GEOLOGY AND LANDSLIDE INVESTIGATION USING RESISTIVITY SURVEY METHOD AT KAMPUNG SUNGAI TUPAI, GUA MUSANG, KELANTAN

by

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

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DECLARATION

I hereby declare that the work embodies in this report is the result of the original research and has not been submitted for a higher degree to any university or institution.

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APPROVAL

I certify that the Final Year Project Report entitled "Geology and Landslide Investigation Using Resistivity Survey Method at Kampung Sungai Tupai, Gua Musang, Kelantan" has been examined and all the correction recommended by examiners have been done for the degree of Bachelor Applied Science (Geoscience), Faculty of Earth Sciences, University Malaysia Kelantan.

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Supervisor,

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ABSTRACT

The study area is located at Kampung Sungai Tupai, Gua Musang, Kelantan. It is located in the longitude between 101º58′30.00″ to 102º01′42.00″ E and latitude between 3º40′05.00″ to 3º42′42.15″ N. The research covered 25km^{2} of Gua Musang area. The aim of this research is to produce the geological map with scale of 1:25000 and to investigate the factor that triggers the slope failure in the study area. Geological map prepared by satellite image interpretation method. Digital Elevation Model (DEM) data extracted using Google Earth and the satellite image was obtained from USGS website. The data processed using ArcGIS software. The type of lithology identified in the study area is Tuffaceous Mudstone unit, Limestone unit, Sandstone unit, Granite unit and Alluvium unit. The factor for slope failure investigated using 2D Electrical Resistivity Imaging (ERI) method with two 200 m cable of Wenner-Schlumberger configuration. The obtained data processed by using RES2DINV software to determine subsurface condition of the area. Based on result of two resistivity pseudo sections, the main triggering factor of the landslides in study area is the presence of water and water accumulation that comes from the surface runoff that seeps into it.

ABSTRAK

Kawasan kajian terletak di Kampung Sungai Tupai, Gua Musang, Kelantan. Ia terletak di garis longitude antara 101º58′30.00″ T hingga 102º01′42.00″ T dan garis latitud antara 3º40′05.00″ U hingga 3º42′42.15″ U. Penyelidikan merangkumi 25km^2 dari kawasan Gua Musang. Tujuan penyelidikan ini adalah untuk menghasilkan peta geologi dengan skala 1: 25000 dan untuk mengkaji faktor yang mencetuskan kegagalan cerun di kawasan kajian. Peta geologi disediakan dengan kaedah tafsiran gambar satelit. *Data Digital Elevation Model* (DEM) diekstrak menggunakan *Google Earth dan* gambar satelit diperoleh dari laman web USGS. Data diproses menggunakan perisian ArcGIS. Jenis litologi yang dikenalpasti di kawasan kajian adalah unit tuff bercampur batu lumpur, unit batu kapur, unit batu pasir, unit granit dan unit alluvial. Faktor kegagalan cerun yang disiasat menggunakan kaedah Pengimejan Resistiviti Elektrik 2D (ERI) dengan dua kabel 200 m berkonfigurasi Wenner-Schlumberger. Data yang diperoleh diproses dengan menggunakan perisian RES2DINV untuk menentukan keadaan permukaan bawah permukaan. Berdasarkan hasil dari dua keratan rentas resistiviti. Faktor pencetus utama tanah runtuh di kawasan kajian adalah adanya pengumpulan air dan berasal dari permukaan yang meresap ke dalam tanah.

CHAPTER 1

INTRODUCTION

1.1 General Background

Landslide is one of the natural disasters or hazards that always occur within the world. Landslide is described as the landform that formed from the movement of soil or rock under gravity affect. There are two types of landslide movement which is rotational slide which is curved and translational slide which is planar (Highland, 2008). The type of landslides or slope failure can be differentiated by referring to the movement and the material involved. Landslides occur despite of there is failure of the slope. Gua Musang area consist of both low and high elevation area. However, requirement for landslides to occur is not only places with humidity. Both dry and humid are having possibility to be affected by slope failure. The study that related to the field testing is crucial to determine the current condition of the slope to minimize such disaster. This is because if no action is taken, there are tendency of past landslide happen again at the same place.

Geophysical method especially resistivity survey is often used to investigate slope failure. This method was quite popular in subsurface profiling because it is cheap and has ability to indirectly replicate the images of the subsurface. Resistivity is a method to investigate how the material conducts and resists electric current. Basically, the method runs when applying direct current (DC) to the ground using electrodes and the data that will be recorded is the voltage or the potential difference. The apparent resistivity of the subsurface will be generated and inversed and ready to be interpreted.

Resistivity survey is commonly used due to fast investigation of the subsurface especially on the geometry, water content and fluid movement. For problem that requires shallow interpretation of the subsurface, resistivity is the standard method to do the geological prospecting.

1.2 Study Area

The study area of this research is located in Kampung Sungai Tupai which is based in Gua Musang, Kelantan. Figure 1.1 shows the map of Kelantan region.

Figure 1.1: Map of Kelantan

1.2.1 Location

The study area is located at Gua Musang which 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 25km^2 of the total area. It is located in the longitude between 101º58′30.00″ to 102º01′42.00″ E and 3º40′05.00″ to 3º42′42.15″ N. The study area is located at the border of Pahang and Kelantan district which is at the Kuala Lipis - Gua Musang Highway FT8. As seen in Figure 1.2, the location Gua Musang, figure 1.3 displayed the position of area covered by this research while figure 1.4 shows the basemap of the study area.

Figure 1.2: Location of Gua Musang district.

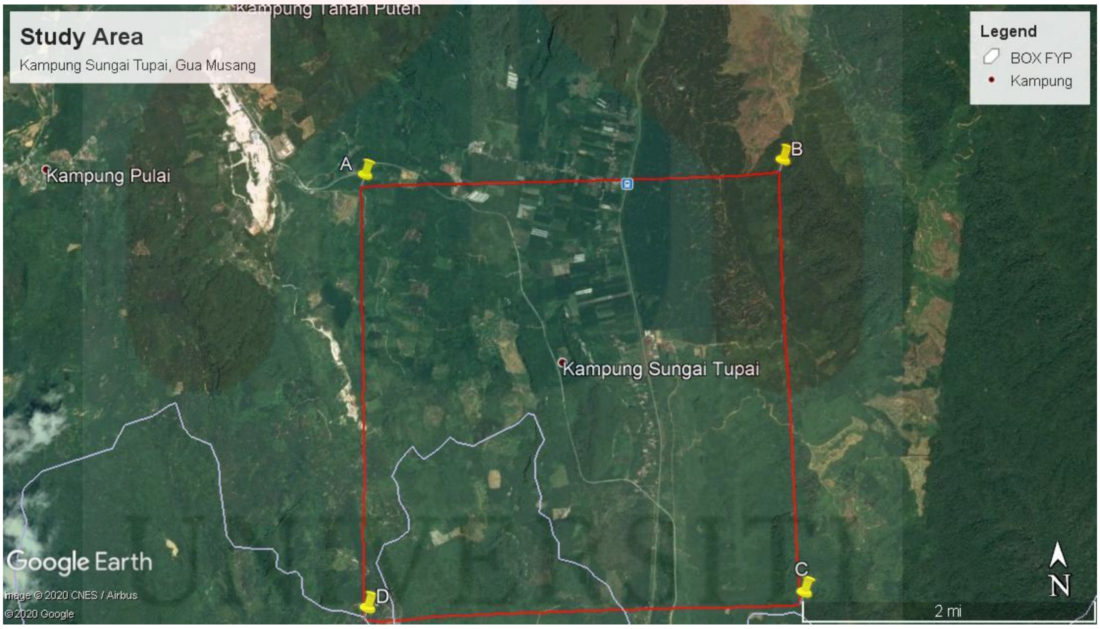

Figure 1.3: The study area in position of Southern part of Gua Musang.

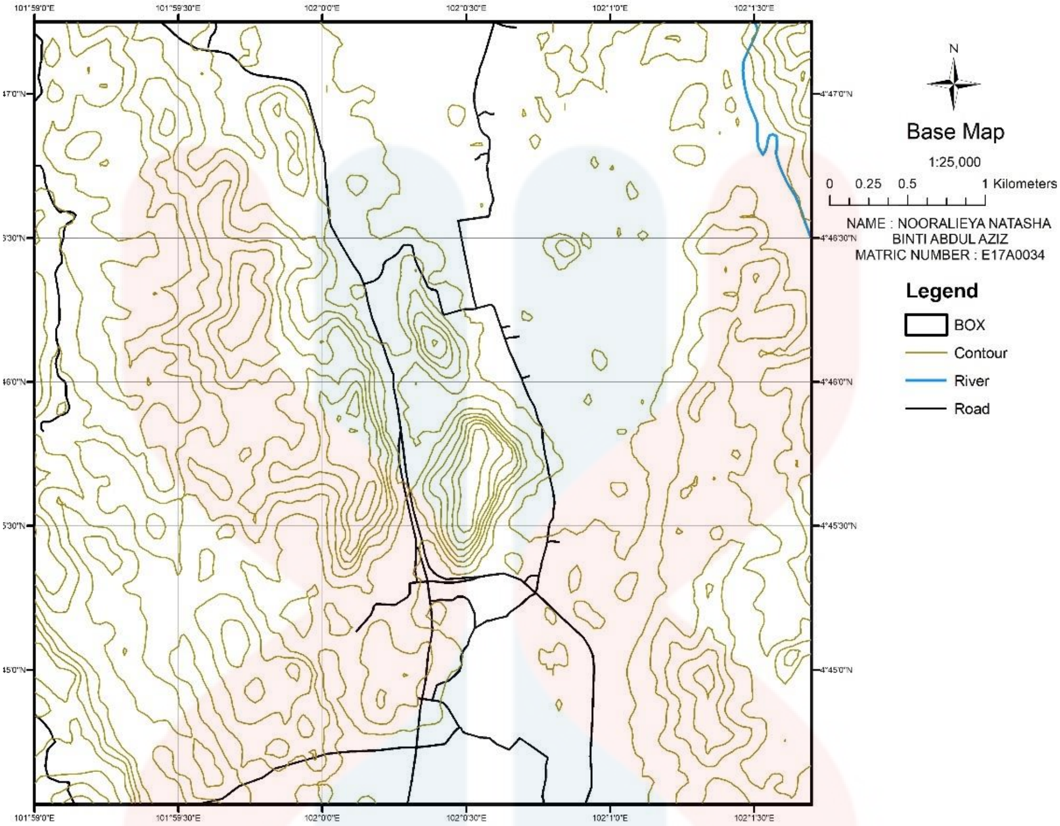

Figure 1.4: Basemap of study area

1.2.1 Road Connection/Accessibility

Kampung Sungai Tupai is located 16.3km at the south of Gua Musang city. It is located 9.7km from a small town of Kuala Lipis district, Pahang which is Merapoh, as shown in the Figure 1.5. There is also railway halt of Keretaapi Tanah Melayu (KTM) which is named Mentara Baru Railway Halt which is located in Kampung Mentara Baru. It is the railway facility to the border of Pahang and Kelantan.

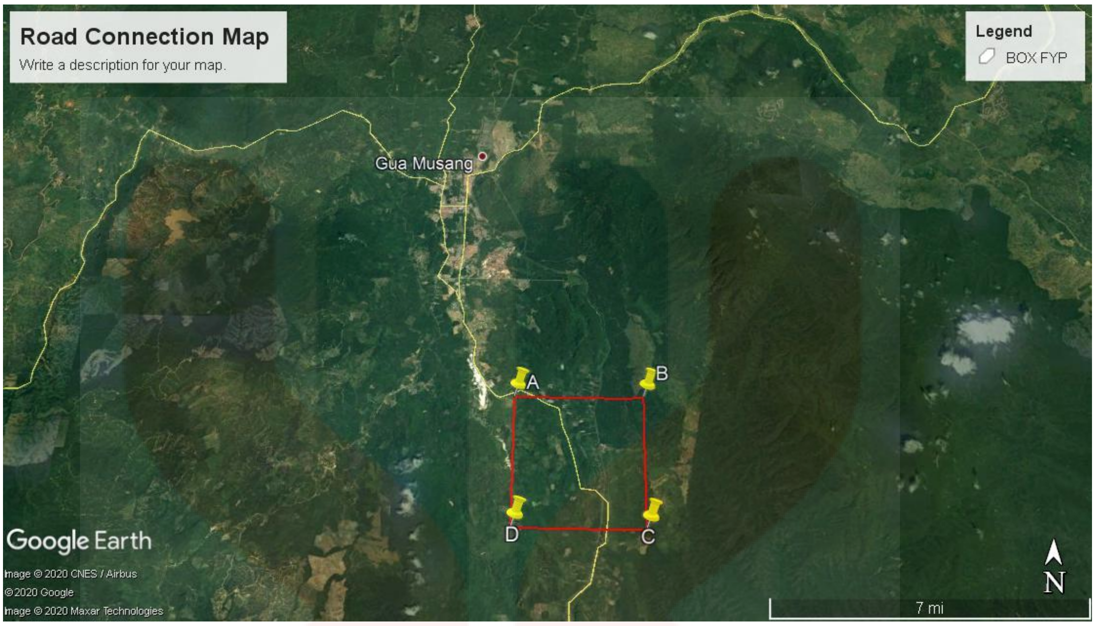

Figure 1.5: Road connection map from nearest city to study area.

1.2.2 Demography and Rainfall Distribution

Gua Musang is the largest district in Kelantan with the total area of 8,214.3 km². Based on Department of Statistics Malaysia, the amount of population in Gua Musang is 103,300 people in 2010. While in 2014, the population of Gua Musang residents increases to 114,500. This is showed in Table 1.1 which is the annual population in Kelantan.

Table 1.1: Annual population in Kelantan. Source; Department of Statistic Malaysia.

Year	2010	2011	2012	2013	2014
Bachok	142,100	146,000	149,900	153,800	157,700
Kota Bharu	509,600	522,000	534,500	547,200	569,100
Machang	101,300	103,900	106,400	109,000	111,700
Pasir Mas	212,000	217,300	222,800	228,300	233,800

Pasir Puteh	134,200	137,700	121,100	144,600	148,200
Tanah Merah	133,400	136,700	140,000	143,300	146,700
Tumpat	137,200	177,700	182,200	186,800	191,400
Gua Musang	103,300	106,000	108,800	111,700	114,500
Kuala Krai	120,800	123,700	136,500	129,500	132,400
Jeli	48,000	19,300	50,600	51,900	53,200
Kelantan	1,641,900	1,690,300	1,772,800	1,806,100	1,849,700

Table 1.2: Total rainfall in Kelantan from year 2010 to 2014

District	**Year/Rainfall (mm)**				
	2010	**2011**	**2012**	**2013**	**2014**
Bachok	2713	4149	3136	2841.5	3078
Kota Bharu	2246.5	3033	2741.5	1984.5	2436.5
Machang	2844	4249.5	3136	3730.5	4080.5
Pasir Mas	2717.5	3711.5	2673	2358.5	2782
Pasir Puteh	2902.5	4647	2911	3350.5	3414
Tanah Merah	3258.5	4258.5	3874	3434.5	3999.5

Tumpat	2370	3226	2538	2125	1743.5
Gua Musang	2020	1765.5	2721	2418	2784.5
Kuala Krai	2106.5	2065.5	2191.5	3339.5	1602
Jeli	3103.5	4359.5	3250.5	3592	4094
Kelantan	26282	35465	29238.5	29174.5	30014.5

1.2.3 Landuse

The type of vegetation that consist 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. Amongst the categories of land use are rural, industrial, leisure, transport, commercial use and land for vegetation. Forests or natural forests or rubber plantations cover much of the land. Because most individuals living in that region rely on natural sources, the residential area is widely spread in the study area. Farming and rubber tapping are examples of the jobs that village people work on.

