GENERAL GEOLOGY AND PREDICTION OF LIMESTONE GEOHAZARD BY USING ELECTRICAL RESISTIVITY IMAGING (ERI) AT KAMPUNG LEPAN JAYA, GUA MUSANG, KELANTAN

by

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THESIS DECLARATION

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

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ABSTRACT

Electrical Resistivity Imaging (ERI) survey is a geophysical technique that rapidly produces high-resolution profiles of the subsurface under the most field condition using measurements of the ground's resistance to an electrical current to develop a two-dimensional model of the subsurface. The objective of this study are to produce geological map of Kampung Lepan Jaya, to study the limestone subsurface condition using ERI survey and to find the probability of limestone geohazards in the study area. The study area is located at Kampung Lepan Jaya, Gua Musang Kelantan with the latitudes 04° 48′ 30″ N - 4o 45' 50" N and longitudes 101º 59' 0" E - 102° 01′ 40″ E for a total area of 25 km^2. The probability of limestone geohazard is figured out by using ABEM Terrameter S4000 and RES2DINV software. The result shows that, from four survey line, one of the Resistivity Survey Image has high probability of sinkhole while the other three has stable and strong rock formation in the subsurface with very low probability for sinkhole. Overall analysis shows Kampung Lepan Jaya is a stable area and has low probability of sinkhole occuring.

ABSTRAK

Kajian Imejan Keberintangan Elektrik (ERI) adalah teknik geofizik yang cepat menghasilkan profil resolusi tinggi bagi permukaan bawah tanah menggunakan ukuran rintangan tanah untuk arus elektrik bagi membangunkan model dua dimensi. Objektif kajian ini adalah untuk menghasilkan peta geologi Kampung Lepan Jaya, mengkaji keadaan batu kapur bawah permukaan menggunakan kajian ERI dan mencari potensi geohazards batu kapur di kawasan kajian. Kawasan kajian terletak di Kampung Lepan Jaya, Gua Musang Kelantan dengan latitud 04 ° 48 '30 "N - 4o 45' 50" N dan longitud 101o 59 '0 "E - 102 ° 01' 40" E untuk keluasan 25 km^2. Imej potensi geohazard batu kapur digambarkan dengan menggunakan ABEM Terrameter S4000 dan perisian RES2DINV. Hasil kajian menunjukkan bahawa, dari empat baris kajian, salah satu daripada imej ERI mempunyai potensi yang tinggi untuk tanah jerlus manakala tiga yang lain mempunyai pembentukan batu yang stabil dan kuat di bawah permukaan dengan potensi tanah jerlus yang sangat rendah. Analisis keseluruhan menunjukan Kampung Lepan Jaya adalah kawasan yang stabil dan mempunyai potensi yang rendah untuk pembentukan tanah jerlus.

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CHAPTER 1

INTRODUCTION

1.1 General Background

Kampong Lepan Jaya is located in south of Gua Musang, Kelantan. It is surrounded by hills in the west area and forest in the east area. Kampung Lepan Jaya is located in the middle of limestone area that is Gua Panjang limestone cave. The Kampung Lepan Jaya is located near Gunung Rabong in Jajahan Gua Musang of Kelantan, Malaysia which is accessible from Kampung Batu Papan and Kampung Sungai Tupai.

Geohazard is the natural disaster or geological state that can leads to disaster such as landslide, earthquake, sinkhole, rock fall and more. However, this research is only focusing on the potential limestone geohazards in subsurface of study area.

Geohazard can impede the development and construction of building and transportation especially in the urban area. Moreover, the natural disaster cause human casualties which will impede the economic growth and country's human capital. These can affect and cause huge losses to the development of the country.

As a geologist that has learned and analyse the process of Earth system, it is important to help the government to prevent the destruction of area development and human casualty due to geohazards or at least reduce the effects of the natural disaster.

It can be done by using the geophysical technique such as seismic and soil electrical resistivity to develop the subsurface imagings which help them to determine the area with highly possibility for geohazards to occur. With this method, the geologists can collects and analyzing the data to advise the government to avoid these high risk areas when planning the country's development.

