GEOLOGY AND LANDSLIDE POTENTIAL USING RESISTIVITY METHOD IN PALOH, GUA MUSANG, KELANTAN

By

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

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DECLARATION

I declare that this thesis entitled Geology And Landslide Potential using resistivity method in Paloh , Gua Musang , Kelantan is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently. submitted in candidature of any other degree.

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APPROVAL

“I/ We hereby declare that I/ we have read this thesis and in my/our opinion this is sufficient in terms of scope and quality for the award of Bachelor of Applied Science (Geoscience) with Honors”

Signature : ……………………………….

Name of Supervisor : :……………………….

Date : ………………………………

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Geology And Landslide Potential Using Resistivity Method,Paloh,Gua Musang,Kelantan

ABSTRACT

Research entitled geology of Kampung Paloh Tiga,the research was carried to fully understand the general geology of the research area.The main lithology at this area is Meta Mudstone,Andesite,Phyllite and Vitric Tuff. This geological mapping is conducted to update the geological map and study the general geology of study area. This part conductucted by interpreting the map such as land use map, stream map, terrain map and others. It helped the study of landslide at that area. This study also discusses the geomorphology, stratigraphy, structural geology, and historical geology of the study area. Kampung Paloh Tiga is located in Gua Musang district, which is positioned at the foot of Peninsular Malaysia's Main Range. The distribution of rocks found in the study area is igneous rock,sedimentary and metamorphic rock, according to research and data collection during mapping. To obtain a more accurate rock type, rock samples were collected and sent to a laboratory for petrographic analysis. The parameters that triggered the occurrence of landslide were identified.. In this research electrical resistivity method is used to analyses the subsurface and weathering grade that affect the landslide hazard. This geophysical method can review the structure and conditions under the surface. Besides, classified the grade of weathering which is a factor of landslide to occur. ArcGIS and Google Earth processed satellite-based geological mapping. . ArcMap's extension tool delineates landform units. Landform components were analyzed using geological maps. The research data were analyzed descriptively to characterize the subject area's geomorphology, landforms, and natural catastrophe risk. Next, electrical resistivity imaging is employed with parallel and perpendicular resistivity lines. The ABEM resistivity system measured subsurface earth's resistance. ABEM resistivity systems include Terameter LS, multifunctional cable, 40 jumper cables, 41 stainless-steel electrodes, a 12-volt battery, and a remote cable. Resistivity survey by Werner and Gradient. The result of apparent resistivity value that will be inversed using software to determine the true resistivity. Resistivity data then will be analyzed using Res2Dinv software.Results shows weak zones at each of the pseudosection that have the potential of landslide will occur which concluded that landslide is potentially happen in area that have swollen area that consist of water.

Keywords: Geological map, landslide potential, lithology, electrical resistivity imaging

Geologi Dan Pemetaan Kecenderungan Tanah Runtuh Menggunakan Kaedah Keberintangan Di Paloh,Gua Musang,Kelantan.

ABSTRAK

Penyelidikan bertajuk geologi Kampung Paloh Tiga, penyelidikan dijalankan untuk memahami sepenuhnya geologi umum kawasan kajian. Litologi utama di kawasan ini ialah Meta Mudstone, Phyllite, Andesite dan Vitric Tuf,Meta Mudstone, Phyllite, Andesite dan Vitric Tuf. Pemetaan geologi ini dijalankan untuk mengemaskini peta geologi dan mengkaji geologi am kawasan kajian. Bahagian ini akan dijalankan dengan mentafsir peta seperti peta guna tanah, peta aliran, peta rupa bumi dan lain-lain. Ia dapat membantu kajian tanah runtuh di kawasan tersebut. Kajian ini juga membincangkan tentang geomorfologi, stratigrafi, geologi struktur, dan geologi sejarah kawasan kajian. Kampung Paloh Tiga terletak di daerah Gua Musang, yang terletak di kaki Banjaran Utama Semenanjung Malaysia. Taburan batuan yang terdapat di kawasan kajian ialah batuan igneus, batuan enapan dan metamorf, mengikut kajian dan pengumpulan data semasa pemetaan. Untuk mendapatkan jenis batuan yang lebih tepat, sampel batuan dikumpul dan dihantar ke makmal untuk analisis petrografi. Parameter yang mencetuskan kejadian tanah runtuh dikenal pasti.. Dalam kajian ini kaedah kerintangan elektrik digunakan untuk menganalisis gred bawah permukaan dan luluhawa yang mempengaruhi bahaya tanah runtuh. Kaedah geofizik ini boleh menyemak struktur dan keadaan di bawah permukaan. Selain itu, kita juga boleh mengklasifikasikan gred luluhawa yang merupakan faktor kejadian tanah runtuh. ArcGIS dan Google Earth memproses pemetaan geologi berasaskan satelit. . Alat sambungan ArcMap menggambarkan unit bentuk muka bumi. Komponen bentuk muka bumi dianalisis menggunakan peta geologi. Data kajian dianalisis secara deskriptif untuk mencirikan geomorfologi kawasan subjek, bentuk muka bumi, dan risiko bencana alam. Seterusnya, pengimejan kerintangan elektrik digunakan dengan garisan kerintangan selari dan serenjang. Sistem kerintangan ABEM mengukur rintangan bawah permukaan bumi. Sistem kerintangan ABEM termasuk Terameter LS, kabel pelbagai fungsi, 40 kabel pelompat, 41 elektrod keluli tahan karat, bateri 12 volt dan kabel jauh. Tinjauan kerintangan oleh Werner dan Gradien. Hasil daripada nilai kerintangan ketara yang akan diterbalikkan menggunakan perisian untuk menentukan kerintangan sebenar. Data kerintangan kemudiannya akan dianalisis menggunakan perisian Res2Dinv. Hasil daripada nilai rintangan yang jelas yang akan songsang menggunakan perisian untuk menentukan kerintangan sebenar. Data rintangan kemudian akan dianalisis menggunakan perisian Res2Dinv. Keputusan menunjukkan zon lemah di setiap kawasan yang berpotensi berlaku tanah runtuh akan berlaku yang menyimpulkan bahawa tanah runtuh berpotensi berlaku di kawasan yang mempunyai kawasan bengkak yang terdiri daripada air.

Kata kunci: Peta geologi, potensi tanah runtuh, litologi, pengimejan kerintangan elektrik

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CHAPTER 1

INTRODUCTION

1.1 Background Of Study

Research is conducted in Kelantan, Malaysia, which is located in the north eastern part of Peninsular Malaysia. Kelantan has a tropical climate, with temperatures ranging from 22 to 33 degrees Celsius. Paloh Tiga is near by the Gua Musang formation where it is dominated by volcanic rock and sedimentary rocks. The geomorphology of Paloh Tiga is consists of a small resident area, police station, masjid, hills and forest area.

Study of geophysics is a study that focused on the physical process that occur on a large and small and others type of scales, it is included from the microscopic scales of properties to the forces like gravity and magnetism that acts towards the planetary and inter-planetary type of scales. Geophysics study is crucial because it has an important impact in the welfare to society and the planet of Earth. Generally, geophysics is the study to measure the physical properties under the earth surface. This research is first part of final year undergraduate research project which is to investigate about landslide hazard that occur at Paloh,Gua, Musang,Kelantan.

Movement of rock or soil residue that move down a slope is called landslide. There are two common things that occur during landslide which they are result of soil failure and rock materials that make up the hill slope and they are driven by gravity forces. In a rock fall, it can require variation of size from a single boulder or topple tons of millions of cubic meters of material in a debris flow. However, in Malaysia case, most of the landslides occur because of flawed design, improper construction and non-maintenance of slopes which correlates with the human error, (Kazmi ,2016).For example, case in highland tower landslide in 1993. As a result of the fall of the Highland Towers in Kuala Lumpur, Malaysia, in 1993, 48 people lost their lives. Inadequate soil testing was identified as one of the primary reasons of the landslide in the study that was compiled by Maverick. The surrounding characteristics of the site led to the formation of an undercut. The failure of retaining walls brought on by severe rains was one of the contributing factors that caused a landslide, which in turn led to the collapse of the structure. There were two different kinds of mistakes in the design: an improper soil's bearing test and a pre-construction site visit during the pre-design phase; a failure to identify the peripheral condition at the site; and a failure to design an inadequate retaining wall to contain the site and the building that stood on it. Both of these types of mistakes were made during the pre-design phase.

Slope failure is a common natural hazard in Malaysia and many cases leading to significant economic losses and even fatalities, (H. Hussin,2015) Human action such as mining, quarrying, deforestation, and construction also will lead to cause geohazard of landslide. The slope failure phenomenon is a common natural hazard in Malaysia in which due to the change in slope angle, weathering, heavy rainfall, and overloading, (Nur Azra Zainol Abidin,2020)

In this research electrical resistivity method is used to analyses the subsurface and weathering grade that affect the landslide hazard. This geophysical method can review the structure and conditions under the surface. Besides, classiffied the grade of weathering which is a factor of landslide to occur. This project also consisted of a geological mapping in Paloh area. This geological mapping is conducted to update the geological map and study the general geology of study area. This part will be conduct by interpreting the map such as land use map, stream map, terrain map and others. It help the study of landslide at that area.

1.2 Location

The study area is located at Gua Musang is in Kelantan and it is the largest district of Kelantan. This study will be conducted in a position of southern part of Gua Musang which is covered 25km² of the complete area which is at Paloh. The study area is located at Gua Musang is in Kelantan and it is the largest district of Kelantan. This study will be conducted in a position of southern part of Gua Musang which is covered 25km² of the complete area which is at Paloh. The study area is located at Gua Musang is in Kelantan and it is the largest district of Kelantan. This study will be conducted in a position of southern part of Gua Musang which is covered 25km² of the complete area which is at Paloh

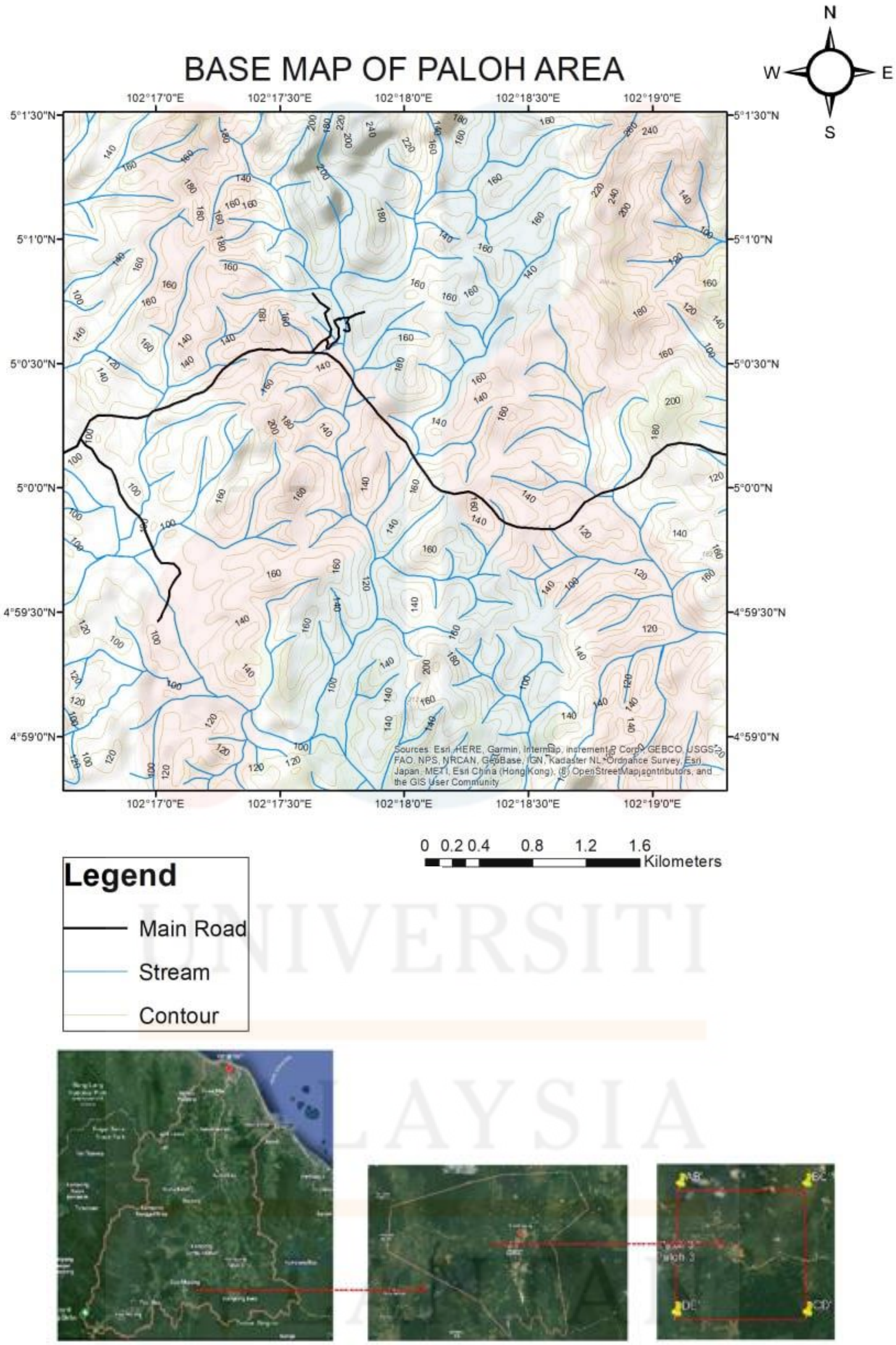


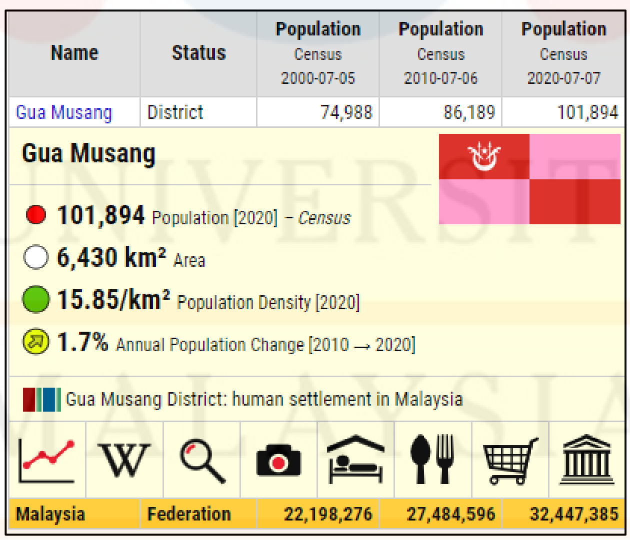
Figure 1.1: Base Map of Paloh Area

1.2.1 Road Connection/Accessibility

There are a few ways to reach Gua Musang including planes, trains, bus or travel by cars. People can come and go to Kelantan by using transport plane and landing at the Sultan Ismail Petra Airport in Pengkalan Chepa, Kota Bharu. In addition, it is around 195km, and it took about 2 hours and 58 minutes to travel from the airport to the Gua Musang. From Kuala Lumpur to Gua Musang it took about 260km and around 3 hours and 53 minutes through Kuala Lumpur to Gua Musang Highway and it took about 4 hours and 36 minutes around 354 km via the East-West Highway that connect Kuala Lumpur to Perak and through Gerik to reach Gua Musang.

1.2.2 Demography

Based on 2020 statistic, the population of Gua Musang is 101 894 people who still living in 6430km².



Name	Status	Population Census 2000-07-05	Population Census 2010-07-06	Population Census 2020-07-07
Gua Musang	District	74,988	86,189	101,894
Malaysia	Federation	22,198,276	27,484,596	32,447,385

Gua Musang

101,894 Population [2020] – *Census*

6,430 km² Area

15.85/km² Population Density [2020]

1.7% Annual Population Change [2010 → 2020]

Gua Musang District: human settlement in Malaysia

Figure 1.2: Population of Gua Musang people

1.2.3 Land use

Palm oil plantations and rubber estates make up most of the study area, with palm oil plantations accounting for around 60% of the total area and rubber plantations, settlements, and forest areas accounting for the remaining 40%. Rural, industrial, leisure, transportation, commercial use, and land for vegetation are some of the land use types. Much of the area is covered with forests, natural forests, or rubber plantations. Because most people in that area rely on natural resources, the study area's residential area is quite large.

1.2.4 Social Economy

The Gua Musang residence mostly gain their own social economic by palm oil plantation. This can be proved by the study area which consist about 60% of palm oil plantation.

1.3 Problem Statement

The first problem statement that need to be emphasize is the geological mapping. The information about the lithologies and geomorphological at the study area is insufficient. Recent construction at Paloh, Gua Musang might expose hidden rocks.

Gua Musang is rapidly becoming more urbanized. Every growing area is vulnerable to geohazards such as landslides. Every year, landslides cause millions of dollars in damage and a significant number of deaths. Many factors contribute to geohazards. Water was the key component or mechanism that caused the landslide to occur. Water can weaken and modify the character of a rock until it becomes soil. Rainfall, precipitation, and water saturation are all examples of water triggers. Because some parts of Gua Musang are at a higher elevation than others, they will receive more rain. The slope's strength will deteriorate as it approaches gravity, making a landslide more likely.

Landslides, on the other hand, are not caused solely by water. Dry weather can also cause rock or soil to deteriorate. To reduce the hazards to the public, a study must be undertaken to show how water affects the occurrence of landslides, as water is the key factor that causes landslides to occur. This will be demonstrated by evaluating the resistivity data to determine the subsurface state. The picture of the subsurface will serve as evidence to raise public awareness. The public must be warned about the slope failing to ensure that they are aware of the existing situation. Before the slope began to fail particles, the current status of the slope needed to be monitored.

1.4 Objective

1. To update the geological map of Paloh Gua Musang in the scale of 1:25000
2. To investigate landslide potential in Paloh area using resistivity method

1.5 Scope of Study

The study was concentrated on of landslide hazard that will be occur Paloh Gua Musang.Geological and landslide potential are two main areas of this study. Electrical resistivity is used to determine the subsurface of the soil or rock and the weathering grade of the slope. For the geological map, the interpretation area' characteristic is used to make map. For the resistivity study, two arrays are use in the method which is Gradient and Werner.

1.6 Significance of study

This research would be an important one to examine the rock weathering quality causes of the landslide. This study will also give important information to the authorities of Paloh to take action and steps to prevent more landslides occurs.

In order to access the area at risk for landslide, the landslides potential map must be created. Therefore, this study may serve as a guide for government and the public in the event of a landslide. In order to develop new roadside or development in the study, the government sector such Public Work Department should more prudence while the villagers may take preventative measure in the event of excessive rainfall or in the monsoon. Thus, human mortalities may be minimized, and public awareness will rise as a result.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is focusing on understanding the general geology of the research area. Regional geology of Gua Musang and existing research about landslides that happened in this area are reviewed and recorded in this chapter as a reference source.

In advance, the idea of resistivity survey method is also included in this chapter with the relatable physics principles to show how the survey works to get the overview of how the work is done get the subsurface condition of the study area. The literature review is one of the basic things of a preliminary study that must be done before starting the data collection and data processing so that it can be as a guide to relate the interpreted result and the previous research.

2.2 Regional Geology and Tectonic Setting

Gua Musang is located within Bentong-Raub Suture zone which is in central belt of Peninsular Malaysia. Formation of the Bentong–Raub Suture is from the subduction of the Palaeo-Tethys Ocean. The subduction process happened when there is collision between Sibumasu and Indochina during the Permian and Triassic (Metcalfe,2000).

Figure 2.1 shows the illustration of how the subduction zone formed when the Sibumasu and Indochina collide. Formation of the Bentong–Raub Suture by subduction of the Palaeo-Tethys Ocean and collision of the Sibumasu and IndoChina.Figure 2.1 shows a formation of subduction zone.

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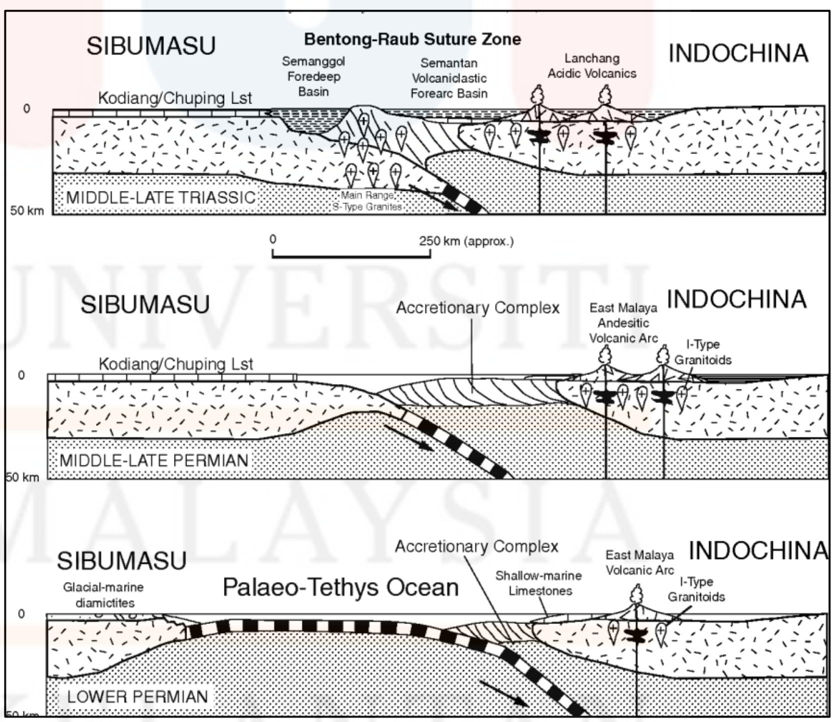


Figure 2.1: Formation of subduction zone (Metcalfe,2000)

As the accretionary complex continues to grow, the argillic carbonate sediments were deposited within the shallow marine Gua Musang platform (Metcalfe, 2013).

Gua Musang Formation, Aring Formation, Telong Formation, and Nilam Marble are included. Middle Permian through Late Triassic. The lithology is argillaceous, calcareous, and volcanic. Arenaceous rocks are present. Shale, siltstone, mudstone, slate, and phyllite dominate argillaceous facies. Shallow deposition.

2.3 Stratigraphy

Late Devonian to Early Permian ages suggests an ocean between Sibumasu and East Malaya. This ocean may not have closed until late Early Permian. Various rocks prove this. Middle Devonian to Early Permian oceanic cherts and mélange includes chert and calcareous clasts.

