GENERAL GEOLOGY AND INFLUENCES OF REGIONAL STRUCTURAL PATTERN WITH SLOPE FAILURE AT KAMPUNG SUNGAI ASAP, GUA MUSANG, KELANTAN

by

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A report submitted to fulfillment the requirements for the

Degree of Bachelor of Applied Science (Geoscience)

FACULTY OF EARTH SCIENCE

UNIVERSITI MALAYSIA KELANTAN

2017

DECLARATION

I declare that this thesis entitled "Genereal Geology and Influences of Reginal Structural Pattern with Slope Failure Distribution at Kampung Sungai Asap, Gua Musang, Kelantan "is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ________________________________

Name : ________________________________

Date : ________________________________

ACKNOWLEDGEMENT

In the name of Allah, the most Gracious and The Most Merciful.

I would like to give a big thanks to Allah SWT, the almighty God of creatures for giving me many opportunity, chances, bless and guidance in order to assist me completing the final year project thesis.

Foremost, from the beginning I started doing this project until I finished fulfilling the requirement of Degree of Bachelor of Applied science (Hons.) Geosciences, I would like to express my gratitude to my advisors, Encik Shukri Maail and Encik Hamzah Hussin. They had been a source of encouragement and knowledge for me in completing this project. Besides, thanks to others UMK Geosciences's lecturer for all the guidance and knowledge given for me to apply in this thesis.

I would like to express my gratitude to my parents and all of my siblings. Thank you for your uncompromising support and love through years. Thank you for never refuse to fulfill my need and requirement especially for the financial support.

Also a big thanks and sincere appreciation to my dear course mate friend who had help me lots in completing this project without giving up and bored especially Nadia, Wahidah, Hasmimi, and Azian for endless support. A biggest thanks to my coursemate whose support me physically and mentally, understand, help, guide, and educate me to complete my final year thesis. Thank you very much.

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ABSTRACT

Slope failure is mainly control by geological structure such as joint, bedding, foliation and others. Slope failure is defined as the mass movement includes all the processes that involved the outward or downward movement of slope forming material under the influences of gravity. The study area is located within the latitude of 4°57’60” to 4°55’0’’ and longitude 102°1’30” to 102°4’0’’ in Gua Musang, Kelantan. The objectives of this research are to an updated geological map of Kampung Sungai Asap in scale 1:25 000, to analyses the regional structural pattern using satellite imagery, and to investigate the relationship between regional structural pattern with slope failure distribution. The lithologies found in the study area are volcanic tuff, limestone, mudstone, metasiltstone and sandstone. Slope failure mapping was done and the total slope failures are 11 and all of them are translational type of failures. Two slope failures were choose to investigate the influences of structural pattern with slope failure. From the stereonet analysis of slope failure, the present of discontinuities on slope has influences the failure because there are discontinuities sets plotted on critical area for sliding and they are daylighting into the slope. As a result, structural pattern mainly controlled the slope failures.

Geologi Am dan Kaitan Antara Struktur Regional Dengan Taburan Kegagalan Cerun Di Kampung Sungai Asap, Gua Musang, Kelantan.

ABSTRAK

Kegagalan cerun dipengaruhi oleh struktur geologi seperti retakan, lapisan, foliasi dan lain-lain lagi. Kegagalan cerun didefinisikan sebagai pergerakan jasad termasuk semua proses yang menyebabkan pergerakan keluar dan kebawah bahan yang membentuk cerun di bawah pengaruh gravity. Kawasan kajian terletak di antara latitud 4°57’60” hingga 4°55’0’’dan longitud 102°1’30” hingga 102°4’0’’ di Gua Musang, Kelantan. Objektif kajian ini adalah untuk menghasilkan peta geologi terbaru di kawasan Kampung Sungai Asap, untuk menganalisis struktur regional menggunakan imej satellite, dan untuk menyiasat hubungan antara struktur regional dengan taburan kegagalan cerun. Litologi dijumpai di kawasan kajian adalah tuff volkanik, batu kapur, batu lumpur , batu lodak and batu pasir. Pemetaan kegagalan cerun telah dijalankan dan terdapat sebanyak 11 kegagalan cerun di kawasan kajian, dan kesemua kegagalan cerun adalah jenis translasi. Sebanyak 2 kegagalan cerun dipilih untuk menyiasat pengaruh struktur terhadap kegagalan cerun.. Daripada analisis stereonet, kehadiran ketakselanjaran pada cerun telah mempengaruhi kegagalan cerun kerana terdapat beberapa set ketakselanjaran di kawasan berpontesi untuk menggelongsor dan ketakselanjaran ini adalah “daylight” terhadap cerun.

CHAPTER 1

INTRODUCTION

1.1 General Background

This research is conducted in order to fulfil the requirement of bachelor of degree of applied science (Geoscience) of University Malaysia Kelantan. The research is entitled "General geology and influences of structural pattern with slope failure distribution at Kampung Sungai Asap, Gua Musang, and Kelantan. In spite of studying the general geology of study area, the research scope is mainly focussed on the influences of structural pattern with slope failure. In geology aspects, there are - few things will be discussed about the study area such as in aspects of structural geology, lithology, topography, geomorphology and others.

Slope failure is very common feature in tropical countries such as Malaysia, which is characterized by a humid, tropical region and thick weathering profile. The example of case of slope failure in Malaysia is Highland Tower. This case was recorded on 11th December 1993 after 10 days of continuous rainfall, Block 1 collapsed. The collapsed of Block 1 of the apartment caused the death of 48 peoples and lead to the complete evacuation of the remaining two blocks due to safety concerns.

Slope failure is defined as the mass movement includes all the processes that involved the outward or downward movement of slope forming material under the influences of gravity (Crozier, 2004). Planar, wedges, toppling, rock fall and rotational (circular or non-circular) are the common types of failure in slopes. There are three principal triggering events for landslides which are excessive rainfall, human activity and earthquakes, although many other factors can contribute to slope instability (Tajul and Ahmad, 2001). Strength of rock and soil, discontinuities and plane of weakness, groundwater seepage, external loading, and slope geometry are other factors influence the slope failure.

1.2 Problem Statement

Slope failures are major natural hazards that occur in many areas throughout the world. The stability of cut slopes is significantly influenced of structural discontinuity in rock mass. Slope failure is mainly control by geological structure such as joint, bedding, foliation and others. These geological structures commonly measured directly from the outcrop but in this research, it will emphasize geological structure in regional scale. The idea is to look in detail any significance relationship between structural patterns with slope failure distribution. The existing geological map that is used as reference is not up-to-date information. So, the geological mapping needs to conduct to update the geological information and determine the general geology of the study area.

1.3 Research Objectives

The objectives of this research are listed as below:

i. To produce an updated geological map of study area at scale 1:25000.
ii. To analyse the regional structural pattern using satellite imagery.
iii. To investigate the relationship between regional structural pattern with slope failure distribution.

1.4 Study Area

The study area is located within the latitude of 4°57’60” and 4°55’0’’ and longitude 102°1’30” and 102°4’0’’. The total area covered about 25km². Figure 1.1 shows the location of study area in Kelantan. The study area covers some small town in Gua Musang. Gua Musang is a town and territory in Kelantan. It is the largest district in Kelantan. Gua Musang is run by district council, bordered by the state of Pahang to the south, Kuala Krai and Jeli to the north, Terengganu to the east, and Perak to the west. Figure 1.2 shows the base map of kampong Sungai Asap, Gua Musang, Kelantan.

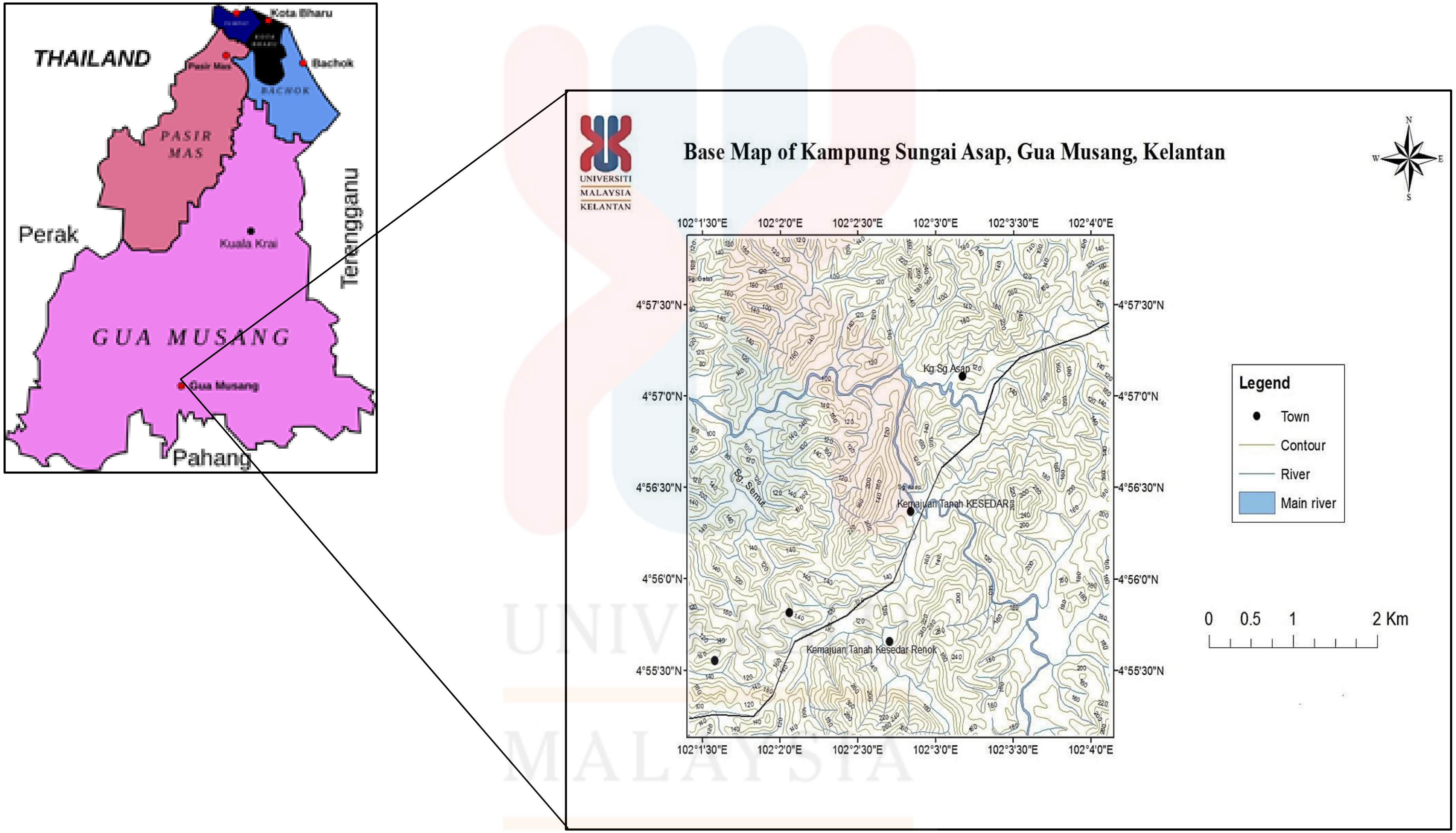

Figure 1.1: Location of Study Area in Kelantan

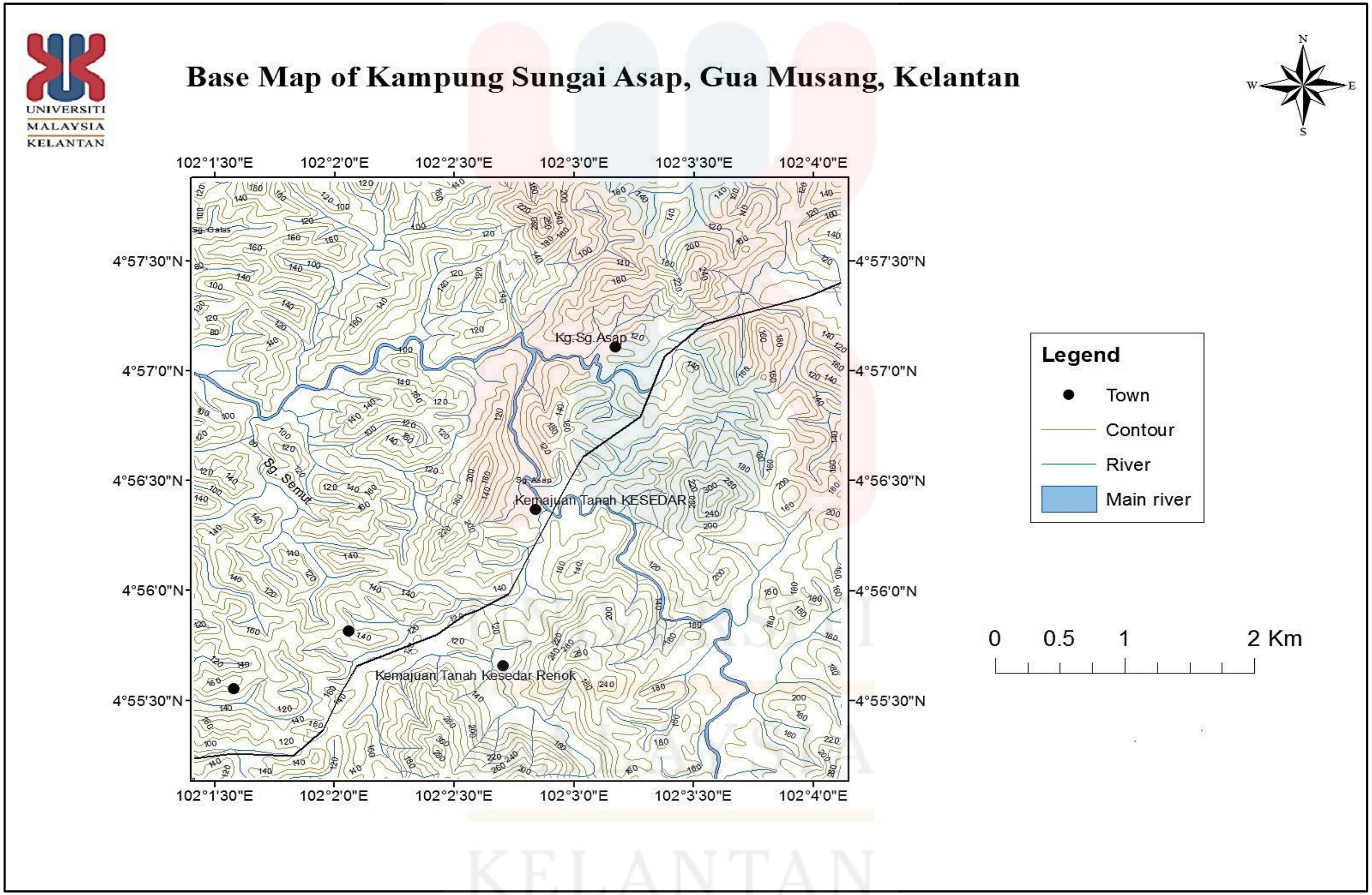

Figure 1.2: Base Map of Study Area.

1.5 Geography

1.5.1 People distribution

Based on Table 1.1, Malay races are the highest population in Gua Musang which are 15 285 peoples then followed by Chinese race which are 2217 peoples. Non- Malaysian citizens are third majority in this area with the population of 2217 peoples. There are also others Bumiputera and Indian population in Gua Musang which gives the total population of peoples are 18 420 in 2010.

Table 1.1: People distribution in Gua Musang area
Sources: Jabatan Perangkaan Malaysia, 2010

Local Authority Area	Total	Malaysian Citizens					Non-Malaysian Citizens
		Bumiputera		Chinese	Indians	Others	
		Malay	Other Bumiputera				
M.D. Gua Musang	86,189	64,253	12,570	3,870	350	161	4,985
Batu Papan	2,594	1 ,512	8	883	132	8	51
Bertam	1,142	1 ,131	-	1	1	-	9
Chegar Bongor	494	3 98	-	24	-	4	68
Gua Musang	18,420	1 5,285	88	2,217	155	30	645
Kerinting	157	1 28	-	1	15	-	13
Limau Kasturi	975	8 93	-	5	-	7	70
Paya Tupai	337	3 25	-	-	-	-	12
Remainder of M.D.	62,070	4 4,581	1 2,474	739	47	112	4,117

1.5.2 Rain distribution

Based on Table 1.2, the highest rain distribution in Kelantan is during December 2014 which is 97.0 mm. During this month, Kelantan has suffered the worse flood disaster which affected the majority of district in Kelantan include Gua Musang. During February until April 2015, Kelantan has experienced hot and dry climate due to North-East Monsoon. Malaysia weather benefits from a tropical climate with high temperature, high humidity, and high rainfall distribution throughout the year.

Table 1.2: Total rainfall in millimetre (mm) of Kelantan State from January 2014 until March 2015.
Sources: Malaysian Mineralogy Department (2015)

Year (2014)		Year (2015)	
Month	**Rain distribution (mm)**	**Month**	**Rain distribution (mm)**
January	178.0	**January**	0.0
February	0.0	**February**	0.0
March	16.0	**March**	67.0
April	0.0	**April**	-
May	146.0	**May**	-
June	129.0	**June**	-
July	56.0	**July**	-
August	427.0	**August**	-
September	258.0	**September**	-
October	227.0	**October**	-
November	262.0	**November**	-
December	967.0	**December**	-
TOTAL	**2666.0**	**TOTAL**	**67.0**

1.5.3 Soil use/land use

The land in study area are mostly of covered by forest either natural forest or oil palms and rubber plantations. Figure 1.3 shows the soil use in Kampung Sungai Asap. Based on figure, the area in green shaded region shows the land use for plantation either oil palms or rubber plantation. These cover about 50% of land use in the study area. The other 15% are used for housing or industrial purposes, shown in the area of orange shaded region. The brown shaded region shows the natural forest which covers the remaining 35% of land use in study area.

Figure 1.3: The land use in study area.

1.5.4 Social economic

Gua Musang is an area where most people are from the settler community. This area is home to two large agencies, FELDA and KESEDAR that open the land scheme. FELDA was given the responsibility of developing nine land schemes, namely Kemahang 3, Chiku 1, Chiku 2, Chiku 3, Chiku 5, Chiku 6, Chiku 7, Perasu and Aring 1. Almost the entire land scheme is planted with oil palm. However, there were also rubber plantations in Perasu in 2008 and in Chiku 3 during April 2009. The overall land area are the FELDA oil palm plantation in Gua Musang was 10 552.50 hectares in 2008 and 8867.23 hectares in 2009 (Fauzi and Hussin, 2012).

1.5.5 Road Connection

There are several ways to access the road to Gua Musang. Firstly, Gua Musang can be reached by main road that connected to Kuala Krai and Merapoh, Pahang. Gua Musang also can be reached through public transport which is train. The road users are usually resident's car, lorry which carries raw rubber, motorcycle and bus. Based on Figure 1.4, the study area can be reach by using the main road of Gua Musang.

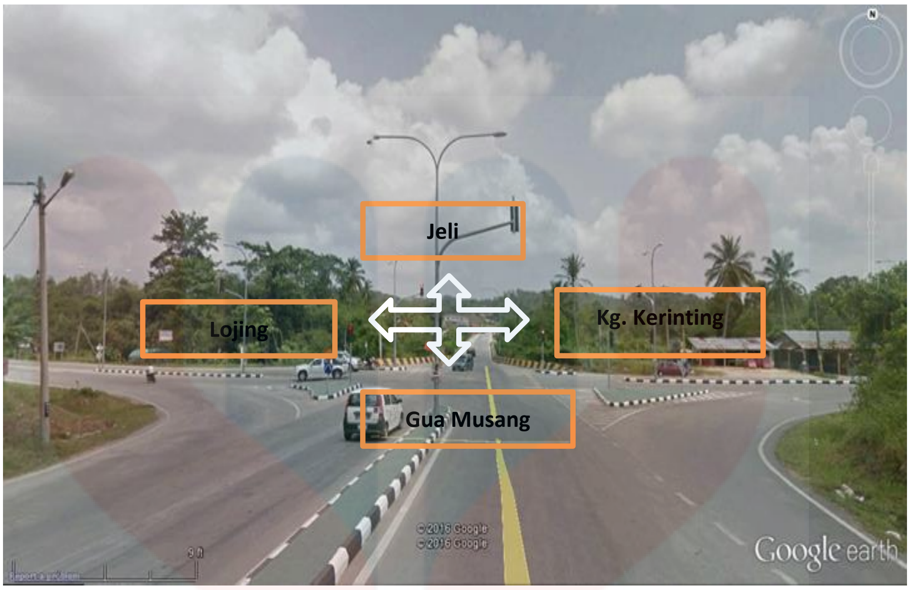

Figure 1.4: Road access to study area

1.6 Research Significance

The significance of the research is to produce the latest geological map of Kampung Sungai Asap and its surrounding area. However, with the current development progress for agriculture and residential area, new outcrop will be exposed. So, detail and accurate observation or study can be done to update the previous geological map. For the engineering geology part, determination of structural pattern can be fully utilizes for other area if finding from this research can show significance relationship between slope failure distribution. In other word, potential area or weak zone can be determined at early stages if any major construction works want to be done at any place.

