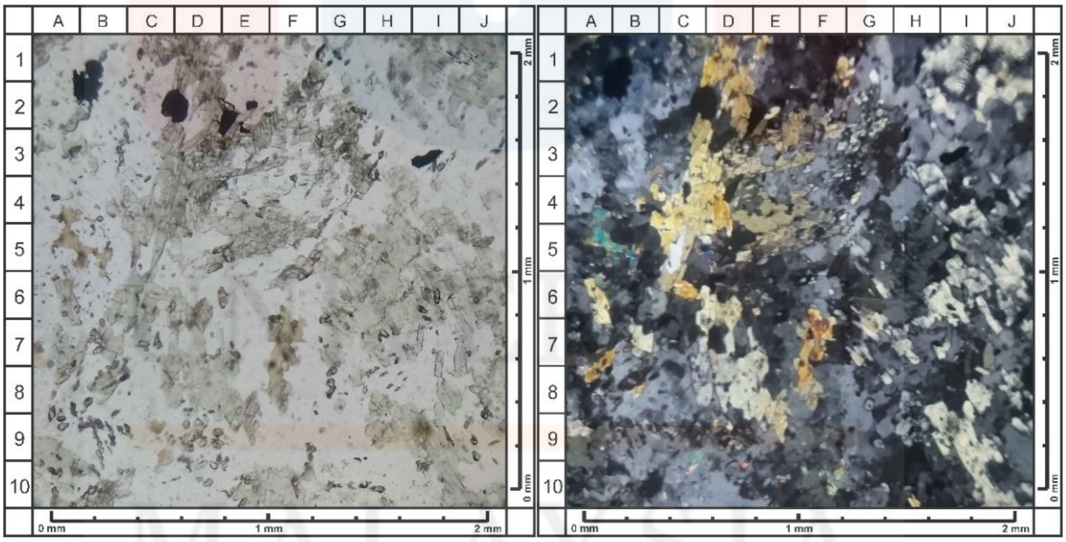


Figure 4.34: PPL (Right), XPL (left).

<u>**Microscopic observation:**</u>

The observation was done by using 10X magnification and 5X objective magnification to observe the massive structure non-foliation (granulose), Palimset (blastopsamit) textures including grain size <1/256-0,8 mm, good sorting.

Mineral composition:

Quartz (C10) - In PPL observation, the colour of the plagioclase is white, and at XPL it shows white-greyish black colour, anhedral, low pleochroism, low relief with no cleavage, present scattered in thin section. Contain about 45% of mineral.

Epidote (F7) - In PPL observation, brown while in XPL the colour shows reddish purple-orange, medium relief, medium pleochroism, two way cleavages, present scattered in thin section. Contain about 3% of epidote.

Pyroxene-orto (C4) - In PPL observation, the colour is light brown, XPL is yellowish grey-brownish-orange, low relief, two way cleavage, low pleochroism, present spotted in thin section. Contain 49% of minerals.

Opaque mineral (B1) - In PPL observation and XPL show the black or opaque colour of mineral, present scattered in thin section. The composition is about 3%.

Rock Name: Granulite (Gillen, 1982).

5. **Marble (UI49)**

Figure 4.35: Hand specimen of marble and the outcrop at coordinate: N 05˚ 46' 20'', E 101˚ 44' 55.8''.

Rock description: The colour of the marble is white. Coarse grained mineralised. Contained many joint and located at Sg. Tadoh.

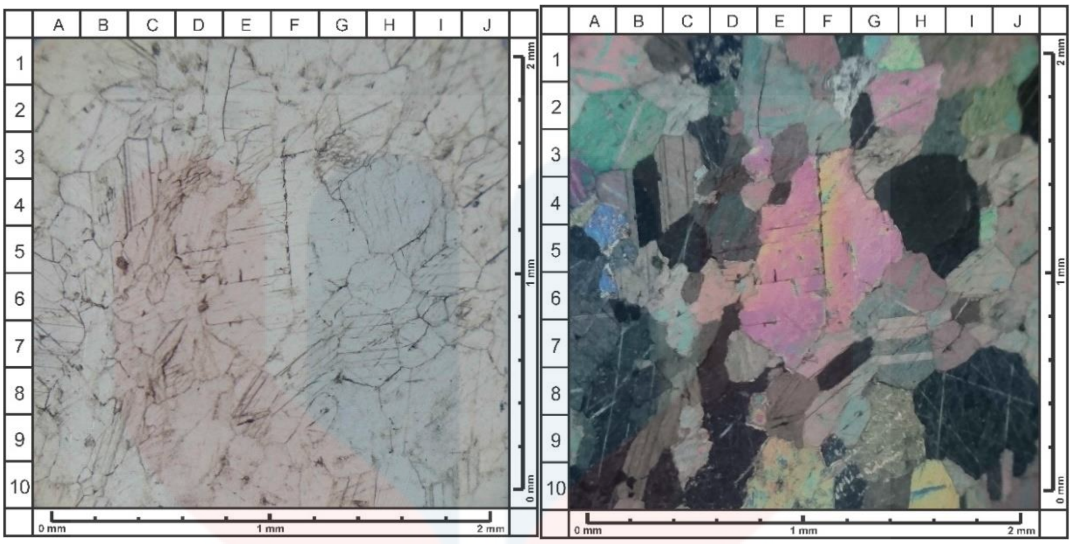


Figure 4.36: PPL (Right), XPL (left).

<u>Microscopic observation:</u>

The observation was done by using 10X magnification and 5X objective magnification to observe the massive structure non-foliation (granulose), palimset textures including grain size <1/256-0,8 mm, medium sorting.

<u>Mineral composition:</u>

Calcite (A1) - In PPL observation, the colour is white, and at XPL it shows light red-greenish, 1-2 cleavage, very high-low relief (double reflection), high pleochroism, present scattered in thin section. Contain about 100% composition.

Rock Name: Marble (Gillen, 1982).

4.4 Structural Geology

Structural geology helps in understanding about the tectonic movement history, past geological event and environment that deformed the rock. Structural geology analysis helps finding the stress field that resulted in the observed deformation and geometries of the rock. Deformation helps in remodel the nature of the forces which are related to the formation. The stressed field that resulted in analysis is calculated. Structural geology analysis is done by GIS processing from lineament analysis, interpretation of geological maps and identifying the structures such as folds, faults and joint in the field for early interpretation the confirm when mapping.

The deformation of the rock is depends on the stress, strain, condition, time and the characteristic of the rock. If the rock is brittle it tends to fracture while if the rock is ductile the rock tends to deform or folding because it follows the rule of inelastic deformation and plastic deformation. The triaxial stress is the common rule for the orientation of the stress that strikes them. The most common types of structural geology are fold, fault and joint. Folds are formed result from plastic deformation where the flat or planar surface is bends because of the force strike to the rock. The structural geology will describe and interpreted using software such as GeoRose for Rose Diagram and Streonet for fault analysis. There are much structural geology found within the study area such as joint, fault, fold, xenolith, fault breccia, quartz vein, gash joint, lamination, foliation, minor fault, bedding and ductile deformation as in Figure 4.37. Xenolith is the foreign rock that becomes enveloped in the larger rock which is meta-quartz wacke, schist during development and solidification as figure above. The deformation of marble occurred because of the plasticity properties of the rock before achieve their brittle failure.

Figure 4.37: Lamination (upper left), Ductile deformation (upper right), Xenolith (lower left), Foliation (lower right).

Figure 4.38: Bedding. Coordinate: N 05˚ 45' 20'', E 101˚ 45' 45.8''.

As in Figure 4.38, the origin structures of the parent rock can be seen which is bedding. Bedding still can be seen in schist rock. But in the small scale, the foliation can be seen, in Figure 4.39, the anticline is found which shown the ductile properties of the rock. But the weathering of the rock resulted in the fractures on the surface of the rock. This type of weathering is physical weathering.

Figure 4.39: Anticline at coordinate: N 05˚ 38' 19', E 101˚ 41' 57'' (OO48).

4.4.1 Lineament Analysis

According to Cracknell and Heyes (1993), "Lineaments are the terrain surface expression of fractures, jointing and other linear geological phenomena that occur anywhere from the terrain surface down to possibly great depths. Typically lineament is a fault-aligned valley or series of fault or fold-aligned hills, ridges, rivers and more. There are two types of lineament which are positive and negative lineament. Lineaments also express the fracture zones, shear zones, and igneous intrusions such as dykes.

Lineament is analysed and interpreted by using GIS and satellite imagery for analyse the regional movement of the plate due to the force. They can be a great indicator and idea where the structural geology at the study area from the map. So the clue of having a structural geology at certain location by the lineament analysis is then confirmed by geological mapping. The major orientation of lineaments can be the indicator of the direction of the forces coming from where.

The correlation is done by making comparison between lineament maps generated in this study with the fault location found in when mapping. But the comparison was made with the map from Malaysia Peninsular geological map and the map done in the study area and the resulted shows that there is overlap between the lineaments. But the overlap between lineaments and the fault found when mapping was found and so it proved that the fault are exist at the lineament analysis done in the study area.

The major fault occur at the study area is along Sungai Tadoh which is overlap with the lineament analysis done. From the Figure 4.40 shows the orientation of lineament that represent in the study area. 23 lineaments were determined in the study area but only 7 of them matched with the real fault from the observation and mapping done. The orientation of the lineament is divided into two groups which are the dominant orientation is at NE-SW direction. This pattern of lineaments has been observed particularly in the east part of the study area. The other directions are from N-S direction. The orientation of the lineament is correlated with the joint analysis in Rose Diagram to show the direction of the major forces as shown in Figure 4.40.

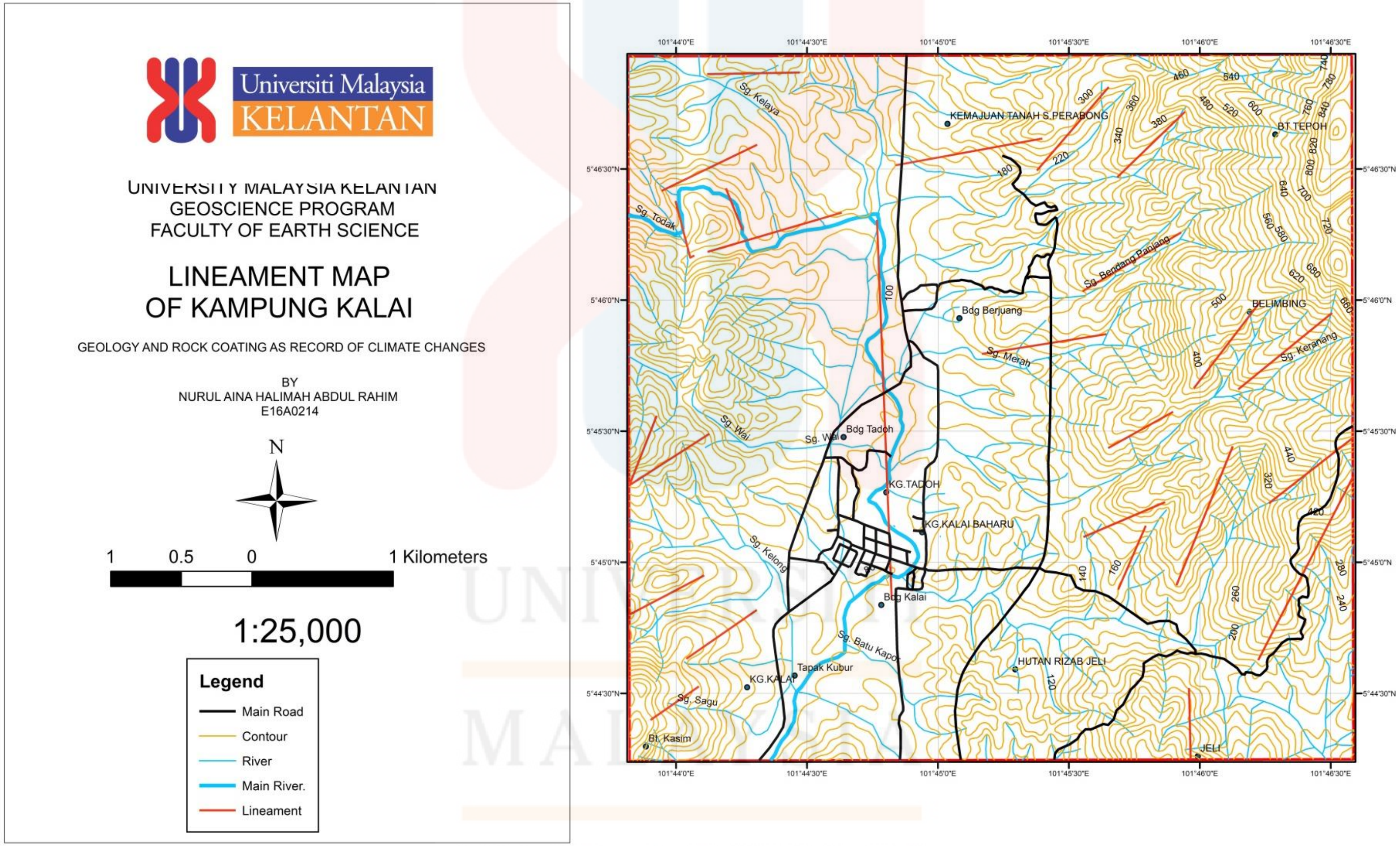


Figure 4.40: Lineament Map analysis of Kampung Kalai.

