GENERAL GEOLOGY AND SLAKE DURABILITY INDEX FOR DIFFERENT LITHOLOGY OF ROCK AT KAMPUNG RENYOK JELI, KELANTAN

by

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DECLARATION

I declare that this thesis entitled “General Geology and Slake Durability Index Test for Different Type of Lithology of Rock at Kg Renyok, Jeli, Kelantan”is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ______________________________

Name : ______________________________

Date : ______________________________

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General Geology and Slake Durability Index Test for Different Type of Lithology of Rock at Kg Renyok, Jeli, Kelantan.

ABSTRACT

Research was conducted around Kampung Renyok area which covered approximately 25km². The purpose of this study is to produce geological map at scale 1,25000, to determine slake durability index of rock and to relate slake durability index of rock with different weathering grade classification. The study area composed of rock from granite, gneiss, metasedimentary, limestone and sandstone. Every type of rocks, igneous, metamorphic, sedimentary have different strength and its own durability. The durability of rocks depends on degree of weathering that changes the texture and mineralogy content of rock. Sensitivity of rock types against weathering can be determined by using durability parameter called as slake durability index that proposed by Franklin and Chandra (1972). Test was conducted with collecting 11 samples of granite and gneiss near Renyok waterfall area and 5 sample of sandstone near Felcra Reka area. The result of durability index from the test is used to determine durability classification and identify weathering grades. From the laboratory test, the range index durability value for granite samples is 98.11% to 99.05% in grades II, for gneiss samples 98.53% to 99.18% also in grades II, and for sandstone samples is 96.06% to 98.97% in grades II and 87.56% to 94.90% in grades III. It conclude that low value durability of rock caused the weathering grades increased. From the result obtained, granite and gneiss have almost same durability index value but different in texture and mineralogy content. For sandstone, it composed of different durability index value that are caused from its texture condition which nearly weathered during collecting the sample.

Geologi Umum dan Ujian Indeks Keperoian untuk Litologi Batuan yang Berbeza di Kampung Renyok, Jeli, Kelantan

ABSTRAK

Kajian telah dijalankan di kawasan Kampung Renyok yang mempunyai keluasan kira kira 25 km^2. Tujuan utama kajian ini dijalankan ialah untuk menghasilkan peta geologi yang berskala 1,25000, untuk memperoleh nilai ketahanan batuan, dan mengaitkan indeks nilai ketahanan sesuatu batuan dengan klasifikasi gred luluhawa yang berbeza. Kawasan ini mempunyai jenis batuan daripada granit, gneiss, metasediment, batu kapur, dan batu pasir. Setiap jenis batuan, igneus, metamorf dan sedimen mempunyai kekuatan berbeza dan ketahanannya yang tersendiri. Ketahanan sesuatu batu bergantung kepada darjah proses luluhhawa yang menukarkan tekstur dan komposisi mineral dalam batuan. Tahap sensitif batu terhadap proses luluhawa boleh di kenalpasti menggunakan ketahanan parameter yang dikenali sebagai indeks keperoian yang diperkenalkan oleh (Franklin dan Chandra, 1972). Ujian telah dijalankan dengan mengambil 11 sampel dari granit, gneiss di air terjun Renyok dan 5 sampel batu pasir di kawasan Felcra Reka. Keputusan yang didapati daripada ujian digunakan untuk klasifikasikan ketahanan batuan dan menentukan gred luluhawa terhadap batuan. Daripada ujian makmal, nilai indeks ketahanan untuk batuan granit ialah 98.11% ke 99.05% di gred II, untuk batuan gneiss adalah 98.53% ke 99.18% juga di gred II, dan batuan pasir 96.06% ke 98.97% di gred II dan 87.56% ke 94.90% di gred III. Didapati batu yang kurang ketahanan mempunyai gred luluhhawa yang tinggi. Dari keputusan ujian, granit dan sabak mempunyai nilai ketahanan yang hampir sama tetapi berbeza dari segi tekstur dan kandungan mineral. Manakala untuk batu pasir, ia mempunyai pelbagai nilai ketahanan disebabkan oleh keadaan teksturnya yang separuh terluluhawa.

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LIST OF ABBREVIATION

N	Number of Sample
Id1	Index Durability after first cycle
Id2	Index Durability after second cycle

CHAPTER 1

INTRODUCTION

1.1 General Background

Geology is the study of Earth process, how geological structure are formed and what material its produce. Geological map is produce by record the observation made such as geological mapping to understand more about the process and lithology involved. According to Lucy M. Njue (2010), geological field mapping is the process of selecting an area of interest and recognize all the geological aspects of that area with the intention of preparing a detailed geological map. Generally, geological map contain information about the type of rock, geomorphology of study area and structure involved at study area.

In geology field, engineering geology is the one of the sub-discipline. With the knowledge in geology, factors such as good location for construction can be assured by the engineering geologist for further development at specific target area of project. In geotechnical investigation involved with surface and subsurface structures, the evaluation of durability and deformability of rock and rock mass frequently most needed.

The durability of rock depends on weathering stage where it have close relationship with physical, chemical and mechanical properties of rock and their degree of weathering. The weathering process change and modifies the mineralogy and texture of the geological materials and thus the process of weathering may be considered to be one of the greatest sources of the potential difficulties in geotechnical engineering.

In order to use the engineering application for construction, certain criteria are need to be considered such as rock material properties and rock mass properties. Rock material properties means properties of rock itself while rock mass properties is the strength of the rock mass. Thus, to prevent or to avoid dangerous things happen at the construction area, the rock durability must be measured. The one of the method used to measure the rock material durability of weak rock is slake durability index test.

Slake durability index test has long been used to identify the durability and water sensitivity of rocks as subjected to engineering requirements under in-situ conditions. The test has widely accepted also had standard by the American Society for Testing and Materials (ASTM) in 2001 and International Society for Rock Mechanism (ISRM) in 1981. Several investigators have utilized this method with a common goal of correlating the rock durability, and sometimes durability with the chemical or mineral composition and the state of weathering.

1.2 Problem Statement

In Malaysia, the study of durability of rock and weathering profile is essential and the need to understand the behaviour of the rock strength and weathered are vital for further development to be carried out in particular areas. According to Ibrahim Abdullah and Jatmika Setiawan (2003), Renyok waterfall consist of unique rock formation which composed of metasedimentary enclaves with leucogranite intrusion that have potential to form as geo-tourism area. The development can be done at this place such as chalet or recreational park that need to further investigation to the durability and stability of rock condition at particular area. Weathering process effect the durability of rock, cause rocks have different weathering grades. This research is concern with the investigation the durability and weakness of rocks, and also identify weathering grade of rocks by measure it using slake durability index test. The durability of rock subjects to degree of weathering. The degree of weathering can influenced the stability of rock in engineering application. Therefore, the need to understand the durability of rock and weathering grades is essential.

1.3 Research Objectives

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

ii. To determine slake durability index of rock found at study area.

iii. To relate durability index of rock with weathering grade classification.

1.4 Study Area

1.4.1 Location

The study area is located at Kampong Renyok, Jeli Kelantan. Kampong Renyok is located around 14 KM from main town which is Jeli and around 132 KM from Kota Bharu. The citizen here use the water supply from two main rivers which is Pergau River and Sam River. In the study area also consist of recreational place or potential geo-tourism place, known as Renyok Waterfall, which consist of unique lithology and also have mini hydroelectric use to supply the electricity to surrounding area. The longitude of study area is 101°52’0.0”E until 101°55’0.0”E and latitude 5°34’30.0”N until 5°37’15.0”N. The study area covered around 25km^2 and composed of Kampung Renyok, Kampung Tebing, Kampung Rangka Lama and Baru, and Kampung Chegar Bedil. Figure 1.1 shows the base map of study area at Kampong Renyok, Jeli Kelantan.

1.4.2 People Distribution

The number of people distribution based on Malaysia data collected in 2010 shows that in Kuala Balah district, the total number of distribution of people is 10,385. In study area, the total of population is around 3299 both male and female, and this number of residents maybe decrease and increase from time to time due to migration of people. Table 1.1 shows the population of Kuala Balah district and Renyok area.

Table 1.1: Total population by sex, households and living quarters district/state, Malaysia (Majlis Daerah Jeli, 2011)

District	**Population**			**Households**	**Living Quarters**
	Total	**Male**	**Female**		
JELI	39,170	20,362	18,808	8,318	9,122
Batu Melintang (Belimbing)	8,456	4,419	4,037	1,682	1,854
Belimbing	6,678	3,509	3,169	1,344	1,491
Kalai	1,778	910	868	338	355
Jeli	20,329	10,622	9,667	4,382	4,847
Kuala Balah	10,385	5,281	5,104	2,254	2,421
Bunga Tanjong	2,229	1,138	1,091	465	485
Kuala Balah	4,857	2,452	2,405	1,099	1,178
Renyok	3,299	1,691	1,608	690	758

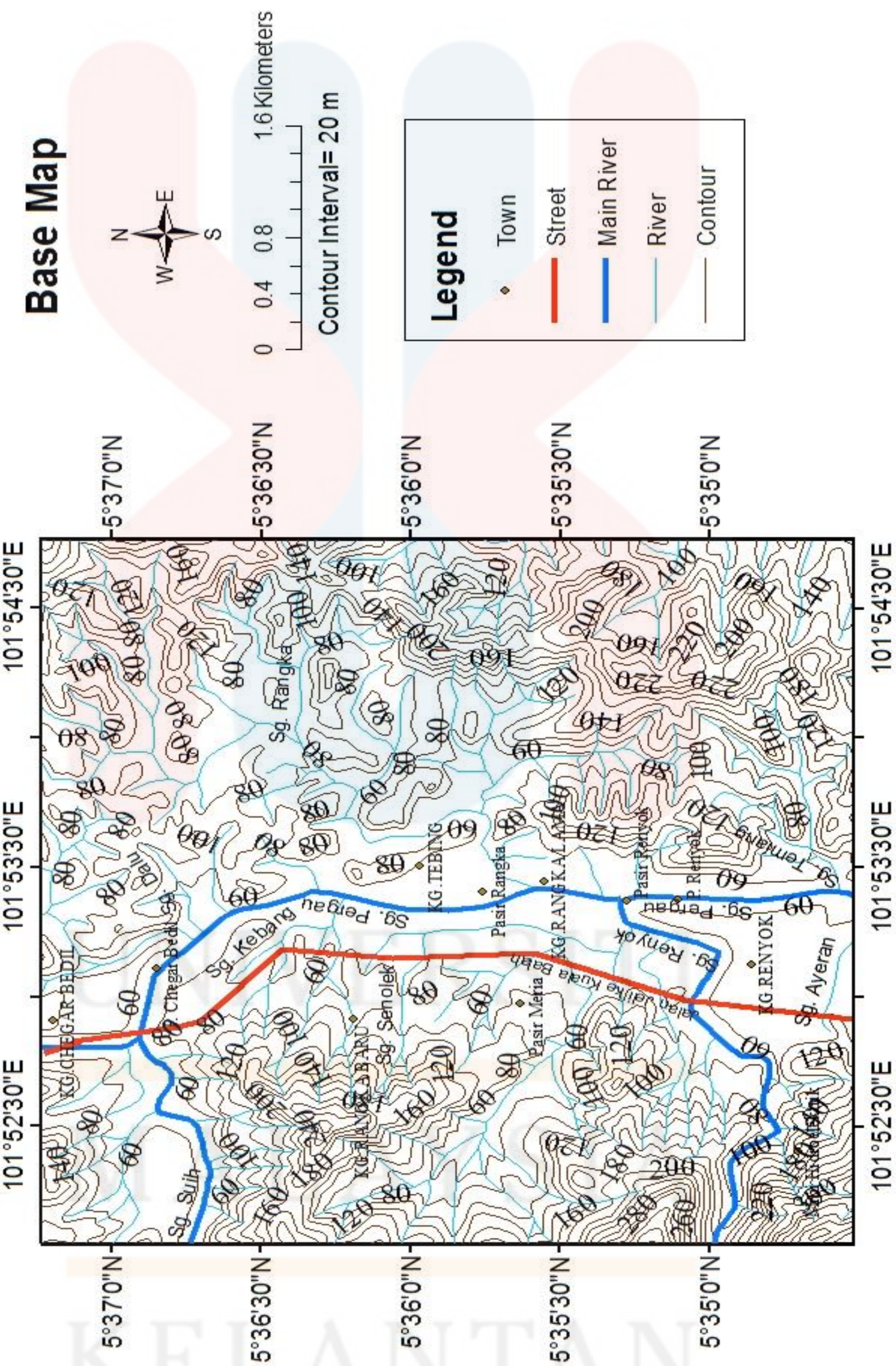


Figure 1.1: Base map of study area at Kampung Renyok.

(Source: JUPEM, 2006)

1.4.3 Rainfall Distribution

Malaysia known as tropical country that have unique rainfall pattern and characteristics than other countries in the world which may rain throughout the year. Major flood event especially in Kelantan caused from Monsoon season start from November to February and Table 1.2 clearly show flood happen in December. This situation may lead to weathering and erosion process that cause the formation or interaction to weak rocks. This rain distribution result is collect in 2014 by JPS (Jabatan Pengairan dan Saliran) Kelantan.

Table 1.2: Volume of rain precipitation distribution of Kelantan (JPS Kelantan, 2014)

Station	Month												Total (mm)
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	
Jeli	432.0	6.0	225.0	245.0	368.0	251.0	198.0	446.0	301.0	451.0	442.0	1542.0	4907.0
Dabong	178.0	0.0	16.0	0.0	146.0	129.0	56.0	427.0	258.0	227.0	262.0	967.0	2666.0

1.4.4 Land Use

For soil use at the study area, it is mostly covered by forest which is about 50% of the study area. Plantation such as rubber tree at the study area is about 20% and 10% palm oil tree since the study area is near alluvial plain. About 15% is covered by the development such as house and other 5% are covered by road, and mixed farming such as banana and corn. Figure 1.2 (a) and (b) show palm oil and rubber tree plantation found at the study area.

a) Palm oil plantation

b) Rubber tree

Figure 1.2 (a) and (b): Palm oil and rubber tree plantation at the study area.

1.4.5 Social Economic

Majority residents at Kampung Renyok are either self-employed or working on government sector. The residents that work on government sector mostly as teacher, clerk and others. While residents which are self-employed mostly work as a rubber tapper, or in agricultural sector, for example in mixed farming. This is because plantation cover most of the soil use at the study area.

1.4.6 Road Connection

Figure 1.3 shows the main road that can be accessed to the study area, Kampung Renyok. The main road of the study area is connected Jeli to Dabong. The study area accessed by using this road. Kampung Renyok is located about 19 km away from the Jeli town. It also located 37 km from the town of Kuala Krai Dabong, and can acess city center via Jalan Kuala Krai Jeli-Dabong Sam Rivers, Kuala Krai or via Jalan Gua Musang, Jeli-Jelawang-Gua Musang. Map in Figure 1.4 shows road connection in Kampung Renyok area

Figure 1.3: The road access to the study area.

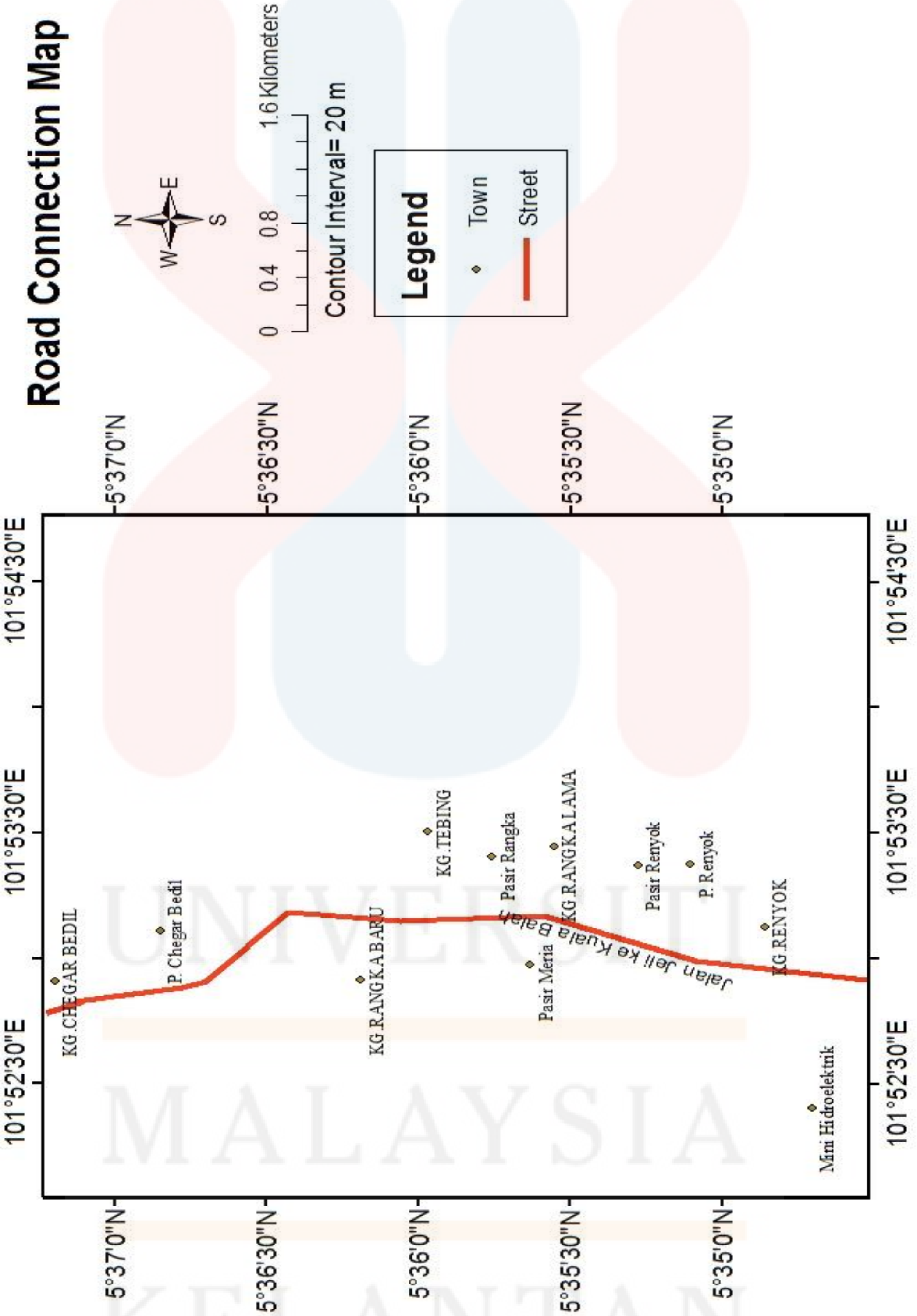


Figure 1.4: Map of road connection of study area.

