GENERAL GEOLOGY AND DETERMINATION OF POTENTIAL LIMESTONE GEOHAZARD BY USING GIS AT KAMPUNG GUNONG BATU MELINTANG, JELI , KELANTAN

by

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

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THESIS DECLARATION

I hereby declare that the work embodied in this report is the result of the original research and has not been submitted for a higher degree to any universities or institutions.

____

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Date:

I certify that the report of this final year project entitled " General Geology and Potential of Limestone Geohazard by using GIS at Kampung Gunong Batu Melintang ,Jeli , Kelantan". Matric number E13A133 has been examined and all of the correction recommended by examiners have been done for the degree of Bachelor of Applied Science (Geoscience) , Faculty of Earth Science, University Malaysia of Kelantan.

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General Geology and Determination of Potential Limestone Geohazard by using Geographic Information System at Kg.Gunong Batu Melintang, Jeli, Kelantan

ABSTRACT

This study is about the general geology and determination of potential limestone geohazard by using geographic information system at Kg.Gunong Batu Melintang in Jeli, Kelantan. Geographic information system is a system designed to capture, store, manipulate, analyze, manage, and present all kinds of spatial or geographic data. The study area is located between coordinates N 5˚42'16.65 "to N 5˚45'1.22" and E 101˚43'14.32 "to E 101˚ 46'1.70"E. The aim of this study is to produce and improve an existing geological map of the study area, identify the limestone karst condition by using geographic information system and to produce potential of limestone geohazard map for the study area. For the determination of potential limestone geohazard, the raster multi-overlay analysis method was choosed. The analysis of raster data was performed by using the weightage corresponding to the specifications assessment. At the end of the study, the potential of limestone geohazard map of the study area was produced. Based on the GIS analysis interpretation, the potential of limestone geohazard in the study area is considered to give moderate hazard. The results of this study can contribute to the understanding of the geology of the study area, and may help in the development of the future.

Geologi Am dan Penilaian Kemungkinan Geobencana Batu Kapur Dengan Menggunakan Sistem Maklumat Geografi di Kg.Gunong Batu Melintang, Jeli, Kelantan

ABSTRAK

Kajian yang dijalankan ini adalah mengenai geologi am dan penilaian kemungkinan geobencana batu kapur dengan menggunakan sistem maklumat geografi di Kg.Gunong Batu Melintang Jeli, Kelantan. Sistem maklumat geografi adalah satu sistem yang direka untuk menangkap, menyimpan, memanipulasi, menganalisis, mengurus, dan membentangkan semua jenis data spatial atau geografi. Kawasan kajian terletak diantara koordinat N 5˚42'16.65" ke N 5˚45'1.22" dan E 101˚43'14.32" ke E 101˚ 46'1.70''E. Tujuan kajian ini dijalankan adalah untuk menghasilkan dan menambahbaik sebuah peta geologi yang sedia ada bagi kawasan kajian, mengenal pasti keadaan kars batu kapur dengan mengunakan sistem maklumat geografi dan untuk menghasilkan peta potensi geobencana batu kapur bagi kawasan kajian. Bagi proses penilaian potensi geobencana batu kapur, kaedah penindihan kepelbagaian lapisan data raster telah dipilih. Analisa data raster dilakukan dengan menggunakan nilai pemberat yang bersesuaian dengan spesifikasi kajian. Diakhir kajian, peta potensi geobencana batu kapur bagi kawasan kajian telah dihasilkan. Berdasarkan pengolahan analisis daripada GIS, kadar potensi bagi bencana batu kapur di kawasan kajian boleh dikatakan sebagai sederhana bahaya. Hasil kajian ini dapat menyumbang kepada pemahaman geologi kawasan kajian, dan mungkin dapat membantu dalam pembangunan di masa hadapan.

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LIST OF ABBREVIATIONS

GIS	Geographic Information System
DSMM	Department of Surveying and Mapping Malaysia
KDPS	Kelantan Department of Population Statistic
DDI	Department of Drainage and Irrigation
ESRI	Environmental System Research Institute
GPS	Global Positioning System
HCL	Hydrochloric Acid
MDM	Meteorological Department of Malaysia
DEM	Digital Elevation Model
LHEF	Landslide Hazard Evaluation Factor

LIST OF EQUATIONS

NO.		PAGE
3.1	$S = (W_{lith} \times R_{lith}) + (W_{L.U} \times R_{L.U}) + (W_{Slope} \times R_{Slope}) + (W_{D.D} \times R_{D.D}) + (W_{R.F} \times R_{R.F})$	45

LIST OF SYMBOLS

σ_1 Compressional forces

σ_3 Extensional forces

CHAPTER 1

INTRODUCTION

1.1 General Background

Based on the general geology, the research area is located at Kg. Gunong Batu Melintang, Gunung Reng which becomes a part of Jeli District. The process of geological mapping generally has been focused on the behaviour of the study area that includes the geohazard potential of the limestone karst, types of rock distributions, the weathering processes and also its topography.

The most important things that need to be highlighted during conducting geological mapping are the relationship between the limestone karst and the potential of geohazard. Then, the updated geological map only can be done based on the types of rock found which can be further explained in petrography analysis. The Geographic Information System (GIS) software is very helpful and useful in determining and identifying the surrounding topography area.

The study area owned a limestone karst named by the local as Gunung Reng. It is well known for its beautiful karst topography. Not many regions in Malaysia have karst topography except for Bukit Keteri in Beseri, Perlis, Gua Bama, Gua

Merapoh and Gunung Senyum in Pahang, Kilim Karst Geoforest Park in Langkawi, Gua Bewah in Terengganu and Batu Caves in Selangor.

Limestone can be classified into a sedimentary rock which generally composed of mainly minerals calcite and aragonite, which are in different crystal forms of calcium carbonate ($CaCO_3$). Limestone karsts can have many special and unique features such as stalactite, stalagmite, pinnacles, depression, steeply bedding inclination and etc. In addition, most of limestone is made up of skeletal fragments of marine organisms such as coral, forams and molluscs. This composition can show the deposition environment of that area in the past geological time.

Based on fact, limestone makes up about 10% of the total volume of all sedimentary rocks. The solubility of limestone in water and weak acid solutions resulting the formation of karst landscapes. In fact, most of cave systems are through the limestone bedrock. Commonly, sedimentary rocks are very easy to undergo the weathering process.

As the limestone is easy to weathered, some area around or nearby the study area now is possibly threatened by geohazard. A geohazard is known as a geological state that may lead to widespread of damage or risk. Geohazards are geological and environmental conditions that involves long-term or short-term geological processes. Karst features, developed over and within soluble rocks, are a well-known potential geohazard which can cause a lot of significant problems, such as subsidence, rock fall, cavities in the limestone bedrock, sinkhole and etc.

Instead, there have been numerous examples of subsidence and infrastructure damaged resulting from collapse of karst features which cause the properties to collapse and put lives at risk. Furthermore, karstic rocks can make ground conditions more difficult which increase the construction costs. Underground cavities can also act as pathways along which hazardous liquid and gaseous contaminants can travel, commonly some distance from their source, thus posing an environmental risk.

There are many case study related to this kind of geohazard. According to local newspaper, New Straits Times, a huge sinkhole has opened up in the middle of Jalan Tuaran Likas in Kota Kinabalu on November 8, 2016. The disaster has caused traffic congestion. According to the statement, the sinkhole was formed due to a broken sewer connection. By time, the structure of limestone in the area already affected by water flowing out from the sewer which making it fragile and easily crumble in the form of sinkhole, thus threatening the safety. The sinkhole was estimated to be about five metres deep.

Another case of sinkhole was reported on Tuesday, January 19, 2016 which occurred along Jalan Kempas, Taman Megah Ria in Johor Bharu as shown in Figure 1.1. The problem was believed to cause a lot of problems to local residents especially during rush hour. The sinkhole was about five metres wide. Other than that, on November 27, 2011 the rock falls was reported to block the railway path in Gua Musang Keretapi Tanah Melayu (KTM Station).

To be clear, all of the cases mentioned were happened in karstic area which leads to huge threat to people nearby. Therefore, this study is important to identify the potential of limestone karst geohazard in the study area.

Figure 1.1: Sinkhole along Jalan Kempas, Taman Megah Ria in Johor Bharu.

(Source:http://www.thestar.com.my/metro/community/2016/01/19)

1.2 Problem Statement

The main problem in this study is the geological map that has been provided show less information and not up to date. It is hard when the map that will be used as a reference was not up to date. Besides, the surface landform or the geology environment of a certain area also might be changed by time due to the geological processes. Thus a new update geological map is needed to be created to give the latest information about that particular area.

When conducting geohazard limestone mapping, the data collection needs to be collected in details to ensure that any of the geohazard features can be located. The geohazard limestone mapping and the geological mapping need to be parallel or simultaneously to avoid any data redundancy and to obtain more accurate data. The problem is there are some parts within study area cannot be accessible. These can be either due to security or very thick forest.

Up until now, the limestone karst on that area has not been classified. The map show by Department of Surveying and Mapping Malaysia (DSMM) only show the distributions of limestone without showing the actual types of that limestone belongs to. The data for limestone geohazard in Kg.Gunong Batu Melintang, Jeli considered being none at all. Besides, there is still no research about Gunung Reng limestone by using GIS especially an explanation about its geohazard potential.

Thus, this problem could leads to unpredictable limestone geohazard in the future. The application of GIS is important in order to generate a potential limestone geohazard map in that area.

1.3 Research Objectives

I. To produce a detailed and updated geological map of Kg. Gunong Batu Melintang area with scale of 1: 25 000.

II. To identify karst surface condition by using GIS.

III. To produce the potential of limestone geohazard map in study area.

1.4 Study Area

1.4.1 Location

The study area covers an area of 5 km x 5 km (25 km²) in Kg.Gunong Batu Melintang and its surroundings. It is located in the western corner of Jeli District, at Batu Melintang sub-district, Jeli, Kelantan. The coordinate for the latitude ranges between N 5˚ 42'16.65" to N 5˚45'1.22" and the longitude extends between E 101˚ 43' 14.32" to E 101˚ 46'1.70''. The journey takes about 14 km from Jeli town to the study area. Figure 1.2 refers to the base map of the study area.

1.4.2 Demography

According to the data obtained from Kelantan Department of Population Statistic (KDPS), the number of population in Kelantan state which increases gradually from the year 2010 with the total number of 1,641,900 of populations until the year 2014 with the total number of populations of 1,849,700 (Appendix A(1)).

Based on the statistic table, it can be conclude that most of the populations dominated in Kelantan were in Kota Bharu. The main reason that there is a huge difference in number between Kota Bharu and other districts is because the Kota Bharu is the capital city of Kelantan. The population in Kota Bharu increase drastically from year 2010 with total of 509,600 populations to 560,100 populations in the year 2014. Kota Bharu offers a wide variety of job opportunities to people which directly make it become a major attraction for placement.

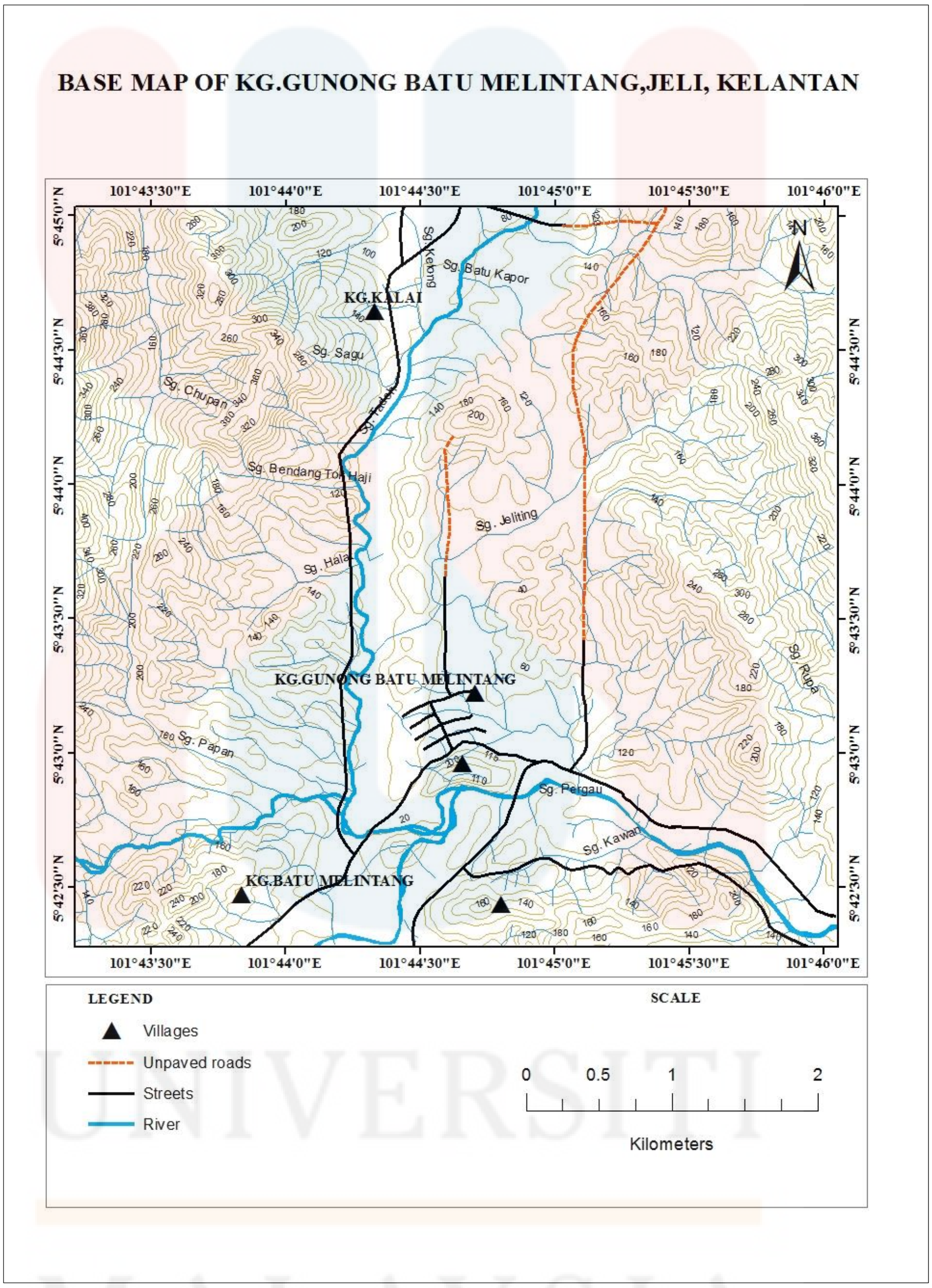


Figure 1.2: Base map of the study area

The focused area in this study is in Jeli district, because Kg Gunong Batu Melintang is located in Jeli. According to the statistic data, we can conclude that Jeli has the least population among the others which only from 48,000 people in the year 2010 to 53,200 people in year 2014. The population were said to increase steadily throughout the years. By time, the increasing in the population in Batu Melintang, Jeli could be resulted from the development of the area. Refer to Figure 1.3.

Undoubtedly, the Jeli district is one of the smallest districts in Kelantan. Thus, the small population may be affected by factors of rural-urban migration. However, the residents of the area around Kg.Gunong Batu Melintang are still vulnerable to limestone geohazard if not taken any precaution steps.

1.4.3 Rainfall

The data for rain distribution were taken from the Department of Drainage and Irrigation (DDI). The total rainfall for the whole Kelantan including Jeli was tabulated in the Appendix A(2). The rainfall distribution data was taken from 2010 until 2014. Based on Figure 1.4, the highest peak of the total rainfall in Kelantan was in the year of 2011 with the value of 35465.0 mm followed by the year 2014 with the value of 30014.5 mm, then in the year 2012 with total value of 29238.5 mm over a year.

In the year 2010, Gua Musang has the least total of rain distribution with the value of 2020 mm a year compared to Tanah Merah which is the highest with the value of 3258.5 mm a year.

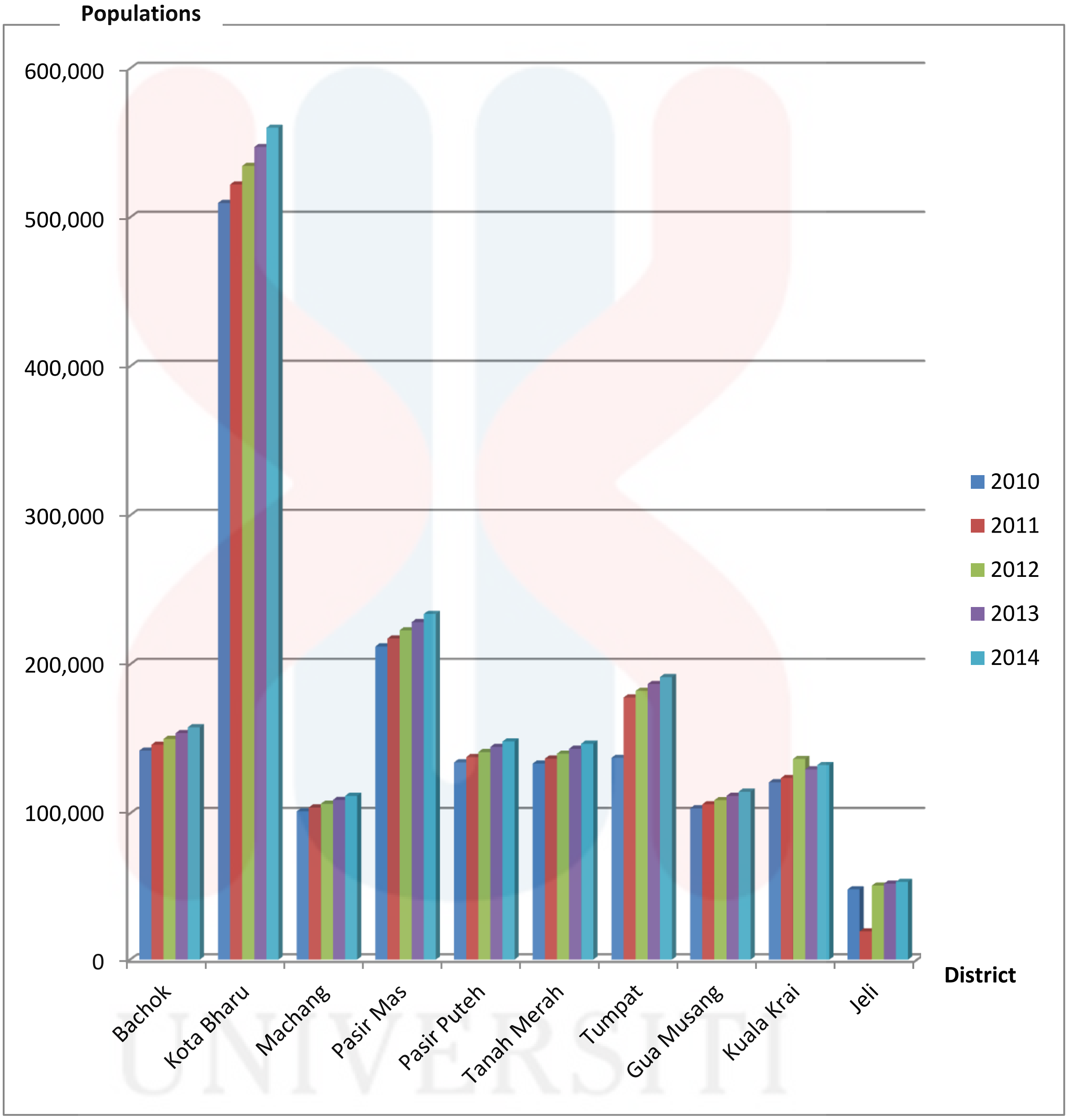


Figure 1.3: Total population in Kelantan from the year 2010 to 2014.

In the year 2014, the highest total of rain distribution recorded was Jeli with the value of 4094.0 mm followed by Machang with the total value of 4080.5 mm a year. Kuala Krai was recorded to have the least total of rain distribution in year 2014 with the value of only 1602.0 mm a year.

According to the Figure 1.4, the total distribution of rainfall for Jeli was fluctuated from the year of 2010 to the year 2013 before it increased gradually in the year 2014. The total of rain distribution in Jeli from year of 2010 to 2014 was recorded to be 18,399.5 mm. The highest total rainfall in Jeli was recorded in 2011 with the value of 4359.5 mm, while the lowest rain distribution was recorded in year of 2010 with only the total value of 3103.5 mm a year. The difference between the highest and the lowest total of rainfall for Jeli was 1256 mm. Thus, to be considered, the year of 2010 can be considered as the driest year for Jeli but for 2011 it can be considered as the wet year for Jeli.

Based on the total rainfall's data for Jeli, it can be conclude that during the year of 2011 and 2014, Jeli, Kelantan have received an enormous amount of raining which more than the usual. These phenomenons have caused some parts of low area in Jeli to be flooded as the main river cannot contain the water anymore. Therefore, the excessive water will spill out into the surrounding area which triggers the hazard to nearby people.

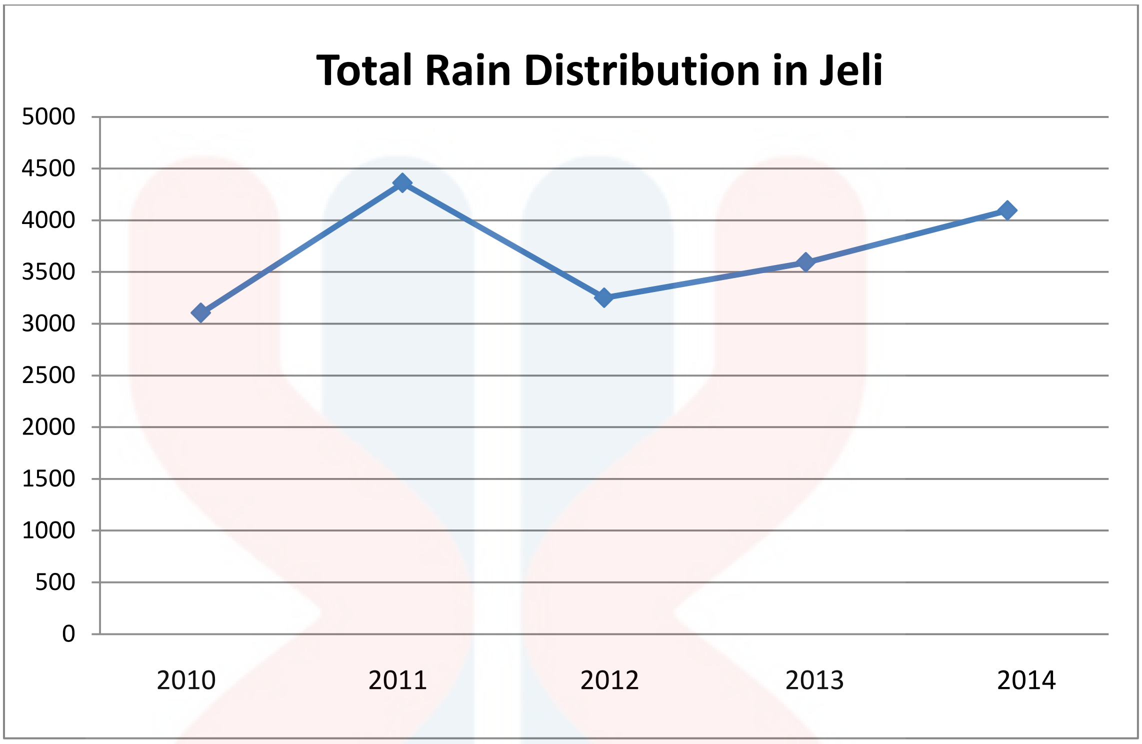


Figure 1.4: Total rain distribution in Jeli, Kelantan from year 2010 to 2014.

