Geology and Tectonic Deformation of Kilometer 185 Gua Musang – Cameron Highland, Lojing, Kelantan

By

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

Faculty Of Earth Science

UNIVERSITI MALAYSIA KELANTAN

2021

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DECLARATION

I declare that this thesis entitled **"GEOLOGY AND TECTONIC DEFORMATION OF KILOMETER 185 GUA MUSANG – CAMERON HIGHLAND, LOJING, KELANTAN"** is the resulted of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

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

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ACKNOWLEDGEMENT

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

Thank to Allah s.w.t for the blessing in life for me and meet me with the helpful people that help me to capable complete my research successful. First and foremost I would like to dedicated my biggest gratitude and humble thank to my supervisor Dr. Hamzah Hussin. Thank for being supportieve, comprehensiv and competent for me to in order to finished my research. Thank for the assistance, teaching, sharing, guidance, motivation and dedicated involvement in every step throughout the process rhis paper would have never been accomplished without his favor.

Moreover, I would like to express my very profound gratitude to coordinator, Dr. Zamzarina Sulaiman and Dr. Elveane James and not to forget to my advisor Ir. Arham Muchtar Achmad Bahar for the continuous guidance and enthusiasm given throughout this dissertation. In this opportunities I dedicated the most thankful and greatful to Dr. Muhammad Firdaus Che Yaacob (Faculty of Creatif Technology and Heritage) for being the most supportive for me and always guide me in order to finished this research, being the most tolerance, helpful for me while I really need something and idea to finished this research and also to Dr. Muhammad Firdaus Abdul Karim (Faculty of Earth Science) thank for sh aring the idea and teaching me how to make a better research which suitable to present ourself toward the interest that we should take as priority.

To my parents, Azizah Hussin and Wan Bharudin Wan Ahmad a very sincere and special thank for unfailing support me and continuously encourange me throughout my years of study and most important thing is never give up and always be here with me. This most successful accomplishment would never been possible without them.

Difficult for me to mention one before the other. Hence, I undoubtedly owe much to my friends Mohd Azlan Zainudin, Nur Umirah Mahmut, Roszuadi Abdul Ghani, Tuan Muhamad Firdaus Tuan Mohamad Adnan and my classmate especially Mahendra Abiyoga Hidayat, Muhammad Afiq Kahar and all the others for sharing the knowledge and teaching the unknown with learning the opinion together.

Last but not least, thank to all who those directly or indirectly involved throughout the process of completing my research study. Together we expect the unexpectedted, believe the unbelievable, achieve the unachievable anf ordinary the extraordinary.

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Geology and Tectonic Deformation of Kilometer 185

Gua Musang – Cameron Highland, Lojing, Kelantan

ABSTRACT

Rheology or also known as a deformation is the study of respected their stress. In determine the deformation of the rocks, the investigate of the structure geology which includes fault, fold and joints would be the better part in identified the deformation. Bentong – Raub Suture Zone would be the inherited to identified the fault, folds and joints. The research that conducted at highway of Gua Musang – Cameron highlands on kilometer 185, Kelantan as there is no comprehensive structural geology towards tectonic deformation of the study area from the previous research. The study area that been conducted is in a square box shape with 25km^2. By focussing on the objective of the this research where to generate geological map of study area with the scale 1:25,000 and to produced structural map by looked at the fault that collected from the prevous research. Most important thing towards this research is to use the measurements of the present day rock geometries to explore and updated the stress field that produced the structure observed in the study area in present day. In this research the method that have been used to conducted this research are by identified in previous research, collecting the information from other agencies and process the data by using ArcGIS 10.8 for presenting the map and Dips 7.0 for collecting the stress system in order to produces the structural map. From the research, there are three types of rocks that can be identified in this study area which is the oldest rocks are schist, phyllite and the youngest one is quartzite. The tectonic deformation in this research can be identified toward the structure,where there are two types of fault in this area which is Thrust Fault happen in the between of schist – quartzite rock and Strike Slip Fault where can be seen in the Brooke's River that caused by the ESE – WNW principal stress. From the observation towards the stress their show the corresponding to the principal stress of the Bentong – Raub Suture Zone form by looked at the collision between Sibumasu Plate and Indochina Plate in Late Palaeozoic and Triassic.

Keywords: Tectonic Deformation; Thrust Fault; Strike Slip Fault; Gua Musang Formation

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Geologi dan Ubah Bentuk Tektonik Di Kilometer 185

Gua Musang – Cameron Highland, Lojing, Kelantan

ABSTRAK

Rheology atau juga dikenali dengan ubah bentuk merupakan kajian berkaitan dengan tekanan yang berlaku terhadap bentuk muka bumi. Dalam mengenal pasti ubah bentuk terhadap batuan, kajian terperinci terhadap struktur geologi yang merangkumi sesar, fold dan joint terhadap *Bentong Raub Suture Zone* yang merupakan indicator yang terbaik dalam menganalisis ubah bentuk. Kajian yang dijalankan di Kawasan lebuhraya kilometer 185 Gua Musang – Cameron Highland, Lojing, Kelantan ini merupakan salah satu kajian yang tidak pernah dijalankan oleh mana-mana pihak sebelumnya berkaitan dengan ubah bentuk tektonik. Kawasan kajian kali ini merangkumi keluasan 25km^2 dengan berfokuskan kepada objektif utama iaitu menghasilkan peta geologi bagi kawasan kajian dengan skala 1:25,000 dan menghasilkan peta struktur dengan berpandukan kepada keputusan yang diperoleh daripada kajian sesar. Dalam menghasilkan kajian ini, matlamat yang paling utama adalah untuk menggunakan ukuran geometri batuan bagi mengetahui, mengenalpasti dan mencapai matlamat berkaitan dengan sejarah yang terdahulu dan memahami bidang tekanan yang mendorong kepada struktur geologi yang boleh di temui di kawasan kajian pada masa kini. Bagi memastikan kajian ini berjalan dengan lancar, kaedah yang digunakan adalah dengan membuat kajian dengan lebih terperinci terhadap kajian yang terdahulu dan mengumpul segala maklumat yang berkaitan sekaligus menggunakan segala maklumat yang ada untuk diproses dengan mengunakan perisian ArcGIS 10.8 untuk menghasilkan peta geologi dan Dips 7.0 untuk mengumpul dan memproses segala maklumat berkaitan dengan tekanan bagi penghasilan peta struktur. Berdasarkan kepada kajian yang dilakukan, terdapat tiga jenis batuan yang boleh diklasifikasikan mengikut umur batuan iaitu batuan syis, filit dan kuarzit. Terdapat dua jenis sesar yang dapat dikenal pasti dalam kawasan kajian iaitu sesar menaik dan sesar mendatar yang terjadi di Kawasan Timur – Barat sekali gus merungkai jawapan kepada perubahan ubah bentuk tektonik yang mana sepadan dengan tekanan utama daripada pembentukan *Bentong Raub Suture Zone* yang terhasil disebabkan oleh pertembungan antara dua plat tektonik iaitu Sibumasu dan Indochina semasa Akhir Palaeozoik dan Triasik.

Kata kunci: Ubah Bentuk Tektonik; Sesar Naik; Sesar Mendatar; Formasi Gua Musan

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CONTENT

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LIST OF ABBREVIATIONS

N	North
E	East
W	West
S	South
KM	Kilometer
CM	Centimeter
M	Meter
GIS	Geographical Information System
FELDA	Federal Land Development Authority
FELCRA	Federal Land Consolidation and Recovery Board
DOSM	Department of Statistic of Malaysia
JMG	Department of Mineral and Geoscience Malaysia
e.g	Example

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LIST OF FIGURES

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LIST OF MAPS

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LIST OF SYMBOL

º	Degree
‘	Minute
“	Second
%	Percent
<	Less than
>	More than
μ	Micro
ε	Strain
δ	Strain rate
σ	Sigma
ºC	Temperature
c	Cohesion
Pa	Pascal
Km^2	Kilometer square
Mi^2	Miles square

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LIST OF TABLE

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CHAPTER 1

INTRODUCTION

1.1 Background of Studies

"Uniformitarianism" or more explain about *"plate tectonics is the key to the past"*. Coming out with something more cynical thing, this research will be explain more about the historical of the Earth's and the process of been the most phenomenal area. This research will focus on area of South Kelantan, which is Gua Musang. Essentially, the understanding about the tectonic plate, is where there would be some process that come out to form the plate tectonic and the framework of it, the tectonic plate that generally known by the process of convergent and divergent process literally included oceanic ridge.

Rheology or deformation according to Ranalli, 2000 state that the tectonic deformation often happens when the movement of the Earth' surface affects the surface of rocks. It can be known by looking at the changes in the mode of bedding, volume, relative position, and internal structure of the rocks that was under the action of deep–seated forces. In given rise to a condition of unidirectional or multidirectional extension, compression or displacement towards the deformation. The evidence of this phenomenon can be seen in all three types of rocks which is: sedimentary, igneous and metamorphic rocks in form folded and faulted. Otherwise, in magmatic rock and schist it can be lead to reorientation or recrystallization of the constituent minerals.

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The tectonic deformation of towards fault study at area of Gua Musang – Aring was one of the initiation for other to study and get some knowledge of the deformation at this area were by studying in this area it could see the structure and the activity of the tectonic. Literally, some people understand that the Formation of Gua Musang – Aring were happen by the collision between Sibumasu – Indochina tectonic that were happen million years ago, after the years we can see the formation and development on that area. By the historical of this area after all of the phenomena that would happen like collision between two plate boundaries; Sibumasu and Indochina, there might be something different or changes that maybe happen because of the development now days. With advance in modernization, this has resulted in the opening of new areasto meet the needs of the local community. Because of that many changes would happen and the historical of the phenomena of the Earth at that area might be disappear or vanish from sight.

Deformation at Kilometer 185 Gua Musang – Cameron Highland would be divided several part by looked at the deformation by step of the age of the rock, in this area, the geologist believe fault that existed here could be divided by two part of the aged which is: Upper Triassic and Lower Jurassic where certain part and formation could happen in different way. For this research, it would be more focusing on Gua Musang Formation and maybe included a little bit of Aring Formation because of to find the correlation between this two formation and the other. By that time, Sungai Beruk Valley was the perfect area to understanding this phenomenon where it could be found some evidence of the deformation of tectonic activity that happen in this area.

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1.2 Study Area

This research will conducted about the tectonic deformation and depositional environment of Gua Musang Area which is will consist about the beginning of the forming of that area and study about all of the phenomenon that had happen through the age at this area. The study area was the place that are already prepared with some access from the government to help villagers in term of daily activities.

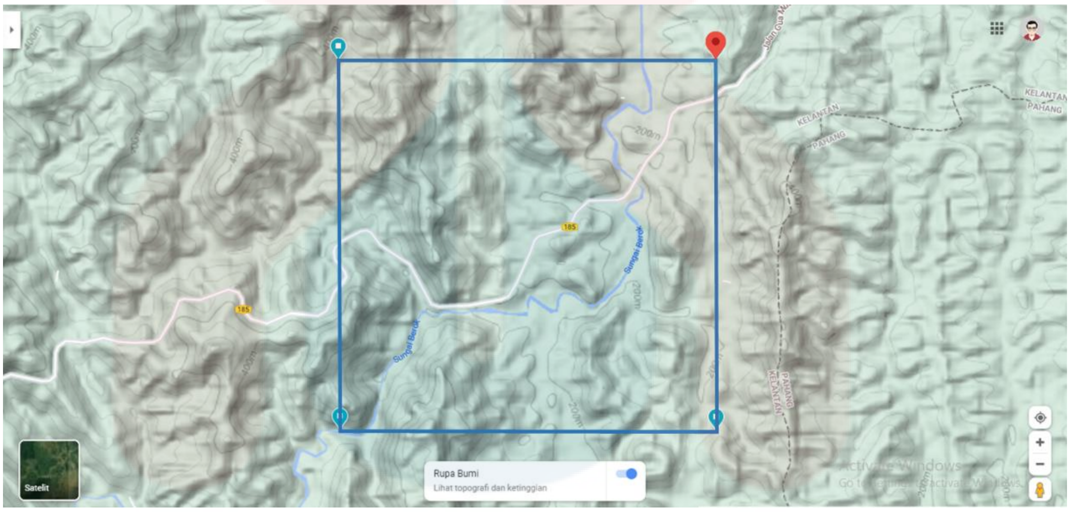

Figure 1.1: Terrain map of study area

1.2.1 Location

Lojing is located in Gua Musang Regency in Southern Kelantan Province with coordinate 4°43'00" - 4°46'00" N, 101°43'00" - 101°46'00" E, covered 25km^2 with dimension 5×5 km on scale 1:25,000. Technically this area of Gua Musang consists the stratigraphy that are correlated with Telong Formation. The Gua Musang area that form from Permian – Triassic Era that are consist of lot of the fossil and other rocks.

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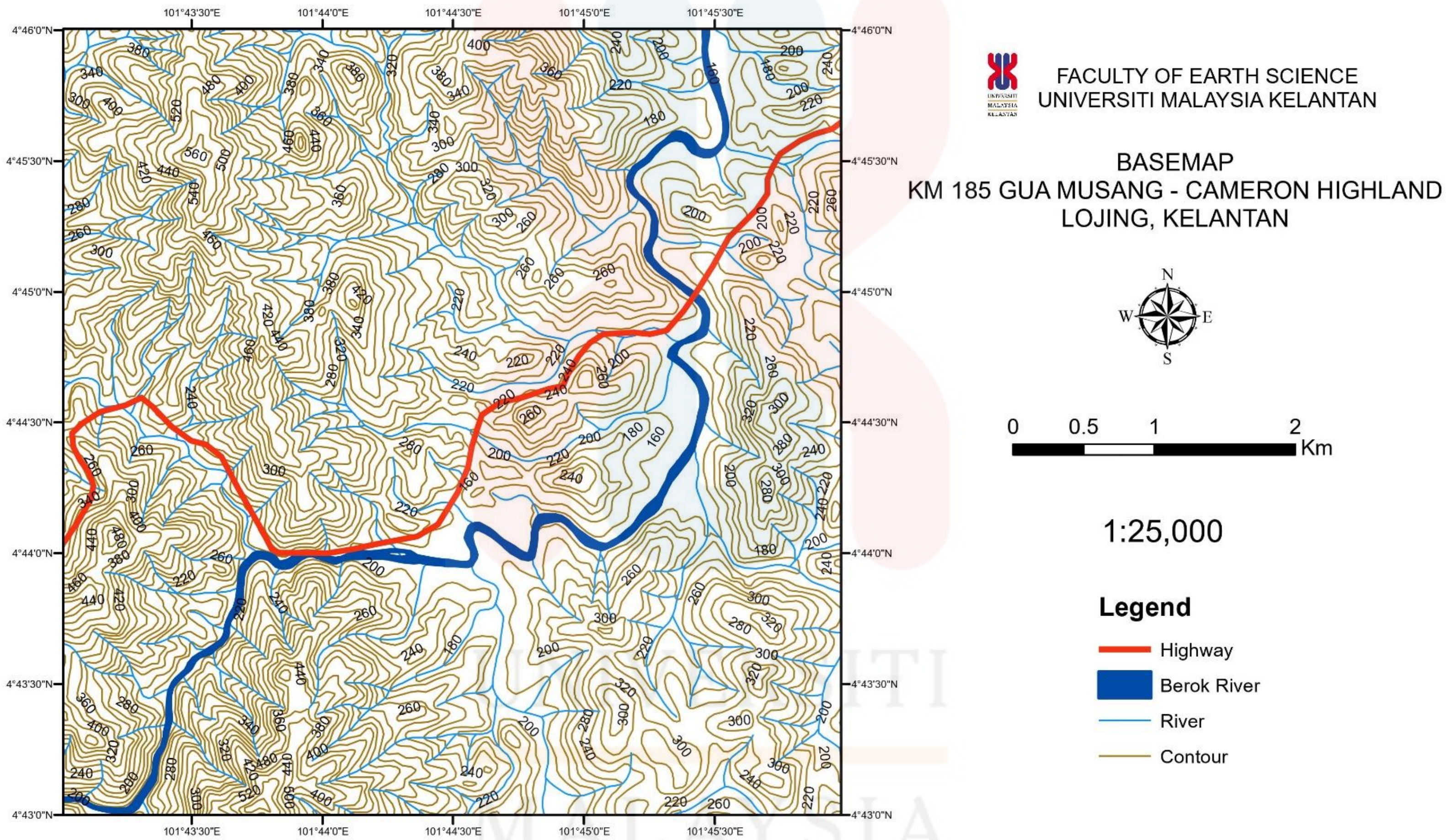

Map 1.1: Study area

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1.2.2 Accessibility

The study area are located on the highway where connected with two country which is Kelantan and Pahang. The highway that have been named as a Highway Gua Musang – Cameron Higland is one of the highway that have been used many people from Gua Musang to Cameron Highland. With this accessibilities community get the facilities for daily activities for some work that needed to explore and discover in the way to get on the destination. The road that connected to Cameron Highland which is it is one of the resort area and tourist attraction in area of highlands.

1.2.3 Demography

Refer to the government agencies which is by Department of Statistics of Malaysia, there are 32.73 million humans that are live in Malaysia from 14 state and about 1.89 million people are from Kelantan. By the statistic from Department of Statistic Malaysia (DOSM) state from the latest statistic show the population in Gua Musang is 86, 189 which is 4.6% from Kelantan population where it is divided by 64,253 (74.55%) Malay, 12,570 (14.58%) Chinese, 350 (0.41%) Indian, 161 (0.19%) other ethnic like Orang Asal (Indigenous People) and about 4,985 (5.78%) Non Permanent Residents where some of them come from other country like Thailand, Indonesia, Myanmar, Philipine, Bangladesh and others where they come here for works.

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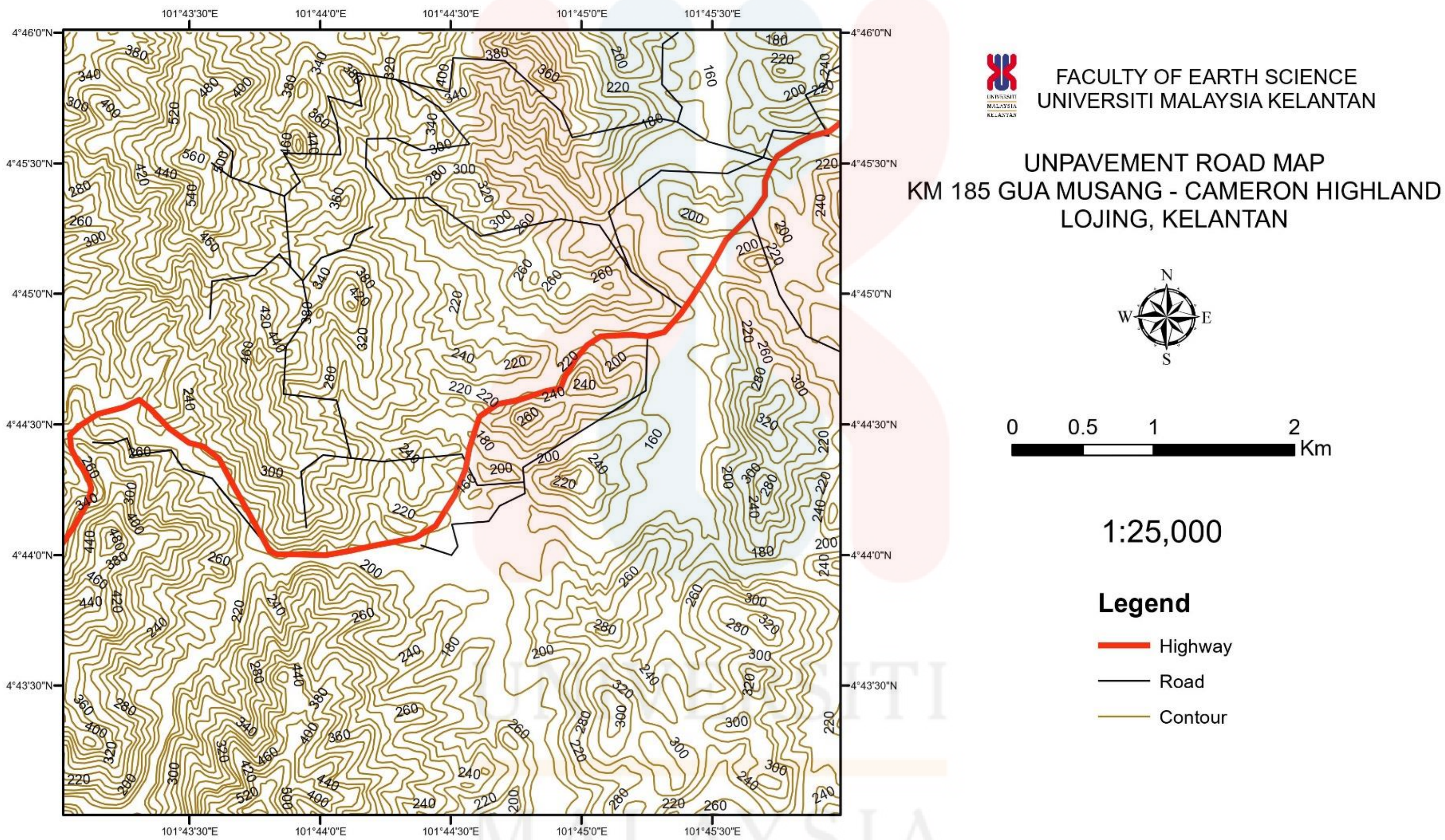

Map 1.2: Accessibility in study area

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1.2.4 Landuse

Basically, in this area are population of Orang Asal (Indigeneous People) where they usually work on farming the some herbs and other plantation for daily uses other than for sales to the community on Pos Blau and surrounding area. Beside, refer by Department of Statistic of Malaysia (DOSM) stated that on this study area also have oil palm plantation and rubber plantation from one of the largest company operator from Federal Land Development Authority (FELDA) and Federal Land Consolidation and Recovery Board (FELCRA). Other than that, there also have some development in term of the tourism community where on Jeram Gajah is one of the tourist attraction where it is all about the waterfall that flow on that area.

1.2.5 Social Economic

Obviously, on this study area, the social economi is more focusing on two different part by two community where can be seen the first community which is the developer with the high company will develop on plantation area and tourist area beside providing job opportunities to the community especially to the villagers. Second community is Orang Asal (Indigeneous People) is where they will develop and create the peace situation between them where their do the norm of their population doing a long time ago like farming, fishing and other. Sometimes this area and the community also can be one of the tourist attraction to know and understand more about archipelago community.

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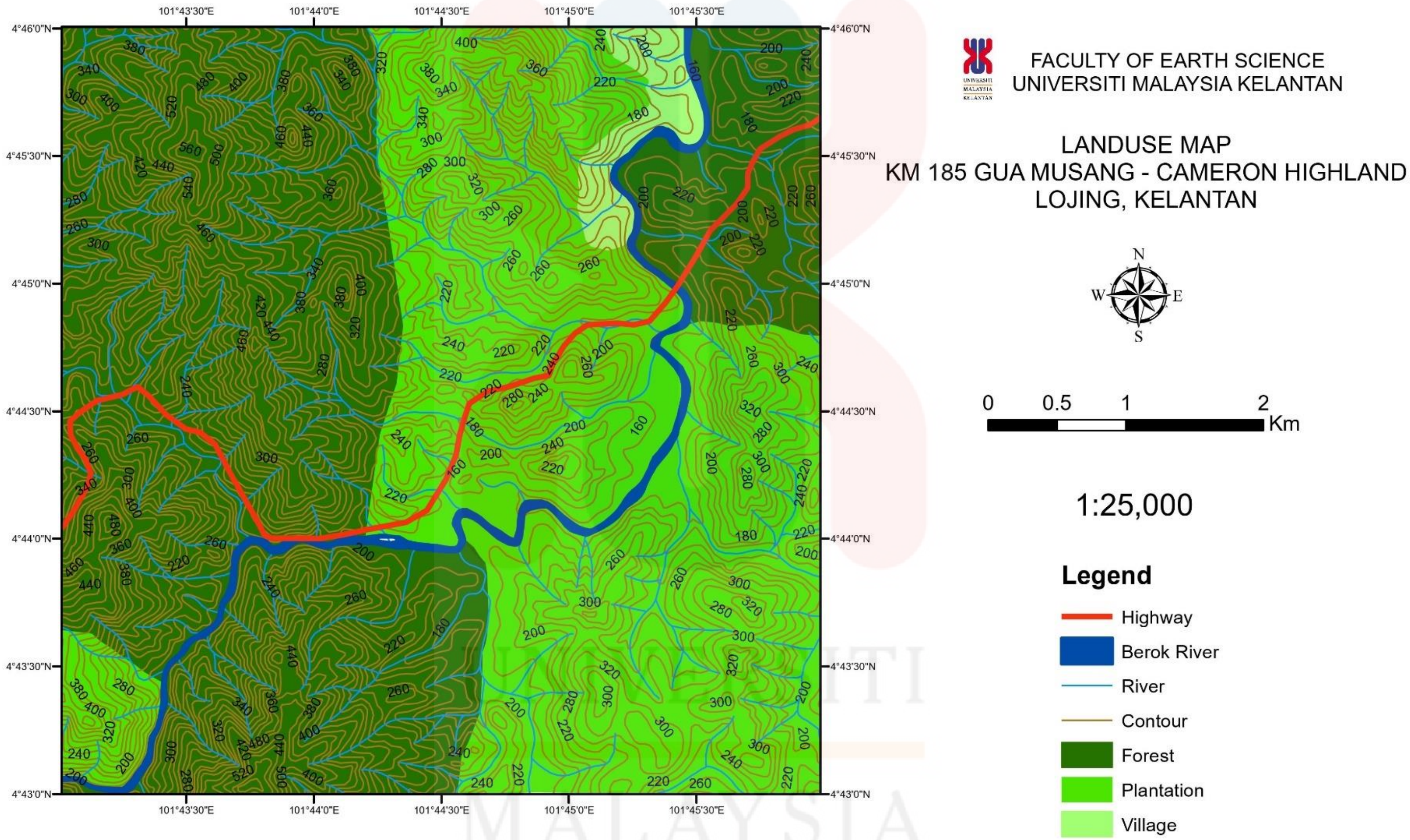

Map 1.3: Landuse map in study area

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1.3 Problem Statement

Development in rural and urban area is one of the method for being a successful area of any territory area, for being most iconic place for combination of handmade product and manmade area for plantation and development study. The fault that consist in between 3 corner of Gua Musang Formation, Aring Formation, Telong Formation was placed that are popular with highway road that were connect between Kelantan Colonies and Pahang District.

Lojing, where the study area was located are the area where connects Kelantan and Pahang is slated for future developments to increase the standard of living of the local community that stays close by. However, from the previous research there is no comprehensive geology and structural ananlysis that have been updated on the study area. Meanwhile, some of the studies that been conducted in this study area, there's are less related on the structural analysis that discuss on tectonic deformation.

