GEOLOGY AND JOINT ANALYSIS IN LIMESTONE OUTCROP AT BATU MELINTANG, JELI, KELANTAN

By

UMI SAFIQAH BINTI ISMAIL

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

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UNIVERSITI MALAYSIA KELANTAN

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DECLARATION

I declare that this thesis entitled Geology and Joint Analysis in Limestone Outcrop at Batu Melintang, Jeli, Kelantan is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ______________________________

Name : ______________________________

Date : ______________________________

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TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF ABBREVIATIONS

GIS – Geographic Information System

GDP– Gross Domestic Product

FELCRA – Federal Land Consolidation and Rehabilitation

GPS–Global Positioning System

LIST OF SYMBOLS

N –- North

S – South

E – East

W – West

% – Percentages

1:25000 – 1 cm on map equal 25000 cm

mm – millimetre

km² – kilometre per second square

M – meter

º – degree

Geology and joint analysis of limestone outcrop in Batu Melintang, Jeli, Kelantan.

This research provides a study of a joint analysis of the study area located at the Batu Melintang, Jeli, Kelantan. This research aims to produce the study area's geological map, classify the study area's joint structure, and examine the dynamic and kinematic aspect of the study area's joint structure. Geological mapping was conducted to determine general geology of the area. The joint research study was carried out on the study area by morphological, stratigraphic and structural observation. Three types of rock exist in the study area, which are igneous rock, sedimentary rock and metamorphic rock. The rock that has found in the study area are hornfels, marble, limestone, gneiss, slate and schist. Then data collection was processed in laboratory works and analyses to get the result of the research. The result of the joint analysis was shown based on Rose diagram, and the maximum force direction in the study area also have been identified, and it is almost NE-SW direction. The recommendations are made to improve practice in assessing the joint analysis in order to obtain a more accurate result and possible outcome.

Geologi dan analisis retakan pada singkapan batu kapur di Batu Melintang, Jeli, Kelantan.

Kajian ini menyediakan kajian mengenai analisis bersama kawasan kajian yang terletak di Batu Melintang, Jeli, Kelantan. Kajian ini bertujuan untuk menghasilkan peta geologi kawasan kajian, mengklasifikasikan struktur bersama kawasan kajian, dan mengkaji aspek dinamik dan kinematik struktur bersama kawasan kajian. Pemetaan geologi dilakukan untuk menentukan geologi umum kawasan tersebut. Kajian penyelidikan bersama dijalankan di kawasan kajian oleh pemerhatian morfologi, stratigrafi dan struktur. Tiga jenis batu terdapat di kawasan kajian, iaitu batuan beku, batuan sedimen dan batuan metamorf. Batu yang terdapat di kawasan kajian ialah tanduk, marmar, batu kapur, gneiss, batu tulis dan schist. Kemudian pengumpulan data diproses dalam kerja makmal dan dianalisis untuk mendapatkan hasil penyelidikan. Hasil analisis bersama ditunjukkan berdasarkan rajah Rose, dan arah daya maksimum di kawasan kajian juga telah dikenalpasti, dan hampir arah NE-SW. Cadangan dibuat untuk meningkatkan amalan dalam menilai analisis bersama untuk mendapatkan hasil yang lebih tepat dan kemungkinan hasilnya.

CHAPTER 1

Introduction

1.1 General Background

Fractures in the rock are fundamentally crucial to how rock masses behave in terms of settlement, stability, and excavation projects and as for the through-flow and storage of liquids and gases. Still, the nature of and, in particular, the origin of rock joints and other naturally occurring structural discontinuities or fractures dealt with rather lightly in most rock mechanics and standards for rock description.

In rock engineering, when characterizing rock masses, joints and other structural discontinuities tend to be dealt with simplistically. Only open fractures are generally recorded. The choice of fracture "type" is limited to joint, fault, bedding or cleavage (BS5930:1999). The focus of interpretation of joint is on geometry and frequency, and little attention paid to the origin, strength evolution, or the environmental setting of the fractures.

Joints are fractures found on most rocks near the Earth's surface and their origins have been the subject of debate for a number of years (Pollard and Aydin, 1988). Joints are the outcome of the rock overstressing (even in its soil-like condition). Many form in sedimentary environments, some due to cooling or other forces in igneous bodies, while others result from tectonic forces (e.g., Rawnsley et al., 1990; 1992). Some of the joints are the direct result because stress conditions at the Earth's surface. Einstein & Dershowitz, 1990 review and dicussed the formation of joints in tensile and shear stress regimes based on modern concepts of fracture mechanics. What remains poorly recognized, however, many of joints do not fully develop as visible structures and controlling mechanical discontinuities until the rock is significantly de-stressed and exposed to the elements. They are locked in as weaknesses but only will be fully develop at later stages.

By understanding the mechanism by which fractures form, and able to interpret the evidence observed in the rock can deduce the physical conditions that prevailed in the rock during this fracturing process, thereby opening another window on the tectonic evolution of the Earth's crust and the dynamic processes that drive that evolution.

Beyond their use in investigating the tectonic evolution of the Earth's crust, the joint is significant to the environment and the continued viability of the society. First, because joints often serve as conduits or groundwater, they are the site of preferential weathering and thereby control the form of much of the Earth's topography. Indeed, some of the world's most inspiring landforms, such as Yosemite Valley in California, the Grand

Canyon, the Alps, the islands of the Mediterranean, and Ayer's Rock in Australia, owe much of their form to preferential erosion caused by the presence of joint.

Furthermore, because joints provide conduits for the migration of fluids through solid rock, they are of great significance in the migration of groundwater, hydrocarbons, and hydrothermal or metamorphic fluids. Thus they are significant in the field of hydrogeology, geothermal heat extraction, and oil and gas migration and recovery. Besides, fractures affect the location of hydrothermal mineral deposits and the integrity of nuclear waste disposal sites, which must safely contain their harmful waste for 10000 years or more. As a consequence of this association with the world economy and the safety of future generations, understanding the characteristics of fractures and the conditions of their formation is of genuine social importance.

Moreover, because the cohesion of the rocks lost across fracture surfaces, they are planes of weakness in the rock. This inherent weakness must be accounted for in the building of dams, bridge abutment, tunnels, mines, and similar engineering projects.

In summary, joint may seem to be dull and featureless geological structures, but in fact worth studying, not only because it is vital to control the morphology of the landscape, but also because joint deeply affects rock strength, influences hydrological properties such as permeability, and because joint can also provide a detailed but subtle history of stress and strain in a region.

1.2 Problem Statement

During the past decades, a lot of research was conducted in the study area, but there is still no research carried out in the study area based on joint structures of limestone. However, most of the studies conducted mostly covers on the geoheritage potential of the area especially for instance past research on Systematic Studies of Geoheritage in Jeli District, Kelantan, Malaysia by Dony Adriansyah Nazaruddin. Therefore, this study will focus on a detailed investigation of the joint structure that presents in the study area and analyze the forces, stress, strain, and any related process that causes the joint structure to form.

Besides that, the geological map and data for the study area are not been updated. The earth is evolving to this day, while the geological processes continue to change the earth's landform. The study area also continuously exposed to weathering and erosion that changes the landform of the earth, so the existing geological map of the study area is needed to be updated.

1.3 Research Objectives

1. To identify the joint structure of limestone outcrop in the study area.
2. To analyze the dynamic and kinematic aspect of the joint structure in the study.
3. To produce a geological map of the study area with the scale 1:25000.

1.4 Study Area

The study area covers an area of 5 km x 5 km (25 km^2) in Batu Melintang and its surroundings. It located in the western corner of Jeli District, at the Batu Melintang sub-district, Jeli, Kelantan. The coordinate for the latitude range between N 5˚ 45'0" to N 5˚41'0" and the longitude extends between E 101˚ 43' 0" to E 101˚ 47'0". The journey takes about 14 km from Jeli town to the study area.

Besides, the study area owned limestone karst named by the local as Gunung Reng. It is a magote hill towering above the flat alluvial topography. The hill is composed of metamorphed limestone (marble) sitting on the intrusive body (granitic rocks) surrounded by Quaternary alluvial deposits. The hill possesses some caves, where the main cave goes through the top of the hill. There are some exciting features inside the cave, such as stalactites and stalagmite.

This area can classify as a rural area because of about half of the study area in the forest. In this study area, there also have a lot of agricultural activities such as rubber plantation and oil palm plantation. Another attraction of the study area is the main river, which is the Pergau river. It was the largest river in the district of Jeli flowing through the south of the Gunung Reng, which significantly beautify the area.

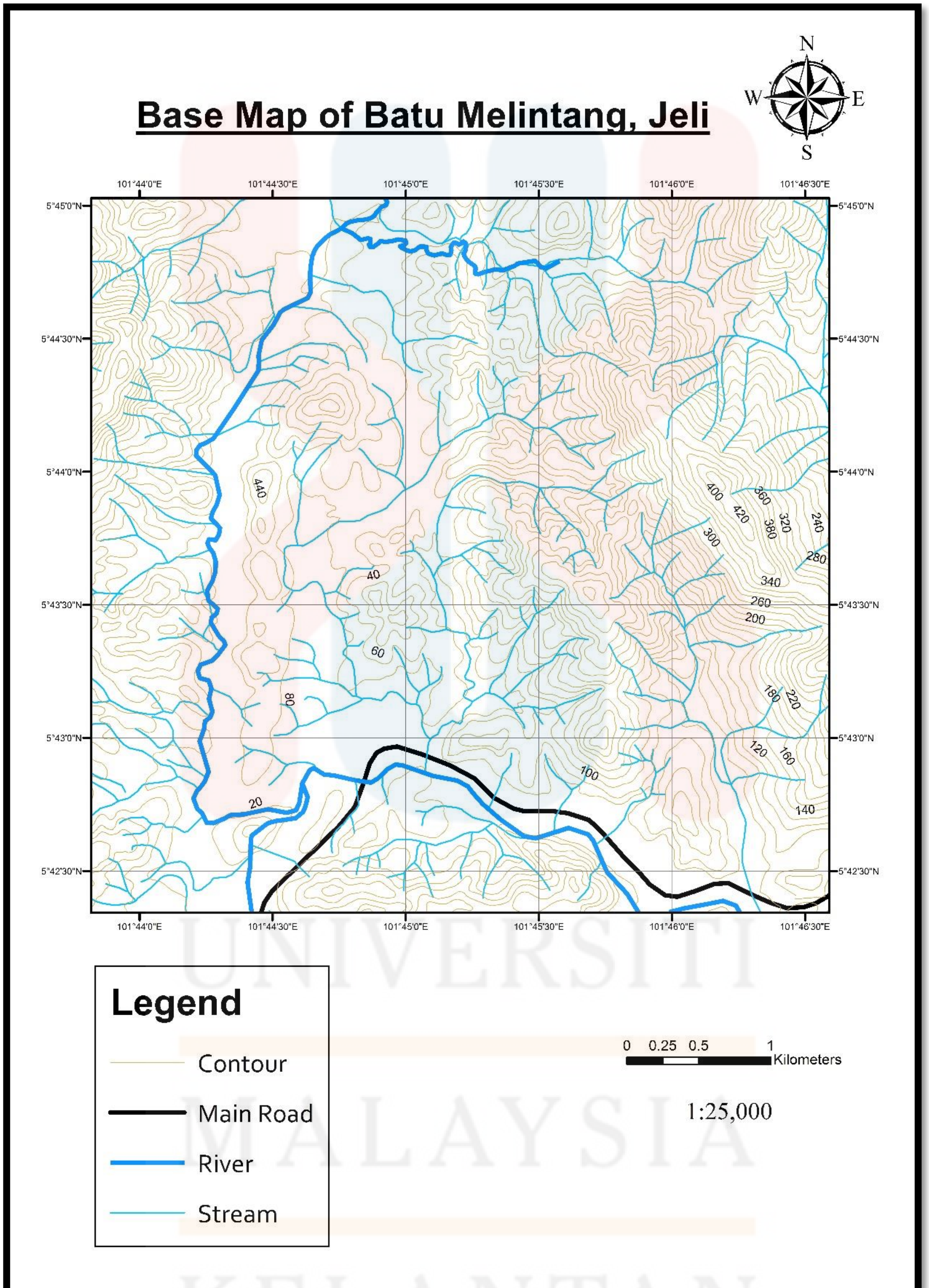


Figure 1.1 Base map of the study area.

1.4.1 Demography

The graph of population of Kelantan is showed in Figure 1.5. From the Table 1.1, the population of Kelantan has increased from 2000 to 2010 by 226,587 persons. The population for all the districts in Kelantan are increased. Jeli district went through raising in population from 2000 to 2010 by 4,125 persons.

Name	**Status**	**Population** (2000-07-05)	**Population** (2010-07-06)	**Area** (Hectares)
Kelantan	State	1,313,014	1,539,601	1,502,200
Bachok	District	111,040	133,152	27,900
Gua Musang	District	76,655	90,057	817,700
Jeli	District	36,512	40,637	131,800
Kota Bharu	District	406,662	491,237	39,400
Kuala Krai	District	93,550	109,461	227,700
Machang	District	79,032	93,087	52,700
Pasir Mas	District	165,126	189,292	56,900
Pasir Puteh	District	106,138	117,383	42,400
Tanah Merah	District	103,487	121,319	88,000
Tumpat	District	134,812	153,976	17,700

Table 1.1 Population of Kelantan

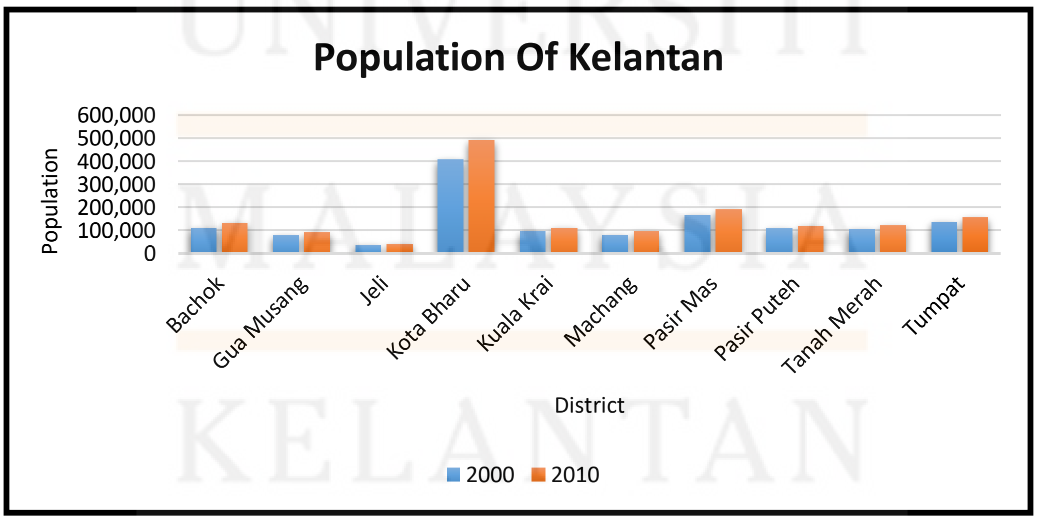


Figure 1.2 Graph Population of Kelantan

1.4.2 Rainfall

			Purata Taburan Hujan (mm)											
ID Stesen	**Nama Stesen**	**District**	**Jan**	**Feb**	**Mac**	**Apr**	**Mey**	**Jun**	**Jul**	**Aug**	**Sep**	**Okt**	**Nov**	**Dis**
5718033	Kg. Jeli	Jeli	32.7	7.5	6.8	7.2	6.3	6.6	6.6	8.1	12.8	5.7	25.5	9.2

Table 1.2 Rainfall Distributions in Year 2017 (Department of Irrigation and Drainage Kelantan)

From the rain distribution provided by Department of Irrigation and Drainage Kelantan, it included rain distribution in 2017 from January to Disember. The station number is 5718033 which named Kg. Jeli in Jeli Kelantan Malaysia. It located at the Rergau River. In 2017, the minimum rainfall is 1.1 mm while the maximum is 35.5 mm which recorded in November. Mac 2017 has least rainfall which is only 65.3 mm. The total rainfall distribution of Kampung Jeli station is 135.5 mm. Figure 3 showed rain distribution of Kg. Jeli station Kelantan 2017.

1.4.3 Landuse

Land use in Kelantan state is dominant by the forest reserve. It covered around 59.5 % in 2001 while forest and water body has covered total of 72.7% of Kelantan total land area in 2002. It followed by agriculture which is 22.3% and 25.35% respectively in 2001 and 2002. The urban area and mining area both cover 0.3% of Kelantan land while the other land use category covers 17.6% in 2001. Hassan (2004) stated that the urban change in the land use category has been changing gradually from the 1970s to 1990s with growth of 7% and after the 1990s there were very slow developments in the area with only 1.4% of growth. Table 1.3 showed the category of land use of Kelantan in 2001.

Within the study area the land use is dominant by forest which covered around 50% of the total land use. It followed by rubber and others. The other categories of land use included river, mines and tailings, municipal and related, mixed plantations, various plants, clearings area, swamp forest and idle grass or weeds. In this area, it is only minor land use for municipal purpose while other land is major use for vegetation. The map of land use of Batu Melintang, Jeli, Kelantan is shown in Figure 1.4.

Category	Area (hectare)	Percentage (%)
Forest reserves	894271	59.5
Agricultures	335660	22.3
Urban	4967	0.3
Mining	3737	0.3
Other	265	17.6
Total	1502200	100

Table 1.3 Category of land use of Kelantan in 2001 (Source: Department of Mineral and Geoscience, 2003).

Figure1.3 Logging Company

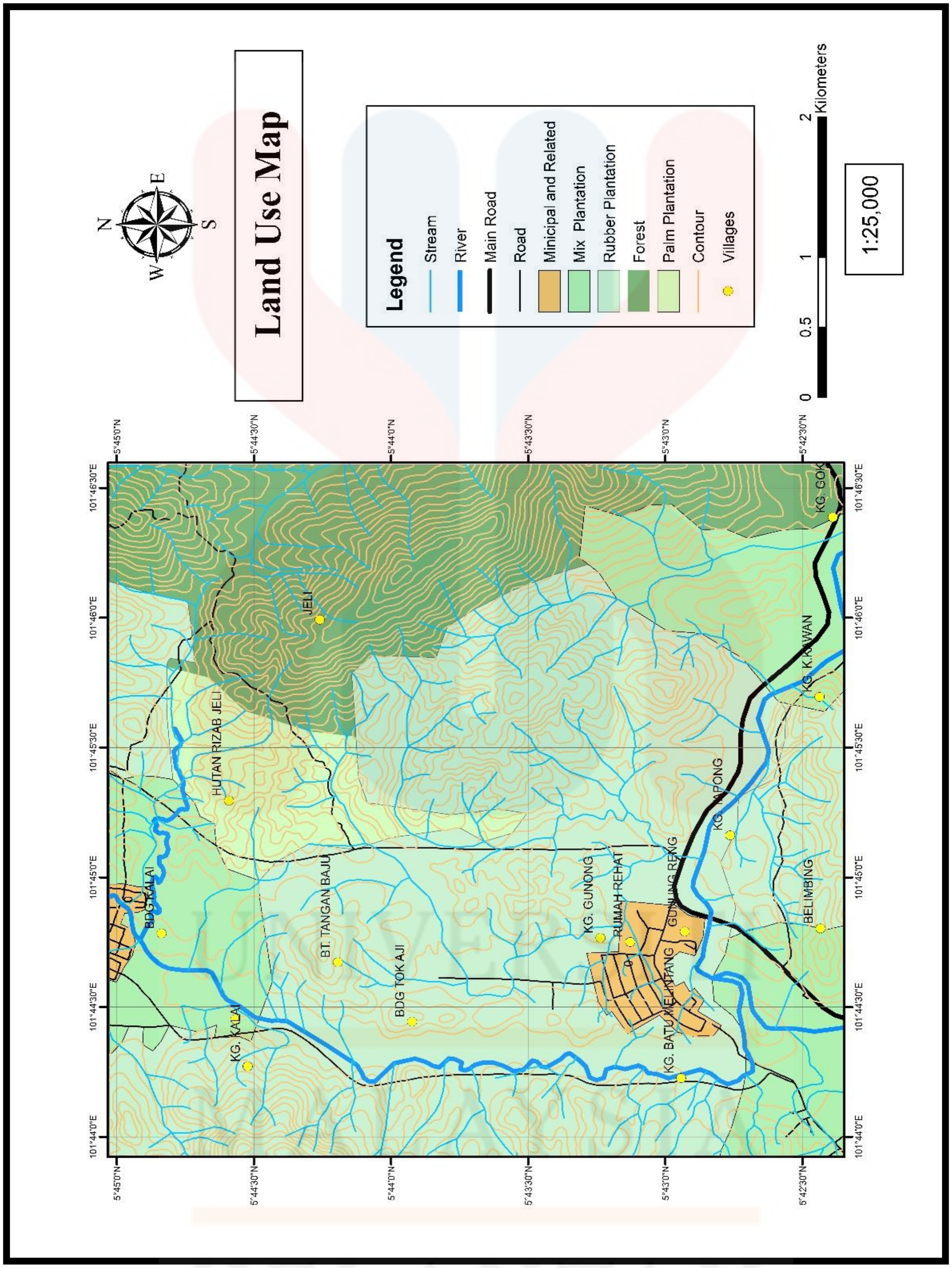


Figure 1.4 The map of land use of Batu Melintang, Jeli, Kelantan.

1.4.4 Social Economic

The Gross Domestic Product (GDP) per state and GDP per capita for Kelantan is RM 5,404 million and RM 6,720. For the national average, GDP per country is RM 15,457 million and RM 14,100 for GDP per capita. The wholesale and retail trade, hotel and restaurant subsector (29.0 %) and agriculture sector (15.2 %) are the main contributors to the GDP. The agriculture yields are rubber, oil palm, paddy, tobacco, fruits, vegetables, forestry and fishery. The industrial sector produces wood-based, food-based, textile, electrical and non-metallic mineral products. For the period 1991 to 1995, the economy grew at an annual rate of 6.2 % while 3.2 % for 1996 to 2000 due to the downturn in the economy in 1997 and 1998 (Department of Minerals and Geoscience Malaysia, 2003). Table 1.4 showed the GDP by economic sectors for 2001.