1.2.4 Social Economic

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

Gua Musang develops at an accelerating rate toward urbanization. Every place that growing is dealing with geohazards such as landslide. Every year landslide responsible for millions of damages and contributing to a lot of life loss. There are many factors lead such geohazards. The primary factors or mechanism that triggered the landslide to occur is water. Water can change the character of the rock and weaken it until it became soil. The water can trigger in many ways such as rainfall, precipitation, and water saturation. Since some places in Gua Musang is high area, so the high elevation area will receive many rains than another place. The slope strength will decrease towards the gravity and the landslide easily occurs. However, the landslides do not affect by the water only. Dry weather also will lead to weakening of rock or soil particles.

To minimize these risks to the public, a study must be conducted to show how the water is affecting the landslides to occur as it is the primary factor that trigger the landslide to happen. This will be proven by interpreting the subsurface condition from the resistivity data. The illustration of subsurface will act as a prove to give awareness to people. Precaution about the slope failure to the public must be given to make sure they are aware of the current condition. The current condition of the slope must be monitored before it started to fail.

1.4 Objective

The objectives of this research are:

i. To produce the geological map of the study area with a scale of 1:25000.

ii. To investigate the factor that triggers the slope failure in the study area by using the resistivity method.

1.5 Scope of Study

The geological mapping is limited and cannot go to field due to the pandemic so there is limitation of data collection. The geology of study area involved a map interpretation to collect data in the study area by using secondary data. With help of satellite imagery, the surface model or elevation model can be made and geomorphology element which is the lineament plus the geological feature assumption and detection can be made. This interpretation includes the regional geology and stratigraphy from existing research. Furthermore, the geological map will be updated by combining this result of the map interpretation and previous data collection.

For the landslide study, the resistivity method will be used to identify the subsurface conditions of the study area by using secondary data too. It is conducted by referring inventory data of past landslide from each area that have the potential outcrops to be investigated. Then with addition of resistivity data, the data will be linked to identify the potential landslides in the future by which resistivity produce the illustration of subsurface that will be focusing on resistivity and conductivity of materials.

1.6 Significant of Study

Identifying areas that already at risk for slope failure could prevent loss of property and lives are the most important significant of this study. This is important so it can help the planners to avoid or minimize the infrastructure development in the landslide area. Settlement in the high hills area needs to double-check the condition of rock and soil of that area. The foundation of the base of the infrastructure must be really strong to support it. In 1993, Malaysia shaken by a major landslide occurred and the apartment building collapsed and resulted in 43 loss of life. This is happened because of the base of the apartment that is not strong enough to settle on the high hill area. This research will give public awareness and a better understanding of slope failure by giving examples of landslides that already occurred. Slope monitoring can be conducted to provide early warnings to the public.

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 researches 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 is the work 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.

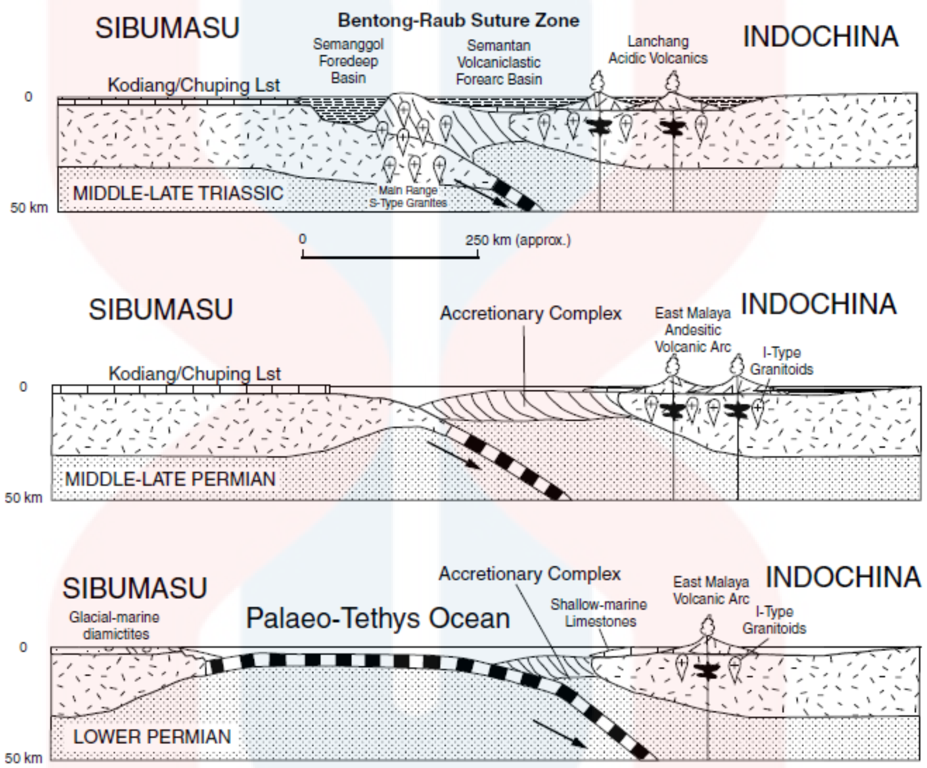

Figure 2.1: Formation of the Bentong–Raub Suture by subduction of the Palaeo-Tethys Ocean and collision of the Sibumasu and Indochina.

As the accretionary complex continues to grow, the argillic-carbonate sediments were deposited within the shallow marine Gua Musang platform (Metcalfe, 2013). Concurrently, pyroclastic and volcanic input were being supplied by the volcanic arc nearby, hence there are presence of volcanic rocks within Gua Musang Group. Shallow marine sedimentation by argillite-carbonate-volcanic deposition progressed throughout the Permian until the Early Triassic characterized the Gua Musang Group as a shallow marine platform depositional environment. The proposed Gua Musang Group includes the Gua Musang Formation, Aring Formation, Telong Formation, and Nilam Marble. Figure 2.2 shows the distribution of the Gua Musang Group in Peninsular Malaysia.

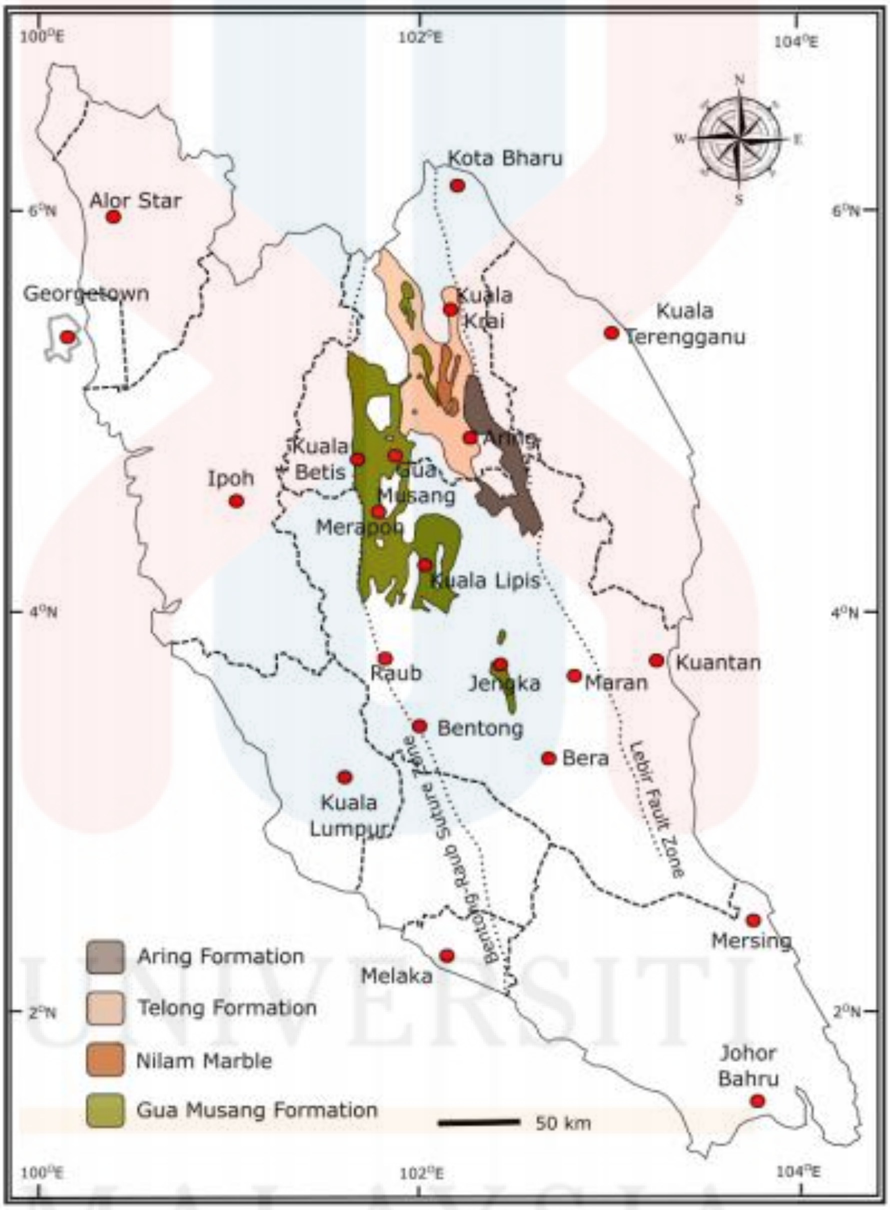

Figure 2.2 Distribution of the Gua Musang Group. Modified from Mohamed (1995).

Gua Musang Formation is aged Middle Permian to Late Triassic. The type of lithology is argillaceous and calcareous rock interbedded with volcanic rock. There is also minor presence of arenaceous rocks. The dominant lithology of argillaceous facies is shale, siltstone, mudstone, slate and phyllite. Depositional setting is shallow marine shelf deposit with active volcanic activity. Along the Merapoh-Kuala Lipis route, argillite-carbonate interbeds can be seen and extend further south to northern Raub (Richardson, 1939). Hundreds of meters of light to medium grey fissile shale intertwined with thick-bedded medium grey carbonate bodies are roadcuts in Merapoh-Kuala Lipis. In southern Kelantan to north Pahang, the abundant limestone is inferred to be a continuous carbonate platform deposited during Permo-Triassic within the Gua Musang platform until subjected to erosion and karstification.

2.3 Stratigraphy

The presence of an ocean between Sibumasu and East Malaya from at least Late Devonian to Late Early Permian indicate from the range of ages from Late Devonian to Early Permian. The ocean between these two terranes may not have been closed well after late Early Permian period. This is confirmed by presence of varies type of rock. Palaeo-Tethyan oceanic cherts found in the suture zone from the Middle Devonian to Early Permian age, and melange includes chert and calcareous clasts from Lower Carboniferous to Lower Permian age. 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 2.3 shows the stratigraphy column illustration of Bentong-Raub suture zone.

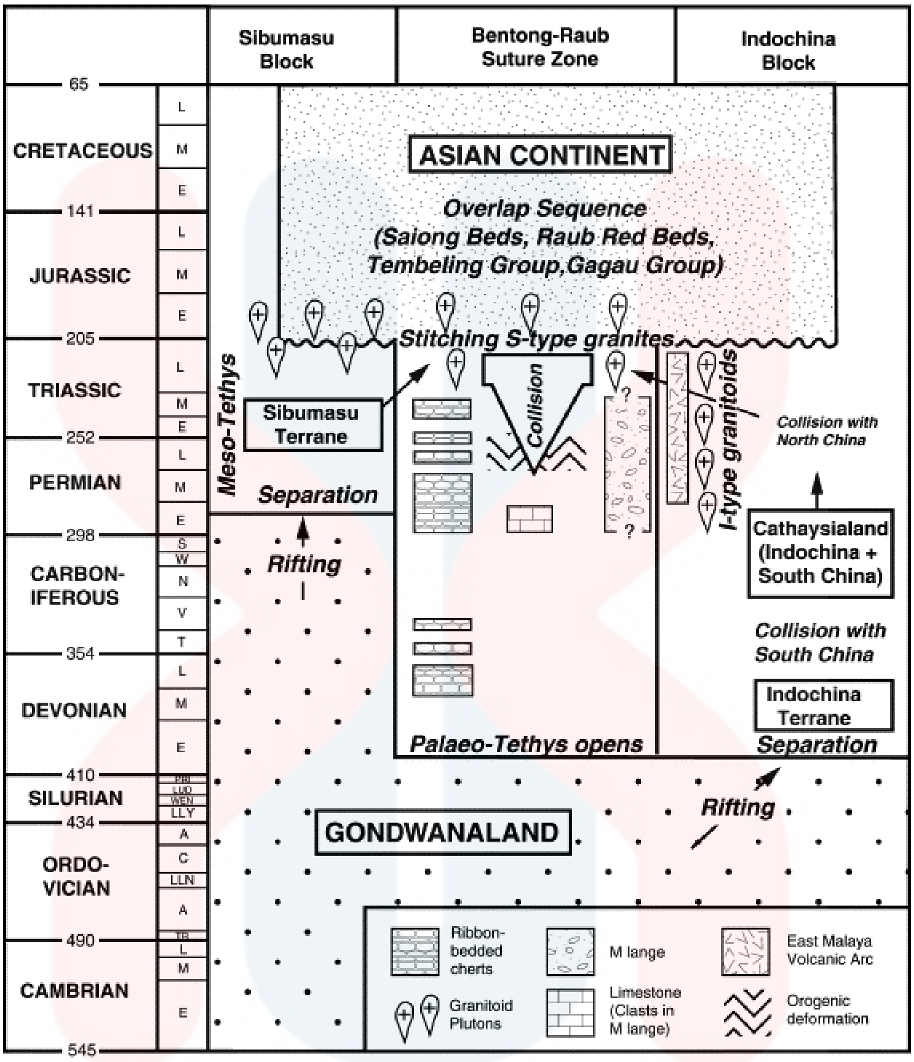

Figure 2.3: Stratigraphy Column of Bentong-Raub suture zone.

2.4 Structural Geology

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). Figure 2.4 showed the geological map of Peninsular Malaysia that consist of major faults and main rock groups.