This research would be one of the advantages for make an updated data for geological map and the development for that area. In fact, with this research also can be identified the potential area for development method and rural placement for the better life in future. Moreover, from this research also would conducted about an updated towards tectonic deformation and depositional environment on study area where the goal of this study are more to analysis to use measurements of presents rock geometries to discover some information about the Eart's history on that area and understand about the stress field that will be proven by the observation on structure.

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1.4 Research Objective

i. Generate a geological map in the study area through the interpretation from secondary data process.

ii. Produce a structural maps by analyzed using stereonet to see the fault density and stress system.

1.5 Scope of Study

Focusing on the general geology where to identify the structural geology, geomorphology and stratigraphy will come out with the geological map of Gua Musang, Kelantan. There is where the process of doing this research will be use the method where focusing on analyzing, conducting and interpretation of the data. Besides, the research also will be conducted in measurements and analysis on their structure to updated the information of deformation history of the rocks while more understanding about the stress that could be the references in the future. From this research, the data that have been collected will be analyzed by using two different application which is Dips 7.0 for identify the potential deformation and analyzed the bedding planes, fold planes, fault planes and joint. Other than that, ArcGIS 8.0 will be used in updated the geological mapping on the study area and classify the lithology for the rock unit.

The secondary data like dips, dip direction, strike and joints from previous research and collected data from other agencies will be taken for determine the direction of the principal stress of the deformation.

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1.6 Significance of Study

This research will conducted the geological mapping by using the topographic map with scale 1:25,000. By doing this research, it will provide the geological structure, rock identification for confirmation and study of the formation on study area. Focusing on the deformation, this research will updated the latest geological structure of tectonic deformation of Gua Musang and recover the lacking data from the previous mapping. In fact, after the research, the geological map can be used to the society, geologist, student and government for the development of surrounding area.

Otherwise, for proper planning and construction development, Stereographic analysis will be used for collecting the data and interpret the data collection for more identification of the best and low risk for development area and can prevent from any disaster like earthquake, flood, landslide and others. For development and plantation area like Lojing, is a big opportunity for this study because it will give some of awareness of risk assessment and potential of hazard. Beside, other than that, this research also can be used and acknowledge for identification of mineral and classification of rock also will be done by using the application of science where all the sample will be bring to the laboratory for experiment.

Beside, to support the study, data would be collecte from the previous research and previous study which is located at the same place, Lojing. The data collected will be supported with some significant result that considered the location and study that purposed on that area.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Generally, this research explain about the tectonic deformation that happen to the rock by certain elements and phenomena that causes the deformation happen. Literally, the deformation happen because of the stress and strain that pressure the rock other than the temperature happen on the rocks. The deformation can be detect by studying about the brittle or ductile deformation with some of the experiments towards the rocks. By this research it would explain about the deformation phenomena that happen on when continental crust exploid and how the continental drift affect to the deformation of the rocks.

2.2 Regional Geology

Earth's history shows the some magnificent occurrence of formation of tectonics plate and the whole of the universe. The tectonics plate were one of the prestigious thing that happen on this Earth's surface. Beyond the years, that are many revolution and formation are built in term of the miracle process of the the Earth's. This activities not just happen in certain area but it is include the whole of the universe include the Peninsular Malaysia. The Peninsular Malaysia is form by collision of two huge terrences which is Sibumasu and Indochina to form

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Bentong Raub Suture at the end of the Permian. By the beginning of Mesozoic Era, uplifted and subaerially were exposed at Peninsular Malaysia (Lee, 2008).

These occur a continuous outcrop along the axial belt running from the north in the state of Kelantan to south state of Johor (Khoo, 1983). The uplifting of the blocks craft the two areas of marine sedimentation, namely the northwestern Kodiang – Semanggol Depocenter (Lee, 2008) and Gua Musang – Semantan Deponcenter is the Central Belt of Peninsular Malaysia where it shows that it was the largest deponcenter built on the Easetern Province's Upper Palaeozoic shelf deposits and consisted of Peninsular Malaysia Central Belt and Eastern Belt.

According to the Yin (1963), approximately 250 mi^2 were occupied a surface area by Gua Musang formation. Where its predominantly in south Kelantan where located of Gua Musang area contain with argillaceous and calcareous sequence interbedded with volcanic and arenaceous rocks. The formation of Aring consists of dominant pyroclastic sequances which is tuff with a thin interbedded layer of argillite and marble. According to Yin (1995) Aring Formation predominant by volcanic where it is excluded from the Gua Musang Formation.

History of Malaya area shows that there are involve the contexts between two tectonic which are consists part of an orogenic belt extended northward through west Thailand, east Burma and southwest China and southward Indonesia. By Late Triassic orogeny and plutonism are been shown on this belt where tis belt are cratonized, so subsequently, by the part of Sunda Shield, Malay was formed and the recorded of geological history of Malaya started with Cambrian to Silurian orthoquartz-ite-carbonates fades, largely predating geosynclinals condition which apparently initiated in the later of Ordovician period. By the existence of the

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geosyncline, it comprised a eugeosynclinal zone where it located in the eastern and axial parts of the country and a miogeosynclinal zone situated on western Malaya. The succession geosynclinals was on an Ordovician to Lower Denovian euxinic facie swat the earliest to be known and the facies passes up into flysch od Middle Denovian to Early Carboniferous age.

2.2.1 Historical Geology

Gua Musang stratigraphy is classified on the lithology of the area and costamize refers to Department of Mineral and Geoscience Malaysia (JMG). For the study area was Aring location, were believed that Aring have the same lithology like Gua Musang were it consists by five types of lithologies which is limestone unit, interbedded sandstone, siltstone and shale unit, phylite, slate and shale with subordinate with sandstone and schist unit, felsic unit and also alluvium units.

Those of the lithologies are well grouped in Palaeozoic and Mesozoic were been looked at the age of the rock and the research before shows the same result as well. There was a carbonate platform on the East of the Gua Musang Basin which are rhought to have existed due to the Aring Volcaniclastic deposition. In fact, with the fantastic fossil from the family of brachiopods and fusulinids in marble outcrops, shows that the shallow water depositional environment emerges with the fossil where instability continued and its affected the southern margin that cause the basin to experience higher subsidence rates and being posed by the outliner shallow water limestone.

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2.2.2 Structural Geology

Gua Musang Formation happen because of the collision between Sibumasu plate and Indochina plate, from this collision there woul happen some part that called structural geology. In structural geology it will be discussed about faults, folds, joints and the other structure in the lithosphere and also on the occurence the formed of the site. In peninsular Malaysia it is be divided into terranes which from Sunda shelf which is Eurasian plate – Indochina and Sibumasu (Shan Thai) terranes. The evidence in identified this two terranes can be see on Bentong – Raub Suture Zone where from the nortwards subduction of Palaeo – Thethys Ocean underneath Indochina in the Late Palaeozoic and Triassic collision of the Sibumasu terrain with under thrusting of Indochina.

In the middle Permian the oceanic sediments were occur with indicates that the Palaeo – Tethys was devided into two depositional basin where in the Western Belt, there are Semanggol basin while in the Central Belt there are Semantan/Gua Musang/Aring basin which these basin were separated by Bentong Raub Suture Zone. Meanwhile, the Bentong Raub Suture were extension to the north and south speculatively since the exposure is limited only to Bentong – Raub and Kuala Lipis area.

2.2.3 Stratigraphy

Western part of Southern Kelantan were distributed by the Lower Palaeozoic Rocks of Bentong Group that are distribution of the Permian and Triassic sedimentary rocks, meanwhile in East of Kelantan were found the

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sedimentary rocks that are from Jurassic – Cretaceous (Kamal Roslan, 2006). Raub Group in Pahang and Kepis Beds in Negeri Sembilan on the Western part of the Central Belt was affected by Upper Palaeozoic rocks of Gua Musang and Aring Formations in South Kelantan and Taku Schist in East Kelantan, to the South are Raub Group in Pahang and Kepis Beds in Negeri Sembilan. The Upper Palaeozoic consists mainly of argillaceous strata and volcanic rocks with subordinate arenaceous and calcareous sediments with occasional submarine valcanism from the Upper Carboniferous towards Permian to Triassic. In South Pahang and Johor, the Lower Triassic lava was unconformably overlies on Permian phyllite by indicating a transfer from submarine to subaerial volcanism in there.

In Kelantan, there are seven formation that are built up in stratigraphy record, there are Aring Formation, Taku Schist, Gua Musang Formation, Telong Formation, Gunung Rabong Formation, Koh Formation and Badong Conglomerate. During the Palaeozoic Era, Aring and Taku Schist were formed while the others are formed during Mesozoic Era. Aw on 1976 were introduced Aring Formation in the Sungai Lebir Valley, which is the lower reaches of Sungai Aring and Sungai Relai in South Kelantan consist a mainly predominant of pyroclastic series. On late Carboniferous to Early Triassic was ranging age where it is indicated by fossil evidences. The upper layer of interbedded with slate or limestone, there are formed as the Paloh member where the entire formation reported about 3000m of total thickness and 1000m. Although the Koh Formation was overlain the Telong Formation was unconformable and inaccessible. Sungai Relai and Sungai Nuar was the type of locality where it is tributaries of Sungai Lebir where the unit named after Sungai Aring that are another tributary of Sungai Lebir.

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The Triassic lies conformably on Permian in southern Kelantan (Aw, 1990). Probably, Aring Formation are forms uncomformable contact with Koh Formation to the south area. The Aring Formation stratigraphy reveals that the connection between Gua Musang Formation and metasediments in Southeast Pahang (Lee, 2004). Throught the stratigraphic range is unclear that the Raub Group together with the Pahang Volcanic (Aw, 1990). In fact, the Aring Formation stratigraphic equivalent is seen in East Johor which is Sawak metasediments and Dohol Formation (Aw, 1990).

2.3 Sedimentology

Central belt of Peninsula Malaysia shows the formation that formed between Permian to Jurassic age at the Central Belt's Paleozoic rocks that as a linear belts flanking Mesozoic sediments were consist with consist Permian clastics with Carboniferous limestone outcrops. The western region of Central Belt consisting of Gua Musang and Aring Formations upon Upper Paleozoic rocks in southern Kelantan and Taku Schist in eastern Kelantan, while in the south is the Raub Group in Pahang and Kepis Beds in Negeri Sembilan. Primarily, the argillaceous strata and volcanic rocks are deposited in a shallow-sea environment on Upper Paleaozoic rocks with subordinate arenaceous and calcareous sediments, with sporadicsubmarine volcanism starting from the Upper Carboniferous and peaking from the Permian to the Triassic. Southern Pahang and Johor, the Lower Triassic lava overlays unconformingly marking a change from northern to southern underwater volcanism (Hutchinson & Tan 2009).

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Generally, the marine Triassic sediments upon Central Belt are more tuffaceous related to the Western Belt rocks of the same age (Mohd Shafeea Leman, 2004) and Aring Formation, Telong Formation, Nilam Marble Formation and Koh Formation, respectively with mapped the Aring area are four formation that have been divided, Aw (1990). In Kelantan and northern Pahang, the Permo-Triassic which is Aring, Gua Musang and Gunung Rabong Formations consist primarily of shallow marine groups and volcanic interspersed carbonates, while deeper marine turbidite sediments are more prevalent in the Telong Formation to the south. (Mohd Shafeea Leman, 2004).

It is believed that Upper Permian-Upper Triassic age is Telong Formation, which overlaps Gua Musang Formation. The rock sequence of this formation consists mainly of thin tuff, andesite argillite and marble. The ammonoid assembly suggests the 240 – 220 million years ago on Middle – Late Triassic period (Hussain Zakaria *et.al,.* 2008) and belonged to the province of Tethyan, (Dony Adriansyah Nazaruddin *et.al,.* 2014).

Two sedimentary rock outcrops of Telong Formation found middle triassic ammonoid fossils. The outcrops are located along the road between Gua Musang Town and Kuala Berang in Felda Aring 5. These two sites contained two ammonoid assemblages associated with the Tethyan region's Standard Ammonoid Zone (Ahmad Rosli & Mohd Shafeea, 2010). In thin layers of dark grey tuffaceous Telong Formation mudstone formed from mud deposited in a deep-water marine environment, a large assemblage of ammonoid fossils was found. Other fossil fauna along with these are cephalopods where also include some bivalves and crinoids (Mohd Shafeea Leman *et. al,.* 2008). Some discovered fossils recorded from this region are include molusc fossils like ammonoids, bivalves and

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grastropods with brachiopods where represented to the The Middle Triassic – Anisian period, (Ahmad Rosli & Mohd Shafeea, 2010).

Palaeo-Tethyan oceanic ribbon-bedded cherts preserved in the suture area in age ranges from Middle Denovian to Middle Permian and me'lange includes chert and calcareous clast ranging from the Lower Carboniferous to Lower Permian. Triassic limestones are commonly distributed in the Central Belt of Peninsular Malaysia, according to previous discoveries (H. Fontaine, 1995).

2.4 Regional Tectonics

Theory of the Earth by James Hutton, 1795 stated by Windley, 1995 in his journal describe that *"uniformitarianism"* refers to *"plate tectonics is the key to the past"*. It is because, plate tectonics was one of the paradigm that can be applied convincingly back to the beginning of the geological history by understanding of the Earth's process, where by time, the process of tectonophysical and geochemical process was one of the greater heating production. In this process of plate tectonics, oceanic and continental rock were produced to perform the tectonic boundaries. Simple words, studying the plate tectonic is refers to the structure, formation, setting and evolution of the tectonics plate where definitely show the whole of the geological history from the beginning of the Earth until present.

On behalf of Charles Lyell, (1836, 1837) on his books, *Principle of Geology* through Windley, 1995 state that uniformitarian was the ancient changes of animate and inanimate world where can be find memorials in the Earth's crust, it could be the similar both in kind and degree to those which are now in progress. According to Bailey, 1962, Lyell conduct others to understand the term *"from the*

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known to unknown" where there started with the recent and worked backward. Logically both between Hutton and Charles totally want describe that to know the beginning of the Earth's history with investigate and know more about the tectonic is where do start from the learn about continental drift or oceanic ridges and how it become the movement of the plate tectonics to form all the fantastic creature of environment by this phenomena where its build the highest mountain of Himalaya, the historical of geyser in Iceland

There are two types of plate tectonic where each types of plate boundary generates distinct geological process and landform (Hutton, 1795, Windley 1995): divergent boundaries and convergent boundaries. The divergent boundaries are where the plates separate to form a narrow valley by the time it will also forming a new crust from the solidies that are from the basalt but it will never really separate because the magma continuously move up from the mantle into the boundary and build a new plate material on both side of the plate boundary. The convergent boundaries is the plates that collide with one another where the collision buckles of edges of one or both to forming and creating the mountain range where there were subducting one of the plates under the others that can made up the subduction zone with deep trenches.

The *Theory of Plate Tectonics* by Jackson 1994 in Kearey, Klepies & Vine, (2009) books *Global Tectonic* state that the Earth's solid outer crust where the lithosphere will separated into plates that moves over the asthenosphere. The molten upper portion of the mantle and the oceanic and continental plates come together, spread apart and interact at boundaries all over the planet. Obviously, can be define that the tectonic plates boundaries have diverged, converged and reshaped the Earth's throughout the geological history where can be able to

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observe, and measure the raising and eroding the mountain, expanding and shrinking of the ocean, volcanoes erupting and earthquakes striking.

2.4.1 Convergent Boundaries

This boundaries Only deep-sea trenches and associated 'subduction zones' exist in the strict plate tectonics sense. Regions of active mountain building on continents (e.g. Alpine-Himalayan zone) are plate convergence zones which are characterized by broad and almost continuous deformation zones. This is partly because the continental lithosphere is softer and harder to deform than the oceanic lithosphere, and partly because it is less thick and subduction is not easily removed. Plate tectonics does not give these large continental convergence zones a very useful explanation.

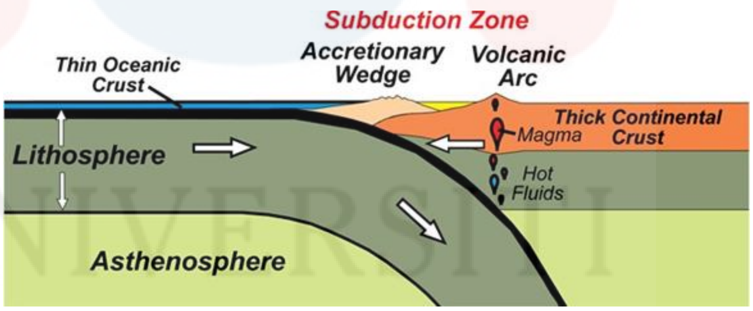

Figure 2.1: Subduction zone in convergent boundaries

Where one of the converging plates consists of oceanic lithosphere, the other can overtake it and, in a phase known as subduction, force it down into the asthenosphere. This can happen since the oceanic lithosphere (unlike the continental lithosphere) has a similar density to the asthenosphere underlying it. If both plates are oceanic, either one may be subdued under the other, and often the 'polarity' of subduction may reverse depending on local conditions (i.e. the subdued plate breaks off and eventually becomes the overriding one, while the overriding one starts to subduct). The plate boundary at a subduction zone is marked by a deep trench, the deepest and perhaps most prominent of which is the western Pacific Mariana Trench, whose base is more than 11 kilometers below sea level. It is deformed, when the slab subducts, and causes earthquakes. Such occur in a narrow band, known as the Wadati – Benioff line, which matches the subducting slab location and is some of the best evidence of the presence of subduction zones.

Subduction zones are rather complex and involve both compression deformation which primarily at the actual boundary of the plate and at the leading edge of the overridinf deformation in local areas where maily with the subductiong plates bend to begins its descent. This is reflected by earthquake mechanisms, and also show variation in mechanism with depth in the subducting plate. Many of the world's largest earthquakes apply to area of subduction where it heats up and gives off the water trapped in the crustal rocks as the slab goes down. The presence of this water decreases the melting point of the surrounding mantle and magma is formed at a depth of about 100 km that rizez to create a volcanic arc which a hundred kilometers or so behind the trench through the overriding plates where it is depending on the angle at which the slab descend. The theory of plate tectonics allows oblique subduction as with ridges and normally relative.

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2.4.2 Divergent Boundaries

This boundaries often occur on the mid-ocean ridges, which are the sites of the formation of new lithosphere by the spreading of the seafloor. Typical examples are the Mid-Atlantic Ridge, and East Pacific Rise. Extensive tectonics dominated by the natural faulting and extensive local mechanism form the earthquakes define these limits. The separation or spreading direction of the plate is generally approximately orthogonal to a divergent plate boundary but this is not sufficient and there are relatively common ridges of greater or lesser degree of obliquilty.

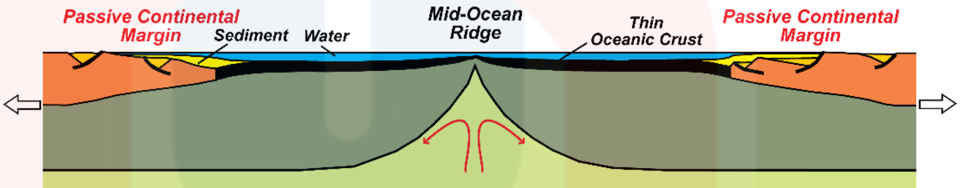

Figure 2.2: Mid-Ocean ridges by divergent boundaries

As the new plates is formed at the boundary, the mid-ocean ridges associated with these boundaries of the plates emerge, hence, the plate grows older with increasing distance from the boundary of the plate and as it does, cools becomes denser and thermally contracts. The plate boundary is therefore the region's youngest, hottest, and shallowest, forming the mid-ocean ridge crest. Detailed plate boundary morphology tends to depend on the temperature of the underlying mantle, which is regulated mainly by the rate of spread. For 'slow spreading ridges' (with a plate separation rate of less than about 60 km per million

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years), there is usually a 'medium valley,' a few kilometers deep and a few tens of kilometers wide, formed by rifting.

To support rifting at ‘fast spreading ridges where it is separation greater than 70 km/million years, the plate is too hot and thin with then there is a high axial volcano formed. Ridges are formed at depths of approximately 60 km by melting the dry mantle, releasing basaltic magma. Basaltic volcanism is widespread at the borders of the mid-ocean ridge plate. Plate tectonics theory makes it possible to spread asymmetrically as one plate accreting more rapidly than the other. The average net effect over millions of years is usually around symmetric, although transient asymmetric spreading is common.

2.4.3 Transform Boundaries

This boundaries are those where plates slide past each other with essentially no convergence or divergence; thus, they preserve the adjacent plates' areas. Because of this, they have significant property that they are precisely parallel to the direction of the relative plate motion and can be used to approximate it. Transform boundaries are defined by earthquake strike-slip faults and strike-slip mechanism. The San Andreas Fault Zone in California, USA is a typical example of a transform boundary.

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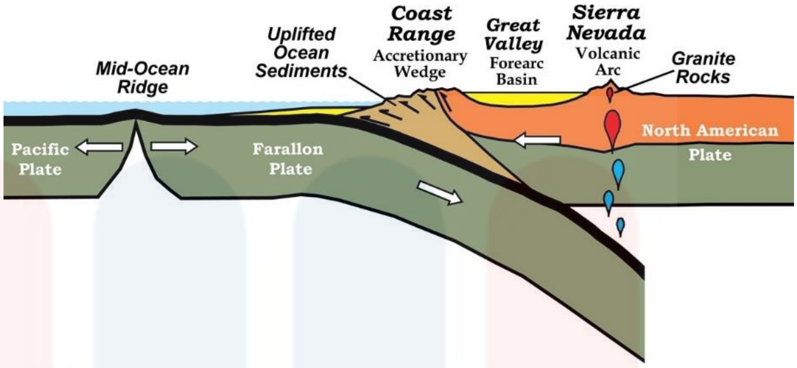

Figure 2.3: Transform boundaries

A transform boundary consists of a single fault called ‘ transform fault’ in the plate tectonics theory, but there is sometimes a region of such fault a few decades wide in practice. Since there is no large-scale convergence or divergence at these boundaries, there is also very little verticle relief while tiny valleys and scarps normally mark the trace of the transformation fault itself. Transforms link other boundaries of the plate, and can thus 'transform' one type of tectonic boundary (e.g., extensional) into another (e.g., compressional) hence the name. many transformation faults offset the mid-ocean ridges creating an alternating ridge staircase pattern and transforming boundaries. The length of such offsets varies from a few tens kilometer to over 1,000 kilometers. Boundaries of transformation occur in both continental and oceanic lithospheres.

Roughly there, from this research it is more concern about the deformation and tectonic on Gua Musang area which is include all the tectonic setting that happen from the existence of the Gua Musang Formation.

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2.4.4 Normal Fault

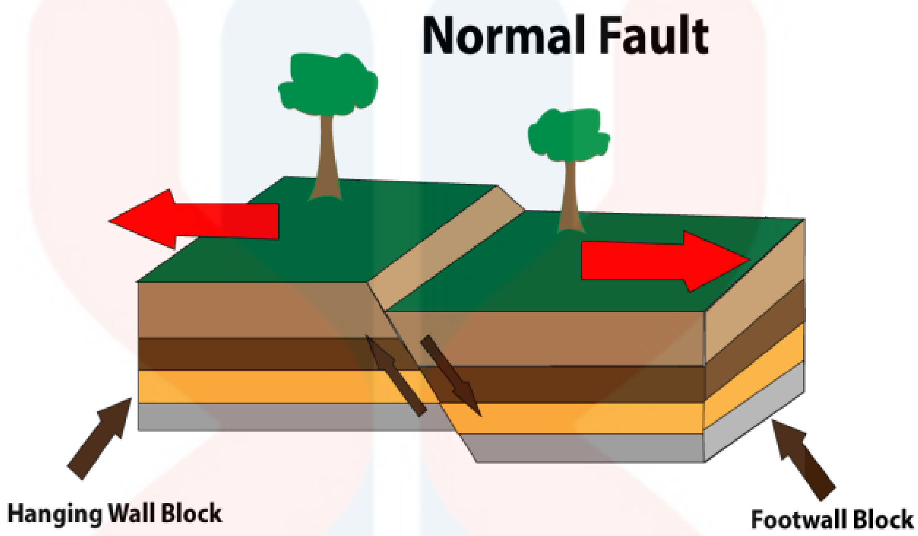

Figure 2.4: Normal fault

Normally, it is the fault where the hanging wall has been sliding down compared to the footwall. Normal fault can dip at any angle. Average high angle faults normally dip between 50° and 70°, and show fairly straight topographical traces. Detachment faults (a special class of normal low-angle faults) can, however, dip below 30° and closely conform to topographic contours (Rowland *et. al*, 2007) . Usually, normal faults position young rocks in the hanging wall against older rocks in the footwall, that is, the fault dips towards the *younger rocks* (Rowland *et. al*, 2007). Depending on the angular relationship between the fault and bedding, normal faults may cause strata to be skipped across the fault (Rowland *et. al*, 2007), or the repetition of strata across the fault.

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2.4.5 Thrust Fault

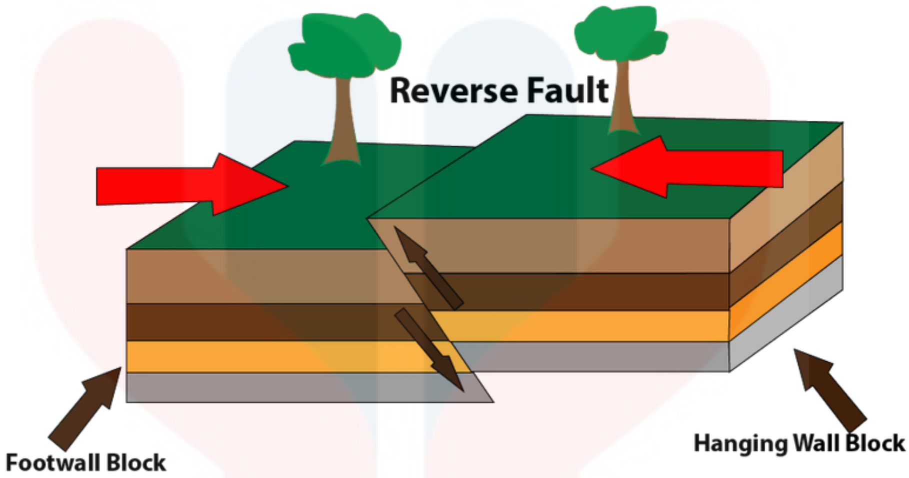

Figure 2.5: Thrust/Riverse Fault

Generally, this fault is a reverse low-angle fault, usually dipping below 30°. Thrust (reverse) faulting allows older rocks to be put on top of younger rocks, — for example the fault dips into older rocks. This results in strata being replicated through individual faults. Faults in thrust (reverse failures dipping at angles less than 30°) will carry fairly thin sheets of rock over distances measured in tens of kilometres. Often a part of a thrust sheet travels farther than an adjacent section, leading to a tear fault forming. Tear faults are strike-slip faults confined to the upper plate (hanging wall) of the thrust which they strike parallel to the direction of movement. Erosion can substantially alter the original extent of a thrust sheet, sometimes creating erosional windows *(fensters)* and isolated outliers *(klippen).*

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2.4.6 Strike – Slip Fault

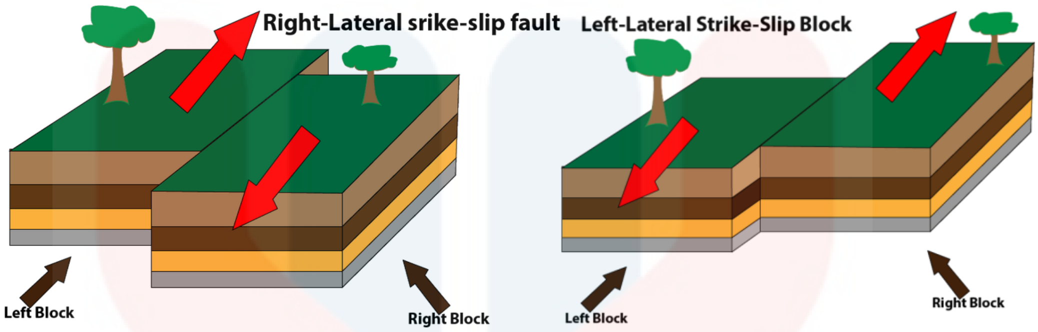

Figure 2.6: Strike slip fault (right and left theory)

Basically, it is the fault where the movement is parallel to the strike of the fault plane. It is also can be known with *wrench faults, tears faults and trancurrent faults* (Rowland *et al.*, 2007), are where the right-lateral (dextral) strike – slip fault is one in which the rocks on the fault block appear to have moved to the right when viewed from the other fault block while the left – lateral (sinistral) strike – slip fault reflect the opposite sense of displacement (Rowland, *er al.*, 2007). Strike-slip faults are characterized by vectors with horizontal slips. Strike-slip faults usually not always display dips greater than around 70°.

