GEOLOGY AND ROCK SLOPE STABILITY ANALYSIS ON MODERATELY WEATHERED ROCK OF GUNUNG AYAM, GUA MUSANG.

by

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APPROVAL

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Applied Science (Geoscience) with Honours"

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DECLARATION

I declare that this thesis entitled "**GEOLOGY AND ROCK SLOPE STABILITY ANALYSIS ON MODERATELY WEATHERED ROCK OF GUNUNG AYAM, GUA MUSANG**" 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.

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Geologi dan Analisa Kestabilan Lereng Batuan ke atas Batuan mengalami Separa Luluhawa di Gunung Ayam, Gua Musang.

ABSTRAK

Muhammad Amir Mat Nuri, Quek Tiang Beng-Patrick

Gunung Ayam adalah salah satu bentuk tanah yang mengalami pengangkatan tektonik melalui 'Bentong-Raub Suture Zone' di tengah Semenanjung Malaysia. Kawasan penyelidikan terletak di antara latitud (N 04º 48' 0" hingga N 04º 50' 0") dan logitud (E101º 41' 0" ke E101º 43' 0") di mana terletak di Barat Daya Kelantan. Objektif utama penyelidikan ini adalah untuk memperbaharui peta geologi Daerah Lojing. Objektif lain menganalisa kestabilan cerun Gunung Ayam pada batu yang telah mengalami separa luluhawa. Objektif terakhir adalah menentukan faktor cerun keselamatan untuk pembangunan di masa hadapan. Bidang-bidang litologi batuan penyelidikan terdiri daripada tiga jenis unit konglomerat, unit kuartzait dan unit syis mika. Dalam kajian ini terdapat geologi struktur iaitu lipatan bergelombang, lipatan chevron, foliasi, sesar tujahan dan tubir sesar. Lereng batu 1 menunjukkan batuan konglomerat dan lereng batu 2 mewakili batuan kuartzait. Dalam kajian bidang kejuruteraan geologi menunjukkan dengan menggunakan kaedah 'Rock Mass Rating (RMR)' sistem and analisa kinematic menunjukkan keputusan bahawa cerun batuan 1 adalah lebih stabil berbanding dengan cerun batuan 2. Analisa kinematik menunjukkan keputusan cerun batuan 1 lebih cenderung untuk gagal di kegagalan menumbang berbanding kegagalan membaji. Cerun 2 menunjukkan keputusan analisa kinematik lebih cenderung untuk gagal di kegagalan membaji berbanding kegagalan menumbang. Manakala keupayaan kekuatan batuan ke atas batuan cerun separa luluhawa, cerun batuan 2 lebih kuat berbanding cerun batuan 1.

Kata Kunci: Ayam, Konglomerat, Kinematik, RMR, Kecerunan.

Geology and Rock Slope Stability Analysis on Moderately Weathered Rock of Gunung Ayam, Gua Musang.

ABSTRACT

Gunung Ayam is one of the landforms that undergoes the tectonic uplifting through the Bentong-Raub Suture Zone in the middle of Peninsular Malaysia. The research area located at between the latitudes (N 04^{o}48’0’’ to N 04^{o}50’0’’) and longitudes (E101^{o} 41’0’’ to E101^{o}43’0’’) where its located at Southwest Kelantan. The primary objective of this research is to updated the geological map of the Lojing District. Another objective is analysed slope stability of Gunung Ayam on weathered rock. The last objective is determining the factor of safety slope for the future development. The lithologies of research area is comprised of three types conglomerate unit, quartzite unit and mica schist units. Within this research the structural geology is a wavy fold, chevron fold, foliation, thrust fault and fault scarp. Rock slope 1 present a conglomerate rock and rock slope 2 represent quartzite rock. The engineering geology part of research by using the Rock Mass Rating (RMR) systems and kinematic analysis showed the result of rock slope stability is rock slope 1 is more stable than the rock slope 2. The kinematic analysis showed rock slope 1 tend to failure in toppling failure than wedge failure. Rock slope 2 more tend to wedge failure than toppling failure. Point load test on weathered rock, rock slope 2 is strongest than rock slope 1.

Keyword: Ayam, Conglomerate, Kinematic, RMR, Slope.

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ArcGIS	Arc Geographic Information System
GSI	Geological Strength Index
FYP	Final Year Project
GPS	Global Positioning System
HCl	Hydrochloric Acid
UMK	Universiti Malaysia Kelantan
RMR	Rock Mass Rating

CHAPTER 1

INTRODUCTION

1.1 General Background

Geology is about understanding cycle of earth that uncover resources for example energy and metals, regard recognizing and reducing the environmental consequence for exploit those resources and about learning manage the hazards associated to volcanic eruptions, earthquakes, and slope failures.

According to Abramson et.al., (2002) in the evolution of slope stability analyzes in geotechnical engineering, developments in soil and rock mechanics play an important role. Increasing demand for engineered cut and fill slopes in construction projects has increased the need for a deeper understanding of analytical methods, research tools, and methods of stabilization to solve slope stability issues.

The Malaysian Slope Engineering Branch (2010) carried out research landslide state that landslide records from 1966 to 2003 showed that 42% of landslides occurred in hilly terrain areas and over 90% occurred in developed areas such as infrastructure, residential and commercial areas.

Based on slope failure costs are highest in urbanized areas with high population densities where even small slides can destroy houses and block transport routes (Transportation Research Board,1996). Geotechnical investigation is necessity in urban planning because if the slope failure happened it could affect the urban population in a large scale.

These slopes have two types rock slopes and soil slopes. Each type has their own methodology to measure the safety slope. This research more focused on rock slope that have features moderately weathered. Many places can be seen on rock slopes, whether manmade or artificially created during the excavation process. Any imbalance of these slopes can result in failure and a serious concern at all times. Depending on the rock structures development, the slope may fail in various modes. With very slow motion of the sliding mass/block or instantaneous without much indication or warning, these failures may be gradual.

Structural geology refers to tectonic settings that occur naturally, such as bedding planes, joints and faults, generally called discontinuities. The stability related properties of discontinuities include orientation, persistence, roughness and infilling. The site's structural geology should be addressed by almost all rock slope stability studies, and such studies involve two steps as follows. First, determine the discontinuity properties, which involves mapping outcrops and existing cuts, if any, as appropriate to the conditions of the site. Second, determine the stability influence of discontinuities, which involves studying the relationship between discontinuity orientation and face orientation. These all could be done by geological mapping which is investigate the lithology and geological structure. Through geological map people could understand the geology of the area without having a site investigation. The objective of this study is to identify possible modes of slope failure, which is called kinematic analysis (Wyllie & Mah, 2004).

This research carried out the kinematic analysis for stability of rock slope context. Necessity for rock slope analysis to carried out a kinematic analysis for produce with safety slope for urban planning in future. Based on Wyllie & Mah (2004) once the block failure type has been identified on the stereonet, it is also possible to use the same diagram to examine the direction in which a block will slide and provide an indication of stability conditions. Stereonet analysis provides a good indication of stability conditions, it does not take into account external forces such as water pressure or reinforcement with tensioned rock bolts, which can have a significant impact on stability.

After the kinematic analysis is done. Based on slope if the slope is not stable. The Factor of Safety (FoS) analysis was carried out. FoS analysis is the final step in investigate the stability of rock slope. Based on its value, which is either below 1 or above 1.

1.2 Research area

Research area in this study is 5 km length times 5 km width in a square box which is about 25 km^2. The Gunung Ayam located included in the research area. Therefore, the research area is named on because of the mountain. The research area consists of Hutan Simpan Kekal Sg. Kuala Betis and Hutan Simpan Kekal Perias. Based on Google Earth, most of the area cover by forest and palm plantation.

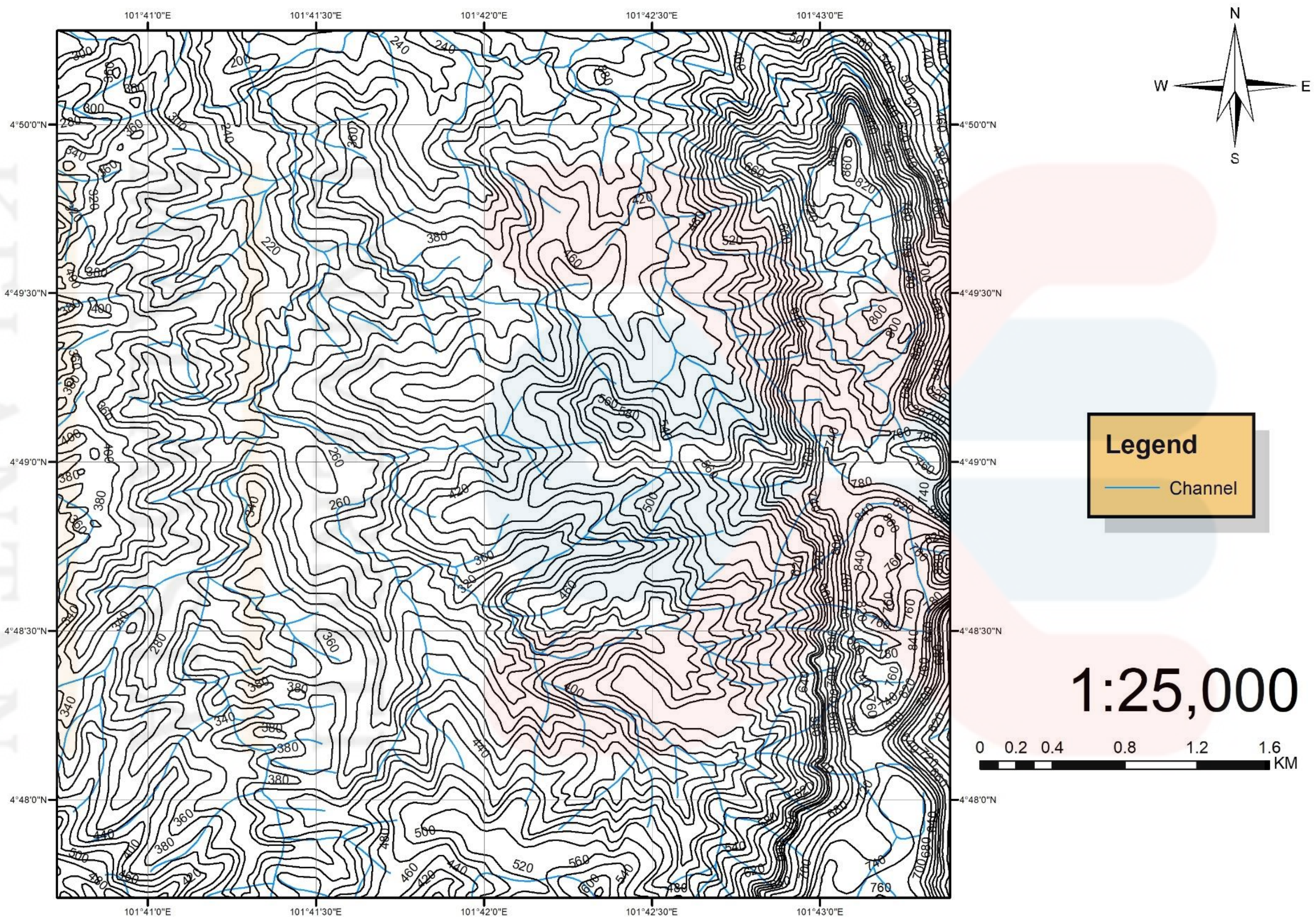


Figure 1.0: The base map of research area.

1.2.1 Location

The research area is located near with highway Jalan Gua Musang – Cameron Highland. At southern from my research box is near with border of Pahang and also in south west direction near to Cameron Highland, Pahang about 70 kilometre and also near with Mountain of Yong Belar around 40 kilometres. In eastern direction about 50 Kilometres to the city of Gua Musang that have population about 90,000 live in. Commonly, a place rest before continued journeys for traveller came from west Malaysia to go East coast before continue the journey for example Terengganu and Kelantan. From research area to Universiti Malaysia Kelantan (UMK) campus Jeli around 160 kilometres away.

1.2.2 Accessibility

The research area located besides the highway which is Jalan Gua Musang – Cameron Highland. This highway connected between city of Gua Musang, Kelantan to Cameron Highland, Pahang. Thus, the research area could be access by several ways. Firstly, from Jeli will passing Dabong take the road to Lojing. Its takes 2 hour 20 minutes to arrive. Second ways are from Cameron Highland, Pahang enter highway Jalan Gua Musang - Cameron Highland will be arrived at Lojing. It takes 1 hour and 30 minutes. Last ways are taken about 5 hours to arrive from Kuala Lumpur to Gua Musang then take road Jalan Gua Musang – Cameron Highland until arrive at Lojing, Kelantan. Accessibility inside the research box could be classified as moderate where only a small road for logging activities and some road created by palm oil plantation. These roads are use during geological mapping the research area.

1.2.3 Demography

Based on Department of Statistics Malaysia (web), population of Gua Musang district is 90,057 people. Moreover, Lojing area is a just a rural area and small part of Gua Musang. There are aboriginal live in Pos Blau which is located at Lojing area. The aboriginal village located near with the research area. Mainly people there is aboriginal people, Malays and Chinese.

1.2.4 Landuse

In research area, the landuse is majority for agriculture, national forest reserve and urban purpose. Purposely urban landuse is for human settlement and infrastructure of built environment follow the demand from population in the Lojing area. Moreover, landuse for agriculture is palm oil plantations and rubber plantations. National forest reserved landuse is to maintain the flora and fauna habitat in Malaysia and also part of logging plan wood industry.

1.2.5 Social Economic

In the research area there is aboriginal village as living society. There is only a national forest reserved, palm oil plantation, and rubber plantation. Lojing area part of Gua Musang only a rural area, only certain profession has and it is very limited here. There are primary schools, restaurants, houses, mosques, police station, and grocery stores. Generally, people live in Lojing district work as teacher, part of them work as policeman, some of them work as entrepreneur and as a farmer which their garden at Lojing Highlands. Teachers always live in town Gua Musang then shuttle from town to school every workday. Most of people there work as teachers, trees logging, construction, at plantation rubbers and palm oil, farmers, grocer, and miners.

1.3 Problem Statement

Slope stability analysis is an essential analysis basically in a human development project close to the slope area. This survey is carried out to create the safe design for future development such as highways, open-pit mining, buildings, plantation area and tourism place. Inappropriate slope analysis design might trigger slope failure which generally everyone assumes the most recurrent disaster that lead to the serious damage to the properties and life. Furthermore, very important to start construction with initial soil investigation need to be done properly to acquire actual soil condition for avoid disaster in future.

Landslide, the slope stability of land areas is a about existing movements or planned slopes for people safety and things or utility of the area. There are a lot of slope stability analysis already investigated but chances to slope failure still high. Phenomena that always had an erroneous when carried out the stability analysis or imprecise speculation made in phase of calculation or unsuitable location for machine on the slope. Based on Das (2011) justification of the misleading analysis of the slope stability could be imprecise determination of the geological structure of the slope in the question.

The previous research in Gunung Ayam area especially about slope stability analysis and geological research are difficult to find. Therefore, the aim of study is to research on a slope stability analysis on weathered rock in the same time could be used for the future development safely at Gunung Ayam area.

1.4 Objectives

1. To study the geological mapping of Gunung Ayam area.
2. To analyse slope stability of Gunung Ayam area on weathered rock.
3. To determine the factor of safety slope for the future development on weathered rock of Gunung Ayam area.

1.5 Scope of study

The investigation is limitation to slope stability on weathered rock. Kinematic analysis is used to analyze the high probability of a slope failure. The research area is located near Gunung Ayam, Gua Musang, Kelantan. Use the best of two slope that exposed to weathered rock to carried out the slope stability analysis.

1.6 Significant of study

Different types of rock simplify how get earth resources for economic growth. The geological map helpful in resolve problems involving earth resources, environment and hazards. Overall purpose geological mapping to find the geological features such as fault, joint for updated the geological map. This research produced a high impact to future plan from hazard for development project such as highways, open mining-pit and buildings. Safety planned slopes for residents and development. The result of slope stability analysis can use as guideline for awareness to residents.

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

Slopes are easily damaged by weathering because they are disturbed by topography and rock mass. These acting on the rock can degrade and change its engineering properties and the rock slope's stability in its lifetime of engineering. Analyses were performed for kinematic, point load test and discontinuity survey for each stop. Two test cycles were found to be insufficient to assess rock degradation based on the results of the slake durability test.

Groundwater investigation plays an important role in any slope design program. Water pressures should always be included in the design in climates with high levels of precipitation. Because of the average seasonal water table, the design water pressures should account for likely peak pressures that may develop during intense rainfall events instead of the pressure. In addition, if drainage measures are installed, due to lack of maintenance, the design may account for the potential degradation of these systems (Wyllie & Mah, 2004).

According to Köppen – Geiger, Gua Musang's climate is tropical. Gua Musang rainfall is significant, even during the driest month with precipitation. The annual average temperature in Gua Musang is 26.4 °C. The average one-year rainfall is 2365 mm. Hoek's (1994) Geological Strength Index (GSI), surface conditions of discontinuities were considered as weathering degree and roughness, and rock mass structure. GSI values were used to obtain strength parameters of the rock masses in the Hoek–Brown failure criterion (Hoek et al. 2002).

Slope stability analyzes were performed to observe their stability state for each exposure outcrop. Kinematic analyzes were conducted for discontinuity-controlled failures, taking into account the discontinuity data obtained from the field study and the internal friction angle of the existing discontinuity at each rock slope. Kinematic analyzes can be performed taking into account the dip and dip direction values of traffic cuts and related discontinuities and the internal friction angle of discontinuities (Goodman and Bray 1976; Evans 1981; Hoek and Bray 1981; Goodman 1989; Sharma et al. 1995).

2.2 Regional Geology and Tectonic Setting

Regional geology is large-scale geological study. It usually encompasses multiple geological disciplines in order to bring together an area's history. It is the regional geography geological equivalent. Each region's size and boundaries are defined by geologically significant boundaries and geological processes occurring.

Next, Peninsular Malaysia's tectonic setting was clearly. As a result of East Malaya-Indochina separated from Gondwanaland in Paleo-Tethys Ocean. It was formed in the Early Permian period (Hutchison & Tan, 2009). Sibumasu (Continental Crust) subduction under East Malaya-Indochina (Continental Crust) at the Late Triassic period and formed Bentong-Raub suture with the elimination of Paleo-Tethys ocean (Oceanic Crust) (Hutchison & Tan, 2009). Under East Malaya-Indochina, the Paleo-Tethys were eliminated by subduction and this subduction contributed to the formation of Permo-Triassic volcanic rocks and granite I-types on Peninsular Malaysia (Hutchison & Tan, 2009).

Under East Malaya-Indochina, Paleo-Tethys are believed to subduct instead of the other way around because Permian andesitic volcanic rocks are found only on East Malaya instead of East Malaya and Sibumasu and are believed to result from subduction (Hutchison & Tan, 2009). Sibumasu bumped into East Malaya-Indochina after the elimination of the Paleo-Tethys, resulting in crustal thickening, later known as the event of Indosinian Orogeny (Hutchison & Tan, 2009). The Indosinian Orogeny created S-type granites that intruded into suture rocks and formed Main Range, said by Hutchison & Tan (2009).

Based on Figure 2.1 Permo-Triassic Indosinian Orogeny focused on the subsidence and segmentation model of the forearc basin. (a) Early Permian: Thick argillite and volcanic deposits parallel to the volcanic arc of Indochina are deposited (Kamal Roslan Mohamed et al.,2016). When Paleo-Tethys Ocean was subduct, the accretionary complex builds up. (b) Middle-Late Permian: Thick argillites and volcanics developed a shallow marine Gua Musang platform favourable for the growth of carbonate and benthic fauna.

Volcanism peaks as the forearc basin began to subside. In the west, limestone Kodiang-Chuping was developed in a shallow setting while chert was deposited in the foredeep basin of Semanggol. (C) Early Triassic: Intensified Forearc subsidence on the Gua Musang platform, providing more accommodation space for carbonate-argillite-volcano deposition. When Sibumasu docked in Indochina, Paleo-Tethys Ocean was completely subducted. (d) Middle-Late Triassic: Oblique subduction of Sibumasu aided the basin segmentation process on the subsiding Gua Musang platform thereby forming the Semantan-Gemas deep sea basin. This basin was enclosed by shallow marine platform as represented by the Central Belt zone as we observe today. The existence of slump deposits and intraclasts in Pos Blau, Krau, Raub, and Kota Gelanggi was triggered by basin faulting and segmentation. Rudite-arenite was found in Semanggol foredeep basin submarine fans in the west (Kamal Roslan Mohamed et al.,2016).

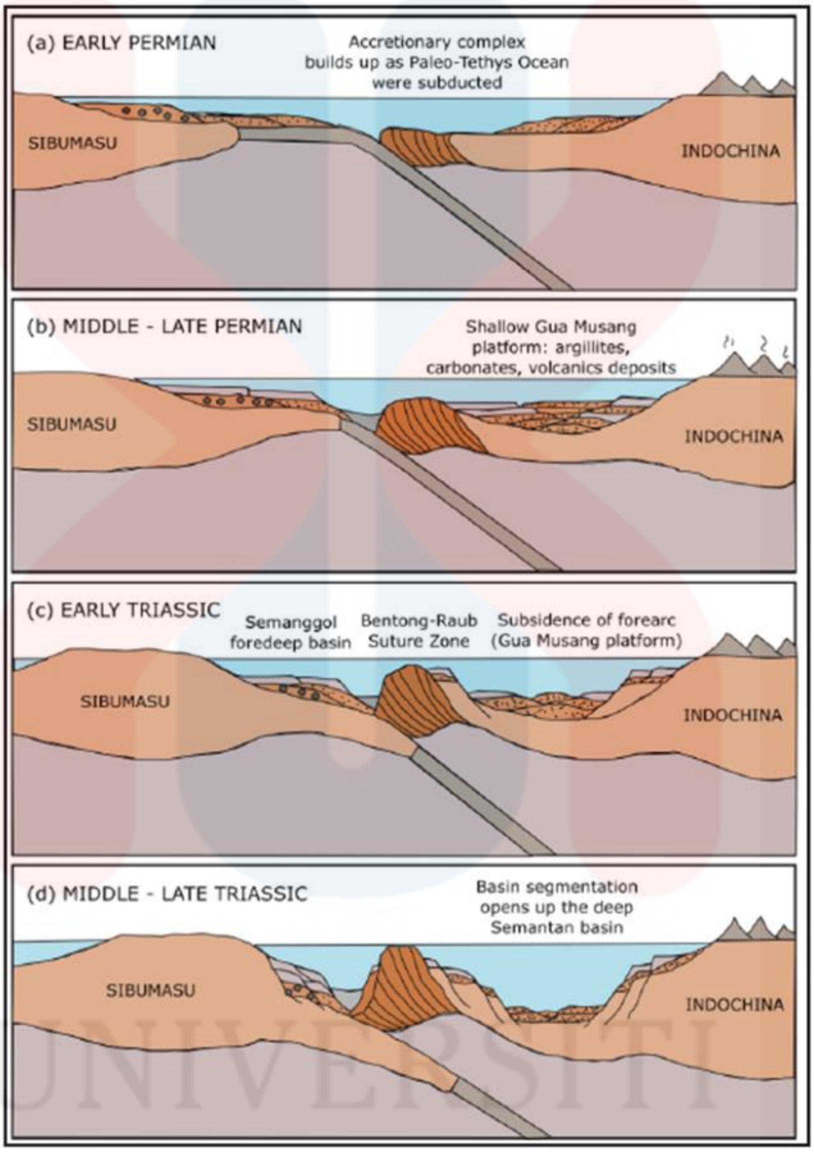


Figure 2.1: The Permo-Triassic Indosinian Orogeny

(Source: Kamal Roslan Mohamed et al., 2016)

The interfingering facies change in sedimentary deposits when discussing a sedimentary basin system, or an orogen's leading or boundary thrust, are examples of geologically significant boundaries. By having an overall view of Kelantan's general geological map shown in figure 2.2. Kelantan consists of sedimentary and metastatic rocks in its central area and igneous rock, granite unit in its eastern and western border

(Goh et al., 2006). Looking at this central area, there is a trace of ignorant intrusion where granite units are surrounded by metamorphic or metasedimentary rock units.