4.4.2 Joint Analysis

Joint is the most universal geological structures that can be found in most every exposure of the rock. Joint is a one of the types of fractures of natural origin of the body of rock without any displacement that occur at the surface of the rock. They occur mostly as a joint set which means that they appear as a group of parallel and even same spaced joint that can be identified through mapping. The analysis of joint includes the Rose Diagram analysis by using GeoRose and the analysis of the orientation, spacing and the physical properties. The characteristics and the measurement of the joint were done in mapping process.

There are three types of joint which are systematic, unsystematic joint and columnar joint. Systematic joint are planar, parallel which have the same spaced distance and orientation from two joint or more set of joint. The unsystematic joints are set of joint which have irregular in spacing and orientation. Columnar joint is the distinctive joints that join together at triple junctions either at or about 120˚ angles. Joint are most found on granite, marble and schist in the study area. Joint can be found open fractures with infilling and none. The infilling joint is called veins or extension joint while non- filling joints is called shear joint.

Joints can be a result from brittle fracture of a rock body as a result from tensile stress. Tensile stress can come from stretching layers, the rise of pore fluid pressure or internal stress which result in shrinkage caused by cooling or desiccation of rock body. The maximum principal stress is parallel and perpendicular to the minimum principal stress when the fracture is happen. As a result, typically the exposure or outcrop within study area contains only symmetrical and unsymmetrical without columnar joint. The joints found have its own distinctive properties such as orientation and spacing. Conjugate joint which have dihedral angles from 30-60 within joint system also found at the study area as in Figure 4.41. Joint analysis helps in understanding the geology and the geomorphology of the earth and very crucial in development of natural resources, safety design for construction and environment protection. Joints also influence the groundwater, pollutant, petroleum and hydrothermal.

The measurement is done in mapping by collecting data of the orientation such as strike azimuth against the frequency of joint that are found within particular orientation intervals. Rose diagram is done represent the orientation axis transformed into a circle. The internals of angle are plotted as pie-shaped of a circle in their true orientation and the proportional to the length of the radius. From Figure 4.46 the major force is coming from the direction of NE-SW.

Figure 4.41: Conjugate joint on Granite. Coordinate: N 05˚ 45' 13.5'', E 101˚ 45' 31.8'' (left). Shear joint at Schist. Coordinate: N 05˚ 45' 18.2'', E 101˚ 45' 43.3''.

Figure 4.42: Shear joint at Marble. Coordinate: N 05˚ 46’ 20’’, E 101˚ 44’ 55.8’’ (left). Extension Joint. Coordinate: N 05˚46’ 35.3’’ E 101˚ 44’ 51.7’’ (right).

Figure 4.43: Non-symmetrical joint on Marble. Coordinate: N 05˚ 46’ 30.9’’ E 101˚ 44’’ 45.1’(upper). Symmetrical joint on Marble. Coordinate: N 05˚ 45’ 37.6’’, E 101˚ 44’46.3’’.(lower).

Figure 4.44: Gash Joint/en enchelon. Coordinate: N 05˚ 46’ 23’’, E 101˚ 43’ 59’’.

As the Figure 4.44 above, gash joint appear as sets of short parallel, planar, and mineral-filled lenses within body of rock. Then, they originate as tension fractures that are parallel to the major stress orientation, in shear zone. The rose diagram below, shows the major forces for the extension joint where the major forces is parallel to the maximum frequency of the joint set.

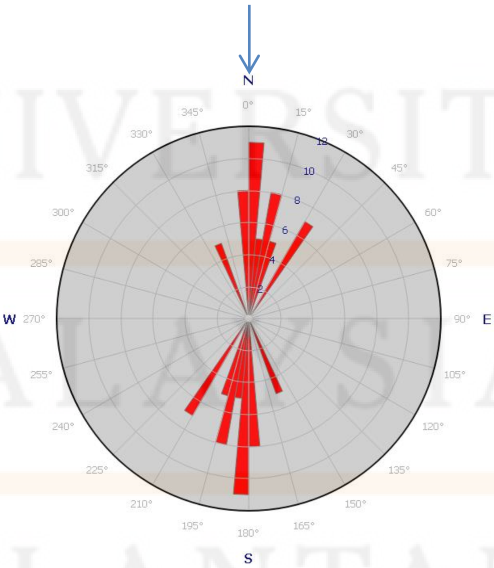


Figure 4.45: Extension joint at checkpoint 24 which located at southern of the study area. Coordinate: "N 05˚ 44’ 52.5’’, E 101˚ 44’ 50".

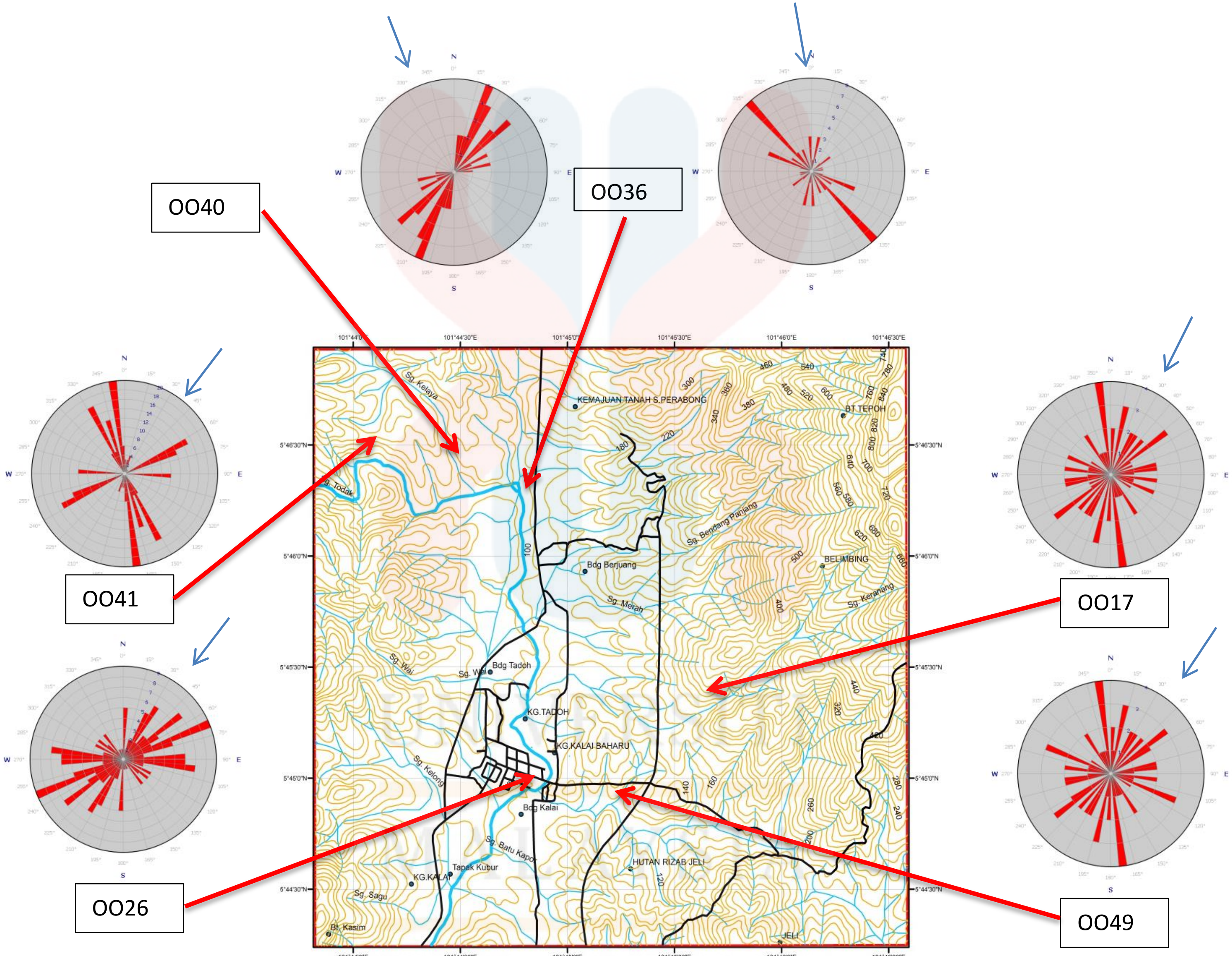


Figure 4.46: Rose Diagram of the study area (shear joint).

4.4.3 Fault Analysis

Faults are the fractures that have displacement due to the force. There are few types of fault which are normal fault, reverse fault and strike-slip fault. Normal fault happens where the rocks are pulling apart result from tensile stress and one side of fault is moved down (normal wall) while the other side moved upward (hanging wall). Reverse dip-slip fault happen when the rocks are pushed together due to compression force. Normal wall is pushed up while foot wall pushed downward. Thrust fault is the same like reverse fault varies in angle which thrust fault have low angle. Transform faults is where the plate moving in one side while the other one in opposite direction.

Fault is a result from the action of tectonic forces between plates. Fault trace is a line that plotted on geologic maps that represent a fault as can be seen in geological map of Kampung Kalai. There are few faults that can be analyses from the topography of the area using map and with the evidences that can be found in mapping. There are normal fault at the centre part from N-S direction of the area. Majority strike-slip fault that can be analysed with direction of NE-SW is at the eastern part of the area while a few strike-slip fault at the western part of the study area. The indicator of the faulting was found such as waterfall, fault breccia and minor fault in Figure 4.7. Fault breccia is a medium to coarse grained cataclastic that containing more than 30% visible fragments. Few waterfalls found within study area which as indicator to the fault activity and the location of the waterfall is overlap with the fault trace that mapped at the geological map after GIS processing.

Figure 4.47: Minor fault (left). Fault Breccia (right).

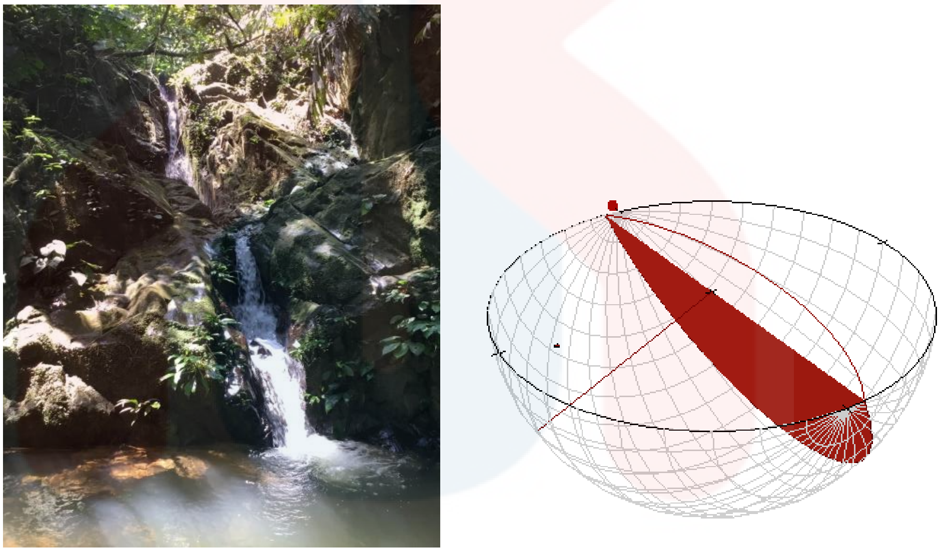


Figure 4.48: Waterfall with fault plane= 355/67.
Coordinate: N 05˚ 45’ 05.5’’, E 101˚ 44’ 03.0’’.