The effect of geohazards due to the limestone bedrock in subsurface can be seen in the news report April 28, 2014 which show the formation of two sinkholes in Jalan Bukit Bintang during the construction of Mass Rapid Transit (MRT). These sinkholes formed due to inconsistent pressure of limestone formation beneath the road. Another examples of limestone geohazard are sinkhole at the intersection of Jalan Pudu and Jalan Hang Tuah, Kuala Lumpur that sunk in 2 July 2014 and sinkhole at Jalan Bukit Bintang (Jalan Tun Razak-bound) between Chulan Square and the Jalan Tun Razak intersection on 27 April 2014.

Electrical Resistivity Imaging (ERI) is geophysical technique that used the electrical resistivity of the materials for subsurface imaging. It is done by planting electrodes at an interval on the surface. By introducing the current to the ground, subsurface image can be produced based on the electrical field. Besides determining the type of materials on the subsurface, it is used to determine geological structures, groundwater, contamination and others. The ERI method inject electrical current into the subsurface through electrodes and the resulting potential difference is measured at other electrode positions in the vicinity of the current flow.

This research studies the ERI application technique to determine the possibility of limestone geohazards in subsurface in Kampung Lepan Jaya.

1.2 Problem Statement

This research is proposed to study general geology and the potential of limestone geohazards in the subsurface area of Kampung Lepan Jaya, Kelantan. For this reason, the 1:25,000 geological map of study area is required to observe the changes in the area of Gua Panjang. This allow the general geology of Gua Panjang to be studied.

This research is conducted to demonstrate the application and effectiveness of Electrical Resistivity Imaging (ERI) in imaging the condition of subsurface of limestone karst and determine the possibility of geohazard based on the geological features shown. However, there is no previous subsurface investigation on the study area using ERI to be studied.

Previous investigation focus in the study area is the application of GIS and geology of Gua Musang. Thus, there is no data that study the limestone subsurface that can be used as reference while conducting this research especially the data about the ERI application and imaging in the study area.

1.3 Research Objective

This research is proposed to achieve the following objectives:

i. To produce geological map of the study area to the scale 1:25,000.
ii. To study the limestone subsurface condition using Electrical Resistivity Imaging (ERI).
iii. To find the probability of limestone geohazards in the study area.

1.4 Study Area

Study area is a 25 km^2 area which is chosen based on requirement needed to complete this thesis. This research focusing on the study of prediction of limestone geohazard by using Electrical Resistivity Imaging (ERI). Thus, the study area chosen must satisfied the requirement for limestone lithology and suitable for conducting the ERI survey. Kampung Lepan Jaya is chosen as study area also due to its easy accessibility. This will help the research to progress faster and able to transverse wide area.

1.4.1 Location

This research is conducted at Kampung Lepan Jaya located in Gua Musang, Kelantan. Gua Musang is the largest district located at the south area of Kelantan. It is bordering with Pahang in its south, Terengganu its west and Perak in its east. Gua Musang is mostly made up of limestone which resulting in a lot of limestone hill and cave in the Gua Musang districtas shown in Figure 1.1.

Figure 1.1: Limestone karst in study area.

The study area is Kampung Lepan Jaya located near Gua Panjang and Gua Tok Kong in the Jajahan Gua Musang, Kelantan. The study area latitude/longitude is located at (04° 48′ 30″ - 4° 45’ 50”) N and (101° 59’ 0” - 102° 01′ 40″) E with a total area of 25 km^2 (5 km x 5 km).

This study area is selected due to its location that near Gua Panjang, a limestone cave which show the potentials of limestone karst formed in the study area. Thus, it is important to investigate the limestone condition in the subsurface area using the geophysical technique, Electrical Resistivity Imaging (ERI).

This study area is active with human activities due palm oil plantation and residential areas with school, SK. Lepan Jaya as shown in Figure 1.2. The highest elevation in the study area is 580 m while the lowest elevation is 160 m. Base map of Kampung Lepan Jaya is shown in Figure 1.3.

Figure 1.2: Palm Oil Plantation.