Kemahang pluton, The Stong Igneous Complex and Ulu Lalat (Senting) batholith are the most evident places with the trace of igneous intrusion (Goh et al., 2006). All Kelantan rock units have a north-south trend and the rock units in the southern part of Kelantan can be viewed from Pahang as continuing geology (Goh et al., 2006). In other words, Kelantan's southern region geology can be correlated with Pahang's northern region geology. In Kelantan's western and central area, the rock units continue north into Thailand-Kelantan's boundary. For Kelantan's eastern area, Sungai Kelantan's coastal alluvial flat overlays the Boundary Range Granite (Goh et al., 2006).

To summarize Kelantan's regional geology, Kelantan basically consisted of four types of alluvium rocks, extrusive rocks, sedimentary or metastatic rocks, and granite rocks (Nazaruddin et al., 2014). Based on Kelantan's geological map in Figure 2.2, the highest formation in Kelantan was marked by sedimentary or metasedimentary rocks while alluvium was the lowest formation in Kelantan.

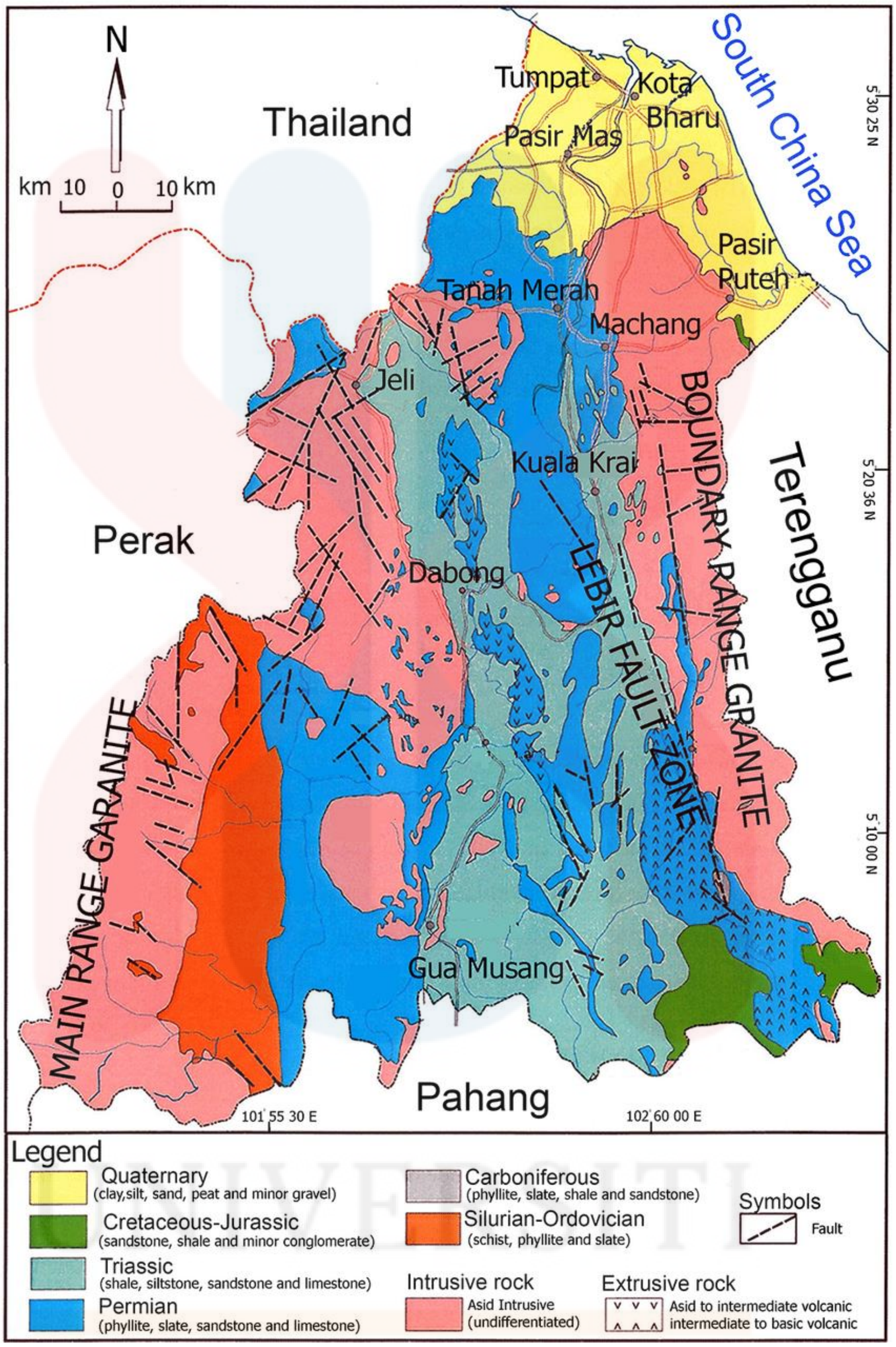


Figure 2.2: General Geological Map of Kelantan.

(Source: Nazaruddin et al., 2014)

2.3 Stratigraphy

The research area is situated between Kelantan and Johor in the Central Belt, region from the eastern foothills of the Main Range to the western boundary defined by the Lebir Fault in between north down to the western boundary of the Dohol Formation in the south (Lee Chai Peng, 2009). Based on Lee Chai Peng,2009 studied the Palaeozoic rocks consist primarily of Permian clastics with Carboniferous limestone intermittent outcrops which develop on both edges of the belt as linear belts flanking Mesozoic sediments. The Upper Palaeozoic rocks of the Gua Musang and Aring Formations in southern Kelantan and Taku Schist in eastern Kelantan are found in the western part of the Central Belt, and the Raub Group in western Pahang and Kepis Beds in Negeri Sembilan are further south said by Lee Chai Peng,2009. According to Lee Chai Peng 2009, Upper Palaezoic rocks are primarily argillaceous strata and volcanic rocks, with secondary arenaceous and calcareous sediments deposited in a shallow marine environment, with sporadic submarine volcanism, originating from the Upper Carboniferous and peaking in the Permian to the Triassic.

According to Kamal Roslan Mohamed et al. (2016), Gua Musang consisted, as shown in Figure 2.3, of four formations, Gua Musang Formation, Telong Formation, Aring Formation and Nilam Marble. As far as Gua Musang Formation is concerned, Yin stated that it was formed between the Middle Permian period and the Late Triassic period. Kamal Roslan Mohamed et al. (2016) will further prove this range of geological age based on their fossil findings. Based on fossil discoveries, the Gua Musang Formation is Middle Permian to Late Triassic age and its lateral correlates were defined. Among them are Sungai Toh, Sungai Yu and Padang Tengku were in Middle Permian age fauna discover (Leman, 1993; Campi *et al.*, 2000, 2002, 2005);

Kamal Roslan Mohamed et al. (2016) stated that it consists of argillaceous and calcareous rocks with volcanic rocks intercalated between them and that it also contains a small amount of arenaceous rocks. It is found primarily in the area of Gua Musang and extended to Pahang from north Kelantan (Kamal Roslan Mohamed et al., 2016). Its lithology suggested the formation of active volcanism in shallow marine environment. Furthermore, its later part of formation is suspected to interfere with three other formations, Gunung Rabong Formation, Semantan Formation and Telong Formation (Kamal Roslan Mohamed et al., 2016). The lower boundary remains unclear and Koh Formation is assumed to overlap (Kamal Roslan Mohamed et al., 2016). In Figure 2.3, it indicates Gua Musang Formation's stratigraphic dispersal with their corresponding geological time formation.

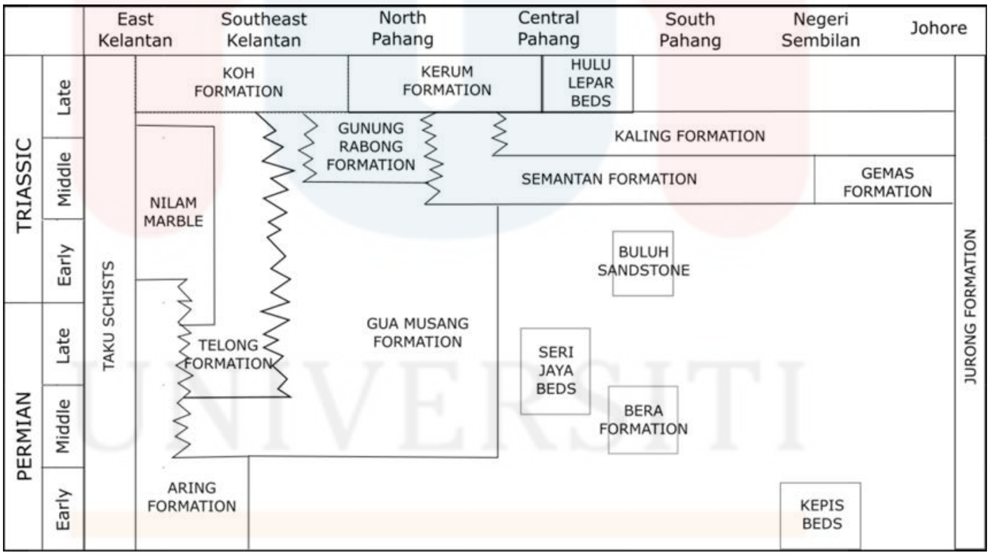


Figure 2.3: Central Belt Peninsular Malaysia's Permo-Triassic stratigraphic correlation diagram.

Modified by Kamal Roslan Mohamed et al., (2016).

There are many other formations within the Permo-Triassic Central Belt of Peninsular Malaysia other than the four formations included within the Gua Musang Group. However, on the basis of lithology, depositional settings and distance from the core Gua Musang Group, they were excluded from the Group (Kamal Roslan Mohamed et al.,2016). The Gunung Ayam Conglomerate was historically known as the basal conglomerate for the formation of Gua Musang in central south Kelantan (Aw, 1974). The Upper Carboniferous to Lower Permian Conglomerate exposed in the Kuala Betis-Gunung Ayam region in central-south Kelantan and is interpreted as deep-water deposits by the presence of debris flows that mass-transported large-scale rocks from the neighbouring Bentong Group (Mohamed Kamal Roslan et al., 2016). Accoding to Tjia & Almashoor, 1996 it is because of distinctive conglomerate-rudite facies, diverse depositional setting and its incorporation into the Bentong Raub Suture Zone. The researchers suggest removing from the Gua Musang Group of the Gunung Ayam Conglomerate. This exemption also corresponds to the Blau bedded chert, the easternmost component of the Bentong Raub Suture Zone, which is formed in deep water from radiolarian ooze (Tjia & Almashoor, 1996).

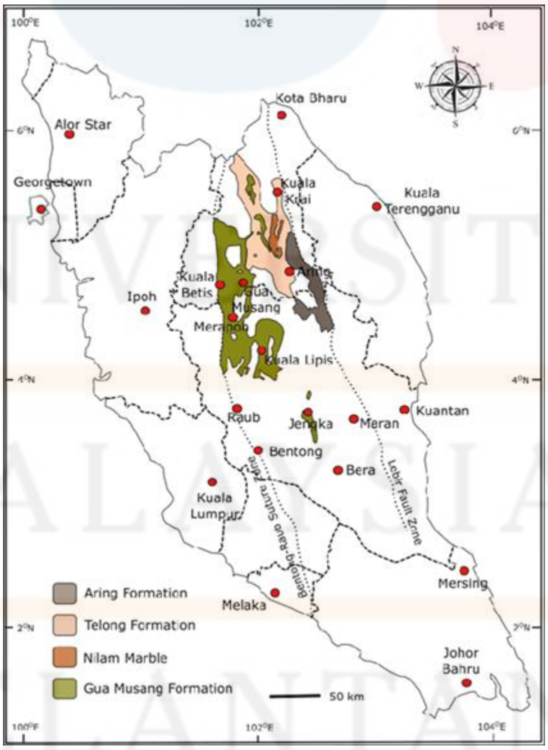


Figure 2.4: Distribution of formations that comprised up Gua Musang district. Modified by Kamal Roslan Mohamed et al., (2016).

2.4 Structural Geology

Structural geology of the system is about folds, faults and other mechanisms of deformation in the lithosphere. From hundreds of kilometres long features to microscopic specifics, structures arise in many different settings and have encountered exciting stress and strain changes (Fossen Haakon, 2010). The Peninsula has an elongated NNW-SSE shape near Klang and Mersing with a slight dog-leg bend in the south. Regional structures control the shape. The regional structural trend of the NNW-SSE is also manipulated by the distribution of the Peninsula Main Range Granite as the backbone of Peninsula Malaysia (Hutchison & Tan, 2009). A main axis stretches from the boundary between Malaysia and Thailand to the southern state of Negeri Sembilan, essentially dividing the eastern and western regions of the Peninsula. The general structural pattern of the NNS-SSE is superimposed by major faults of later N-S, NW-SE, NNE-SSW and E-W (Hutchison & Tan, 2009). According to Hutchison & Tan (2009) based on bedrock lithologies, these later structures dominated the irregularity of surface topography and shorelines. Due to NW-SE trending strike-slip faults and, to a lesser extent, NNE-SSE trending faults like the dog-leg curve, which is from the western coastlines near Klang and ends at the eastern shoreline near Mersing.

The structural pattern of the NNW-SSE is expressed in the extension of the Peninsula, Straits of Malacca and Sumatra. According to the regional orocline, there are significant differences as well as correlations between the Peninsula and Sumatra. The Peninsula's NW-SE faults are simultaneous to the most of Sumatra's structural grain. On the other side, the Peninsula's N-S structural grain is simultaneous to faults in central Sumatra (Hutchison, 1994). The magnificent Bengkalis Graben, at 102.3^0 E, stretches over a length of 265 km south from the Straits of Malacca. The structural grain from N-S to NNW-SSE was used to split the Peninsula into 3 large belts with the NW's less evident fourth realm (Tjia & Zaiton, 1985). A distinct N-S lineament along the Main Range's eastern foothills, called the Bentong-Raub line (Hutchison, 1973d), segregates the Central Belt from the Western Belt. The Lebir Fault Zone marks the boundary between the Central and Eastern Belts. Such structures demonstrate many brittle-ductile deformations from the pre-late Lower Permian to the Tertiary (Hutchison & Tan, 2009). It is stated that the general structural trend of the NNW-SSE is the result of three main phases of deformation: Upper Triassic-Lower Jurassic transpression and Upper Cretaceous and Tertiary strike-slip deformations. Popularly thought to be related to the collision between Sibumasu and East Malaya is the Upper Triassic-Lower Jurassic orogenic activity (Hutchison & Tan, 2009). Not only might the Upper Cretaceous activity deformed the intermontane basin strata, but it was also a major faulting occurrence that affected the entire Peninsula (Hutchison & Tan, 2009).

The Bentong-Raub Suture is situated in a 20-kilometer wide area along the Gua Musang-Cameron Highlands Road. Tjia and Syed Sheik (1996) split the rocks into at least seven tectonic units within the suture. A completed tectonic unit consists of a sequence of schist and phyllite, olistostrome and bedded chert with intercalations of clastic (Hutchison & Tan, 2009). In one of the tectonic units a serpentinite lens exists. Tectonic units are consistently considered to have developed an imbricated structure (Tjia & Syed Sheikh, 1996). Zone of north-east to dextral-reverse phyllonitites or mylonites in sub-vertical to steep northeasterly-dipping, striking NW-SE, each imbricated unit separate, and steep southwesterly-dipping reverse dextral faults cut across units, indicating that the imbrication was a consequence of dextral transpression (Mustaffa, 1994c). In the western boundary of the suture zone is a region of a granitoid injection complex in an Upper Triassic-Jurassic (Tjia & Syed Sheik, 1996).

Regarding to Hutchison & Tan (2009) the injection complex is characterized by a network of granitic dykes and sills. Some were sheared along with country rock and had N-S dextral mylonitic regions. These all packages were consequently split by dextral and sinistral N-S strike-slip faults, sinistral NNW-SSE strike-slip faults, NNE-SSW to NE-SW dextral strike-slip and sinistral strike-slip faults. E-W was a normal fault. The Suture Zone regarded by Tjia and Syed Sheikh (1996) to originated from a Lower-middle Palaeozoic oceanic region closed by the Lower Triassic collision between the Gondwana Plate and the Cathaysian Plate. Mustaffa (1994c) figured that the suture was the consequence of dextral transpression, suggesting that the subduction and collision was oblique. Suture was begun in Late Permian, as the disappearance of deep ocean radiolarian revealed and Late Triassic entirely came to an end with tectonic movements.

2.5 Historical Geology

Based on sedimentological and paleontological evidence, we conclude that the formations within the study area were deposited in a warm, shallow marine environment within the Paleo-Tethys Seaway of the Central Belt during Permo-Triassic time. On the basis of sedimentological and paleontological records, the deposits were formed during Permo-Triassic period on the Paleo-Tethys Seaway in a warm and shallow marine environment. Widespread argillite and a high carbonate presence signify a warm shallow and clear water platform deposition (Fontaine, 1986). In the event of high-low detrital supply from an adjacent landmass, the present argillite-carbonate interbeds indicate depositional interplay. This setting occurred in the midst of the Indosinian Orogeny, as the Paleo-Tethys Ocean and Sibumasu terrane were being subducted under the Indochina volcanic arc (Tjia & Almashoor, 1996; Metcalfe, 2000) as the suturing of Peninsular Malaysia was progressing.

This environment was in the center of the Indosinian Orogeny, as Paleo-Tethys ocean and Sibumasu Terrane were subducted under the volcanic arc of Indochina (Tjia and Almashoor, 1996; and Metcalfe, 2000). Tjia & Almashoor (1996) proposes that the central belt has been formed in the middle to late Triassic as a response to a divergence of two latterly shaped continental plates (western and eastern belt). Metcalfe (2000) supports the complex model of an accretionary basin where the central belt is a forearc basin. This paper stated by researchers propose a subsidence and segmentation model for the forearc basin within in order to justify the morphology of the shallow and deep-marine environment within the Central belt of Permo-Triassic (Figure 6).

According to Kamal Roslan Mohamed et al., 2010 Permo-Triassic orogeny focused on the subsidence and segmentation models of the forearc basin. (a) Late Permian: The thick volcanic and argillite and the present Aring and Telong formations have been deposited beside the Indochina volcanic arc. In the west there were found the pebbles of the origin of the Singa formation and the argillites from Kubang Pasu formation. The complex of accretionary develops with the subducted of the Paleo-Tethys Ocean. (b) Middle-Late Permian: Gua Musang platform splendid marine habitat for carbonate growth and benthic fauna is generated by thick argillites and volcanics. The present Gua Musang formation began to develop in the east. Volcanism increased as the forearc basin starts to decline. In the western part of the Semanggol, chert was deposited in foredeep basin and Kodiang-Chuping limestones are formed in a shallow deposition. (c) Early Triassic: The subsidence in the Gua Musang platform have increased and more accommodation has been created for the deposition of carbonate-argillite and volcanic deposition. When Sibumasu plate was docked and subducted Indochina plate, the Paleo-Tethys Ocean was fully subducted. (d) Middle-Late Triassic: Oblique subduction of Sibumasu and thus created deep marine basin of Semantan-Gemas, help to segmentation the basin on the subduction platform Gua Musang (Refer figure 2.1).

This basin was enclosed in the Central Belt morphology as seen today, by a shallow marine platform. Faults of basins and segmentation in Pos Blau, Krau, Raub and Kota Gelanggi triggered the existence of slump deposits and intraclasts. The accretionary complex continues to grow as argillites-carbonate sediments are accumulated on the shallow marine Gua Musang foundation, while Paleo-Tethys Ocean and Sibumasu regions are subducted obliquely under the Indochina volcanic arch (Metcalfe 2013). Concurrently, pyroclastics/volcanics input were being supplied by the volcanic arc nearby, hence the presence of volcanics within Gua Musang Group. At the same period, the volcano arc was provided with the pyroclastic/volcanic input consequently volcanics are existence in the Gua Musang Group throughout Permian shallow marine sedimentation transitioned to Early Triassic. The existence of deep marine Mid-Triassic ammonoids enclosed by the Telong Formation (Othman & Leman, 2010) proves a steep continental slope zone that was formed during the basin segmentation and transition to the deep Semantan-Gemas basin from the shallow marine Gua Musang platform. It is a new platform implemented for the Central Belt and therefore more work and studies are required.

According Kamal Roslan Mohamed et al., 2010 to the differences and similarities in sedimentary and palaeontological conditions among the formations of Gua Musang, Telong, Aring and Nilam Marble, these group of rocks can be grouped into an informal group of Gua Musang which is recognized for argillite-carbonate-volcanic deposited in a shallow marine platform during the Permo Triassic period.

2.6 Research Specification

2.6.1 Discontinuity Survey

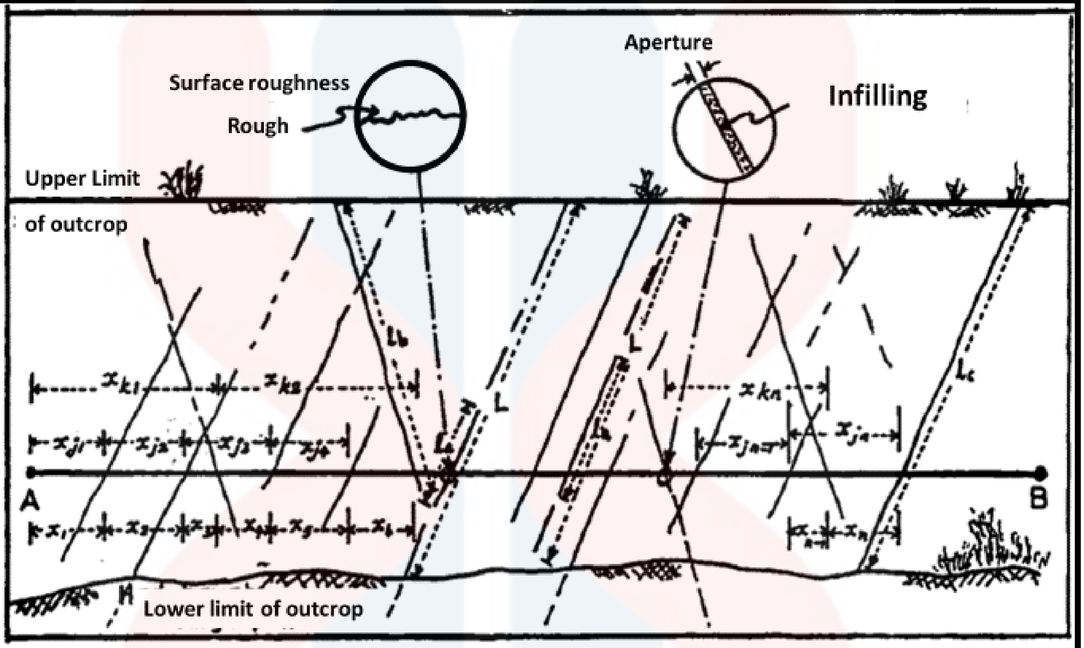
Geological information is the most significant of which is structural geology. This data includes the orientation and characteristics of discontinuities including such length, spacing, roughness and infilling. The rock strength is the shear pressure of the discontinuity surfaces or rock masses and the compressive pressure of the fresh rock for a lesser extent. This can be due by failures to a wide variety of indirect costs eliminating the defect rock and stabilizing the surface (Wyllie & Mah, 2004).

