GEOLOGY AND THE DEFORMATION OF POTENTIAL LIMESTONE GEOHAZARD BY USING ELECTRICAL RESISTIVITY IMAGING (ERI) SURVEY AT KAMPUNG JIAS, KUALA BETIS

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 THE DEFORMATION OF POTENTIAL LIMESTONE GEOHAZARD BY USING ELECTRICAL RESISTIVITY IMAGING (ERI) SURVEY AT KAMPUNG JIAS, KUALA BETIS, KELANTAN " is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ____________________________

Name : ____________________________

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APPROVAL

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

Signature	:	……………………………........
Name of Supervisor	:	……………………………….
Date	:	………………………………..

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GEOLOGY AND THE DEFORMATION OF POTENTIAL LIMESTONE GEOHAZARD BY USING ELECTRICAL RESISTIVITY IMAGING (ERI) SURVEY AT KAMPUNG JIAS, KUALA BETIS

ABSTRACT

Limestone are very soluble rock which causes it easy to formed karstic feature such as cavities, caves, solution slots, pinnacled bedrock, stalactites or stalagmites and basal notches overhang cliffs. A major fault and joint are structurally controlled most of sinkhole and cave.While 45 % of the study area consist limestone. This research was conducted to study the geology and the deformation of potential limestone geohazard by using electrical resistivity imaging (ERI) at Kampung Jias, Kuala Betis. The main objectives of the study were to produce the geological map of study area with the scale of 1:25 000 and to determine the potential of limestone geohazard in the study area using ERI. Method was being used in this study is by using geological mapping to identify the geomorphology, lithostratigraphy and structural geology of the study area. The rock unit exist in the study area is limestone, tuff and metasediment rock which is phyllite.. The formation of the study area is Gua Musang formation. While potential of limestone geohazard being determined by using ERI. The equipment has been use in ERI survey is ABEAM, 2 cable and electrode. Three survey line has been run in the study area. The result is Line 1 and Line 2 has low possibility for limestone to occur. While line 3, that used pole dipole principle might has high possibility of sinkholes to occur. The conclusion geological map with scale 1:25000 managed to being produced and in the study area has possibility sinkholes to occur.

Keywords: sinkhole: limestone: ERI

GEOLOGI DAN UBAH BENTUK POTENSI GEOBENCANA BATU KAPUR DENGAN MENGGUNAKAN PENGIMEJAN RESISTIVITY ELEKTRIK (ERI) DI KAMPUNG JIAS, KUALA BETIS

ABSTRAK

Batu kapur sangat mudah larut menyebabkan mudah untuk membentuk ciri karstik seperti rongga, gua, slot penyelesaian, batuan dasar pinnacled, stalagtite atau stalagmite, takungan basal yang tidak terjual tebing. Manakala 45% daripada kawasan kajian terdiri daripada batu kapur. Kajian ini dijalankan untuk mengkaji geologi dan ubah bentuk potensi geobencana batu kapur dengan menggunakan ERI di Kampung Jias, Kuala Betis. Objektif utama kajian ini adalah untuk menghasilkan peta geologi kawasan kajian dengan skala 1:25 000 dan untuk menentukan potensi geohazard batu kapur di kawasan kajian menggunakan ERI. Kaedah yang digunakan dalam kajian ini adalah dengan menggunakan pemetaan geologi untuk mengenal pasti geomorfologi, lithostratigraphy dan geologi struktur kawasan kajian. Unit batu yang ada di kawasan kajian ialah batuan batu kapur, tuf dan batu metediment iaitu phyllite. Pembentukan kawasan kajian adalah Formasi Gua Musang. Walaupun potensi geohazard batu kapur ditentukan dengan menggunakan ERI. Peralatan yang telah digunakan dalam kajian ERI ialah ABEAM, 2 kabel dan elektrod. Tiga garis kaji selidik telah dijalankan di kawasan kajian. Hasilnya adalah Garisan 1 dan Garisan 3 mempunyai kebarangkalian yang rendah untuk sinkhole berlaku. Manakala garisan 3 yang menggunakan prinsip pole dipole mempunyai kebarangkalian yang tinggi untuk sinkhole berlaku. Konklusinya, geological map bernisbah 1:25,000 telah berjaya dihasilkan dan potensi geobencana batu kapur berjaya dikesan dalam kawasan kajian.

Kata kunci: sinkhole: batu kapur: ERI

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ERI	Electrical Resistivity Imaging surveying
HCL	Hydrochloric acid

CHAPTER 1

INTRODUCTION

1.1 General background

The research is about the potential of limestone geohazard by using electrical resistivity imaging (ERI) survey at Kampung Jias, Kuala Betis. This research was chosen based on the past study in Kuala Betis. This is because no research about limestone geohazard had been done in Kuala Betis. The past study mostly emphasized about river around Kuala Betis. Figure 1.1 show the geological map of Kelantan.

ERI is to investigates variation of electrical resistance by causing an electrical current to flow through the subsurface using wires that connected to the ground. By making measurements on the ground surface, electrical surveys is used to determine the subsurface resistivity distribution . The true resistivity of the subsurface can be estimated from the measurements.(Loke, M. H. 2013).

Limestone geohazard is landforms of dissolution such as sinkholes, dry valley, broken bedrock surface and caves. Limestone geohazard also can increasing cost in design and construction which effect planning and development. It is also can cause damage to building and infrastructure. Limestone geohazard can be detect by using ERI.

Dissolution of limestone mostly drive by the rain and carbon dioxide from the air dissolved in limestone which cause it is slightly acidic. The minerals in rocks may react with rainwater. This causes the rock to be weathered and it is know as chemical weathering. Limestone and chalk are easily to weathered because they are made of calcium carbonate minerals. Chemical reaction happen because of acidic rainwater are falls on the limestone. In the reaction, new soluble substances are formed. The new soluble solution will washed away and the rock become weathered. (KS3 Bitesize Science).

This research also to study about the geology of study area. The geology of study area will explained about lithology, stratigraphy, structure, geomorphology and structural geology. This data can be used to explain about composition of rock and the relationship of study area with certain formation. The study also will give information about drainage pattern and landform that exits in study area. The data also can be used to determine the age of rock in study area.

1.2 Study area

This subchapter will explain more about the study area based on the geologic mapping process and other resources such as web and journal.

1.2.1 Location

Kampung Jias, Kuala Betis is located at south of Gua Musang. It is located 30km away from Bandar Gua Musang. Kuala Betis also known as placement of Orang Asli. The study area covers an area of 5×5 kilometers in Kuala Betis. The study area is within coordinate 101°44'52.749"E to 101°47'35.881"E and 4°57'56.098"N to 4°55'15.698"N.

Based on the base map provide in Figure 1.2, the average elevation in the study area is around 220 meters. The elevation around the study area are moderate elevation. Based on the based map, the highest elevation is 560m while the lowest elevation in the study area is 160m. The study area consist of main road, village, river and plantation. The plantation that exists in study area is palm and rubber plantation.

1.2.2 Road connection

Kuala Betis are located at South of Kelantan. The study area also consist of two road which one is main road while the other road is all along the Betis river. Main road is used as route for farmer and logger. The main road being use mostly by farmer in both plantation. The study area is is about 26.2km away from Bandar Gua Musang. Take about almost 30 minute to reach Bandar Gua Musang. The main vehicle that mostly used in the study area is four wheel drive such as Hilux or Pajero and motorcycle. This is because the both road is non-tar road and it suitable for this type of vehicle.

1.2.3 Demography

In 2010, the total population of Gua Musang is 90,057 based on the census of population and housing 2010. Based on the Table 1.1, 75% of the population are Malay, 14% other Bumiputera, 5% Chinese, 0.4 Indian, and 0.2 others.

Table 1.1: Total population in Gua Musang

No	Ethnic	Total Population
1	Malay	67,200
2	Other Bumiputera	13,034
3	Chinese	4,000
4	Indian	400
5	Others	200

(Source: Population and housing census of Malaysia, 2010)

1.2.4 Landuse

Based on observation, half above part of the study area is plantation area. Which the study area had rubber and palm plantation. The main road also being use mostly by farmer in both plantation. While the other half below part of study area are forest area. Which is the logging is the main activity at the forest. The right part of the study area consists a few village.

1.2.5 Social economic

At the study area, it has lot of plantation which show that the main economic of this study area is plantation. It has palm and rubber plantation. This both plantation has lot of usefull. Plantation also give job opportunity for community around the study area. Forest in the study area also give a lot of income in handicraft sector especially for Orang Asli. Because they can used the source to create handicraft like basket and rattan bag.

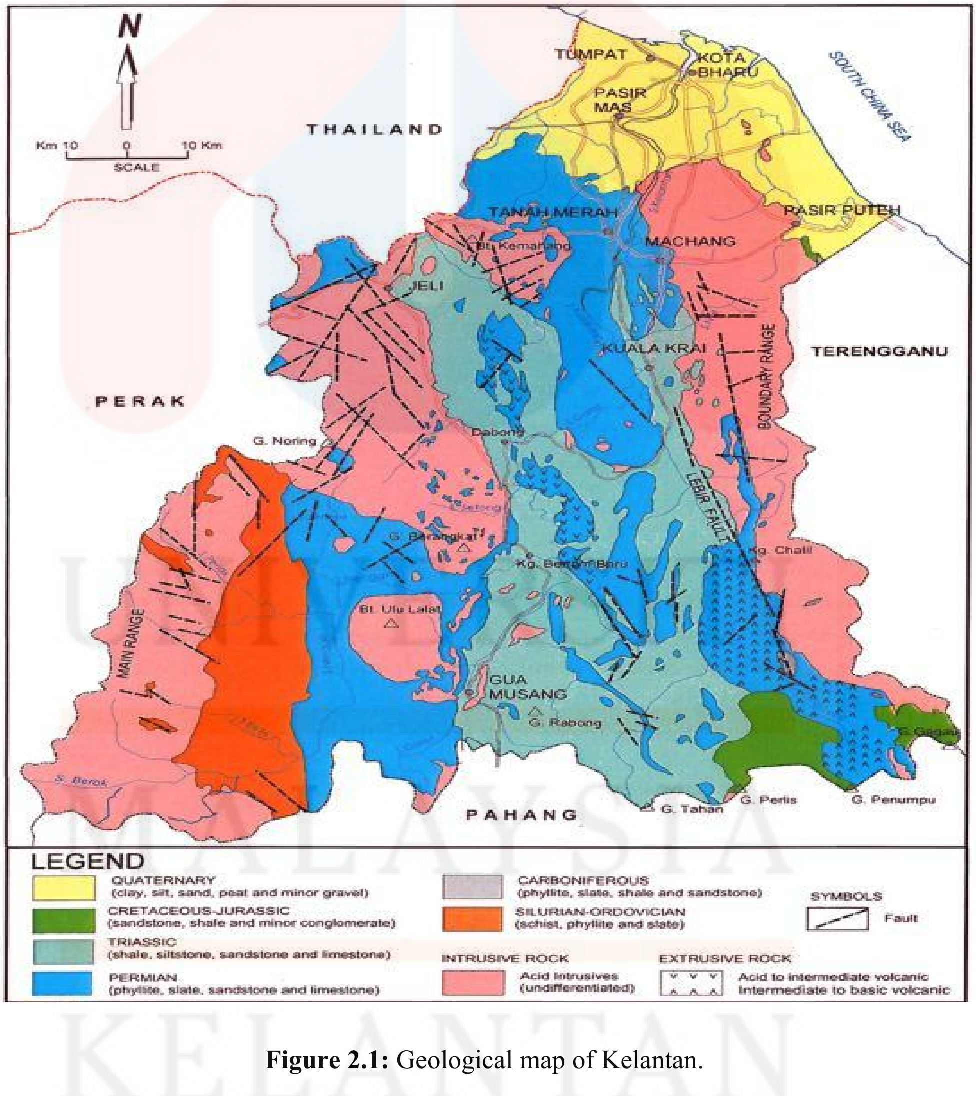

Figure 2.1: Geological map of Kelantan.

(Source: Amin Beiranvand Pour, Mazlan Hashim, 2016)

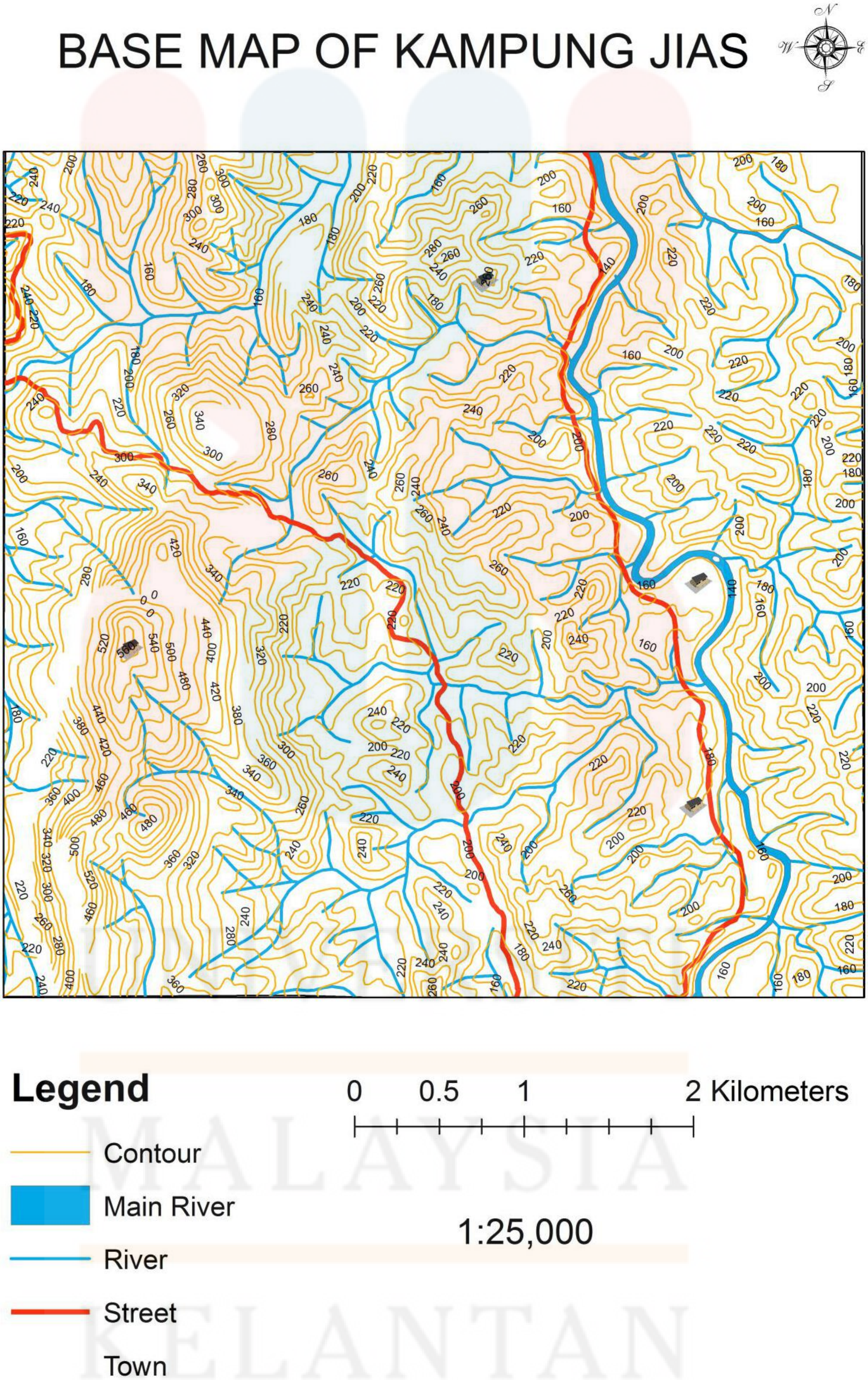

Figure 1.2: Basemap of Kampung Jias, Kuala Betis

1.3 Problem statement

The study area contain few limestone hills. Which show the study area might had possibility of limestone geohazard to occur. This is because limestone are landform of dissolution. Dissolution of limestone mostly causes by rain and it is slightly acidic because carbon dioxide from the air dissolves in it. The minerals in rocks may react with rainwater. This causes the rock to be weathered and it is known as chemical weathering. Limestone and chalk are easily weathered because they are made of calcium carbonate minerals.When acidic rainwater falls on limestone this causes a chemical reaction happens. New soluble substances are formed in reaction. This will washed away and the rock will be weathered. (KS3 Bitesize Science). ERI are used to confirmed the existence of limestone in Kampung Jias, Kuala Betis. This study area also has lack of geology information. This is because is only a few research has been done in this study area. The study will show the data about lithology, stratigraphy, structure, geomorphology and structural geology. It will tell about the composition of rock and the relationship of study area with certain formation. Lastly, the data also can be used to determine the age of rock in study area.

1.4 Objectives

The objectives of this research are:

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

ii. To determine the potential of limestone geohazard in study area using ERI method.