This indicates that in the Devonian, when Indochina and other China plate separated from Gondwana and closed in the Late Triassic which is when the Palaeo-Tethys Ocean opened. The disrupted accretionary complex that included in the Bentong-Raub suture zone is proven by the varies of ages and rock types from different depositional environments.

The suture zone is formed by a latest series of Triassic, Jurassic, and Cretaceous-age, mainly continental, red bed overlap. Figure 2.2 shows the stratigraphy column illustration of Bentong-Raub suture zone.

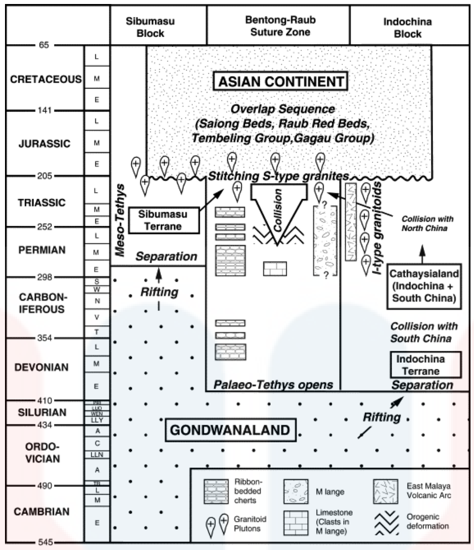


Figure 2.2: Stratigraphy Column of Bentong-Raub suture zone. (Metcalfe,2000)

2.3.1 Argillaceous Facies

The major facies in the Gua Musang and Telong formations is the argillaceous facies, which is composed of shale, siltstone, mudstone, slate, and phyllite. It also appears as interbeds or lenses in the Aring Formation and Nilam marble. The argillaceous facies is the most extensive and fossiliferous facies in the study area, with rocks found in the northern section of the Gua Musang Group being more fossiliferous than those found in the southern area.Figure 2.3 shows Comparison of type sections for Aring, Telong, and Nilam marble formations. Gua Musang formation has not been assigned with any type sections. Modified from Aw (1990).

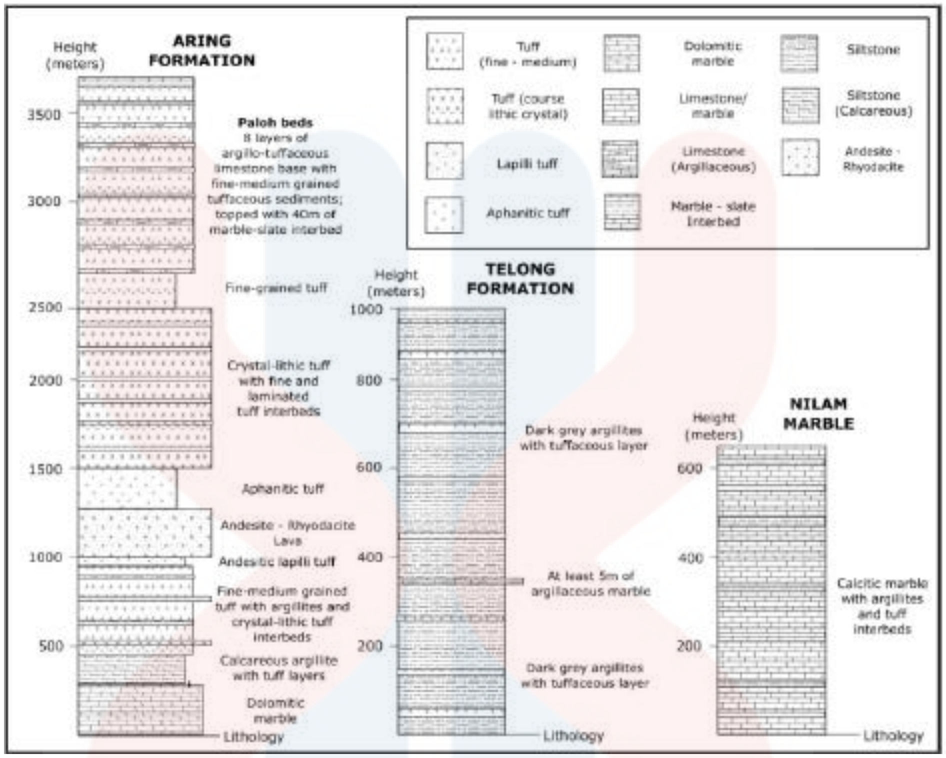


Figure 2.3:Stratigraphy of column of Aring,Telong and Nilam Marble formation(1990)

2.4 Structural Geology

Peninsular Malaysia is stretched north-north westerly in accordance with its longitudinal extent pattern (Hutchison & Tan, 1989). Bentong-Raub Suture zone is one of a major structural that well known in Southeast Asia. Since Gua Musang located in the Bentong-Raub Suture zone, there will be so many of geological feature especially fault as the result of deformation and mountainous uplifting. Main Range granites that is major structural lineaments in central belt of Peninsular Malaysia were detected and mapped at large scale using remote sensing data by Pour (2016). Permian folding has been discovered in the northwest corner of the Peninsula (Khoo and Tan, 1983). The major compression that caused the Gua Musang Formation to fold and fault (Yao, Oludare Idrees, & Pradhan, 2017)

2.5 Historical Geology

During the period of Carboniferous, East Malaya was attached with Indochina plate and Sibumasu attached with Gondwana; become a part of Cimmerian plate. But from the Devonian to the Permian, an ocean called the Palaeo-Tethys kept the Sibumasu and East Malaya blocks apart.

The geological history of Kelantan's predominantly Gua Musang formation has been traced by Yin (1984) in South Kelantan from middle Permian to Upper Triassic (Mohamed, 1995). The formation is estimated to be 650 m deep, consists of crystalline calcareous, interbedded with thin shale beds, tuff, chert nodules, subordinate sandstones and volcanic. The light grey calcite is hard, brittle, non-porous, and splintery. Small amounts of carbonaceous, argillaceous, and pyroclastic impurities are present in the grey to black varieties of the recrystallized limestone. According to Department of Minerals and Geoscience Malaysia (2003), the Main Range Granite had been from the late Triassic period between 200 until 230 million years ago. Geologically, Kelantan's geologic units are unconsolidated sediments, volcanic extrusive rocks, granite, and sedimentary or meta-sedimentary rocks. Main Range and Boundary Range classify Kelantan's granite.

2.6 Geophysics

Geophysics is a branch of geoscience that use principles of physics to study about the earth. This method was expanding fast during this decade, and it became one of the technologies in earth subsurface survey. Geophysics also helps more researchers in order to understands about the earth tectonic theory (Samsudin,2016).The amount of groundwater present and the salts dissolved in the rocks determine the resistivity of the rock. In addition, the presence of various ore minerals and high temperatures reduced the resistivity.

The major goal of employing this method is to map the existence of different porosity rocks that are specifically related to hydrogeology for discovering aquifers, contamination, and mineral prospecting. Other applications include saline and other types of pollution investigation, archaeological mapping, and the detection of heated rocks. Similarly, ER method is a widely used method. It is an inexpensive, non-invasive, and fast method that generates appropriate information about subsurface settings. It is sensitive to the water content of the soil layers and good to examine potential landslide areas (Wu et al. 2018).

2.6.1 Landslide

Landslides are characterised by movement. Falls, topples, slides, and flow are the four main movements. Landslides are known as falls when they involve the precipitous descent of material from a cliff or other steep slope

1.Falls

Falls are typically made up of a combination of falling freely through the air, bouncing, and rolling. The accumulation of rock or debris near the foot of a slope is characteristic of the type of landslide known as a fall.Figure 2.41 shows the example of rockfall.

Figure 2.4: the example of rockfall(British Geological Survey)

2.Topples

A mass of rock, soil, or debris moving forward while rotating and moving out of a slope is an example of a slope failure known as a topple. In most cases, this type of slope collapse happens around an axis (or point) that is either at the base of the block of granite or very close to it. Figure 2.42 shows the example of rock topple.

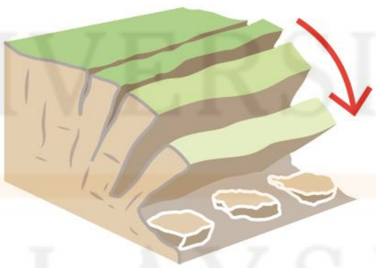


Figure 2.41: the example of rock topple(British Geological Survey)

3.Slides

A slide-type landslide is a movement of material downslope that occurs along a defined rupture or slip surface. This form of landslide can also be referred to as a slide. The slip surface is typically not controlled physically and tends to be deeper than that of other types of landslides. A noticeable main scarp and a back-tilted bench or block at the top distinguish these landslides, which also have modest internal deformation. Movement that occurs below this point is predominantly rotational around an axis.

The failure of material at a depth is characteristic of slides, which are then characterized by movement that occurs by sliding over a rupture or slip surface. There are two different kinds of slides that can fail: rotational slides (also known as slips) and translational slides (also known as planes).

4.Rotational Slides

The slide is rotational if the surface of the slip is listric, which can be described as curved or spoon shaped. The landslide known as Holbeck Hall, which occurred in Scarborough, North Yorkshire, is an excellent illustration of a rotational landslide. Figure 2.43 shows example of rotational slides.

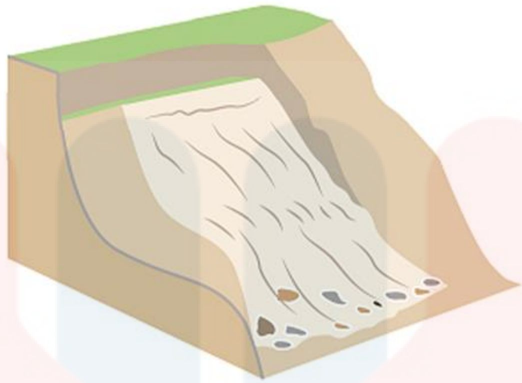


Figure 2.42: the example of rotational slides(British Geological Survey)

5.Translational Slides

A translational or planar landslide is when material moves downslope along a fault, joint, or bedding plane, which is a flat area of weakness. Translational landslides are some of the biggest and most damaging on Earth. These landslides happen at all sizes and don't stop on their own. When there are sharp changes, they can move very quickly. In Scotland, debris flows are often caused by translational landslides, like the Stob Coire landslide. Figure 2.44 shows example of translational slides.

Figure 2.43 : Translational slides (British Geological Survey)

6.Flows

Flows are landslides that happen when fluid-like material moves down a slope. When a flow stops moving, it often leaves behind a distinctive deposit that looks like an upside-down funnel. Different kinds of flows include mud, debris, and rock (rock avalanches). Mud flows and debris flows are two that happen often in the UK. On the south coast of England, you can find mud flows, which are often linked to bigger, more complicated landslides like the one at Stone barrow Hill in Dorset. Debris flows can move very quickly and usually happen on steep slopes, like the ones at the Rest and Be Thankful Pass in Argyll and Bute. Figure 2.45 shows the example of flows.

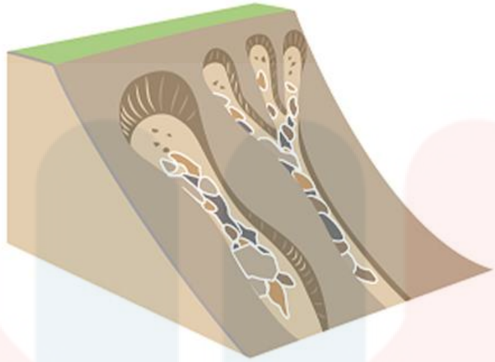


Figure 2.44: the example of flows(British Geological Survey)

2.6.2 Landslides Factors In Malaysia

In Malaysia, the rise in landslides is linked to the building of new roads, highways, and dams, as well as the fact that more people want to live in the country, which means that more homes must be built on high ground. In Bukit Antarabangsa, there are often reports of landslides in residential areas. This is because a residential estate was built in the hills, which makes them a high-risk area for landslides. Also, there were landslides on highways in Malaysia, one of which happened on the North-South Expressway at Gua Tempurung.

Landslides in Malaysia's highlands were caused in part by people building on hills. It is often caused by mistakes in design, construction, or maintenance. In Malaysia, slope failures are still very popular year after year. Rainfall-caused slope failures look like a shallow slope collapse with slip surfaces that are parallel to the slope surface. This is especially true in parts of Hulu Kelang where the residual soil profile has formed over the bedrock interface. In one sectoral report from Malaysia, there were 49 landslides, of which

88 percent happened on slopes that were made by people. About all of the landslides in Malaysia that happen in hilly areas are caused by cutting into the slopes, which is a mental activity. As a result, landslides happen often because of a combination of bad design and construction mistakes, geological features, and poor maintenance.

2.6.3 Existing Research

Hashim et al2017.'s study shows that landslide mapping using GIS and the Analytical Hierarchy Process (AHP) method in the state of Kelantan produced a map of landslide inventory occurrences and a map of landslide susceptibility for the whole state. Rainfall from heavy rain has the biggest effect on whether or not a landslide happens. From a hydrological point of view, precipitation is the water that falls from the sky to the Earth's surface (Jayarami, 1961). The susceptibility map shows that 65 percent of Kelantan is in a low susceptibility zone, while 35 percent is in a high susceptibility zone. These areas are in the south and south-west of Kelantan, especially in the high elevation areas like Gua Musang. The Gua Musang rainfall data shows that the amount of rain that falls during floods, which usually happen in November and December, is higher than other times of the year.

Work by Syafril et al. (2020) on the GIS-based landslide hazard zonation in Kuala Betis, Gua Musang, which uses the Weightage Overlay Method (WOM) to find the most important factor in all landslide-triggering parameters. The landslide zonation map shows that there are five zones with different levels of landslide risk: very high risk, high risk, moderate risk, low risk, and no risk. Based on the zonation map, 60% of the scattered data about risk showed a moderate risk, 20% showed a low risk, 10% showed a high risk, 8% showed no risk, and 2% showed a very high risk. This information comes from how important the cause was. Limestone is a type of lithology that shows a high level of risk. Colluvium, rather than alluvium, also shows a very high level of risk. The local people were also asked to fill out a questionnaire that asked what they thought caused landslides in their areas.

Elhaj (2016) that using geophysical method such as resistivity, seismic refraction, gravity and magnetic survey to delineate the subsurface in Gua Musang shows the result that the bedrock is limestone with the depth is around 5 to 7meters from the surface.

A research of limestone geohazard that was conducted by Muhammad Faez bin Sofian (2018) at Kampung Lepan Jaya, Gua Musang, using electrical resistivity imaging (ERI), and which is currently still unpublished, gave a result of a resistivity survey that consisted of four lines. Only one of the four survey lines has a high risk of a sinkhole developing, but three of the lines have a low probability of this happening.

Jamaluddin (2006) states that Malaysia is not a country that makes hasty decisions. The constant failing of the slope is caused by the monopoly that rainwater has over the environment. According to the findings of Abdullah's (2013) research, Malaysia is prone to experiencing numerous instances of both flooding and landslides.

2.7 Resistivity Arrangement

Schlumberger arrays, Wenner arrays, Gradient and Dipole-dipole arrays are four types of electrode arrays that are extensively employed.

1.Wenner Arrays

Wenner is made up of four collinear electrodes that are evenly spaced. The spacing between each electrode will be expanded around the array middle while keeping an equal spacing between the Wenner arrays. This array only can survey in moderate depth of investigation (Loke,2018).

Table 2.1 : The advantages and disadvantages of Wenner Arrays

ADVANTAGES	DISADVANTAGES
when profiling only has to move four electrodes for each new measurement along the line	When electrode separation is large, moving all four electrodes for each new measurement implies a lot of walking.

2. Dipole-dipole Arrays

According to Loke (2000), this survey is approximately use because of the low electromagnetic connection between the current and potential circuits. This arrangement is involving of the potential electrodes, pair of electrodes and currents. The dipole is a paired electrode set with the electrodes located closed to one another.

Table 2.2: advantages and disadvantages of dipole dipole array

ADVANTAGES	**DISADVANTAGES**
high resolution and multi-channel capability; it provides a very detailed image instead of providing a “big picture” image like the Wenner array.	Dipoles will lose the signal if they’re placed too far apart, thereby decreasing the ability to see deeper into the earth.

3. Schlumberger Arrays

Sclumberger employed four collinear electrodes. Current electrodes and inner two electrodes formed this array. Potential electrodes are in the same place whereas current electrodes are further apart. Six times every decade, electrodes are expanded. These types of configuration array have better depth penetration and better resolution of a subsurface image (Sulaiman, M.S,2021).

Table 2.3 : Advantages and disadvantages of Schlumberger Array.

ADVANTAGES	DISADVANTAGES
Need to move the two current electrodes only for most readings. This can significantly decrease the time required to acquire a sounding.	Because the potential electrode spacing is small compared to the current electrode spacing, for large current electrode spacings, very sensitive voltmeters are required.

4.Gradient Arrays

The Gradient Array is similar to the Schlumberger array. The difference is that the Schlumberger array records only the center receiver dipole, whereas the gradient array measures all adjacent dipoles from one transmitter electrode to the other, including the center-most dipole.

Table 2.4: advantages and disadvantages of Schlumberger Array.

ADVANTAGES	**DISADVANTAGES**
Using the Edge Gradient algorithm, a complete spread of 56 electrodes spaced one metre apart will produce a very strong signal near the two current electrodes.	In the past, these arrays were deemed impracticable, sluggish, and difficult to visualise. Prior to the development of automatic multi-electrode systems, resistivity imaging equipment consisted mostly of four electrodes coupled to a voltmeter.

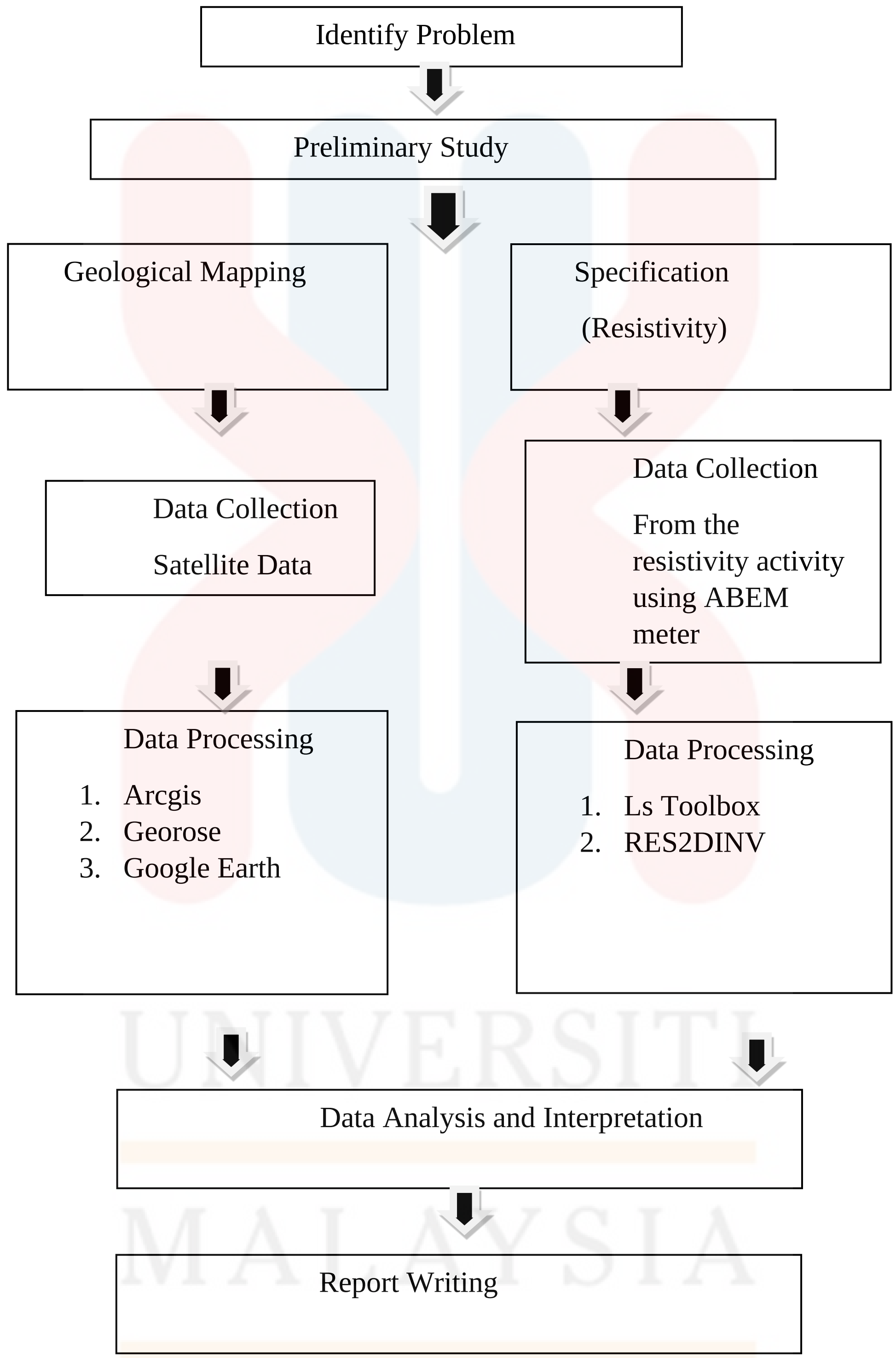
CHAPTER 3

MATERIAL AND METHODOLOGIES

3.1 Introduction

The purpose of this chapter is to explain the materials and procedures that were employed in this study, as well as the role that each of them played in achieving the study's goals. The preliminary research, field investigation, laboratory work, data analysis, and report writing are the five steps of this project. Materials and procedures were investigated and chosen to complete data collection for the study to get and analyses data. The preliminary research consists of two parts: a literature review and the creation of a base map based on desk research and remote sensing using ArcGIS 10.2 software. Literature reviews were conducted using data from libraries, journals, government books and research notes, books, and e-publications as sources of data for the study field. Fieldwork is then carried out employing mapping activities.

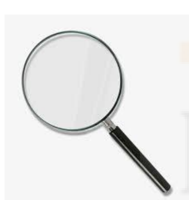
Figure 3.1: Flowchart for geology and specification



3.2 Materials

Geology mapping and the specification of landslide potential using resistivity are the two primary categories into which the material might be placed. To accomplish the goal of our research, we had required a few different types of materials. The following is a list of the necessary materials and equipment that had been utilized.