1.4.4 Landuse

Some parts within the study area are covered with development area or residential area. Most of the infrastructures such as schools, mosque, police station, market, stalls and etc. are located here. Figure 1.5 shows a school in Kg.Gunong Batu Melintang, which was in residential area.

Besides that, within the study area, there are also some vegetation areas such as rubber plantation, oil palm plantation and mixed plantation which covered the rest of the area. Figure 1.6 shows the landuse of study area as plantation. This area was known as vegetation area.

Figure 1.5: The schools in Kg.Gunong Batu Melintang, Jeli

Figure 1.6: Plantations in Kg.Gunong Batu Melintang, Jeli (A) Banana plantation, (B) Oil palm plantation, (C) Rubber plantation

1.4.5 Social Economic

Based on the economical aspect, most of the people in this area doing plant-based economy. This is because the study area is covered mostly by plantation such as rubber, palm oils, vegetables, sugar cane, and also some mix plantation. There are also some villagers selling vegetables from their own garden for the basis of their family needs. In the middle of the study area, there is a huge area for rubber plantation that may come to conclusion by saying that rubber plantation is the major economic sources in this area. The rubber fibres or extract that is obtained probably sold on external markets for specific purposes to cover the living expenses.

Besides that, there are also a few villagers who carry out animal husbandry such as chickens and goats to be sold to the outside markets. The farming activities are run on a commercial basis but within a small scale. Last but not least, the villagers in the area are also doing business on a small scale such as opening a workshop, petrol station, grocery, food stalls, selling fried foods such as fried bananas, crackers and so on. Figure 1.7 shows the business running by the locals in that area which become the source to fulfil the needs of people in area of Kg.Gunong Batu Melintang, Jeli.

1.4.6 Road Connection

There is main highway available in this area. The highway is known as East West Highway. This is the major road within the study area. Based on Figure 1.8, the road are very broad and wide which indicates that the roads frequently used by cars and lorry as a main connection to somewhere else.

Figure 1.7: Varieties of social economic in Batu Melintang, Jeli. (A) Grocery store, (B) Food stall, (C) Petrol station, (D) Animal husbandry

The highway frequently used by the people to travel to the northern area such as from Jeli to Gerik. East West Highway was built to connect between Gerik in Perak and Jeli in Kelantan. This huge project was costing around RM296 million to facilitate land transportation between the east coast to the west coast of Peninsular Malaysia.

This highway is about 123 kilometers long which 61 km of its total long is in the state of Perak and the remaining distance in the state of Kelantan. This road connection makes traveling faster and help to grow the economy, not only in Perak but nationwide. The logging operation also becomes easier. The fact says that, before the highway was opened on July 1 in 1982, a trip from Alor Setar to Kota Bharu takes more than 1,000 km, but after this project is completed, the travel distance has been shortened by several hundred kilometres.

1.5 Scope of Study

The scope of this study was focused in Kg.Gunong Batu Melintang area which in Jeli. This research is focusing on the determination of potential of the limestone geohazard. It involves the study of limestone geohazard by using ArcGIS from Environmental System Research Institute (ESRI). Besides that, this study also has been conducted in order to find the evidence and to prove either the limestone within the study area has potential in geohazard or oppose.

Figure 1.8: Road connection to the study area (N 5˚42’50.00” E 101˚48’34.44”)

The method used to identify potential of limestone geohazard zone was raster multi-overlay analysis method. During the analysis, all the data obtained during geological mapping which is related to the limestone geohazard will be overlay on top of the others. At the end of the study, a potential of limestone geohazard map will be able to produce.

1.6 Research Importance

The importance of this research is to study about the potential of limestone geohazard in Kg.Gunong Batu Melintang which might cause lost, damage or even loss of life to the surrounding people. This is because, the limestone karst can undergo certain geological processes such as weathering over period of time and when this is happened, the possible hazards that might be occur are sinkholes, rock falls and etc. At the end of this research, a potential limestone geohazard map also will be produce. Thus, this research will be conducted as a precaution to avoid any of the risk possibility in the future.

Besides, this research also is to establish the new updated geological maps at this area. Some changes maybe occur over a time due to some geological process. Thus, with the scale 1:25,000 it will provide more geological information such as geomorphology, rock boundary, and others. Apart from that, this research also can act as a guideline for any authorities in future development.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discuss on the past studies which already been done by some researchers which relating to limestone karst and the geohazard that it imposed. The previous research from other researchers needs to be reviewed in order to take or improve the studies.

The most important part is the methodology used. The methods that are going to be conducted in this research can be the same as the previous research and studies. The literature review can assist and help a researcher throughout the studies and at the same time it helps for better improvement in conducting research.

2.2 Regional Geology and Tectonic Setting

Kelantan is one of the states in Malaysia that was located at north east of Peninsular Malaysia Kelantan had a longitude extend from E 101^{o} 20’ to E 102^{o} 41’ and a latitude extend from N 4^{o} 33’ to N 6^{o} 14’. It covers an area of 15.022 km^{2} and was divided into ten districts including Tumpat, Kota Bharu, Pasir Mas, Bachok, Tanah Merah, Machang ,Pasir Puteh, Jeli, Kuala Krai and Gua Musang.

The major rocks type can be found in Kelantan were unconsolidated sediment, extrusive rocks, sedimentary or meta-sedimentary rocks and also granitic rocks (Department Of Mineral and Geoscience Malaysia, 2003). Figure 2.1 show the geological map of Kelantan State.

According to Malaysia and Thai Working Group in 2006, from the transect area of Batu Melintang with Thailand boarders, the formation formed are Tiang Schist, Mangga formation, Taku Schist, Telong formation, Ai Ba Lo formation, Bu Yong formation and some quaternary geology formation which are Simpang formation, Beruas formation, and Gula formation. They composed of variously igneous rock, sedimentary rock and metamorphic rock.

2.2.1 Stratigraphy

The oldest rock unit reported was the Silurian- Devonian Tiang Schist through the Ban Sa Formation. The oldest rock units showed highly folded and faulted structure which then forming the mountainous belt at the western region of transects which trending north south from Ai Ku Sa stream, Thailand to Bukit Luat Lantai down to Kuala Sungai Machang in the south, Malaysia. The formation is described as the sequence of metamorphic rocks that cropping out in the east of the main range granite in the Belum area.

Silurian Devonian Tiang Schist predominantly comprised of quartz garnet schist and also quartz mica-schist. Then the Silurian – Devonian Tiang Schist rock unit which is Ban Sa Formation was then unconformably overlain by the Mangga Formation which was probably in the age of Carboniferous – Permian. Mangga

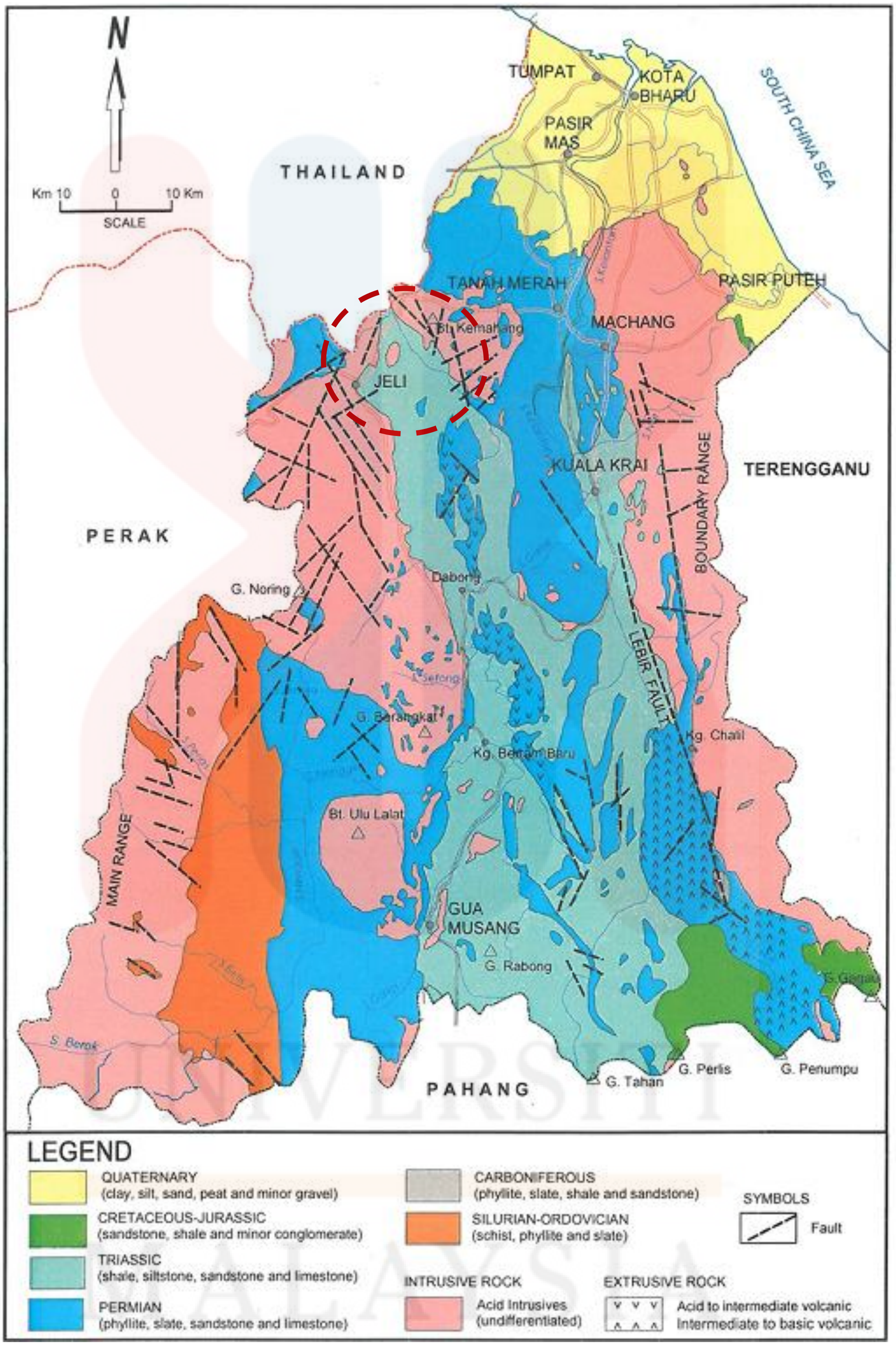


Figure 2.1: The geological map of Kelantan State

(Source: Department of Mineral and Geosciences, 2003) formation was distributed at the south western part of the Transect area (Malaysian & Thai Working Groups, 2006).

The Mangga formation showed low grade metamorphic sequences of argillaceous, arenaceous pyroclastic , horn felsic and calcareous rock (Malaysian & Thai Working Groups, 2006). It is well exposed in the upper reaches of Sungai Machang and extending to south-eastwards to Kampung Gunong. In the north side, the Mangga Formation is said to have extended into Thailand frontier. Apart from it, this rock unit also is well exposed in the western part of the Transect area and southwards to the area of Temengor and Sungai Jenera.

Under this formation, the low graded metamorphic rock sequence can be further divided into four different types of facies which are argillaceous, arenaceous, pyroclastic and calcareous. Generally, there are two argillaceous facies representing the lower and the upper part of this formation.

The upper part of this formation was said to be consisted of hornfelsic rocks such as calc-silicate hornfels which can be observed at Felda Tumbi Rapat, near Gunug Reng area, and Batu Melintang. In contrast, the arenaceous unit is composed of meta-sandstone and meta-graywacke interbedded with minor meta-siltstone and schist. The schist was said to be comprised of quartz-mica schist, quartz-mica-garnet schist and quartz-mica-graphite schist.

Besides that, the pyroclastic rock unit is composed of mainly rhyolitic tuff and existed as lenses within the arenaceous and argillaceous strata. In addition, the calcareous facies was said to be composed of impure marble and pure white marble as lenses within the other facies. For example, Gunung Reng is a limestone lens within hornfelsic rocks that form karst topography at Kg.Gunong Batu Melintang, Jeli.

After the development of Mangga Formation, the Taku Schist Formation is described as the metamorphic rock which is equivalent to the Mangga Formation. This is because, the Taku Schist Formation possess low to high grade of metamorphic rock which probably in the age of early Permian and overlain by the Telong Formation. The Taku Schist Formation was said to be extended at broad belt in central north of Kelantan State from the railway line south of Sungai Galas to Tanah Merah in the south-eastern part of the Transect area.

The Taku Schist Formation or Buke Ta Formation composed mainly of schist which are wholly crystalline and completely schistosed. Moreover, the mica schist in this formation mostly consist of quartz-mica-schist, mica-garnet-schist and quartz-mica-garnet schist (Malaysian & Thai Woring Groups, 2006).

Telong Formation was said to be exposed at Kg. Legeh and extends towards eastwards of Tanah Merah area on the eastern part of the Transect area. Telong Formation is not exposed in Thailand. This is because, most of the outcrops and bedrock were covered by the thick Quaternary sediment. The Telong Formation consist of shale, slate, phylite, schist and hornfels. Based on the lithological correlation of the same rock unit, the age of this formation is believed to range from Late Permian to Triassic.

Next, the name of Panau beds is given to refer as a sequence of continental, channel lag deposit, sedimentary rocks cropping out at Tanah Merah town (Malaysian & Thai Working Groups, 2006). The Panau beds comprised of interbedded thin argillite beds, laminated fine-grained sandstone, poorly sorted pebbly sandstone and also para conglomerate. The argillite rocks are maroon in terms of colour. Some of the argillite rocks are channel lenses within the sandstone beds. This indicates that the rocks were deposited in a channel lag, in oxygenated and continental environments.

Other than that, Batu Melintang-Sungai Kolok Transect area also has a Quaternary deposit which is formed in both marine and non-marine environments. The Quaternary deposits are divided into three formations such as the Simpang Formation, Beruas Formation and Gula Formation.

The Simpang Formation are dominantly characterised by gravel, sand, silt and laterite, with abundant iron concretions. Meanwhile, the young fluviatile sediments of the Beruas Formation is mainly characterised by silty clay, sand, and gravel with abundant mottles and iron concretions. Whereas, the Gula Formation were characterised by sand, gravelly sand, and silt repectively. Figure 2.2 show the schematic stratigraphic column of the Batu Melintang-Sungai Kolok Transect area in Malaysia.

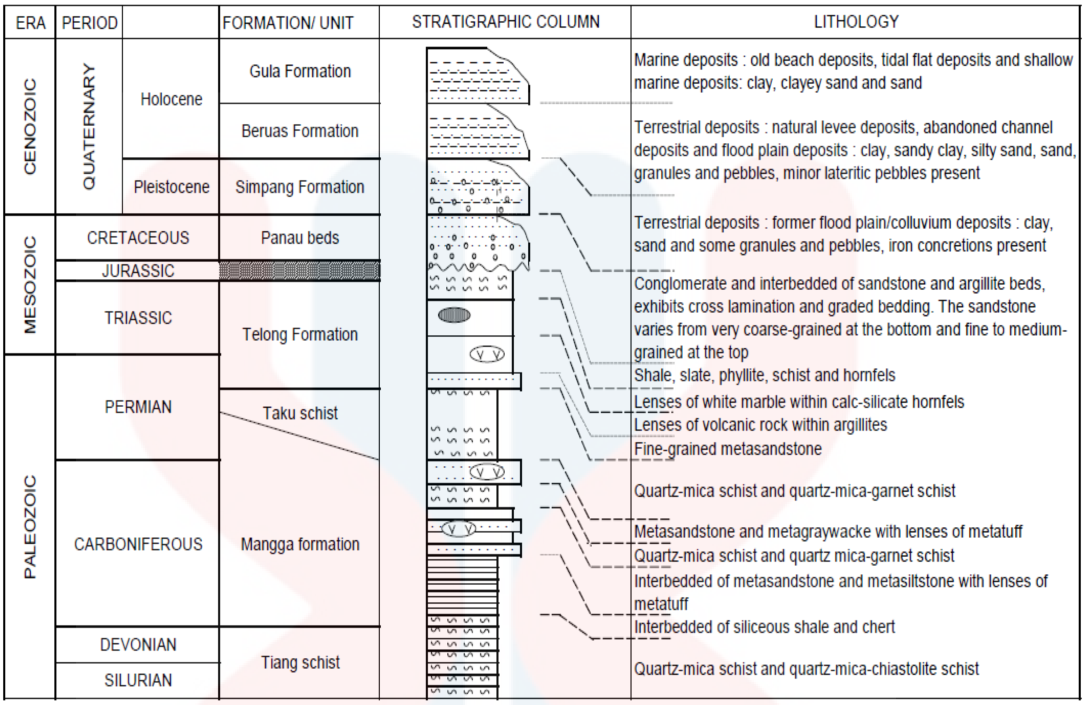


Figure 2.2: Schematic stratigraphic column of the Batu Melintang-Sungai Kolok Transect area in Malaysia.

(Source: Malaysian & Thai Working Groups, 2006)

2.2.2 Structural Geology

According to the past research, the major collision between Sinoburmalaya to the west and Eastmal-Indosinia blocks to the east formed the peninsular of Malaysia. The zone of collision is represented by the Bentong-Raub Suture which can be traced northward into Thailand and southward into the Banka and Billiton Islands. Along with this event, the major tectonic event during Late Triassic also has resulted in the rock deformation of Malay-Thai Peninsula (Malaysian & Thai Working Groups, 2006).

Generally, the pre-orogeny sedimentary successions in the Transect area were folded into a series of synclines and anticlines. The folding structure is characterized by the tight, asymmetric and open folds, which cause the repeated and overturn sequence in the older sedimentary rock unit. The NW-SE and N-S trending fold axes are sub-parallel to the long axis of the Malay Peninsular and most of the bedding planes were dipping towards the east with various dip angles.

Faulting considered to be widespread throughout the Transect area. Owing to the thick soil cover and deep tropical weathering, fault zones are seldom exposed at more than a few places along their traces. Faults are generally varies in width characterised by fractured, or sheared rocks. There are several faults, which are mainly strike-slip and normal faults, trending N-S, NW-SE and NE-SW. In fact, the NE-SW trending fault is the main fault of the Transect area. The major faults are Long-Kolok fault (NE-SW), Pergau fault (NE-SW), Kalai-To Mo fault (N-S) and Ka To-Bu Yong fault.

2.2.3 Historical Geology

Peninsular Malaysia can be divided into 3 longitudinal belts, Western, Central and Eastern, each of which has its own distinctive characteristics and geological development (Hutchison, 2009). The Central Belt is underlain predominantly by Permian-Triassic clastics, volcanics and limestones. Pre-early Devonian deposition of coarse clastics, argillaceous sediments chert and other rock types occur in the marginal belt forming the foothills of the Main Range Granite (Khoo & Tan, 1983).

In the rest of the Central Belt, this late Triassic orogenic uplift also terminated marine sedimentation. Continental deposition began soon after and continued up to the early Cretaceous. (Khoo & Tan, 1983). In Malaysia, karst in most of limestone formations are dominated by its highly variable rockhead and is thus classified as extreme karst (Zabidi et.al, 2016).

2.3 Limestone

2.3.1 Definition

Limestone is a sedimentary rock consisting primarily of calcium carbonate in the form of the mineral calcite. Rainwater dissolves the limestone by the following reaction:

Calcite + Carbonic acid = Calcium ions dissolved in ground water + Bicarbonate ions dissolved in ground water (Alpha, Galloway, & Tinsley III, 1997).

Limestone consists largely of the mineral calcite, which is composed of calcium carbonate, which is only slightly soluble in pure water. Limestone are however much more soluble in acids, and the most important process in the overall development of surface karst landforms and caves is solution by carbonic acid, that is produced by the introduction of carbon dioxide. The process of dissolving the rock, to create the liquid solution of calcium and bicarbonate ions in water, may be referred to as either solution or dissolution (Waltham et.al, 1997).

2.3.2 Limestone Formation

Limestone is the only common rock that is highly soluble in natural surface waters, so nearly all karst is formed on limestone. Dolomite may have karstic landforms, generally less well developed than those on limestone (Waltham, 1997).

The process of karst formation commences as rainfall (H_2O) passes from the atmosphere onto the top soil, where it then infiltrates the ground. Mixed with (CO_2) gas from the air and soil, this water produces weak carbonic acid (H_2CO_3), which seeps further into the ground and makes contact with the limestone ($CaCO_3$) and/or dolomite ($CaMg\ (CO_3)_3$) . This leads to the dissolution of these rocks and the development of the karst, which is characterised by voids and cavities, sinkholes, sinking streams, and the presence of irregular rock surfaces with soil-filled lots and pinnacles (Bakhshipour et al., 2013).

2.3.3 Limestone Karstic Feature

Some karst features are formed by solution of gypsum or salt, but pseudo-karsts on basalt or ice are not due to rock solution. (Waltham, 1997). Limestone is characterized by cliff hills almost vertical to vertical and has a natural geological structure as a result of natural processes such as caverns, cavities, undercut, grooves dissolution, stalactite and stalagmite. The occurrence of discontinuities structures such as joints, faults and bedding planes will form a loose rock blocks and has the potential to suffer catastrophic rock falls (Wan Salmi et. al, 2014).

2.3.4 Limestone Potential Geohazard

Geohazard is a kind of geological process or phenomenon, it can deteriorate natural environment, threaten human life and property, and destroy resources and environment which are necessary to human survival and development. It includes geohazard and the object geohazard affected. The two aspects are complementing each other and indispensable (Cheng & Huo, 2014).

Karst features, developed over and within soluble rocks, are a well-known potential geohazard, and can cause significant engineering problems, such as subsidence and irregular rockhead (Farrant & Cooper, 2008).

Karst areas are known to have a unique set of geotechnical and environmental difficulties that affects land use. Irrespective of whether karst structures are exposed or not, they still pose serious threats to properties such as buildings, agricultural farmland, roads, and railways. An example of karst-related destruction is the collapse of a highway bridge over the Seti River (Bakhshipour et al., 2013).