1.7 Scope of Study

This research will focused on two main scopes which are geological mapping and engineering geology. Geological mapping are carried out to identify and observed the lithology, geological structure and geomorphology such as drainage and topography to produce an updated geological map. For engineering geology, the slope failure mapping was conducted for the purpose to investigate the relationship between regional structural pattern with slope failure distribution or pattern. The GIS study was used for the analysis of drainage, lineament and geomorphology of study area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss about the literature review of the past study and the study that can be related to the topic of study. The purpose of the literature review is to give guidance in writing the report. The chapter provides a review on the literature study done to obtain an understanding of various geological structure studies. This chapter also can guide for choosing the best method suitable for this topic study. This chapter will be cover literature review of geological mapping, regional of study area and geological structure.

2.2 Regional Geology and Tectonic Setting

Peninsular Malaysia is divided into three main geological domains which are Western, Central and Eastern belts. These domains are characterized based on several aspects including lithology, age, tectonics, structures and paleogeography. The Lebir Fault and Bentong Suture define respectively, the western and central belts, which cover the entire state of Kelantan, the western and central part of Pahang, the eastern part of Negeri Sembilan, and the western part of Johor (Hasnol et. al, 2007).

Kelantan was located at the west of Malaysia and it is considered as the extended of pre-Tertiary stratigraphy range in west of Malaysia (MacDonald, 1967).

The geology of Kelantan can be classified as unconsolidated sediment, sedimentary or metasedimentary, extrusive rocks and granitic rocks as shown in Figure 2.1 (Mineral and Geoscience Department JMG, 2003). The unconsolidated sediment occupy around 6%, extrusive rocks is about 10%, sedimentary or metasedimentary rocks is about 51% and granitic rocks is about 31% .

In Kelantan, the dominant rock types are sedimentary or metasedimentary, which occupies north-south central area of Kelantan. The granites of the Main Range and Boundary Range are bordered on west and east respectively. These belts of granite and other country rocks trend in a north-south direction and truncated to the north by unconsolidated sediment of Kelantan alluvial plain.

2.3 Historical Geology

The state of Kelantan belongs to the Eastern region of Peninsular Malaysia. The State of Kelantan is divided into north and south, and composed of ten districts. Gua Musang is one of the districts in Kelantan. The geological formation of Kelantan ranges from Lower Paleozoic until Quaternary and can be divided into three main chronology; Paleozoic, Mesozoic and Cenozoic.

According to Hutchison and Tan (2009), the Paleozoic formation in Kelantan was found in the central belt of Peninsular Malaysia. The bulk of the Upper Paleozoic sediments consist of marine Permian strata that occur as linear belts flanking Mesozoic sediments in the Central Belt. The Upper Paleozoic rock consists of Gua Musang Formation and Aring Formation in the south of Kelantan while Taku Schist in eastern part of Kelantan. The Upper Paleozoic formation is dominated by argillaceous and volcanic facies while the rest belong to calcareous and arenaceous facies. The depositional environment is typically shallow marine area with intermittent active submarine volcanism starting in the Late Carboniferous and reaching its peak in the Permian and Triassic.

The Mesozoic formation are dominant in the central belt that form continuous north-south trending belt extending beyond the international boundaries with Thailand (the Gua Musang Formation) in the north and Singapore (the Jurong Formation) in the south. The Permian-Triassic of Gua Musang, Aring and Gunung Rabong Formation in Kelantan is dominated by shallow marine clastics and carbonates with volcanic interbeds. Towards the south, deeper marine turbiditic sediments are more dominant in Telong Formation. These turbidites are commonly tuffaceous in nature with volcanic interbeds.

The Cenozoic formation is mainly represented by Quaternary sedimentary deposit. The Quaternary sediments covering part of north Kelantan consist extensively of unconsolidated to semi-consolidated boulders, gravel, sand, silt, and clay that underlie the coastal and inland plain.

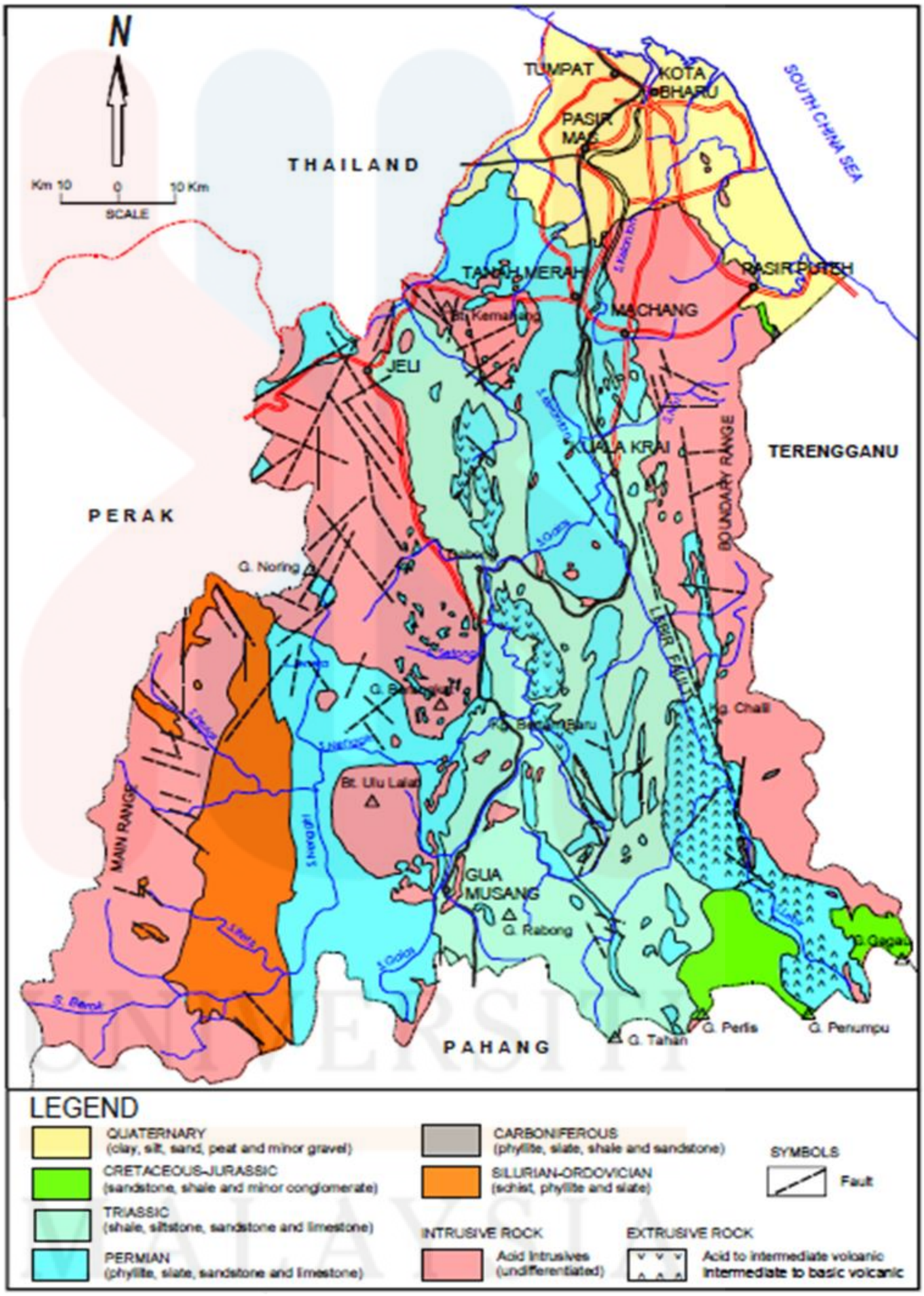

Figure 2.1 : Rock distribution and geology of Kelantan

Source: Department of Minerals and Geoscience (2003)

2.4 Stratigraphy

According to Mohd Shafeea Leman (1993 and 2004), Gua Musang Formation in south Kelantan was introduced informally by Yin (1965) for a predominantly argillaceous and calcareous sequences interbedded with volcanic and arenaceous rocks in the Gua Musang area of south Kelantan. Gua Musang Formation is made up of crystalline limestone, interbedded with thin beds of shale, tuff, chert nodules and subordinate sandstone and volcanic. The light grey calcitic limestone is hard, non-porous, brittle and splintery. Small amount of carbonaceous, argillaceous and pyroclastic impurities are present in the grey to black varieties of the often recrystallized limestone. Traces of the bedding cross lamination and oolites can be still detected.

Poorly preserved fusulines, including Verbeekina from Gua Musang give the Permian age to the parts of limestone, and Lower Triassic(Scythian) ammonoids have also been reported from the limestone nearby (Hada, 1966). The unit extends to north Kelantan and southward to North Pahang. It is unconformably overlain by the Gunung Rabong Formation and named after Gua Musang town in south Kelantan.

2.5 Geomorphology

The state of Kelantan can be divided into four types of landscape, which are mountainous areas, hilly areas, plain areas and coastal areas (Tanot et. al, 2001). However there is no coastal in Gua Musang area. The Kelantan river basin is located in the north eastern part of Peninsular Malaysia between latitudes 4°40’ and 6°12’ N, and longitudes 101°20’ and 102°20’ E. The maximum length and breadth of the catchment are 150 km and 140 km respectively. The river is about 248 km long and drains an area of 13 100 km², occupying more than 85% of the state of Kelantan. It is divided into Galas Lebir River near Kuala Krai at about 100 km from the main river. Galas River is formed from the junction of the Nenggiri and Pergau Rivers. The Nenggiri River originates in the south western part of the central mountain range (Main Range) while the Pergau River originates from the Tahan Mountain Range. The Kelantan River system flow northward passing through such major towns as Kuala Krai, Tanah Merah, Pasir Mas and Kota Bharu before finally discharging into the South China Sea.

2.6 Structural Geology

During the Paleozoic and Mesozoic era, the land mass of Peninsular Malaysia was affected by tectonic activities such as formation of faulting and folding (Adriansyah et. al, 2015). The main force acting on the land mass was compressional and the effects are principally faulting and folding has been observed as regional as well as localized structures .Localized structures include folding, jointing and faulting in the sedimentary rocks, and jointing and faulting in granitic rocks.

The dominant structures are along a north-south to northwest-southeast direction resulting from past orogenesis. The Perm-Triassic central zone of sediments deposited in unstable basin has been isoclinically folded in asymmetrical antiforms and synforms. Dips are generally steep to the east (JMG, 2003).

The Peninsula structures reflect a long and complex tectonic evolution, starting possibly from early Cambrian right up to Cenozoic (Hutchison, 1975). Structure is divided into two which is primary and secondary structure. Primary structure formed at about the same time as their host rock while secondary structure imposed on older rocks as a result of deformation. Rocks deform when stresses placed upon them exceed the rock strength brittle deformation (fractures) ductile deformation (folds). Types of secondary structural geology are fault, bedding or strata, fractures and joint (Tongkul and Chang, 2003)

The application of the structural geology is important to analysis as a contribution to the solution of neotectonic problem. The structural analysis supplies a good improvement to the deformation data when the last deformational events are recorded on the bedrock series and when it is possible to have some evidence of deformations in the Pleistocene series to confirm structural data (Fabrizio and Roberta, 1993).

The fault is characterized by mylonite zones, fault breccias and large quartz veins. Microscopic and field studies on the mylonites showed that the early ductile microstructures were superimposed by later brittle-ductile and brittle structures. Within the mylonites, a distinct foliation and stretching lineation defined by symmetric to asymmetric lenses of feldspar and elongated quartz are commonly found. The sub-horizontal to moderately inclined stretching lineation in the mylonites along the fault zone shows that it is a strike-slip fault zone with a significant dip-slip component. Fault kinematic studies on the mylonites at Bukit Tinggi show that the early ductile movement had a dextral sense of shear (Ng, 1994; Shuib, 2009) but at Kuala Kelawang and along the Karak Highway (Zaiton Haron, 2002; Shuib, 2009) shows that the movements were sinistral. This is attributed to the reactivation of the early dextral Bukit Tinggi Fault Zone by later sinistral fault movements.

The result of structural analysis show that deformation recorded over the Mesozoic carbonatic sequence by present of dip-slip, oblique-slip and strike slip kinematic indicators on the fault plane. The kinematic indicator, it was possible to recognize a sequence, point out that the strike slip movement indicators. The genesis and deepening of the closed depression system, bordered by prevalent normal and oblique-slip faults, can be attributed to vertical deformation (Fabrizio and Roberta, 1993).

2.7 Engineering Geology

Slope failure is very common feature in tropical countries such as Malaysia, which is characterized by a humid, tropical region and thick weathering profile. The term slope failure also can be described as landslide, slope instability and terrain instability. Slope failure also described as the mass movement includes all processes that involve the outward or downward movement of slope forming material under the influences of gravity (Thomas and Michael, 2004). A complete slope failure classification has been proposed by Varnes (1987) as shown in Figure 2.2.

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly coarse	Predominantly fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow (deep creep)	Debris flow (soil creep)	Earth flow
COMPLEX		Combination of two or more principal types of movement		

Figure 2.2: Types of Slope Failure. Abbreviated version of Varnes' Classification (Varnes, 1978)

According to Stephen (2013), there is several factors influence slope stability. Firstly is gravity, gravity is the main force responsible for mass movement. On a slope the force of gravity can be resolved into two components which are acting perpendicular to the slope and acting tangential to the slope. On a steeper slope, the shear stress or tangential component of gravity, increases, and the perpendicular component of gravity, decreases. Beside water also play an important role that influences slope stability. Water from rainfall or snow melt adds weight to the slope. Water can seep into the soil or rock and replace the air in the pore space or fractures. Since water is heavier than air, this increases the weight of the soil that can lead to slope instability. Another factor is compaction. Compaction of the soil or shaking of the soil can thus cause a rapid change in the structure of the material. The clay minerals will then line up with one another and the open space will be reduced. If there are any disturbs on such thixotropic clays they lose their shear strength. Thus, small earthquakes or vibrations caused by humans or the wind can suddenly cause a loss of strength in such materials. Weak material and structures of rock also influences slope stability. Slope modification, volcanic eruptions, changes in hydrologic characteristics, slope undercutting, a sudden shock, such as an earthquake may trigger slope instability.

According to Tajul Anuar Jamaluddin and Ahmad Nizam Hassan (2001), landslide is one of the hazardous impacts commonly associated with development in hilly terrains. The three principal triggering events for landslides are excessive rainfall, human activities and earthquakes, although many other factors can contribute towards the slope instability. Strength of rock and soil, discontinuities and plane of weakness, groundwater and seepage, external loading, and slope geometry are other factors that influence the slope failure.

Structural discontinuities of rocks and other features related to tectonic activity often results in morphological. Structural trends such as discontinuity can be detected in many forms, such as faults, joints, bedding planes or foliation, and may be useful in several environmental applications including landslide studies, hydrogeology and mineral exploration (Ramsay and Hitber, 1987). The properties of discontinuities such as orientation, persistence, roughness and infilling are play important role in the stability of jointed rock slope. The orientation of major geological discontinuity relative to an engineering structure also controls the possibility of unstable conditions and mode of failure. According to Gasim and Brunotte (1987), rock failures of the Crocker Formation in Sabah are due to structural behavior of the rock formation, which consists of folded, faulted and strata which has generated a series of landslides. Then the future study has been conducted by Roslee et.al (2006) and they found that most of failures in Croker Formation are correlated with discontinuities problem.

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

This chapter will discussed about all the method that involves in order ensuring the objectives of the research will achieve completely. Figure 3.1 show a flow chart of my research.

3.2 Preliminary Research

Preliminary research is the process that involved in gathering information and then explores the information in particular subject of research study to provide systematic and organize result. It is done by referring to the previous case study that related to the topic to obtain the general knowledge of research subject. The information of the research can be obtained by referring articles, books, journal, internet and geology map. The information is focuses on geology of the study area, slope failure analysis, geomorphology and also structural analysis. Topography and geology data was obtained from ArcGIS version 10. This software is used to produce map that provide the information of surrounding area in study area.

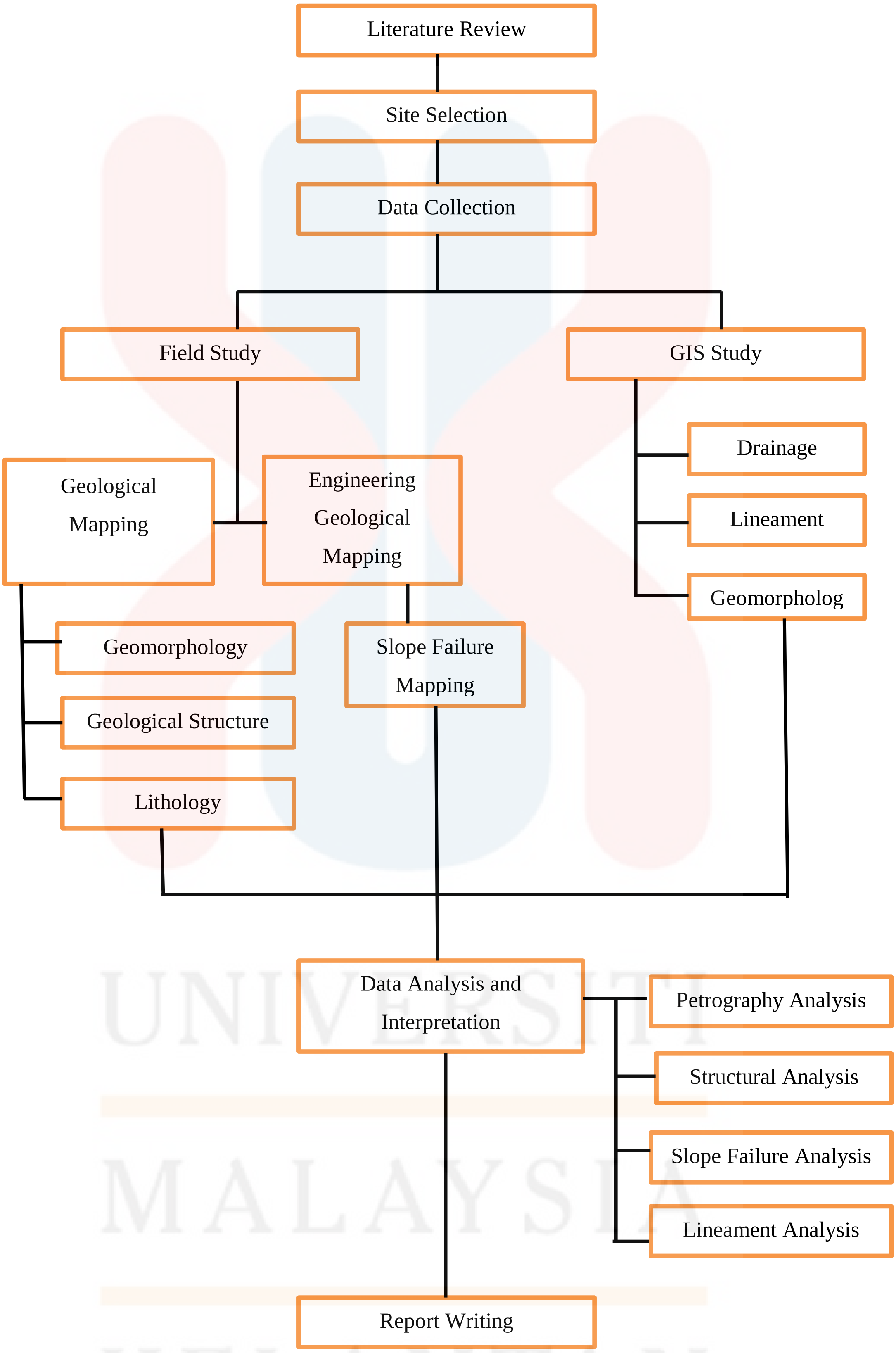

Figure 3.1: Research Flowchart

3.3 Materials

The materials that are used during conducting this research are divided into two components which are field materials and laboratory materials. Field materials are such as Global Positioning System (GPS), Brunton/Suunto compasses, geological hammer, hand lenses, measuring tapes, HCl acid and base map will be used during the mapping. While the laboratory materials are such as aerial photograph or stereoscope, ArcGIS software and also machines for preparation of thin section like the slab saw, the trim saw, the grinder, the cut-off saw and the lap wheels.