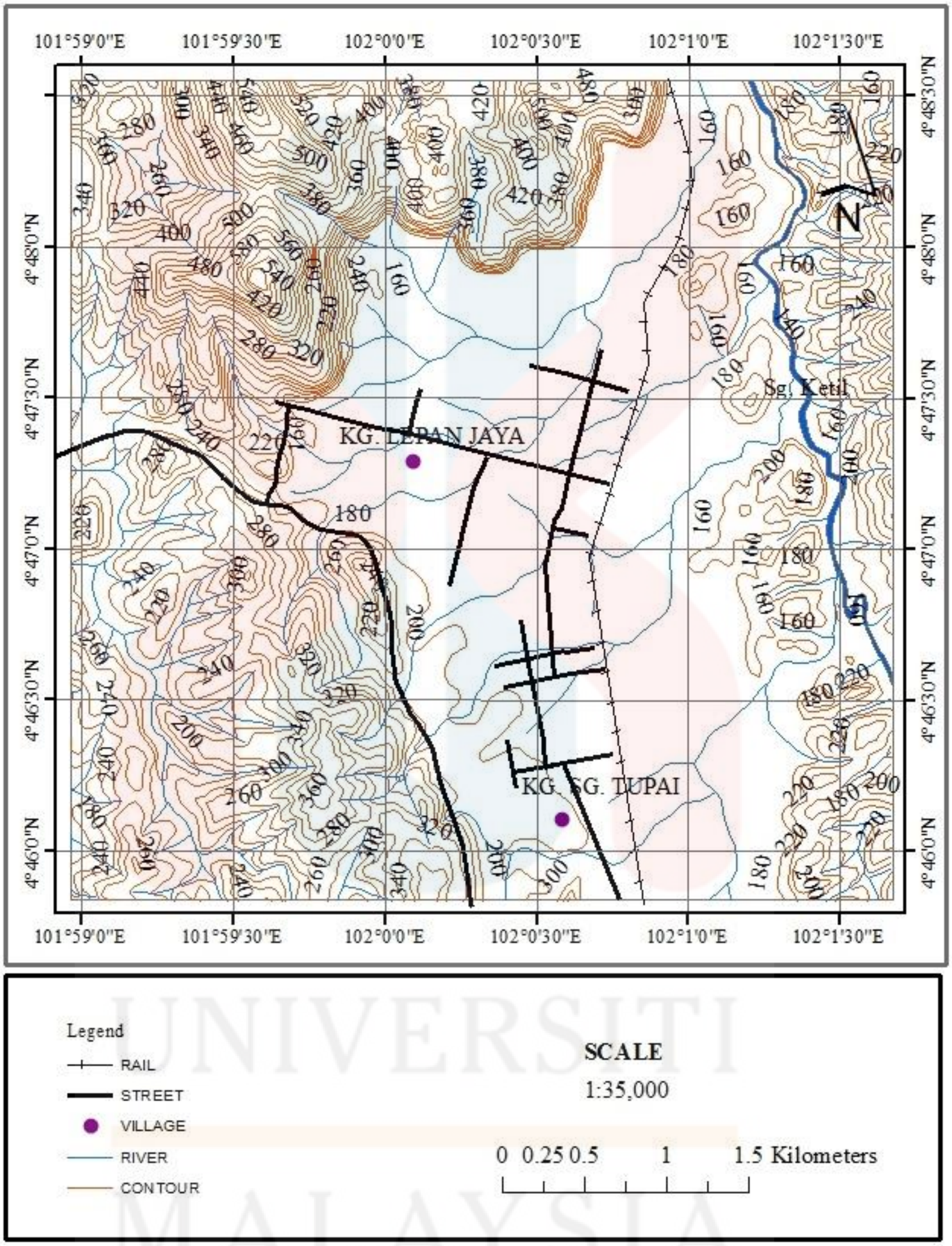

Figure 1.3: Base Map of Kampung Lepan Jaya

1.4.3 Demography

Gua Musang is the largest district in Kelantan with the 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 and Figure 1.4.