Table 3.1: Material for mapping and geophysical survey

MATERIAL	FUNCTION
Global Positioning System (GPS) 	Used to track and navigate any location on the Earth's surface
Compass 	A compass is a device that shows direction and used it to read the strike and dip of the outcrop.
Hands lens 	Lens used to observe the mineral in the rock more accurately.

Sample bag 	Preserve the sample that collected
Field book 	To record the data during mapping
Hammer 	Hammer use to collect outcrop sample
Measuring tape 	To measure the length of the outcrop, structure and the thickness of sedimentary bed

ArcGIS 10.2	Software that uses to interpret the data after mapping
Topographic map 	Act as a reference for geological mapping
ABEM Terrameter 	For electrical resistivity survey

3.3 Methodology

This research is carried out by adhering to a set of protocols, processing the data, and creating it in software. It is necessary to use software in order to generate the geological mapping and to determine the region that has the potential to contain groundwater.

3.3.1 Preliminary study

Preliminary research was a main data gathering from journals, publications, reports and prior studies regarding both geological mapping and specification of groundwater exploration. Preliminary study was a step that needed to be done before beginning the field work in order to get ourselves ready for all of the potential outcomes and surprises that may show up at the conclusion of the research.

3.3.2 Field Study

Field study was a must to generate the geological mapping. Observation through traversing process at the study area and collecting rock sample for further study. Structure analysis is carried out by following the lineament on a topographic map while identify the geomorphology around the research study and selecting the fresh samples of rock for further examination in petrographic.

a) Sampling

Sampling was a process of obtaining rock samples from the outcrops located at the research area. When collecting rock samples, make sure they were in fresh condition and not weathered. It was necessary to break the exposed rock up into tiny pieces in order to get the fresh section of the rock. The size of the rock sample ought not to be too little or excessively large.

b) Traversing

By walking the path and mapping the geology seen along the way, the traverse method was used to survey the research region. observation such as noting the local lithology, outcrops, geomorphology, and river channel. Gathered all kinds of data to produce an exhaustive geological mapping.

c) Geological Survey

This investigation was done to determine Kampung Paloh Tiga's potential landslide resource. Electrical Resistivity Imaging (ERI) with a suitable electrode array arrangement was the geophysical technique used. Electrode arrangements come in a variety of styles, including Wenner, Schlumberger, Pole-Pole, Dipole-Pole, Dipole-Dipole, and Gradient. Considering the study's goal helped select the electrode array that was used.

Different electrode arrangement covers different in depth. Wenner covers less depth compared to Schlumberger while Pole-dipole results the greatest depth. Wenner array provides information about the structure trace whereas Pole-dipole array was more to exploration of groundwater potential. Reading from 3 survey lines were collected using Gradient and Pole-dipole array with electrode spacing 5m for 200m lines.

3.3.3 Laboratory investigation

The main component of laboratory activity was the thin section and petrography analysis that was performed there. Rock samples were gathered in thin section form and observed under an electronic microscope at various magnifications. This procedure was used to determine the rock's mineral makeup.

1. Thin Section

The rock samples collected during field study were gathered to make thin section. Thin section of rock specimen was prepared using glass slide, frost the glass slide, 43 cutting and grinding the slide to a correct thickness which was suitable to be used as thin section. Finally, the thin section was ready to be analyzed under microscope.

2. Petrography Analysis

Petrography analysis was observing the mineral composition, color, shape and cleavage of the minerals in the thin section. This analysis helped to identify the origin rock whether it is a igneous, sedimentary or metamorphic rock. So, microscope was the important tool during this analysis.

3.3.4 Data processing

Data processing method involves usage of software as ArcGIS, Terameter LS Toolbox, RES2DINV and GeoRose to update geological mapping and to process geophysical survey. This method basically uses software.

a) Data Processing for Geological Mapping

ArcGIS and Google Earth will process satellite-based geological mapping. DEM satellite image interpretations were used to analyze geomorphological features (DEM). ArcMap's extension tool delineates landform units. Landform components were analyzed using geological maps. The research data were analyzed descriptively to characterize the subject area's geomorphology, landforms, and natural catastrophe risk. Landform, slope, drainage density, aspect, hill relief, stream order, and watershed maps will be used for interpretation. Additionally, a geological map of the Paloh region may be generated using the programmed.

b) Data Analysis for Electrical Resistivity Imaging

Electrical resistivity imaging is employed with parallel and perpendicular resistivity lines. The ABEM resistivity system measured subsurface earth's resistance. ABEM resistivity systems include Terameter LS, multifunctional cable, 40 jumper cables, 41 stainless-steel electrodes, a 12-volt battery, and a remote cable. Resistivity survey by Schlumberger and Pole-Dipole. One 200-m Werner lines and 4 Gradient lines were surveyed. The electrode spacing for each survey line is 5m. The total electrodes used are 41 electrodes, (Nur Azra Zainol Abidin,2020).

The result of apparent resistivity value that will be inversed using software to determine the true resistivity. Resistivity data then will be analyzed using Res2Dinv software. RES2DINV software was known as a 2D inversion software. The software worked very easily where it imported data for inversion and visualization. It supported all electrode configurations and cross-borehole surveys (“Geotomo Res2DInv,” 2020).

3.3.5 Data Analysis and Interpretation

The gathered data will be evaluated under the supervisor's supervision. The analysis's findings will be related to the lithology after viewing the study region. Utilizing specialist tools, the data will be examined in accordance using the resistivity table, which was specific to the circumstances.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

The general geology of the study area is discussed in this chapter. Geologists use general geology to learn about rocks and soil. This includes the study area's geomorphology, which includes topography, drainage systems, and weathering of rock formations, as well as lithostratigraphy, structural geology, and historical geology. This information is critical for understanding the origin of rock, the strength of rock and soil, weathering activities on the rock formation, and geological structures that formed in the rock formation.

4.1.2 Accessibility

The study area can be access through Kuala Krai from Jeli straight to Paloh,which we will arrive at Kampung Paloh 3 about 2 hours.,the study area consists in the study area is Kampung Paloh 1,Kampung 2 and Kampung Paloh 3.

4.1.3 Vegetation

The type of vegetation that consists in the study area is palm oil plantation and rubber estate which about 60% of the whole study area is palm oil plantation and the rest is rubber plantation, settlement and forest area. . Figure 4.1 shows the google of the study area.

Figure 4.1 : Google map from Jeli to Kampung Paloh 3

4.2 Geomorphology

Geomorphology is the study and description of the morphology of the Earth in terms of its geometry and in relation to the formation and development of landforms in each region. It is also the study of the landform and nature of the land surface as a whole and of its various parts, such as mountains and valleys, rifts and scarps, river channel profiles and patterns, which comprise the landscape. The topography, faults, drainage system, and also the weathering process influenced the geomorphology.

Methods which utilized the topographic map of the study area and ground observations from the peaks of hills in the study area. Using these two techniques, information about the landform, drainage, contour pattern, and weathering was gathered. This geomorphological study provides an approximation of the topography of the study area and its environs.

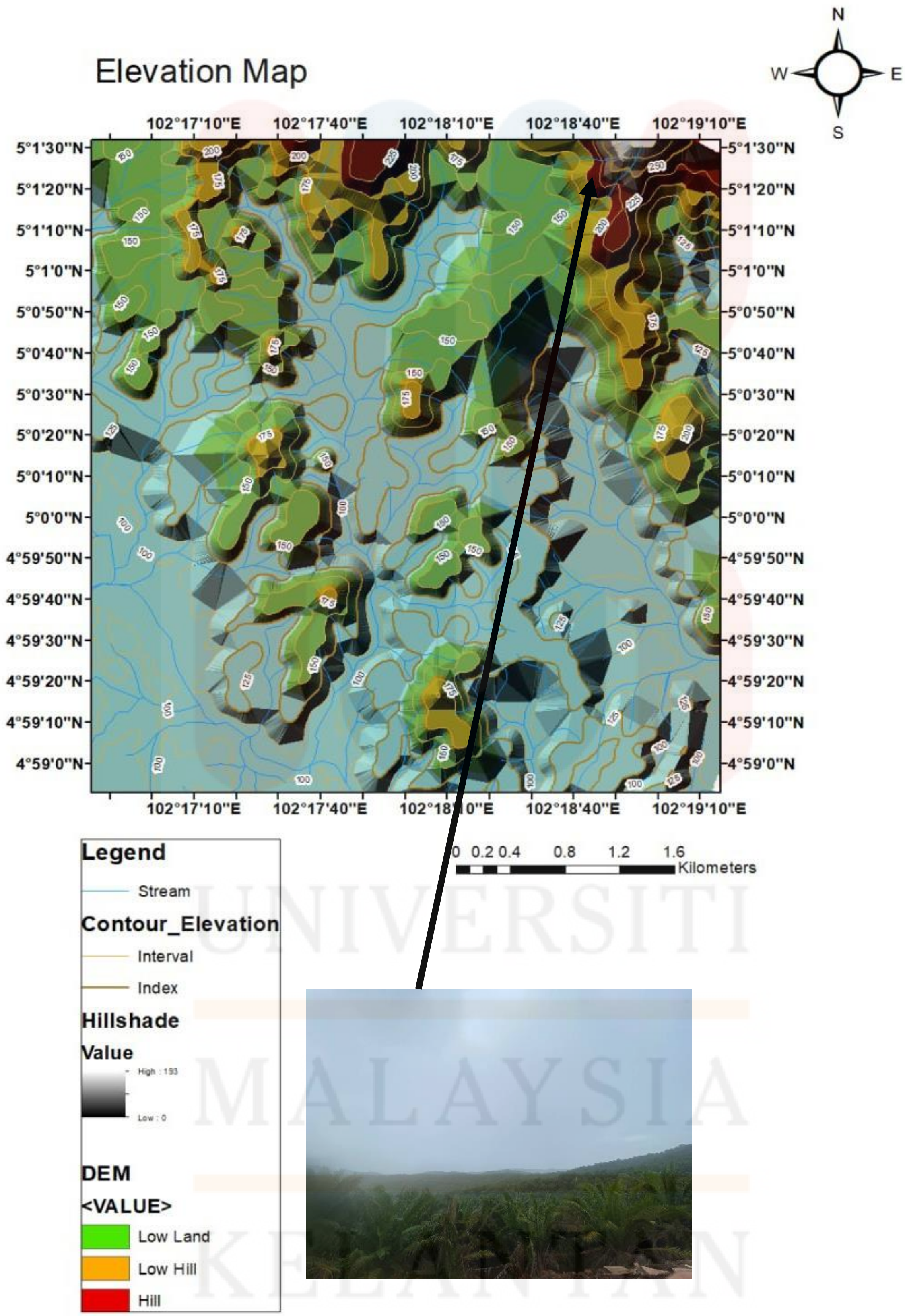


Figure 4.2 : Elevation map

4.2.1 Topography

The term "topography" refers to the Earth's surface, which includes all of the distinct characteristics known collectively as "landform." It is measured at the difference in elevation across the Earth's surface, where the difference is between high and low elevation. This distinction is what is measured. A relief modification is the name given to this type of modification. There are three different types of classes that are included in the topographic unit, and they each show a different elevation. The topographic units are broken down into their component parts and summarized in table 4.1.

Table 4.21: Landform classification

Landform	
60-100	Low land
100-180	Low hill
180-280	hill

4.2.2 Weathering

Weathering is an important Earth process. When exposed to the atmosphere, rock minerals and rock masses undergo alteration and breakdown. Weathering processes occur in situ, that is, in the same location, with no significant movement of rock materials. There are three kinds of weathering that occur. The first is physical weathering, which is caused by temperature and mineral changes that cause mechanical disruption of rocks. The second type of weathering is chemical weathering, which is caused by water, temperature, oxygen, hydrogen, and mild acids. Third, biological weathering is the disintegration of rocks caused by the action of living organisms (plants, animal and microbes).

Figure 4.2.2 depicted the physical and biological weathering that occurred in this study area of Kampung Paloh 3. The large-scale outcrop is undergoing rock disintegration, resulting in smaller sizes of rocks being presented; additionally, green plants are beginning to cover the rock. It was a hilly outcrop that had been heavily weathered, making it difficult to observe the properties of rocks and minerals due to the changing colors of minerals.

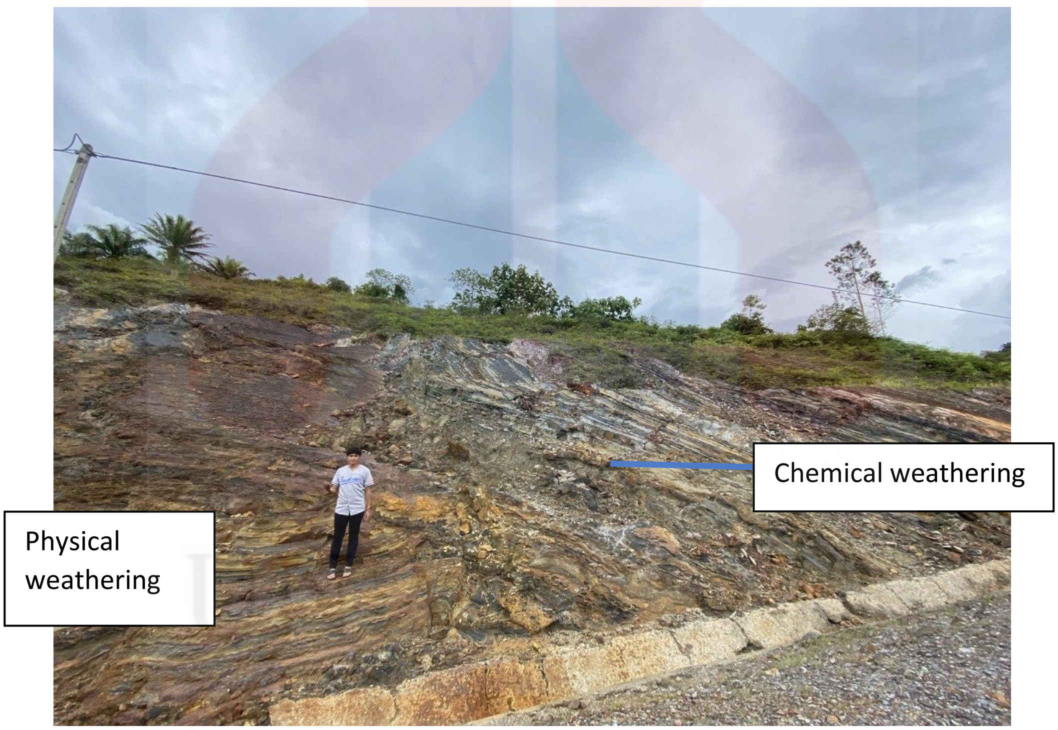


Figure 4.22 :Mechanical and physical weathering of the study area

4.2.3 Drainage Pattern

The drainage system is a pattern that forms in a particular drainage basin and affects rivers, streams, and lakes. The drainage pattern is typically determined by the type of rock, distribution of rock, and location of rock on the surface. The arrangement of the weakness of rock planes, such as bedding planes, faults, joints, shape, and other variables such as folding, rainfall amount, and erosion, causes it. The surrounding hills and basins serve as the main water flow channel for the river in the study area.

According to the map in Figure 4.23, dendritic drainage patterns dominate the drainage pattern in the study area. The most common drainage pattern is dendritic, which resembles the branching appearance of tree roots. They form when the river's channel follows the slope of the terrain. This pattern allows the downhill and uphill streams to flow in the same direction and meet on a large or mainstream.

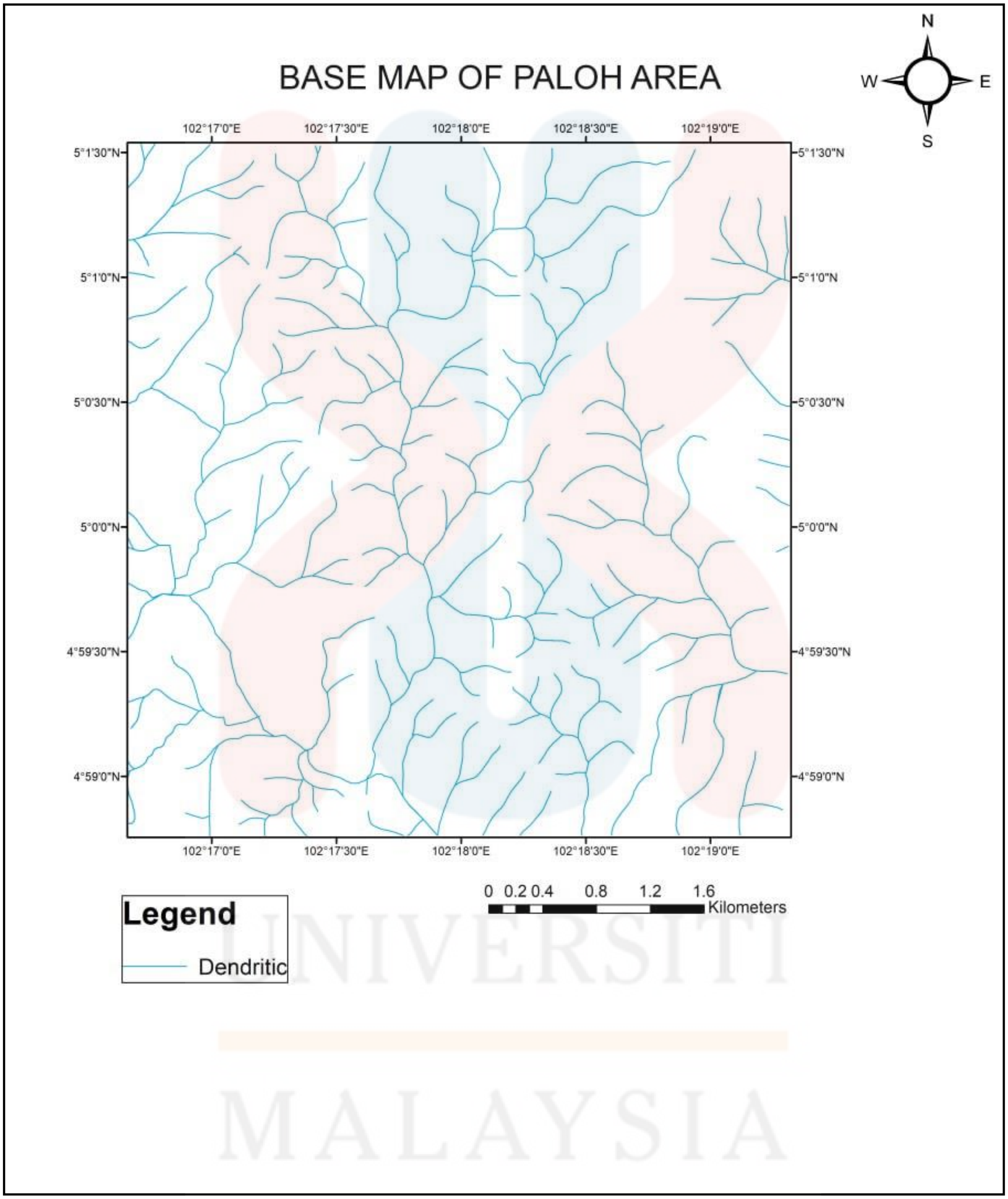


Figure 4.23 : Drainage pattern map

4.3 Lithostratigraphy

Lithostratigraphy is a branch of stratigraphy, the geological science that studies strata or rock layers. Geochronology, comparative geology, and petrology are major research areas. In general, the strata associated with rock formation are either igneous or sedimentary. The age of the rocks will be determined by the layer that is first deposited and then intruded. Meta mudstone and Andesite are the oldest rocks studied in this area, while phylite is the youngest. The lithostratigraphy depicts the lithology of the rocks that existed in Table 4.3

According to the geological map in figure in Kampung Paloh 3, sedimentary and metamorphic rocks cover about 75% of the study area and igneous cover about 25% of the study area. This data was gathered from geological mapping in the study area and interpreted in an ArcGIS map.Figure 4.3 shows lithology map.

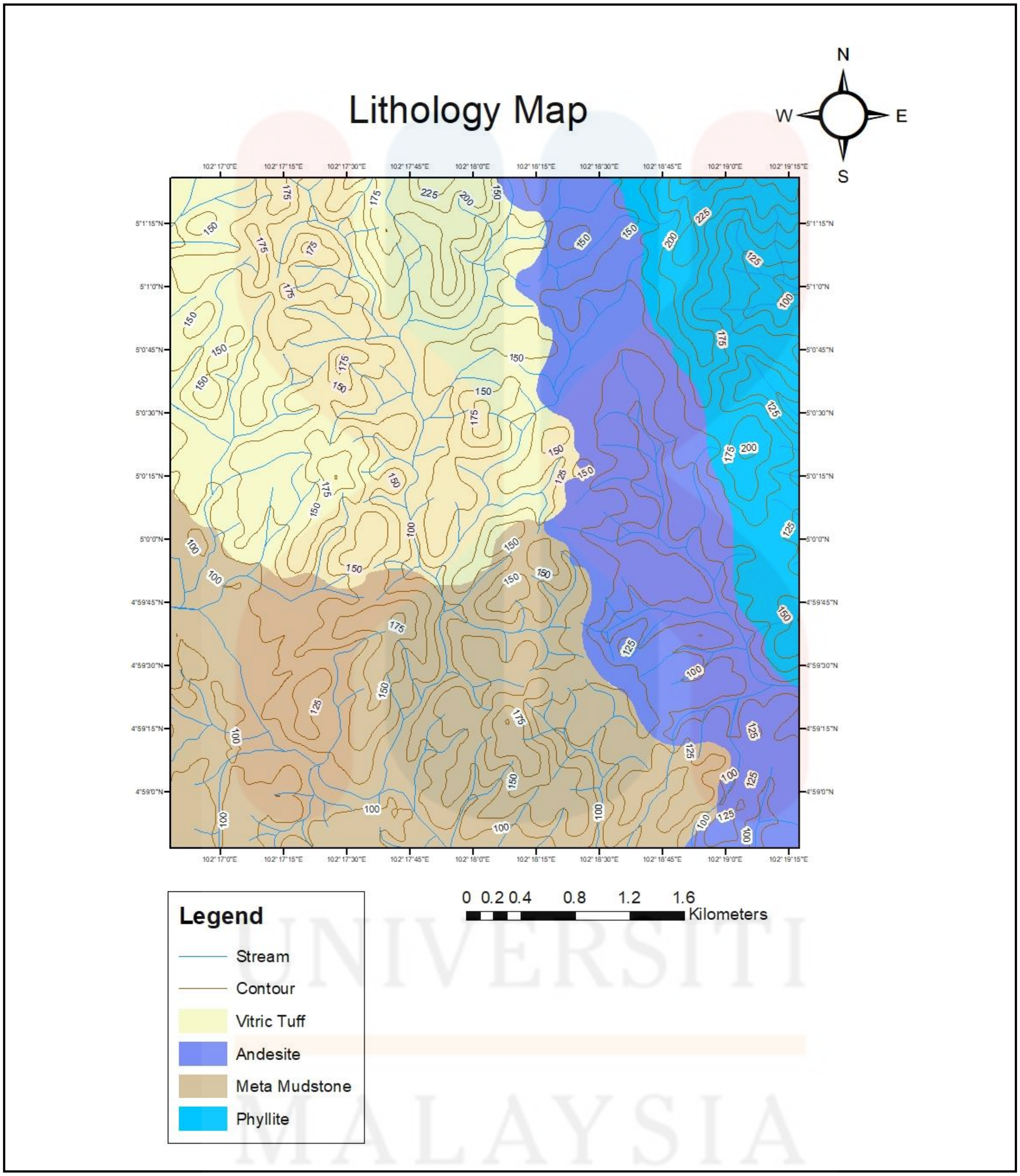


Figure 4.3: Lithology map of Paloh

4.3.1 Unit Settlement

a) Meta Mudstone

Meta Mudstone is a fine-grained sedimentary rock composed primarily of clay and silt-sized particles. A mudstone that has undergone some metamorphism. Terms such as claystone and siltstone are frequently used in place of mudstone, but these refer to rocks whose grain length falls within much narrower stages and are frequently technically mudstones under close examination. Shale is frequently used to describe difficult and fissile mudstones (wreck along bedding planes).