3.3.1 Global Positioning System (GPS)

GPS (Geographic Positioning System) is a satellite based navigation system comprising three basic parts; the satellites in space, monitoring stations on earth and the GPS receivers. This equipment is used in geological field mapping for finding ones position, mapping lithology, tracking structures, measuring elevation, storing sampling points and descriptions of formations when samples are collected. The GPS functions and capabilities are improving rapidly with advancement in technology and as such it is important to purchase one that is relatively modern.

3.3.2 Geological Hammer

Hammer is a tool use to obtain rock specimens for laboratory work and for chipping away weathered rock surfaces. The best geological hammers are the ones with a piece chisel head made of hardened steel and a rubber coated shock reduction handle. A crack geological hammer forged from fine grain carbon steel with fiberglass shaft fitted with comfortable shock-absorbing rubber grip is recommended for harder rocks or outcrops.

3.3.3 Hand Lens

It was used to make the first analysis of rock samples in the field before further analysis is performed in the laboratories. It was used to determine features like mineral content, grain shape and micro fossils in a rock.

3.3.4 Sample Bags

Sample bags which best suit geological samples are canvas in fabric have a sewn in tie tape and a label tag on the outside to insert the sample number and location point. Plastic bags may be used where the sample is soft, disintegrated or wet.

3.3.5 Hydrochloric Acid (HCL) Solution

Hydrochloric acid (HCL) solution is used to determine the present of calcite mineral in a rock. When a rock contain calcite, the rock will fizzes as a result of reaction between HCL and calcite mineral in the rock.

3.3.6 Compass

A compass is an instrument used for navigation and orientation that shows direction relative to the geographic points. A compass is used to measure the orientation of the geological structures, as they map in the map, to analyses the geometry of bedding planes, joints and/or metamorphic foliations and lineation. The measurements are obtained through the use of the Earth's magnetic field.

3.3.7 Measuring Tape

Measuring tape is important for taking actual measurements of lithology and structures. For instance in lithology that exhibit layering, it is necessary to measure the thickness of each layer precisely, as this can be used as a correlation tool with other similar sequences that may be encountered.

3.3.8 Base Map

During the research phase all existing data and maps of the field in question are collected. All suitable maps available whether physical, political, relief, road, physical, and topographic should be carried to the field as it is possible that details in one may not be present in another. Most importantly for geological fieldwork, a geological map is expected to be handy especially as a reference. Depending on the area extent of the field and the detail required, the scale of the map is an important aspect to consider.

3.3.9 Aerial Photograph/Stereoscope

This 3D imagery tool is very vital for all geological field work especially where large features such as volcanoes, calderas craters etc. are involved. In addition photos are also used to pinpoint thermally anomalous areas in geothermal fields when infrared thermography is applied. These photographs are studied with the aid of a stereoscope and are put to use before and during the field study; for planning in the case of the former and for confirmation purposes in case of the latter. Where aerial photographs may not exist, satellite imagery may be used although it may not possess the fine detail as seen on the aerial photographs.

3.3.10 ArcGIS Software

GIS stand for Geographic Information System. It purposed for working with maps and geographic information. It is used for creating and using maps, compiling geographic data, analysing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in database.

3.4 Method

3.4.1 Geological Mapping

Geological mapping is the important methods in carried out this research. Mapping has been done to acquire geology data of the study area for example; types of rock found, lithology and geomorphology. Route tracking (traverse) by using GPS is a method use for geological mapping. During field work, carefully describe observation and measurement of geomorphology, lithology and structural geology and should documented by using the digital camera with scaling. The several of lithology should be sampling in the field and structural element like strike and dip are also recorded and marked in the log of outcrop for further analysis. All these components are important for data collection in the field work to be analysed.

3.4.2 Engineering Geological Mapping

Slope failure mapping is carried out to acquire data such as types of failure, orientation of the failure, geomorphology, slopes angle, soil or rocks types, and also lithological factors. The slope failure will be mapped by using GPS together with the integrated ArcGIS software to produce the slope failure distribution map. The purpose of this mapping is to relate the slope failure distribution with structural pattern. Aerial photo or satellite imagery will be used to analyse the structural patterns.

3.4.3 Sampling

In order to collect the data, rock sampling is necessary. During mapping, we must collect rock samples at different places in order to identify the lithology of study area. This method is called random sampling method. The sample has to be bigger than the size of a normal human's fist and it also should be fresh and not weathered.

3.5 Laboratory Work

3.5.1 Thin Section

For the research, several rock samples are taken, and a small part of each sample are sent to the laboratory for thin section. Thin section analysis is use in many areas of geological study firstly in mineralogy than in petrography. It is important to identify the type of rock sample. There are several step in processing a thin section such as prepare the glass slide, cleaning the grinding wheel, frost the glass slide, mark the rock, cut and clean up the slab, follow by cut the chip, glue the slide to the chip, cut off the chip from the slide, grind slide to the correct thickness next is add a cover slip.

3.5.2 GIS Study

GIS software is used together with remote sensing system to analysis the drainage system, geomorphology and lineament of the study area. Then the geomorphological map, drainage map, lineament map and also geological map will be produced by using this GIS software.

3.6 Data Analysis and Interpretation

After getting all data and information from the pre-study, geological mapping and laboratory analysis, the interpretation and conclusion of this research can be made. Several analysis and interpretation should be done after getting the data and information. One of the analyses is petrography analysis. Mineral content of the rock is used to analyses using polarized microscope to determine the composition of mineral and lithology of rock in study. Different rock classification type will used for thin section analysis. Rose diagram and stereonet is used in structural analysis and also for slope failure analysis. It is purposed to determine the orientation of the geological structure with slope failure.

3.6.1 Thin section/Petrography Analysis

Igneous rock analyses are based on the mineral content and also texture of rock itself under the microscope. Igneous rock is divided into two types which are plutonic rock and volcanic rock. Plutonic rock is classified according the IUGS system classification. Three minerals (Quartz, Alkali feldspar and Plagioclase) are identified and their percentages are determined. Then the values of Q, A and P mineral will be plotted on IUGS triangular diagram to determine their name.

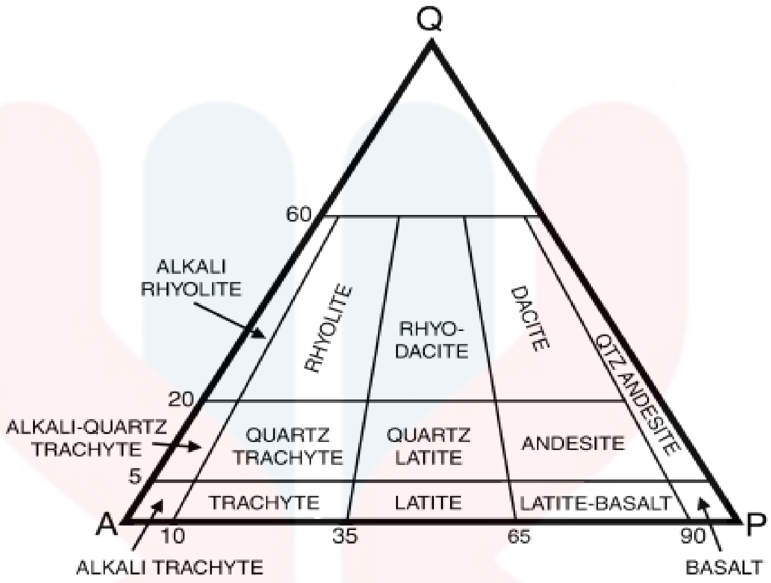

Figure 3.2: IUGS classification for volcanic igneous rocks (based on Streckeisen, 1976)

For volcanic rock, the analysis is based on mineral content. Figure 3.3 shows the classification of volcanic rock based on mineral content.

Simple Field Classification of Volcanic Rocks (For use in EENS 212)		
Rock Name	Essential Minerals*	Other Minerals (may or may not be present)
Basalt	Olivine	Cpx, Opx, Plag.
Basanite	Olivine + Feldspathoid (Nepheline/ Leucite)	Cpx, Plag.
Andesite	No olivine, abundant Plagioclase	Cpx, Opx, Hornblende
Trachyte	Sanidine + Plagioclase	Na-Cpx, Hornblende, Biotite
Dacite	Plagioclase + Hornblende	Cpx, Opx, Biotite
Rhyolite	Quartz	Sanidine, Biotite, Plag., Hornblende, Cpx, Opx
* The amount of glass in the groundmass increases, in general, from the top to the bottom of the chart.		

Figure 3.3: The classification of volcanic rock based on mineral content

Metamorphic rocks are named primarily by using descriptive structural terms. A metamorphic rock displaying a gneissose structure. This term gneiss is almost exclusively used for rocks containing abundant feldspar (quartz), but may also be used in exceptional cases for other compositions A metamorphic rock displaying on the hand-specimen scale a pervasive, well-developed schistosity defined by the preferred orientation of abundant inequant mineral grains. For phyllosilicate-rich rocks the term schist is usually reserved for medium- to coarse-grained varieties, whilst finer-grained rocks are termed slates or phyllites.

While for sedimentary rock analysis is based on the texture analyses which are including grain-size and its distribution, morphology and surface features of grains, and the fabric of the sediment. The grain-size of sediment may fine- or coarsen-upwards through the bed to give a graded bed (Figure 3.6).

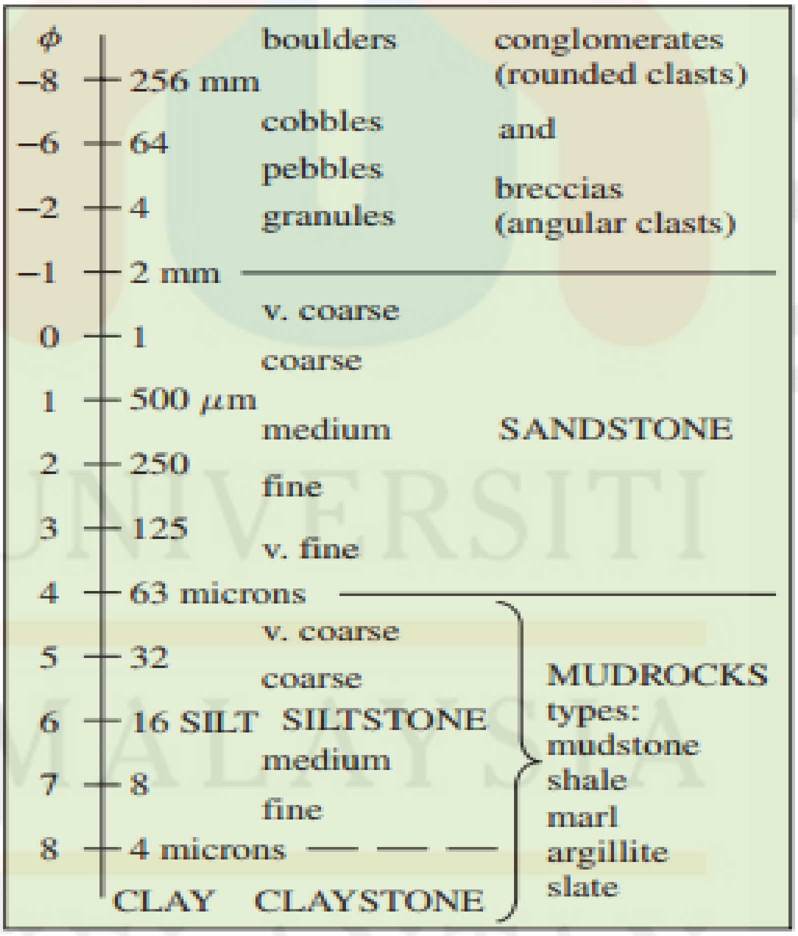

Figure 3.4: Terms for grain-size classes and siliciclastic rock types (Maurice E. Tucker, 2011)

Source: Maurice E. Tucker, 2011

3.6.2 Structural Analysis

Rose diagram is used for structural analysis. The orientation such as strike and dip of the structure was plotted on rose diagram to know the direction of force of the structural deformation. At least 100 readings of geological structural were obtained to plot in rose diagram.

3.6.3 Slope Failure Analysis

Stereonet is used for slope failure analysis. Stereonet are circular graphs used for plotting planes based on their orientations in terms of dip direction (direction of inclination of a plane) and dip (inclination of a plane from the horizontal). Orientations of discontinuities can be represented on a stereonet in the form of great circles, poles or dip vectors. Clusters of poles of discontinuity orientations on stereonets are identified by visual investigation or using density contours on stereonets (Hoek and Bray, 1981). Single representative orientation values for each cluster set is then assigned. These single representative orientation values can be the highest density orientation value within a cluster set, or the mean dip direction/dip of a pole cluster as calculated using equations in Borradaille (2003).

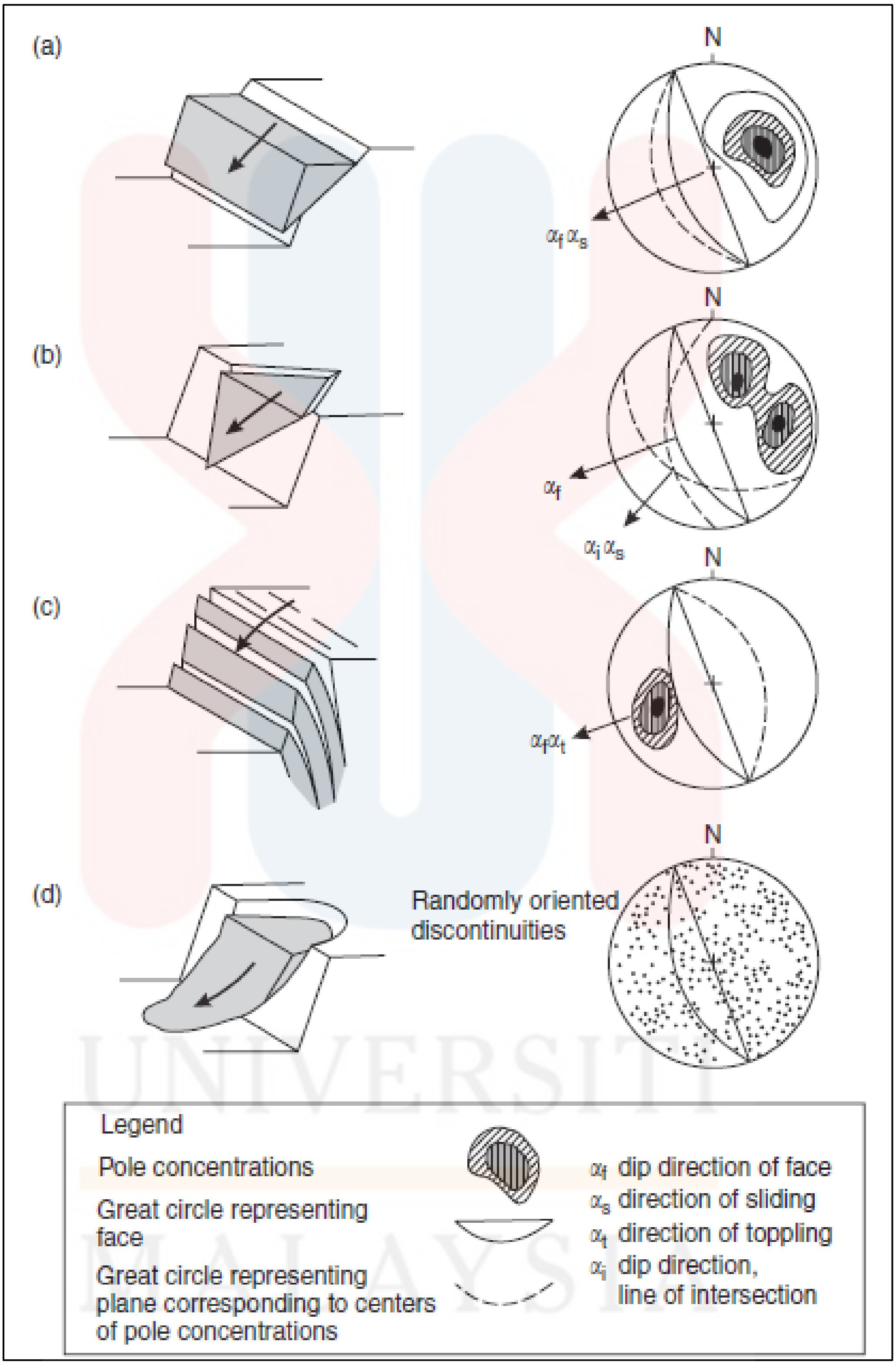

Figure 3.5: Slope failures associated with unfavorable orientation of discontinuities: (A) Planar failure; (b) wedges failure; (c) toppling failure; and (d) circular failure.

Source: Hoek and Bray, 1981

CHAPTER 4

GENERAL GEOLOGY

4. 1 Introduction

In this chapter, the related information involved geomorphology, petrography, stratigraphy, structural geology, and historical geology. The petrography are involving thin section to prove the name, types, and the composition of the rocks. General geology is the important part of this research. The information, data collection and analysis were measured through the field mapping observation. Figure 4.1 show the traversed map that produced after conducting the geological mapping by using GPS.

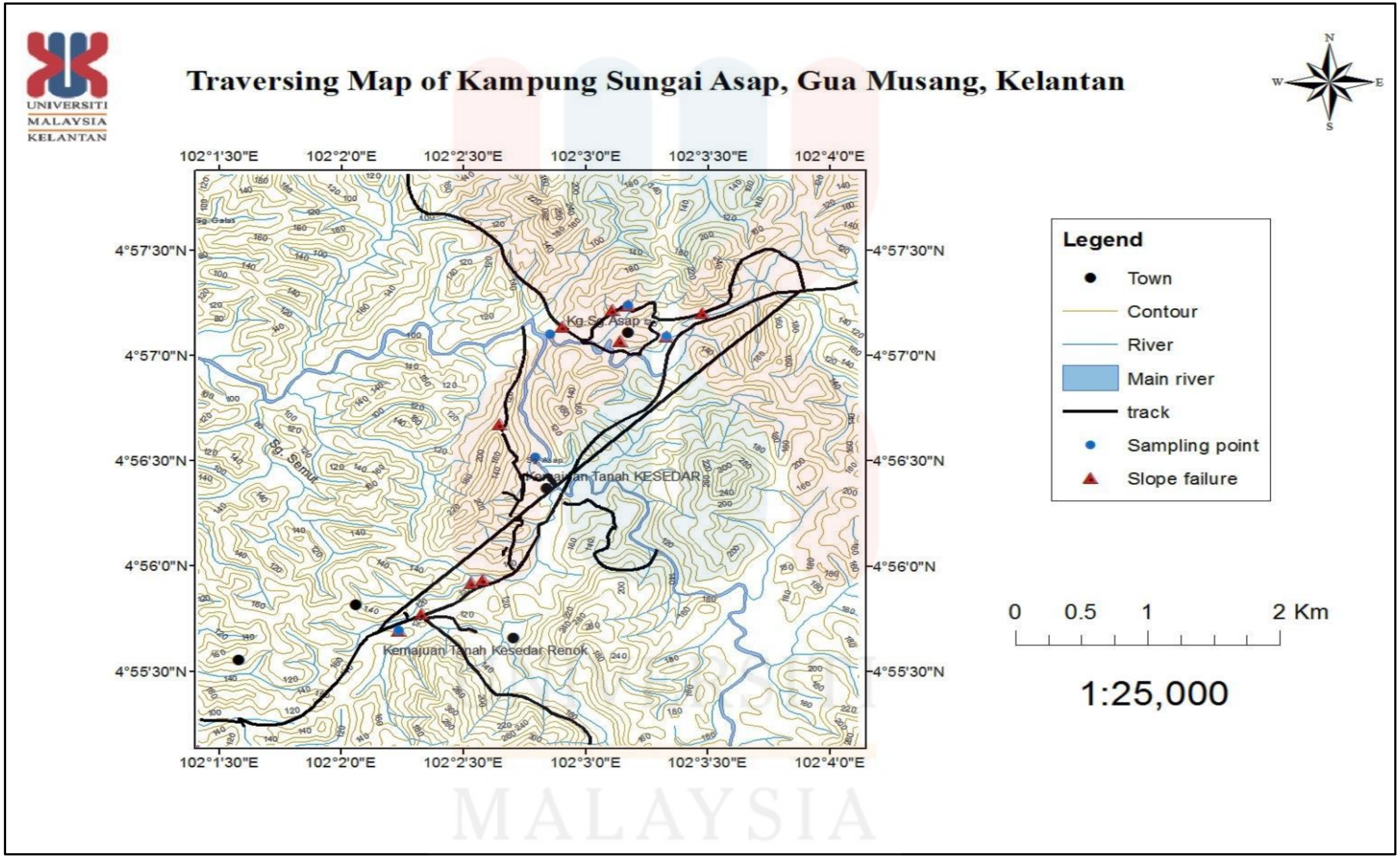

Figure 4.1: Traverse Map of the study area.