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

District	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**

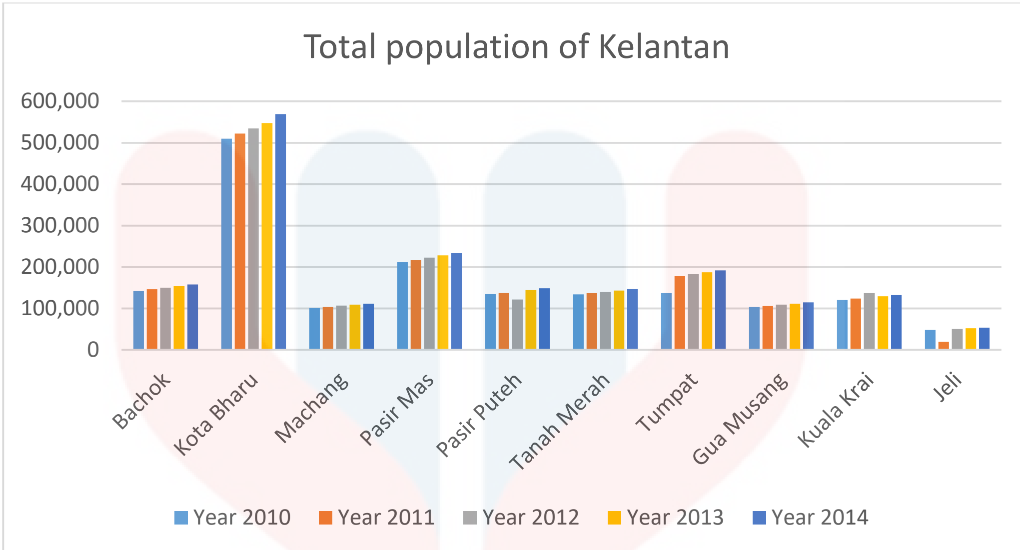

Figure 1.4: Total Population of Kelantan from year 2010 to 2014

1.4.4 Rainfall Distribution

The hydrological stations is built in order to supervise the drainage system in Kelantan. It can be used to observe the rainfall distribution, river water level or groundwater in subsurface. It also used for flood controls especially during monsoon season.

In the monsoon season, the rate of rainfall distribution and water precipitation will increase. Normally there will a drought season before the monsoon season that will increase the amount of water evaporated into the atmosphere that will resulting to the increased amount of rainfall. With the rate of rainfall increase, the rate of limestone dissolution increases as the rain will reacts with the carbonate or calcium in limestone.

Thus, the rate of limestone karst formation increases as well due to the increasing amount of water precipitation and water infiltration into the ground. Gua Musang has a tropical climate with the average annual temperature is 26.4 °C in Gua Musang. Total rainfall distribution is shown in Table 1.2 and Figure 1.5.

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**

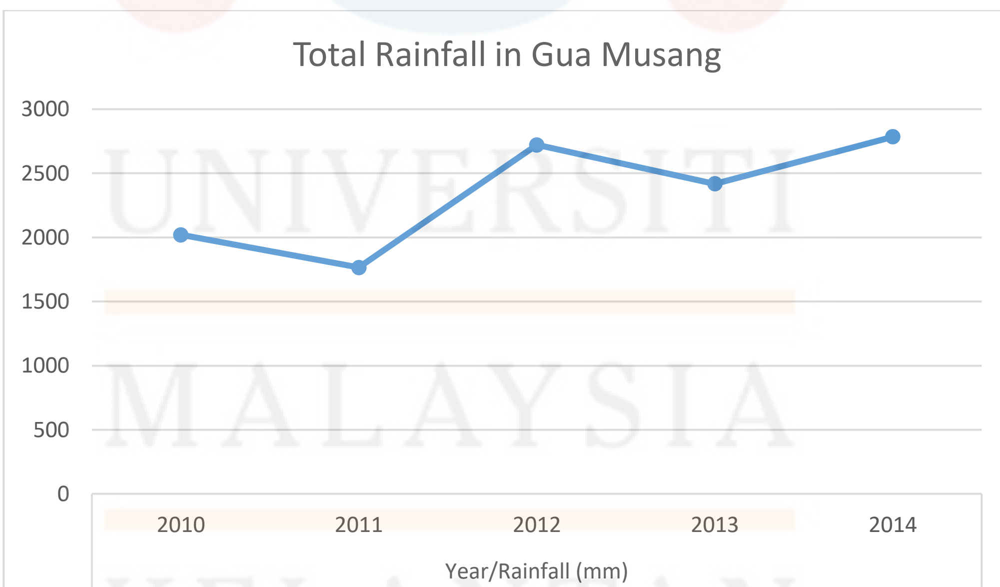

Figure 1.5: Total rainfall in Gua Musang from year 2010 to 2014.