(Source: JUPEM, 2006)

1.5 Scope of Study

The scope of study for this research in terms of geology is to produce geological map of study area. With the geological map, it can give an information about the lithology, structural geology, and geomorphology at the study area such as topography and drainage pattern. In terms of engineering geology, it focuses on the investigation the durability of rock and relate it with weathering grade profile by using slake durability index test value. This test method covers the determination of the slake durability index of rock and also to access the resistance offered by a rock sample towards weakness and disintegration when subjected to standard cycles of drying and wetting cycles with abrasion. Three types of rock used in this study are igneous rock composed of granite, metamorphic rock composed of gneiss and sedimentary rock composed of sandstones commonly encountered at study area, were collected from the field for the laboratory testing. The laboratory testing, slake durability index testing followed as much as practical ASTM standards and ISRM Suggested Method.

1.6 Research Importance

By doing this research study, the geology characterization of the weak or weathered rock such as their durability and weathering grade at the study area can be obtain. When the durability and weathering grade of the rock are identified, it can give the data about the behaviour of rock at the study area, and in engineering geology, it can give the information weather it is suitable or not for further the development at Renyok waterfall area and also excavation activity at Felcra Reka area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter summarizes the results of literature review carried out to improve an understanding of general geology, durability of rock and also weathering grade. The topics reviewed here include the factors influencing the rock weathering and laboratory test methods that can be correlated rock durability and its resistance.

2.2 Regional Geology and Tectonic Setting

Eastern Belt, Central Belt and Western Belt is three of belt from Peninsular Malaysia. Within this belt, it consists their own geological development and characteristic. The boundary between Central Belt and Eastern Belt are separated by Lebir Fault in Kelantan to the south of Johor (Ibrahim Abdullah, 2004). At the east of Kelantan, it consist of granites from Main Ranges Granite and Boundary Range Granite, and at central zone consist of sedimentary and metasedimentary rocks bordered on the west.

At the central zone, there are granitic intrusive and it is more prominent at Kemahang Pluton, Ulu Lalat batholith and Stong Igneous Complex. These belt of granite and country rock continue to the regional geology of north Pahang and also have a north-south trend. The Boundary Range Granite is overlain by the coastal alluvial flat of Sungai Kelantan at the east. According to Goh et al., (2006), the youngest rocks of Jurassic Cretaceous continental rocks overlie the boundary Range Granite. According to Azman A.Ghani et al., (2002) the granitic and other igneous rock of Central Belt from a narrow and well defined line of single plutons emplaced into Permian-Triassic rocks.

Based on S. Senathi et al., (1977) the Boundary Range Granite are extend from the Kelantan alluvial plain in the north near Gunung Gagau. The Boundary Range Granite is the largest and most prominent granitic formation form from Terengganu – Kelantan boundary with about 138km long and 20km width. The bulk of Boundary Range Granite consist of granodiorite and granite. According to Mustafa Kamal Shuib and Azman A.Ghani (2003), the granitoid and other igneous rock of the Central Belt of Penisular Malaysia from a long, narrow,and a well- defined chain of plutons. Based on Azman A.Ghani (2005) the granites have been divided into two provinence which is Westren provinence that comprises from granites confined to the Western Belt and Eastern provinence that consist of granites from both the Eastern and Central Belt. Figure 2.1 shows the general geology map of Jeli district.

2.2.1 Stratigraphy

Kelantan is situated in the Central Belt, the oldest rock are those located in the eastern part of Main Range Granite. Central Belt is largely underlain by rocks in Mesozoic and Permian. Central Belt is mainly from marine Permian and Triassic rock that consist of shales, sandstone, limestone and volcanic. Taku schist may consist of older rock such as metamorphosed Carboniferous. The term of Taku schist, named by the origin of Sungai Taku have been introduced by MacDonald (1967) that used to describe the sequence of metamorphic rock cropping out in Kelantan.

For this study area it's located at Kampung Renyok that consisted of plutonic and metasedimentary rock which is part of Migmatite Stong Complex. It is situated at the northeastern part of Stong Complex and found within Kenerong Leucogranite plutons. Metasedimentary enclaves, which is the country rocks, are considered to be Permo-Carboniferous to Early Triassic, is a part of Gua Musang Formation. Varieties of structures developed in both leucogranite vein and metasedimentary enclaves are very striking as had been described by Singh et al. (1984).

2.2.2 Structural Geology

According to Ibrahim Abdullah and Jatmika Setiawan (2003), at late Cretaceous, Kenerong Leucogranite, a component of the Stong Complex exposed near TNB mini power station, at Renyok waterfall, Jeli, Kelantan consists of a sequence of leucogranite vein and metasedimentary enclaves. Here, variations of structures developed in both rock types. Structural studies indicate the rocks here had undergone at least four phase of deformation (Ibrahim Abdullah and Jatmika Setiawan, 2003). It is interpreted that the first deformation (D1) with the compression from ESE, which was responsible in the development of foliation and reverse faults was related to the regional stress system during the Late Cretaceous time.

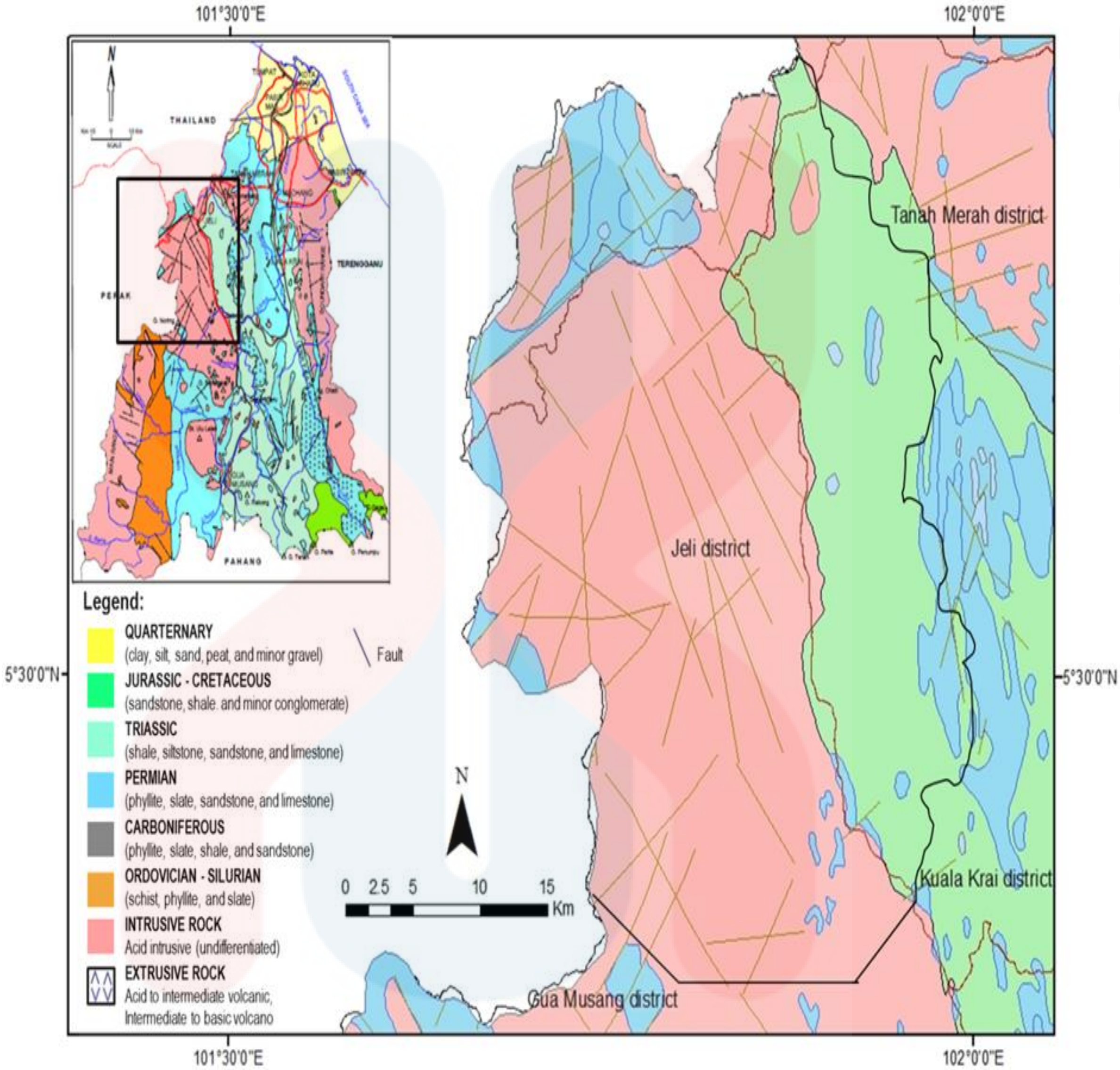


Figure 2.1: General geology map of Jeli district.

(Source: Department of Minerals and Geoscience, 2003)

The formation of lateral faults system, pinch-and-swell, boudinage, drag folds and small-scale kink folds during the second and third deformation (D2 and D3) with the compression from NE sector might be related to the stress system that were generated by the emplacement of the younger granite in the vicinity. Ibrahim Abdullah and Jatmika Setiawan (2003) also state that the fourth deformation (D4), which was responsible for the normal faulting by the reactivation of the pre-existing faults, was probably related to the relaxation period after the granite intrusion of the area.

2.2.3 Historical Geology

The Central Belt is overlain by Permian-Triassic clastics, volcanic and limestone. The Taku Schist that composed of amphibolites, phyllites and schist occupy on the northern part and central part of Central Belt. In the late Triassic, oregenic uplift cause the rest of Central Belt terminated the marine sedimentation. Between Central Belt and Western Belt, Central Belt are more abundant in intrusive of mafic and ultramafic (Azman A Ghani, 2005).

2.3 Slake Durability of Rock

Rock have different time to undergo weathering process, for example, when rock being exposed to the water and climate changes, hard rock takes long time to weathered and low durability rock disintegrate within a short time period from days to several years. This loss of strength is not reversible under normal conditions whereas in cohesive soils it is possible due to changes in water content (Marion et al, 2006). From Figure 2.2, it show the process of weathering takes place that change the hard rock to (cohesive) soils and over the geological time, it undergo the cementation process that change the (cohesive) soils to hard rock through diagenesis and metamorphism activity. In engineering geology, weak rock, also known as low durability rock can lead to the slope failure at specific area or construction area. Example of rock that has low durability is rock that have highly weathering grades which easily broken to pieces. The main cause that influence the durability of rock is weathering process.

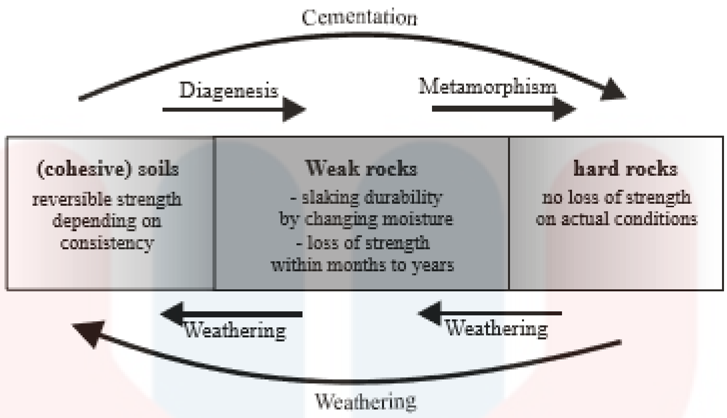


Figure 2.2: Position of weak rocks between cohesive and hard rocks.
(Source: Marion et al., 2006)

To investigate or characterize the durability of rock and their durability to the weathering process, the important geotechnical parameters can be used is slake durability index test. Slake durability is the one method that suitable to measure the rock durability and also for studying weathered rock. Franklin JA et al., (1972) established a method of a standard cycle of drying and wetting for determining the slake durability index and proposed a classification of soil and rock slake durability. Yamaguchi H et al., (1988) studied the slake durability of the rock associated with rock absorbing water and their environmental temperature. The slake durability test is used to evaluated the influence the rock that has been altered from weathering process by measuring their resistance to change and breakdown when subjected to wetting and drying cycles.

According to Didi S. Agustawiyaja (2003), for rocks containing clay materials, the exchange of cations and anions take place with the adsorption and absorption of water which makes the rock swell in size and slaking occurs. The wetting process, within ten minutes may only take for parts of the rock, generally for the surface part but due to appropriate rotation speed and the level of the water most of the parts of the rocks get wet.

The reduction of capillary tension at grain contacts and the tips of cracks are result from rock that become saturated after water menisci within the rock pores increase (Didi S. Agustawiyaja, 2003). Due to pores condition which increasing in water content, the fracture may develops in the rock which leads to the weathering of rocks. This test mechanism seems suitable for rock that have porous behaviour. Water certainly influences the mechanical characteristics of rock.

The slake durability test, not only wet-dry conditions are given to the rock specimen, but also involve with the mechanism, which is the drum rotation. These mechanisms have not been explored. Mechanisms factors may be influenced to the weight and shape of the specimen. Therefore the main objective of the study is to determine the slake durability index of the rock samples rather than analysing the mechanisms of the specimen.

The rocks has different durability and durability of a rock can be define as their resistance to breakdown under weathering process over the time. To summarize how slaking of the rock form, based on G.F. Ayakwah et al., (2009), it form from the swelling of clay minerals when contact with water. Thus, the result of durability of the rock can measure by slake durability index test. Based on Fookes et al., (1972) slake durability index test give quantitative information on the mechanical behaviour of the rock according to the amount of clay and other secondary mineral produce in them due to exposed to weathering.

There are many different rock type within the group of weak rock, from soft sandstone to claystone, all of these rock showing strongly different behaviour. The types of slake durability are, right after water supply, spontaneous has been decay into small fragment (grains and aggregates), decay into aggregates after desiccation and dehydration such as precipitation within days to weeks, and slow degradation into aggregates in months to years (Marion et al., 2006). Thus, the different type of slake durability leads to different effect for the construction cycle including stability, transport or reassembly of excavated materials.

2.4 Weathering of rocks

Process of weathering usually takes long time to react for example from hundreds to thousands years, and the total time taken to rock and mineral exposed at the surface of the earth influence the degree to which they have weathered. Weathering in general is a group of processes by which surface rock disintegrates into a smaller particles or dissolves into water due to the impact of atmosphere and hydrosphere (Abramson et al., 1995). The process of weathering are divided into three types, which are chemical weathering due to chemical changes, physical or mechanical weathering that influenced by temperature change, wind, erosion by the rivers and streams and biological weathering caused by animals and plants. Chemical weathering process is defined as breakdown of minerals into new compound by the action of chemical agent such as acid in rain, air and rivers. Mechanical weathering is a process by which rock that broken down into a pieces by physical forces for example wind and temperature change. Biological weathering is the weakening and subsequent disintegration of rock by plants, animals and microbes.

The initial process of weathering that conclude by Moon, V. et al., (2004) the rock fracture by the physical process followed by secondary mineral process will reduce durability of the rock. Environmental agents such as climate or plant growth that vary from place to place throughout the time, and upon properties of the rock material and rock mass are the reason for weathering to occur. For the rock material, mineralogy, grain size, porosity and permeability are used to determine sensitivity or resistance to weathering. Figure 2.3 show the rock cycle three different type of rock.

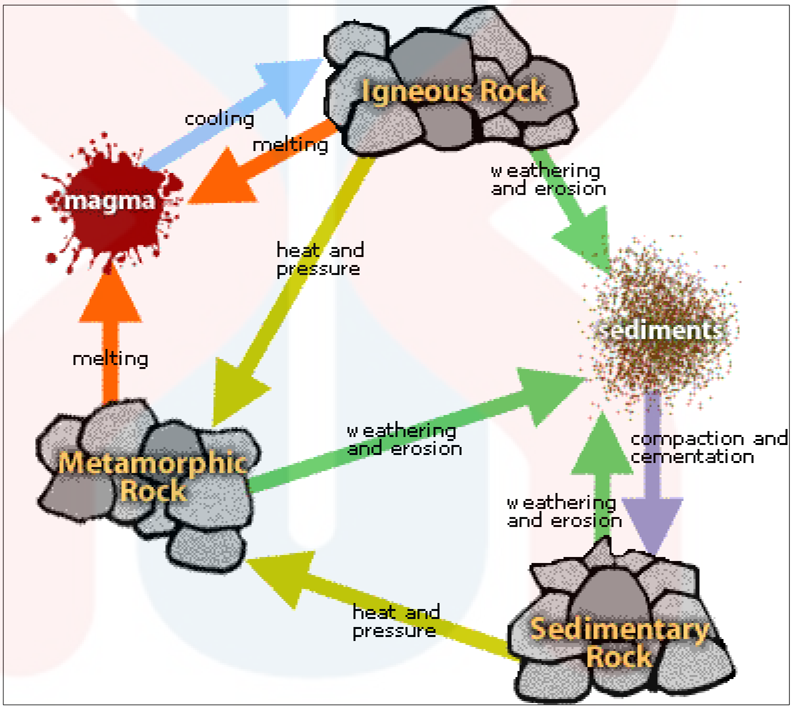


Figure 2.3: The rock cycle where igneous, metamorphic and sedimentary rock undergo variety of processes to form new kind of rock and mineral.

(Source: Wheeling Jesuit, 2004)

2.4.1 Sedimentary Rocks

In coarse grained clastic sedimentary rocks, the weathering probably least complex. The porosity of sedimentary rocks are influenced by the grain packing and quantity of cement. Mudrocks such as mudstones and shales that contained silt and clay size particles are commonly laminated and closely jointed. In geotechnical engineering, out of all rocks, the most that have to pay more attention is mudrock. The surface of the rocks that weathered have cracks results from greater frequency of integral discontinuities, as well as cracks produced by cyclic wetting and drying, while final weathering product is a soil usually of clayey character.

2.4.2 Igneous Rocks

Differences in grain size and mineralogy in igneous rock produced different resistance to weathering. Coarser grained rock, example in granite tend to weather more readily than any aplitic intrusions that contained within pluton while fine grain is not necessarily indicative of high resistance to weathering. Coarse grained igneous rock, granites, has been given attention to describe the weathering because these granites often quite well exposed and before weathering, relatively uniform.

2.4.3 Weathering in Rock Engineering

Weathering process is the factor of change the rock strength and also that cause reducing of rock strength. According to Ibrahim Komoo (1995), strength of the rock is very much dependent on the degree of weathering that it has undergo. The type of weathering, can be important depending on climate, elevation, temperature and variations. Parent rock play an important role in the composition of the weathered materials because it give the clue either it transported or residual soils. According to Goodman (1993), the rate of weathering depends on the rock type, composition, climate, temperature and the elevation. Figure 2.4 shows the effect of temperature and rainfall on weathering based on (Kehew, A.E. 1995).