If there is no differential vertical motion over a single strike-slip fault, there are no predetermined age associations between rocks on those faults' opposite sides. Note that strike-slip fault in a horizontal strata region does not produce an offset in map view (Rowland *et al.*, 2007). If old and young rocks on both sides of a high-angle fault occur in a non-systematic manner, the possibility of either strike-slip fault or a complex , multi-phase deformation history should be considered (Rowland *et al.*, 2007).

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2.5 Tectonics Deformation

Rheology refers to study of the deformation and the flow of materials under the influence of an applied stress (Ranalli 1995, Kearey *et al.*, 2009). When the temperature, pressure and magnitudes of the applied stresses are relatively low to form fractures and faults, the rock appears to crack along the distinct surface. (Kearey *et al*,. 2009). Commonly when it is under the action of deep-seated forces, the tectonics deformation will change in mode of bedding, volume, internal structure or relative position of body of rock and it will be rise when give the condition or unidirectional or multidirectional extension, compression or displacement of the rocks.

Mostly, it can be seen clearly in sedimentary, igneous and metamorphic rock in the form of various folded and faulted distribution of the rock initially horizontal bedding. To define and study about the deformation, there some term or calculation that might be used for identified towards the surface that form fracture and faults where it is related to deform ductile flow which is directly to the high of rocks tend. The strain will be measure to quantify the deformation.

Stress (σ) and *strain* (ε) is a mathematically relevant concepr to be used to measure the deformation in which *stress* is defined as the force exerted by per unit area of a surface in *Pascal's* (Pa) and *strain* is defined for any changes in term of shape or size of a material (Kearey *et al.*, 2009). Usually, the stress acting on a surface that can be conveyed perpendicular to the surface in normal stress and shear stress that has two components of the planes surface. There are mutual used called $\sigma_{1,}$ $\sigma_{2,}$ σ_3, referring to the orthogonal maximum, intermediate and minimum principal stresses that are orthogonal. If the positive value refers to comprehensive

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stresses, the value of the result that comes out is defined and the the negative one is the state of tensile stresses where the difference in magnitude betweeb maximum and minimum is called *differential stress* and the deviation of the stress field from the symmetry was *deviatoric stress* (Kearey *et al.,* 2009). The value of the differential stress and the function of deviatoric stress was the degree and form of distortion experienced by the body, (Kearey *et al.*, 2009).

The law of Hooke been used on the strain in elastic materials which proportional to the stress and the strain was reversible before the critical stresses were reversible (Kearey *et al.,* 2009). The strain generally expressed in ration and changes in the structure of a solid as dicided by the originals of the length.. Typically, the deformation are divided into two types:

2.5.1 Brittle Deformation

Brittle fracture is causes by progressive failure along a network of the micro-scale and meso-scale cracks, Kearey *et al.,* (2009). The cracks is where the orientation relatively the applied stress that determine the location and magnitude of the local stress maxima. *Griffith theory* state that when the local stress maxima exceed the strength of rocks its will occur the fracture. In this theory also shows that the fracture well works under conditions od applied tensile stress or other principal stresses like compressional. It is happen when the magnitude of the tensile stress exceed the tensile strength by the material, it will shows the fail first upon to the crack orthogonal on this stress and an extension fracture occurs.

When all the principal stress are usually compressional hundred meter depth away, the behaviour of crack are more complex, Kaerey *et al.*, (2009).

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Owing to the increasing overload of pressure, the crack is likely to be fully closed at depths of >5 km under the compression. This means that the compressive strength of a material is substantially greater that the tensile stregth. Where all cracks are closed, fracturing depends on the material's underlying strength and the differential stress magnitude, Kaerey *et al.,* 2009.

In certain circumstances, the relationship between critical stress and normal stress exist on potential failure planes and the internal fraction coefficient on those planes that resists relative motion across them. Based on Kaerey *et al.,* (2009) stated the Mohr-coulomb fracture criterion can also be defined by describing the following linear equation:

$$|\sigma_s| = c + \mu\sigma_n$$

The resistance of the material to shear fracture is refer to the cohesion (c) that happen on plane of zero normal stress. Byerlee (1978) by Kearey et. al. (2009) state many rocks have nearly same cohesion friction within range 0.6 – 0.8. the written equation that utilizes the absolute value of critical shear stress enables the fracture to be symmetrical around the highest main compressive stress axis. (Kearey *et al.,* 2009). The pore fluid pressure improves fracturing and induces faulting at the fluid pressure depth by reducing the factional coefficient and counteracting the normal stress (σ_n) through fault which would tend to require very high shear stresses due to the high normal stresses, (Kearey *et al.,* 2009).

According to the theory of Anderson (1951) cited by Kearey et al., (2009), the type of fault that results depends on which of the principal stress is vertically under the compressional closed crack regime. Normal, strike-slip and thrust fault occur depending on whether σ_1, σ_2 or σ_3 respectively, is verticle (Kearey *et al.,* 2009). Theory may be conceptually practical, but it does not really explain the

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existence of certain fault such as low-angle of normal faults, where dips of about ≤ 30°, flat fault or faults that develop in previously fractures anisotropic rock are been seen, (Kearey *et al.,* 2009).

Confining pressure or the strength of rock that increase with the pressure of the surrounding rock, but decrease with temperature. The deformation of brittle solids can take form of cataclasis (Ashby & Verrall, 1977; Kaerey *et al.*, 2009). The effect is repeated shear fracturing, which decreases the rock's grains over each other.

2.5.2 Ductile Deformation

Ductile mechanism is the movement of crystalline solids deducted from metals which has the benefit to fast flow at the low temperature and pressure (Kearey *et al.,* 2009). Generally, when the temperature of a materials is less than about half its melting temperature (T_m in Kelvin), by following or slipping in the solid state, material are been react to low stresses. At high temperature and pressure, the strengthand flow of silicate minerals that characterize the crust (Tullis, 2002; Kearey *et al.*, 2009) and mantle (Li *et al.*, 2004; Kearey *et al.*, 2009) have been studied using experimental apparatus. According to Ashby & Verall. 1977 stated by Kearey *et al.*, 2007, several forms of ductile flow reported in the crust and mantel can occur and it depends on the ambient temperature and less importantly on pressure (Kearey *et al.*, 2009). When increased the pressure will produces a more sluggish flow while increased the temperature acts to lower the apparents viscocity and increase the strain rate (Kearey *et al.,* 2009). For ductile

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flow, the differential stress ($\Delta\sigma$) and the strain rate ($\delta\varepsilon/\delta\tau$) are related through a flow law of the form:

$$\Delta\sigma = [(\delta\varepsilon/\delta\tau) / A]^{1-n} \exp [E / nRT]$$

E : activation energy (assumed creep process)

T : temperature

R : universal gas constant

n : interger

A : experimentally determined constant

Plastic flow occur when the yield strength of the materials is surpassed and the movement takes place through gliding movements of large numbers of crystal lattice defects as individual bonds of neighboring atoms that break and reform through glide planes (Kearey *et al.,* 2009). This process where been called as *dislocations* where the process result in linear defects that separate slipped from unslipped parts of crystal. The movement of dislocation are controlled bythe the magnitude of the stresses that required to overcome the resistance of the crystal framework and makes the yield strength of materials deformed in that way (Kearey *et al.,* 2009). The strain produces tends to be constrained by the density of dilocations and the greater density, the more difficult it is for dislocation to move in the process known as strain or work-hardening (Kearey *et al.,* 2009).

Dislocation creep or *power-law creep* at temperatures in excess of $0.55T_m$ will takes place, by the form of creep the strain rate is proportional to the *n*th power of the stress where $n \geq 3$. Dislocation creep is the same as plastic flow where the deformation takes place by *dislocation glide* but the higher temperature allow the diffusion of atoms and positions unoccupied vacancies (Kearey *et al.,* 2009). *Dislocation climb* is the diffuse method in which barriers to the movement of

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dislocation can be eliminated as the shape but work-hardening does not result and steady creep is encouraged (Kearey *et al.*, 2009). *Dynamic recrystallization* results in the new creation of the new crytal frains from old grains due to the higher temperature, the yield strength is lower than the plastic flow and lower stresses resulting from the pressure. Other agree that power-law creep is an essential type of upper mantel deformation where convective flow is controlled (Weertman, 1978; Kearey *et al.*, 2007). According to Newman & White (1997) cited by Kearey et al., (2007) the continental lithosphere of deformation is governed by power-law creep with the stress exponent of three.

As a temperature, diffusion creep dominates and assumed to occur in the asthenosphere and lower mantel as a result of the migration of individual atoms and vancancies in stress gradient (Kearey *et al.*, 2009). *Nobarro-Herring* is the migration that occur along crystal lattice along with crystal boundaries that also be known as *Coble creep* (Kearey *et al.*, 2009) where this strain rate ($\delta\varepsilon/\delta\tau$) wth both modes of creep is propotional to the differential stress ($\Delta\sigma$) with the dynamic viscosity (η) being constant of proportionality. This relation is given by:

$$\Delta\sigma = 2\eta(\delta\varepsilon/\delta\tau)$$

Superplastic creed has been observed in matel and may also occur in some rocks. The result was clear that crystal sliding along the grain-bound aries where the motion occurs without opening gaps between grains and both diffusion and dislocation can be accomodate (Kearey *et al.*, 2009). The super-law rheology was associated with high strain rates with a stress exponent of one or two superplastic cree characterized (Kearey *et al.*, 2009). Some controlversioal was interpreted about the deformation in the lower mantel that contributes with the superplstic creep (Karato, 1998; Kearey *et al.*, 2009).

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2.6 Deformation Style

The fault that are located in border of the Central Belt is the Bentong Suture and on the Eastern Belt is the Lebir Lineament of Peninsular Malaysia is the divider for some of the formation in Malaysia (Tjia, 1889, Tjia 1996). The Lebir Lineament that consists in the north of the left lateral Lebir Fault zone but south of the latitude of Kuantan where the lineament poorly defined and comprises a wide zone of north-south faults (Tjia, 1996). Bouguer gravity and magnetic anomalies has indicated that southern part of the Lebir Lineament most probably coincides with newly named and north-south trending East tectonic zone (Tjia, 1978, Tjia 1996).

Based on the previous researcher there are believe that in Peninsular Malaysia there are the upper Triassic – lower Jurassic granitoids form the Main Range or Titiwangsa then these granitoids were emplaced during a strong orogenic event in Southeast Asia, named as the *"Cimmerian Orogeny"* that are normally domain by four geological that can be recognized based on the differences in structural patterns, ages of sedimentary formation, ages of plutons and types of mineralization's (Foo, 1983, Tjia 1996).

The Lebir Fault that are can be identified by these four geological domain might be can be used on the investigation of the sedimentary rock that consist on the area. By this time, the structure that contain in this area can be divide by the age of their started to formed and can be identified by looked the structure, texture of the rocks and by looked out on the Peninsular Malaysia, the two age is:

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2.6.1 Deformation Styles of Permian – Triassic Strata

Permian – Triassic strata shows the sedimentary Triassic strata are widely distributed in Peninsular Malaysia's Central Belt. The field survey of 1995 was limited to the formations of Gemas and Semantan at Johor and Pahang. Examples of deformation styles in the Temerloh and Bera areas of Triassic Semantan Formation are given in this article. The formation is deep marine middle-late Triassic, mostly turbidite (Kamal Raslan Mohamed, 1990, H.D Tjia, 1996). In addition to the channeling and intraformational conglomerate horizons, significant slump intervals and zones of softsediment deformation are normal. *Daonella sp.* Refers to deep marine climate. Such characteristics indicate deposition in a turbidite deepsea fan. Characteristic of the volcanic constituents is their abundance. A volcanic center was postulated in the region of Mentakab Centered on hypabyssal rocks commonly occurring (Law and Tjia, 1985; Tjia 1996). Kamal Raslan Mohamed mapped Palaeocurrents, suggesting a source in Eastern.

Usually Semantan Formation turbidites which also consist of meters long slump intervals, palaeoslope indications coming down towards the NE-E sector, and a small -10 m long graben on the south side of the region (Tjia, 1996). The folding style along the bypass near Temerloh in turbiditic Semantan beds, N-S fold patterns and east vergence. Complicated structures in Semantan beds along the Temerloh bypass consisting of slump folds that are tectonically refolded. Listric deficiencies and slump fold attitudes suggest palaeoslope to the NE sector (Tjia, 1996). The high roadcut displaying medium-sized zigzag folds in a slump zone narrows eastward in length, and a gliding surface decapitating zigzag folds. The latter occurrence suggests face stratigraphy. Palaeoslope turned eastward.

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Tectonic deformation is represented by an anticline's outcropping, moderately steep eastern limb which eastward (Tjia, 1996).

Semantan beds in a slump block 10 meters long that turned 100° degrees around a subvertical axis in clockwise direction. The SW strike of unrotated, but tectonically tilted strata, dipping 37°-39° degrees toward NW. There are three deformation forms at Ladang Sebertak near Bandar Bera, in central Pahang, in Semantan beds. The eastern segment consists of concentrated slump folds that were convolutely folded in sandstone- mudstone interludes. Strata tops are indicated in the same direction by graded beds and lowering of fold tightness and folding strength. A decimetre-wide zone of detachment is clearly shown on its stratigraphic bottom.

The central section consists of a diamict interval composed of chaotically distributed small to large clasts and sandstone slabs in a mylonitised groundmass. The diamict interval seems to have encouraged eastward reverse fault movement. Sense of fault movement is demonstrated by clast arrangement and deformed slab arrangement (Tjia, 1996). The third section forms the hanging wall block and consists of tuff and tuff sandstone steep to almost vertical, medium thick beds towards SE. According to Tjia (1996) the pattern of stratigraphic facings in graded beds indicates an isoclinal syncline striking NW -SE to 130°. Upon restoration to horizontal location, a palaeoslope towards SE is suggested by the attitudes of slump folds. Tabular cross beds indicate southward toward palaeocurrents.

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2.6.2 Deformation Styles of Jurassic – Cretaceous Strata

Jurassic – Cretaceous strata shows the JK strata occur in the NW domain as Sayong Beds, but the majority are mainly in the central and eastern domains, (Tjia, 1996). The key JK strata areas are in the Central Domain. A descriptions indicate elongation in direction NNW (Koh and Tembeling) and in direction N-S to the south of the Kuantan latitude elongation. Rather steep, vertical to overturned beds and often major reverse fault suggest highly compressed Central Belt JK strata. Field surveys showed that strong compressional characteristics occur especially along the boundaries of the different JK areas.

Deformation forms are represented towards the centres, with free, upright folds with slight dips. The symbolic type of deformation of JK beds away from border region. This portion of the Tekai-river is the crestal region of an open anticline in Mangking Sandstone with smaller folds attending. The geological map of the Pahang Tekai area shows the Tembeling group 's large, regular NNW-striking folds. JK strata occur in smaller areas in the Eastern Domain, from Kelantan to Johor. The stratigraphic units of Gagau, Lesung, Ulu Endau, Tebak, and Panti are weakly folded into open structural basin (Rishworth, 1974; Tjia, 1996) or tilted only gently. The exception is the Gerek Beds, which are heavily inclined and folded, and even flipped at one stage as a result of significant reverse failure.

Koopmans (1968) stated by Tjia, 1996 said that he carried out groundbreaking analyses of the lithostratigraphy and composition of the Tembeling and adjacent areas from aerial photographs. He found that its strike ridges and strike valleys defined great striking folds of the NNW-SSE. The

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thematic mapper imagery recently interpreted by Landsat confirms the NNW trends and fold sizes in the JK strata in the same areas and farther afield. Furthermore many arcuate to circular structures with diameters of 2 to 5 km have been recorded. Therefore, these features may reflect structural basins or domes in JK strata (Tjia, 1996).

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CHAPTER 3

MATERIALS AND METHOD

3.1 Introduction

Material and method are the core in every thesis and research, where it is the main factor in term to achieve the objective. Material and method could be anything and can be any reason to use it. By this time, the material and method would be the factor of the succesfull the research. The research would going to the flow of process of process will used the material and the follow the method in order to achieved the target.

3.2 Materials

There are two way of using the material in this research which is: hardware and software. The hardware material is something that we deal with physical and touch method that need to use to get the data or in simple term is raw data. While software material is a material from the computer to precessing and interpret the data by using other support processing software.

3.2.1 Hardware

There are a lot of the hardware material that can be use to create the work in term of the to support the result. The process is by using this material to contribute with the other method, some material that are been used are:hardware

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components of the development systems used for development data or portions of such components,

a. Topography Map

To acknowledge the position and the location of the outcrop and understanding material and surrounding of study area.

b. Previous Research

To gain more knowledge and understand the whole concept of the of the study area, previous research is one of the good material to get a lot of descreption of the study area. This material can be part where the previous research are overlay with the study area.

3.2.2 Software

From this research, some of the material that have been used is from software where the software is the programs and other operating information used by computer in term as a guidelines that tell a machine what to do and the entire set of programmes, procedures, and routines associated with the operation of a computer system includes software (D. Hemmendinger, 2000). In this case, the software are used in conducting the mapping and interpret result by using software like:

c. ArcGis

To interpret data that have been measure the day before and interpret on this software for method of remote sensing and geological information system (GIS) for geological mapping. The arcgis is the software that aare generate and

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produce by Environmental Research System Institute (Esri) for build and use maps, collect geographic data, analyse mapped information, exchange and discover geographic information, use maps and geographic information in a variety of applications, and to manage geographic information in a database. In the arcgis software consist, ArcGis, ArcMaps, ArcScene, ArcGlobe, ArcCatalog and etc.

d. Google Earth

To identified and get the latest updates of the Earth's surface for interpretation method. The Google Earth usually uses to get the apparent surface of the study area for more knowledge on how the structure involve and affecting the rocks. By this Google Earth, it will show roughly about the surface area and it can be interpret by the knowledge that already have by take part of the theoretical and practical part.

3.3 Method

Generally, to understand the tectonic revolution is by investigate the deformation of rock will help to more understand with using several method. This method will be used to identified and classified the best result at the end of this research. All of the method will bring to one conclusion that will not be debunk by the others where the collective data and the interpretation of the data will shows the most and cynical result that have to be understood by the others. The result that will be shown at the end of the research is result weather the objective of the research successful or not and is it true with all of the hypothesis are good or not.

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By study of this cases, the best method that have been used is quantitative method were the result can be more accurate with the purpose of this research.

The quantitative method was the method that can be count with scale. With the quantitative method, there are could be any kind of interpreted of data that can be explain and identified which is looked at the collective data and the result at the end of the collected. The quantitative method that have been used are include:

3.3.1 Data Collecting

The data collecting, the method that have been using are be divided into two way which is:

a. Preliminary study

This main method is where are going to make a mapping and the study area and come out with some data to interpret and study about the formation/phenomena that might be happen at the study are. From this method, it will be more practically accurate for understanding what happen on the study area because it is can be see, taste and feel the environment of the area.

b. Previous study

From the previous study or previous research from the senior or researcher, the data have been identify on their research will be collected and been analyzed again to see the possibility lacking data of the study area. Meanwhile, the previous research also can be one of the good example in understanding the geology process that happen on that particular area.

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c. Secondary Data

The main method for this research is by this method where from this method it will collected all of the information from the government agencies or non-geverment agencies. From this data, it could be help to identified and recognize the study area and also can get some of the information from here. Based on this method also, it would be more easier to characterize the specific area for some experiment on some topic such as sedimentology, stratigraphy and also the main objective which is the tectonic. The secondary data consist with many way like: (1) Get from other journal or article, (2) Refer to library and other public references, (3) Refer to the government and non-government sector and many more.

3.3.2 Data Processing

The data processing is where all of the data collected were been processing by using several method that have been provided and choose to identify and getting the result. Fro this research the method that have been using are:

a. ArcGIS 10.8

In conducting the geologicap map of study area, ArcGIS software were been using in produced the map. The data that have been using in perform the map is by the data collecting from the previous research and from the othr agencies like Deparment of Minerals and Geosciences. The component that will be shown on the map of geological mapping are area of mapping, title, scale, stratigraphy units, lengends, cross section and other explaination if needed.

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b. Dips 7.0

In showing the result for the deformation in study area, the Dips software are been using for perform the potential deformation happen on that study area. Other that that, the Dips 7.0 also one of the software that will be used in conducting the stereographic analysis for showing the fault and also in identify the the rose diagram. In the end of the identification of deformation study in structure map will shows the possible fault structure in study area ade the possible and potential way of fault in identify the major fault at the study area.

3.3.3 Data Analysis

For analyzed the data collected, the analysis of the data collection will be perform in several method, but on this research that will be more simple where to analyzed the result just have to conducted in interpretation study.

a. Interpretation study

The method that will be used to identify the types of rock by looked at the mineralization on the rocks, this method will be conducted in the laboratory by bring out the sample and turn it into the smallest particle. The small particle of rocks will be adjust the great one for make a good sample of the rock. The chosen of the sample of rocks should be the greatest one that show all the the particle, mineral and identification of the rocks that can describe more about the study area.

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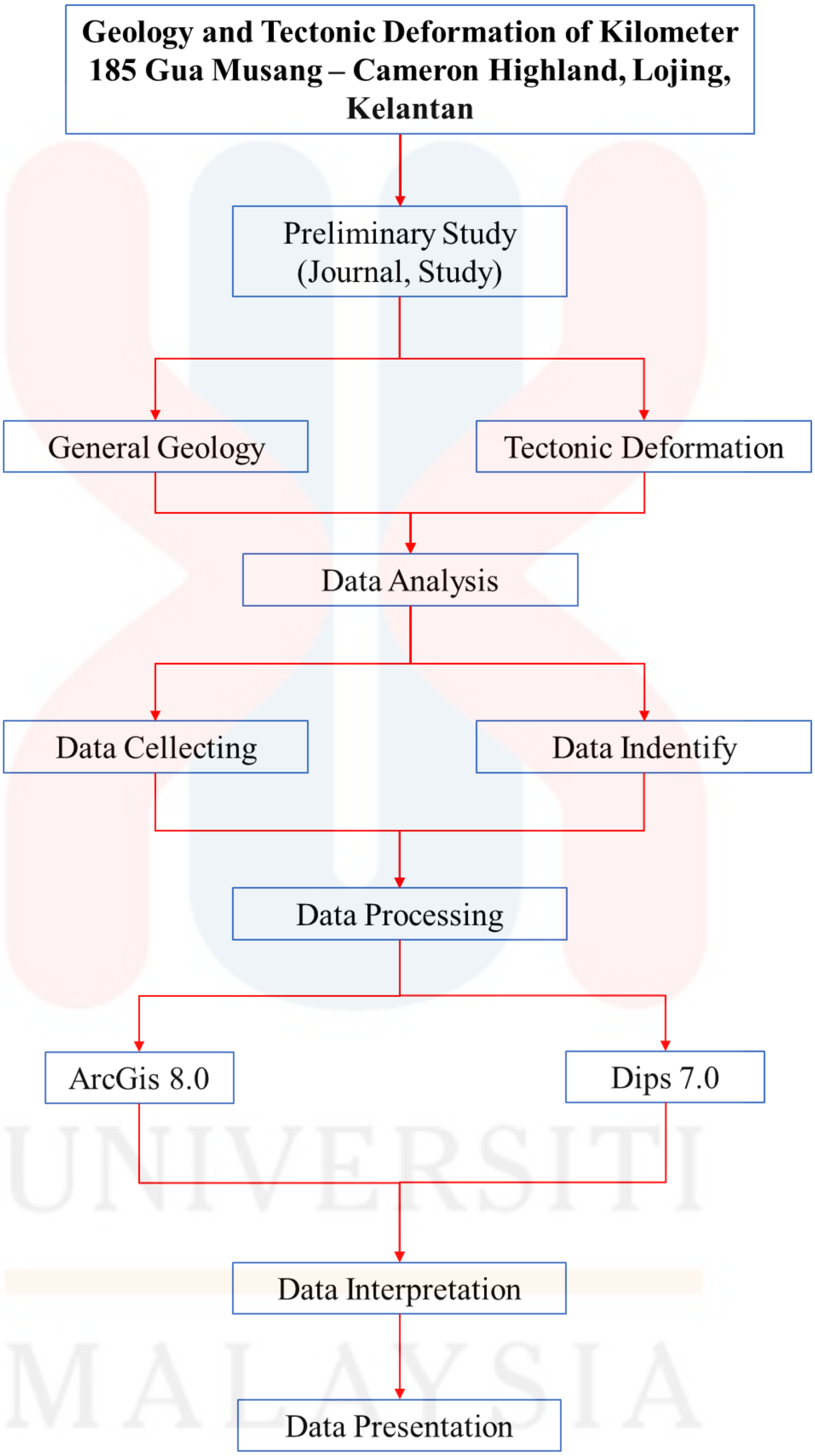

Figure 3.1: Flowchart for final research

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CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

Geology is the study of science where it is deal with the physical structure and substance of the earth where it is including the history and the process. In Lojing area, there are some historical of geology that can be describe and identify based on the geology element. Lojing area is located kat Gua Musang, Kelantan were it is the road that connected between two country which is Kelantan and Cameron Highlang, Pahang. It is also where located with one of the uniqness village which full of ingineous people (orang asal).