4.2 Geomorphology

Geomorphology is defined as the science of landforms with an emphasis on their origin, evaluation, form and distribution across the physical landscape. An understanding of geomorphology and its processes is therefore essential to the understanding of physical geography (Richard, 2007).

The study of geomorphology is broken down into the study of various geomorphologic processes. Most of these processes are considered to be interconnected and are easily observed and measured with modern technology. In addition, the individual processes are considered to be either erosional, depositional or both. An erosional process involved the wearing down of the earth's surface by wind, water, or ice. A depositional process is the process of lying down of material that has been eroded by wind, water, or ice.

In this chapter, the geomorphologic process will be described from topography, drainage system and weathering process in the study area.

4.2.1 Topography

Topography is a field of earth science comprising the study of surface shape and features of the Earth and other observable astronomical objects including planets, moon and asteroids. The topography of an area can also mean the surface shape and features them. Topography specifically involves the recording of relief or terrain, the three dimensional quality of the surface and the identification of specific landforms.

Table 4.1 show a topographic classification based on mean elevations that prepared by Ng Tham Fatt, 1986 which is in digital terrain model.

Table 4.1: Topographic classification based on mean elevation
Source: Ng Tham Fatt, 1986

No	Topographic Unit	Mean Elevation in Meters (above the sea level)
1	Low lying	<15
2	Rolling	16-30
3	Undulating	31-75
4	Hilly	76-300
5	Mountains	>301

Topography features of study area are mainly can recognize as hilly area because the elevation are range from 80 meters to 300 meters. Figure 4.2 shows the 3D topography map of the study area. Based on the 3D topography map, there are 6 highest hills which the elevation reach 300 meters above the sea level. These highest hilly areas are located mainly at Eastern and Southern part of the study area. The lowest elevation are located at the mainly at Western part of study area. The highest elevation covers about 30% of the study area while the other 70% are dominated by the medium to lower elevation from above the sea level.

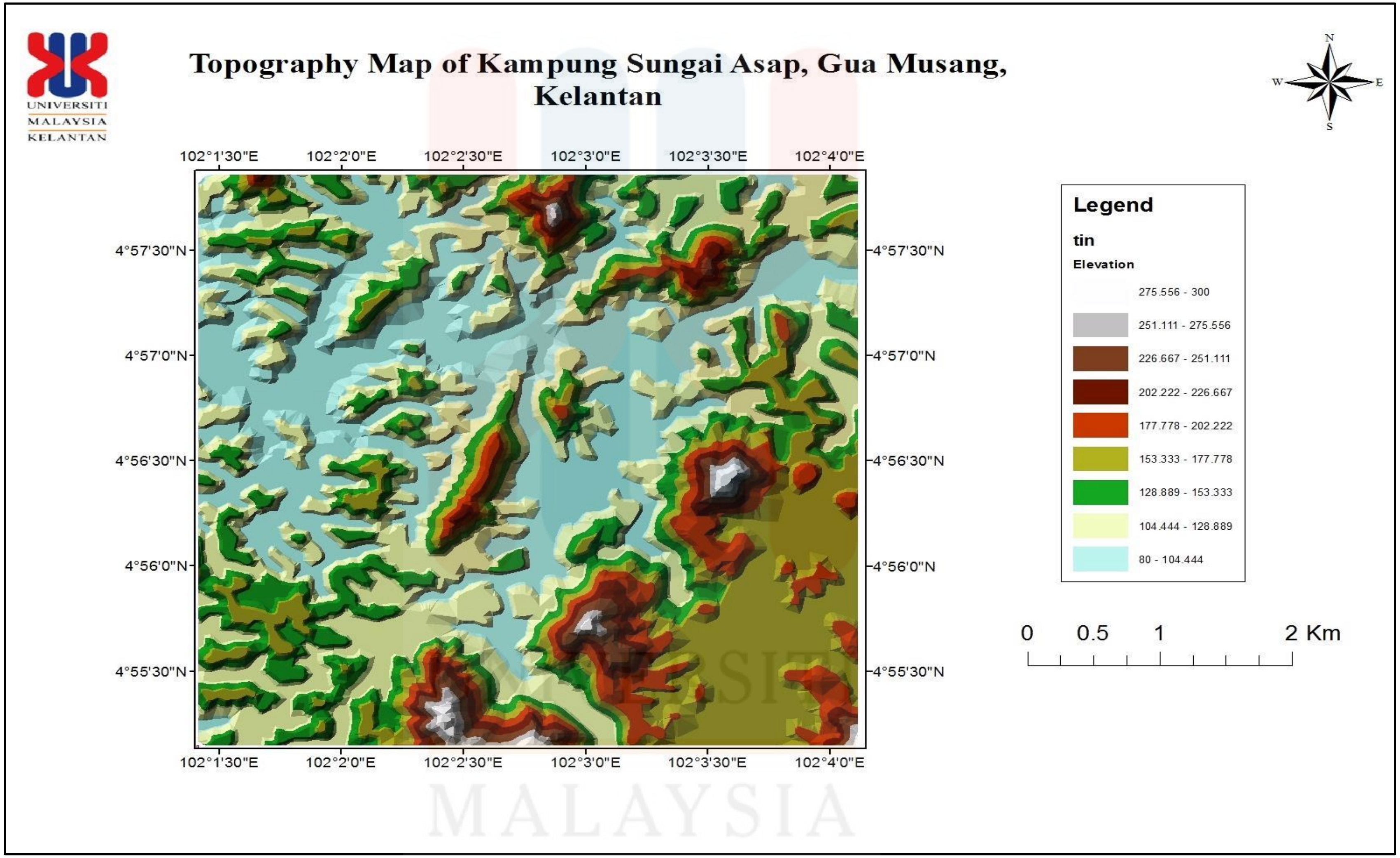

Figure 4.2: The Topography Map of Kampung Sungai Asap.

4.2.2 Drainage System

In geomorphology, a drainage system is the pattern formed by the streams, rivers and lakes in a particular drainage basin. They are governed by the topography of the land, whether a particular region is dominated by hard or soft rocks and the gradient of the land. Stream often views as being part of drainage basin. A drainage basin is the topographic region from which a stream receives runoff, through flow and groundwater flow.

Drainage basins are divided from each other by topographic barriers called a watershed. A watershed represents all of the stream tributaries that flow to some location along the stream channel. The number, size and shape of the drainage basins found in an area vary and the larger the topographic map, the more information on the drainage basin is available. Table 4.2 shows the drainage pattern characteristics.

Table 4.2: Drainage pattern characteristics

Sources: Ling Zhang and Eric Guilbert, 2012

Drainage Pattern	Geometric and Topologic Characteristic
Dendritic	• Tributaries joining at acute angle
Parallel	• Parallel-like • Elongated catchment • Long straight tributaries • Tributaries joining at small acute angle
Trellis	• Short straight tributaries • Tributaries joining at almost right angle
Rectangular	• Tributary bends • Tributaries joining at almost right angle
Reticulate	i. Tributaries cross together forming a cycle

There is main river in study area which is Sungai Asap. The entire streams are connected from the main river, Sungai Asap. The drainage patterns in the study area are consisting of dendritic and parallel drainage pattern. A dendritic pattern is a pattern of growth that resembles a tree and associated with the pattern water takes as it drains off of land. It formed when a kind of random motion occurs, such as diffusion-limited aggregation. This kind of diffusion usually occurs in flow water on flat land and when the resources travel about randomly until they hit each other and join a static structure. The dendritic drainage pattern can be found at the north-east part of the study area. The parallel shapes of the river indicate the slope of the study area which is moderate to steep slope. The parallel drainage pattern in the study area is located at south-west. Figure 4.3 show the drainage pattern map of the study area which shows the dendritic and parallel drainage pattern.

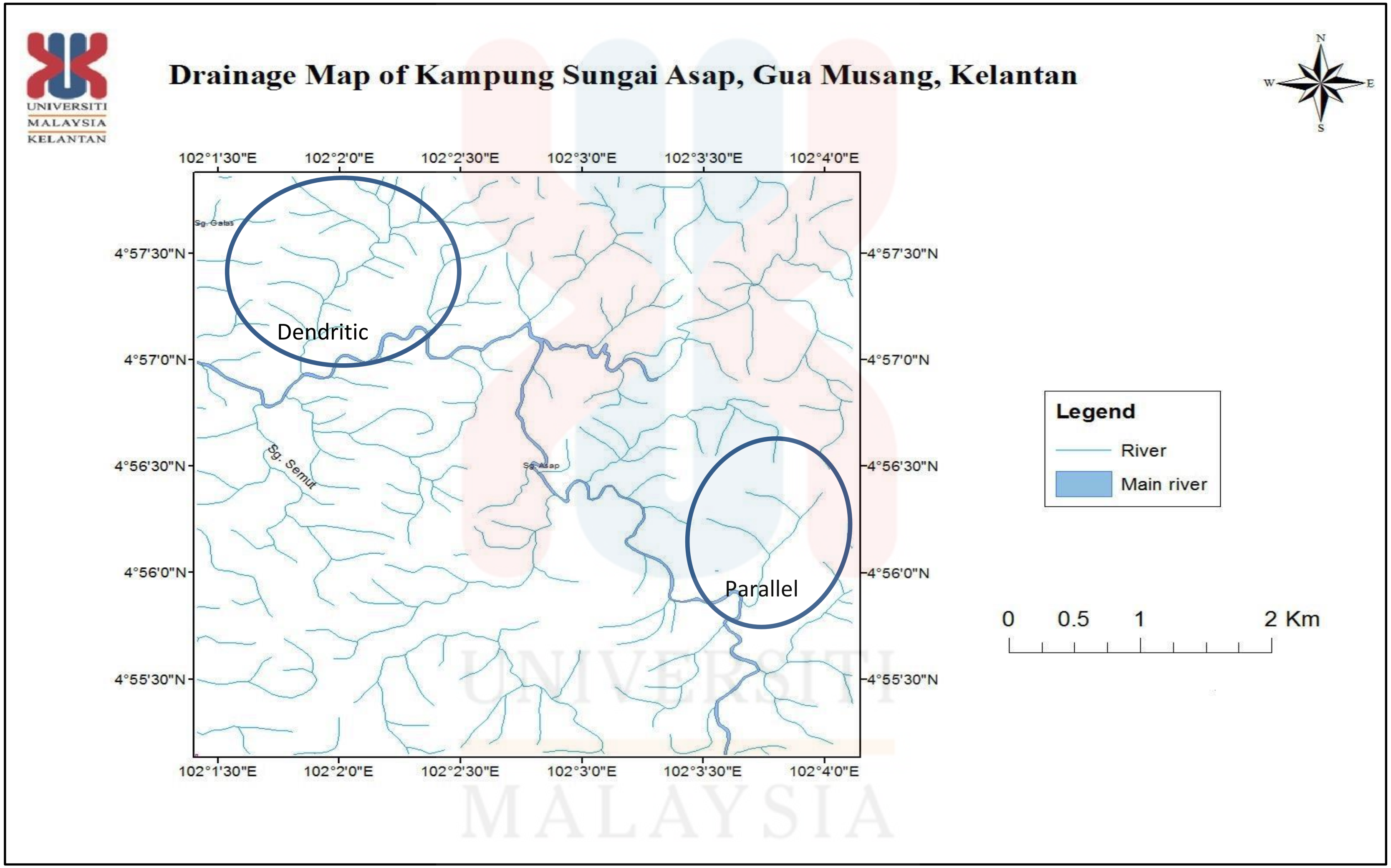

Figure 4.3: The drainage map of Kampung Sungai Asap

4.2.3 Weathering Process

Weathering can be defined as structural and/or mineralogical breakdown of rock and soil materials by physical, chemical and biological processes at or near the surface of the Earth (Warke, 2005). Weathering process occurs in situ. It will changes rocks from a hard state, to become much softer and weaker, making them more easily eroded.

There were three types of weathering which is physical, chemical and biological weathering. Malaysia country is located under tropical climate; the rate of weathering is more aggressive than the cool climate. High humidity in air causes chemical weathering processes is higher in decreasing physical properties than erosion.

i. Physical weathering

Physical weathering also known as mechanical weathering is the class of processes that cause the disintegration of rocks without chemical change. Physical weathering can occur due to temperature, pressure, frost and others. Physical weathering commonly leads to opening of discontinuities by rock fracture and breaking down the original rock or soil (Gunjam, 2014). Figure 4.4 shows the example of physical weathering in the study area that causes the rock become cracks. Cracks form as a result of expansion due to cooling or relief of pressure as overlying rocks are removed by erosion. The cool night and hot days always cause things to expand and contract. That movement can cause rocks to crack and break apart.

Figure 4.4: Physical weathering which causes the rock become cracks.

ii. Chemical weathering

Chemical weathering occurs when rocks are broken down by a chemical change. Rainwater can become slightly acidic by absorbing carbon dioxide in the atmosphere and this reacts with the mineral grains in the rock giving rise to new minerals and salts. The degree of chemical weathering depends on the type of rock.

Chemical reactions occurred rapidly by the present of warm temperatures and moisture. Different mineral has its own resistance towards the weathering. For example, quartz has high resistance compare to feldspar which may turn to clay after reaction occurs. Figure 4.5 shows the example of chemical weathering of the study area where the rocks undergo the chemical weathering and leads to the iron stain appears on rocks surface.

Figure 4.5: Chemical weathering that cause the iron stain appears on rocks.

iii. Biological weathering

Biological weathering takes place when rocks are worn away by living organisms. Trees and other plants can grow within the cracks in a rock formation. As the roots grow bigger, they push open cracks in the rocks making them wider and deeper. Over time, the growing tree eventually prizes the rock apart. Tiny organisms like bacteria, algae and moss can grow on rocks and produce chemicals which can break down the surface layer of the rock. Biological weathering is caused by the presence of vegetation or to lesser extent animals including root wedging and the production of organic acids. Figure 4.6 shows the example of biological weathering in the study area where the root cracked the root.

Figure 4.6: Biological weathering where the mosses grow on the rock surface.

4.3 Stratigraphy

4.3.1 Introduction

Stratigraphy is the science of rock strata, their relative age, and the relationship between strata. It is used to infer past environments of earth based on the physical characteristics of rocks and the changes in environment that occurred over time. Specifically, stratigraphy refers to the application of the Law of Superposition to soil and geological strata containing archeological materials in order to determining the relative ages of layers. In addition, stratigraphy can tell us much more about the processes affecting the deposition of soils, and the condition of sites (Nichols, 2009).

4.3.2 Lithostratigraphy

A lithostratigraphic unit is a defined body of sedimentary, extrusive igneous, metasedimentary, or metavolcanic strata which is distinguished and delimited on the basis of lithic characteristics and stratigraphic position. A lithostratigraphic unit generally conforms to the Law of Superposition and commonly is stratified and tabular in form.

Correlation is a procedure for demonstrating correspondence between geographically separated parts of a geologic unit. In study area, there are 5 types of rock found which silicified limestones and volcanic tuff are in Late Triassic period, while, volcanic sandstone; mudstone and metasiltstone are in Middle Triassic period. Table 4.3 below shows the lithostratigraphy in study area.

Table 4.3: Lithostratigraphy column of study area.

ERA	PERIOD	EPOCH	LITHOLOGIES	COLOR
Mesozoic	Triassic	Late Triassic	Volcanic tuff Silicified limestone	
		Middle Triassic	Mudstone Metasiltstone Sandstone	

4.3.3 Petrography

Petrography is a branch of petrology that focuses on detailed description of rocks. The mineral content and the textural relationships within the rock are described in detail. Petrographic descriptions start with the field notes at the outcrop and include megascopic description of hand specimens. However, the most important tool for petrographer is the petrographic microscope. The detailed analysis of minerals by optical mineralogy in thin section and the micro-texture and structure are critical to understanding the origin of the rock (William Nicol, 1828).

i. Limestone

Limestone is a sedimentary rock made principally out of calcium carbonate ($CaCO_3$) as the mineral calcite. Figure 4.7 shows the hand specimen of limestone found at a river at coordinate N 04°56’24.4” and E 102°02’54.7”. The outcrop of the study area can be identify as a limestone after the outcrop is being tested by hydrochloric acid which the frizzy sound indicate the carbonate contain.The limestone is grey in color and has fine grain in size. The structure of the limestone found was structureless.

Figure 4.7: Hand specimen of limestone

The petrography analysis was carried out for limestone to determining the limestone classification. Dunham's Classifications have been used in order to identify the class of limestone in the study area. Dunham's Classification was depend on the depositional textures which included, grain packing and the abundance of carbonate grains, and depositional binding of grains. Figure 4.8 shows the thin section of limestone observed under microscope by using magnification of X4.

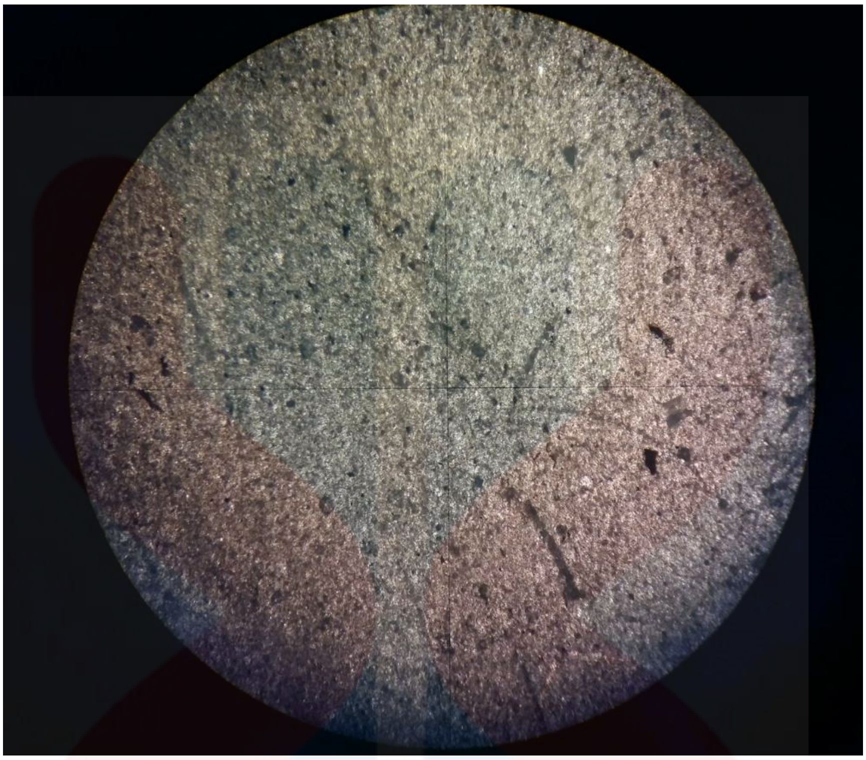

Figure 4.9: Thin section of limestone under plane polarized with x4 magnification.

After being observed below the microscope, it can be clearly seen that the limestone contain mud which are clay and also fine silt size carbonate. This limestone is mud-supported and classified as mudstone because it contains less than 10% grain (Figure 4.9).