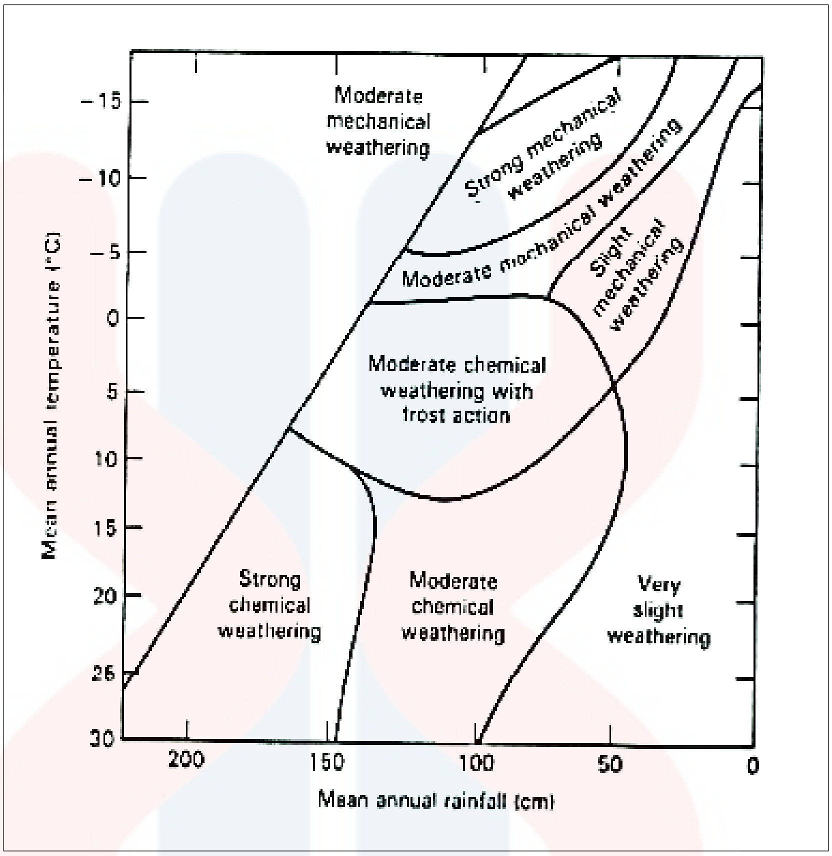


Figure 2.4: Type of weathering processes influenced by climatic change.

(Source: Kehew, A.E. 1995).

The engineering properties of a rock change if weathering takes place. Determination the degree and pattern of weathering in or on site exploration are most important things need to be done to avoid geologic hazard happen in weathered areas such as block movement or landslides. In rock engineering, the study of rock behaviour is important such as the study that involve with various level of rock within the weathered zone. It can give information to the engineers about the location and elevation of the structures and also to select the types of foundations.

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

This chapter focused on materials and methodologies that was used in this research. The materials that used in this research was list wisely as shown in Table 3.1 because its play an important role in conducting geological mapping. For the method, to get the precise result, method was carefully studied on the previously research, and organized every steps properly and follow the step until the right result obtained.

In methodologies part, it divided into two parts which are field mapping or geological mapping and GIS (Geographic Information System) study. For the geological mapping, it is used to complete the general geology part such as structural, geomorphology, stratigraphy and lithology. While for the GIS study, it focused on lineament, drainage pattern, land use and contour.

After the mapping completed, the samples was undergo the laboratory test that involved thin section test and slake durability test using the machine. When the result from laboratory test was obtained, then proceed to the data analysis which comprising structural analysis, thin section analysis and slake durability analysis. Figures 3.1 show the methodologies flowchart of the research.

3.2 Materials

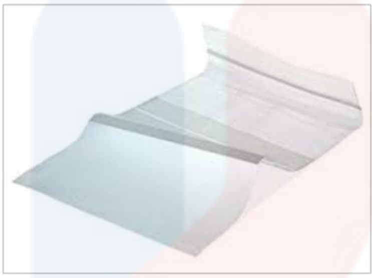
Materials that used during the research project, show in Table 3.1.

Table 3.1: Materials that used in the research project.

Materials	Explanation
a. Base Map	Important thing in this study research, to locate where the study area. The data of the map is obtained from Mineral and Geosciences Department of Kelantan.
b. Field Equipment	Geological Hammer -Basic equipment and tools that used by geologists in  collecting sample. Compass -In order to measures the strike and dip such as bedding plane, joint and fault, the compass is used.  Global Positioning System (GPS) -Use to measuring elevation of outcrop and tracking the traverse. 

Sample Bag

-Use to keep the sample after took it from the outcrop.



Measuring Tapes

-Use to measuring the outcrop. For example height, length and thickness of the bedding.

Hand lenses

- This instrument uses for analysis the rock before get detail Information about the rock appearance and the mineralogy contain.

c.	Software-Geographic Information System (GIS)	Data that obtained from Mineral and Geoscience Department was used to produce map using this software.
d.	Slake Durability Machine.	Machine for laboratory test which used to determine durability index Id2 of rock sample after being subjected to two wetting and drying cycles. 

3.3 Methodology

3.3.1 Preliminary Studies

Preliminary studies is the study of research contains information that needs to be verified. Conducting preliminary research involves choosing a topic that is interesting and give initial overview of the study area that was done by observation of topographic map and references from the library and internet. The reference of the researches was obtained from the journal or bulletin that related to the research tittle and study area.

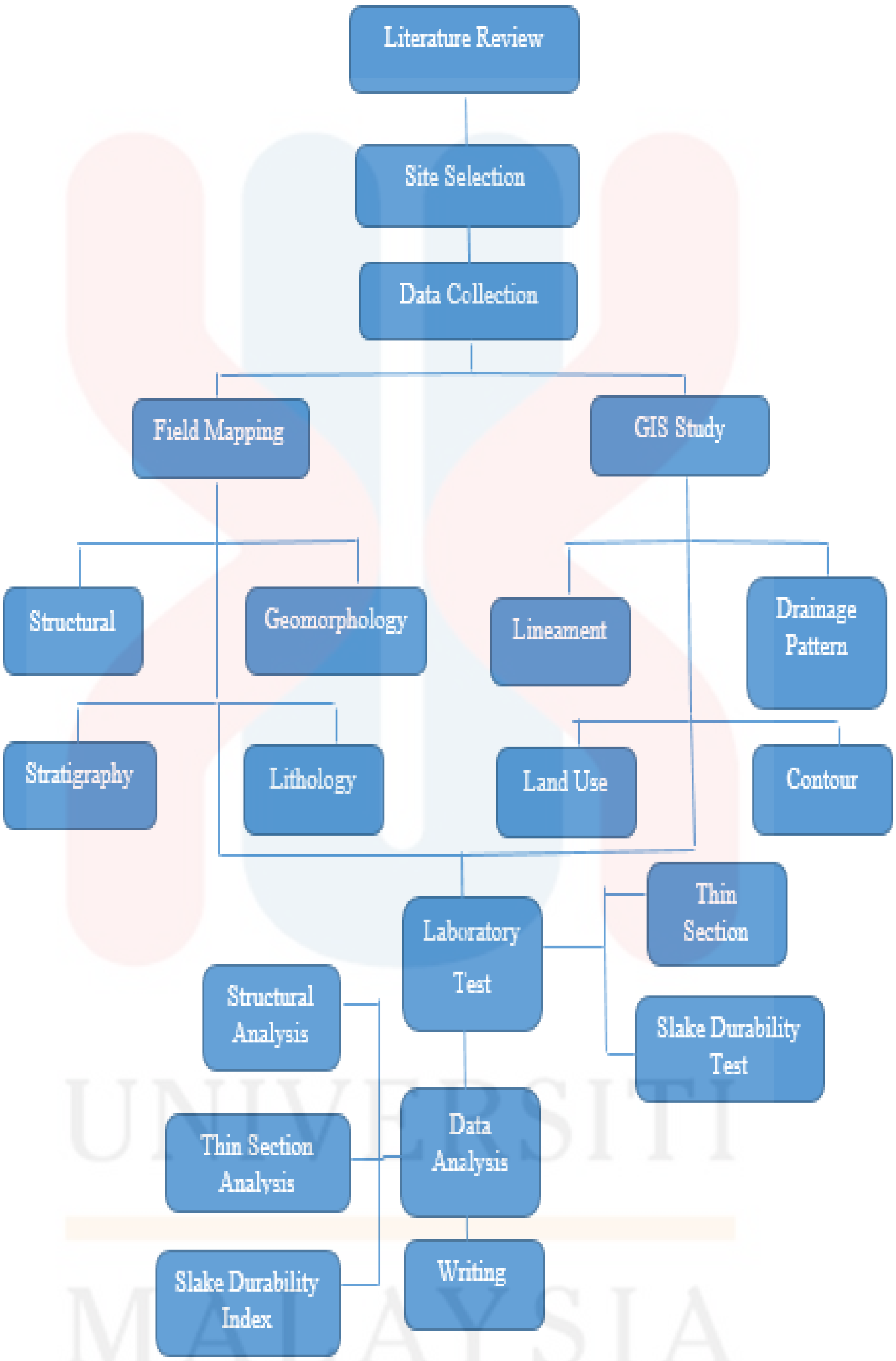


Figure 3.1: Flow chart of the research project methodology.

3.3.2 Field Studies

The main purpose of doing field study is to get detail information about the study area such as lithology, geomorphology at the area, stratigraphy, structural geology and others that related to the study area for further interpretation. The methodology that was used was geological mapping by collecting the data such as joint, strike and dip, also collect the outcrop samples at the study area used for laboratory test purpose, and while traverse the road it tracking by using geological positioning system (GPS). The data and information obtained from the field study was used to produce geological map of the study area.

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3.3.3 Sampling

Collecting the sample in field mapping is an important things because it can help in interpretation and give more information about the study area. For this research, sampling collection was done by collect the rocks sample such as igneous, metamorphic and sedimentary rock around the study area. Figure 3.2 show the map of the sample collection at the study area. A total number of 16 samples from study area were used in this experiment composed of 6 samples of granite, 5 sample of gneiss and 5 samples of sandstones. A minimum of ten rock pieces or fragments for one type of rock are prepared for each test used in laboratory and further analysis. Table 3.2 (a), (b) and (c) show the samples description and coordinates that was mark by using Geographical Positioning System (GPS).

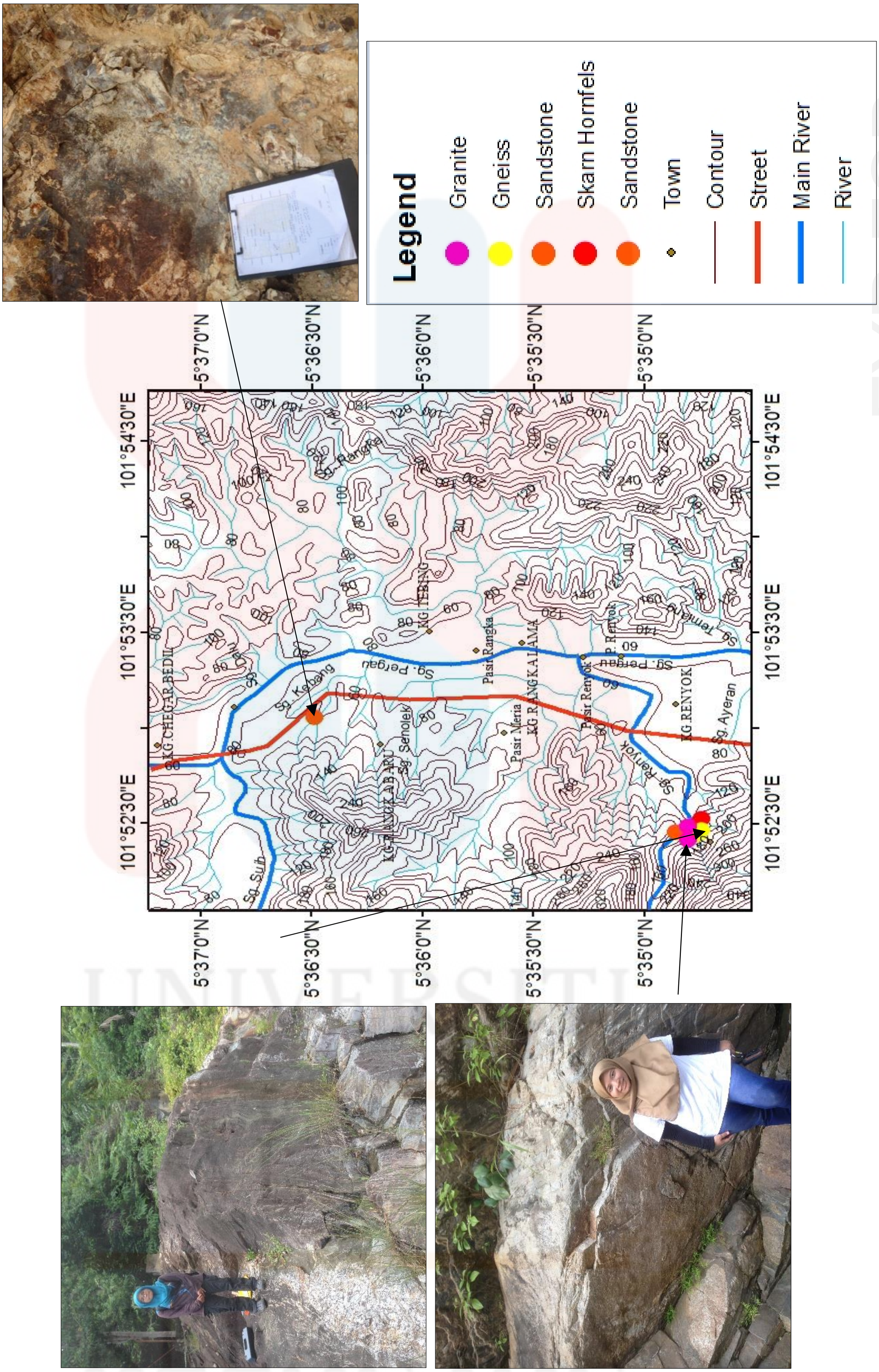


Figure 3.2: Map of sample collection for slake durability test at the study area.

(Source: JUPEM, 2006)

Table 3.2 (a): Sample location for granite rocks that was collected at the study area.

Sample	Location	Weathering Grade (Before laboratory test)
S1	N05°34'45.1 E101°52'28.8	I
S2A	N05°34'46.4 E101°52'27.5	II
S3A	N05°34'46.1 E101°52'28.2	II
S4B	N05°34'44.1 E101°52'29.0	II
S5B	N05°34'44.2 E101°52'28.3	I
S5A	N05°34'46.2 E101°52'28.4	I

Table 3.2 (b): Sample location for gneiss rocks that was collected at the study area.

Sample	Location	Weathering Grade (Before laboratory test)
M1	N05°34'38.0 E101°52'28.9	I
M2	N05°34'39.4 E101°52'28.3	II
M3	N05°34'39.1 E101°52'28.3	I
M4	N05°34'40.1 E101°52'27.3	I
M5	N05°34'41.9 E101°52'28.8	I

Table 3.2 (c): Sample location for sandstones rocks that was collected at the study area.

Sample	Location	Weathering Grade (Before laboratory test)
O1A	N05°36'30.3 E101°53'02.0	II
O2A	N05°36'30.2 E101°53'02.01	II
O3	N05°36'30.0 E101°53'02.01	I
O4B	N05°36'30.1 E101°53'02.0	III
O5	N05°36'30.2 E101°53'02.3	II

3.3.4 Laboratory Work

The slake-durability test is regarded as a simple test for assessing the influence of weathering on rock and its disintegration. For lab analysis, the slake durability test follow the method of ASTM (D4644), standard method for slake durability of shales and similar weak rock. This test measured the durability of weathered rocks in the service environment. This test method covers the determination of the slake durability index of a shale or other similar rock after two drying and wetting cycles with abrasion. Figure 3.3 show slake durability machine used in this research.

Figure 3.3: Slake Durability test apparatus.

The procedures involved are, rock samples about 10 fragments of each rock type with mass of 40-60 g were put into an apparatus that comprises two sets of drums of the length of 100 mm and the diameter of 140 mm. Figure 3.4 show the sample is placed in a clean drum before rotation. The initial weight of drum without lid is recorded as mass D. The samples with drum is dried in oven at the temperature 105°C to constant mass or requires 2 to 6 hours. The drum plus sample of mass A is then recorded as shown in figure 3.5. The samples is cooling before being tested. The two drums is placed to the slake durability machine and rotated in water that had a level of about 20 mm below the drum axis.

The rotation was driven by a motor capable of rotating the drums at a speed of 20 rpm, which was held constant for a period of 10 minutes. After slaking for the period of 10 minutes, these rock samples were then dried in an oven at a temperature of 105°C for 2 to 6 hours. Finally, the mass B of dried samples was weighted to obtain the first cycle. The test was conducted over two cycles, in which the weight of mass C in these wet-dry cycling tests were therefore determined.

Figure 3.4: The sample in a clean drum.

Figure 3.5: The sample with drum without lid is recorded.

For thin section, it used to determine the composition of mineral contain in rock sample by using microscope. Rock sample such as granite, gneiss, marble and metasandstones was collected from the study area to prepare for thin section for further interpretation. The result obtained from thin section analysis give the answer regarding exactly rock type and what kind of mineralogy that rock sample consist.

3.3.5 Data Analysis and Interpretation

Petrography analysis was done by identified mineral content through the observation of the thin section under the microscope. Example of mineralogy content are quartz, biotite, feldspar, hornblende, and plagioclase. After the petrography analysis for example by using QAP diagram was done, the name and type of rock sample was identified based on mineralogy content on the rock sample. Discussion and conclusion of this aspect was made.

For slake durability index analysis, it was done after two rotation of drying and wetting complete. Slake durability index classification are divided into two part, Id1 which is first cycle and Id2 is provide from second cycles. After slake durability index Id2 achieved, the sample classification are observed based on Gambles slake durability classification show in table 3.3. The classification of weathering profile for rock also obtained by using Id2 value. Table 3.4 shows weathering profile classification for rock based on (Ibrahim Kamoo and Jasni Yaakub, 1990).

Table 3.3: Gambles' Slake Durability Index Classification (Gamble, 1971)

Group Name	% Id1 (after first cycle)	% Id2 (after second cycles)
Very high durability	> 99	> 98
High durability	98-99	95-98
Medium high durability	95-98	85-95
Medium durability	85-95	60-85
Low durability	60-85	30-60
Very low durability	< 60	< 30

Table 3.4: Proposed weathering profile classification for rock (modified from Ibrahim Komoo and Jasni Yaakub, 1990).

Classification	**Grade**	**Slake Durability Index, Id2 (%)**
Completely Weathered	V	0% to 20%
Highly Weathered	IV b	20% to 30%
	IV a	30% to 80%
Moderately Weathered	III	80% to 95%
Slightly Weathered	II	95% to 100%
Fresh Rock	I	100%

The slake durability index (second cycle) is calculated as the percentage ratio of final to initial dry sample weights follows (Franklin and Chandra 1972): Slake durability index were calculate using Equation 1.

Slake durability index Id (1) = $\frac{B-D}{A-D}$ x100

Slake durability index Id (2) = $\frac{C-D}{A-D}$ x 100 Equation 1

Where;

A - The weight of the drum plus initially rock samples after dried to constant mass at 105°C temperature

B - The weight of sample plus drum after completing first cycle

C - The weight of the drum plus retained portion of the samples after second cycle

D – The initial weight of the drum.