Numerous engineering problems are believed to be linked with construction in karst environments, such as the disastrous collapse of the ground surface or a slow unnoticeable subsidence, which among other things, could lead eventually to the collapse of buildings, the destruction of railways and roads due to subsidence, and dam failures.

The formation of large voids in areas underlain by carbonate rocks may lead to either a gradual ground subsidence due to the slow migration of fine particles from the sub base or to a sudden and catastrophic pavement failure, such as a sinkhole (Bakhshipour et al., 2013).

Damage related to sinkholes is not limited to properties and structures such as buildings and roads but it also affects water and environmental resources, creating pathways for draining surface water such as streams and lakes, directly into the underlying aquifers. Furthermore, this leads to the contamination of groundwater through the transportation of pollutants into the aquifer (Bakhshipour et al., 2013).

A major challenge facing researchers and engineers in assessing karsts is the identification and delineation of underground cavities. These structures are usually unpredictable and their effects can either lead to a slow and gradual subsidence or to a catastrophic collapse feature.

2.4 Application of GIS in Limestone Geohazard Mapping

A geographic information system is a system that designed to capture, store, manipulate, analyse, manage, present and display all types of spatial or geographical data. GIS applications are tools that enable users to create interactive queries (user-created searches), analyse spatial information, editing data in maps, and present the results of all these operations. GIS is a broad term that can refer to a number of different technologies, processes, and methods. Moreover, GIS can map any of the possible geohazard area in the study area by using GIS overlay analysis.

The GIS software can be used to identify and quantify the geo-hazard evaluation index, the weights were gotten using a method combining the qualitative analysis with quantitative calculation, geo-hazard risk can be evaluated by weighted sum method (Cheng & Huo, 2014).

GIS is a kind of international advanced level geographic information system software. Spatial information and its attribute information will be accurately and truly output to users according to the user's needs in texts and pictures.

Spatial technology was used intensively to study and map aspects of karst area (Al-kouri et al., 2013). Relying on its unique spatial analysis function and visualization capabilities, intuitionist maps can be generated and provide a scientific basis to a variety of decision.

Its rapid evaluation unit subdivision and layer overlay analysis function can eliminate a lot of tedious data statistics works during the geo-hazard susceptibility evaluation, and the same time, the evaluation result is more scientific and accurate evaluation (Bakhshipour et al., 2013) .

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

This chapter is divided into two which are geological mapping and also GIS analysis. In geological mapping, geological analysis will be done. Same goes to GIS analysis, it have its own analysis. The materials used for these two tasks were different. But even so, they are both relevant to each other.

This chapter includes materials and method used in this study. Materials (include equipment) consists of some basic data, such as base map (topographic map) and some standard geological equipment used in this study. Methodologies that are used in this research include preliminary studies, field studies (including geological mapping, data collection, and sampling), laboratory works, data analysis and interpretation. Last but not least, report writing is the last step where all the findings and result will be discussed and also be written in a thesis.

3.2 Materials

The materials used in this study composed of three different components which were geological mapping, lab work which involves thin section analysis, and also software for GIS analysis. In geological mapping, the equipment used is shown in Figure 3.1.

There are some tools and equipment that are compulsory for geological mapping. First of all is geological hammer. It is used to break the rocks in order to get fresh sample. Next is hand lens. Hand lens is important in order to observe mineral composition and content in a rock. Brunton Compass is used to determine the direction and to record the reading of strike, dip, crack, bedding, faults and fractures. It also can measure an elevation of a place. Besides that, a digital camera also helps to take pictures of rock samples and site environment as a proof for the research activities.

A Global Positioning System (GPS) also considered to be one of the most important things to have during conducting a mapping session as it helps us to locate and record the track and at the same time can be used to create a waypoint for each different sample that has been taken. Besides, 1 mol of HCL acid also important to differentiate carbonate rocks from other rocks. Furthermore, a topography map or a base map that has been produced by using ArcGIS also needs to bring during field work mapping as a guide.

A measuring tape can be used to measure the distance or length of an outcrop or rocks during field work. Next, sample bags also play an important role which will be used to keep the rock sample for each site. Field Notebook is used to record the data and sketching while the stationary are used as tools to record the data during field work.

For thin section analysis which considered as a lab work, the equipment that are used to prepare the thin section slide for the sampling are cutter blade to cut the rock, and thin section glass. A polarized microscope also will be used in the process of thin section analysis. The total number of thin section prepared depends on the variability of the lithology in the study area.

ArcGIS 10.0 is the software that is used for GIS analysis. As shown in Figure 3.2, ArcGIS can be defined as a Geographic Information System (GIS) which working with a map and geographic information. All of the GIS analysis purposes mainly being done by using this software.

Figure 3.1: Geological tools for mapping

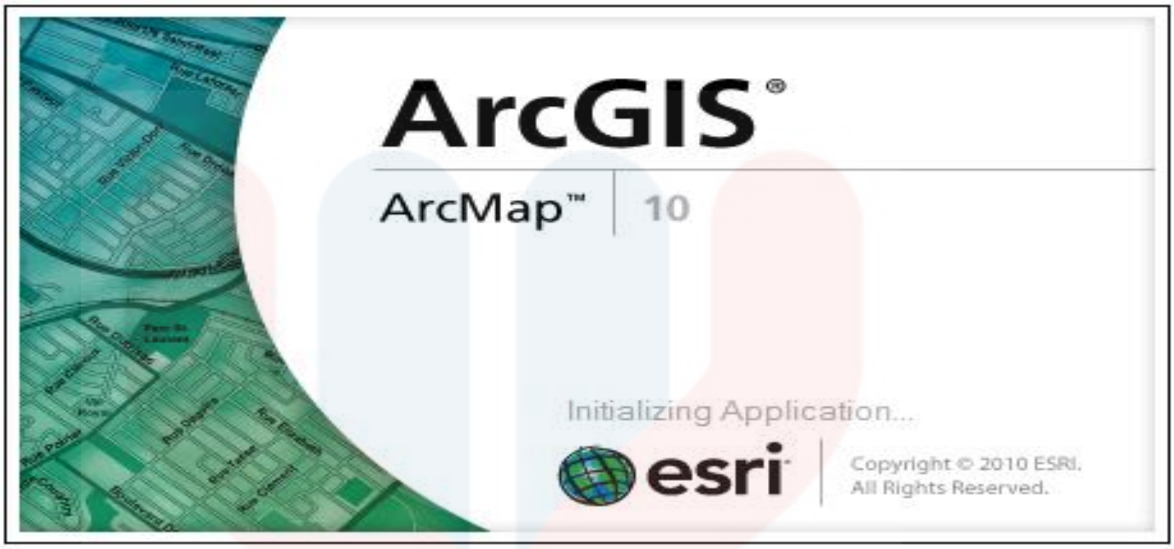


Figure 3.2: The software used for GIS analysis

3.3 Methodology

Methodology can be defined as the method used in the study or a steps that should be taken in order to complete the research. The methodology involves a lot of phases or stages. To be clear, Figure 3.3 shows the flowchart or steps of overall research.

3.3.1 Preliminary Studies

Preliminary studies were conducted by collecting some references of previous study and supporting secondary data before collecting primary data or before going to the field. A strong exposure about the background of the study area can save a lot of time from being wasted during fieldwork.

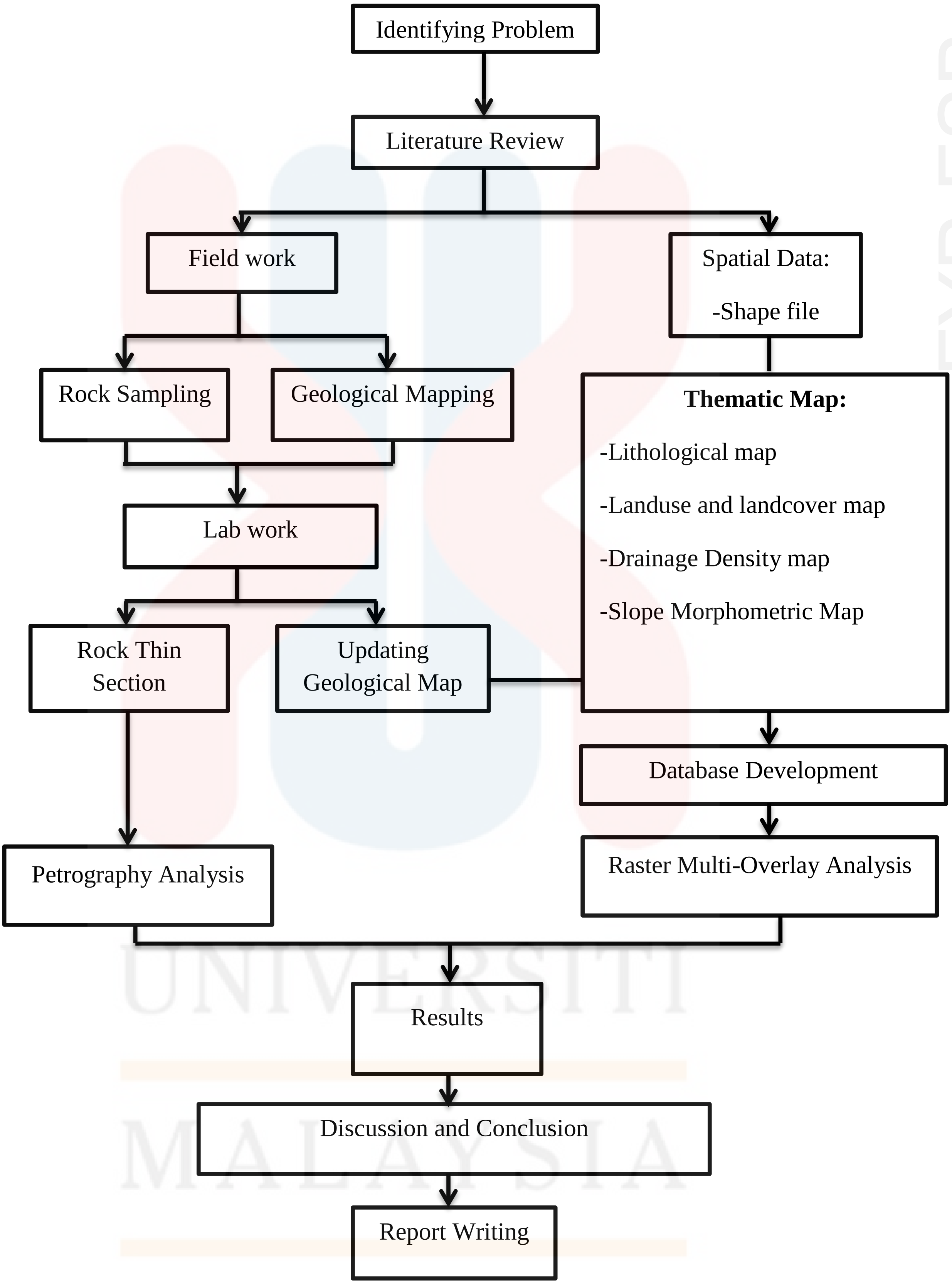


Figure 3.3: Research flowchart

A wise planning is important not only to save time but it is also important to reduce cost as well. A careful planning can ensure an enough times to cover all sections of the study area within a given period.

Literature review is a research or a study about the past research which have been conducted. The references can be collected through internet, such as online journals and scientific articles, e-books and websites, meanwhile journal books and printed journals can be accessed through libraries. It will be more advantage if we can find several case studies that relates to our topic which means that past research was conducted on the same study area or same topics.

3.3.2 Field Studies

Data collection can be divided into primary and secondary data. Primary data is the data that obtained from geological mapping. The secondary data is the data that obtained from other resources either from government or private sector. The examples of secondary data are rain distribution, people distribution, and etc.

The data collection can be obtained based on the data inventories, field work, lab work, and spatial data from GIS analysis. Data inventory is a systematic and productive ways to organize the obtained data in a systematic ways. Table 3.1 shows the data inventories.

a) Field Work

After getting the general information from the preliminary studies, the next step is data collection from field work. This is focusing on study area. The base map that had been produced is really needed as for an observation tools for this study. The steps in field work data collection can be divided into surveying or reconnaissance and detailed observation study.

i. Initial study and survey

The survey across the study area is an initial first stage during field work. This survey includes the process of identifying the outcrop potential and surrounding area.

ii. Detailed observation study

This second stage shows the detailed observation from the first one at the outcrop that identified at the first stage. This process includes the lithology of rock boundaries, geological structures and sketches photo. The value of strike and dip will be recorded for each structures found. The fault and joint structures also need to be considered. The data collected in study area will be analysed. All the characteristics and the behaviour of the surrounding area need to be recorded in order to fulfil the research objectives.

Table 3.1: Data inventories

No	TYPE OF DATA	DATA DESCRIPTION	SOURCE
1	Topographical Sheet	- Sheet 3767, Kampong Batu Melintang, Jeli, Kelantan	Department of Surveying and Mapping Malaysia (DSMM)
2	Field Data	- GPS locations	Garmin and Maverick Pro version 2.7.4
3	Shape file Data	- Contour - River and drainage - Street - Landuse	Department of Surveying and Mapping Malaysia (DSMM)
4	Statistic Data	-Rainfall in Kelantan (include Jeli District)	Meteorological Department of Malaysia (MDM)

3.3.3 Laboratory Work

The process of preparing the thin section for each rock samples considered to be a lab work. Each of the hand specimens that were obtained from geological mapping needs to be made or transfer into a thin section. Thin section is important to know the percentage of the minerals based on the type of rocks (igneous, sedimentary, and metamorphic). The thin section will be analysed under polarized microscopy with the thin slices (thickness: 0.03 mm). The complete thin section will help in interpretation of the study area and the geological units. Moreover, it helps to know how rock is formed and what kind of mineral composition on it.

The process called as petrography analysis will be carried out to identify the types, and composition of the rock before naming each of the rock samples. Each of the rock samples will be examined and classified for detailed description. The technique in preparing thin section involves three steps:

i. Sectioning and cutting

The rock sample is cut into the certain size with the given thickness. The sectioning process used to provide the exposed surface of interest rock.

ii. Grinding

First, the rock samples must be ground smoothly using a horizontal diamond impregnated diamond wheel. Grinding is performed to remove deformation induced in sectioning and to planar grind. Remove the saw marks while doing as little grinding to get a flat surface before it is cemented and gluing into a glass slide.

iii. Lapping

The sample will be moved on rotary motion with a glass slide (carborundum powder and water). The sample will be examined by using transmitted light before it undergoes polishing session. Polishing will removed the final deformation during grinding process. Lastly, view the sample under polarized microscopy to observe the minerals composition.

3.3.4 Data Processing

In this research, the shape files obtained from the Department of Surveying and Mapping Malaysia (DSMM) will be analysed. There are a lot of data, but the chosen data only been made based on the study requirement for analysing and interpretation.

There are several types of thematic map that were used in this study such as lithology map, landuse and landcover map, drainage density map, slope morphometry map, and etc. Each of the thematic map produced should be contributed to limestone geohazard. Any area or region within the study area that have possibility to generate geohazard will be given a weightage. Each weightage value contributes to the geohazard stages.

Each of these thematic maps have been selected due to the factors that could contribute to limestone geohazard in the study area. These thematic map were then been classified according to the weighting and rating scheme of landslide hazard evaluation factor (LHEF). LHEF rating scheme is a numerical system based the major inherent causative factors of slope instability which includes the lithology or rock types, slope morphometry, land use and others (R.Anbalagan, 1992).

The maximum weighting was determined according to their contribution of causing the instability. Appendix A(3) show the proposed maximum of LHEF weighting for each contributory factor for geohazard. The total maximum value of the overall estimated hazard factors was at scale of 7.

Lithological map is the map that shows the distribution of rock types on a certain area that sometimes describes about the geochemical, mineralogical, and physical properties of rocks abundant. The further explanation of the chemistry, mineral composition, and physical properties of rocks is known as lithology. The study of lithology provides valuable information about the formation and productivity of soils, the movement of water, and other important properties of the environment that are influenced by underlying rock type such as limestone bedrock.

Lithology is classified into one of the most important controlling factor for slope stability. In this study, the maximum weightage for lithology is given at scale 2. By further explanation, the different types of rock are the factors that control the weathering and erosion so, the weightage at scale of 2 is considered to be suitable and proper. Instead, different kind of rocks will have different values of rating.

The actual ratings for lithology can be further divided into three classes which are type I, type II, and type III but in this study, the rankings of lithology only was added based on the rock that has been found during geological mapping. The rank for limestone in the study area will be overlay with the weightage during raster calculation. The ranking for the rock types is shown in Appendix A(4).

Slope morphometry map is a map that provides a colorized representation of slopes in an area which are generated systematically by using a server-side slope function on the Terrain layer in ArcGIS followed by the application of a colormap. The degree (˚) of slope is represented by a colormap indicator that display flat surfaces as grey, shallow slopes as light yellow, moderate slopes as light orange and steep slopes as red-brown in colour.

The slope angle data is represented through visualization. A scaling is applied at small scales to generate appropriate visualization. The slopes were categorized based on the frequency of the occurrence of particular slope angle in study area. Generally, there are six types of slope which can be further divided into escarpment or cliff (>55˚), very steep slope (45˚-55˚), steep slope (35˚-45˚), moderately steep slope (25˚35˚), gentle slope (15˚-25˚) and very gentle slope (<15˚).

In this study, the limestone karst which is known as Gunung Reng shows the maximum value of slope at 51˚. Thus the limestone karst in the study area can be classified into very steep slope. The possible kind of failure or hazard that may happen is rock falls and topples. Meanwhile the rest of the areas remain as moderately steep slope. Therefore, there is no escarpment or cliff present in the study area. Appendix A(5) show the types of each slope along with their angles and rankings whereas Appendix B(1) show the slope morphometry map that has been produced.

Another factor that can control the occurrences of possible limestone geohazard is landuse or landcover. This is because, uncontrolled landuse and development can lead to significant changes in topography and also geomorphology such as sinkholes and land subsidence within an area.

Landuse can be used as an indirect indication of karst slope stability. In fact, landuse can affect the rate of weathering and erosion. Depending on the area, the human activities can affect the surrounding conditions. Barren and sparsely vegetated area has faster rate of erosion and higher instability compared to the heavy vegetation. Therefore, heavy vegetation has low weighting value. Meanwhile, in an agricultural area, the slope is considered to be low hence, the value of its weighting is the lowest.

For barren and sparsely vegetated areas, the slopes will undergo faster erosion resulting low stability compared to the heavy forest (R.Anbalagan, 1992). The sparsely areas generally composed of development areas and roads. Appendix A(6) show the ranking for landuse and landcover while Appendix B(2) show the landuse and landcover map that has been produced.

Drainage density map is a map that is known as the ratio of the total length of streams to drainage basin area. It is a measure on how well or how poorly a watershed is drained by stream channels. When the drainage density is high, the infiltrations are low hence, the movement of the surface water are fast. Instead, the relationship between this map and potential limestone geohazard is the higher the drainage density of a particular region, the higher the rate of dissolution in limestone bedrock thus the higher the rate of possibility in limestone geohazard.

The drainage density values of the study area were classified from very low (<1.0) until very high (>3.0). The weighting for very high drainage density value contributes to high weighting while the lower value indicates the lowest weighting. Appendix A(7) show the ratings for drainage density map. The drainage density map can be refer to Appendix B(3).

The annual rainfall distribution is considered to be the most influence factor that can trigger the rate of dissolution in limestone. Thus, continuous rainfall not only can weaken the ground floor but, also affected the soluble rock. Appendix A(8) show the rating for rainfall.

3.3.5 Data Analysis and Interpretation

There are two data analysis that should be done in this study such as petrography analysis and multi index overlay analysis by using GIS. Petrography analysis will come out with the naming of the rock samples based on its dominant minerals presented in the whole thin section.

Meanwhile, for limestone geohazard analysis, the method used will be known as raster multi- overlay analysis. This analysis only was done by using ArcGIS software. During the process, each of the thematic map that has been weightage will be overlaid by each other in order to create a zone that have possibility to trigger limestone geohazard in the study area.

A) Multi-Overlay Analysis

The purpose of multi index overlay analysis is to produce result analysis for the study. This method applies some common values to diverse and dissimilar inputs to create an integrated analysis. To be more details, overlay analysis involves mathematical equation. The mathematical form that is used for overlay analysis was as below.

$$S = (W_{lith} \text{ x } R_{lith})+(W_{L.U} \text{ x } R_{L.U})+(W_{Slope} \text{ x } R_{Slope})+(W_{D.D} \text{ x } R_{D.D})+(W_{R.F} \text{ x } R_{R.F}) \quad \textbf{(3.1)}$$

Where,

W_{lith} = Weightage for lithology

R_{lith} = Ranking for lithology

$W_{L.U}$ = Weightage for landuse or land cover

$R_{L.U}$ = Ranking for landuse or land cover

W_{Slope} = Weightage for slope morphometry

R_{Slope} = Ranking for slope morphometry

$W_{D.D}$ = Weightage for drainage density

$R_{D.D}$ = Ranking for drainage density

$W_{R.F}$ = Weightage for annual rainfall

$R_{R.F}$ = Ranking for annual rainfall

There are some general steps that will be taken during generating overlay analysis (Esri, 2007), such as:

1. Define the problem.
2. Break the problems into sub models.
3. Determine significant layers.
4. Reclassify or transform the data within a layer.
5. Weight the input layers with suitable weighted and rank values.
6. Add or combine the layers.
7. Analyse.

The steps starting from 1 to 3 considered to be the most important steps during overlay analysis. For a single raster data, the value must be known to enable the data being interpreted. Besides that, some values only suited for a certain purposes. The evaluation for each of the values is depending on the researcher.

Basically, there are two methods to perform multi-overlay analysis. The first one is raster overlay analysis and for the second one is feature or vector overlay analysis (Al-kouri et al., 2013). However, in the study of GIS, both methods are distinct in displaying or representing the spatial data.

In this study, raster overlay analysis was considered to be the best method in order find locations that meet certain criteria in the study compared to feature or vector overlay analysis. However, it is depends on the user's data whether it is already stored in features or raster.

i) Raster Overlay

In this study, the method used in overlaying the maps was done by using raster multi-overlay overlay analysis. In raster overlay, each cell of each layer refers to the same geographic location which makes it well suited in combining characteristics for numerous layers into a single layer. Basically, numeric values are assigned to each characteristic, which will enable the mathematically combining the layers and assign a new value to each cell in the output layer.

In addition, all raster data is built up of pixels which known as cells. Each of the pixels has their own associated values. A digital photograph is an example of a raster dataset where each of the pixels value corresponds to a particular colour. Next, in GIS, the pixel values may represent elevations, slope, rainfall and etc. Simply said, as all of this data is represented as a grid of cells, the possible result and outcomes can be much more detailed and accurate compared to feature data.