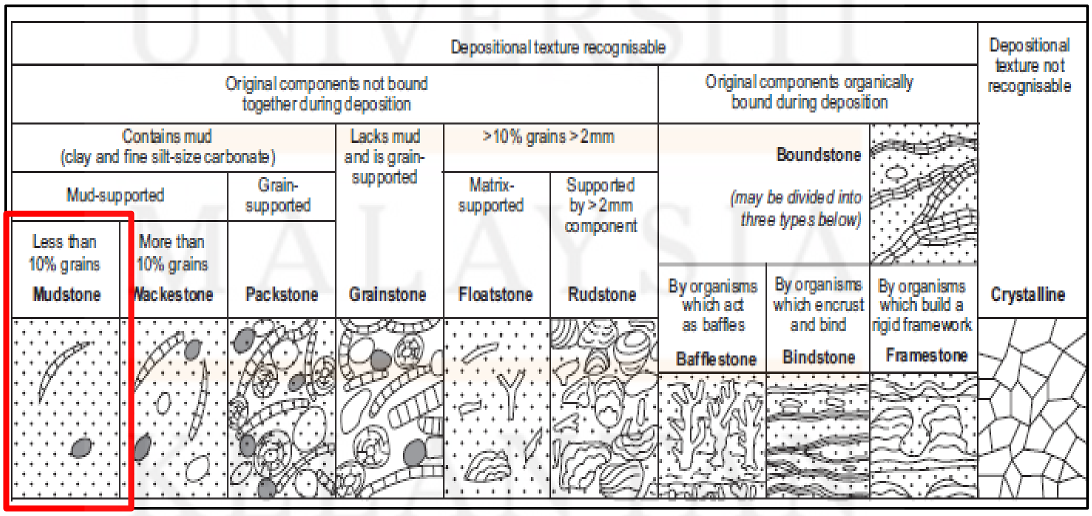

Figure 4.10: Dunham's Classification of carbonate rocks.

ii. Sandstone

Sandstone is a sedimentary rock formed from cemented sand-sized clasts. Sand grains are formed by the breakdown of pre-existing rocks of weathering and erosion, and from material that forms within the depositional environment. The breakdown products fall into two categories: detrital mineral grains, eroded from pre-existing rocks, and sand sized pieces of rock or lithic fragments. Grains that form within the depositional environment are principally biogenic in origin, that is, they are pieces of plant or animal, but there are some which are formed by chemical reactions (Dickinson and Suczek, 1979).

Figure 4.10 show the hand specimen of sandstone found at coordinate N 04°55’51.3”, E 102° 02’ 30.5”. The sample has light grey in color and fine grain in size. This fine-grained sandstone found from folding structure which is interbedded with mudstone.

Figure 4.10: Hand specimen of sandstone.

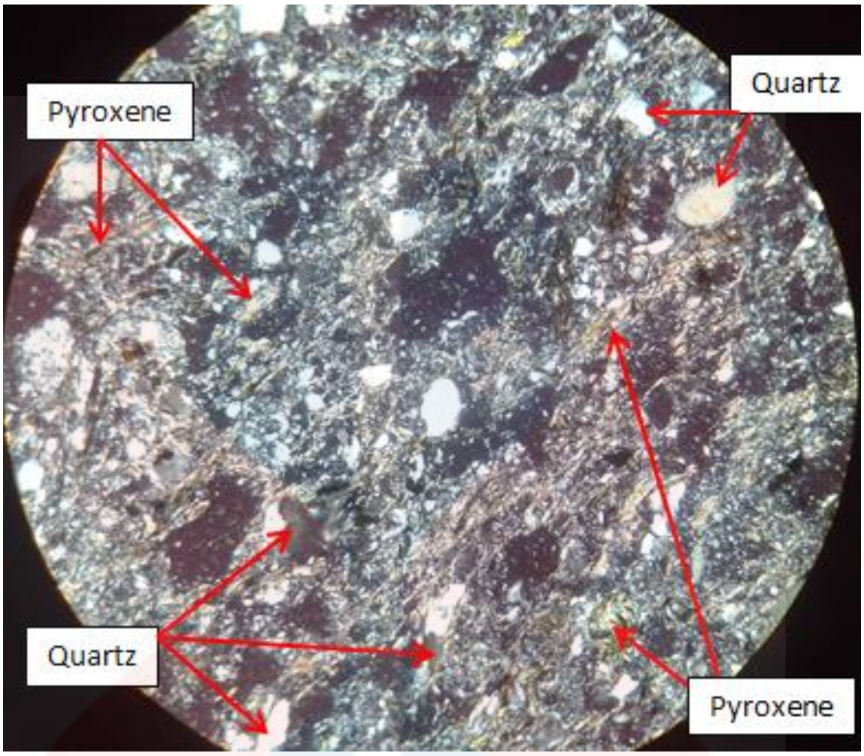

Figure 4.11: Thin section of sandstone under plane polarized with x10 magnification

From the microscopic observation, the sandstone is poorly sorted. The contacts between the clast are mostly floating grain where long contacts are hardly to see. The roundness of a clast affects the maturity of the sedimentary rock. As grain of sandstone sample is observed below the microscopes have low sphericity with the sub rounded shape. This indicates that the samples are low maturity. The transportation of rock from its sources was not far enough. Quartz and pyroxene minerals also can be observed.

iii. Mudstone

Mudstones are the most abundant kind of sedimentary rock. Figure 4.12 shows the hand specimen of mudstone found at study area. This mudstone found interbedded with sandstone in folding structure. This sample was dark grey in color. Besides, it has very fine grain in size.

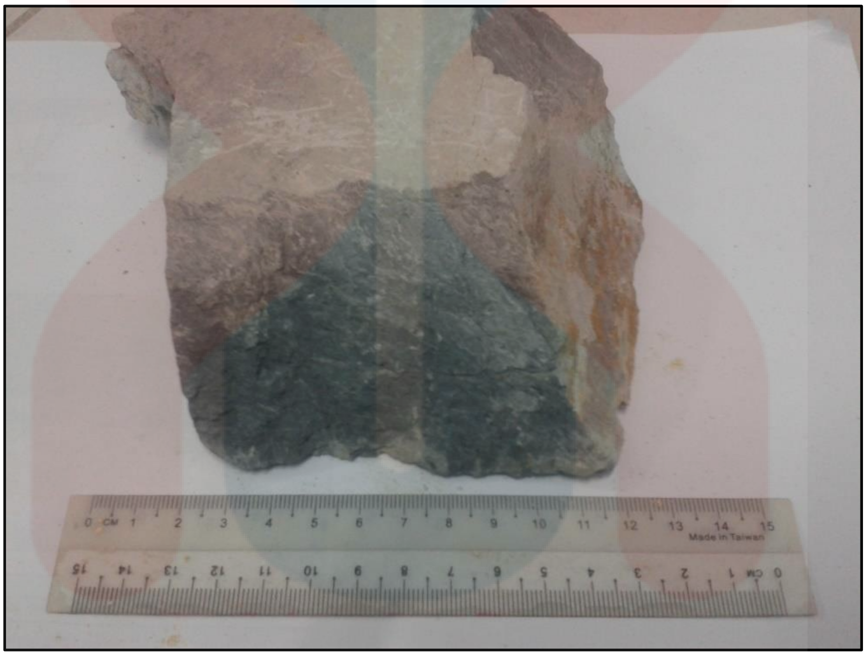

Figure 4.12: Hand specimen of mudstone.

Petrography analysis cannot be conducted towards mudstones due to their grain size which is to fine to be analysed. But, the determination of mudstone or shale can be studying using the geochemistry analysis by looking at their major element composition in the rocks.

4.4 Structural Geology

4.4.1 Lineament Analysis

A lineament is a linear feature in a landscape which is an expression of an underlying geological structure such as fault. Typically, a lineament will comprised a fault-aligned valley, a series of fault or fold-aligned hills, a straight coastline or indeed a combination of these features. Fracture zones, shear zones and igneous intrusions such as dykes can also give rise to lineaments. Lineament comprises of two types which are positive and negative lineament (Prabu and Rajagopalan, 2013).

The digitalization of lineament was carried out by using TIN features in ArcGIS software. Figure 4.13 shows the lineament analysis map produced. Based on the map, the positive lineament can be shown in areas which have high topographic value above the sea level while the negative lineaments were in areas which have low topographic values. There are thirteen major positive lineaments and fifty six major negative lineaments can be interpreted. The analysis of lineament then carried out by measuring the bearing of the lineament using protractor and then plotted the bearing in the rose diagram.

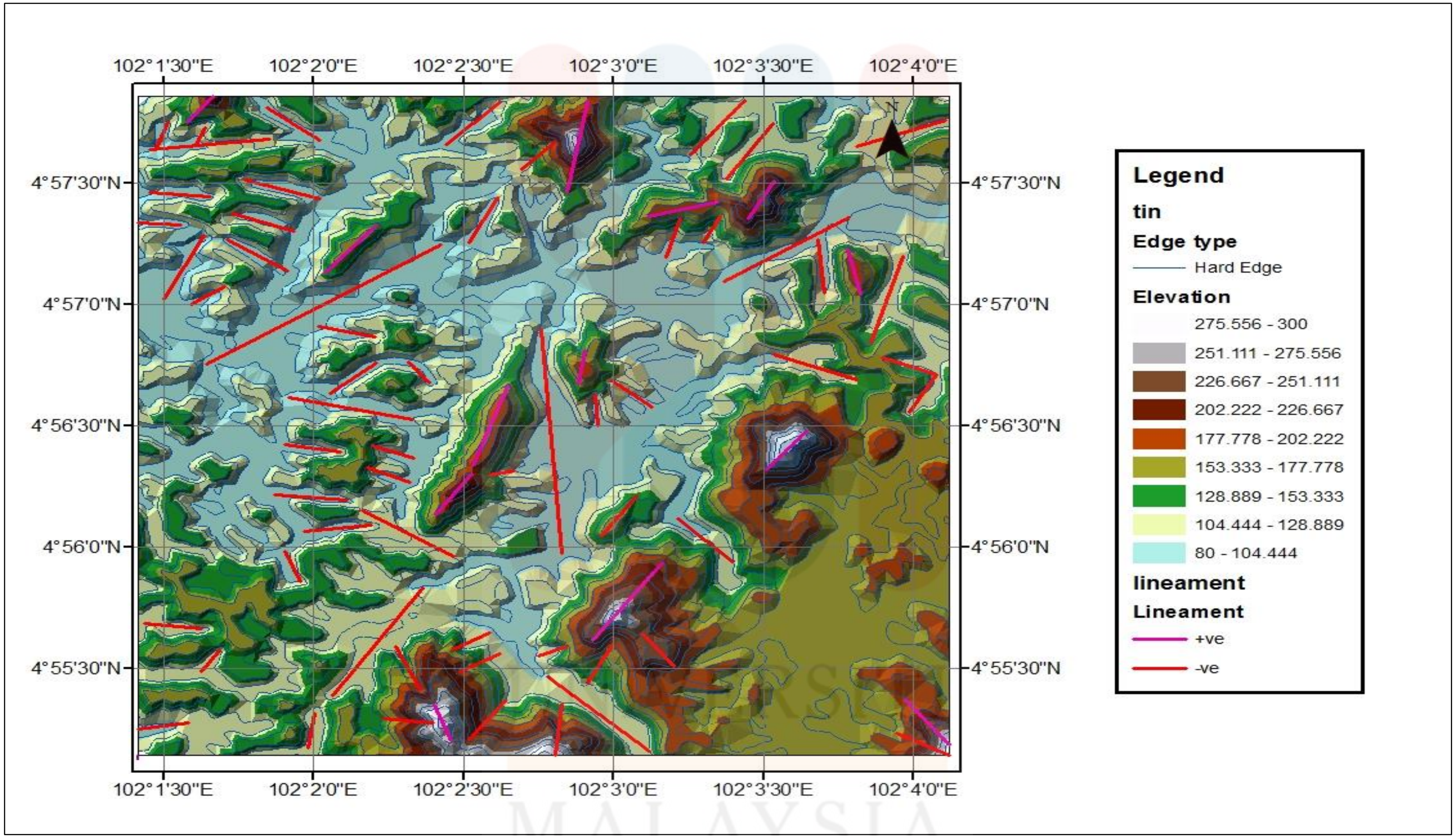

Figure 4.13: The lineament analysis map of Kampung Sungai Asap. The pink line shown the positive lineaments while the red line shown the negative lineaments

i. Positive Lineaments

From the rose diagram in Figure 4.14, the directions of the force for positive lineaments are extending from North-West to South-East direction.

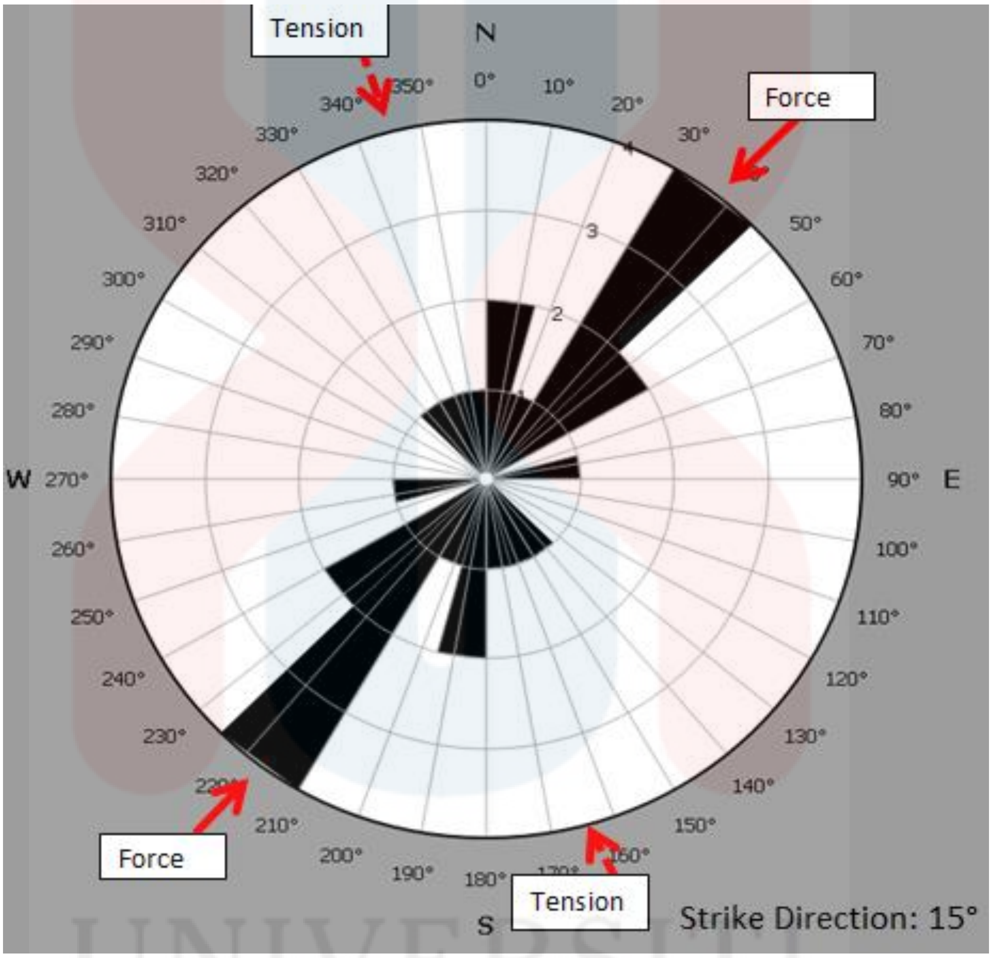

Figure 4.14: Rose diagram of positive lineaments

ii. Negative Lineaments

From the rose diagram in Figure 4.15, the directions of the force for negative lineaments are extending from North-West to South-East direction which is in the same direction with positive lineaments.

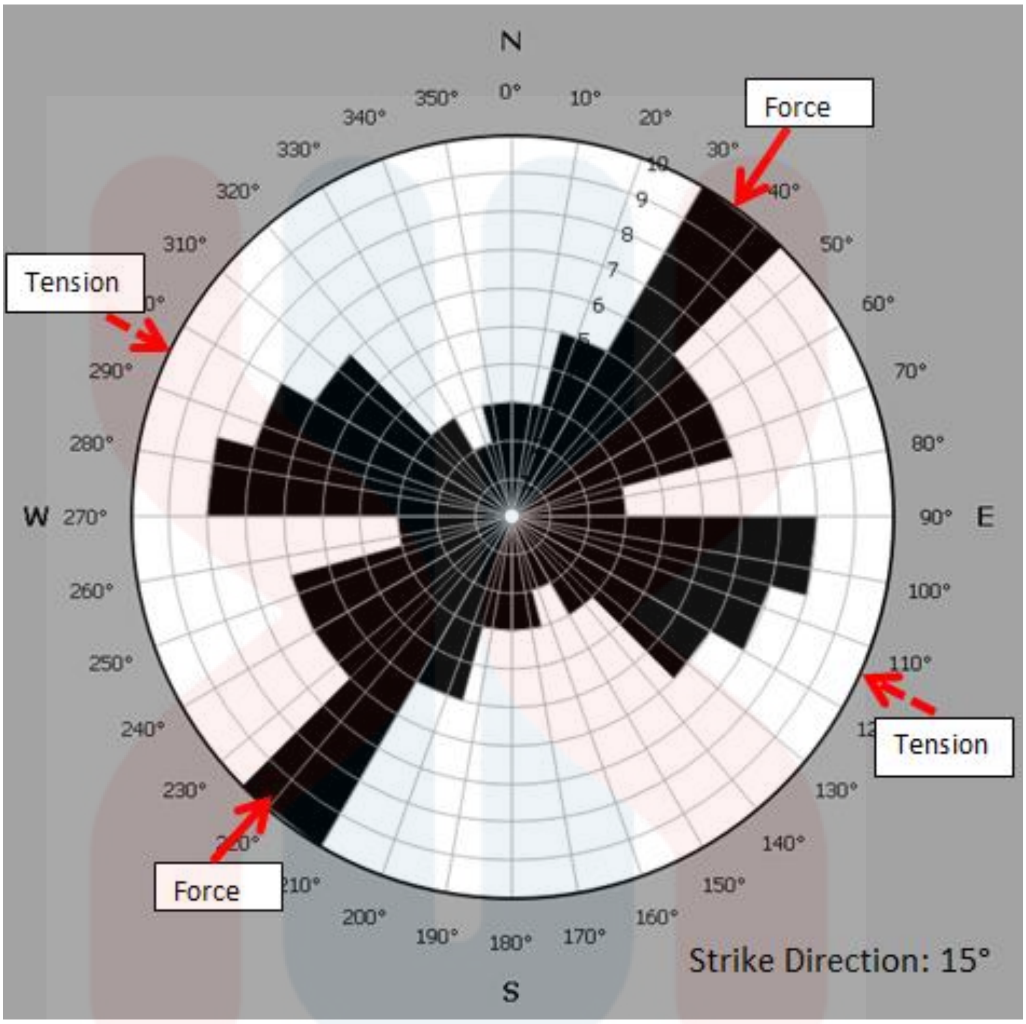

Figure 4.15: Rose diagram of negative lineaments

4.4.2 Folding Analysis

Processes in which rocks are bent are crumpled due to compressional forces arising from the convergence of two plates. The compressional forces cause the rock to fold in which syncline or anticline. The forces acting on outcrop changes the rock structures by means the foliation are fold due to force action.

Folding is secondary features which form imposed on rocks by events (such as compression or stretching) experienced by rocks after their original formation. Folds are most obvious and common structures that demonstrate the existence of ductile deformation. At the study area, there are major and minor folding occurred. This fold can be found at coordinate N 04°55'51.3" and E 102°02'30.5". Figure 4.16 shows the major fold at the study area.