3.4 Report Writing

All the geological data collected from the field and preliminary research was gathered to make the interpretation. Thesis writing constructed according to the chapter provided. Chapter one consists of introduction this research. The second chapter is the literature review and the third chapter is material and method was used in this study. Chapter four is the general geology and the fifth chapter contain result and discussion of specification for slake durability index test. The last chapter which is chapter six is the conclusion and suggestion for this research in the future research.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter focused on the general geology of the study area such as geomorphology, petrography of minerals, stratigraphy, structural geology and historical geology. General geology of the study area was done by doing observation at that place throughout geological mapping activity such as observe the geomorphology and structure involve at the area, collect the sample for laboratory analysis and traverse the study area using Geographic Information System (GPS).

The geological mapping is very important in geology to describe in detailed the process occurs at the study area, what kind of rocks exist and how it forms. Figure 4.1 shows the traverse map that was conducted through geological mapping activity at the study area. Based on mapping, the study area is covered mostly by forest with little plantation and development. Figure 4.2 shows land use the map at the study area.

The traverse at the study area was done by vehicles such as car and motorcycle that can be access using pave road and also by walking at the place that cannot be access by vehicles.

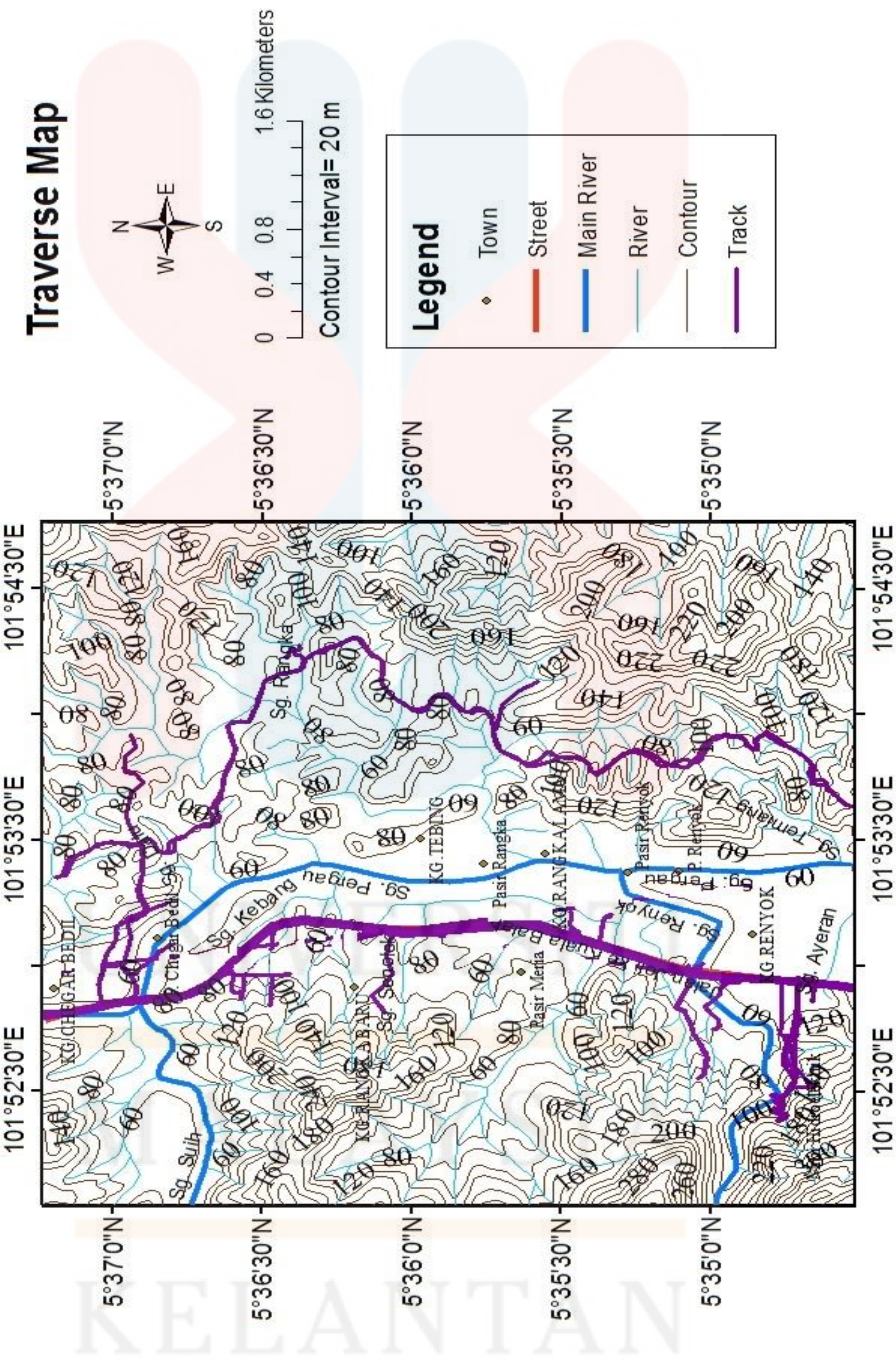


Figure 4.1: Traverse map of study area.

(Source: JUPEM, 2006)

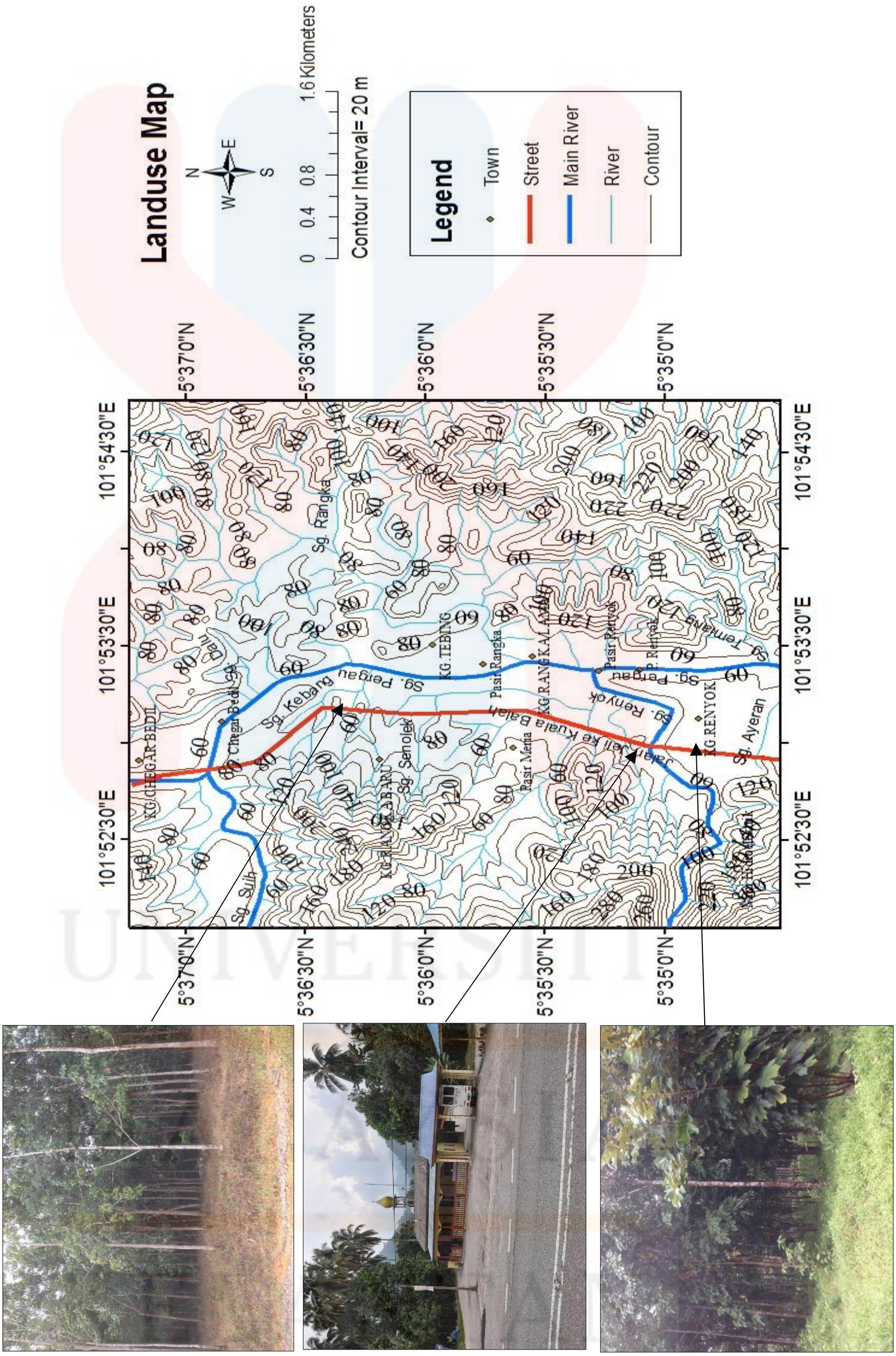


Figure 4.2: Land Use map of the study area.

(Source: JUPEM, 2006)

Based on figure 4.2, land use at the study area mostly covered by forest with plantation and development. Example the plantation occur in this study area mostly rubber plant, oil palm, corn, and mixed farming.

4.2 Geomorphology

Geomorphology is the scientific study of the origin and evolution of topographic and bathymetric features created by physical or chemical processes operating at or near the earth's surface. Also the study of landforms, their processes, form and sediments at the surface of the Earth. From this, it can seek the understands about why landscapes look the way they do, understand landform history and dynamics and also can predicts changes through a combination of field observation through the mapping. Figure 4.3 show the geomorphological map of the study area. It show the landform at the study area mostly composed of undulating and hilly area. In this chapter, geomorphology consist of observation and analysed topography map of landform, and drainage pattern.

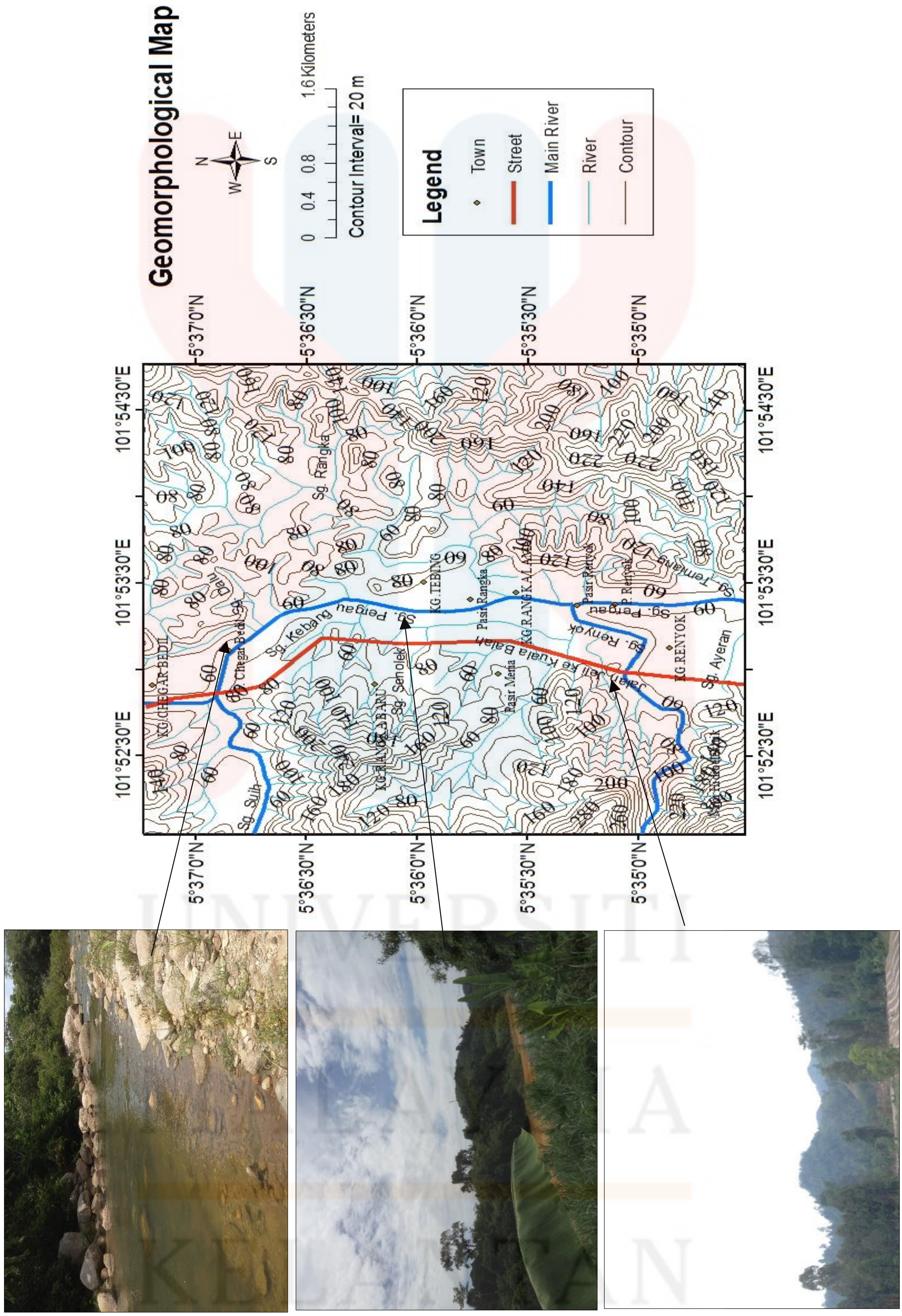


Figure 4.3: Geomorphological map of the study area.

(Source: JUPEM, 2006)

4.2.1 Topography

Topography is a map of the surface features of land includes the mountains, hills, creeks, bumps and lumps occurs on the earth surface. Topographic unit based on mean elevation consists of five units as shown in Table 4.1. The hilly to mountainous area (>76 m mean elevation) are marked by several continuous and discontinuous N-S to NNW-SSE trending belts, whilst the rolling and undulating areas (with mean elevations between 16 m to 75 m) are found within the belts of hilly to mountainous terrain, and between the inland hilly to mountainous terrain and the coast. Topography map in Figure 4.4 show the 3D elevation map at the study area that consisted of undulating, hilly and mountainous area. The low relief of this study area is about 60 meters and high relief is 380 meters.

Table 4.1: Topographic unit based on mean elevation, (Raj, 2009).

Description	Low Lying	Rolling	Undulating	Hilly	Mountainous
Mean Elevation	<15 meters under sea level	16-30 meter	31-75 meter	76-300 meter	>301 meter

Based on the table 4.1, it show that the study area consist of undulating area which range 31-75 meter, hilly area which range 76-300 meter and mountainous area which more than 301 meters of elevation.

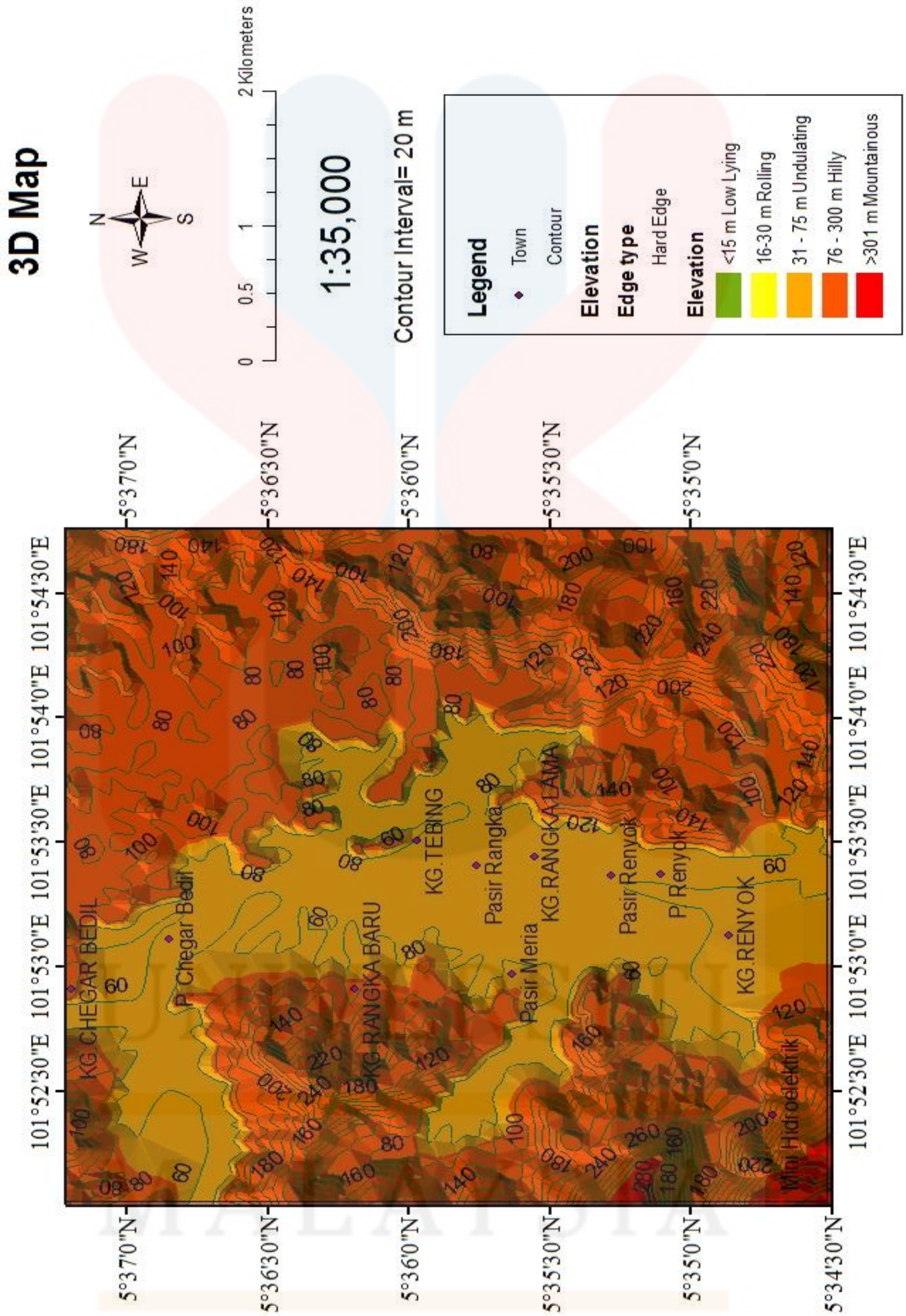


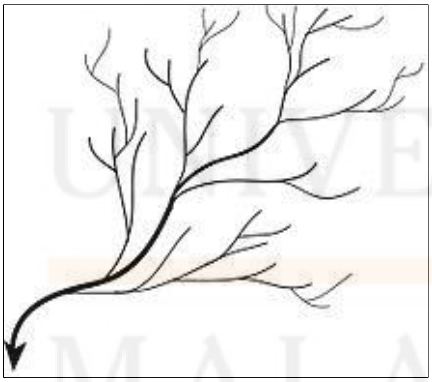
Figure 4.4: 3D elevation map of the study area, range from 60 m to 420 m.