1.4.5 Landuse

The study area is located at Kampung Lepan Jaya, Gua Musang, Kelantan with the landuse mainly focusing on agriculture such as rubber and palm oil plantation areas. Half of the study area in the west is used for the palm oil plantation as shown in Figure 1.6.

Figure 1.6: Palm oil plantation at west of study area

Residential area is focused in the center and south of the study area. These areas are consisted of Kampung Lepan Jaya and Kampung Sungai Tupai. A school also built in this study area which is SK Paloh.

Small amount of the area in the south is used for cow raising while the rest of the area which is east of the study area is forest or karst tower that is not suitable for development. Landuse Map is shown in Figure 1.7.

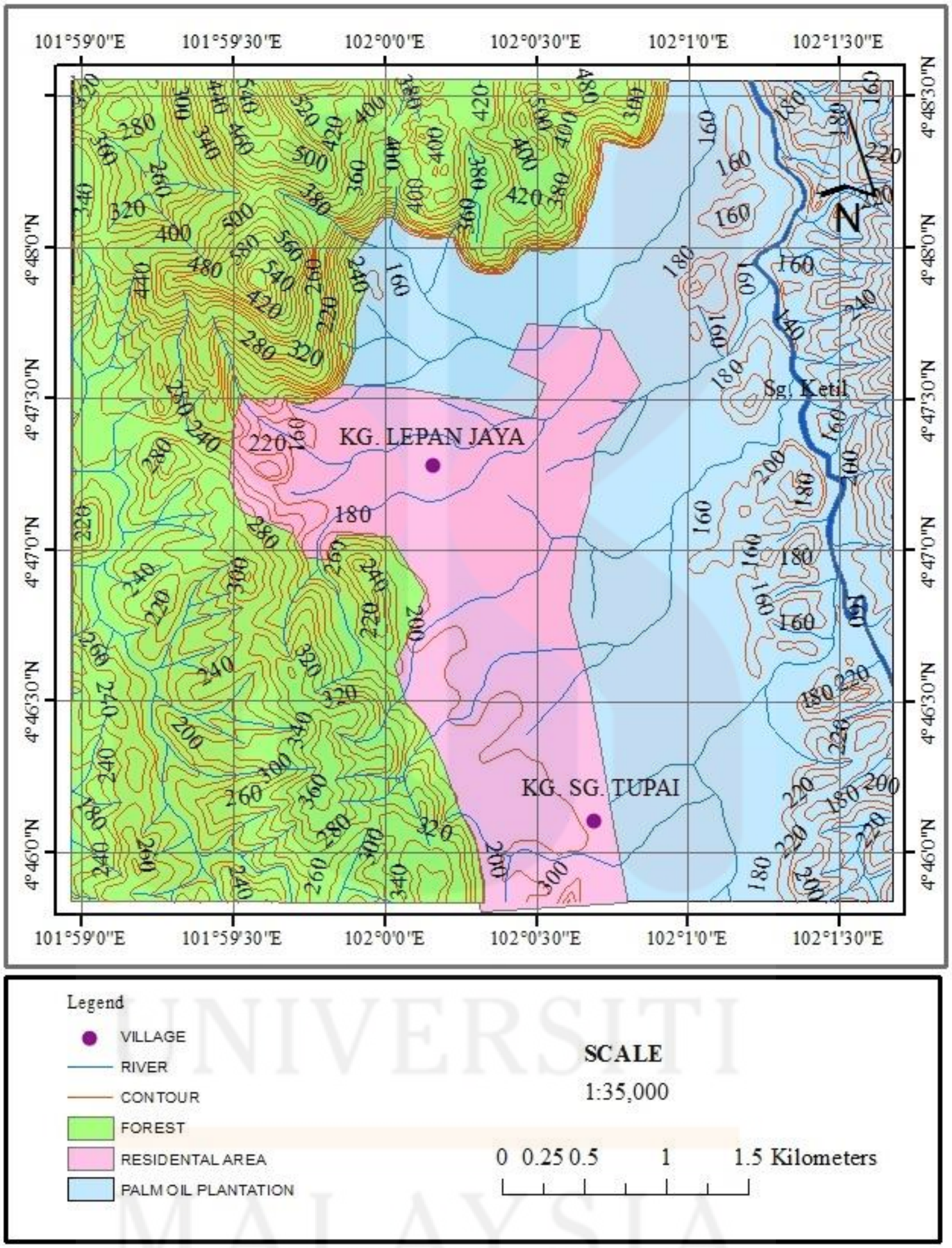

Figure 1.7: Landuse map of Kampung Lepan Jaya

1.4.6 Social Economic

People in the study area mostly depended on agriculture-based economy. This can be seen as most of the people the work in palm oil plantation and rubber plantation. There are also many villagers that plant vegetables for their own family's needs. Besides that, there are also rearing livestock such as chickens and cows by using the waste product from palm oil plantation as the animal's feed.

The economy also focused to business near the school SK. Lepan Jaya in Kampung Lepan Jaya. Most of the business deals with preserved food and daily necessity. There are also many stalls opened that selling food and drink.

1.4.7 Accessibility

Kampung Lepan Jaya is accessible from Kampung Batu Papan and Kampung Sungai Tupai. The main road in the study area is connected to Jalan Merapoh – Gua Musang (Central Spine Road). There are railroad that passed through the study area as shown in Figure 1.8. This railroad separates the residential area and palm oil plantation. However, there is no rail station located in the study area.

The main road and the road in residential area is paved roads which connected the west, south and center area of Kampung Lepan Jaya. Unpaved road mainly used in palm oil plantation to ease the movement of vehicle.

Figure 1.8: Railroad at N 4º 47’ 13.6”, E 102° 00′ 44.0″

1.5 Scope of Study

This research is studying the application of Electrical Resistivity Imaging (ERI), a geophysical technique to determine the potential of limestone geohazard in study area. This determination can be investigated by using the ERI method to study the limestone subsurface condition of the study area. This research determines the usage, suitability and accuracy of ERI in imaging the subsurface condition of soil, especially limestone to analysis the possibilities of geohazard.