Figure 4.31: Meta mudstone

b) Vitric Tuff

Vitric tuff is being reported from Archipelago Group of South Andaman (Gupta,2002). The tuff is composed of delicately shaped glass shards with variable amount of microlites and broken phenocrysts of quartz, plagioclase, and mica. Major oxide analyses show dacitic composition of the tuff. The sedimentary structures in tuff beds suggest these as products of ash turbidite.

Figure 4.32: Vitric tuff outcrop.

c) Andesite

Andesite is an extrusive, fine-grained igneous or volcanic rock. It's dark grey and composed of equal parts light and dark minerals, though the crystals are too small to see without a magnifying glass. Andesite may occasionally contain larger crystals. Alternatively, small round pockets that were gas bubbles. Andesite is formed by magma with less quartz (silica) than rhyolite but more than basalt. As a result, it is frequently referred to as 'intermediate' in composition.

Figure 4.33: Andesite outcrop

d) Phyllites

Fine-grained metamorphic rock formed by the reconstitution of fine-grained parent sedimentary rocks like mudstones or shales. Because of the parallel alignment of platy minerals, phyllite has a high fissility (a tendency to split into sheets or slabs); it may have a sheen on its surfaces due to tiny plates of micas. It has larger grain size than slate but smaller grain size than schist. Phyllite is formed in the lower part of the greenschist facies by relatively low-grade metamorphic conditions. Parent rocks can only be partially reconstituted, preserving the original mineralogy and sedimentary bedding. Phyllite sheets may parallel or crosscut the original bedding depending on the direction of the stresses applied during metamorphism; in some rocks, two stages of deformation, known as precrystalline and postcrystalline deformations, can be distinguished based on two orientations of definable surfaces in the rock. Slaty or flow cleavage occurs in precrystalline surfaces, whereas false, fracture, or strain-slip cleavage occurs in postcrystalline surfaces. Such terms can only be used when the type of deformation and its relationship to time are known.

Figure 4.34 : phyllite outcrop

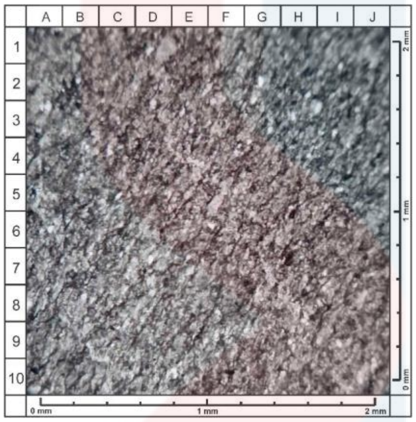
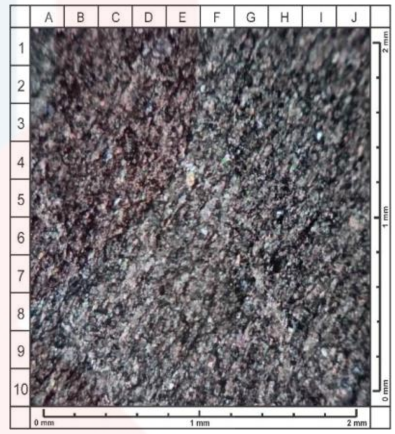
Table 4.3: Lithostratigraphy column

LITHOLOGY	DESCRIPTION	UNIT	PERIOD	ERA
	Fine grained sedimentary rocks consisting of mostly silt.	Meta Mudstone	Permian	Paleozoic
	Mainly consist of Phylite,shale and tuffaceous sandstone	Phyllite	Late Permian	Paleozoic
	Fine grain, volcanitic rock, Aphanitic to porphyritic with reddish garnet	Andesite	Late carboniferous	Paleozoic
	Microlites, quartz and mica.	Vitric Tuff	Late carboniferous	Paleozoic

4.3.2 Petrographic Analysis

This section contains a petrography analysis of the rock, which is based on macroscopic and microscopic properties. Petrographic analysis is used to classify rocks by revealing their origin, whether igneous, sedimentary, or metamorphic, as well as their mineral content. The identification and description of microscopic characteristics of the studied material in thin sections, such as mineral composition, texture, grain size, and evidence of alteration and/or deformation, is typical, as is the description of macroscopic aspects of the rock, such as texture, color, grain size, and other relevant characteristics visible in hand specimens or outcrops. Based on data acquired, there are 3 types of rock which is sedimentary, igneous and metamorphic.

Table 4.31: Meta Mudrock

CODE SAMPLE ABBAS			
PPL (*Plane Polarized Light*)		**XPL (*Cross Polarized Light*)**	

Microscopic Observations :

The observations were made at 10x ocular magnification and 5x objective magnification and at observations it was known massive – weak foliation, texture includes grain size <1/256 – 1/16 mm, sorting well, packing open. It is a meta-sedimentary rock, characterized by the apparent arrangement of parallel minerals but has not yet formed a foliation structure.

Mineral Composition :

Quartz (I4) – 1%

In PPL color absorption is colorless, relief is low, pleocroism is absent, anhedral crystalline forms, hemispheres are absent. In XPL the color of the gray – white interference of the 1st order, the dark corners are wavy, twins are absent.

Calcite (E4) – 10%

In PPL the absorbtion color is colorless, the relief is low – medium, pleochroism is absent, the anhedral crystalline form, the 2-way hemisphere – is absent. In XPL the color of interference is pink – green of order 4 – order 5, the angle of darkness is symmetrical, twins are absent – polysynthetic.

Carbonate Clay (J1) – 88%

In PPL, the absorbtion color is not brown – brown. On XPL the color of interference is brown – brownish-pink. It consists of micron-sized carbonate material.

Opaque Mineral (B2) – 1%

In PPL black absorbtion color, low relief, pleocroism is absent, euhedral crystalline form – anhedral. In XPL the color of black interference of the 1st order, twins are absent.

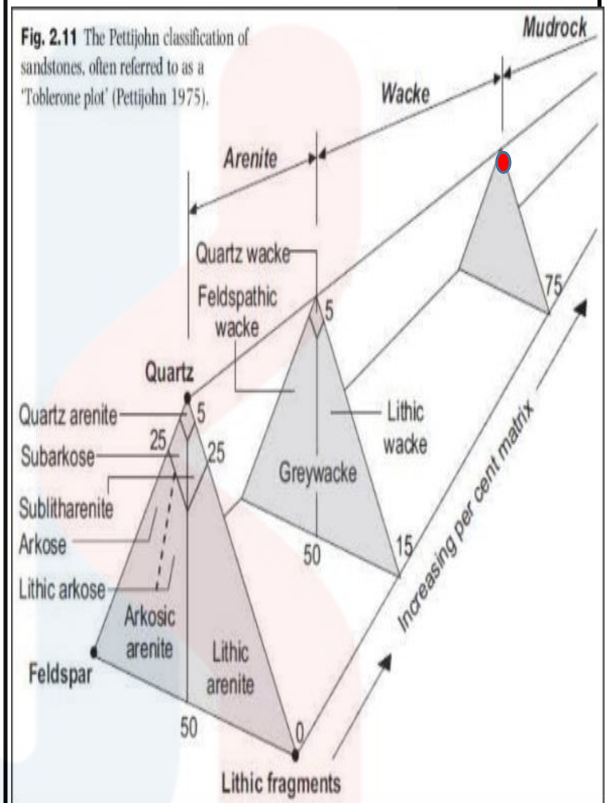
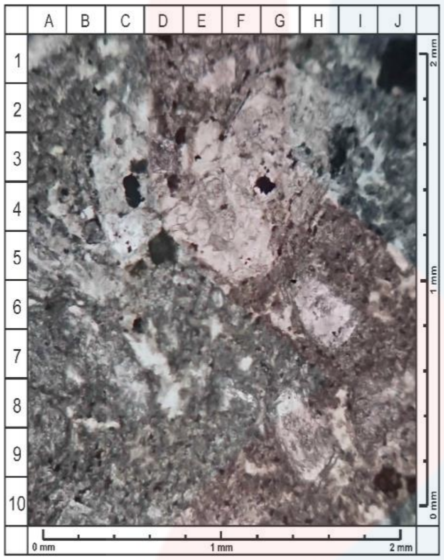
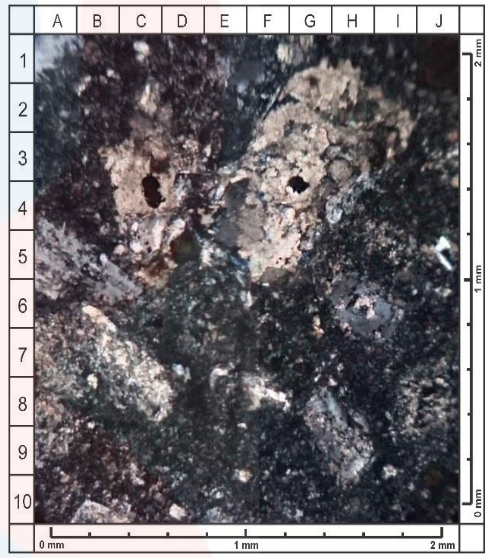


Fig. 2.11 The Pettijohn classification of sandstones, often referred to as a 'Toblerone plot' (Pettijohn 1975).

ROCK NAME: META-MUDROCK (MODIFIED FROM PETTIJOHN, 1975)

Table 4.32 : Andesite

CODE SAMPLE: ABBAS			
PPL (*Plane Polarized Light*)		**XPL (*Cross Polarized Light*)**	

Microscopic Observation:

Observations are made at 10x ocular magnification and 5x objective magnification and at the observation of massive structure, the aphanitic texture of the mineral size is simple - smooth, is the change of the rock alteration process , which is characterized by the appearance of mineral rock index changes in the form of sericite.

Mineral Composition :

Sericite (A5) – 10%

In PPL the absorption color is colorless, the relief is low, pleochroism is absent, the crystalline form is euhedral – anhedral, the 1-way hemisphere – is absent. In XPL the color of the 1st order gray – white interference, the dark angle is parallel, the twin is not visible.

Quartz (C1) – 1%

In PPL color absorption is colorless, relief is low, pleocroism is absent, anhedral crystalline forms, hemispheres are absent. In XPL the color of the gray – white interference of the 1st order, the dark corners are wavy, twins are absent.

Calcite (G2) – 20%

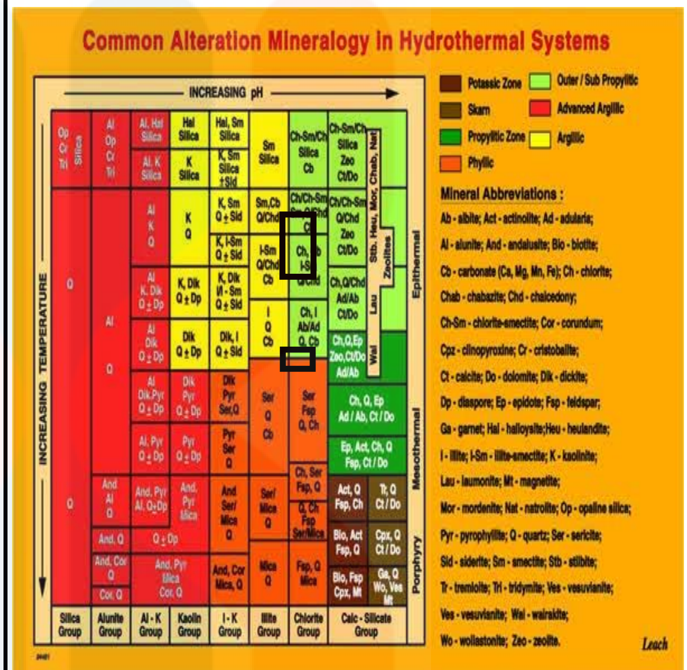
Changes from Ca-type plagioclase. In PPL the absorbance color is colorless, the relief is low – medium, pleochroism is absent, the anhedral crystalline form, the 2-way hemisphere – is absent. In XPL the color of interference is pink – green of order 4 – order 5, the angle of darkness is symmetrical, twins are absent – polysynthetic.

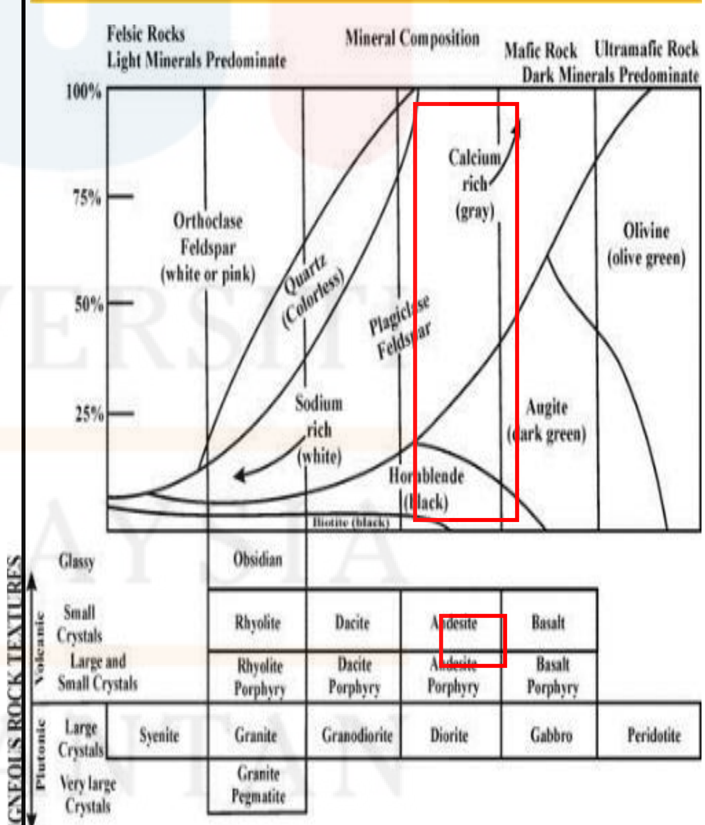
Base Mass (F10) – 67%

In PPL the absorbance color varies from colorless – light gray – brown, high relief. In XPL the color of interference varies dark gray – black – brown. Consists of quartz microlites, feldspar microlites and volcanic glass.

Opaque Mineral (J1) – 2%

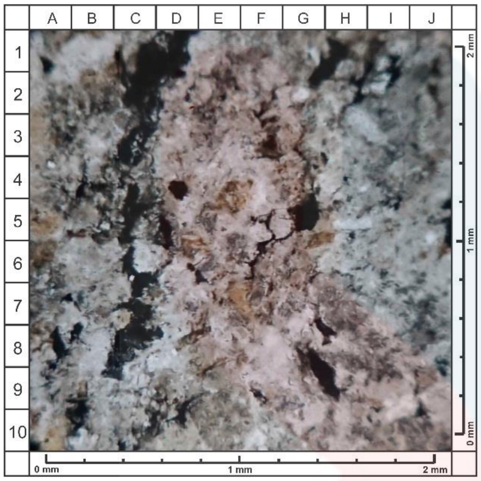
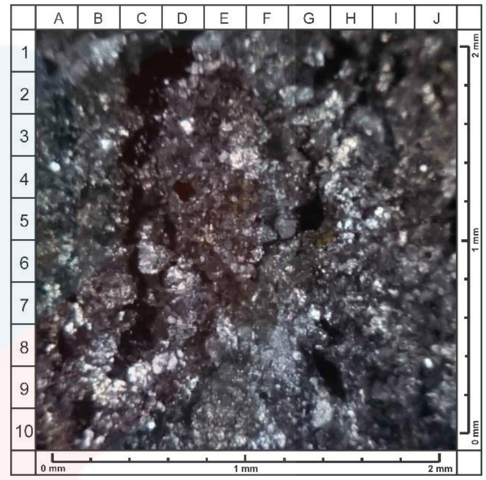
In PPL black absorbtion color, low relief, pleocroism is absent, euhedral crystalline form – anhedral. In XPL the color of black interference of the 1st order, twins are absent.





ALTERATION ZONE: PHYLLIC| ILLITE GROUP (LEACH, 1995)
NAME OF ORIGIN ROCK/WALL ROCK: ANDESITE (O'DUNN & SILL, 1986)

Table 4.33 : Petrographic of vitric tuff

<table>
<tr><th colspan="4">CODE SAMPLE ABBAS</th></tr>
<tr>
<td>PPL (Plane Polarized Light)</td>
<td>
</td>
<td>XPL (Cross Polarized Light)</td>
<td>
</td>
</tr>
<tr>
<td colspan="2">
Microscopic Observation :
The observation was carried out at 10x ocular magnification and 5x objective magnification and in observations it was known that the structure is massive, the texture includes item sizes <1/256 – 1/6 mm, sorting both open containers.

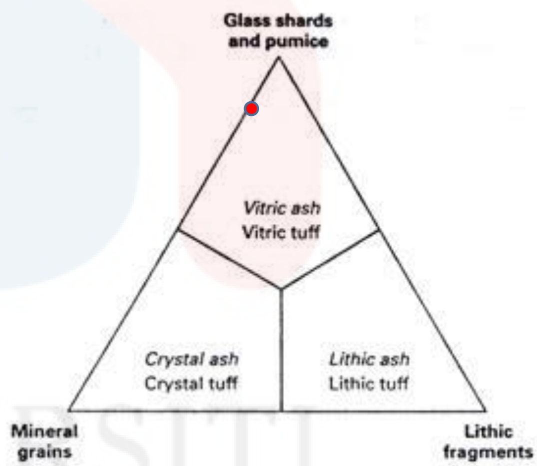
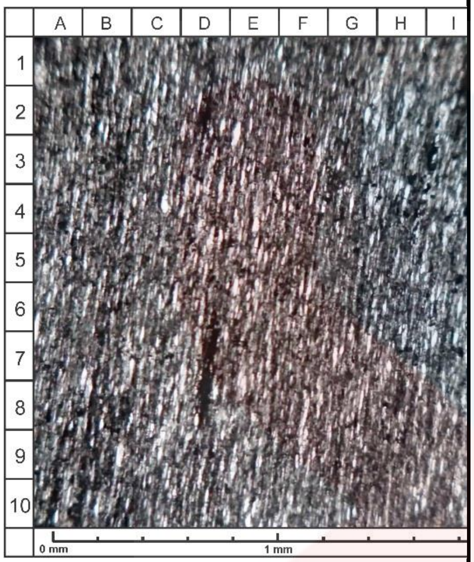
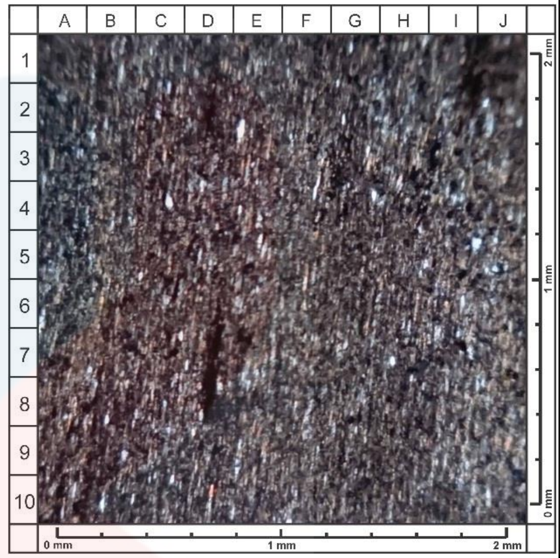
Mineral Composition :
Quartz (B9) – 12%
In PPL color absorption is colorless, relief is low, pleocroism is absent, anhedral crystalline forms, hemispheres are absent. In XPL the color of the gray – white interference of the 1st order, the dark corners are wavy, twins are absent.
Volcanic Glass (J10) – 80%
In PPL color absorption is colorless, high relief. In XPL the interference color is dark gray – black. It has a characteristic fibrous/filamentous shape.
Opak Mineral (I10) – 8%
In PPL black absorbtion color, low relief, pleocroism is absent, euhedral crystalline form – anhedral. In XPL the color of black interference of the 1st order, twins are absent.
</td>
<td colspan="2">
</td>
</tr>
<tr><th colspan="4">ROCK NAME: VITRIC TUFF (SCHMID, 1981)</th></tr>
</table>

Table 4.34: Phyllite

CODE SAMPLE ABBAS			
PPL (*Plane Polarized Light*)		**XPL (*Cross Polarized Light*)**	

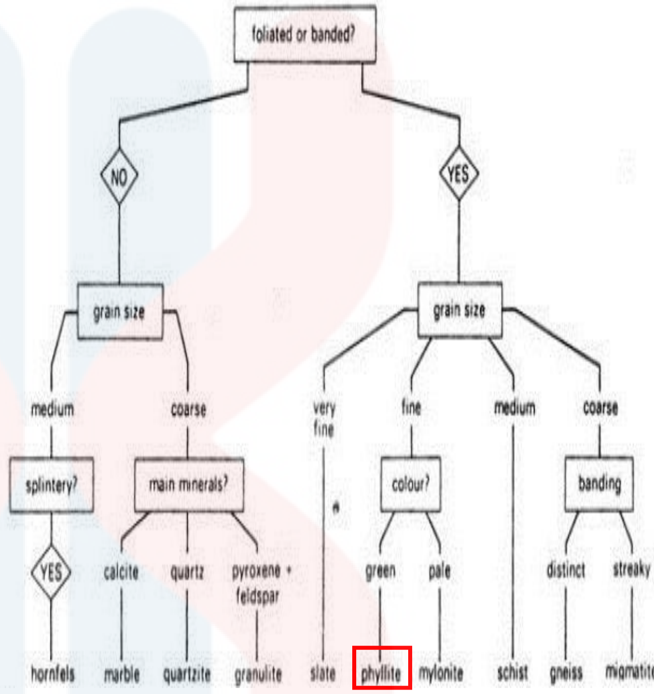
Microscopic Observation:

The observations were carried out at 10x ocular magnification and 5x objective magnification and on the observation of foliation structure (phylittic), palimpette texture (blastopellite) including grain size <1/256 – 1/12 mm, good sort..