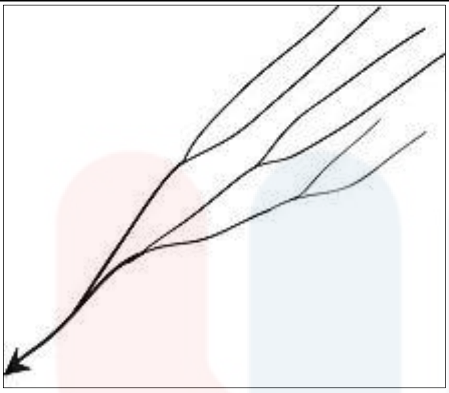
(Source: JUPEM, 2006)

4.2.2 Drainage Pattern

The Peninsula is characterised by a dense network of streams and rivers that can be attributed to its prolonged sub-aerial exposure as well as present-day humid tropical climate. The pattern formed by the streams, rivers, and lakes in drainage basin is called as a drainage system, also known as river systems. A drainage basin is the topographic region from which a stream receives runoff, through flow, and groundwater flow. Drainage patterns depend on the topography and geology of the land. Drainage pattern composed of different types of patterns and it form by different kinds of process. Table 4.2 shows the drainage basin pattern types based on (Pidwirny M, 2006).

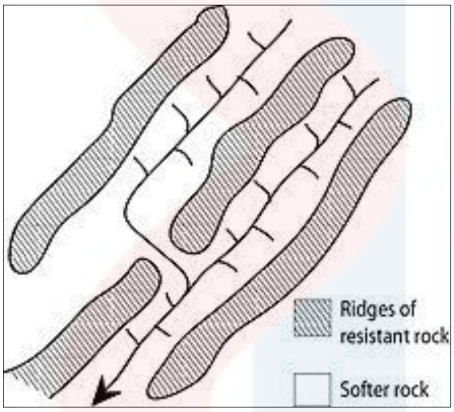
Table 4.2: Types of drainage pattern.
(Source: Pidwirny M, 2006).

Drainage Pattern	Description
Dendritic Pattern 	• Dendritic system consist of many contributing streams that joined together into tributaries of the main river. • Shaped like branches of a tree. • Form where the river channel follow the slope of the terrain.
Parallel Pattern	• Parallel drainage pattern is the type pattern of river that caused by steep slope with some relief.



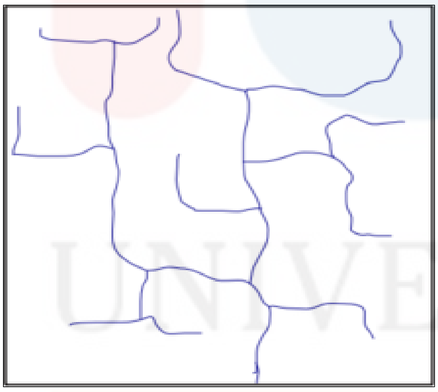
- Steep slopes caused the stream swift and straight, flow in the same direction.

Trellis Pattern



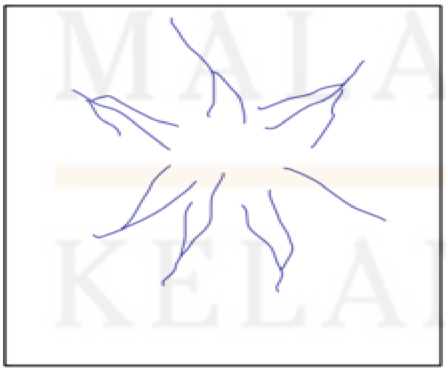
- Develops where bands of hard and soft rocks vary in resistance.
- Soft rock was erode and flows along the band of source rock.
- Hard rock was cut and erode, flows down the slope forming a river gap.

Rectangular Pattern



- Develop on rocks have uniform resistance to erosion, but which have two directions of joining at approximately right angles.

Radial Pattern



- Develop near volcanoes, domes and laccoliths area.
- This shape form when the stream radiate outwards from a central high point.

Based on drainage map of Renyok area in Figure 4.5, it assumed that the type of drainage pattern is dendritic pattern. Dendritic drainage pattern are the most common form of drainage pattern, characterized by flat lying and composed of homogenous rock and impervious soil. . The flow of streams and rivers develops in an area which comprises rocks with a uniform structure. The map shows many contributing streams which are then joined together into the tributaries of the main river. The direction taken by the river and its tributaries is largely dependent on the slope. The waterfalls and rapids are common features of the rivers that have their headwaters in hilly to mountainous terrain. Renyok area also consists of waterfall that form caused by the river encountering some highly resistant rocks whilst deepening the valley and also developed where the streams cut the valley through rock of very unequal hardness, as the contacts between granite and sedimentary rocks.

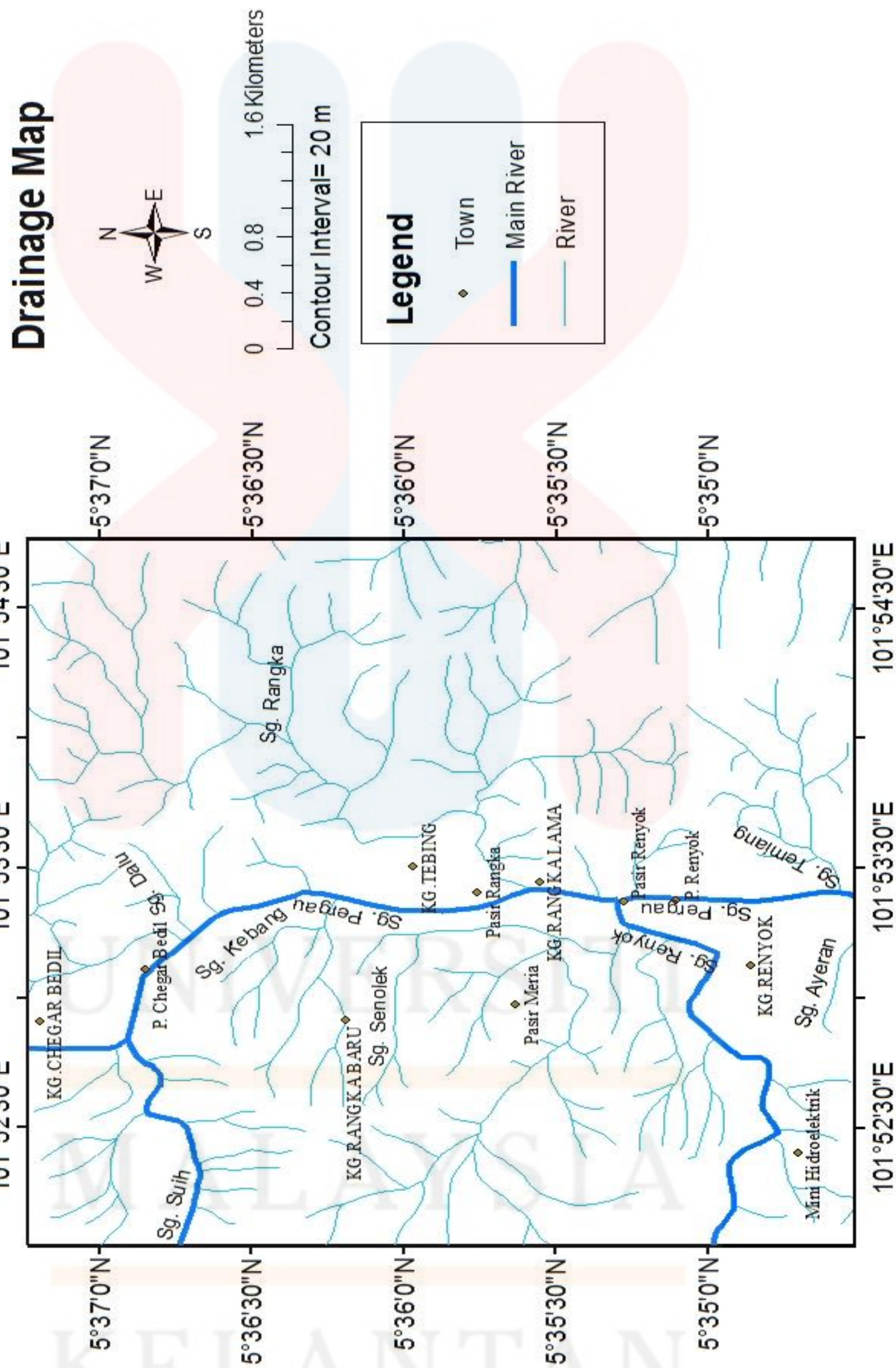


Figure 4.5: Drainage map of Kampung Renyok.

(Source: JUPEM, 2006)

4.2.3 Weathering Process

Weathering is defined as the breakdown of rock, soils and minerals through the contact with Earth's atmosphere, waters and sometimes biological organism. Weathering is the process that occurs in *in-situ* place which means on site or in the same place with no movement. The process of weathering that takes place on rock is different for every rocks depend on their properties and mineralogy content. This process is more active in wet condition and environment with high temperature. Weathering is divided into three types, which are physical weathering, chemical weathering and biological weathering.

Physical weathering or also known as mechanical weathering is the process of breaking down of rock without changing their chemical composition. Example type of physical weathering is exfoliation that occurs as cracks develop parallel to the land surface a consequences of the reduction in pressure during uplift and erosion.

Chemical weathering also known as decomposition is the breakdown of rock by chemical mechanisms. It changes the chemical composition of the rocks usually through carbonation, hydration, hydrolysis and oxidation. Chemical weathering alters the composition of the rock material toward surface minerals such as clays.

Biological weathering is disintegration of rocks as a result of the action by living organisms. Plant and animals have a significant effect on rocks as they penetrate or burrow into the soil respectively. Some plants and trees grow within the fractures in the rock formation and make the crack wider and deeper that eventually disintegrate the rocks.

Table 4.3: Weathering grade profile for rock mass (after ISRM, 1981).

Term	Description	Symbols
Fresh	No visible sign of rock material weathering; perhaps slight discolouration on major discontinuity surfaces.	I
Slightly weathered	Discolouration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker than its fresh condition.	II
Moderately weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones	III
Highly weathered	More than a half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones	IV
Completely weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact	V
. Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

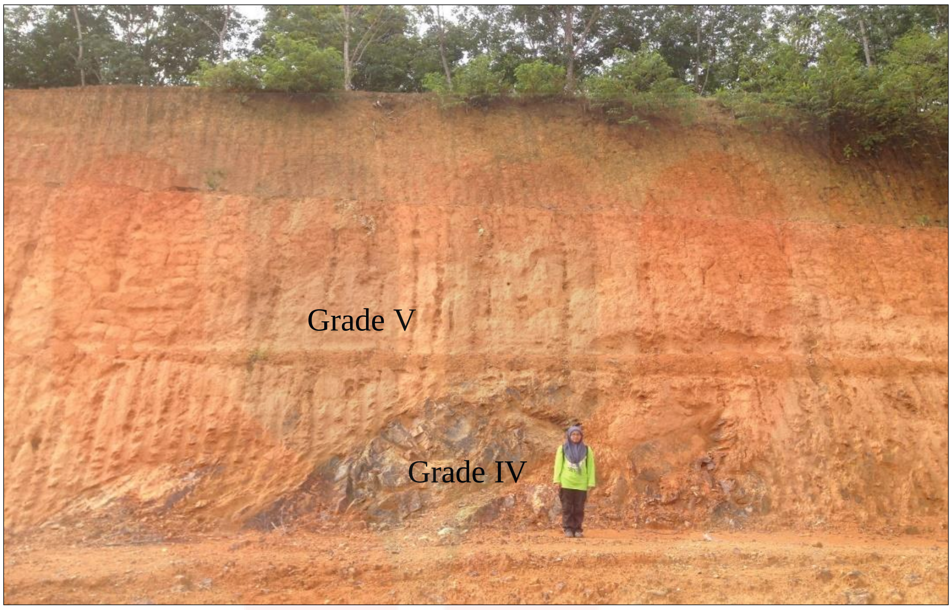


Figure 4.6: Different weathering grades of outcrop with coordinate N05°36’30.3 E101°53’02.0.

Weathering composed of different kind of grades, from grade I to grade IV as shown in Table 4.3. Figure 4.6 shows physical weathering that breaking down rocks into fragments because of the pressure and temperature take places on rock that caused it weathered in different weathering grades. Figure also shows different weathering grade of outcrop at the study area. This outcrop consist of two different grades of weathering which are IV (highly weathered) that shows discoloured rock present as core-stones and V (completely weathered) that show the mass material was integrated into soil.

Figure 4.7: Chemical weathering that change the colour of rock surface with coordinate N05°34’47.1 E101°52’25.8.

Figure 4.7 display the process of chemical weathering that take places on the rock surface. This type of chemical weathering is oxidation in which the reaction of rock minerals with oxygen, thus changing the mineral composition of the rock. When mineral in rock is oxidized, they become less resistance to weathering and rock surface is discoloured when oxidized.

Figure 4.8 show restricted to boulders sized of rock that known as spheroidal weathering that occurs from chemical weathering. It formed when chemical weathering affects jointed bedrock and results in the formation of concentric or spherical layers of highly decayed rock within weathered bedrock that is known as saprolite. When saprolite is exposed by physical erosion such as water, these concentric layers peel and spall off as concentric shells. This type of weathering occur as the result of chemical weathering of systematically jointed, massive rocks including granite, dolerite, basalt and sedimentary rock such as silified sandstone.

Figure 4.8: Spheroidal weathering occurs from effect of chemical weathering process with coordinate N05°34’45.1 E101°52’28.8.

4.3 Stratigraphy

Stratigraphy is a branch of geology that concern with the description of rock successions and their interpretation in term of a geological time scale. It deal with litho-stratigraphy and bio-stratigraphy subfield that provide historical geology information of the earth. Figure 4.9 show geological map of the study area. Based on lithostratigraphic column as shown in Table 4.4, the formation or lithological information according to (Ibrahim Abdullah and Jatmika Setiawan, 2003), was used to correlate with lithology unit that was found at the study area.

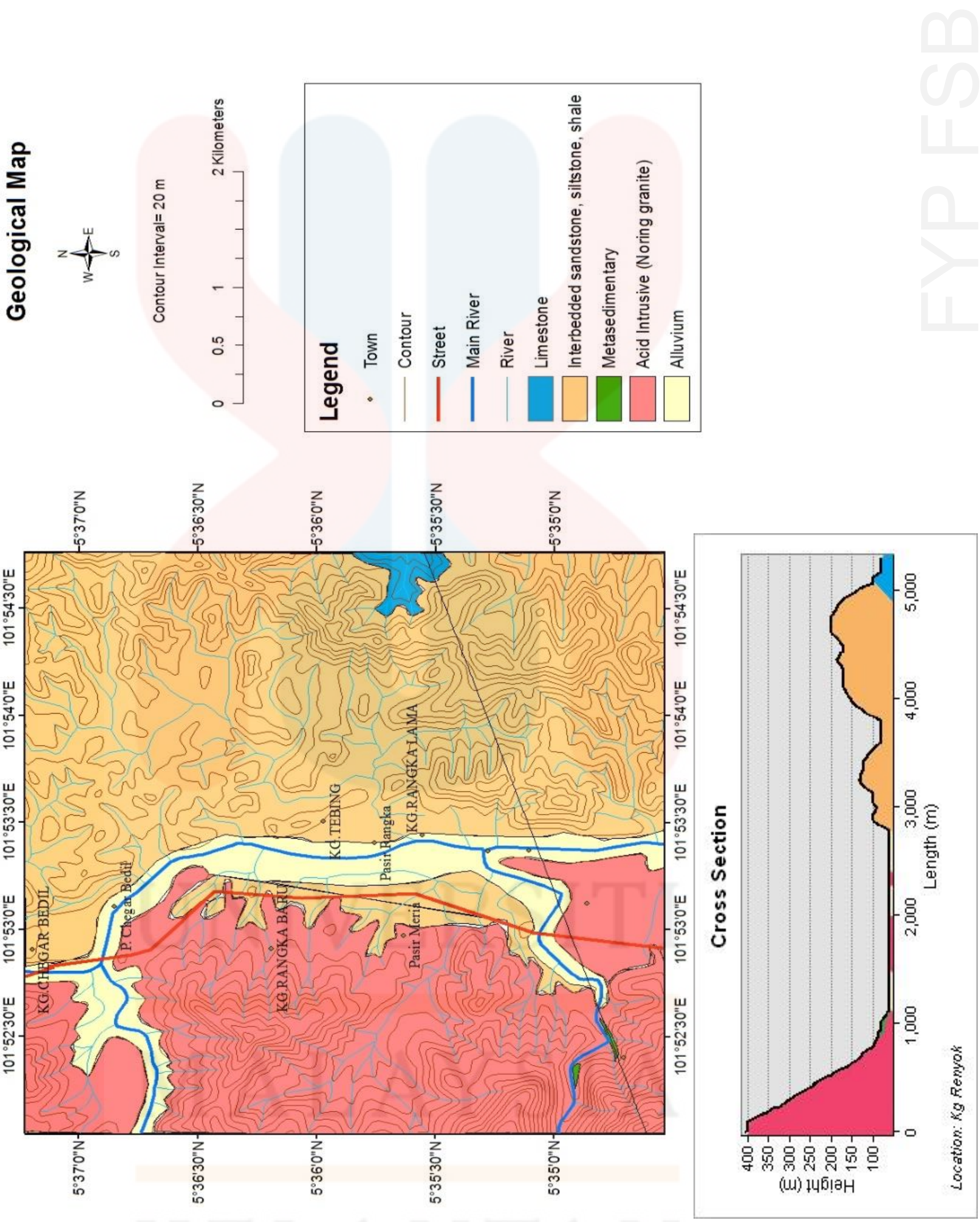


Figure 4.9: Geological map of study area

(Source: JUPEM, 2006)

Table 4.4: Lithostratigraphic column.

Era	Period	Formation (Ibrahim Abdullah and Jatmika Setiawan, 2003)	Description	Unit	Lithology
Cenozoic	Quaternary	Alluvium	Alluvium	Alluvium	
Mesozoic	Cretaceous	Noring Granite	Granite	Biotite granite, Biotite granite porphyry	
Mesozoic	Early Cretaceous	Kenerong Leucogranite	Granite	Dykes/ Intrusion	
Mesozoic	Triassic	Metasedimentary	Metasedimentary rock	Meta-pelite, Meta-arenite, Gneiss, Skarn hornfels	
Late Paleozoic	Permian	Sedimentary rock	Interbedded sandstone, siltstone and shale.	Sandstones, siltstone, shale	
Late Paleozoic	Early Permian	Sedimentary rock	Limestone	Limestone	

Based on lithostratigraphic column in the Table 4.4, it shows that study area composed of six unit lithology from late Palaeozoic to Cenozoic era. Permian period are composed of sedimentary rock such as limestone, interbedded sandstone, siltstone and shale that possibly part of Gua Musang formation. Sandstone that was found at the study area are fine to coarse grains sized. Metasedimentary rock that occur at the study area are from Mesozoic era and in Triassic period. This type of rock form because of the plate tectonic activity that caused sedimentary rock metamorphosed and changed in texture and composition.