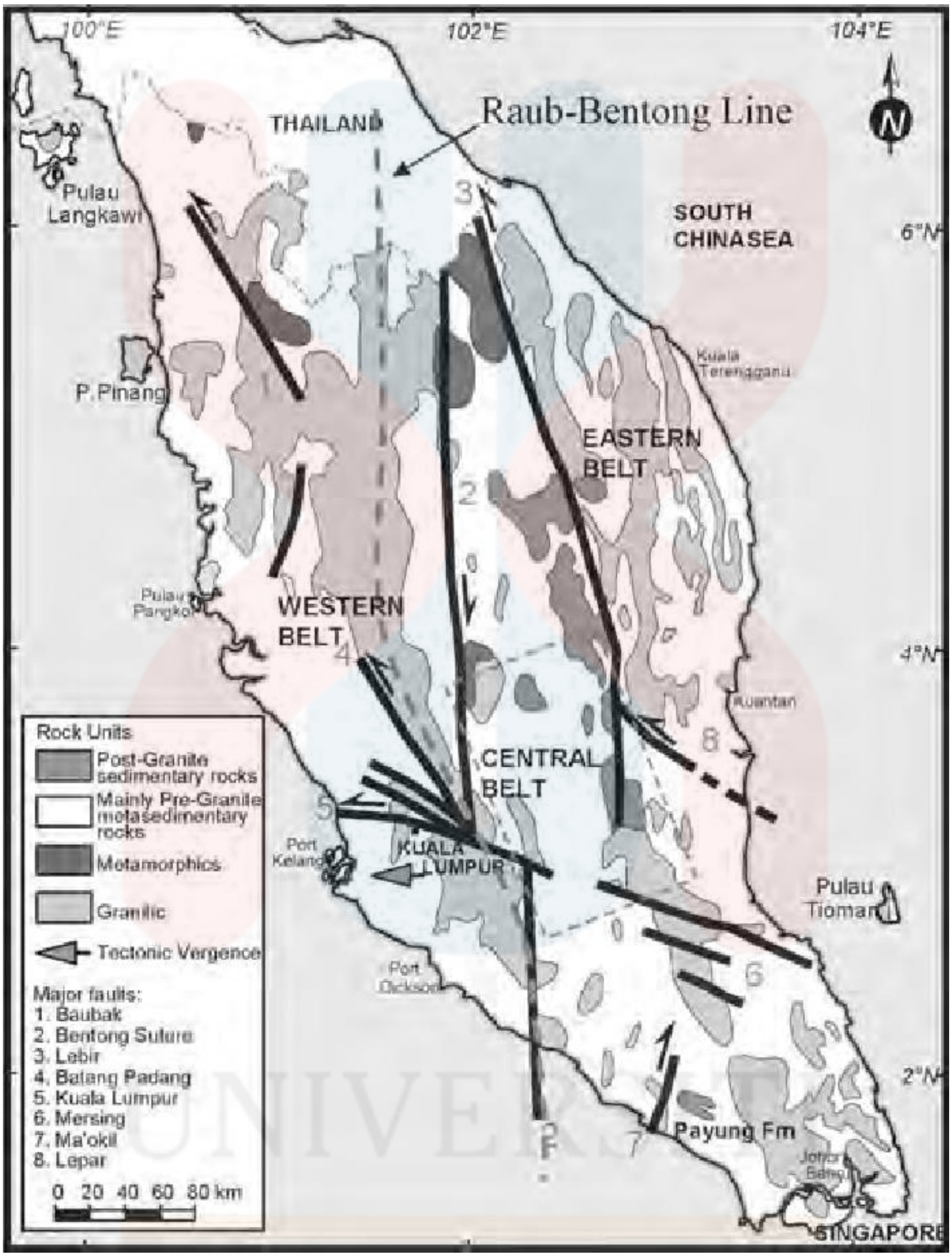

Figure 2.4 Simplified geological map of Peninsular Malaysia consist of the main rock groups and faults. (Hutchison, 1989)

2.5 Historical Geology

Based on fossil findings, the Middle Permian to Late Triassic age of the Gua Musang formation and its lateral equivalents were determined. At Middle Permian to Middle Triassic age, there are presence of ammonoids and pelecypods (Khoo, 1983).

Seven species of Early Triassic conodonts, namely *Hindeodus parvus erectus, Hindeodus parvus parvus, Hindeodus latidentatus latidentatus, Hindeodus latidentatus praeparvus, Hindeodus postparvus, Hindeodus eurypge* and *Isarcicella staeschi* were found in a limestone sample. Few Triassic conodont species found in limestone of Gua Panjang, Merapoh that show the similarities with those found in limestone of Gua Sei, Kampung Gua, west of Kuala Lipis (Metcalfe 1995). This includes *Hindeodus parvus* and *Hindeodus latidentatus.*

2.6 Research Specification

This subtopic described and separated into several sections which are geophysical survey, theory of resistivity value, existing research and landslide types. Geophysical survey explained more on how previous researcher figured out this method. The theory is basically about the related principles and formula of this resistivity methods. Existing research that study on the landslide also referred to know about the triggering factor and of course the type of landslide must be identified first to relate it.

2.6.1 Geophysical Survey

Geophysics is the geology branch that highlight on the phenomenon of the earth and explained with logic and formula calculation. Geophysical survey is always chosen to deal with subsurface investigation as it includes phenomena of earth's magnetic field which is related to electric. Geophysical prospecting is conducted usually for exploration of economic minerals such as groundwater, gold and many else.

Compared to other physical quantities mapped by other geophysical methods, resistivity values have a much larger range of physical quantities. The resistivity of rocks and soils in a survey area can vary by several orders of magnitude. In comparison, density values used by gravity surveys usually change by less than a factor of 2, and seismic velocities usually do not change by more than a factor of 10. This makes the resistivity and other electrical or electromagnetic based methods very versatile geophysical techniques (Looke, 1999). Resistivity survey method works to investigate how the material conducts and resists electrical current or how well the material rejects the electrical current flow. Basically, the method runs with electrodes which applying direct current (DC) to the ground, and the data to be recorded is the voltage or the potential difference. The resistivity of the rock will be determined together with the conductivity value. The conductivity value not only showing the geological structure, but also the water conducting zone of the ground. There is resistivity value to indicate and differentiate the certain type of material.

The resistivity method is a simulated source method. It is easy and effective method. It senses and interpreted the currents produced from the surface inside the subsurface of the earth. It is known with groundwater prospecting and engineering investigation. Its divided into two types which is resistivity profiling survey method and resistivity sounding survey method. The profiling of electrical resistivity surveys is focused on lateral modifications in the electrical properties of subsurface materials and resistivity soundings are used to investigate variations of resistivity with depth. Besides that, it used in geophysical investigations like geothermal exploration, archaeological investigation, engineering studies, mineral exploration, permafrost mapping and geological mapping. Briefly, the method is to regulate the subsurface geology of a place. It is by far the most used method for geo-electrical surveying.

According to Reynolds (1997), geo-electrical resistivity can be detecting and sensing the distribution of material lithology under the earth surface because all types of rock can be given different resistivity values.

The study Reynolds (1997), found that there are numerous ways the current flow through the rock mass. There are electrolytes, electronic and dielectric conductivity. The movement of ions in the electrolyte is the study field of the electrolytic conductivity. Ion concentration and mobility of ion are depending and rely on the type of ion. The specific charges will be controlling the movement of the ions. For the weak conductor it just exists the dielectric conductivity. In research by Reynolds (1997), in every rock have their own conductivity and porosity. Later, the conductivity will be affected the porosity of the lithology. For the rock such as graphite, pyrite, chalcopyrite, and magnetite will have categorized and grouping as a good electrical conductor.

The study of subsurface by using the resistivity surveys is originated in 1912 which the one who performed the first experiment on resistivity in the fields of Normandy is Conrad Schlumberger. Next, a similar concept was developed by Frank Wenner (1915) in the United States of America (Kunetz, 1966). Resistivity surveying has since advanced and has become a common and useful method in prospecting research such as hydrogeological research, mineral exploration, mining, and environmental and engineering applications (Aizebeokhai et al., 2010).

The presence of water will control much of the conductivity in the shallow subsurface. The conductivity value is inversely with the resistivity value. Measurement of resistivity is in general is the measure of water saturation and connectivity of pore space. The electric current will follow the path of least resistance, such as water that have a low resistivity value. When there is water in voids area and increasing number of fractures that filled with water it is means that the increasing of saturation, salinity and porosity tends to decrease resistivity value. Soils or rock units will compact and will expel more water and this will increase resistivity effectively. But if the structure or voids is filled with air, it will produce a high resistivity value.

2.6.2 Theory of Resistivity Value

Ohm's Law

This Ohm's Law equation named after the Georg Ohm, a German physicist.

$$V = I R \text{…………………...} (2.1)$$

This equation 2.1 relates a circuit's voltage to the result of the current and the resistance. The movement of electric current is directly proportional to the voltage applied and inversely proportional to the resistance. The measurement of resistivity is in ohm-m or ohm-ft.

According to Looke (2000), the resistivity measurements are usually made by inserting and injecting current into the ground through two current electrodes and it will be calculating the resulting voltage difference at two potential electrodes. From the voltage (V) values current and (I), an apparent resistivity (p_a) value is calculated.

$$p_a = kV / I \text{…………………...} (2.2)$$

In the equation 2.2, k is known and describing as geometric factor which is control the arrangement of the four electrodes. Generally, resistivity meter gives a resistance value, R = V/I, so in practice the value of apparent resistivity is calculated in equation 2.3 by

$$p_a = kR \text{…………………...} (2.3)$$

Ohm's Law defines and describes as the electrical properties of any medium. Ohm's Law, V = I R, tells the voltage of a circuit is equal to the product of the current and also the resistance. The relationship has clarified that earth materials are same with circuits.

2.6.3 Wenner-Schlumberger Array

Every array has its geometric factor and electrode configurations. Figure 2.5 shows the electrode arrangement of Wenner-Schlumberger array and Figure 2.6 shows the pseudosection of datum point for Wenner-Schlumberger array.

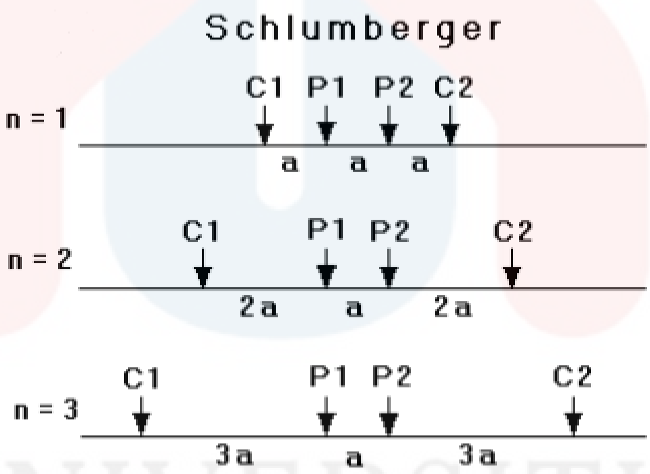

Figure 2.5 Electrode arrangement of Wenner-Schlumberger array

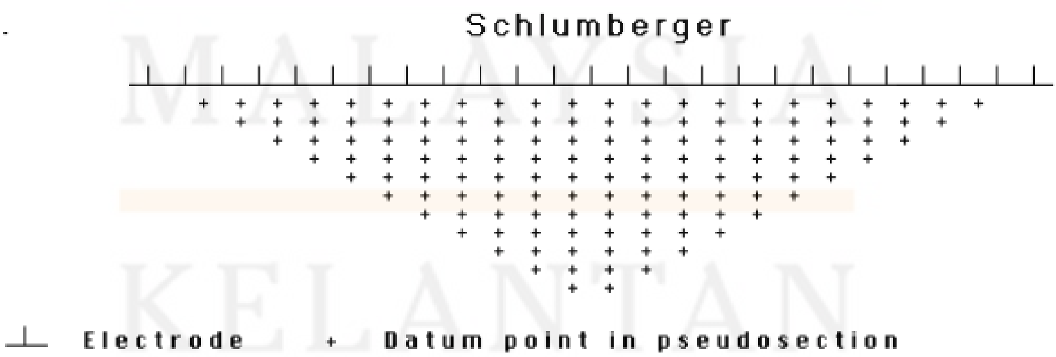

Figure 2.6 Pseudosection of datum point for Wenner-Schlumberger array

Figure 2.7 shows the sensitivity pattern for the Wenner-Schlumberger array to vertical and horizontal changes. The inversion model is showing the condition where the arrangement of the model blocks directly follows the arrangement of the pseudosection plotting points. The pseudosection gives a very approximate picture of the true subsurface resistivity distribution. This is important to know which array will give the pseudosection point condition weather fall in the area that have high sensitivity value and low sensitivity value. Wenner and Wenner-Schlumberger arrays is the array where the pseudosection point falls in an area with high sensitivity values. The sensitivity pattern shows that there is sensitivity value between P electrode and C electrode and also between the P electrode. This means that this array is moderately sensitive to both horizontal and vertical structures. The Wenner-Schlumberger array has a slightly better horizontal coverage compared with the Wenner array. The horizontal data coverage is slightly wider than the Wenner array.

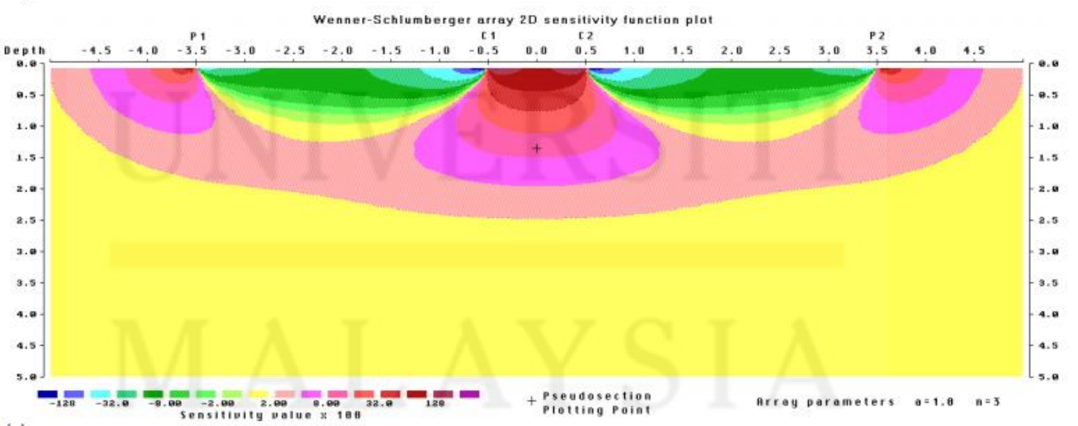

Figure 2.7 The sensitivity pattern for the Wenner-Schlumberger array to vertical and horizontal changes

2.6.4 Existing Research

Study by Hashim et al. (2017) shows the landslide mapping using GIS method which is Analytical Hierarchy Process (AHP) method in Kelantan state give the result of landslide inventory occurrences map and landslide susceptibility map for entire Kelantan. The most influenced factor of landslide occurrence is precipitation resulting from intense rainfall. Precipitation is the moisture that reach the surface of Earth from the atmosphere from the hydrological view point (Jayarami, 1961). The susceptibility map shows 65% of the whole Kelantan is low susceptibility zone while another 35% is high susceptibility zone which is at southern and south-western part of Kelantan especially the high elevation area which is includes Gua Musang. Gua Musang rainfall data gives the highest percentage of rainfall amount during flood episode that usually during November and December than the rainfall amounts that occur in the year.