1.5 Scope of study

This research focus on the general geology and potential of limestone geohazard at Kampung Jias, Kuala Betis by using ERI. In this study area, we will study more about general geology of Kampung Jias, such as geomorphology, lithology and structural geology. This general geology can be obtain through field study. This geohazard can be identified using geophysics method which is electrical resistvity imaging method. Which consists of straight line of electrode with the equal distance with each other will be install along the ground surface. The Wenner array configuration will be used then connected to ABEM Terrameter SAS 4000 and the direct current (DC) will be applied at alternating outer electrodes along the electrode line.

1.6 Significant of study

The significance of this study is to produce a new geological map of study area with scale of 1:25 000. It will provided geological information such as lithology, stratigraphy, landform, geomorphology, drainage pattern and others. By produced the new geological map, it will also updated old data in Kuala Betis. The new geological map and geological data will be useful for researcher for future study. By determination of limestone geohazard such as sinkholes, dry valley, broken bedrock surface and caves. The data can be use for future reference for another researcher Especially for future development. This is because Kuala Betis had potential to be developed in future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section will be discuss more about previous study of study area which is Kuala Betis, limestone geohazard and electrical resistivity imaging (ERI). It is also will discuss about geology of previous study about study area such as regional geology and tectonic setting, stratigraphy, structural geology, and historical geology. To learn and understand about previous study. It is also how to related the previous study with the newest research.

2.2 Regional geology and tectonic setting

Based on Swee Heng et al (2006), Kelantan consists of a central, west and east. Which is central zone is sedimentary rock and metasedimetary rock, while bordered by granites of the Boundary Range and Main range at east and west. In the east belt, the coastal alluvial flat of Sungai Kelantan are overlain the Boundary Range granite and in central and west Kelantan, the belts continue northward into south Thailand. While, window of granitic intrusives are exists in the central zone and featured by the Stong Igneous Complex, the Kemahang pluton, and the DIu Lalat (Senting) batholith that prominent. The granite and country of belt have the north-south direction and on the basis, it continuation of the regional geology of north Pahang.

The oldest rocks in the Kelantan are in Lower Paleozoic age, outcropping as a northerly-trending belt bordering the foothills of the Main Range and extending eastward up to Sungai Nenggiri. They are mainly metapelites with lesser volcanic fragmentals and calcareous intercalations and minor arenaceous. It has been recorded the rare occurrences of serpentinite and amphibolite. Predominantly Permian volcanic-sedimentary rocks occur extensively on the eastern side of, and overlying uncomformbly, the Lower Paleozoic sequence in southwest Kelantan. The Taku Schist, the age of which is still questionable but defmitely pre-Triassic, dominates central north Kelantan. Triassic rocks are confined mainly to south and central Kelantan. These rocks are mainly argillo-arenaceous sediments with limestone and intercalated volcanics. Several inliers of Permian rocks crop out through this veneer of Triassic sediments (MacDonald, 1967).

The youngest rocks are the Jurassic-Cretaceous continental rocks which overlie the Boundary Range Granite and Triassic sediments in the Gunung Gagau area at the common state boundary between Pahang, Terengganu and Kelantan and to the west in the Gunung Pemumpu and Gunung Perlis areas. This sequence consists of conglomerate overlain by sandstone (MacDonald, 1967). Kelantan stated is located in North-Eastern area of Kelantan. It is composed of high slopes in the southern part of the river basin and flat slope to moderately sloping areas in northern part and steep scraps. A wide variety of rocks belong of igneous, metamorphic and sedimentary rocks could be seen in the state of Kelantan, which are distributed in a North-South direction. Typically, four types of rocks are classified in the region, including granitic rocks, sedimentary/metasedimentary rocks, unconsolidated and sediment extrusive rocks. There were a few of geological features which is fold, fault and joint in sedimentary rocks and fault and joint in the granite rocks. (Pour, A. B., & Hashim, M., 2016)

2.3 Stratigraphy

According to Samsudin, et al (1994), Kuala Betis and area its surrounding consists of several units rock which is metamorphic rock of Paleozoic, rocks of Gua Musang Formation, several igneous rock bodies and kuaterner. Metamorphic rocks which also know as the oldest rocks of Paleozoic located at west region.

At the east region, It consist of Gua Musang Formation rock, several igneous rock bodies that breaking through Gua Musang Formation and kuaterner which is the youngest in their sequel. Quterner which most of them are alluvium deposit in river valley.

Stratigraphy based on for area of Kuala Betis are Paleozoic rocks which was believed to be Devonian - Silurian old age. It is overlapped by inconsistent rock of Gua Musang Formation. There were tectonic activities before the formation of Gua Musang Formation therefore causes the occurrence of fold in the rock Paleozoic and lifting sedimentation. Gua Musang Formation happen after lifting, with formed of conglomerate unit and the rock of this unit originated from the Paleozoic rock.

Tectonic activities act once again after the deposition of Gua Musang Formation and this resulted in a large open crease in this rocks. (Samsudin, et al,1994).

2.4 Structural geology

Gua Musang consists of five types of lithology. Which are siltstone, shale unit, limestone unit, interbedded sandstone and phylite. Slate and shale with subordinate with sandstone and schist unit , felsic unit and also alluvium unit. All the lithologies are Paleozoic and Mesozoic era. After Triasic period end, new regional pattern of sedimentation was established in the aftermath of tectonic disturbances and widespread plutonism that formed the Central Belt, Main Range and the Eastern Belt plutons. These new basins were infilled rapidly by red, ferric-rich, siliciclastics that were deposited in diverse terrestrial settings, ranging from alluvial fans, braided rivers, flood plains, lakes and deltas. These red beds, named in reference to their colour, were identical to molasse deposits and marked the end of marine (Abdullah, 2009).

2.5 Historical geology

Based on Mohamed et al, (2016),The Gua Musang formation in South Kelantan North Pahang was mapped by Yin (1965) to descri be Middle Permian to Late Triassic argillite, carbonate, and pyroclastic/volcanic facies within Gua Musang area.

Now, the term has been loosely used for nearly all Permo-Triassic carbonate-argillite-volcanic sequences in the northern part of Central Belt Peninsular Malaysia.Widespread distribution of argillite-carbonate-volcanic across northern Central Belt has triggered issue regarding current names assigned. For example, similar lithologies to the Gua Musang formation in Felda Aring is named as Aring Formation, while those in Sungai Telong is called Telong formation (Aw, 1990).

Mohamed and Leman (1994) and later Mohamed (1995) explained that these lateral facies changes could be gathered within the same group as long as these sediments were deposited in shallow marine environment of the Gua Musang platform during the Permo-Triassic period.The relevance of grouping these formations lies behind the close associations observed among these formations in terms of sedimentological and paleontological aspects. The authors find the need to reasses the usage of the informal 'Gua Musang formation' for future rank elevation, formalization, and clearer understanding on the geology of the northern Central Belt, particularly with regards to deposition of various lithostratigraphic units within the Gua Musang platform.

2.6 Resistivity array

This topic will explain about electrode array can used in ERI which is Wenner Array, Schlumberger array, Pole-pole array, Pole-dipole array and Dipole-dipole array

2.6.1 Wenner array

Based on Hassan (2018), the simplest array is Wenner array. Four electrodes are set in line and the electrodes are arranged in equal distance between each other. Two inside electrodes are potential electrodes and the two outside electrodes are current electrodes. The resistivity of subsurface layers is found by increasing the distance between the electrodes while maintaining the location of the center point of the array in the Wenner array. This method is known as vertical electrical sounding (VES) or electrical drilling. By moving the four electrodes across the surface while maintaining constant electrode separation, the detection of horizontal changes of resistivity is achieved. This method is called profiling or also known as electrical trenching.

2.6.2 Schlumberger array

Based on Hassan (2018),The Schlumberger array is where four electrodes are set in line around a common midpoint. The two inside electrodes, M and N, are potential electrodes placed close together, and the two outside electrodes, A and B, are current electrodes. For each measurement the current electrodes A and B are moved outward to a greater separation throughout the survey, while the potential electrodes M and N stay in the same position until the observed voltage becomes too small to measure (source) which in Schlumberger array. At this point, the potential electrodes M and N are moved outward to a new spacing. As a rule of the thumb, the reasonable distance between M and N should be equal or less than one-fifth of the distance between A and B at the beginning. Depends on the signal strength, the ratio goes about up to one-tenth or one-fifteenth.

2.6.3 Pole-pole array

Based on Hassan (2018), the four electrodes in the pole-pole array are arranged so that the distance between the transmitter (A&B) dipole and the receiver (M&N) dipole is small in comparison. In fact, the distance ought to be 10% that of the A&B dipole. In a pole-dipole survey, one transmitting electrode is moved away from the dipole to infinity (i.e., 10 times the distance of the survey area) so the instrument doesn't sense the pole electrode. In a pole-pole survey, one receiver electrode is also moved to infinity, but additionally, one of the potential electrodes is moved to infinity in the opposite direction. In other words, in a pole-pole array, you have a stationary infinity electrode on either side of the survey area. Then proceed with your resistivity or induced polarization measurements exactly as you would with a pole-dipole array: Move the A and M electrodes to a new location inside the survey area and take a reading with AGI's SuperSting instrument.

2.6.4 Pole-dipole array

Based on Hassan (2018), a pole is a single transmitting electrode, and a dipole is a pair of oppositely charged electrodes that are so close together that the electric field seems to be a single electrode field instead of fields from two different electric poles.

The pole-dipole array is similar to the dipole-dipole array, but the pole-dipole array is used when the surveyor needs to see deep within a cross section of the earth. The achievable depth is based entirely on the distance between the two electrodes (the dipole and the pole). The dipole-dipole array, on the other hand, is used to provide a very detailed image of a cross section of the earth—but will lose signal if the dipoles are placed too far apart. Like the dipole-dipole array, the pole-dipole array is most often used for mineral and ore exploration.

2.6.5 Dipole-dipole array

Based on Hassan (2018), a dipole is a pair of oppositely charged electrodes that are so close together that the electric field seems to form a single electric field rather than a field from two different electric poles. (On the other hand, when the separation of the two charged electrodes is large enough that the observer detects the electric field from two poles, it's called a bipole. The dipole-dipole array consists of a current electrode pair A and B and a potential electrode pair M and N, and it offers a way to plot raw data in order to get an idea of a cross-section of the earth. Those using the dipole-dipole array look at a measurement value called apparent resistivity, which represents a weighted average of the resistivities under the four electrodes used to take the reading. The apparent resistivity is typically calculated by modern instruments from the geometry between the four electrodes and the injected current and measured potential.

The result of a dipole-dipole survey is plotted in a pseudo-section. For each measurement, the apparent resistivity data is plotted at the midpoint between the two dipoles and at a depth half the distance between the two dipoles. The value is finally contoured and colorized, which represents a rough (and often severely distorted) image of the subsurface. So while this array doesn't provide an actual image of the ground, the data points resulting from these measurements provide an image of the cross section that one can then try to interpret. Today, modern inversion software (EarthImager 2D) can recalculate all of these apparent resistivity values to "true" resistivity values so that a realistic image of the ground can be created.

The primary advantages of the dipole-dipole array are its high resolution and multi-channel capability; it provides a very detailed image instead of providing a "big picture" image like the Wenner array. The dipole-dipole array is fast because it supports multiple receiver channel measurements simultaneously (the AGI SuperSting R8 can measure eight simultaneous measurements for each current injection) whereas the Wenner array can only collect one data point for each current transmitter injection. Additionally, it is relatively simple to perform a survey along profile lines using the dipole-dipole array. The disadvantage of this array is that the dipoles will lose the signal if they're placed too far apart, thereby decreasing the ability to see deeper into the earth.

2.7 Electrical resistivity imaging (ERI) survey

For subsurface investigtion, Electrical resistivity imaging (ERI) is a non-destructive method. The measurement of the apparent electrical resistivity of subsurface materials are involved in ERI. Through a pair of current electrodes, the electrical current is insert into the earth, and the potential difference is calculated between a pair of potential electrodes during the ERI survey. The potential electrodes and current are usually laid in a linear array (Utility Survey Corp, 2017).

Based on Utility Survey Corp, the bulk average resistivity is the apparent resistivity is of all subsurface materials influencing the flow of current. A typical ERI survey involves multiple such various configurations of electrode locations with measurements of apparent resistivity. Resistivity variations along depth and horizontal positions is shown when the data is then processed and resistivity contour maps are produced. Since the electrical resistivity of subsurface materials varies with their water contents and compositions, the resistivity contour maps can be used to find interested targets or to get a general background of the subsurface condition. For example soils and bedrocks,this is because they have different resistivities,

ERI also can be used to pictured soil-bedrock interfaces. Which ERI produce 2D or 3D subsurface images. ERI give images with lower resolutions but deeper investigation depths. In one hand, the minimal sizes of targets are typically in feet instead of inches; in the other hand, its investigation depth can easily reach 50 feet or more. Applications of ERI are not limited to sinkhole, mapping of depth to bedrock, mapping of bedrock fracture zones, groundwater table investigation, mapping extents of conductive contaminant plumes, archaeological site mapping and landfill delineation (Utility Survey Corp, 2017).

Based on Loke and Meng. (2011),Electrical resistivity survey pictured the subsurface structure by produced electrical measurements near the ground surface. Through two electrodes and the voltage difference is measured between two other electrodes, an electric current is injected into the ground. By making the calculation of potential difference at different positions of the current and potential electrodes, converting these values into apparent resistivity and then inverting the data set, the true subsurface resistivity can be estimated. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity,and degree of water saturation in the rock

According to Reynolds, J. M. (2011), electrical resistivity methods have become very much more widely used since the 1970s mainly due to the availability of computer to process and analyse data but it actually were developed in the early 1900s. It is always used to monitor pollution of groundwater and used in the search for suitable groundwater sources. While in engineering surveys, it is used to located subsurface cavities, permafrost, mine shaft, fissures and faults, and so on. It is also used in archeology.

The physical properties of rocks that are important for electrical surveying are the resistivity (or conductivity) and the permittivity (for georadar),which are based on several technique. For example is anomalies arise which when a good conductor such as orebody and mineralized dike is present in rocks that have higher resistivities. The resistivity contrast between orebody and host rock is often large, because igneous rocks that contain no water can have a very high resistivity, but the resist can be very low (Lowrie,W. 2007).

For example, in a high-grade pyrrhotite ore r is of the order of 105 m and in dry marble it is around 108 m. The range between these extremes spans 13 orders of magnitude. Furthermore, the resistivity range of any given rock type is over- laps with other rock types and wide. Acts as an electrolyte, the resistivity of rocks is strongly influenced by the existence of groundwater. In porous sediments and sedimentary rocks, this is especially important (Lowrie,W. 2007).

The conductivity of the sediment increases with the amount of groundwater that contain because the minerals that form in the matrix of a rock are generally poorer conductors that groundwater. This depends on the fraction of this pore volume that is water filled (the water saturation, S), and the fraction of the rock that consists of pore spaces (the porosity, f). The conductivity of the rock is proportional to the conductivity of the groundwater, which is quite variable because the concentration and type of dissolved minerals and salts it contains is depends on (Lowrie,W. 2007).

2.8 Limestone geohazard

Limestone is a sedimentary rock that are formed from small particles of rock or stone that have been compacted by pressure and heat composed by primarily calcium carbonate ($CaCO^3$) in the form of mineral calcite. Another common mineral is dolomite . Limestone are very soluble. Because of that can formed karstic feature such as cavities, caves, solution slots, pinnacled bedrock, stalactites or stalagmites, basal notches overhang cliffs. Limestone also known as most significant karst rock based on the nature and environmental control of their deposition (Ford & Williams, 2013).

According to (Abdeltawab, 2013), major fault and joint are structurally controlled most of sinkhole and cave. This is because limestone is a sedimentary rock that are consist mineral calcium. Limestone known as unique rock because it can soluble to acidic water due to the existence of mineral calcium. The reaction between mineral and acid water can produced karstic features such as cavities, caves, pinnacled block, stalagmite and stalagtite that are can formed a sinkhole or subside this area to the deep (Kong,2002).

CHAPTER 3

MATERIALS AND APPARATUS

3.1 Introduction

This chapter will discuss about materials and methodology that will be used in this research. This chapter will explain more about the apparatus and advantages of the apparatus. This chapter also will discuss about all the methodology used in this research which is preliminary studies, field studies, data processing, data analysis and interpretation to report writing. Figure 3.1, show the flowchart of research methodology.

3.2 Materials

This section will discuss about all the apparatus and the use of apparatus that will be used in the research. The important of apparatus will be discussed in the table 3.1.