Technically, in general geology it would be going to discuss about all the factors and dimension of geology where include the formation of the rocks, mineral, biosphere, atmosphere, structure, physical and chemical properties and also the historical of the Earth's component as well as the process that happen to become them. In addition, in this topic, it also analyse about all of the hazards that caused by the process that occurs within the Earth like earthquake and landslide that changes the outcrop at the study area

Theoritically, in this chapter there would be focus on discussion about the geomorphological in study area where it going to study about the surface of the planets with all the process that happen towards the formation. Besides, it is also will describe more about the stratigraphy, where, generally it will discussed about two element which is lithostratigraphy and biostratigraphy. The structural geology

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also will be discuss in this chapter where it will show us about the deformation process on within the Earth's crust include the materials and the mechanics that lead all deformation process. The historical geology will be touched where it will revealed about the techniques and principles of geology to reconstruct geologic process in sequences to understand about the process that happened during ancient time.

All of the factors of general geology that will be discuss are about in study area that provided to make a research. In this research, the area that are located in Highway Gua Musang – Cameron Highlands that are estimate 502 km along with Tasik Kenyir, Terengganu – Manjung, Perak were that placed full of modern life. The area are mostly covered by rubber plantation and palm oil plantation are been one of the source of income for locals villagers, besides 70% of this area are mostly covered with rain forest. Moreover, in this area also located the Brooke's River (also been known as Berok's river) that are estimate around 144 meters (472 feets). To be more succesfull in doing this research at this area, previous research and references from the expert are more important to get the solids and accurate data that would be less debunk from the others.

4.1.1 Accessibility

Lojing is located at the south of Kelantan where it is connected by Tasik Kenyir, Terengganu – Manjung, Perak. Maps 4.2 show that the study area can be accessed by Gua Musang – Cameron Highlands highway by transportation network. Futhermore, through unpaved road that available in this study area also can help to acces and go through the study area.

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4.1.2 Settlement

The study area are placed with three village refer to the previous data which is Kampung Pos Blau. On this location mostly covered by oil palm plantation with rubber plantation. Kampung Pos Blau is one of the famous indigeneous people (orang asal) in Kelantan. Refer to Department of Orang Asli Development (JAKOA), in 2018 there are 6 village that are registered in Pos Blau which is Kampung Orang Asli Selyeh, Kampung Orang Asli Kelaik, Kampung Orang Asli Blau, Kampung Orang Asli Om, Kampung Orang Asli Sintang and Kampung Orang Asli Batang Baru. In this area, people believe there are two group of Indigeneous People in this area where it is either from Negrito (also known as Semang) and also Senoi. The Negrito group are mostly are from Jahai Tribe, Mendriq Tribe and Bateq Tribe while Senoi group are Temiar Tribe. The population in this village are shown on table above and maps 4.3.

Table 4.1 : Population of Indigeneous People (Orang Asal) in Pos Blau. (source Department of Orang Asli Development)

No.	Village	Population
1	Kampung Orang Asli Selyeh	7
2	Kampung Orang Asli Kelaik	62
3	Kampung Orang Asli Blau	293
4	Kampung Orang Asli Om	33
5	Kampung Orang Asli Sintang	13
6	Kampung Orang Asli Batang Baru	11

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4.1.3 Forestry

In geology, forestry been describe by the study of the forest ecosystem and the environmental components and process where it is included the biological, physisical and chemical that effected them. The study area are estimately, there are 70% of forestry in this study area. Equivalently, in this study area there are 30% are lcated with oil palm plantation and rubber plantation where it is contribute to economic factors surrounding the area of Pos Blau. In fact, there are several percent in this area are irrigated the forest and turned into local population.

4.2 Geomorphology

Study of the Earth's shape or Earth's landform and its process that related to the origin and the evolution of the Earth's shape are been called geomorphology. Moreover, in other parts, the geomorphology also can classify as a study of soil types, shapes, mechanism and sediment on the surface towards the Earth's surface by looked at the landscapes and identify how the surface of Earth's process such as ice, water and wind could affect the landscape. In other words, refer to Davis (1905) state tahta the geomorphology is Earth's science that focus on the surface of the planet and related to every process that responsible towards the formation.

Otherwise, all of the origin and evolution of topographic and bathymetric feutures resulting from physical , chemical and biological process that occurs at Earth's surface. Earth's surface is something that modified by the combination of surface process that shapes landscape and geologic process that cause tectonic uplift and subsidence and shape the coastal geography.

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Furthermore, the landsforms are formed by erosion and deposition, as deposited in different locations. Landforms is been characterized as any regognizable feature of the solid surface on the Earth that has a distinctive shape with large and small features such as plateaus, mountains, plains, valleys, hills, canyons and volcanoes that are naturally formed. There are two types of landsform, which are: (1) Physical attributes, (2) Cros physical attributes

4.2.1 Topography

Topography is the study of the Earth's surface where it is include with the mountain, hills and where the arrangement of the natural and artificial physical feature at the area are been identify and studied. In other words, topography is the forms and features of land surface. In geomorphological unit, topography been the key of criterion where it is been used in central part of geomorphology for research the physical requirements, hydrology parameters or any hazard exposure region. To differentiate between types of landforms of different part of study area also can be identified with using topography part and it is possible to understand and comprehend the history of landforms process once the topography of one area was examine.

According to Hutchinson (2009), its already been classified the topographic system depends on their mean elevation which is have been shown like table 4.2 above

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Table 4.2: Classification of topographic units by average elevations (Source: Hutchinson, 2009)

TOPOGRAPHIC UNITS	MEAN ELEVATION
Low Laying	<15
Rolling	16-30
Undulating	21-75
Hilly	76-300
Mountainous	>301

In determination of topographic units, the mean elevation is the important role because the elevation is the method and references in determininf the topography classes, either Low laying, rolling, undulating, hilly and mountain. It is also shows the situasion where mostly the study area is covered by hilly landforms unit and mountain areas, (Hutchinson, 2009). In this study area, by referring on Hutchinson (2009) the highest elevevation is the quartzite ridge with 480 meters. Besides, there are a lot of hilly area in this study area with below 100 meters.

Meanwhile, by conducting topographic map, there are another investigation that can make together with topography to been maps such as aspect map, and relief map. Aspect is the downslope direction of the maximumvertical change in the surface determined over a given horizontal distance where it can be identify by using arcgis software. Relief is to showing the indicating hills and valleys by shading rather than by contour lines alone.

Map 4.5 – 4.10 show the data for slope map, aspect map, hillshade map, tin map, landform map and topography map in study area, where it is show that the lowest elevation is about <100 meters, whereas the highest elevation is around <480 meters. There are different types of landform by looked at the some

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elevation. Topographical units occur that the depositional landscape tells the inland plains, filled valleys and river terraces with wide gaps in contour marks.

4.2.2 Drainage Pattern

Drainage pattern (also known as Drainage system) is the distribution of the streams, rivers and lakes in drainage basin. In the topography they are directed to particular area is dominant by hard or soft rocks of the Earth.Dranage pattern have several types that usual been discuss by geologist such as angular, dendritic, contorted, parallel,rectangular and trellis as shown in figure 0.0

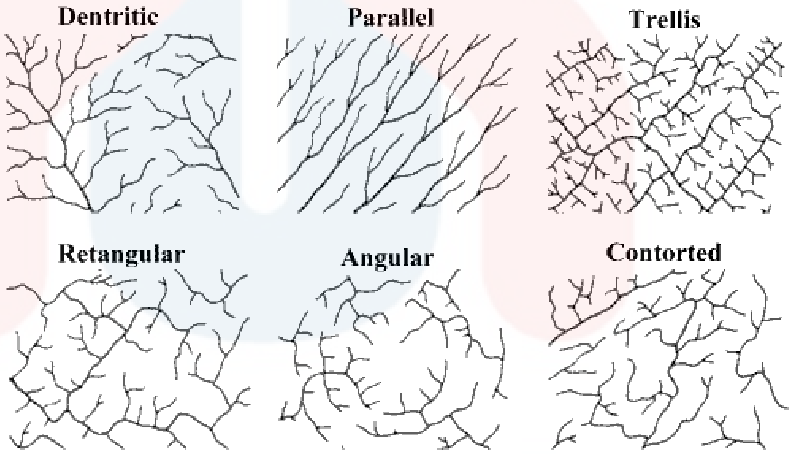

Figure 4.1: Types of drainage pattern (Thornbury, 1969)

The field identification by using topography maps shows in map 0.0 that there are two types of drainage pattern that happen which have different significant geological where that two types are most commonly happen in Peninsular Malaysia because of their landforms and Earth's surface which more notorious with this two types which is:

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a. Dendritic

Dendritic is the most common pattern that happen in most of the place where it is look like the branching of the tree root paand it is can be characterized by the irregular branching in all directions with the tributaries joining the main streans at all angles. In areas where the rock or unconsolidated material underneath the stream has no unique material or structure and can be eroded equally and easily in all directions, these seem to be the most common. Examples will be granite, gneiss, volcanic rock, and non-folded sedimentary rock. Looking on the research area, the stream flowing downward to south direction while several of it going upward to north direction. Sungai Brooke (Sungai Berok) is the main factor for the stream river where the water flow comes from this area.

b. Parallel

Parallel flow is identified where looked at the flowing of the water stream shows it is parallel with the main river and connected with the same river with nearest angle with each other include straight due to the extreme steep slopes with only a few tributaries. The parallel pattern with several relief caused by steep slopes. Parallel form where surface has a pronounced slope and also occurs in regions of parallel including outcropping resistans rocks and elongate landforms. Identify in study area shows the river that parallel with the main river on north direction to upward.

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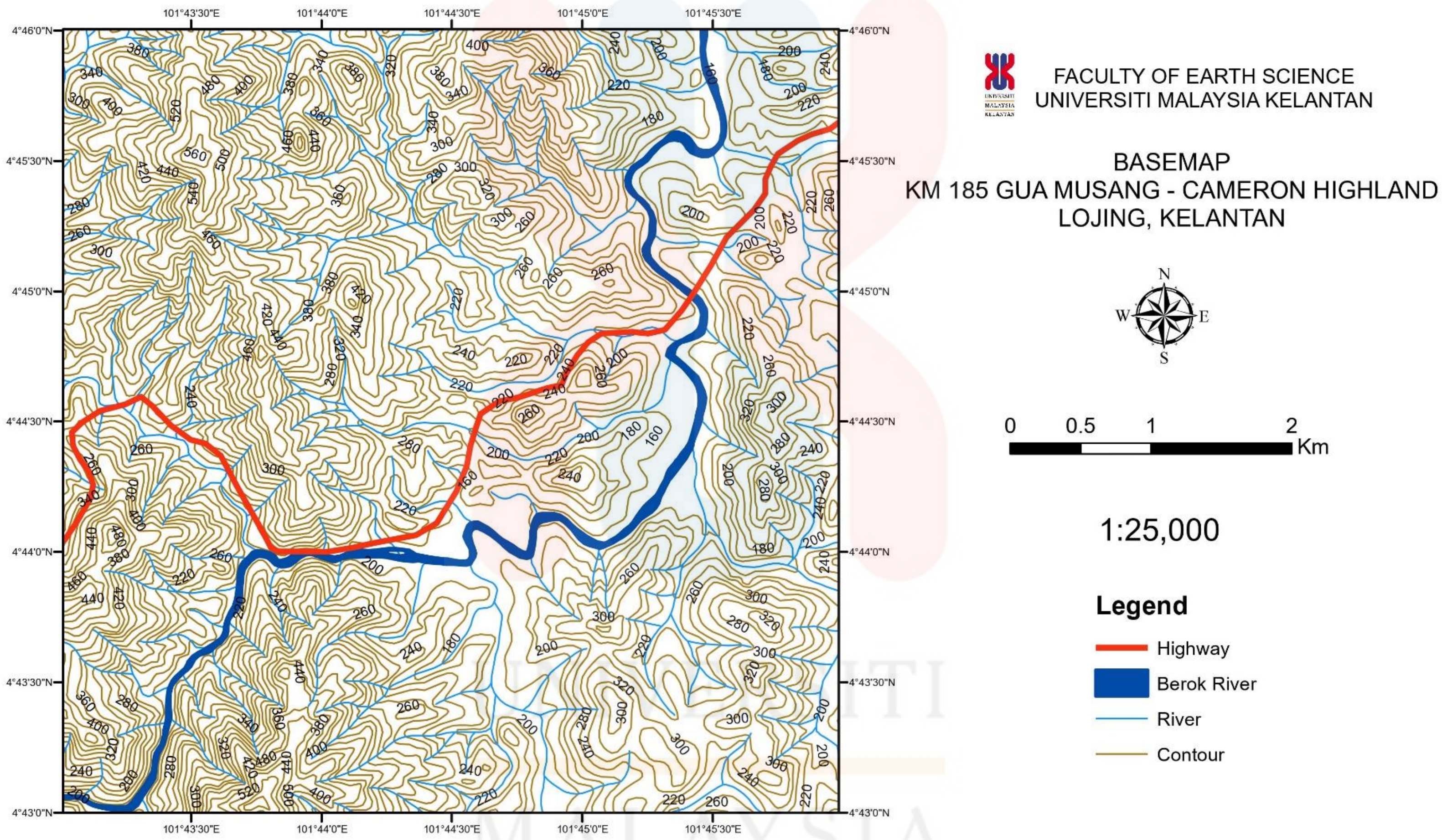

Map 4.1: Basemap for study area

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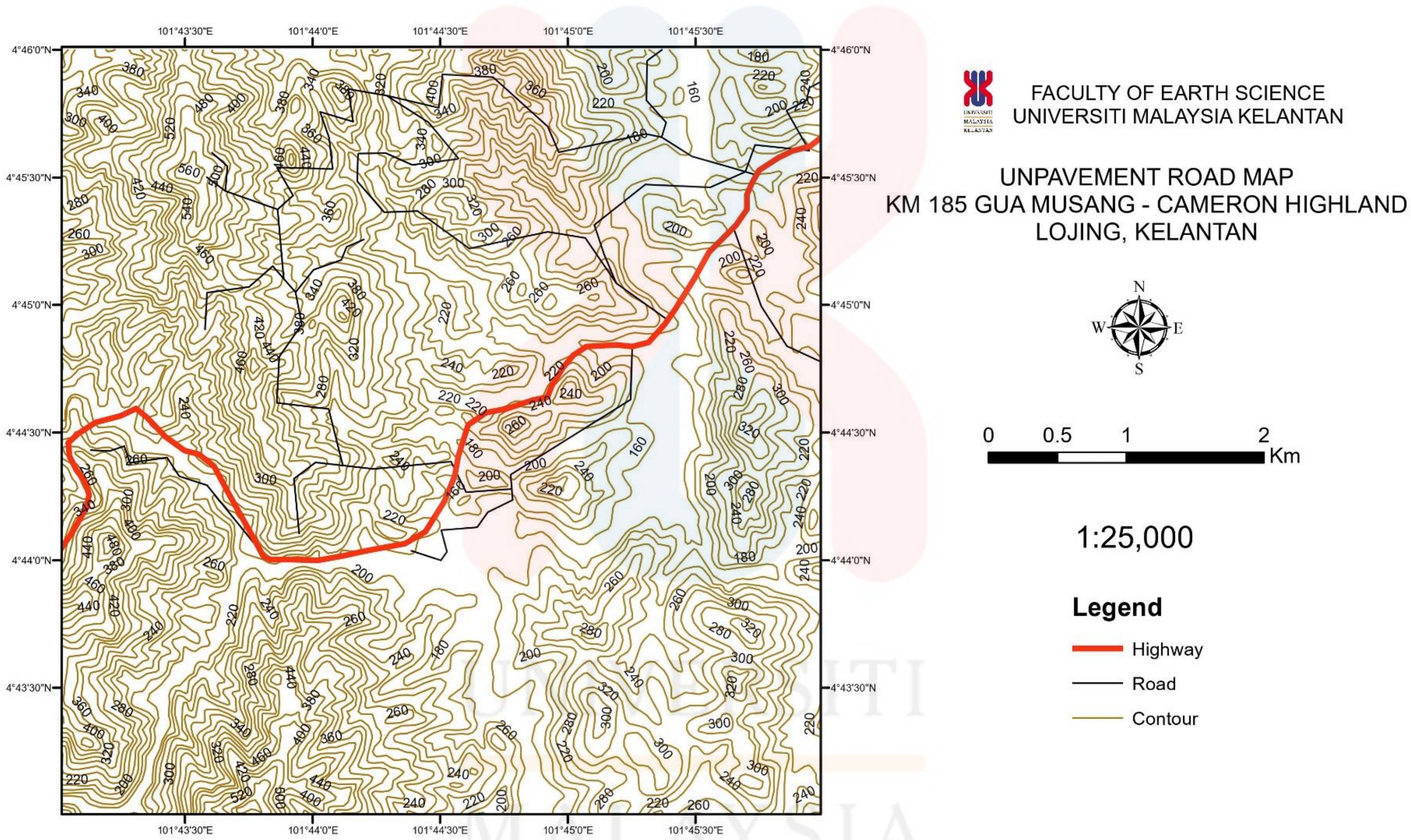

Map 4.2: Accessibility in study area

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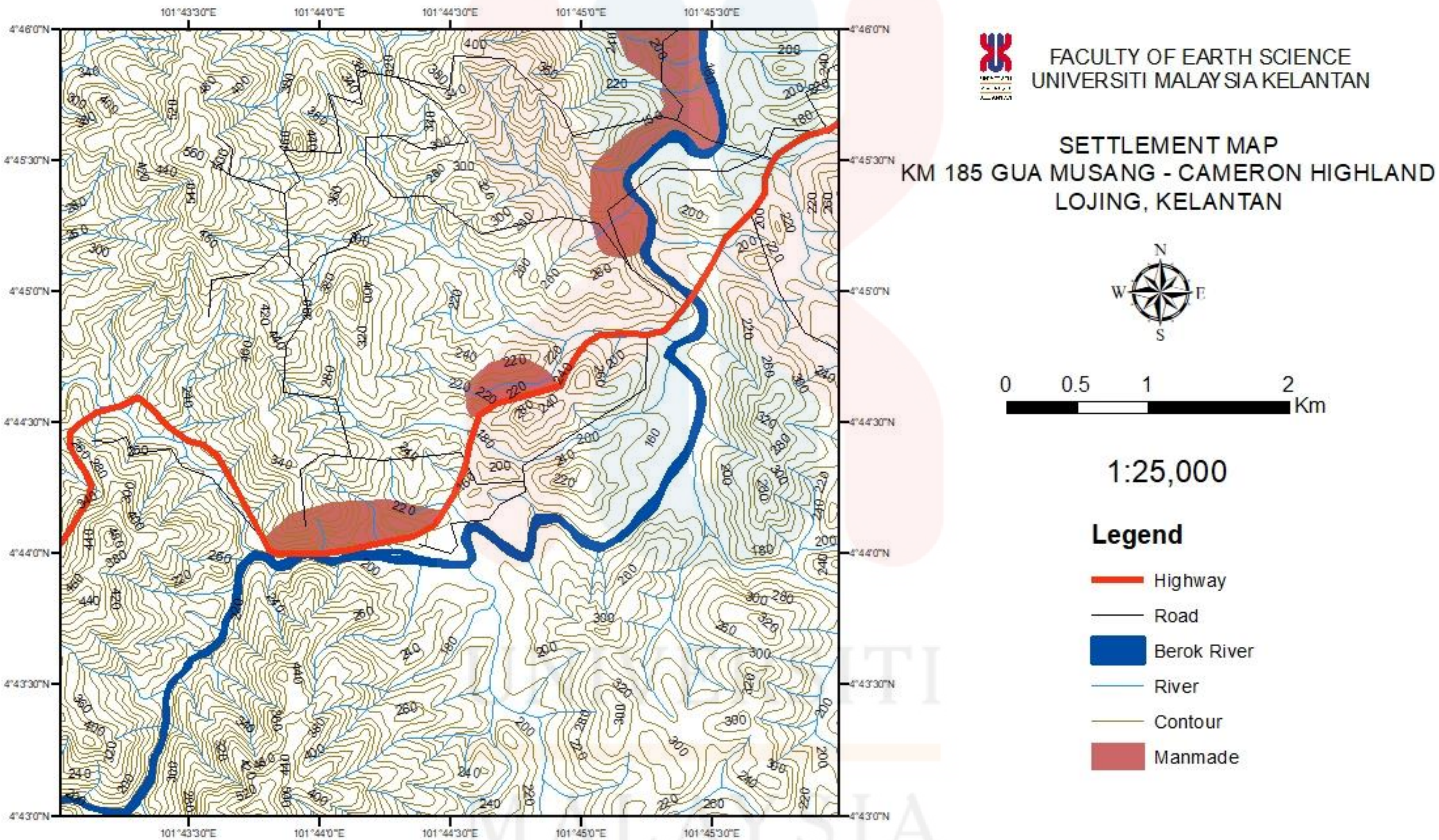

Map 4.3: Settlement map on study area

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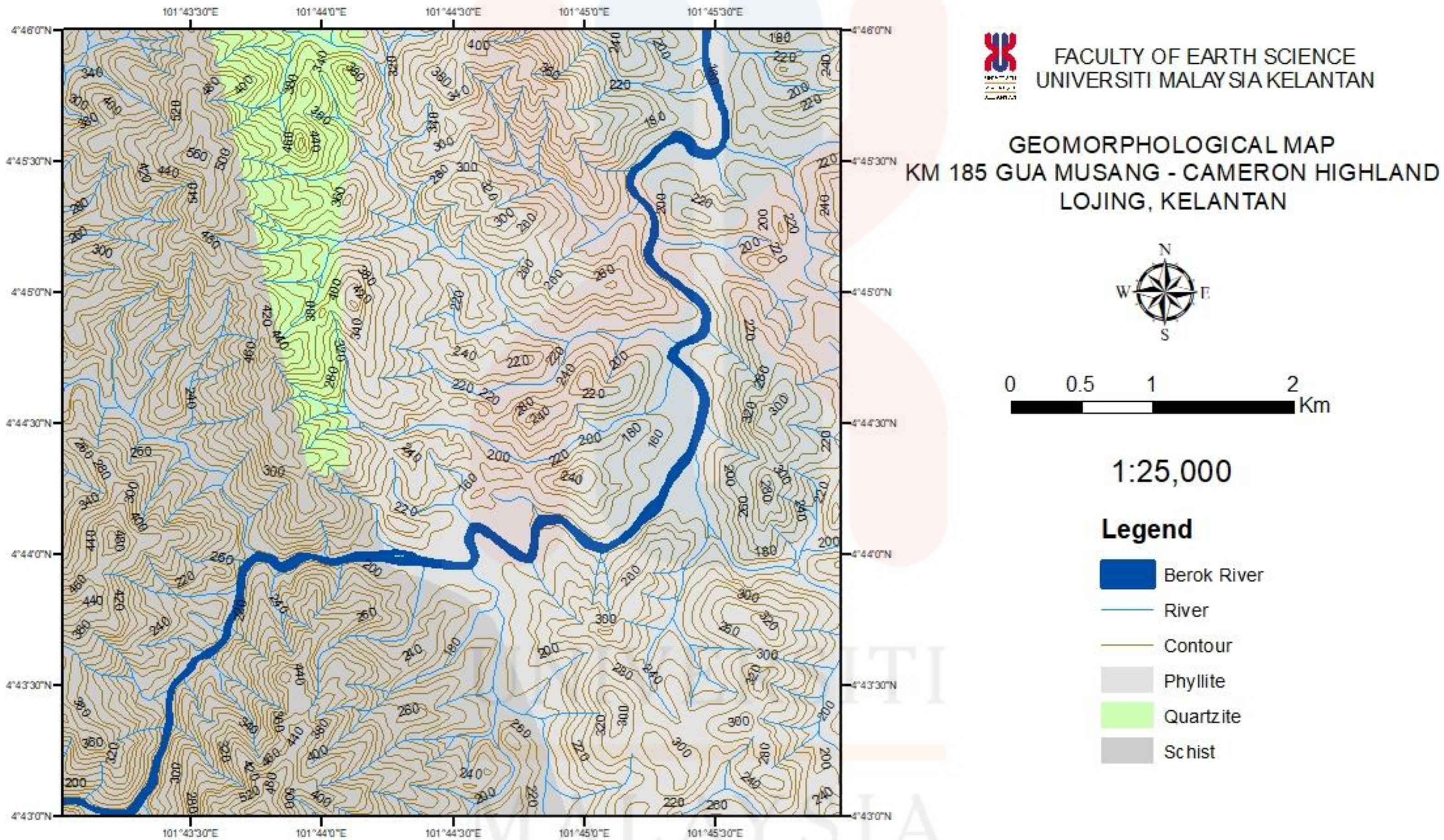

Map 4.4: Geomorphology map on study area

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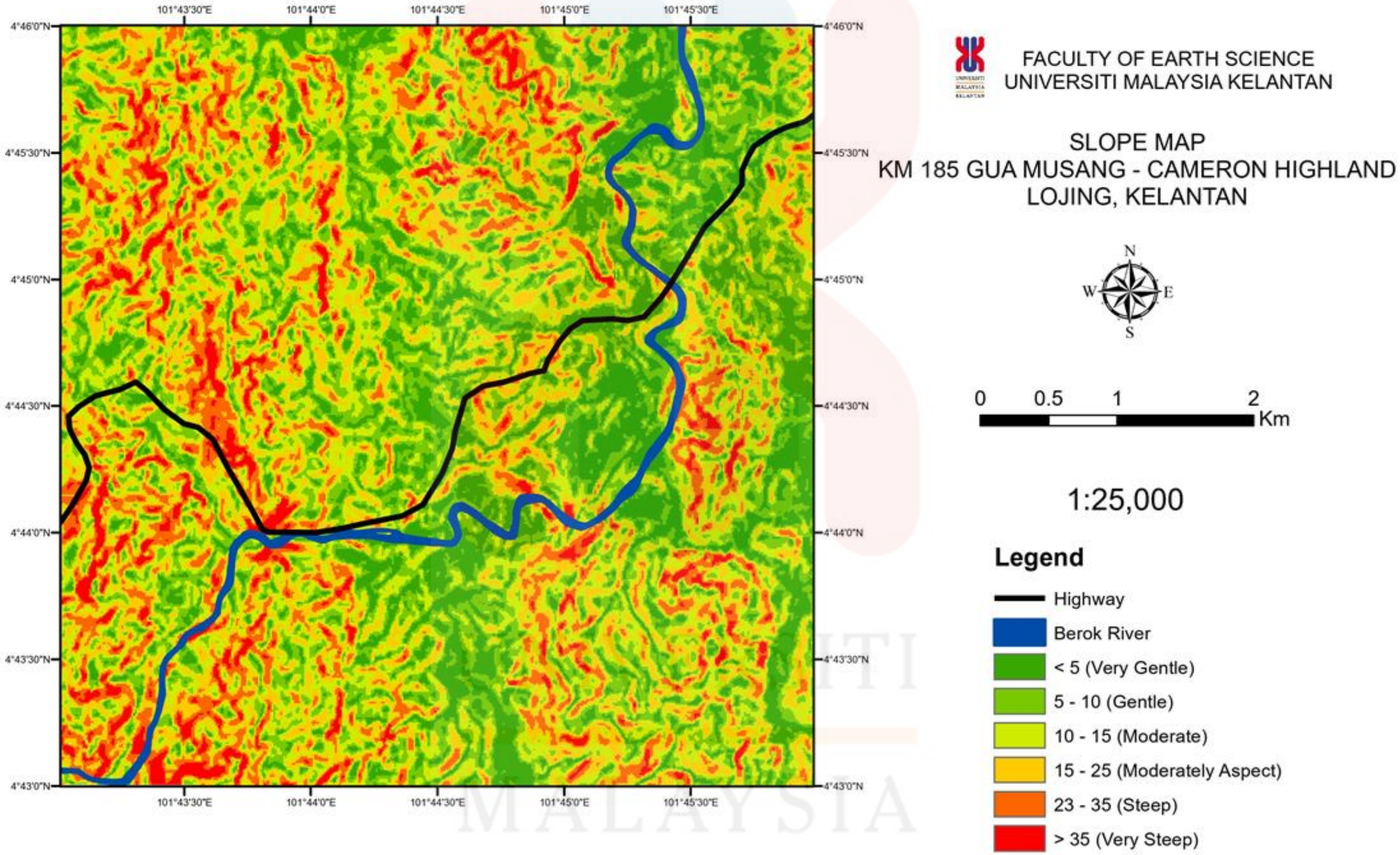