Based on Wyllie & Mah (2004) it is important that discontinuities are planes of fragility in the more strong, intact rock which tends to lead to a failure on the surfaces. Nearly all of the stability experiments of rock slopes will include the site's structural geology, and these tests have two stages. Next, to assess as relevant for site requirements, the properties of discontinuities including mapping outcrops and existing cuts and inspecting the diamond drill core, if any. Second, evaluate the impact which discontinuities have on stability, that implies studying the connection between discontinuity orientation and the face.

The overall objective program of geological mapping is to identify a set or sets of discontinuities, or a single feature for instance a fault, to manage the stability of a certain slope. The discontinuities are common in three orthogonal sets (mutually at right angles) with probably one additional set. It is proposed that a maximum of four sets can be included in a slope model, and that any additional sets that occur to be present will more likely represent scatter in the sets of orientation. Discontinuities that seldomly occur in the rock mass are unlikely to affect the stability of the overall slope and thus can be minimized in design. However, single feature such as a through-going, orientated fault which can be a control feature for stability these all must be identified because it is important (Wyllie & Mah, 2004).

By Tajul Anuar Jamaluddin (1990) said the presence of discontinuities are one of the primary factors lead to rock slope failure. Another factor such as rate of weathering rock, water flow on rock surface and groundwater, unsatisfied step of slope stability, as well the weakness on slope model also identified as a necessity of slope failure. Various methods of surveying are used by surveying purpose and type of engineering project has been implemented due to their various parameters (Tajul Anuar Jamaluddin, 1991). For example, the quantitative description of discontinuity methods was introduced by ISRM (1978) and IAEG (1981), introduced by Priest & Hudson's (1981) is scanning line method. Though Hong Kong Geotechnical Control Office (1981) introduced to the measurement of discontinuity method.

For the discontinuity survey in the research field, the scanning line method is used. The scanning lines on the rock slope surface (Tajul Anuar Jamaluddin, 1991) (in Figure 2.5) are used for the implementation of the same procedure. Figure 2.5 present certain discontinuity terminology. It is a convenient method where the discontinuities that cross the scanning line only are measured and sampling (Priest & Hudson, 1981). By Tajul Anuar Jamaluddin (1991) said that the positioning of the scanning line depends on the general orientation of discontinuities and the length of scanning line that stretched are compulsory depends on the denseness of the discontinuity sets. But this method has limitations for the scanning line. This be unused on rock slopes such as the steep slope face and the rock slopes, which have a very rough surface that allows the gap between discontinuities becomes wider in measurements (Tajul Anuar Jamaluddin, 1991).



AB	Scanning Line
x_{j1}	Spacing for the first set of discontinuity in discontinuity set j
x_{k1}	Spacing for the first set of discontinuity in discontinuity set k
x_i	Apparent spacing between discontinuities
L	Discontinuity trace length
l_a	Length of discontinuity that crosses the scanning line, Exposed two ends
l_b	Length of discontinuity that crosses the scanning line, Exposed only one end
l_c	Length of discontinuity that crosses the scanning line, Hidden two ends

Figure 2.5: Scanning line method with discontinuity terminology

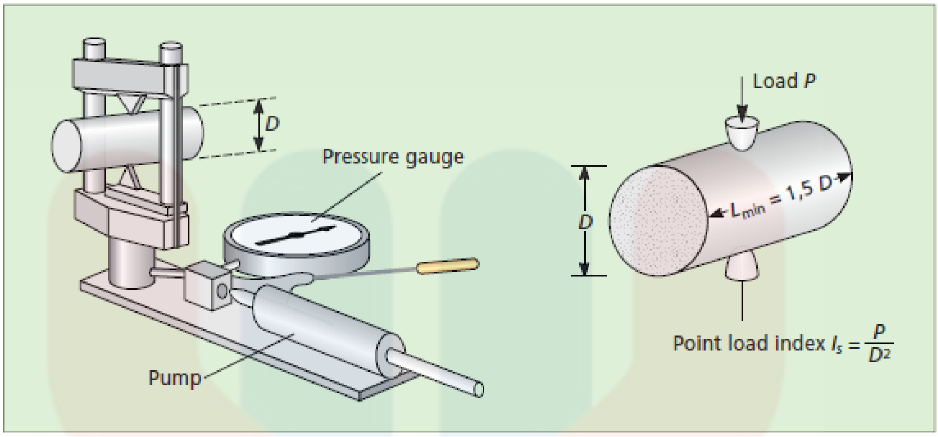
(Modified from Tajul Anuar Jamaluddin, 1991)

2.6.2 Point Load Test

There are three types of rock that have their own strength. Generally, the hardest is igneous rock followed by metamorphic and sedimentary rock. Perhaps rock slope depends on the lithology itself for their strength. According to Wyllie & Mah (2004) rock strength parameters used to design a slope include, if appropriate, the shear strength of the discontinuities and the rock mass and the compressive strength of the intact rock in a lesser extent. In laboratory specimens from the drill core can calculate the shear strength of discontinuities and samples cut from rock lumps that are intersected by discontinuity. Though, the rock mass has their own strength within the condition of rock itself.

According to the Wyllie & Mah (2004) the test is used as an index for the classification of strength and the correlation with the uniaxial compressive strength of the rock, it is called the Point Load Strength Index, I_s. The experiment is to split a rock sample with a point load (Figure 2.6) and can be performed in a laboratory testing machine or by portable equipment. The samples may be cylindrical cores, blocks cut off or irregular lumps. But the result conducts the test more reliable on the core samples.

The testing process consists of the inserting of a rock sample into the two plates of the tester conical steel. The distance D is recorded between the platen points. The load will then increase steadily until a failure takes place within 10–60 second and P is recorded for failure load (Wyllie & Mah, 2004). If the fracturing surface goes through only one loading point (ISRM, 1985) these tests should be dismissed as null.



Figured 2.6: The point load test equipment and test.

(Modified from Wyllie & Mah, 2004)

ISRM (1984) stated that there are four types of point-load test which are diametral test, axial test, block test and irregular lump test. Then the rock sample for each test is different shapes as presenting on Figure 2.7. For irregular lump test, the rock sample is essential in the form of irregular shape. For diametral test and axial test, the rock sample in core form are essential. For the block test, the cut block form is essential to perform the test.

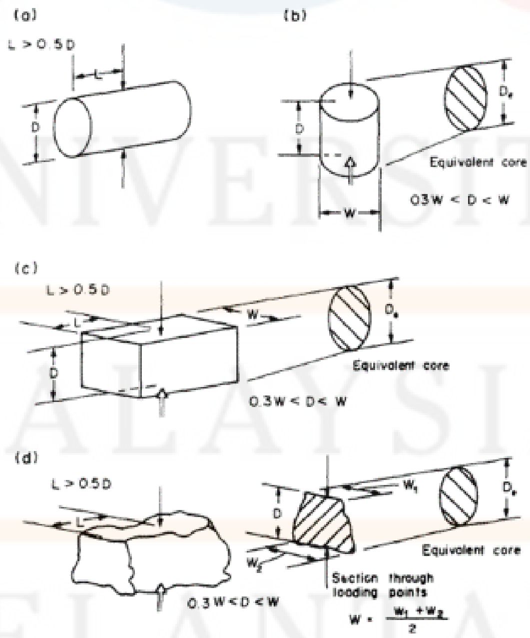


Figure 2.7: Specimen shape requirement for a) Diametral test, b) The axial test, c) The block test, and d) The irregular lump test.

(Source ISRM, 1984)

2.6.3 Rock Mass Classification

In similar geological formations to that in which the excavation is made, geological mapping of the surface outcrops and/or existing cuts usually provides essential information regarding the site specifications for slope design. Although mapping is a vital component of the investigation programme, it is also an inconsistent process because it is usually necessary for a certain amount of judgment to extrapolate the small quantities of information from surface outcrops to the general cut slope (McClay, 1987).

A rock mass classification is based on one or more factors determining the mechanical behaviour:

- **I.** Present of water.
- **II.** Properties of intact rock.
- **III.** *In situ* state of stress.
- **IV.** Degree of weathering.
- **V.** Type and frequency of discontinuities.

(Vallejo & Mercedes, 2011)

The great variability of these factors and the discontinuous and isotropic nature of the rock masses make it difficult to establish general geotechnical or geomechanical classifications that are valid for different types of rock mass (Vallejo & Mercedes, 2011).

2.6.4 Rock Mass Rating (RMR) System

According to Vallejo & Mercedes (2011) this system of Rock Mass Classification System relates qualitative indexes to rock mass geotechnical parameters as well as excavation. This also support parameters in tunnels, which was developed by Bieniawski in 1973 and was updated in 1979 and 1989. This following geomechanical parameters are included in this classification:

- **I.** Orientation of discontinuities.
- **II.** Condition of discontinuities.
- **III.** Uniaxial compressive strength of intact rock.
- **IV.** Spacing of discontinuities.
- **V.** Degree of fracturing (RQD).
- **VI.** Groundwater conditions.

The influence of these parameters is expressed by means of the quality index RMR (Rock Mass Rating) in the geomechanical behaviour of a rock mass that is between 0 and 100 (Vallejo & Mercedes, 2011) . The RMR classification is focused on field observations in which data and measurement are evaluated in relation to the properties and characteristics of intact rock and its discontinuities, through areas or sections of different geological characteristics. This classification distinguishes five classes, the geotechnical importance outlined in Table 2.1, with quality and geotechnical characteristics assigned to each rock mass class.

Class	Quality	RMR rating	Cohesion (MPa)	Friction angle
I	Very good	100 - 81	> 0.4	> 45^o
II	Good	80 - 61	0.3 - 0.4	35^o - 45^o
III	Fair	60 - 41	0.2 - 0.3	25^o - 35^o
IV	Poor	40 - 21	0.1 - 0.2	15^o - 25^o
V	Very poor	< 20	< 0.1	< 15^o

Table 2.1: Rock Mass Quality according to the RMR Index.

(Modified by Vallejo & Mercedes, 2011)

Therefore, a rock mass known as Very Good (Class I) will be hard, slightly jointed, without any major seepage and slightly weathered, with strength and stability will be occurring a few problems. It can be concluded that its bearing capacity is high, that steep slopes are excavated and no support or reinforcement measures in tunnels are required (Vallejo & Mercedes, 2011).

2.6.5 Kinematic Analysis

The same diagram can be used to analyze the direction in which a block is to slide and to indicate stabilization conditions once a block failure has been detected on a stereonet. This is called kinematic analysis (Wyllie & Mah, 2004). If the slope face was less steep than the line of crossing between the two planes or the actual strike is 90, the two planes form a wedge would have been unable to slide off from the face. The relation between the direction the block rock glides into and the face orientation on the stereonet is readily visible (Wyllie & Mah, 2004). Whilst, stereonet analysis gives a good indication of the conditions for stability, external forces such as water pressure or strengthening including tensioning rock bolts, which could have a significant impact on stability are does not account (Wyllie & Mah, 2004).

2.6.6 Rock Slope Failure

According to the Vallejo & Mercedes (2011) the type of fractures and degree of fracture affecting the rock mass as well as the orientation and distribution of the discontinuities with respectively to the slope face are determined by the various types of rock slope failure. The location of failure planes is defined by discontinuities in hard or strong rock masses. The intact rock also plays an important role in the development and positioning of such planes and in the failure mechanism in weak rock masses. Planes failure, wedge failure, topple failure, buckling failure and non-planar failure are the most frequent types for failure (Vallejo & Mercedes, 2011).

For the condition of rock slope, rock slope may have been unfavourable or previously existing long ago, but the lack of a triggering event keeps the rock slope steady (Pantelidis, 2009). For example, a rock slope is located near an earthquake's epicenter. But the slope of the rock tends to be stable as long as an earthquake does not happen. Fundamentally, these causing events lead to rock slope failure by altering the stress to the rocks (Pantelidis, 2009).

2.6.7 Classification of Rock Slope Failure

Rock slope is commonly classified based on types of failure. According to Robinson et al., (1998) the presence of joints throughout the slope face are dominant part of the slope failure in most scenarios. For rock slopes, three main types of failure which is planar failure, wedge failure and toppling failure.

a. Planar failure

Based on Vallejo & Mercedes (2011) planar failure occurs along a pre-existing surface which is the bedding plane, the tectonic joint or by fault. The occurrence of discontinuities dipping into the slope in a same strike is a precondition for the plane failure; the plane failure (in figure 2.8 and figure (a)2.11) should be exposed, or "daylight", on the slope face (ψ > α) with friction angle is less than a dip (α > φ).

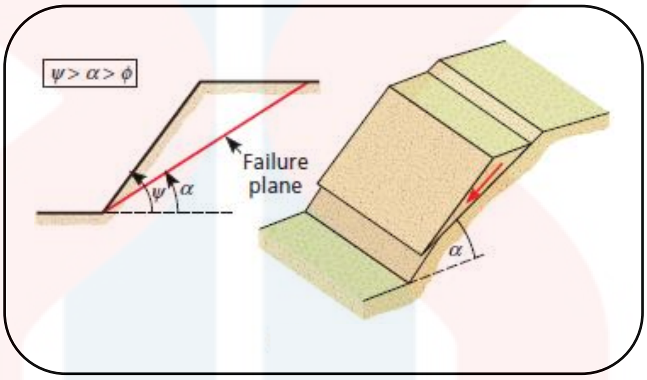


Figure 2.8: The Plane failure.

(Source Vallejo & Mercedes, 2011)

b. Wedge failure

Based on Vallejo & Mercedes (2011) type of failure is composed of a sliding wedge-shaped block generated slope face which is by two discontinuity planes whose line of intersectional dips. In order of wedge failure presence, two planes should outcrop on the slope surface and meet the same criteria as for plane failure: ψ > α > φ; where α is the dip of the intersection line. Comparing slope angle, wedge planes intersect of lines and friction planes, this resolute whether movement is possible in a kinematic and if the wedge is stable or unstable. The details more in figure 2.9 and (b)2.11:

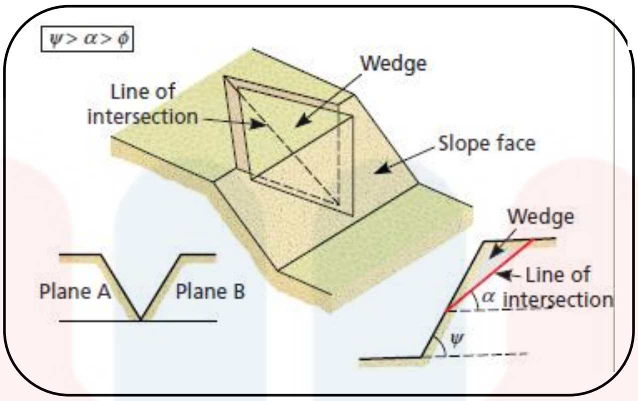


Figure 2.9: The wedge failure.

(Source Vallejo & Mercedes, 2011)

c. Toppling failure

Toppling (figure (c) 2.10) develops rock masses on slopes where the strata steeply dip the surface slope, distinctly parallel or sub-parallel to it. Defined by discontinuity set typically the strata form columns that orthogonal to each other are block toppling. Rotational movement are subjected the stability of the blocks that is not only influenced by the shear strength of the discontinuities. In occurrence thin gradually steeply dipping strata, or columns, that fracture in flexure as they bending called flexural toppling. The phase of toppling may start with sliding, excavation or erosion of the slope toe, with tension cracks formed a retrogression back into rock mass (Vallejo & Mercedes, 2011).

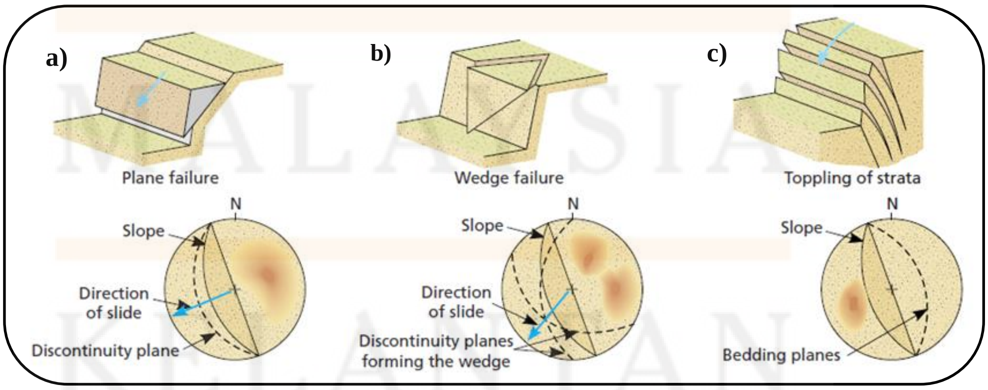


Figure 2.11: The stereographic representation of discontinuity planes in relation to slope orientation for common types of failure in rock masses.

(Source Vallejo & Mercedes, 2011)

2.6.8 Factor of Safety (FoS)

According to Admassu (2012) said factors of Safety (FoS) is potential for failure from kinematic analysis which is interpreted to be not stable calculated based on the rock slope. Generally, FoS is scrutinize with its value either more than 1 or less than 1. Limiting condition represents 1 equal to FoS value (Admassu, 2012). The slope stable when FoS value is greater than 1 and vice versa (Admassu, 2012). Nevertheless, FoS value could be contrasting for different localities in different slope. Based on Admassu (2012), the ideal FoS is depending on the impact brought by the slope failure and importance of the rock slope.

However, minimum standard FoS value required for different slopes has been set by multiple authorities such as JKR Road Works, Hong Kong Geoguide and more as shown in figured 2.12 in order to ensure the stability of slopes and communities' safety. These standard FoS values are the compulsory requirements that needed to be achieved by all slopes even they are saturated conditions, highly jointed or even worst geological conditions (Admassu, 2012).

References	FOS Requirements
BS6031	1.3~1.4 for first time slide 1.2 for slide with pre-existing slip surface
JKR Road Works	1.2 for unreinforced slope & embankment on soft ground 1.5 for reinforced slope
Hong Kong Geoguide	1.0~1.4 for new slopes depending on risk categories 1.0~1.2 for existing slope depending on risk categories
NAVFAC DM7.1	1.5 for permanent loading condition 1.15 to 1.2 for transient load
Britain National Coal Board 1970	1.5/1.35 (peak/residual strength used) for risky slope 1.25/1.15 (peak/residual strength used) for non-risky slope
Canada, Mines Branch 1972	1.5/1.3 (peak/residual strength used) for risky slope 1.3/1.2 (peak/residual strength used) for non-risky slope

Figure 2.12: FoS requirements for different references (Source: Liew, 2010)

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

This report highlighted the materials and methodology chosen and used throughout the whole study in this chapter. As said by Lisle at el. (2011), some tools or materials are necessary by a geologist to facilitate in his fieldwork, such as mapping. Sample bags, geological compass, Global Positioning System (GPS), chisel, topographic map, hand lens, hydrochloric acid (HCI), fieldwork notebook, and measuring tape were the materials or tools used for geological mapping in this study. It used geological compass, measuring tape, electronic Vernier calliper, chisel and point load testing machine for geotechnical engineering.

3.2 Materials/ Equipment

All equipment or materials used in this study addressed their purpose and significance in this section. Again, all the above equipment or materials were used to gather data such as bedding thickness, outcrop length, rock sample, bedding orientation and more in the field. All these equipment or materials were borrowed from the Universiti Malaysia Kelantan (UMK) Geoscience laboratory Jeli Campus. There were 7 equipment or apparatus used during fieldwork and 2 equipment will be used for laboratory test.

3.2.1 Topographic map (Base map)

Before conducting a geological mapping, it is compulsory to create and study the topographic map before going out to the field. Topographic can guide us for the high point and low point.

3.2.2 Global Positioning System (GPS)

Geologist must know where they are doing their research. GPS is important for locality data of the study area.

3.2.3 Chisel

Rock sampling can be easily break when using geology hammer.

3.2.4 Geological Compass

Topographic map is useless without compass to guide it to correct direction.

3.2.5 Hand lens

Hand lens is used for look closely minerals in rocks with maximum 40x only.

3.2.6 Sample bag

Sample bag is used to sort rock sampling in orderly manner.

3.2.7 Digital camera

Digital camera is used to capture the image of rock sample and panorama of the study area.

3.2.8 ArcGIS

ArcGIS software is compulsory for digitizing geological mapping. This software can show us the result finding and outcomes after finish mapping.

3.3 Methodology

Various methods for geological mapping and rock slope stability engineering have been used in this section. Before going to the field, the first preliminary study was conducted in terms of understanding and extract more data from previous works or scientific papers linked to the field and approaching methods. The limitation and advantage of approaching methods were both known from the preliminary study as well as some safety measures that needed to be taken into consideration.

After that, field research was conducted using the methodologies recommended to retrieve all field data. Basic mapping methodologies that are observation, recording, sampling and mapping throughout the entire study area were used for geology. RMR system and kinematic analysis were carried out on 2 chosen rock slopes for geotechnical engineering. Samples were taken for both fields of study and these samples were further processed with laboratory work that was thin section preparation for geology field and point-load testing. Then, all field and laboratory data were processed into useful information in the future. ArcGIS software has been used for geology to produce various types of maps based on specific purposes. Stereonet software has been used for geotechnical engineering to facilitate in the kinematic analysis of the stability of the rock slope. Finally, it analyzed and interpreted all the related data. Figure 3.1 shows this research's research flow chart.

3.3.1 Preliminary Study (Geological Mapping)

Practical research, geological mapping done by geology data of the study area. Before going out to the field need to plot a traverse on the map which is to set up the purpose for not run away from the original purpose. Every finding and their location are plot on the map. GPS is use to acquire locality data. Geological attraction data and outcrop data of every part of the study area are collected as many as possible. The daily data is recorded. The data will be validated by Co- Supervisor as a third party.

3.3.2 General Geology

I. Field Data Analysis

According to Hoek and Bray (2003) stability of rock slopes is often significantly influenced by the rock's structural geology in which the slope is dig out. Structural geology refers to natural breaks in rock such as bedding planes, joints and faults, which are generally referred to as discontinuities. The geological structure will be collected during geological mapping. The main purpose of geological mapping is to find any structure geology could create the safety factor for the stability on the slope.

a. Observation

In the context of geological field work the first thing should do is study the geomorphology of research area to identify what types of geomorphology included research area. There are 4 important things should do including the observation. Furthermore, the important things of geomorphology are landform, mass movement, weathering process and drainage pattern. Typically, the geomorphology is done by observed at the highest elevation of the research area could observed in depth view from top that catch view wholly the research area.

In the chapter of stratigraphy, existence outcrop in research area was observed in terms of the types of rock, grain size, colour, texture and hardness. Based on existence of rock that composed the history geology and their depositional environment. Lastly, the study of structural geology is the most important things that related to the forced of existence structural of rock. Observed the structural by doing preliminary research in terrain map to find the major fault throughout lineament that usually indicated to the massive structure and unknown rock that would not see by naked eyes but through the thin section. Besides, it also for the double checked in field.

b. Recording

In this part, a field notebook was prepared. All these materials need in the field work because usually were used for record any data to recorded. This were necessary things to do as a geologist in term of record data typically the main thing including the characteristic rock, grain size, colour, strike and dip, joints and sketching.

c. Sampling

Sampling are fundamentally for test the hardness in laboratory. Also used for consult the lecturer which specialist in petrography and equivalent with it. Within sampling, there are essentially things need to prepared which is the sample bag and the chisel hammer. Chisel hammer are used for breakout the rock to take sample. In other hand, plastic sample are used for protected the sample from weathering and water.

d. Mapping

Mapping is creation of maps through the software ArcGIS based on purpose study area. There abundance types of maps. Maps are important in field study because it helps researchers to and geologists to recognize with their research area. Its helps geologist and researcher to find the coordinate of someplace. Types of maps that are generally created by geologists and researchers is geological map, geomorphological map, traverse map, terrain map, cross section and slope map.