Figure 4.49: Fault Breccia (left) and anticline (right) with limb 335/75 and 230/83.

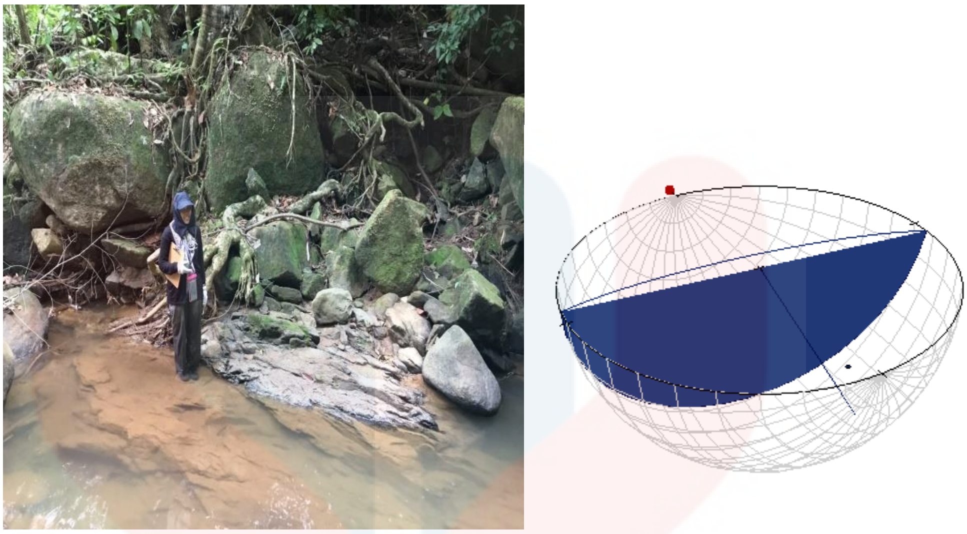


Figure 4.50: Fault zone. 276/79. Coordinate: N 05˚ 45’ 17.8’’, E 101˚ 45’ 43.2’’ (OO15)

Figure 4.51: Fault breccia. Coordinate: N 05˚ 45’ 17.8’’, E 101˚ 45 42.7’’ (OO16)

Figure 4.52: Fault zone with small waterfall (left), ductile deformation. Coordinate: N 05˚ 45’ 18.2;;, E 101˚ 45’ 43.3’’ (OO17).

Figure 4.53: Waterfall (WF2) (down). Coordinate: N 05˚ 45’ 20’’, E 101˚ 45’ 45.8’’

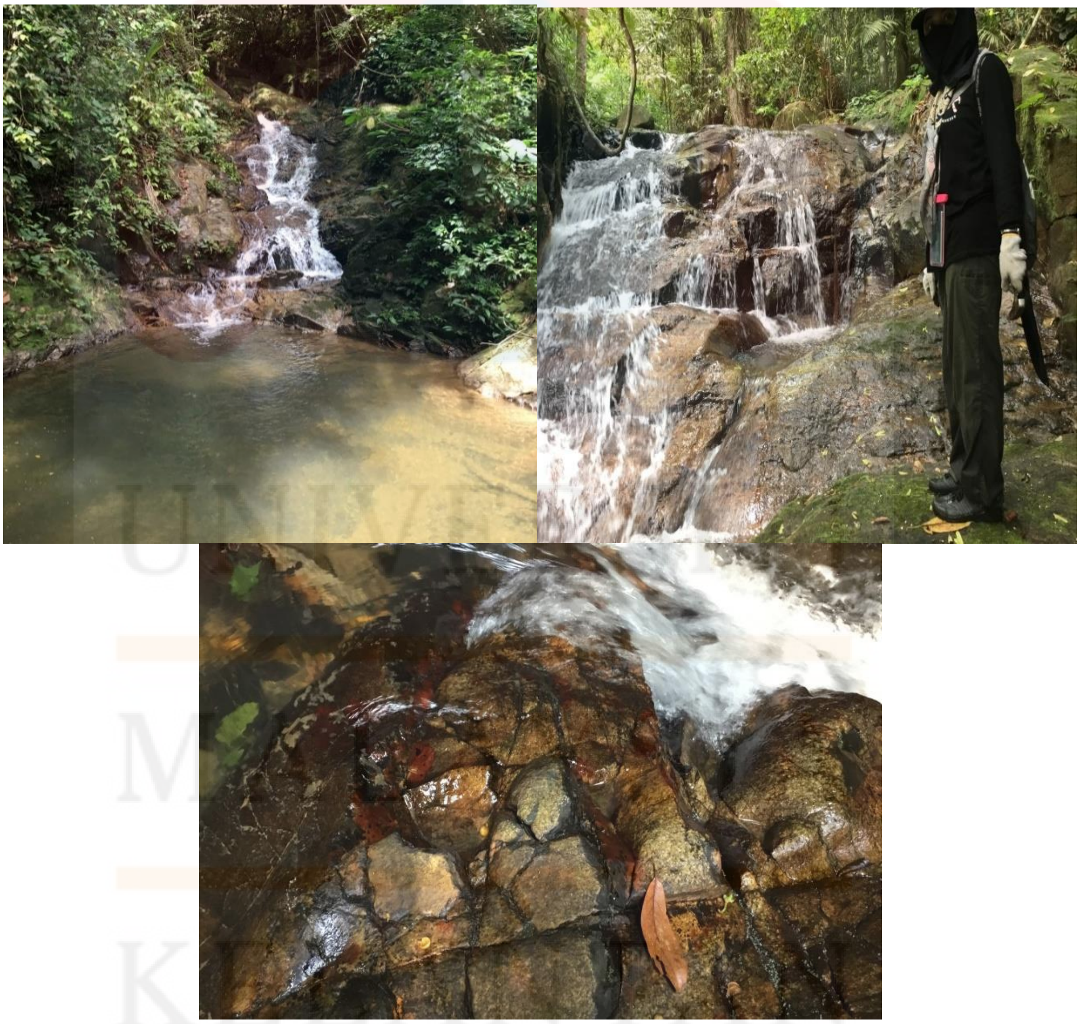


Figure 4.54: Waterfall at WF3, fault breccia (down). Coordinate: N 05˚ 45’ 21.3’’, E 101˚ 45’ 49.5’’.

Figure 4.55: Minor fault, contact carbonate rock and metaclastic rock. . Coordinate: N 05˚ 44’ 52.5’’, E 101˚ 44’ 50’’.

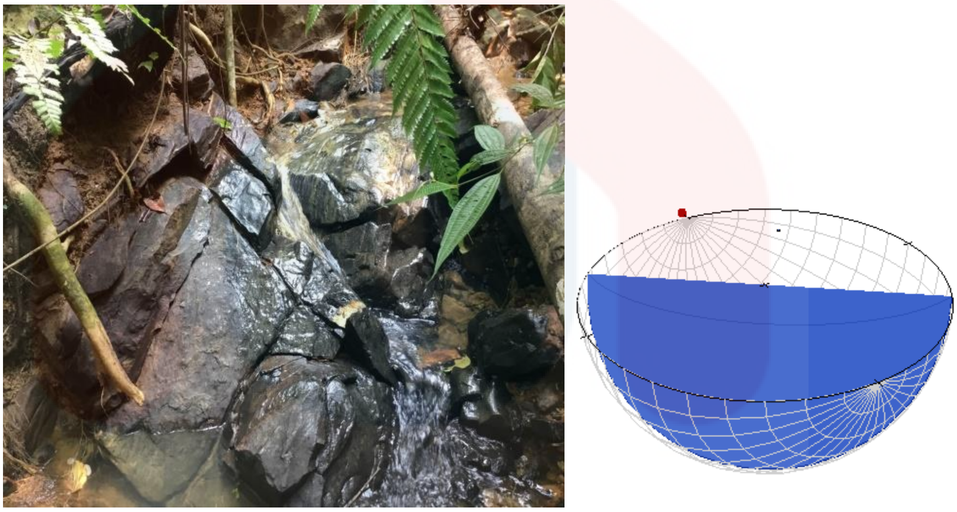


Figure 4.56: Fault plane 58/127. Coordinate: N 05˚ 46’ 23’’, E 101˚ 43’ 59’’.

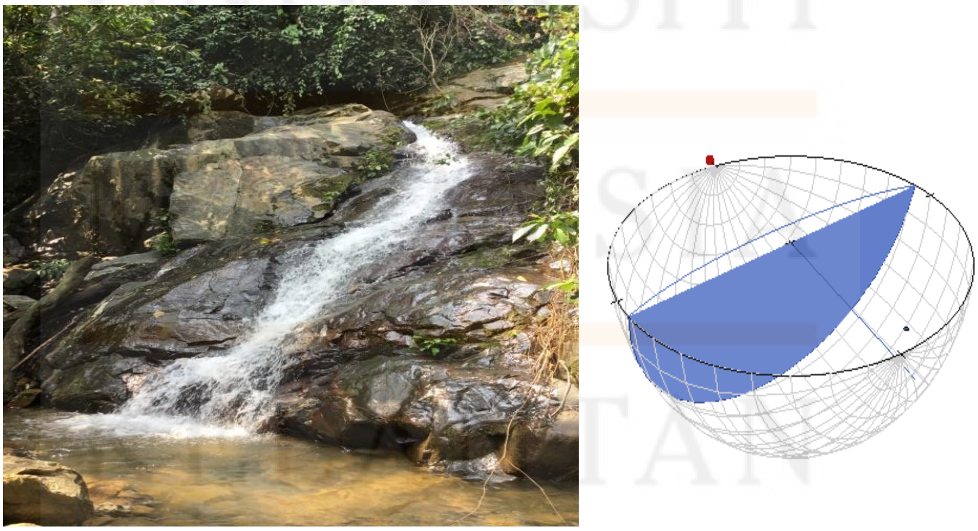


Figure 4.57: Waterfall at Fault plane 77/066. Coordinate: N 05˚ 38’ 19’’, E 101˚ 41’ 57’’.

4.5 Historical Geology

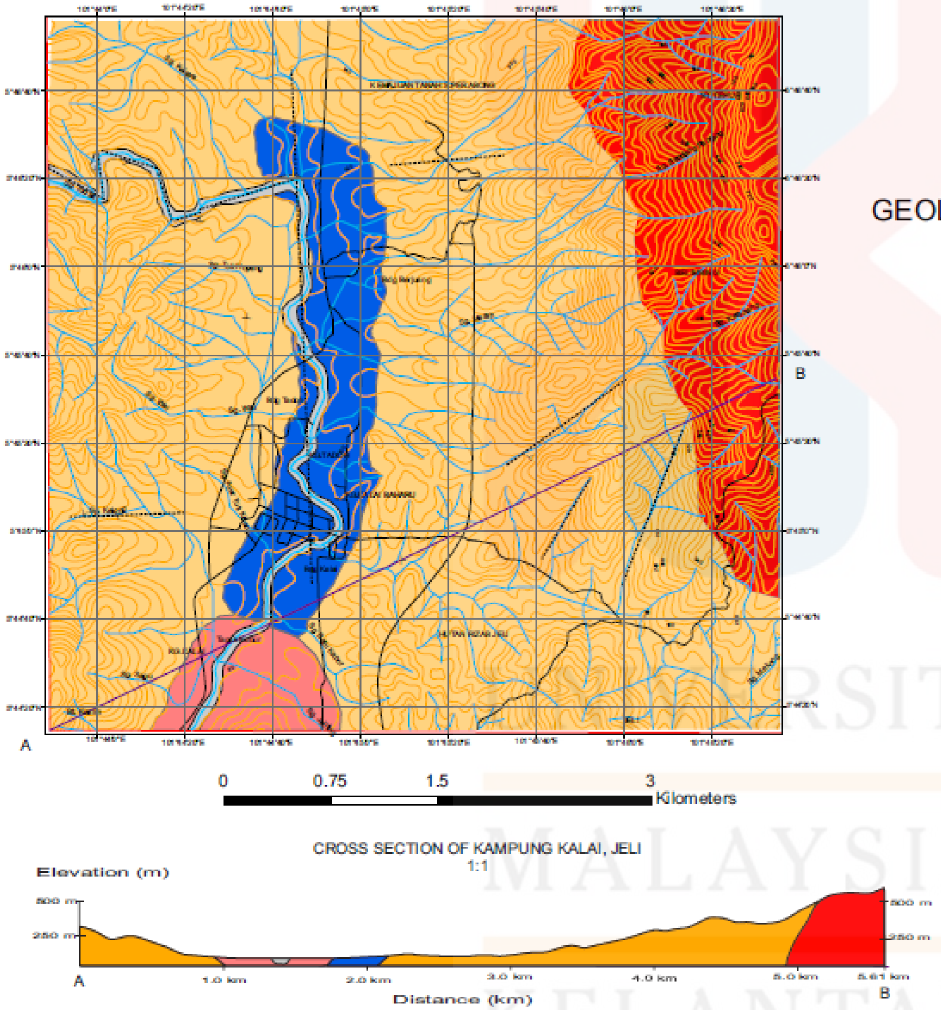
Peninsular Malaysia is formed by three belt which are eastern belt, central belt and western belt. They formed when Indochina and Sibumasu plate collides and subduction occur. Jeli is located at central belt where many hydrothermal activities occurred. Many mineralisation and structural geology formed because of the collision between plates. North-south trending quartz dykes and some igneous stocks intruded the country rocks, especially in the Kalai area. Contact metamorphism derived from igneous intrusion and its association with late stage mineralisation.