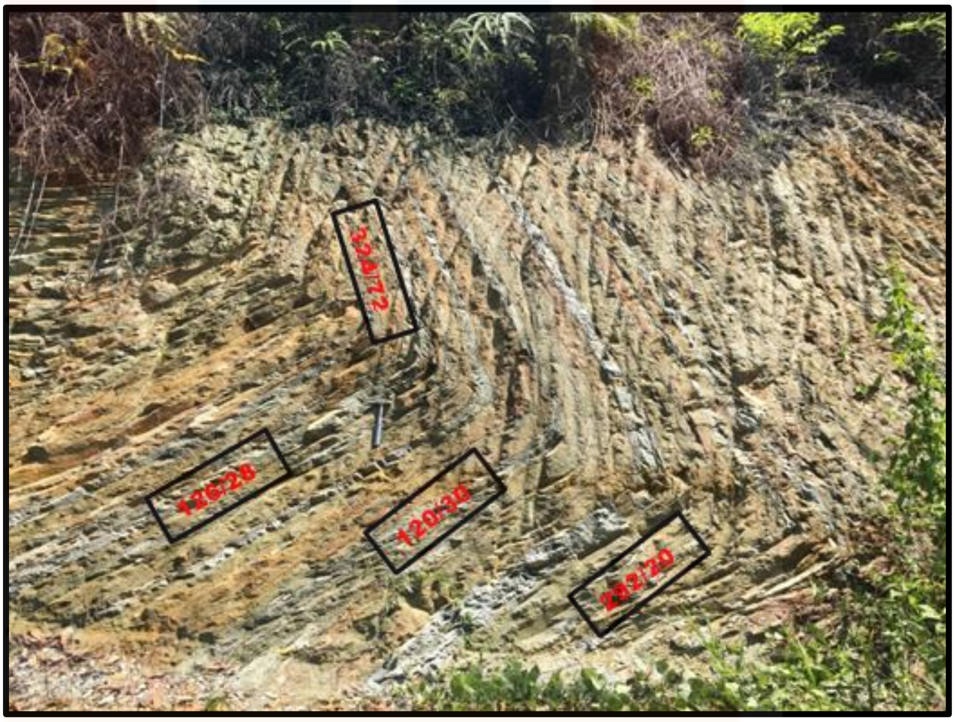

Figure 4.16: Major folds at the study area with the strike and dip.

This type of major fold is recognized as chevron fold. Chevron fold is a type of fold which shows characteristically long, planar limbs with a short, angular hinge zone. Chevron folds occur in sequences of regularly bedded layers of alternating competent and incompetent material which deform by flexural slip and ductile flow respectively. At study area, this chevron fold are composed of interbedded between metasiltstone and also volcanic sandstone. Figure 4.17 shows the stereonet analysis of major folding.

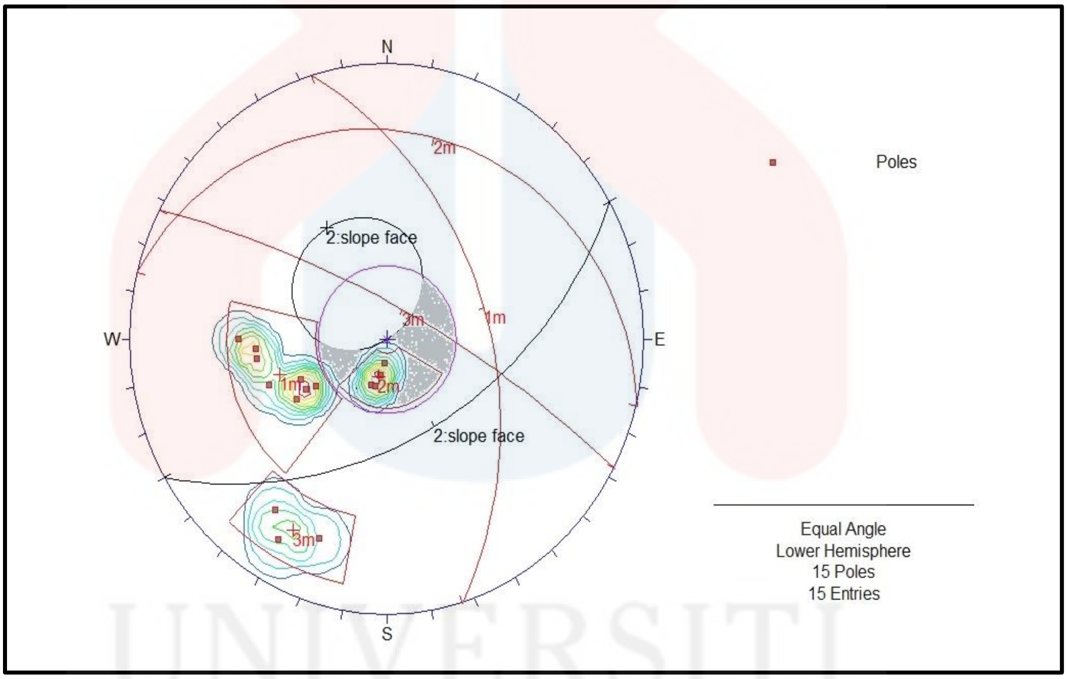

Figure 4.17: Stereonet analysis of major folding

Based on the stereonet analysis, the major folding is daylighting into the slope. These discontinuities are favourably oriented to cause planar failure. The shaded region in Figure 4.17 has shown the planar zone which is the zone between slope face and cone of depression.

Minor folds are quite frequently seen in outcrop. Minor folds, however can often provide the key to the major folds they are related to. They reflect the same shape and style, the direction in which the closures of the major folds lie and their cleavage indicates the attitude of the axial plane of the major folds and their direction of overturning. At the study area, there are two types of minor fold recognized which are syncline and overturned fold. Figure 4.18 showing the syncline fold while Figure 4.19 shows the overturning fold which is located at the same location with major fold at the main road of Kuala Krai-Gua Musang.

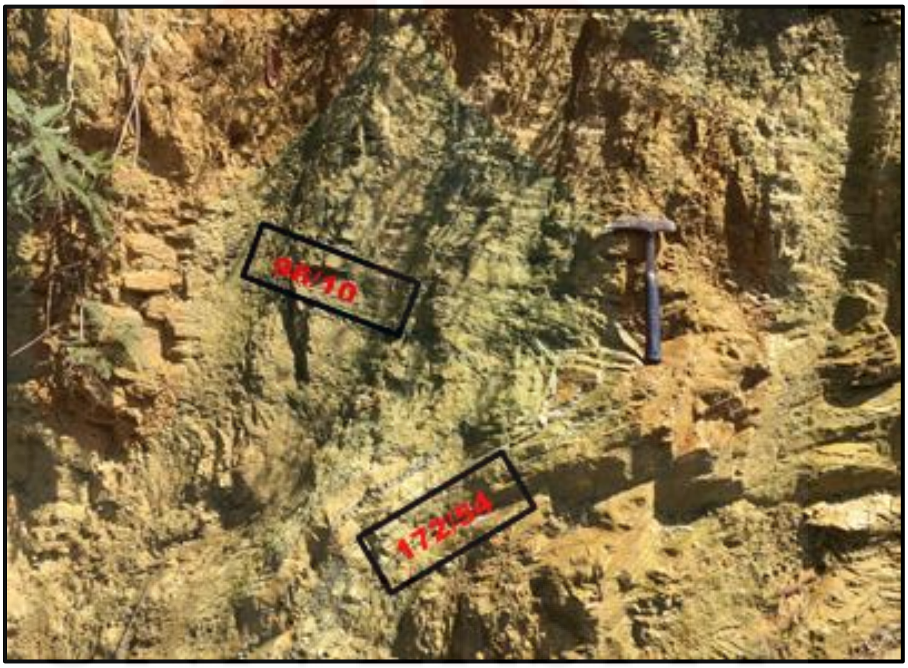

Figure 4.18: The syncline fold with the reading of strike and dip

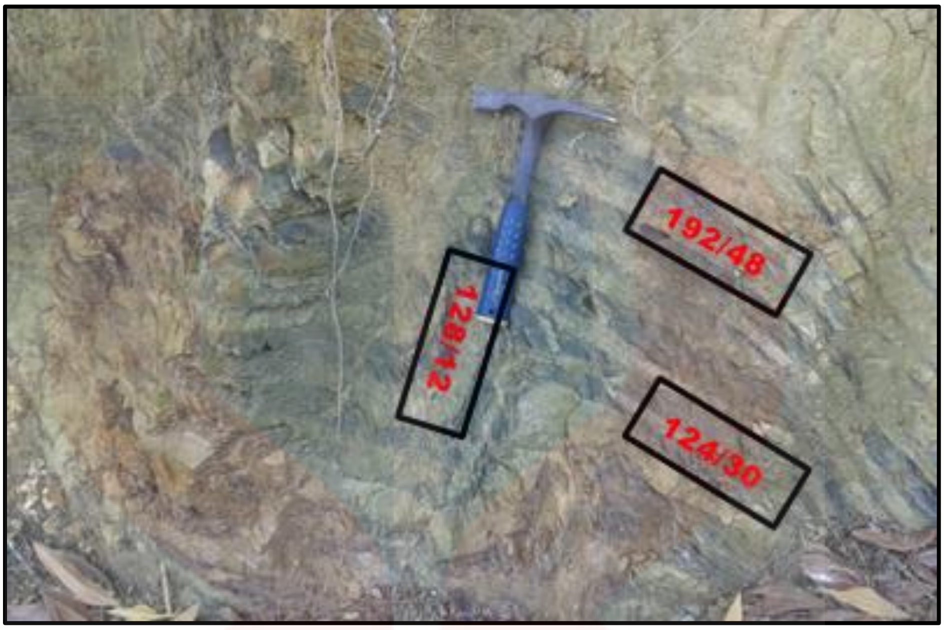

Figure 4.19: The overturned fold with the reading of strike and dip

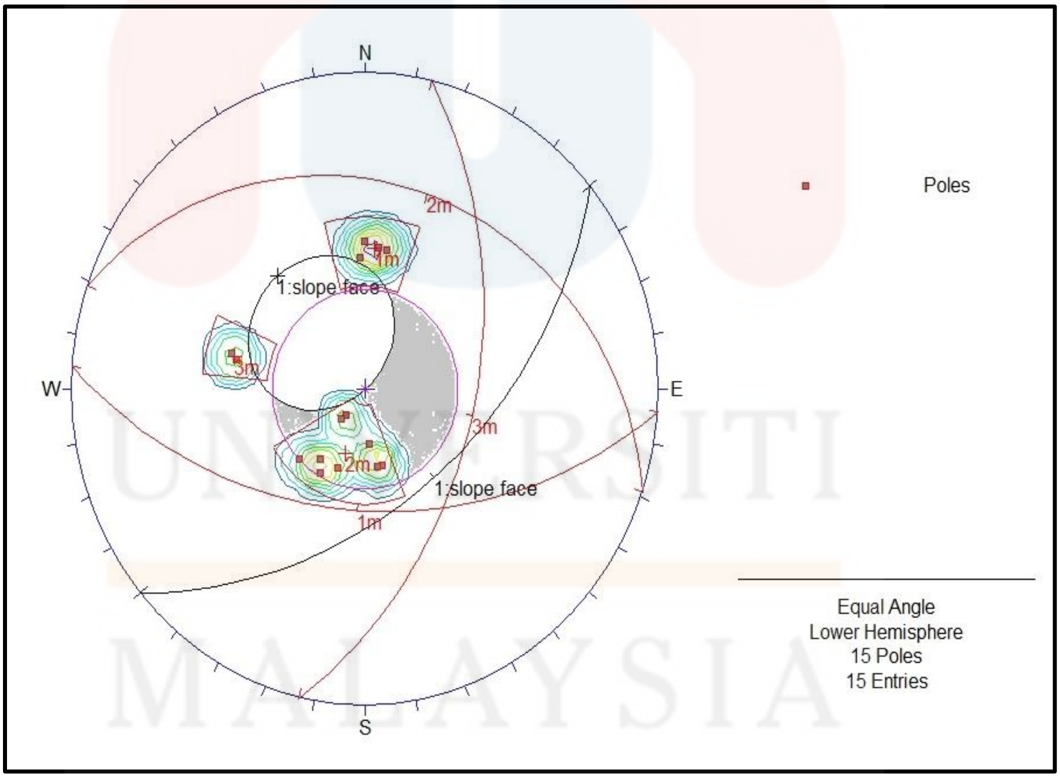

Figure 4.20: Stereonet analysis of syncline fold(minor fold)

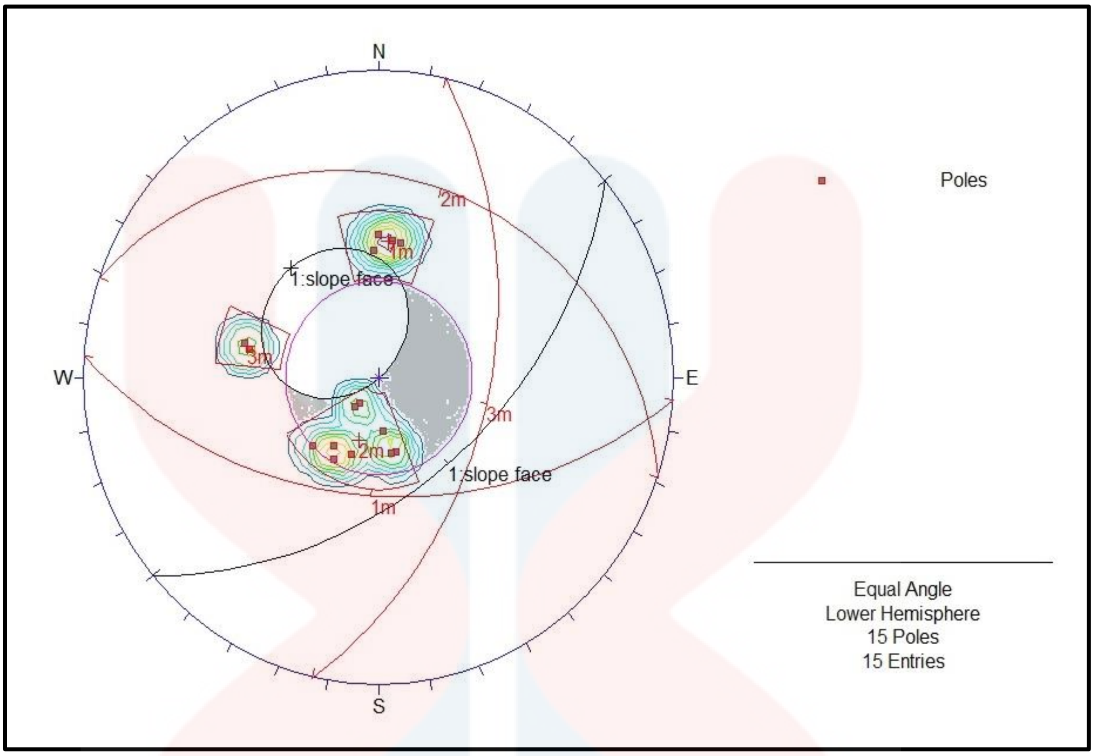

Figure 4.21: Stereonet analysis of overturned fold

Based on the stereonet analysis, both of the minor folding are daylighting into the slope. These discontinuities are favourably oriented to cause planar failure. The shaded region in Figure 4.20 and Figure 4.21 showed the planar zone which is the zone between slope face and cone of depression.

4.4.3 Joint Analysis

A joint is described as a fracture dividing rock into two sections that have not moved away from each other. This joint analysis was carried out at location with coordinate N 04°55'51.3" and E 102°02'30.5". Figure 4.22 shows the joint structure at study area. The total 100 reading of strike and dip were taken for the analysis using GeoRose software. Based on the rose diagram in Figure 4.23, the major force shown the direction from North-east to South-West. These directions show the similar to the direction of positive and negative lineaments of the study area. As a conclusion, the direction of forces applied at the location similar to the direction of both positive and negative lineaments of the study area.

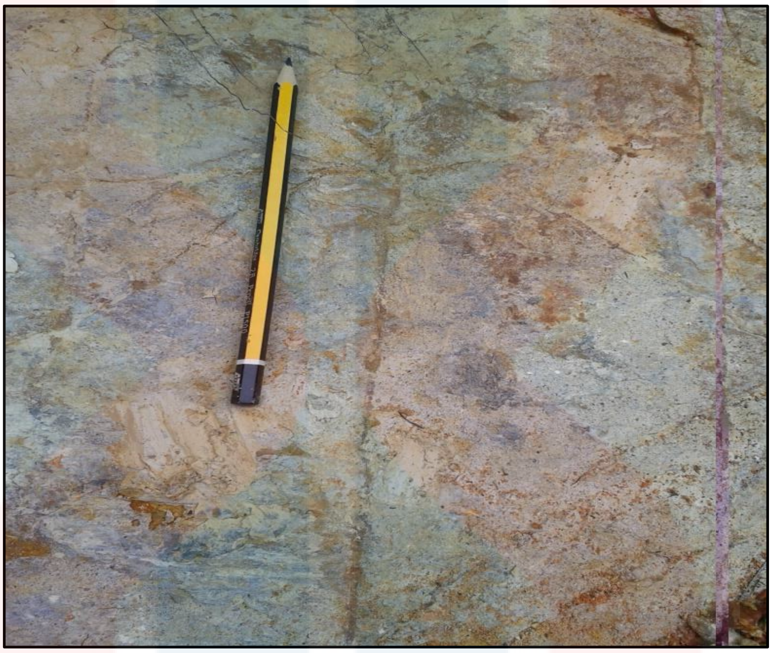

Figure 4.22: Joint structure at study area.

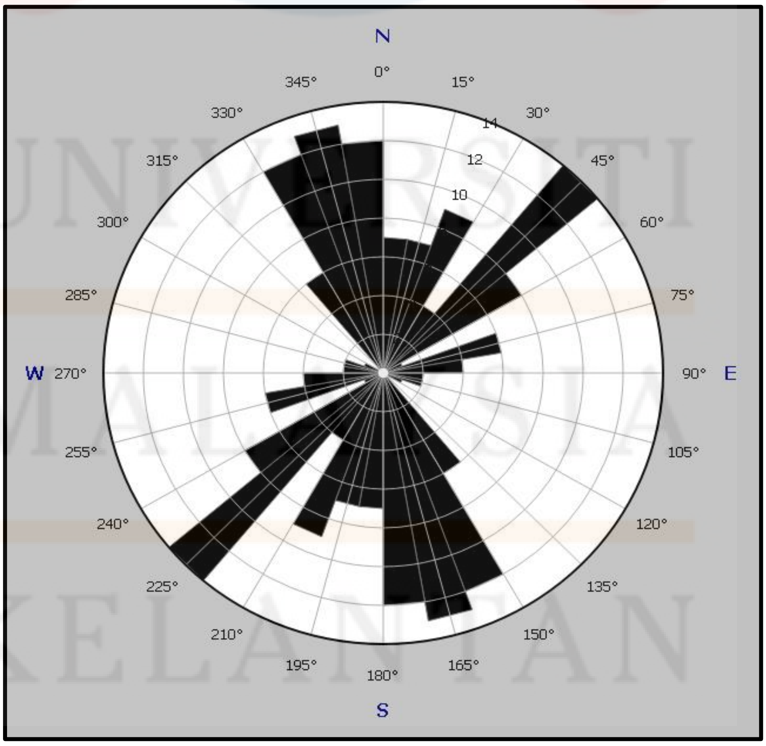

Figure 4.23: The joint analysis of study area.

4.4.4 Bedding Analysis

Bedding is the most common structure in sedimentary rock. Beds are tabular or lenticular layers of sedimentary rocks that have lithologic, textural or structural unity that clearly distinguishes them from strata above and below (Sam Boggs, 2006). Figure 4.24 shows the wavy bedding found at study area. The sizes of beds are range from 1 cm to 3 cm. This bedding comprises of mudstone and claystone. The reading of strike and dip of the bedding were measured for analysis. Figure 4.25 shows the analysis of bedding at study area. Based on analysis, the slope are stable because the bedding plane is not daylighting to slope.

Figure 4.24: Bedding structure at study area.