Mineral Composition:

Quartz (G1) – 10%

In PPL color absorption is colorless, relief is low, pleochroism is absent, anhedral crystalline forms, hemispheres are absent. In XPL the color of the gray – white interference of the 1st order, the dark corners are wavy, twins are absent.



NAMA BATUAN: PHYLLITE (GILLEN, 1982)

4.3.3 Lapilli and Tuff

1) Lapilli

Lapilli are spheroidal, teardrop, dumbbell, or button-shaped droplets of molten or semi-molten lava expelled from a volcanic eruption and falling to the earth while at least partially molten. Lapilli tuffs are a frequent type of volcanic rock typical of pyroclastic eruptions of rhyolite, andesite, and dacite. During a base surge eruption, substantial layers of lapilli can be deposited at this location. Most lapilli tuffs which exist in ancient terrains are generated by the aggregation and fusing of semi-molten lapilli into what is known as a welded tuff.

The heat of the newly created volcanic pile tends to cause the semi-molten material to become fused and flatten down. Within the layers of welded tuff, flattened lapilli, fiamme, blocks, and bombs form oblate to disc-shaped formations (termed eutaxitic). Accretionary lapilli are spherical tephra balls composed of volcanic ash particles. Moisture or electrostatic forces cause the formation of accretionary lapilli in an eruption column or cloud, with the volcanic ash nucleating on an object and accreting to it in layers before falling from the cloud. The deposition of concentric layers of moist ash around a core nucleus produces accretionary lapilli, which resemble volcanic hailstones.

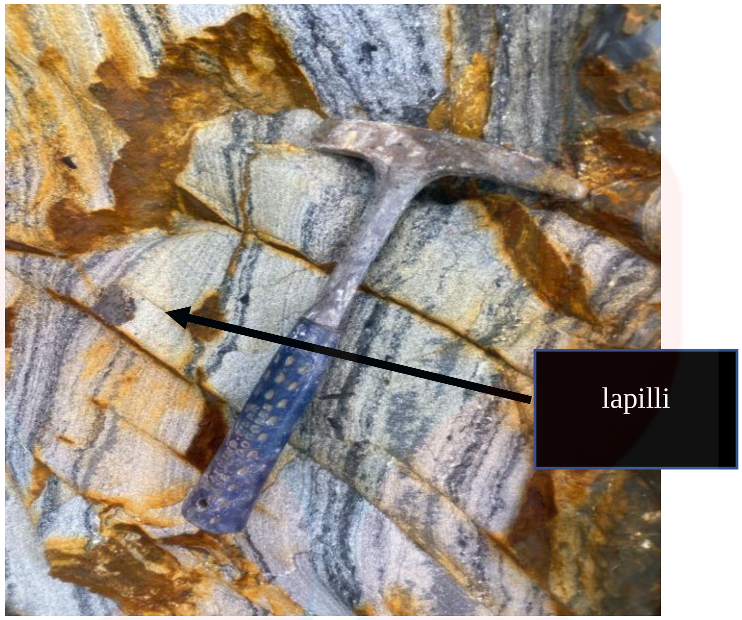


Figure 4.35: lapilli

2) Tuff

Tuff is a soft, porous rock composed of volcanic ash and various materials that have solidified. In a process known as consolidation, ash is compressed into a solid rock after ejection and deposition,(Geology science,2023) Rock composed of greater than fifty percent tuff is tuffaceous. It can be characterized as either igneous or sedimentary rock. They are often researched in the context of igneous petrology, although they are occasionally characterised using sedimentological terminology.

Figure 4.36: Tuff texture

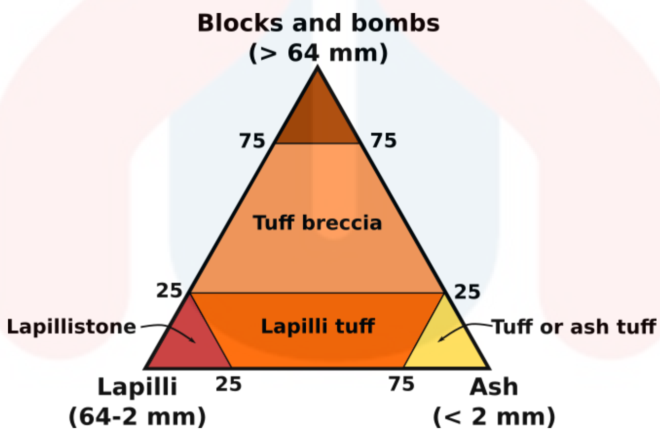


Figure 4.37: Proportions of blocks/bombs, lapilli, and ash, polymodal pyroclastic rocks are classified.(Modified from Le Maître, 2005)

4.4 Structural Geology

Primary structures formed during rock mass formation, whereas secondary structures formed as a result of primary structure deformations caused by plate tectonic movement. The study of the three-dimensional distribution of rock units in terms of their deformation histories is known as structural geology. It also includes the processes that lead to the formation of geological structures and the effects of these structures on the rocks. This study's structural geology includes structures such as lineaments and fault lines that can be interpreted using processed satellite imagery.

4.4.1 Fault

The fault process occurs when the earth's crust moves and causes the rocks to break. The purpose of this movement was to cause earthquakes. The movements of the earth's crust affect the stress that can build up over time before releasing a massive amount of energy, resulting in an earthquake (Britannica, 2020).

The three types of faults are normal faults, thrust faults, and strike-slip faults. Although the normal fault moves towards the downthrown block, the youngest rocks remain in the oldest rock above. It differs from the thrust fault. This is because the fault is the break that occurs above the youngest rocks, affecting the oldest rocks, and the strike-slip fault is the type of fault that occurs in the vertical or horizontal of the fault plane. Because the fault occurred on ignimbrite rock, the ignimbrite rock is older than the fault (Britannica, 2020).

The fault is easily identified on the map by lineament. Aside from that, because a fault is defined as a planar fracture, contour and rock boundary can be indicators in fault observation.

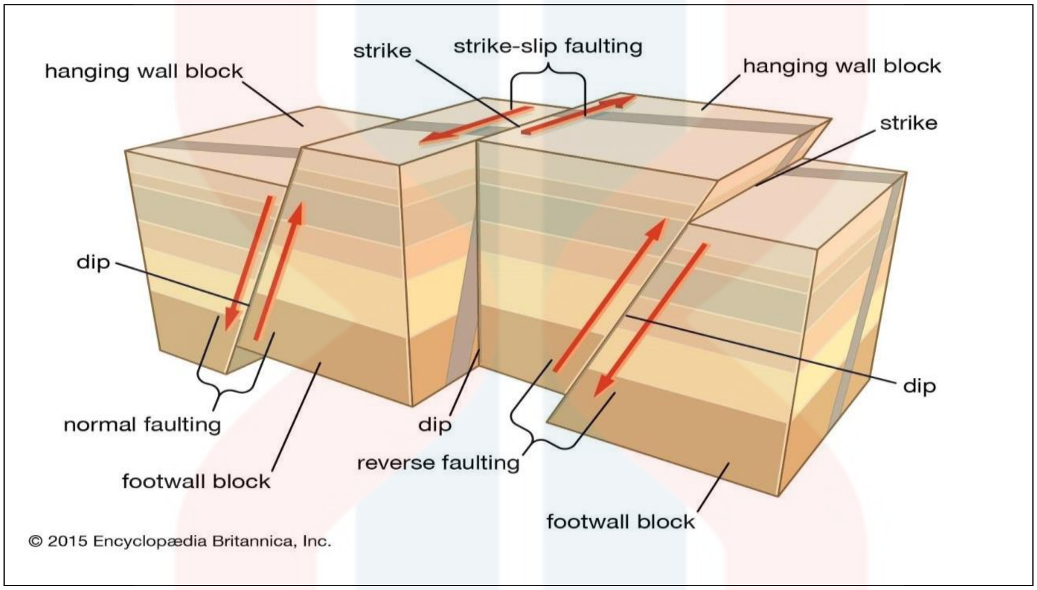


Figure 4.4 :Type of fault (Britanica,2020)

Figure 4.41 : Faulting that have in the study area .

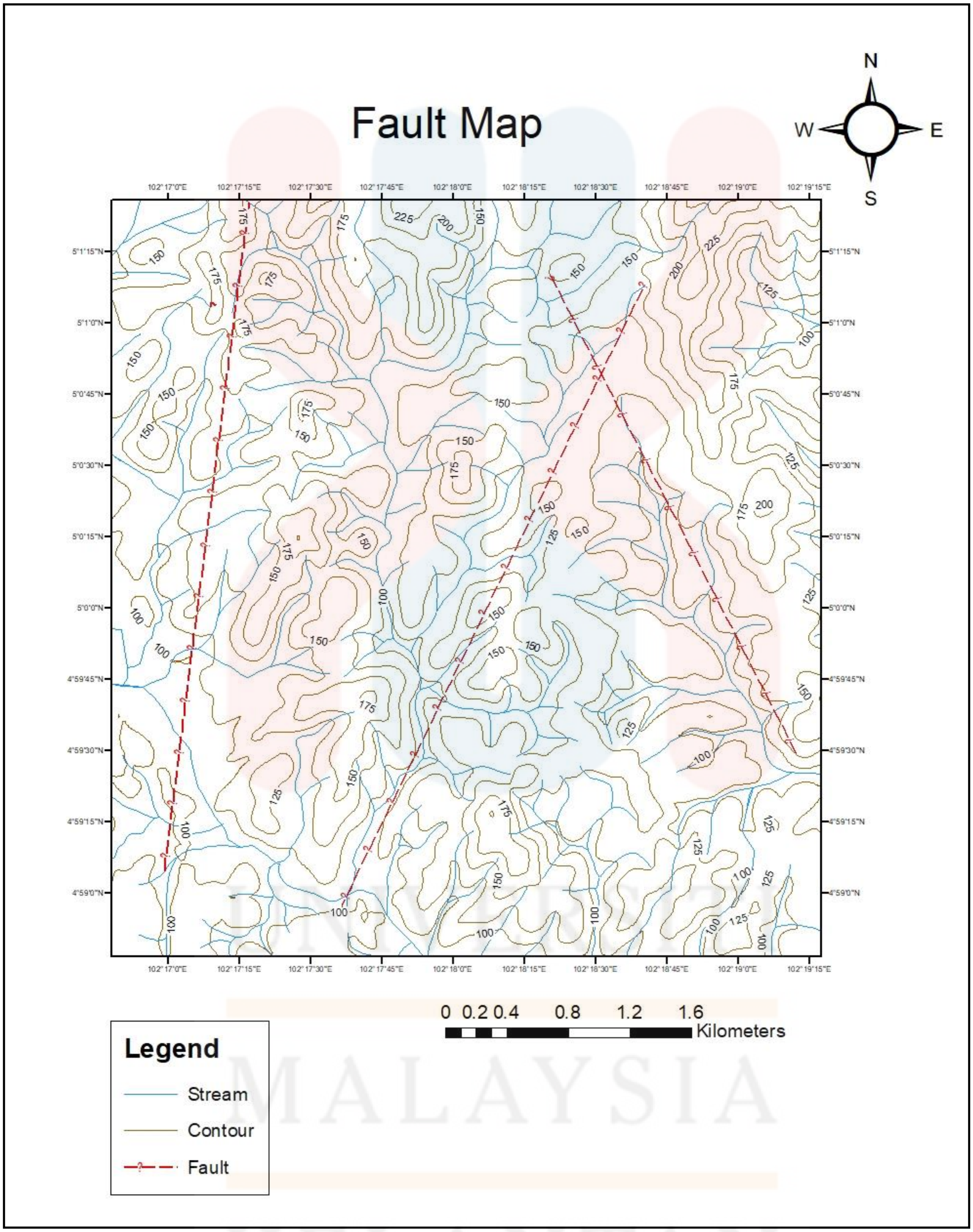


Figure 4.42 : Faults map

4.4.2 Fault Analysis

Tensional stress, compressional stress, and shear stress are the three causes of defects. When rocks are pulled apart from one another, tensional stress occurs, whereas compressional stress occurs when rocks are pressed together. However, shear stress occurs when rocks slide over one other in opposite directions; in this scenario, the rocks do not collide.

The types of flaws depend on the movement that caused them. Normal faults occur when rocks separate to create space and one of the two sides descends. When rocks are pushed together, reverse faults form, with one rock moving on top of the other. Strike slip faults, unlike other fault types, travel horizontally; the two blocks move in opposite directions.

Nevertheless, not all errors are so straightforward; one problem may be a combination of a normal fault, reverse fault, and strike slip fault. One side of every fault is referred to as the "hanging tree" and the other as the "footwall." The footwall is the movable side, and people can therefore physically stand on it. In contrast, the hanging tree is so named because it protrudes and allows people to hang objects from it.

In addition to active, inactive, and reactivated faults, defects can also be categorised as active faults. Active faults are faults that are anticipated to move again in the future and produce earthquakes. It is essential to highlight that faults are deemed active if they have shifted once or more times within the past 10,000 years. Reactivated faults are the result of movement in the opposite direction of the fault's original movement. Inactive faults have not moved in millions of years.

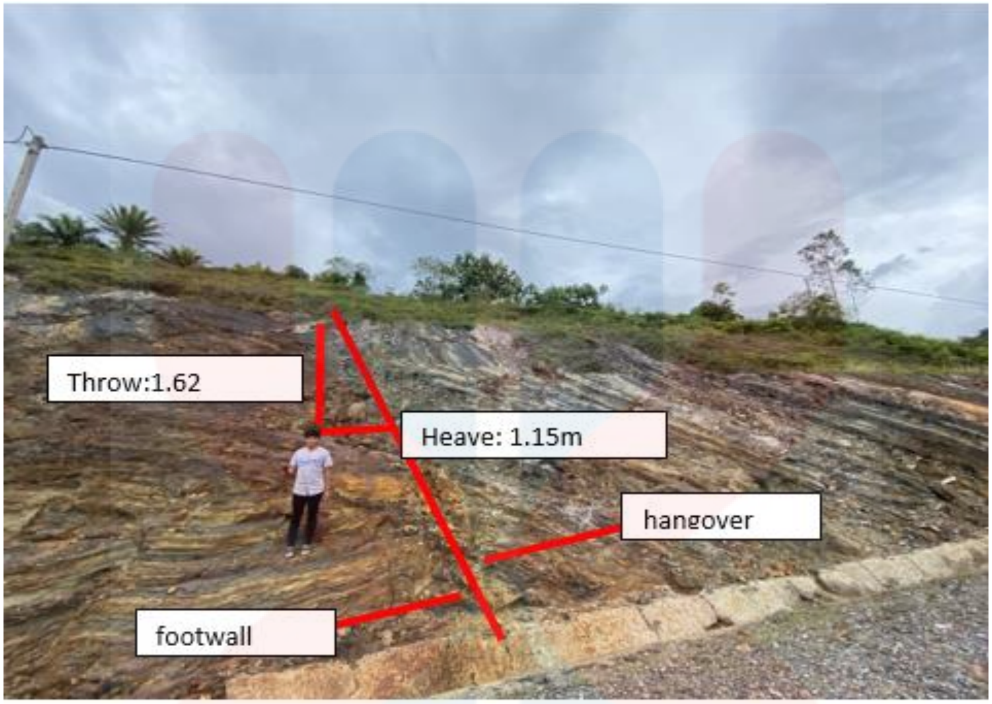


Figure 4.43 : Fault at the outcrop with fault analysis

From Stein and Wysession, 2003

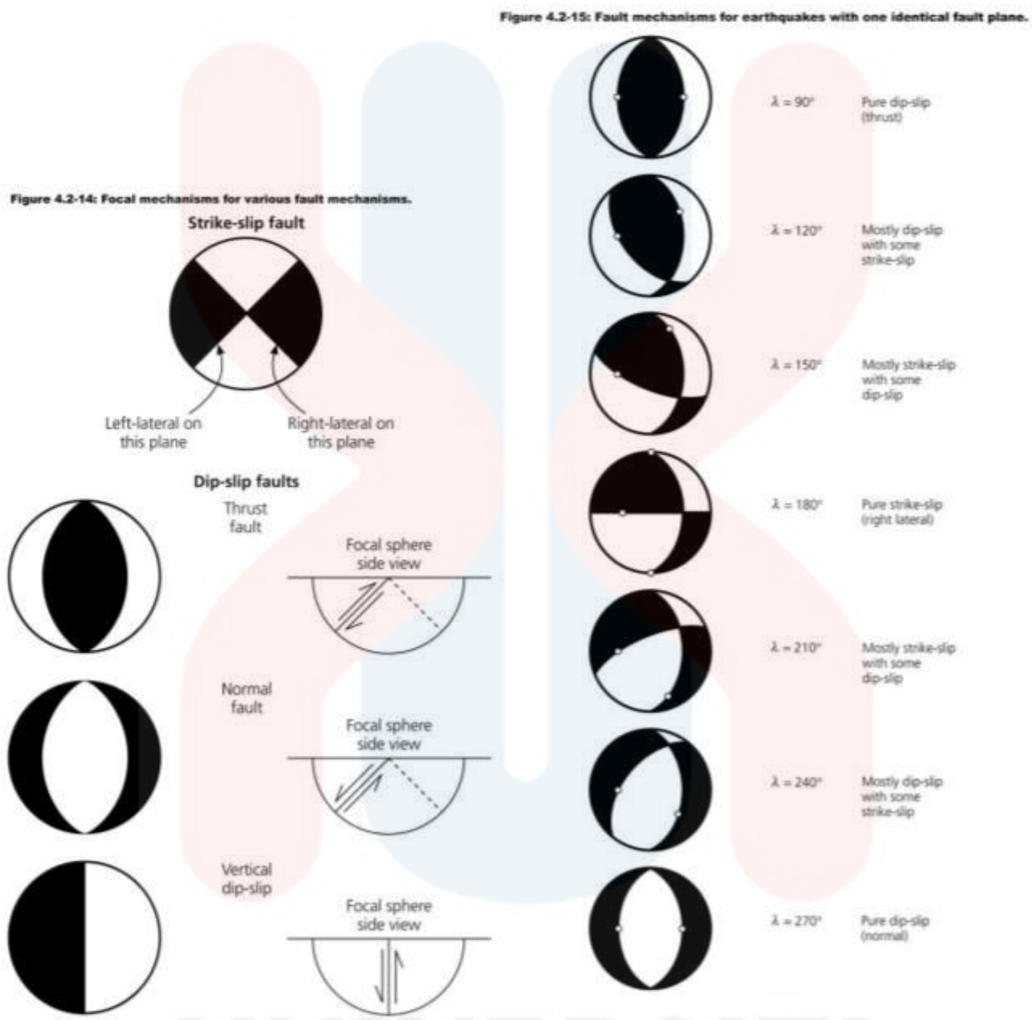


Figure 4.44 :The type of fault by Stein and Wysession,2003

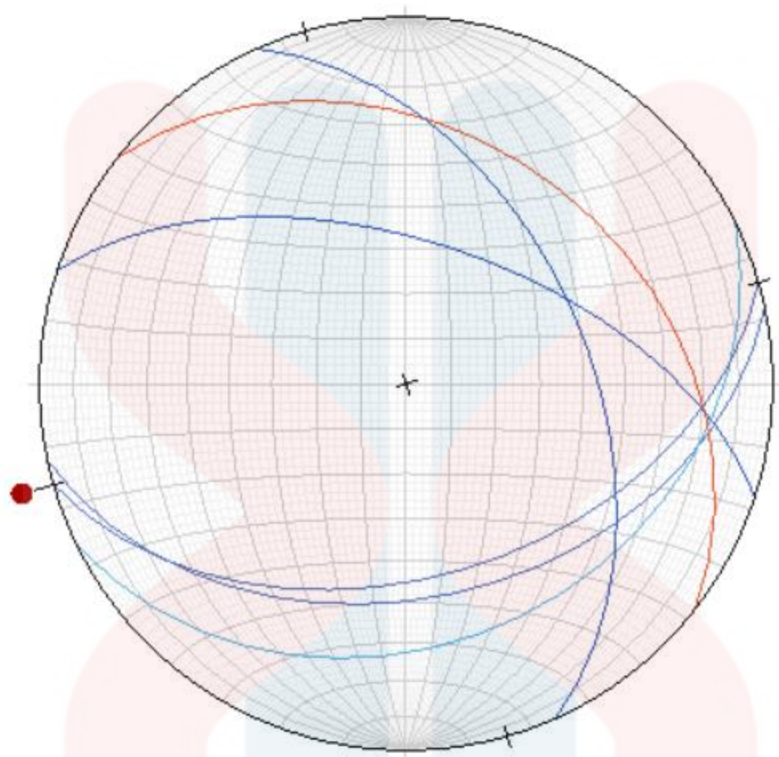


Figure 4.45: Stereonet of fault of study area.

4.4.3 Folding

When tectonic forces squeeze a body of rock, especially sedimentary rock, it is likely to fracture and/or become faulted if it is cold and brittle, or to fold if it is warm enough to behave plastically. An anticline is an upward fold, while a syncline is a downward fold. Many areas have a series of anticlines and synclines, though some rock sequences are folded into a single anticline or syncline. The axial plane of the fold is a plane drawn through the crest of a fold in a series of beds. Limbs are the sloping beds on either side of an axial plane. If the angles between each limb and the axial plane are generally similar, an anticline or syncline is said to be symmetrical; otherwise, it is said to be asymmetrical. The fold is known as an overturned anticline or syncline if the axial plane is sufficiently tilted that the beds on one side are tilted past vertical.