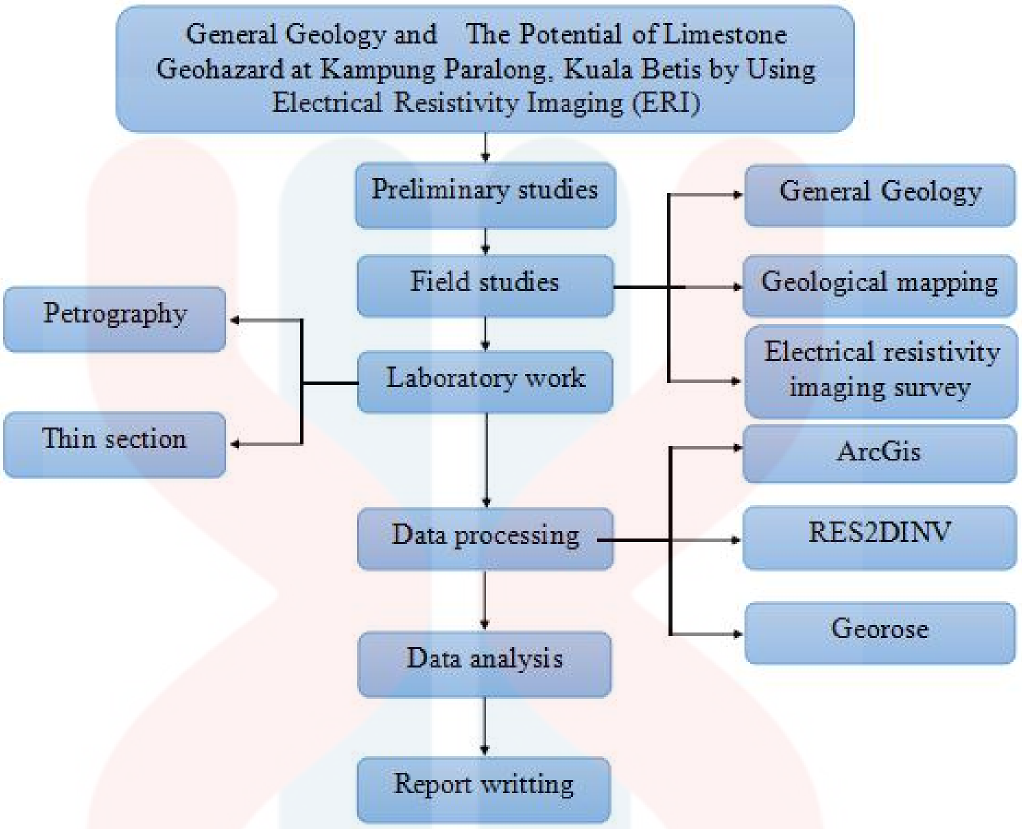

Figure 3.1: The flowchart of research methodology.

Table 3.1 : List apparatus and software

Apparatus and Software	Explanation
Portable global positioning system, GPS	Gps was used to keep track traverse and used in mark outcrop at our study area. The track that gps keep was being applied on the map to updated the map like route or change on the study area. Gps is based on satellite based navigation system which they can collect data of coordinate and elevation.
Compass	Compass are used to determine north direction. Compass also used to determine the bearing,

	azimuth, strike and dip. It is also used in collect data for joint analysis.
Geology Hammer	Geology hammer was used to get sample. Fresh sample used to determine type of rock by observe the sample.
Measuring tape	Measuring tape was used in measure the wide and height of outcrop. It is also used to measure the length of joint.
Hand lens	Hand lens was used to zoom mineral in rock. The mineral in rock can be see clearly and help in determine type of rock.
ABEM Terrameter SAS 4000	ABEM Terrameter SAS 400 was used in electrical resistivity imaging surveying. ABEM was used to determine the earth subsurface conditions.
Hydrochloric acid solution, HCL	HCL was used to test reactivity of mineral on outcrop toward hcl. This is to test the existence of carbonate minerals in the outcrop. This test know as acid test.
Sample beg	Sample beg was used to keep all the sample taken from the outcrop. The sample that taken was labeled with marker pen on sample beg to differentiated with other samples. Usually, clear plastic was used and can come with various size.
Base map	Base map was used as referenced during the field

	work. It also used to record data such as strike and dip, and lineament. Base map is the first thing needed to be referred before mapping. Base map was used to determine type rock in base map by observing the contour pattern.
Arcgis 10.1 software	Arcgis 10.1 was used to produce the base map of study area. All data saved by GPS was transfer into Arcgis and was interpreted in map. ArcGis also was used in produced drainage pattern map, landuse map, 3D map and also for cross section.
Georose software	Georose was used in plotting rose diagram and stereonet diagram. Stereonet also was used in fault and bedding analysis.
RES2DINV software	RES2DINV software was processes value of electrical resistvity on the electrical resistivity profile generated by field data.

3.3 Methodology

Methodology is the system of methods that applied in research. It is also know as the study or description of methods. The method to be applied firstly is preliminary study follow up by laboratory work, data processing, data analysis and interpretation. The final method is report writing.

3.3.1 Preliminary studies

Preliminary study is collecting data and information from the past study. The data and information can be gain from journal, thesis or book that related with the research. From the preliminary study, all the information such as the detail of study area, the research had been done before and general geology data that exits in the area can be gain.

3.3.2 Field studies

This study is focused on the general geology and the potential of limestone geohazard using electrical resistivity method at Kampung Chas, Kuala Betis. There were a few processes had to be done in field study. The first process is by study the base map. This is because the data of geological features can be identified from studying base map such as lineament, fault and drainage pattern. This geological feature can be identified based on the landform and river pattern. This is an important data for general geology.

Next is follow up by geological mapping. Usually geological mapping is to confirm and to observe the geological features that exits based on base map. Then certain geological structure feature also can be gain from the observation toward outcrop which will be record in field book. From the mapping, the reading of strike, dip and bearing of outcrop will be recorded. The bearing of joint, fault and fold also will be recorded for structural analysis.

In geological mapping, it is important for geologist to get know very well the feature because it is easy to had misconceptions of geological structures features

(Edwin Sherbon Hills, 1972). In geological mapping, it is important to do traverse, take reading of strike and dip, sketch and take a sample. This procedure will help more geologist to know well the feature. The data will be collected in the form of photography of outcrop with scale, the measurement of outcrop and physical samples.

The electrical resistivity imaging (ERI) method will be use to investigate the potential of limestone geohazard in Kampung Paralong area. ERI consists of straight line of electrode with the equal distance with each other will be install along the ground surface of specific study area. The number of electrodes installed and spacing for each ERI test based on the condition of subsurface and the desired depth and resolution of the survey.

The direct current (DC) will be applied at alternating outer electrodes along the electrode line once the electrodes have been installed. Voltage of measurements are being recorded from inner electrodes along the the lines and are converted to apparent resistivity value while the current is being applied to the outer electrodes. The result is in the form o continuous 2 dimensional subsurface resistivity profile. There were many different array types that can be used in resistivity survey but it important to know the advantages and disadvantages of each array. The choice of array type is depends on uses of of previous familiarity with array type, availability of cable and data acquisition software and of data processing and inversion software (John, 2011)

The array was used in this electrical resistivity method is Wenner array configuration, Schlumberger array and Pole Dipole array. The best feature to choose the best array is depends on sensitivity of the resistivity meter,background noise level and type of structure to be mapped. Those featured were being considered when choosing which array was chosen which is signal strength, horizontal data coverage, sensitivity of the array to vertical and horizontal structures, and depth of investigation. This array will be connected to ABEM Terrameter SAS 4000.

The survey line has been setup at 3 places that chosen based on observation the landform from based map and satellite map.The survey line start from 0 meter label as A and end at 200 m label as B. ABEM will be set up and located at the middle of the both cables. Each electrode is 5 m away and need to be mark in GPs. This will mark the coordinate and elevation of each electrode.

3.3.3 Data processing

Software such as ArcGis, Terrameter LS Toolbox, RES2DINV and Georose was used in processed all the geological data that obtained from field study. ArcGis software was used in produced base map and geological map of study area. ArcGis also was used in make 3-D map which illustrated based on their elevation. It is also produced map for topographic, drainage pattern, and lithology. It is also was used to make cross section of study area. Terrameter LS Toolbox and RES2DINV software were used to produce the pseudosection of the apparent resistivity of study area. Terrameter LS Toolbox was the first software were used to process the data after the data were exported from Abem. This software were used in editing the data such as space between array and elevation for each array based on the GPS data. Then after that the data will be exported as Res2Dinv (.dat). Next, the data was processed until the rms of each data is below 15% using RES2DINV in producing the 2D imaging profile. The last data will be used to interpreted the subsurface based on the value of resistivity and chargeability of pseoudo. Lastly, Georose was used to produced rose diagram to trace the direction pf force acted on the study area for joint, fold, and fault analysis. Rose diagram was produced from reading of joint direction and their frequency for joint analysis.

3.3.4 Data analysis,and interpretation.

The result that obtained from electrical resistivity imaging survey is 2D electrical imaging profiles. 2D electrical imaging profile has been produced by using Terrameter LS Toolbox and RES2DINV. 2D survey can give useful results that are complementary to the information obtained by other geophysical method. For example, 2d electrical survey provided detailed information about subsurface (Loke, M. H. 2013). The imaging profile has been interpreted based on colour and shape that present in profile. While interpreted the data, the value of resistivity and induced polarization (IP) has been refer based on Table 3.2 and 3.3. The joint, fold and fault analysis can be done by based on the result after plotting the geological data in Georose. Joint, fold and fault analysis can be doing by take reading of joint, fold and fault reading. From the reading, rose diagram was produced and it was being analysed.

Table 3.2: Chargeability of various minerals and rocks

Material	Chargeability (ms)	Material	Chargeability (ms)
20% sulfides	2,000 – 3,000	Ground water	0
8 – 20% sulfides	1,000 – 2,000	Alluvium	1 – 4
2 – 8% sulfides	500 – 1,000	Gravels	3 – 9
Volcanic tuffs	300 – 800	Precambrian volcanics	8 – 20
Sandstone, siltstone	100 – 500	Precambrian gneisses	6 – 30
Dense volcanic rocks	100 – 500	Schists	5 – 20
Shale	50 – 100	Sandstones	3 – 12
Granite, grandodiorite	10 – 50	Argillites	3 – 10
Limestone, dolomite	10 – 20	Quartzites	5 – 12

(Source: Telford, W., Geldart, L., & Sheriff, R. 1990)

Table 3.3: The resistivity vaue of earth materials\

Material	Resistivity (Ωm)
Alluvium	10 to 800
Sand	60 to1000
Clay	1 to 100
Groundwater (fresh)	10 to 100
Sandstone	8 - 4 x 10^3
Shale	20 - 2 x 10^3
Limestone	50 – 4 x 10^3
Granite	5000 to 1,000,000

(Source: Saad, Rosli & Tonnizam, Edy. 2012)

3.3.5 Report writing

Final step of this study is by writing the report. This report will act as written data of general geology and potential limestone geohazard in Kampung Paralong, Kuala Betis. All the data have been collected from the preliminary study, field study, data processing,and data analysi and interpretations.This report should been done before deadline and submit to supervisor. The report is divided into 6 chapter which is:

a) Chapter 1: Introduction
b) Chapter 2: Literature review
c) Chapter 3: Materials and methods
d) Chapter 4: General Geology
e) Chapter 5: Electrical Resistivity Imaging Survey
f) Chapter 6: Conclusion and suggestion

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter will explain about accessibility, settlement, vegetation and traverse that has been done at study area. This chapter also will cover about geomorphology which explain about geomorphology classification, weathering and drainage pattern.Lastly, this chapter will explain about lithostratigraphy and structural geology that have been compiled while mapping. The data for this chapter has been gain from geological mapping and will save as geological map like Figure 4.1. From the geological mapping like traverses and collect all the geological data and sample.

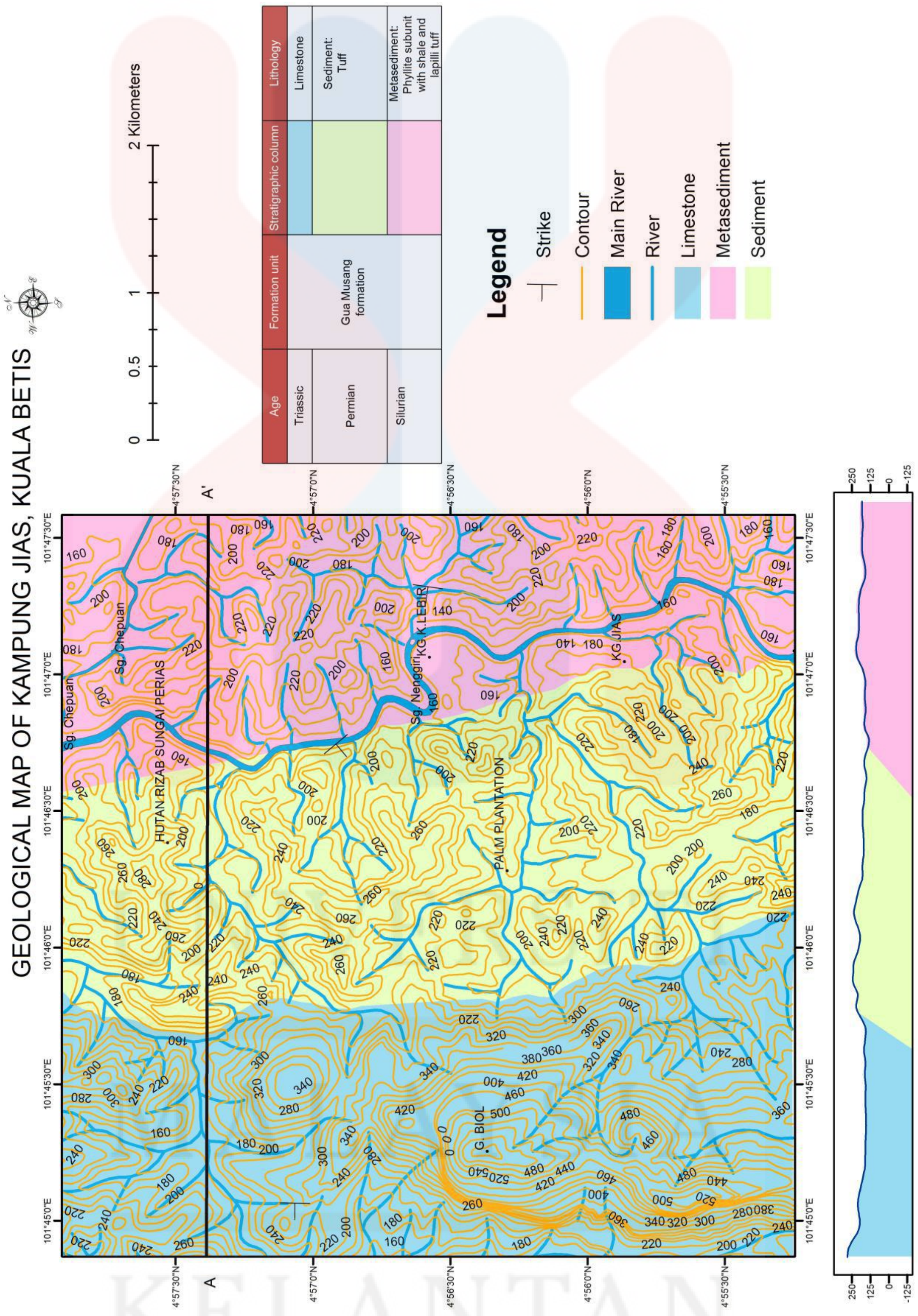

Figure 4.1 : Geological map of Kampung Jias.

4.2 Accessibility

Kuala Betis is located about 30km away from Bandar Gua Musang, while Kampung Jias is located about 2 km away from Kuala Betis Town. The main economy of Kuala Betis is palm plantation, rubber plantation and logging activity. That is why Kuala Betis can be access easily from Bandar Gua Musang. In the study area also has one main road that usually used to commute by plantation worker and also used for logging. While the other road is was used mostly by Orang Asli. This is because located at the right side of the study area and also located all along the road is Orang Asli village such as Kampung Jias, Kampung Langsat. Both road important because is being used in daily work life.

4.3 Settlement

The settlement of the study area is mostly Orang Asli settlement. Kuala Betis is known as the largest settlement of Orang Asli Temiar in Kelantan. Almost 75% of the population consist of Orang asli, 20% Orang Melayu and others is foreigner. Villages that exist in the study area is Kampung Jias, Kampung Langsat and others. The main economy in Kuala Betis is palm plantation. This is why half of the Orang Asli in Kuala Betis worked as a worker in plantation. Mostly the main vehicle in the study area is motorcycle. They prefer to used motorcycle in their daily activity. While some of the villager, used 4 wheel drive car such as Hilux or Pajero. This is because those vehicle are really suitable with landform of Kuala Betis which is hilly area and those road located at the upper of Kuala Betis still has not been paved.

4.4 Vegetation

The vegetation of the study area is mostly a forest area which is Hutan Rizab Sungai Perias. Hutan Rizab Sungai Perias were located at the north of study area. The forest also being one of economy resouces for Kuala Betis which come from logging activity. Other vegetation of study area is plantation which is palm plantation. Palm plantation located at the south in the study area. Palm plantation become the major economy resources in the study area.

4.5 Traverse

Traverse is the track of traverse in the study area. Traverses need cover the area of the study area which is 5x5km. While traversed, all the field observation and geological mapping has been done. This is to collect all the geological data in the study area. Usually the traverse has been done by walking, using motorcycle or car. Figure 4.2 showed the traverse and observation map of the study area.