II) Laboratory Work

After the data have been collected, laboratory work necessarily do to investigated the mineral composition through thin section in each rock that are collected from field in term of petrography analysis.

III) Data Processing

Through this part, data from field and laboratory need to processed with ArcGIS software and different types of map. These field data such as name outcrop, location outcrop, structures, strike and dip, traverse and mass movement were plotted in ArcGIS software. For lithology, data lithology essentially takes through observing thin section slide under transmitted light microscope. These lithologies data need impute to ArcGIS software to plotted outcrop.

IV) Data Analysis and Interpretation

Through this part which is geology, data analysis and interpretation are generally done by explaining the maps that are produced. Several maps are produced which is geomorphology map, geological map, traverse map, and lithology map. Many data analysis and interpretations recorded in each map with dissimilar. Many interpretations done based on the map purpose. For instance, based on map is landform, structures, drainage and equivalents. Nevertheless, Data analysis and interpretation necessity a difference level of geology proficiency or experience. Perhaps, a different people have a different perspective and point of view.

3.3.3 Geotechnical Engineering

I) Field of Study

Within this part, field data were collected from 1 selected foothill and 1 road cut rock slopes in Gunung Ayam, Gua Musang. All these data gathered for analyzed the weathered rock slopes stability. The data were collected in the perspective of kinematic analysis and RMR system for the rock slopes stability.

a. Discontinuity Survey

On 2 selected weathered rock slopes had been investigated the study of discontinuity survey. Using scanning line method on exposed rock surface and the discontinuities that intersected with line were measured, described and recorded (Chamine et al., 2015). Generally, collecting data were used to resolute and identify parameter which have 6 in RMR system and also for kinematic analysis. Based on Tajul Anuar Jamaluddin (1991) stated that each discontinuity that cross-cut the scanning line was described in term of;

I. Spacing
II. Types of Discontinuity
III. Orientation of Discontinuities
IV. Discontinuity Length
V. Aperture
VI. Roughness
VII. Infillings
VIII. Presence of Water

Refer figure 2.5 for better understanding all of above which is discontinuity parameters.

b. Sampling

Within this part, generally same with the method (3.3.2: General Geology c. Sampling) using chisel hammer to break out the rock outcrops. This part only collected 2 sampling from 2 rock slope outcrop totally difference than the general geology sampling that need collected entire the research area.

II) Laboratory Work

a. Point- Load Test

In order to get the results of the rock strength of rock samples that taken from the field were proceed with Point-Load Test. Before to complete the point-load test, rock samples necessity to measure the length (mm) and width (mm) of the rock sample. Next, the sample of rock placed in 2 shaped points. Types of point-load test depends on the contact point on the rock sample (Sundara, 2009). Special cases for irregular lump test carried out within the centre point of rock sample as a contact point.

Before carried out the test, digital readout unit need to be a 0 value. According to Sundara (2009), the hydraulic jack handle was gradually increased the load applied on the rock sample until the rock failure occurred within 10 to 60 seconds. The digital readout unit showed the load at failure, P in kilonewton (kN) unit was recorded. The test done when the loading cone-shaped point returned back to its position in original stated. Based on ISRM (1984), one loading point fractured surface considered as invalid.

III) Data Processing

a. Point-Load Index Strength

RMR system is the first parameter. For calculating and obtaining point-load index strength of rock samples, there are several steps which is after the load failure was obtained P value by point-load test in laboratory works. Then, processed with calculation for obtained the point-load index strength, I_s in megapascal (MPa) unit. Based on ISRM (1984) the equation for calculating $I_{s,}$ is:

$$I_s = P/De^2 \qquad (3.1)$$

When I_s *= Point-load index strength in MPa,*

P = Load at failure in kN,

De = Diameter core equivalent in mm.

ISRM (1984) stated that irregular lump test that De^2 is calculated through equation below:

$$De^2 = 4\,\frac{WD}{\pi} \qquad (3.2)$$

Where W = Width of rock sample in mm,

D = Rock sample diameter in mm.

Hence, irregular shape of rock sample, so factor of size correction, F was necessity in order to acquire a corrected point-load index strength. Equation proposed by ISRM (1984) stated that as:

$$F = \left(\frac{De}{50}\right)^{0.45} \qquad (3.5)$$

Last but not least, a point-load strength that are corrected, $I_{s\,(50)}$ using MPa unit was calculated through this equation:

$$I_{s\,(50)} = F \times I_s \qquad (3.4)$$

b. **Rock Quality Designation (RQD)**

Rock Quality Designation (RQD) is the second parameter of RMR system. Generally, this parameter is figured out the quality of rock masses in situ. Then, the data discontinuity survey was collected on slope surface, then it was calculated with the equation that proposed by Palmstrom (2005):

$$RQD = 115 - 3.3\,J_v \qquad (3.5)$$

Where J_v = total of joints per unit volume on slope surface.

Examining the J_v value in field, blast induced discontinuities are excluded. Calculation was calculated by the equation below:

$$J_v = \frac{1}{S1} + \frac{1}{S2} + \frac{1}{S3} + \ldots.. + \frac{1}{Sn} \qquad (3.6)$$

Where S = Average spacing of particular joint set.

Between relationship of J_v Palmstrom (2005) and RQD stated that RQD is 0 % if J_v is more than 35 and if RQD 100% then the J_v is less than 4.5.

IV) Data Analysis and Interpretation

a. Rock Mass Rating (RMR) system

There are 6 parameters included in Rock Mass Rating (RMR) system. These parameters were observed by guideline proposed by Bieniawski (1989) in table 3.1. All these data were rated based on the data acquire at field for instance discontinuity survey and point load test from laboratory work. The rate and class number of rock mass were classified based on total rating from 6 parameter as presented on Column C in table 3.1. Lastly, conclusion was drawn for resulted class number by using details RMR systems is shown in Column D of Table 3.1.

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

	Parameter		Range of values						
1	Strength of intact rock material	Point-load strength index	>10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial comp. strength	>250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	< 1 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core Quality *RQD*		90% - 100%	75% - 90%	50% - 75%	25% - 50%	< 25%		
	Rating		20	17	13	8	3		
3	Spacing of		> 2 m	0.6 - 2 . m	200 - 600 mm	60 - 200 mm	< 60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5 mm thick or Separation 1-5 mm Continuous	Soft gouge >5 mm thick or Separation > 5 mm Continuous		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (l/m)	None	< 10	10 - 25	25 - 125	> 125		
		(Joint water press)/ (Major principal σ)	0	< 0.1	0.1, - 0.2	0.2 - 0.5	> 0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)

Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 21
Class number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK CLASSES

Class number	I	II	III	IV	V
Average stand-up time	20 yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m span
Cohesion of rock mass (kPa)	> 400	300 - 400	200 - 300	100 - 200	< 100
Friction angle of rock mass (deg)	> 45	35 - 45	25 - 35	15 - 25	< 15

E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions

Discontinuity length (persistence) Rating	< 1 m 6	1 - 3 m 4	3 - 10 m 2	10 - 20 m 1	> 20 m 0
Separation (aperture) Rating	None 6	< 0.1 mm 5	0.1 - 1.0 mm 4	1 - 5 mm 1	> 5 mm 0
Roughness Rating	Very rough 6	Rough 5	Slightly rough 3	Smooth 1	Slickensided 0
Infilling (gouge) Rating	None 6	Hard filling < 5 mm 4	Hard filling > 5 mm 2	Soft filling < 5 mm 2	Soft filling > 5 mm 0
Weathering Ratings	Unweathered 6	Slightly weathered 5	Moderately weathered 3	Highly weathered 1	Decomposed 0

Table 3.1: The Rock Mass Rating System.

(Source from Bieniawski,1989)

b. Kinematic Analysis

Kinematic analysis plotted on Stereonet, these methods determined the possible mode for slope failure either planar failure, wedge failure or toppling failure. Slope failure has its own criteria to develop as listed down in Chapter 2. If the criteria a single mode failure are met, the specific rock slope interpreted as a high possibility for generated particular mode of slope failure.

c. Factor of Safety (FoS)

Generally, Factor of Safety (FoS) used to analyse the stability of slopes. It is calculated right after the kinematic analysis of rock slope concluded that the rock slope is unstable. Stable slope is no point to calculated FoS. Rather a rock slope is predicted to be unstable from kinematic analysis then it will be more concerned with its FoS value and differences between the resulted FoS value and the standard FoS value set by related to the government authorities that acceptable rock slope stabilization measure can be known and proposed.

Research Flow Chart

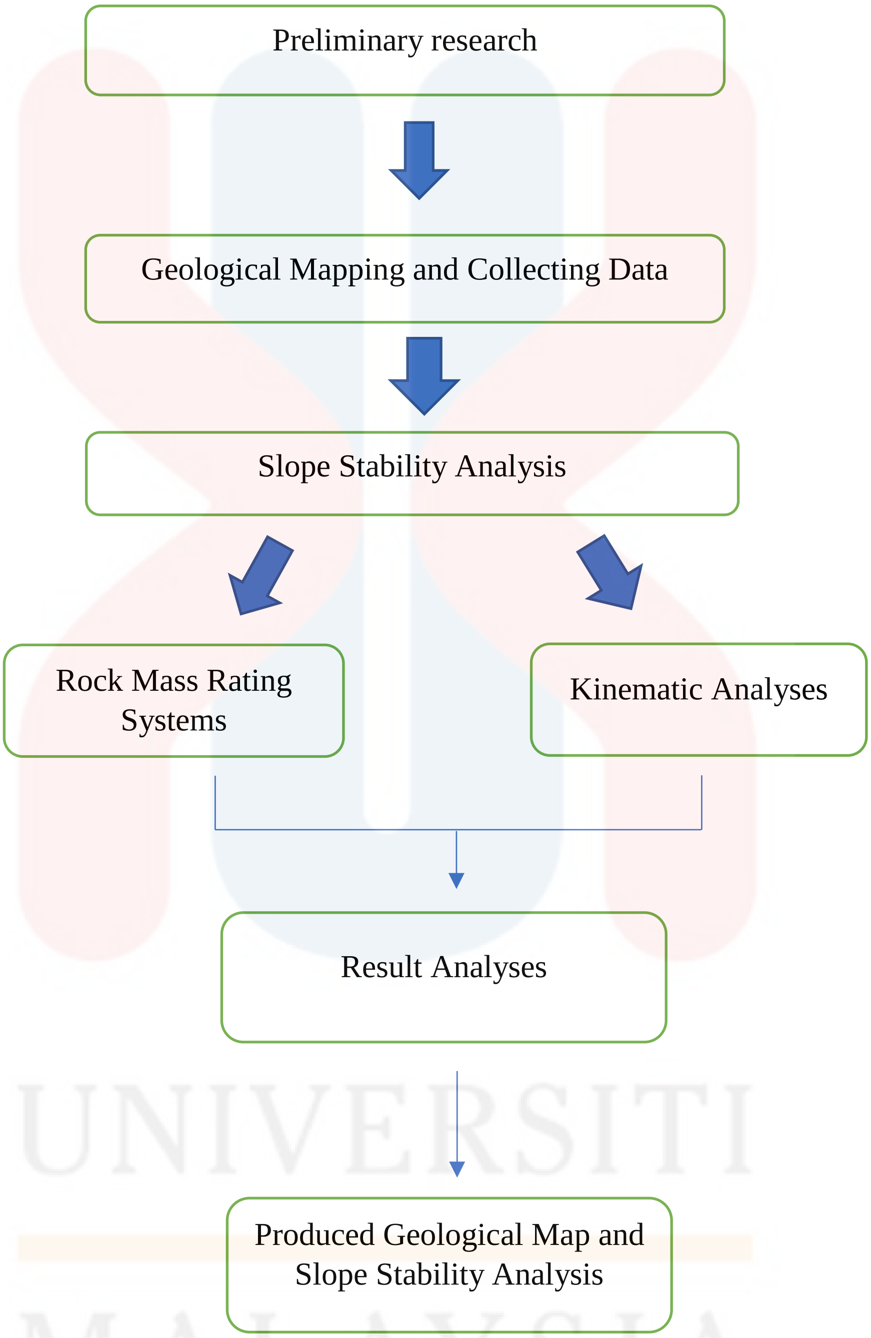


Figure 3.1: Research flow chart.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

Through this chapter, explained more related to the general geology of research area that consist of the geomorphological process, stratigraphy, structural geology, historical geology, field data, field observation and also plentiful types of map that generated by observation in field works. These maps also review about the research data obtain from the research area. The general geology is most necessity part that deliver many geological information that related to the geotechnical engineering that used conducted in this research.

There are a several methods used for field research for instance the accessibility of the research area, types of lithology, the morphology and the slope map that based on elevation in the research area. The main equipment that used throughout mapping of geological which is the GPS, Brunton compass, hand lens, measuring tape, sample bag, hammer, camera and HCL liquid. These tools are useful for collecting data in the field.

The research area is located Gunung Ayam, Lojing, Kelantan which situated at southwest Kelantan. Peninsular Malaysia divided by three belt which is western belt, central belt and eastern belt. Locality of Gunung Ayam is situated at end of southwest Kelantan. Gunung Ayam are included in the central belt of Peninsular Malaysia. Sibumasu (Continental Crust) subduction under East Malaya-Indochina (Continental Crust) at the Late Triassic period and formed Bentong-Raub suture with the elimination of Paleo-Tethys ocean (oceanic crust) (Hutchison & Tan, 2009). Gunung

Ayam situated in the Bentong-Raub Suture Zone in which the Gunung Ayam are form from the suturing between the Sibumasu Plate and Indochina plate.

Figure 4.1: The Gunung Ayam (yellow rectangular) from West side.

Landuse map is map shows the usage land for currently development and this map could use for the future in planning for development. The research area has the indigenous village inside the palm oil plantation. They lived there for many decades with population about less than 100 peoples. In the research area, majority area was a covered by rubber plantation. These rubber trees just planted for less than five years. And also, there is palm oil plantation situated besides the rubber plantation. These palm oil plantation still new planted and not ready for harvesting. Refer the landuse map in Figure 4.2 for the details cover area.

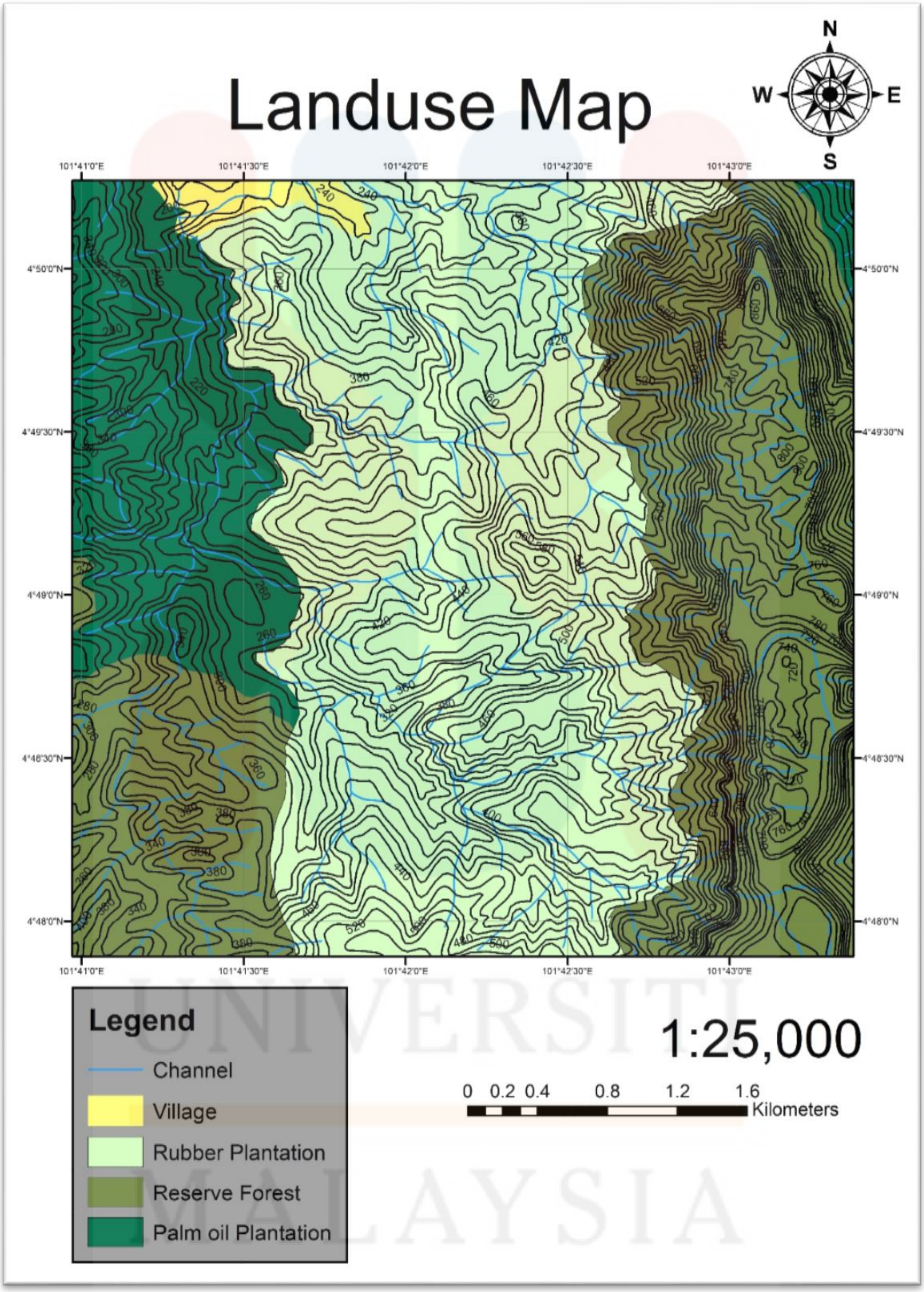


Figure 4.2: The Landuse Map of Gunung Ayam.

4.2 Geomorphology

Geomorphology represents the study of physical terrestrial characteristics of the Earth, its forms, rivers, hills, plains, beaches, sand dunes, and myriad forms (Huggett, 2011) .The research explores landscapes in order to determine which earth surface systems including air, water and ice could transform the landscapes. Landforms are formed by erosion and deposition, when rock and sediment are carried away or deposited in various locations through these earth-surface processes. The diverse environments develop different sets of landforms.

In order to obtain data geomorphology preferred to find a highest elevation in the research area which is could observed the geomorphology of the research localities and figured it out what type of geomorphology. Through the first observation of the highest elevation could find out how the exactly processes happened in the past. Observation through geomorphology also for correcting the map of geology either the map needs to correction or not. By looked out to river from highest point also could watched the river changed from the past by tracked the trace from the past deposition.

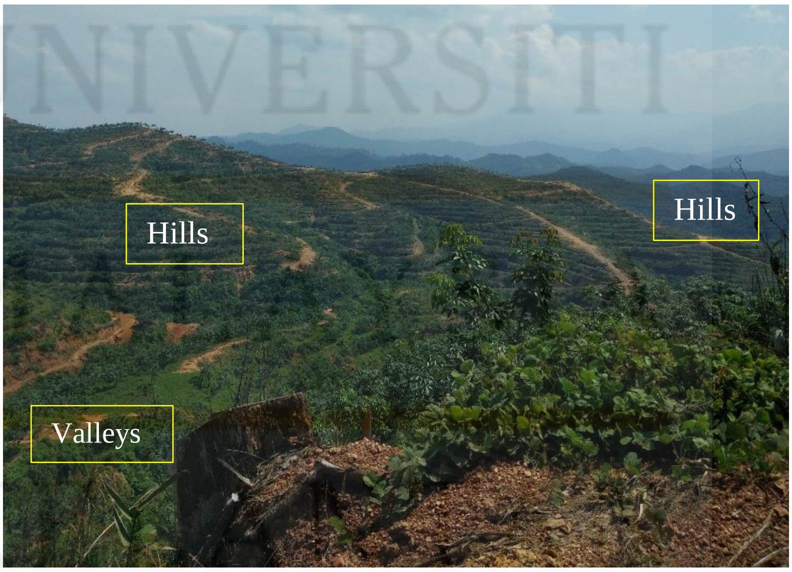


Figure 4.3: The geomorphology from highest point.

4.2.1 Geomorphologic Classification

According to Haskins et al., (1998) the categorization and description of the nature, origin and landform development is geomorphic classifications. The geomorphic classification system comprises four elements which is geomorphic process, landform, morphometry and geomorphic generation. The basic principle of this scheme of classification is that a geomorphic unit can be categorized collectively by reference to its origin and formation (process), its general structure and shape (landform), its measurement and characteristics (morphometry) and its overprints process and status of process (geomorphic generation).

Figure 4.4: The waterfalls with scarp slope showed.

The researcher interprets that the ridge of Gunung Ayam have a source of water from groundwater that seeping out then flowing to the lowest point through small channel develop an evolution landform look like in the Figure 4.4. There is waterfall located at hillslope of Gunung Ayam resulted from faulting arise processes because there is fault scarp that obvious showed (Figure 4.4) after arise faulting processed. According to Huggett (2011) the commonest form to arise faulting called fault scarp.

Landform are complex features that occur of the earth and everywhere. These range from molehills and mountains to big tectonic plates, and their 'lifespans' ranges from days to millennia to aeons (Huggett, 2011) . Based on Figure 4.3 hills are form by geomorphic processes. According to Huggett (2011), said the myriad chemical and physical mechanisms by which the composition of the surface of Earth alters modification are geomorphic processes. The geological factors which come from within the earth (endogenic processes), forces from origin at or near to the Earth's surface and the atmosphere (exogenic processes), and forces from outside the world (extraterrestrial systems, including asteroid impacts). These are powered by the natural forces which emanate inward and outward. In the research area generally found that the hills and mountains are generated by trend of NNW-SSE regional structure that obviously shows the Bentong- Raub suture zone in the Peninsular Malaysia.

Through millennia to eons hills eroded by majority within the rainfall or streams flow. And occurs the valleys in between the hills. The valleys generated the hillslope because of the flowing water from rainfall or the streams flow creates the channels. From these processes generated the colluvial, alluvial and fluvial. Refer the Figure 4.5 for more details.

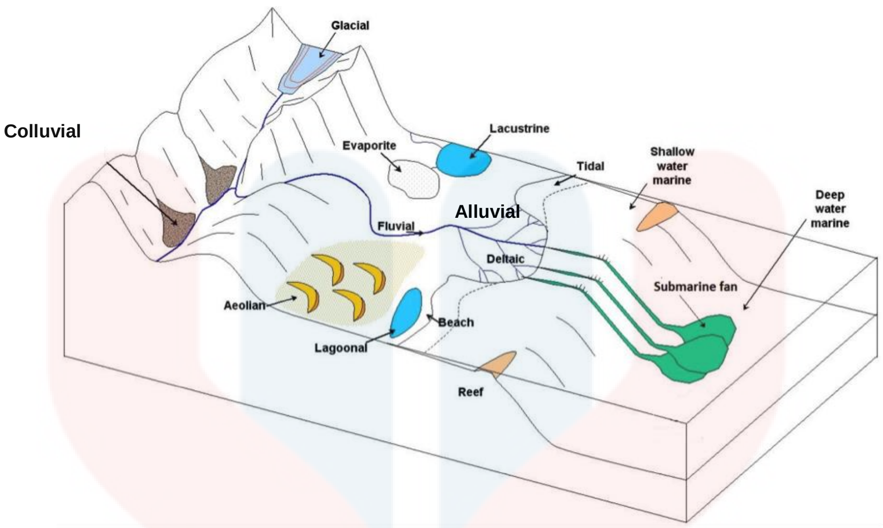


Figure 4.5: The depositional environment for sedimentary rocks.