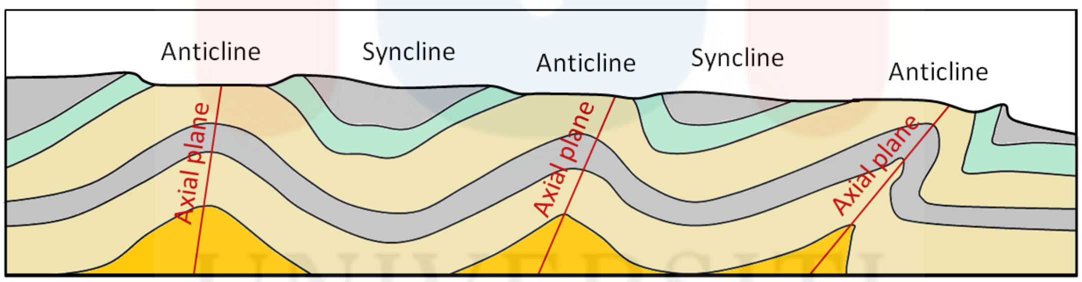


Figure 4.46 : the type of folding formation(Le Maitre,2023)

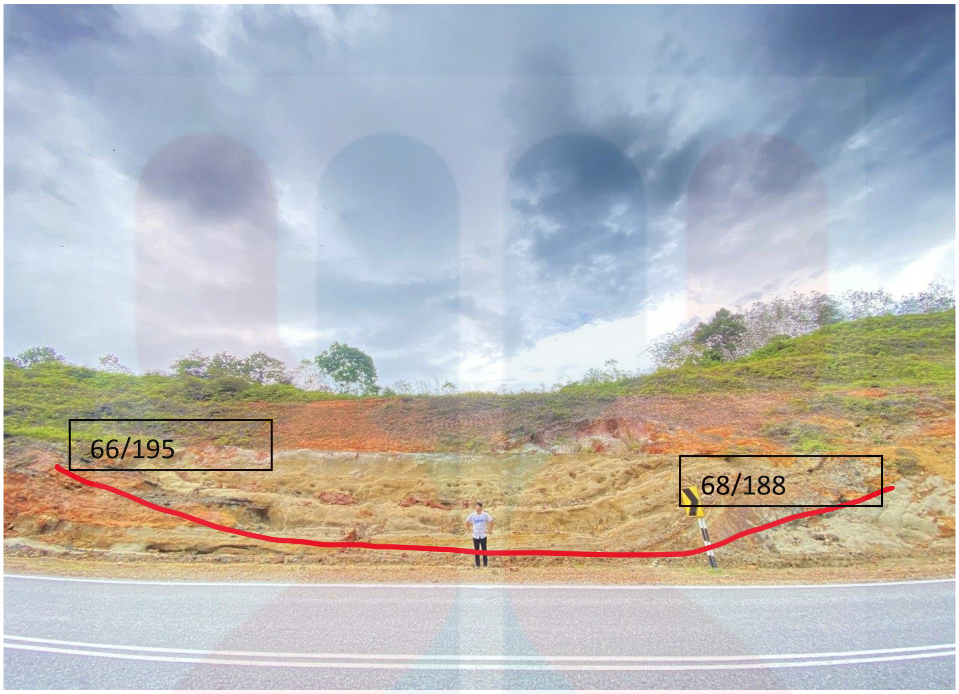


Figure 4.47 : Syncline fold

Figure 4.48: Anticline fold

4.4.3 Mechanism of structure

Lineament is a linear feature found on the terrain map. One of the indicators used to locate geological structures in the study area is lineament. Before the ground observation, a lineament analysis is performed. The study of linear features or straight features in the topography map was done to locate geological structures such as faults, fractures, and joints. Geomorphic lineaments include fracture zones, shear zones, and igneous intrusions such as dykes. Geomorphological features such as aligned ridges and valleys, displacement of ridge lines, scarp faces and river passages, straight drainage channel segments, pronounced breaks in crystalline rock masses, and aligned surface depression are commonly used in lineament mapping.

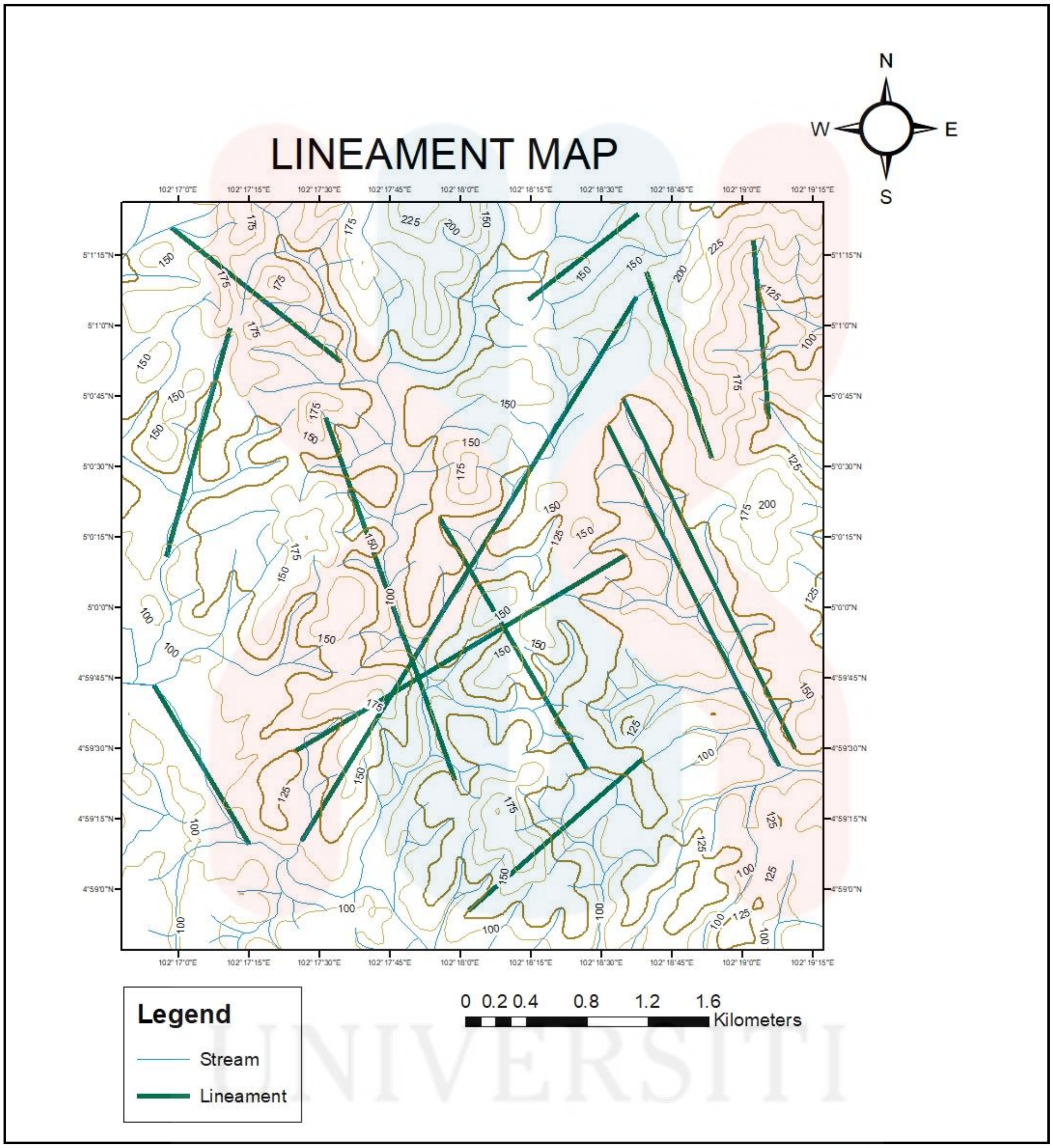


Figure 4.49: lineament map

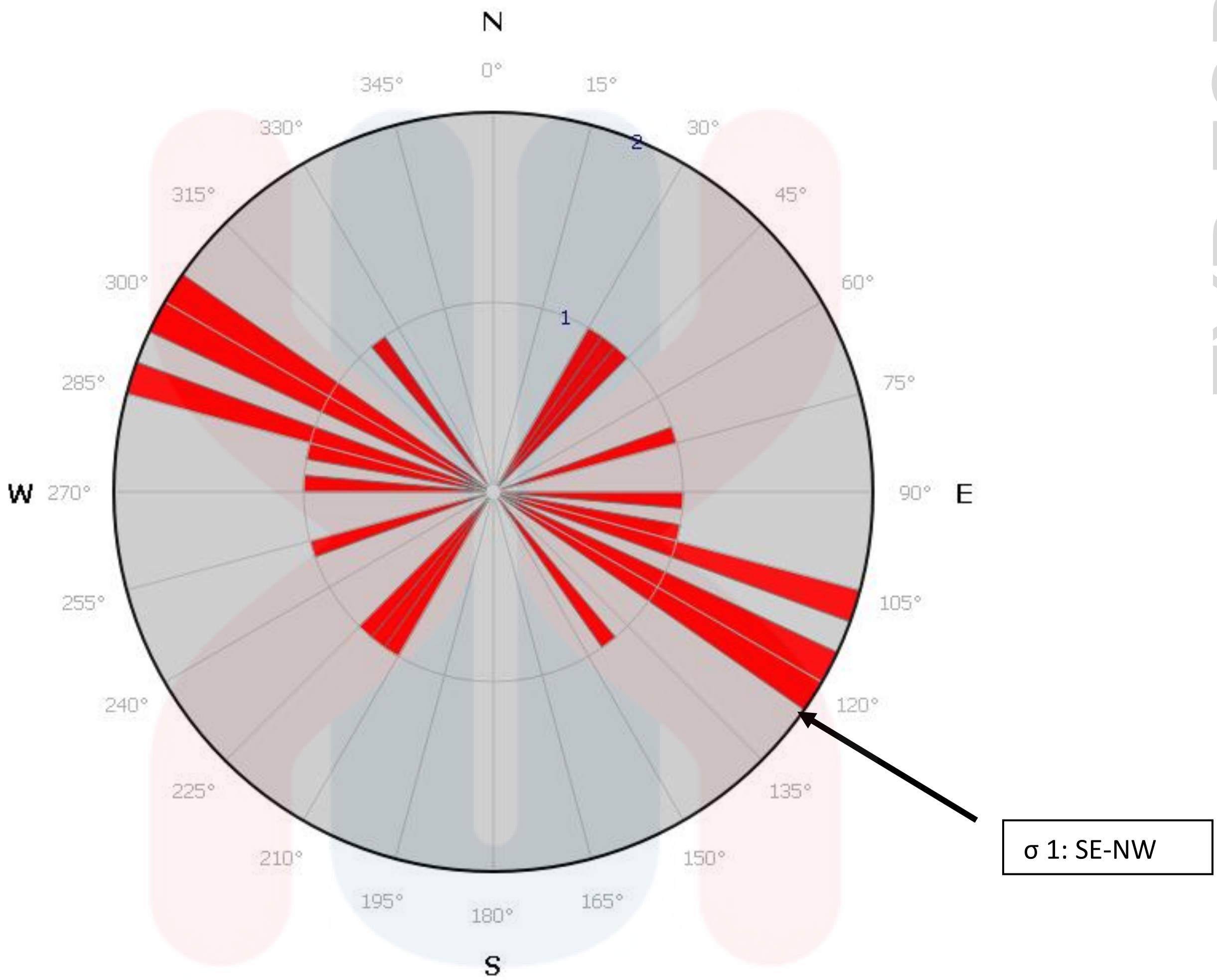


Figure 4.5 : lineament analysis.For compressional force is SE-NW while extensional force SW-NE

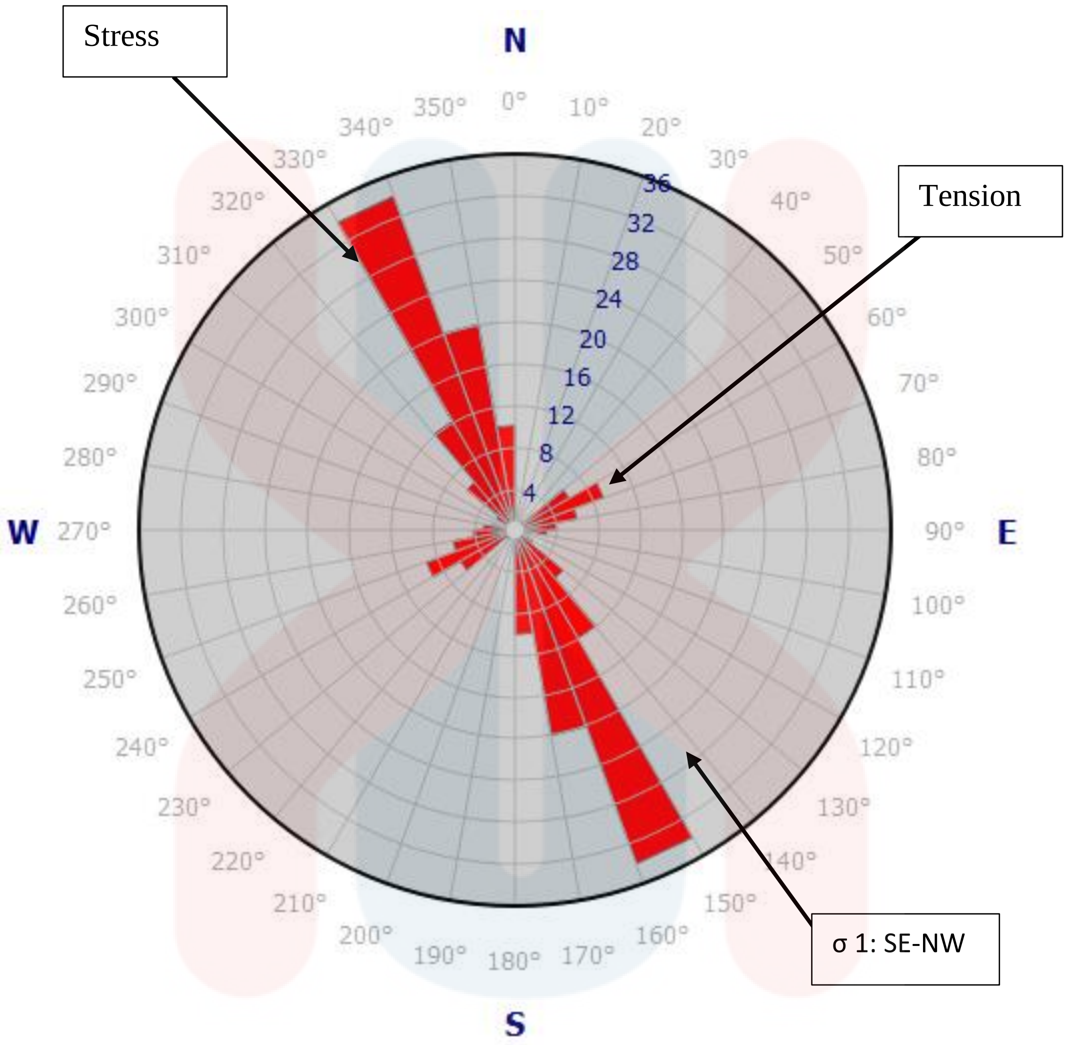


Figure 4.51: Joint analysis show stress and tension

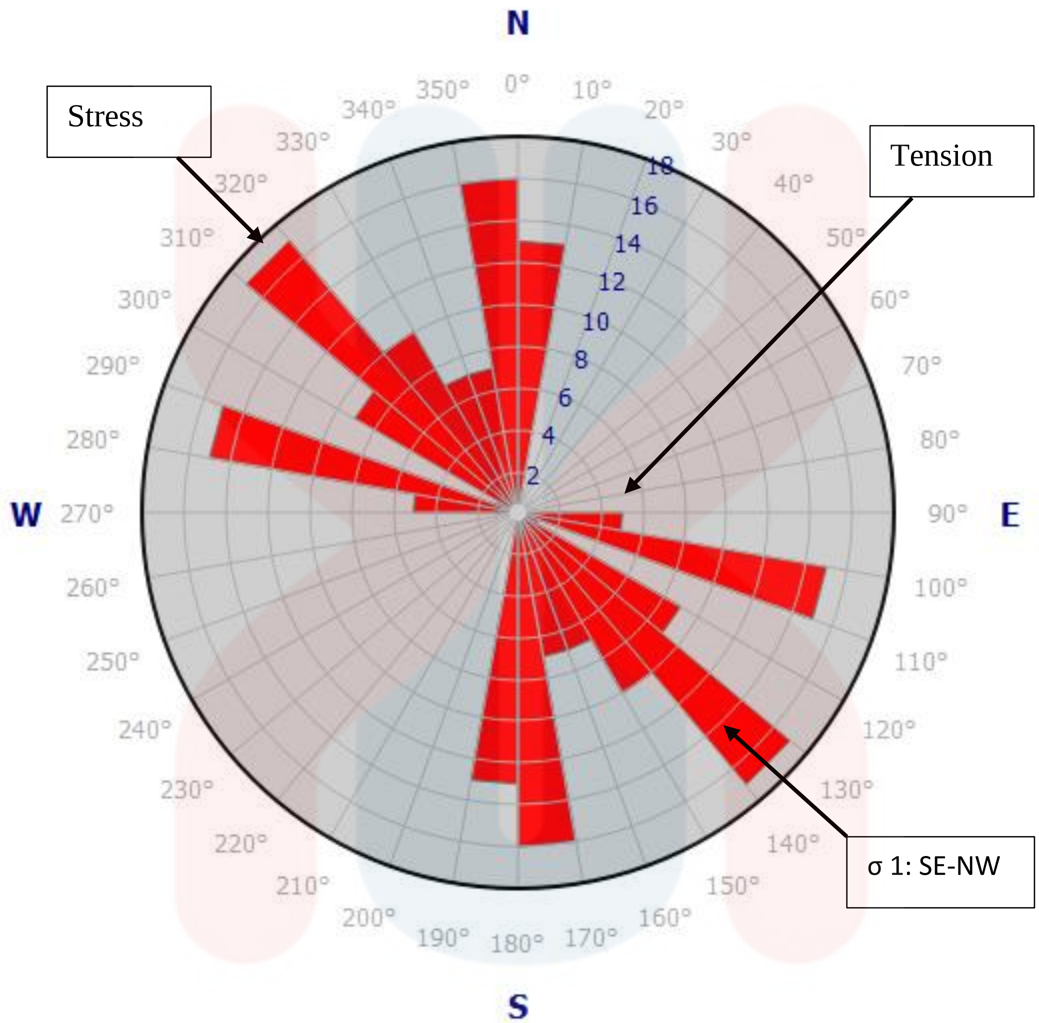


Figure 4.52: Extensional Joint

4.5 Historical Geology

Kampung Paloh 3 is a part of Aring Formation, since the nearest river which is one of the tributaries of Sungai Lebir. The age of study area is Mesozoic which is from late Carboniferous to the Early Triassic. Chronologically, there are deposition form at the study area where deposited rock at the bottom is the oldest rock whereas the upper boundary of the deposited area mostly is the younger rock compared to the bottom . The older rock at the study area is meta-mudstone which is a meta morphed sedimentary rock. After a while, phyllite also found at the deposited area which is located at the upper boundary of the deposited area. After the deposited occur, there is a sharp contact sedimentary rock and Andesite, this is because of eruption of volcanic occur. Besides Andesite, there is also Vitric tuff which is the major prove that the study area is a causes of volcanic eruption. This is because during the deposition process occur, there is volcanic eruption occur, therefore the volcanic ash or the cooling of magma merge onto the Earth 's surface to form extrusive igneous rock which is Andesite.Next,there are structural geological activity which is faults. The major fault effected the formation of folding occur at the study area. The major fault causes other minor fault that contribute to the formation of folding. Folding formed at the study area which is anticline and syncline. Anticlines and synclines are usually made up of many rock units that are folded in the same pattern. The tip of a fold is called the nose. The center axis of a fold is called the hinge line and lies in the axial plane that separates the rocks on one side of the fold from the rocks on the other side that dip in the opposite direction.