The study is also study the general geology of the study area to update the geological map. This research is only focusing on the limestone and the geohazard related to the limestone karst. The study area of the research that are chosen is the area near Gua Panjang, Gua Musang, Kelantan with an area of 25 km^2 which focusing the area of Kampung Lepan Jaya.

1.6 Research Importance

This research is important due to the information that can be collected about the limestone bedrock or formation condition in the subsurface of the study area. The research not only study the limestone subsurface condition and its characteristics but also used the data collected to analyses and investigate the effects on surrounding geology in order to determine the potential geohazards.

The result of this research not only beneficial to the government to plan the urban development in the study area, Kampung Lepan Jaya but can also be used by other students or researchers to help them with the research related to the study area.

Probability of limestone geohazards can be found using Electrical Resistivity Imaging (ERI) to investigate the subsurface area, resulting to early warning and prevent large casualties and destructions. Moreover, ERI can be used to guide the construction of buildings and roads to avoid high risk hazardous areas.

Moreover, this research allowed architect and government to prevent catastrophic collapses of structures and other related geohazard problems by providing the information necessary to produce a sustainable management plan. This research allows them to plan better construction of residential and city areas.

Lastly this research can be used to produce the latest map of the area of Kampung Lepan Jaya, Kelantan and also can provide ERI data of the study area for future reference.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review is conducted to obtain previous data and investigation to guide this research. There are 28 literature reviews, journals, articles and news reports that are used as reference to conduct this experiment which discussed about the general geology of Gua Musang, Electrical Resistivity Imaging (ERI), limestone and geohazard that caused by limestone karst.