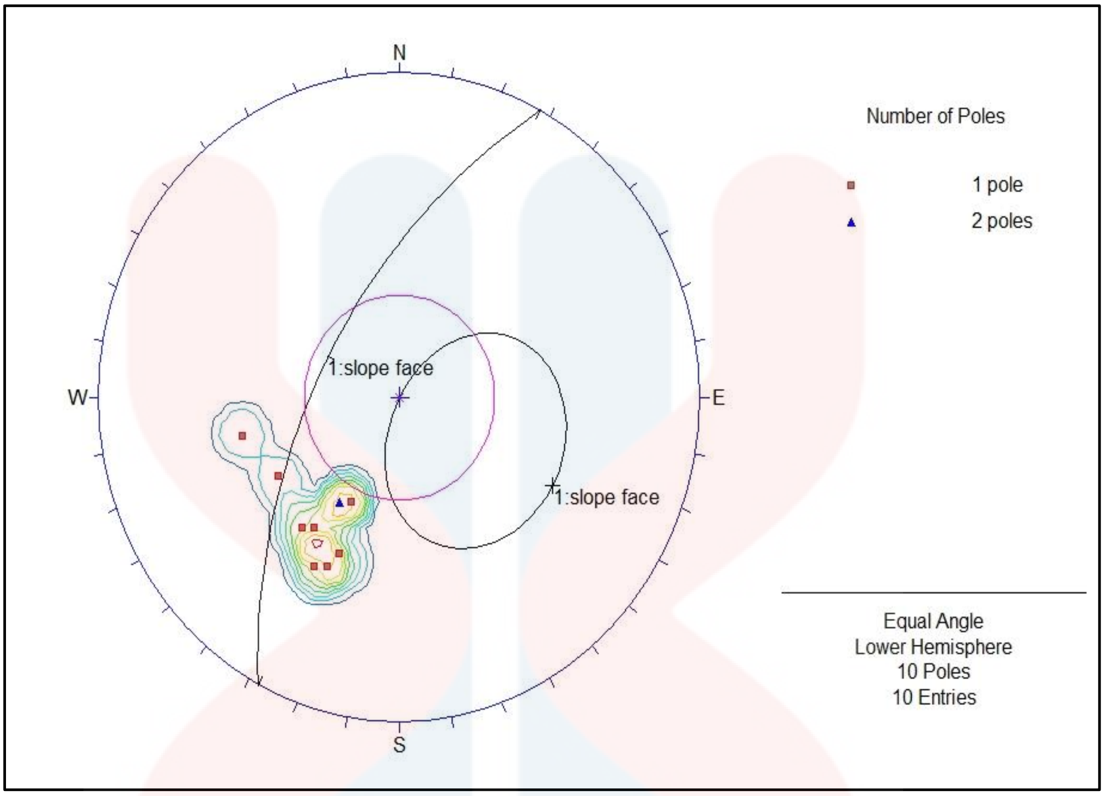

Figure 4.25:Stereonet Analysis of Bedding

4.5 Historical Geology

The study area was under Gunung Rabong Formation. The age of Gunung Rabong Formation are range from middle Triassic (Ladinian) and Upper Triassic (Carnian). Gunung Rabong Formation uncomformably overlying the Gua Musang Formation. Gunung Rabong Formation consists of different lithologies that are predominantly with arenaceous to argillaceous rocks sequence with subordinate calcaraceous, rudaceous, and volcanic band. According to Yin (1965), the sequences of rocks of Gunung Rabong Formation are shale, mudstone, siltstone, sandstone and conglomerate.

4.6 Geological Map

Figure 4.26 shows the geological map of study area produced at scale of 1:25,000. There are five lithology can be observed in the study area, which are volcanic tuff, silicified limestone, mudstone, metasiltstone and sandstone. Almost 60% of the map is dominated by Middle Triassic age of lithology which is mudstone, metasiltstone and sandstone while the other 40% are belong to Late Triassic age of lithology which are volcanic tuff and silicified limestone.

A cross section was plotted from line A to A' .Next, several strike dip are taken from the structure found at the study area. There are structures such as folding, joint and also bedding.

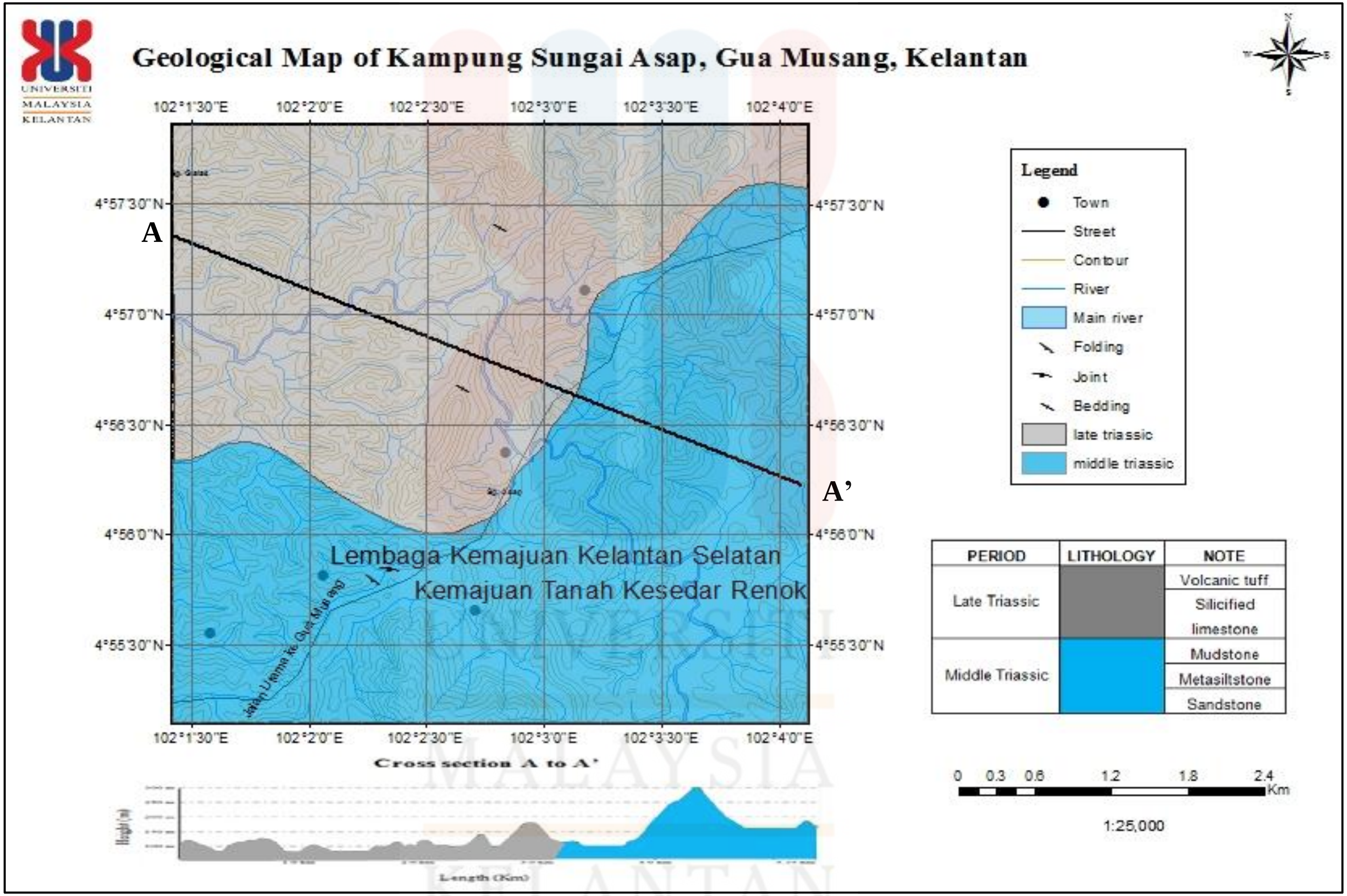

Figure 4.26: Geological Map of study area at scale 1;25 000

CHAPTER 5

SLOPE FAILURE ANALYSIS

5.1 Introduction

This research was carried out to look in details between the influences of structural pattern with slope failures. Slope failure can be defined as the downslope movement of rock debris and soil in response to gravitational stress. Details slope failure survey was done and their findings were summarized in Table 5.1. There are total eleven (11) slope failures found. Three (3) of them occurred at large scale while the other eight (8) occurred at small scale. Based on surveying, there are two types of slope failure at study area which are translational slides and also block slide.

Translational slides occurred when the landslides mass moves along a roughly planar surface with little rotation or backward tilting. A block slides is a translational slide in which the moving mass consists of a single unit or a few closely related units that move downslope as a relative coherent mass (Varnes, 1978).

The grade of weathering varies and different for each failure. For example, the weathering grade for slope failure 1 is range from grade II-III. It can be clearly seen the outcrop are exposed on the surface. While the of grade weathering for other failure are range from IV until VI. Figure 5.1 shows the slope failure distribution map obtained.

Table 5.1: Slope failure survey in study area.

NO. OF SLOPE	COORDINATE	SLOPE GEOMETRY			SLOPE FAILURE GEOMETRY			STRUCTURE	WEATHERING GRADE	LITHOLOGIES	TYPES OF SLOPE FAILURE	SLOPE PROTECTION
		WIDTH (ft.)	HEIGHT (m)	ANGLE (°)	WIDTH (ft.)	HEIGHT (m)	DIAMETER (m)					
1	N 04°55'51.3" E 102°02'30.5" Elevation:109m	30	3	60	15	3.5	2	Folding Joint Quartz Vein	II – III	Sandstone Mudstone Metasiltstone	Rotational	No
2	N 04°55'48.5" E 102°02'35.5" Elevation : 99 m	35	7	72	20	5	3	Relict structure	IV – V	Metasediment	Translational	No
3	N 04°57'11.69" E 102°03'28.77" Elevation:106m	25	3	65	18	1	1	Relict structure	V – VI	Metasediment	Translational	No
4	N 04°57'07.3" E 102°02'55.5" Elevation:111m	50	7	70	40	6	3	No	VI	No lithology found	Translational	No
5	N 04°56'38.2" E 102°02'38.6" Elevation:115m	55	2.5	32	30	2	1	No	VI	No lithology found	Translational	No
6	N 04°56'56.8" E 102°03'19.5" Elevation:113m	30	5	78	15	2	2	Bedding	IV – V	Metasediment	Translational	No

NO. OF SLOPE	COORDINATE	SLOPE GEOMETRY			SLOPE FAILURE GEOMETRY			STRUCTURE	WEATHERING GRADE	LITHOLOGIES	TYPES OF SLOPE FAILURE	SLOPE PROTECTION
		WIDTH (ft.)	HEIGHT (m)	ANGLE (°)	WIDTH (ft.)	HEIGHT (m)	DIAMETER (ft.)					
7	N 04°55'55.27" E 102°02'31.60" Elevation:110m	50	10	70	25	3.5	25	No	VI	No lithology found	Translational	Gabion Wall
8	N 04°55'56.30" E 102°02'34.48" Elevation:110 m	50	10	70	30	5	30	No	VI	No lithology found	Translational	Gabion Wall
9	N 04°57'13.34" E 102°03'10.63" Elevation:111m	25	2.5	60	18	2	18	Relict structure	V – VI	Metasediment	Translational	No
10	N 04°57'12.73" E 102°03'6.50" Elevation:114m	40	3	50	25	2.5	25	No	VI	No lithology found	Translational	No
11	N 04°57'3.83" E 102°03'8.36" Elevation:115m	35	3	55	25	2.5	35	No	VI	No lithology found	Translational	No

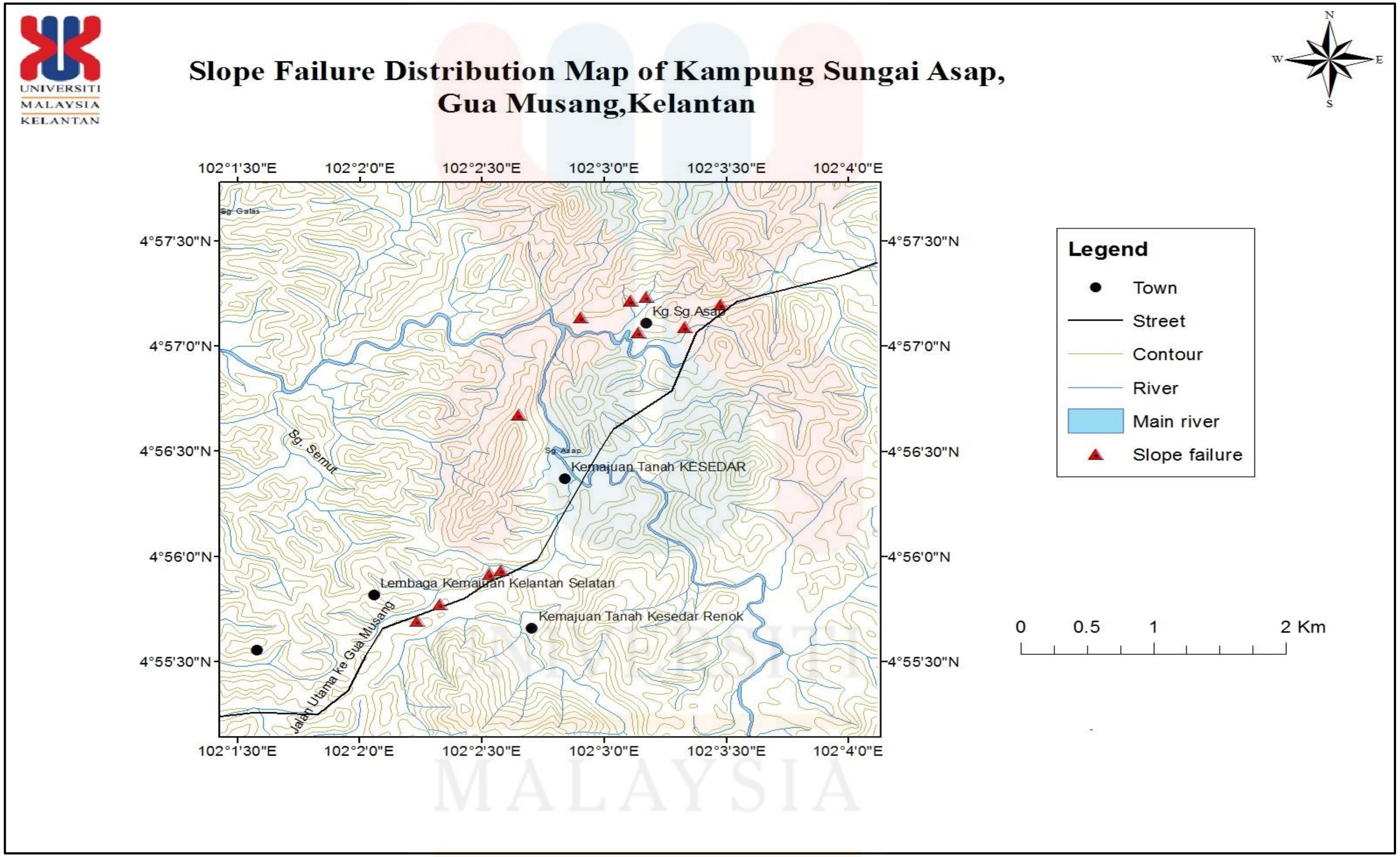

Figure 5.1: Slope Failure Distribution Map of Study Area.

5.2 Slope Failure Analysis

The detailed slope failures analysis was carried out to determine the influence of structural pattern with slope failure. These detailed analyses were done on two slope failure because the structure can be clearly seen at this failure. First analysis is at slope failure with coordinate N 04°55'55.27" and E 102°02'31.60". Figure 5.2 shows the overview of slope where the slope failure 1 occurred.

Figure 5.2: Overview of slope where slope failure 1 occurred.

This slope contains lithology of sandstone, mudstone and metasiltstone. The weathering grades of this slope are range from grade I (fresh rocks) until grade III (weathered rock). The presence of discontinuities such as joint and folding are strongly influences the slope failure. This can be proved by the stereonet analysis in Figure 5.3. Based on figure, there is discontinuity sets plotted on the critical area for sliding and they are daylighting into the slopes. These discontinuities are favorably caused the planar failure.

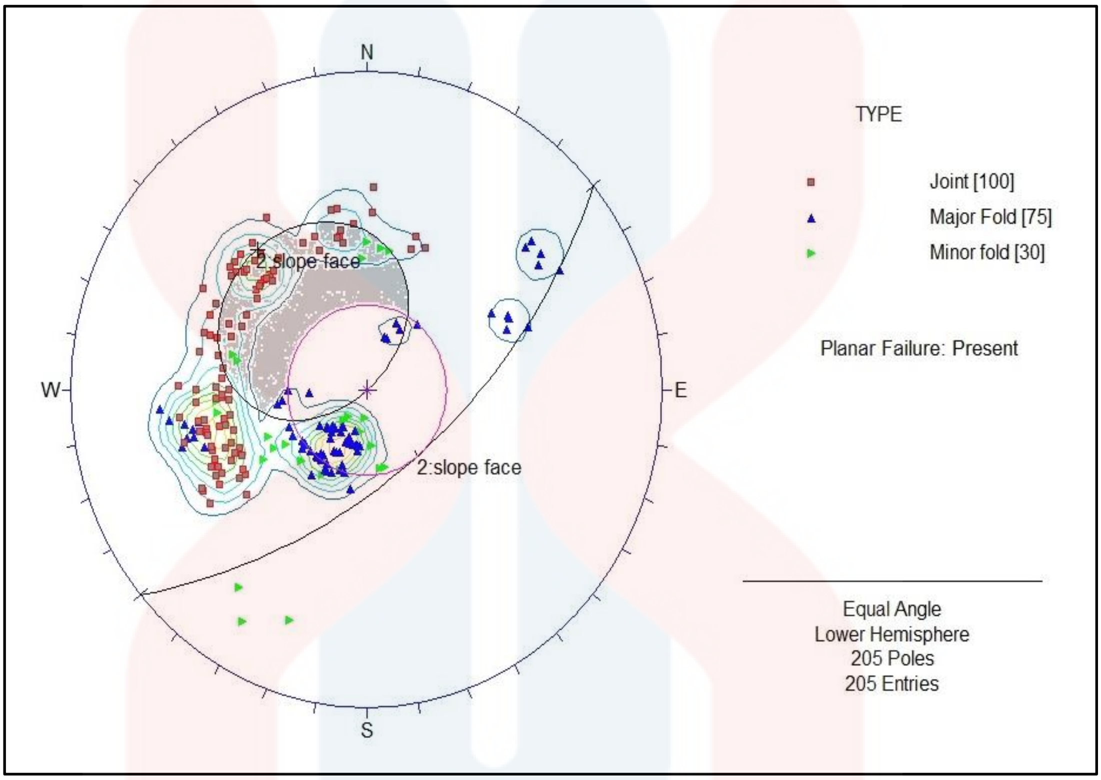

Figure 5.3: Stereonet Analysis of Slope Failure 1

The second analysis was done at slope failure with coordinate N 04°56'56.8 and E 102°03'19.5”. Figure 5.4 shows the slope failure at this coordinate. This slope contains lithology of metasediment with highly weathered condition.

Figure 5.4: Slope failure at coordinate N 04°56'56.8 and E 102°03'19.5”.

The weathering grades of this failure are range from grade IV (highly weathered rock) until grade VI (completely weathered rock).The presence of bedding (Figure 5.5) influences the slope failure. This can be proved by the stereonet analysis in Figure 5.6. Based on figure, there is discontinuity sets plotted on the critical area for sliding and they are daylighting into the slopes. This discontinuity is favorably caused the planar failure.

Figure 5.5: Bedding structure at the slope failure.

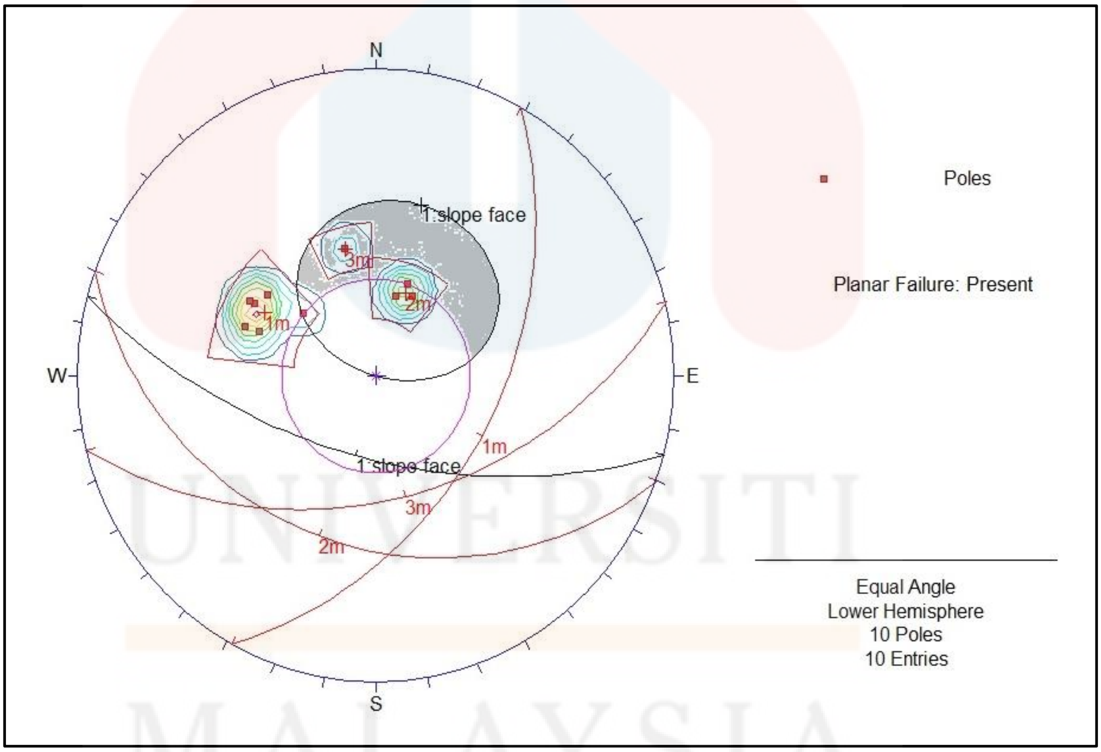

Figure 5.6: Stereonet Analysis of Slope Failure 2 .