Sector		Share of GDP-2001	
		RM (million)	%
Agriculture		823	15.2
Mining & Quarrying		38	0.7
Industrial (Manufacturing)		495	9.2
Construction		107	2.0
Services	Electricity, Gas & Water	221	4.1
	Transport & Storage	563	10.4
	Wholesale & Retail Trade, Hotel & Restaurant	1569	29.0
	Finance, Insurance & Real Estate	324	6.0
	Government Services	471	8.7
	Other Services	793	14.7
TOTAL		5,404	100.0

Table 1.4 Showed the GDP by economic sectors for 2001. Department of Minerals and Geoscience Malaysia, 2003).

1.4.5 Road Connection/ Accessibility

The main road within this 25 km2 is connected Jeli – Dabong – Gua Musang and named as Malaysia Federal Route 66. It is around 7 km in the study area. The other roads in the study area are connected to the villages and part of the Kuala Balah town. Figure 1.8 represented the road connection of Batu Melintang, Jeli, Kelantan.

Figure 1.6 Paved road at Batu Melintang, Jeli

Figure 1.7 Unpaved road at Batu Melintang, Jeli

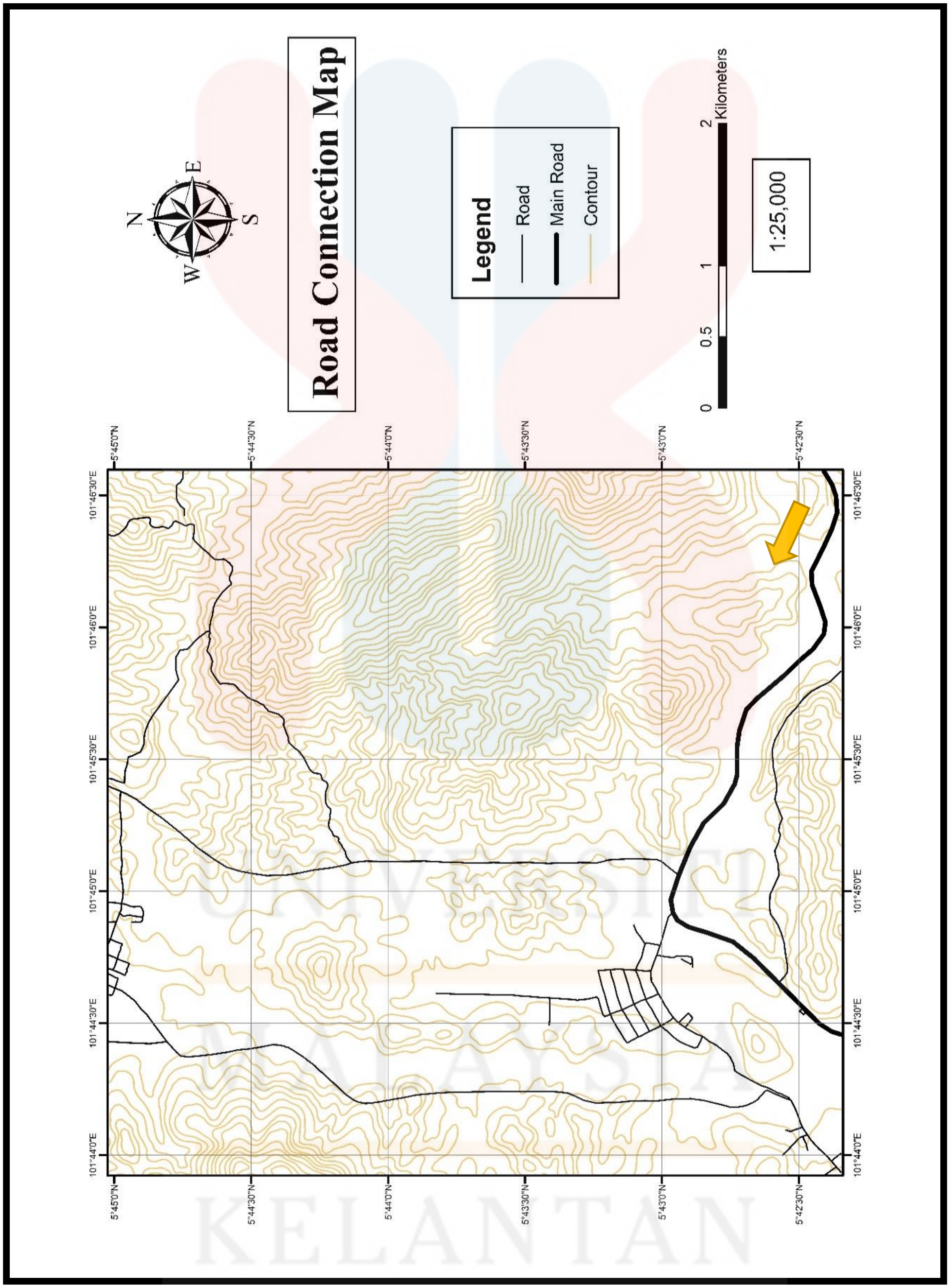


Figure 1.8 The map of road connection of Batu Melintang, Jeli, Kelantan

1.5 SCOPE OF STUDY

The scope of the study in this research is to identify the joint structure and analyze the joint formation of limestone outcrop at Batu Melintang, Jeli. The method to analyze the joint structure data will be determined using the dynamic and kinematic analysis. The dynamic and kinematic analysis will be using software such as ArcGIS and rose diagram to analyze all the joint structure data obtained. All the data collected during geological mapping at the field. At the end of the study, a geological map will be able to produce.

1.6 SIGNIFICANCE OF STUDY

This research helps provide geological information about the research area, such as lithology, stratigraphy, and structural data. Throughout the study, one can identify what type of rocks located in the study area. This study also vital to understand what kind of rock situated in the study area**.**

First of all, the important thing about this research is to gain the body of knowledge about this research topic, which is about the geology of the area of Batu Melintang, Jeli and the joint structure present at the study area's limestone outcrop. By study the morphological characteristic and identify orientation and distribution of joint set and system, it will give benefit for the development of the study area such as to build tunnel, roads, excavation and slopes construction as the joint has enormous influences on rock strength and rock permeability.

Besides, to get some of the information in the study area and produce the geological map of the Batu Melintang area and this study will be useful and can be used as references by the future for the researcher to learn about the geological area of the study area.

Moreover, this research study indicates the cause of joint formation, joint distribution, and joint orientation in the study area. It able to provide information about paleostress in the region to Geologist who are interested in studying joint and geomorphologist can use to find out about drainage pattern or orientation of escarpments.

Lastly, this research will also set up new updated geological maps in this area. Due to some geological process, some changes may happen over a while. It will thus provide more geological information like geomorphology, rock boundaries, and others with scale 1: 25,000. Moreover, in future development, this research can also act as a guideline for any authorities.

CHAPTER 2

Literature Review

2.1 Introduction

This chapter is discussing the previous research that has been done by another researcher before. This chapter is presented about the geological review, which is a regional geology and tectonic setting, regional stratigraphy, structural geology, historical geology, and research specification.

In conclusion, 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 which was located at the northeast of Peninsular Malaysia Kelantan and had a longitude from E 101° 20' to E 102° 41', and a latitude extends from N 4° 33' to N 6° 14'. It covered an area for 15.022 km² and was divided into ten districts including Tumpat, Kota Bharu, Pasir Mas, Bachok, Tanah Merah, Machang, Pasir Puteh, Jeli, Kuala Krai and Gua Musang.

Jeli district is located in the foot of the Main Range, the backbone of Peninsular Malaysia. The range consists mostly of granitic rocks with several enclaves of sedimentary/metasedimentary rocks. The Main Range granite is located roughly in the west of Kelantan stretching along western of the state up to the state boundary of Perak and Pahang. Based on the general geology of Kelantan (Department of Minerals and Geoscience Malaysia, 2003).

Jeli district is generally composed of three rock types which are Triassic sedimentary rocks (Gunong Rabong Formation), which consists of shale, silstone, sandstone, and limestone, Permian sedimentary rocks (Gua Musang Formation) which consists of phyllite, slate, sandstone and limestone and Granitic rocks (acid intrusive). The general geology of Kelantan and Jeli district can be seen in Figure 2.1.

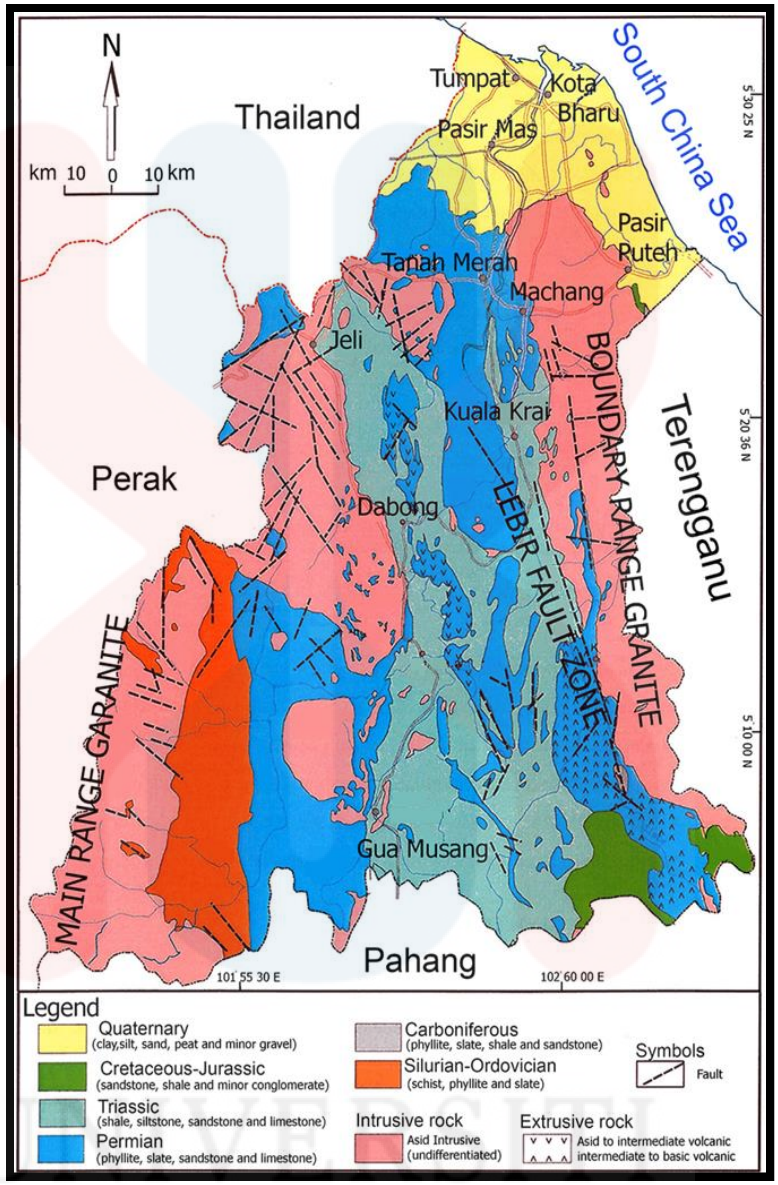


Figure 2.1 Geological Map of Kelantan

2.3 Stratigraphy

The state of Kelantan can be divided into four types of landscape which are mountainous areas, hilly areas, plain areas and coastal areas. All these types of landscape exist in Jeli district except the coastal areas which only form in the northern part of Kelantan. Mountainous landscape forms in the west and north of the district. This landscape is composed of the Stong Migmatite Complex, the Main Range granite and schist. Some features of this landscape are mountain ridges and mountain valleys. Hilly areas in Jeli are distributed in the foot of mountain ranges. This landscape forms two types of hill, they are isolated hills and elongated hills. The limestone isolated hills usually exposed in the low lying areas, such as Gunung Reng. Elongated hills are ridges but usually lower than mountain ridges. Plain landscape forms in the central and east of the district. (Tanot et al., 2001)

Batu Melintang, Jeli is also composed of Mangga formation. The Mangga formation has exposed of low-grade metamorphic sequences of argillaceous, arenaceous pyroclastic, horn felsic and calcareous rock in the upper reaches of Sungai Machang and extending to south-eastwards to Batu Melintang. (Malaysian & Thai Working Groups, 2006)

In the upper part of Mangga formation, consisted of hornfelsic rocks, for example, calc-silicate hornfels that can be observed at Felda Tumbi Rapat which is near Gunung Reng area and Batu Melintang. Besides, it 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 Batu Melintang, Jeli. The schist was supposed to be consist of quartz-mica schist, quartz-mica-garnet schist, and quartz-mica-graphite schist. (Malaysian & Thai Working Groups, 2006)

Furthermore, the study area is composed of The Taku Schist Formation which can be described as the metamorphic rock which same as Mangga Formation. This is because the Taku Schist Formation has low to the 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 the wide Belt in the 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 is wholly crystalline and completely schistose. Moreover, the mica schist in this formation mostly consists of quartz-micaschist, mica-garnet-schist, and quartz mica-garnet schist. (Malaysian & Thai Working Groups, 2006)

Telong Formation has exposed at Kg. Legeh and extends towards eastwards of Tanah Merah area on the eastern part of the Transect area. The Telong Formation consists of shale, slate, phyllite, 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.

Then, Simpang Formation is mostly composed of gravel, sand, silt and laterite, and abundant iron concretions. In the meantime, the young fluviatile sediments of the Beruas Formation are composed mainly by silty clay, sand, and gravel also highly of mottles and iron concretions. However, the Gula Formation were formed by the sand, gravelly sand, and silt.

Moreover, Batu Melintang-Sungai Kolok Transect area has a Quaternary deposit which has formed in both marine and non-marine environments. The Quaternary deposits can be divided into three formations, such as the Simpang Formation, Beruas Formation, and Gula Formation.

2.4 Structural geology

Tectonic activities in Peninsular Malaysia during the Paleozoic and Mesozoic era affect the land mass principally on the formation of faulting and folding. Faulting and folding have been observed as regional as well as localized structures. Localized structures include folding, jointing and faulting in the sedimentary rocks and jointing and faulting in the granitic rocks. The dominant structural pattern in Kelantan is along a north-south to northwest-southeast directions. However, the dominant local structures in Jeli district is along northwest-southeast and northeast-southwest directions. (Department of Minerals and Geoscience Malaysia, 2003)

This research will be conducted at Batu Melintang, Jeli, Kelantan on joint analysis. The study area also includes Pergau River, one of Kelantan's foremost and largest river in Jeli district. Therefore, in the study area, the structure could be a lot. The primary focus of this study is the joint structure in the area. Joint is a fracture in a rock layer or body due to the strength and stress of the rock. The mostly joint structure could be in the form of a joint system and joint sets.

There are several characteristics of a joint set that is set together as a planar with uniform spacing. Secondly, the joint set propagated normal to bedding, and thirdly joint set is depending on the lithology. For the classification of joints, first is non-systematic joint, systematic joints, columnar joint, tectonic joint, hydraulic joints, and exfoliation joint, unloading joint and lastly is cooling joint. (Terry, 2009)

Next is the orthogonal system of two vertical joint sets are common, and it required at least one 90^{o} change in local principal stress direction during the joint system formation so it will minimize the compressive of stress (William, 2003). Besides that, individual joint planes with joints in bedded sedimentary rocks are developing typically in the sets of pervasive parallel surfaces terminating at mechanical boundaries with the sequence of sedimentary (Tindall, 2003).

As studied in the past research, the major collision between Sinoburmalaya to the west and Eastman-Indochina 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 activity during Late Triassic also has resulted in the rock deformation of Malay-Thai Peninsular. (Malaysian & Thai Working Groups, 2006)

Faulting considered to be widespread throughout the Batu Melintang 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 varying in width characterized 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. 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. (Malaysian & Thai Working Groups, 2006)

2.5 Historical Geology

Peninsular Malaysia can be divided into three types of main belts, which are Western Belt, Central Belt, and Eastern Belt. But each of the Belt has its distinctive characteristics and geological development (Hutchison, 2009).

In Batu Melintang area of north-west Kelantan Darul Iman are found regionally metamorphosed rocks that have been derived from a suite of Palaeozoic pelitic, psammitic and calareous sediments as well as pyroclastic and basic igneous rocks. The politic assemblage comprises muscovite schist, biotite schist, garnet schist, andalusite schist, andalusite-garnet schist and gneisses of the same composition, whilst the basic rocks have yielded hornblende schists and gneisses. The calcareous assemblage comprises marble and calcareous schists and the meta-volcanic consist mainly of meta-agglomerate with minor meta-tuff. These metamorphic rocks have also been locally subject to thermal metamorphism brought about by later Cretaceous igneous intrusions (Wong, 1974).

At the junction of the East-West Highway with Jalan FELCRA Bechah Pulai, near Kg. Gunong exposed a sequence of such contact metamorphic rocks consisting of alternating bands of dark greenish grey, light greenish grey, and light brown to cream colored hornfelses. (Ahmad Nazmi,1993)

2.6 Research Specification

Structural geology is a tool used by the Geologist to understand about the history of the deformation, understanding strains and rates, interpreting the displacement, pressures, through to stress and lastly temperature. In other words, structural geological analysis is a practical application to find structural geology. (Steve, 2005)

2.6.1 Kinematic and dynamic analysis

Kinematic is through observation, while dynamic is to know the direction of the force that involve that make the rock to deform. Kinematic analysis is about the displacement pattern or motions within a material such as strain, rotation, and translation that produced the structures without considering associated stresses. Kinematic will be carried out the by way of descriptive analysis in which without reference to the forces which indeed caused or causing the troops. As can be said, kinematics is simply focused more on the motions. Besides, the kinematic analysis also will be focused on the history of deformation rate along with the deformation rate. (Steve, 2005)

Also, there are more to the kinematic analysis besides velocity vectors. It can be used to have information about the actual deformation path, which followed by each material point start from the starting position (unreformed volume) to the final position (deformed volume). But there in certain cases the displacement vector and the deformation path can be coinciding.

Gene Humphreys of Oregon State University state dynamic analysis is all about the interplay between stresses that tend to deform and strengths that tend to resist. The dynamic analysis deals with the physics of deformation. It involves interpreting the force, traction, stress, and mechanic that give rise to structures, taking into consideration the rheology (strength and behavior) of the materials at the time they were deforming. For dynamic analysis to be significant, it must explain the physical and geometric character of the structures, the displacements and strains and also the relationships between stress and strain. Thus, the main aim of this analysis is to interpret the orientation and character of the structures in the context of the direction and magnitude of the loads, forces, tractions, and stresses. (Davis et.,1996)

The dynamic analysis is more profound than the descriptive that result from the kinematic analysis of the understanding the structure provides and also the assumptions of kinematic analysis of the specific natural structure are fewer and more testable compare to the dynamic analysis. The result of the cinematic analysis is, therefore, more direct to the observation that the results of the dynamic analysis (Randall and Ortega, 1999).

2.6.2 Various papers describe the pre or post and importance of development of joints:

Sedimentary rocks also commonly contain three sets of joints, one of which is invariably parallel to the bedding planes. The other joints commonly intersect the planes at approximately right angles (Piteau, 1970; Terzaghi, 1946; Deere et al., 1969).

Even when strong sedimentary rocks like limestone and well cemented sandstones predominate can introduce pervasive weakness planes. In limestone and sandstone, the joint spacing of each set are commonly of meter size. (Terzaghi, 1946).

The relationships between these structures are important in determining the tectonic history of a region. Joints may record subtle features of the stress history of a region (e.g. Hancock et al., 1984). For example, Rawnsley et al. (1998) used joint patterns in the Bristol Channel Basin to show that there was an anti-clockwise rotation of stresses during or after the main N±S contraction of the Alpine Orogeny.

Early joints can influence later fault development (e.g.Martel et al., 1988). Many faults initiate as mode I cracks (e.g. Reches and Lockner, 1994), and it is possible that faults cannot initiate as mode II or mode III cracks (e.g.Petit, 1988). Likewise, early faults can influent subsequent joint development, providing stress concentration points for joint initiation and acting as barriers for joint propagation (e.g. Rawnsley et al., 1992).

CHAPTER 3

Materials and Methods

3.1 Introduction

This chapter discusses the workflow of the research start from materials and methodology, preliminary studies, field study, laboratory work, data processing, data analysis and interpretation, and lastly, is a complete report writing. All the data collected will be used as guidelines and parameters to proceed with the project.