(Source: Earle, 2015)

Rock mass (Figure 4.3) is from Gunung Ayam's conglomerate that naturally breaks rock that occurring along the channel within transportation flowing streams. Based on the Huggett (2011) the dilation generates large or minor cracks in parallel to the surface (fractures and joints). Rock falls and other kind of mass movements are encouraged with the dilution joints. Otherwise, rock mass breaks into cobble because of weathering and transportation processes.

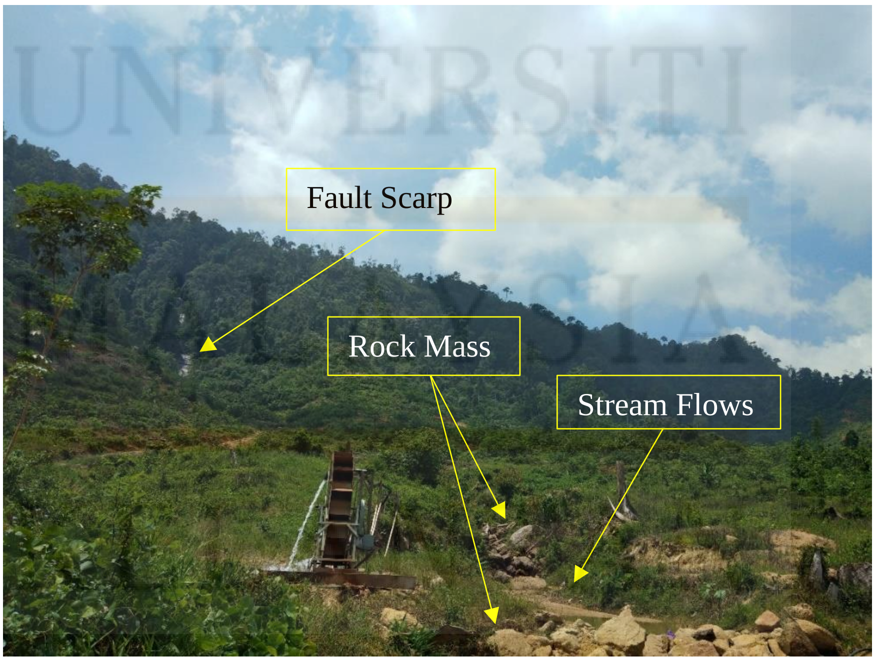


Figure 4.6: The Fault Scarp at waterfalls of Gunung Ayam.

Based on the researcher, Huggett (2011) a hillslope elongated from an interfluve crest, within a valley side to the valley floor. Refer on Figure 4.7 displays model storage systems (waste mantle), inputs (e.g. wind deposition and debris production), outputs (e.g. wind erosion), throughputs (debris transport) and units (channel, valleyside slope, interfluve. In the research area are similar methods processes in term of hillslope systems. Uplifting or subsidence event still undergoing processes with a small-scale change. It is hardly to investigated within a month research carried out. This hill slope systems are long investigating duration for the changes.

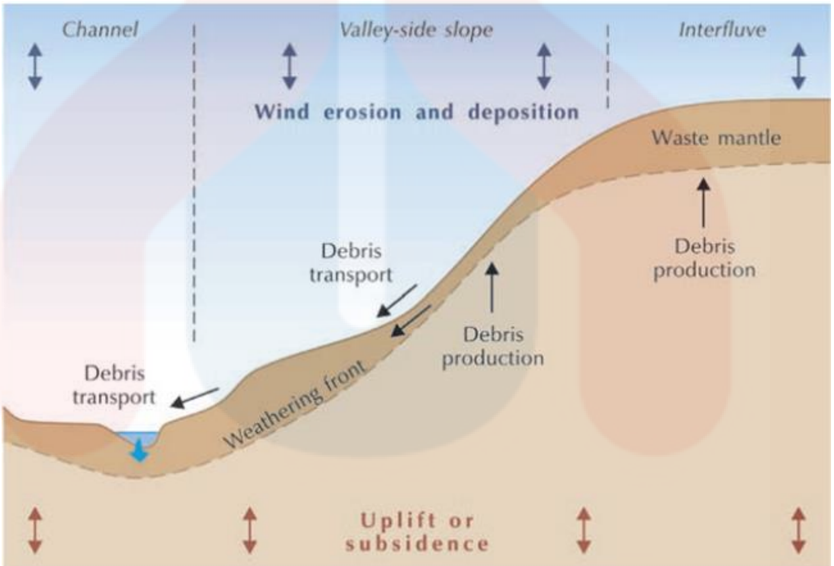


Figure 4.7: A hillslope systems.

(Source: Richard John Huggett, 2011)

Intriguingly, the basic antagonisms between endogenic processes (tectonic and volcanic) driven by geological forces and exogenic processes (geomorphic) driven by climatic force can be considered in all geomorphic systems (Scheidegger 1979). Based on the Huggett (2011) tectonic forces generate land through weathering and erosion is determined by climatically. Most intrigues geomorphologists are the activities between creation and final destruction.

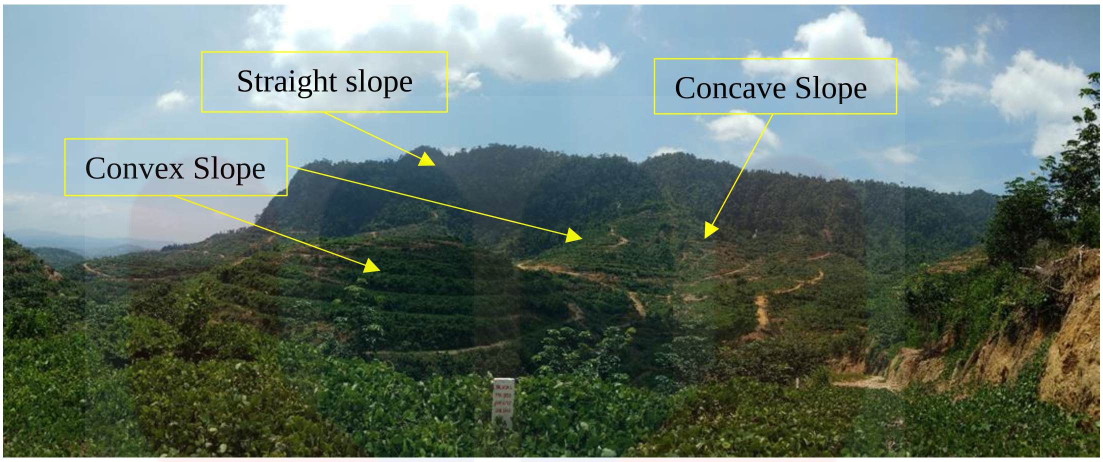


Figure 4.8: Three form elements of hillslope.

Mostly the hillslope has these elements (refer Figure 4.9). These elements consist of convex, straight and concave slope. There are one or more slopes of differing orientation, inclination, length and shape in every type of landforms (Butzer 1976, 79). The term used for describe the slope units are myriad: Anthony Young (1971) defined by the slope is a segment or component, while the segment is part of a slope profile with a nearly equal angle, and the component is part of a slope profile on which the curvature is approximately similar. A geomorphic catena is comprised of a sequence of related slope units which is convex, straight and concave (Speight, 1974; Scheidegger, 1986).

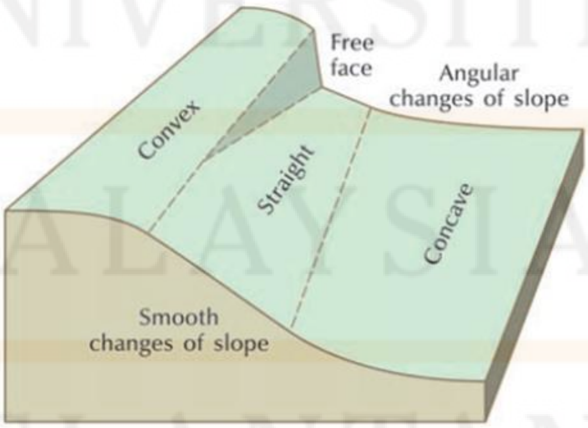


Figure 4.9: Abrupt and smooth transitions between slope elements.

(Source by Huggett, 2011)

4.2.2 Weathering

Malaysia climate classified as allitization zone which is based on Thomas (1994) said the allitization zone corresponds with extreme rainy tropics leaching regimes and is aligned with the Amazon Basin, Congo Basin and South-East Asia tropical rainforest.

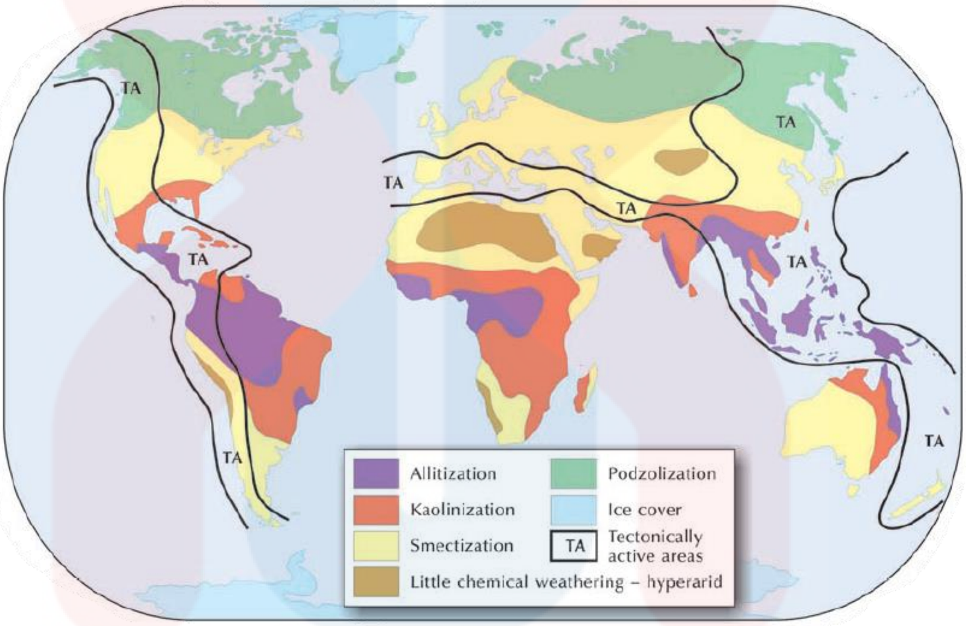


Figure 4.10: The primary weathering zone on earth.

(Modified by Huggett, 2011)

Furthermore, rainfall rate played a role in term of erosional processes through the evolution landform. These processes could watch a landform change during a long period within a millennium or through aeons. So, based on analogy models in Figure 4.11 could watched a demonstrate landform changes through a divergent time within a water flow.

Figure 4.11: An analogy model simulates long-term evolution landform with an uplift and variable rainfall rate.

(Modified by Huggett (2011)

Based on model through the Huggett (2011) said a change in the water pressure and configuration of the sprinklers can be used to control the precipitation rate. A running water at the surface eroded the surface of the model and the separation of grain was carried and mainly through shear removal by surface runoff.

The process in the research area is same as the model in Figure 4.11. These running water from ridges of the Gunung Ayam eroded the surface and carried a rock mass through the stream flows. Along the stream locality at N 04^{o} 49' 22.5'' E 101^{o} 42' 50.9 full with the conglomerate rock because Gunung Ayam is dominantly covered by conglomerate rock.

Hillslope transportation processes have three main point which is surface processes, subsurface processes and bioturbation. These elements are mandatory for transportation hillslope processes in order form a landform. Surface processes is the sediment dislodge after falling raindrops into a ' splash ' that moves through the air in all directions resulting in the net transport of the material downslope (Huggett, 2011).

After the tectonic uplifting Gunung Ayam the conglomerate rocks are started to denudation process then rock breaks apart became a rock mass after erosion from rainfall through year by year same circulation and create an evolutional landform. These landforms will always be changing by years following the climate. Extensive field measurements since around 1960 that hillslope processes show a significant change with climate (Young 1974; Saunders and Young 1983; Young and Saunders 1986).

Rain power is a mathematical term that incorporates rainfall, hillslopes and vegetation characteristics and allows for flow depth modulation (Gabet and Dunne 2003). Plus, climate in Malaysia mostly support the growth of plants. These factors slow down the rate of erosional processes. According to Richard John Huggett (2011) the enormous impact on precipitation, rainflow and sheet erosion because of vegetation cover. Soils containing or without plant cover, leaf litters, or crop residues are significantly more vulnerable to erosion.

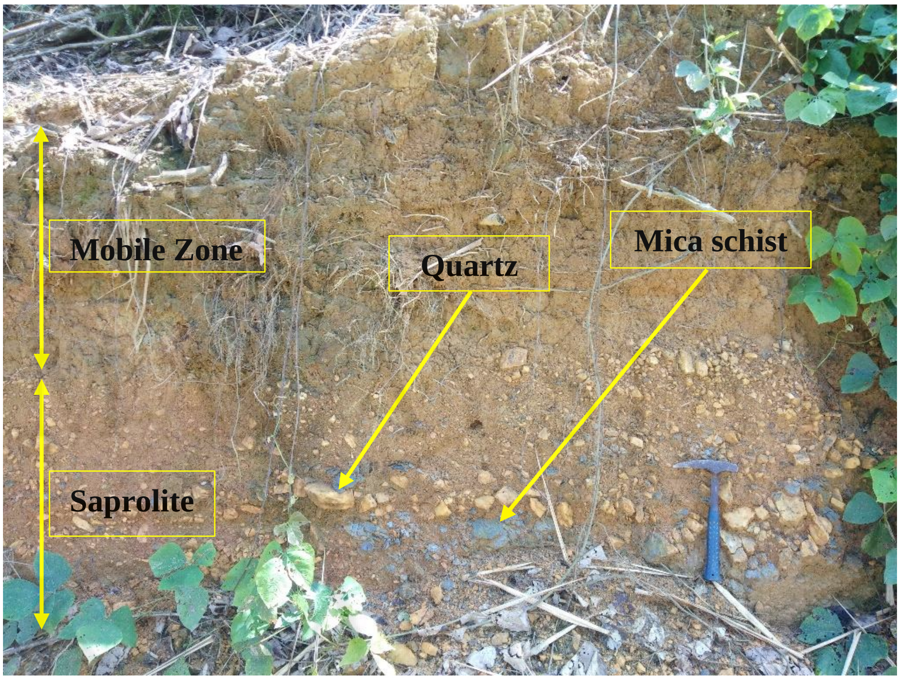


Figure 4.12: The weathering profile in outcrop on quartz-mica schist.

Outcrop the bedrock is quartz-mica schist rock that through weathering process. The bedrock undergoes all types weathering which is physical, biological and chemical weathering. Mechanical processes gradually reduce rocks to finer fragments. The degradation raises the surface area vulnerable to chemical attacks (Huggett, 2011). Casually, the rock disintegrated by joint and fractures rock that generated by heating and cooling weathering. Quartz mineral as shown in the Figure 4.12 that milky rock colour consistently be the last mineral breaks because of the high resistant and high stability from weathering.

According to Huggett (2011) mechanical weathering processes are mainly unloading, frosting, heating and cooling by thermal stress, swelling and shrinking due to wetting and drying and pressures caused by the growth of salt crystals. The researcher interpreted that a metamorphic rock (mica schist) generally generated by high temperature and pressure within it the rock normally will reduce the resistance. Alternate swelling and shrinking, in conjunction with the fatigue effect in combination with wet-dry weathering or slaking, which disintegrate rocks physically (Huggett,2011).

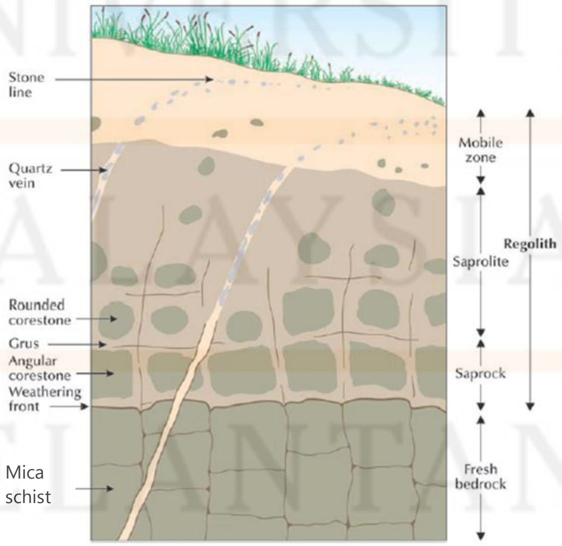


Figure 4.13: The typical weathering profile.

(Source: Huggett, 2011)

According to Huggett (2011) the rock decomposition involves 6 principal chemical reactions which is solution, hydration, oxidation and reduction, carbonation, and hydrolysis. The researcher said all these types chemical reaction on weathering undergoes to mineral in the rocks. All these rock types have their own chemical reactions. Most of the rock after affected with chemical reactions turns the degradation of rock. Chemical weathering takes a long period to degrade. Based on Figure 4.14 the quartzite outcrop undergoes a chemical weathering where mineral composition of quartzite is silicon dioxide, SiO_2 and other mineral may contain iron oxide. Trace element composition of quartzite is rutile, zircon and magnetite. These minerals could undergo oxidation which oxygen dissolve in water and made contact with the iron mineral would be reaction.

Figure 4.14: The honeycomb on quartzite outcrop undergoes chemical and physical weathering.

Biological weathering generally associated with plant roots. In order plant root growing and reach the bedrock it will break most of the bedrock to applied the gravity centre of earth. Plant roots and particularly tree roots, which growing in bedding planes and joints become biomechanical effect mounting pressure may cause rock fracture as they grow (Huggett, 2011). It is obviously shown in figure 4.3.4 on quartzite outcrop which undergoes biological weathering within plant roots that growing in joints. Otherwise, by Huggett (2011) dead lichen leaves the rock surfaces with a dark stain. The dark spots consume more thermal radiation than the light areas, so that thermal weathering is encouraging. Figure 4.15 shown a lichen growing on the surface rock near peak of Gunung Ayam. Lichen slowly degrading the rock strength because there is chemical were release during growing and photosynthesis to make a surrounding suitable.

Figure 4.15: The dead lichen on surface rock (conglomerate contact with quartzite) near peak of Gunung Ayam.

Based on Huggett (2011), soluble materials in some situations, precipitate within to form duricrusts, hardpans and plinthite in or around the weathered mantle. In the development of land, Duricrusts is important-because they act as a resistant rock band and perhaps caps hills. They are hard nodules or crusts, or just hard layers. Refer figure 4.16.

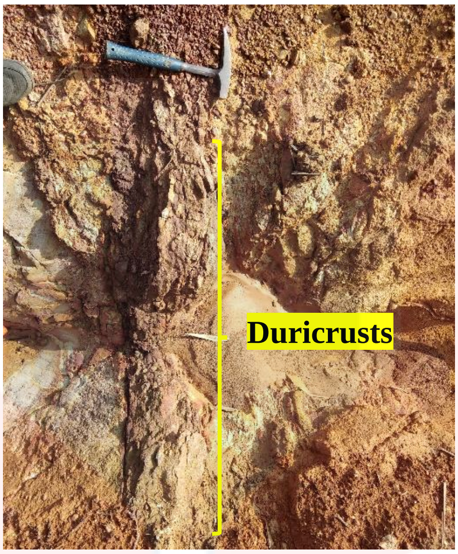


Figure 4.16: The duricrust on mica schist rock.

4.2.3 Drainage Pattern

The research area contains a dendritic drainage pattern which cover all over the study area. Refer the dendritic pattern in Figure 4.18 modified model by Huggett (2011) similar with drainage pattern map in Figure 4.17 (research area) shown obviously the dendritic pattern. Dendritic pattern usually spreading like a tree roots pattern in any irregular branch. Commonly, the drainage is location for geologist find out the structural geology because of the flowing streams always leached the surface bedrock.

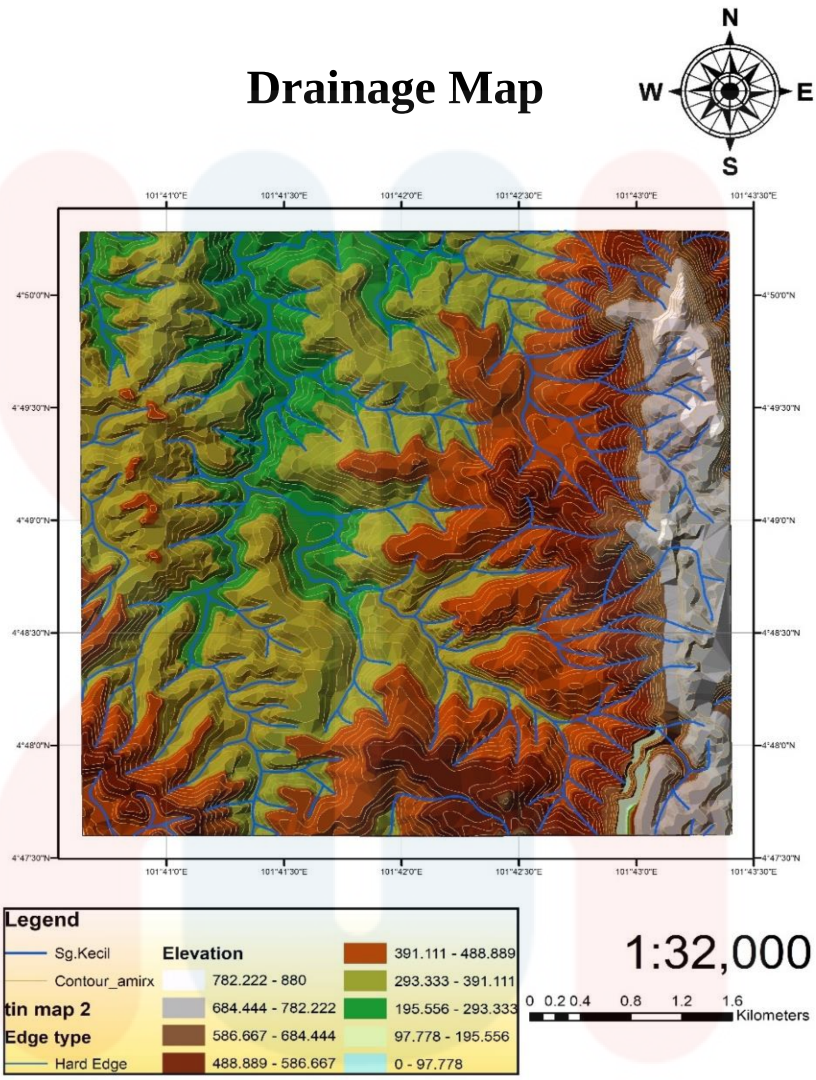


Figure 4.17: The drainage pattern map.

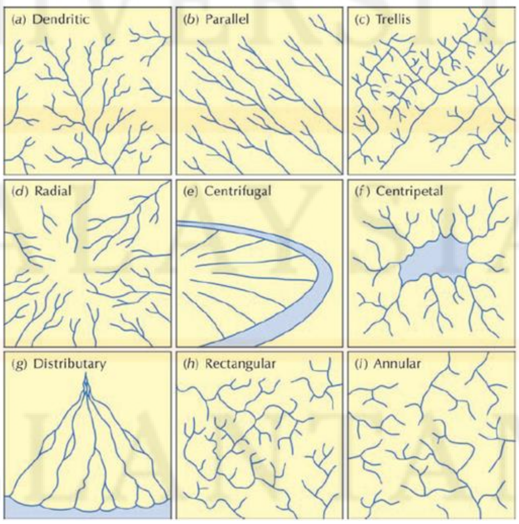


Figure 4.18: The drainage pattern types.

(Modified: Huggett, 2011)

4.3 Stratigraphy

Stratigraphy is the scientific discipline dealing with the characterization and analysis in general terms time scale of rock evolutions. Stratigraphic research mainly focuses on sedimentary rocks but may also involve layered igneous rocks (e.g. those from lava flows) and metamorphic rocks produced from such extrusive igneous or sedimentary rocks (Britannica, 2014).