Map 4.5: Slope map for study area

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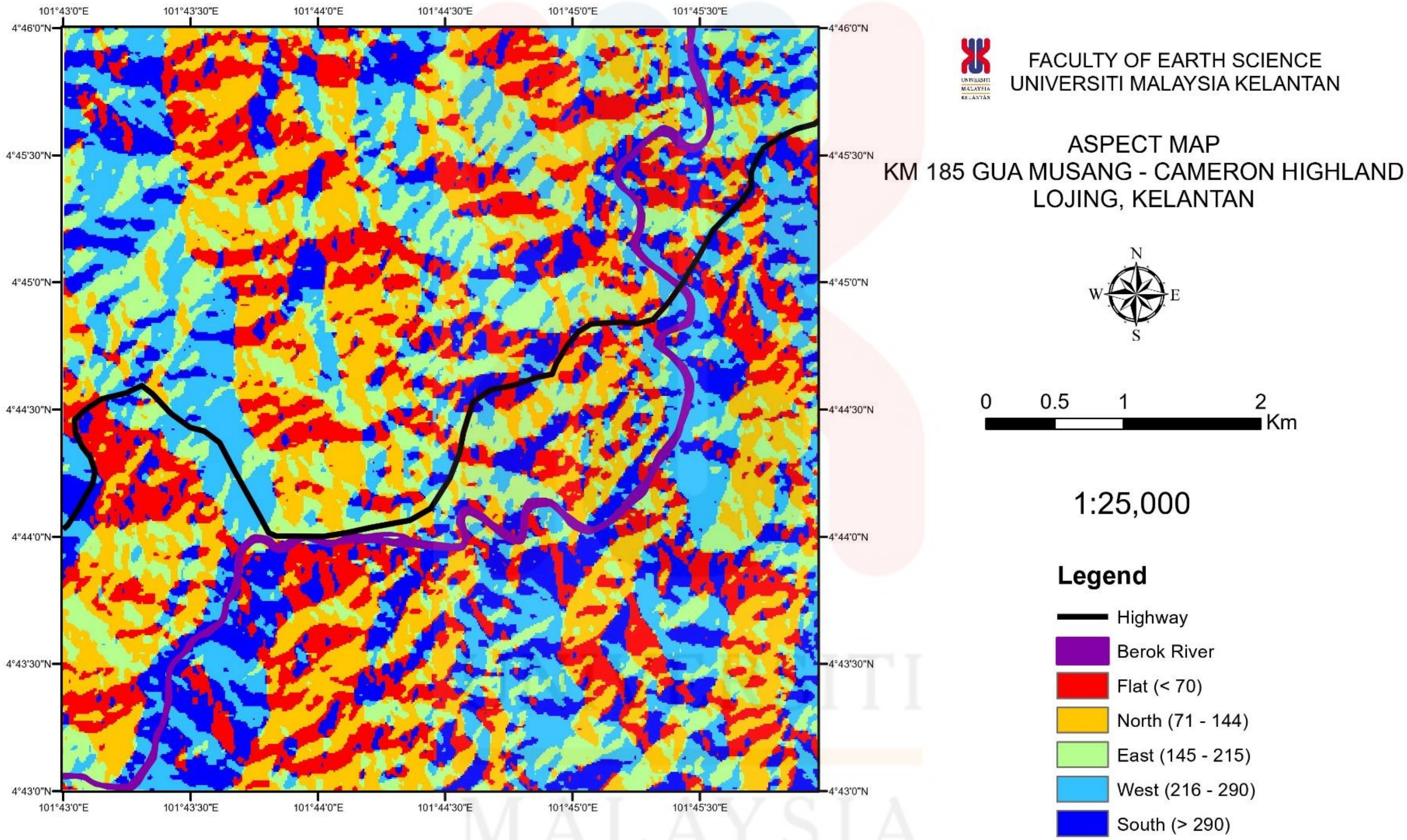

Map 4.6: Aspect map in study area

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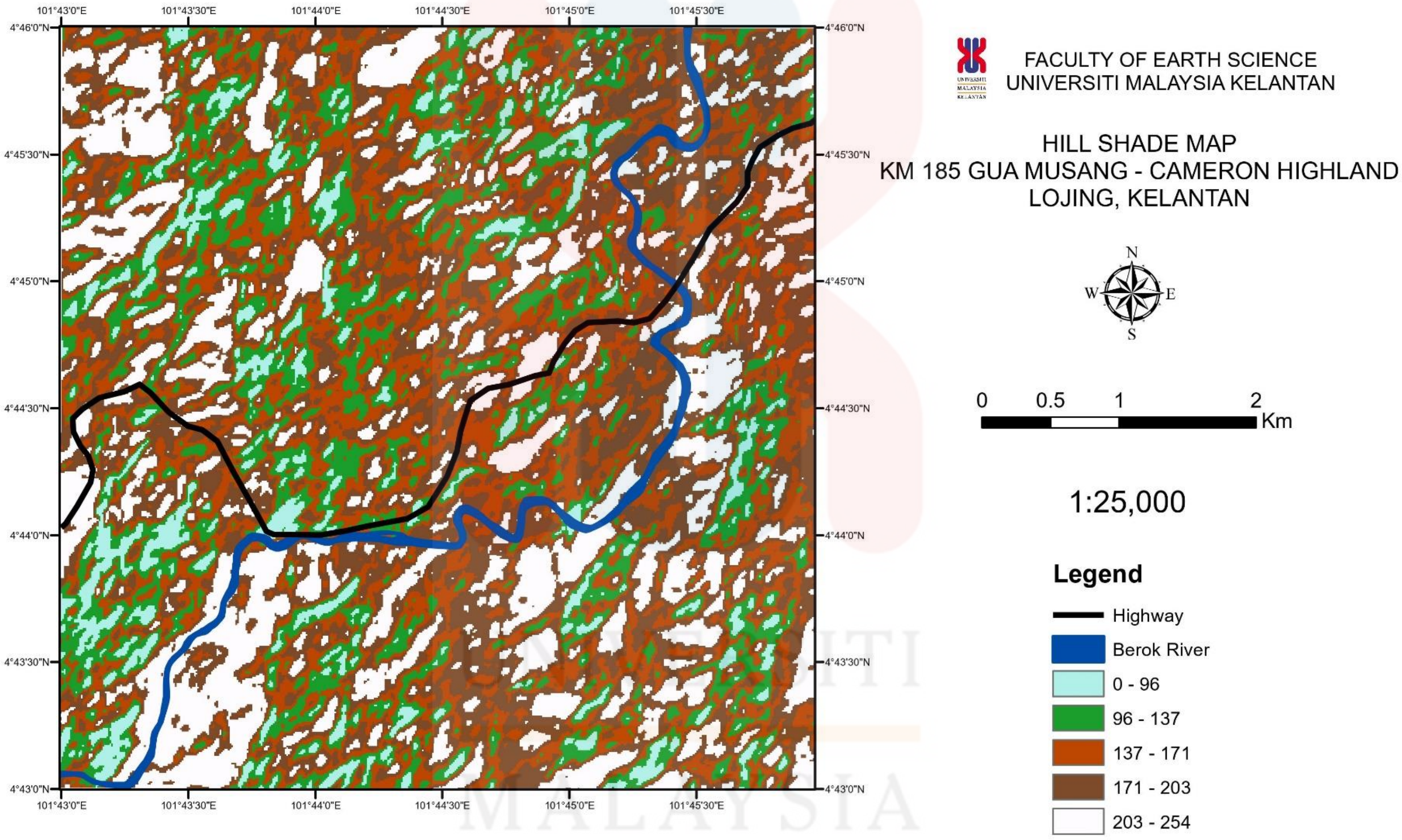

Map 4.7: Hillshade/Relief maps in study area

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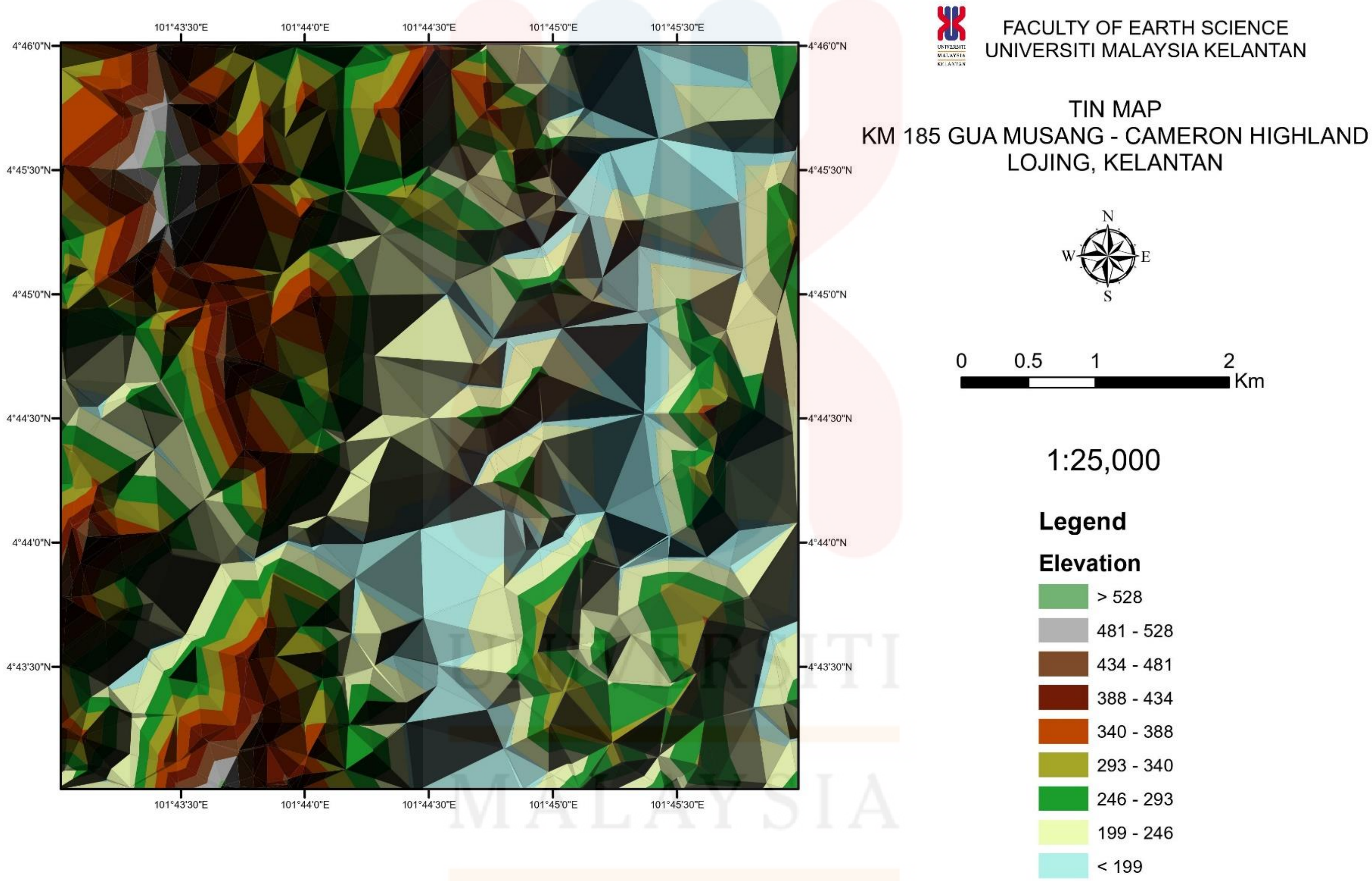

Map 4.8: Tin map for study area

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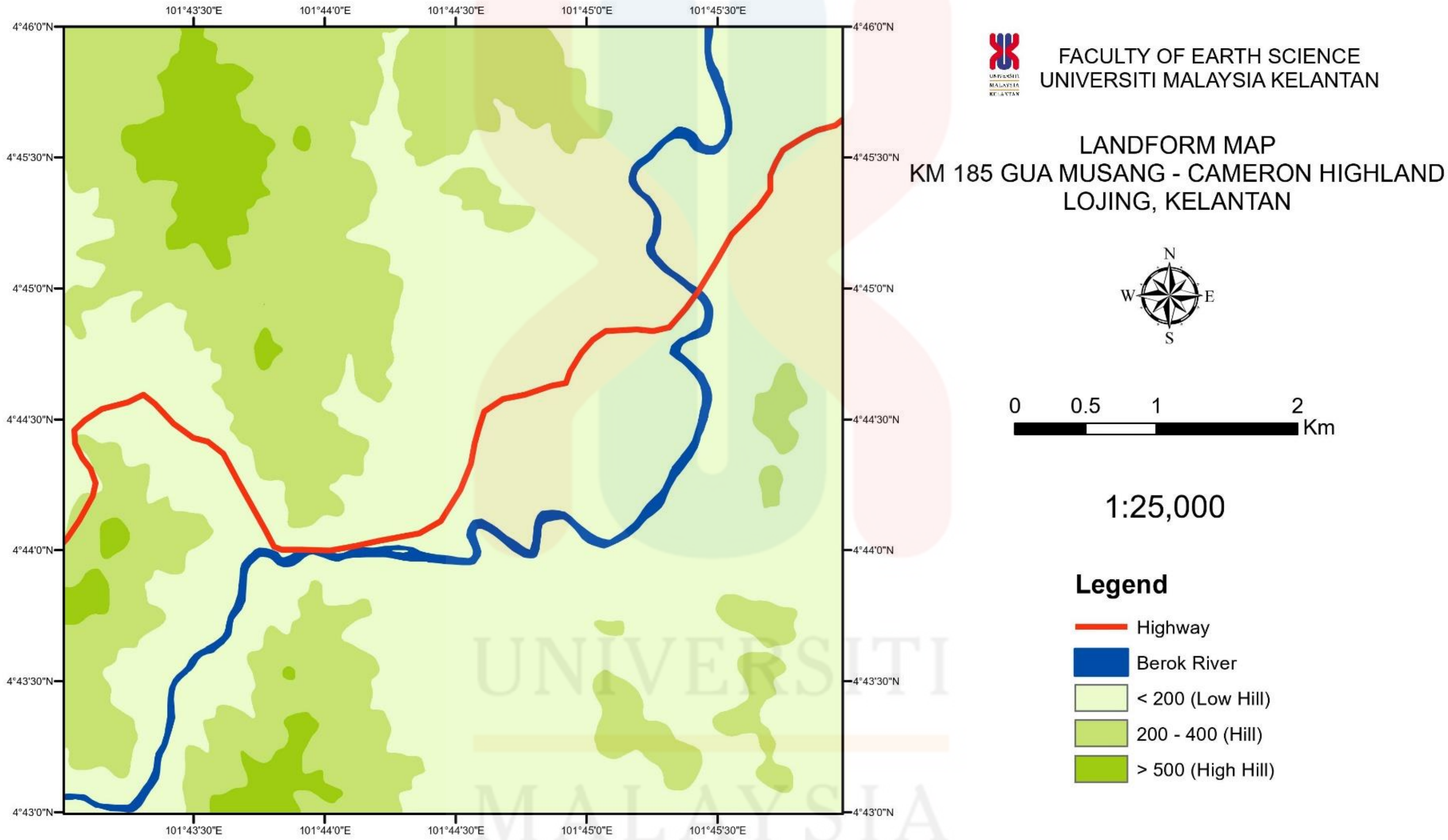

Map 4.9: Landform map for study area

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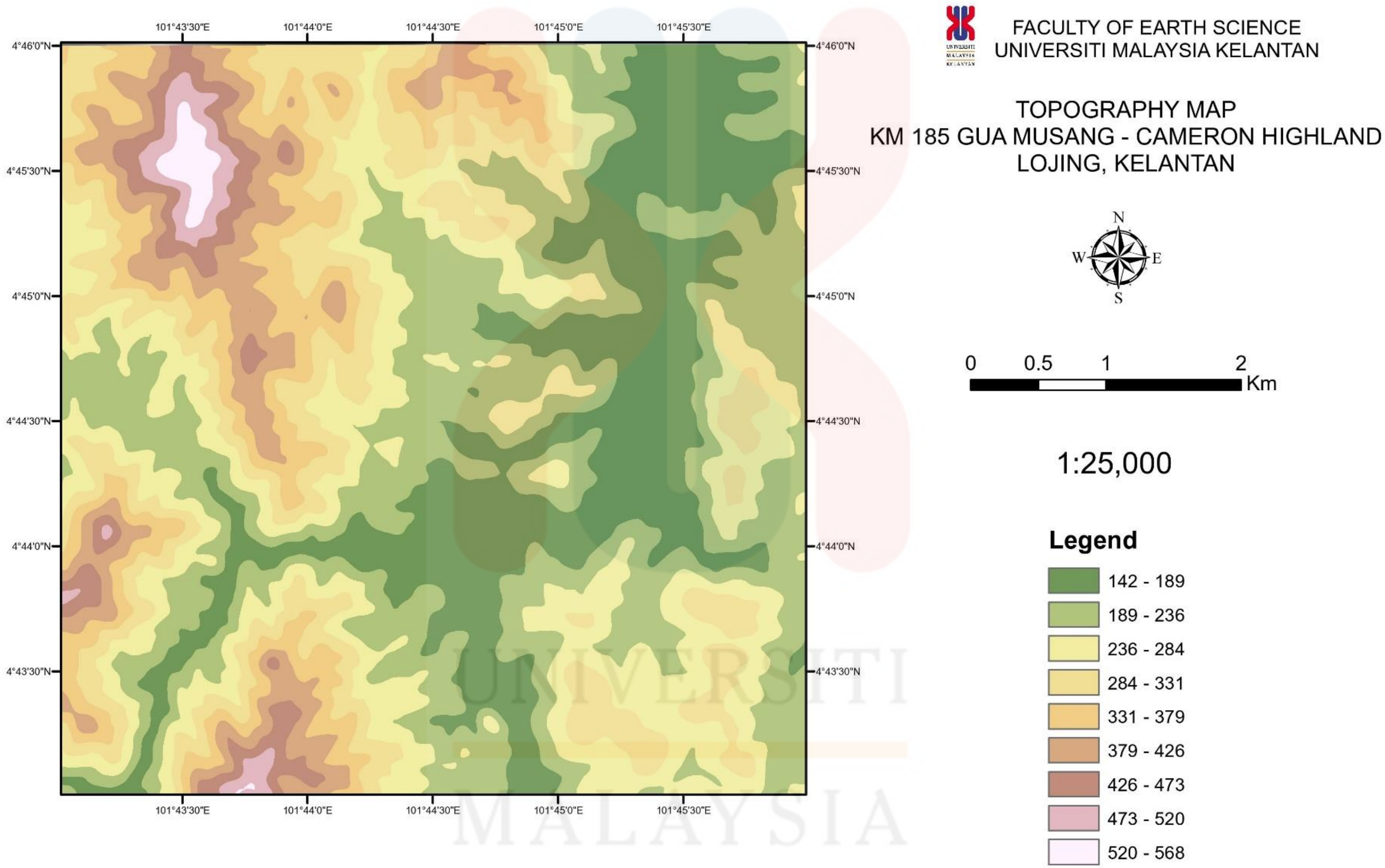

Map 4.10: Topography map for study area

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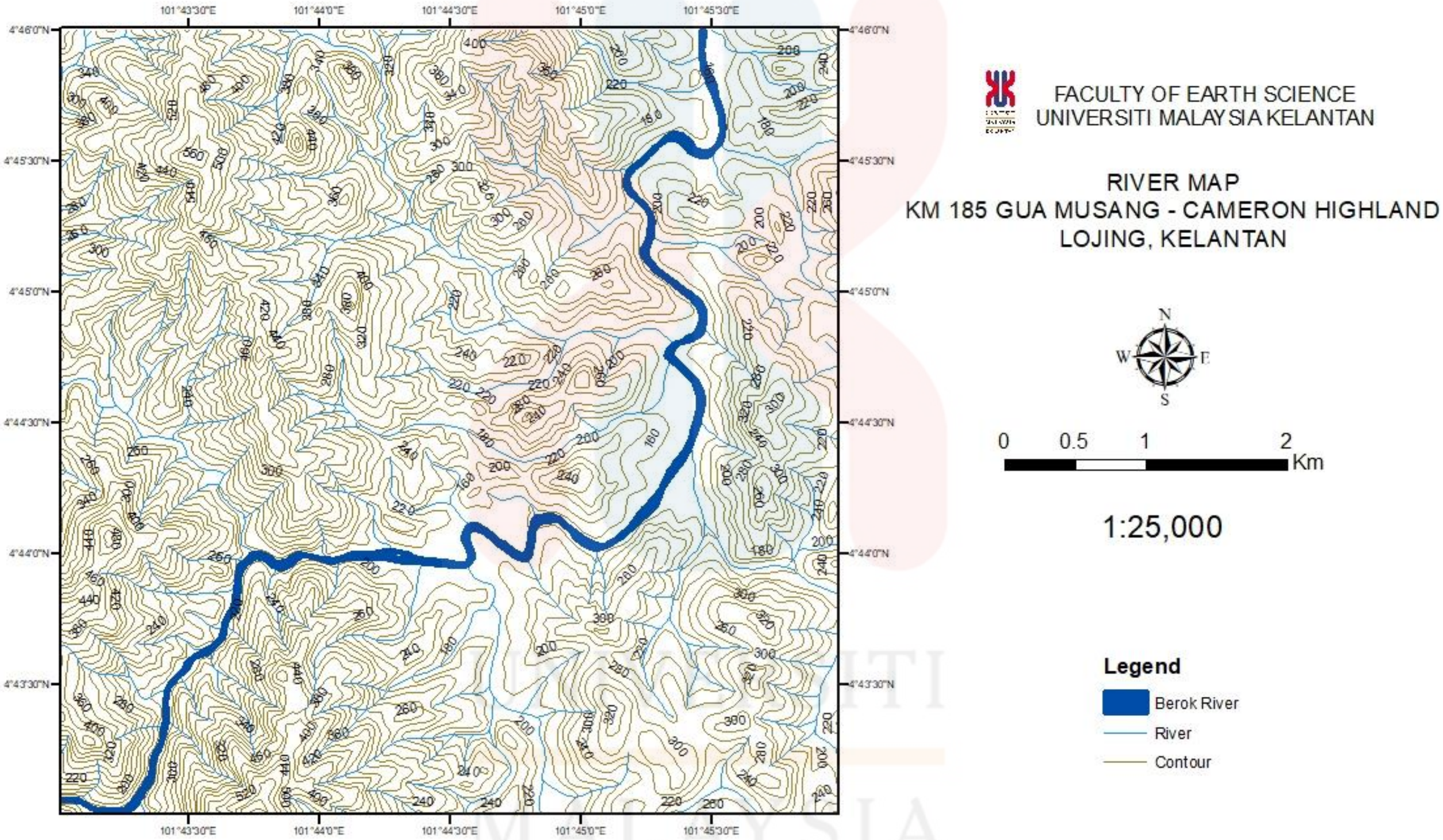

Map 4.11: River map in study area

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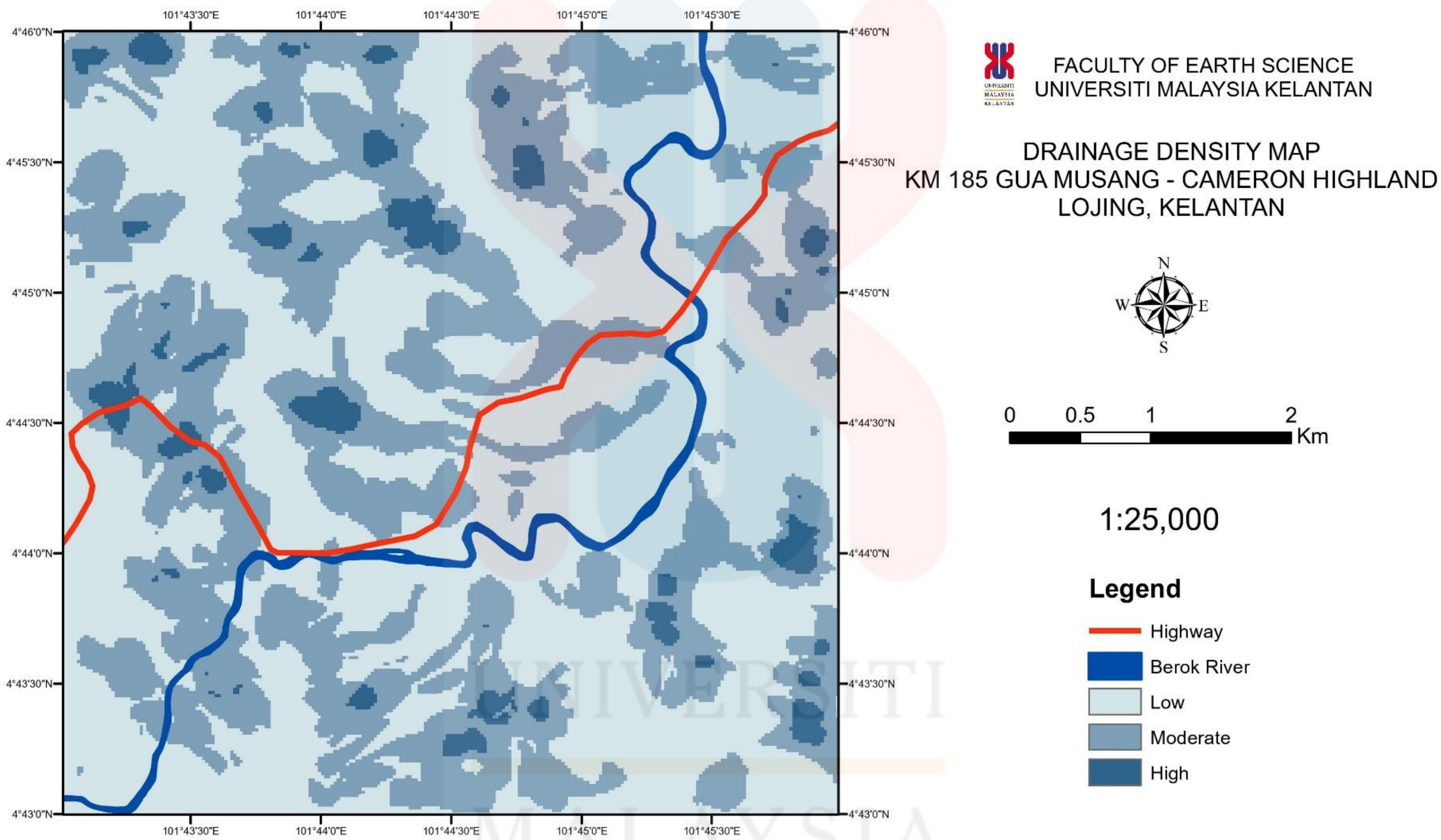