3.2 Materials

Name	Picture	Detail
Geological Hammer		This instrument is used for breaking and splitting rocks sample. It can attain the rock sample to determine its mineralogy, composition and history factor. Occasionally, geological hammer can be used as the scale in a photograph

Brunton Compass		This compass is much accurate than Suunto compass. Brunton compass is used on the field by geologist, students and lecturers. Brunton compass provide hand level capability and can be used by waist and eyes level. Examples of the usage of Brunton compass are taking reading azimuth, pinpoint location on map, folding and used in geological mapping
Garmin GPS		Garmin GPS (Global Positioning System) is a satellite based navigation system involving three parts, the satellite in space, monitoring stations and the GPS receivers. GPS provide latitude and longitude data. It also provides the altitude reading. In field, it can store up our track movements and also act as a compass.
Hand lens		It used to identify the mineral on the volcanic rock by naked eyes on the field. Basically, it used to identify the physical properties such as color, texture and identifiable mineralogy

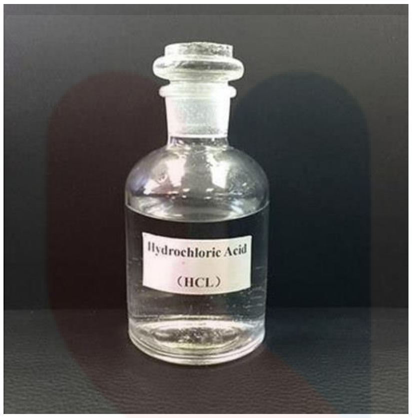
Hydrochloric Acid		It is used to observe the reaction of the rock in order to differentiate between calcite and chlorite. It also used to distinguish most common carbonate rock, dolomite and limestone
Measuring Tape		It is used to take measurement of lithology and structure. As an example, in layering, it is necessary to measure the thickness of each layer precisely

Table 3.1 Showed equipment uses during Geological Mapping

3.3 Methodology

The methods that are used to conduct this research activity from the beginning is collecting the data. Next is by doing the geological mapping. While doing the geological mapping, the things we need to consider are the geomorphology, stratigraphy, and structure of the study area. There are three methods in doing the geological mapping, which is traversing, mapping in the poorly exposed region, and by using the remote sensing. Then is doing the observation, measurement, sampling, and process the data by using the laboratory work. All the data collected will be used as guidelines and parameters to proceed with the project.

Besides, the detailed analysis is done, which is kinematic and dynamic analysis. The geological map and the complete writing thesis will be done entirely at the end of this research. The flow chart of the methodology for the study is shown in the Figure 3.1.

3.3.1 Preliminary study:

This research starts in July 2019. Before going into the field, the study of this research is done. This is done by studying in detail any inquiry related to the joint studies in the field and a better understanding of the area of study by collecting data or information from the journals, books and internet database as references from previous research around the world. The study area base map can be used to identify the geology, such as the study area's geomorphology, structural geology, and lithology. It also can be used to plot strike and dip of joints. The map can be divided into several such as a topographic map, base map, and structural map. The base map is prepared by considering by referring to the previous map supplied by Jabatan Mineral and Geosains Negeri Kelantan in years 2012.

Wise planning is essential not only to save time, but it is also vital to reduce cost as well. Careful planning can ensure enough time to cover all sections of the study area within a given period. The literature review is a research or a study about past research which have been conducted. The references can be collected through the 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 can find several case studies that relate to topic, which means that past research is conducted on the same study area or the same issues.

3.3.2 Geological Mapping

Traversing is the primary method for geological mapping. It is done by walking and pointing to the map each time for an outcrop observation. Determination of track plan is the first step that have been done before going to study area. The starting point of the traverse is in South East part of the study area. Global Positioning (GPS) reading served as a guide to identify the position and finding outcrops on the map. The traversing is done mainly through the unpaved road, across the forest, across the plantation, stream and main river which are Sungai Tadoh and Sungai Pergau. Due to limited amount of exposed fresh outcrop. All the geographical changes such as road, railaways, drainage, elevation, boarder of the rock and types of lithology need to be note in the map to update the base map of the study area.

All the data taken at the outcrop recorded with detail and correctly. The data taken included the coordinate, elevation, type of rock, rock color, orientation of bedding, type of vegetation, type of weathering and length of outcrop and also structural geology. Then, drawing and sketch the outcrop.

The data taken for specification studies are by measure and record all the joint that present at the limestone outcrop by using Bruton. This process includes the lithology of rock boundaries, geological structures, and sketches photo. In this method, visually scan the outcrop and measure all joint that occur within the limestone outcrop by measuring the length of the joint, spacing between joint, and taking joint strikes, dips direction and dips angle by using measuring tape. Also, record the joint surfaces morphology and add outcrop sketches to the notes. All the characteristics and the behavior of the surrounding area need to be recorded to fulfill the research objectives.

Then, in order to obtain rock samples at the outcrop, geological hammer is used. To identify the minerals present, hand lens is used to magnify the grains. Diluted hydrochloric acid (HCI) is used to test the presence of calcareous minerals. Data such as GPS coordinates of the outcrop, onsite observations and strike/dip measurements using Brunton compass are recorded. Samples of rocks are taken at selected outcrop depending on the variations of lithology and the availability of graptolites. All the rock sample taken in study area is at standing rock mass.

Sample of the rock will then be taken for further analysis, measurement and inspection will be performed at the locations where outcrops are found. The data is taken at fresh outcrop, cause the data are more accurate and well-recorded. It hard to find fresh outcrop in study area due to Malaysia has tropical climate so the erosion is intense. It will be easier to find a soil than a fresh rock. So to overcome that, is by looking for the indirect evidence such as:

- Soil colors, signing what is the original rocks, taking from man-made holes, animal burrows, or cliff.
- Vegetation, can show the bedrocks. For example, limestone appearance is signing with the juniper or beech.

- Go to the river, and look at the river banks. It will be more effective cause every river bank certainly eroded and the bedrock can be exposed.

- Go to the structural geology area, it can indicate the uplifted or unresistant rocks.

After taking sample rock and put in the sample bag. The sample bag will be mark with information of outcrop like a number of outcrop, date and sample number. Also, remote sensing is being used in geological mapping. It has been done by using aerial photographs and satellite imageries. This method is carrying out before entering the study area, need to examine the main geological features of the study area by reviewing the photographs.

Another crucial step while mapping an area is creating cross-sections. It is important to understand the geology, and may provide critical insight into developing a map. It is usually drawn along a line perpendicular to dominant strike of strata and structures so that it shows the subsurface structures more clearly. It is important to show real elevation scale and the topography along the line. If any subsurface structure is also needed to be shown, scale for depth also has to be shown.

3.3.3 Preparation of thin section

For thin section analysis which considered as lab work, the equipment that is used to prepare the thin section slide for the sampling is 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.

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. The thin section is essential to know the percentage of the minerals based on the type of rocks (igneous, sedimentary, and metamorphic). The thin section will be analyzed under polarized microscopy with the thin slices (thickness: 0.03 mm). The complete thin section will help in the 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 petrography, the 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 a detailed description. The technique of preparing a thin section involves three steps:

i. Sectioning and cutting The rock sample is cut into a specific 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 remove the final deformation during the grinding process. Lastly, view the sample under polarized microscopy to observe the minerals composition.

3.3.4 Data Processing

The data are processed through laboratory work, which is producing the thin section and also using software such as ArcGIS and GeoRose.

All the data taken for specification studies such as joint strike, dip angle and dip direction in limestone outcrop will be process through GeoRose software. To analyze data, enter all the joint amount and direction into GeoRose software. Then, the joint orientation and distribution will create by rose diagrams. Rose Diagram creates circular charts to display data that contain direction and magnitude variables. A rose diagram normally comprises of 8 or 16 radiating spokes, which represent degrees of a circle or compass points North, East, South, West and their intermediate directions. Each direction axis has values increasing outwards and similar to pie charts, the data are divided into proportional slices or sectors. The arc length of each slice is proportional to the quantity it represents. With small data sets, directions can be binned. Step to create a rose diagram in GeoRose Software:

1. Open the output table of the Segment direction histogram operation, and choose the Create Rose Diagram command from the File menu in the table window.

2. Then, choose the Create Rose Diagram command from the File menu in the Main window.

3. Next, double-click the New Rose Diagram item in the Operation-list, or

4. Click a table with the right mouse button in a Catalog, and choose Create Rose Diagram from the context-sensitive menu.

3.3.5 Data analysis and Interpretation

The details analysis is done by details explanation in geomorphology, lithostratigraphy, structure, geological history and stress-strain analysis of the study area which is Batu Melintang, Jeli and also from this data analysis, the geological map of the Batu Melintang, Jeli are producing. For the joint structure, dynamic and kinematic analysis is done. Dynamic analysis is by using software such as GeoRose Diagram and Rose diagrams will show by a pie-slice segment whose radius is proportional to the number, or to the percentage, of joint with that orientation.

ArcGIS 10.0 is the software that is used for GIS analysis. 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. Such as Topography Map, Drainage pattern, and Lineament Map.

Kinematic analysis is by analysis the stress at the field. In this method, measure all joint that occur within the limestone outcrop by measuring the length of the joint and taking joint strikes, dips direction and dips angle. This will allow determining dominant joints orientation. Besides, record the joint surfaces morphology and add outcrop sketches to the notes.

Flowchart

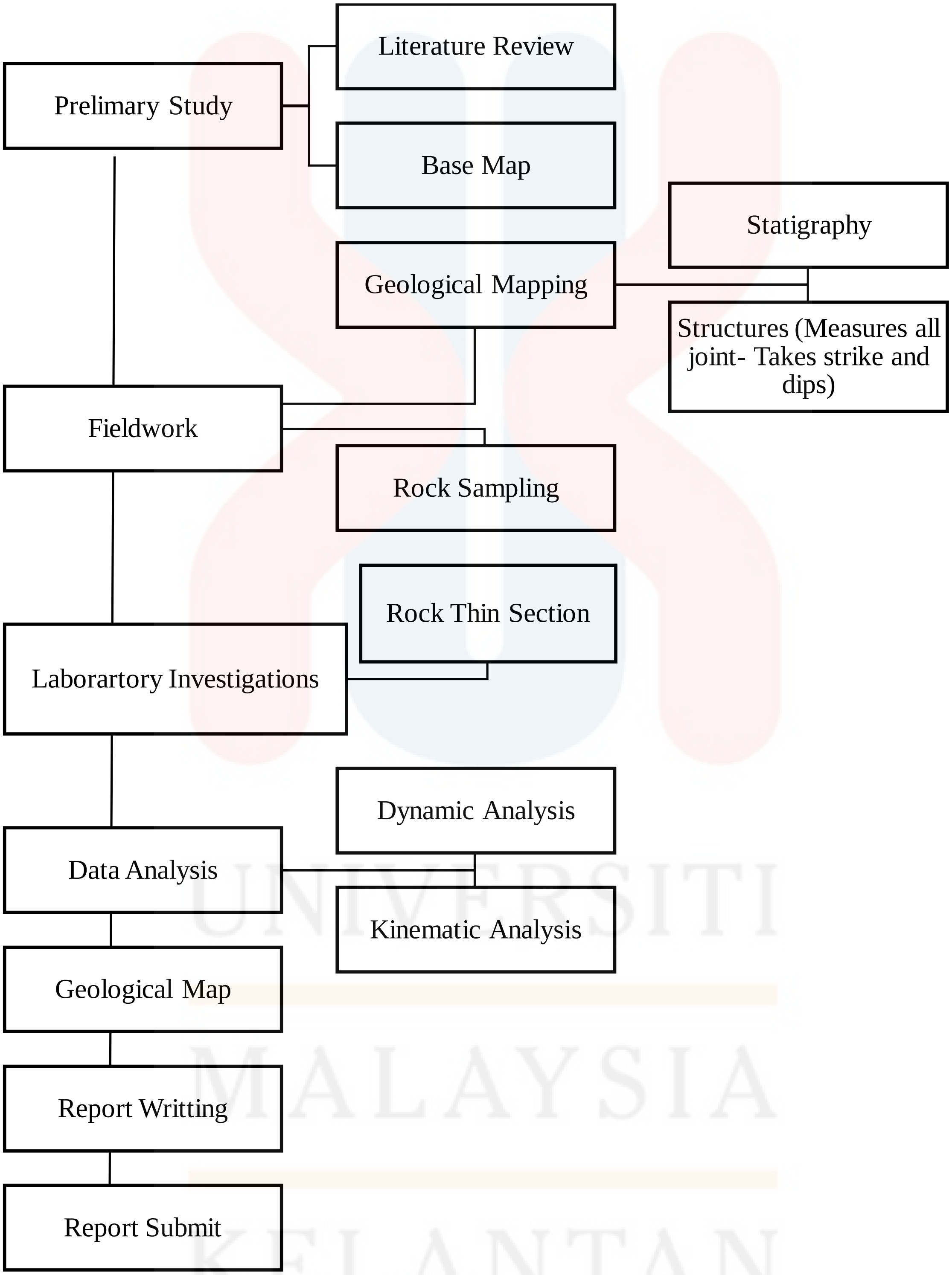


Figure 3.1 Flowchart

CHAPTER 4

Data Collection and Preliminary Analysis - Geology of Study Area

4.1 Introduction

In this chapter, the discussion topics would be more focused on the data collection and preliminary analysis based on the geology of the study area. This chapter discussed the geomorphology, stratigraphy, structural geology and historical geology of the study area.

This section is done by traversing within the study area through geological mapping. Also included in this section are several maps that are drainage pattern map, geomorphological map, transverse map and lithological map.

All the data obtained are based on field observation, rock sampling and geological mapping analysis as well. The important thing about all the data collected is to update the geological map in more detail with a scale of 1:25000. Besides, all the data found in this chapter is essential for the specification of the research. The traverse map in Batu Melintang, Jeli, Kelantan shown in Figure 4.1. There are several ways to access to the study area. The traversing is done through the unpaved road, across the forest, across the rubber plantation and the river.

Figure 4.1 Unpaved road in Batu Melintang, Jeli.

Figure 4.2 Traversing along Sungai Pergau, Batu Melintang, Jeli, Kelantan.

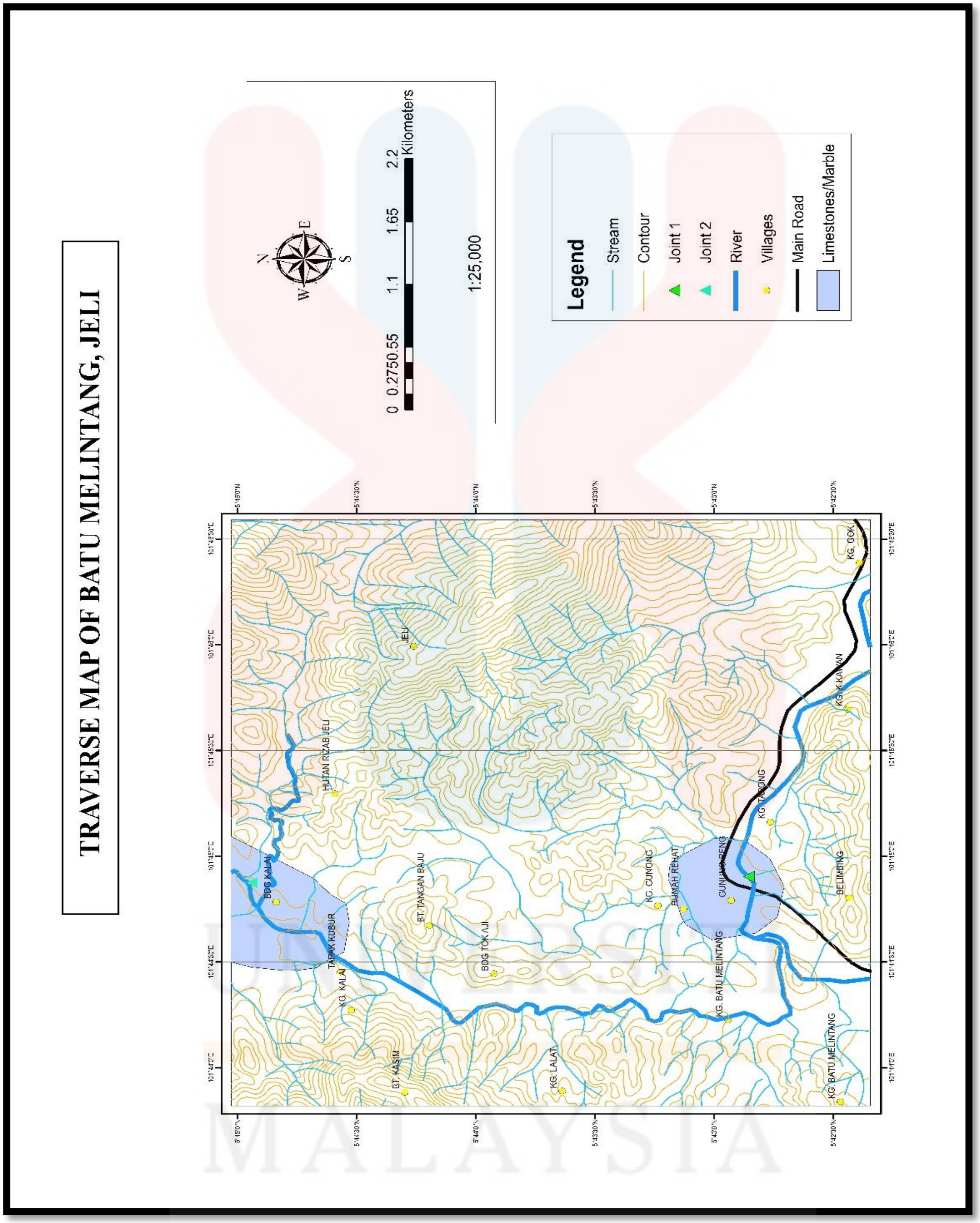


Figure 4.3 Showed the traverse map in Batu Melintang, Jeli, Kelantan.

4.2 Geomorphology

Geomorphology referred as study of landform of the Earth. The major type of landforms in study area included mountains, hills and plains. The geomorphology of the study area can clearly be seen from high elevation view. It is easy to describe the landform or the process that make up a certain place by getting full view of the whole area. Another way is by traversing through the map of the study area as mentioned in the introduction.

Mountain is the large landform in the form of a peak that rises high to its surrounding area. Plain is a landform that has flat area commonly occurs as lowland. Fluvial is a morphology formed by the processes and deposits of rivers and streams. While, Karst is a topography formed from the dissolution of soluble rocks such as limestone, dolomite and gypsum. Figure 4.4 showed the plain area with plantation, Figure 4.5 presented the mountain and plain landform, Figure 4.6 illustrated the fluvial morphology in the study area and Figure 4.7 showed Karst topography.

As for the study area at Batu Melintang, Jeli, it was estimated that about 50% are the forest, waterbody is about 20%, plantations are about 15% and about 15% covered by low-lying area which is village and town.

4.2.1 Topography

The topography is the shape of the land surface, and topographic maps exist to represent the land surface. Beside, topography can be explained based on the contour line on the map that refers to the land surfaces. The topography of a particular area can show by the topographic map, which included the elevation of the area.

Within this 25km2, the landforms observed are a mountain and hilly area, as well as the plain area. The elevation of the mountain and hilly area ranges from 40m to 440m. This area is made up of different types of igneous rocks due to the intrusion and deformation and small amount of metamorphic rock — the highest elevation in the west part of the study area. The landform of the highest elevation is the mountainous area. In this area, the rubber plantation is dominant. Figure 4.10, there are two types of landform can be observed, which are hills and valleys. The mountainous region can be seen in Figure 4.6.

Based on the map, the topography and contour elevation value is easier to be identified based on the color indicator provided by the topographical map. The white color indicates a steep slope while the red color indicates a moderate slope, and yellow color indicates a gentle slope. The West part of the study area has the highest elevation, which is 400 m above sea level. Besides, the most top mountain present at the steep contour marked in red color as the contour lines are mostly very close to each other.

The gentle contours are considered to be around 80 m to 160 m above sea level. At the central and southern of the map, the contour lines are lying far from each other, which indicates that the contours are gentle. Instead, the contour lines also were marked in yellow color. In the meantime, the steep contours can be considered ranging from 320 m and above. Based on the map, the distribution of the steep contour located in the Northwest and Northeast of the map. The contour lines possess a similar pattern that varied closely to each other but in an isolated way while the different parts of the map considered moderated. Figure 4.10 showed the topographic map of Batu Melintang, Jeli, Kelantan and Figure 4.11 presented 3D topographic map of Batu Melintang, Jeli, Kelantan in meter

Although the topography and landform for the study area are mostly hilly, there is also massive limestone karst named Gunung Reng. The karst topography is formed by the dissolution of carbonate rock, such as limestone. Limestone is known as a highly soluble rock which quickly to become weathered by the actions of water. Besides, the limestone cave also presents in the study area (Figure 4.9).