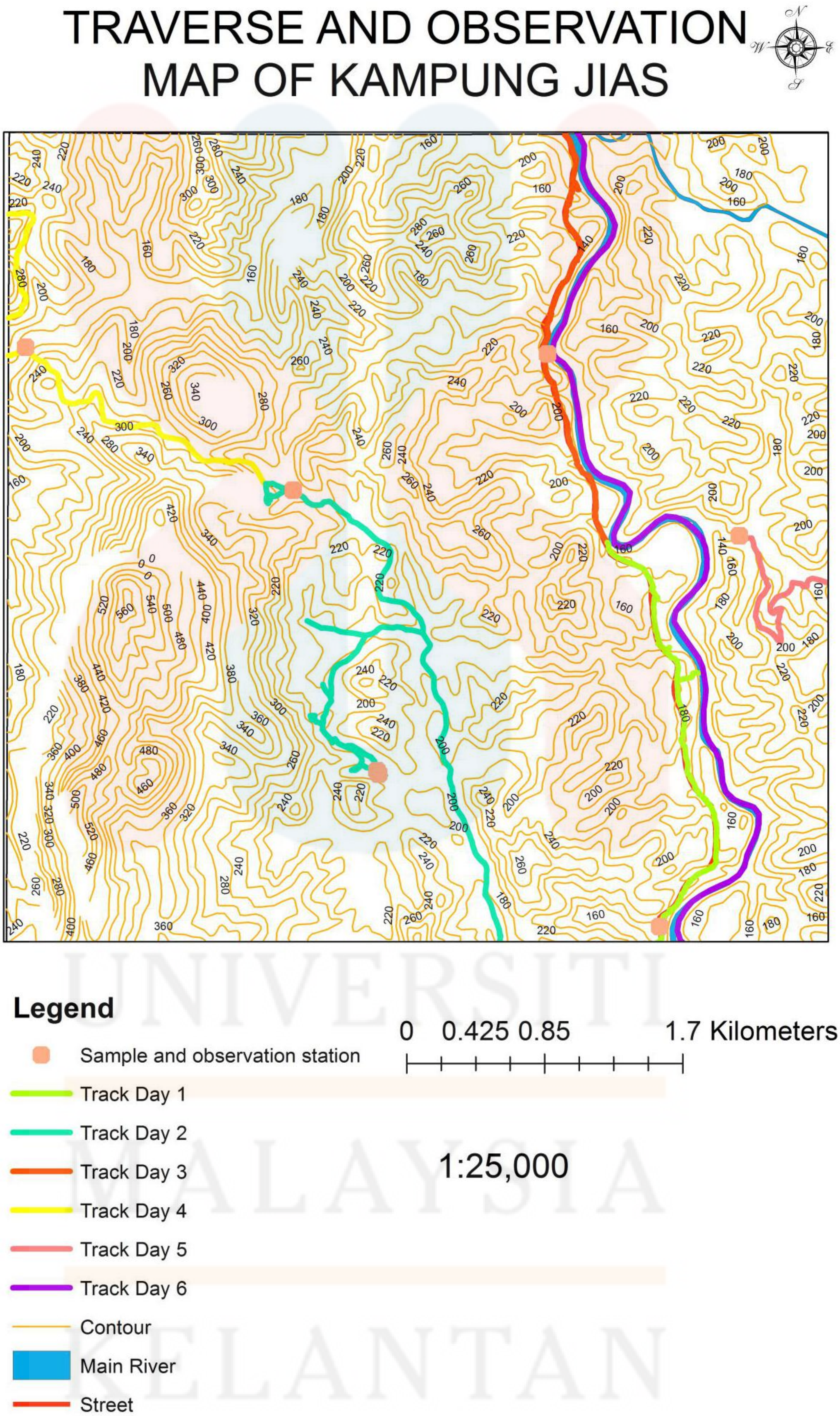

Figure 4.2 : Traverse and observation map.

4.6 Geomorphology

Geomorphology is scientific study of the origin and evolution of topographic and bathymetric feature created by physical, chemical or biological processes operating at o near the Earth's Surface. It is also study of landform, their processes, form and sediments at the surface of the earth. The landform found in the study area is hilly area and karst area. Geomorphology has 3 processes which is endogenic processes, exogenic processes and extra-terrestrial processes. Which is endogenic process is is large scale building and transforming processes. surface and the landform maybe come from structural and tectonic.

One of the endogenic processes can be found in the study area is small anticline fold which is located near the south-west of study area. This will be discuss more at geological structure. While for exogenic, it driven by climatic force or from external force. Type of process is erosion, deposition and organism action. The exogenic process that exist in the study area is degradation which is divided into weathering and mass wasting. At the study area consist of two type of weathering which chemical and biological weathering. While mass wasting has been found in a few places in study area.

Karst morphology also has been found at the study area. This is because 45 % of the study area is limestone. The landform of karst morphology is hilly and mountainous karst. Cave, stalactite and stalagmite is type of karst morphology exits in the study area..

4.7 Topography

Topography map is used to studied shape and feature of earth.surface of earth. Feature and shaped of the physical features can be read through the reading of the value of the contour and it shaped. Based on Figure 4.3 , it shown the number of elevation in the study area. Which is the elevation range from 160 to the 220. This range of value show the landform of this type contour is plane landform but it located at high places which told us why the lowest elevation is 160. There were a few places that contain contour in the range of 220 to340 or the highest elevation which is 220 to 560. This type of elevation show hilly landform or karst landform. The elevation of the study area which arranged together very closely and very steep.Show the characteristic of karst landform.

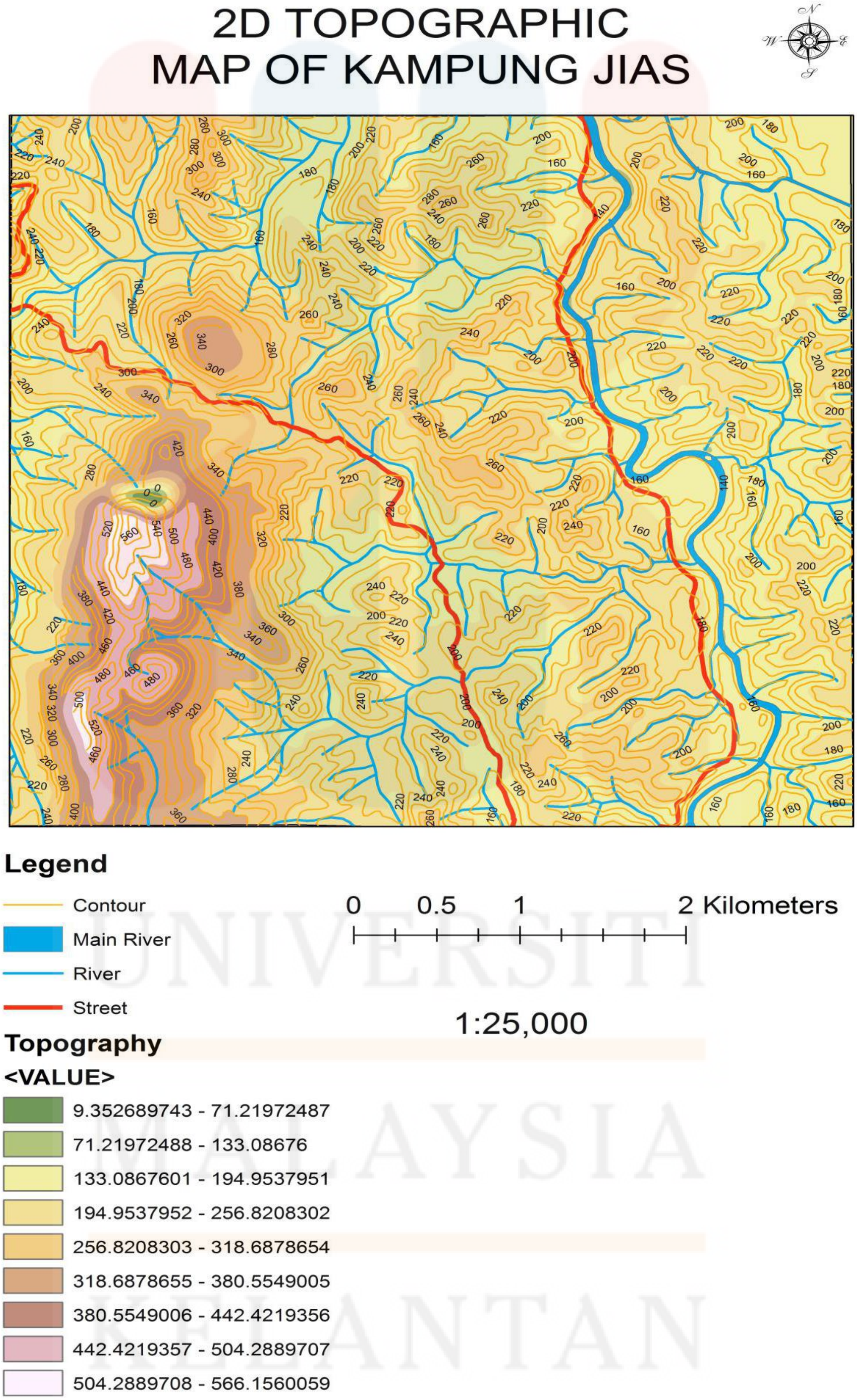

Figure 4.3 : 2D Topography of Kampung Jias

4.8 Weathering

Weathering is when rocks, soil and mineral as well as wood and artificial materials are breaking down via contact with water, biological organisms and earth's atmosphere. Weathering occur on site which more known as in situ. It is happen in the same place with little or more movement. Weathering are divided into three type which is physical, chemical and biological.

Physical weathering is when the rock are break apart because of the changing temperature on rocks. Sometimes this process was assisted by water. Physical weathering is divided into two main types which is freeze-thaw and exfoliation. Physical weathering usually occur in places with a little soil and less grow of plants. For example, hot dessert and mountain regions. It is usually occur through repeated melting and freezing of water. It is also occur when rock have been through expansion and contraction of the surface layers of rocks that are baked by the sun.

Next is a chemical weathering. Which is when the rock form new minerals and soluble salts because of the mineral grains in rock is reacting with rain water. It is usually occur when the water is slightly acidic. Chemical weathering occur in presence of water and occur rapidly at higher temperature so warm, damp climates are best. The first stage in the production of soils is chemical weathering.

One type of chemical weathering is dissolution of rock which usually occur in limestone. This weathering can be found at Gua Cawas. This show that the limestone at Gua cawas has been through chemical weathering which causes by dissolution of water. This can be seen in Figure. 4.4

Figure 4.4: Dissolution of limestone.

At Gua Cawas also has been through biological weathering. Which is biological weathering caused by plant, animals and microbes. Which can be seen in Figure 4.5 which the some of limestone at Gua Cawas has been covered with plant.

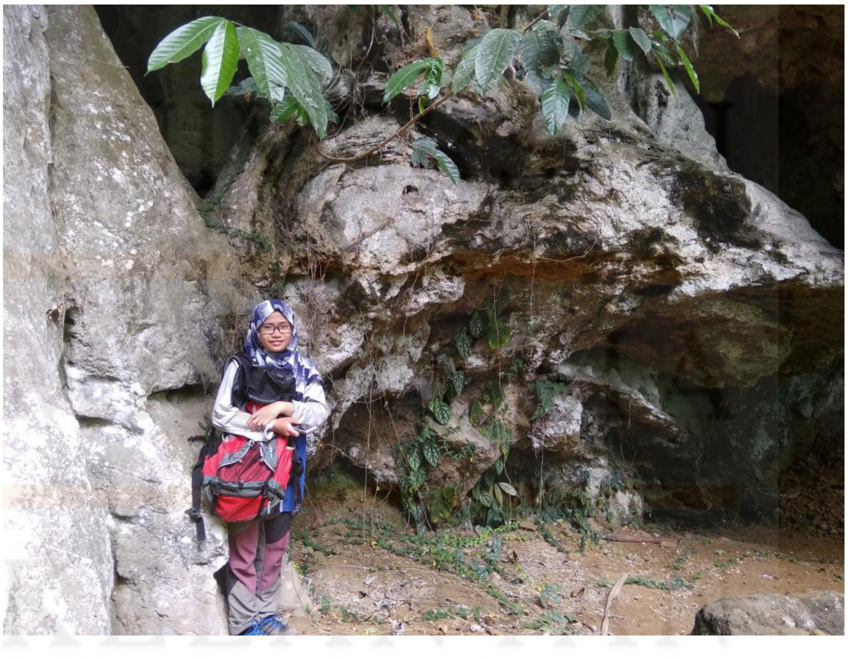

Figure 4.5 : Biological weathering on limestone

4.9 Drainage Pattern

Drainage pattern is a pattern that created by stream erosion over time that reveals characteristics of the type of rocks and geologic structures in landscape region drained by steams. It is created by the rivers, lake and streams on a particular drainage basi. Drainage pattern are governed by the topography of the land, whether a particular region is dominated by hard and soft rock and the gradient of the land. The pattern of tributaries within a drainage basin depends largely on the type of rock beneath, and on structures within that rock. There a few type of drainage pattern which is dendritic patterns, trellis drainage, rectangular patterns, parallel drainage, radial drainage, centripetal drainage, dreanged pattern and angular drainage.

From the study, a few type of drainage pattern can be identified in the study area which is rectangular and dendritic. These pattern can be discover by looked up at the shaped of river and stream on the drainage pattern map. The drainage pattern shown in Figure 4.6. In Figure 4.6, the red line show dendritic pattern which far the most common in the develop area where the rock beneath the stream has no particular fabric or structure and can be eroded easily in all directions. Examples would be granite, gneiss, volcanic rock, and sedimentary rock that has not been folded.

While the yellow line show rectangular pattern. Rectangular patterns develop in areas that have very little topography and a system of bedding planes, fractures, or faults that form a rectangular network. Rectangular drainage patterns are rare in Canada.

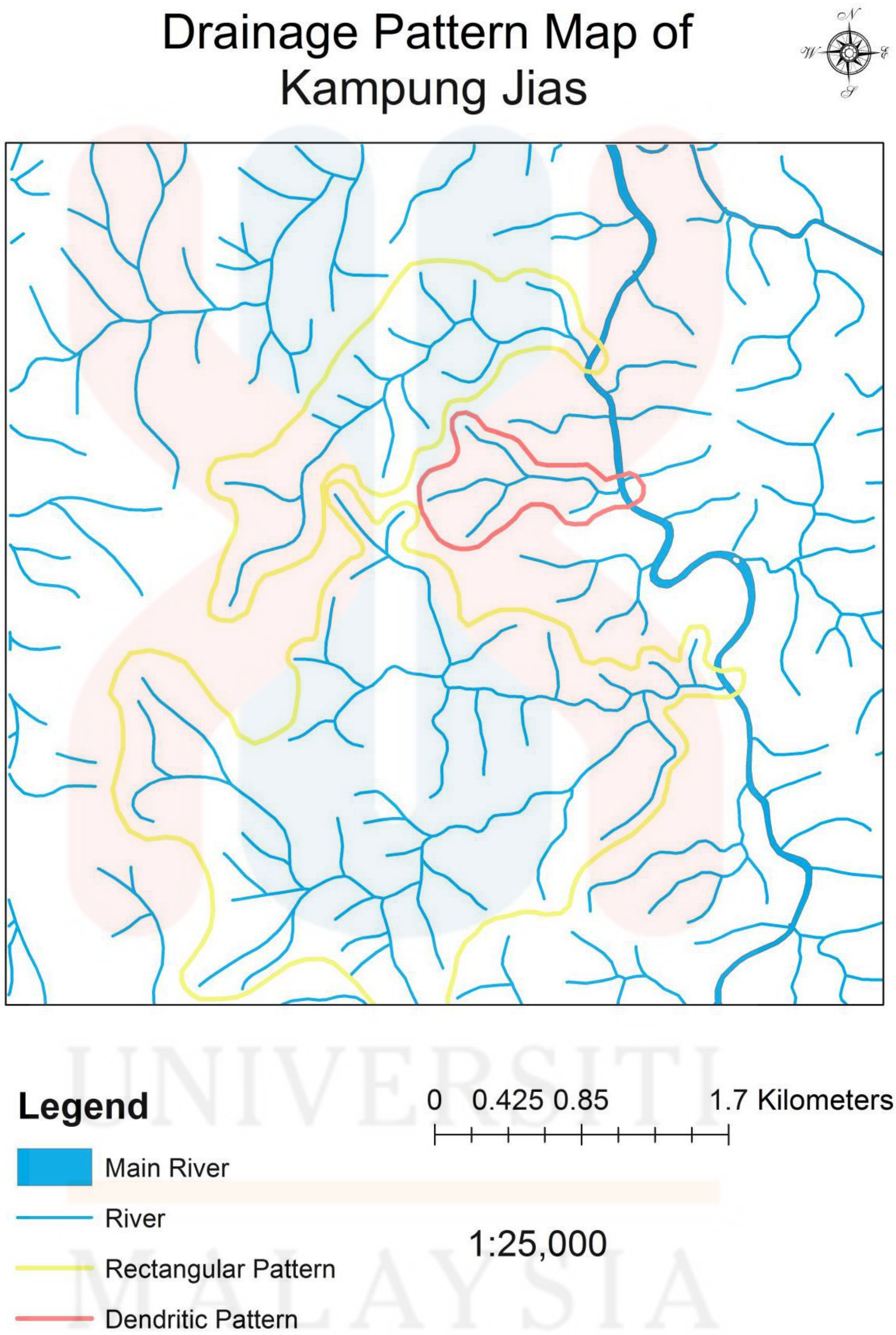

Figure 4.6 : Drainage map

4.10 Lithostratigraphy

Lithostratigraphy is one of the discipline of stratigraphy. It is associated with the study of strata or rocks layers. Lithostratigraphy known as the categorization of bodies of rock depends on the observable lithological properties of the strata and their relative stratigraphic positions. The rock were classified into lithostratigraphic unit. Which is lithostratigraphy unit is a body of rocks that characterised and acknowledged based on its basis of the lithologies properties or combination of lithologic properties and stratigraphic relations.