Map 4.12: Drainage density map in study area

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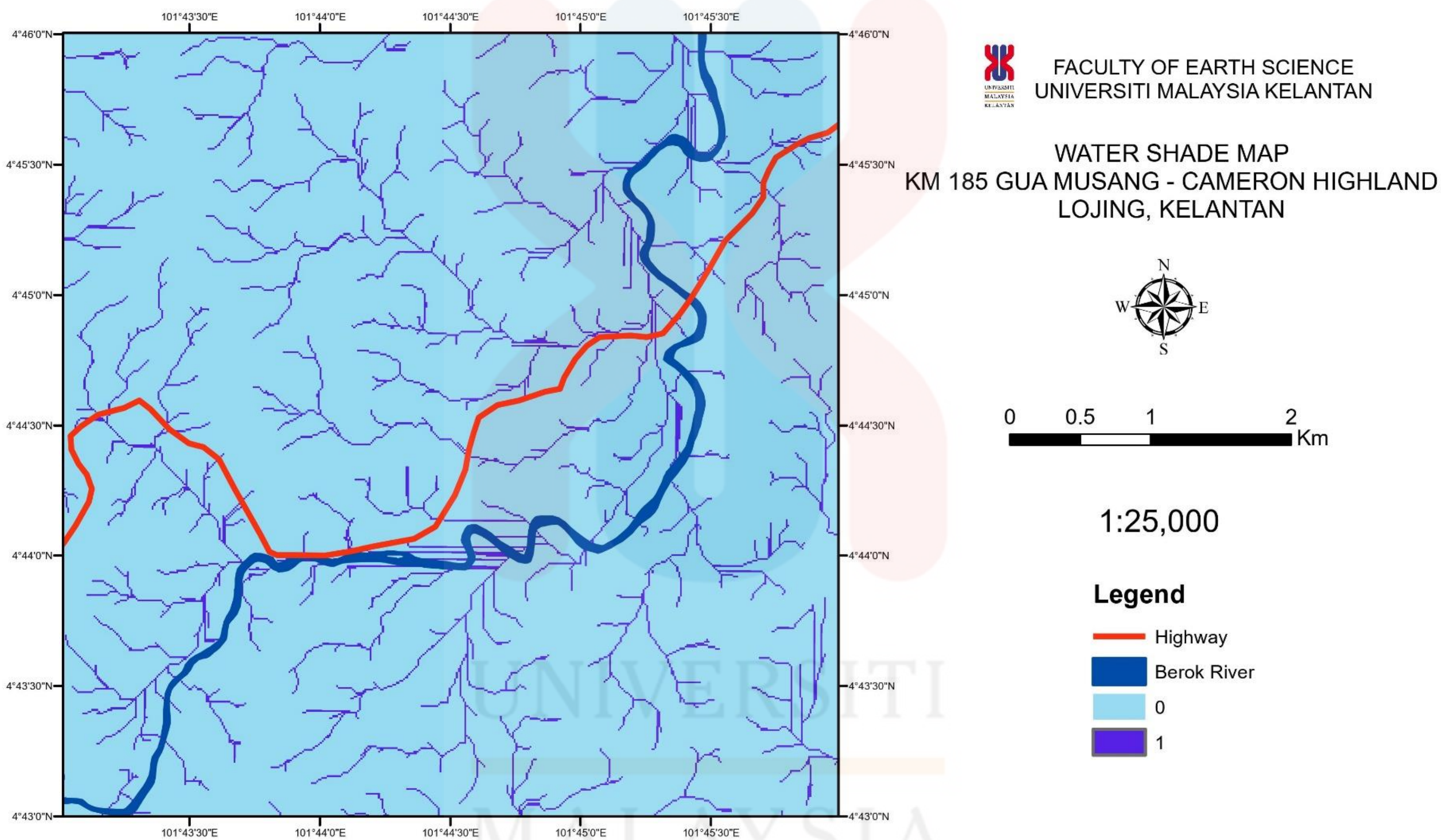

Map 4.13: Watershade in study area

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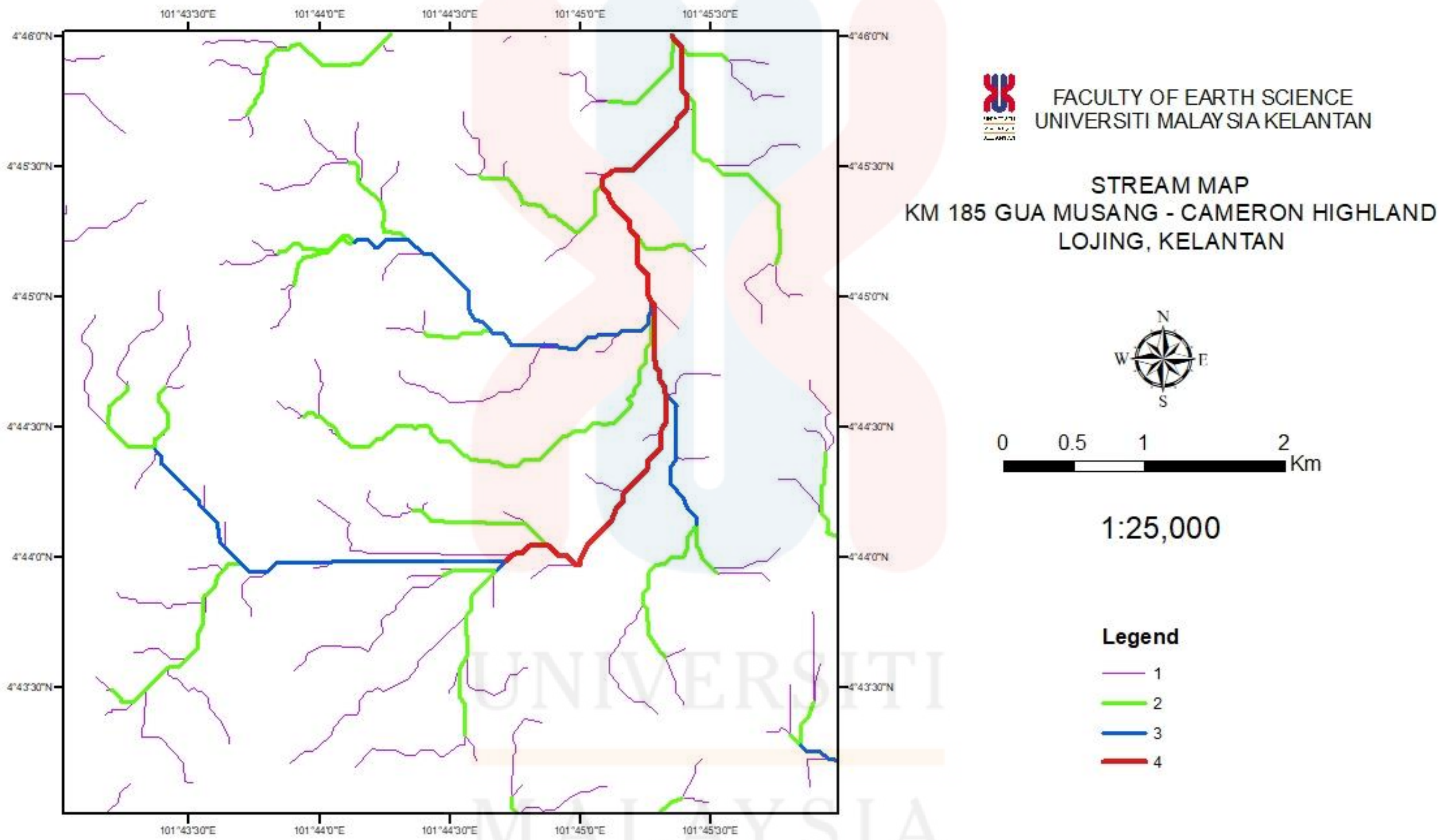

Map 4.14: Stream river map for study area

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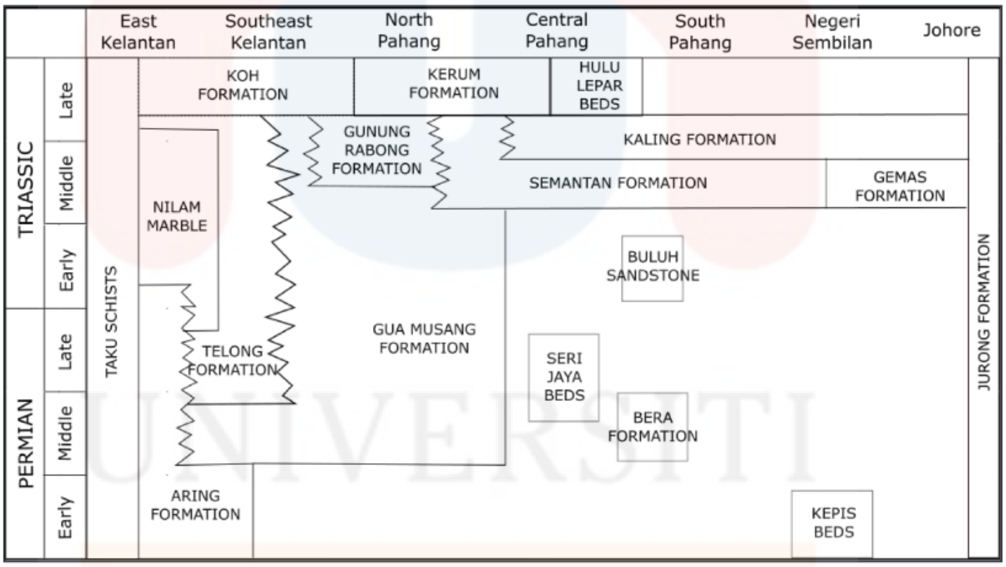
4.3 Stratigraphy

Hutchinson, 2009, stated that the stratigraphy on western par of central belt are Upper Palaezoic rocks of the Gua Musang abd Aring Formation in south Kelantan and Taku Schist in east Kelantan. Rocks in Upper Palaezoic are predominantly with argillaceous strata and volcanic rocks, with subordinate arenaceous and calcareous sediments deposited in a shallow-marine environment, with intermittent submarine volcanism, starting with Upper Carboniferous and peaking in the Permian to Triassic.

Table 4.3: Stratigraphy colum of Gua Musang Formation (Source: Yin, 1965)



Referring by Yin, (1965) the Gua Musang formation are in age Permian to Triassic where in this age been recorded with predominantly from argillaceous rocks interbedded with volcanic, minor presence of arenaceous rocks. Where this Gua Musang formation are formed by the shallow marine shelf deposit with active volcanic activity.

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4.3.1 Lithostratigraphy

Lithostratigraphy is the study that related to strata of rock and how it was formed million years ago which can be recognized and identified by looked at the basis of lithic characteristics and stratigraphy position. The lithostratigraphy can be characterized with classified from their mineralogy, palaeontology, petrology, lateral variation and relationship with adjucent units weather by horizontal or vertical on their rocks.

Lojing area normally are the same stratigraphy with Gua Musang Formation where come from Permian - Triassic era. The lithology on this study area that can be found by previous data, are contain with three types of rock units which is: schist, phyllite and quartzite. Each of the lithology contain the different explaination toward their mineral. Besides, together with the process of determination of their mineralogy its also can describe more about the phenomena that might happen at that area.

Table 4.4: Stratigraphy Colum (Source: Department of Mineral and Geoscience)

<table>
<tr><th colspan="5">Stratigraphy Colum</th></tr>
<tr><th>Formation</th><th>Era</th><th>Period</th><th>Rocks</th><th>Note</th></tr>
<tr><td rowspan="3">Gua Musang</td><td rowspan="2">Mesozoic</td><td>Middle Triassic</td><td></td><td>Schist</td></tr>
<tr><td>Early Triassic</td><td></td><td>Quartzite</td></tr>
<tr><td>Paleozoic</td><td>Middle Permian</td><td></td><td>Phyllite</td></tr>
</table>

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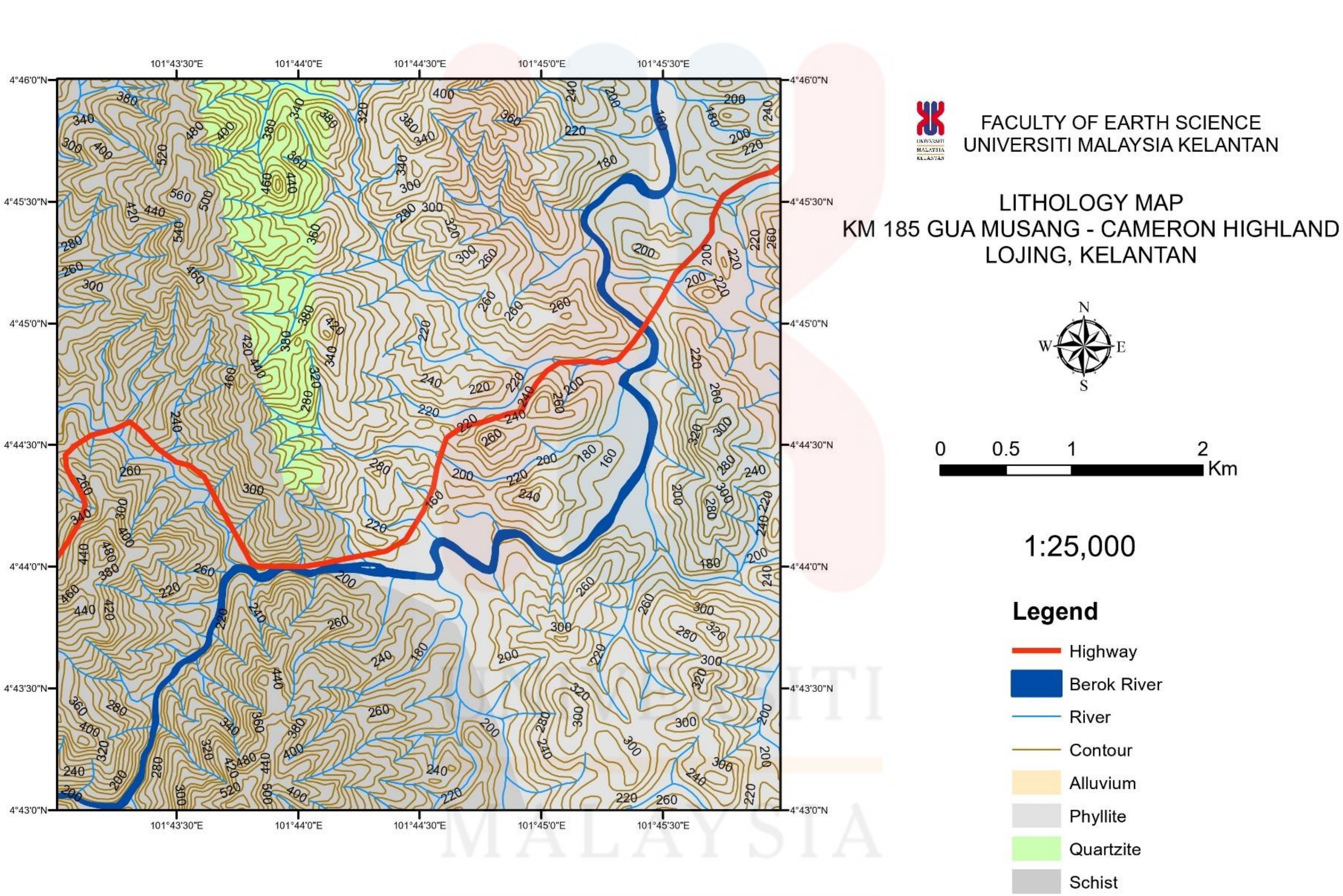

Map 4.15: Lithology map in study area

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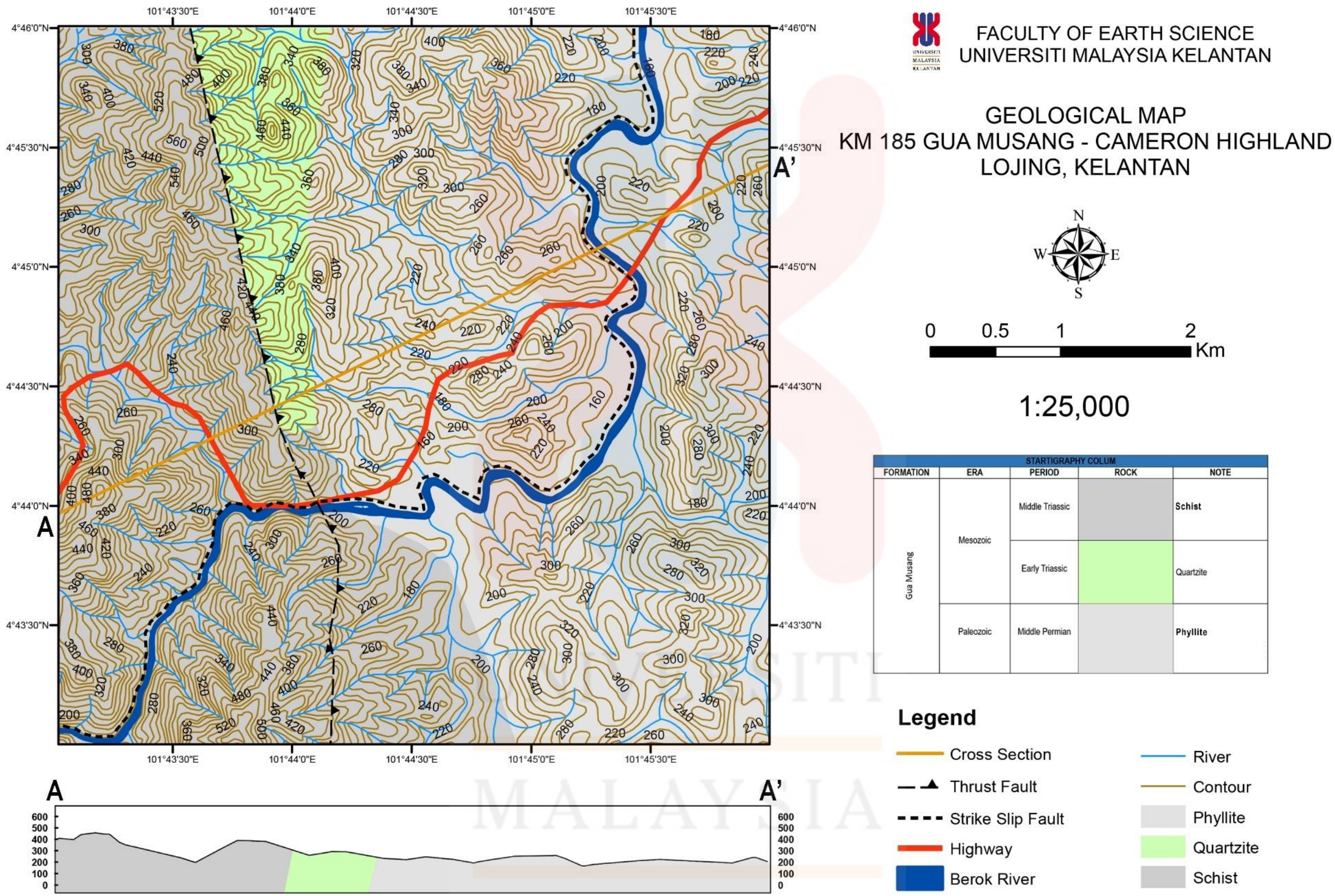

Map 4.16: Geological map for study area

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4.3.2 Rock Unit

Rock units is the rock group that been classify by their characteristic including the major and minor of their physical, chemical and biological process with their groups, formations and members. The formation is the distictive enough in appearance the rocks units where it is can tell apart from the surrounding rock layers.

a. Schist

Approximately, 30% of the total extent of study area are from this schist unit. Map 4.12 show the schist unit are been found on the west region of study area at the reserved forest area. Schist are been classified as a medium grade of metamorphic rock and most appeared in dark, black colour od rocks. The hardenes of the schist are moderate and it is been approved by the Mohs Scale with the medium grain size. The schist rocks are form by the metamorphosis of sedimentary rock sama as mudstone and shale or several types of igneous rocks that have been classified as a compressive forces, heat and chemical activity. In mineral identification, the mudstone or shale are converted into planty mica minerals like muscovite, biotite or chlorite by the intense metamorphic environment.

Looked into the moderate metamorphic environment, the sedimentary rock of shale will becomes the lowest grade of metamorphic rock known as slate whe it directed on the pressure push the transforming clay minerals from their random orientations to parallel alignment with the long axes of plentyminerals and

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it is perpendicular oriented tp the direction of the compressive force. The slate will transform to phyllite when the mica grains in the slate rocks grow and elongate perpendicular to it compressive force. Schist is formed when the phyllite is exposed to the additional metamorphism and the properties of mica grain that it large enough to seen.

b. Phyllite

Obviously, on the map shows there are 60% of the map are covered by phyllite rocks which is also one of the netamorphic rocks that happen on study area. Phyllite rocks is one of the foliated rocks where it is a fine-grained from the metamorphic rock and usually from metapelite with intermediate in grade between slate and schist. Meanwhile, the phyllite rocks are minute platy crystals of sericite, chlorite or graphite where its give a characteristics sheen to the cleavage surfaces which distinguishes it from duller slate. This cleavage are planar cleavage where it is produced by allingment of micas, less perfectly planar than in slates.

Phyllite are been developed from clayey or clayey to sandy sedimentary rocks with a residue of organic material, and transformed it into graphite. The phyllonites may be drived from many rocks types in particular from mica schist and gneiss because of the effect of retrograde metamorphism. In study area, phyllite occur in eastern site of sdtudy area.

c. Quartzite

Apparently, there are 10% of the study area are been fill with the quartzite rock unit where by referring towords the mineralogical of the quartzite rock, there are the rock that are from non-foliated rock where the parent rock area

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quartz sandstone. Quartzite is a medium to coarse grained where it is from the metamorphic rock that consisting largerly or entirely of quartz. Quartzite apparence in very white colour which is composely with quartz, fairly patchy gray if other minerals are present and can become to black if there is abundant by biotite, graphite or magnetite dispersed as very tiny grains.

Tecture of quartzite normally granoblastic, mosaic-type with mainly minute grain size where sometimes can also saccharoidal. Structure of quartzite were massive, foliated or schistose but depending on the abundance of mica, grading in some cases to arenaceous schist or quartz schist. The quartzite derived from arenaceous with fairly pure by the sedimentary rock like orthoquartzite, fraywacke or arkose fromquarzite-rich siltstones, jaspers and flints can also be derived from aplites and pegmites (Hutchinson, 2009)

4.4 Structural Geology

Structural geology is the process of conducting to the geological structures from how it is been formed until the effect for the rocks where it is focusing on the three dimensional distribution with the large rock bodies, surface and the composition of the inside with maintain their logical deformation. The deformation is alteration by the size or shape of rocks where it is cause by the stress or force applied at the certain area.

The structural geology that can be identifiesd in study area by studing all of the structure and behaviour of rock which is the fault, fold and joint where have been effected by the deformation of plate tectonic.

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4.4.1 Fault

Fault in this study area are believe there have two type of fault which is strike-slip fault and thrust fault. Fault is the fracture that happen along the Earth's crust where it can be defined when two adjacent blocks of the rocks moved towords each other during the induced stresses. Fault can be recognized in the field by several types which is geological evidence, fault plane evidences and physiographic evidences. The geological evidence are the evidence that will be prove by looked at the offset of the rocks unit which are the displacements of rocks beds, dyke or vein that occur on opposite of the faults. Also it is also can be shown from the repitation and omission of the strata that occur during the traverse line other than the stratigraphic sequence where can be identified by looked at the sequence of the older rocks above the younger rocks.

The study area are shows the physiographic evidence where it is shows the fault control of streams where it can be identified by look at the changes of the Brooke's River (Sungai Berok). The fault that have been identified in study area are thrust fault which happen in between of two rock unit which is schist and quartzite and strike slip fault that happen along the Brooke's river. This two fault are been proved and supported by the previous research that also been explain by some of the evidence. The more detailed about this two fault will be discussed futher in chapter 5.

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4.4.2 Fold

Fold is bending and curving formation by the original flat or planar surface upon the shortening that altered the competent and less competent layer of rocks. The fold formation in sediments indicates various condition of stress, pressure and temperature that the body of rock encounters. In the study area, by looked at the previous study and previous fieldtrip, there are several types of folds that can be found in the study area such as anticline, syncline, chevron, recumbent and etc.

In certain part in study area, can be found the chevron fold where this kind of fold are the angular fold with straight limb ang small hinges. Besides that, the syncline fold also can be found where normally the syncline is a concave structure in which the dipping is downward towards the centre of the structure where it is caused by compressional stress. Refer to the previous study, the syncline that can be looked at the study area are asymmetrical fold where this fold is a bed in one limb dip more steeply than those in the others. Some of the observation, stated that there are several structure that shows the anticline fold where half of the folds dips away from the crest. The anticline known as a fold that shown the "A" shape and formation by the compressional stress.