Tiang schist is the oldest unit of lithology in the study area where formed at Devonian-Silurian period. It is consists of quartz schist and quartz-mica schist. Then, the rock strikes by high pressure and temperature, it strongly schistosed, and foliated. Then, Mangga formation which consists of sedimentary and low grade metamorphism sequence of rock occurred in the western part of the study area. The age of Mangga formation believed that it formed in Carboniferous-Permian period. The low metamorphic sequences of arenaceous, argillaceous described are meta greywacke, and metagilities.

Then, Telong formation was formed in range Permian-Triassic age which consists of lenses of white granite, schist, phyllite, minor rhyolitic tuff and hornfels where the distribution of the formation can be found at the centre-eastern part of the study area. Paleozoic rock sequences were intruded by two granitic rocks. The N-S trending granitic rocks was formed at period Triassic where it is considered as Kemahang granite where biotite granite and diorite was found.

Central belt is underlain by Permian-Triassic clastic, volcanic and limestone. Most of the belt body was metamorphosed by the igneous intrusion and because of the convergent activities. The Kemahang granite was intruded to Tiang schist formation at the eastern part of the study area. Kemahang granite believed to form in Triassic period which is the youngest rock in the study area. The intrusion makes the other lithology deformed and produces more hydrothermal activity which produced the crystallization of ore mineral such as gold that can be found in the study area. The type of deposit is believed to be skarn deposit which the hydrothermal activity intruded in the carbonates group of rock.

After more years later, the loose, unconsolidated sediments were formed resulted from the weathering and erosion activities which age about Quaternary period. Local deformation and low-grade metamorphism took place in the shear and contact zones and metamorphosed the original rocks to metamorphic rocks and formed lots of structural geology and mineralisation.



N

GEOLOGICAL MAP OF KAMPUNG KALAI, JELI KELANTAN

NURUL AINA HALIMAH BINTI ABDUL RAHIM

E16A0214

Legend

- CONTOUR
- SMALL RIVER
- MAIN RIVER
- MAIN ROAD
- STRIKE-SLIP FAULT
- CROSS SECTION
- STRIKE/DIP

ERA	PERIOD	UNIT/ FORMATION	LITHOLOGY	LEGEND
Cenozoic	Quarternary	Alluvium	Loose, unconsolidated sediments	
Mesozoic	Triassic	Kemahang Granite	Alkali feldspar granite, quartz-rich Granitoid,	
			Foliated Diorite	
		Telong formation	Lenses of white marble with calc-silicate hornfels	
Paleozoic	Permian			
	Carboniferous	Mangga Formation	Quartz-mica schist and quartz mica garnet schist	
	Devonian-Silurian	Tiang Schist Formation	Quartz-mica schist	

Figure 4.58: Geological Map of Kampung Kalai, Jeli.

CHAPTER 5

ROCK COATING AS A RECORD OF CLIMATE CHANGES IN KAMPUNG KALAI, JELI, KELANTAN.

5.1 Introduction

This chapter explains about the factors of rock coating that influenced the climate changes. The analysis like Scanning Electron Microscope (SEM) and X-Ray Fluorescent (XRF) were used for soil sample and rock sample. The soil sample is collected at 14 different locations to see the different in the composition of oxides and element by using XRF analysis. The soil rich with heavy metals, organic materials, clays and the colour of soil varied from light green, light brown to reddish brown. There are no fixed factors of distance or depth of taken soil. The grain size of the soil also varied from smaller grains to coarse grains. The result form XRF analysis obtained in composition of element oxides in percentage. The 14 station of soil sampling localities is shown in Figure 5.2 and Table 5.1.

Table 5.1: The data on soil sampling localities.

NO.	WAY POINT	COORDINATE	STATION DESCRIPTION	SAMPLE DESCRIPTION
1	SS01	N 05 46 23.6 E 101 44 06.1 E=123m	Lithology: Schist metasediments, weathering: medium biological weathering, geomorphology: main river Sg.Tadoh surround by high vegetation. The type of river is meandering river. Structure geology: foliation, joint, gash joint and minor fault.	Grain size: poorly graded sand, mix with a little organic matter. The particle shape is combination of sub-angular and sub rounded. The colour of the soil is light brown.
2	SS02	N 05 44 53.5 E 101 45 10.9 E=113m	Lithology: schist with some weathered material from igneous rock. Weathering: medium stage of weathering, small river with outcrop and surround by vegetation. Structure geology: foliation, joint.	Grain size: poorly graded sand, mix with a little organic matter. The particle shape is combination of sub-angular and sub rounded. The colour of the soil is light orange.
3	SS03	N 05 44 41.7 E 101 45 51.4 E=140m	Lithology: schist. Weathering: low chemical weathering. It is surrounding by orchard and rubber plantation. Structure geology: joint, foliation. Have quartz intrusion.	Grain size: poorly graded sand, contain many compositions of quartz and other leaching material. The colour of sand is yellowish brown.

4	SS04	N 05 45 02.2 E 101 46 06.5 E=182m	Lithology: schist/ mafic igneous. Surrounds by jungle and rubber plantation. Geomorphology: waterfall and have outcrop of mafic schist rock. Weathering: low weathering. Structure geology: fault, joint.	Grain size: coarse grain particle. Poorly graded sand. The colour of the sand is light brown.
5	SS05	N 05 46 50.6 E 101 44 52.1 E=200m	Lithology: igneous rock. Hill slope beside main road. It surround by oil palm plantation. The weathering stage is low. Small landslide occurs.	Grain size: fine grain, very silty sand with the mixture of organic matter. The colour or the sand is light orange.
6	SS06	N 05 46 30.9 E 101 44 45.1 E=123m	Lithology: marble. Small river with massive marble and surround with orchard. The weathering stage: medium biological and low chemical weathering.	Grain size: poorly graded silty. Compacted. The colour: light brown and have leaching material.
7	SS07	N 05 45 57.7 E 101 44 59.0 E=139m	Lithology: the nearest lithology is marble. Small river and surround by oil palm plantation. Weathering stage is low.	Grain size: poorly graded sand, mix with a little organic matter. The particle shape is combination of sub-angular and sub rounded. The colour of the soil is creamy. .

8	SS08	N 05 45 40.2 E 101 44 47.8 E=112m	Lithology: alluvium, marble and hornfels. Main river Sg.Tadoh. Weathering stage: medium biological weathering.	Grain size: very fine clayey sand, mix with the organic matter. The colour of the soil is light brown.
9	SS09	N 05 45 37.6 E 101 44 46.3 E=115m	Lithology: marble and metasediments. Channel of main river Sg Tadoh. Have many set of shear joint. Medium biological weathering.	Grain size: compacted with sandy clay. Low mix with the organic matter. The soil colour is greenish brown.
10	SS10	N 05 44 55.4 E 101 44 23.3 E=114m	Lithology: alluvium channel of small river named Sg. Kelong. Sedimentation occurs at different size of grain sand. Low stage of weathering.	Grain size: graded sand with clay. Mix with organic material. The Colour of the soil is brick orange.
11	SS11	N 05 45 15.3 E 101 44 30.1 E=136m	Lithology: alluvium. Landslide area with scattered small fragment of quartz. Low weathering stage.	Grain size: fine grain silty clay mix with organic material. The colour of the soil is brownish orange.

12	SS12	N 05 45 22.7 E 101 44 59.0 E=108m	Lithology: alluvium with massive marble. Surround by jungle. Medium stage of chemical weathering and medium stage of biological weathering. Structural geology: fault, foliation, joint.	Grain size: sandy clay with mixture of organic matter. The colour of the soil is light brown.
13	SS13	N 05 45 04.1 E 101 44 57.5 E=107m	Lithology: hill alluvium slope. Low biological weathering and chemical weathering. The height of the slope is 4 m.	Grain size: medium compacted material with fine silty sand. The colour of the soil is light brown.
14	SS14	N 05 44 37.2 E 101 44 24.8 E= 103m	Lithology: alluvium at small river. Low biological weathering and chemical weathering. Low sedimentation state.	Grain size: uniform graded silty sand with mixture of organic material. The colour of the soil: greenish brown.

For SEM analysis, the samples used were rock samples which contain a layer of rock coatings. The rock samples were collected randomly to observe the rock coating within the study area. All the methods used to analyse rock coatings yield data at micron scale with all the geographical scales that rely on microscopic imagery and chemical data obtained at this spatial scale. The focus for this study is on rock coatings that develop in the terrestrial weathering environment, at earth's surface or in regolith near the earth's surface. There are several types of rock coating such as iron film, weathering rind, lithobiontic and others. Koppes, 1990 said that lichens are dominant biological on over eight percent of the earth's surface and it is one type of lithobiontic rock coating. There are 8 locations for rock coating sample as shown in Figure 5.2 which sampled scattered within study area.

Table 5.2: The data on rock coating sampling localities.

NO	WAY POINT	COORDINATE	LEVEL OF WEATHERING	TYPES OF COATING/ COLOUR	Level of rock coating
1	WF	N 05 45 05.5 E 101 44 03.0 E=140m	Medium weathered. Contain many discontinuities such as fault, joint but the discontinuities are discoloured. The discolouration of the outcrop extends too many part of the outcrop at the surface. And it mostly covered by mossed. Not broken easily by hammer.	Rock varnish (clay mineral, mn, fe oxides, trace element). Brown to black in colour.	Medium
2	OO12	N 05 45 13.5 E 101 45 31.8 E= 137 m, bearing= 182	Moderately weathered. Discolouration extends through the greater part of the rock mass. The rock is not friable. The discontinuities are stained and contain filling such as quartz which is altered material. The mineral in the rock is having a slightly discolouration except for quartz. The rock is hard to crash by using geological hammer.	Case hardening. Dark brown to black.	High

3	OO24 (B)	N E 05 44 52.0 E 101 45 41.4 E=143 m Bearing= 314	Slightly weathered. Discontinuity discoloured surfaces but only slight weathering of rock material. Discolouration of the surface of the rock extend to the partly area of the rock. Discontinuity contains a little altered material. The mineral still have lustre and not friable.	Oxalate crust. Thin coating orange to dark brown.	Low
4	OO42	N 05 46 23.6 E 101 44 06.1 E=123m	Grain size: poorly graded sand, mix with a little organic matter. The particle shape is combination of sub-angular and sub rounded. The colour of the soil is light brown.	Dust film	Low
5	OO11	N 05 46 54.1 E 101 45 31.4 E = 243 m	Slightly weathered. Have few open discontinuity surfaces. The discolouration of the rock surface is slightly occurring on rock mass. The colour of the mineral slightly changed.	dust film/ heavy metal skins/ iron films	Low