Figure 4.4 Plain Area. (Coordinate: N 05° 42' 54.08", E 101° 44' 34.6")

Figure 4.5 Plain area with plantation. (Coordinate: N 05° 42' 54.08", E 101° 44' 34.6")

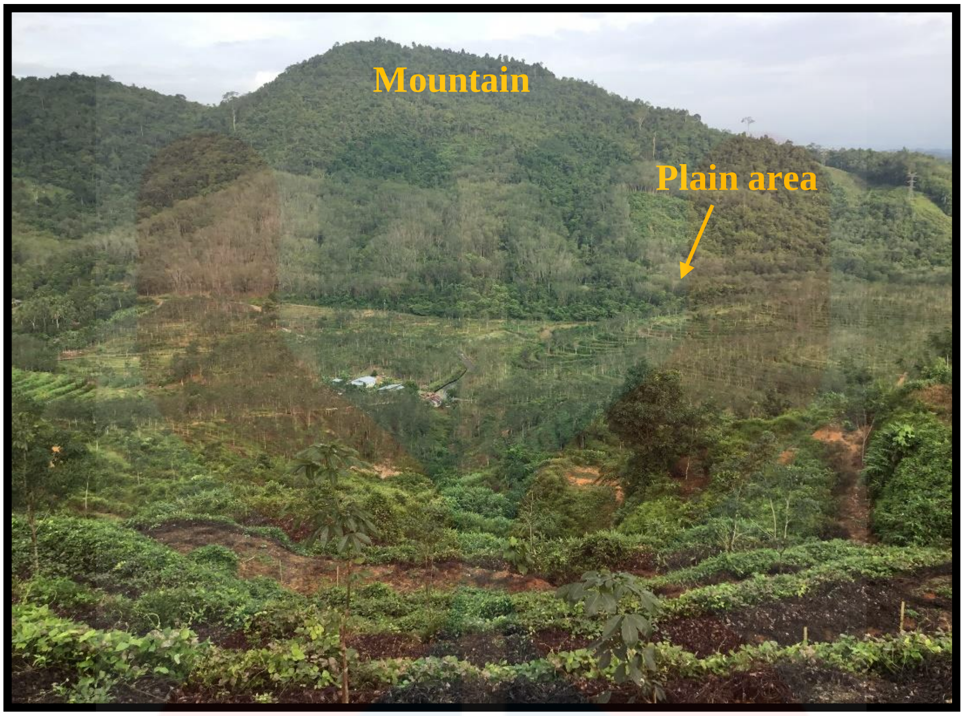


Figure 4.6 Mountain and plain landform. (Coordinate: N 05° 43' 6.06", E 101° 45' 59.5")

Figure 4.7 Fluvial morphology – Sg. Tadoh. (Coordinate: N 05° 44' 23.5", E 101° 44' 23.5")

Figure 4.8 Showed Karst topography. (Coordinate: N 05° 42' 52.6'', E 101° 44' 37.4'')

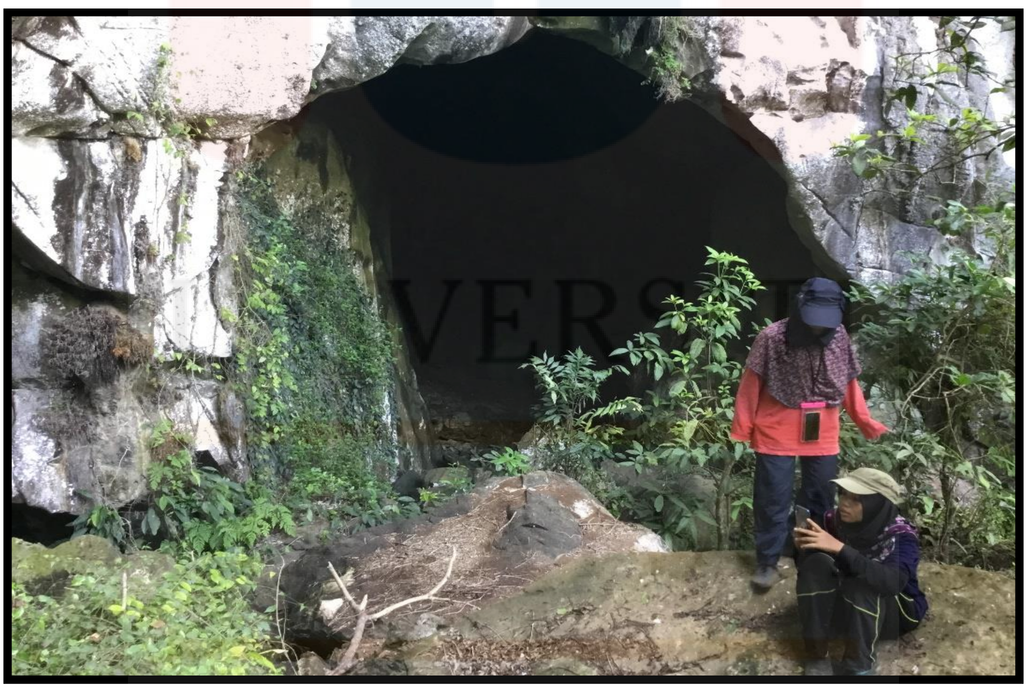


Figure 4.9 Gunung Reng Caves. (Coordinate: N 05° 42' 52.6'', E 101° 44' 37.4'')

Figure 4.10 Observation from Mountain. (Coordinate: N 05° 43' 6.51'', E 101° 45' 59.5'')

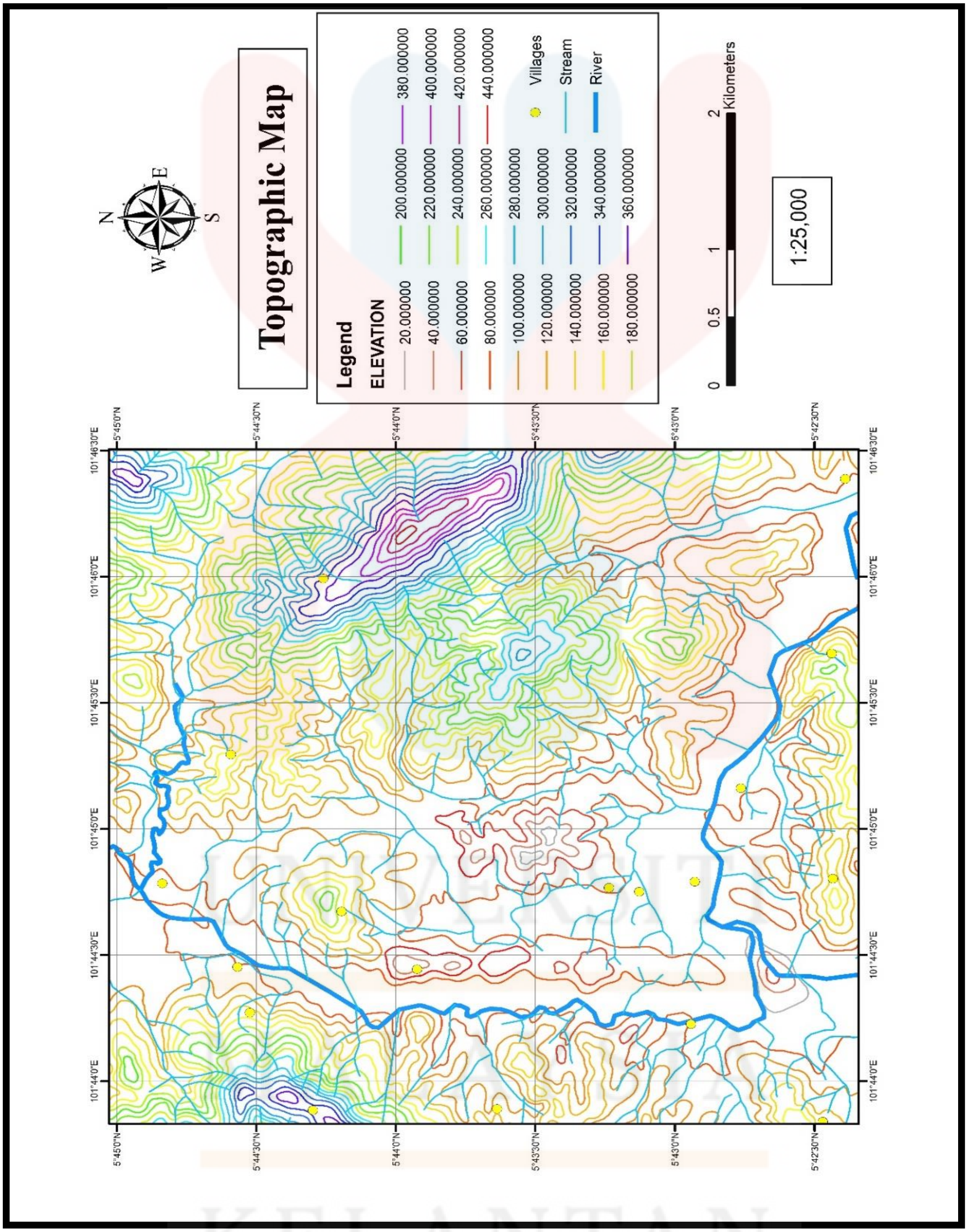


Figure 4.10 Topographic Map of Batu Melintang, Jeli, Kelantan

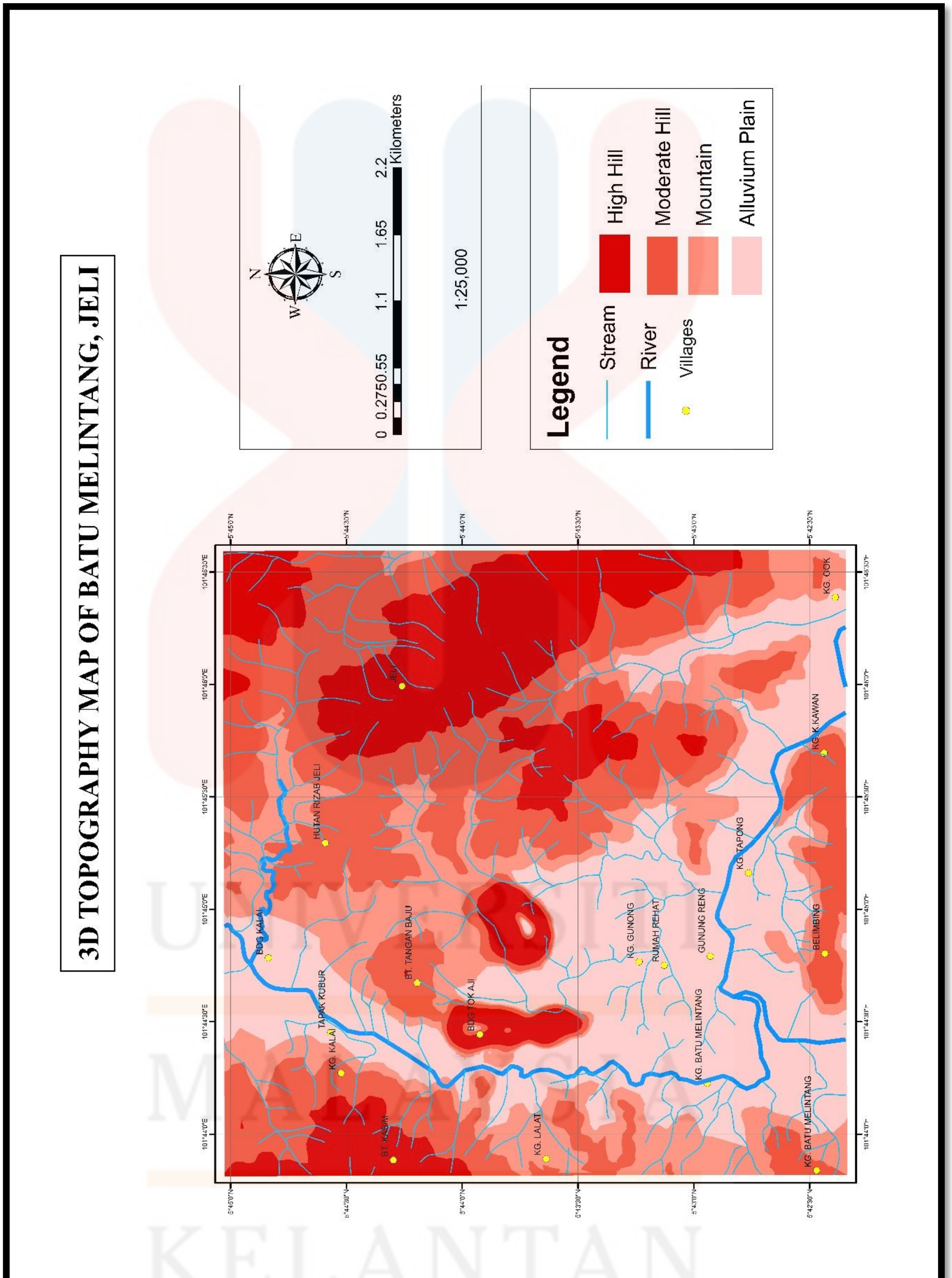


Figure 4.11 3D Topographic Map of Batu Melintang, Jeli, Kelantan

4.2.2 Drainage pattern

The river in the study area is have developed into channel patterns such as straight or meandering. The study area consists of two major streams, which are the Pergau River and Tadoh River. Both streams are in southward flowing. These two streams join in the southern part of the study area.

The drainage systems can fall into one of several categories known as drainage patterns. Based on observation during geological mapping, this drainage pattern usually based on the type of rock in a particular place, whether the region dominated by a soft rock or hard rock and topography area. Drainage pattern develops along a weak zone where rocks easily eroded. Figure 4.12 showed the flood plain at the main river area.

Figure 4.12 Fluvial morphology. (Coordinate: N 05° 44' 23.5", E 101° 44' 23.5")

Figure 4.13 Fluvial morphology. (Coordinate: N 05° 44' 23.5", E 101° 44' 38.5")

Since the study area dominated by hilly topography, and the drainage system flows from the high elevation areas to the lower elevation areas. Many drainage patterns can be observed based on the map, which includes the dendritic, parallel, trellis, and rectangular patterns. It matched very well the theory and the field data. Figure 4.14, which includes the dendritic, and parallel pattern.

Dendritic drainage system is the most common form of drainage system. In this area, it is the most abundant. In a dendritic system, there are many contributing streams (analogues to the twigs of a tree), which are then joined together into the tributaries of the main river (the branches and the trunk of the tree, respectively).

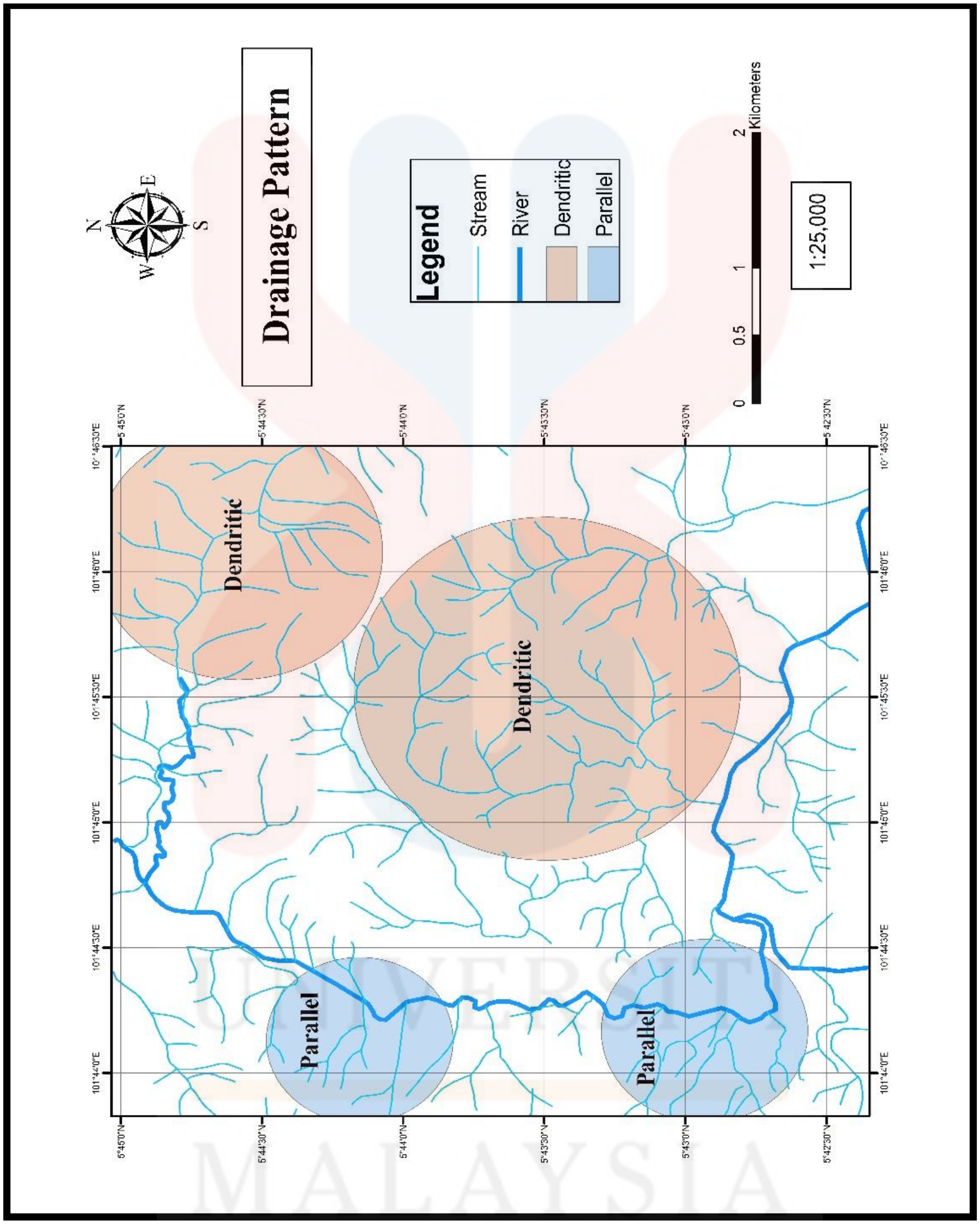


Figure 4.15 Dendritic and parallel of drainage pattern

4.2.3 Erosion

Erosion is a process such as water flow, the wind that removes the rock, soil, and other dissolved material from one location to another location by transport the materials on another earth's crust. From the field observation at Batu Melintang area, there are two types of erosion which are Rill erosion and Sheet erosion

Rill erosion occurs when water moves or flows on the land surface continuously through small streamlets. The example of this kind of erosion in the study area shown in Figure 4.16. Sheet erosion is the removal of the surface layers of soil by wind and water activity. It can be found in the estate area as the forest been removed by human activities, as shown in Figure 4.17.

The erosion of the river bank also observed during traverse along Sungai Pergau. Erosion of the riverbank has occurred when the water level of the river is higher than the average level, and the high velocity of water flows erodes the side of the river. This type of erosion happened when there is heavy rainfall or flood. The erosion of the riverbank can change the size and shape of the rivers. As it continuous eroded the side, the river will be enlarging. Figure 4.18 showed the erosion of the river bank.

Rock Fall

In the study area, a rock fall can be observed along the Pencawang Elektrik, refer to Figure 4.19. In this figure, the size of the rocks that fallen is 0.5 m to 1.2 m in diameter.

Figure 4.16 Rill erosion can be seen clearly. (Coordinate: N 05° 43' 39.08", E 101°44' 35.6")

Figure 4.17 Sheet erosion. (Coordinate: N 05° 44' 17.27", E 101°44' 41.11")

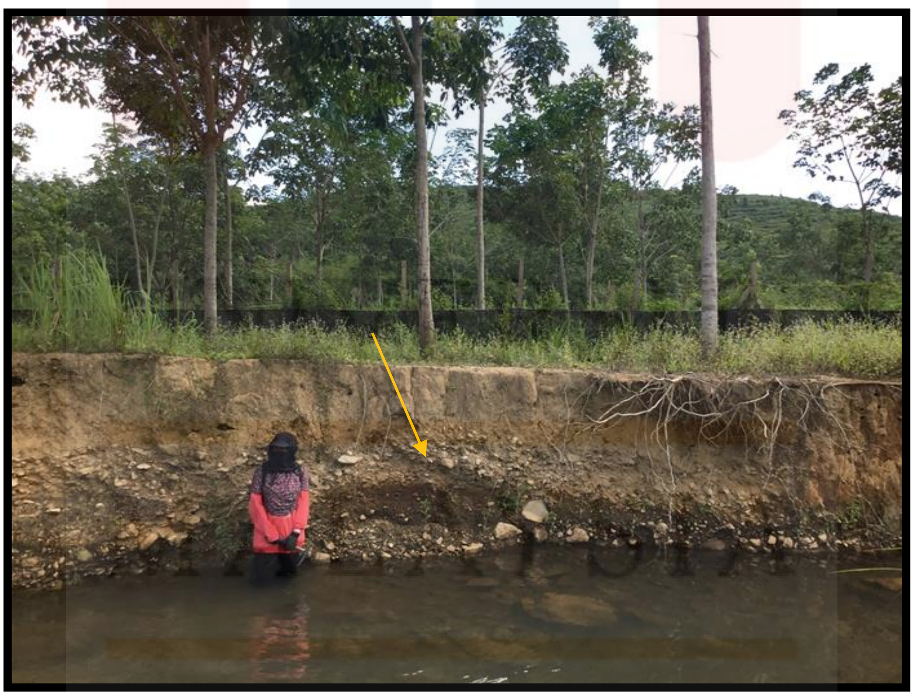


Figure 4.18 Showed the erosion of the river bank. (Coordinate: N 05° 43' 15.03", E 101°46' 2.22"

Figure 4.19 Rock Slide (Coordinate: N 05° 43' 14.82", E 101°46' 2.45")

4.2.4 Weathering

Weathering changes rocks which in hard state to become softer and weaker that cause them to be eroded and deposited into another area. Due to the logging and plantation activity in Batu Melintang area, rocks are highly exposed that increase the rate of weathering. Peninsular Malaysia tropical climate also contribute to the increase of weathering rate due to the amount of rainfall, humidity and temperature. In the study area, there are three types of weathering processes are found which are physical weathering, chemical weathering and biological weathering. One of the physical weathering observed is gully erosion. Figure 4.20 represented the gully erosion and physical weathering. Biological weathering by plant is showed in the Figure 4.21. Chemical weathering at limetones in the Figure 4.22.

Figure 4.20 Represented the gully erosion and physical weathering. (Coordinate: N 05° 43' 14.82", E 101°46' 5.467")

Figure 4.21 Biological weathering by plant. (Coordinate: N 05° 43' 14.82", E 101°46' 3.45")

Figure 4.22 Chemical weathering. (Coordinate: N 05° 42' 52.6", E 101° 44' 37.4")

4.3 Stratigraphy

Stratigraphy is the study of the characteristics of layered rocks, relationships between the layered rocks and the relative and absolute ages of the rocks. Lithostratigraphy is one of the sub-discipline of stratigraphy which concern on the study of rock layers. It usually uses to describe the relationships between the formations of igneous or sedimentary rocks. Figure 4.18 illustrated the geological map of Batu Melintang, Jeli Kelantan with cross section.

Based on geological mapping, the areas around Batu Melintang, Jeli 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 Mangga Formation. Hence, hornfel rock was the oldest among all the rock.

The Diorite rock can be found in the study area. Table 4.5 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 4.18. It is determined that the diorite is felsic igneous rock. The granite has phaneritic texture in which it consists of large phenocryst of minerals in which most of the minerals can be seen by naked eye on hand specimen. This texture shows that the diorite was forms by slow cooling of magma deep underground in the plutonic environment.

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 second oldest rock within the study area among the other rocks found. 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.

Limestone or marble 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. The limestone found within the study area is greyish colour with fine crystalline texture.

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.