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4.5 Historical Geology

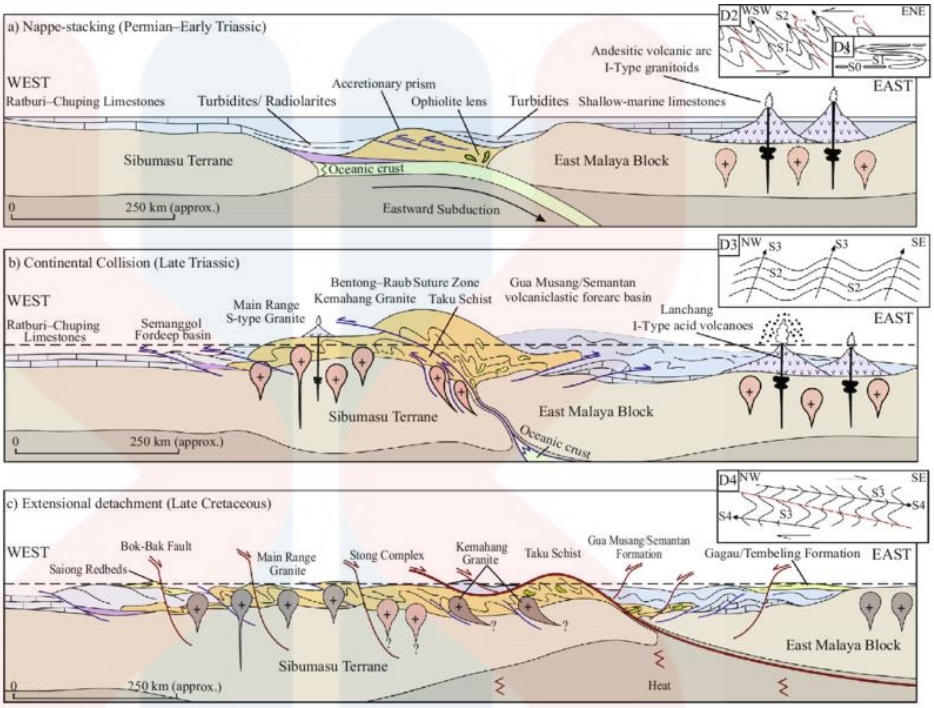

Figure 4.2: Subduction on Sibumasu and Indochina (source: Afiq Ali)

Historical geology is to explain the historical natural geological process that effect the environment at the study area where it is will discussed about the tectonic setting that affected the Earth's surface by focusing at the study area. Gua Musang formation and Bentong – Raub Suture Zone is the nearest phenomena that happen on study area. The Bentong – Raub Suture are the phenomena where the Sibumasu Plate collision with Indochina Plate during the age of Upper Permian to Upper Triassic. The Bentong – Raub Suture Zone are been formed with felsic and volcanic activity. Gua Musang Formation are the depositary setting under the shallow marine shelf with active volcanic activity.

Begins in the age of Permian until Late Triassic, Gua Musang Formation are beautifully take place on the study area where by referring from the previous

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data and Hutchinson, (2009), under the study area there are three types of lithology were found which is, schist, phyllite and quartzite. The deformation records on this area are occur with major thrust fault and strike slip fault where inherited frim the Bentong – Raub Suture Zone formation due to the collision between Sibumasu and Indochina block. From this activity subduction of the Palaeo-Tethys, begun in the carboniferous on Bentong Raub Suture by referring on the evidence where shows the abundant vplcanics in continental margin Carboniferous sediments in eastern Peninsular Malaysia and presence of a Carboniferous volcanic arc through Thailand and Western Yunnan. The futher understanding of historical geology will be dicussed in subtopic tectonic evolution in chapter 5.

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CHAPTER 5

TECTONIC DEFORMATION

5.1 Introduction

Hutchinson, (2009) have discussed the deformation where it conclude that the deformation happen in central belt of Peninsular Malaysia. The deformation on Gua Musang Formation are been identified by the two major fault that been found on that area which is thrust fault and strike slip fault. Meanwhile, to support this theory the research study from the earliest and the latest one have been made and looked out the comparison between this two theory.

From ther earliest, the deformation that happen on this study areas are been describe that deformation have been happen on ESE – WNW by looked at two major fault that have been identified in this study area. The two major fault are thrust fault and strike slip fault where the thrust fault been identified in between schisc rocks unit and quartzite rocks unit while the strike slip fault lies along the Brooke's River. This two fault and other structural analysis will bee prove in lineament analysis to find out the major direction that can be identified, fault analysis which is understanding more about the fault that lies on the study area and lastly is by using the stereonet analysis which is the method to prove the deformation by using the kinematic and dynamic analysis.

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5.1.1 Tectonic Evolution

To be more understand about the tectonic deformation on study area, the tectonic evolution should be known first and identified more about the evolution where on that journal by the previous research shows that the evolution happen on the Malay Peninsular which are the Bentong Raub Suture Line, There are separation between Indochina/East Malaya from the Sibumasu Terrane bisects where from the north to south (Barber et al., 2005) and regarded as the suture zone marking the site of subduction of Denovian to Permian ocean (Metcalfe, 2000). Bentong raub suture are been formed the boundaries from Sibumasu Terrane on the Western Belt and Sukhotchoi Arc (Central and Eastern Belts) and the Denovian – Permian of Palae-Tethys ocean basin were preserves remnants to destroyed by subuction beneath the Indochina Block/Sukhothai Arc.

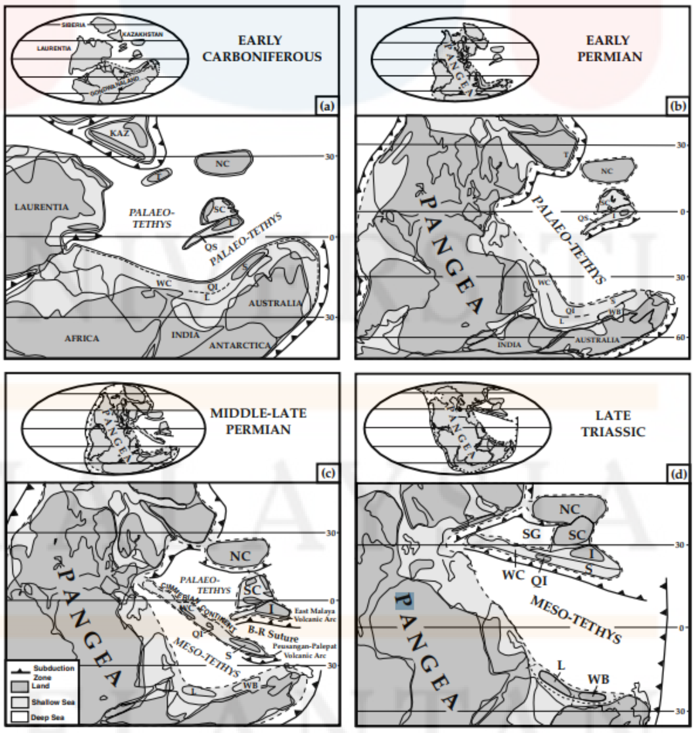

Figure 5.1: Palaeographic Reconstruction

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Figure 5.1 show During the Permian – Triassic, the northwards subduction of the Palaeo-Tethys beneath the Indochina been recorded in I-types granitoid and intermediate to acidic volcanics of the East Malay Volcanic Arc. The part of the elongate Cimmerian Continental strip, Sibumasu Terrane were separated from the margin Gondawana in late Lower Permian times. Permian and Triassic Sibumasu drifted rapidly northwards during on that time.

Upon the Permian – Triassic, the subduction towards Indochina constructed an accretionary complex of offscraped oceanic sediments and me'lange where it is also produces the East Malay Volcanic Arc and I-type granitoids. On that time, accretionary compelx built up into an outer arc on shallow marine limestoned were formed and some of it were incorporated as clast into me'lange and the volcanic arc migrated westwards. The thick volcaniclastic sediments, during the Triassic, it filled the fore arc Semantan basin where it is corresponding with the Central Belt of Peninsular Malaysia and turbiditic rhythmites and conglomerates of Semanggol Formation where it is deposited in Semanggol foredeep basin by the top Permian – Triassic cherts and pelagic limestones.

Figure 5.1 shows the period of tectonic evolution where the During the Early Triassic (C), the fore arc subsidence intensified in Gua Musang platfrorm where it is create more arrangement of space fro carbon-argillite-volcanic deposition that cause Palaeo – Tethys Ocean had been completely subducted as Sibumasu docked into Indochina. Meanwhile, in Middle – Late Triassic, Sibumasu aided a process of subduction of segmentation on subsiding Gua Musang Platform that cause the deep marine Semantan – Gemas basin were created on bounded by the shallow marine platform as potrayed by the geometry of Central Belt.

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5.1.2 Tectonic Deformation

Deformation that happen on this study area are believed that caused by the collision between Sibumasu and Indochina where upon the collision happen on Peninsular Malaysia the effected towards the two plate becomes the Peninsular Malaysia. Deformation of rocks are been describe by the term of changing in size or shape of an imagery sphere where normally the imagery sphere are the rocks that becomes an ellipsoid during the homogeneous deformation.

Strain ellipsoid are the deformation which the orientation and dimension that describe the deformation of the plane in which it lies. In understanding the trully of the ellipsoid happen in the study area, the fault that have been identified in study area can be the evidence in determine the deformation that happen on that area. The ellipsoid that been identified by the data collected cab be correlated with the major fault in the study area which is thrust fault and strike slip fault. The deformation of the rocks can be investigate using the principal stress (σ_1) that comes from the direction of ESE-WNW, the circle will pressed and deformed as ellipse and the rocks bodies will experience deformation. The deformation that happen on this study area are in perpendicular which is the character of the thrust/reverse fault.

The strike slip fault in this study area are parallel and been shown in map 5.2. thus, the theory from the previous reserch about the deformation in this study by look inti the thrust fault and strike slip fault can be accepted. From above are been shown the mechanism and technically about the study area by looked at the structural analysis.

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5.2 Structural Analysis

Structure analysis in this study area are more focusing on the fault and lineament where it believe that on this two method there would be the prove for the deformation that might be happen on the study area. The structural analysis will be conducted by the two software which is ArcGIS 8.0 and Dips 7.0. In this analysis, the lineament will be interpreted by analyzed their direction by plotting the direction and identify the value of the direction. While for the fault analysis, from the previous research, there would identified on the previous data and correlated by the theoretical that have been preved.

5.2.1 Lineament Analysis

Lineament is the landscape linear feature whis is an expression of underlying geological structure. Lineament normally will comprise a fault aligned valley of fault and fold aligned hills, straight coastline or indeed a combination of the features. In other words, the lineament analysis is some method that have been using in identified the the geological structures like fault or fold where the lineament are extractable in linear feture from the aerial photography like remote sensing or topographic map where it is just ceen identified on the atmosphere surface not on ground surface. In identifying the the different information on geological setting like type of drainage pattern and landslide lineament also can be used as one indicator depends on how to interprete and look into the resolution that have been provided.

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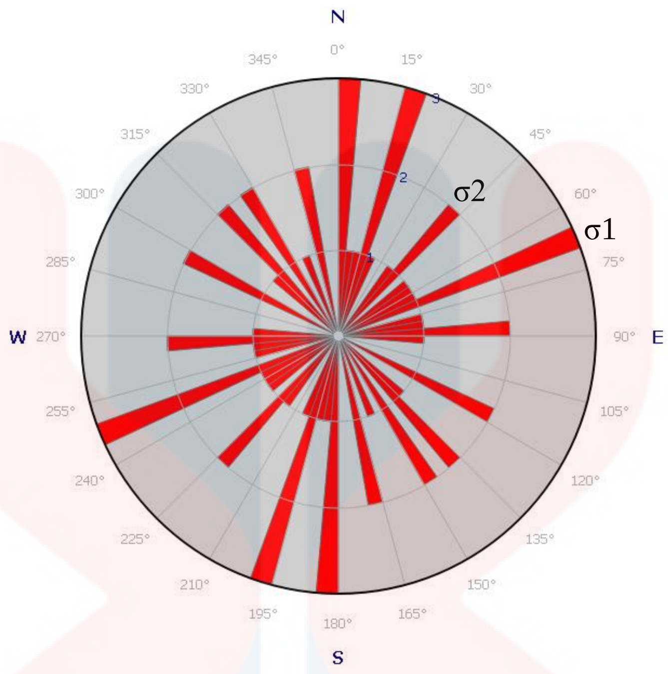

Figure 5.2: Rose diagram for lineament set

Table 5.1: Date set for lineament interpretation

No.	Strike	No.	Strike	No.	Strike
1	85	12	3	23	273
2	295	13	55	24	36
3	310	14	18	25	66
4	42	15	51	26	337
5	40	16	12	27	349
6	2	17	17	28	348
7	79	18	85	29	65
8	328	19	22	30	298
9	319	20	15	31	8
10	62	21	1	32	325
11	316	22	68	33	82

In this study area, lineament analysis have been used where the lineament have been done by doing on the terrain map and topography map (map 4.10) on the study area with the scale 1:25, 000, in map 5.1 the lineament have been identified and drawn the direction of the lineament. All the lineaments are represented as a straight line where it is the approximately follow the linear futures on the image and been represented on the rose diagram in determine the major of force.

5.2.2 Fault Analysis

Depending on the lineament analysis above, the major structure that can be interpreted is the fault where in this study area, there would be two different fault that can be recognized which is strike slipe fault and thrust fault. These fault can be used in identified the deformation that happen on this study area. The fault that have been identified before is shows the significant of the deformation happen between the rocks on the study area where it is can be known when doint the site visit or justification the topography maps.

Thrust fault that believe happen on this study area where the type of dip slip fault which is dips at ± 45º where the thrust fault on this study area were analysed along the lithology between schist and quartzite which the hanging wall moves up relative to the footwall. From the previous research, they belive that thrust fault that caused by the older rocks are pushed above the younger rocks during the horizontal compression stress by the plate mechanism. The lithostratigraphic unit have been prove that schist as the oldest units rocks occur in study area due the hanging wall which consist of the metamorphic rock unit found over the younger non clastic metamorphic rock.

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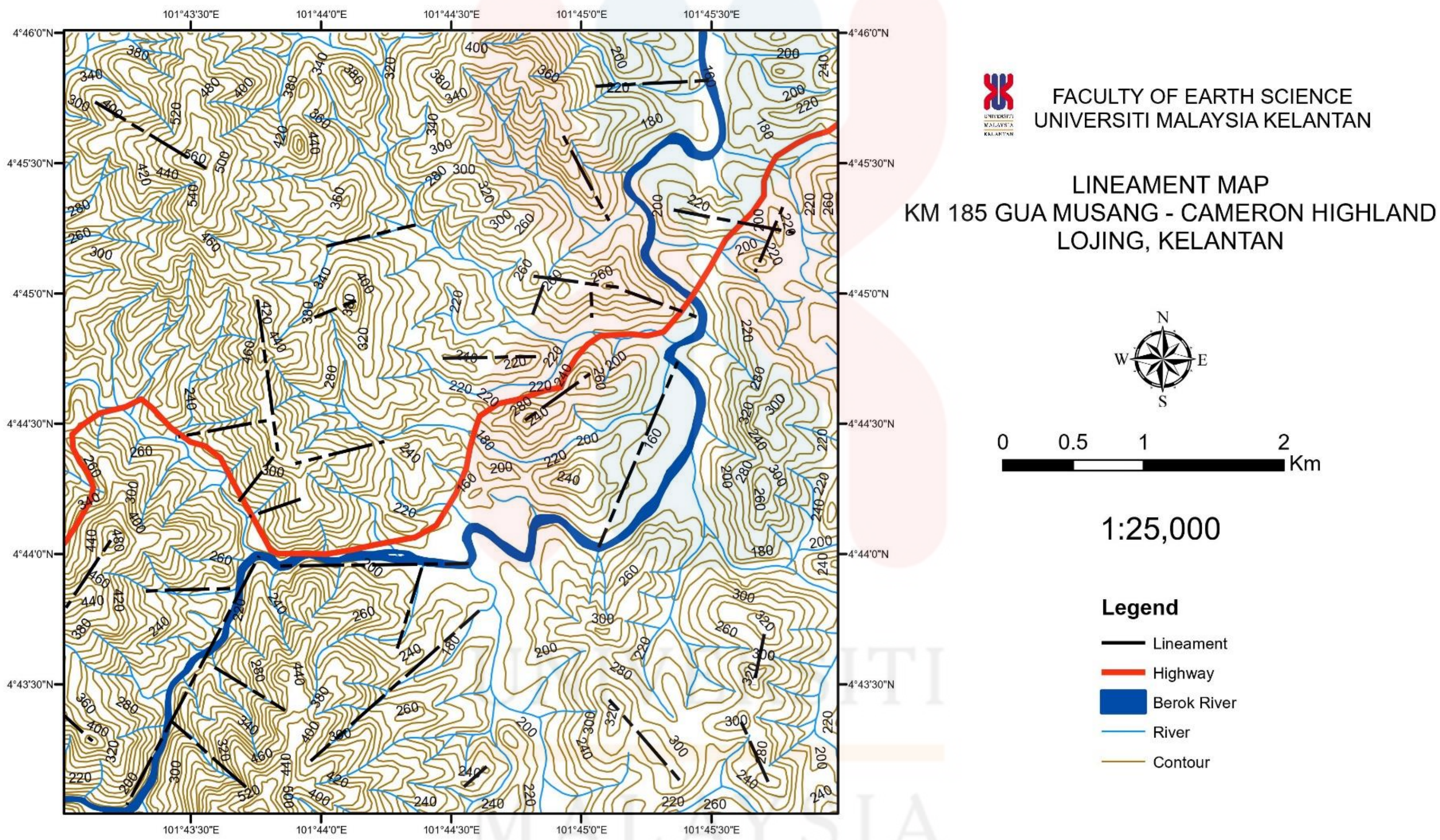

Map 5.1: Lineament map analysis

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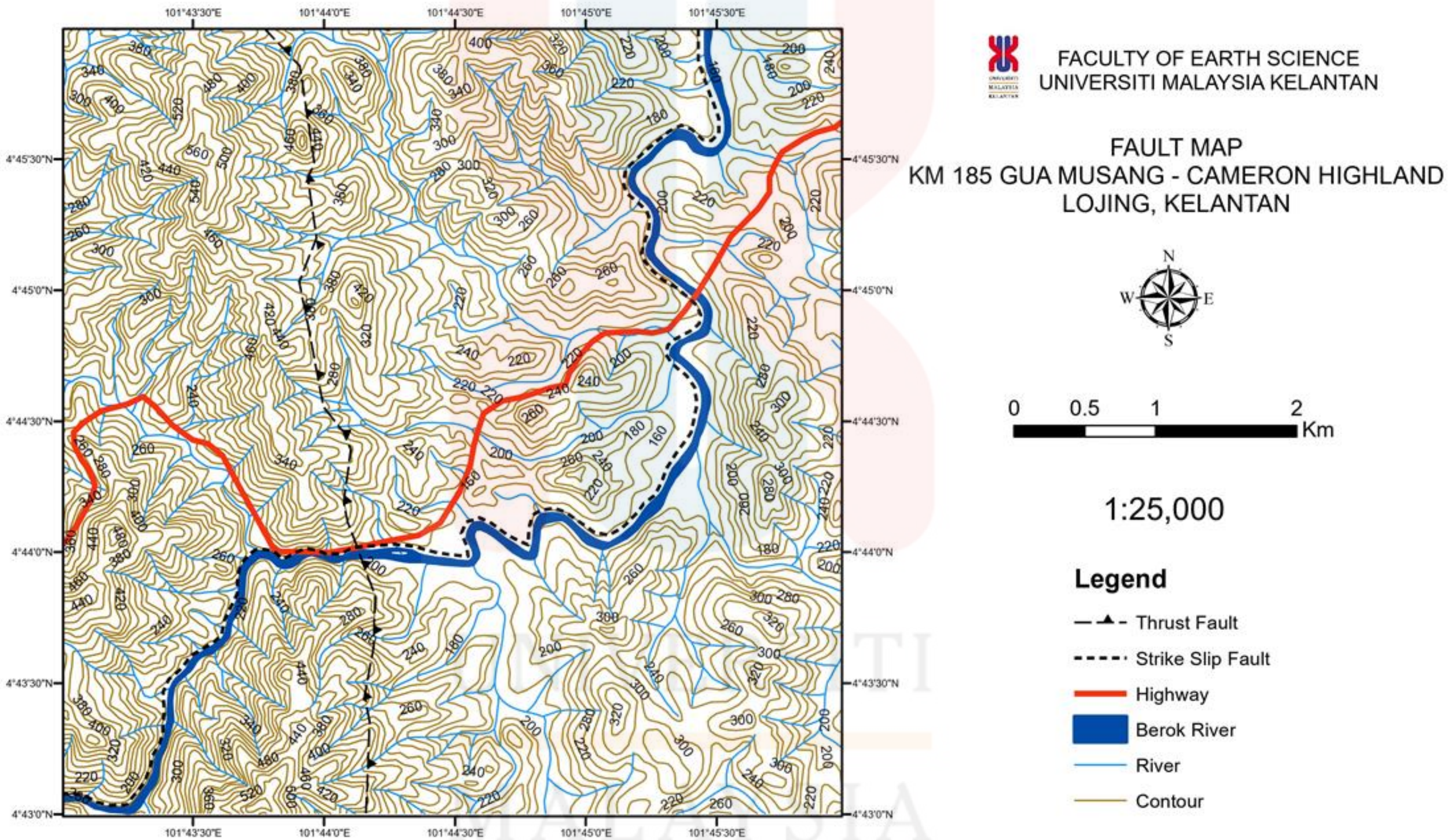

Map 5.2: Fault map analysis

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5.3 Stereographic Analysis

To identify the deformation on the study area, the stereographic analysis is on of the main method and relevant indicator that can be used to acknowledge the existence of the deformation in the study area. With the stereonet analysis, the kinematic which is the movement of the rock during the deformation can be analyzed and proved. Which mean, the kinematic that used the data of fault is to analysed by using the stereonet software.

5.3.1 Kinematic Analysis

To find the movement of the rock during the deformation, kinematic analysis were been using to identified it. the kinematic analysis will be analysed bt the mean graphical method which have been collected from the previous research that doing it on the field observation. By using the stereonet, the data that have been collected will be correlated with the strain analysis which shows the real deformation on the study area.

Figure 5.5 shows the data that have been collected that form the result towards the thrust fault at the western part of the study area. Gentlely, the dipping lies on 20º which the angle of 45º occurs due to the thrust fault activities. The strike and dip that have been collected from the previous research where happen in between the schist rock and quartzite that happen on western part of study area, Fault that occur by the compression force on ESE – WSW direction where the principle stress of sigma one where in figure 5.5 shows that position of strong

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force is about 85º SE. Other site in study area, the figure 5.6 shows the dips that also < 45º where due to the vertical dragging effect of major thrust fault formation on the hanging wall that causing by the other side of the rocks that resembles the thrust fault that more less steepness.

In part of the strike slip fault, the fault that involve of the shear stress that happen between two faults blocks. Looking after the strike slip fault that have been identified on the Brooke river, the faults that occur across the schist units and phyllite units where the rocks strata are displaced mainly in a horizontal direction which is the parallel to the line of fault where in the map 5.4 believe that the truly river are the straight line but might be something happen that make it the river been pushed and reshaped.

The data that have been collected determine that the strike slip fault on the study area are from the sinistral type of strike slip which the block across the fault are moves to the left that occurs an angle abouts 30º from the principal stress which from figure 5.7 shows the position of the principal stress about 88º SE. Meanwhile, from the figure 5.8 shows the various pattern of result which mean that maybe the strike slip on that area were disturbed by the occurrence of the sinistral strike slip which the deformation happen and drag along together of the structure and caused the rock changed from the original form and not in uniform direction. In fact, towards the changes of the river flows, that strongly believe that the movement of the hill and mountain that maybe happen because of the uplifted of the rocks are also one of the factors of the changes of the river flows.

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5.3.2 Dynamic Analysis

The dynamic analysis is the study of the motion of particles from the kinematic analysis that caused the part of the the structural geology that includes energy, force, stress and strength which involves the measurement and estimation of the forces or stress that affected the rocks. The rocks will start to move when it receive the high level of stress from the forces that generated the body. On the field study, the dynamic analysis were using on determine the orientation and magnitude of stress that have been caused by the deformation which the rock that been affected by the stress due to the external force resulted from tectonic movement or tectonic subduction in the study area where it is involve with three principal stresses which is σ1, σ2 and σ3.

The principal stress are the stresses that have been applied on the surfaces where the stress are acts into two ways which is the normal stress that acts perpendicular to the plane (σ_n) and the shear stress that acts parallel to the plane surface (σ_s). Which mean, the three planes of zero shear stress will existed when a body of rock is under stress from all the direction where it been called principal plane of stress.

In the study area, the joints of the rocks have been collected and identified where shows in figure 5.3 the major direction from joint distribution are NE – SW which the major stress about 30º and been interpreted as the major joint distribution where trending ESE – WNW.

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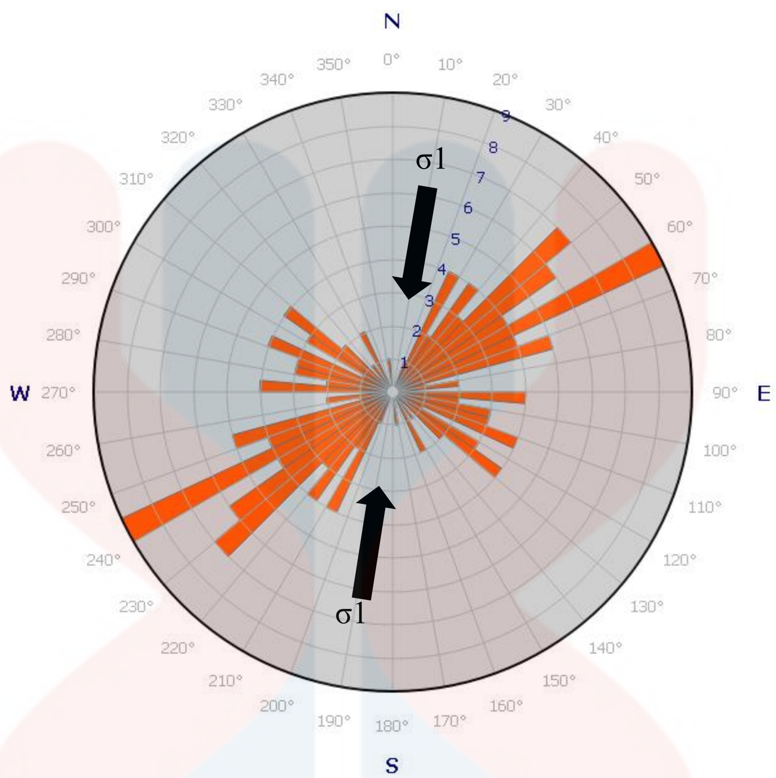

Figure 5.3: Rose diagram for joint set

Table 5.2: Joint reading for study area (source: Mas Assyiqim, 2019)

No.	Strike	No.	Strike	No.	Strike	No.	Strike	No.	Strike
1	105	21	278	41	93	61	234	81	115
2	235	22	300	42	48	62	232	82	144
3	142	23	28	43	253	63	62	83	152
4	33	24	43	44	45	64	228	84	134
5	47	25	273	45	35	65	214	85	58
6	20	26	280	46	28	66	274	86	54
7	220	27	229	47	235	67	200	87	110
8	230	28	68	48	240	68	106	88	67
9	295	29	71	49	94	69	102	89	70
10	50	30	220	50	243	70	113	90	96
11	50	31	27	51	241	71	110	91	123
15	46	32	215	52	237	72	311	92	151
13	250	33	222	53	290	73	29	93	127
14	27	34	244	54	73	74	60	94	52
15	13	35	45	55	241	75	127	95	75
16	284	36	66	56	230	76	64	96	34
17	96	37	35	57	81	77	127	97	171
18	252	38	250	58	262	78	64	98	49
19	14	39	108	59	281	79	128	99	124
20	312	40	39	60	225	80	52	100	249

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5.3.3 Strain Analysis

The strain analysis is purposed to acknowledge about the changes of the shape or size of imagery sphere within the rocks into the ellipsoid during the homogenous deformation. Strain ellipsoid are the orientation and dimention that describe the lies of the plane of deformation. To determine the strain ellipsoid, the major fault which is thrust fault and strike slip fault were been correlated with the study area where shows that the circle will be pressed and deformed as ellipsoid wher the principal stress (σ1) comes from the ESE-WNW make the rock bodies experience the deformation. The thrust/reverse fault are the deformation that perpendicular to the principal stress while the strike slip fault and normal fault are parallel to the principal stress which make the other deformation like folding and joints.