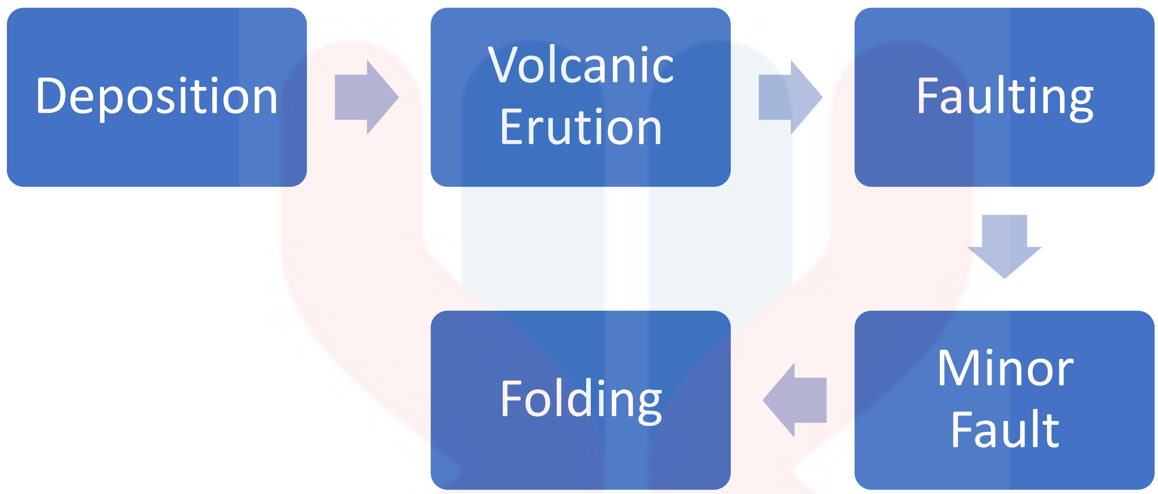


Figure 4.53: Flowchart of historical geology

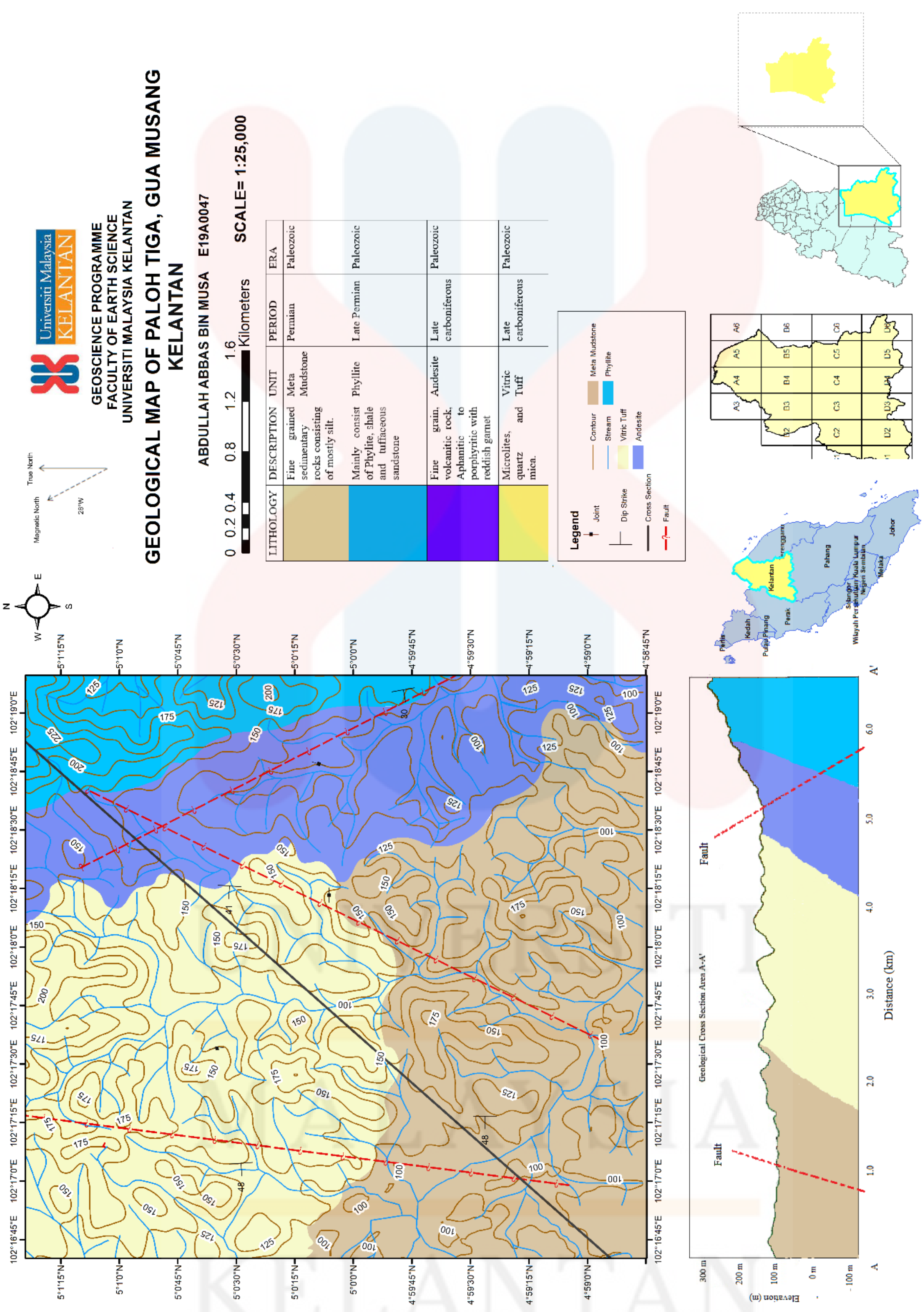


Figure 4.54: Geoloigcal Map of Paloh Tiga

CHAPTER 5

ANALYSIS OF LANDSLIDE POTENTIAL USING ELECTRICAL RESISTIVITY IMAGING (ERI)

5. 1 Introduction

The research area is located in Paloh , which contains an east-west highway in its centre. Observations indicate that several landslide potential occur along the roadway as a result of slope cutting for construction and exposed outcrops that are susceptible to landslide owing to the weathering process. The process of weathering will have a significant impact on the stability of the slope and the strength of the rocks. Additionally, slope steepness and surface and subsurface water movement may also contribute to landslide. The presence of surface and subsurface water, as well as drainage and precipitation, should be emphasized as a primary element influencing slope stability. During heavy rainfall, the water table rises, the soil becomes saturated, and the pores between the grains of soil are filled with water, causing the soil to grow denser. Electrical resistivity surveys can be used to detect these issues. Electrical Resistivity Imaging is the approach employed for this survey (ERI). Using the typical chart, the geophysical properties of rocks that rely on electrical resistivity can be interpreted. According to Palacky (1987), the resistivity values of significant rock groups are comparable.

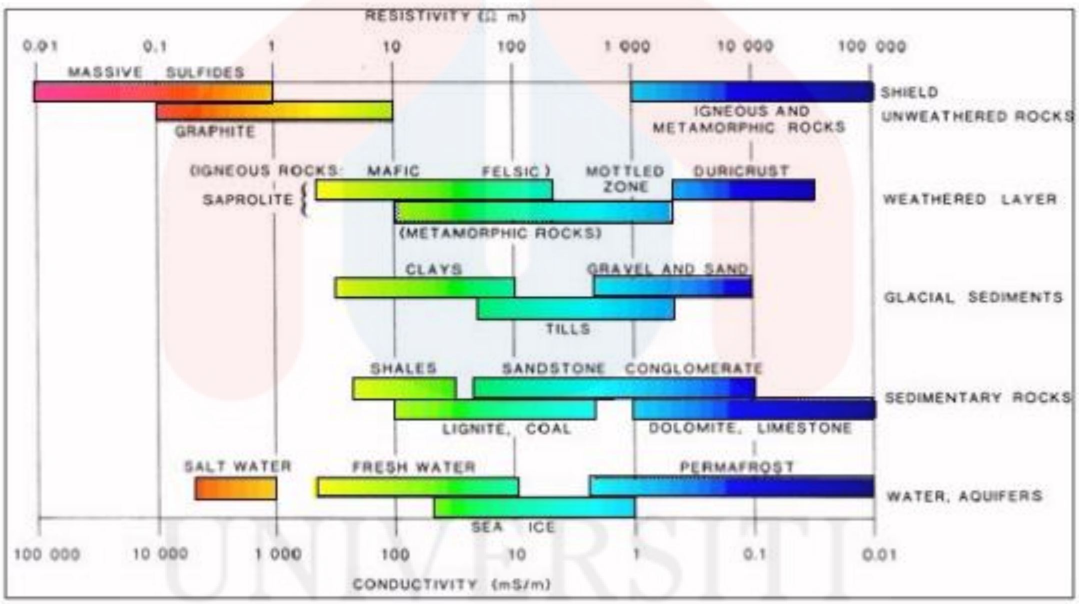


Figure 5.1 : Chart of resistivity value(Developers G,2018)

Along the roadway, five slopes have been selected for the electrical resistivity survey. Two lines were conducted on each slope, resulting in a total of five lines conducted at five slope locations.For the first slope, the first line was conducted utilising a gradient array electrode setup with a horizontal distance of 200 metres and a 5 metre electrode spacing. The second line was done utilising a Werner array electrode setup with a 100-

meter vertical span over the slope and a 2.5-meter electrode spacing. For the second slope, the third line was conducted utilizing a gradient array electrode arrangement with a horizontal distance of 200 meters and 5 meters between electrodes. Gradient array was used to conduct the fourth line electrode arrangement with a distance of 200 meter across the slope horizontally and electrode spacing is 5 meter. For slope number five, the fifth line was conducted using a gradient array electrode configuration with a 200-meter vertical distance and a 2.5-meter electrode spacing. Figure 5.2 depicts five lines of slope survey as Line 1, Line 2, Line 3, Line 4, and Line 5.

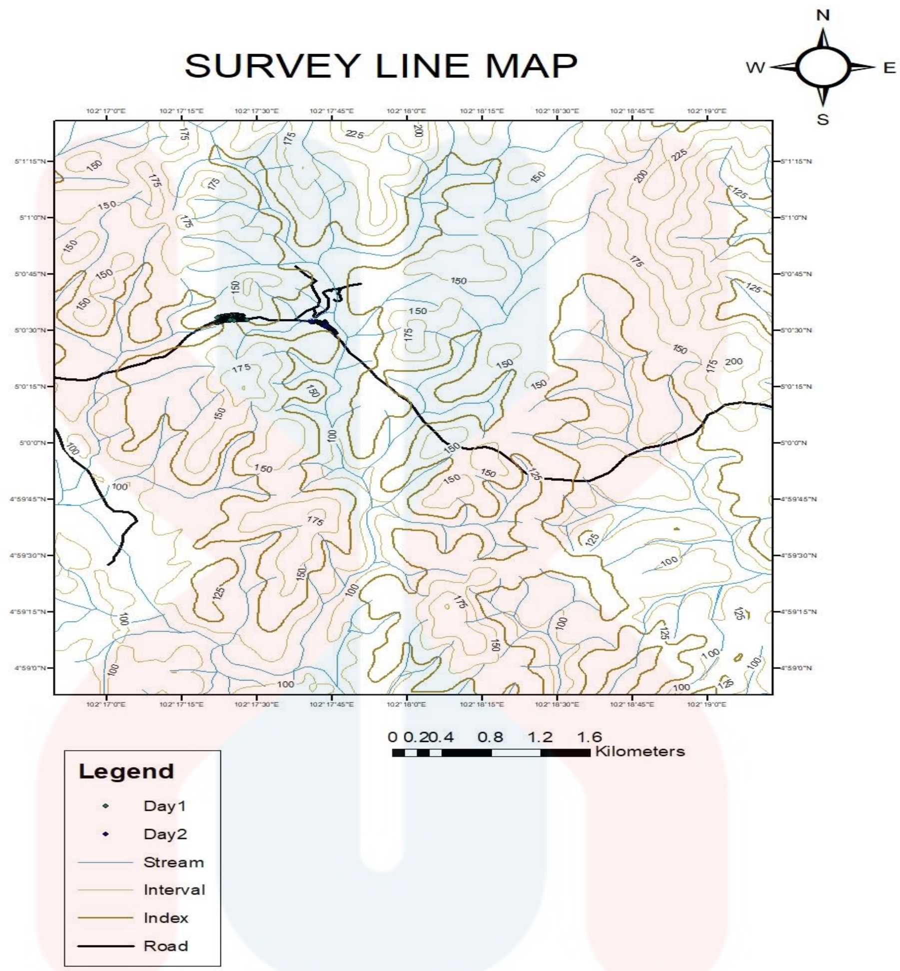


Figure 5.11: Survey line map

5.2 Geophysical Resistivity Method

The chosen gradient in the study area is located at the coordinates N 05° 30', E 102° 412". In addition to being chosen based on lineament research, the location has landslide potential. The lithology consists of mudstone interbedded with tuffaceous sandstone that has been slightly weathered. . For the purpose of identifying potential layers of rock that may have held water, the survey line's orientation should be parallel to or across the lineament. The three resistivity lines are placed in a flat location which is horizontally and other 2 lines placed in slope area which vertically, and RES2DINV software is used to measure all the resistivity line data.

Figure 5.2 : locality of the resistivity activity

5.2.1 Resistivity line 1

The array configuration for line 1 is Gradient. Table 5.2 displays the coordinates of electrodes 1, 21, and 41, which correspond to the first, middle, and last electrodes, respectively

Table 5.21 : coordinates of electrodes 1, 21, and 41, which correspond to the first, middle, and last electrodes, respectively.

Electrode No	Coordinate	Elevation (m)
1	N 05° 28’ 37”, E 102° 29’ 37”	124
21	N 05°29 ’11.4 ”, E 102° 29’13”	127
41	N 04° 46’ 11.7”, E 102° 19’ 10”	122

On the berm of the slope in the research area, a horizontal survey line is established in the direction of the surface of slope instability. The survey line running from northeast to southwest. The weather is cloudy during the survey.

Figure 5.21: Set up for line 1.(A)

The result of pseudo section is shown in Figure 5.22. The number of iteration for inverse resistivity model and IP model is 5. The root-mean-square (RMS) error in inverse resistivity model is 6.4%. For IP model, the RMS error is 7.3 which is higher than inverse resistivity model by 0.13%. Based on the pseudo section of inverse resistivity model, the range of chargeability values for survey Line 1 is 38.2 Ωm to 1181 Ωm while the range of chargeability of IP model pseudo section is 1.00 msec to 15 msec. based on Figure 5.21, the area with high resistivity value of > 1181 Ωm has been classify as moderately weathered to hard material zone which this zone may consist of bedrock or dry material. This area is represented by dark red to dark purple color which located at elevation < 125 m.

the area with resistivity value 166 Ωm to 724 Ωm has been classify as weathered material zone which may composed of soil with high content of water and may be classified as weak zone of the slope.This zone is located at elevation between 85m to 115m.The area with resistivity between 38.2 Ωm to 102 Ωm has been classify as surface water. The surface water is located at elevation between approximately 215 m to 230 m. the color of this zone is light blue to dark blue.

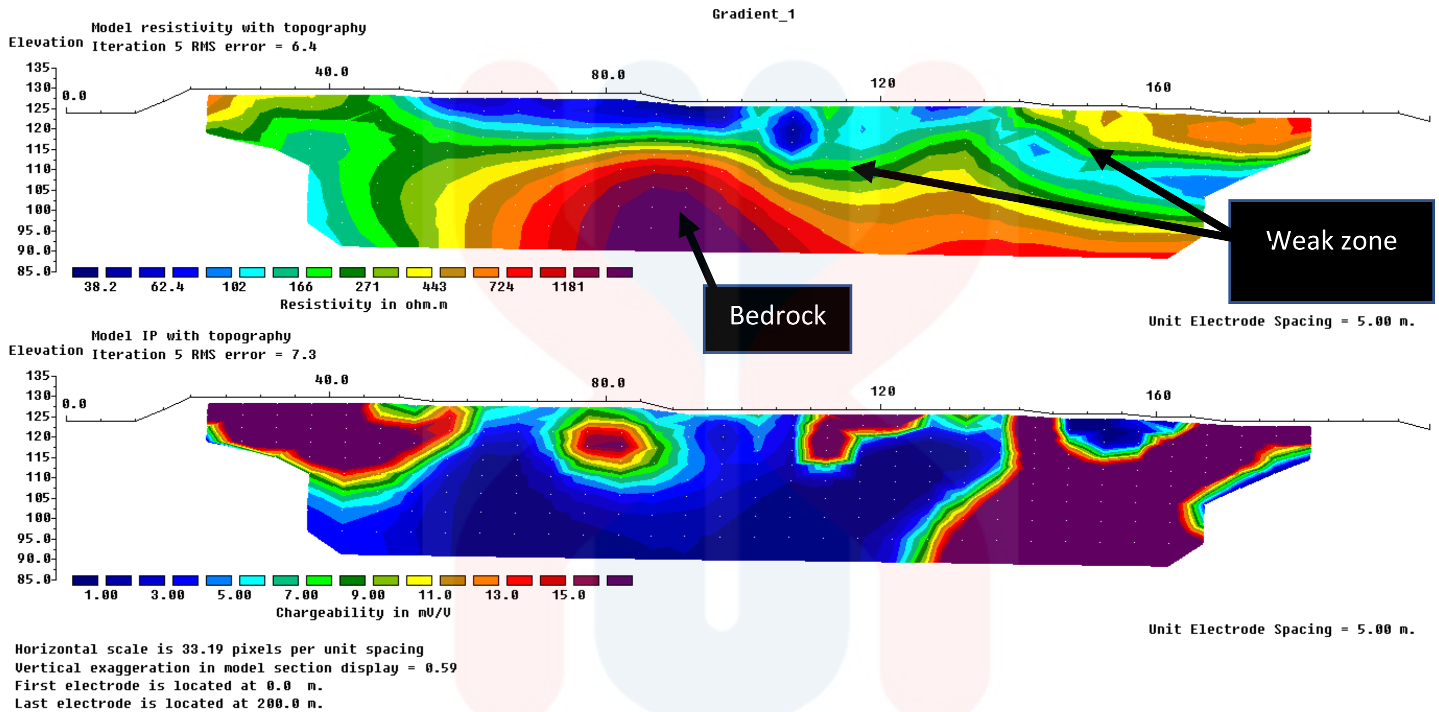


Figure 5.22 : Pseudo section of Gradient 1 line 1

5.2.2 Resistivity Line 2

The array configuration for line 2 is Werner.

Table 5.22: Coordinates of electrodes 1, 21, and 41, which correspond to the first, middle, and last electrodes, respectively.

Electrode No	Coordinate	Elevation (m)
1	N 05° 29’ 15”, E 102° 29’ 37”	102
21	N 05° 29’ 45”, E 102° 29’ 71”	102
41	N 05° 29’ 45”, E 102° 29’ 59”	102

The survey line is set up vertically and set up opposite of line 1. e. The survey line in the direction of NE – SW. The weather during the survey is cloudy.

Figure 5.23: Set up for line 2 (A)

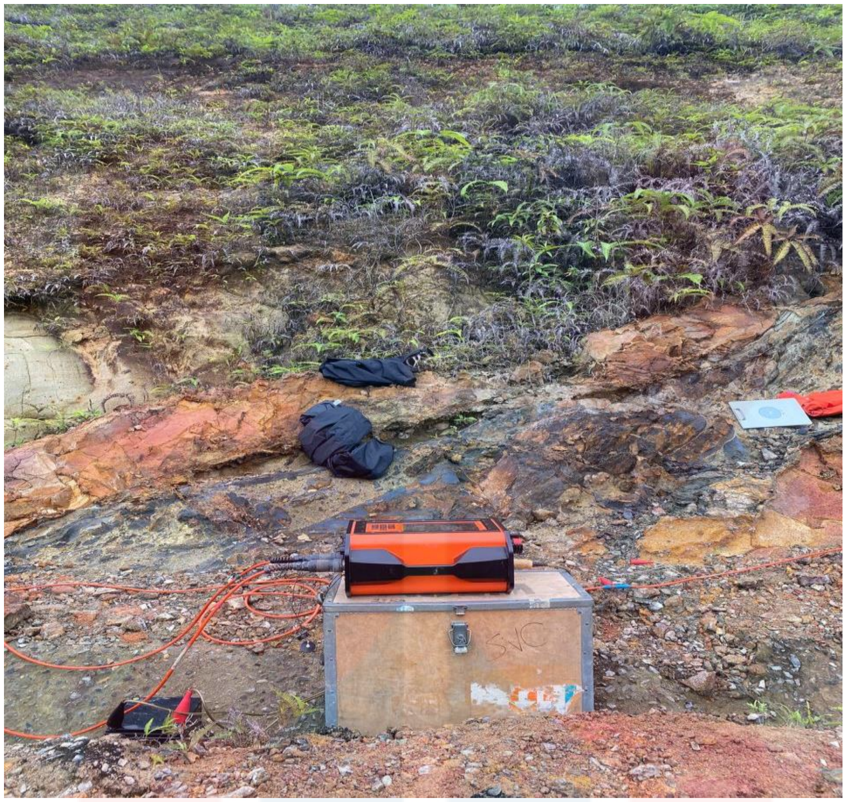


Figure 5.24 Set up for line 2 (C)

Figure 5.25: Set up for line 2 (B)

Figure 5.26 demonstrates the consequence of pseudo section. 8.2% of inverse resistivity model and IP model iterations are complete. The root-mean-square (RMS) error for the inverse resistivity model is 1.9%, whereas the RMS error for the inverse resistivity model is 0.3%. Based on the pseudo section of the inverse resistivity model, the range of chargeability values for survey Line 2 is between 1,3m and 876m, whereas the range of chargeability for the IP model pseudo section is between 1.0 msec and 15.0 msec.

Based on Figure 5.26, the region with a high resistivity value of > 876 m has been classified as a zone of moderately worn to hard materials, which may include bedrock or dry material. This region has a dark red to dark purple hue and is located at a depth of 13.1 meters. The region with resistivity values between 72.8m and 253m has been designated as a zone of weathered material. This zone may consist of materials with a high-water content and may be classed as a slope's weak zone. This zone is between 3.38 and 6.72 metres deep. This zone may contain clay silt sediment. The region with a resistivity value less than 11,3 m has been designated as a water-saturated zone. The water-saturated zone is located between 3,38 and 10,8 metres in altitude. This zone's colour ranges from mild to dark blue.

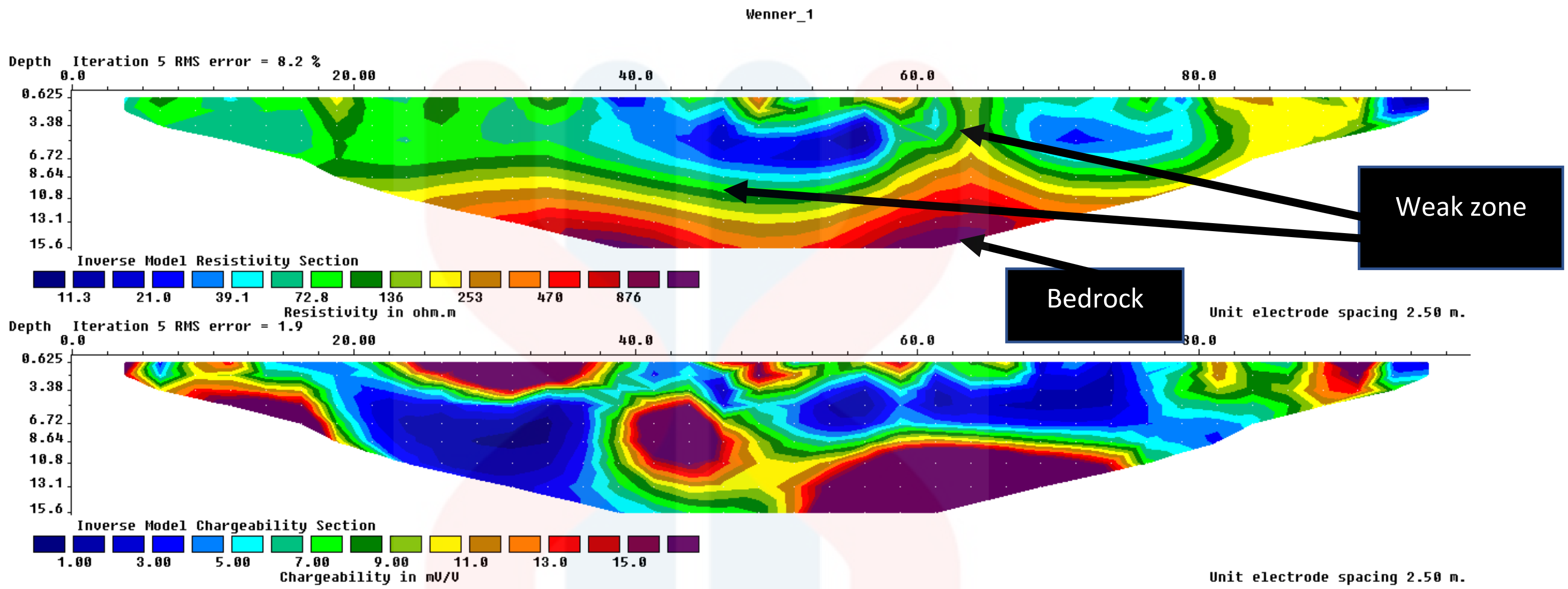


Figure 5.26: Pseudo section of Werner 1

5.2.3 Resistivity Line 3

The array configuration for line 3 is Gradient.