Figure 4.23 Slate rock outcrop

Figure 4.24 Marble rock outcrop

Figure 4.25 Schist rock outcrop

Figure 4.26 Gneiss rock outcrop

Figure 4.27 Hornfel rock outcrop

Figure 4.28 Diorite rock outcrop

Figure 4.29 Hand specimen of Slate

Figure 4.30 Hand specimen of Gneiss

Figure 4.31 Hand specimen of Schist

Figure 4.32 Hand specimen of Diorite

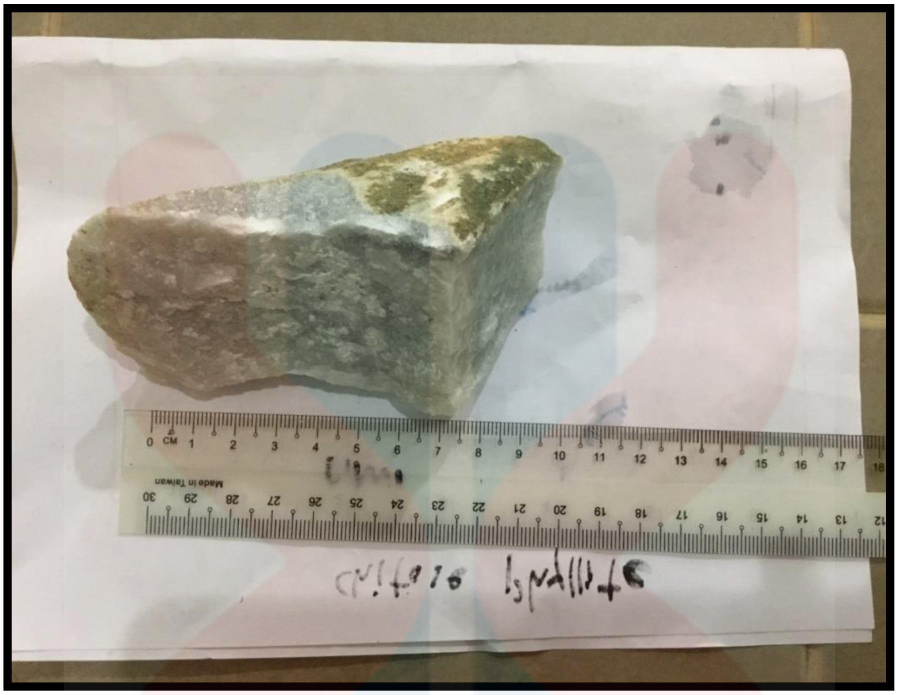


Figure 4.33 Hand specimen of Marble

Figure 4.34 Hand specimen of Hornfel

4.3.1 Petrography Analysis

The petrography analysis will be focused on detailed descriptions of rocks and its composition. 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 location where the rock sample which is schist were taken near the Hutan Rizab Jeli area and at North East (NE) of the study area. The outcrop is found at the coordinate of E 101° 45' 40.5", N 05° 44' 48.45" with the elevation of 127.8 meter. Schist is one of a medium-grade metamorphic rock formed by mudstone or shale.

The minerals composition of schist under thin section can be referred based on the Table 4.1 whereas, Figure 4.30 shows the plane and cross polarization of schist under thin section.

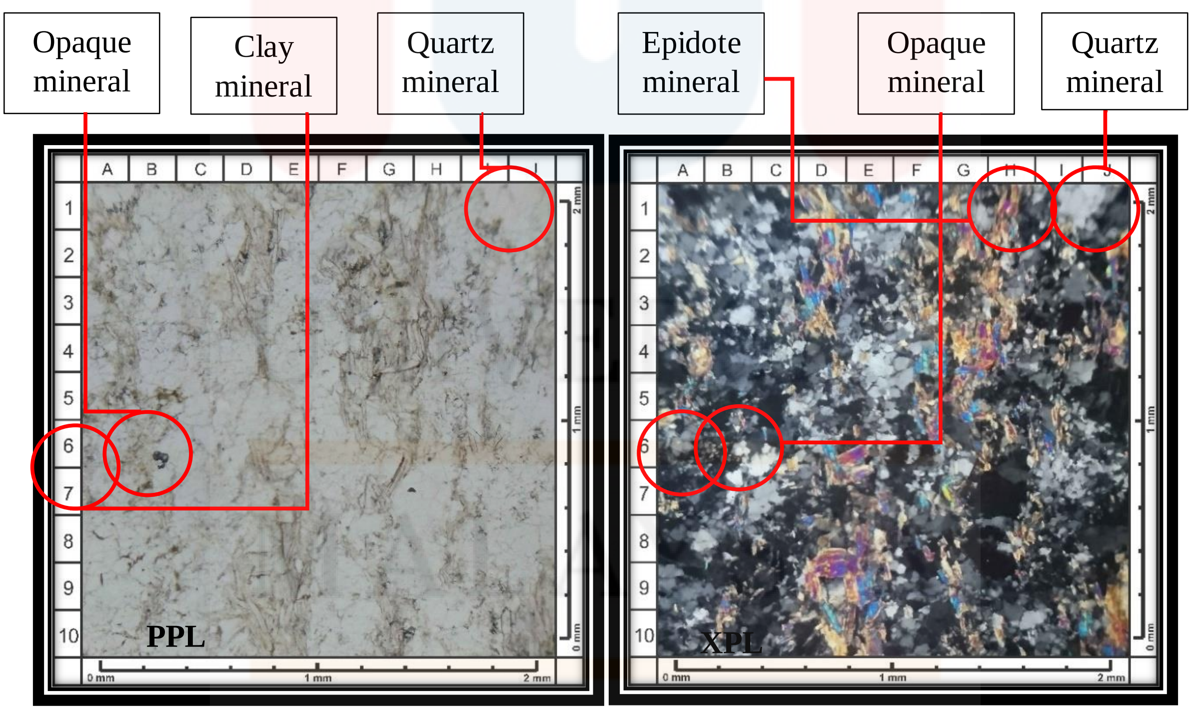


Figure 4.35 The plane and cross polarization of Schist rock under thin section.

Type of minerals	Percentages (%)
Quartz	53
Chlorite	25
Epidote	5
Silica Clay	15
Opaque	2

Table 4.1 Percentages of the type of mineral in the Schist.

Sample 2

The location where the rock sample which is marble were taken at Sungai Tadoh near Kampung Kalai area which is the North West (NW) of the study area. The outcrop is found at the coordinate of E 101° 44' 55.0", N 05° 44' 59.49" with the elevation of 98.69 meter. Marble is a metamorphic rock composed of recrystallized carbonate mineral.

The minerals composition of marble rock under thin section can be referred based on the Table 4.2 whereas, Figure 4.31 shows the plane and cross polarization of marble rock under thin section.

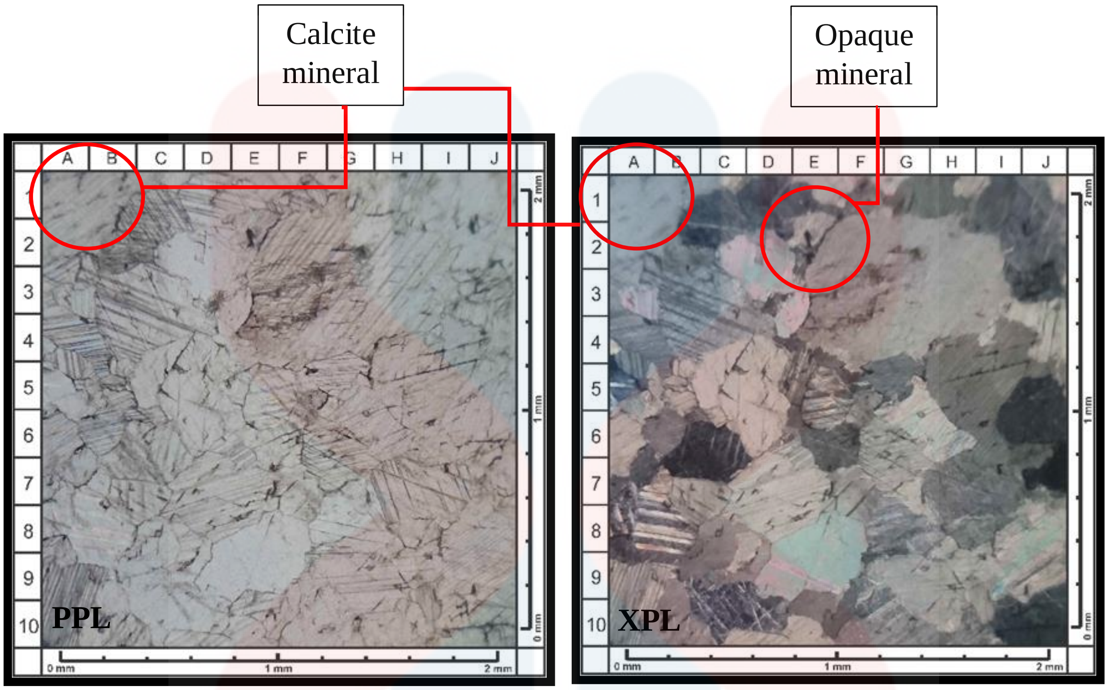


Figure 4.36 The plane and cross polarization of Marble rock under thin section.

Type of minerals	Percentages (%)
Calcite	97
Opaque	3

Table 4.2 Percentages of the type of mineral in the rock.

Sample 3

The location where the rock sample which is Hornfel were taken at Sungai Pergau near Gunung Reng area which is the South West (SW) of the study area. The outcrop is found at the coordinate of E 101° 44' 38.0", N 05° 42' 48.30" with the elevation of 88.72 meter. It undergoes metamorphism and show little sign of the action of directed pressure.

The minerals composition of Hornfel rock under thin section can be referred based on the Table 4.3 whereas, Figure 4.32 shows the plane and cross polarization of Hornfel rock under thin section.

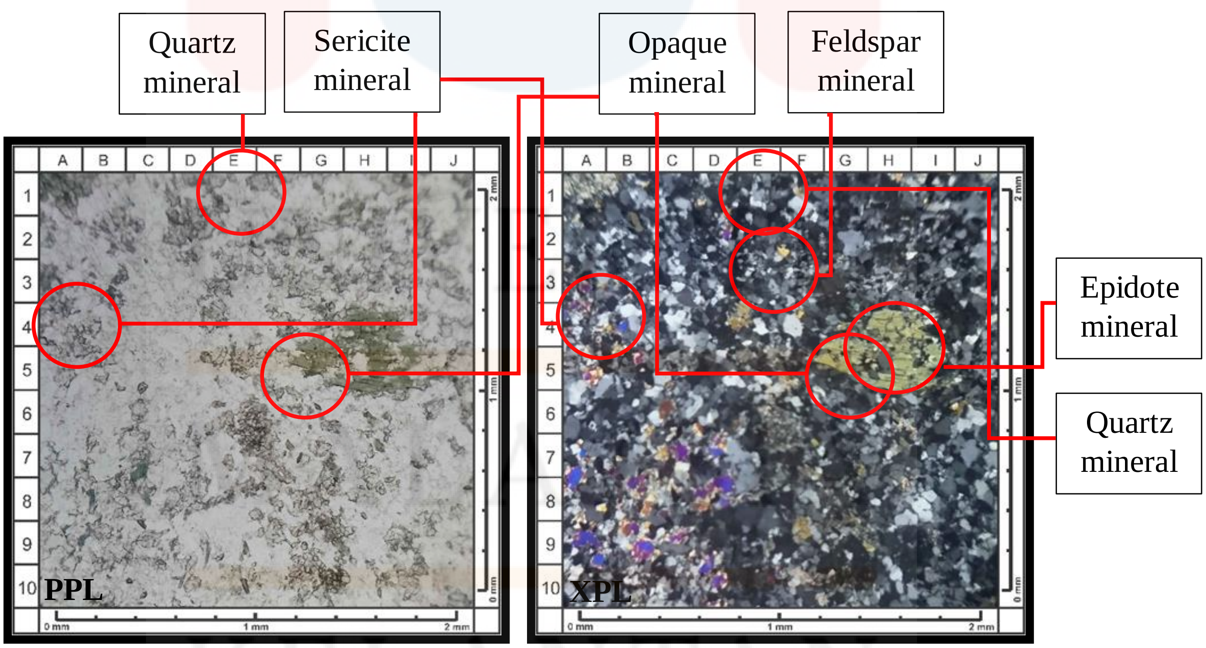


Figure 4.37 The plane and cross polarization of Hornfel rock under thin section.

Type of minerals	Percentages (%)
Quartz	70
Sericite	5
Epidote	7
Feldspar	17
Opaque	1

Figure 4.3 Percentages of the type of mineral in the rock.

Sample 4

The location where the rock sample which is Gneiss were taken at Sungai Pergau near Gunung Reng area which is the South West (SW) of the study area. The outcrop is found at the coordinate of E 101° 44' 13.0", N 05° 42' 59.48" with the elevation of 108.04 meter. It is a metamorphic rock which undergoes high-grade metamorphism.

The minerals composition of gneiss rock under thin section can be referred based on the Table 4.4 whereas, Figure 4.33 shows the plane and cross polarization of gneiss rock under thin section.

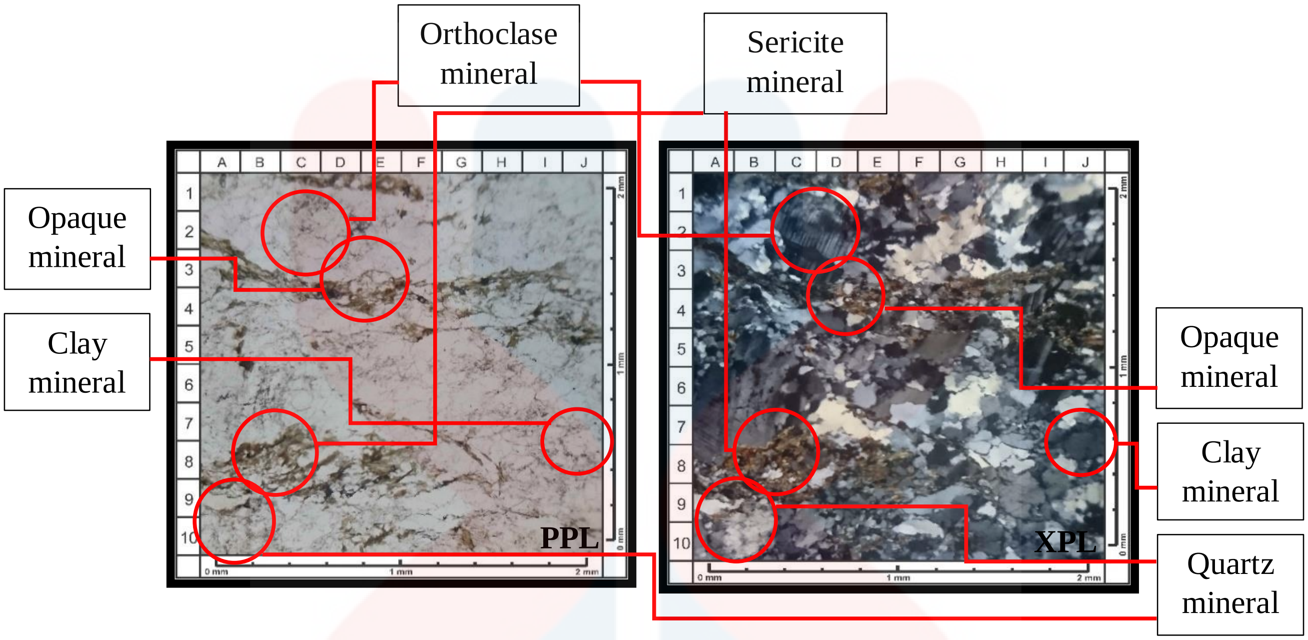


Figure 4.38 The plane and cross polarization of gneiss rock under thin section.

Type of minerals	Percentages (%)
Quartz	43
Orthoclase	10
Sericite	45
Silica Clay	10
Opaque	2

Figure 4.4 Percentages of the type of mineral in the rock.

Lithostatigraphic Column				
Period	Formation	Description	Lithology	
Quaternary		Consist of gravel, sand and clay.	Alluvial plain	
Triassic	Kemahang Granite	Coarse grain consisting plagioclase feldspar and hornblende.	Diorite	
	Telong Formation	White in color with crystalline texture	Marble	
		Darkest grey color with foliation	Gneiss	
Carboniferous	Mangga Formation	Fine grain with obvious foliation	Hornfel	

Table 4.5 Lithostratigraphy column of the study area

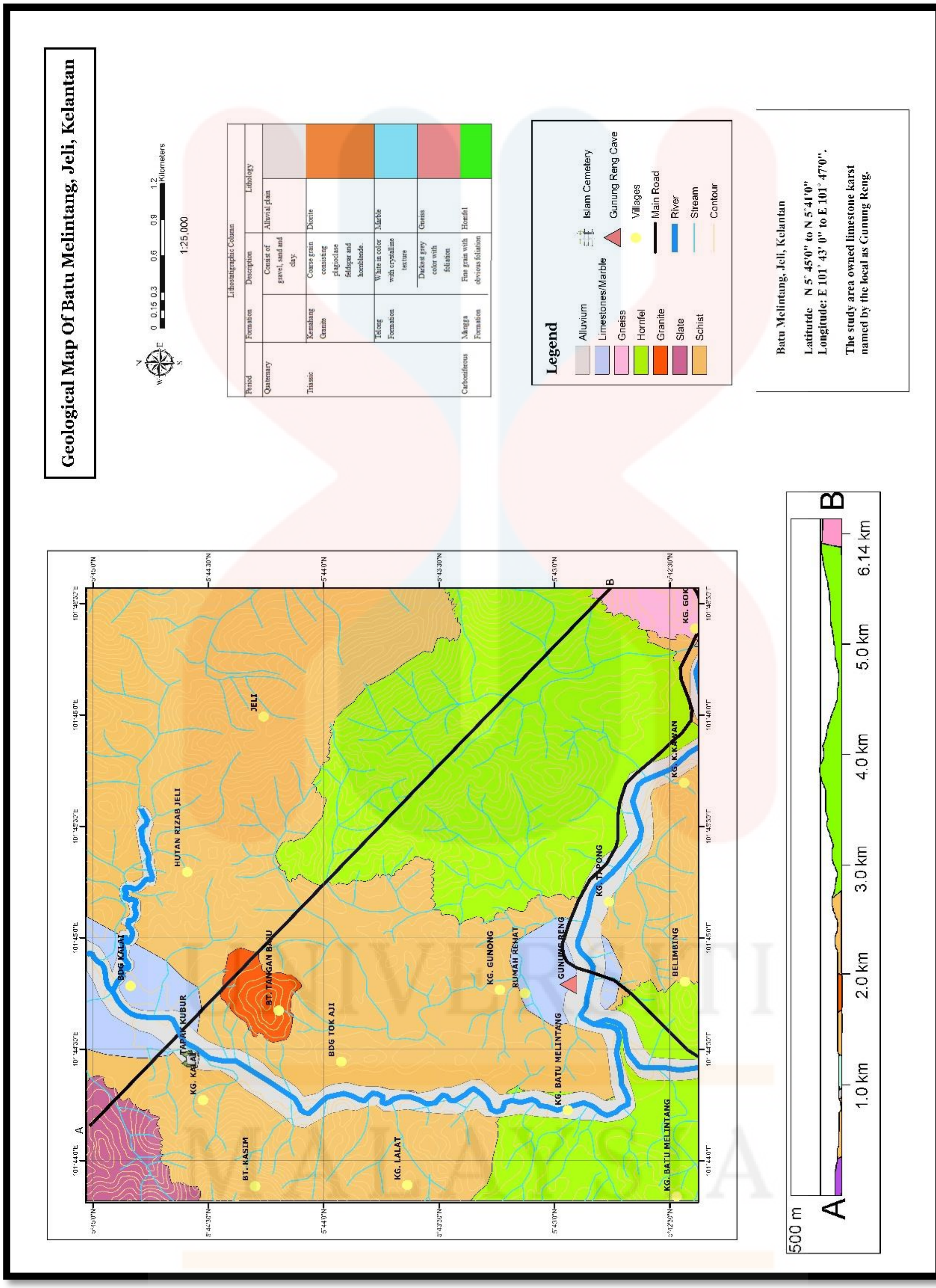


Figure 4.39 Geological Map of Batu Melintang

4.4 Structural Geology

There are a number of structural features that can be observed during the fieldwork. The most dominant feature found at rock are joints and some faults. The deformation features on the rock are mostly caused by tectonic forces. This is probably due to the presence of a granitic range within the area. The data is based on the outcrop observed in the field during geological mapping. The data is analyzed by using GeoRose software.

4.4.1 Joint Analysis

Based on the fieldwork conducted, the type of joint that is found in the area are mostly non-systematic joints due to the irregularities of the rock joints.

The joint analysis was being 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"(Figure 4.40). the type of the joint was shear joint. The location shows 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. Meanwhile, based on the plotted rose diagram in Figure 4.41, 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.