During mapping, several outcrop were found and the outcrop has been identified into their rock unit. Type of rock in study area has been identified into sediment and metasediment. Which limestone and tuff for sediment and phylite for meta sediment.

The rock unit of each rock were discussed later in more detail. The rock unit were discussed started with the oldest rock to younger rock in the rock unit. These rock were identified based on the characteristic rock in hand specimen. The classification of rock unit must considered three thing which is the origin, composition and texture

4.11 Stratigraphy Position

Stratigraphy is the study layer of rock which also known as strata. Stratigraphy also study of process of layer creation especially in sedimentary and volcanic rock. Stratigraphy cover up the interpretation, correlation and description of the rock was on the earth.

Danish geologist, Nicholas Steno has proposed the laws of the stratigraphy. Steno also concluded the upper layer of rock layer is the youngest and the lowest layer is the oldest rock. He also stated the rock layers also indicate a chronological history of the earth and its past life. Steno has proposed three fundamental principles of stratigraphy which known as Steno's laws. Those laws is law of super posiition, law of lateral continuity and law of original horizontality (Mwaniki, A. 2018).

Based on Mwaniki, A (2018), the law of superposition is youngest layer are found at the top layer while the oldest layer are found at the bottom layer of strata. For law of original horizontality,sediment deposits are layered in a horizontal position due to gravitational settling. Lastly, law of lateral continuity is when horizontal layers stretch laterally until they thin to a negligible thickness at the edge of their basin of deposition.

The stratigraphy of the rock in the study area consist of limestone, tuff and metasediment and each of the rock has their own specific age. The youngest rock in the study area is limestone which from age of Triassic. While in the middle stratigraphy column is tuff which from the age of Permian. Lastly, the oldest one is metasedimentary from the age of Silurian

.

Table 4.1 : Stratigraphy column

Age	Formation unit	Stratigraphic column	Lithology
Triassic			Limestone
Permian	Gua Musang formation		Sediment: Tuff interbedded with sandstone, some with mudstone
Silurian			Metasediment: Phyllite , shicst.

4.12 Limestone unit

The rock unit of limestone covered approximately 40% of the study area. Limestone was found at the west region of study area. Mostly the limestone outcrop located at palm plantation area and has been exposed to weathering process. Weathering of limestone in the study area mostly caused by rainwater.

4.12.1 Limestone

Limestone is classified as sedimentary rock. Limestone composed of calcium carbonate ($CaCO_3$). Calcium carbonate exist in form of calcite mineral. Limestone usually form in shallow, clear and warm marine waters. It is formed from accumulation of coral, shell, fecal debris and algal which known as organic sedimentary rock. It is also formed from precipitation of calcium carbonate that comes form ocean water or lake.

The limestone has been found in the study area shown in Figure 4.7 has light grey colour and some part of limestone shown crystallization line in limestone. The limestone is very fine grained in hand specimen. Crystalline limestone has been identified based on the linear shape of white crystal located in limestone. Limestone can be identified in the field by using Hydrocholoric acid, hcl shown in Figure 4.8. Whether limestone do react or not with hcl. Limestone will showed a vigorous fizz effect when react with hcl. Limestone in the study area was the youngest rock in the rock unit. There is no fossil was found at the limestone. The limestone in Gua Musang formation mostly come from the age of Triassic.

From microscope observation, the most abundant minerals in the thin section is calcite. Which calcite can be seen clearly in the microscope in the linear shape. The Figure 4.9 and Figure 4.10 show cross and plain polarised of limestone.

Figure 4.7 : Limestone outcrop

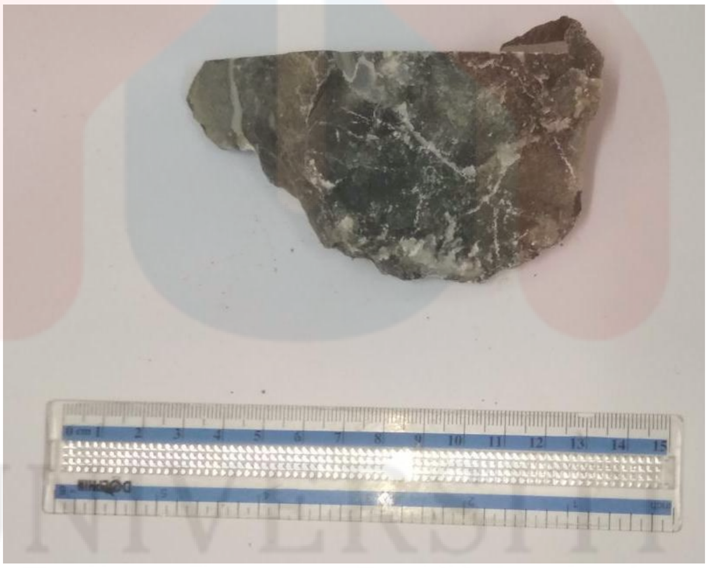

Figure 4.8 : Hand specimen of limestone

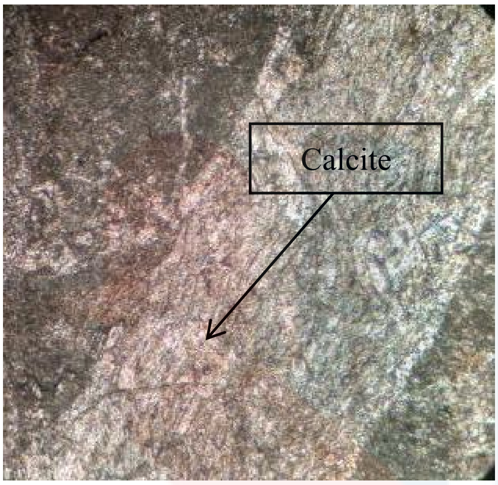

Figure 4.9 :Cross polarised of limestone

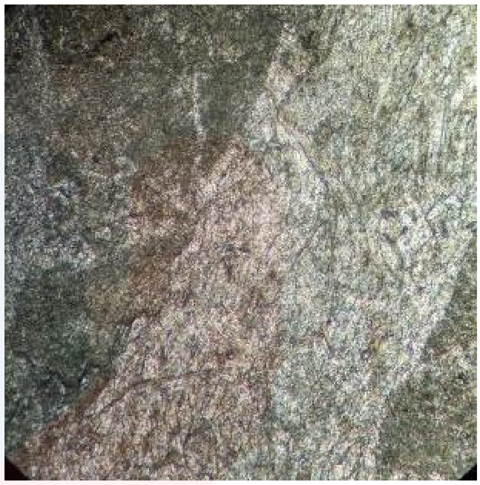

Figure 4.10: Plane polarised of limestone

4.13 Sediment unit

The rock unit of tuff covered approximately 35% of the study area. Tuff was found at the center region of the study area. Tuff is located near the palm plantation and forest area. Tuff that located in palm plantation mostly highly weathered. This is because a lot of of activity happen in this area such as plantation activity and the movement of vehicle.

4.13.1 Tuff

Tuff comes from Italian word which is tufa. Tuff was made of volcanic ash that throw out from a volcano during a volcanic eruption happen. Then, the ash was compacted into a solid rock after the ejection and deposition which called as consolidation. It is also classified as either sedimentary or igneous rock. Tuff can be classified as sedimentary rock when it formed by the chemical deposition of calcite or calcium carbonate or silica. Sedimentary tuff relatively is soft and porous rock.

Tuff rock has been found in the study area has light orange colour in Figure 4.11. The tuff has very fine grain and easily broken into dust. Tuff has smooth and soft surface. This is because tuff in the study area was highly weathered. The age of tuff in the study area is from Permian. The characteristic of the tuff shown the tuff can be identified as sedimentary rock. This is because tuff in the study area is soft and has porous.

Figure 4.11: Tuff outcrop

4.14 Metasediment rock

The rock unit of metasediment cover approximately 25% of the study area. Metasediment in the study area composed of phyllite with sub unit of shale and lapilli tuff. Mostly the phyllite and shale are highly weathered in the study area. Phyllite and shale mostly can be found at the plantation area. In the stratigraphic column, metasediment is the oldest rock in the study area and the age of metasediment rock is Silurian.

4.14.1 Phyllite

Phyllite is foliated metamorphic rock. It has been exposed to low level of pressure, heat and chemical activity. The main mineral exist in phyllite is mica minerals with flake shaped. Phyllite can be differentiated from slate by the alignment of the mica grains gives phyllite a reflective sheen. Phyllite is the most common metamorphic rock found in the world. Phyllite form when sedimentary rock are buried then it being mildly altered by the directed pressure and heat of regional metamorphism. In the study area,the sample of phyllite has been found in the river are shown in Figure 4.12. The phyllite are mostly highly weathered because it being exposed to river water. The colour of the phyllite is dark brownish in the outside and grey in the inside. In hand specimen, Phyllite has very fine grained and has smooth surface shown in Figure 4.13. from microscope observation, the most abundant minerals in phyllite is feldspar. The feldspar can be seen clearly in the microscope in white colour. The Figure 4.14 and Figure 4.15 show cross and plane polarized.

Figure 4.12 : Phyllite outcrop at small river

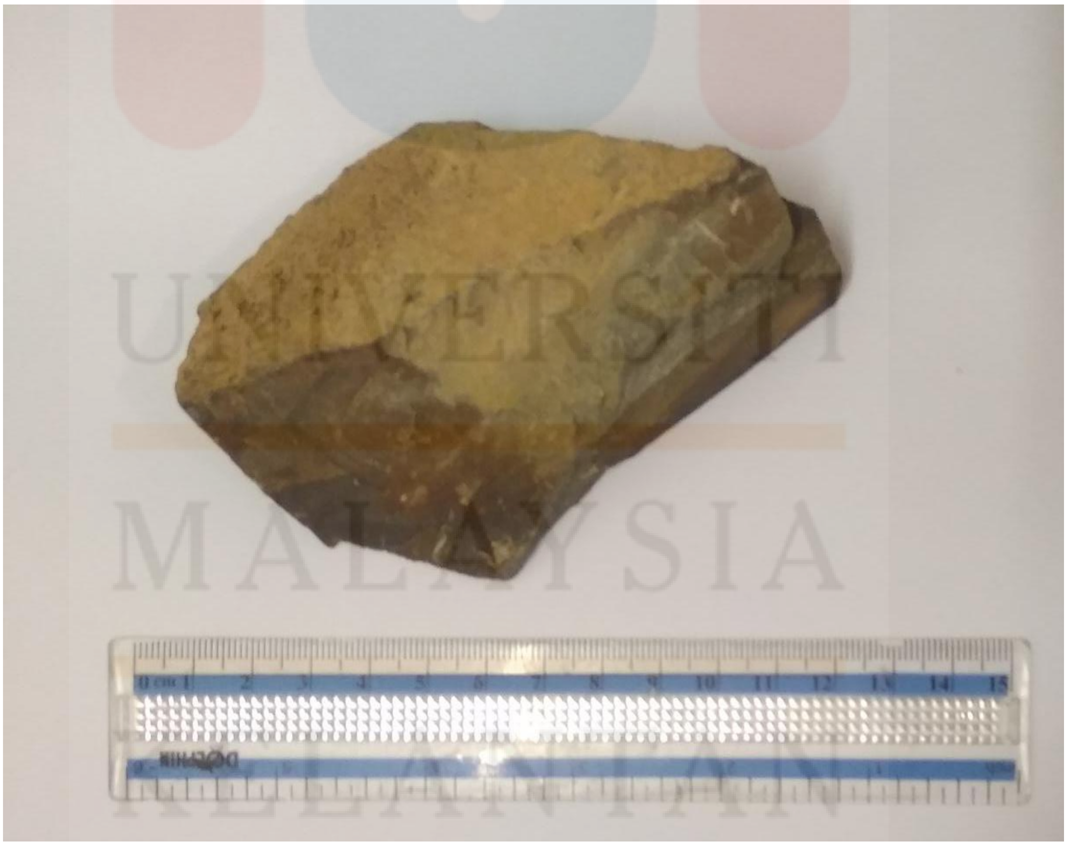

Figure 4.13 : Hand specimen of phyllite

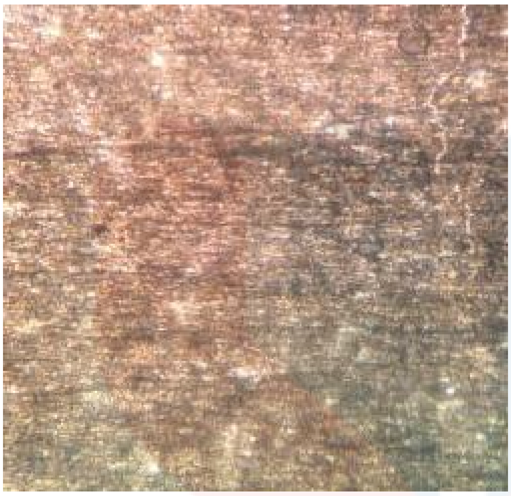

Figure 4.14 :Cross polarised of phyllite

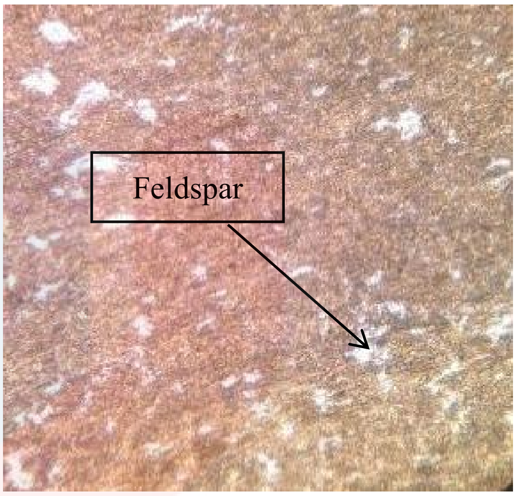

Figure 4.15: Plain polarised of phyllite

4.14.2 Shale

Shale is clastic sedimentary rock composed of mud mix with flakes of clay minerals and tiny fragment of other minerals shown in Figure 4.16. The characteristic of shale is parallel layering or bedding less than one centimeter or breaks along thin laminae. This called as fissiliy and it common in sedimentary rock. The shale is a fine grained sedimentary rock. In the study area, the colour of shale is white and the shale are easily to broken. The shale are highly weathered.

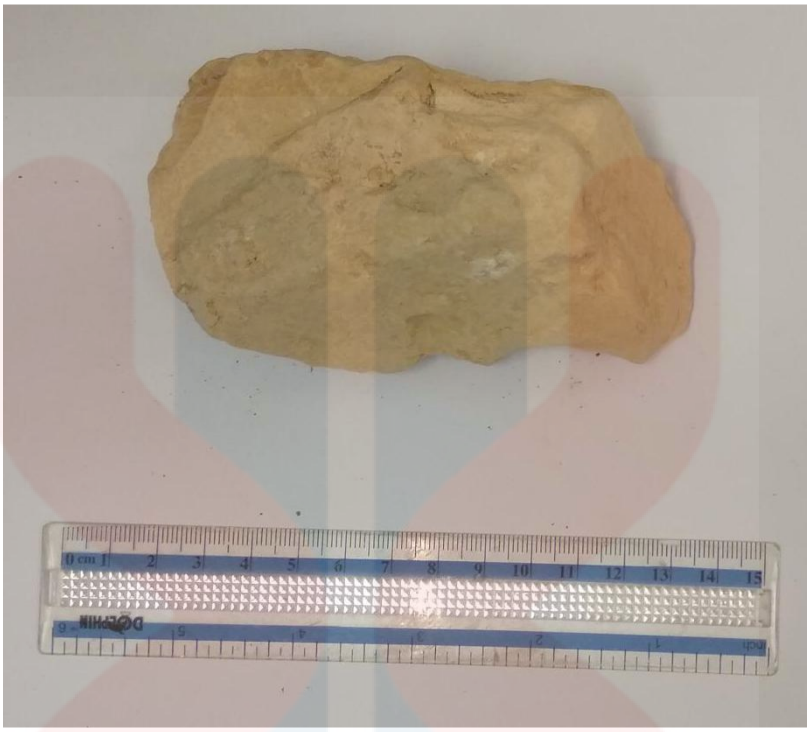

Figure 4.16 : Hand specimen of shale

4.14.3 Lapilli tuff

It produced from material that fall out of the air druing the volcanic eruption or during some meteorite impacts. The words lapilli was taken from latin word, lapillus which means little stones. In the study area, lapilli tuff was found at Nenggiri river area shown in Figure 4.17 . The colour of the lapilli tuff is grey with some medium grained. The sample was taken from the river shown characteristic of weathering rim around the lapillli tuff show in Figure 4.18. The lapilli tuff are classified as volcanic rock.