6	OO54	N 05 44 41.7 E 101 45 51.4 E=140M	Slightly weathered. Discontinuity discoloured surfaces but only slight weathering of rock material. Discolouration of the surface of the rock extend to the partly area of the rock. Only slight weathering of rock material.	Iron film/ heavy metal skins/ oxalate crust.	Medium
7	OO38	N 05 46 30.9 E 101 44 45.1 E=123m	Grain size: poorly graded silty. Compacted. The colour: light brown and have leaching material.	Lithobiontic coatings	Low
8	OO33	N 05 46 01.6 E 101 45 32.1 E=140M	Highly weathered. Weathering extends throughout the rock mass and the rock material is friable. Rock has no lustre. All material is discoloured. Rock can be easily being picked by using hammer. Some of the rocks become soil.	Iron films. Orange to light brown in colour.	Low

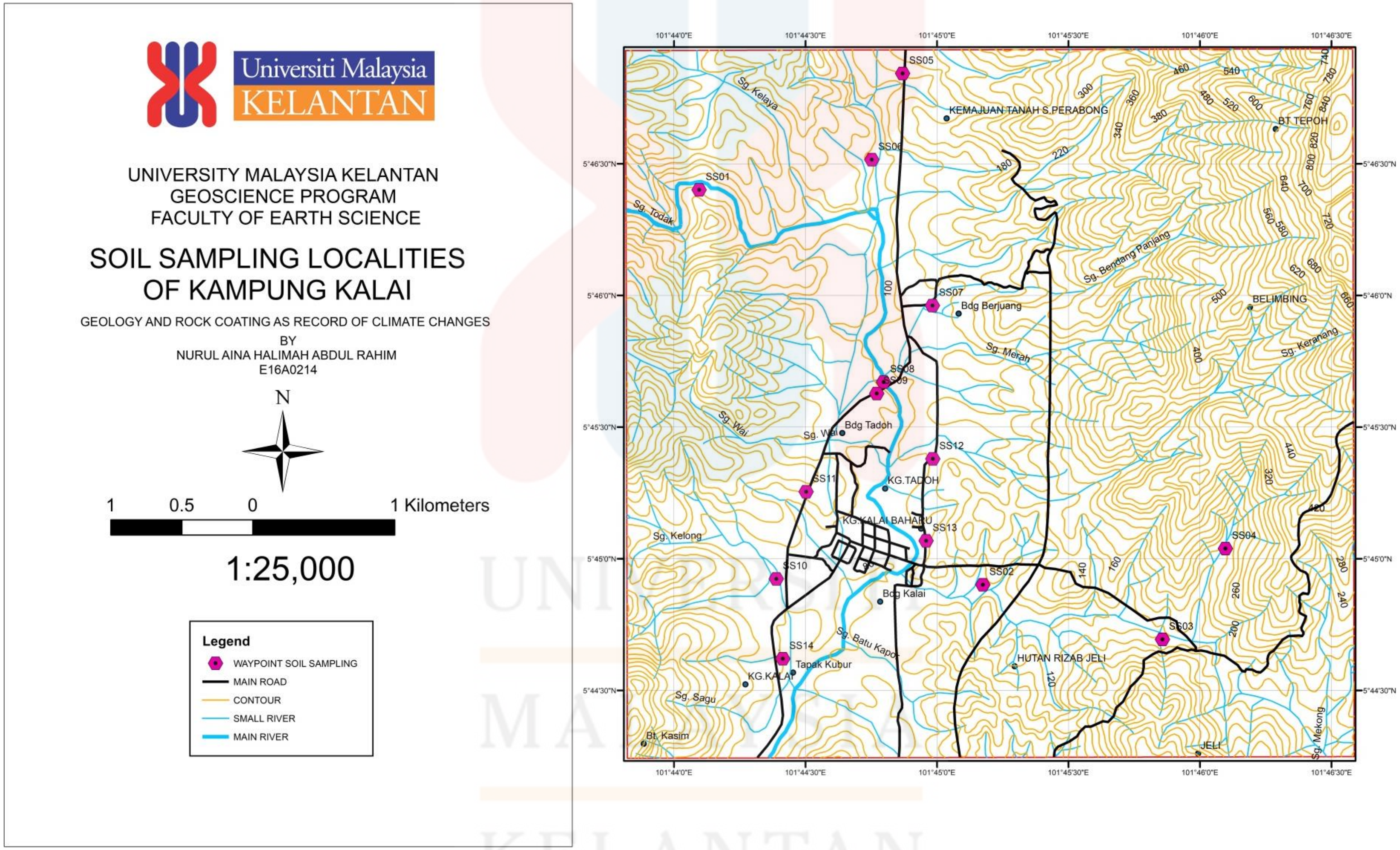


Figure 5.1: Soil sampling localities of Kampung Kalai.

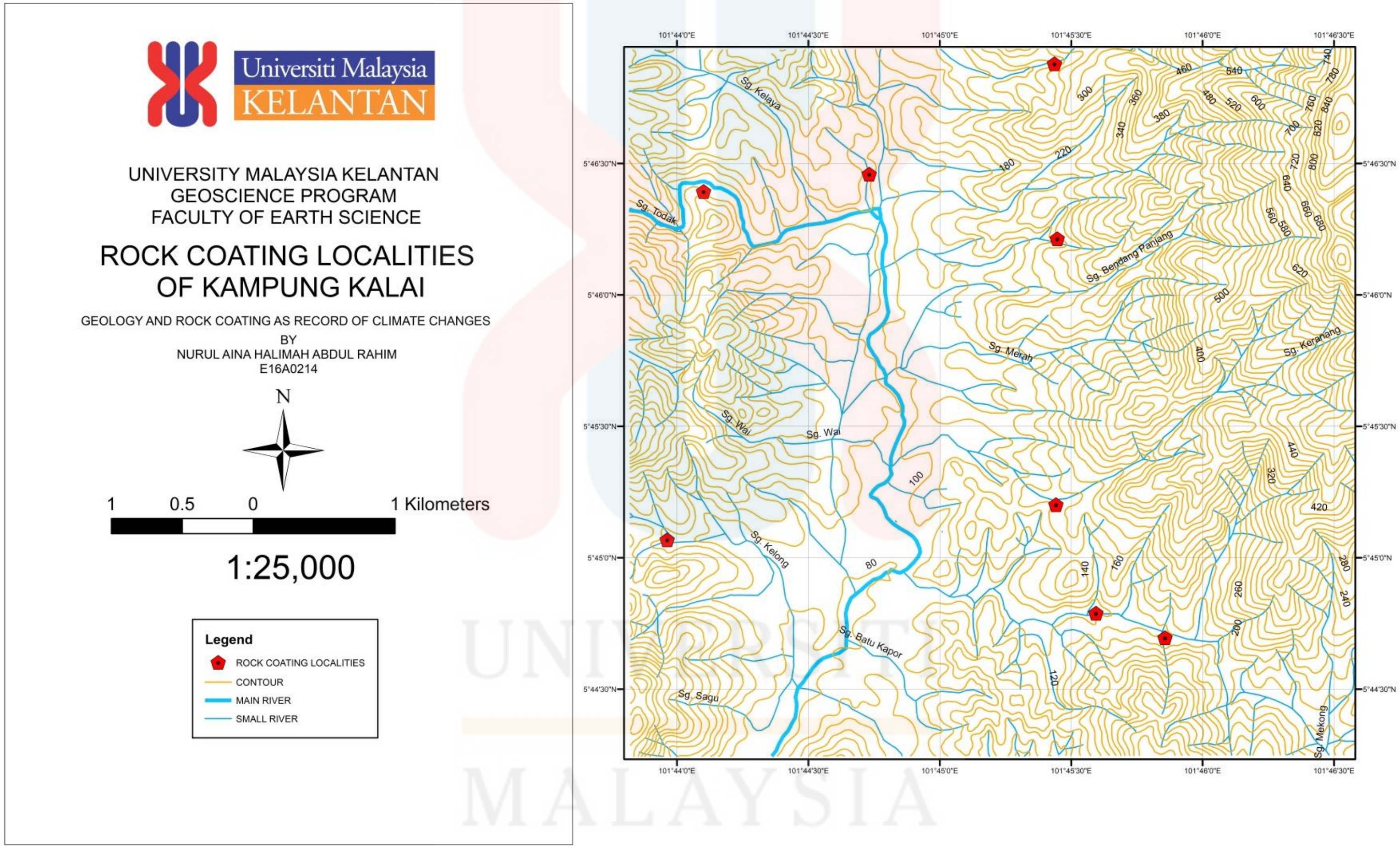


Figure 5.2: The rock coating sampling localities of Kampung Kalai

5.2 Result and Interpretation.

5.2.1. X-Ray Fluorescence (XRF) analysis.

The result showed the oxides and elements in the composition of soil sample. The result shows the different concentration based on the localities of sampling. The major oxides within the study area are discussed. The oxides are normalised to 100% anhydrous weight. 10 oxides were examined through the XRF analysis of 14 locations at the study area. This data obtained to determine the percentage composition of rock and to relate with the parameters from the environment that influence the presence of the oxides. There are 14 soil samples chosen and the geochemical data is tabulated in Table 5.3.This elemental data is to provide insight on the possible origin of the parent materials of the soils.

Table 5.3: Geochemical analysis result of major oxides in Kampung Kalai, and its surrounding.

LOCATION	Al2O3	CaO	Fe2O3	K2O	MgO	MnO	Na2O	SiO2	TiO
SS01	14.3	0.527	4.13	8.46	1.13	0.111	0.425	69.7	0.915
SS02	15.1	1.43	2.6	4.26	0.899			74.9	0.503
SS03	15.9	0.799	3.36	8.11	0.789		0.409	69.7	0.582
SS04	17.1	1.19	5.26	8.34	1.18	0.137	0.4	65.2	0.798
SS05	31.3		5.23	3.12	0.601			58.5	0.758
SS06	17.7	0.431	3.77	5.81	1.19	0.104		70	0.68
SS07	8.74	0.189	0.698	11.2	0.274			78.5	0.173
SS08	16.7	0.171	3.86	6.55	1.06			70.6	0.753
SS09	21.1	0.452	4.84	6.63	1.59			64.1	0.858
SS10	21.3		8.86	6.82	0.705			60.6	1.13
SS11	15.5	0.348	4.78	5.04	1.08	0.157		71.9	0.937
SS12	13.5	0.345	2.32	5.73				77.3	0.491
SS13	19.3		5.55	4.73	1.2			67.7	1.05
SS14	15.1	0.498	4.67	4.94	1.21	0.149		72.1	1.02

Based on the Table 5.3, $Al2O_3$, Fe_2O_3, K_2O, SiO_2 and TiO are the major oxides that present in all sample while SO_3 is the least oxides which only presence at one location. SiO_2 is shows the highest percentage followed by Al_2O_3, K_2O, Fe_2O_3 and MgO which indicates the major oxides in the sample. The other group which is minor oxides are CaO, MnO, Na_2O, TiO and SO_3 which occur in low concentration that have less than 1.5%.

a) Silicon Dioxide, SiO_2.

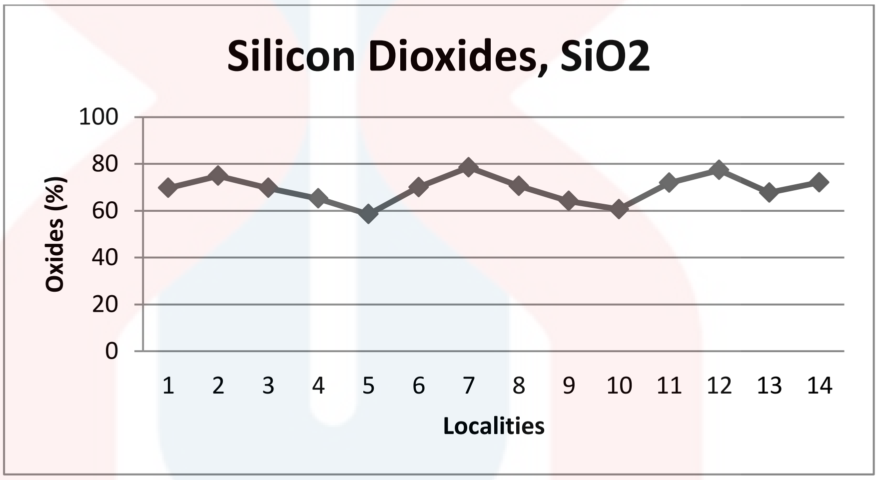


Figure 5.3: Graph showing the percentage of Silicon dioxides (SiO_2) in soil of 14 locations.