Figure 4.40 Outcrop of Joint 1

Strike Orientation									
3	83	84	60	86	66	83	84	87	60
290	309	314	70	23	336	84	34	303	310
283	317	273	83	86	63	87	68	85	86
88	60	290	311	315	73	35	335	85	28
305	313	283	318	270	80	85	88	271	274
60	87	84	83	66	86	60	84	83	273
310	303	34	84	336	23	70	314	309	290
86	85	68	87	62	86	83	273	317	283
38	85	335	35	73	315	311	290	60	88
274	271	88	65	80	270	283	318	305	313
3	82	84	60	86	66	83	84	87	60
290	309	314	70	23	336	84	24	303	310
283	317	273	83	86	62	87	68	85	86
88	60	290	311	315	73	25	335	85	28
305	313	283	318	270	80	85	88	271	274
60	87	84	83	66	86	60	84	82	272
310	303	24	84	336	23	70	314	309	290
86	85	68	87	62	86	83	273	317	283
28	85	335	25	73	315	311	290	60	88
274	271	88	65	80	270	283	318	305	313

Table 4.6 Joint 1. (N 5°42'23.80" E 101°45'51.30")

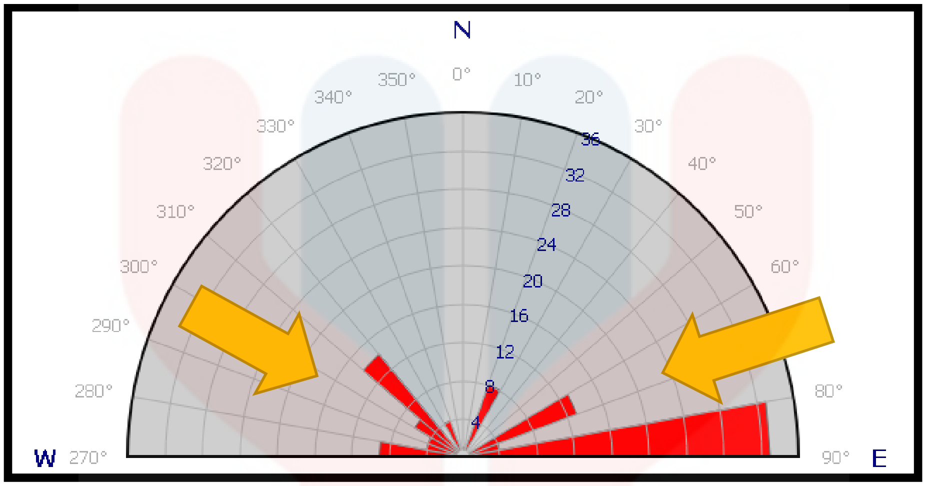


Figure 4.41 Rose Diagram of Joint 1

The second joint analysis was collected at the coordinate of N 5°42'53.00" E 101°44'58.20" (Figure 4.42) which is 2 km far from the first joint analysis outcrop. Figure 4.43 shows the orientation of the rock in the study area. The outcrop found was located along the Pergau River. The type of the joint was shear joint. Based on the plotted rose diagram, the direction of the compressional forces came from NE-SW direction.

Figure 4.42 Outcrop for Joint 2

Strike Orientation									
56	75	77	33	333	337	353	356	337	343
309	327	18	353	331	66	83	84	87	80
290	309	314	70	23	272	82	84	60	87
336	84	24	305	309	284	318	272	83	87
63	86	69	87	89	61	291	310	314	86
60	87	84	83	66	86	60	300	278	273
310	303	336	34	84	314	309	70	290	33
343	337	356	352	337	333	32	77	327	66
33	70	314	309	314	290	60	87	84	353
309	305	34	84	336	87	60	84	273	83

Table 4.7 Joint 2. (N 5°42'53.00" E 101°44'58.20")

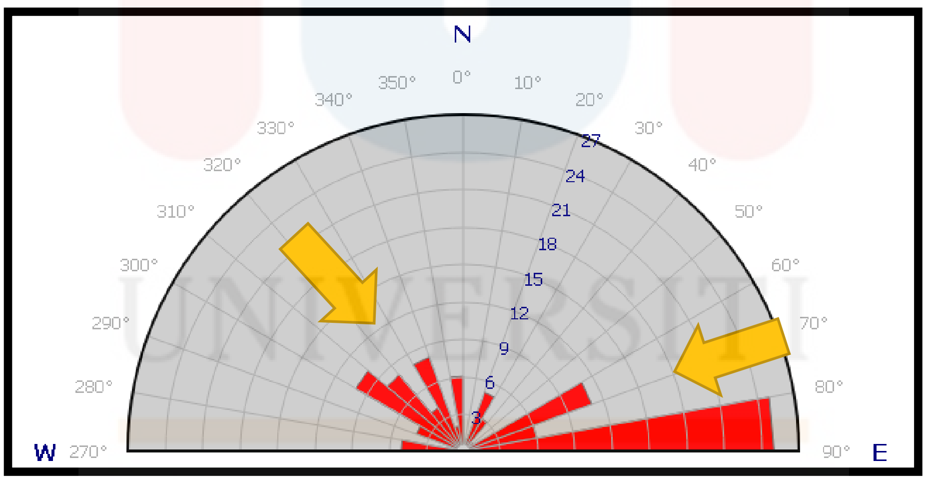


Figure 4.43 Rose Diagram for Joint 2

The third joint analysis was collected at the coordinate of N 5°42'51.00" E 101°44'53.70"(Figure 4.44). The type of the joint was extension joint. Based on the plotted rose diagram in Figure 4.45, the direction of the compressional forces came from NE-SW direction. The outcrop appears light grey and heavily fractured. Erosion effects also can be observed. Vegetation only heavy on the right and left side of the exposure so it does not affect the observation made

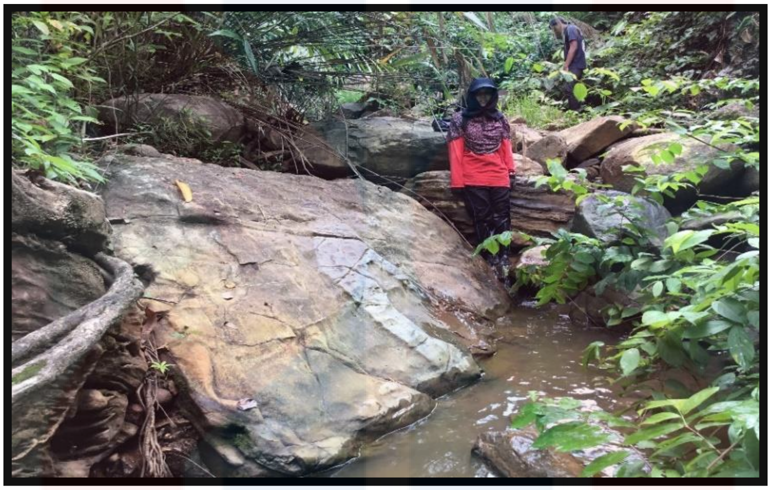


Figure 4.44 Outcrop for Joint 3

Strike Orientation									
85	317	313	305	61	327	319	311	64	68
69	65	307	327	322	302	66	304	301	70
73	278	305	77	334	55	273	83	85	61
65	82	80	86	62	288	307	310	73	25
337	85	26	307	308	281	316	273	80	88
84	310	313	308	70	272	82	84	60	86
65	80	83	86	60	85	313	317	61	306
63	86	80	83	65	61	85	272	55	330
334	77	305	278	73	70	301	304	66	303
86	275	315	310	84	80	65	86	83	60

Table 4.8 Joint 3. (N 5°42'51.00" E 101°44'53.70")

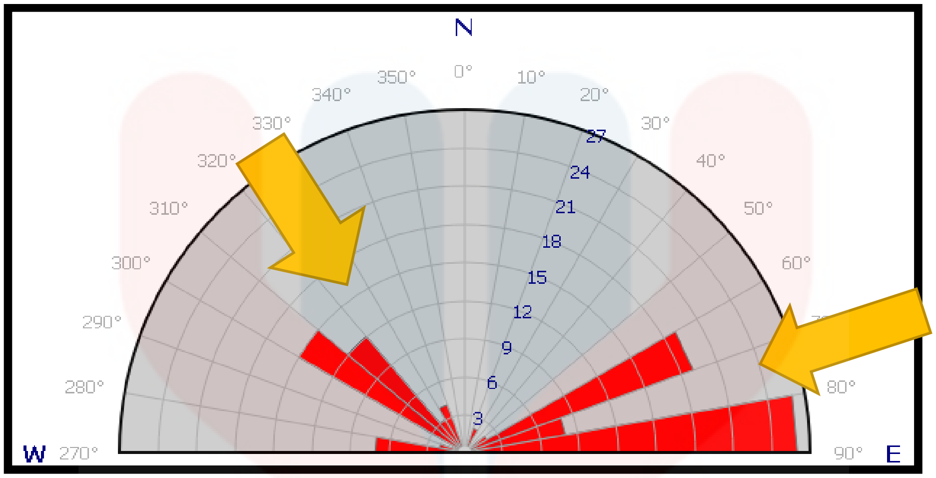


Figure 4.45 Rose Diagram for Joint 3.

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.

4.4.2 Fault

Based on the regional lineament map in Figure 4.41, 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. However, during geological mapping, the fault structures are barely identified perhaps due to the limited exposed area.

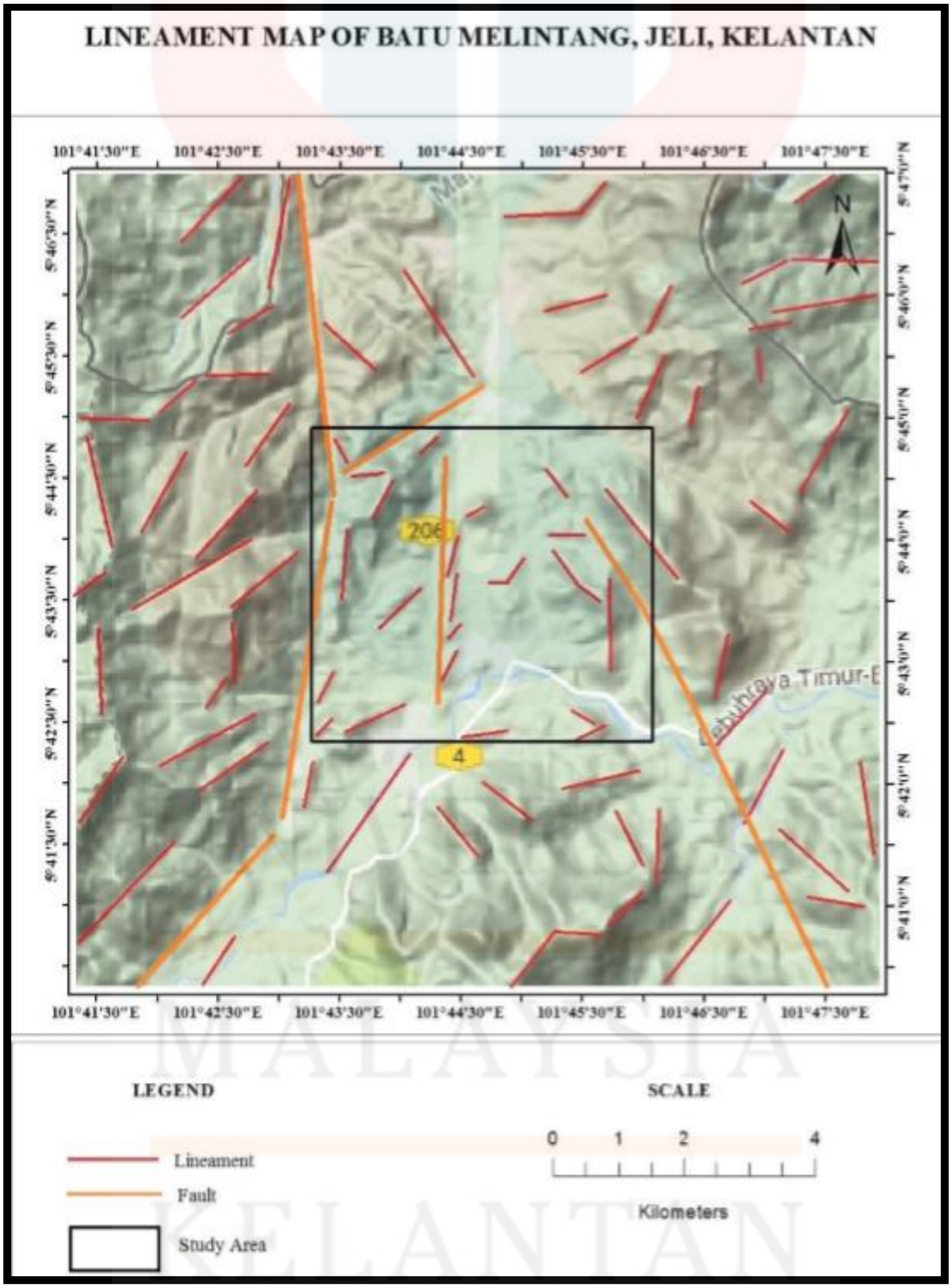


Figure 4.46 Regional lineament map

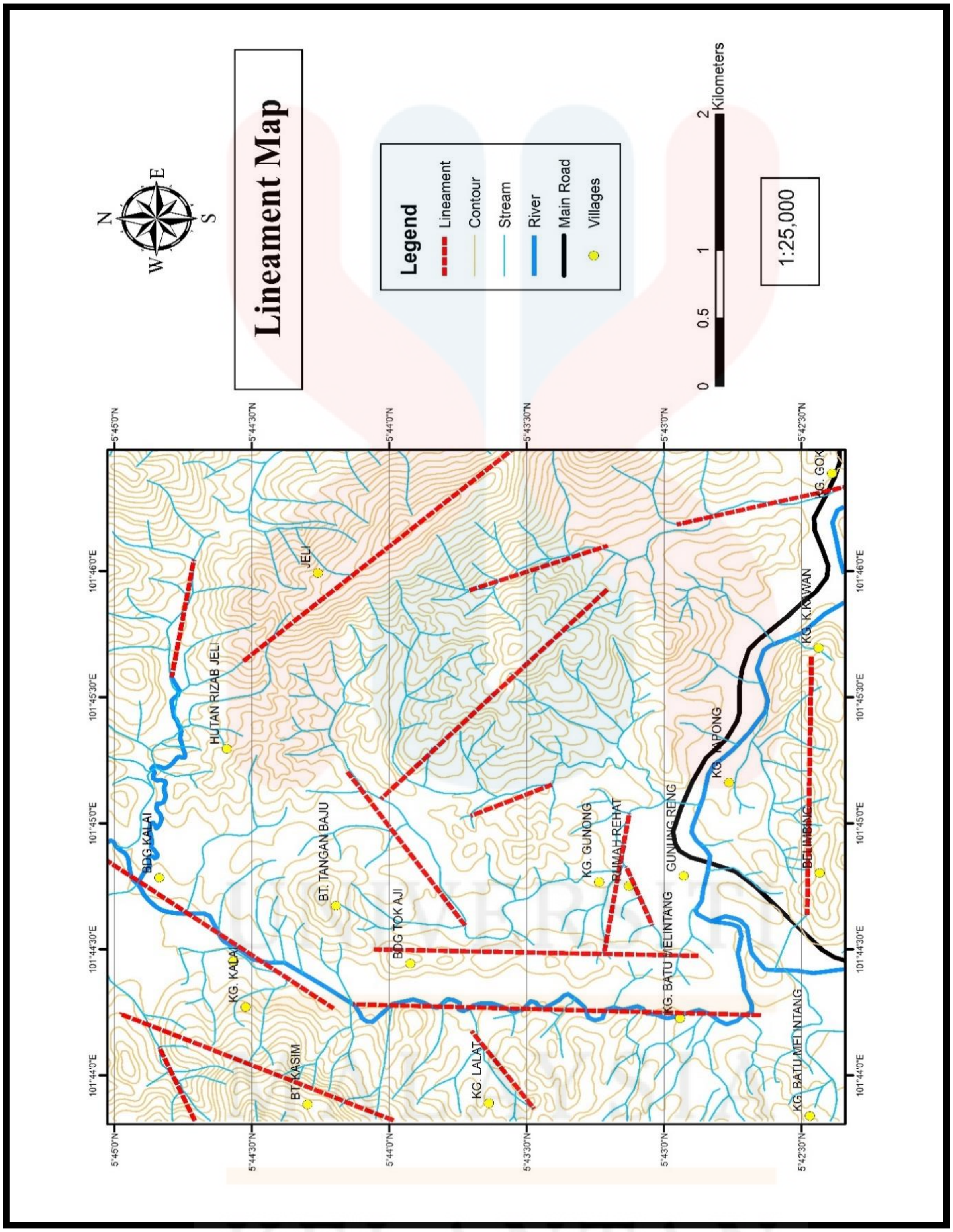


Figure 4.47 Lineament map

4.5 Historical Geology

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 shows the rapid cooling of volcanic process during the past geologic event. 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.

4.6 Summary

Based on Figure 4.1, the traversed mostly done along the main river. As an exposed outcrop and contact between rocks were generally easier be seen along the river. Based on the observations during the mapping session, Batu Melintang can be classified into hilly topography. This is because the contours are mostly ranging from 100 m to 300 m above sea level.

Many drainage patterns can be observed based on Figure 4.11, which includes the dendritic, parallel, trellis, and rectangular patterns. Overall, the rocks in Batu Melintang are considered to be ranging from slightly weathered rocks to highly weathered rocks.

Based on geological mapping, the areas around Batu Melintang comprised of three lithological units, which are igneous rock, sedimentary rock, and also metamorphic rock. The most abundant rock is the metamorphic rock, which consists of Gneiss, Hornfel, Schist and Marble.

According on the joint analysis in different places, it shows that the overall direction of forces acting on the study area came from NE-SW direction. Therefore, the study area is said to undergo the same compressional force.

CHAPTER 5

Data Analysis of Joint Structure at Limestone Outcrop

5.1 Introduction

Chapter 5 discussed the specification of this research, which is the joint analysis of limestone outcrop. The joint structure is essential. To do research, regarding joint is very complicated. As for research activity, the investigation of the joint structure is done only in two stations because in the study area. It is mostly made up of intrusive rock and metamorphic rock, which is granite and gneiss.

Then, the fieldwork is done to gather the data, and to prove the area contain joint structured features. All the data regarding structure analysis, such as strike and dip of the joints, had been collected, then the data is interpreted using a Rose diagram. The accuracy of data depends on how much the reading of strike and dip of the joint taken during the fieldwork, as much data will give a much better and accurate result. With the joints analysis, the direction of forces within the study area can determined.

Moreover, joint analysis is the method that determines the direction of force acting on a rock mass. In geological point of view, among the essential properties of rock need to be observed for a joint analysis is fracturing and discontinuities on a rock. Fractures and discontinuities have exposed most of the rock.

Joints play an essential role in the economical and safe development of petroleum, hydrothermal, and groundwater resources and the research related to these resources. Figure 5.1 shows the Joint station map in the study area, Batu Melintang Kelantan.

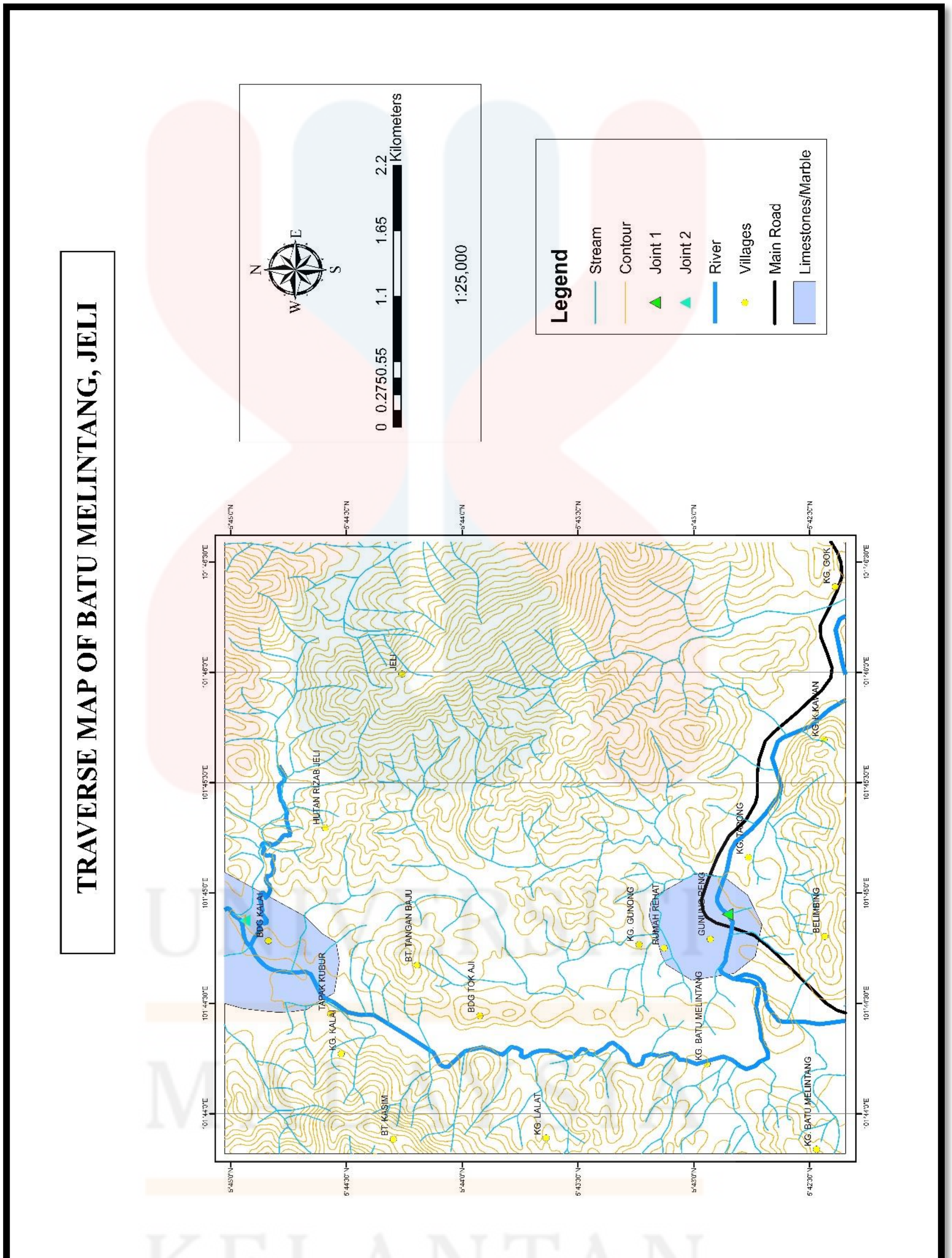


Figure 5.1 Shows the Joint station map in the study area, Batu Melintang Kelantan.