Through geological mapping, the researcher not found any trace fossil and fossils because of the difficulty of geomorphology the research area. Furthermore, the research area lithology consists of metamorphic rock which is conglomerate, mica-schist and quartzite. Generally, most of the metamorphic rock difficult contain a fossil. If fossils were found it will be a huge achievement. So, the lithostratigraphy age are based on previous research interpretation.

The research area classified in Gua Musang Formation. Aw (1975) proposed that Basal Conglomerate of Gunung Ayam as the bottom part of Permo-Trias sequences (Gua Musang Formation) for Kuala Betis area. The Upper Boundary conformable with Semantan Formation. According to Aw (1975), for conglomerate called conglomerate Gunung Ayam which is basal conglomerate to rock units Permo-Trias. Conglomerate are exposed to differential with rock units of Gua Musang formation that existed in Gua Musang. Located besides Sungai Berok, near with Blau, there is Chert Units that layered and comprises of many fossils, like Radiolaria and ammonoid (Aw, 1975).

Lithologically, the suture is split into pre-Silurian schists in the west adjacent to the Titiwangsa, whereas its eastern zone comprises of Lower Silurian and Permian clastics and chert.(Tjia & Almashoor, 1996).

Table 4.1: The lithostratigraphy of Gunung Ayam research area.

Lithostratigraphic Column				
Formation	**Period**	**Lithology**		**Description**
Gua Musang Formation	Quaternary	Alluvium		Consist of clay, silt, sand and gravel
	Triassic	Conglomerate		Crush conglomerate type consist of quartzite and schist
	Permian	Quartzite		Quartzite and hornfels contact metamorphism with conglomerate
		Hornfels		
	Silurian	Schist: Mica schist, Quartz-mica schist		Mainly mica schist and some mixed quartz and arenaceous-argillaceous rocks invariably metamorphosed

4.3.1 Unit Explanation

The observation should having done to accomplish the field observation. The research required all the method that use during the mapping observation. The research outcome by the observation in the field is enough information that can be taken through geological mapping methodology. Plus, using traverse methodology during fieldwork to research about any geological features such as structural geology, geological hazard, geological heritage, landform, drainage and lithology in the research area.

Schist Unit

A foliated crystalline rock that strongly was formed by dynamic metamorphism which readily split into the thin flakes or slabs due to the well-developed parallelism of more than 50 percent of minerals, especially lamellar or elongated prismatic habit such as mica and hornblende (USGS Department). Mostly the research area was covered by mica schist rock with the shining thin flakes obviously showed in the rocks.

According to USGS, the mica schist whose main components are mica and quartz, which primarily are schistosity because of the mica flakes in parallel arrangement.

Figure 4.19: The Mica Schist Outcrop.

Based on the Figure 4.20 shows the thin section of the mica schist. From the petrographic analysis found out the schistose structure. Schistose structure clearly showed the characteristic of the metamorphic rock which is mica schist. Mineral sortation of mica schist is moderately. The pleochroism are low within the shape of crystals are anhedral types.

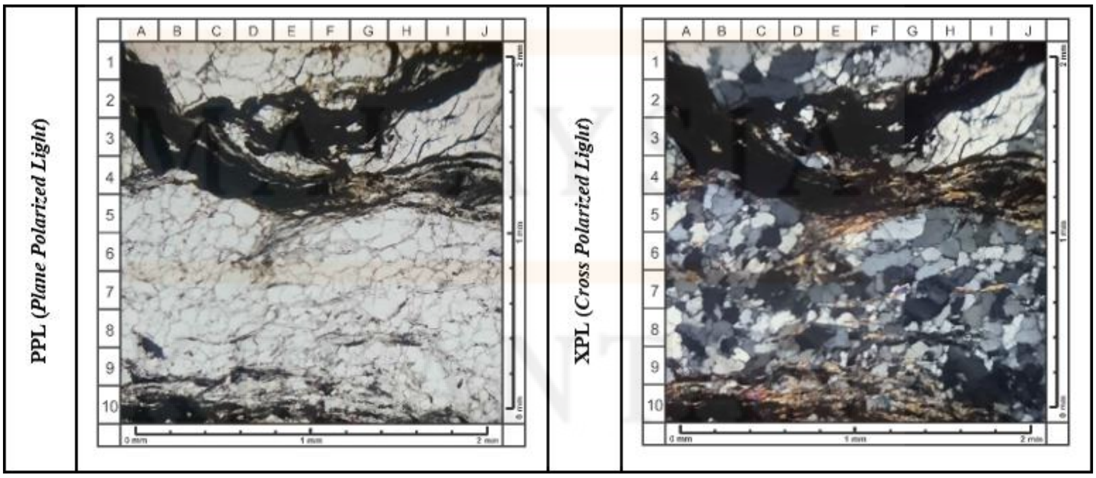


Figure 4.20: The thin section of mica schist. Enlargement: 5x10

Quartzite Unit

Quartzite is a metamorphic known as non-foliated rock consisting almost primarily of quartz. It forms when the heat, pressure, and chemical activity of metamorphism changes a quartz-rich sandstone. This recrystallizes sand grains and the silica cement that ties them. The consequence is a network of unprecedented strength and interlocking quartz grain. The crystalline structure of quartzite interlocks makes it a rock hard, tough and durable. Quartzite has the interlocking crystalline structure that make it hard, tough and durable rock. It is so intense that it breaks the quartz crystals instead of splitting their boundaries between them. This distinguishes true quartzite from sandstone (Geology.com).

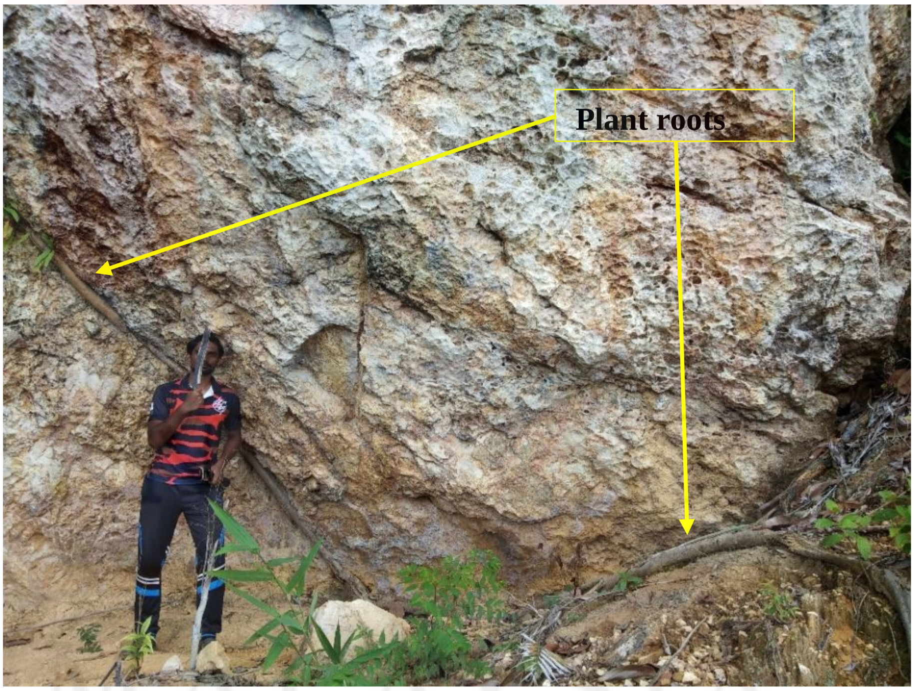


Figure 4.21: The Quartzite outcrop.

Based on the petrographic analysis, mineral structure shows the non-foliated clearly refer to quartzite rock. Within the thin section showed the composition of mineral are consist 97 percent of quartz anhedral crystals (refer Figure 4.22).

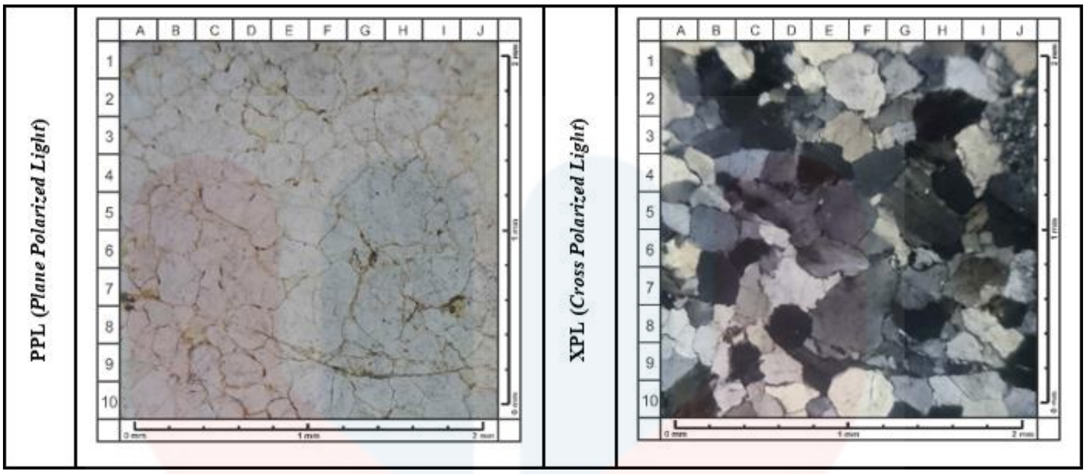


Figure 4.22: The thin section of quartzite rock. Enlargement: 5x10

Conglomerate Unit

Conglomerate is lithified sedimentary rock in petrology composed of rounded fragments of more than 2 millimetres (0.08 inches) in diameter. Conglomerate is traditionally classified into pebble (fine), cobble (medium) and boulder (coarse) respectively based on the average size of their constituent material. Conglomerate classification is based on the variety of lithologies in the pebbles, degree of size-sorting, matrix composition and whether or not clasts are in contact with each other. Based on these criteria has their own genetic implication (Britannica, 2013).

Based on Mansfield (1907) said there are five general conglomerate types which is marine, river, estuarine, lacustrine, and glacial have been considered. Therefore, they were studied by another type, generally called crush-conglomerate but pseudo-conglomeratic in its nature. Most conglomerates are perceived as the outcome of several conglomerate-forming processes but the outcomes are categorized in each phase. In the research area were found during geological mapping a conglomerate rock that consist of crushed rock as their clasts. This showed that the types of conglomerate are a crush-conglomerate (figure 4.23). These clasts are a rock fragment that crushed during the over thrust faulting or slickensliding.

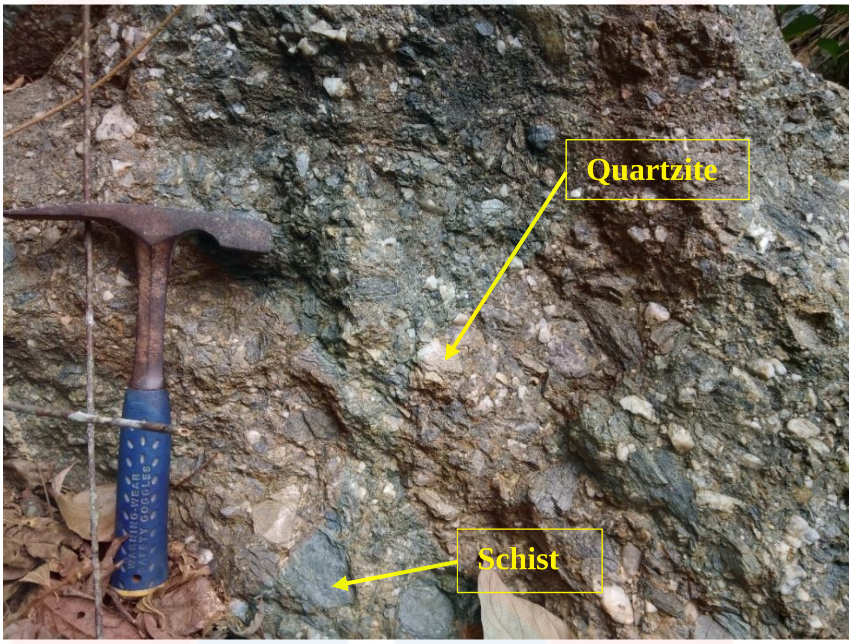


Figure 4.23: The crush-conglomerate types.

Based on Figure 4.24, the thin section clearly showed these rock types is conglomerate rock. Composition mineral based on the fragment lithic in conglomerate is found out the rock fragment are quartzite and schist with compose about 72 percent in those thin section. This is reaffirming the evidence of conglomerate are from a crush types because of the overthrust fault in past.

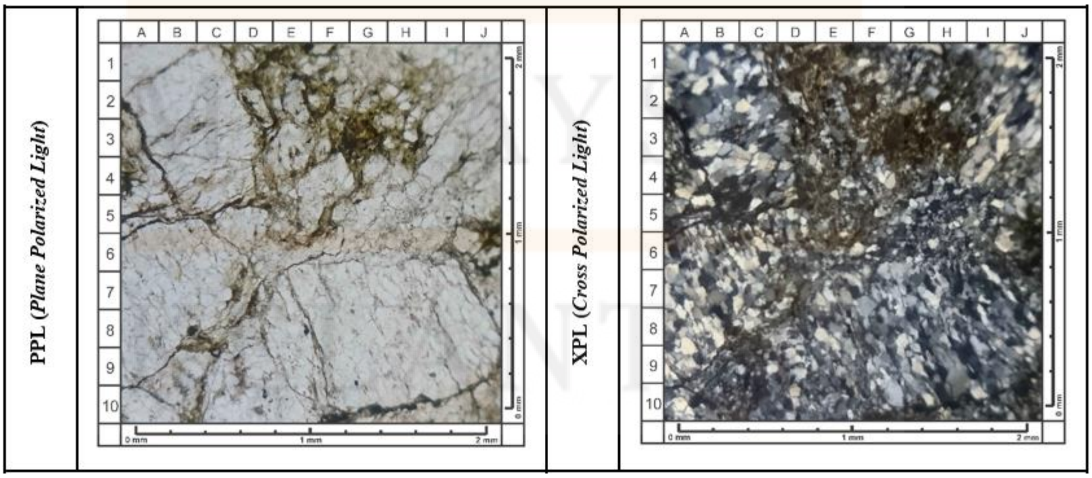


Figure 4.24: The thin section of conglomerate rock. Enlargement: 5x10

Hornfels Unit

Based on Flett & John (1911) hornfels is the magma heats and recrystallizes the original rock forms a metamorphic rock. Pressure is not a forming element. Colours of hornfels vary as much as the source rock used to produce them. Typically, brown or black in traditional colour (biotite hornfels), but white, purple, green and other shades is the most common colour. Many hornfels are banded, but the rock can so quickly split through a band. The rock is small, but may include visible garnet, andalusite or cordierite crystals. Most of the minerals appear only as small grains, which cannot be seen to the naked eye, but under magnification look mosaic-like patterns. One notable characteristic of hornfels is that it rings like a bell when struck (even more clearly than shale).

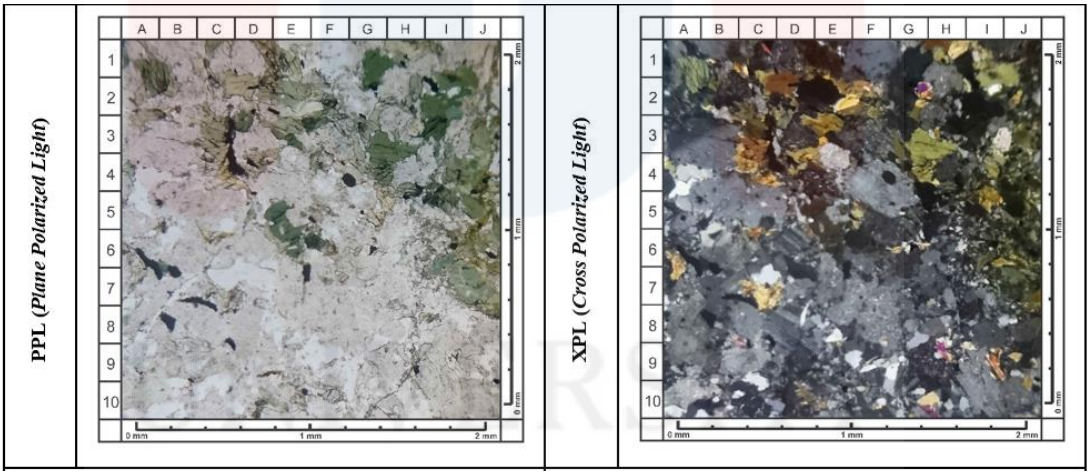


Figure 4.25: The thin section of hornfels rock. Enlargement: 5x10

Hornfels unit was located at outcrop MAL 021which coordinates N 04° 49’ 3’’, E 101° 42’ 39’’. The outcrop of hornfels have two localities which found also at MAL 022. These outcrops show the rock have the banded layers look like sedimentary. Rock banded colour was greyish black and white. These rocks are hard to breaks because of metamorphic rock.

Figure 4.26: The outcrop of hornfels.

All these fieldworks are observation from field that refer to Figure 4.27 showed all the sample taken and traverse that happened in the field.

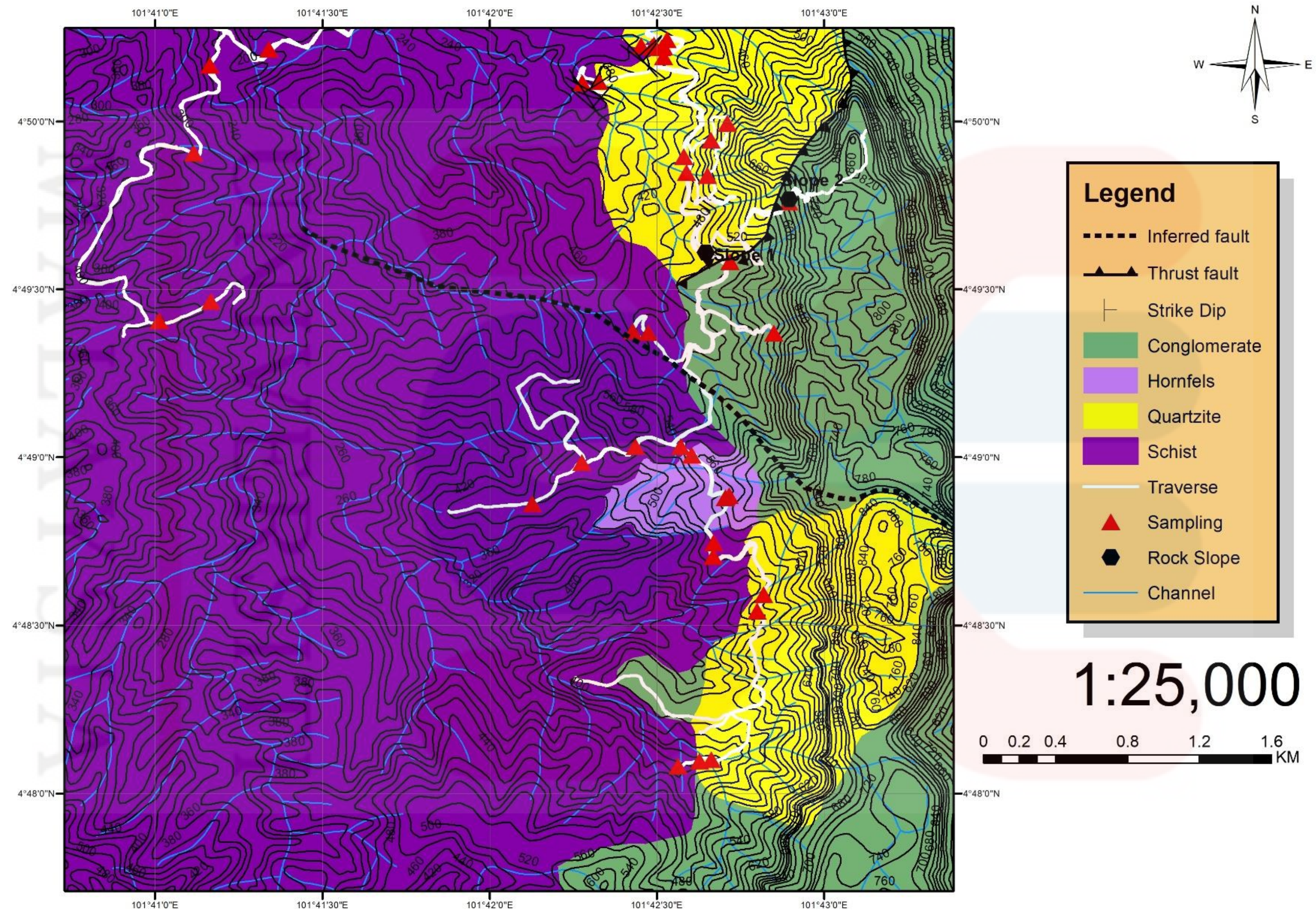


Figure 4.27: Observation and traverse in the research area.

4.4 Geological Structures

According to Patrice (2016), the objective of structural geology is to classify structures of deformation (geometry), to distinguish flow paths pursuing particles during deformation (kinematics) and to identify the direction and magnitude of forces involved in the deformation process (dynamics).

4.4.1 Fold

Figure 4.28: The wavy folded situated near the Gunung Ayam.

Figure 4.29: The folding on mica schist outcrops.

4.4.2 Fault

Many structural geology that found in research area which is faulting, and the derived from fault like the slickensides. All these occurred after the stress affected the research area became the Gunung Ayam today. In the Figure 4.39 showed the geological map that derived from fieldwork and there is thrust fault between the conglomerate unit and quartzite unit.

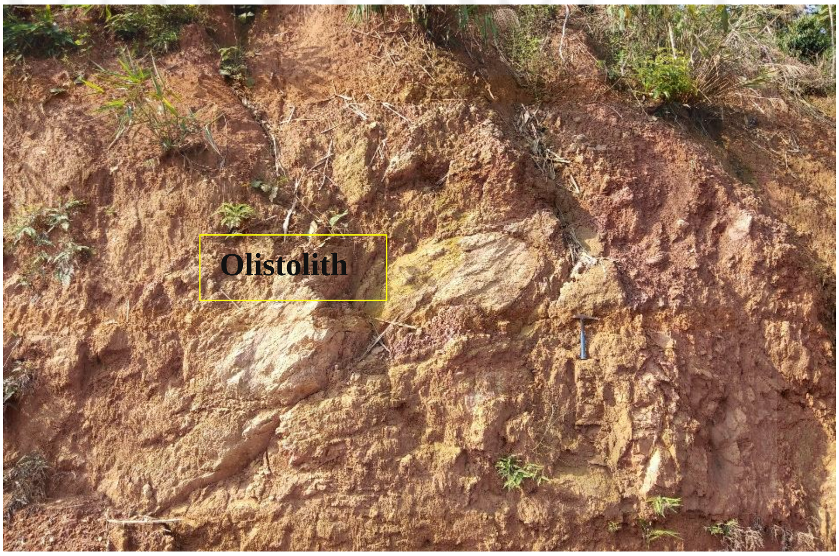


Figure 4.30: The quartzite olistolith in mica schist olistostrome.