Thus, this means that the raster images such as digital elevation model (DEM), hillshade, slope map and etc. can be allocate correctly relative to one another before producing the final map.

Raster overlay often used to rank attribute values by suitability or risk then added them to produce the overall rank for each cell. Various layers also can be assigned to a relative importance to create a weighted rank. This process involves the use of math algebra in raster calculation which can be done by the system itself. The raster algebra also can often produce results much faster than the equivalent vector or feature workflow.

ii) Feature Overlay

Meanwhile, in feature or vector data, there are three keys of elements in feature overlay which are the input layer, the overlay layer, and the output layer. The overlay function divides the features in the input layer where they are overlapped by features in the overlay layer. New areas are created where polygons intersect. If the input layer contains lines, the lines are divided where polygons cross them.

These new features are stored in the output layer where the original input layer is not changed. The attributes of features in the overlay layer are assigned to new features in the output layer, along with the original attributes from the input layer.

In comparison, the vector data is not build in pixels or grid cells. Instead, it is made up of vertices and path. The continuous data is poorly stored and displayed as vectors. In order to display continuous data as a vector, it would require substantial generalization. Even though topology is useful for vector data, the processing is very intensive. Any feature edits requires an updates on the topology. Besides, vector manipulation and analysis algorithms are much more complex.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

The study area is specified in Kg.Gunong Batu Melintang which located at Batu Melintang, Jeli. In this chapter, the discussion topics would be more focussed on the general geology of the study area. The discussion might be includes the geomorphology, stratigraphy, structural geology and the historical geology. Several maps also will be included in this chapter.

For this chapter, the method used to obtain the geological data during the field is geological mapping. Traversing method is used along with geological mapping session by finding and observing an exposed outcrop. This is because, traversing method is the most easier method to be run in term of accessibility. In addition, this method also involves landuse covering. Figure 4.1 shows the traversing map of the study area.

Based on the Figure 4.1, the traversed was mostly done along the main river. This is because, an exposed outcrop and contact between rocks were generally easier to be seen along the river.

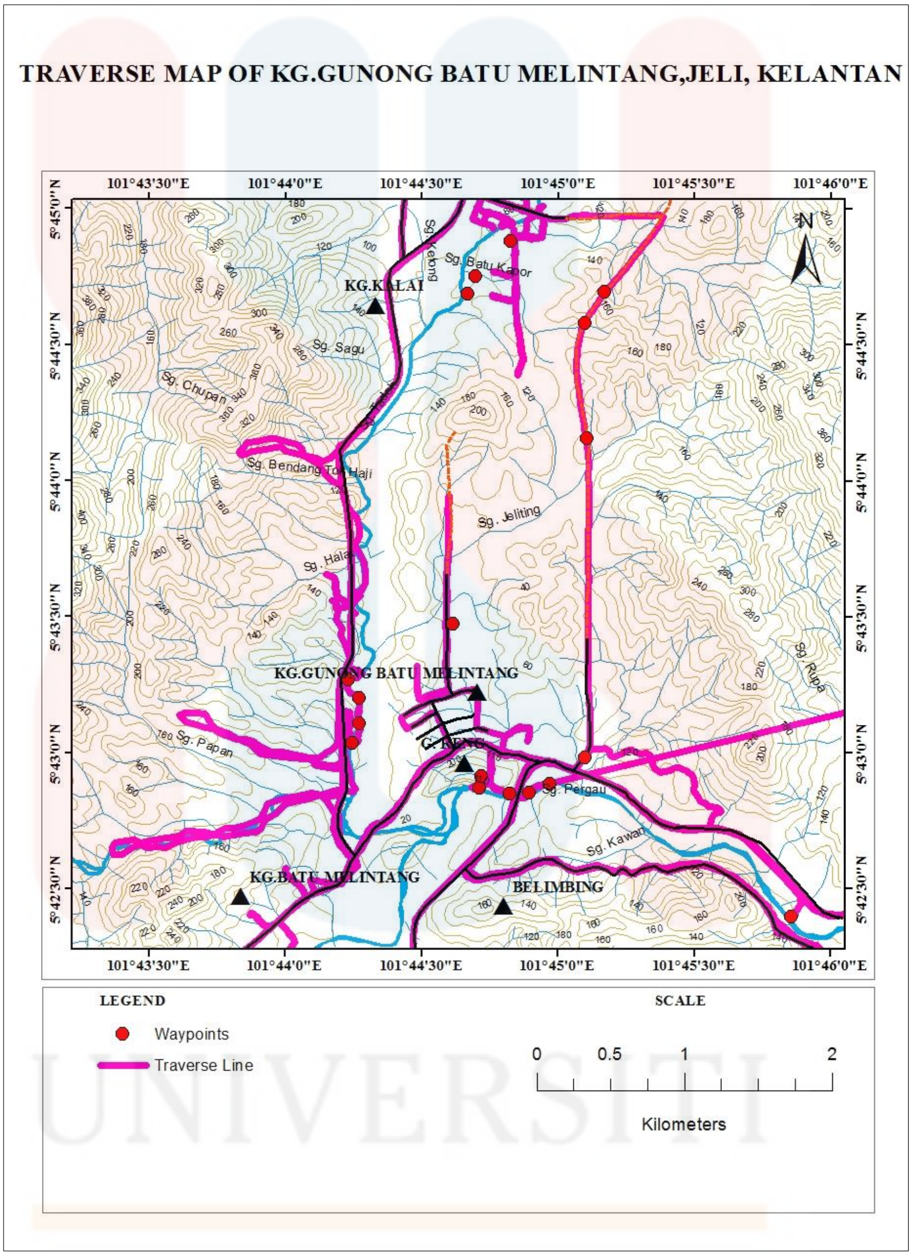


Figure 4.1: Traverse map of the study area

4.2 Geomorphology

Geomorphology can be describe as the scientific study about the origin and the evolutions of earth related to its topographic and bathymetric features which was created by physical, chemical or biological processes. Differences in landscapes tell us about the differences landform history.

According to Huggett, (2007) the word geomorphology was derived from Greek words which means geo (the Earth), morph (form), and logos (discourse). Thus, simply said, geomorphology is the discourse on the Earth form or the study of the landform. It is very related to the Earth's physical land surface features which includes hills, plains river, and others.

The geomorphology of a certain area can clearly be seen from high elevation view. It is easy to describe the landform or the process that make up a certain places by getting full view of the whole area. Another ways is by traversing through the map of the study area as mentioned in the introduction.

4.2.1 Topography

The topography of a particular area can be said as the surface shapes and features in a detailed map. Generally, topography always being related with the existing or the occurrence of hills, mountain, or creeks and other features such as lumps and bumps of Earth. The topography map is important in order to describe either that particular area is natural or human made. For examples rivers, valleys, lakes, road and others. The topography can be described based on the contour line that refers to the land surfaces.

Based on the Figure 4.2, the topography and contour elevation value is easier to be identified based on the colour indicator provided by the topographical map. The red colour indicates steep slope while the yellow colour indicates moderate slope and green colour indicates gentle slope. The West part of the study area has the highest elevation which is 400 m above the sea level. In addition, the highest elevation present at the steep contour was marked in red colour. This is because, the contour lines are mostly very close to each other.

The gentle contours are considered to be around 80 m to 160 m above the sea level. At the central and southern of the map, the contour lines are lying far from each other which indicate that the contours are gentle. Instead, the contour lines also were marked in green colour. In the meantime, the steep contours can be considered ranging from 320 m and above. Based on the map, the distribution of the steep contours are located in the Northwest and Northeast of the map. The contour lines possess similar pattern which varied closely to each other but in an isolated way while the other parts of the map are considered as moderated.

Based on Figure 4.3, the 3-dimensional (3D) topographical map is used to give a better view about the surrounding landform. The topographic unit can be classified based on the high of the elevations. In addition, the topographic units are divided into five distinct groups and are distinguished based on the differences in the elevation (Raj, 2009). The classification of topographic units is shown in the Table 4.1. Based on the observations during mapping session, Kg.Gunong Batu Melintang can be classified into hilly topography. This is because, the contours are mostly ranging from 100 m to 300 m above the sea level.

Although, the topography and landform for the Kg.Gunong Batu Melintang are mostly hilly but there is also a massive limestone karst which was named as Gunung Reng. The karst topography known as a landscape which was formed by the dissolution of carbonate rock such as limestone. Limestone is known as highly soluble rock which easily to become weathered by the actions of water.

The dissolution of limestone produced many unique karst features. In addition, limestone cave also present in the study area (Figure 4.4). Cave is produced when the acidic groundwater enter through the joints and fractures in limestone before undergo the dissolving process. As time passes, the cavities are formed and became big enough to form a cave.

Limestone cave contain a lot of interesting features as a result of the physical and chemical processes that formed them. Among these features are breakdown blocks of rock which formed by collapse of cave ceilings. Instead, the structure of stalactite and stalagmite also can clearly be observed within the cave.

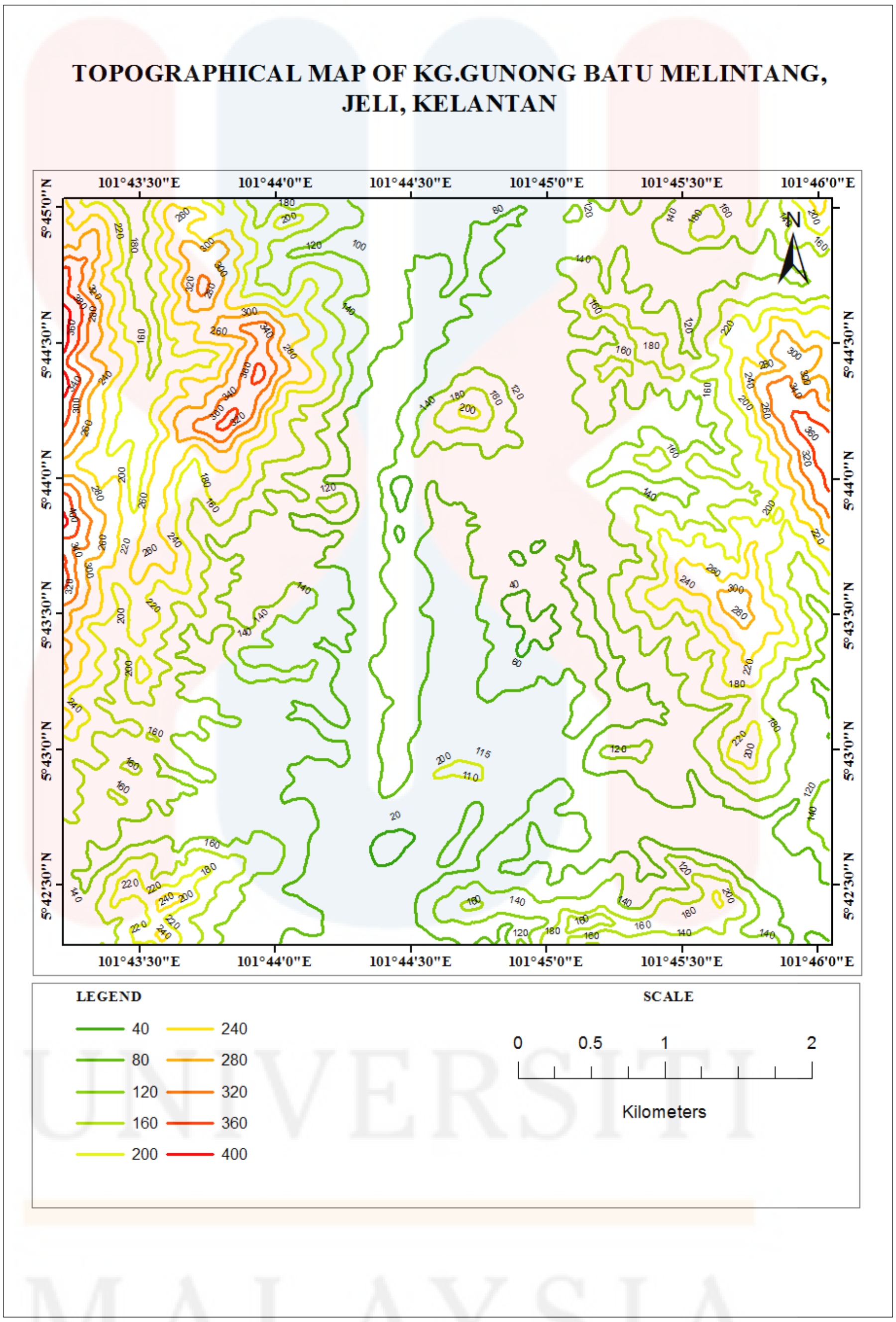


Figure 4.2: Topographical map of Kg.Gunong Batu Melintang

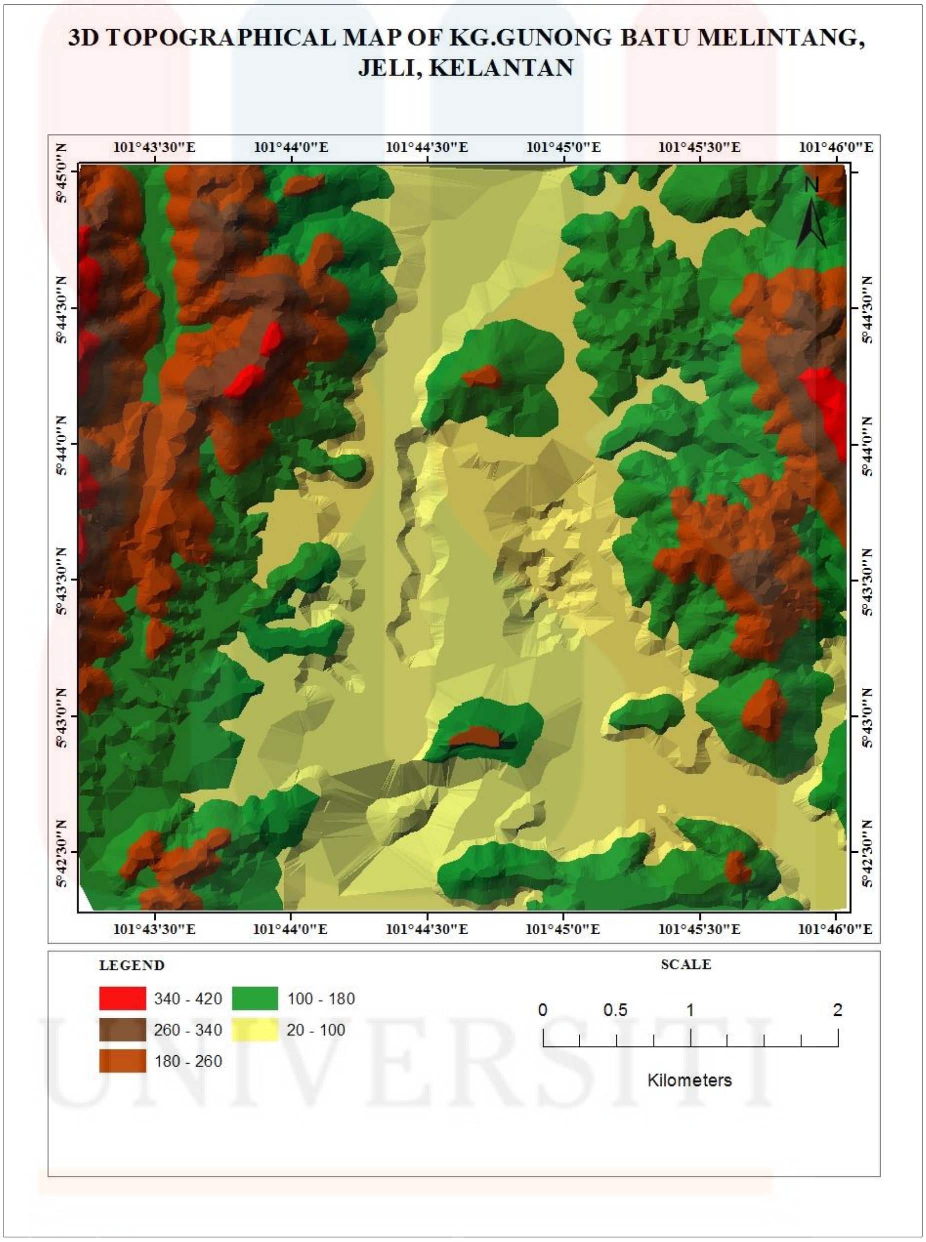


Figure 4.3: 3D topographical map of Kg. Gunong Batu Melintang

Figure 4.4: Limestone cave

Table 4.1: Classification of topographic unit based on elevation

Elevation, m (above sea level)	Description
< 15	Low lying
16 – 30	Rolling
31 – 75	Undulating
76 – 300	Hilly
>301	Mountainous

(Source : Raj 2009)

4.2.2 Drainage System

By further interpreting the geomorphology, the drainage system can be defined as the pattern formed by the streams, rivers, and lakes within a particular drainage basin. They are influenced by the topography of the land, whether a particular region is dominated by hard or soft rocks, and the gradient of the land. A drainage basin is the topographic region from which a stream receives runoff, through flow, and groundwater flow. The number, size, and shape of the drainage basins found in an area are varies. Thus, the larger the topographic map, the more information on the drainage basin is available.

The study area consists of two major streams which is Pergau River and Tadoh River. Both streams are in southward flowing. These two streams join in the southern extreme of the study area. Since the area of Kg. Gunong Batu Melintang is dominated by hilly topography, the drainage system flows from the high elevation areas to the lower elevation areas. There are many drainage patterns that can be observed based on the Figure 4.5, which includes the dendritic, parallel, trellis, and rectangular pattern.

Based on Figure 4.5(A), the dendritic drainage pattern is the most easier to identify as it looks like tree branches. Dendritic pattern is considered to be the most common form of drainage system. In a dendritic system, there are many contributing streams which are then joined together into the tributaries of the main river. They develop where the river channel follows the slope of the terrain. Dendritic systems form in V-shaped valleys, as a result, the rock types must be impervious and non-porous.

Figure 4.5(B) refer to parallel drainage pattern. A parallel drainage system is a pattern of rivers which caused by steep slopes with some relief. Due to the steep of the slopes, the streams become swift and straight, with very few tributaries in similar direction. This system forms on uniformly sloping surfaces. Tributary channels tend to stretch out in a parallel-like fashion following the slope of the surface. A parallel pattern sometimes indicates the presence of a major fault that cuts across an area of steeply folded bedrock. All forms of transitions can occur between parallel, dendritic, and trellis patterns.

Besides that, Figure 4.5(C) shows trellis pattern. The pattern of a trellis drainage system is similar to that of a common garden trellis used to grow vines. As the river flows along a strike valley, smaller tributaries feed into it from the steep slopes on the sides of mountains. These tributaries enter the main river at approximately 90 degree angle, causing a trellis-like appearance of the drainage system.

Next, Figure 4.5(D) shows the geometry of rectangular drainage pattern. Rectangular drainage develops on rocks that have uniform resistance to erosion. The joints are usually less resistant to erosion than the bulk rock. Thus, the erosion tends to preferentially open the joints and streams eventually develop along the joints. The result is the streams consist mainly of straight line segments with right angle bends and tributaries join larger streams at right angles. Last but not least, Figure 4.5(E) shows the radial drainage pattern. This kind of patterns radiate outwards from a central of high point.

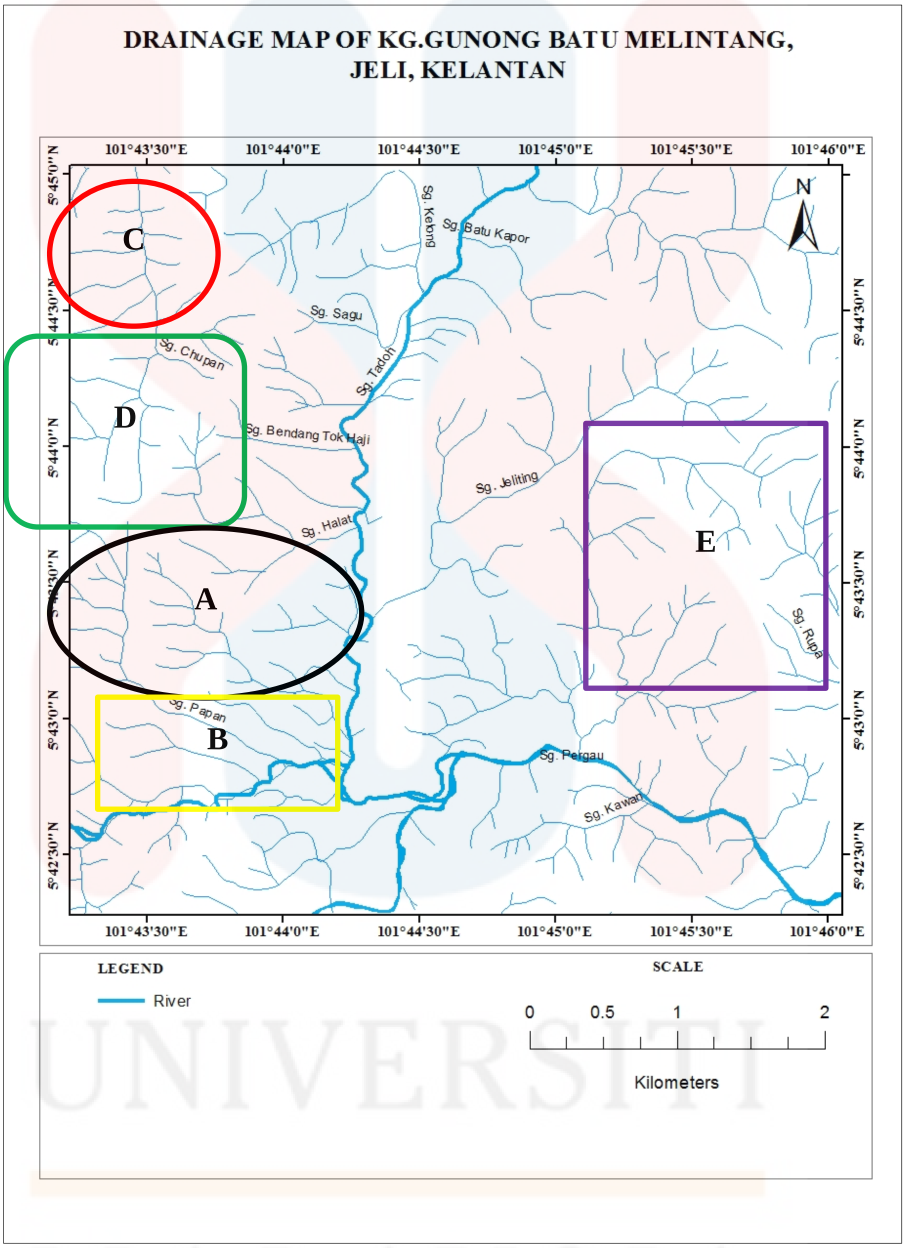


Figure 4.5: Drainage map of study area. (A) Dendritic, (B) Parallel, (C) Trellis, (D) Rectangular, (E) Radial

4.2.3 Weathering

Weathering is the breakdown of rocks, soils and minerals on the Earth's surface due to physical and chemical alteration. Basically, there are three types of weathering which are physical, chemical and biological.