Work by Syafril et al. (2020) of the GIS-based landslide hazard zonation in Kuala Betis, Gua Musang which is using Weightage Overlay Method (WOM) to evaluate the main factor of all landslide triggering parameter. The landslide zonation map show there are five zone of landslide hazard which are very high hazard, high hazard, moderate hazard, low hazard and no hazard. From the zonation map, the percentage of scattered data of hazard is 60% showed moderate hazard, 20% low hazard, 10% high hazard, 8% no hazard and 2% of very high hazard. This data is from the weightage of the causative factor. The type of lithology that showing a high hazard class is limestone, the colluvium also showed very high hazard factor rather than alluvium. The questionnaire from local respondent also gathered which focus on their perspective of what is the factor of landslide happen at their places. It is because of heavy rainfall during the season and followed by extremely dry season and also caused by the major flood in Kelantan that happen in year 2014. The Normalized Different Vegetation Index (NVDI) method also used to detect the changes of vegetation as it is also one of the parameters that triggered the landslide to happen and there can be clearly seen the changes of the vegetation from the major flood in 2014.

Thesis of master student from Universiti Sains Malaysia, 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 study of limestone geohazard by using electrical resistivity imaging (ERI) in Kampung Lepan Jaya, Gua Musang by Muhammad Faez bin Sofian (2018) which is now still unpublish give a result of resistivity survey of four lines. From the four survey lines, there are three lines that is interpreted as low probability of sinkhole to happen and only one is high probability.

According to Jamaluddin (2006), Malaysia is not a rash country. The slope failure always happens because of the monopoly of the rainfall. The study of Abdullah (2013) found that Malaysia always experience the frequent flooding and also landslides. Table 2.1 shows the example of landslides occurring to Kuala Lumpur city centre.

Table 2.1 Example of landslides occurring close to Kuala Lumpur city centre.

Date	Location	Type of Landslide	Number of Death	Notes
December 1993	Ulu Klang,	Shallow rotational slide. Heavy rain triggered makes the failure of cut slope behind the Highland Tower	48	Cut slope in granitic formation
June 1995	Karak Highway – Genting Highland slip road, Selangor – Pahang border, 20 km to Kuala Lumpur City	Debris flow. 'Snowball effect' debris avalanche triggered the failure of upstream natural dam during heavy rain triggered.	22	Natural slope in meta-sediment formation
January 1999	Squatters settlement, Sandakan Town, Sabah	Shallow rotational slide. Heavy rain triggered landslide – buried	13	Natural slope in meta-sediment formation

		a number of houses		
November 2002	Hillview, Ulu Kelang, outskirt of Kuala Lumpur city	Debris flow. Sliding of debris soil of abandoned projects during heavy rain.	8	Dumping area of abandoned project in granitic formation
November 2004	Taman Harmonis, Gombak, outskirt of Kuala Lumpur City	Debris flow. Sliding/ flowing of debris soil from uphill bungalow project.	1	Dumping area of project ongoing project in meta-sediment formation
December 2004	Bercham, Ipoh City, Perak	Rock fall	2	Natural limestone cliff in karsts formation

(Source: Abdullah, 2013)

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

The purpose of this chapter is to explain the materials and methods that has been used and the function of each of them in this research so that the objectives of this research will be achieved. List of material is important so that the methods can be done perfectly without any flaws. It is relatable to each other. This chapter divided into two sections which are focusing on both geological mapping using satellite imagery and specification which is a resistivity survey. Figure 3.1 shows the research study flowchart that functioning as a guideline along the research processes.

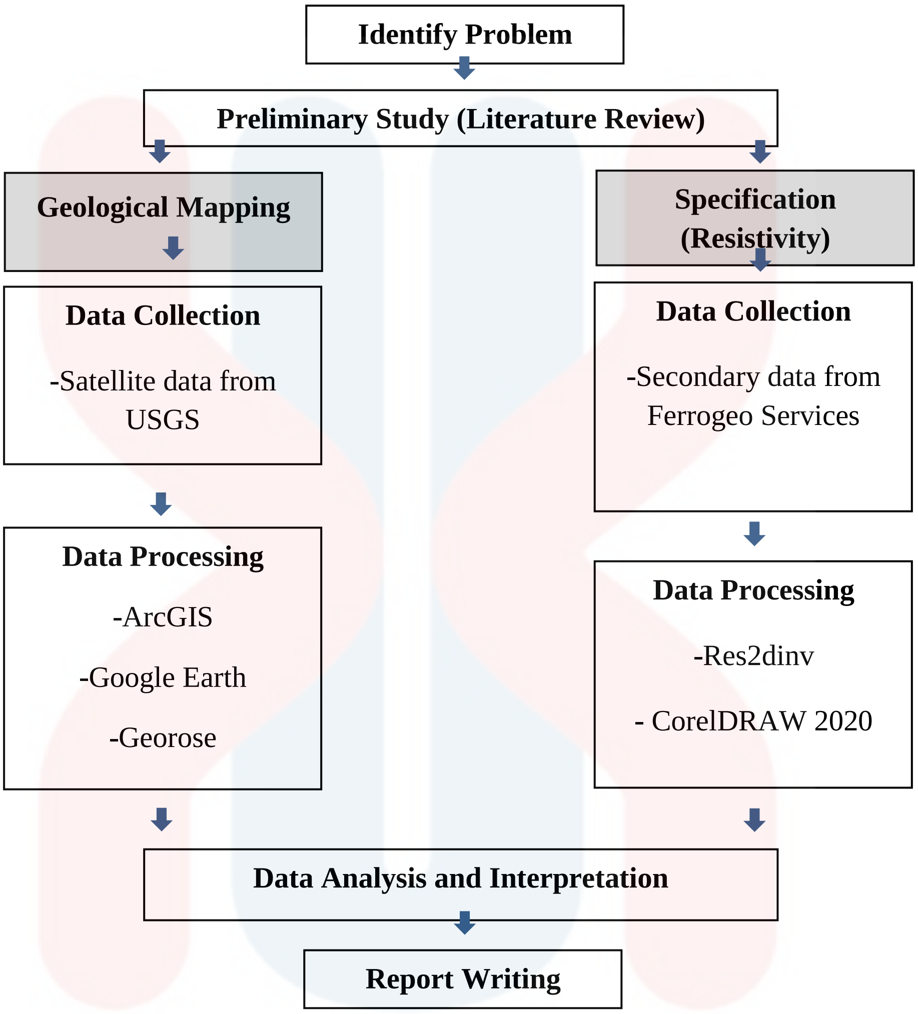

Figure 3.1: Research flowchart of the research.

3.2 Materials

The materials that has been used in the geological mapping are secondary data of satellite imagery. The satellite imagery data processing using the ArcGIS, Google Earth and Georose software.

The material that has been used in data processing for resistivity is the secondary data of the resistivity survey. Then, the Res2Dinv and CorelDRAW software were using for processing and interpret the survey data.

3.3 Methods

This subtopic highlights on the methodology of the research that shows the technique or procedure of the research with the systematic sequence. The methods also divided into two sections which are geological mapping using satellite image and specification. Based on the flowchart in Figure 3.1, the sequence shows that there is preliminary study then proceed with the data collection and data processing. The sequence continued with the data analysis and interpretation for the result and conclusion of the research and next proceed with report writing.

3.3.1 Preliminary Studies

Preliminary study is about the planning and research project tittle. At first, it needs a lot of readings of journals and research papers written by other geologist who have done some research on the same area that were going to be observed. This had to be done in advance before doing any field observation. This is for the purposes of being prepared to what can be found in the field area, to get familiar to the geology of the study area, to find lacking or the gap of research aspects in the previous studies so that it can be improved to get additional information of study area.

3.3.2 Data Processing

The geological mapping using satellite data will be processed into the ArcGIS, and Google Earth software. The study of geomorphological characteristics was carried out by satellite image interpretations which from Digital Elevation Model (DEM). The data processing of landform unit delineation is by the extension tool in ArcMap. Analysis of geological maps was also used to obtain the information about the landform components. Descriptive analysis of the research results was conducted to characterize study area's condition in term of geomorphological features, landforms, and the danger of natural disasters. The maps that will be used in the interpretation is landform map, slope map, drainage density map, aspect map, hill relief map, stream order map and watershed map. The step of processing the data in the ArcGIS is stated below.

Landform Map

a. DEM data added and inserted into the layer.

b. Click Arctoolbox > spatial analyst tool > surface > contour.

c. Processing tool > clip. to clip the box.

d. Arctoolbox > spatial analyst tool > topo to raster. Add contour.

e. Change the properties and classified it as 3.

Slope Map

a) Add DEM data and insert it to the layer.

b) Click Arctoolbox > spatial analyst tool > surface > slope.

Drainage Density Map

a) Add DEM data and insert it to the layer.

b) Click Arctoolbox > spatial analyst tool > Hydrology > fill

c) Click Arctoolbox > spatial analyst tool > Hydrology > flow direction

d) Click Arctoolbox > spatial analyst tool > Hydrology > flow accumulation

e) Click Arctoolbox > spatial analyst tool > Hydrology > stream order

f) Click Arctoolbox > spatial analyst tool > Hydrology > stream to features

g) Click Arctoolbox > spatial analyst tool > density > line density

Aspect Map

a) Add DEM data and insert it to the layer.

b) Click Arctoolbox > spatial analyst tool > surface > aspect

Hill Relief Map

a) The layer is right clicked to select properties, in order to select coordinate system for the map. Geographic Coordinate System is choosing, followed by World > WGS 1984.

b) Add data from folder in computer choose DEM data and click to insert to the layers.

c) Add box data and do the clips feature from Geoprocessing at DEM data into the box area only.

d) Click Arctoolbox > spatial analyst tool > surface > hillshade

Stream Order Map

a) Click DEM data and insert it to the layer.

b) Click Arctoolbox > spatial analyst tool > Hydrology > fill

c) Click Arctoolbox > spatial analyst tool > Hydrology > flow direction

d) Click Arctoolbox > spatial analyst tool > Hydrology > flow accumulation

e) Open raster calculator.

f) Click Arctoolbox > spatial analyst tool > Hydrology > stream order

g) Convert the layer raster to vector.

Watershed map

a) Add DEM data and insert it to the layer.

b) Click Arctoolbox > spatial analyst tool > Hydrology > fill.

c) Click Arctoolbox > spatial analyst tool > Hydrology > flow direction

d) Click Arctoolbox > spatial analyst tool > Hydrology > flow accumulation

e) Click Arctoolbox > spatial analyst tool > Hydrology > snap pour point

f) Click Arctoolbox > spatial analyst tool > Hydrology > watershed

g) Click Arctoolbox > conversion tool > from raster > raster to polygon

Next, the method used in this study is using the secondary data which involves the standard method of resistivity survey which is using parallel and perpendicular array resistivity line to the slope. The result of apparent resistivity value that will be inversed using software to determine the true resistivity. Resistivity data then will be analysed using Res2Dinv software.

The steps of processing the resistivity data using the Res2Dinv software;

(a) The Res2DInv x32 programme opened and system requirement checked.

(b) The file of data selected (in .dat form).

(c) Bad data points exterminated too large negative value using edit menu and notepad. The process function is used to eliminate further bad data value. This process can be done selecting the points of those were not in line. The dat.file saved as a new file when exit the display window.

(d) The model resistivity values set values depending on the number of iterations of required while the damping factor applications, mesh refinement, convergence limit, and when the data set have a value that was too high or low. The resistivity data must be modified.

Change Settings > Inversion Damping Parameters > Damping Factors.

Change Settings > Forward Modelling Method Settings. Choose 4 nodes for horizontal mesh size for more accurate calculated apparent resistivity values. For vertical mesh size, choose finest mesh. It is recommended to use finest mesh if the resistivity contrast if between the range of 50 to 1. For the type of forward modelling method, choose finite-difference method.

(e) The data then initiated using the data inversion process. Then, do adjustment and smoothing the resistivity model using the robust inversion procedure.

Inversion > Inversion Method and Settings > Select Robust Inversion. Change the absolute error to RMS error. RMS error statistics menu selected to reduce RMS (Root Mean Square) error that will affect the inversion process and the building of the model resistivity data. RMS error statistics must be less than 10%. To produce resistivity pseudo section, the resistivity data need to be modified and recalculated. From pseudo value, the inverse model resistivity sections produced for the quantitative interpretation.

Inversion > Model Discretization > Use Model Refinement > use model cells with widths of half the unit spacing.

Inversion > Model Discretization > Use Extended Model. The display window the showed arrangement of model block and apparent resistivity data points.

Inversion > Carry Out Inversion.

(f) Then the software displays the actual resistivity model using show display menu after completing the inversion process.

(g) The resistivity model interpreted by using the colour scale and the resistivity value.

3.3.3 Data Analysis and Interpretation

The method in this geological mapping interpretation is used the secondary data of satellite imagery to identify the features in the image manually. The most basic elements of image interpretation are location, size, shape, shadow, tone or colour, texture, pattern, height, altitude or depth. The process of interpreting the satellite image is stated below.

(a) Look for a scale which is the location of our study area.

(b) Identify the patterns, shapes, shadows and textures.

(c) Define the colours and the tones.

(d) Consider and assume the geological feature based on knowledge and do the lineament analysis.

i. Shape

The general configuration of the outline. For example, road has linear shape, building have polygonal shape and vegetation have random shapes.

ii. Size

The space occupied by the object in the image. For example, we can calculate and assume the size of a house by using the scale.

iii. Shadow

The inclination angle from the sun on the object. The shadow is used in interpreted man-made object and the high topographic area such as hills.

iv. Colour

The colour expresses the reflection of light on the object. For example, vegetation of the normal colour is green colour and ocean is in blue colour.

v. Tone.

Changes of tones in one colour. For example, different type of vegetation will give different tone may be light or dark.

vi. Texture.

The repetition of the intensity of colour the image. For example, rough texture represents big tree while soft texture represents small plant.

Next, the interpretation continues on the landslide using the secondary data of inventory map that have the compilation of the landslide occurred in the past. Then, map of landslide hazard that will show the detailed information about where is the past, recent and future landslide. Another advantage of these data is it will give the data of the type of the past landslides and it can be linked to the research study.

The analysis and interpretation of geomorphology using the colour scale and the resistivity value will be determining the assumption of the type of lithology of that area. The electrical resistivity value of each part of the cross section will be determined. The presence of geological structure or disturbed layer of strata also can be detected. The depth of bedrock and the thickness of overburden topsoil also can be figured out. The results of resistivity survey will show produce illustration and profiling depth in a two-dimensional (2D) model. Conductors which are materials that conduct electrical current easily are having a low resistivity. A good conductor will have less resistivity. Example of conductor is water. So underground water shows low resistivity value. Materials that do not conduct electricity easily are called insulators and it have a high resistivity. The material that have resistivity value that lower than 100 Ohm is clay material or water body. If the value of resistivity ranges from 100 Ohm to 300 Ohm, it is silty sand. The geological structure also can be detected from the resistivity values.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter discuss about the general geology of the study area. General geology provides the information of rock and soil to the geologist. This includes the geomorphology of the study area which consist of topography, drainage system and the weathering of the rock formation, proceed with lithostratigraphy, structural geology and historical geology of the study area. This information is important to study the origin of rock, strength of the rock and soil, the weathering activities on the rock formation and geological structures that formed in the rock formation.