According to Ibrahim Abdullah and Jatmika Setiawan, (2003), in early cretaceous period from Mesozoic era, Kenerong leucogranite was intruded into metasedimentary enclaves. The Kenerong Leucogranite intrusion that exposed at study area, Renyok consists of a sequence of veins of fine to medium grained leucogranite, pegmatite and aplite. The veins are predominatly leucogranite and some other lithological variation particularly in biotite content, but generally light colour, ranging from a few cm to 5 m wide. Figure 4.10 show the metasedimentary encalves with leucogranite intrusion. The kenerong Leucogranite is not map able because of the small scale and not included in the geological map.

Figure 4.10: Metasedimentary enclaves rock with leucogranite instrusion with coordinate N05°34’45.2 E101°52’28.4.

Noring granite are from cretaceous period in Mesozoic era composed of two type of granite, biotie granite and biotite granite porphyry. The texture of biotite granite are medium grains in size, phaneritic and holocrystalline while the texture of biotite granite porphyry are coarse grain in size, porphyritic and also holocrystalline. Kenerong leucogranite and Noring granite is a part of Stong Complex formation. Alluvium is grouped in Cenozoic era and in quartenary period. It composed of loose and unconsolidated sediment or soil that has been eroded and redeposited. Generally alluvium is made up from variety materials such as fine particles of silt, clay, sand and gravel. From the lithostratigraphic column, the oldest rock unit is sedimentary rock, followed by metasedimentary rock, Kenerong Leucogranite, Noring granite and the younger, alluvium.

4.3.1 Petrography Analysis

Petrography is the study of mineralogy that focuses on detailed description of rocks. The science of petrography is largely based on the study of the appearance of thin, transparent sections of rocks in a microscope fitted with polarizers. Petrography analysis is describing the rock minerals by using microscopic features that used polarizing or petrographic microscope that have plain and crossed polarized lighting condition.

a) Igneous Rock

Figure 4.11: Hand specimen of granite rock.

From the figure 4.11, the characteristic hand specimen of granite is light in colour. The grain size is coarse enough mainly >1mm to allow recognition of the major minerals that can be seen by naked eyes. The black grain are biotite and hornblende, while the pink grain are feldspar. The clear to smoky grains are quartz and muscovite. Figure 4.12 and figure 4.13 show the granite under cross and plain polarized. Figure 4.14 show the QAP diagram used for plutonic rock types.

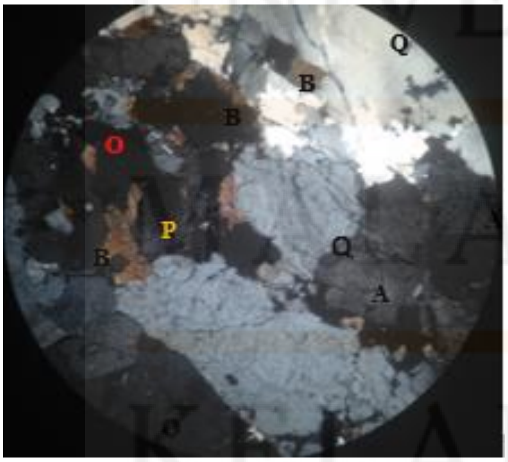


Figure 4.12: Cross polarized of granite (B-Biotite, P-Plagioclase, Q-Quartz, A-Alkali Feldspar, O-Opaque).

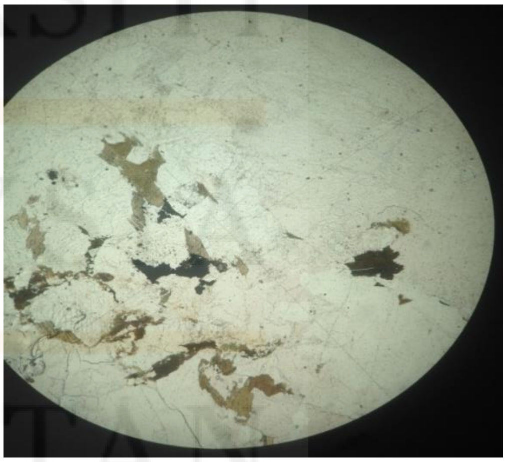


Figure 4.13: Plane polarized of granite.

Figure 4.12 and figure 4.13 shows photograph of granite under cross polarized and plane polarized microscope with magnification 10x. In the cross polarized figures, we can see there are three type of minerals in this granite rock: Biotite (dark brown in cross polarized and brown in plane polarized), plagioclase (cross polarized it grey in colour and multiple twining while in plane polarized it colourless), quartz (cross polarized is grey and white in colour and plane polarized is colourless) and alkali feldspar. The minerals composition in this sample are biotite 10 %, plagioclase 23 % and alkali feldspar 25 %, quartz 40 %, opaque 2% and accessories mineral about 5%. Based on the mineral contain, this granite was classified as biotite granite porphyry because excluding quartz, alkali and plagioclase feldspar from QAP diagram, the major minerals is biotite.

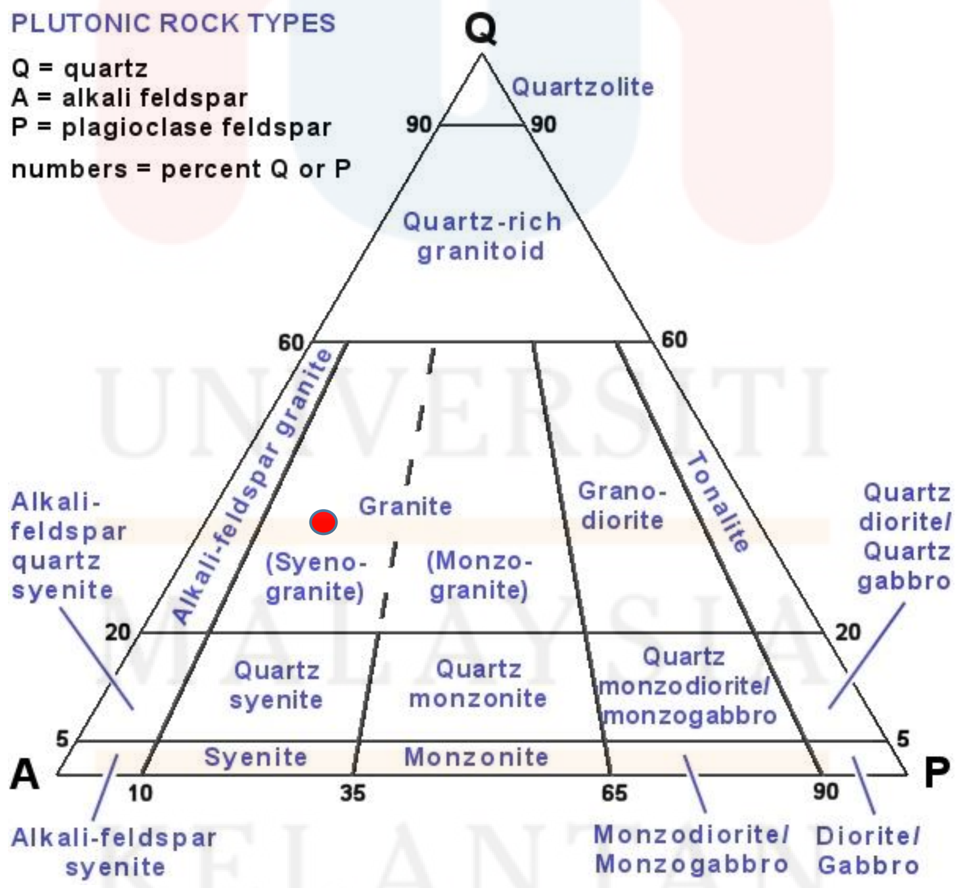


Figure 4.14: QAP diagram for plutonic rock.

(Source: IUGS, 1970).

b) Metamorphic rock

i) Gneiss

Figure 4.15: Hand specimen of gneiss.

Figure 4.15 show hand specimen of low grade gneiss that grey in colour and poor banding. This rock is foliated and formed through metamorphism process. Gneiss is metamorphic rock that formed in regional metamorphism and the original rock from igneous and sedimentary rock. Banding in this rock appear because of the protolith was subjected to extreme shearing force. Gneiss is coarse grained and consists of feldspar, quartz, mica and may have mafic minerals.

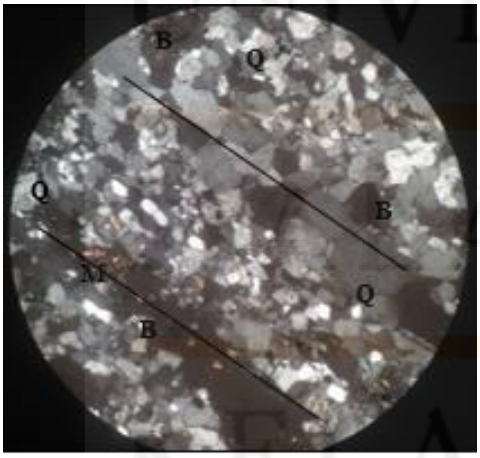


Figure 4.16: Gneiss under cross polarized (B-Biotite, Q-Quartz, M-Mica).

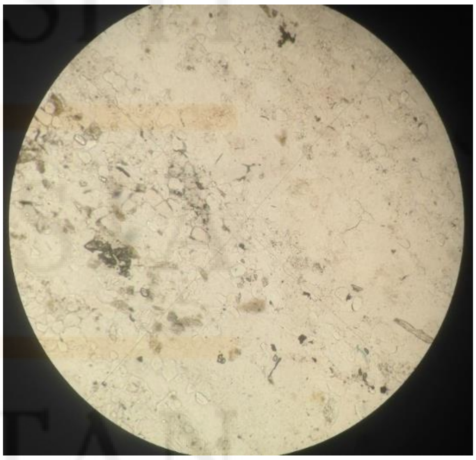


Figure 4.17: Gneiss under plain polarized.

Figure 4.16 and figure 4.17 shows the gneiss under cross and plane polarized. Based on the figures, it can describe that this type of gneiss consist of abundant quartz and biotite minerals. Quartz is white in cross and colourless in plane polarized. Lines in figure show that the banding of gneiss that composed of quartz and biotite. Light banding is quartz, and dark banding is biotite. This type of gneiss can be named as biotite gneiss based on presence of biotite minerals.

ii) Skarn Hornfels

Figure 4.18: Hand specimen of skarn hornfels.

Based on figure 4.18, it show the skarn specimen that was collected near intrusion of granite at Renyok waterfall. It react with HCL and light in colour (white and slightly pink). Skarn hornfels is a metamorphic rocks that calcium bearing calc-silicate rocks found adjacent to pluton, lower crustal depths in buried metamorphism terrains and along faults and major shear zones. Generally, skarns often formed near contact zone between carbonate sedimentary rock such as dolostone and limestone and intrusion of granitic magma bodies. It also formed near regional metamorphism. Typical mineral that skarn contain are garnet, pyroxene, staurolite, epidote, barite and hematite. Figure 4.19 and figure 4.20 shows the skarn rock under crossed and plane polarized microscope. Based on the figures, it show that skarn specimen sample containing garnet, staurolite, pyroxene that surrounds with groundmass.

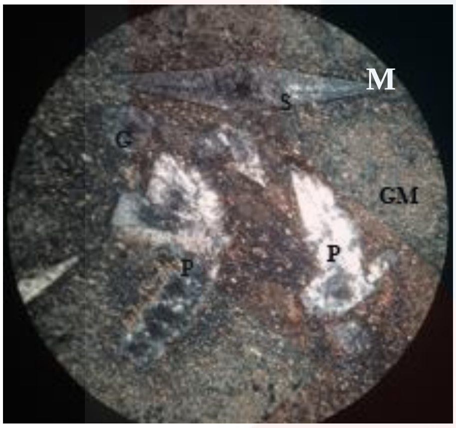


Figure 4.19: Skarn under cross polarized thin section.
(G-Garnet, S-Staurolite, P-Pyroxene, GM-Groundmass).

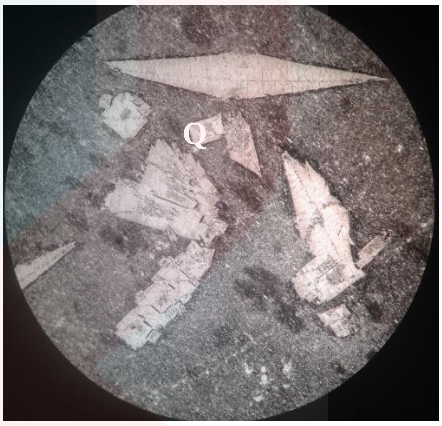


Figure 4.20: Skarn under plane polarized microscope.

c) Sedimentary rock.

i) Sandstone

Figure 4.21: Hand specimen of sandstones.

Figure 4.21 shows hand specimen of sandstones that was collected near Felcra Reka, it light grey and brown in colour. The grain size of this sample is medium to coarse grain. The surface of the rock is rough and sandy.

Sandstone usually composed majority of quartz and feldspar mineral with minor biotite, mica and muscovite (lithic fragment). From the figure 4.22 and 4.23, it show that the most abundant mineral of this sample is quartz with white, grey and black in colour. Feldspar mineral also occur in this sample with grey in colour and polysynthetic twinning. Accessories mineral such as mica mineral composed of variety colour, mostly reddish in colour. The grain minerals show in figure mostly subangular and angular with low sphericity. This type of sandstone may be called as micaceous sandstone because of the mica rich presence.

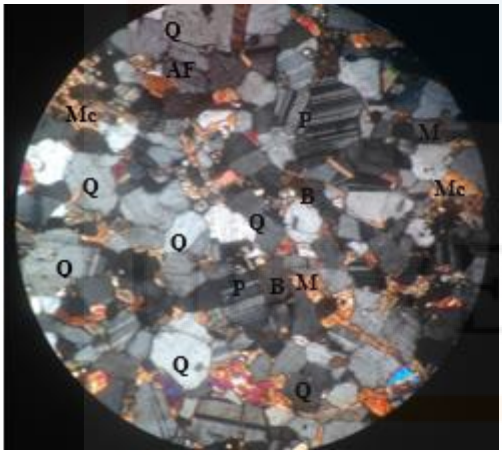


Figure 4.22: Cross polarized of sandstones. (B-Biotite, P-Plagioclase, AF-Alkali Feldspar, Q-Quartz, Mc-Mica, M-Muscovite).

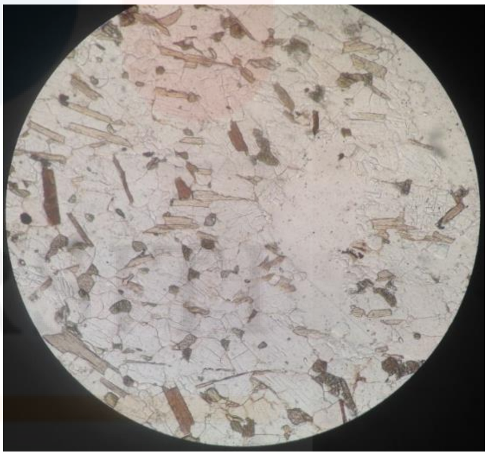


Figure 4.23: Plane polarized of sandstones.

b) Sandstone

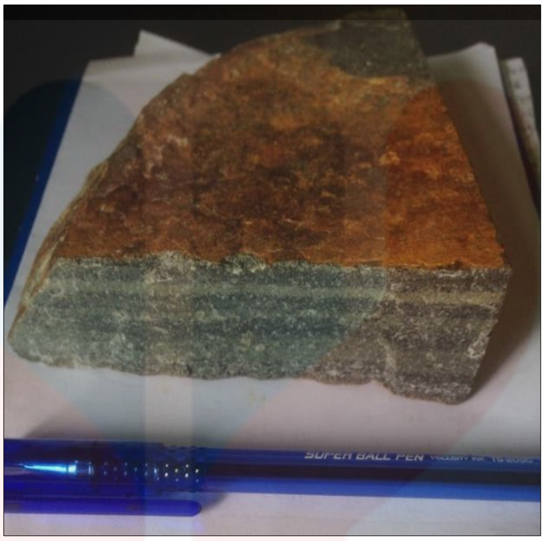


Figure 4.24: Hand specimen sandstone.

Figure 4.24 show hand specimen of sandstone. It was collect near Renyok waterfall. The texture is fine to coarse grain and composed of well foliated layer. The layer composed of grey and light in colour. Figure 4.25 show the sample under cross polarized with 40x magnification.

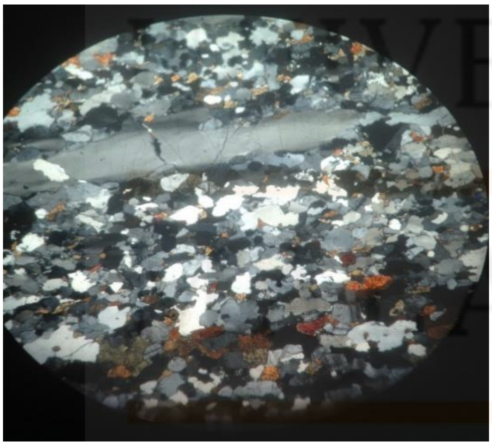


Figure 4.25: Sandstones under cross polarized with magnification 40x.

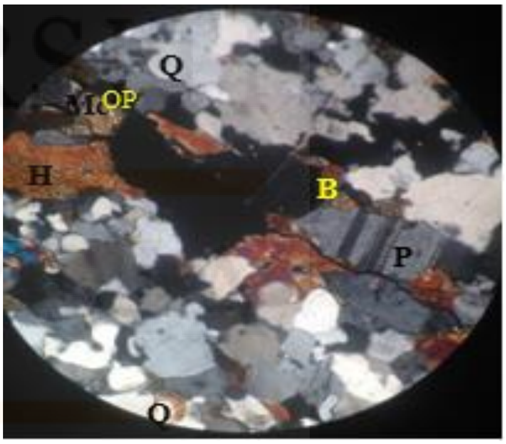


Figure 4.26: Sandstones under cross polarized with 10x magnification (B-Biotite, Q-Quartz, P-Plagioclase, H-Hornblende, Mc-Mica, O-Opaque).

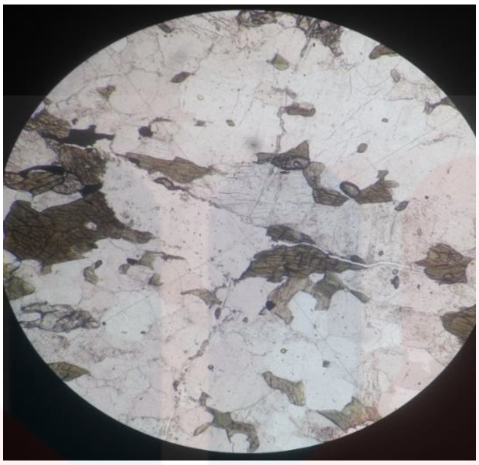


Figure 4.27: Metasandstones under plane polarized.

Figure 4.26 and figure 4.27 shows the sandstone specimen under cross and plane polarized light. From the figures, sandstones specimen consist of a few type of minerals which are: Biotite (dark and brown colour in both polarized), Quartz (grey and white and colourless in plane polarized), Plagioclase (grey in colour and consist of multiple twinning, colourless in plane polarized), Opaque mineral shows black in colour for both polarized, and Hornblende (brown in both polarized). This sample contains majority quartz mineral with a few plagioclase, biotite and hornblende minerals. This sample can be called as lamination sandstone based on its texture that formed in well lamination layer.