The concentration of SiO_2 is the highest oxides in the soils with the range concentration about 58.5% until 78.5% at all 14 locations. This oxide is the most common that can be found in the earth because silica covers about 46.6% in the earth. Location 7 yields the highest concentration while location 5 shows the lowest concentration of the SiO_2. The result show a peak in location 7 indicating that quartz is the main mineral composition of the sample. The grain size is coarse which contain lots of quartz mineral that withstand the erosion and weathering since quartz has high resistance properties. The colour of the soil is light brown because of the high silica content. The particle shape of sand is combination of sub angular to sub rounded where resulted from the erosion and transported process. The concentration of silica contents also because of the present of quartz-rich granitoids near the station, so the weathering of the feldspar influence the silica content. Location 5 was taken at hill slope beside main road. It surround by oil palm plantation. The weathering stage is low so the leaching process may be low. The colour of the soil is reddish orange where showed the less concentration of SiO_2 in the soil.

b) Aluminium Oxides, Al_2O_3

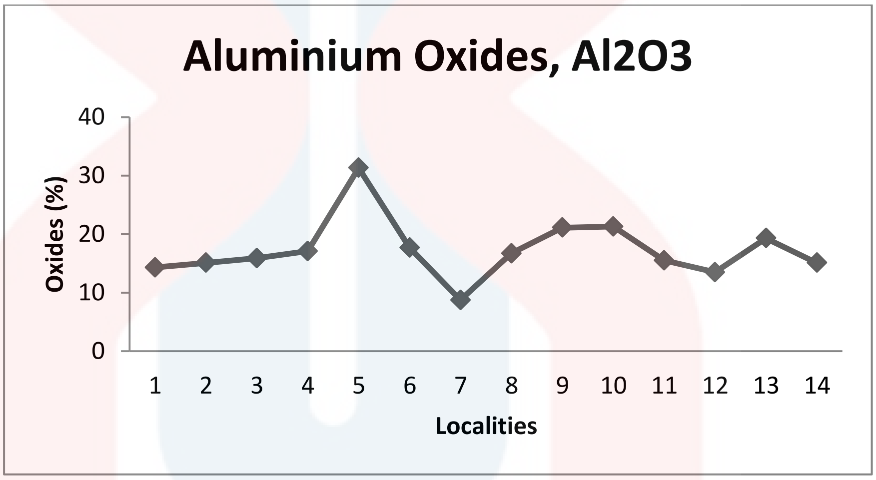


Figure 5.4: Graph of percentage of Al_2O_3 in soil of 14 locations.

The concentration of aluminium oxides is the second highest composition within the study area. The percentage concentration of the Al_2O_3 is the highest at the location 5 while the lowest at the location 7. The percentage concentration is between ranges 8.74 to 31.3. Then, location 9 and 10 showed the same concentration of the aluminium which is 21%. Both sample was taken at alluvium area believe that aluminium transported and deposited in the river. The colours of the soil are greenish brown and have clay properties. The aluminium solubility is controlled by kaolinite reactions of alkalinity production. The clay properties of the soil are caused by the destruction of feldspar by CO_2 in the river that leaves aluminium in clays.

c) Iron (III) Oxides, Fe_2O_3

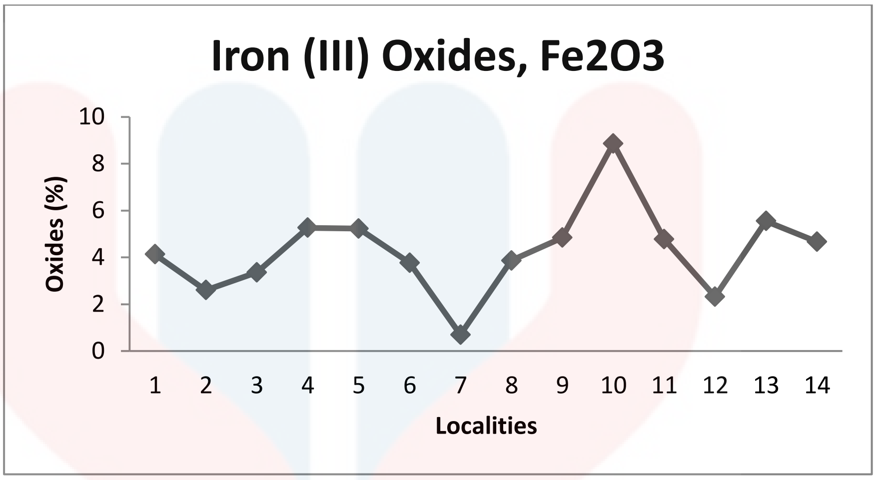


Figure 5.5: Graph showing the concentration ppm of Fe_2O_3 at 14 locations.

Fe_2O_3 is the iron (III) oxides where is showing the highest percentage at the location 10 with the concentration 8.86%. The high concentration of iron in location 10 may be resulted from high intensity of weathering since ferric iron easily substitutes into the tetrahedral site of alkali feldspar which many types of granite turn reddish upon incipient weathering. When exposed to the atmosphere at low temperature, Fe is normally oxidised to Fe3+. The colour of the soil reflected the Fe content, which are higher redder soils the higher Fe content. The lowest percentage shows at the location 7 with the value 0.698%. The concentration of iron is low at location 7 maybe because of the lithology nearby which is marble. Also, this is because of the low intensity of weathering.

d) Calcium Oxides, CaO

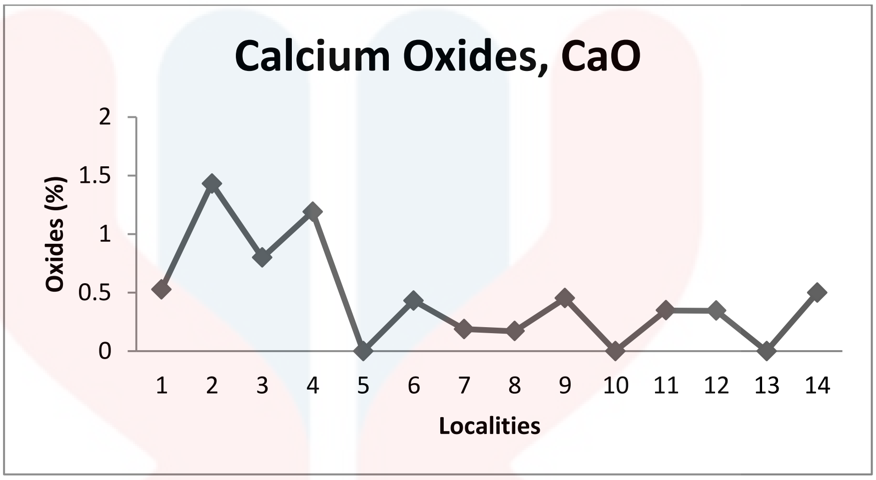


Figure 5.6: Graph showing the distribution of the concentration of CaO at 14 different locations within the study area.

CaO showing the many different in percentage concentration of different location while there are three locations that did not yield any CaO oxides. Location 2 shows the highest concentration of CaO percentage with value 1.43%. This is because it is surrounding by the weathered igneous rock. The weathered igneous rock resulted in high concentration of calcium in the form of alkaline earth element. Calcium formed also formed from the calcic plagioclase in the igneous rock. The weathering intensity is high at location 2 and calcium is mobile elements that form from the interaction with water. The mineral from igneous rock such as plagioclase, pyroxene and amphibolite can easily weathered by water equilibrated with CO_2. So, the high Ca content shows that the plagioclase feldspar were present in the parent rock.

There is no concentration of calcium at location 5, 10, 13. This is because of the factor of the lithology there since the lithology at these locations is metamorphic rock. Feldspar may have the content of Ca but the intensity is very low.

e) Potassium Oxides, K_2O

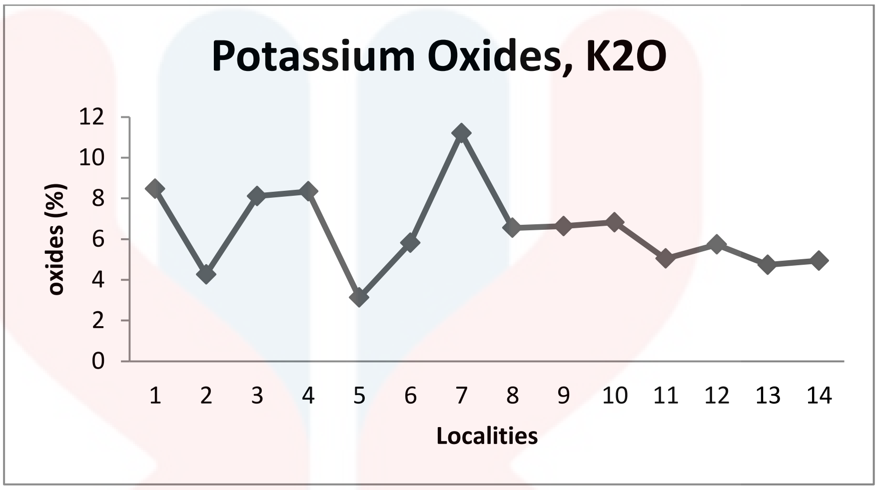


Figure 5.7: Graph showing the ppm concentration of K2O at14 different locations at study area.

From the graph, location 7 shows the highest concentration of K_2O while locations 5 yield the least concentration of K_2O. The value of the highest concentration is 11.2% while the lowest value 3.12%. At location 8 and 9 the intensity of the Potassium is nearly the same which ranging about 6% until 7%. The concentration of potassium at location 8 and 9 is near the same where this is shows that the lithology is carbonaceous rock. From the geological mapping, there lithology found at these location is interbedded of hornfels and marble. The factor of lithology influence the potassium concentration since potassium is depleted in the earth with respect to carbonaceous.

At location 7, the lithology found is schist and marble, so the traces of high potassium because of the mica present at the location. Weathering also the factor that influence where feldspar reacts with water where location 7 is sampled near the river. Anthropogenic which is human activity is also one of the factors in high concentration of K_2O. for example, potassium is used in agriculture activity, so it is believed that the potassium content may leached or transports by water and wind and deposited in the soil nearby.

5.2.2. Rock Coating Properties

8 localities of sampling points on rock coating have been done for characterisation of colour, topography, microscopic images and shape as well as correlate with types of coating presence. All the interpretation of geographical scales is influenced by the microscopic imagery and the elemental data obtained. From the observation, the rock coatings even thinner than 0.010 mm, its altered the appearance of almost all of the rock surfaces of the parent rock in the study area. The control on thickness may vary by the type of coating for example case hardening is thicker than dust films. There are few types of coating that commonly found which influence by the parameters from the surrounding environment and also the type of parent rock. For example, from the naked eyes observation, estimated there are at least about five types of coatings found within the study area. In another example, the lithobiontic like lichens are normally associated with the rock weathering. The general appearance varies quite a bit ranging from almost transparent to opaque material of rock coating. Also, may cause by the moisture condition and the underlying rock surface and the weathering and erosion level.

From the Figure 5.8, the textural features of coated rock fragment are schist with only minor amounts of fine materials. From observation of naked eyes shows that the coatings are thin surface deposited of dark fine material typically reactions from clay minerals, Mn, Fe oxides and the trace elements. Manganese and iron is form in early stages of magmatic crystallization then it oxidised as Mn and Fe is easily oxidised and giving rise in concentration at the earth's surface. The colour ranges from orange to black in colour because produced by variables concentrations of different manganese and iron oxides. The grey colour of the parent rock was covered by the brown-black coloured of the rock coatings. Clays mineral form flat hexagonal sheet similar to the micas where can be seen in Figure 5.13. (a). Clay minerals are common weathering products especially feldspar. The thickness of coating is about 2 mm. They typically form over long periods of time as a result of chemical weathering such as leaching through upper weathered layer of silicate-bearing mineral.