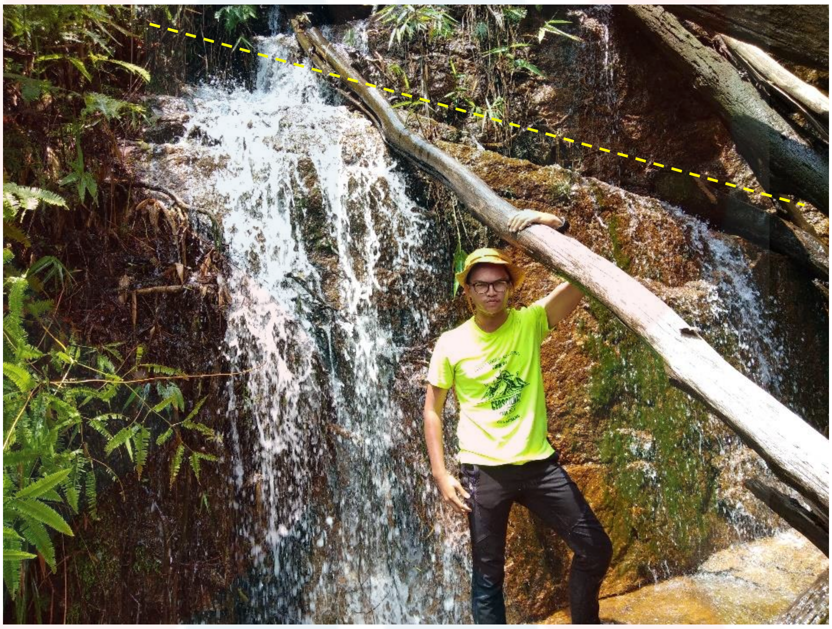


Figure 4.31: The Thrust Fault and the slickenside.

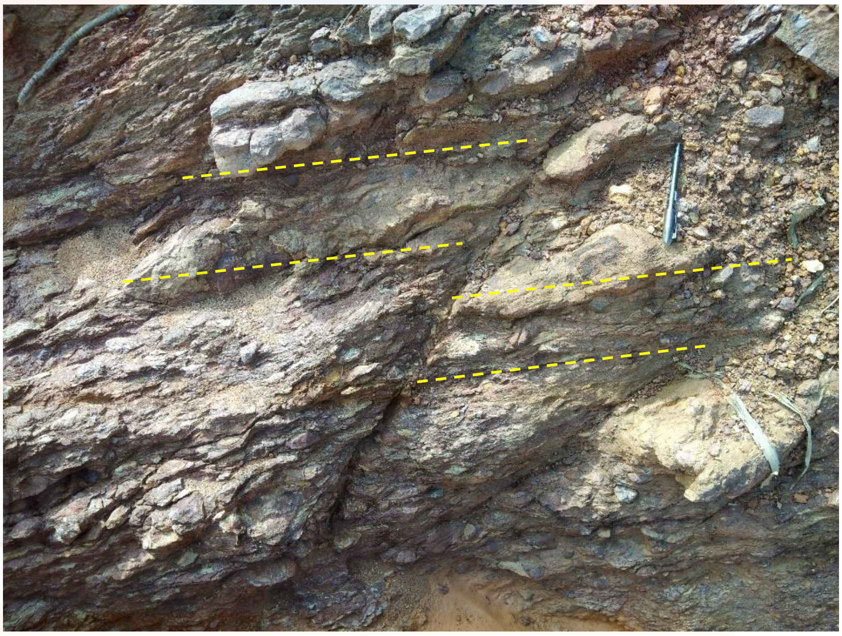


Figure 4.32: The strike-slip fault.

Figure 4.33: The wavy fold and a chevron folds on the mica schist.

The fold is folding because of the stress and strain on the rock which depend on the plasticity and elasticity of the rock. This normally happened on the hill geomorphology unit which the folding structure become a hill look like.

Figure 4.34: The chevron fold and wavy folded mica schist.

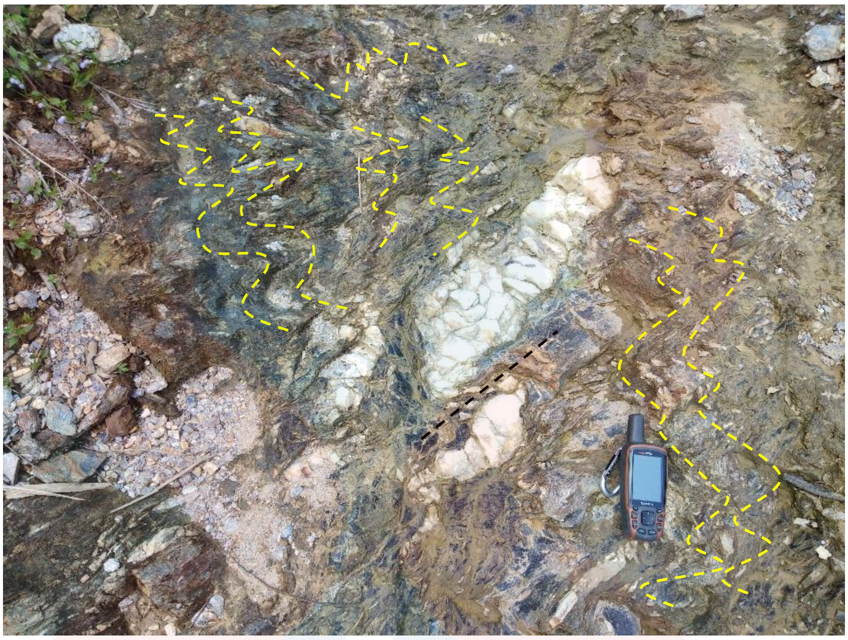


Figure 4.35: The wavy folds mica schist intercalated with quartz vein.

Quartz vein intruded in the mica schist unit when the folds is folding then leave the space to other minerals can intruded.

Figure 4.36: The wavy folds structure on mica schist.

Figure 4.37: The wavy folding on metamorphic rock.

From the observation localities in the Figure 4.37 showed that these areas are near the fault zone as researcher mention the geological map in Figure 4.39 as an inferred fault. Because of the massive structural geology there interpreted the fault zone located near the observation point. Within this area, there is a channel that straight line to the downhill. Perhaps the strike-slip fault occurred as the researcher mention in the geological map as inferred fault. But there is no evidenced on how long the displacement.

4.4.3 Joint

Mostly the joint analysis on strike orientation in research area are non-systematic joints due to the rock irregularities in the rock of joints orientation based on the research conducted in the geological mapping. The table 4.2 below shows the joint 1 analysis through the strike orientation data taken in the field at quartzite rock.

Table 4.2: Joint 1 (Coordinate N 04º 42' 06'', E 101º 49' 53'').

Strike Orientation									
312	319	307	316	117	140	160	357	352	195
028	314	304	352	358	338	326	192	181	009
192	140	148	186	202	197	196	193	146	195
017	263	200	284	263	282	140	184	160	166
210	134	95	162	358	332	274	294	350	

The joint analysis shows in the Figure 4.37 that compression force is from NE-NW direction in this coordinate. This analysis could not accurate much because the data joint analysis based on the abilities of the researcher.

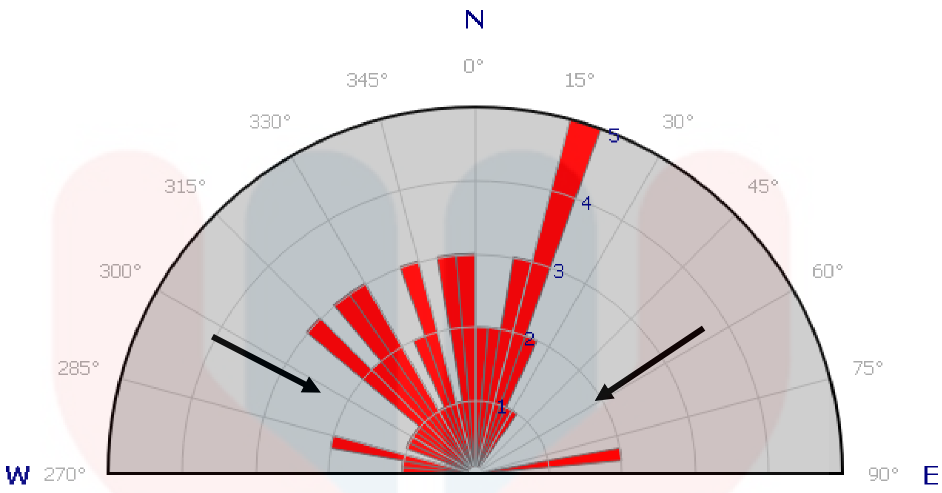


Figure 4.38: The joint analysis based on strike orientation.

4.5 Historical Geology

The research of the Earth transitions and its life forms over time is the historical of geology. This covers palaeontology and paleoclimatology for example. Historical geology gives important information regarding past climatic changes, volcanic eruptions and earthquakes to predict the sizes and the rates of future events as well as offering a theoretical basis for understanding Earth growth over time.

The historical geology of the research area is the forces of tectonic activities on Bentong-Raub suture on NNW-SSW regional structure between Sibumasu plate and Indochina plate that are suturing together. The tectonic forces from an NNW-SSW triggered the landform to change. These landform in the beginning tectonic forces slowly compressing the rock. Many rocks were compacted from sedimentary to metamorphic rock which is quartzite, conglomerate and mica schist.

Tectonic movement keeps compressing the landform until the rock reach the limit of the ductility and elasticity. Many structural geological arise and enormous scale evidence in form of Gunung Ayam. Gunung Ayam are evidence of compressing forces from tectonic movement through enormous thrust fault. Thrust fault uplifting the Gunung Ayam because regularly the conglomerate rock is form from deposition of marine, fluvial, estuarine, lacustrine and glacial. Clearly shown the Gunung Ayam are form through the uplifting processes. Figure 4.39 showed the geological map of research area.

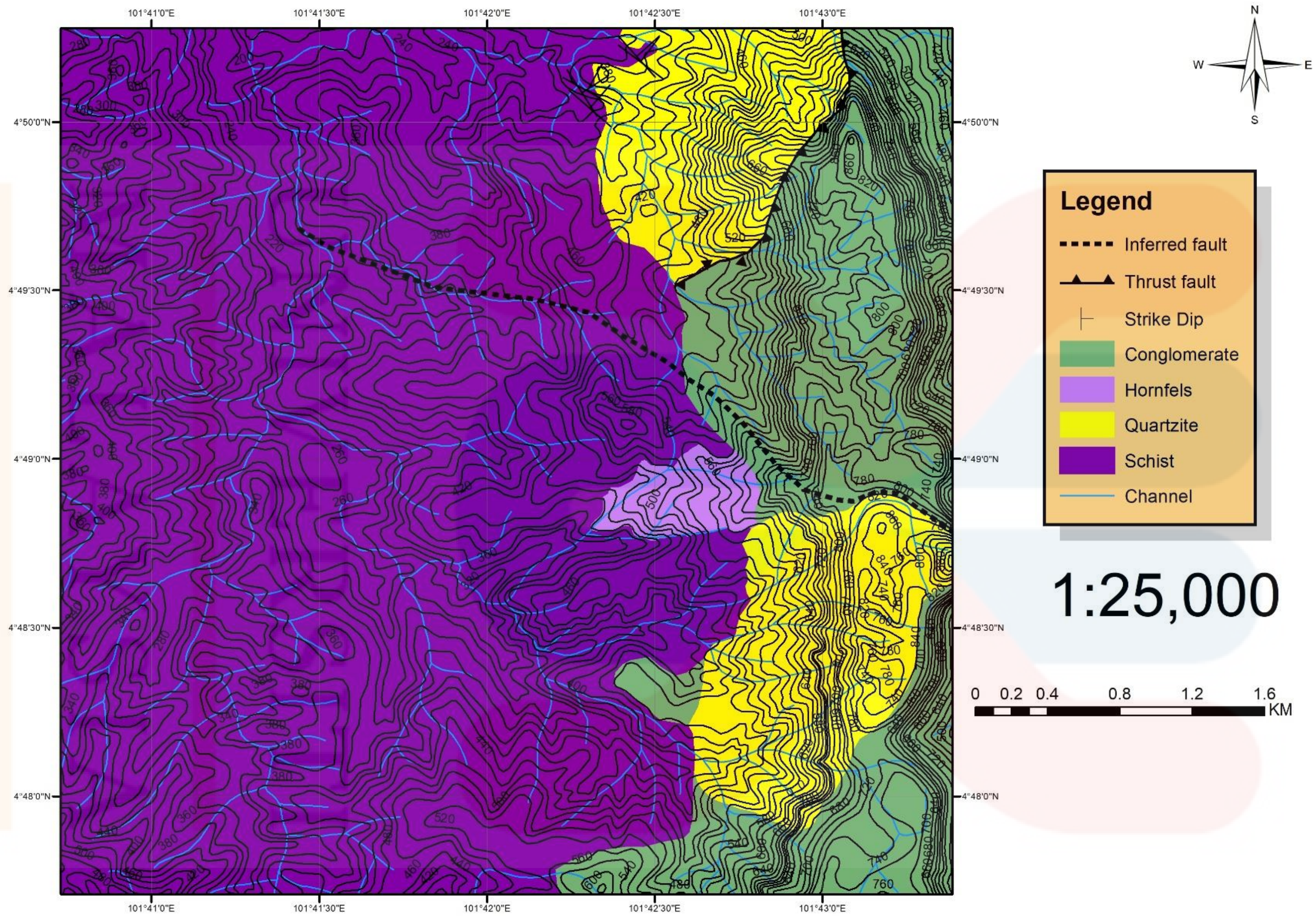


Figure 4.39: The Geological Map of Gunung Ayam, Lojing.

CHAPTER 5

DATA ANALYSIS OF SLOPE STABILITY ANALYSIS

5.1 Introduction

Malaysia are one of the extremely high weathering rates where known as tropical country. Most of the rocks in Malaysia disrupted by chemical and biological weathering which is lead to loosen component of rock and tend to breaks. Consequently, 2 targeted weathered rock slopes were research on their rock quality through Rock Mass Rating (RMR) system suggested by Bieniawski (1989). The RMR system was also using the geotechnics methodology on rock slope for instance rock strength and discontinuities parameters.

5.2 Geology of targeted rock slopes

Research area of this study is consisting of 25 km^2 box area. There is a Gunung Ayam located in the research area at Lojing district. Respectively, the name of the research takes from Gunung Ayam. About rock slope stability, 2 rock slopes included in the research area which exposed along roadside and hillslope of Gunung Ayam.

5.2.1 Rock Slope 1

Rock slope 1 is encompassed of quartzite outcrop MAL 025. The localities for rock slope 1 are located at N 04° 49’ 48’’, E 101° 42’52’’. Slope surface of conglomerate was mostly covered by moss. It was measured to 10m width and 7m height. The conglomerate rock is moderately weathered. The location of the rock slope 2 is located on a trail for hiking of Gunung Ayam. The rock slope is the slope face of foothills of Gunung Ayam. The outcrops shown a moss on the surface slope it called biological weathering that possibly disrupted the rock strength and loosen the particles of rocks. The rock slope cover with the moss because of the condition of rock and weather there that normally not dry. The condition of slope slightly damp.

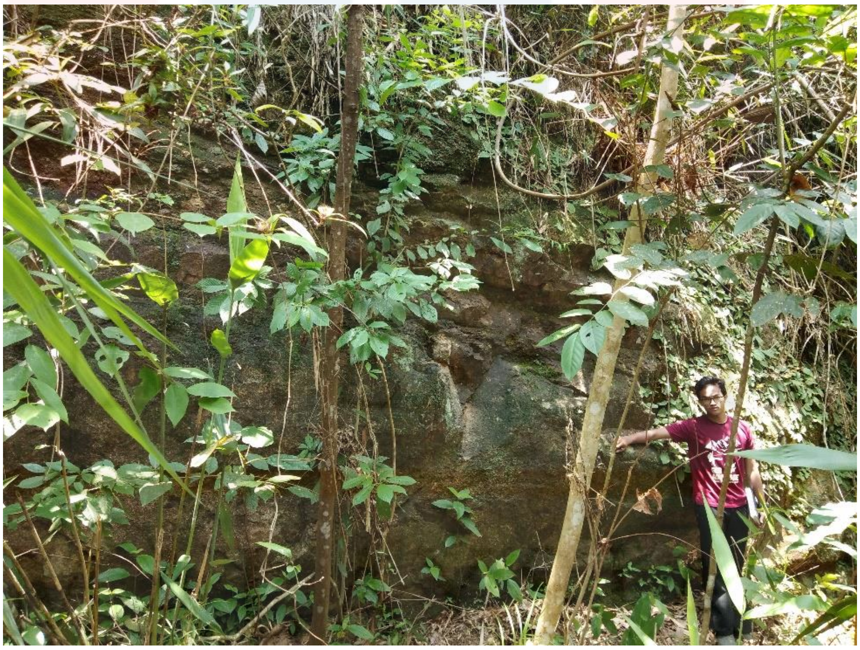


Figure 5.1: The conglomerate rock slope 1.

5.2.2 Rock slope 2

Rock slope 2 is encompassed of conglomerate outcrop MAL 028 which marked with a rock fragment angular and rounded. The localities for the rock slope 2 located at N 04^{o} 49’ 38’’, E 101^{o} 42’ 37’’. Generally, it was cut slope for plantation road that located at near of Gunung Ayam. Plantation road was used by rubber plantation workers on daily works. It was measured about 6m width and 4m height of slope face. The outcrop was shown a red-blockish colour on the surface slope rock because of chemical weathering. The outcrops are moderately weathered suitable with research title for analysis rock slope stability on moderately weathered.

Figure 5.2: The quartzite rock slope 2.

5.3 Point Load Test

This test carried out to determine of the rock strength on weathered rock slope in research area discussed previous chapter. Generally, the rock was done by applying the compressive force on rock sample from those slopes. Regarding to this research used the point load test methodology because of the lower cost than the uniaxial compressive strength (UCS) test. Irregular test was chosen because of the rock sample in an irregular shape. There are two rock sample in two rock slopes carried out the point load test. Before the test was carried out the rock sample 1 and rock sample 2 measured the rock sample with the ruler.

Result of point load test was summarized and tabulated in the table 5.1. Rock sample 1 represent of rock slope 1 and rock sample 2 represent of rock slope 2. The result shows the rock slope 2 has higher rock strength than rock slope 1.

Table 5.1: Result of Point-Load Test.

Rock slope	**1**	**2**
Diameter, D (mm)	66.80	47.20
Width, W (mm)	80.84	85.50
Load at failure, P (kN)	37.35	46.27
Point Load Index Strength, I_s (MPa)	0.0054	0.009
Size Correction Factor, F	1.256	1.175
Equivalent core diameter, De^2 (mm)	6875.64	5138.29
Corrected point load index strength, $I_{s\,(50)}$ (MPa)	0.0067	0.0106

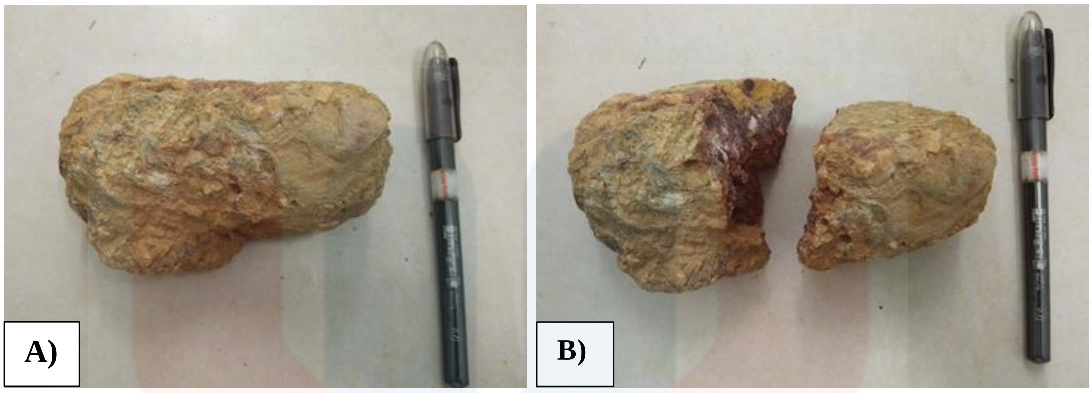


Figure 5.3: Rock sample 1. A) Before point load test B) After point load test.

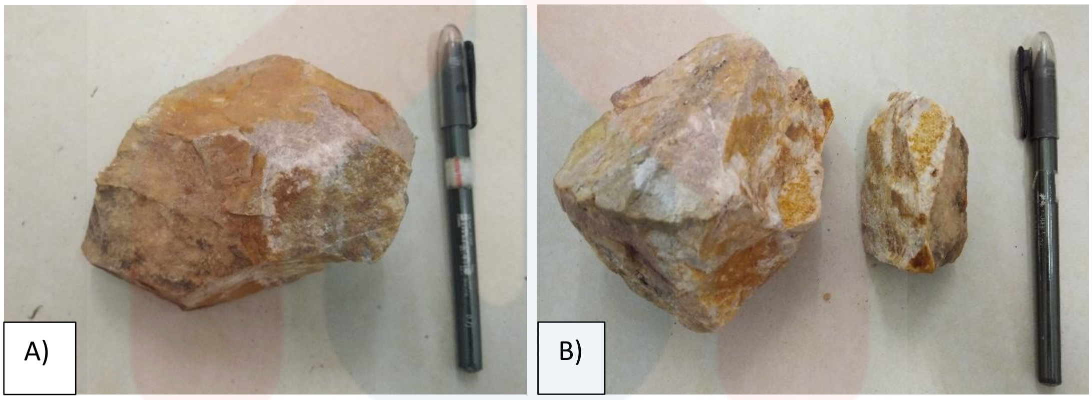


Figure 5.4: Rock sample 2. A) Before point load test B) After point load test.

5.4 Discontinuity Survey

Commonly, discontinuities have a high impact on rock engineering properties and are important factors for stability on the rock slope. It is consequently essential that it is enforced to be carried out. Essentially the discontinuities of joints, cleavage, bedding planes, foliation planes and other factors of rock deformation were evaluated and analyzed. Scattered across the rock surface naturally and can be seen quickly. The identified discontinuity data has been included in RMR and kinematic rock slope analysis. The scanning line method has been used in this research in discontinuities on targeted rock slopes in research areas. The process was carried out by a line (measuring tape) were cross cut on the bare rock side and the exposed discontinuities (Chamine et al., 2015). The discontinuities that intersected with lines have been measured, described and recorded.

5.4.1 Discontinuity survey of rock slope 1

The rock slope 1 was measured 6m width and 4m height of slope face. The data dip direction and dip angle of slope face was measured is $85^o/128^o$. The measuring tape as a scanning line was pulled along the length of the slope on the Figure 5.1. Based on the geological structures in Chapter 4, which the discontinuities were found in a small amount in others outcrop. Furthermore, the bunch of discontinuities also found in rock slope 1.

Table 5.3: The data of joint of slope 1

Strike (°)	Dip (°)	Length (m)	Strike (°)	Dip (°)	Length (m)
355	80	3	299	80	1
329	35	1	307	35	2

42	51	1	307	51	4
38	33	3	291	38	2.1
301	34	2	58	34	1
326	60	2	342	60	4
54	68	1	20	68	2
352	62	2	297	62	2
331	62	1	313	62	3
308	88	3	28	88	2
346	80	1	61	49	1
49	35	3	331	43	1
34	51	2	352	62	2
302	38	2	54	68	2
24	34	1	326	61	2.3
293	49	3	38	46	1.4
355	62	2	307	67	2.1
49	67	2	342	62	2.5
346	72	1	313	42	3.1
291	38	3	55	43	1

5.4.2 Discontinuity survey rock slope 2

Rock slope 2 was measured 10m width and 7m height of slope face. The value of the dip direction and dip angle was measured to be 84^{o}/ 137^{o}. Within this slope the scanning line methodology was used in order to gaining data collection in the rock slope. A total of 40 discontinuities had been recorded and traced. These discontinuities taken in order to complete the data collection for the kinematic analysis.