According to (Cabria, 2015) , physical weathering also known as mechanical weathering. It is the disintegration of rock materials into smaller pieces without any change in the original property of the rock. It is usually resulted from temperature and pressure changes. Figure 4.6 shows the joints developed in rock structure. Joint is a fracture formed in a rock that lacks any visible or measurable movement parallel to the surface of the fracture.

Chemical weathering is the breakdown of rock by chemical mechanisms. It does not break rocks into smaller fragments through wind, water and ice. Instead, it changes the chemical composition of the rock, usually through carbonation, hydration, hydrolysis or oxidation. Chemical weathering is caused by rain water reacting with the mineral grains in rocks to form new minerals (clays) and soluble salts. These reactions occur particularly when the water is slightly acidic.

Chemical weathering occurs more rapidly at higher temperature. Chemical weathering (especially hydrolysis and oxidation) is the first stage in the production of soils. Figure 4.7 shows the example of chemical weathering.

In the meantime, biological weathering can be defined as the weakening and subsequent disintegration of rock by plants, animals and microbes. For example, the plants use their roots to penetrate into the cracks, joints or fractures in order to find the water sources. As the size of the roots become bigger, the size of the crack also becomes larger. Figure 4.8 shows the example of biological weathering within the study area.

The rate of weathering on each rock depends on their composition. Some minerals are strongly resisted to weathering while others are very easy to become weathered. For example, rocks that have higher composition of quartz minerals are very hard to undergo weathering. This is because, quartz minerals are physically and chemically resist to weathering. In compared, rocks that have the abundance composition of feldspar or iron minerals are easily to become weathered. Thus, if the rock mineral is weak, then the rock is easier to become eroded.

According to the past research, the rocks can be classified based on the grades of weathering (Borrelli,et al. , 2007). Appendix A(9) shows the grades of weathering. In overall, the rocks in Kg. Gunong Batu Melintang are considered to be classified into class II, III, and IV which ranging from slightly weathered rocks to highly weathered rocks.

Figure 4.6: Joints in rock structure indicates physical weathering.

Figure 4.7: Chemical weathering in rock.

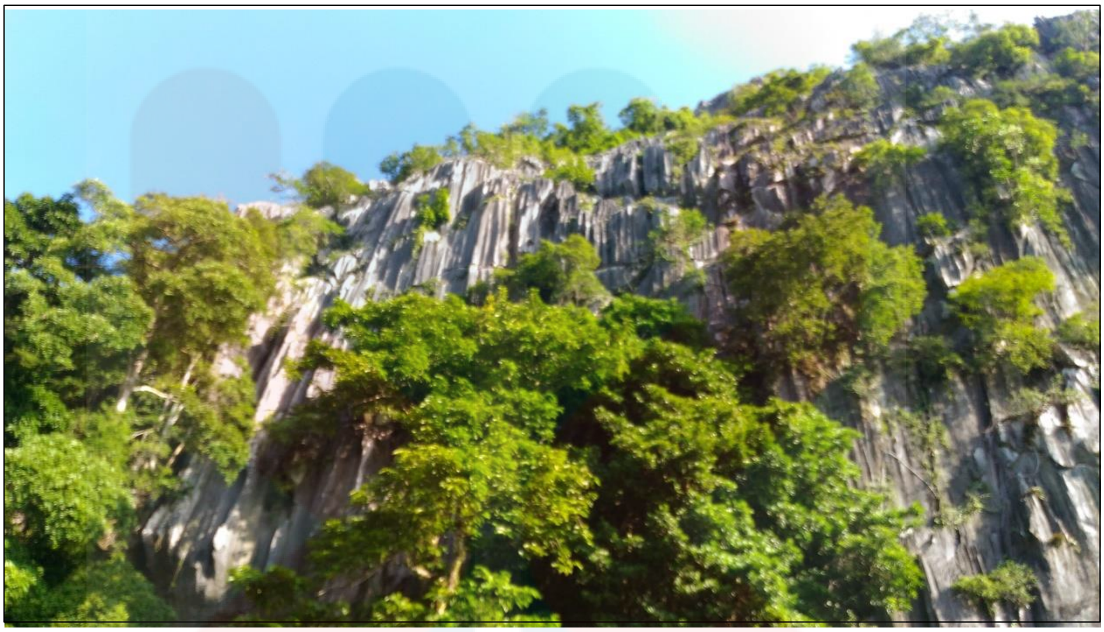


Figure 4.8: Roots penetrate the rock structure indicates the biological weathering

4.3 Stratigraphy

Stratigraphy is a branch of geology that studies about rock layers or strata. The study of stratigraphy is very important as it can help to determine the sequence of past events in a sedimentary basin. The principal behind stratigraphy is that younger sediments are deposited on top of older sediments. Thus, the stratigraphy sequences can gives a series of relative ages based on geological time scale.

4.3.1 Lithostratigraphy

Lithostratigraphy is a sub-discipline of stratigraphy. Lithostratigraphy helps to explain about lithological characteristics of rock layers and the relationship of its stratigraphic position by using the law of superposition. Based on geological mapping, the areas around Kg.Gunong Batu Melintang were comprised of three lithological units which are igneous rock, sedimentary rock and also metamorphic rock.

The oldest rock formation in the study area was formed by Telong Formation since the period of Triassic. Table 4.2 show the lithostratigraphy column of the study area whereas the distribution of rocks that has been found in the study area is shown by the geological map in Figure 4.9.

Gneiss is a foliated metamorphic rock. Gneiss found in the study area was developed since the early Triassic through regional metamorphism and it is the oldest among the other rocks found. Figure 4.10 show the gneiss bodies in the study area which composed of layers of sheet-like planar structures. The foliation of gneiss commonly being characterized by the alternating darker and lighter coloured bands which generally known as gneissic banding.

The gneiss bodies within the study area appeared to be striped in bands. The gneissic banding might be formed and developed due to the extremely higher temperature and pressure environment conditions during Triassic period. The rock sample in Figure 4.11 shows the hand specimen of gneiss.

The igneous rock found is andesite. Andesite also was formed during the Triassic under Telong Formation which becomes the second oldest rock within the study area. The rapid cooling process caused this greyish looking andesite to have an aphanitic texture. Generally, andesite has an intermediate composition with aphanitic to porphyritic texture. In facts based on the hand specimen found, the andesite in the study area display greyish colour with fine grained texture due to rapid cooling of lava in the past geological event. Figure 4.12 shows the andesite outcrop in the study area whereas Figure 4.13 shows the hand specimen of andesite.

Next, the formation of mudstone was believed to begin in the middle of the Triassic period under Telong Formation. Mudstone is known as a fine grained sedimentary rock that was derived from the clay and mud constituents. Figure 4.14 shows the brownish colour of mudstone in the study area.

Limestone also was formed under Telong Formation. The limestone found in the study area also was developed since the period of Triassic. Generally, the formation of limestone can be referring to the marine environment in the past geological time. Figure 4.15 show the limestone karst in the study area while Figure 4.16 shows the hand specimen of limestone. The limestone found within the study area is greyish colour with fine crystalline texture.

Marble is formed through the process of metamorphism of sedimentary carbonate rocks when limestone is subjected to higher heat and pressure which resulting the recrystallization of the original carbonate mineral grains. Generally, marble is composed of mainly calcite minerals ($CaCO_3$). Under the same formation, marble is considered to be younger than the limestone in the study area. Figure 4.17 show the marble outcrop in the study area. The marble found within study area was white in colour with crystalline texture. Figure 4.18 shows the hand specimen of marble.

The formation of alluvium begins since the Quaternary period. The alluvium in the study were comprised of gravel, sand and clay deposit. In overall, the stratigraphy within the study area can be divided into Triassic and Quaternary rock unit. The oldest rock unit in the study area is Triassic gneiss by regional metamorphism process. The formation of all rock units within the study area was developed under the Telong Formation.

Table 4.2: Lithostratigraphy column of Kg.Gunong Batu Melintang, Jeli.

Era	Period	Rock Unit or Formation	Description	Lithology	Lithostratigraphy column
Cenozoic	Quartenary	Quaternary sediments (Alluvium)		Gravel, sand, clay	
Late Paleozoic to early Mesozoic	Triassic	Telong Formation	White in colour with crystalline texture	Marble	
			Greyish colour with fine crystalline texture	Limestone	
			Brownish colour with fine grained	Mudstone	
			Greyish colour with aphanitic grain texture	Andesite	
			Darkish grey colour with Foliation	Gneiss	

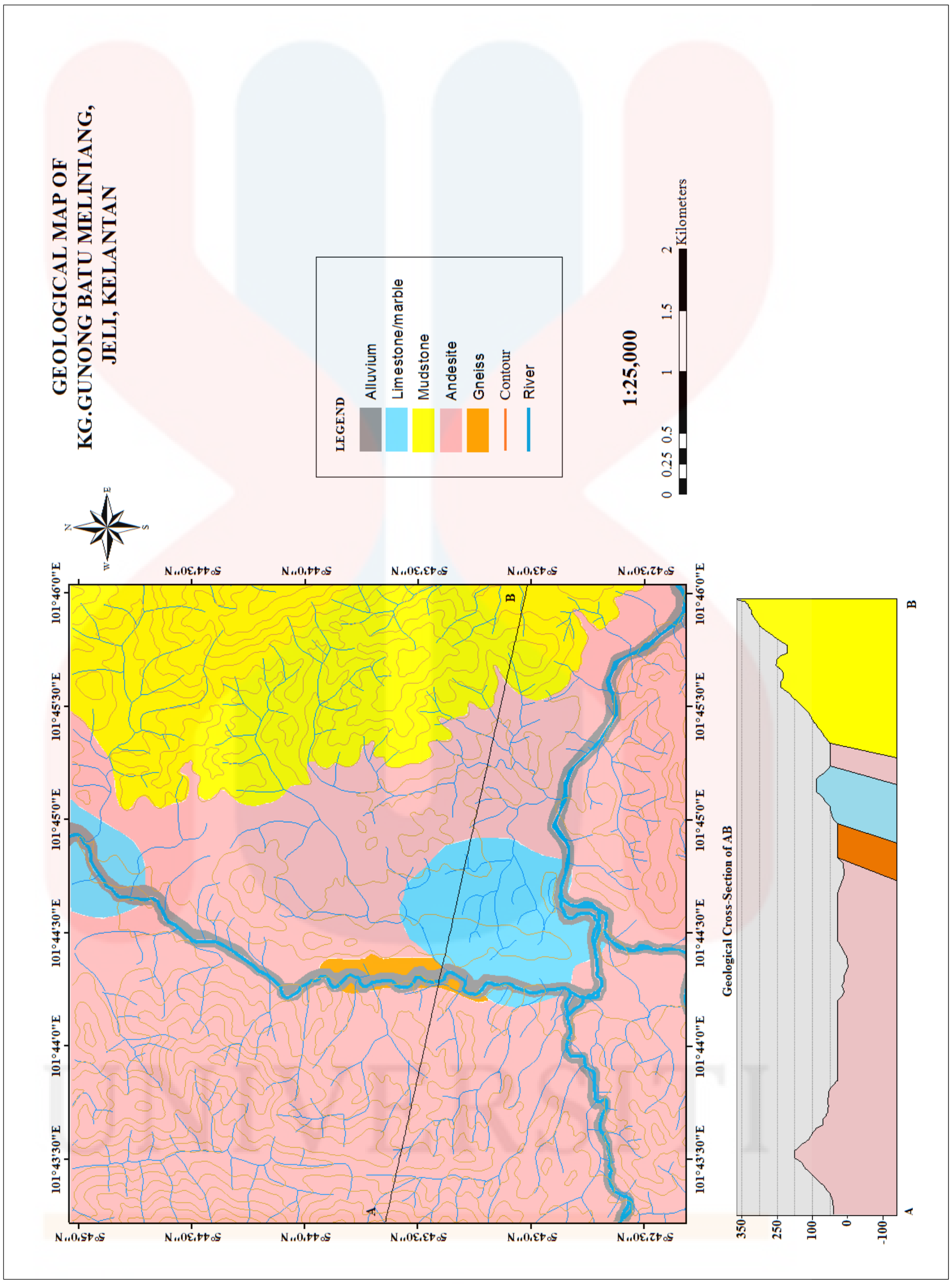


Figure 4.9: Geological map of Kg. Gunong Batu Melintang, Jeli

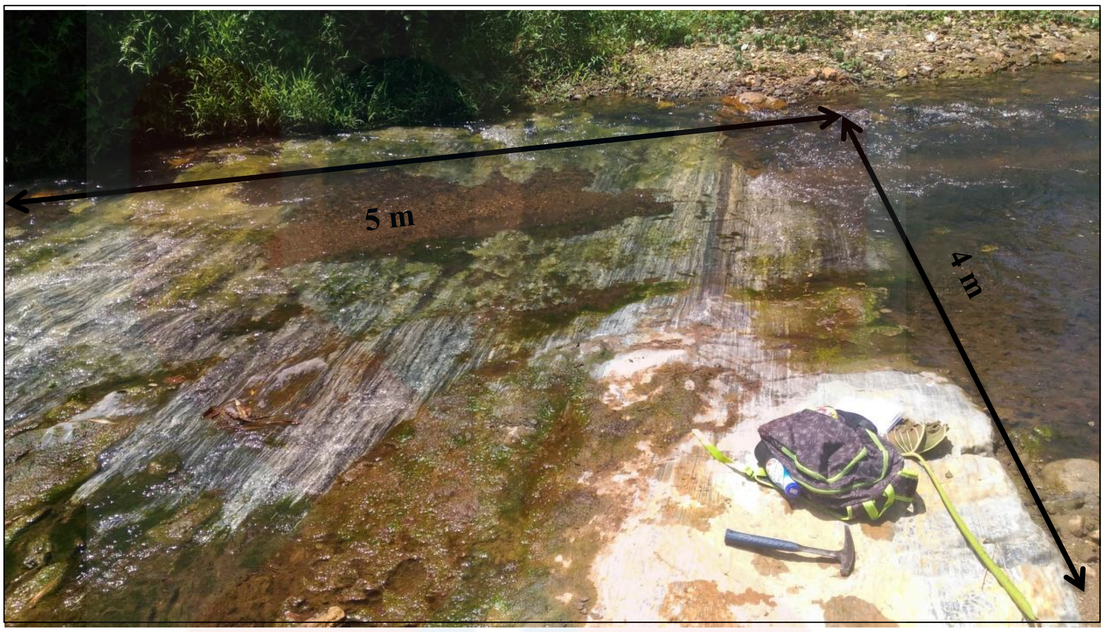


Figure 4.10: The gneiss rock bodies in the study area

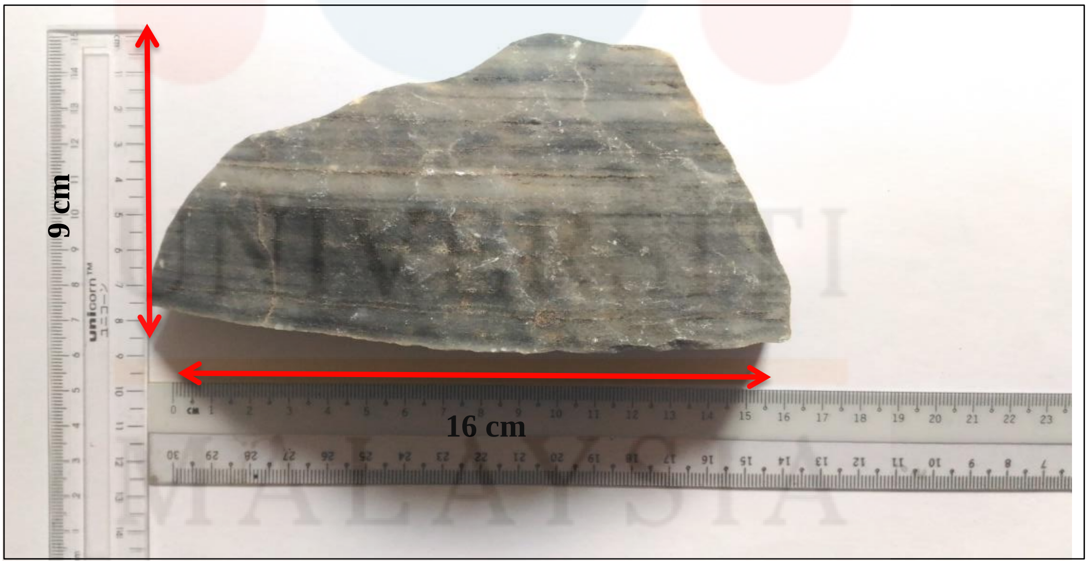


Figure 4.11: Hand specimen of gneiss with scale

6 m

9 m

Figure 4.12: Andesite outcrop found in the study area

Figure 4.13: Hand specimen of andesite with scale

Figure 4.14: Brown colour of mudstone

Figure 4.15: The limestone karst in the study area

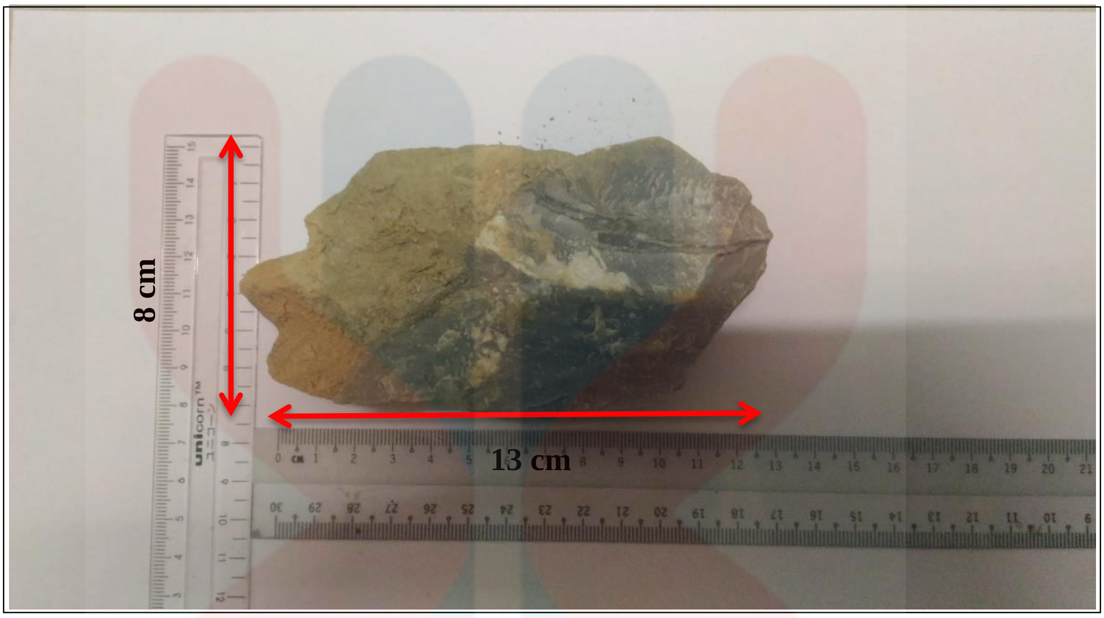


Figure 4.16: Hand specimen of limestone

Figure 4.17: Marble outcrop in the study area

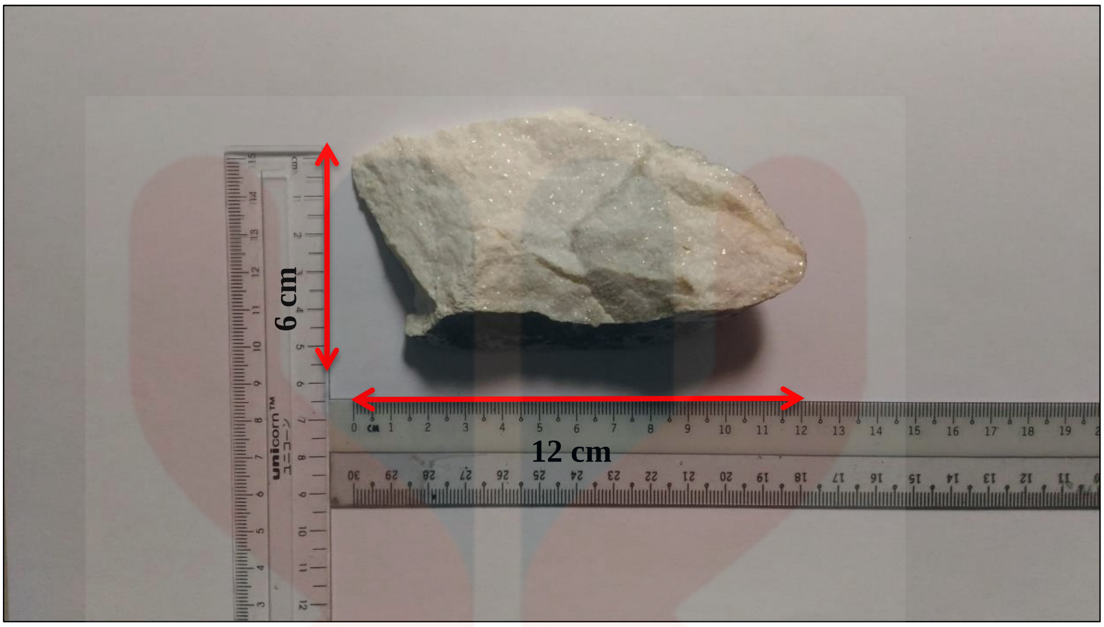


Figure 4.18: Hand specimen of marble with scale

4.3.2 Petrography Analysis

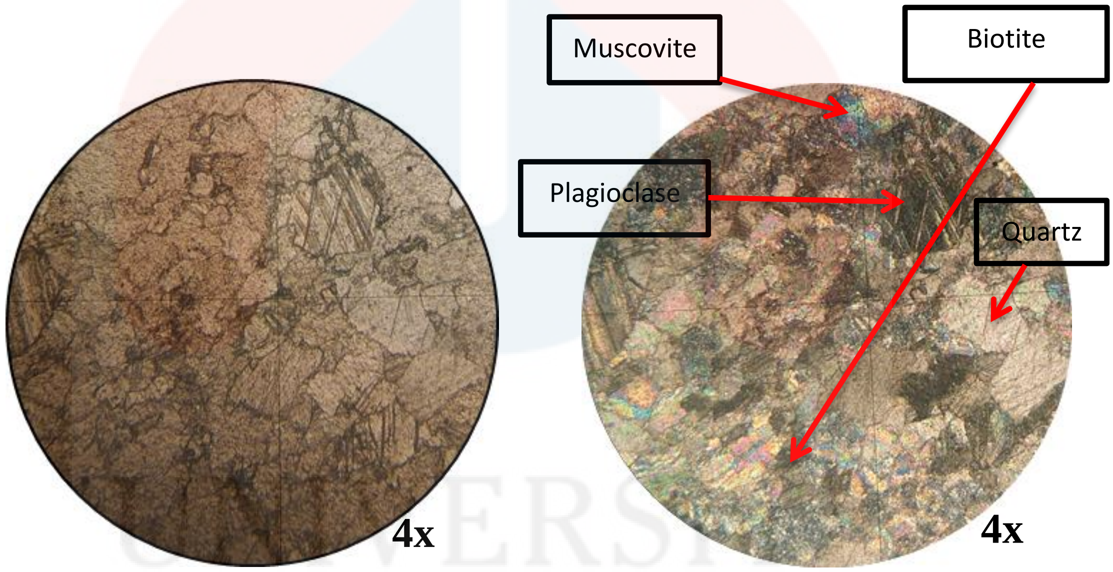
Petrography can be defined as a branch of petrology study which focussed on detailed descriptions of rocks. The classification of rocks will be based on the information acquired during the process of petrography analysis and interpretation. Petrography analysis involves the microscopic descriptions of the hand specimens.