4.4 Structural Geology

Structural geology is the study of three dimensional distribution of rock unit with respect to their deformational histories. Structural geology is important to use as measurements of present day rock geometries to investigate the information about the strain and stress in the rocks to seek and explored about the past history of the Earth.

Structural analysis for this study area was done by geological field mapping. The geology structure consist at the study area was carefully observed for further interpretation. Based on geological field mapping, a few structure have been found near study area.

4.4.1 Geology Structures

a) Folding

Fold is occur when one or a stack of originally flat and planar surfaces are bent or curved as a result of permanent deformation. Fold in rock are vary in size from microscopic crinkles to mountain sized folds with different scales. Figure 4.28 shows the minor fold with small sized that occur in host rock, metasedimentary, result from deformation, high pressure and temperature gradient due to metamorphism process and intrusion of granite.

Figure 4.28: Minor fold occurs on metasedimentary rock at the study area.

b) Joint

Joint is a break or fracture of natural origin in the continuity occurs in a layer or body of rock that lacks any visible or measurable movement parallel to the surface plane or fracture. Joint is divided into two forms, joint set and joint system. Joint set is a group of joint that is parallel, evenly spaced joints that can be observed through mapping and analysis of orientations, spacing, and physical properties while joint system composed of two or more intersecting joint sets. Figure 4.29, show a set of joint found at south west of study area, Renyok waterfall. Total hundred reading of joint was collected and plot in rose diagram as shown in figure 4.30. Based on rose diagram, it show that the force direction NE and tension direction NW.

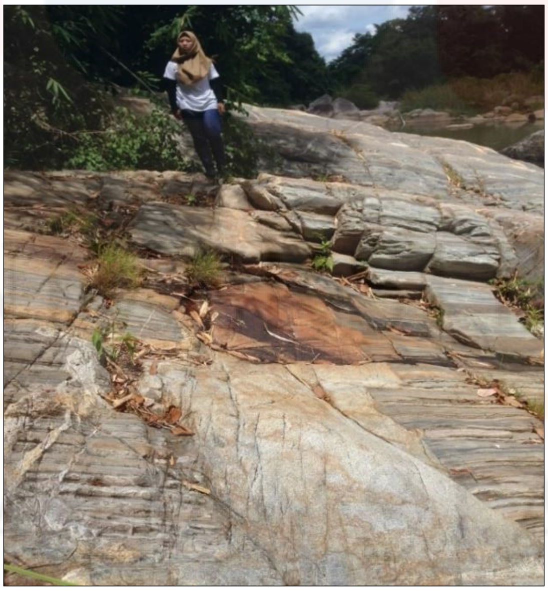


Figure 4.29: A set of joint found at study area, Renyok waterfall.

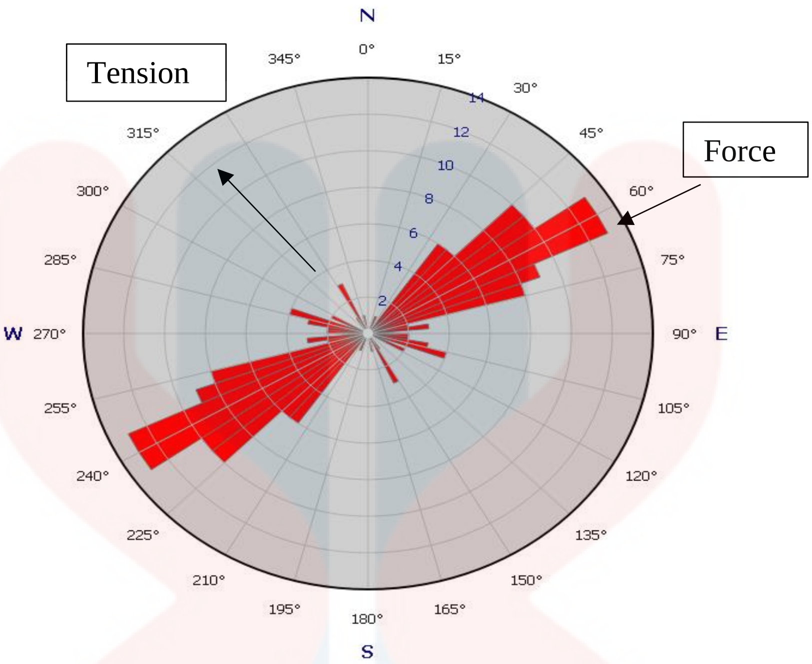


Figure 4.30: Rose diagram for joint analysis.

c) **Pothole**

Figure 4.31 show the pothole that produced by the force of water and abrasion process that cause the surface of bedrock eroded. Pothole is a hole or depression in a layer of exposed rock. It is formed when a circular current of water carrying small pebbles and sediment begins to wear away a rock surface. The force of water and pebbles is greater than the resistance of the rock. When water is present, bacteria, fungi and algae play a greater role in eroding rock layers by extracting silica from rock.

Figure 4.31: Pothole on the rock surfaces form from force of water and abrasion.

d) Vein

Figure 4.32 shows the quartz vein occur on the rock. Vein is a distinct sheet-like body of crystallized minerals within rock and produced when minerals constituents carried by an aqueous solution within the rock mass are deposited through precipitation. . This vein forms as a result from the growth of crystals on the walls of planar fractures in rocks, with the crystal growth occurring normal to the walls of the cavity, and the crystal protruding into open space.

Figure 4.32: Quartz vein occurs on the rock.

e) Boudinage

Figure 4.33 shows the boudinage consist of granite that occur on the surface of metasedimentary rock. Boudinage occurs as a result of extension, where single competent layers are extended into separate pieces through plastic, brittle or a combination of plastic and brittle deformation mechanism. The competent bed begins to break up, forming sausage-shaped boundins. Competent tabular body that are susceptible to boudinage include veins and strata such as metasandstones.

Figure 4.33: Boudinage that form along the metasedimentary due to stretched at tabular body and deformed where embedded within less competent rock surroundings.

4.4.2 Lineament Analysis

Lineament is a straight line features, large scale and clearly shown at the Earth's surface (Ibrahim and Juhari 1990). Lineament analysis was done by referering to the aerial or satellite photograph because it too big in scale to observed by geological mapping. There are two main types of lineament, positive and negative lineament.

Positive lineament may be interpreted as features of ridge and range while negative lineament may represent by valleys, rivers and faults. Figure 4.34 show the lineament of regional scale at the study area. Total 53 reading of lineament was measured and plot in rose diagram as shown in Figure 4.35. From the diagram figure, the direction of force is NE area and the tension is NW.

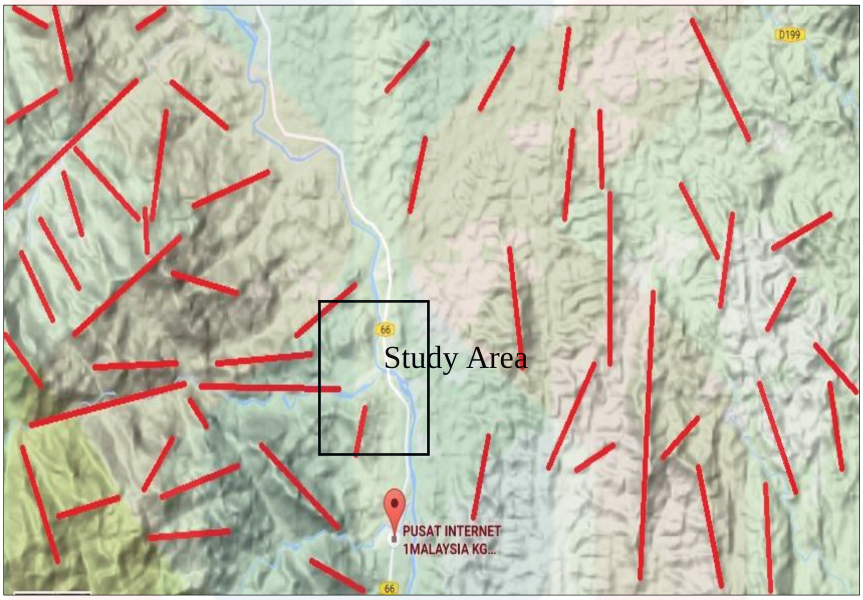


Figure 4.34: Lineament of large scale at the study area.

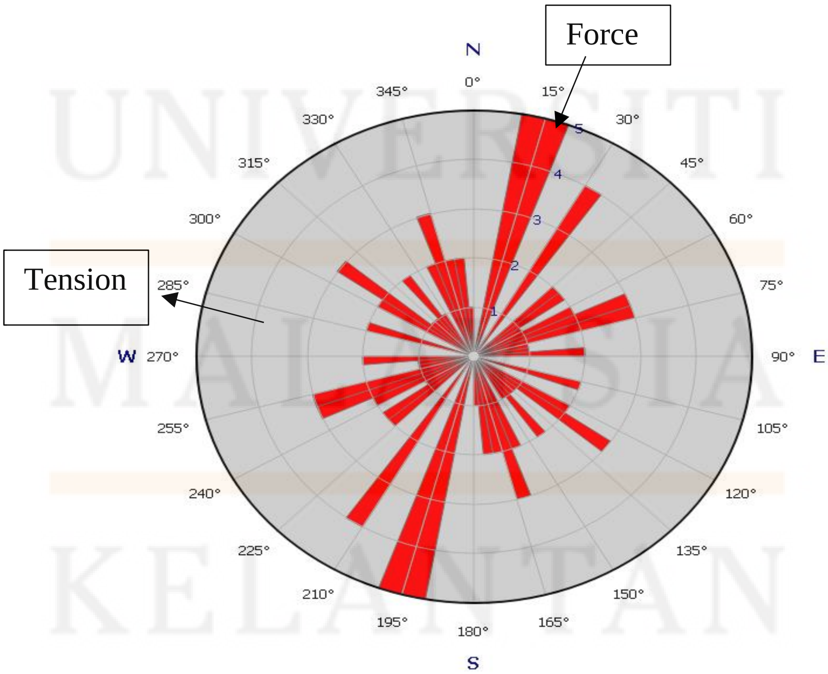


Figure 4.35: Rose diagram of lineament at the study area.

4.5 Historical Geology

Renyok consists of plutonic and metasedimentary rock which is part of Migmatite Stong Complex. It is situated at the northeastern part of Stong Complex and found within Kenerong Leucogranite plutons. The oldest rock is Berangkat Tonalite, followed by Kenerong Leucogranite and the youngest rock is Noring granite. Renyok comprises of 3 dominant lithology which are granite, sandwiched layers of granite veins with metasedimentary rock and grey microgranite. Rapid revolution of rock in Lata Renyok began during Permian Period where there is presence deposition of shale and mud rich matter. This deposition of shale continuously occurs up to the Early Cretaceous (64-67 million years ago) until forming a sedimentary rocks due to the event of igneous intrusion uplifting. According to Ibrahim Abdullah et al., (2003), the rock in Lata Renyok have undergone at least 4 stages of deformation result from the forming of Kenerong Leucogranite found that consist of sequence sub-parallel stretched leucogranite veins and metasedimentary enclaves.

CHAPTER 5

SLAKE DURABILITY INDEX ANALYSIS

5.1 Introduction

This chapter focused on result and discussion obtained from the laboratory work of slake durability index test. To determine the durability index of each samples, the data achieved from slake durability test based on laboratory works was analysed. The samples collected at Renyok area consist of metamorphic and igneous rock, and for sedimentary it was collected at Felcra Reka.

These type of rock have high durability, but through the time and natural condition of repeating wetting and drying can affected the rock and lead to the weathering and deterioration of the rock. The weathering process take places on rocks will cause the durability of rock decreased and possibly lead to the risky condition such as rock fall result from spheroidal weathering at Renyok waterfall area and also influenced excavation work at Felcra Reka area.

5.2 Result and Discussion

The slake-durability test is considered as a simple test for evaluating the influence of weathering on rock. The purpose of slake durability test that introduced by Franklin and Chandra (1972) is to investigate and determine the resistance of rocks material to weathering process after being exposed to wetting and drying cycles. Figures 5.1, 5.2 and 5.3 shows some sample of granite, gneiss and sandstones before the cycle's process, after first cycles and after second cycles. (Id) or slake durability index provided the information about the mechanical behaviour of rock which is important in geotechnical engineering

Table 5.1 presented the result of slake durability index (Id1 %) and (Id2 %) of granite, gneiss and sandstones after being subjected to two wetting and drying cycles. The Id2 values is compared to Gambles slake durability classification to analyse and determine the durability of rocks and Id2 values also used to identify the weathering profile of rock based on Ibrahim Komoo and Jasni Yaakob (1990). Table 5.2 (a), (b) and (c) shows the mean value for Id2 that used to identify durability classification of rocks based on Gambles classification in several weathering grade. The original weight of all sample were recorded before slaking to the second cycle.

Sample	Before test	After first cycle	After second cycle
S1			
S4B			

Figure 5.1: Sample S1 and S4B of granite.

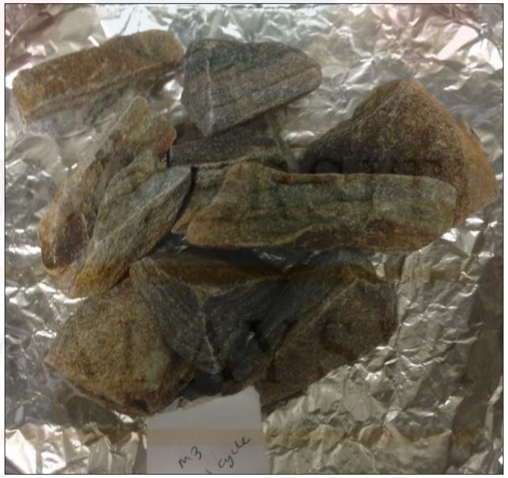
Sample	Before test	After first cycle	After second cycle
M2			
M3			

Figure 5.2: Samples M2 and M3 of gneiss.

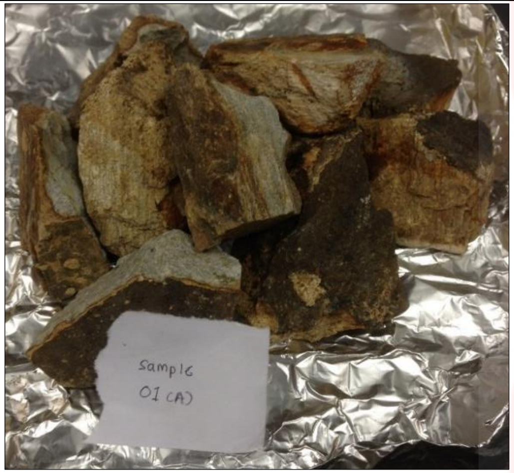
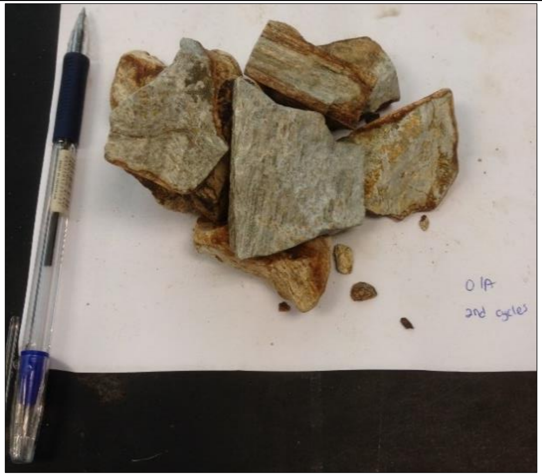
Sample	Before test	After first cycle	After second cycle
O1A			
O4B			

Figure 5.3: Samples O1A and O4B sandstones.

Table 5.1: The values of Id1 and Id2 of granite, gneiss and sandstone samples**.**

Type of rock	Sample	% Id1	% Id2
Granite	S1	99.63	98.82
	S2A	99.39	99.03
	S3A	99.18	98.52
	S4B	99.12	98.87
	S5B	99.09	98.11
	S5A	99.26	99.05
Gneiss	M1	99.62	98.99
	M2	99.27	98.65
	M3	99.20	98.53
	M4	99.34	98.95
	M5	99.51	99.18
Sandstone	O1A	97.02	94.90
	O2A	98.27	96.19
	O3	99.26	98.97
	O4B	91.97	87.56
	O5	98.68	96.06

*Id1 – Index value after first cycle

Id2 – Index value after second cycle

Tables 5.1 shows the values of Id1 and Id2 of granite, gneiss and sandstones, and it can be interpreted that Id1 values is greater than Id2 values because of the decreased or deterioration of rocks after being subjected to two standard drying and wetting cycles. The deterioration value of rock sample were presented in Figure 5.4 (a), (b) and (c).

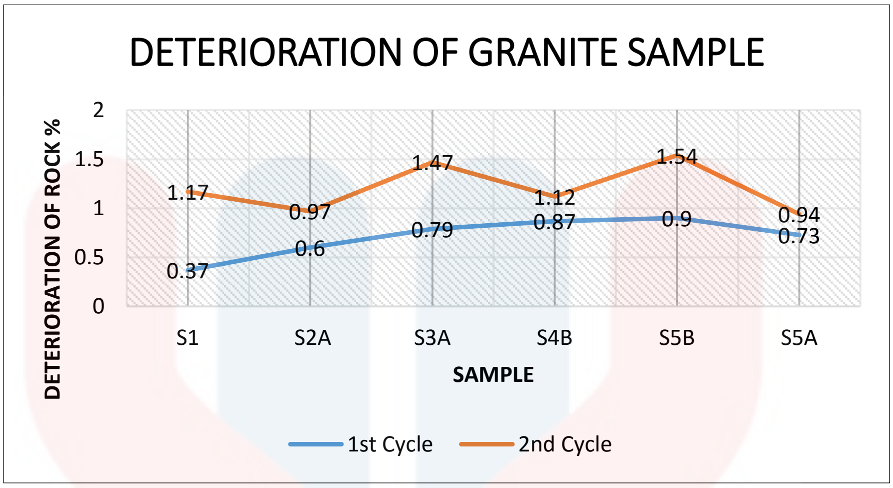


Figure 5.4: Deterioration of granite sample after first and second cycle.

Based on the Figure 5.4, for the first cycle, the range of granite sample decreased in Id2 value are from 0.37 % to 0.90 % and for the second cycle, the range are from 0.97 % to 1.54 %. Among all granite samples, the sample of S5B show high in reduction value after completed the cycles.