The study area can be access by the Gua Musang-Merapoh highway through the Google Earth. The study area consists of three villages which cover Kampung Sungai Tupai in the middle of the box, Kampung Lepan Jaya and Kampung Mentara Baru. 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 land use map of the study area. The traverse has been done using Google Earth in order to identify the condition of the study area which is by following the highway.

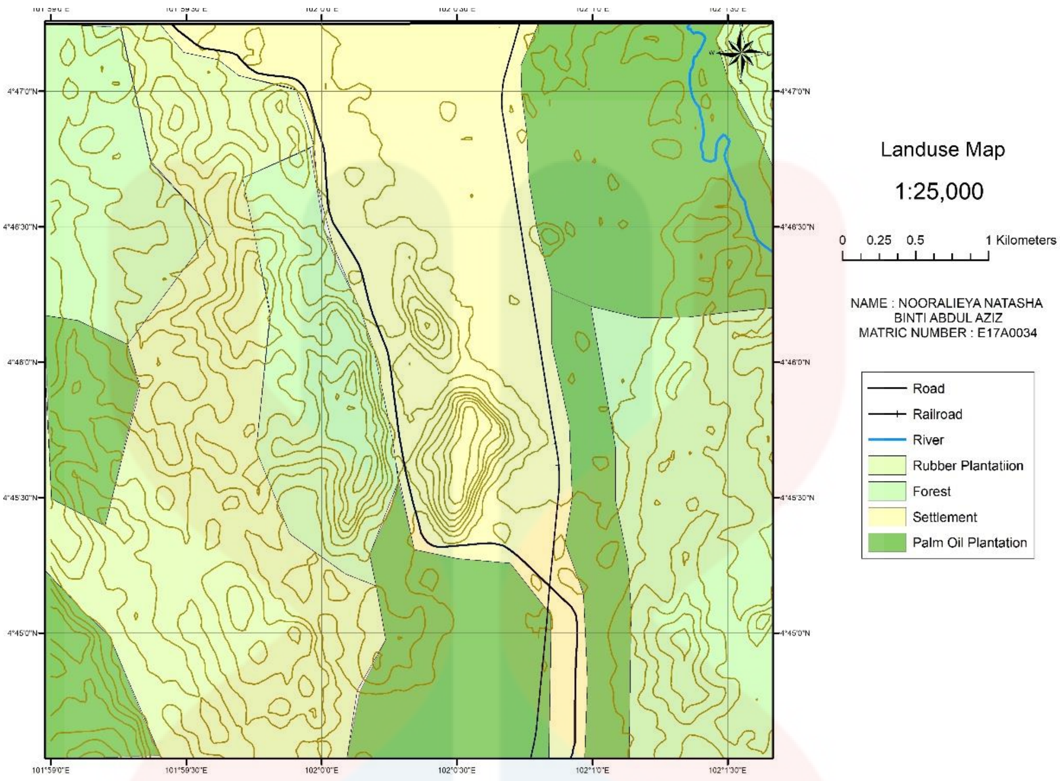

Figure 4.1: Land use Map

4.2 Geomorphology

4.2.2 Geomorphologic Classification

Geomorphology is the study of the landform and the process that creates the landform. It is basically referred to the form of the topography of an area such as hill, river, plains and many others. The aim of the geomorphology study is to correlate the relationship between the features and the processes that happened to know the origin and the development of the landform. Landform is the natural feature of the earth's surface. Example of landform is fluvial landform, and floodplain landform.

The analysis of the shape and function of streams and the relationship between streams and the landscape, the deposits and landforms around them is called fluvial geomorphology. 'Fluvial' refers to flowing water processes,' geo' refers to the earth, and 'morphology' refers to the form of the channel. In both space and time, stream morphology is complex and continuously evolving. Figure 4.2 shows the stream order map of study area.

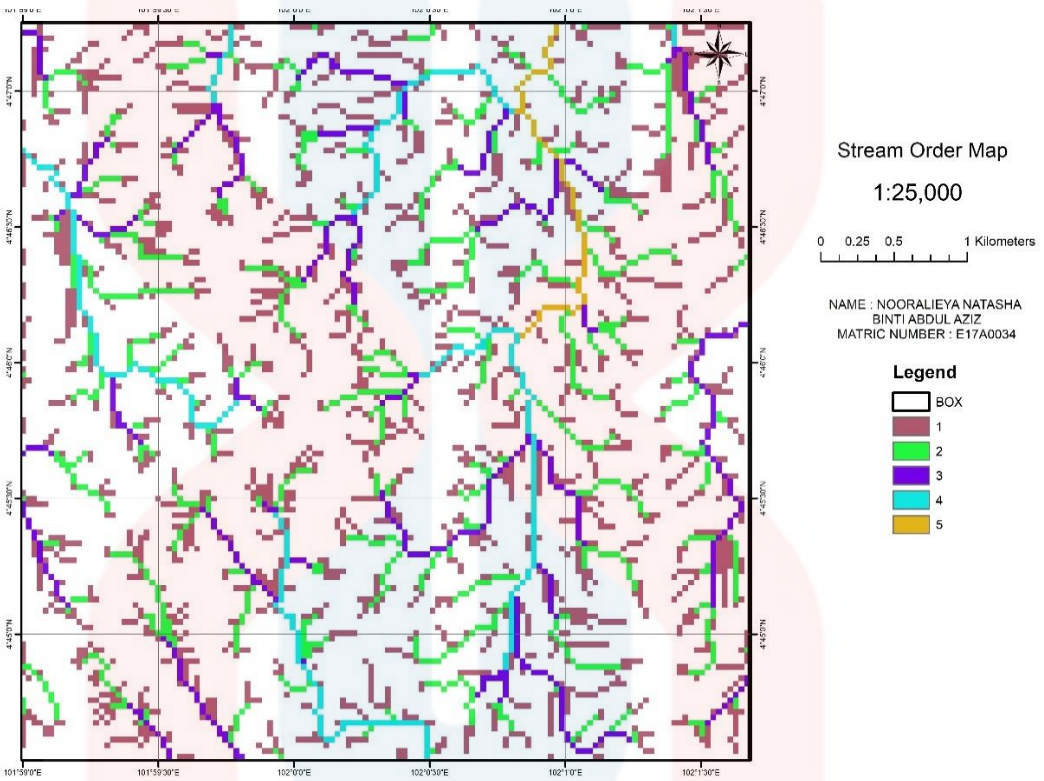

Figure 4.2: Stream Order map

The common type of stream order map is by Strahler (1967). When streams of the same order overlap, the stream order increases. The intersection of two first-order connections would then create a second-order connection, the intersection of two second-order connections will create a third-order connection, and so on. However, the intersection of two connections of separate orders will not lead to a rise in order. From the stream order map, there are four colours in the study area which is the biggest is yellow, proceed with blue, purple and green which is the thinnest tributaries.

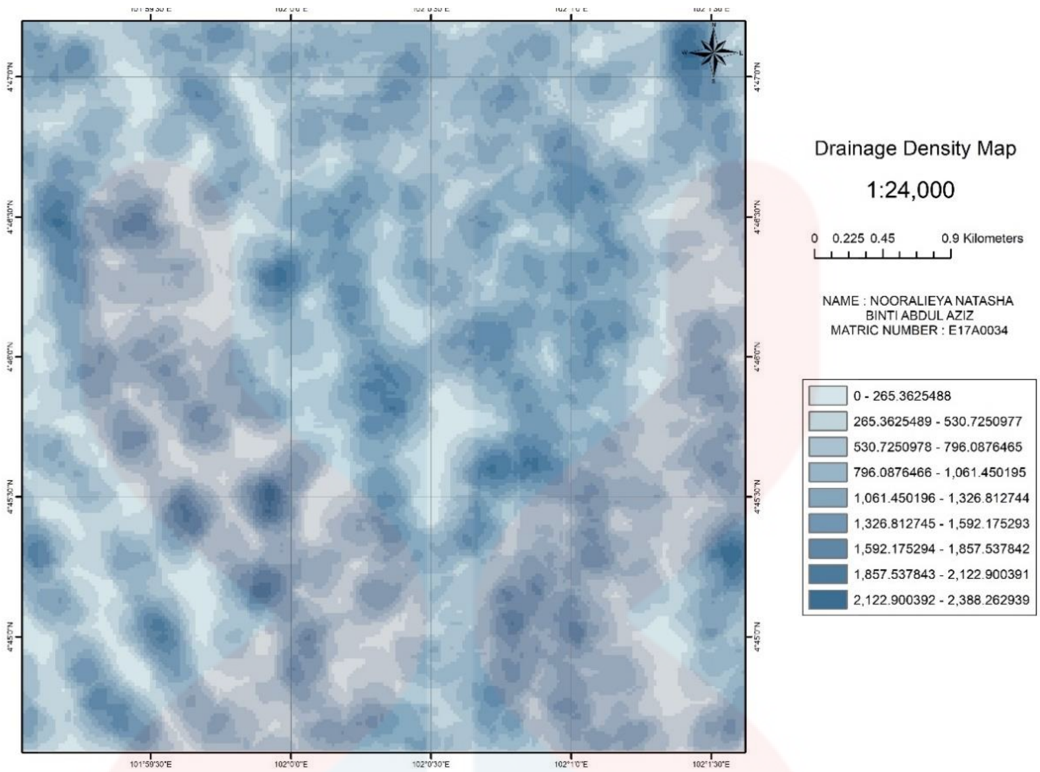

Figure 4.3: Drainage Density map

Figure 4.3 shows the drainage density map. This map explains the area of the whole drainage basin dividing all the stream length and tributaries. It shows how stream channels drains the watershed whether well or poorly drained. The type of rock that underlying is affecting the runoff watershed. Permeable rock and soil tend to have low drainage density while impermeable rock and soil is tending to have high drainage density due to no percolation and infiltration. Permeability shows how the ability of the material allowing the fluids penetrate through it. A higher flood risk may also be demonstrated by high drainage densities value. The light blue colour shows the low stream density and the high steam density is shown by the dark blue colour. Drainage density is significant as it relates to the rate of erosion. The higher the density values suggest the higher erosion rate and are more likely to cause landslides.

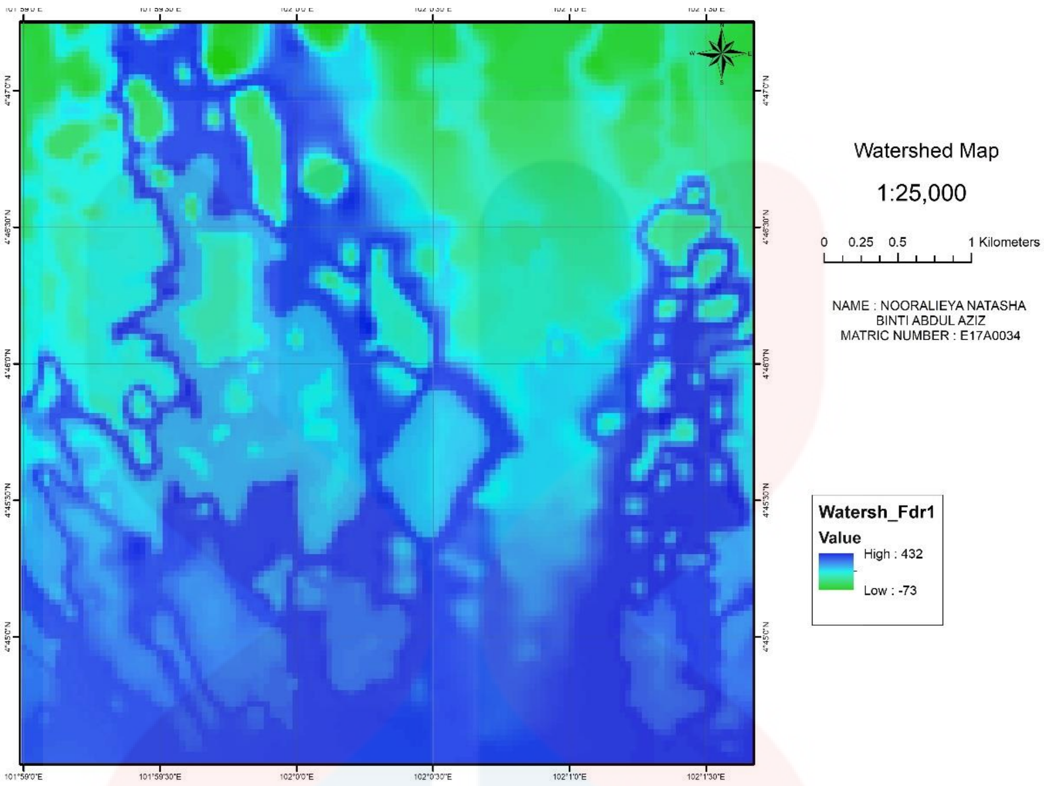

Figure 4.4: Watershed Map

Figure 4.4 shows the watershed map. The catchment area or drainage basin is another word representing the watershed. From the watershed map, the catchment area can be determined by looking at the place where high watershed value. High value of watershed represented by the dark blue colour. The precipitation and rainfall data related and contributing to watershed.

Topography is important to illustrate the feature in study area. The use of elevation of contour lines is to indicate the shape of the surface of the Earth by distinctive the feature of the topographic map. Elevation contours are imaginary lines that linked the points with the same elevation above or below a reference surface on the surface of the earth, which is typically the mean sea level. Contours allow the height and shape of the mountains, the depths of the bottom of the ocean and the steepness of the slopes to be illustrated. Figure 4.5 shows the aspect map.