All collected hand specimens were prepared into thin section in order to identify its composition and mineralogy. The naming process or rocks will be based on the dominant minerals that can be observed under microscopic view.

Sample 1

The hand specimen of gneiss was taken at the coordinates of N 5°43'16.10" E 101°44'14.00". The location was not far from the karst structures in the study area. Generally, gneiss is known as highly graded metamorphic rock which commonly formed by regional metamorphism process.

The minerals composition of gneiss under thin section can be referred based on the Table 4.3 whereas, Figure 4.19 shows the plane and cross polarization of gneiss under thin section.



Plane polarized (PPL) **Cross polarized (XPL)**

Figure 4.19: Plane and cross polarized view of gneiss in thin section

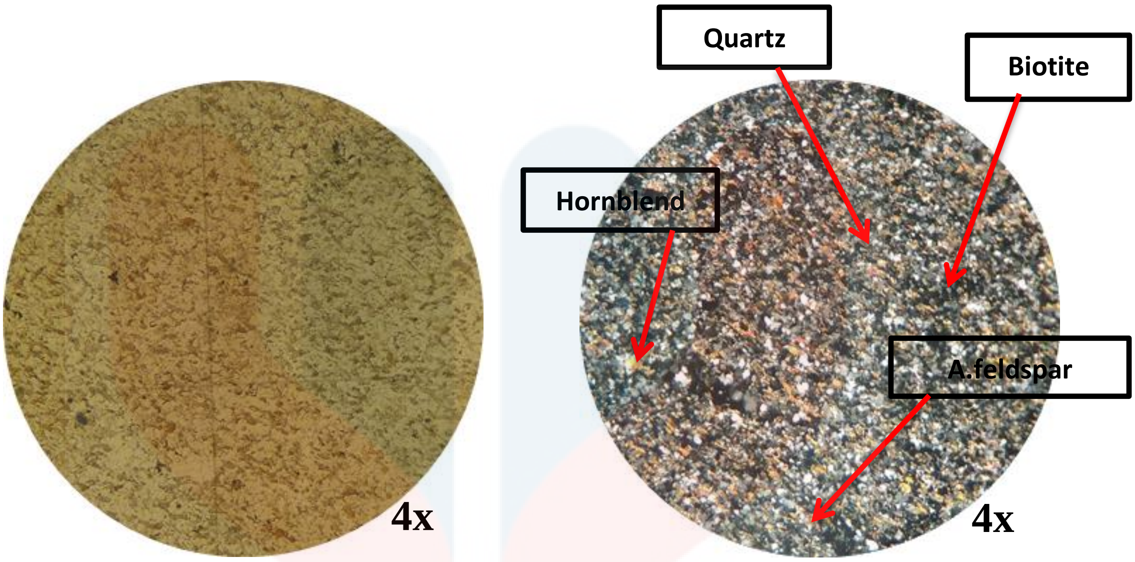
Table 4.3: Mineral properties in gneiss

Grain size	Medium coarse grained	
Foliation	Foliated	
Mineral present	Muscovite, Biotite, Plagioclase, Quartz	
Muscovite	Shape	Subhedral
	Cleavage	Present
	Relief	Low
	PPL	Colourless
	XPL	Colourful
Biotite	Shape	Subhedral to anhedral
	Cleavage	Present
	Relief	Moderate
	PPL	Generally light brown in colour
	XPL	Black in colour and show parallel extinction
Plagioclase	Shape	Subhedral to Euhedral
	Cleavage	Perfect with twinning
	Relief	High

	PPL	Colourless
	XPL	Black in colour
Quartz	Shape	Anhedral
	Cleavage	Absent
	Relief	Low
	PPL	Colourless
	XPL	Milky white and grey

Sample 2

The hand specimen of andesite was collected at the coordinates of N 5°42'58.90" E 101°45'6.10". Andesite can be classified into one of the extrusive igneous rock which is volcanic rock. Based on the thin section analysis of andesite, the minerals assemblage and properties can be refer to the Table 4.4. Figure 4.20 show the plane and cross polarized view of andesite under thin section while Figure 4.21 shows the percentage of andesite composition in QAP diagram.



Plane polarized (PPL) **Cross polarized (XPL)**

Figure 4.20: Plane and cross polarized view of andesite in thin section

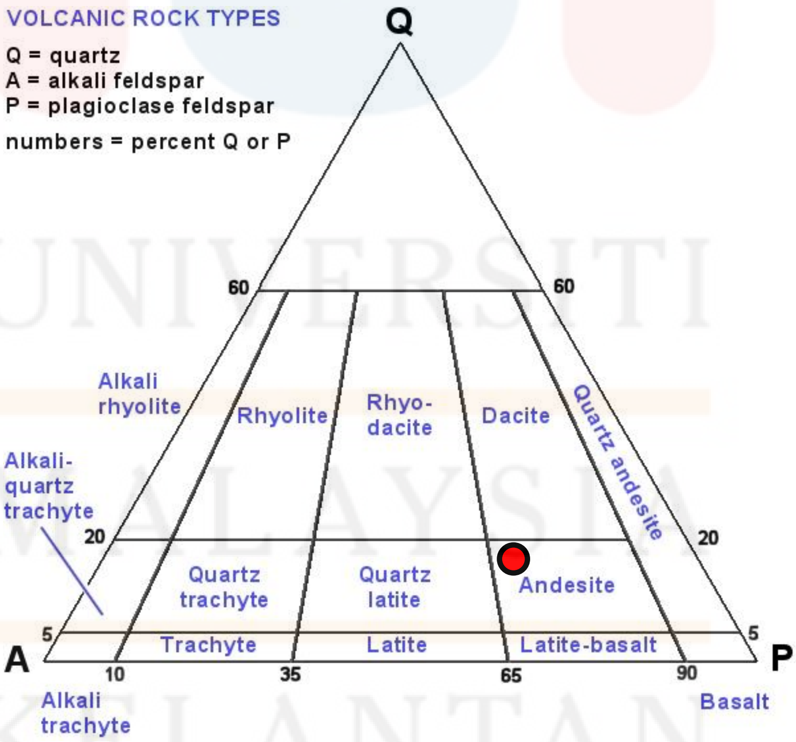


Figure 4.21: QAP diagram for andesite

Table 4.4: Mineral properties in andesite

Grain size	Very fine grained (less than 0.1 µm)	
Degree of crystallinity	Hypocrystalline with aphanitic texture	
Mineral present	Biotite, Quartz, Hornblend, Alkali Feldspar	
Biotite	Shape	Subhedral to anhedral
	Cleavage	Present
	Relief	Moderate
	PPL	Generally light brown in colour
	XPL	Black in colour and show parallel extinction
Quartz	Shape	Anhedral
	Cleavage	Absent
	Relief	low
	PPL	Colourless
	XPL	Milky white and grey
Hornblend	Shape	Subhedral
	Cleavage	Present

	Relief	Moderate
	PPL	Light brown or green colour
	XPL	Dark brown or green colour
Alkali Feldspar	Shape	Subhedral
	Relief	None
	PPL	Colourless
	XPL	Pinkish colour

Sample 3

The hand specimen of limestone was collected at the coordinates of N 5°42'54.60" E 101°44'43.16". During acid test, the limestone reacts vigorously with saturated HCL. This is because, limestone is a sedimentary rock that composed of calcium carbonate ($CaCO_3$) in the form of calcite minerals.

Figure 4.22 show the plane and cross polarized view of limestone under thin section. Table 4.5 explained about the composition of limestone based on thin section analysis.

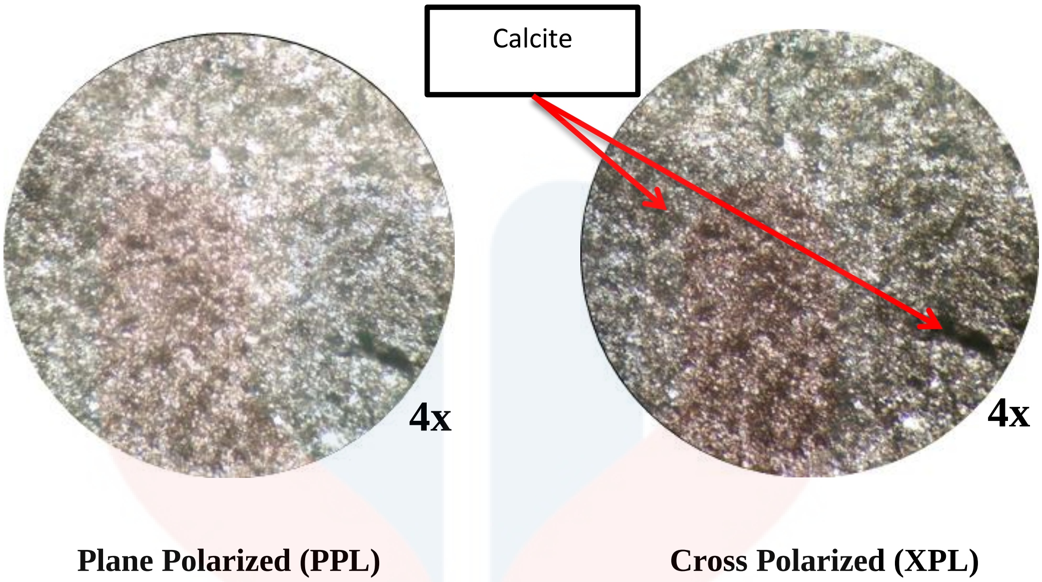


Figure 4.22: Plane and cross polarized view of limestone in thin section

Table 4.5: Minerals properties in limestone

Grain size		Medium in grained size
Colour		Dark grey
Mineral present		Calcite
Calcite	Shape	Subhedral to anhedral
	Cleavage	Rhombohedral
	Relief	High
	PPL	The extinction is symmetrical to cleavage
	XPL	Bands of green

Sample 4

The hand specimen of marble was taken at the coordinate of N 5°44'59.51" E 101°44'55.60". Marble is classified into non-foliated of metamorphic rock. The marble found within study area display white colour with gritty texture when touch. Figure 4.23 show the plane and cross polarized view of marble under thin section. Based on the thin section, the calcite marble shows the abundant twin bands which caused by deformation and accumulation of strain. The mineral composition of marble can be refer to table 4.6.

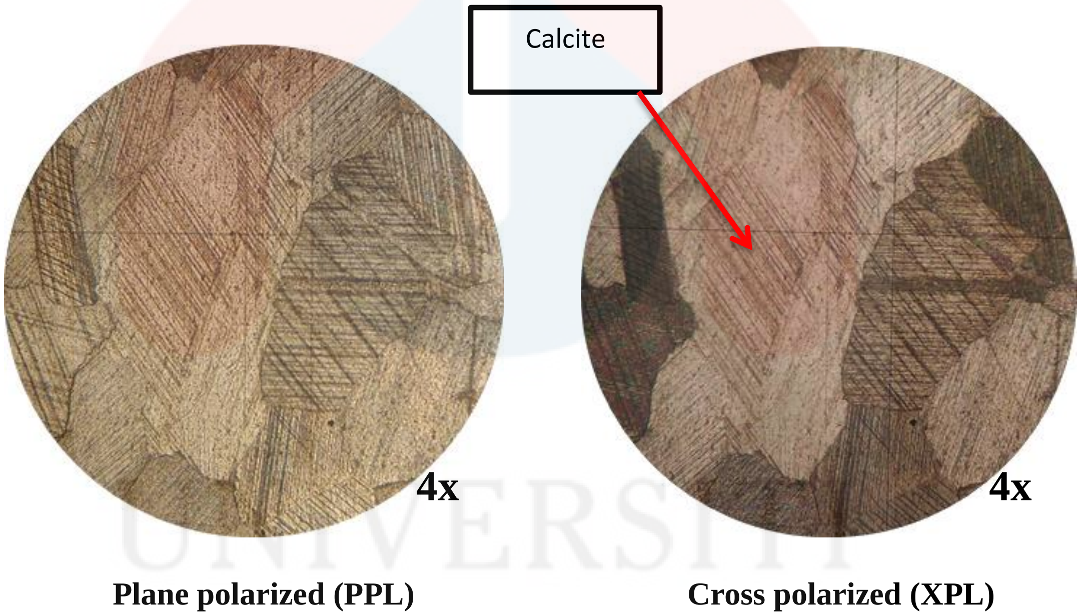


Figure 4.23: Plane and cross polarized view of marble in thin section

Table 4.6: Mineral composition of marble

Grain size		Interlocking crystal
Colour		White
Mineral present		Calcite
Calcite	Shape	Subhedral
	Cleavage	Perfect rhombohedral
	Relief	High
	PPL	Colourless
	XPL	Dark grey in colour

4.4 Structural Geology

Structural geology can be defined as the study of the three-dimensional distribution of rock units with respect to their deformational histories. Simply said, it is the study about deformation process of the rocks. This field of study use measurements of present-day rock geometries to uncover information about the history of deformation (strain) in the rocks. The information helps to understand the stress field that resulted in the observed strain and geometries which then can be linked into some important events in the past geological time.

Generally, geological structures can be divided into two groups which are primary structure and secondary structure. Primary geological structure is known as the structure that was developed during rock formation. Meanwhile, the secondary geological structure can be defined as the structure that is formed after rock formation which already being subjected to an external forces.

The formations of bedding and lamination indicate that the rocks have primary structure. Otherwise, the rocks are considered to have secondary structures if they show the characteristics of folding and fractures. A fracture is known as any separation in a geologic formation, such as a joint or a fault which divides the rock into two or more pieces. Fractures are generally caused by stress that exceeds the rock strength limit, causing the rock to lose cohesion along its weakest plane.

4.4.1 Lineament Analysis

In general, a lineament is known as a pattern or figure in a factual representation (photograph, map, model) of either the earth's surface or a subsurface datum (whether stratigraphically, structurally, or geophysically defined) and the figure must be linear (straight), continuous, reasonably well expressed (having discernible end points, width, and azimuth), and be related to features of the solid earth (Caran, et. al., 1982).

Individual lineaments often coincide with discrete structures, such as faults or fold axes, and with structurally controlled facies boundaries. In addition, regional structural trends are generally correlative with families of lineaments or with breaks in the predominant lineament pattern.

In this study, the lineament analysis was done by observing the linear pattern based on satellite imagery by comparing the terrain map between Arcgis and Google

Terrain map software. Each line is drawn lying on the top of the ridge which can clearly be seen based on its topography. The lines were then being calculated in order to get the azimuth reading which can be plotted and shown by using rose diagram software. The reading of regional lineament can be refer to Appendix A(10). Figure 4.24 show the lineament in the study area whereas Figure 4.25 show the regional lineament map of the study area.

Figure 4.26 shows the plotted lineament in the rose diagram. Based on the rose diagram, the orientation of forces acting on the area can be identified. The σ_3 refers to the extensional forces whereas the σ_1 can be refer as compressional forces. Therefore, the orientation of compressional force in the study area came from NE-SW direction which causes the extensional force to be oriented in NW-SE direction.

Figure 4.24: Lineament in the study area.

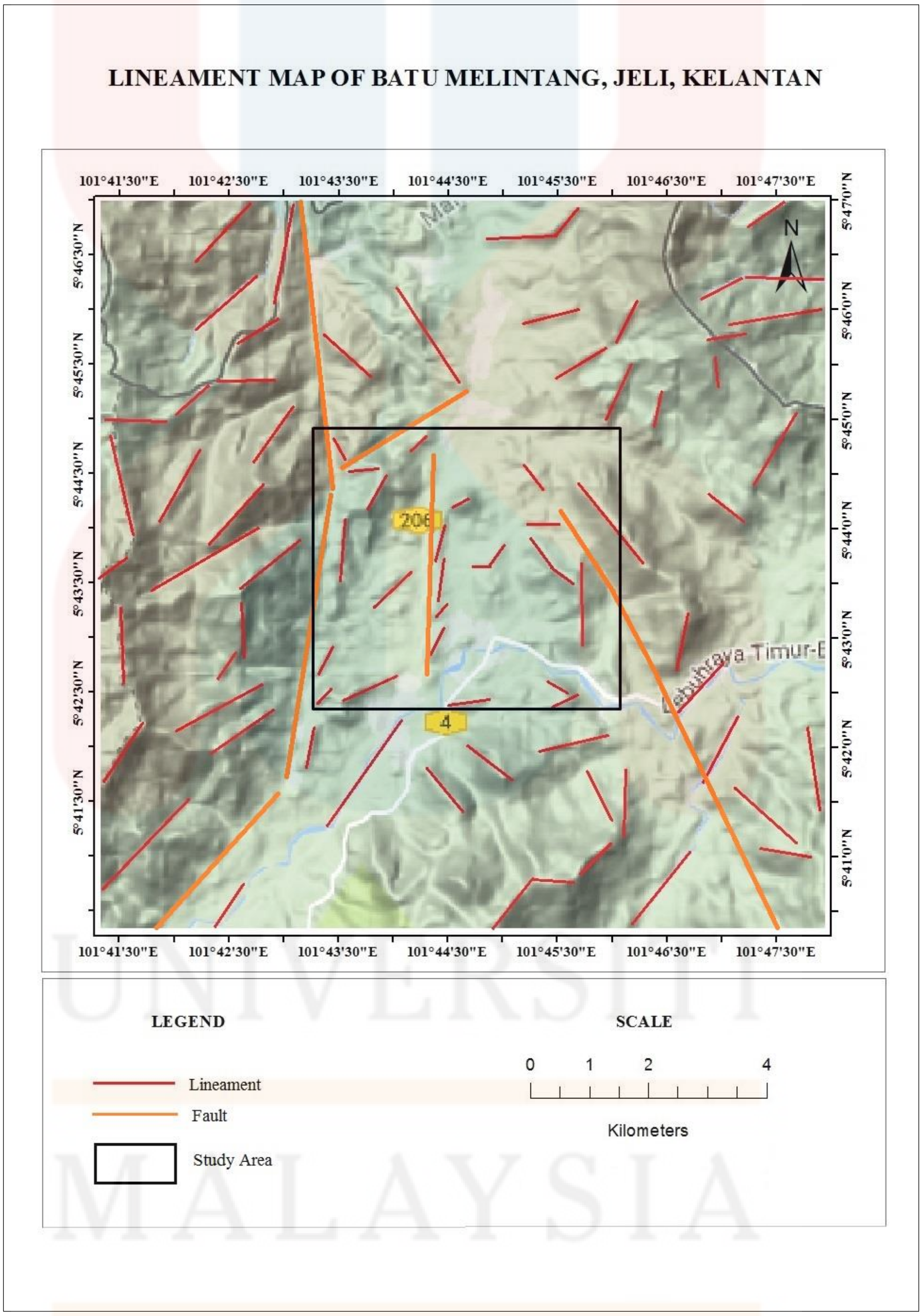


Figure 4.25: Regional lineament map of study area.

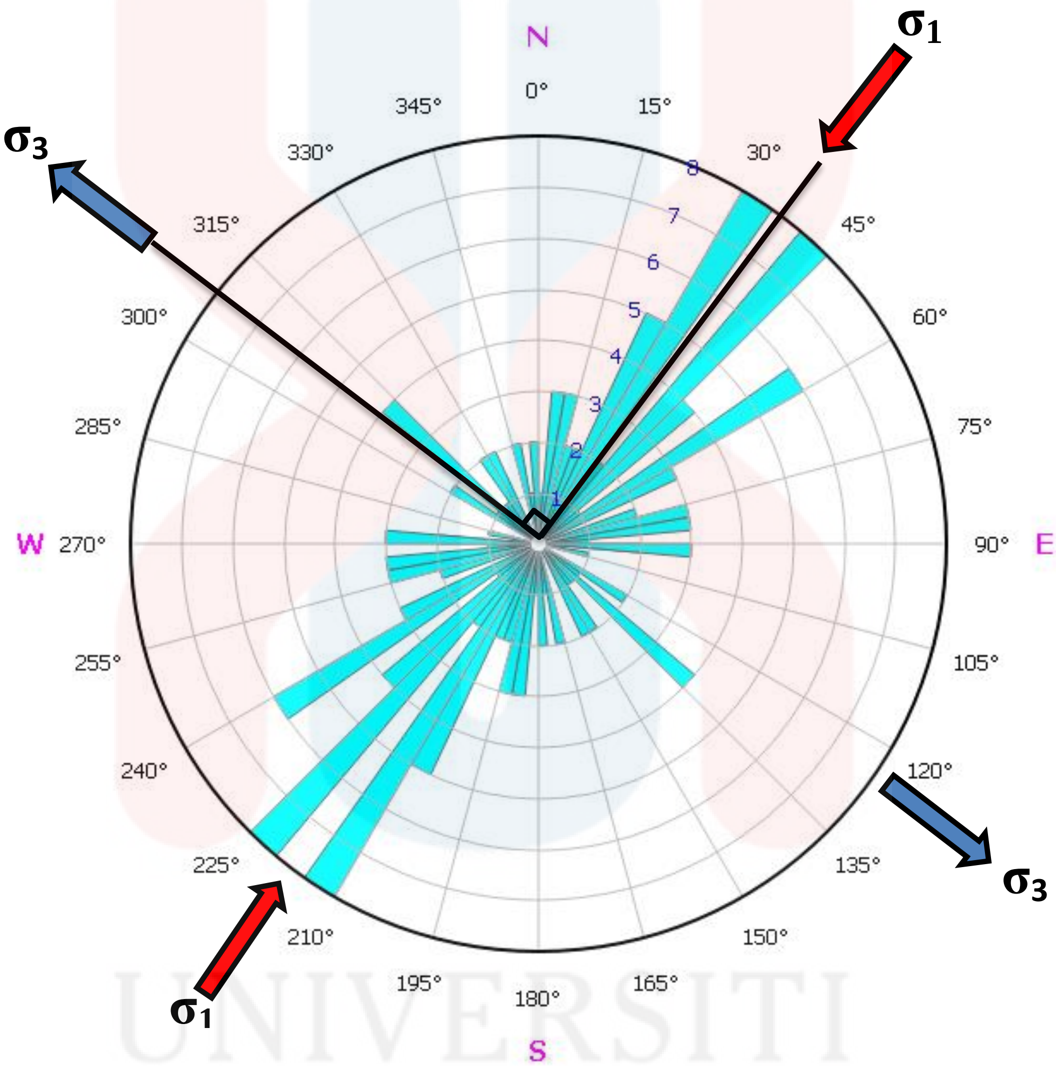


Figure 4.26: Plotted regional lineament in rose diagram

4.4.2 Joint Analysis

Joint is defined as the secondary structure that developed after the rock formation. Joints can be recognized by the brittle structure of a rock body or layers as a result of tensile stresses. The rocks will breaks if the tensile strength exceeding the rock strength. Forces that came into contact with the rock will result the rock to have fractures and fold structure.