5.2 Location Description

a) Station 1: Gunung Reng, Batu Melintang, Jeli, Kelantan

The location where the joint reading was taken at the study area, which is Gunung Reng, Batu Melintang are at Kampung Gunong Reng, near the Belimbing area and the Kampung Tapong area. The description of the area where the reading of joint was taken is described below.

The location of the Gunung Reng located at the South West (SW) of the study area. The outcrop was found at the coordinate of E 101° 44' 54.9", N 05° 44' 58.47" with the elevation of 24 meters. This type of outcrop is limestone karst outcrop which can found beside the mosque called Masjid An-Nur Gunung Reng. The type of the rock here is a sedimentary rock, and the name of the rock is limestones. The Figure 5.2 (a) and (b) shows the outcrop at the Gunung Reng where the reading of the joint taken, and the reading of joint can seen in Table 5.1 (a), Table 5.1 (b), Table 5.1 (c), and Table 5.1 (d).

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
293.5	49	1	20	88	3
332	43	1	339	62	3
355	62	1	303	62	6
18	68	2	316	68	5
342	60	1	326	60	4
20	3	2	24	34	3
339	38	1	302	38	2
34	51	2	34	51	3
49	67	1	49	35	4
346	72	3	346	80	3
28	49	4	28	88	2
313	43	5	313	62	2
334	62	6	297	62	2
20	68	3	20	68	4
342	60	4	342	60	3
58	3	3	58	34	3
291	38	5	291	38	3
307	51	3	307	51	3
307	67	2	307	35	6
299	72	1	299	80	4
61	49	1	308	88	5
331	43	3	331	62	4

352	62	1	352	62	4
54	68	1	54	68	5
326	60	1	326	60	4
14	3	3	301	34	5
38	38	4	38	38	5
42	51	1	42	51	4
329	67	3	329	35	4
355	72	1	355	80	5

Table 5.1(a) The reading of joints

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
293.5	82	1	20	9	5
332	74	3	339	87	3
355	82	1	303	78	2
18	68	3	316	68	3
342	60	3	326	71	4
20	34	3	24	34	5
339	38	3	302	38	2
34	61	3	34	61	4
49	35	3	49	35	3
346	80	3	346	80	2

28	82	4	28	9	2
313	74	4	313	87	4
334	82	4	297	78	4
20	68	4	20	68	4
342	60	3	342	71	4
58	34	2	58	34	4
291	38	3	291	38	2
307	61	5	307	61	1
307	35	3	307	35	1
299	80	3	299	80	1
61	82	1	308	9	1
331	74	1	331	87	1
352	82	1	352	78	3
54	68	2	54	68	3
326	60	3	326	71	1
14	34	5	301	34	3
38	38	3	65	38	38
42	61	3	42	61	3
329	35	1	329	35	1
355	80	3	355	80	1

Table 5.1(b) The reading of joints

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
51	78	4	350	82	3
302	68	4	331	69	6
73	26	4	9	62	8
272	85	2	49	43	8
331	80	1	23	41	7
24	68	1	24	38	6
302	39	1	305	39	6
7	20	1	291	52	3
49	72	1	38	65	3
346	65	3	346	88	2
28	78	4	28	82	2
6	68	4	6	69	3
297	26	4	297	62	2
20	85	2	20	43	3
270	80	1	331	41	3
309	68	1	309	38	6
291	39	1	16	39	8
307	20	1	307	52	8
307	72	2	307	65	3
299	65	1	299	88	3
308	78	5	315	82	6
331	68	5	331	69	4

352	26	9	352	62	5
351	85	2	351	43	4
87	80	5	87	41	4
301	68	5	307	38	5
309	39	7	309	39	4
299	20	8	324	52	5
329	72	4	329	65	5
355	65	3	355	88	4

Table 5.1(c) The reading of joint

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
293.5	62	1	20	89	5
332	62	3	339	72	3
355	72	1	303	82	2
18	60	3	316	85	3
342	34	3	326	58	4
20	38	3	24	83	5
339	51	3	302	39	2
34	67	3	34	17	4
49	72	3	49	45	3
346	42	3	346	88	2

28	62	4	28	89	2
313	62	4	313	72	4
334	72	4	297	82	4
20	60	4	20	85	4
342	34	3	342	58	4
58	38	2	58	83	4
291	51	3	291	39	2
307	67	5	307	17	1
307	72	3	307	45	1
299	42	3	299	88	1
61	62	1	308	89	1
331	62	1	331	72	1
352	72	1	352	82	3
54	60	2	54	85	3
326	34	3	326	58	1
14	38	5	301	83	3
38	51	3	65	39	38
42	67	3	42	17	3
329	72	1	329	45	1
355	42	3	355	88	1

Table 5.1(d) The reading of joint

Figure 5.2 (a) Outcrop at Gunung Reng, Batu Melintang, Jeli

Figure 5.2 (b) Outcrop at Gunung Reng, Batu Melintang, Jeli.

b) Station 2: Sungai Tadoh, Kampung Kalai, Kelantan

The location of the Sungai Tadoh was located at the end of the study area. The Outcrop are found at the coordinate E 101° 44' 55.2", N 05° 44' 58.7" with the elevation of 99.4 meters. This type of outcrop is natural cutting outcrop which are being found at the along of Sungai Tadoh near Kampung Kalai area. The type of the rock here metasediment rock and the name of the rock is Meta-limestone. The Figure 5.3 (a), (b) and (c) shows the outcrop at the middle of the Sungai Tadoh near the Kampung Kalai area where the reading of the joint is taken and the reading of joint can be seen in Table 5.2 (a), Table 5.2 (b), Table 5.2 (c) and Table (d).

Strike(°)	Dip (°)	Length (m)	Dip (°)	Strike (°)	Length (m)
280	31	3	31	341	4
297	78	5	64	37	2
34	84	6	48	290	5
317	53	9	53	313	5
308	84	4	40	28	9
280	81	7	81	293.5	2
37	24	5	79	37	1
34	75	6	77	34	2
313	62	2	69	316	3
346	64	2	64	346	6

28	54	4	54	28	8
41	52	6	52	313	8
334	52	6	52	334	7
299	46	7	46	299	6
342	17	4	17	342	6
58	74	7	81	58	3
309	80	12	39	46	3
307	71	7	56	307	2
307	73	7	73	307	2
299	65	4	65	299	3
299	72	3	72	299	2
284	17	1	17	284	3
350	21	3	21	350	2
54	50	4	50	54	4
37	76	6	50	326	5
331	61	4	61	286	6
14	61	5	43	38	2
289	44	2	24	42	2
277	68	4	46	277	2
6	80	2	89	355	2

Table 5.2(a) The reading of joint

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
293.5	64	1	20	64	3
332	64	1	339	64	3
355	48	1	303	48	6
18	53	2	316	53	5
342	40	1	326	86	4
20	83	2	24	83	3
339	79	1	302	69	2
34	77	2	34	82	3
49	15	1	49	15	4
346	19	3	346	19	3
28	54	4	28	54	2
313	52	5	313	72	2
334	52	6	297	52	2
20	46	3	20	46	4
342	37	4	342	40	3
58	81	3	58	81	3
291	39	5	291	39	3
307	56	3	307	76	3
307	73	2	307	73	6
299	39	1	299	82	4
61	62	1	308	62	5
331	17	3	331	17	4

352	21	1	352	21	4
54	50	1	54	49	5
326	50	1	326	50	4
14	61	3	301	42	5
38	43	4	38	43	5
42	24	1	42	24	4
329	46	3	329	46	4
355	89	1	355	89	5

Table 5.2(b) The reading of joint

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
293.5	59	1	20	78	5
332	52	3	339	52	3
355	48	1	303	70	2
18	70	3	316	59	3
342	49	3	326	49	4
20	83	3	24	83	5
339	69	3	302	69	2
34	82	3	34	82	4
49	15	3	49	15	3
346	54	3	346	54	2
28	83	4	28	83	2

313	72	4	313	72	4
334	52	4	297	52	4
20	46	4	20	71	4
342	6	3	342	6	4
58	81	2	58	46	4
291	39	3	291	39	2
307	76	5	307	70	1
307	66	3	307	66	1
299	87	3	299	87	1
61	62	1	308	62	1
331	17	1	331	17	1
352	21	1	352	21	3
54	49	2	54	49	3
326	22	3	326	22	1
14	42	5	301	26	3
38	25	3	65	25	38
42	31	3	42	68	3
329	46	1	329	79	1
355	89	3	355	89	1

Table 5.2(c) The reading of joint

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
24	78	3	344	78	4

347	64	4	346	64	5
7	53	2	291	53	6
38	53	5	270	53	3
29	49	7	41	73	2
24	83	6	37	77	5
305	69	6	310	75	3
291	70	3	272	70	2
270	15	3	78	15	1
346	54	3	308	54	4
326	83	5	326	83	7
6	88	6	342	88	5
297	52	9	27	32	6
342	71	4	342	71	2
270	6	7	270	64	2
309	46	5	309	46	4
16	73	6	16	67	4
307	53	2	307	53	7
307	66	2	307	65	5
299	83	4	299	83	6
315	61	6	315	61	2
351	17	6	351	17	2
352	21	7	315	21	4
351	49	4	351	76	4

87	57	7	319	57	7
307	26	12	307	26	5
309	25	7	289	43	6
324	68	7	324	68	2
4	79	3	281	79	2
355	89	5	355	15	4

Table 5.2(d) The reading of joint

Figure 5.3 (a) Outcrop at Sungai Tadoh, Kampung Kalai,,Jeli

Figure 5.3 (b) Outcrop at Sungai Tadoh, Kampung Kalai, Jeli

5.3 Types of Joint structures

There are three types of joint structures, which are extensional joint, shear joint and the hybrid joint can be found in the study area. As for joint at structures at limestones outcrop, there is a lot of shear joint compare to the extensional joint. So as for the reading of the joint structure that presents in the study area, the measurement for the first station which is Gunung Reng is the measurement of shear joint reading, the second station which is Sungai Tadoh is also measurement for the shear joint reading. The figure of the shear joint shown based on the location of the study area where the reading of joint taken.

a) Station 1: Gunung Reng, Batu Melintang, Jeli, Kelantan

Figure 5.4 Shear joint

Figure 5.5 Shear joint

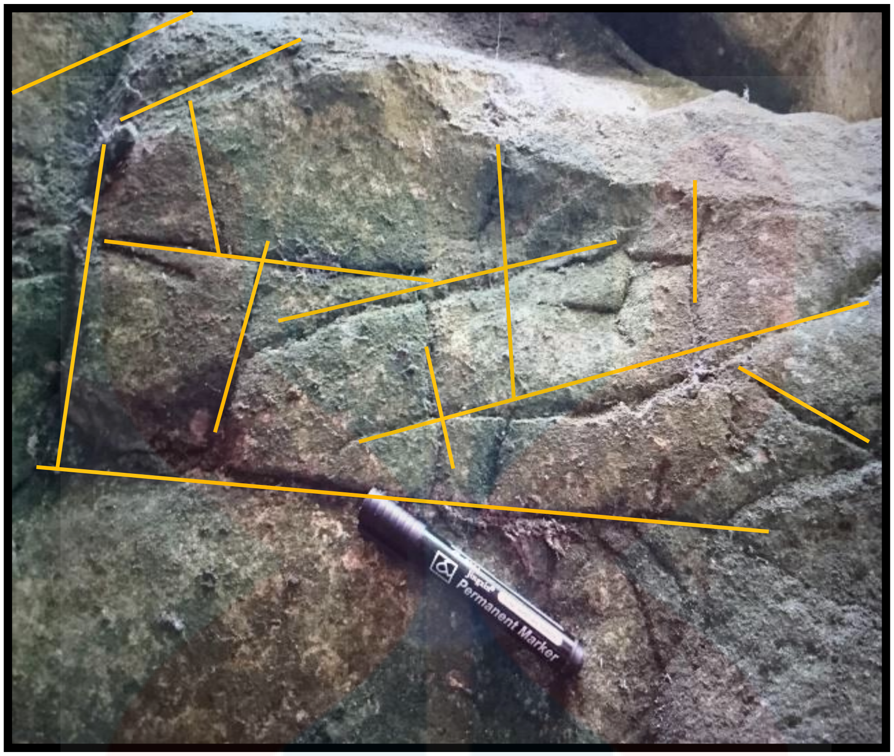


Figure 5.6 Shear Joint

Figure 5.7 Shear Joint

b) Station 2: Sungai Tadoh, Kampung Kalai, Kelantan

Figure 5.8 Shear Joint

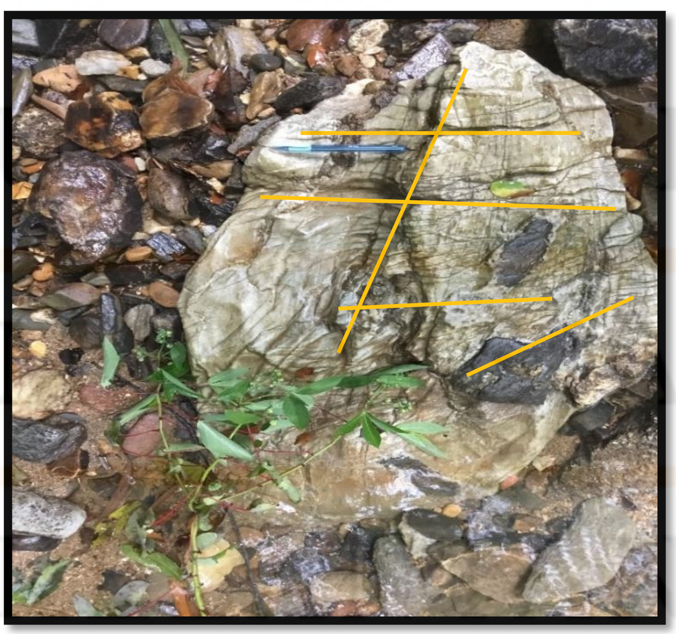


Figure 5.9 Shear Joints

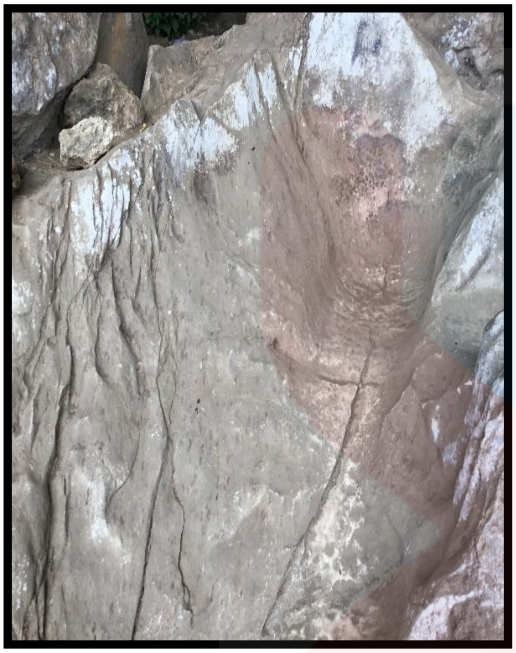
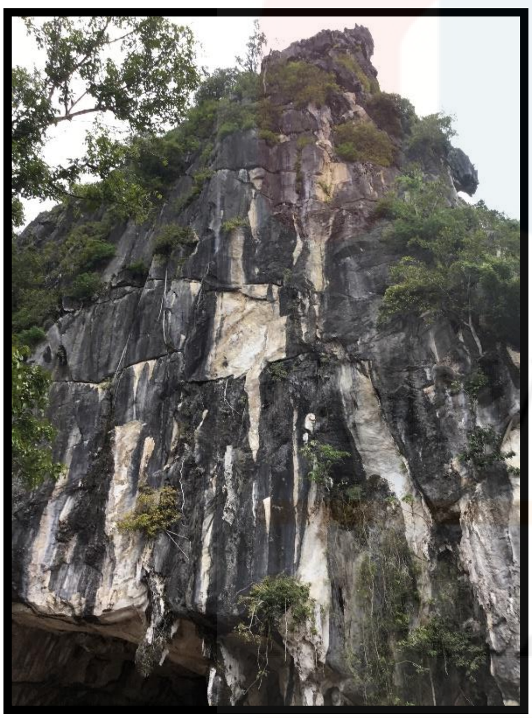
5.4 Classification of the Joint Structures

As for classification of the joint structure in the joint station area, it been classifying by a geometry which can be divided into two systems which are systematic joint and non-systematic joint. In addition, systematic joint can be divided into two joint sets which are conjugate and orthogonal. When the dihedral angles (angle of joint intersect) are mostly 90º within a joint system, the joint sets are said as orthogonal joint sets while the dihedral angles are from 30º to 60º within a joint system, the joint sets are said as conjugate joint sets. Both systematic and non-systematic joint can find in the same outcrop at joint station area. The non-systematic joints are usually short, curved and irregularly spaced while systematic joint is characterized by a roughly planar geometry; they have relatively long traces and typically form sets of approximately parallel and almost equally spaced joints.

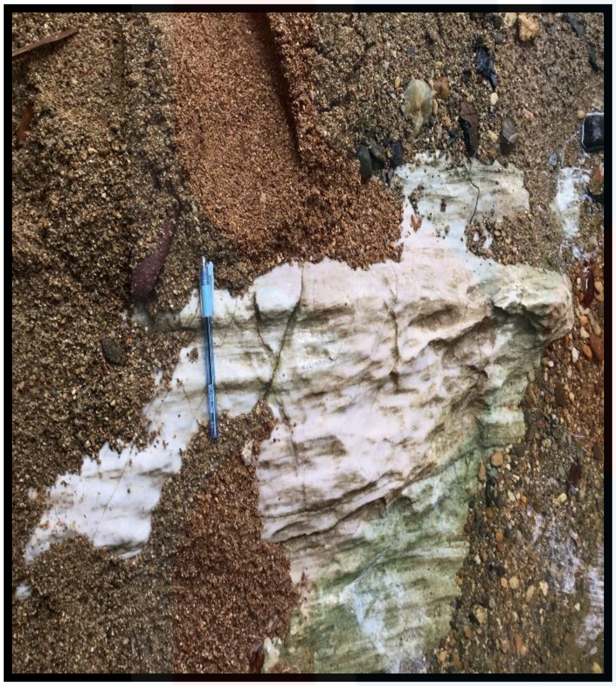
Furthermore, at the joint station area, there is a lot of systematic joint and non-systematic joint. The figure of systematic and non-systematic joint shown with the explanation. In addition, conjugate joint also presents in the joint station area.

a) Station 1: Gunung Reng, Batu Melintang, Jeli, Kelantan.

Joint Structure	Description
	**<u>Non-Systematic Joint</u>** This is non-systematic joint that have been found in the joint station 1 which is Gunung Reng. This joint structure been classify into non-systematic joint because it is irregular in geometry and it is irregular in spacing. This joint formed when limestone is place under tension or pressure. The joints also form because chemical weathering which widened the joint fractures. When the rock rich in moisture in initial stages undergo some contraction on drying up which might have resulted into irregular jointing.
	**<u>Non-Systematic Joint</u>** This is non-systematic joint that have been found in the joint station 1 which is Gunung Reng. This joint structure been classify into non-systematic joint because it is irregular in geometry and it is irregular in spacing. This joint formed when limestone is place under tension or pressure. It is directed stress caused the tensile strength of bedrock to be exceed and result in stretching of rock layers. The joints also form because chemical weathering which widened the joint fractures.

	**<u>Non-Systematic Joint</u>** This is non-systematic joint that have been found in the joint station 1 which is Gunung Reng. This joint structure been classify into non-systematic joint because it is irregular in geometry and it is irregular in spacing. This joint is formed when limestone is place under tension or pressure. It is directed stress caused the tensile strength of bedrock to be exceed and result in stretching of rock layers. The joints also form because chemical weathering which widened the joint fractures.
	**<u>Systematic Joint</u>** This is systematic joint that have been found in the study area which is Batu Melintang. This joint structure classify into systematic joint because it is planar, parallel and regular in spacing. This joint formed by the tectonic activity. It is directed stress caused the tensile strength of bedrock to be exceed and result in stretching of rock layers.

b) Station 2: Sungai Tadoh, Batu Melintang, Jeli, Kelantan.

Joint Structure	Description
	**Systematic Joint** This is systematic joint that have been found in the study area which is Sungai Tadoh in joint station 2. This joint structure been classify into systematic joint because it is planar, parallel and regular in spacing. The joint in this area joints results from brittle fracture of a rock body as the result of tensile stresses and compression stresses. It also has equally spaced joints
	**Non-Systematic Joint** This is non-systematic joint that have been found in the joint station 2 which is Sungai Tadoh. This joint structure been classify into non-systematic joint because it is irregular in geometry and it is irregular in spacing. When the rock rich in moisture in initial stages undergo some contraction on drying up which might have resulted into irregular jointing.