Figure 4.17 : Lapilli tuff outcrop

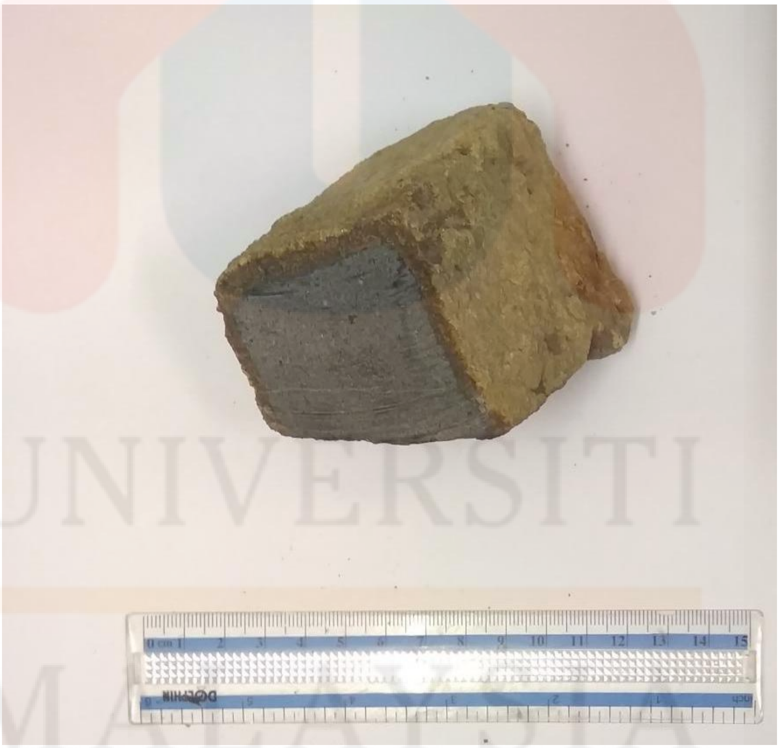

Figure 4.18 : Tuff hand specimen

4.15 Conglomerate

Conglomerate is the other rock was found at the study area. Conglomerate know as coarse grained clastic sedimentary rock. The composition of the conglomerate is a substantial fraction of rounded to sub angular gravel size clasts such as boulders, granules, pebbles and granules. It is larger than 22m in diameter. It is form by lithification and consolidation of gravel. Conglomerate also contain finer grained sediment. In the study area, the conglomerate was found on the road. The colour of the conglomerate is pink colour and the grained size range from very fine to coarse grain. The colour of conglomerate was found at the study area pink colour with some coarse grain. It can be found at North West of the study area shown in Figure 4.19.

Figure 4.19 : Conglomerate outcrop

4.16 Structural geology

Structural geology is the study of rock deformation in small and large scale. The focus of the study is varies from submicroscopic lattice defects in crystals to fault and fold structures of the Earth's crust. In small scale structural, the same method used in petrology will be applied. While for large scale, the techniques of field geology such as geological mapping will be applied. For structural geology that cannot be observed directly, it can be study by computer model which represented mathematically.

4.17 Lineament analysis

Lineament is a linear future in morphology. This linear future indicated underlying geological structures such as fault.Lineament analysis has been used to identified crystalline bedrock which is to identify area with greater well yield (Mabee et al, 1994). Lineament also can be used to identified trending mineralized areas (Mars and Rowan, 2007). The major number of lineament in the study area based on the Figure 4.20 is North West direction. It shown the highest force come from North West direction.

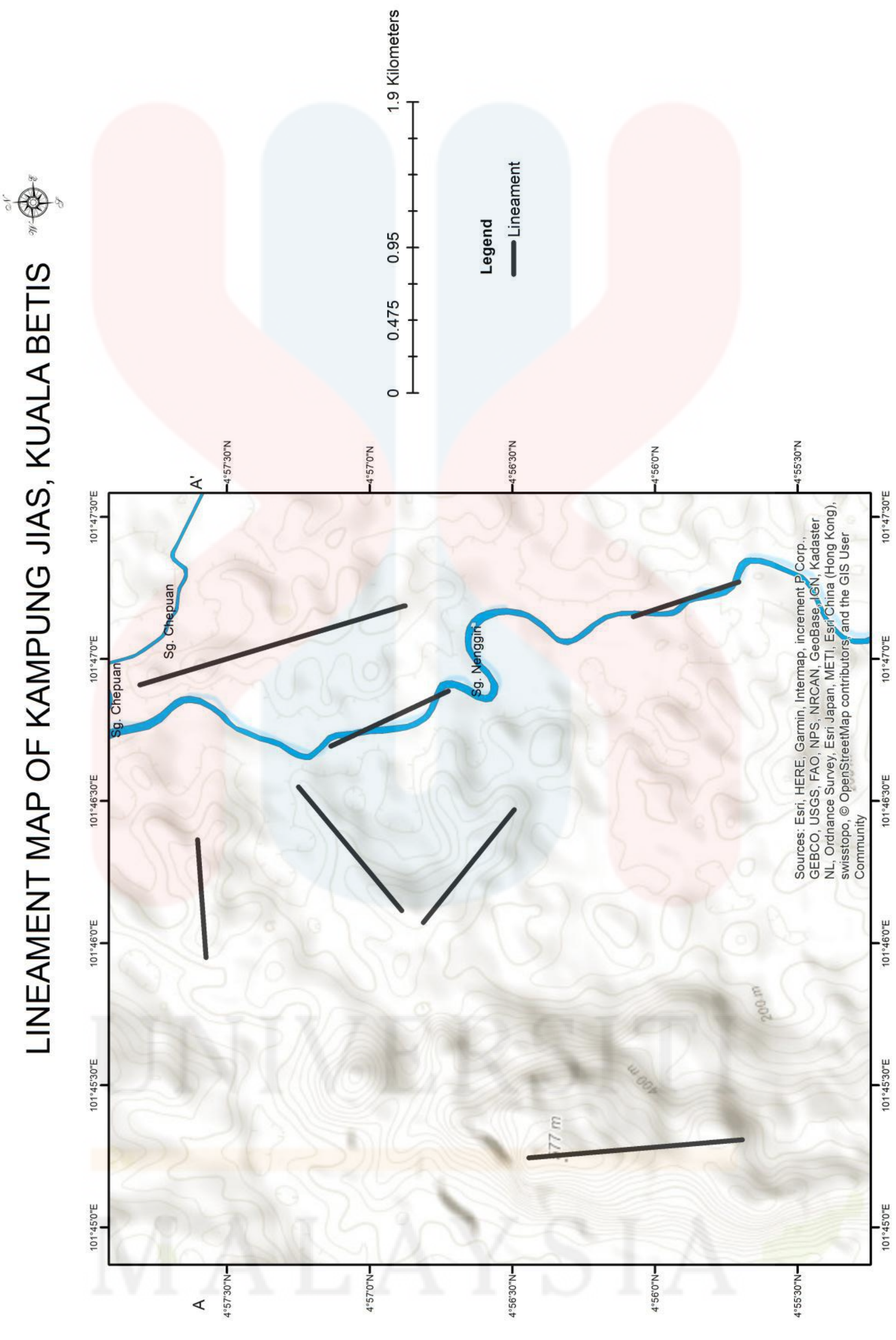

Figure 4.20: Map of lineament analysis

4.18 Joint

Joint is a brittle fracture surface in rocks along which displacement occur little or not. Joint all happen in all surface of rock. Joint mostly form in vertical than horizontal. Joint in igneous and sedimentary rock usually formed in the early stages of rock history. The characteristic of joints are typically short, irregular and discontinuous. Joint happen because of overpowering stresses.

In the study area, joint was taken near the Nenggiri River in Figure 4.21 . The coordinates where joint was taken is at 4°57'12.401"N and 101°46'38.386"E. The type of joint is shear joint. About 50 joint reading was taken at the station. Next, the joint data will be interpreted by using rose diagram. Based on the Figure 4.22, the maximum force or σ1 direction come from N 315˚ W and the minimum force, σ3 is at N 45˚ E.

Figure 4.21: Joint on outcrop

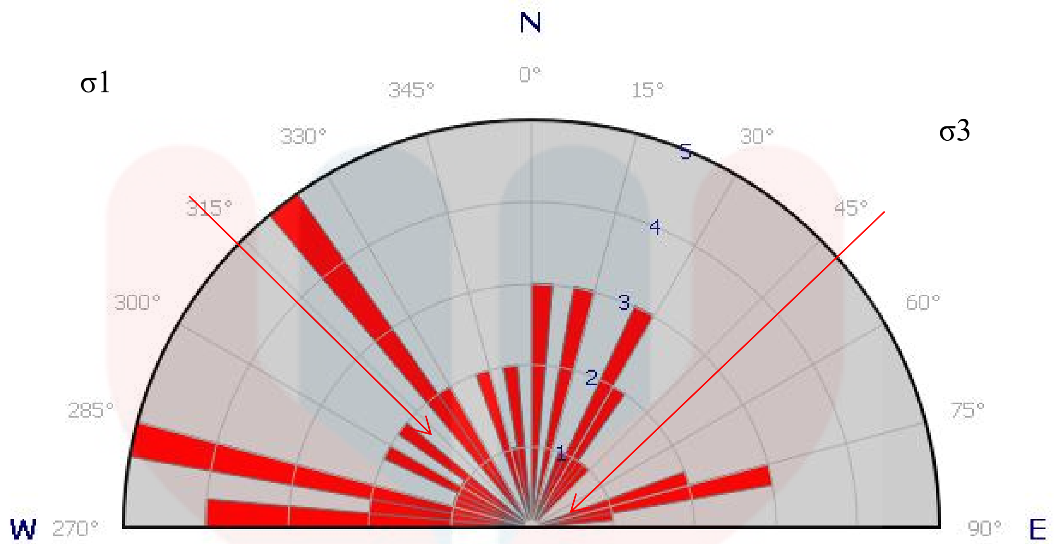

Figure 4.22: Rose diagram of joint

4.19 Fold analysis

Fold is occur when an original flat and planar surface are bent or curved. This is happen because of permanent deformation . Fold happen in varies of scale. Condition which causes fold to formed is by pore pressure, temperature, stress and hydrostatic pressure. Fold are commonly formed by shortening of existing layers. Fold are classified based on their tightness, dip of the axial plane, fold shape and their size.

Figure 4.23 showed a drag fold in tuff outcrop. The outcrop is located at coordinated 4°57'2.353"N and 101°45'4.31"E. Drag fold is a certain kind of fold with quasimonoclinic symmatry but usually occurs on the limbs of larger folds. The drag fold shaped like shaped.

Table 4. 2 : Strike and Dip angle of drag fold

No	Strike	Dip angle
1	191	30
2	296	53
3	99	32

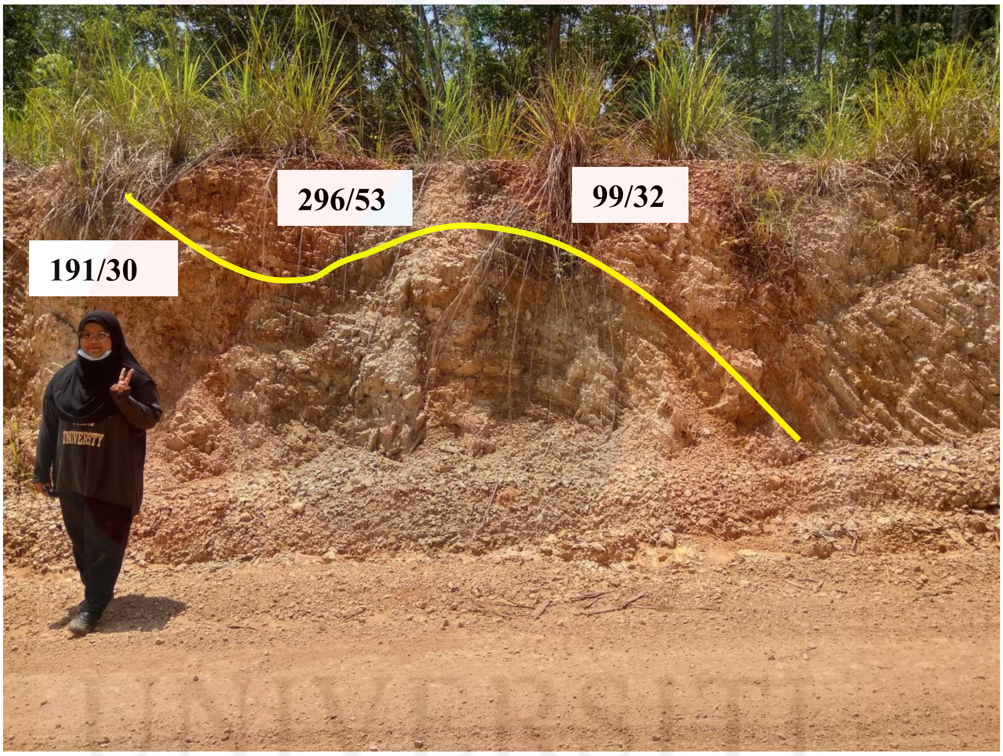

Figure 4.23 : Drag fold in the tuff outcrop

Figure 4.24 show the anticline fold in the tuff outcrop. The outcrop is located at coordinated 4°57'37.037"N and 101°44'49.39"E. The fold identified as anticline because the layer are folded upward like an arch shape. Usually the rock layered were arranged in sequence. Which the rock layer progressively older toward the center of the fold.

Table 4.3 : Strike and Dip angle of anticline fold

No	Dip direction	Dip angle
1	126	53
2	27	30
3	149	47

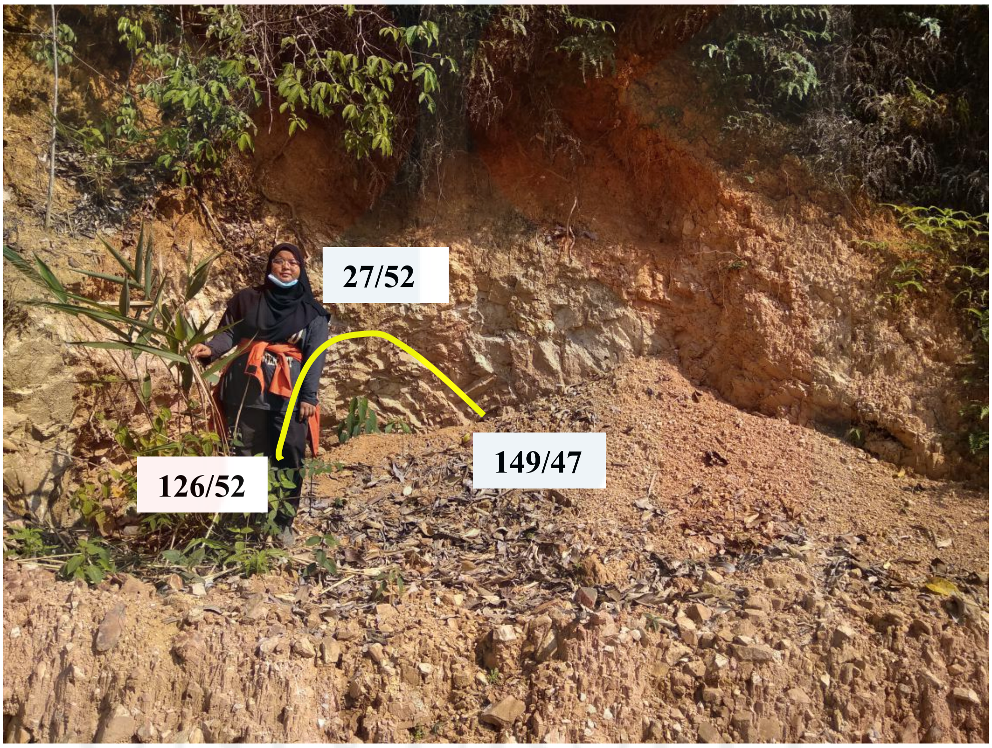

Figure 4.24: Anticline fold in tuff outcrop

Chapter 5

ELECTRICAL RESISTIVITY SURVEYING (ERI) IMAGING

5.1 Introduction

In the study area, 3 survey line has been done to selected area shown in Figure 5.1. The location of the survey line has been selected based on the landform of the area and type of rock in the selected area. This is because the possibility for sinkhole to exist in those area are high. Usually the possibility of sinkhole are high at lower area where it located in the middle of the higher area. While, the type of rock in the survey line also important in detection of sinkhole. This is because limestone are soft and porous rock. Which is causes limestone to eroded especially when exposed to water. The other factors considered while choosing placed for survey line is seen at at the places whether there is any soil subsidence happen. This is because existence of soil subsidence shows that possibility of sinkhole or cavity might happen in the subsurface. Based on Pril, A. (2001), geomorphic evidence of the subsidence and deformation are highly contorted strata, collapse debris, structural sags, deformation of river terrace gravel, piercement structures, and river-centered anticlines are all.