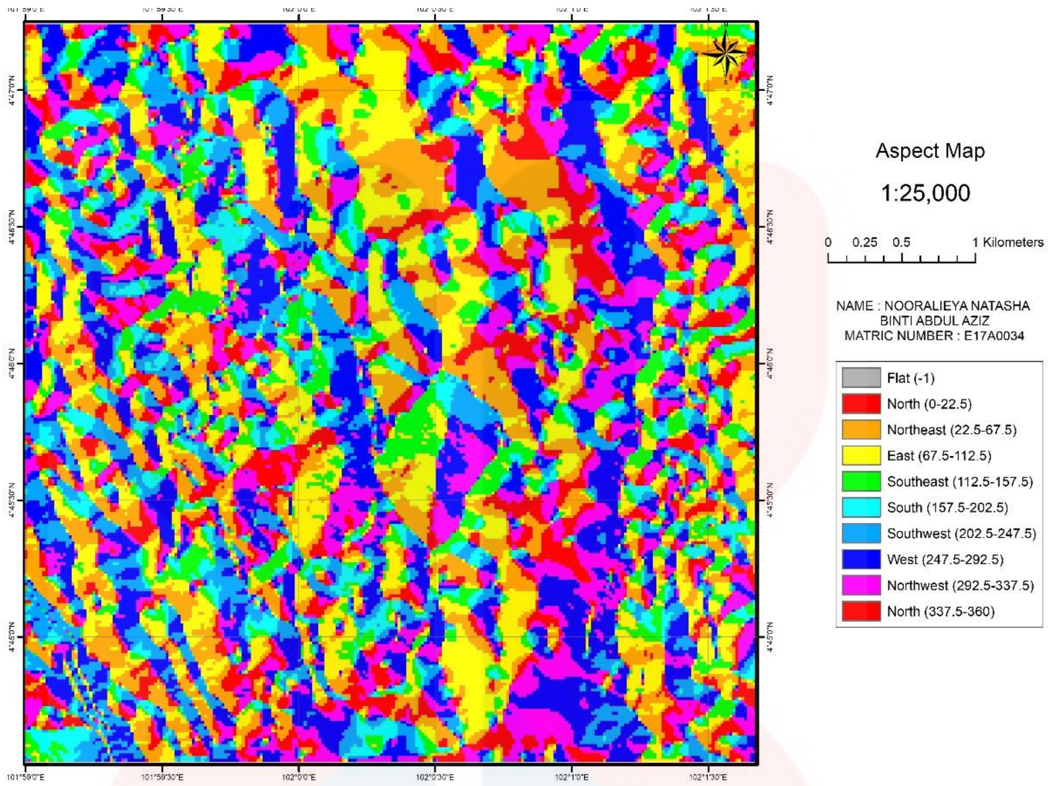

Figure 4.5: Aspect Map

It is easy to comprehend the idea of an aspect map. Aspect values reflect the directions facing the physical slopes. We may identify aspect directions with a descriptive direction depends on the slope angle. Typically, an output aspect raster can result in many classes of slope direction. Different colour indicates different direction. This map also looks like hill shade map but in colourful and easier way to distinguish the dip direction. Table 4.1 shows the classification of aspect map.

Table 4.1: Classification of Aspect Tool

Direction	**Classification**
Flat	(-1)
North	(0°to 22.5°)

Northeast	(22.5° to 67.5°)
East	(67.5° to 112.5°)
Southeast	(112.5° to 157.5°)
South	(157.5° to 202.5°)
Southwest	(202.5° to 247.5°)
West	(247.5° to 292.5°)
Northwest	(292.5° to 337.5°)
North	(337.5° to 360°)

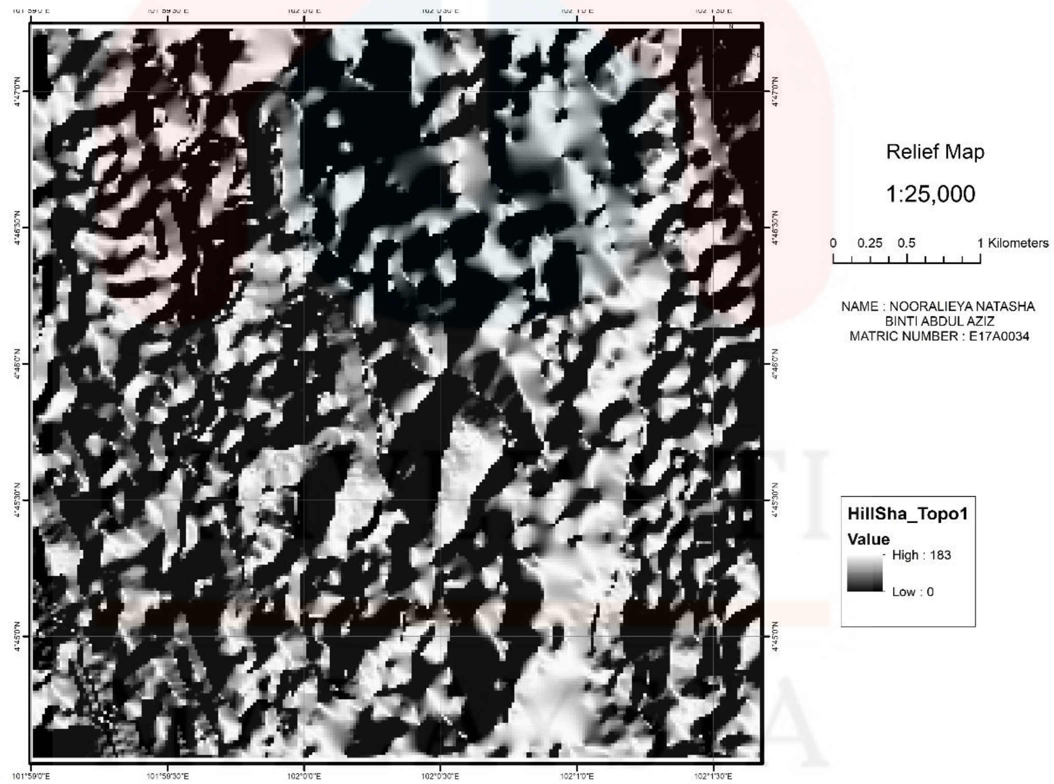

Figure 4.6: Relief map

Figure 4.6 shows the relief map of study area. Relief map which is also called as hill shade map is showing the result of topography when hill shading technique is used to differentiate the slope. The feature and topography can be easily differentiated as it also known as terrain map.

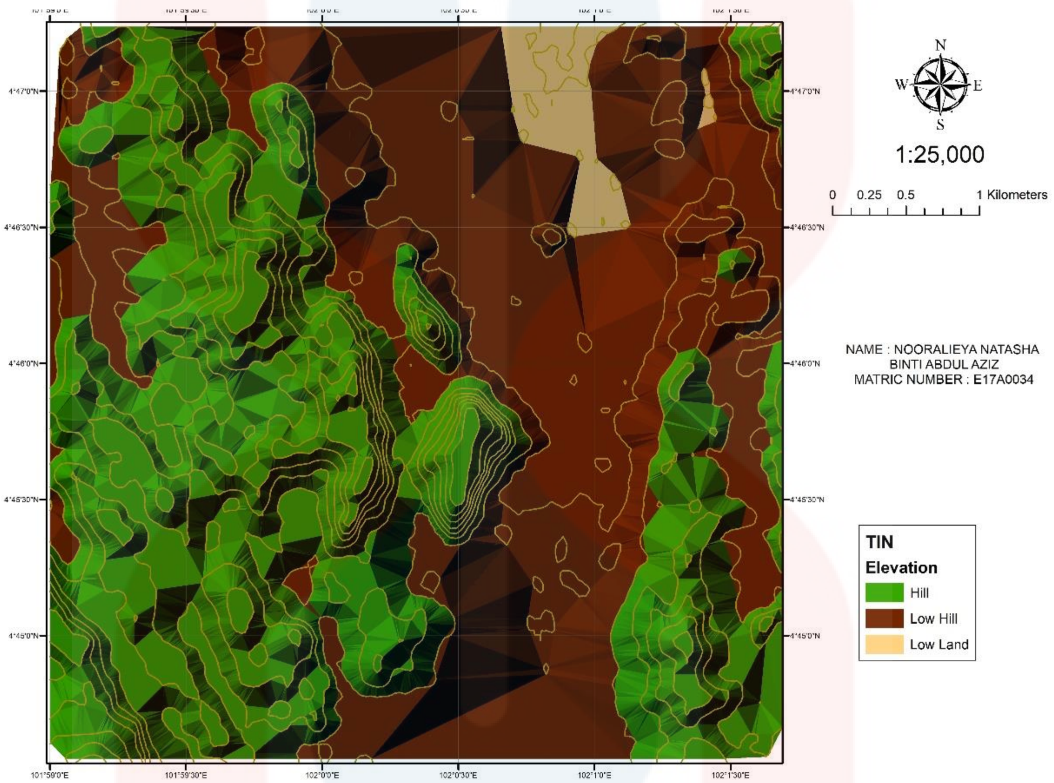

Figure 4.7: 3D Triangular Irregular Network (TIN) Map

Figure 4.7 shows the Triangular Irregular Network (TIN) map. From the landform map, the map is divided into several colours range from dark green to light yellow. The dark green represents the highest hill with most elevation which can be seen from the map is the area that consist of karst topography and igneous rock topography. The lower elevation in the area as it shown brown colour which is consist of settlement area and the light-yellow colour is the lowest elevation in the study area. The landform classification can be classify based on the classification of Van Zuidam(1985) shows in Table 4.2.

Table 4.2 Van Zuidam Classification (1985)

Absolute Elevation	Geomorphology Element
<50m	Low Land
50m - 100m	Inland Low Land
100m – 200m	Low Hill
200m – 500m	Hill
500m – 1500m	High Hill
1500m – 3000m	Mountain
>3000m	High Mountain

4.2.2 Weathering

Weathering is the breakdown of rock by chemical decomposition and mechanical disintegration. This happened when the surface is in contact with air, water and mechanism. They started to lose and decay. There are three types of weathering which are chemical weathering, biological weathering and physical weathering. These types of weathering can be determined by field trip observation.

Chemical weathering is mechanism happen by process which chemical reactions break down the rocks. When this process happens, the rock is being chemically altered. There is different type of chemical weathering such as solution, hydrolysis and oxidation. Solution is happened when the process removal of rock happens in solution by acidic weathering. Hydrolysis is the breakdown of rock by acidic water to produce clay and soluble salts. Oxidation is the breakdown of rock by oxygen and water and give a colour of rusty coloured iron-rich weathered surface. So, when a rock is oxidized, it is quickly weakened and crumbles, causing the rock to break down.

Biological weathering is the process of breakdown of rock that caused by plants and animal. This happen when plant animal releasing its acid that is chemically causing the weathering to happen. Plant will grow everywhere as long as there is presence of water. They will enhance the weathering by growing inside the cracks and fracture. This weathering process of animal is mediated by microorganism.

Physical weathering is the breakdown of rock by the temperature changing effect which is involve the atmospheric condition. It is also called as disaggregation and mechanical weathering. This is because the process of physical weathering happens without chemical changes. Another atmospheric condition is pressure, water and ice. There are two types of physical weathering which is freeze-thaw and exfoliation. Freeze-thaw happens as water constantly seeps, freezes and spreads into cracks, gradually splitting the rock apart. Exfoliation occurs when cracks form as a consequence of the reduction in pressure during uplift and erosion parallel to the ground surface.

However, the weathering also can be assumed and determined by another factor such as the mineralogy and the structure of a rock. Different type of mineral gives different rate of weathering. Mafic silicate mineral such as olivine and pyroxene, the weathering rate is faster than felsic minerals such as quartz and feldspar. The solubility in water also different for different mineral. For example, calcite have more tendency to dissolve in water. Next, the structure of massive rock is usually does not contain weak plane while layering and bedded rock like sedimentary rock is more tend to act with the water and breakdown.

4.2.2 Drainage Pattern

Drainage system is the pattern of the lakes, rivers and streams. Earth landform and topography plays an important role in the formation of the drainage pattern. Erosional processes from the stream will lead the formation of the drainage pattern. It all started from the water from the sources such as rainfall melting snow. The flow will move down to the slope and erode the surface creating the rill. Then by times the rill will deepen and widen into larger channel. The continued erosion will create drainage pattern. Different lithology and topography will give different drainage pattern. Figure 4.8 shows the type of different drainage pattern and Figure 4.9 shows the drainage pattern map of study area.