Table 5.23: Coordinates of electrodes 1, 21, and 41, which correspond to the first, middle, and last electrodes, respectively.

Electrode No	Coordinate	Elevation (m)
1	N 05° 29’ 7”, E 102° 29’ 40”	180
21	N 05°29 ’4 ”, E 102° 29’16”	200
41	N 04° 49’ 3”, E 102° 19’ 23”	221

The survey line is set up horizontally with 5.0 m eletrode spacing. The survey line in the direction of NE – SW. The third line set up a dawn near to night day.

Figure 5.27 : Set up for line 3 (C)

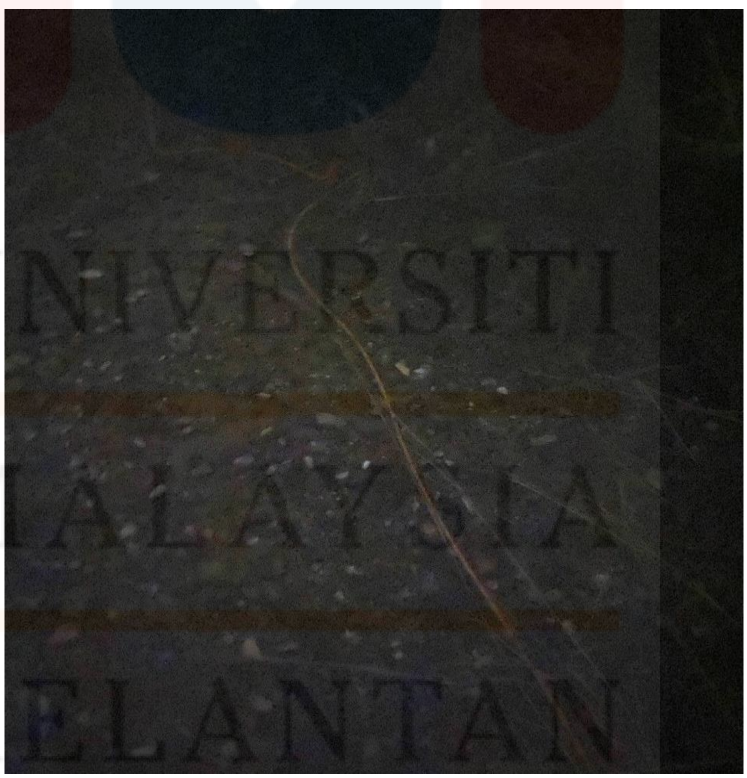


Figure 5.28: Set up for line 3 (A)

Figure 5.29 illustrates the result of pseudo section. 8.3% of the iterations for the inverse resistivity model and IP model are complete. The root-mean-square (RMS) error for the inverse resistivity model is 26.7%, whereas the difference is 19.6%. Based on the pseudo section of the inverse resistivity model, the range of chargeability values for survey Line 3 is between 5.15m and 2754m, whereas the range for the IP model pseudo section is between 1.0 msec and 15.0 msec.

The region with a high resistivity value of > 2754m has been defined as a zone of moderately worn to hard materials, which may comprise bedrock or dry material, based on Figure 5. This area has a color ranging from dark red to dark purple and is located at an elevation of 120 meters. The region between 76.1m and 1123m in resistivity has been classified as a zone of weathered material. This zone may contain materials with a high water content and may be considered the weak zone of a slope. This zone lies between elevation . This area may have silty clay sediment. A water-saturated zone has been classified as the region with a resistivity value lower than 31m. The water-saturated zone is between 5.15 and 12.60 meters above sea level. This zone ranges in hue from light to dark blue.

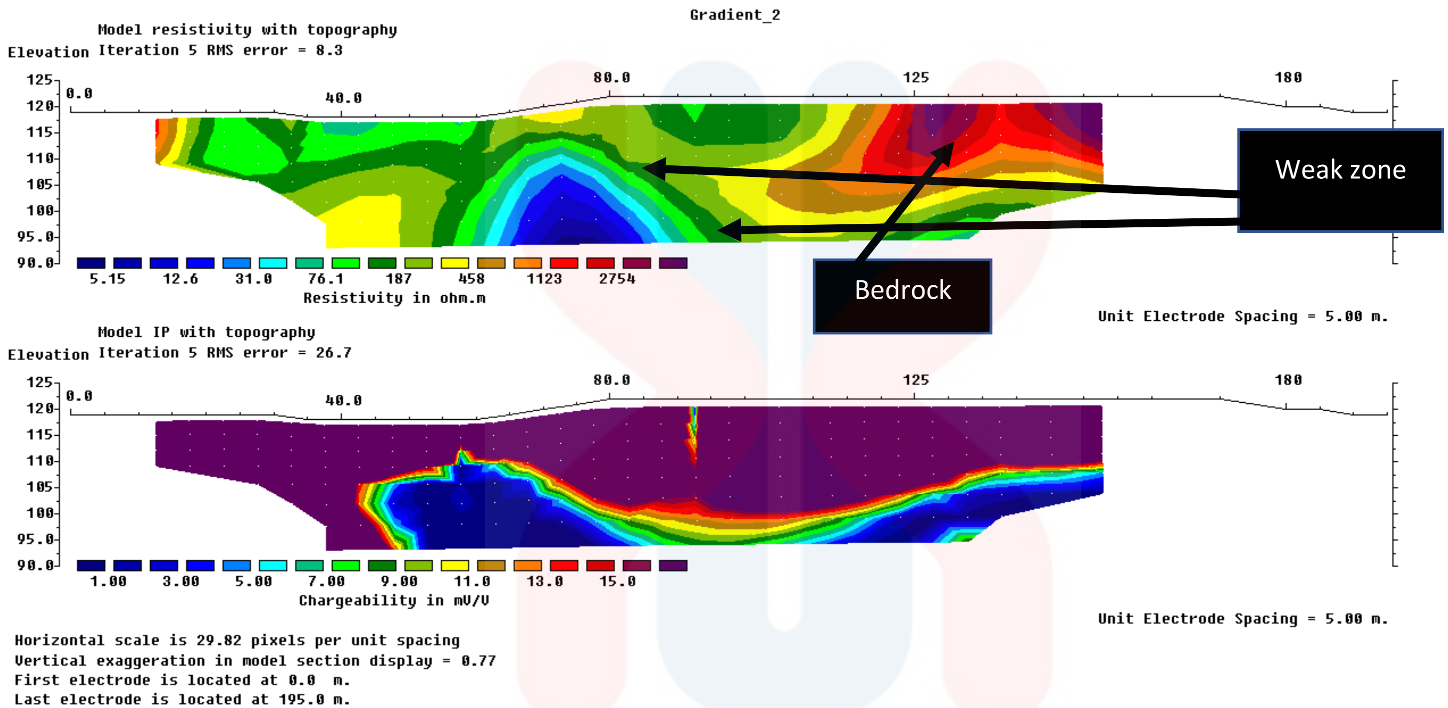


Figure 5.29 : Pseudo section of Gradient 2 line 3

5.2.4 Resistivity Line 4

The array configuration for line 4 is Gradient.

Table 5.24 : coordinates of electrodes 1, 21, and 41, which correspond to the first, middle, and last electrodes, respectively.

Electrode No	Coordinate	Elevation (m)
1	N 04° 54’ 7”, E 102° 20’ 40”	102
21	N 04°54 ’4 ”, E 102° 29’16”	102
41	N 05° ’ 10”, E 102° 19’ 23”	102

The survey line is set up horizontally with 5.0 m electrode spacing. The survey line in the direction of NE – SW. The fourth line set up at cloudy weather.

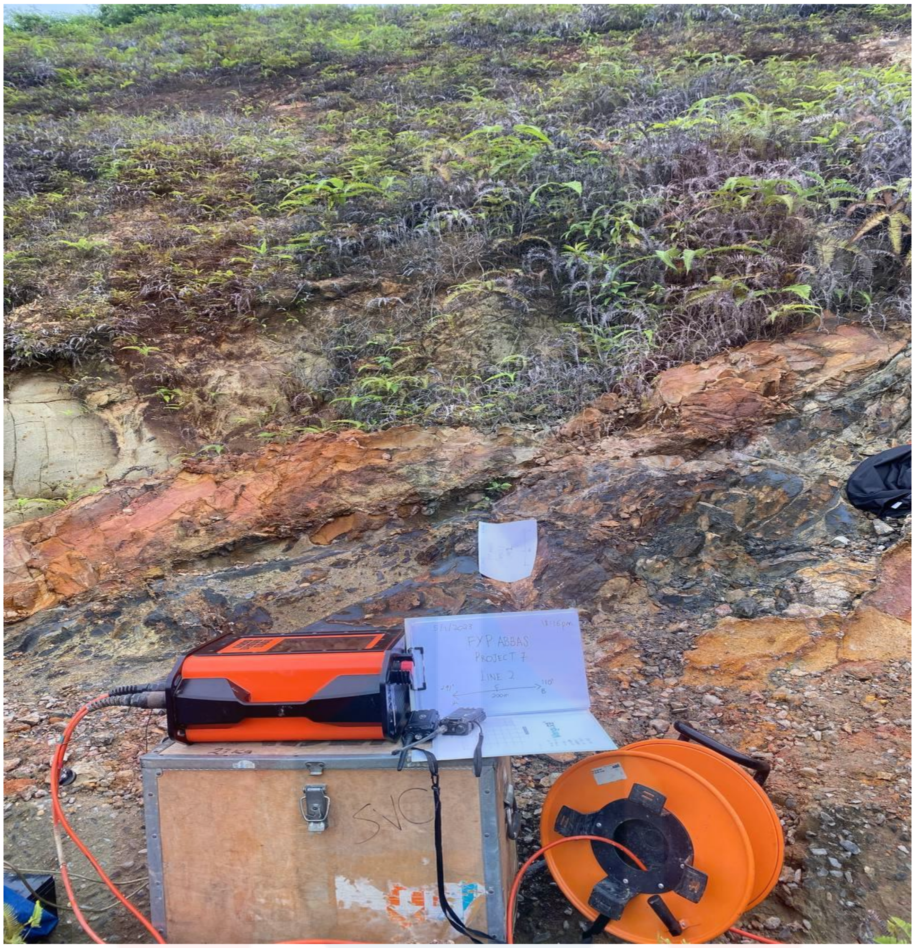


Figure 5.3 : Set up line for line 4(C)

Figure 5.31 : Google earth map,setup line 4 and ,5 day 2

Figure 5.32 illustrates the result of pseudo section. 8.3% of the iterations for the inverse resistivity model and IP model are complete. The root-mean-square (RMS) error for the inverse resistivity model is 26.7%, whereas the difference is 19.6%. Based on the pseudosection of the inverse resistivity model, the range of chargeability values for survey Line 3 is between 11,3m and 876m, whereas the range for the IP model pseudosection is between 1.0 msec and 15.0 msec.

The region with a high resistivity value of > 2754m has been defined as a zone of moderately worn to hard materials, which may comprise bedrock or dry material, based on Figure 5. This area has a colour ranging from dark red to dark purple and is located at an elevation of 120 metres. The region between 76.1m and 1123m in resistivity has been classified as a zone of weathered material. This zone may contain materials with a high water content and may be considered the weak zone of a slope. This zone lies between elevation . This area may have silty clay sediment. A water-saturated zone has been classified as the region with a resistivity value lower than 31m. The water-saturated zone is between 5.15 and 12.60 metres above sea level. This zone ranges in hue from light to dark blue.

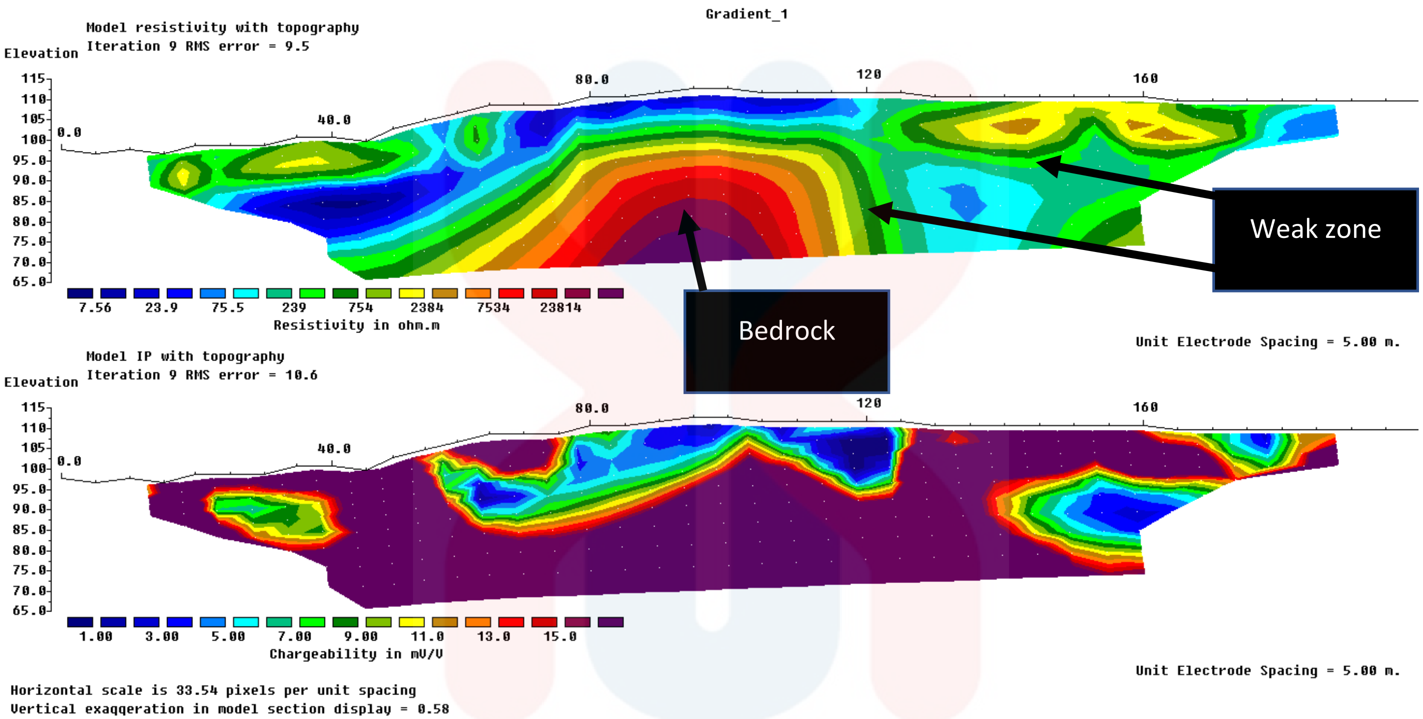


Figure 5.32: Pseudo section of line 4 gradient

5.2.5 Resistivity Line 5

The array configuration for line 5 is Gradient.

Table 5.25: Coordinates of electrodes 1, 21, and 41, which correspond to the first, middle, and last electrodes, respectively.

Electrode No	Coordinate	Elevation (m)
1	N 04° 54' 7", E 102° 20' 40"	102
21	N 04°54 '4 ", E 102° 29'16"	102
41	N 05° 30'10", E 102° 19' 23"	102

The survey line is set up horizontally with 2.5 m electrode spacing. The survey line in the direction of NE – SW. The fourth line set up at cloudy weather.

Figure 5.33 : Set up for line 5 (A)

Figure 5.34: Set up for lne 5 (B)

Figure 5.35: Set up for line 5 (C)

Figure 5.36 depicts the outcome of pseudo sectioning. Five iterations are performed for the inverse resistivity model and IP model. RMS error of the inverse resistivity model is 8.7%. The RMS error for the IP model is 2,7, which is 5% less than the inverse resistivity model. Based on the pseudo section of the inverse resistivity model, the range of chargeability values for survey Line 1 is between 10,5 m and 445 m, whereas the range of chargeability for the IP model pseudo section is between 1.00 msec and 15 msec. Based on Figure 5.36, the region with a high resistivity value of > 445 m has been categorized as a moderately weathered to hard material zone, which may contain bedrock or dry material. This location has a color range from dark red to dark purple and is located at an elevation of 110 meters.

The region with resistivity values between 52,3 m and 152 m has been identified as a zone of weathered material, which may consist of soil with a high-water content and may be classed as a zone of slope weakness. This zone is found between 100 and 155 meters in altitude. The region with a resistivity between 10.5 and 30.6 micrometers has been classified as surface water. The elevation of the surface water is around 105 to 110 meters. This zone's color ranges from mild to dark blue.

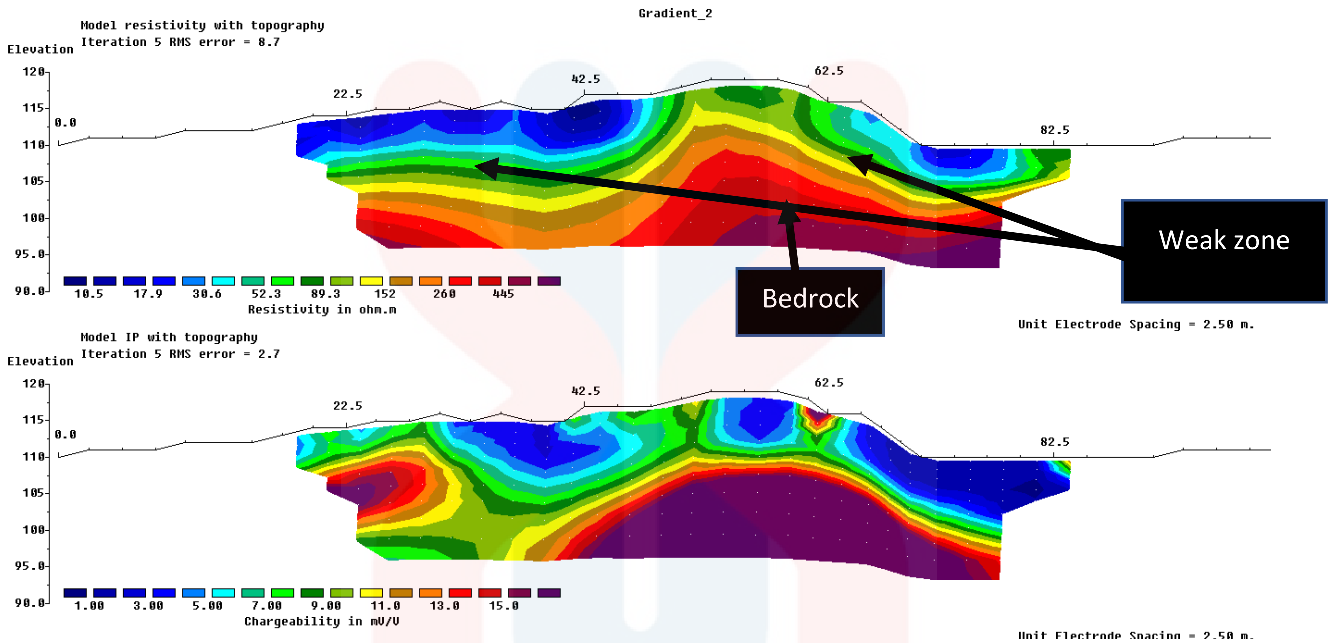


Figure 5.36 : Pseudo Section Gradient 2 line 5

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter will provide an overview of the objectives that have been met. The objective is to update the geological map of Paloh, Gua Musang, and to assess the possibility for landslides using the electrical resistivity approach.

6.2 Conclusion

According to geological studies, the study region includes primarily of the Aring Formation. The lithology of the area under study consists of sedimentary and igneous rock. There are three distinct types of rock: metamudstone, Phyllite, and Andesite. The age of the rock unit investigation is Paleozoic. Approximately 70% of the studied region consists of the meta mudstone unit, 20% of the Phyllite unit, and 10% of the Andesite unit. In terms of geomorphology, over 80% of the studied region consists of hilly terrain, while only 20% consists of mountainous topographic units. The research area's lowest elevation is 100 meters, while its highest point is 250 meters above sea level. The area of investigation has a dendritic pattern.

The first line (Line 1) and second line (Line 2) of the electrical resistivity survey were conducted at the first locality. Line 1 was constructed with a gradient array layout with a horizontal span of 200 meters across the hill. Line 2 was constructed at 200 meters utilizing a vertical Werner array arrangement. The third line is configured horizontally with 2.5 m between electrodes. Line 3 was constructed utilizing a gradient array arrangement with a horizontal distance of 200 meters. Line 4 was constructed at a distance of 200 meters utilizing a vertical gradient array arrangement. Fifth line (Line 5) is vertically conducted. On the hill, Line 5 was constructed at a distance of 200 meters utilizing a gradient array layout. Based on the assessment of each line's resistivity data, lines 2 and 3 become unstable due to the presence of weathered rocks and water in the rock strata, which disturbs the pore pressure. Based on the result of above 5 lines, we can correlate the potential of the landslide with the structural geology which is the 5 lines that conducted resistivity method are included in the of major of fault plane,hence,the major fault slip causes other minor fault such as fault breaccia that causes mechanical deformation to the rock that potentially water filled up the space eventually causes the zone become swollen and have the potential to have geological hazard which is landslide.

6.3 Recommendation

As a recommendation, it is suggested that future researchers combine in-situ and laboratory testing with electrical resistivity surveys. For instance, point load testing. A point load test is used to measure rock strength and will aid in producing more precise justification for a region's slope stability. Next, additional time must be allocated for the electrical resistivity survey, and the data should be processed immediately once the survey is completed. If the data was gathered prior to a problem, it will be simpler to repeat the line in the event of a problem.

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