5.2 Survey line

The electrical resistivity (ERI) survey has been conducted by using ABEM Terrameter S400, 2 cable of 100m. 41 electrode and 40 multi-core cable. The survey line are about 200 meter each of line. The lines need start from cable A, ABEM in the middle and cable B at the end. Type of principle has been used in those survey is Schlumberger array for line 1, Pole dipole for line 3, and Pole dipole and Wenner for line 3.

Before doing the survey, the survey line has been determined based on the landform of the study area on the terrain map. From terrain map, those 3 location has been determined approximately in the selected area. Figure 5.2 and 5.3 show satellite images for survey line 1, 2 and 3. The geology structure found on the map such as fault also become a factor when select the location for survey line.

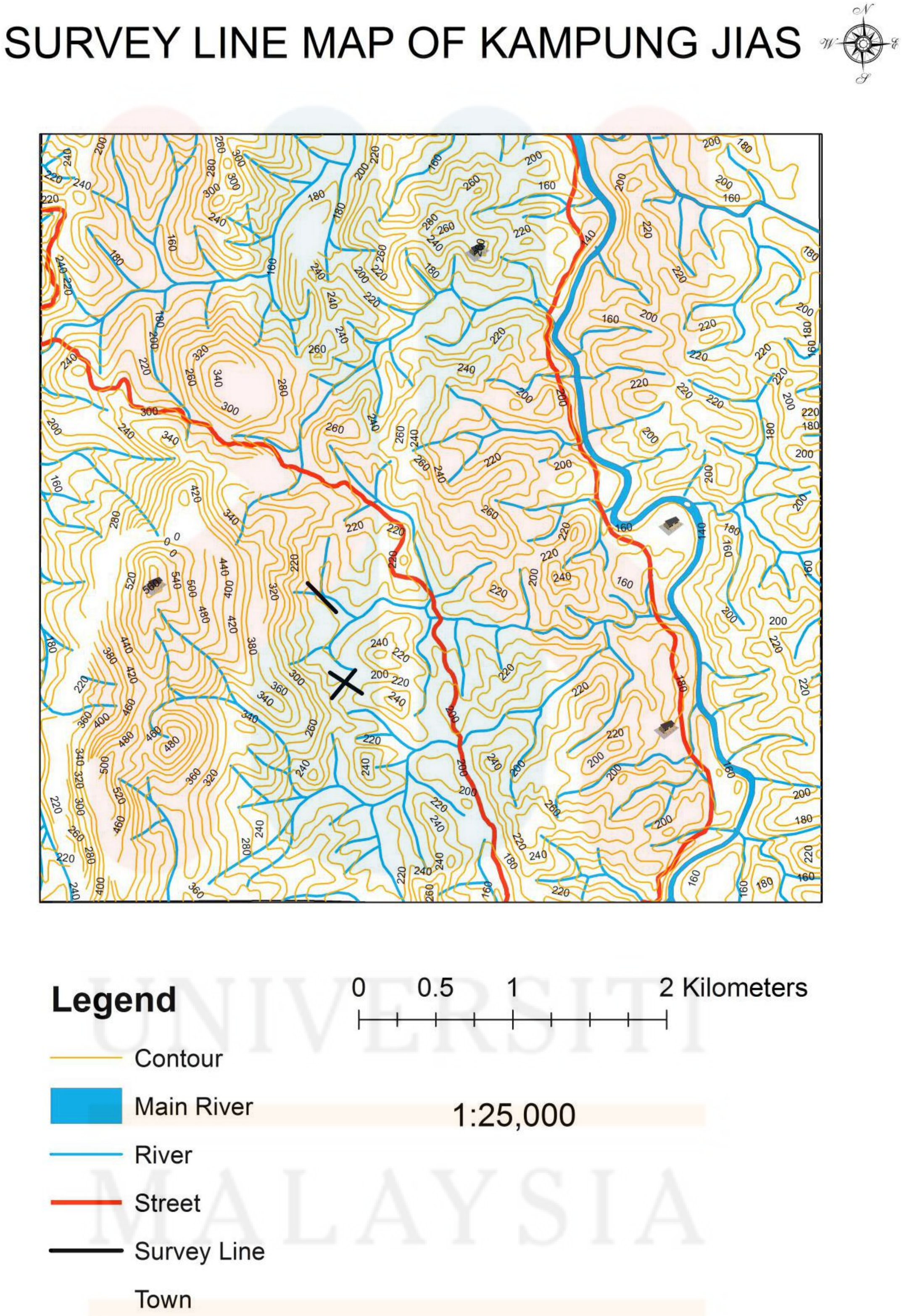

Figure 5.1: Survey line map of study area

Figure 5.2 : Survey line 1

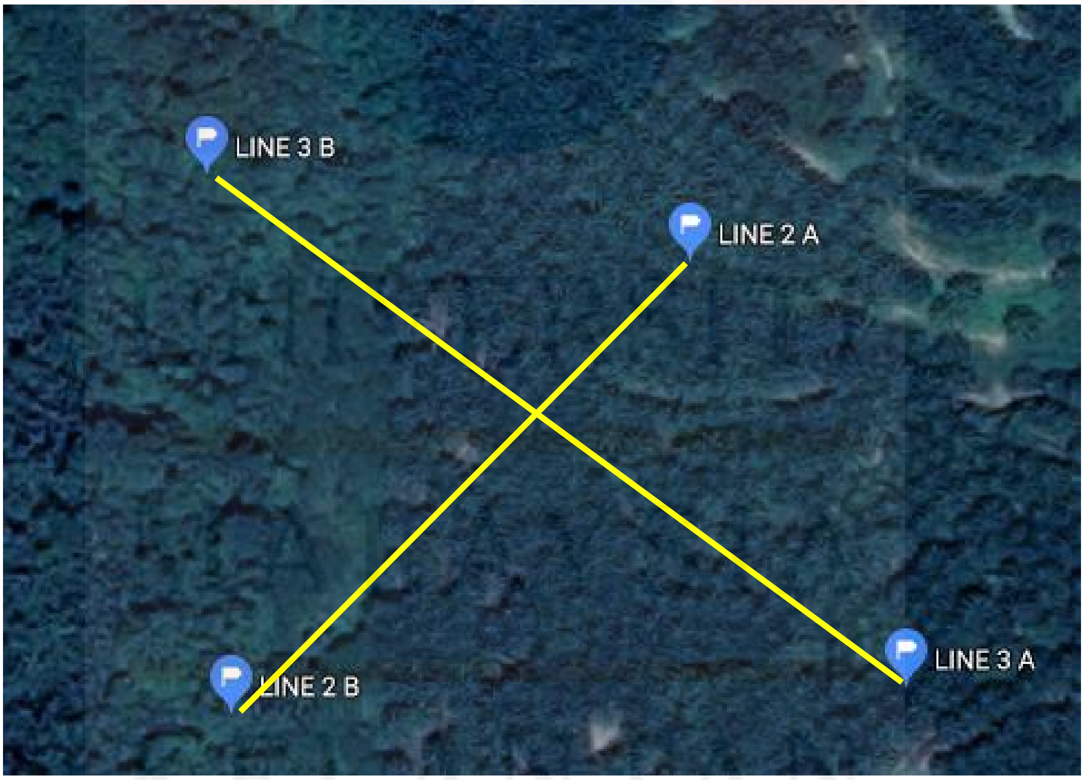

Figure 5.3: Survey line 2 and 3.

5.3 Line 1

The principle used in the line survey 1 is Schlumberger. The total distance of the line survey 1 is 200 meter with spacing of each electrode is 5 meter away. The rms number is 9.1 with the number of iteration was chosen is number 7. Table 5.1 shown the coordinate of electrode A and electrode B. The center of survey line 1 shown in Figure 5.4 which located at the middle of palm plantation.

Table 5.1 : Latitude and longitude of electrode.

Electrode	Latitude	Longitude
1	N 4°56'21.8"	E101°45'47.1"
41	N4°56'16.464"	E101°45'52.998"

The survey site is at the palm plantation. The elevation of the site is upwards towards electrode A. Electrode A located at the higher elevation than the center and electrode B. Electrode B locate at lower elevation and near small river. The direction of line survey is direction of SE-NW. The survey was conducted in rainy day.

Figure 5.4 : Center for line 1

Based on the Figure 5.5, it has been divided into 2 zones which is zones A and B. The interpretation of the model based on the inverse resitivity and chargeability value of each zone. For zone A, the resistivity value is range from 5 Ωm to 100 Ωm while the chargeability value is range from 0.75 msec to 5 msec. The depth of the zone is 185m to 175m.The resistivity values indicated the existence of clay and IP values indicated the values of alluvium and gravel. This indicated zone A has low possibility of sinkhole to occur because this zone consist of clay, alluvium and gravel .

For zone B, the resistivity value is range from 100 Ωm to 8000 Ωm while the chargeability value is range from 0.1 msec to 0.5 msec. The depth of the zone is 175m to 145m. The resistivity values indicated the existence of limestone and IP values indicated the values of water. This indicated zone B has low possibility of sinkhole because zone B consist of limestone and water but there is no existence of any fracture or cavity that lead to sinkhole occurrence. The conclusion is there is no possibility of sinkhole to occur in survey line 1.

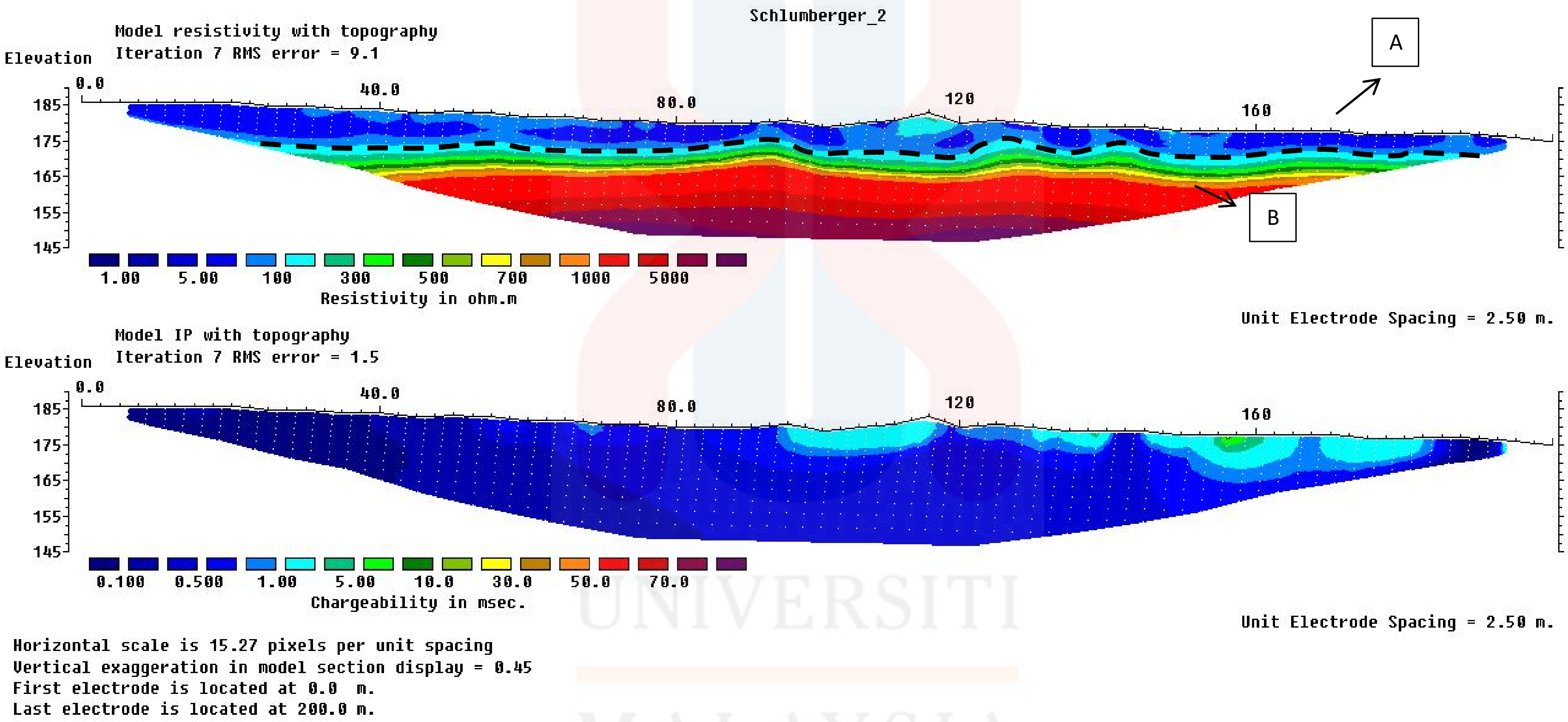

Figure 5.5: Pseudo of schlumberger line 1

5.4 Line 2

The principle used in the line survey 2 is Pole dipole. The total distance of the line survey 1 is 200 meter with spacing of each electrode is 5 meter away. The rms number is 14.1 with the number of iteration was chosen is number 6. Table 5.2 shown the coordinate of electrode A and electrode B. The center of survey line 2 shown in Figure 5.6 which located at the middle of palm plantation.

Table 5.2 : Latitude and longitude of electrode.

Electrode	Latitude	Longitude
1	N 4°56'02.6"	E101°45'57.1"
41	N4°55'57.786"	E101°45'52.06"

The survey site is at the palm plantation. The direction of line survey is direction of NW-SE. The survey was conducted in rainy day.

Figure 5.6 : Center for line 2

Based on the Figure 5.7, it has been divided into 3 zones which is zones A, B and C. The interpretation of the model based on the inverse resitivity and chargeability value. For zone A, the resistivity value is range from 25 Ωm to 200 Ωm while the chargeability value is range from 0.3 msec to 3.0 msec. The depth of the zone is 195m to 180m. The resistivity values indicated the existence of clay and IP value indicated the values of alluvium. This indicated zone A has low possibility of sinkhole to occur because this zone consist of clay and alluvium.

For zone B, the resistivity value is range from 300 Ωm to 8000 Ωm while the chargeability value is range from 0.75 msec to 5 msec for the left side and 0.10 msec to 0.75 msec at the right side. The depth of the zone is 180m to 150m. The resistivity values indicated the existence of limestone and IP values indicated the values of water on the right side while for the left side is alluvium. This indicated zone B has low possibility of sinkhole to occur because this zone consist of limestone, water and alluvium.

For zone C, this zone divided into two region which is the bottom region and top region. In bottom region, the resistivity value is range from 1 Ωm to 100 Ωm while the chargeability value is range from 0.1msec to 5 msec. The depth of the zone is 180m to 150m. The resistivity and IP value indicated the existence of water. While on the top region of zone C, the resistivity value is range from 100Ωm to 300Ωm while the chargeability value is range from 1msec to 5msec. The resistivity and IP value indicated the existence of alluvium. The depth of the top region of zone C is 185m to 180m. This indicated zone C has high possibility of sinkhole because water exist at bottom region of zone C while alluvium exist on the top region of zone C. This shown possibility of alluvium on the top region of zone C will collapse due to gravity force or other factor that will causes existence of sinkhole.