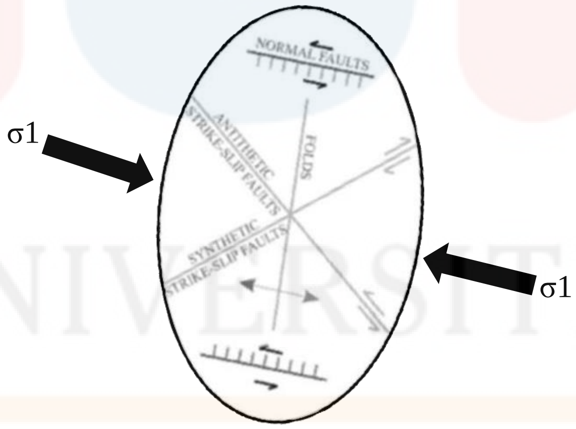

Figure 5.4: Strain analysis reprensented on study area

The synthetic strike slip fault are represented in figure 5.4 where the strike slip fault were been identified. Beside because of the thrust fault is perpendicular to the principal stress. The joint that have been identified before shows the trending of the principal stress are 30º ESE – WNW that make the theory of the strike slip fault and thrust fault of study area are accepted.

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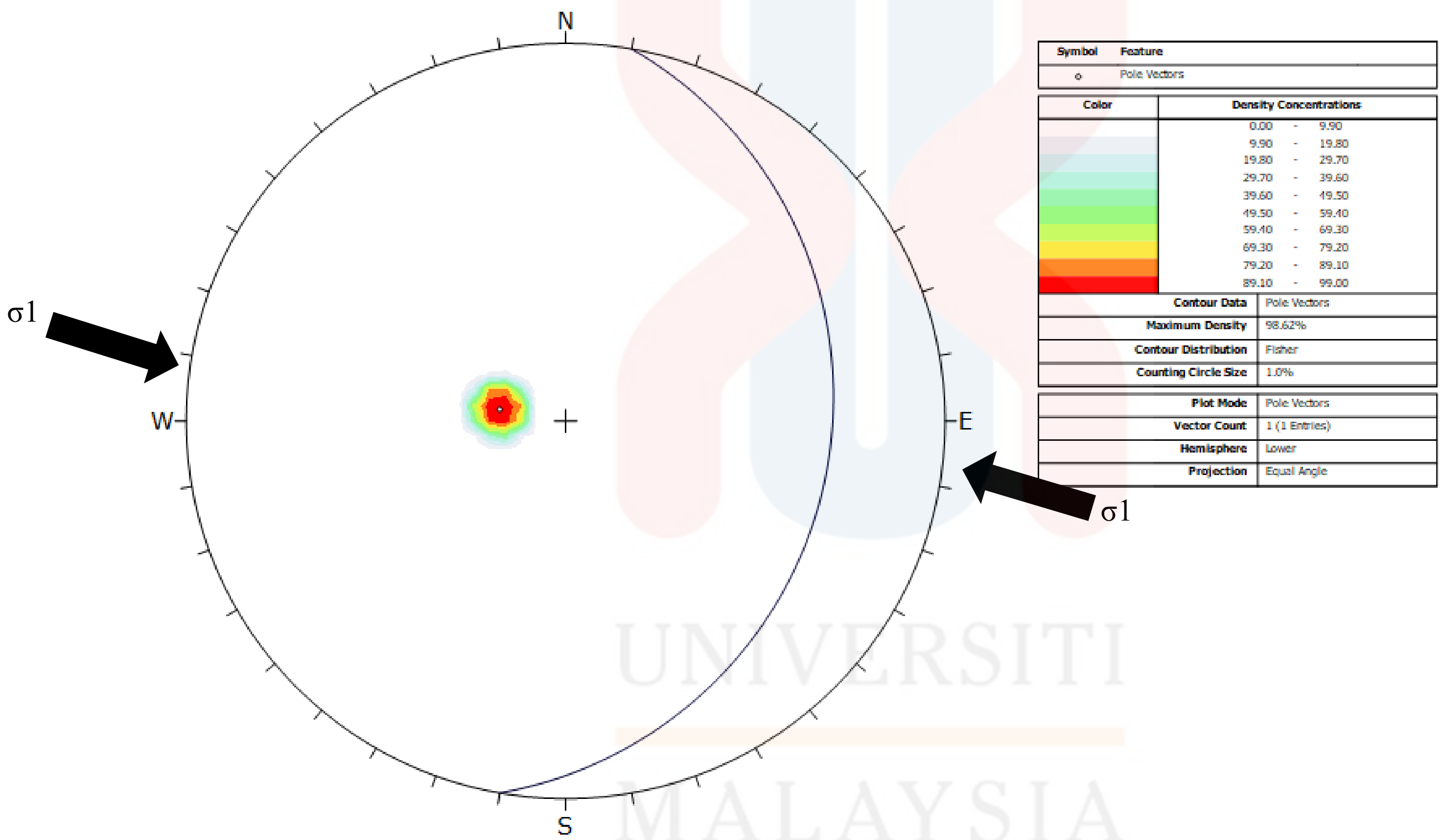

Figure 5.5: Position of the strongest force

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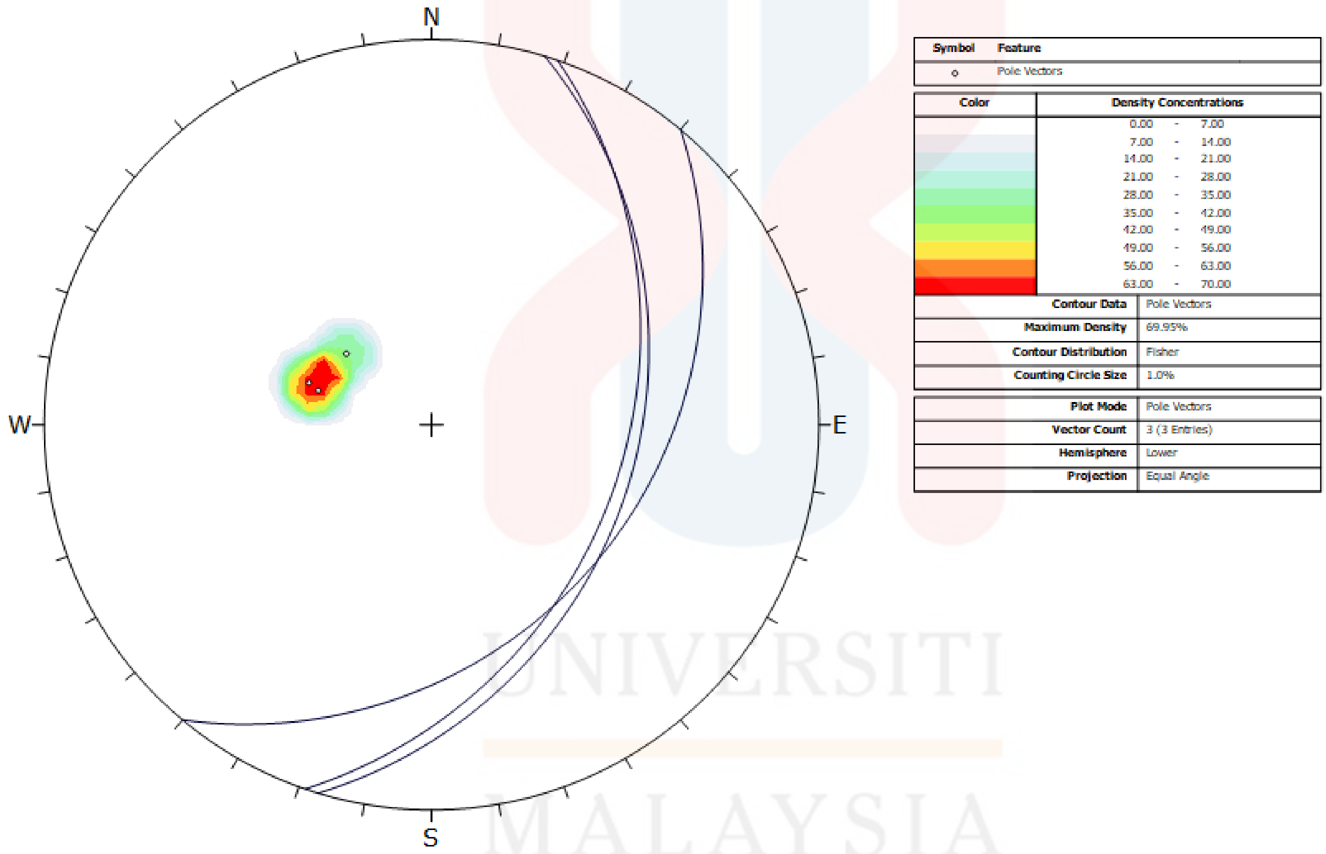

Figure 5.6: Stereonet in location

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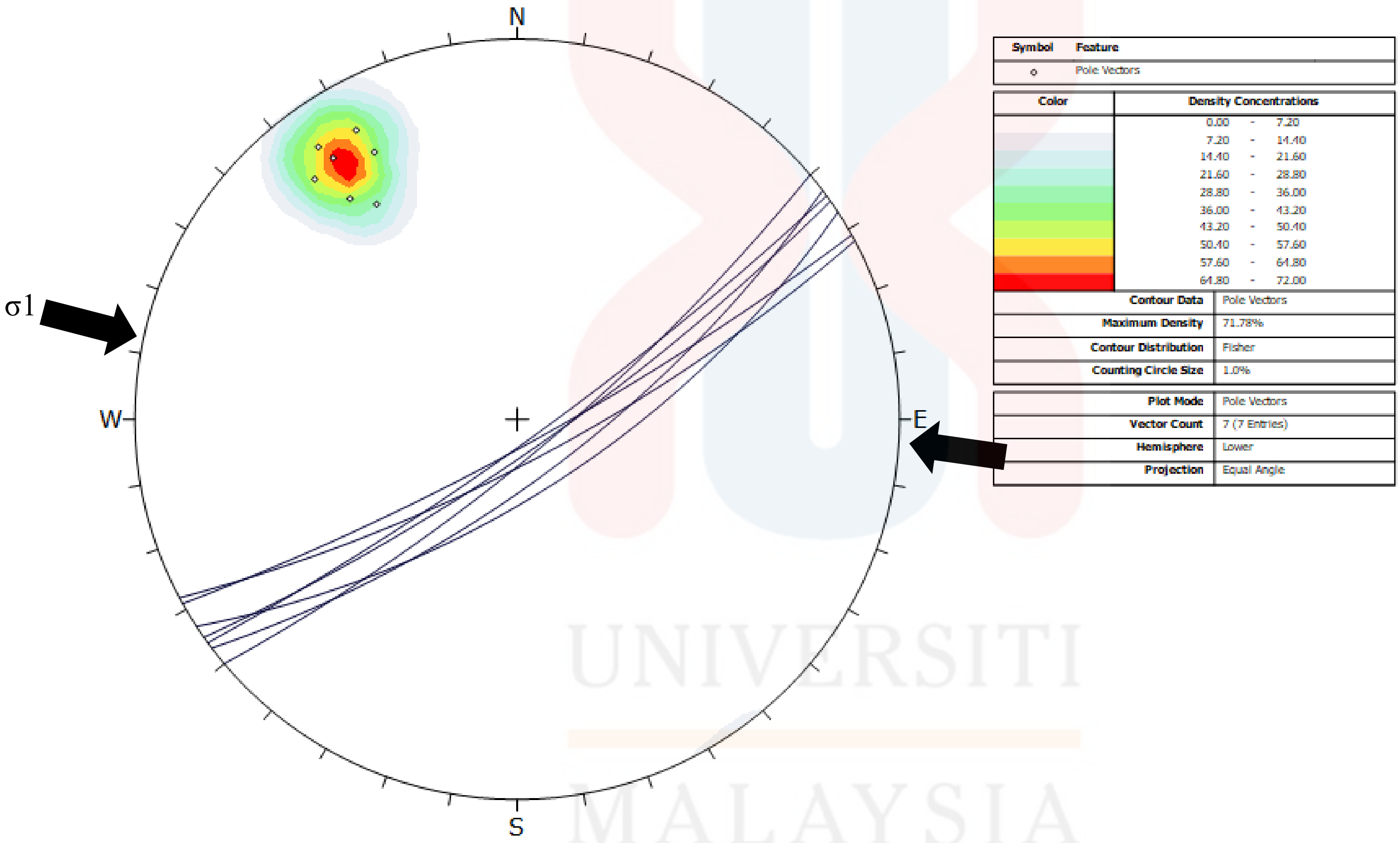

Figure 5.7: Stereonet in location

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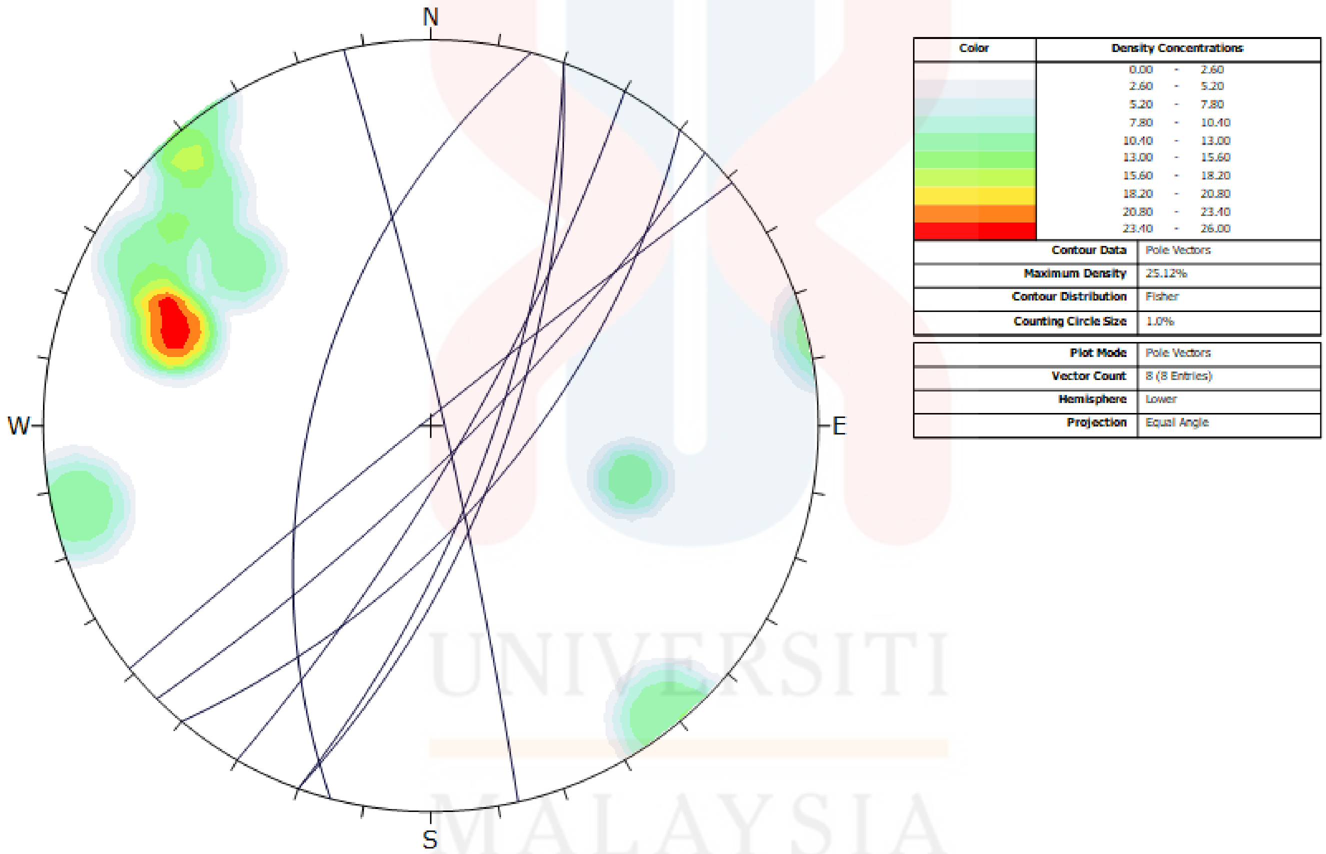

Figure 5.8: Stereonet analysis deform in location

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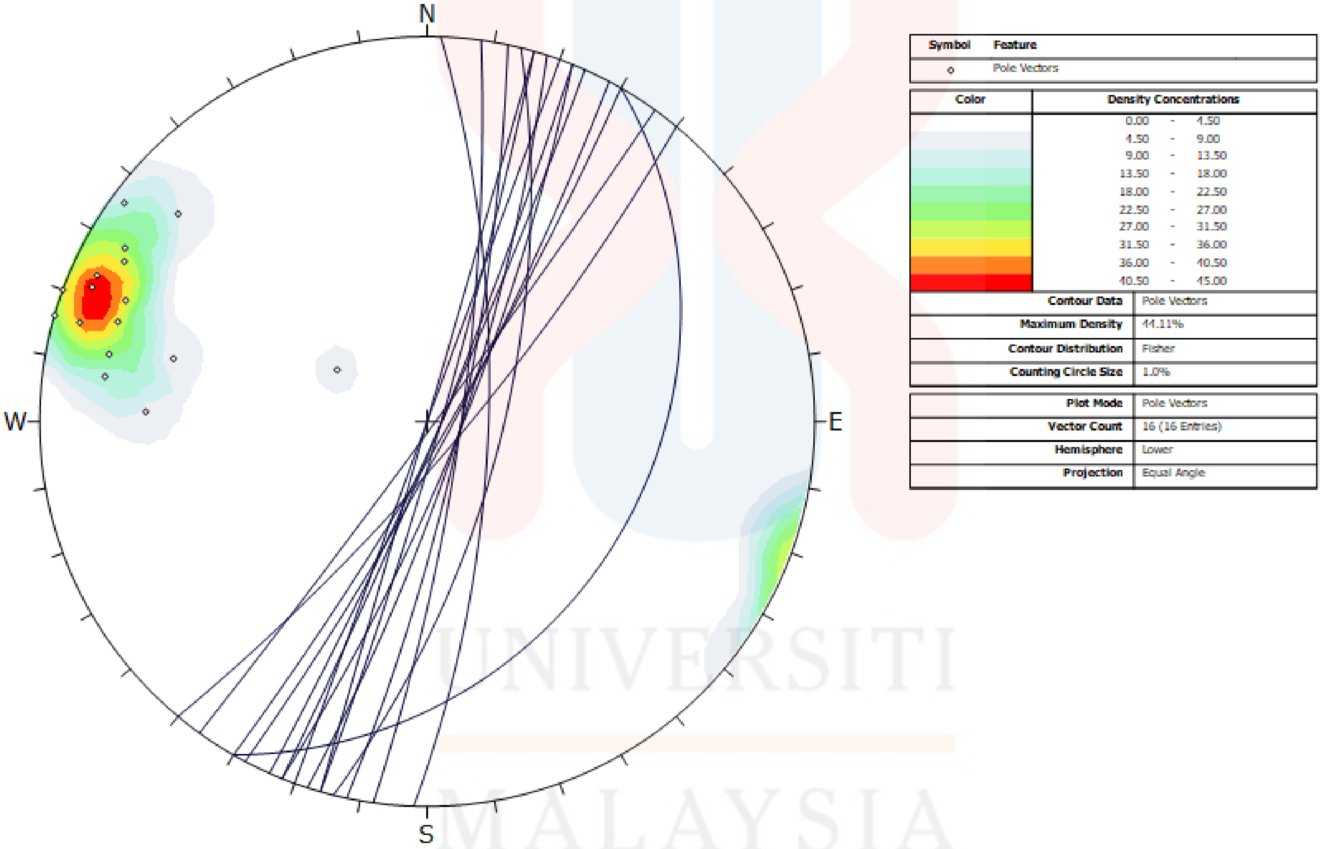

Figure 5.9: Stereonet analysis in location

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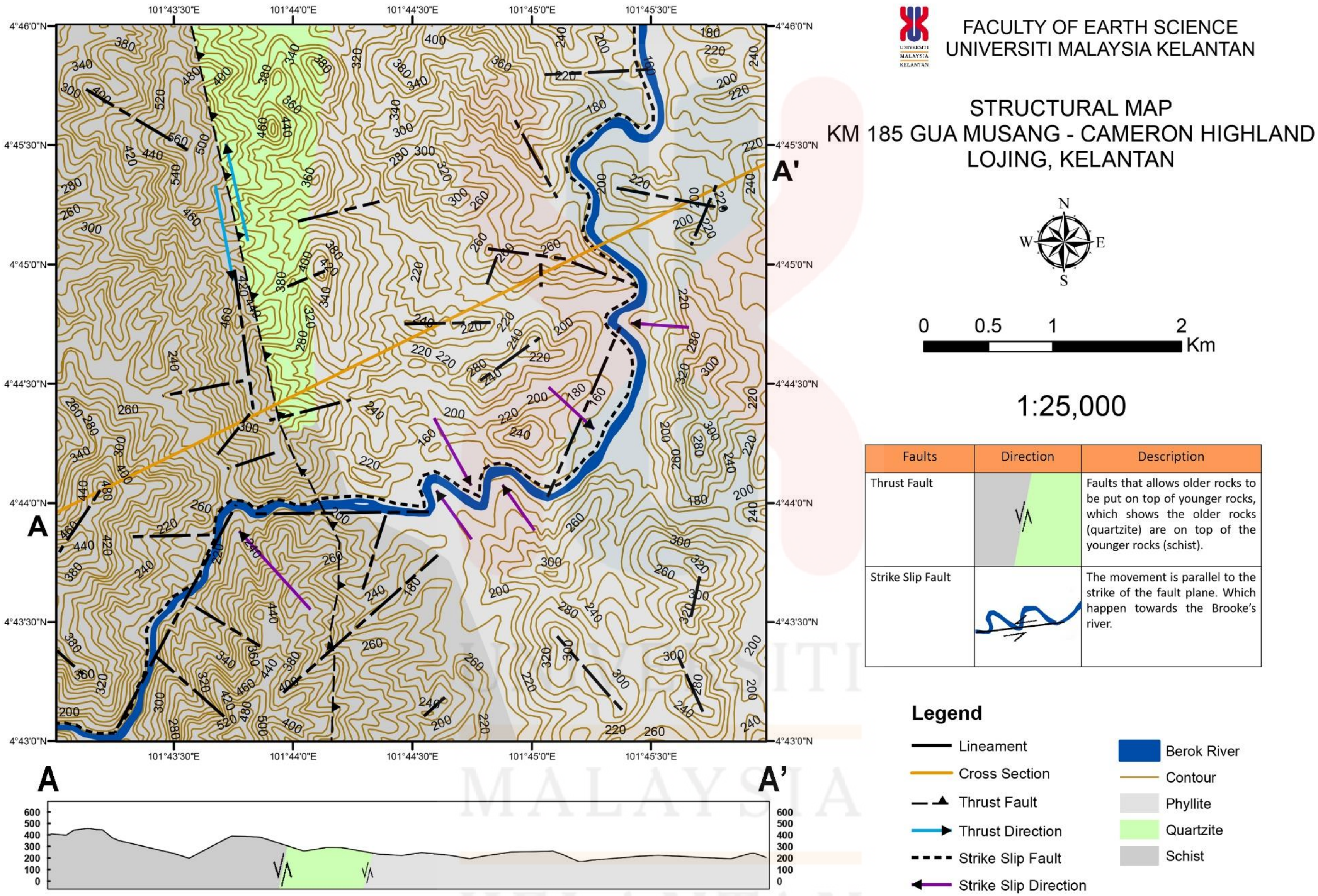

Faults	Direction	Description
Thrust Fault		Faults that allows older rocks to be put on top of younger rocks, which shows the older rocks (quartzite) are on top of the younger rocks (schist).
Strike Slip Fault		The movement is parallel to the strike of the fault plane. Which happen towards the Brooke's river.

Map 5.3: Structural map on study area

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CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Justification towards this research, the research can be said that already achieved the objective on doing this research, which is the main objective is to generate the geological map with 1:25,000 on the study area and to produce the structural map with 1:25,000 on the study area which include the study and result towards the tectonic deformation that happen on this study area.

Go through to the first objective, the geological map on the study area achieved successfully by referring from the previous research and the other agencies to collect all of the data. From the data that have been collected with using the ArcGIS 8.0, the geological map have been produce and been updated with the relevant rock. The rock that consist in the study area are include schist, quartzite and phyllite which three of it was from the metamorphic types of rocks. In fact from the research study also conclude that the study area would be on aged of Permian – Triassic by looked at the rocks and the structure that can be racognize with identify their rock units.

Back to the second objective, the structural map on the study area are gentlely succeed where the data that have been collected shows there are two types of fault that can be identified in this area which is Thrust/Reverse Fault and Strike Slip Fault where many geologist believe the the fault happen because of the movement and stress that contributed to the deformation on that area. By using the

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Dips 7.0, the kinematic analysis have been produced which show the trend direction of the rock are ESE – WNW which mean the deformation happen in synthetic fault of the strike slip. Meanwhile, the theory of tectonic evolution have been proved that from the collision of two tectonic plate which is Sibumasu and Indochina are one of the factors of the deformation happen on the study area.

Conclusion from the whole research of tectonic deformation in kilometer 185 Gua Musang – Cameron Highland, Lojing Kelantan in theoritally and practically proven that the phenomena of deformation is really happen millio years ago where the prove of every deformation lies on the geological structure.

6.2 Recommendation

After doing this research, there's a lot of recommendation that can be identified and suggested to the others where the most important part in learning the new environment of research study to every one. The research study should doing in practical way which is fieldwork, where it is the best experience and experiment in doing any research, because by doing the fieldwork, the student could feel and experience how to know and classified the rock by their own knowledge. Beside in the fieldwork, the knowledge that have been studied before can be practice in performing the research activities where student can be more understand and experience by them self in covering all the theory that have been learn before. In addition, the industrial could be more open towards the student to get the relevant data if something happen that denied the student to do the fieldwork, so the data from the industrial would be the best way in collective the relevant data to achieved the objective of the research.

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