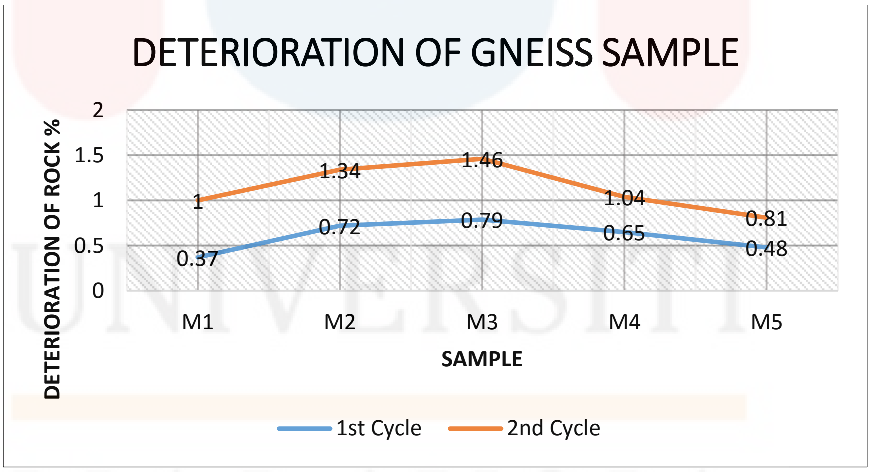


Figure 5.5: Deterioration of gneiss sample after first and second cycle.

Figure 5.5 show the deterioration Id2 value of gneiss sample for first and second cycle. The range for the first cycle are from 0.37 % to 0.79 % and for the second cycle it range from 1.00 % to 1.46 %. Sample M3 show greater decreased in value which are 0.79 % in first cycle and 1.46 % after finished the second cycle.

For sandstone samples in Figure 5.6, range Id2 value for first cycle are from 0.73 % to 2.97 % and for the second cycle are from 1.02 % to 12.43 %. Sample O4B show high value of deterioration which are 8.02 % for the first cycle and 12.43 % for the second cycle.

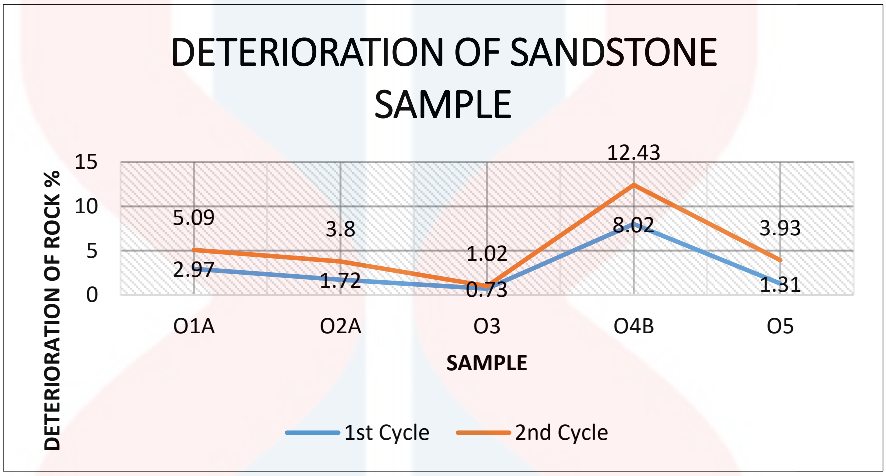


Figure 5.6: Deterioration of sandstone sample after first and second cycle.

Table 5.2: Gamble's durability classification for granite, gneiss and sandstone.

Type of rock	Sample	% Id2	Durability Classification
	S1	98.82	Very high durability
	S2A	99.03	Very high durability
Granite	S3A	98.52	Very high durability
	S4B	98.87	Very high durability
	S5B	98.11	Very high durability
	S5A	99.05	Very high durability
	M1	98.99	Very high durability
	M2	98.65	Very high durability
Gneiss	M3	98.53	Very high durability
	M4	98.95	Very high durability
	M5	99.18	Very high durability

	O1A	94.90	Medium high durability
	O2A	96.19	High durability
Sandstone	O3	98.97	Very high durability
	O4B	87.56	Medium high durability
	O5	96.06	High durability

Based on Gamble's classification, the durability of granite, gneiss and sandstone are determined as shown in Table 5.2. Slake durability index Id2 values was used to identify and determined the durability classification for respective rock samples. The durability index Id2 of granite, gneiss and sandstone is decreased due to deterioration after finished the two standard cycle.

Based on the table, the slake durability index value Id2 for all granite samples that range from 98.11 % to 99.05 % are classified as very high durability of rock. These granite samples are very high durability rock because of the sample possibly contain high resistance minerals towards abrasion of the water and heat after completing two standard cycles. The result on table show the durability index Id2 of all gneiss samples that have range from 98.53 % to 99.18 % are classified as very high durability. Gneiss samples show high resistance to the slaking process because it contain mostly mineral that resist to the weathering process such as quartz and feldspar.

For sandstones, the sample that have high value of durability index Id2 is 98.97 % which is classified as very high durability and the Id2 that have value 96.06 % to 96.19% are categorized as high durability classification. The Id2 value from sandstones that have value 87.56 % to 94.90 % are grouped in medium high durability classification as shown in Table 5.2. From the result, it show that some of sandstone samples responds to the slaking process as a result of porosity, when the pores in the rock are fills with water and lead to the fracturing of rock to a pieces.

Table 5.3: Proposed weathering profile classification for granite, gneiss and sandstone sample (modified from Ibrahim Kamoo and Jasni Yaakub, 1990)

Type of rock	Sample	% Id2	Grade
Granite	S1	98.82	II
	S2A	99.03	II
	S3A	98.52	II
	S4B	98.87	II
	S5B	98.11	II
	S5A	99.05	II
Gneiss	M1	98.99	II
	M2	98.65	II
	M3	98.53	II
	M4	98.95	II
	M5	99.18	II
Sandstone	O1A	94.90	III
	O2A	96.19	II
	O3	98.97	II
	O4B	87.56	III
	O5	96.06	II

The proposed weathering profile classification for rock modified from Ibrahim Kamoo and Jasni Yaakub (1990) are used to identify weathering grade for the rock samples. Weathering grade of the rock samples are identify based on the value of durability index Id2. Based on the table 5.3, it shows that all granite samples that range from 98.11 % to 99.05 % are in grade II. The durability index values of granite are more than 95 % and it show low weathering grade.

The durability index Id2 of all gneiss samples that have range from 98.53 % to 99.18 % are classified as grade II in weathering profile classification. The result show that this type of rock have high resistance to the weathering process because it only show a very low value of rock broken to a pieces after finished slaking process. This weathering profile classification show the sample that have high values of durability index Id2 have lower value of weathering grades.

Table 5.3 show the grades classification of sandstones obtained from the value of durability index Id2. From the result, it shows that majority samples of sandstones have grades III that range from 87.56 % to 94.90 % which is classified as moderately weathered. Sample in grades II have range values from 96.06 % to 98.97 % are classified as slightly weathered rock. Based on the result obtained from sandstone sample, it show that the durability index for Id2 generally affected the increase of slaking index values with the increasing weathering grades. Table 5.4 show the summary range of slake durability Id2 of all samples.

Table 5.4: The summary range of slake durability Id2 result for respective weathering grades.

Type of Rock	Id2 Range			
	II	III	Iva	IVb
Granite	98.11 %-99.05 %	-	_	_
Gneiss	98.53 %-99.18 %	-	_	_
Sandstones	96.06%-98.97%	87.56%-94.90%	_	_

Table 5.5: Mean value of slake durability Id2 for granite, gneiss and sandstone respective to weathering grades.

Weathering Grades	Mean Id2 (%)	N
(Granite) II	98	6
(Gneiss) II	98	5
(Sandstone) II	97	3
(Sandstone) III	91	2
	Total	16

*Id2 – Index durability after second cycle

N – Number of sample

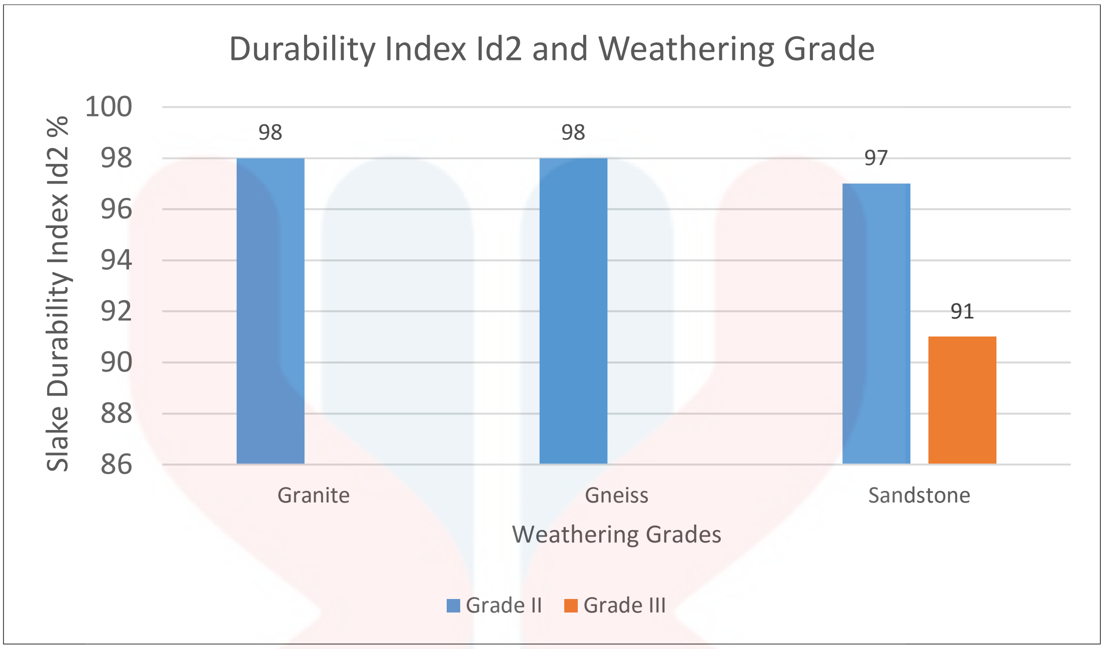


Figure 5.7: Chart of durability index Id2 of granite, gneiss and sandstone with weathering grades.

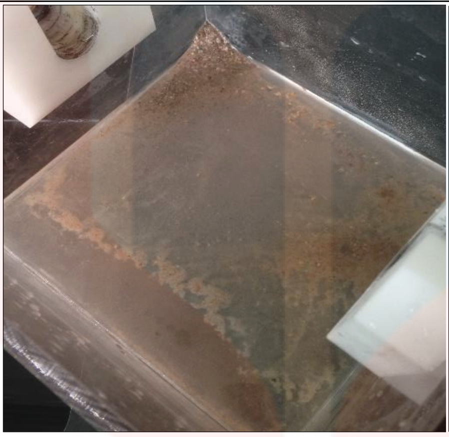
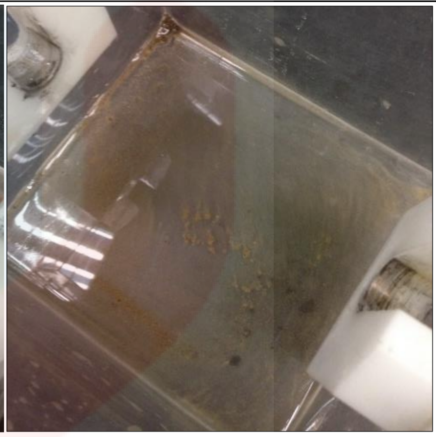
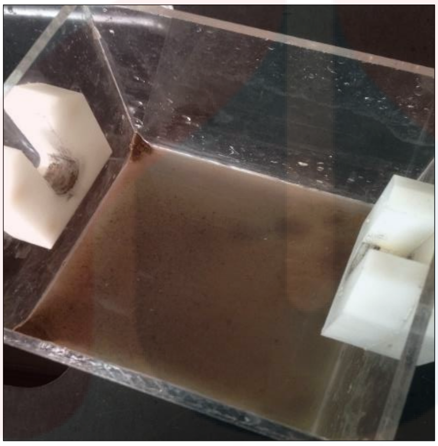
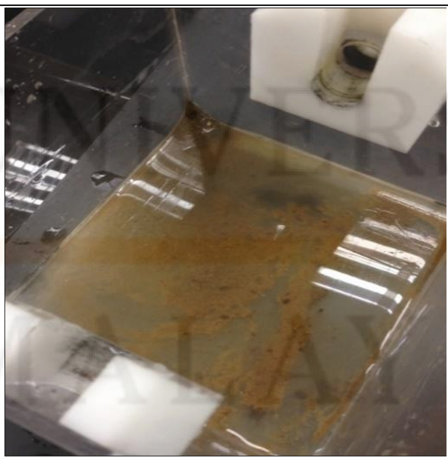
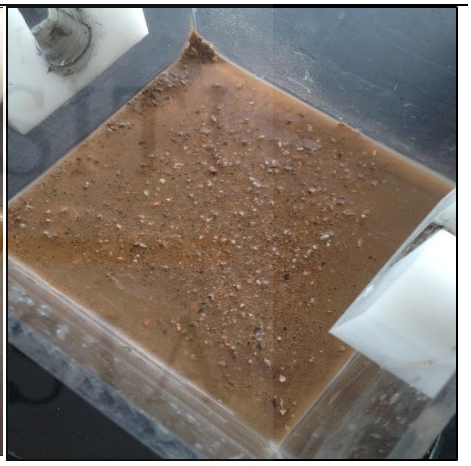
Table 5.5 show the mean value of durability index Id2 from 6 samples of granite rock that collected at the study area and figure 5.5 presented the chart Id2 of granite and weathering grades. Deterioration of granite samples caused the durability index value decreased, it can be seen from the previous tables, the value of Id2 was decreased from Id1 value after completing two standard cycles. Increasing deterioration of sample lead to increasing weathering grade that proposed and modified from (Ibrahim Komoo et al., 1990).

According to the figure 5.5, the weathering of granite sample at grade II show the mean value of durability Id2 98 percent which is classified as slightly weathered. Mean value for gneiss sample is 98 % same as granite sample and also classified as grade II based on the classification. Grade II is classified as slightly weathered rock which means the rock samples have discontinuity surfaces or rock material discoloured and slight weakening.

For the samples of sandstones, from the graph, it shows that grades II from 3 samples out of 5 samples have the Id2 mean value 97 %. This grades II considered as slightly weathered, high durability and may have slightly change on the rock surfaces due to weathering process. The samples that have Id2 mean value 91% and weathering grades at grades III, it considered as moderately weathered rock. The rock samples in grade III have characteristic such as weakening, the rock is discolouring and small pieces of rock can be broke by hand.

From the results, it can concluded that the sandstone sample from Felcra Reka are less durable and more susceptible to degradation than granite and gneiss sample from Renyok area. It is different in durability probably because the mineral composition and textural features of the rocks sample are different. Granite contain the minerals that form in low temperature during crystallized, such as quartz, feldspar and biotite. These minerals, after crystallized are easily stable when exposed to the new environment with low temperature. Gneiss sample is durable because it was formed through highly metamorphism process that make it resistance to the weathering process. Sandstones sample was collected in weathered condition from the outcrop, and it less durable than granite and gneiss because it is porosity and possibly a few mineral content was weathered. Figure 5.6 shows the left of weathered rock after finishing two standard cycles.

Table 5.6: The left of some granite, gneiss and sandstone sample after completing two standard cycles.

Granite		
Gneiss		
Sandstone		

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

After finished this research, the geological map of the study area were produced. The structural analysis, geomorphology form, drainage pattern and stratigraphy of the study area were obtained through geological mapping activity. Generally, the study area composed of different lithology from Permian to Cretaceous period, such as granite, gneiss, metasedimentary rock, limestone and sandstone

From this study, slake durability index parameter provided the value of durability index Id1 and Id2 of rocks after completing two standard cycles. Based on the value of durability index Id2 from slake durability test, the durability classification of rock was obtained by using Gamble’s slake durability classification. The Id2 value of granite sample is range from 98.11% to 99.05, for gneiss samples 98.53% to 99.18%, and for sandstone samples is 87.56% to 98.97%. Granite and gneiss sample from Renyok area show very high durability and resistance to weathering process while for sandstone sample from Felcra Reka area consist of medium to very high durability.

The weathering grades classification that proposed by (Ibrahim Kamoo and Jasni Yaakub. 1990) for rock samples was achieved by relate it with slake durability index Id2 values. Based on the result obtained, the granite and gneiss samples in classified in grade II while for sandstone, two out of five sample is in grade III and another three sample is classified in grade II. Granite and gneiss sample have same durability and weathering grades value while sandstone sample composed of variety of durability and weathering grades value. It show that the high deterioration caused rock to decrease it durability and high weathering grades. Besides, it give the confirmation that durability of rock affects their degree of weathering.

6.2 Recommendation

Based on current research, recommendation for next future study is undergo the test for other types of lithology, for examples, shales, phyllite, siltstones,slate for get more information about durability value, also result of durability classification and weathering grades. The place or study area for slake durability test are recommend at active construction places such as quarry for excavation work, outcrop near highway for avoid from risky condition such as rock fall, and others potential place that have potential development.

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APPENDDICES

The mass values of granite after completing two standard cycles.

Sample S1	Sample S2A
Mass D = 934.72 g	Mass D = 934.71 g
Mass A = 1384.95 g	Mass A = 1418.64 g
Mass B = 1383.29 g	Mass B = 1415.71 g
Mass C = 1379.68 g	Mass C = 1413.96 g
Sample S3A	**Sample S4B**
Mass D = 934.72 g	Mass D = 936.72 g
Mass A = 1386.81 g	Mass A = 1607.67 g
Mass B = 1383.14 g	Mass B = 1601.79 g
Mass C = 1380.15 g	Mass C = 1600.09 g
Sample S5B	**Sample S5A**
Mass D = 936.73 g	Mass D = 934.74 g
Mass A = 1524.65 g	Mass A = 1471.02 g
Mass B = 1519.32 g	Mass B = 1467.09 g
Mass C = 1515.55 g	Mass C = 1465.93 g

The mass values of gneiss after completing two standard cycles.

Sample M1	Sample M2
Mass D = 936.72 g	Mass D = 934.71 g
Mass A = 1453.05 g	Mass A = 1590.23 g
Mass B = 1451.09 g	Mass B = 1585.50 g
Mass C = 1447.87 g	Mass C = 1581.41 g
Sample M3	**Sample SM4**
Mass D = 936.70 g	Mass D = 934.72 g
Mass A = 1423.43 g	Mass A = 1496.28 g
Mass B = 1419.57 g	Mass B = 1492.58 g
Mass C = 1416.31 g	Mass C = 1490.40 g

Sample M5	
Mass D = 936.72 g	
Mass A = 1629.06 g	
Mass B = 1625.70 g	
Mass C = 1623.44 g	

The mass values of sandstones after completing two standard cycles.

Sample O1A	Sample O2A
Mass D = 936.72 g	Mass D = 934.71 g
Mass A = 1393.44 g	Mass A = 1543.28 g
Mass B = 1379.86 g	Mass B = 1532.78 g
Mass C = 1370.19 g	Mass C = 1520.10 g
Sample O3	**Sample O4B**
Mass D = 936.70 g	Mass D = 934.72 g
Mass A = 1576.10 g	Mass A = 1446.53 g
Mass B = 1571.40 g	Mass B = 1405.48 g
Mass C = 1569.56 g	Mass C = 1382.91 g
Sample O5	
Mass D = 936.72 g	
Mass A = 1421.72 g	
Mass B = 1415.34 g	
Mass C = 1402.63 g	