Based on analysis at both slope failures, it can be clearly seen that the structural pattern influences the slope failure caused them to slides because there is discontinuities set in critical area for sliding and there are daylighting to the slope.

CHAPTER 6

DISCUSSION AND RECOMMENDATION

6.1 Discussion

The regional structural pattern such as lineament are mainly controlled the slope failure. Figure 6.1 shows the analysis of structural pattern using satellite imagery. From the analysis, there are structure such as fault scrap (blue line) , positive lineament(red line) and negative lineament(green line).Figure 6.2 shows the lineament analysis and slope failure distribution map produced by using ArcGIS. From the map, most of the slope failures are occurred at the negative lineament. The directions of failure can be determined which are in the same directions of the force for lineaments that extending from North-West to South-East direction. The investigation of lineaments has been connected effectively to structural geology and slope failure distribution.

There are several factors that caused the slope failure at study area. The presence of discontinuities such as joint, folding, and bedding on slope has influenced the slope failures to occur. This can be proved by the stereonet analysis of the structures found at the slope failure. Figure 6.3 and Figure 6.4 shows the analysis of stereonet of the structure controlled the failures. Based on analysis, both slope failures are mainly controlled by the presence of discontinuities. There is discontinuity sets plotted on the critical area for sliding and they are daylighting into the slopes. These discontinuities are favorably caused planar failure.

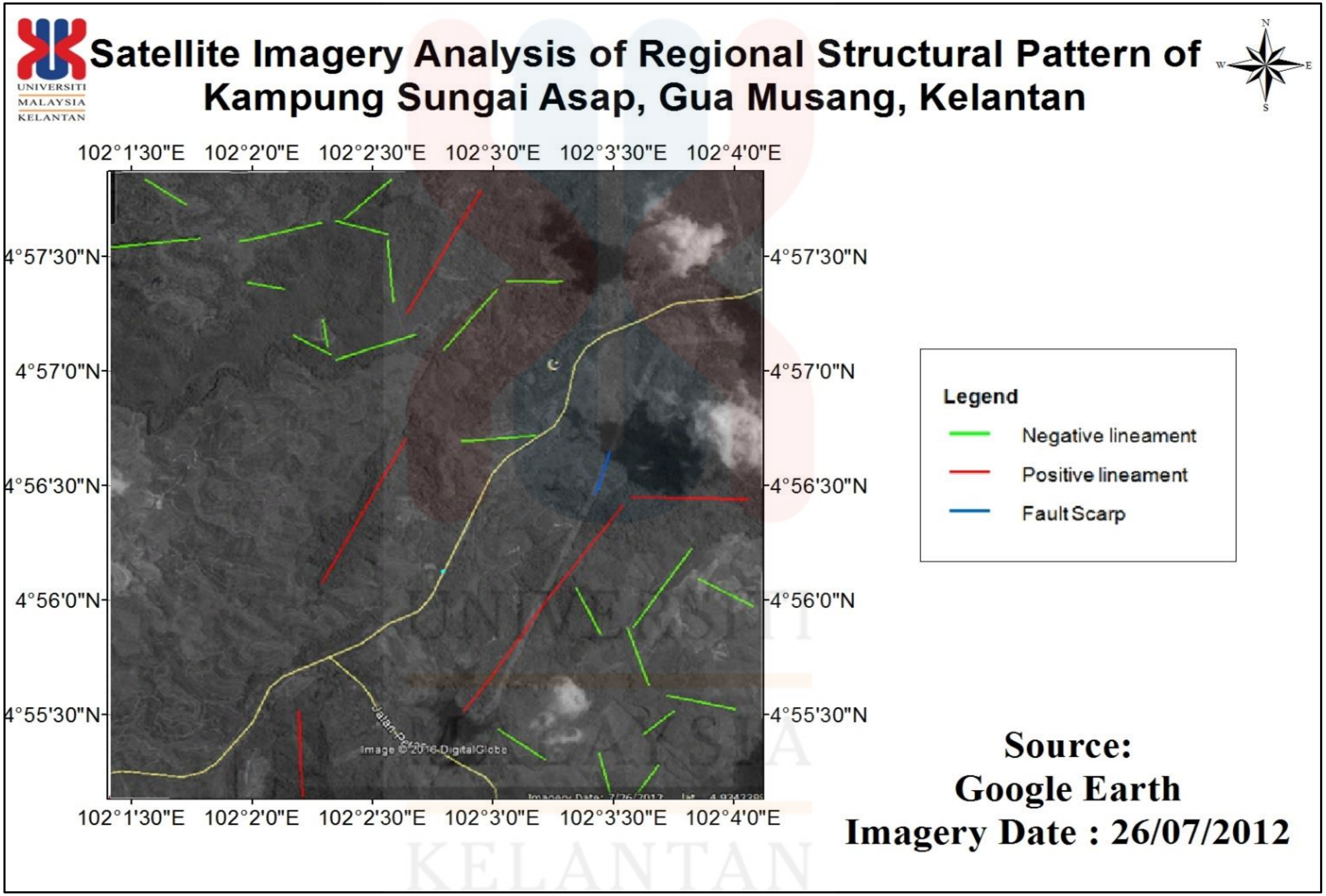

Figure 6.1: Satellite Imagery Analysis of Regional Structural Pattern.

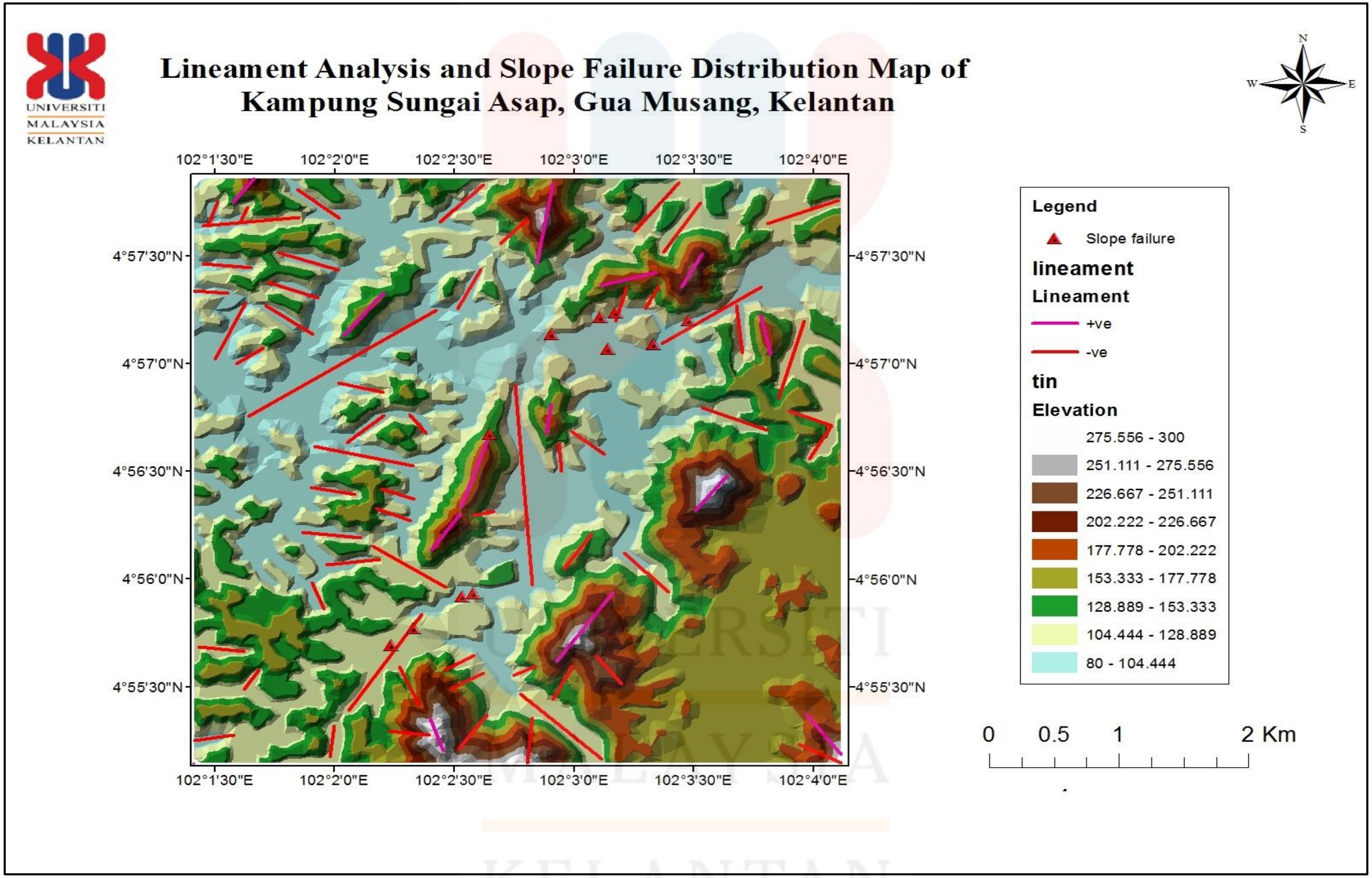

Figure 6.2: Slope Failure Distribution and Lineament Analysis Map of study area.

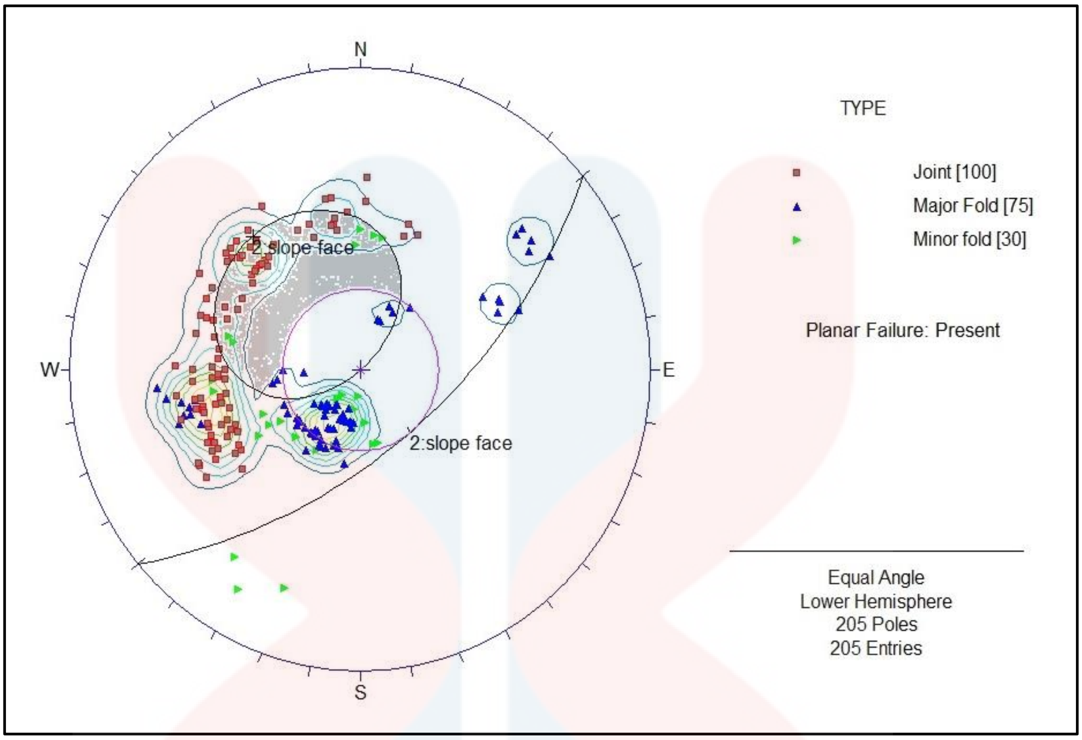

Figure 6.3: Stereonet Analysis at Slope Failure 1

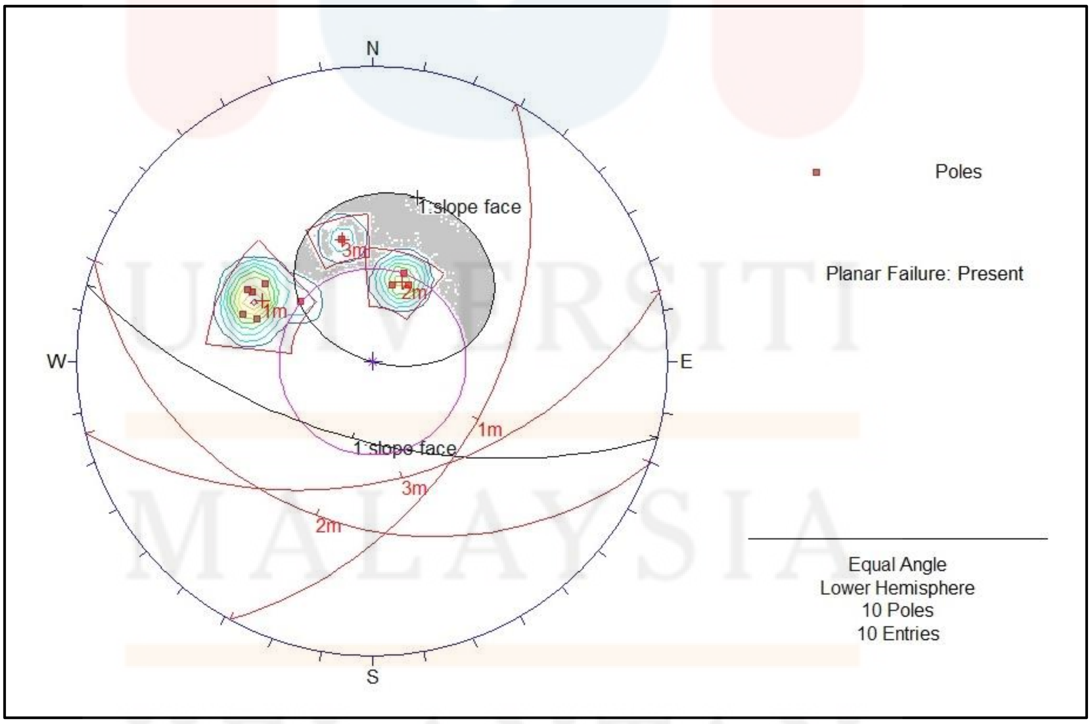

Figure 6.4: Slope Analysis at Slope Failure 2.

In addition, the other caused of slope failure are the direction of flow accumulation at the study area. The map of slope failure distribution with direction of flow accumulation is generated from the ArcGIS. From the map in Figure 6.5, it can be clearly shown that the slope failures are located at the position of low to high rate of flow accumulation. A flow accumulation function is defined as an operator which given the drainage direction matrix and a weight matrix, determines a resulting matrix such that each element represents the sum of the weights of all elements in the matrix which drain to that element (O'Callaghan & Mark, 1984). Weight matrix represents the magnitude of the overland flow. As can be noted, the incorporation of the flow accumulation gives results which are more realistic in terms of the effects of the slope failure distribution.

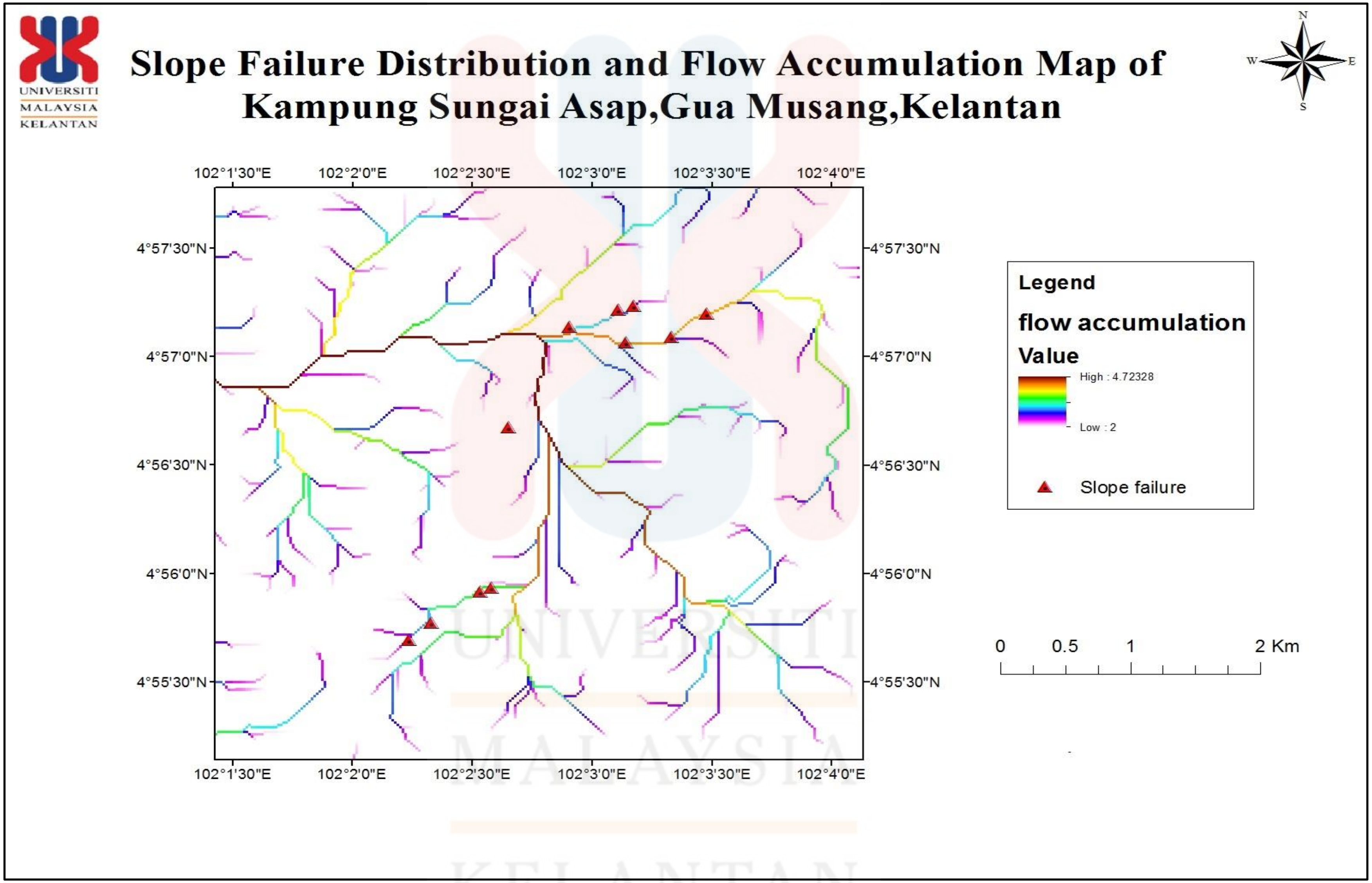

Figure 6.5: Slope Failure Distribution and Flow Accumulation Map of Study Area.

6.2 Conclusion

In conclusion, the study area was comprised lithology volcanic tuff, silicified limestone, mudstone, metasiltstone and sandstone. The study area belong to Gunung Rabong Formation which the age are range from Middle Triassic to Lower Triassic. From the lineament analysis, the directions for both positive and negative lineaments are extending from North-West to South-East direction. With the comparison of all analysis of other structures such as joint and folding, their directions are same with both types of lineaments.

The slope failure in study area are varies in grade weathering. It ranges from grade II (fresh rock) until Grade VI (completely weathered rock). The presence of discontinuities are mainly controlled the failure. Based on analysis, there is discontinuity sets plotted on the critical area for sliding and they are daylighting into the slopes. These discontinuities are favorably caused planar failure. Besides, the rate of flow accumulation also caused the slope failure in study area.

6.3 Recommendation

In order to implement safer and economical engineering design, further study should be done in order to indicate how the structural pattern influenced the slope failure. A detailed structural mapping should be carried out in the site investigation according to help designer to choose the most suitable slope orientation and reduce slope failure in future. A geological mapping need to be done in order to get information about the slope failure before the mitigation was done.

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