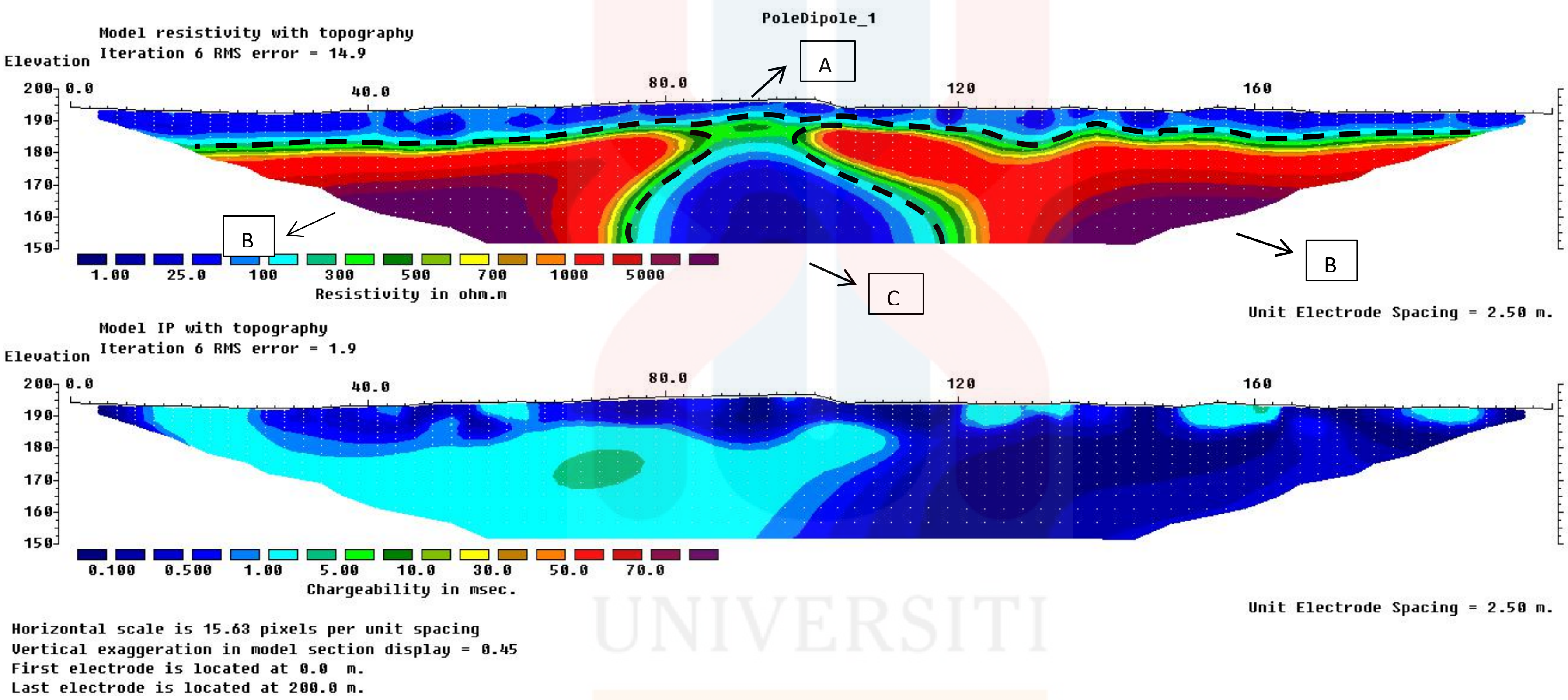

Figure 5.7: Pseudo of pole dipole line 2

5.5 Line 3

The principle used in the line survey 3 is Pole dipole and Wenner.. The total distance of the line survey 3 is 200 meter with spacing of each electrode is 5 meter away. The rms number is 14.9% for pole dipole and 7.2% for Wenner. Table 5.3 shown the coordinate of electrode A and electrode B. The center of survey line 3 shown in Figure 5.8 which located at the middle of palm plantation.

Table 5.3 : Latitude and longitude of electrode.

Electrode	Latitude	Longitude
1	N4°55'58.0"	E101°45'59.3"
41	N4°56'03.5"	E101°45'51.8"

The survey site is at the palm plantation but near to small road. The location also near to Gua Cincin. Line 3 were crossing Line 2. The direction of line survey is direction of NW-SE. The survey was conducted in rainy day.

Figure 5.8: Center for line 3

5.5.1 Line 3 Pole dipole

Based on Figure 5.9, it has been divided into 4 zones which is zones A, B, C and D. The interpretation of the model based on the inverse resitivity and chargeability value. For zone A, the resistivity value is range from 100 Ωm to 500 Ωm while the chargeability value is range from 0.5 msec to 20 msec. The depth of the zone is 190m to 160m. The resistivity values indicated the existence of clay and IP value indicated the value of water, alluvium, gravel and precambrian volcanic. Zone A is indicated as the old minor sinkhole has been filled with clay, gravel, water and precambrian volcanic. This is because zone A shown shape like a small hole but has been filled with other materials. The existence of old sinkhole also can be seen through their landform. This is because start from 120 meter, it shown the existence of soil subsidence and at 140 meter, it shown the existence of small hole about 20 meter wide with range 0.5m depth. The probability of sinkhole to occur is low because the old sinkhole has occur before and the old sinkhole has been compacted with some clay and alluvium which is not easy for sinkhole to occur again.

For zone B, the resistivity value of line 3 is range from 25 Ωm to 200 Ωm while the chargeability value is range from 0 msec to 3 msec. The depth of the zone is 190 m to 180 m. The resistivity values indicated the existence of clay and water and IP values indicated the values of water and alluvium. This indicated zone B has low possibility of sinkhole to occur because this zone consist of clay, alluvium and water .

For zone C, the resistivity value is range from 5 Ωm to 8 000 Ωm while the chargeability value is range from 0 msec to 5 msec. The depth of the zone is 180 m to 120 m. The resistivity values indicated the existence of sandstone rock and IP values indicated the values of water, alluvium and gravel. This indicated zone C has low possibility of sinkhole because of sandstone are compact rock and not easily to erode.

Lastly Zone D, the resistivity value is range from 1 Ωm to 1 000 Ωm while the chargeability value is range from 0.1 msec to 3 msec. The depth of the zone is 160m to 120m. The resistivity values indicated the existence of sandstone rock and i.p values indicated the values of water and alluvium. This indicated zone C has low possibility of sinkhole because it compacted with sandstone and alluvium.

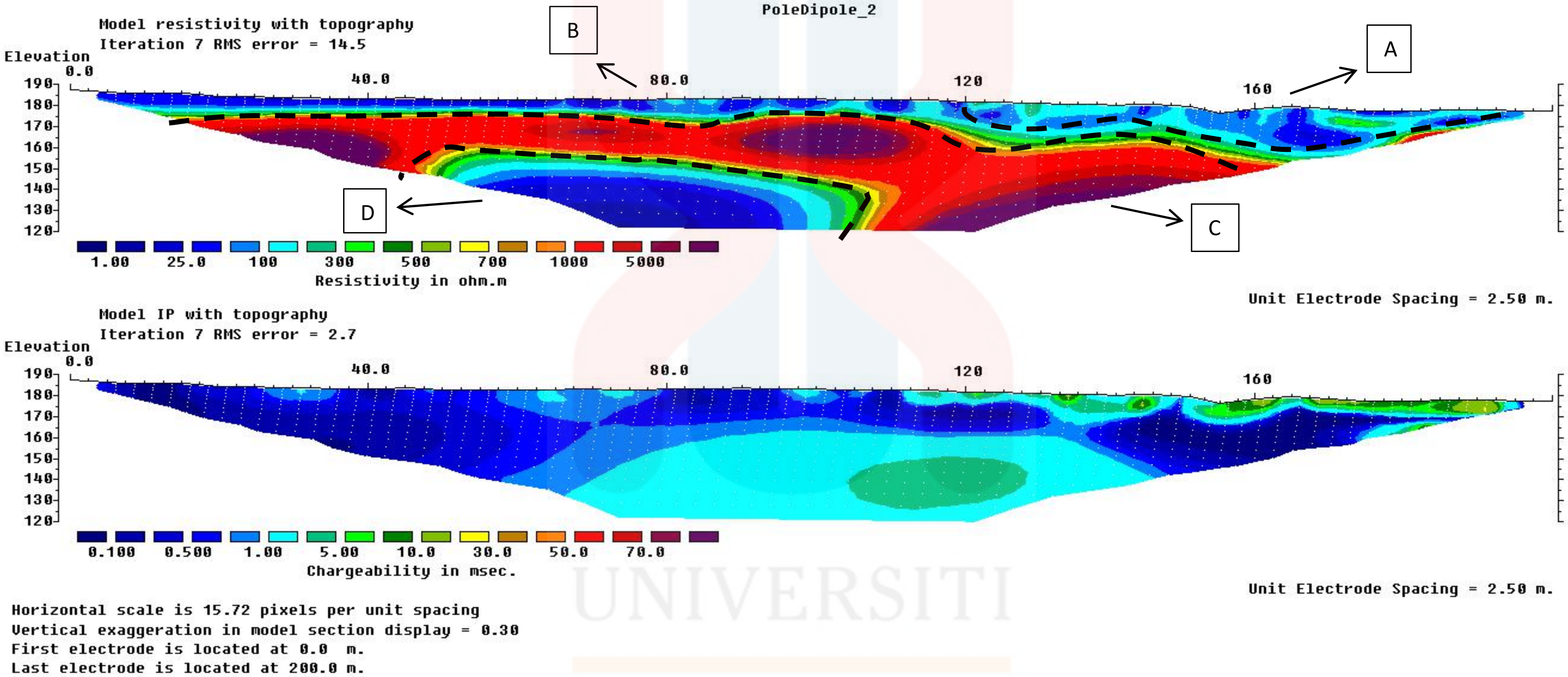

Figure 5.9: Pseudo of pole dipole line 3

5.5.2 Line 3 Wenner

Based on Figure 5.10 , it has been divided into 3 zones which is zones A, B and C. The interpretation of the model based on the inverse resitivity and chargeability value. For zone A, the resistivity value is range from 100 Ωm to 600 Ωm while the chargeability value is range from 0.75 msec to 10 msec. The depth of the zone is 190m to 165m. The resistivity values indicated the existence of clay and IP values indicated the values of water, alluvium and gravel. Zone A is indicated as the old minor sinkhole has been filled with clay. The probability of sinkhole to occur is low because the minor sinkhole has being compacted with clay, alluvium, gravel and water.

For zone B, the resistivity value is range from 12.5 Ωm to 200 Ωm while the chargeability value is range from 0.1 msec to 3 msec. The depth of the zone is 190 m to 180 m. The resistivity values indicated the existence of clay and water and i.p values indicated the values of water and alluvium. This indicated zone B has low possibility of sinkhole to occur because this zone consist of clay, water and alluvium.

For zone C, the resistivity value is range from 3 Ωm to 8 000 Ωm while the chargeability value is range from 0 msec to 1 msec. The depth of the zone is 180 m to 120 m. The resistivity values indicated the existence of sandstone rock and i.p values indicated the values of water. This indicated zone C has low possibility of sinkhole because of sandstone are not easily eroded by water. The sandstone act more as water aquifer.

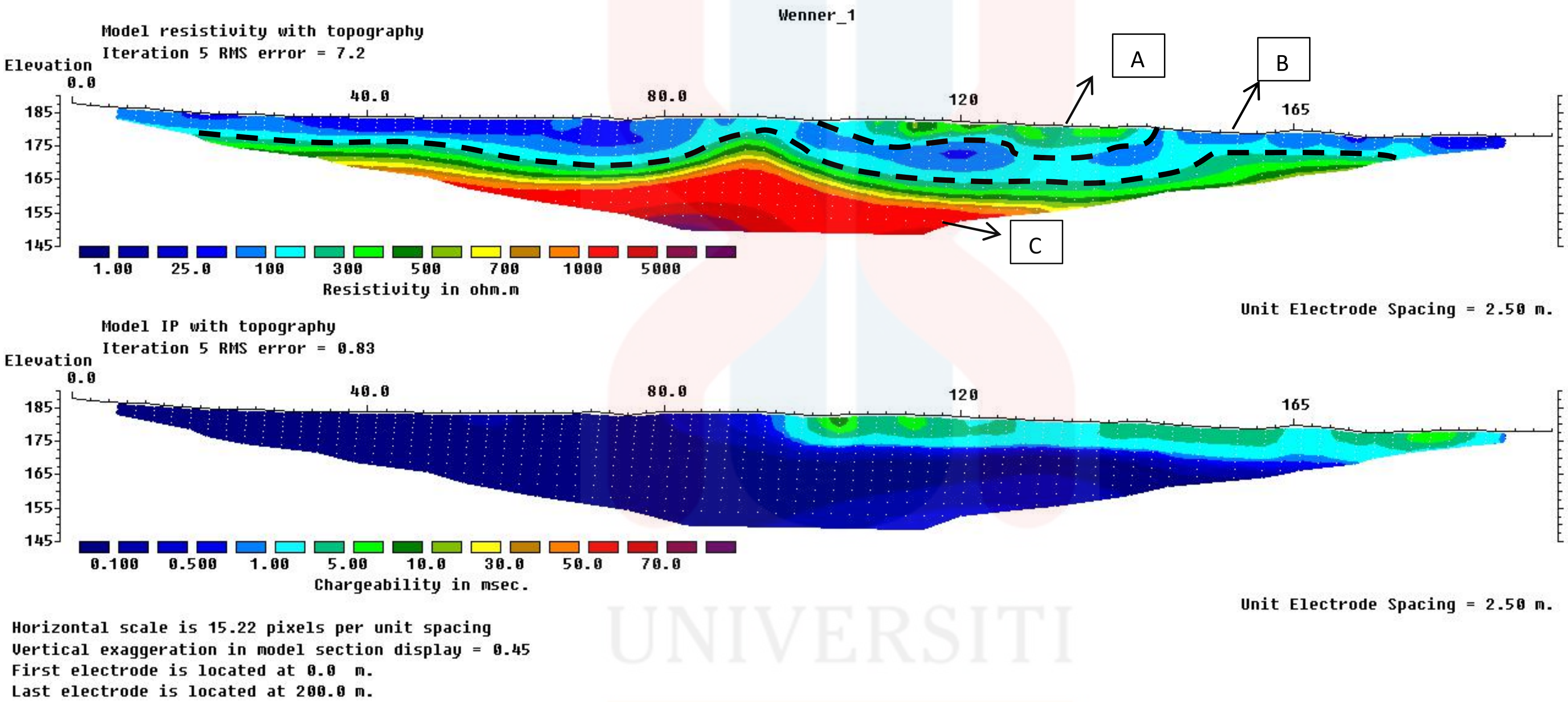

Figure 5.10: Pseudo of wenner line 3

5.6 Discussion

Based on the result, survey line 1 has low possibility of sinkhole to occur because in survey line 1 only has clay, alluvium, gravel, and limestone. There also has no any sign of fracture or cavity that will causes sinkhole to occur. This is because cavity and fractured are one of the main factor causes sinkholes. Next, survey line 2 have high possibility for sinkhole to occur because existence of water at the center region and above the water, there is existence of alluvium that might collapsed due to gravity force and other factor. This can causes sinkhole in the future. While at line 3, two principle has been used in the line survey. Which is wenner principle and pole dipole. The use of principle usually based on their advantages. For wenner, it can used to collect the data in the short time different from other principle. While for pole dipole, it can be used to collect data in more deeper than other principles. Pole dipoles usually need to used extension such as remote to detect the deeper subsurface. The data gain from line 3 shown there is no big differences in the data. Both wenner and pole dipoles data can detect the existence of old minor sinkhole. The value of resistivity and chargeability are not really different. But the data gain from pole dipole has more zone detected which is 4 zone while wenner only detect 3 zones in pseudo, The conclusion is, both principle can be used to detecting the cavity inside the subsurface and each principle has their own advantages.

Chapter 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This research has achieved all the objectives of the study which is to produced the geological map of study area with the scale 1:25,000 and to determine the potential of limestone geohazard in study area using ERI method.

The geological map has been produced by using ArcGis 10.1 with the scale of 1:25,000. Which all the geology data has been collected by geological mapping. All geological data was collected has been written and analyses in chapter 4 in more detail.

The potential of the limestone geohazard has been identified by using ERI method. Three selected places has been selected in the study area. Three type of principle has been used which is schlumberger, pole dipole and wenner.

Based on the result, it shown only survey line 2 that used a pole dipole principle has high possibility of sinkhole to occur. This is because at the middle region of the survey line, there is existence of water around the limestone and covered with alluvium. This show alluvium that covered the water might collapsed in future due to gravity force and causes sinkholes.

Lastly, Line 1 has low possibility of sinkholes due to existence of clay,alluvium, gravel and limestone that cannot cause sinkholes. Line 2 also has low possibility of sinkholes to occur but there is old minor sinkhole has occur at the past. But the possibility for sinkholes to occur are low because the old minor sinkholes has been compacted with alluvium and clay. At line 3, the data has been gain two times using two types of principles which is wenner and pole dipole. Both data shown there is no big differences in pseudo. Which has been concluded, both principles can be used to identify cavity in subsurface. All the detail has been written in chapter 4.

6.2 Recommendation

These are suggestion can be used for other researcher which is by using Ground-Penetrating Radar (GPR). This is because GPR has been used for several engineering problems and has been progressively developed. This is because all open fractures, karst limestone caves and sinkholes are successfully detected in Dry area using GPR surveying. Next is using the seismic surveying, which seismic will produce extraordinary images of the subsurface. This seismic survey help to understand more about subsurface. But this survey do come with high prices.

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APPENDICES

Appendix 1: Bearing reading for joint analysis

Bearing	Frequency
1-10	3
11-20	2
21-30	3
31-40	3
41-50	1
71-80	5
81-90	1
91-100	8
101-110	1
111-120	3
121-130	3
141-150	5
151-160	1
161-170	3
191-200	1
281-290	4

Appendix 2: Strike and dip geological map

Lithology	Strike	Dip angle
Limestone	179	35
Sediment	200	45
Metasediment	172	45

Appendix 3: Type of drainage pattern (source: Howard, 1967)