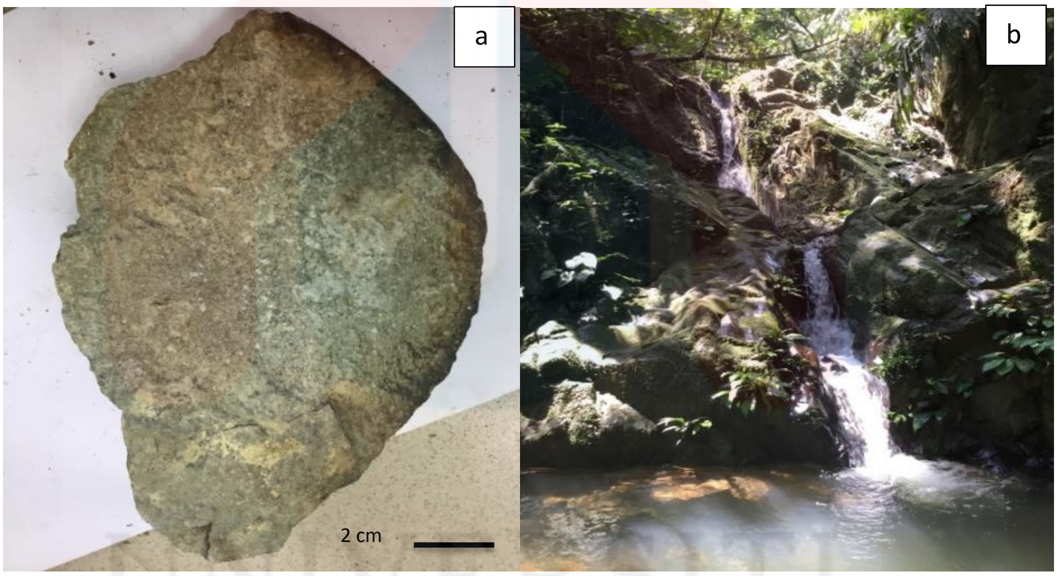


Figure 5.8: The rock varnish. (a) The thin dark coating of rock varnish type on schist can be seen on hand specimen. (b) The schist outcrop that have rock varnish coating.

Based on Figure 5.9 colour of the coating is dark brown to black with the thickness about 2 mm which indicates that the type of coating is case hardening coating. Case hardening form from the addition of cementing agent to rock matrix material which the agent comprised of manganese, sulphate, carbonate, silica, iron, oxalate. The type of rock is quartz-rich granitoids so the composition of silica is high. The common rock forming silicate mineral is weathered by hydrolysis process then deposit of the surface of rock. The iron bearing mineral such as iron and manganese is also weathered and deposited on rock surface and combine with other weathering product to form case hardening. Close up SEM images (200X) shows the coarsely crystalline manganese oxide in the case hardening. The SEM images are the combination of sulphate, silica, manganese and iron minerals characteristics.

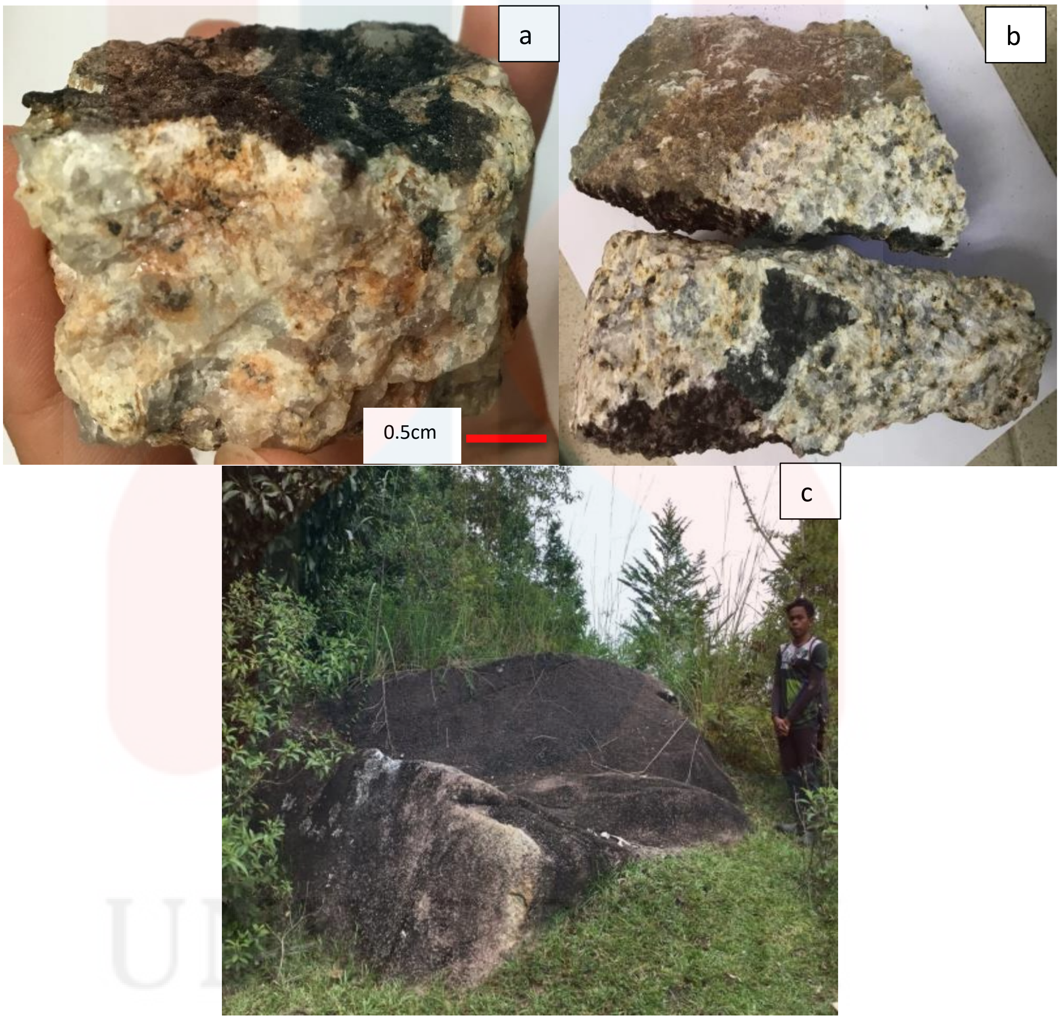


Figure 5.9: Case hardening on alkali feldspar granite. (a) The sample of granite with case hardening coatings. (b) The hand sample of granite with case hardening at different angle. (c) The outcrop of granite that cover by the case hardening.

Figure 5.10 shows the physical features of the rock coating on the schist rock. The colour of the coating is light brown with very thin thickness of coating which believes about 2 microns. The light powder of clay and silt sized particles attached to the rough surface of schist an in the rock fractures. The composition in the dust film is clay mineral which resulted from the chemical weathering process and precipitation process. The characteristic of the SEM images showed that the sheet of clay minerals, it is very common in soils, and in fine grained metamorphic rock such as schist. Also, dust component have uniquely and irregularly shaped form agglomerates, have a preferred orientation can be seen in SEM images.

Figure 5.10: The dust film of Schist rock. (a) Hand specimen of schist that covers with dust film. (b) Shist that coated with dust film. (c) The outcrop of schist that located at Sg.Tadoh.

From the Figure 5.11, the colour of the coating ranging from dark green , brown to black. The thickness of the coating is about 1 mm. The organism forming rock coatings for example lichens, moss, fungi, algae, and cyanobacteria. The surface of the rock form a thin surface which is can consider as organic mat because of the composition is comprised of living orgnanism. The SEM images analysis indicated that and abundance of P and Ca in microorganisms in the black regions, associated with some trace elements. The coatings form resulted from the interaction between minerals and microorganism that play the role in biochemical weathering. The phosphorus content may come from the anthropogenic activity such as agriculture, where it use fertilizer for the plant. There are 3 elements contain in fertilizer such as nitrogen, phosphorus and potassium. Pottasium may be leached by precipitation and dispersed throughout the area. The combination of microorganism and the various biominerals can be seen in the scanning electron microscopy image.

Figure 5.11: The lithobiontic coatings on marble. (a) Closer-focused on lithobiontic coating at marble. (b) The marble hand specimen which coated with lithobiontic coating. (c) The outcrop of marble which covers by biological weathering and coated by lithobiontic coatings.

Futhermore, based on the observation of Figure 5.12, the textural features of the rock coating is very fine grain. The thickness of the coating estimated about less than 1mm. The colour of the coating is light brown-orange. The types of coating is believed the iron films because of the characteristics that of the coating. Iron films composed primarity iron oxides or oxyhydroxides. The iron oxides material may comes form the process of chemical weathering such as oxidation and the leaching of iron-bearing minerals. The colour at the outcrop scale brick orange which indicates that the presence of iron oxides.

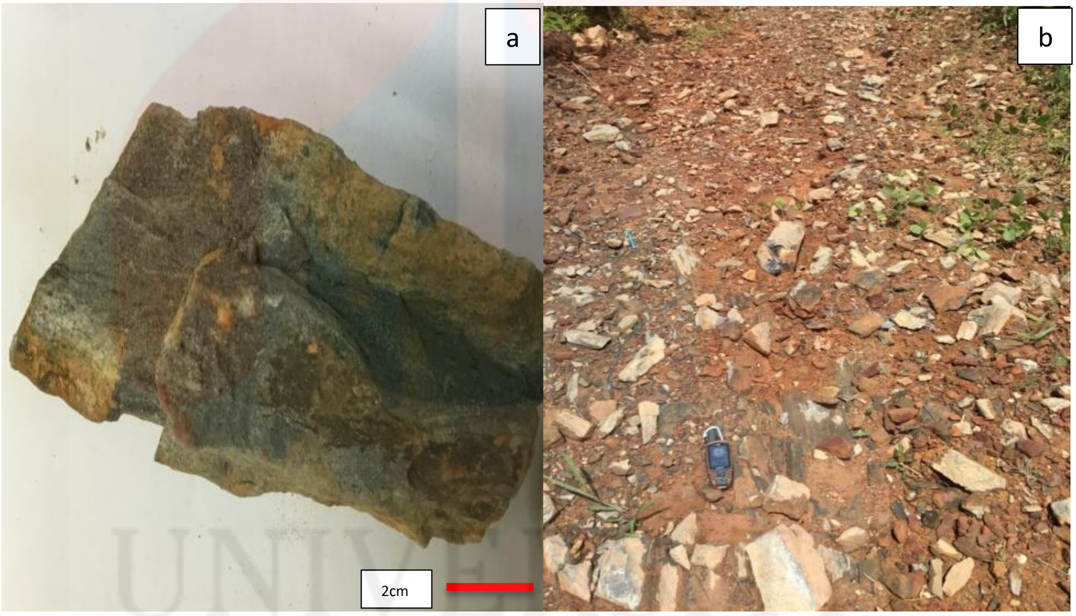
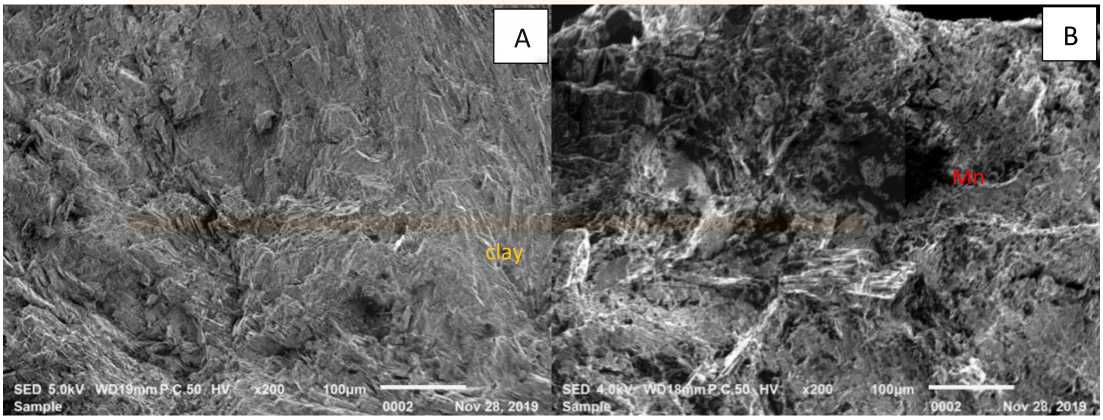


Figure 5.12: Iron films on the schist. (a) hand specimen that show iron films. (b) Outcrop that have iron films and have high weathering rate.