Joint is a fracture that has no movement. Commonly, joint is formed in the rocks at shallow depth. In this case, the joint analysis was been carried out at three different places. The first joint analysis was collected at coordinate of N 5°42'23.80" E 101°45'51.30". The location show many developments of joints structures. Thus, the study of joint analysis was done in order to know the direction of forces that strikes the existing rocks in that area. Figure 4.27 show the place where the joint analysis was conducted. Meanwhile, based on the plotted rose diagram in Figure 4.28, the propagation of the direction of the compressional forces came from NE-SW direction. The higher compressional forces resulting the extensional forces to be elongated at NW-SE direction. The joint reading at this plant can be refer to Appendix A(11).

Figure 4.27: The first joint analysis at coordinate of N 5°42'23.80" E 101°45'51.30"

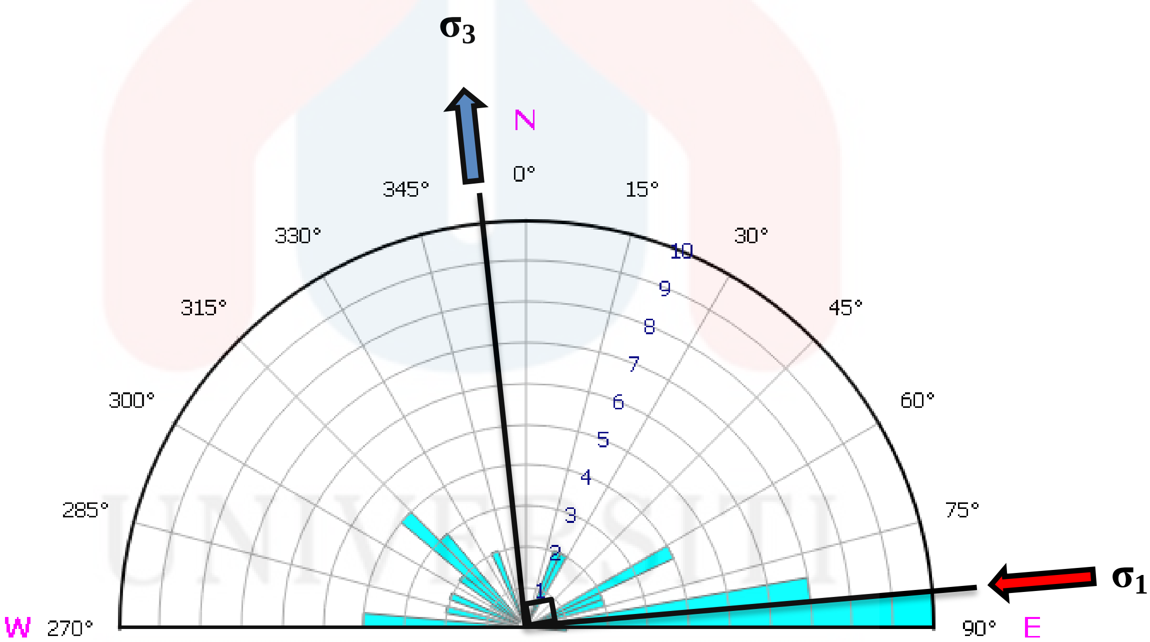


Figure 4.28: Rose diagram for joint analysis at coordinate of N 5°42'23.80" E 101°45'51.30"

The second joint analysis was collected at the coordinate of N 5°42'53.00" E 101°44'58.20" which is 2 km far from the first joint analysis outcrop . Figure 4.29 shows the orientation of the rock in the study area. The outcrop found was located along the Pergau River. Based on the plotted rose diagram in Figure 4.30, the direction of the compressional forces came from NE-SW direction. The joint reading this second analysis can be refer to Appendix A(12).

Figure 4.29: The second joint analysis assessment at N 5°42'53.00" E 101°44'58.20"

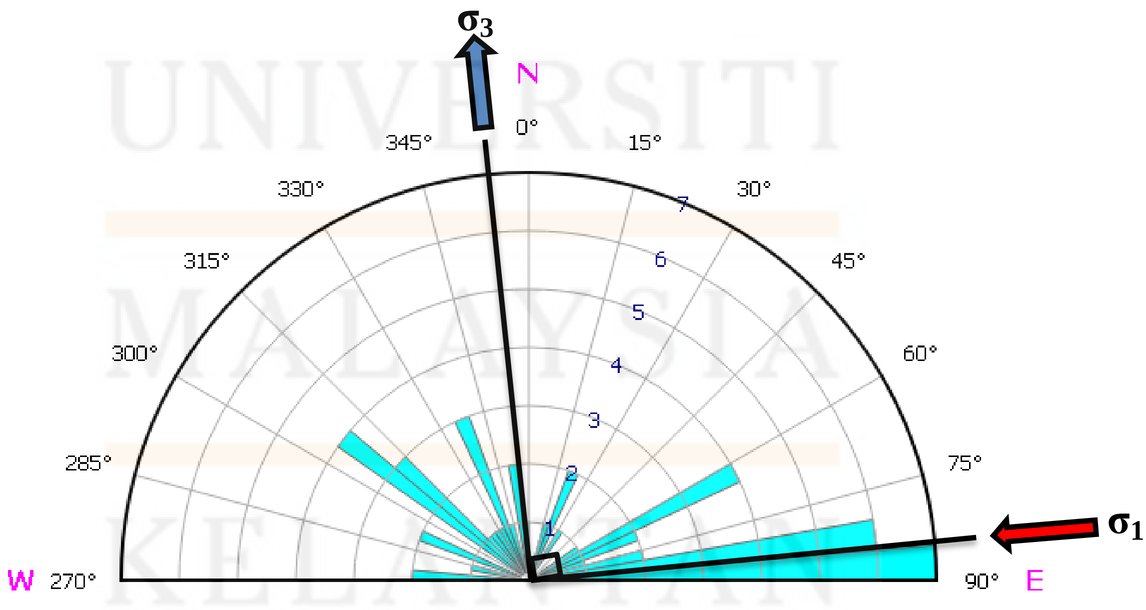


Figure 4.30: Plotted rose diagram for joint at N 5°42'53.00" E 101°44'58.20"

The third joint analysis was collected at the coordinate of N 5°42'51.00" E 101°44'53.70". Figure 4.31 shows the outcrop for the third joint analysis assessment. Based on the plotted rose diagram in Figure 4.32, the direction of the compressional forces came from NE-SW direction. The joint reading for this place can be refer to Appendix A(13).

Figure 4.31: The third joint analysis assessment at N 5°42'51.00" E 101°44'53.70".

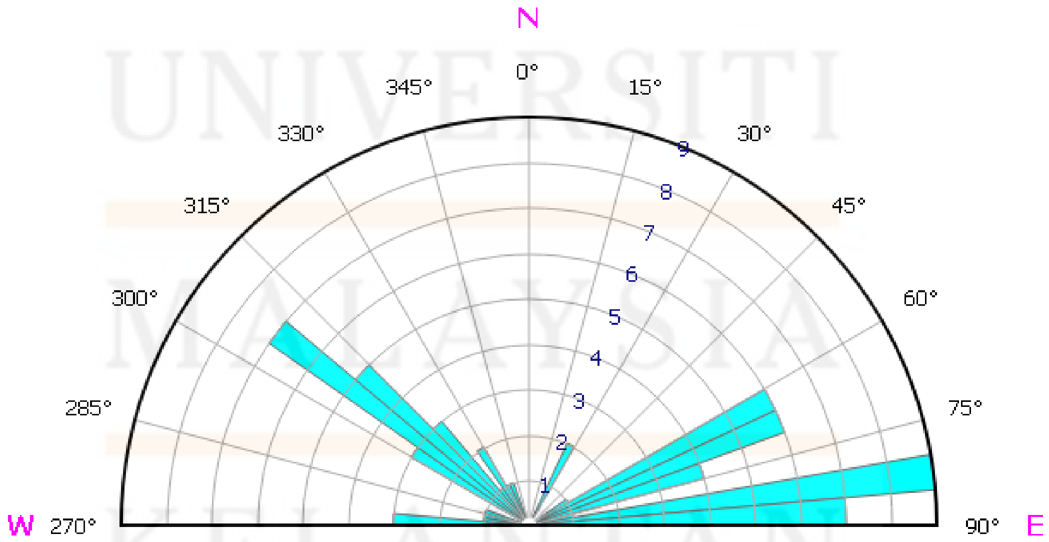


Figure 4.32: Plotted rose diagram for joint at N 5°42'51.00" E 101°44'53.70"

The overall direction of forces acting on the study area can be further explained by combining all of the joint analysis assessment. Figure 4.33 shows the results of the combinations between the three joint analysis assessment in the study area. Based on the result, the orientation of the major compressional force for all joints in the study area came from NE-SW direction which is the same with the force acting on the lineament. Therefore, the study area is said to undergone the same compressional force throughout the event resulting the extensional forces to be elongated in the same orientation which is in NW-SE direction.

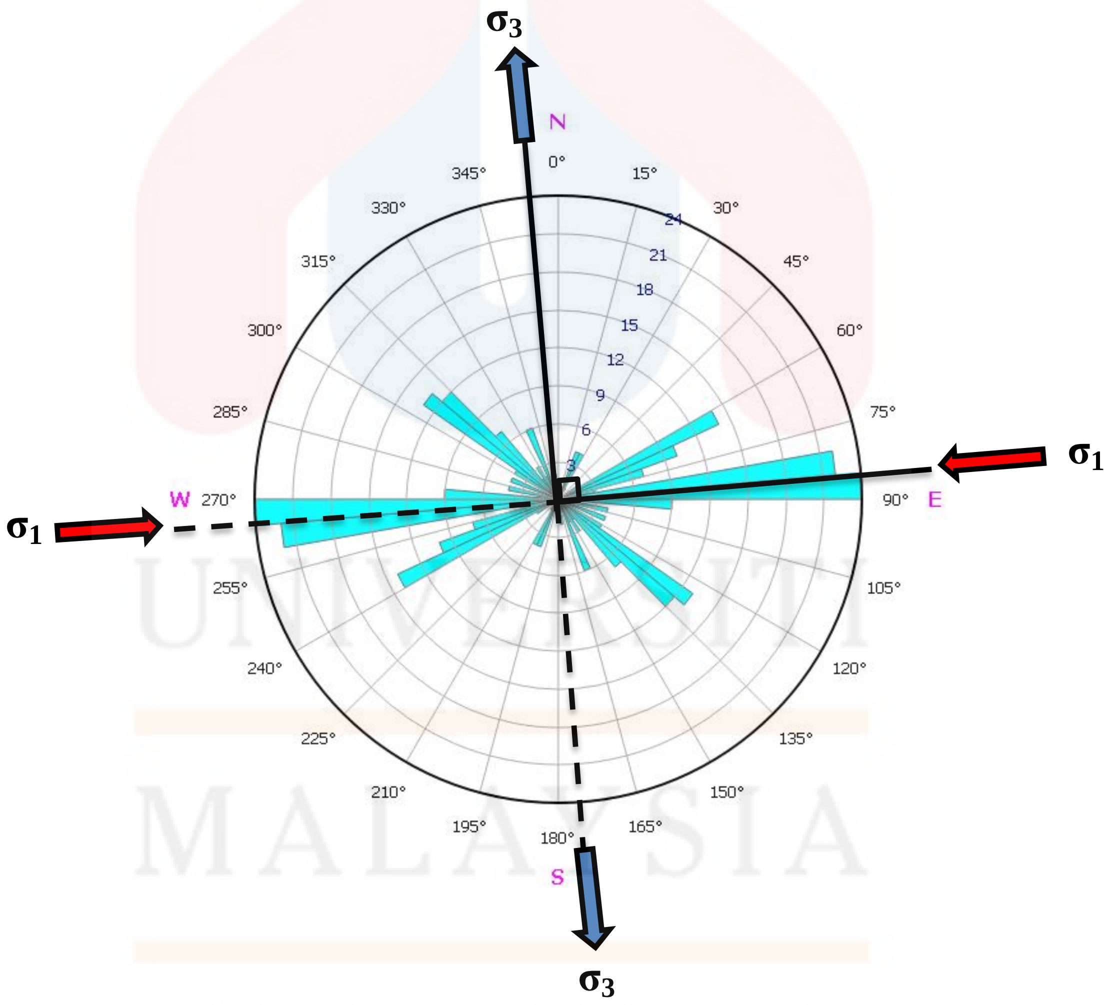


Figure 4.33: The overall plotted joint analysis

4.4.3 Fault

Faults can be classified into one of the geological structure. Fault is defined as planar fracture which shows significant movement or displacement as a result of the movement of rock mass. Based on the regional lineament map in Figure 4.25, there are some major fault lines and minor faults which are clearly can be observed based on the satellite imagery. The fault line was identified based on the linear line or pattern that can be observed along the river. The name of the fault that can be seen along Sg.Tadoh is strike-slip fault. This is because, the bending pattern of the river with its morphology shows the existence of linear pattern. Fault line can be defined as the intersection between fault plane and the ground surfaces. However, during geological mapping, the fault structures are barely identified perhaps due to the limited exposed area.

4.5 Historical Geology

Historical geology is a discipline that uses the principles and geological techniques to reconstruct and understand the geological history of the Earth. Historical geology explain about geologic processes that change either the Earth's surfaces or subsurface. The information regarding stratigraphy and structural geology are compulsory to describe about the sequence of the events based on geological timescale.

The regional metamorphism generally results in forming metamorphic rocks which are strongly foliated, such as slates, schists, and gneisses. In fact, the gneiss bodies found in the study area has strengthened the evidence of this theory.

The formation of rock unit within the study area was predominantly dominated by the igneous body since the Triassic period. The formation of andesite bodies show the rapid cooling of volcanic process during the past geologic event. Besides that, the brownish colour of mudstone with fine grained texture also present in the middle of the Triassic period.

The sedimentary rock such as limestone was formed almost at the end of the Triassic period. Then, the geological process between the rock boundaries causes the certain parts within the study area to undergo metamorphism by the changed in extremely higher temperature and pressure, hence resulting the formation of marble rock units. The types of metamorphism can be divided into regional, contact and dynamic. In this study area, the rock metamorphism is happened maybe due to the regional metamorphism.

The formation of rock unit in the study area is named as Telong Formation. Telong Formation begins since the era of late Paleozoic to early Mesozoic.

CHAPTER 5

POTENTIAL OF LIMESTONE GEOHAZARD BY USING GIS ANALYSIS AT KG.GUNONG BATU MELINTANG, JELI, KELANTAN

5.1 Introduction

Limestone is believed to have the potentials that can contribute to the occurrence of geohazard based on its nature characteristics and behaviour. In this chapter, all of the ratings of the entire parameter were added in order to get the total potential of geohazard. The suitable index or data such as the values of weightage and ranks for each factor maps was inserted and added for further analysis. The zones that were potentially can triggers the limestone geohazard within the study area was been identified and classified according to Table 5.1.

5.2 Analysis of GIS Overlay

Overlay map analysis can be produced by using GIS software through Arcmap. The analysis method used is raster multiple overlay analysis. Each of the parameters were classified into suitability and multiplied by the weight in order to know their importance. This method requires the entire vector or features data to be converted into raster geodatabase format at first.

All the suitable factors or thematic maps were then will be combined or overlay together to produce potential limestone geohazard map. Therefore, different factors are needed to conduct an overlay analysis. In this study, the factors that can give influence to the potential limestone geohazard are slope, land use and such. This is because, different raster information will have different values.

Next, the summation off all parameters between the input weightages and ranks will be calculated by using raster calculator in Arcgis in order to get the final weight value that is suitable for each location on map. Therefore, before analysing, the weightage (W) and suitable ranking (R) column need to be added in the attributes table for each of the map that need to undergo the raster calculation.

The suitable ranks in each layer are multiplied by the layer's weight value before being summed with the other layers. The equation that was used during raster calculation was as in equation in (3.1).

5.3 Result and Interpretation

5.3.1 Potential Limestone Geohazard in Kg.Gunong Batu Melintang

The limestone hazard zonation was generally can be divided into five classes based on the total estimated hazard ratings in Table 5.1. The hazardous zonation can be identified based on the map produced through raster multi-overlay analysis. Figure 5.1 shows the potential of limestone geohazard map of the study area that already has been classified according to its specific hazard zone value. The map was actually shows the overall potential of geohazard in the study area, but the interpretation was only focussed on the limestone region.

Within the study area, the result clearly shows that the potential of limestone geohazard in Kg.Gunong Batu Melintang was only moderate hazard. This is because, the total potential hazard value in the study area especially for area that shows distribution of limestone was not exceed the value of 6.5. In fact, most of the area within the study area was denoted with low hazard zone.

In addition, most of the residential and development areas were built nearby and surrounding the Gunung Reng karst. Based on the potential limestone geohazard map, the area nearby the limestone karst shows the possibility to triggers the geohazard. The limestone geohazard that might be occurring within the marked zone could be rock falls, sinkhole or land subsidence. Even the area was marked as moderate hazard zone, but still, the further precautions should be taken to avoid any misfortune and losses.

Table 5.1: Classification of limestone hazard zonation

Zone	Total Potential Hazard Value	Description
1	< 3.5	Very Low Hazard
2	3.5 – 5.0	Low Hazard
3	5.1 – 6.5	Moderate Hazard
4	6.6 – 7.5	High Hazard
5	> 7.5	Very high Hazard

(Source: Anbalagan,1992)

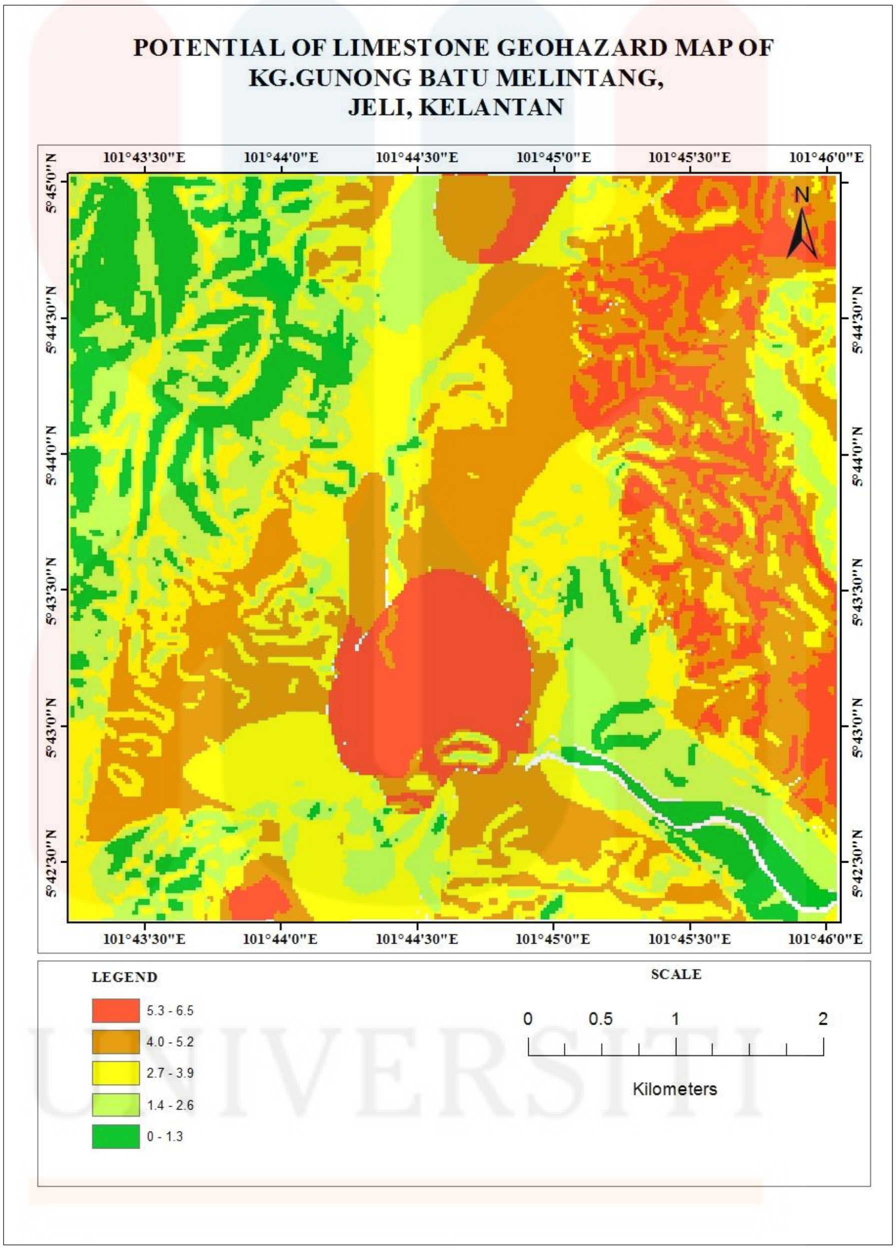


Figure 5.1: Potential of limestone geohazard map in study area

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

The geological map of Batu Melintang is able to be produced with the scale of 1:25,000. An updated geological map is very important and useful for geologist as a reference during conducting some research and geological field or survey. Instead, an updated geological map is also very useful to the future researcher to obtain data and geological information about that particular area with more easily.

Based on the researched that already been done, the karst surface condition within the study area can be considered to give moderate or intermediate hazard. However, some precautions step should be emphasized and always serve as a reminder that someday, it is possible to pose a danger to the local area.

The study area is said to have mostly hilly topography surfaces with the one and only massive limestone karst. In addition, the study area also can be said to have a distribution of the limestone rock in almost all regions. Therefore, the potential of limestone geohazard map in the study area was successfully produced by using GIS multi-overlay analysis.

Limestone is a sedimentary rock which is also known as a soluble rock. Limestone have the ability to form karstic features such as cave or etc. when undergo chemical reaction such as dissolution process. In addition, there were also numerous case studies about limestone which can cause many significant problems to society especially towards engineering problems. Most cases reported are such as subsidence, sink hole, rock fall, and etc.