Table 5.4: The data joint on slope 2

Strike (^{o})	Dip (^{o})	Length (m)	Strike (^{o})	Dip (^{o})	Length (m)
87	56	3	328	80	1
350	50	2	346	77	2
351	20	1	30	40	4
352	23	1	320	70	1
315	60	2	260	60	4
290	80	2	305	43	1
305	65	2	15	64	1
307	53	1	300	50	4
15	70	1	310	60	3
300	45	4	351	75	1
277	15	1	30	50	1
340	70	1	36	50	3
295	50	3	15	45	2
10	85	1	290	50	4
325	82	3	270	54	2
340	52	3	40	70	1

270	20	4	35	75	5
292	78	4	300	70	1
300	70	2	80	21	1
25	80	3	305	55	3

5.5 Rock Mass Rating (RMR) system

RMR system consist of 6 parameters which used to rate the rock masses and the quality of rocks. It requires the results from Point- Load Test and discontinuities survey which discussed in previous part. The RMR ratings for two rock slopes were summarize in the Table 5.5. For the data collection of rock strength was taken by the point load test. Rock slope 2 is the highest strength of the intact rock material. The second parameter out of six is the RQD parameter which rock slope 1 is the highest value than rock slope 2. This research using volumetric discontinuity count for data collection for RQD. However, the best based on accuracy of RQD is by drill core recovery instead of volumetric discontinuity count. Perhaps, the result may not very accurate.

The third parameter is spacing of discontinuities. This parameter was obtained from the mean of the average spacing of joint sets. Rock slope 1 of the spacing discontinuities fell within the range between 0.6 – 2.0 metres. Then spacing for rock slope 2 was range between 200 – 600 millimetres. For the fourth parameter out of six is the condition of discontinuities based on the observation fieldwork mapping. Rock slope 1 showed a rough roughness discontinuities surface. The rock slope 2 showed a rough roughness on discontinuities surface. Rock slope 1 of the aperture discontinuities is less than 0.1 millimetres and rock slope 2 of aperture on discontinuities persistence range between 0.1-1.0 millimetres. Rock slope 1 and 2 is a same condition of types weathering which is moderately weathered rock. Infilling both rock slope is none exist.

Fifth parameter was a groundwater condition which at the rock slope 1 and 2 is different. Rock slope 1 groundwater condition is damp and rock slope 2 is completely dry as no water present perhaps because the weather condition is extremely hot because of there is no biological in surrounding area. Slightly difference in the rock slope 1 because the area was completely in the forest and the weather is normal room temperature. The surface of rock slope 1 mostly have a lichen which showed the rock surface was very damp condition. Otherwise, the seepage also was not found in the both rock slope surface.

Table 5.5: RMR ratings of rock slopes in research area.

No.	Parameter	Rock Slope 1		Rock Slope 2	
		Value/Description	**Rating**	**Value/Description**	**Rating**
1.	Strength of intact rock (Point- load strength index)	0.0067 MPa	4	0.0106 MPa	4
2.	Rock Quality Designation (RQD)	Fair (moderately weathered rock) 60.23%	13	Fair (moderately weathered rock) 52.56%	13
3.	Spacing of discontinuities	0.6 – 2.0 m	15	200 – 600 mm	10
4.	Condition of discontinuities	Discontinuity length 3-10m, Aperture <0.1mm, Roughness rough, Infilling None, Weathering Moderately weathered.	21	Discontinuity length 3-10m, Aperture 0.1-1.0mm, Roughness rough, Infilling None, Weathering Moderately weathered.	20

5.	Groundwater condition	Damp	10	Completely Dry	15
6.	Orientation of discontinuities	Favourable	-5	Fair	-25
	Total Rating	**-**	**58**	-	**37**

Based on the RMR total rating system in Table 5.5, rock masses of rock slope 1 were classified as class number II which is rock quality is good. Furthermore, the rock slope 2 was classified as class number IV which is rock quality is poor. This indicated the rock slope 1 is more stable than rock slope 2 based on the Bieniawski (1989) in Table 2.1. Based on the guideline in Table 2.1, the rock slope 1 were interpreted to have 0.3-0.4 MPa cohesion and the friction angle in range between 35^{o}- 45^{o}. The rock slope 2 as classified in class number IV which the cohesion is 0.1-0.2 MPa and the friction angle in between 15^{o}- 25^{o}. Based on Bienawski (1989) in Table 3.1 the RMR systems indicated that the class number II in rock slope 1 could stand-up time in average was one years for 10 m span and rock slope 2 as class number IV could possibly stand-up time in average for 10 hours for 2.5 m span. These also based on the friction angle of rock masses.

5.6 Kinematic Analysis

Kinematic Analysis of rock slopes is the research regarding on a rock slope stability. It was done by used a software which is the Rocscience Dips version 6.0. Typically, Dips software is used for studied the rock slope stability based on the data discontinuities and orientation of slope face in stereographic projection. Then, the possible mode of slope failure can be predicted from the orientation of discontinuities and orientation of discontinuities and orientation of slope face with the table kinematic analysis and the weakest zone could be seen on the stereographic projection. The Rocscience Dips software also produce the analysis table based on the discontinuities survey from rock slope.

5.6.1 Kinematic Analysis rock slope 1

Rock slope 1 was a slope with Conglomerate rock outcrop. Based on Vallejo & Mercedes (2011) the basic of friction angle possessed by conglomerate is 35^{o}.

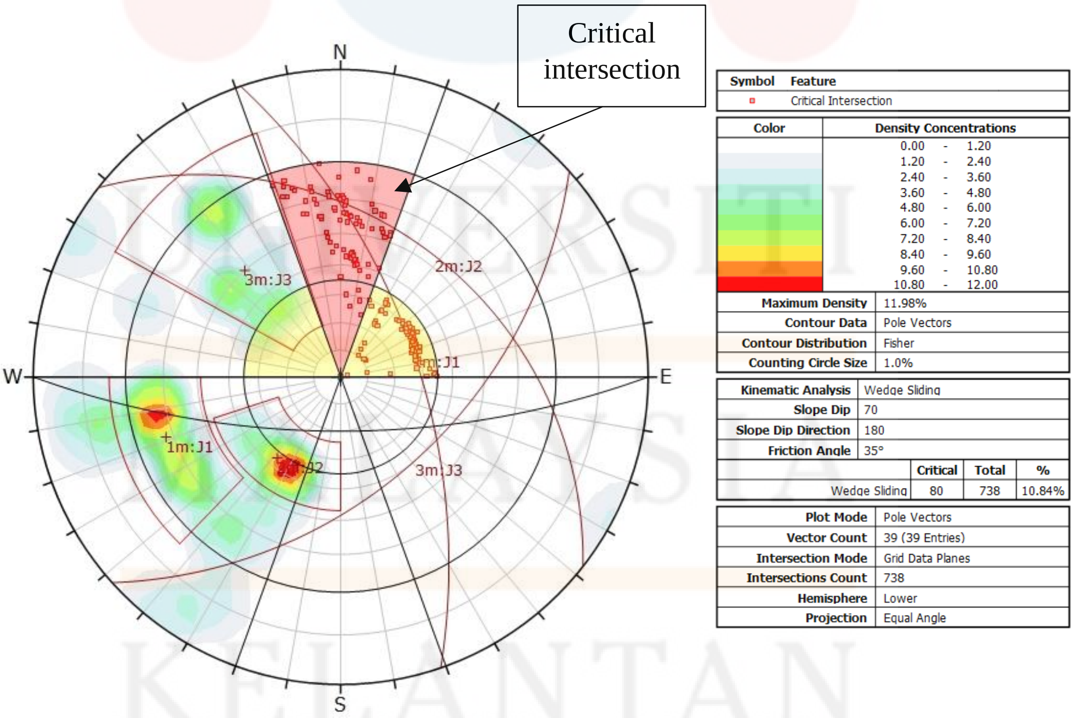


Figure 5.5: Wedge failure on rock slope 1 with analysis.

In Figure 5.5 and 5.6 shows the toppling failure is the most failure possibly happened is rock slope 1. Based on the outcrop of conglomerate at foothills of Gunung Ayam the slope was too steep and high the angle slope which is 85°. All the data discontinuities are taken at the slope. There are three joint set in the Figure 5.5 which is J1, J2 and J3. These joint set intersect between J1 and J2. The red zone is the most critical failure could be possibly happened in future. As much 108 critical intersection in the red zone which is indicated to the direct toppling failure. Based on the table of kinematic analysis the chances to failure is direct toppling which is 14.63%. The high-quality data are based on the more experienced data collector discontinuities.

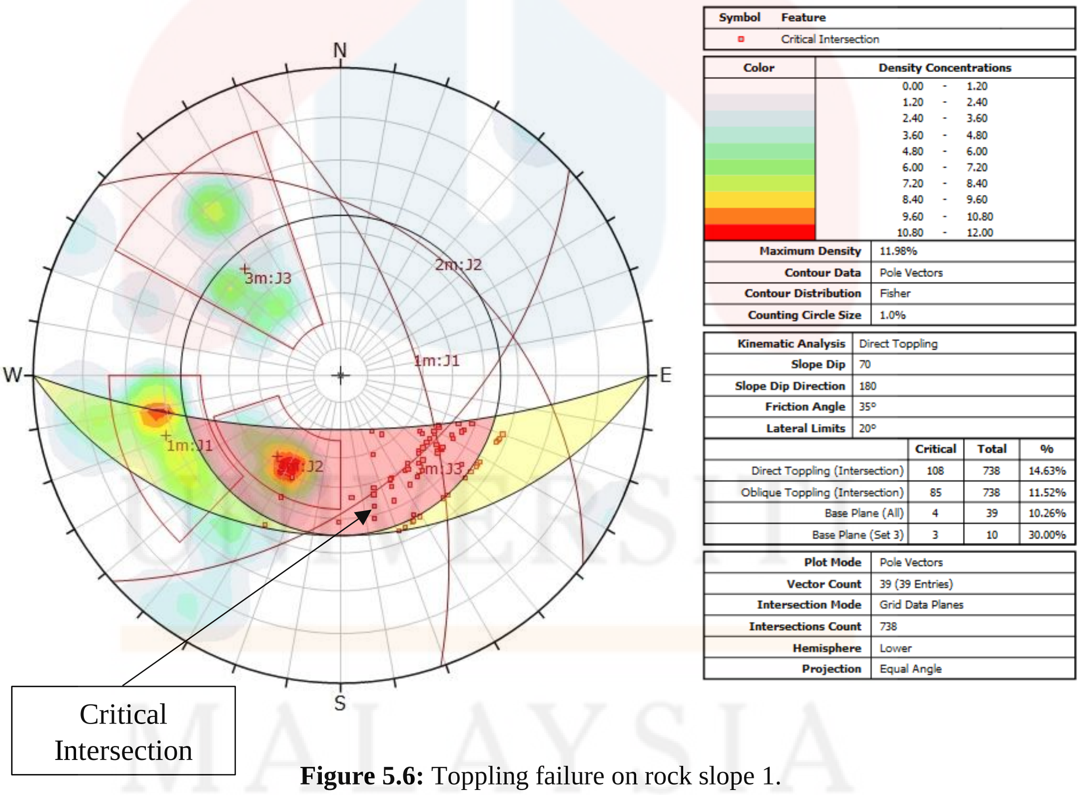


Figure 5.6: Toppling failure on rock slope 1.

Based on the Figure 5.6 shows the toppling failure on the rock slope also possible. The wedge failure at slope 1 was 10.84% are low compared to direct toppling percentages. Only 80 critical intersection than direct toppling failure so the high chances to failure is direct toppling failure.

5.6.2 Kinematic Analysis rock slope 2

Lithology of rock slope 2 was a quartzite rock. Based on the Vallejo & Mercedes (2011) the friction angle of quartzite in range 40-55°. The researcher using 45° in the Dips software as a friction angle in kinematic analysis. The types of failure have 3 types planar, wedge and toppling failure. In the Figure 5.7 and 5.8 is the kinematic analysis. The critical zone is in 38.00 % on wedge failure. The discontinuities survey also have 3 major joint set which shown a wedge failure in SE direction. The red zone was critical intersection which is between J1 and J2 as much 180 critical intersection point.

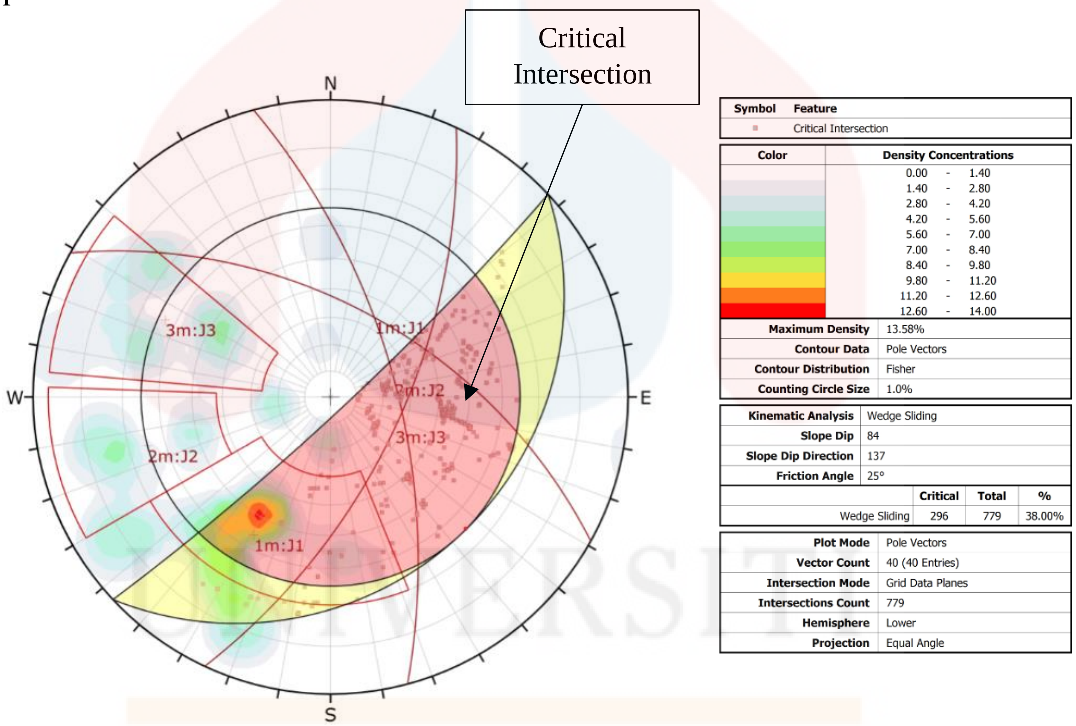


Figure 5.7: The wedge failure on kinematic analysis.

In the Figure 5.8 shown an oblique toppling which is 8.86 % based on the critical intersection between J1 and J2, J3 and J2 which calculated the critical section is 135 point from 779.

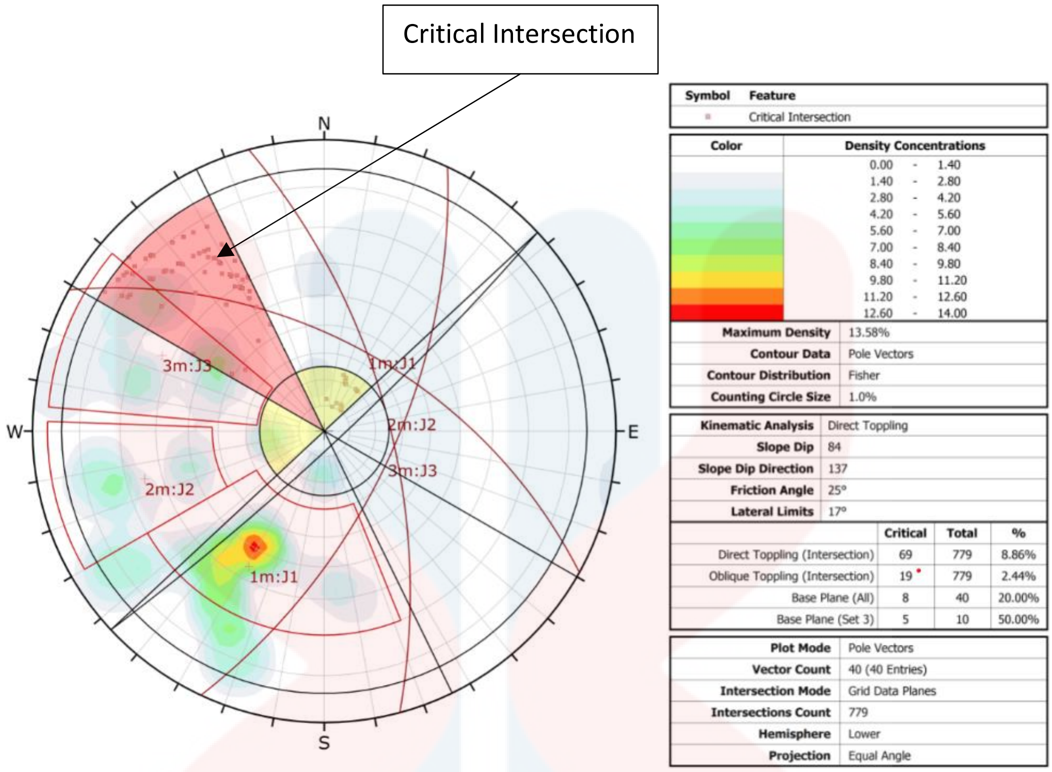


Figure 5.8: The toppling failure on kinematic analysis.

Based on the both figures, the wedges failure very likely to happened on the rock slope 2. Because the dominant of the J1 and J2 in the critical intersections.

5.7 Summary

Discontinuities survey is the mandatory part in order to gained the rock slope stability analysis as in the previous part of discussion. Based on the data analysis in slope stability analysis which is using 6 parameters in order to fulfil the classification of RMR system rating. These are including the discontinuity length (persistence), aperture, roughness, infilling and weathering. Furthermore, the point load test was used than uniaxial compressive strength which is the result could be high accuracy for rock strength. Groundwater classification also used in order to complete the RMR system rating. In addition, the kinematic analysis is used for rock slope analysis is tend to have the result of which types failure in the rock slope stability. Rocscience Dips software is used in order to complete the kinematic analysis. The good accuracy of data collection is based on the researcher expert, experience and knowledge.

Lithology of rock slope 1 is the conglomerate rock with moderately weathered rock based on classification of RMR rating systems. The discontinuities data collection is 40 vectors. There is no fault or any structure on rock slope. The groundwater at slope face for general condition is damp. Based on the data analysis for point load test is rock slope 2 is high strength than rock slope 1. Rock Mass Rating systems rock slope 1 is in the class number II which is good rock masses. In the kinematic analysis the rock slope 1 tend to rock failure in types of toppling failure and wedge failure. The rock slope 1 the most possibly occurred is toppling failure than the wedge failure.

Lithology of rock slope 2 is the quartzite rock with moderately weathered rock based on the classification of RMR systems. The discontinuities recorded was 40 vectors. There is no structural geology was found in the rock slope face. The general condition of groundwater at slope face was completely dry. Based on the analysis for point load test the rock strength rock slope 2 is the stronger than rock slope 1. Rock slope 2 based on the RMR systems is in the class number IV which is poor quality of rock masses. By the kinematic analysis of rock slope 2 is in types toppling failure and wedges failure. The tend the rock failure is prefer wedges failure than the toppling failure. Conclusion, the rock slope 1 is more stable than rock slope 2 based on percentage of failure kinematic analysis which showed in the result analysis and the RMR rating system also showed the result same which rock slope 1 is more stable than rock slope 2.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In conclusion, all the objectives were achieved. In the context of the general geology, a geological map of Gunung Ayam, Lojing was produced in scale of 1:25000. In order to geological map, research area was studied in terms of geomorphology, stratigraphy and structural geology. In the sense of the geomorphology, research area consisted of hills unit, valleys unit and mountains unit which marked with elevation ranged between 200 to 1000 metres above the sea level. The rocks comprised up the research area were subjected to biological, chemical and physical weathering and the mix between them. Drainage pattern in the research area is the dendritic pattern identified in the research area.

In the sense of stratigraphic, research area was mainly comprised of 4 rock units which is conglomerate, schist, hornfels and quartzite which presented green, dark blue, light white and yellow. Based on the geological interpretation the schist unit was the oldest rock unit and conglomerate is the newest rock unit. All rock unit was believed in a Gua Musang Formation. It was believed as the result formed of oceanic-continental convergent plate tectonic between Palaeo- Tethys ocean and East Malaya-Indochina.

In term of structural geology, three geological features were found in the research area. These were fault, fold, vein and joint. They were formed as a result of deformation event. At Permo- Triassic period, the Palaeo- Tethys ocean and East Malaya- Indochina were subduct and formed a Bentong- Raub suture which affected to the Gunung Ayam clearly showed the lineament that indicated to the fault which is thrust fault in between conglomerate and the quartzite unit. These affected to the deformation near Gunung Ayam.

In the sense of geotechnical engineering, quality of rock masses of two rock slopes in the research area was determined by using Rock Mass Rating (RMR) system. Rock slope 1 was the slope at the foothills of the Gunung Ayam. Rock slopes 2 were cut slope near the Gunung Ayam for the road. Lithology of rock slope 1 is the conglomerate rock with moderately weathered rock based on classification of RMR rating systems. The discontinuities data collection is 40 vectors. Based on the data analysis for point load test is rock slope 2 is more strength than rock slope 1. Rock Mass Rating systems rock slope 1 is in the class number II which is good rock masses. In the kinematic analysis the rock slope 1 tend to rock failure in types of toppling failure and wedge failure. The rock slope 1 the most possibly occurred is toppling failure than the wedge failure.

Rock Slope 2 is a lithology focused on the description of RMR classification for the quartzite rock. There were 40 sets with discontinuities. In the face of the rock slope there is no structural geology. The average groundwater situation on the hill was totally dry. The rock strength rock slope 2 is stronger than rock slope 1 based on an analysis from the point load test. Rock slope 2 is class IV relying on the RMR systems and of poor rock mass quality. The kinematic analysis of rock slope 2 toppling failure in types and wedges failure. The propensity of rock failure is tended to wedges failure than toppling failure.

Therefore, some blocks of rock may break and fall due to weathering at rock slope 1 and 2 onto the ground they were all stable. Conclusion, the rock slope 1 is more stable than rock slope 2 based on RMR rating system and kinematic analysis. After all, may the rock slopes could possible to fall in large scale due to weathering but in 20 years or more. Thus, no further study analysis on was carried out on them. By looking on relationship between the general geology and rock slope stability, the general geology helped regarding to understand the geology of rock slope 1 and 2 in further while the rock slope stability more focused on the engineering properties of geology such as discontinuities parameters.

6.2 Recommendation

In term of general geology, the geological age of lithology in this research was mainly interpreted based on the previous research works. Thus, a possibility of actual age the rock not accurate because the previous research works at different localities but still present eventhough in a low possibility. Thus, the recommendation for find accurate of age rock is find out the fossils in the research area since around 20% near Gunung Ayam have limestone unit may have microfossil. Otherwise, the radioactive dating would be found out the actual date of the rock itself.

In the sense of geotechnical engineering, RMR systems is the system that depends on the field observation which is based on the researcher's abilities who is expert and experiences. Moreover, its accuracy can be questioned as everyone has their own interpretation based on the field observation. Roughness of discontinuities can have different interpretation from different researchers based on the standard measurement or calculation methods and it is just simply comparing and referring to the surface roughness profile suggested by Barton and Choubey (1977).

Based on the finding of RQD from J_v is not very accurate because Palmstrom (2005) said that the correlation between RQD and J_v is poor. The best way to find RQD is from the drill core logs but literally the UMK does not have the coring machine and cost of the coring services was high.

Lastly, friction angle used in the kinematic analysis was just referring to typical friction angle value of particular lithology which is based on the Look (2014). The truth is the friction angle might have differentiation based on the localities of the rock slopes, deformation and weathering. Therefore, the uniaxial compressive test or direct shear box are recommended. Those tests are very high cost and UMK do not have it neither one of them. The recommended was UMK could buy all these machines so the engineering student able to use better way or obtain better and more precisely results.

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