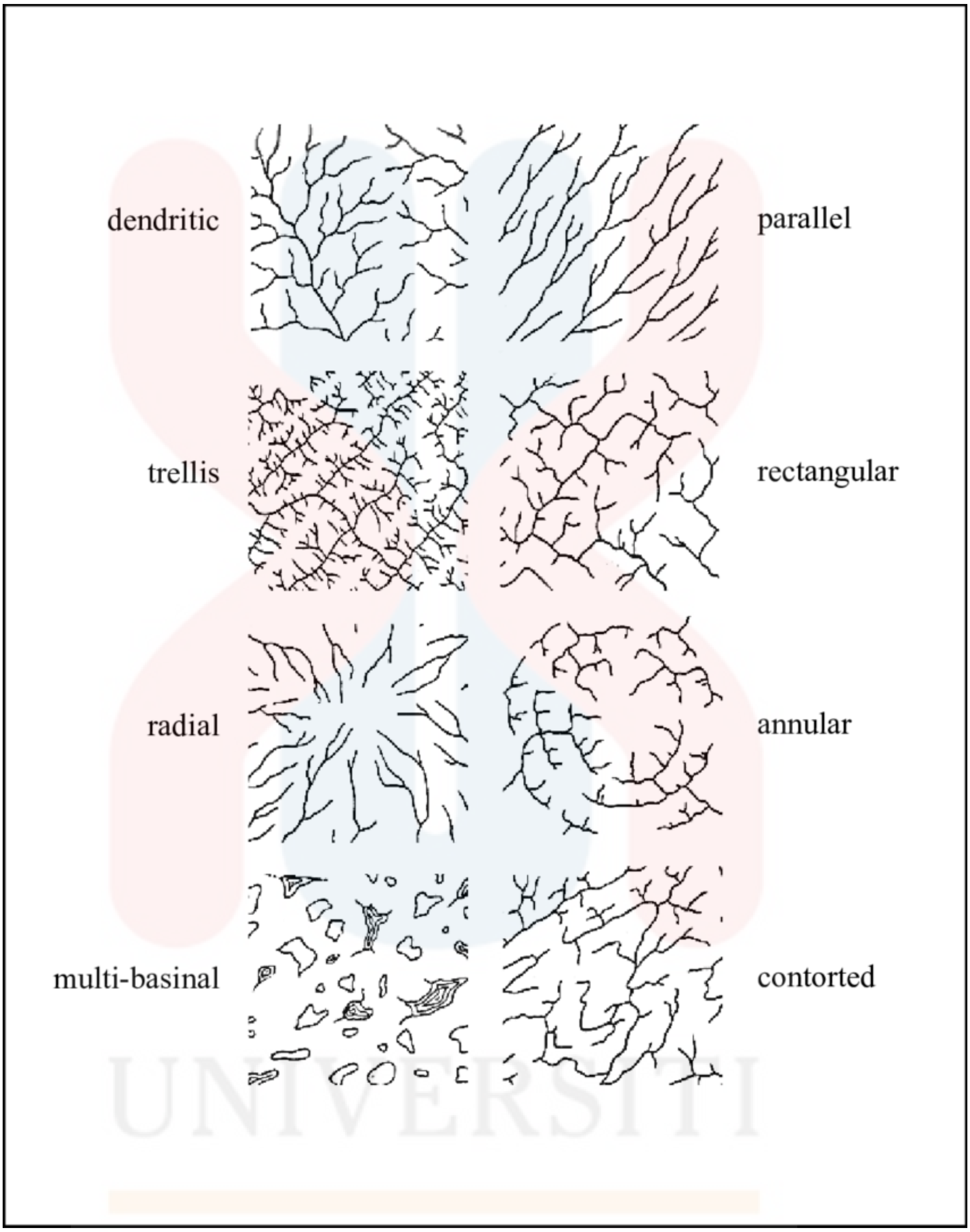

Figure 4.8: Type of different drainage pattern

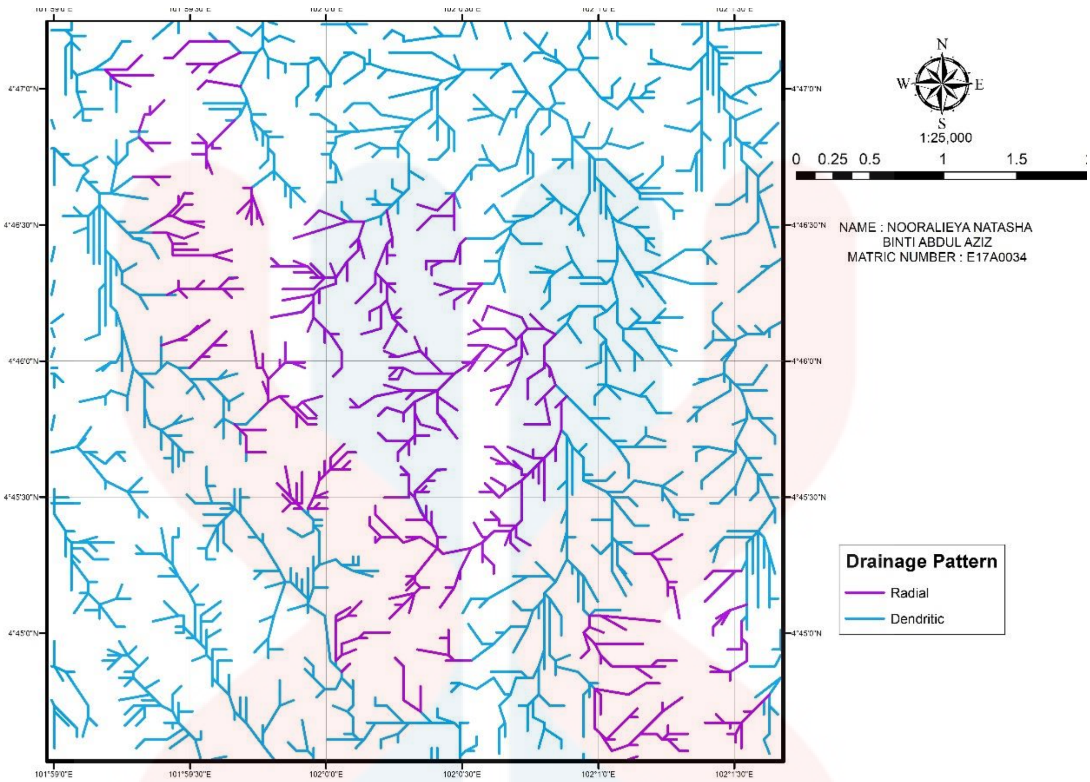

Figure 4.9: Drainage Pattern Map

From the study area, there are two types of a drainage patterns which is radial and dendritic.

i. Radial drainage pattern

This drainage pattern is shows by the stream is coming from or flowing from high elevation places. The high elevation or resistance rock is like igneous rock and also metamorphic rock.

ii. Dendritic drainage pattern

This type of drainage pattern is the most common form. It is looks like branch tree pattern. It develops in surface where the underlying rock is having similarly resistance to the erosion such as homogeneous material region.

4.3 Lithostratigraphy

4.3.1 Geological Map

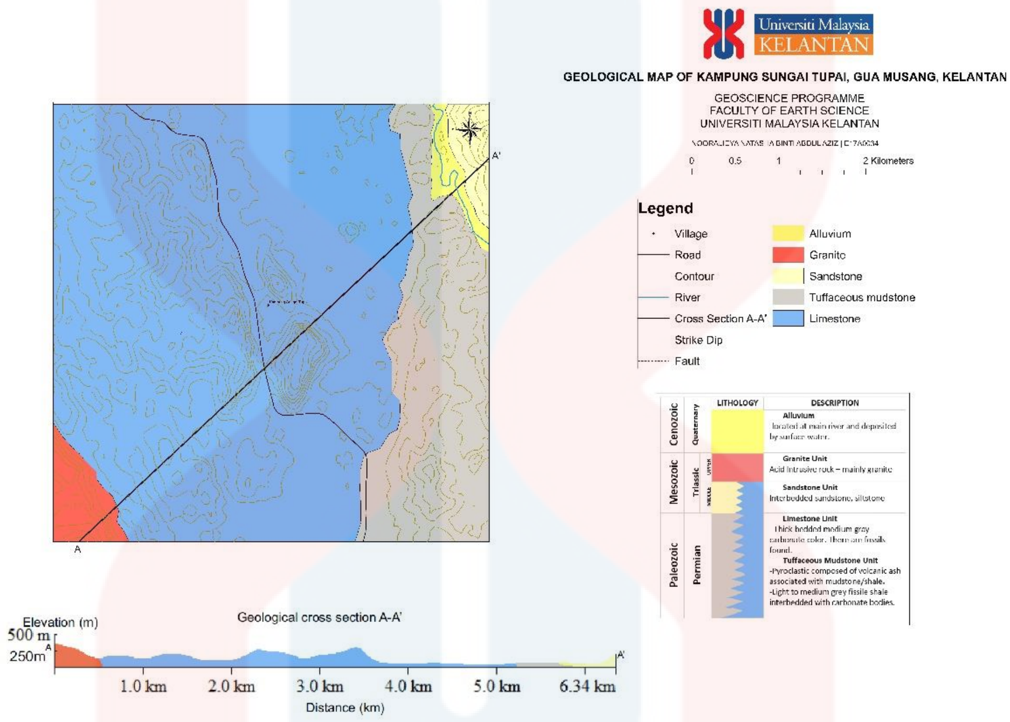

Figure 4.10: The geological map of study area

4.3.2 Stratigraphic Column

The stratigraphy column is shown on Figure 4.10.

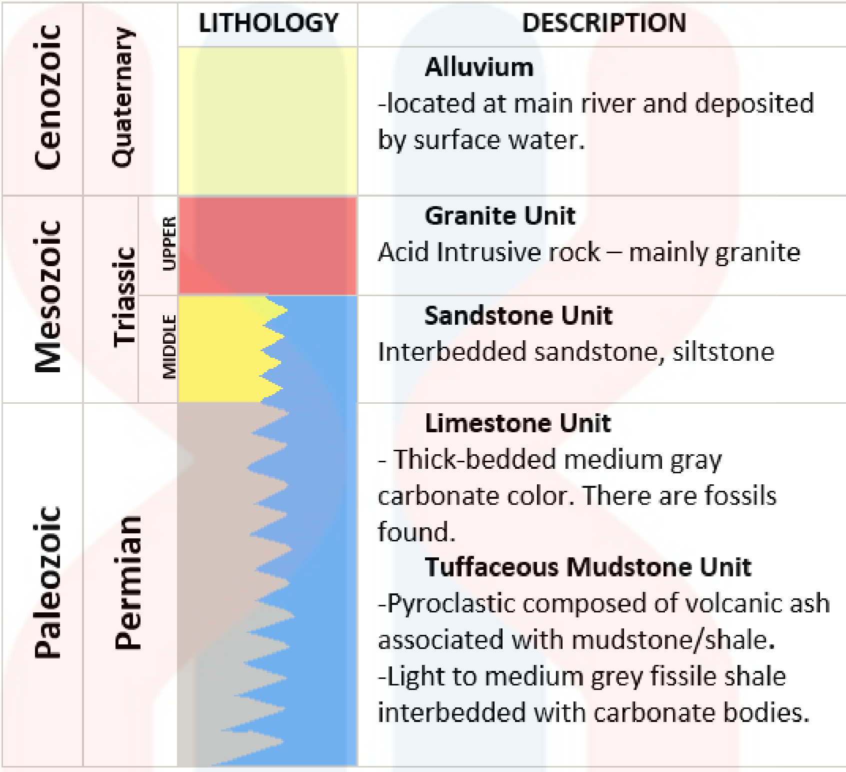

Figure 4.11: Stratigraphy Column of the Study Area

4.3.3 Unit Explanation

The lithology of study area is tuffaceous mudstone unit, limestone unit, sandstone unit, granite unit and alluvium unit.

Tuffaceous Mudstone Unit

The rock type is actually pyroclastic which is igneous rock. Volcanic rock is a type of rock that formed from the volcanic ashes. It is also containing of aphanitic texture which is very fine-grained rock texture. It is called tuffaceous mudstone because it is interbedded with each other.

Limestone Unit

Limestone is a sedimentary rock that is famous and well known because of the characteristic of it that can easily react with water. The topography which is karst feature that can easily be differentiated from other topography. Limestone can easily be detected if it is reacted with hydrocloric acid (HCl).

Sandstone Unit

Sandstone is a sedimentary rock made up mostly of mineral sand or rock grains. Since these are the most common minerals in the earth's crust, most sandstone consists of quartz and/or feldspar. The colour of sandstone is usually yellow, brown and grey in colour. It is a clastic sedimentary rock because it is fragmented. The grain size for sand is ranging from 0.006 to 0.2 cm with the different composition content and it mostly have the feldspar and clay mineral.

Granite Unit

This rock type is acid intrusive. Intrusive rocks crystallize below the earth's crust which is from the magma. It is felsic igneous rock type which is has light coloured. Granite is classified as coarse grained because of the slow cooling of the magma. The dominant mineral in granite is quartz, biotite, feldspar and muscovite.

Alluvium Unit

Alluvium is always changing the deposition by time, so the time scale for it is always Quartenary period to be more specific, Holocene. It is consisting of loose material, gravel which often found in river or stream. It is showing how sediment has been erodes, transported and deposited.

4.4 Structural Geology

4.4.1 Fault

Lineament is linear feature on the surface which express the underlying geological structure such as fault structure. Lineament can be identified from satellite image which is from plan view. Lineament can be divided by two types which is positive and negative lineament. Positive lineament is the linear trend of high topographic while negative lineament is linear trend of low topographic. Positive lineament represents the exposure of high resistance topography such as ridges and mountainous. Negative lineament reflects the exposure of non-resistance topography or zone of weak rock such as valley. Negative topographic lineament can be considered or represented the strike of the fracture. All the data then calculated in GeoRose software. GeoRose is a rose diagram and stereonet plotting program, which can plot structural geology rose diagram, equal area and equal angle stereonet diagram. Figure 4.11 show the lineament map of study area while Figure 4.12 is the rose diagram resulting of the lineament from the data of Table 4.3.

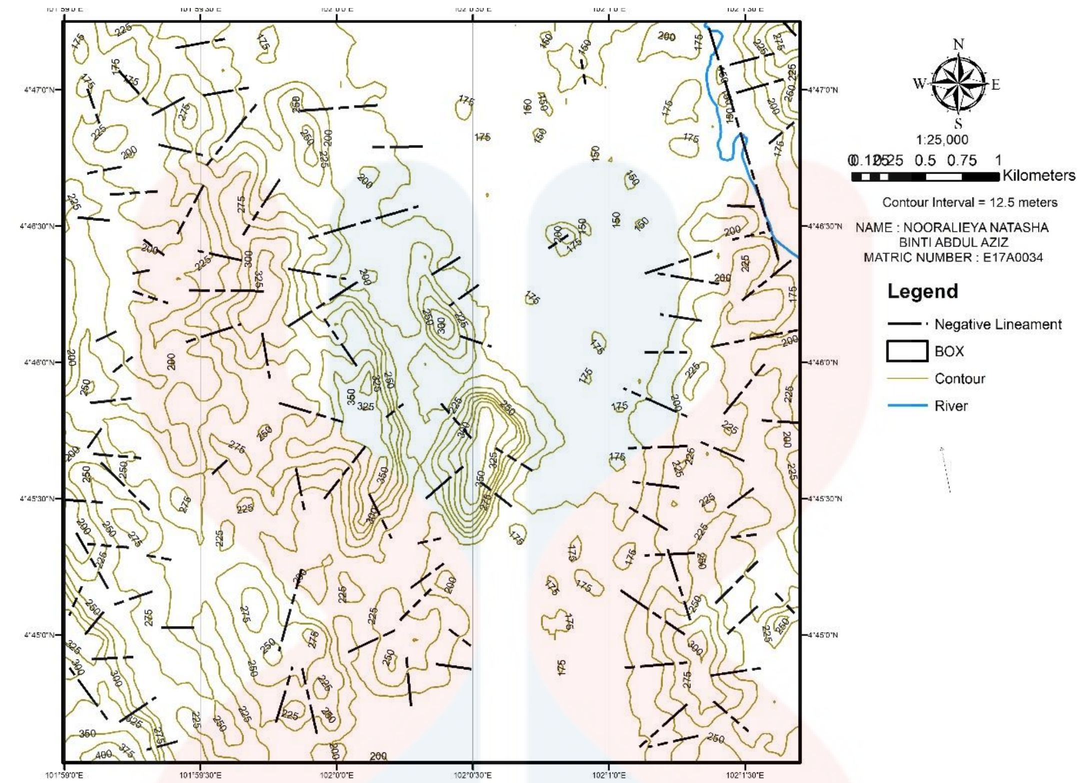

Figure 4.12: Lineament Map of Study Area

Table 4.3: Negative lineament strike data in the study area.

Negative Lineament Reading				
320	342	82	343	74
40	79	81	51	74
64	282	30	71	52
86	275	288	80	279
83	65	271	350	318
35	282	73	88	292
88	86	281	272	290
60	62	58	52	78
288	325	352	341	302

72	82	51	88	300
286	38	348	50	310
48	55	331	89	303
79	52	316	60	57
300	305	306	278	72
66	17	19	55	78
277	274	313	85	280
275	275	278	89	80
72	88	22	47	323
37	89			

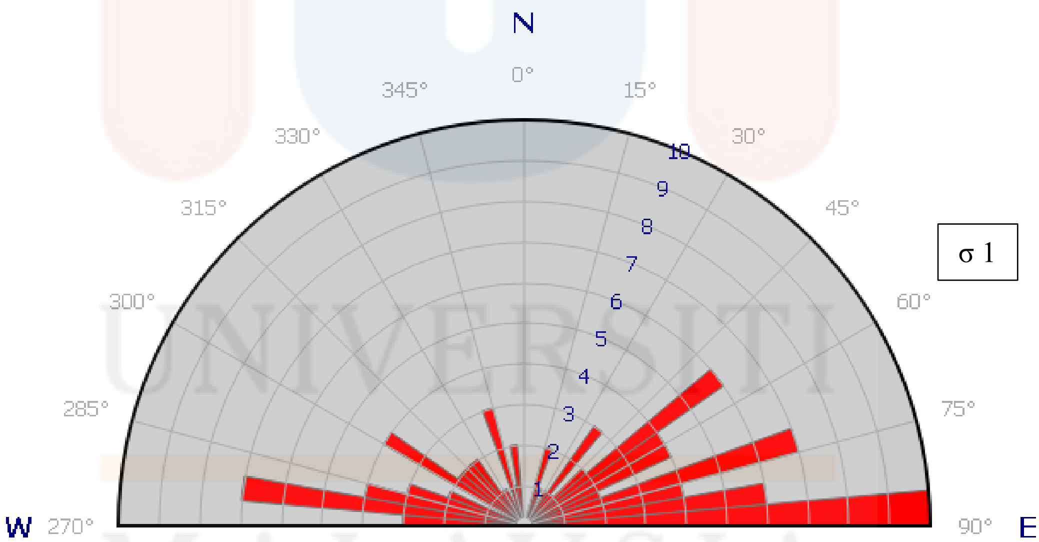

Figure 4.13: Rose diagram of Negative lineament

From the rose diagram, it is shown that there are eight sets of the fracture that can be conclude. A total of 92 lineaments mapped on the satellite image which indicate the structure or weak zone. The maximum principle force which is σ1 is coming from 30° of the longest data of the rose diagram. The direction of the maximum principle force is at N 60° E which is 30° from 90° E. Compressional stress from the force resulting shear fracture formation. The type of fault that can be assume from this rose diagram is strike-slip fault. Dominant fracture is sinistral strike slip fault (left lateral).