As a reminder, a moderate or intermediate potential hazard zone could turn into huge disaster as time passes. Thus, any responsible authorities should take early precautions steps to overcome the problem before it is happen. Any areas or zone that poses geological hazard should be avoided for any development purposes. By doing such things, any accidents that might be fatal and contributing to loss of properties in the future can be avoided. This is because, it is always better to avoid rather than cure.

As a conclusion, any information gained from this study should be implemented and taken benefit as guidance for authorities and future developers in Jeli district especially around the area of Batu Melintang. The potential of limestone geohazard map that is produced can be used as a preliminary study for all responsible authorities.

6.2 Suggestion and Reccomendation

Based on this study, there are several things that should be taken as an improvement and revision. First of all, this case study can be as a guide for any future researchers who are interested to conduct geological survey or mapping which are related to the study area or potential of limestone geohazard by using GIS software. Thus, a more detailed mapping within the study area is highly recommended in order to prove that the existed map was precise and relevant. Some errors could happen through technologies malfunction. Therefore, a manual mapping is compulsory in order to get more accurate data.

Other than that, the analysis of potential limestone geohazard zone only is done by using GIS method. In order to obtain more accurate result and possible outcome, the GIS analysis method must be followed by the geophysical approaches such as resistivity method by RES2DINV software, borehole study or many other optional methods. Geophysical methods are also can be used to identify hazard zone either at the surface or subsurface. Various data in various methods can give more accurate, precise and reliable possible outcome.

Besides, instead of using feature overlay analysis, the future researcher also can consider to use raster overlay analysis which is similar method with this case study. Raster analysis can give more accurate, clear, and precise data. This is because, each shaded areas in raster is divided into many smaller pixels which can display their own values. During calculation, the data in raster analysis can give more accurate values.

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APPENDIX A

Appendix A(1): Total population in Kelantan from the year 2010 to 2014.

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

(Source: Kelantan Department of Population Statistic)

Appendix A(2): Total rain distribution (mm) in Kelantan from the year 2010 to 2014.

District	Year				
	2010	2011	2012	2013	2014
Bachok	2713.0	4149.0	3202.0	2841.5	3078.0
Kota Bharu	2246.5	3033.0	2741.5	1984.5	2436.5
Machang	2844.0	4249.5	3136.0	3730.5	4080.5
Pasir Mas	2717.5	3711.5	2673.0	2358.5	2782.0
Pasir Puteh	2902.5	4647.0	2911.0	3350.5	3414.0
Tanah Merah	3258.5	4258.5	3874.0	3434.5	3999.5
Tumpat	2370.0	3226.0	2538.0	2125.0	1743.5
Gua Musang	2020.0	1765.5	2721.0	2418.0	2784.5
Kuala Krai	2106.5	2065.5	2191.5	3339.5	1602.0
Jeli	3103.5	4359.5	3250.5	3592.0	4094.0
Kelantan	26282.0	35465.0	29238.5	29174.5	30014.5

(Source: Department of Drainage and Irrigation)

Appendix A(3): Proposed Maximum Weighting for Different Contributory Factors for Limestone Geohazard

Contributory Factors	Maximum Weighting (W)
Lithology	2
Slope Morphometry	2
Drainage Density	1
Landuse and Land Cover	2
TOTAL	**7**

Appendix A(4): Rating for Lithology/ Rock Types

Category	Rock Types	Ranking (R)
Type I	Limestone/ Marble	0.2
	Granite/Andesite	0.3
Type II	Interbedded sandstone and clay or shale	1.2
Type III	Shale, slate, phylite, siltstone, and mudstone	1.2
	Weathered phylite, slate, shale, and schist	2.0

Appendix A(5): Rating for Slope Morphometry

Slope Type	Slope Angle (˚)	Types of Failure or Hazard	Ranking (R)
Escarpment/Cliff	> 55	Rock Falls and Topples	2.0
Very Steep Slope	45-55	Rock Falls and Topples	1.8
Steep Slope	35-45	Slides	1.6
Moderately Steep Slope	25-35	Slides	1.3
Gentle Slope	15-25	Slides and Creeps	0.8
Very Gentle Slope	<15	Movement	0.5

Appendix A(6): Rating for Landuse and Land Cover Types

Landuse and Land Cover Types	Ranking (R)
Cultivated/Agricultural Area	0.65
Forest Area	0.80
Road and Water Bodies	1.20
Residential/Development Areas	1.5
Barren Land	2.0

Appendix A(7): Rating for Drainage Density

Category	Drainage Density	Ranking (R)
I	<1.0	0.0
II	1.0-2.0	0.2
III	2.0-3.0	0.5
IV	3.0-4.0	0.8
V	>4.0	1.0

Appendix A(8): Rating for Rainfall

Average Annual Rainfall of the Area (mm)	Ranking (R)
<500	0.2
500-1000	0.3
1000-1500	0.4
>1500	0.5

Appendix A(9): Rock classification based on grades of weathering

CLASS	TERM	DESCRIPTION
I	Fresh rock	The rock material is not discoloured and has its original aspect.
II	Slightly weathered rock	Discolouration is present only near joint surface. The original mass structure is well preserved.
III	Moderately weathered rock	The rock material is discoloured but locally the original colour is present. The original mass structure is well preserved.
IV	Highly weathered rock	All rock material is discoloured. The original mass structure is still present and largely intact.
V	Completely weathered rock	All rock material is completely discoloured and converted into soil, but the original mass structure is still visible.
VI	Residual and colluvial soil	All rock material is converted into soil. The original rock structure is completely destroyed.

(Source: Borelli et al.,2007)

Appendix A(10): Reading for regional lineament

1	55	**11**	100	**21**	40	**31**	49	**41**	340	**51**	49	**61**	60	**71**	5
2	92	**12**	29	**22**	83	**32**	92	**42**	14	**52**	58	**62**	151	**72**	40
3	62	**13**	13	**23**	147	**33**	5	**43**	34	**53**	41	**63**	83	**73**	20
4	78	**14**	39	**24**	130	**34**	150	**44**	43	**54**	54	**64**	180	**74**	46
5	31	**15**	43	**25**	12	**35**	75	**45**	55	**55**	29	**65**	25	**75**	58
6	76	**16**	17	**26**	42	**36**	44	**46**	60	**56**	166	**66**	5	**76**	21
7	168	**17**	28	**27**	47	**37**	128	**47**	34	**57**	132	**67**	42	**77**	82
8	122	**18**	26	**28**	56	**38**	140	**48**	34	**58**	136	**68**	90	**78**	146
9	170	**19**	58	**29**	85	**39**	91	**49**	178	**59**	90	**69**	32	**79**	122
10	133	**20**	74	**30**	34	**40**	37	**50**	177	**60**	30	**70**	16	**80**	132

Appendix A(11): Joint reading at N 5°42'23.80" E 101°45'51.30"

1	272	**11**	290	**21**	103	**31**	268	**41**	125	**51**	240	**61**	130	**71**	266	**81**	28	**91**	274
2	82	**12**	309	**22**	137	**32**	240	**42**	133	**52**	267	**62**	123	**72**	265	**82**	265	**92**	271
3	84	**13**	314	**23**	273	**33**	290	**43**	103	**53**	264	**63**	24	**73**	248	**83**	335	**93**	268
4	60	**14**	70	**24**	83	**34**	311	**44**	138	**54**	263	**64**	264	**74**	267	**84**	25	**94**	85
5	266	**15**	23	**25**	86	**35**	315	**45**	270	**55**	246	**65**	336	**75**	62	**85**	73	**95**	80
6	246	**16**	336	**26**	62	**36**	73	**46**	80	**56**	266	**66**	23	**76**	86	**86**	315	**96**	270
7	263	**17**	264	**27**	267	**37**	25	**47**	85	**57**	60	**67**	70	**77**	83	**87**	311	**97**	103
8	264	**18**	24	**28**	248	**38**	335	**48**	268	**58**	84	**68**	314	**78**	273	**88**	290	**98**	138
9	267	**19**	123	**29**	265	**39**	265	**49**	271	**59**	82	**69**	309	**79**	137	**89**	240	**99**	125
10	240	**20**	130	**30**	266	**40**	28	**50**	274	**60**	272	**70**	290	**80**	103	**90**	268	**100**	133

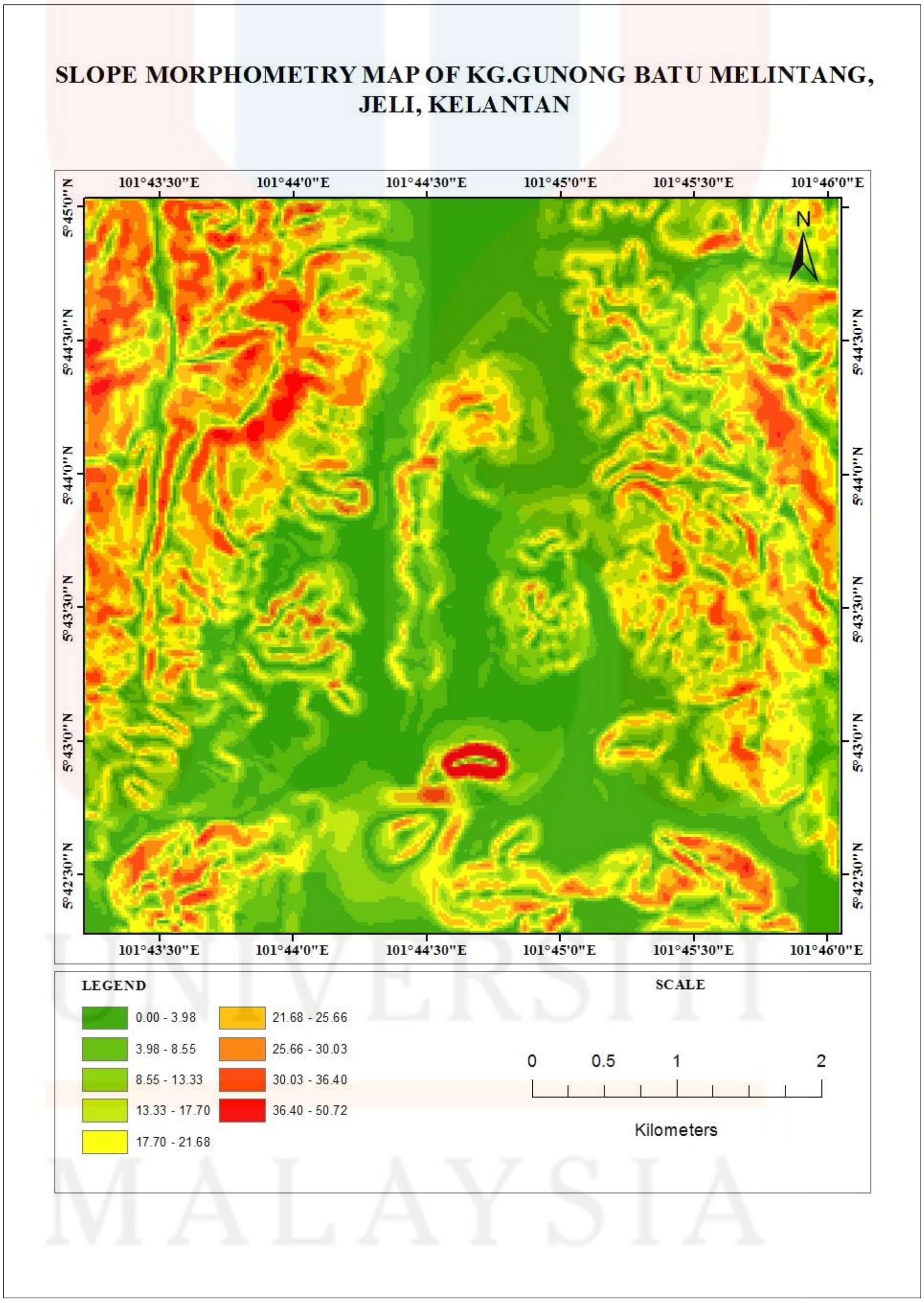
Appendix A(12): Joint reading at N 5°42'53.00" E 101°44'58.20"

1	56	**11**	309	**21**	290	**31**	336	**41**	63	**51**	240	**61**	130	**71**	342	**81**	33	**91**	129
2	75	**12**	327	**22**	309	**32**	264	**42**	266	**52**	267	**62**	123	**72**	337	**82**	70	**92**	125
3	77	**13**	18	**23**	314	**33**	24	**43**	249	**53**	264	**63**	336	**73**	356	**83**	314	**93**	24
4	32	**14**	353	**24**	70	**34**	125	**44**	267	**54**	263	**64**	24	**74**	352	**84**	309	**94**	264
5	323	**15**	331	**25**	23	**35**	129	**45**	269	**55**	246	**65**	264	**75**	337	**85**	314	**95**	336
6	337	**16**	246	**26**	272	**36**	104	**46**	241	**56**	266	**66**	314	**76**	323	**86**	290	**96**	267
7	352	**17**	263	**27**	82	**37**	138	**47**	291	**57**	60	**67**	309	**77**	32	**87**	240	**97**	60
8	356	**18**	264	**28**	84	**38**	272	**48**	310	**58**	120	**68**	70	**78**	77	**88**	267	**98**	84
9	337	**19**	267	**29**	60	**39**	82	**49**	314	**59**	98	**69**	290	**79**	327	**89**	264	**99**	272
10	342	**20**	240	**30**	267	**40**	87	**50**	266	**60**	272	**70**	23	**80**	246	**90**	353	**100**	82

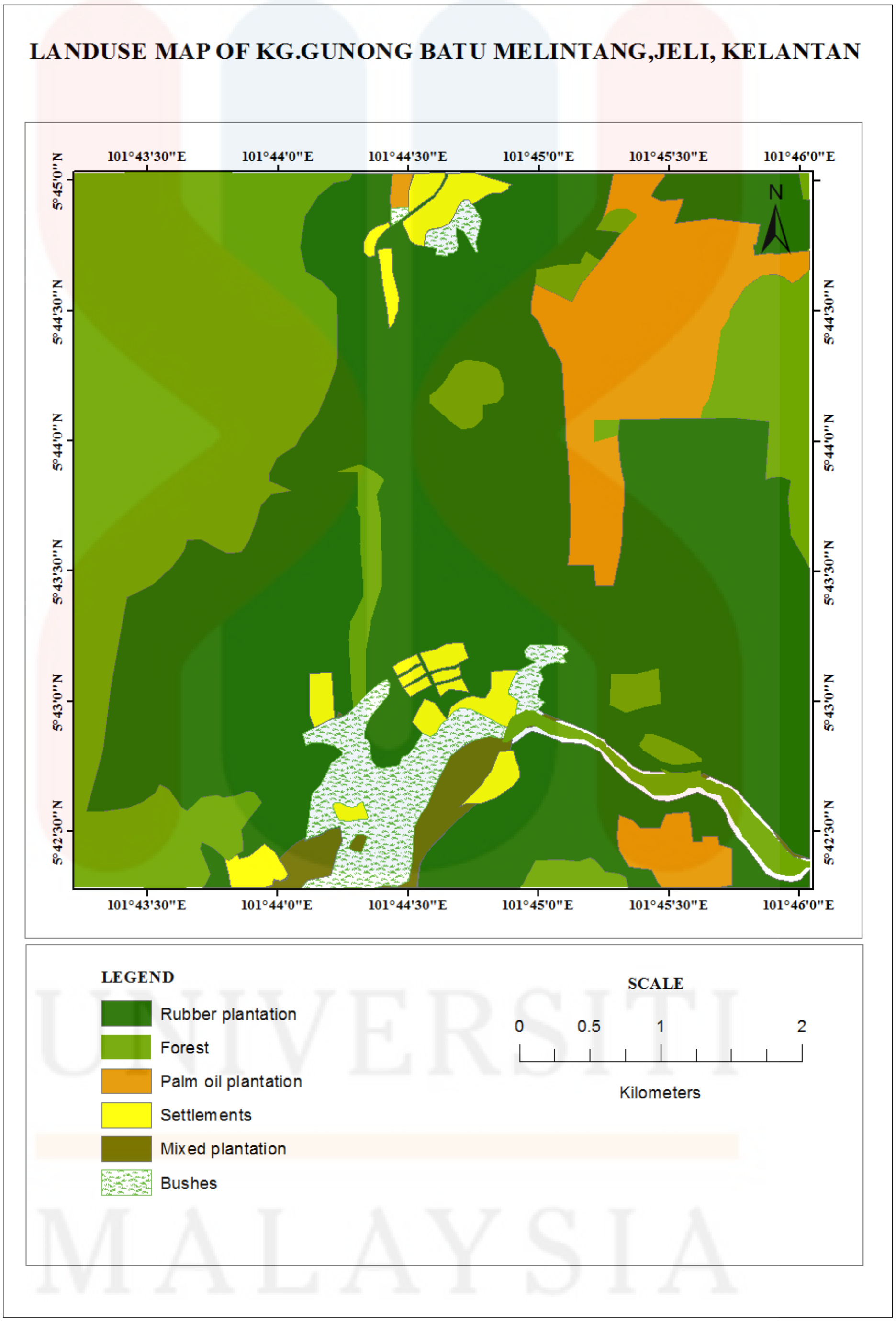
Appendix A(13): Joint reading at N 5°42'51.00" E 101°44'53.70".

1	265	**11**	69	**21**	73	**31**	245	**41**	337	**51**	264	**61**	245	**71**	243	**81**	154	**91**	266
2	317	**12**	65	**22**	98	**32**	262	**42**	265	**52**	310	**62**	260	**72**	266	**82**	77	**92**	275
3	133	**13**	127	**23**	125	**33**	260	**43**	26	**53**	132	**63**	263	**73**	260	**83**	125	**93**	135
4	125	**14**	322	**24**	77	**34**	266	**44**	127	**54**	128	**64**	266	**74**	262	**84**	98	**94**	310
5	61	**15**	327	**25**	154	**35**	243	**45**	128	**55**	70	**65**	240	**75**	245	**85**	73	**95**	264
6	327	**16**	302	**26**	235	**36**	288	**46**	101	**56**	272	**66**	265	**76**	61	**86**	70	**96**	260
7	139	**17**	66	**27**	272	**37**	307	**47**	136	**57**	82	**67**	133	**77**	85	**87**	121	**97**	245
8	131	**18**	124	**28**	83	**38**	310	**48**	272	**58**	84	**68**	317	**78**	272	**88**	124	**98**	266
9	64	**19**	121	**29**	85	**39**	72	**49**	80	**59**	60	**69**	61	**79**	235	**89**	66	**99**	263
10	68	**20**	70	**30**	61	**40**	25	**50**	88	**60**	266	**70**	126	**80**	330	**90**	303	**100**	240

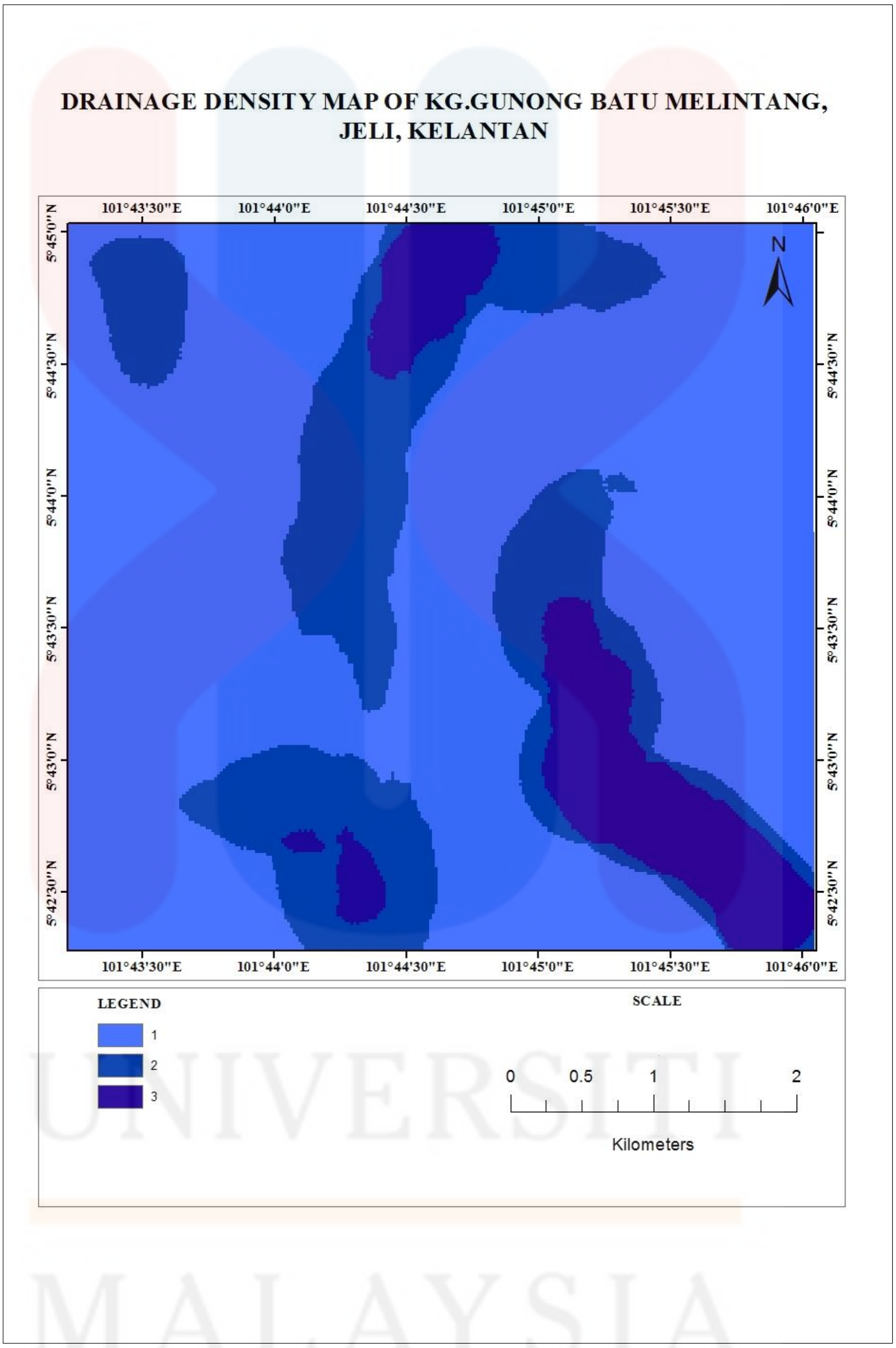
APPENDIX B



Appendix B(1): Slope morphometry map of Kg. Gunong Batu Melintang



Appendix B(2): Land use and land cover types of Kg. Gunong Batu Melintang



Appendix B(3): Drainage density map of Kg. Gunong Batu Melintang