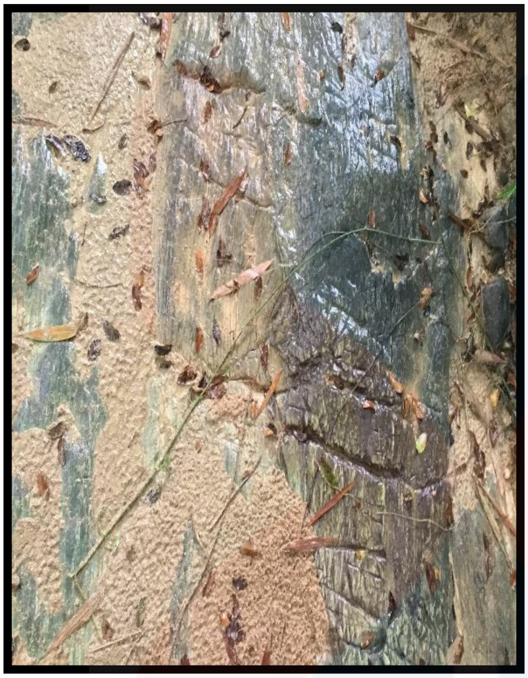
	**Non-Systematic Joint** This is non-systematic joint that have been found in the joint station 2 which is Sungai Tadoh. This joint structure have been classify into non-systematic joint because it is irregular in geometry and it is irregular in spacing. When the rock rich in moisture in initial stages undergo some contraction on drying up which might have resulted into irregular jointing.
	**Systematic Joint** This is systematic joint that have been found in the study area which is Sungai Tadoh in joint station 2. This joint structure have been classify into systematic joint because it is planar, parallel and regular in spacing. The joint in this area joints results from brittle fracture of a rock body as the result of tensile stresses and compression stresses. It also has equally spaced joints

Table 5.3 The Classification of Joint Structures

5.5 Joint Set and Joint System

Term	Description
Joint Set	• Joint that share a similar orientation in the same area. Or it is a family of parallel evenly spaced joints.
Joint System	• Two or more intersecting joint sets in the same area.
Orthogonal System	• Two joint sets in joint system are • perpendicular • Angle is 90
Conjugate System	• Two joint sets intersect with dihedral angle and less than 90º • The pair of joint set formed at the same time • Non-parallel joint set form at different times

Table 5.4 Joint Set and Joint System

5.6 Dynamic Analysis of Joint Structure

i) Analysis through rose diagram

Data collected from the limestone exposure was used to plot Rose Diagram. The objective of this study is to identify joint structure of limestone in study area. All two joint station are determined to have Mode 2 Cracking (In-plane shear). Analysis of Joint is done is done to know the direction of the forces which lead the rock to become crack. The reading of joint structure taken from two stations of the study area, which is at Gunung Reng Cave and area near Kampung Kalai of Batu Melintang, Kelantan which

Sungai Tadoh. The reading for three stations is 300 reading for every station. The type of outcrop where the measurement joint reading taken is Limestone or Marble.

a) Location: Gunung Reng Cave

Coordinate: N 05° 44' 58.47"

E 101° 44' 54.9"

Elevation: 24 meters

Outcrop: Limestone

Type of outcrop: Limestone Cave

Explanation: As for the study area at Gunung Reng Cave, the result shows that the force acting is from the North West (NW) which is about N 330º W. The Table 5.1 (a), Table 5.1 (b), Table 5.1 (c) and Table 5.1 (d) shows the reading of the shear joint structure and The figure 5. 2 shows the rose diagram of the joint structure of Gunung Reng Cave.

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
293.5	49	1	20	88	3
332	43	1	339	62	3
355	62	1	303	62	6
18	68	2	316	68	5
342	60	1	326	60	4

20	3	2	24	34	3
339	38	1	302	38	2
34	51	2	34	51	3
49	67	1	49	35	4
346	72	3	346	80	3
28	49	4	28	88	2
313	43	5	313	62	2
334	62	6	297	62	2
20	68	3	20	68	4
342	60	4	342	60	3
58	3	3	58	34	3
291	38	5	291	38	3
307	51	3	307	51	3
307	67	2	307	35	6
299	72	1	299	80	4
61	49	1	308	88	5
331	43	3	331	62	4
352	62	1	352	62	4
54	68	1	54	68	5
326	60	1	326	60	4
14	3	3	301	34	5
38	38	4	38	38	5
42	51	1	42	51	4

329	67	3	329	35	4
355	72	1	355	80	5

Table 5.1 (a) shows the reading of the shear joint structure

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
293.5	82	1	20	9	5
332	74	3	339	87	3
355	82	1	303	78	2
18	68	3	316	68	3
342	60	3	326	71	4
20	34	3	24	34	5
339	38	3	302	38	2
34	61	3	34	61	4
49	35	3	49	35	3
346	80	3	346	80	2
28	82	4	28	9	2
313	74	4	313	87	4
334	82	4	297	78	4
20	68	4	20	68	4
342	60	3	342	71	4
58	34	2	58	34	4
291	38	3	291	38	2

307	61	5	307	61	1
307	35	3	307	35	1
299	80	3	299	80	1
61	82	1	308	9	1
331	74	1	331	87	1
352	82	1	352	78	3
54	68	2	54	68	3
326	60	3	326	71	1
14	34	5	301	34	3
38	38	3	65	38	38
42	61	3	42	61	3
329	35	1	329	35	1
355	80	3	355	80	1

Table 5.1 (b) shows the reading of the shear joint structure

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
51	78	4	350	82	3
302	68	4	331	69	6
73	26	4	9	62	8
272	85	2	49	43	8
331	80	1	23	41	7
24	68	1	24	38	6

302	39	1	305	39	6
7	20	1	291	52	3
49	72	1	38	65	3
346	65	3	346	88	2
28	78	4	28	82	2
6	68	4	6	69	3
297	26	4	297	62	2
20	85	2	20	43	3
270	80	1	331	41	3
309	68	1	309	38	6
291	39	1	16	39	8
307	20	1	307	52	8
307	72	2	307	65	3
299	65	1	299	88	3
308	78	5	315	82	6
331	68	5	331	69	4
352	26	9	352	62	5
351	85	2	351	43	4
87	80	5	87	41	4
301	68	5	307	38	5
309	39	7	309	39	4
299	20	8	324	52	5
329	72	4	329	65	5

355	65	3	355	88	4

Table 5.1 (c) shows the reading of the shear joint structure

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
293.5	62	1	20	89	5
332	62	3	339	72	3
355	72	1	303	82	2
18	60	3	316	85	3
342	34	3	326	58	4
20	38	3	24	83	5
339	51	3	302	39	2
34	67	3	34	17	4
49	72	3	49	45	3
346	42	3	346	88	2
28	62	4	28	89	2
313	62	4	313	72	4
334	72	4	297	82	4
20	60	4	20	85	4
342	34	3	342	58	4
58	38	2	58	83	4
291	51	3	291	39	2

307	67	5	307	17	1
307	72	3	307	45	1
299	42	3	299	88	1
61	62	1	308	89	1
331	62	1	331	72	1
352	72	1	352	82	3
54	60	2	54	85	3
326	34	3	326	58	1
14	38	5	301	83	3
38	51	3	65	39	38
42	67	3	42	17	3
329	72	1	329	45	1
355	42	3	355	88	1

Table 5.1 (d) shows the reading of the shear joint structure

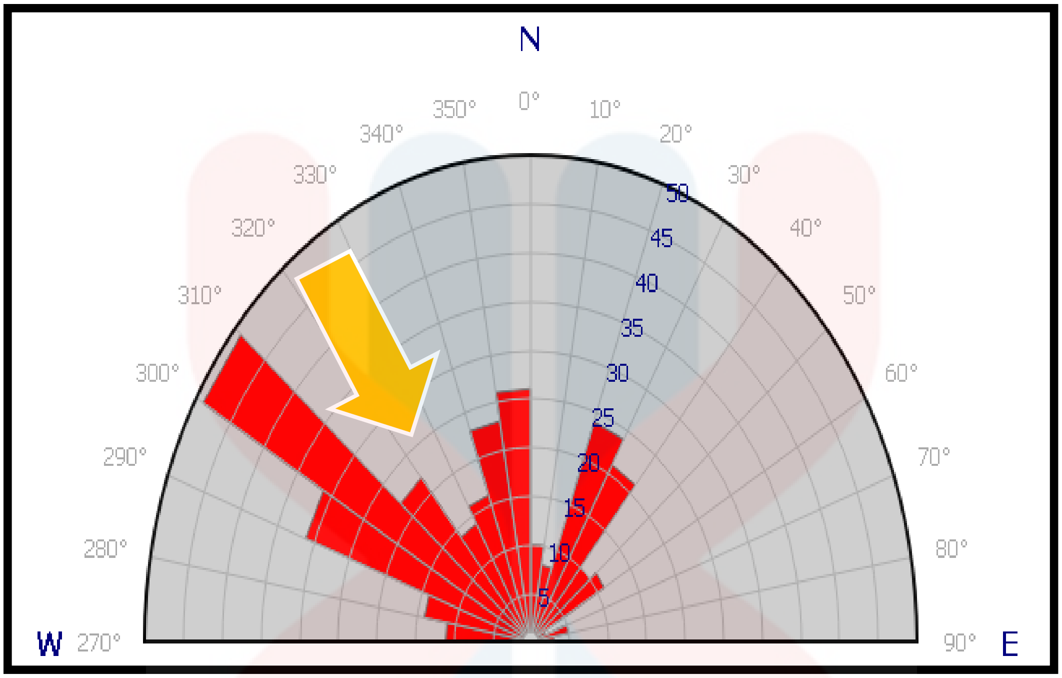


Figure 5.10 Shows the rose diagram of the joint structure of Gunung Reng Cave.

Figure 5.10 shows the orientation of the rock in the study area. The outcrop found was located Gunung Reng nearby Sungai Pergau. Based on the plotted rose diagram, the direction of the compressional forces came from North West (NW) which is about 330º NW where it taken, where the σ3 was NE 85 degree.

b) Location: Area of Kampung Kalai

Coordinate: N 05° 44' 58.7"

E 101° 44' 55.2"

Elevation: 99.4 meters

Outcrop: Limestone

Type of outcrop: Along the river

Explanation: As for the study area at Kampung Kalai, the result shows that the force acting is from the North West (NW) which is about N 350º W. The table 5.2(a), Table 5.2 (b), Table 5.2 (c) and Table 5.2 (d) shows the reading of the shear joint structure and The figure 5. 11 shows the rose diagram of the joint structure of Kampung Kalai.

Strike(°)	Dip (°)	Length (m)	Dip (°)	Strike (°)	Length (m)
280	31	3	31	341	4
297	78	5	64	37	2
34	84	6	48	290	5
317	53	9	53	313	5
308	84	4	40	28	9
280	81	7	81	293.5	2
37	24	5	79	37	1
34	75	6	77	34	2
313	62	2	69	316	3
346	64	2	64	346	6
28	54	4	54	28	8
41	52	6	52	313	8
334	52	6	52	334	7
299	46	7	46	299	6
342	17	4	17	342	6

58	74	7	81	58	3
309	80	12	39	46	3
307	71	7	56	307	2
307	73	7	73	307	2
299	65	4	65	299	3
299	72	3	72	299	2
284	17	1	17	284	3
350	21	3	21	350	2
54	50	4	50	54	4
37	76	6	50	326	5
331	61	4	61	286	6
14	61	5	43	38	2
289	44	2	24	42	2
277	68	4	46	277	2
6	80	2	89	355	2

Table 5.2 (a) shows the reading of the shear joint structure

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
293.5	64	1	20	64	3
332	64	1	339	64	3
355	48	1	303	48	6

18	53	2	316	53	5
342	40	1	326	86	4
20	83	2	24	83	3
339	79	1	302	69	2
34	77	2	34	82	3
49	15	1	49	15	4
346	19	3	346	19	3
28	54	4	28	54	2
313	52	5	313	72	2
334	52	6	297	52	2
20	46	3	20	46	4
342	37	4	342	40	3
58	81	3	58	81	3
291	39	5	291	39	3
307	56	3	307	76	3
307	73	2	307	73	6
299	39	1	299	82	4
61	62	1	308	62	5
331	17	3	331	17	4
352	21	1	352	21	4
54	50	1	54	49	5
326	50	1	326	50	4
14	61	3	301	42	5

38	43	4	38	43	5
42	24	1	42	24	4
329	46	3	329	46	4
355	89	1	355	89	5

Table 5.1 (b) Shows the reading of the shear joint structure

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
293.5	59	1	20	78	5
332	52	3	339	52	3
355	48	1	303	70	2
18	70	3	316	59	3
342	49	3	326	49	4
20	83	3	24	83	5
339	69	3	302	69	2
34	82	3	34	82	4
49	15	3	49	15	3
346	54	3	346	54	2
28	83	4	28	83	2
313	72	4	313	72	4
334	52	4	297	52	4
20	46	4	20	71	4

342	6	3	342	6	4
58	81	2	58	46	4
291	39	3	291	39	2
307	76	5	307	70	1
307	66	3	307	66	1
299	87	3	299	87	1
61	62	1	308	62	1
331	17	1	331	17	1
352	21	1	352	21	3
54	49	2	54	49	3
326	22	3	326	22	1
14	42	5	301	26	3
38	25	3	65	25	38
42	31	3	42	68	3
329	46	1	329	79	1
355	89	3	355	89	1

Table 5.1 (c) Shows the reading of the shear joint structure

Strike(°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
24	78	3	344	78	4
347	64	4	346	64	5

7	53	2	291	53	6
38	53	5	270	53	3
29	49	7	41	73	2
24	83	6	37	77	5
305	69	6	310	75	3
291	70	3	272	70	2
270	15	3	78	15	1
346	54	3	308	54	4
326	83	5	326	83	7
6	88	6	342	88	5
297	52	9	27	32	6
342	71	4	342	71	2
270	6	7	270	64	2
309	46	5	309	46	4
16	73	6	16	67	4
307	53	2	307	53	7
307	66	2	307	65	5
299	83	4	299	83	6
315	61	6	315	61	2
351	17	6	351	17	2
352	21	7	315	21	4
351	49	4	351	76	4
87	57	7	319	57	7

307	26	12	307	26	5
309	25	7	289	43	6
324	68	7	324	68	2
4	79	3	281	79	2
355	89	5	355	15	4

Table 5.1 (d) shows the reading of the shear joint structure

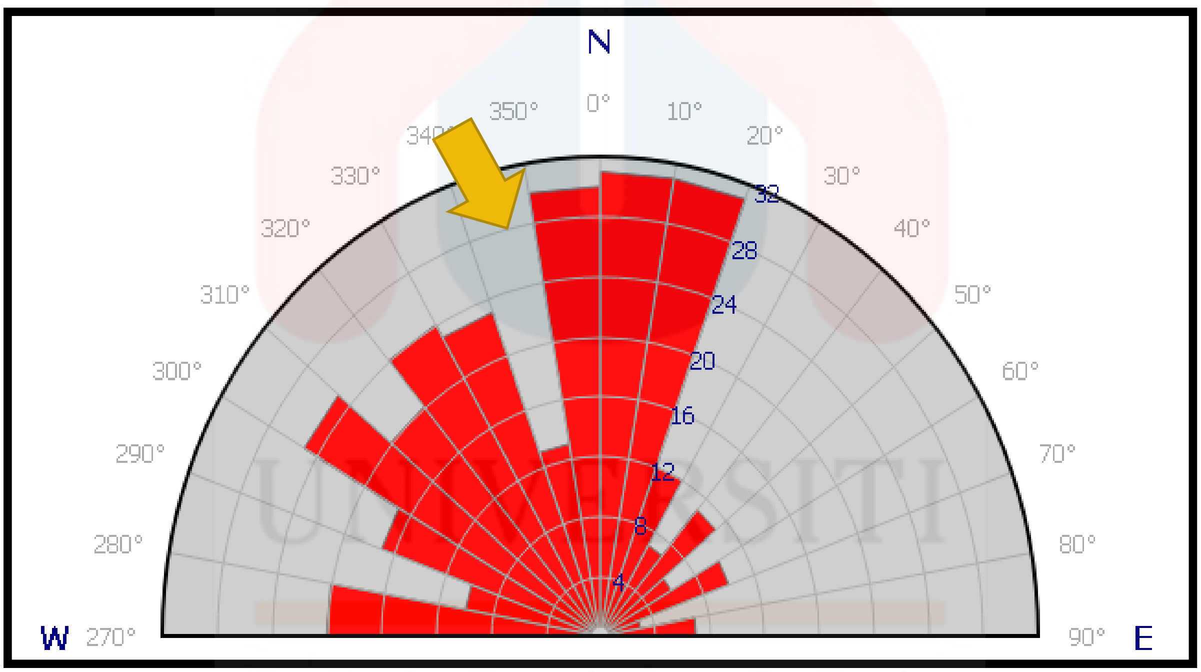


Figure 5.11 Shows the rose diagram of the joint structure of Sungai Tadoh.

Figure 5.9 shows the orientation of the rock in the study area. The outcrop found was located at Sungai Tadoh in Kampung Kalai area. Based on the plotted rose diagram, the direction of the compressional forces came from North West (NW) which is about 350º NW where it taken, where the σ3 was NE 85 degree.

ii) Analysis through graphic projection

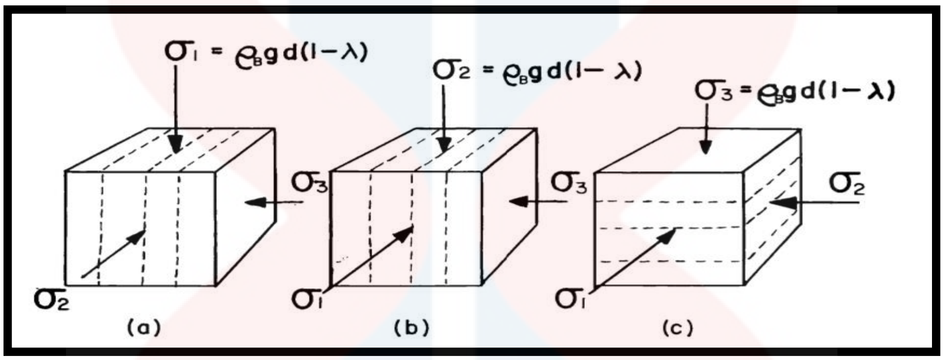


Figure 5.12 Three Principal Stress Configuration in The Earth's Crust. σ1 is the Greatest Principal Stress, σ2 Is the Intermediate Principal Stress, and σ3 Is the Least Principal Stress.

The joint structure also has been identified in the study area are abundant of the shear joint. The shear joint indicates that ***σ1*** bisects the acute angle created by the conjugate joint plane intersection.

Figure 5.13 Conjugate joint in Sungai Tadoh, Kg Kalai

Figure 5.14 Conjugate joint in Gunung Reng

Both of the joint station which is Sungai Tadoh and Gunung Reng formed conjugate joint. For the image in figure 5.15, it is block diagram picture that shows the maximum principal stress are come from the side of the joint structure and the figure 5.15 shows the stereographic projection of the joint structure.

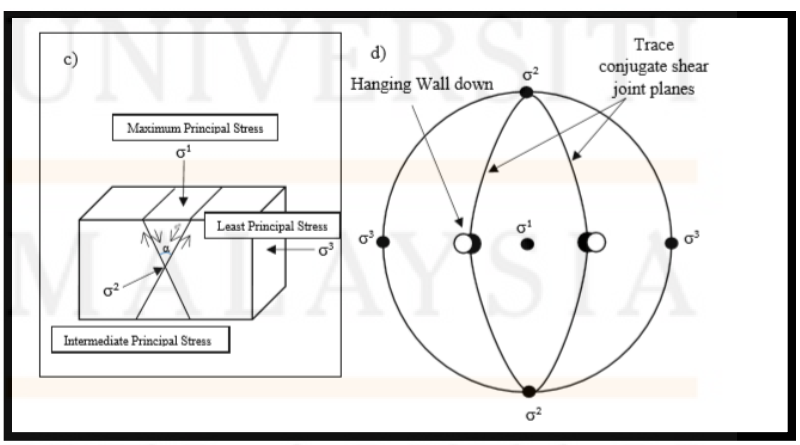


Figure 5.15 Show is block diagram picture that shows the maximum principal stress of the joint structure and the stereographic projection of the joint structure.

5.3 Summary

The name of the rock for joint analysis is Limestones or carbonic rock. The joint station shows the joint structure at first station (Gunung Reng Cave) is N 330º W and for the other forces of the joint structure at second station (Kampung Kalai) is N 350º W. The joint structure also has been identified at the study area are abundant of the shear joint. Mostly the joint structure is non-systematic joints due to the irregularities of the rock. This will be used to update geological map.

CHAPTER 6

6.1 Conclusion

The geological map of Batu Melintang is able to be produced with the scale of 1:25,000. As for the whole research with the mapping area 25km^2 and from the coordinate of the study area are with the latitude range between N 5˚ 45'0" to N 5˚41'0" and the longitude extends between E 101˚ 43' 0" to E 101˚ 47'0".

Even though this project had achieved its objectives, it is recommended for a more thorough studies to be made in this area to gained better knowledge of the area. The joint station shows the joint structure at first station (Gunung Reng Cave) is S 220º W and for the other forces of the joint structure at second station (Kampung Kalai) is N 270º W. Next, is the geological map are produced with the scale of 1:25000 with the type of rock which are found in the study area are igneous rock, metamorphic rock and sedimentary rock. The name of the rock is schist, marble, limestone, hornfel and pylite. The joint structure also been identified at the study area which can be divided into two main type which are shear joint and extension joint. While the joint structure also been identified at the Joint Station are abundant of the shear joint.

6.2 Recommendation

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.

In order to obtain more accurate result and possible outcome, the details analysis of the joint structure or another structure in subsurface of the earth can be analyze by using the method of detection which is Direct Current Resistivity Survey that that is Schlumberger Array. As, it would have better resolution, less time consuming field deployment, greater probing depth.

In addition, resistivity survey is a geophysical method that are suitable for a broad range applications and environments such as groundwater prospecting, geological mapping, mineral exploration and geotechnical investigation. The suggestion system that are perfectly match the requirement are by using the ABEM Terrameter. As, it can give more accurate, precise and reliable possible outcome.

Lastly, as we already know joint can occur to any type of rock that have characteristic of brittle. So when we can detect the joint structure beneath the earth, we can tell that area are not stable for any construction. This is because that joint structure can lead to fault structure. In addition, fault can lead to the movement of the earth and lead to geohazard. So the details analysis under the subsurface of the study area can prevent something worst to occur in the future especially to prevent the construction to build the building at the wrong places.

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APPENDICES

Figure 6.1 Construction Area

Figure 6.2 Sk. Batu Melintang

Figure 6.4 Plantation Area

Figure 6.5 Islam Cemetery Area