4.5 Historical Geology

The historical geology of a place can be determined by the structural geology and stratigraphy includes the existence of fossil. A fossil is a record of past geology that recorded by the traces of naturally preserved animal or plants. There are two types of fossils which are body fossil and trace fossil. Body fossil will include the body of the organism that once lived while trace fossil is the trace where it shows signs the organism was present at the past. Example of trace fossil is the footprint of animal.

Gua Musang Formation is in the Middle Permian to Late Triassic age. The type of lithology is argillaceous and calcareous rock interbedded with volcanic rock. There is also minor presence of arenaceous rocks. The depositional setting is shallow marine shelf deposit with active volcanic activity. So, the type of fossil that have been found is marine organism with the calcareous rock existence.

CHAPTER 5

RESISTIVITY SURVEY METHOD

5.1 Introduction

This chapter includes the analysis and interpretation of data of resistivity survey method. The result from resistivity survey will be correlated with the result from Chapter 4 which cover on the general geology of the study area. Two chosen landslides of the study area evaluated using geophysical method which is 2D Electrical Resistivity Imaging (ERI) method with the length of 200m lines of Wenner-Schlumberger configuration method. The number of electrodes used for the survey is 41 electrodes for both survey lines with the electrode spacing is 5.0 meter. The location of the survey line can be referred to Figure 5.1.

The obtained data were then interpreted by using RES2DINV software to determine subsurface condition of the area. The result reflects the true subsurface condition with a shown resistivity value variation. The result shows calculated apparent resistivity, measured apparent resistivity and the inverse model resistivity. The RMS error must be below 10%. Based on the geological information of the study area, the resistivity contour value is adjusted according to it with their own resistivity range and distinctive colours. The final result of the interpretation was the resistivity and the induced polarization or the conductivity pseudosection profile.

5.2 Interpretation of Resistivity Survey

The depth of penetration of the Wenner-Schlumberger array for these two lines is about 40 meters. The interpretation is done for the Figure 5.3 which is the pseudosection of survey line 1 which is also labelled as Line R8A and the Figure 5.5 shows the pseudosection of survey line 2 that labelled as R2A. It is interpreted referring to the Table 5.1 that shows the range of resistivity and conductivity value of the common rock and chemicals. There is also Figure 5.2 and Figure 5.4 that shows the arrangement of the resistivity model block of survey line 1 (R8A) and survey line 2 (R2A).

Table 5.1 Resistivities and conductivity value of some common rocks and chemicals.

Material	Resistivity (Ω•m)	Conductivity (Siemen/m)
Igneous and Metamorphic Rocks		
Granite	$5x10^3 - 10^6$	$10^{-6} - 2x10^{-4}$
Basalt	$10^3 - 10^6$	$10^{-6} - 10^{-3}$
Slate	$6x10^2 - 4x10^7$	$2.5x10^{-8} - 1.7x10^{-3}$
Marble	$10^2 - 2.5x10^8$	$4x10^{-9} - 10^{-2}$
Quartzite	$10^2 - 2x10^8$	$5x10^{-9} - 10^{-2}$
Sedimentary Rocks		
Sandstone	$8 - 4x10^3$	$2.5x10^{-4} - 0.125$
Shale	$20 - 2x10^3$	$5x10^{-4} - 0.05$
Limestone	$50 - 4x10^2$	$2.5x10^{-3} - 0.02$
Soils and waters		
Clay	1 - 100	0.01 - 1
Alluvium	10 - 800	$1.25 x10^{-3} - 0.1$
Groundwater (fresh)	10 - 100	0.01 - 0.1
Sea water	0.2	5
Chemicals		
Iron	$9.074x10^{-8}$	$1.102x10^7$
0.01 M Potassium chloride	0.708	1.413
0.01 M Sodium chloride	0.843	1.185
0.01 M acetic acid	6.13	0.163
Xylene	$6.998x10^{16}$	$1.429x10^{-17}$

(Source: M.H. Loke, 1999)

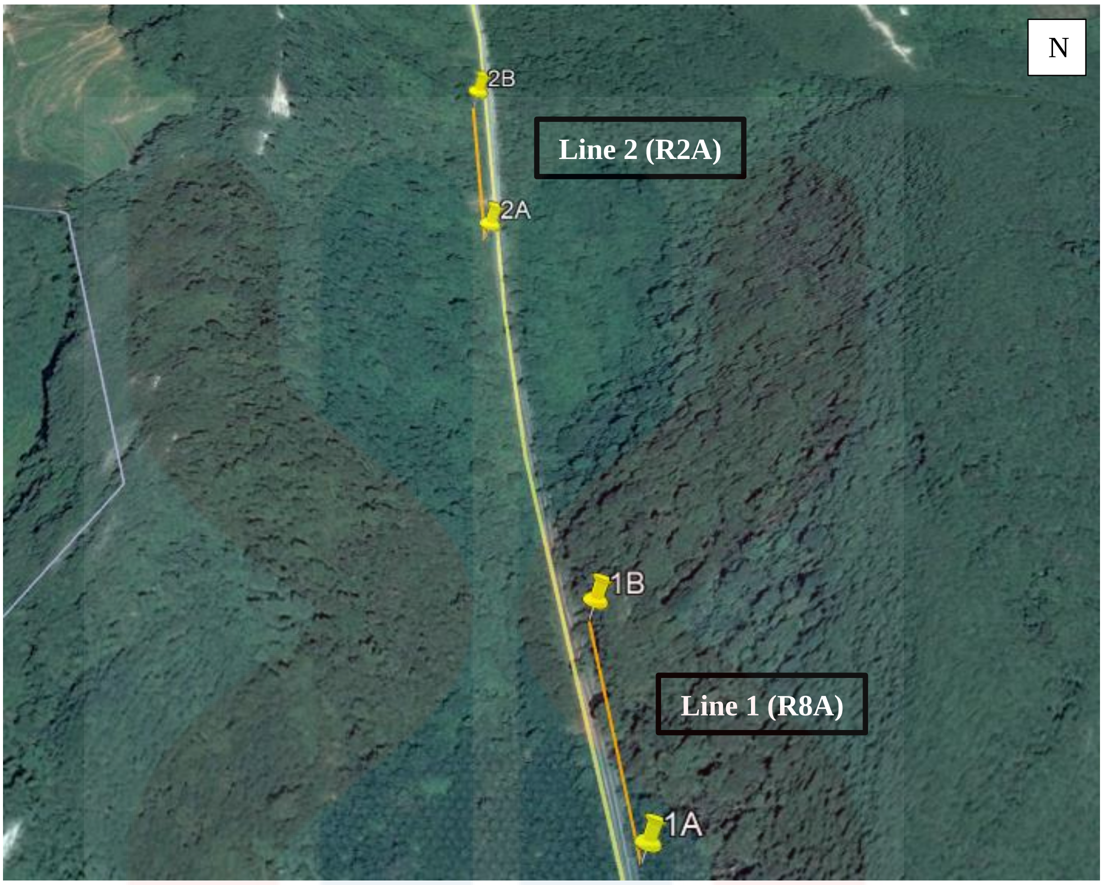

Figure 5.1 The location of survey lines

5.2.1 Resistivity Line 1

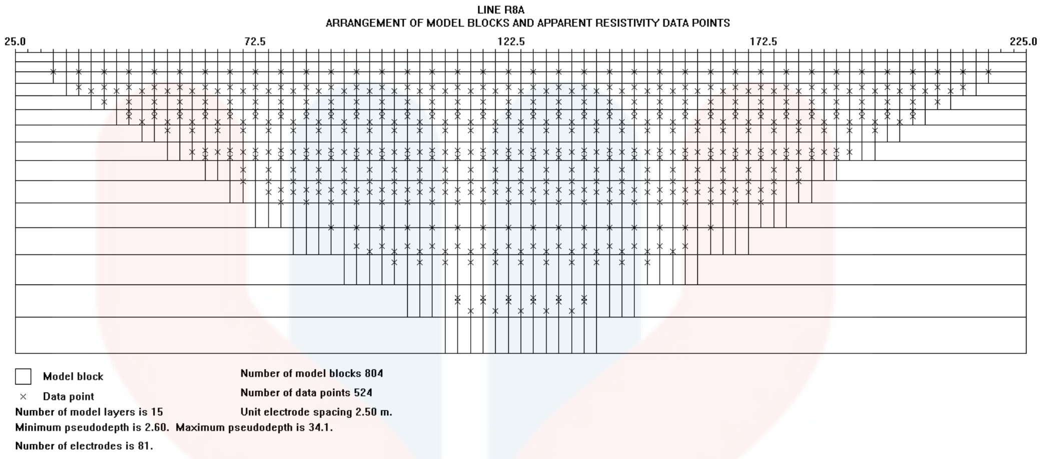

Figure 5.2: The arrangement of the resistivity model block of survey line 1 (R8A)

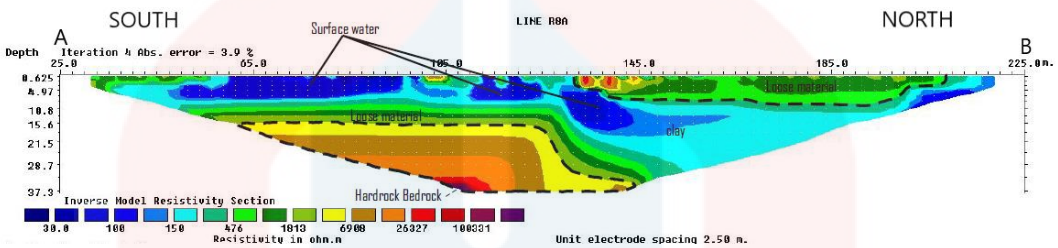

Figure 5.3: The Pseudosection of survey line 1 (R8A)

From the resistivity pseudosection in Figure 5.3, the blue colour shows the low resistivity value with range lower than 100 Ωm indicates there is surface water that connected to the accumulation of water in the subsurface which is the aquifer. It is located form the surface to 8 m depth at the left side of the pseudosection and up to 30 m depth at the the right side. There is zone where the aquifer or water accumulation zone that located on the layer of the basement rock that the colour is ranging from yellow to purple and can be interpreted as moderately weathered to hardrock bedrock with high resistivity value that is > 5000 Ωm located at bottom left of the pseudosection. Between the water accumulation zone and hardrock zone, there is presence of loose material that give the resistivity value ranging from 400 Ωm to 1000 Ωm.

5.2.2 Resistivity Line 2

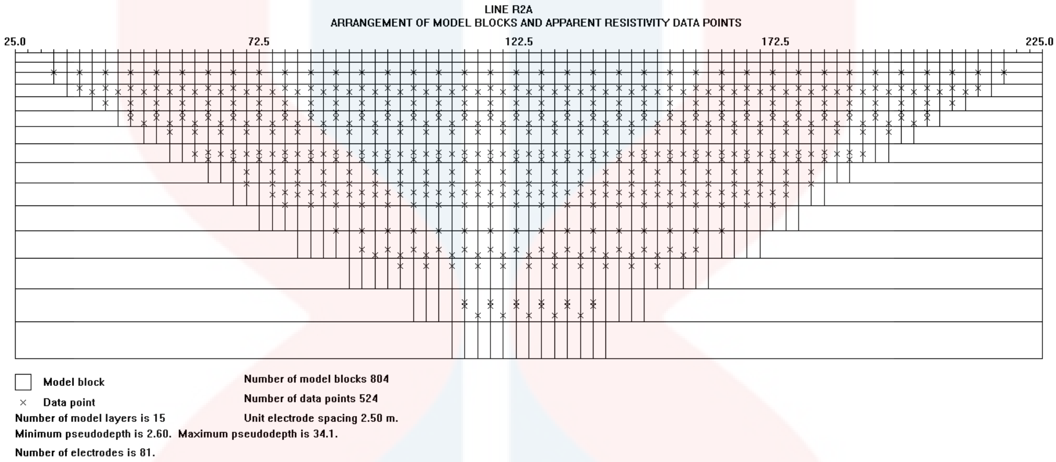

Figure 5.4: The arrangement of the resistivity model block of survey line 2 (R2A)

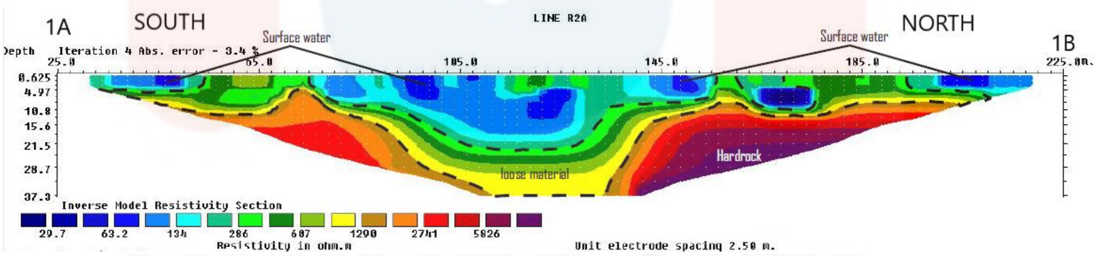

Figure 5.5: The pseudo section of survey Line 2

From the resistivity pseudo section in Figure 5.5, the layer of the regolith or the topsoil of the survey line area is quite thick which is about 37 m depth at the centre of the survey line and at 4 m to 20m depth, there is water accumulation that come from the surface water runoff. At the first and last electrode area the alluvium is not thick and there is clay to sandstone layer on top of the hardrock bedrock.

5.2.3 Discussion

Both pseudo sections show that the weak zone for the landslide to occur is the area that affected by the water. Surface runoff seeps into the ground and accumulate if there is nonpermeable layer such as clay that will not allow water entering the layer. Loose material or the regolith layer is the weak zone that have tendency to move or slide and become the slope failure.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The objective of the research achieved which is the geological map of the study area is updated and the factor that triggered the landslide to occur determined. From both of the lines, it is concluded that the factor of landslide to happen is because of the presence of water accumulation. So, the precipitation and rainfall are the main triggering factors of why the landslide is easily to occur.

6.2 Suggestion and Recommendation

From this research project, there are few improvements that can be applied to produce better dissertation. Future researchers should do the survey by themselves, not interpreting the result from secondary data because it is hard to image the actual condition of surrounding area of the survey line. This thing will be implemented when they working in the industry.

Then, take note even the smallest thing that will affect the survey line. The coordinates of each of the electrodes must be taken to insert the topography value of the survey line for getting the better result. Next, it is recommended to use longer survey line or other array that have greater distribution to investigate deeper subsurface for more accurate analysis. They also should increase the amount of survey line to grasp better understanding of subsurface in the study area and even doing the research using many types of geophysical method such as seismic method, gravity method, magnetic method and borehole logging will have more accurate result and can support the research.

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