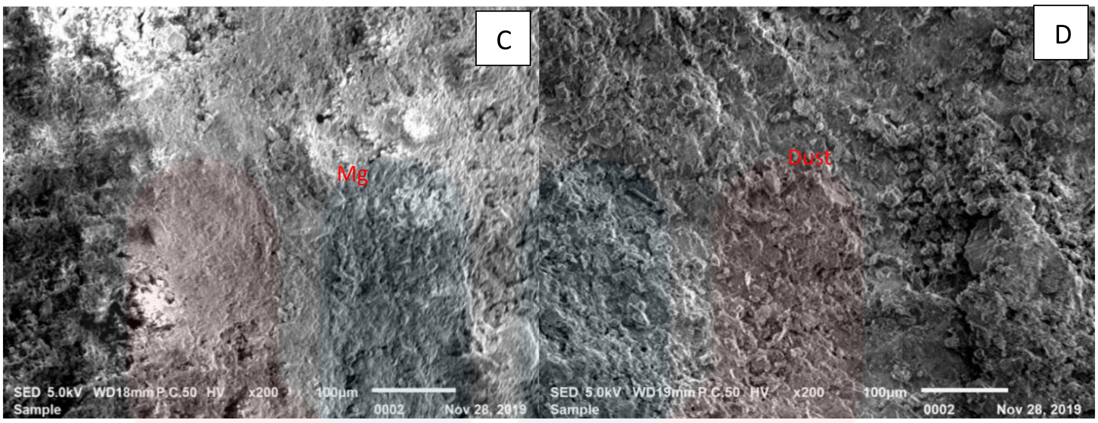


Figure 5.13: The backscattered electron micrograph of rock coating samples. Magnification images of SEM analysis (200X). A) Rock Varnish at schist. The shape of the clay mineral is sheet-like. B) Case hardening at quartz rich granitoids where its shows shape of Mg is monoclinic-prismatic. C) Oxalate crust at hornfels. Images of silica contain on oxalate crust. D) Dust film on schist. Dust uniquely and irregularly shaped form agglomerates, have a preferred orientation.

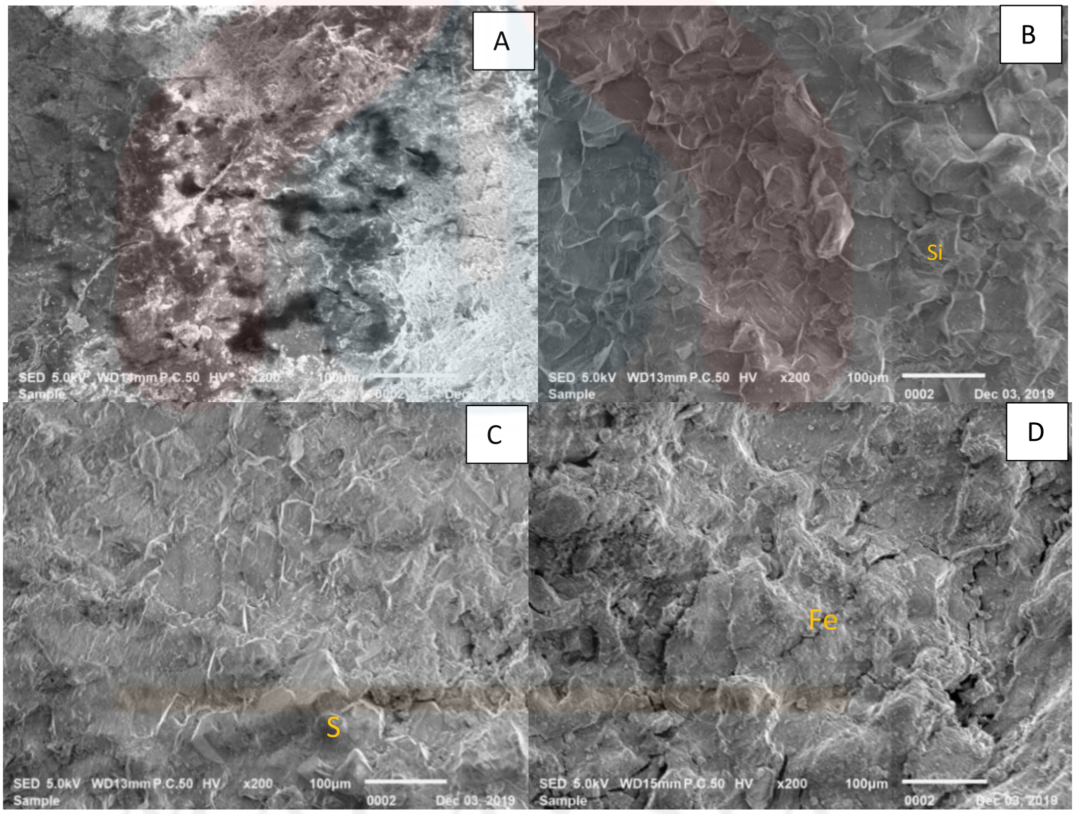


Figure 5.14 : The backscattered electron micrograph of rock coating samples. The magnification images of SEM analysis (200X). A) Coating on Alkali feldspar granite. B) Coating on felsic rock. Crystal system of Si is Hexoctachedral class. C) Coating on marble. Orthorhombic-dipyramidal of sulphide mineral. D) Coating on meta-quartz arenite, schist.

5.3 Discussion

The types of coatings are resulted from the lithology of the area, the weathering types, intensity, and acidity from precipitation and more. Form these factors the relationship between the petrographic analysis and the percentage of the oxides in the soil samples is discussed. The diversity of the rock coating was explained by the weathering stage of the area which affected the physical properties of the coatings. The coatings always occurred on exposed surface of a rock with mats of coatings such as dust films, iron films, oxalate crust, rock varnish, case hardening and lithobiontic coatings. These are the common types of coating which analysed from the study area with respect to the lithology and the weathering stage; those are relevant for the formations of coatings which mostly contain Fe, Al and Si. These oxidation and the reduction reactions directly precipitate minerals or produce chemical species as waste products that may combine with ions in the environment to produce minerals.

From the XRF data Fe, Al and Si comprised a major portion of mineral fraction of the soils including the primary and secondary minerals. Positive factors suggest that the rapid weathering process such as oxidation, leaching of feldspar and the hydrolysis which control the high percentage of Fe, Al and Si among the other oxides. The typical weathering product of feldspar mineral is clay minerals, potassium, sodium and calcium. For example, from the XRF data percentage of the aluminium, silica in station 9 and 10 follow the database information of the feldspar composition which proved that there is the presence of feldspar mineral in the soil. Form the petrographic analysis, the feldspar mineral can be found in the composition of the lithology at station 9 and 10. Other than that, type of weathered rock have been determined by these compositions and the grain size of the soil which shows the silty material believed comes from the leaching process of feldspar. Based on Figure 5.15 the feldspar mineral can be found presence in the thin section specimen form station 9 and 10.

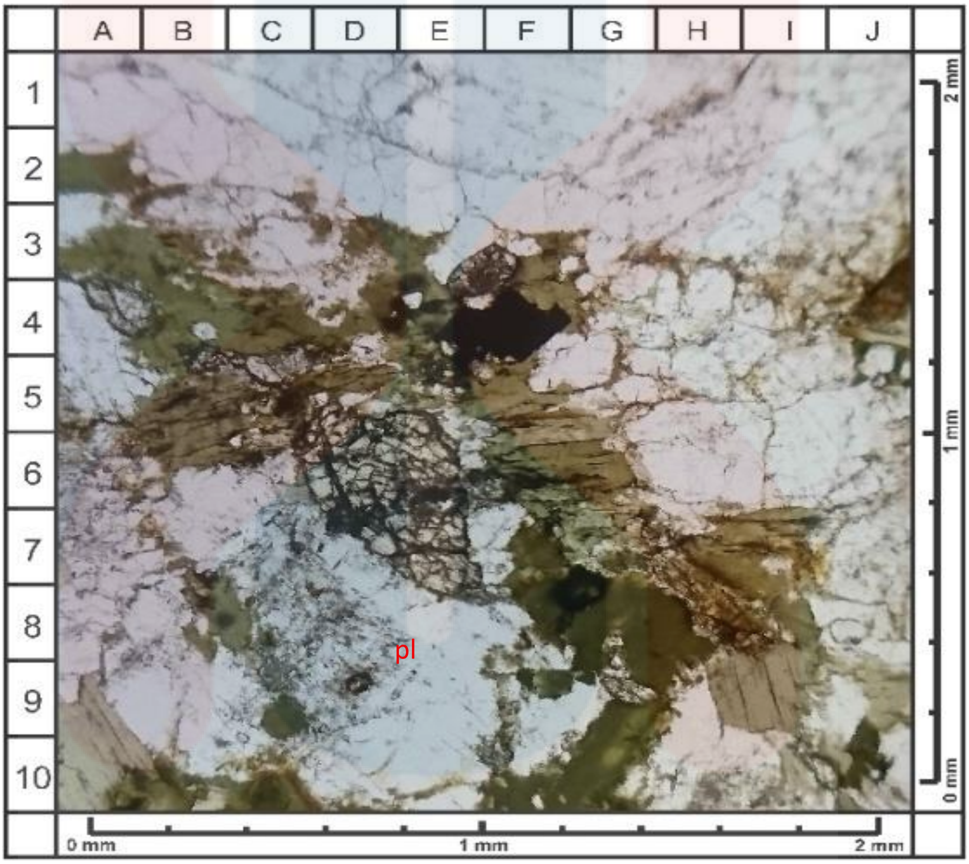


Figure 5.15: The plagioclase feldspar mineral can be found presence in the thin section of the quartz-rich granitoids (E8). The colour of the feldspar is white in PPL.

The types of the coatings formation of certain localities is influenced by the percentage of oxides in soil, petrographic analysis and the types of weathering. The dark brown to almost black colour of the coatings layer formed because it is made up of clay particles combined with mineral deposits of iron and manganese oxides. This is probably believed wind-blown or water transport material that settled on the surface of the rock because of the high composition of Fe, Al and Si oxides in the area. The rock coating may also accrete on rock surface where the interaction between rock and the sulphuric acid from the precipitation. The environmental exposures and inputs to these coatings, determines the coating mineralogy that formed on parent rock. The physical and chemical characteristic of rock coatings shows that there is a change of climate where rock coating can change the surface of the rock. Rock coating is internally layered due to a depositional process resulting from climatic changes. These micro laminations can occur over wide regions and correlate with major paleo-environmental regimes which are alternating dry periods produced orange layers and wet period produces black layers. (Liu, 1994).

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

From the geological study, there are 4 types of formation found in study area with the youngest rock is Kemahang granite followed by Tiang schist then, Mangga formation and the oldest formation is Telong formation. The major forces that affected the deformation of the study area is at direction NE-SW. The lithology and the environment yielded a significant increase in diversity of rock coating. The type of coating have the certain processes and occur at varies micrometre to millimetre scales on earth where the influences of coating formation is exposures of parent rock to the land surfaces, habitation of microorganism, lichens, transport of raw material to sustain rock coating and the biogeochemical barriers. 5 types of coating which covers the study area are rock varnish, dust film, iron film, case hardening and lithobiontic coatings. The properties of rock coating in term of petrography analysis, microscopy image and shape are able to relate with the major composition of oxides in soil, the petrography analysis of rock and the environment which can be a record of climate change. The characteristic of rock coating mineralogy, colours along with process of biogeochemical offers the evidence on the climate changes.

6.2 Recommendations

Rock coating is one of the geological sectors that do not have enough attention from the community. Therefore, more studies about rock coating should be taken into consideration to open up people's mind about the unique of the formation and its advantages. Also, the study or mappings on rock coating distribution by using remote sensing are advised to do. Other than that, use more specific geochemical method such as Energy Dispersive X-ray (EDX) which can helps in the interpretation on SEM images. This is important to analyse the microscopic detail on rock coating and can act as good evidences on justification. Try to make more research on rock coating and variety such as weathering rinds, rock varnish because to get more used for the researcher on the important of rock coating study in many aspect for example geomorphology, arts, construction and many more. Furthermore, use EDX analysis to be more precise on the element component on the rock surface to prove the estimation on the characteristic the types of rock coating. Other than that, the discussion on relationship on rock coating with the climate changes with that change in the rock surface is need to get more understanding on the topic. Also, improvement on SEM data can be done by using coloured images on SEM analysis to get more accurate data on rock coating because the colour of each detail can show different facts. Last but not least, the comparison between uncoated and coated rock can be done to analyse the factors that affected the situation.

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