2.2 Regional Geology and Tectonic Setting

South of Thailand, Sumatra and Malaysia are located in the middle of collision of Sibumasu plate with East Malaya and Indochina in the Late Triassic (the Indosinian Orogeny), causing crustal thickening resulting in important tin-bearing S-type granites, characterized by the Main Range of the Peninsula, the 'tin islands' of Indonesia and parts of central Thailand. This can be seen in the major contrasts of the Carboniferous and Permian rock formations and fossils, resulting from contrasting palaeo-latitude positions (Charles, 2014). Sibumasu is characterized by Carboniferous–Permian glacial pebbly mudstones, whereas the East Malaya and Indochina Block are characterized by fusulinid limestones.

2.2.1 Stratigraphy

Kampung Lepan Jaya is a populated place and is located in the region of Gua Musang, Kelantan, Malaysia. The estimate terrain elevation above sea level is 165 metres. The coordinate of the Kampung Lepan Jaya is 4°47'20.76''N, 102°0'20.52''E. The study area is surrounded by hills and limestone rocks and located near Gua Panjang which is a limestone cave located near Pulai.

Kampung Lepan Jaya is situated in Gua Musang that mainly consist of sedimentary and metamorphic rock which belong to Gua Musang Formation. The geomorphology of the Gua Musang is almost 95% being classes as the undulating terrain and low-lying area. Gua Musang was classified to have a high until moderate suitability of development and a low until moderate geotechnical limitation. (Mistam, 2013)

Gua Musang is a part of Gua Musang Formation which is predominantly argillaceous and calcareous sequence interbedded with volcanics and arenaceous rocks. Gua Musang composed of five types of lithology which are limestone unit, interbedded sandstone, siltstone and shale unit, phyllite, slate and shale with subordinate with sandstone and schist unit, felsic unit and also alluvium unit. All of these lithology are grouped in Paleozoic and Mesozoic era. (Radzir, 2013)

2.2.2 Structural Geology

Kampung Paya Tupai is a village or residential area located at the south of Kelantan bordering with Merapoh Pahang. The local karst, named Gua Panjang has unique shape due to geomorphologic process by rainfall, rich organic acids, abundant of acid and also a lot of carbon dioxide.

To show general geology of an area, a geological map is needed. A geological map is the map that shows the distribution of various types of bedrock in an area. Normally it consists of a topographic map (map giving information about the form of the earth's surface) which is shaded, or colored to show where different rock units occur at or just below the ground surface (Lisle, 2004).

To produce a geological map, a fieldwork or transverse through study area are required. This allows us to investigate and record the rock outcrops and its characteristics such as rock composition, and fossil content. Geological structure such as fold, fault or bedding can also be recorded.

Geological map can be used by civil engineers during planning of the excavation of road cuttings or on the siting of bridges, by geographers that studying geology of that area and by companies that searching for mining area (Lisle R. J., 2004).

Geological fractures used to describe discontinuities that involve faults, joints, fissures, and cleave in the Earth's lithosphere. The geological and topographical maps helped us identify the geological fractures and can be used to correlate with the determination of limestone geohazards.

Geologic fractures can be related to the formation of sinkhole. Some of the sinkhole grouping will aligns to faults systems. During karst development, fault offsets often formed geologic boundaries. Besides that, fractures always affect the direction of groundwater flow. Fractures, with little or no offset and fault gouge, would provide pathway for the groundwater flow (Florea, 2005).

2.2.3 Historical Geology

. Historical geology can be obtained by collecting the necessary geographic information to study structural geology and geomorphology of the study area. Historical geology allows us to learn about past environmental features and the processes that involved during that time.

One of the past environmental features that can be studied is climate. Climate can be determined based on the weathering processes. Weathering processes and weathering crusts are different based on the places because of the interacting factors, chiefly rock type, climate, topography, organisms, and the age of the weathered surface. Climate is the factor affecting the chemical, mechanical, and biological weathering rates (Huggett, 2007).

Historical geology in limestone area can studied by observing the shape of karst or cave in subsurface depending on the lithology, pattern of joints, fractures, and faults, and also cave breakdown evaporate weathering. The shape of the karst is affected by the passages forming along or close to lithological junctions. Besides, the joint networks that controls the flow and direction of water in karst and the collapse of the cave ceiling also responsible in shaping the karst (Huggett, 2007).

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2.3 Limestone

Limestone is sedimentary rock mainly composed of minerals calcite or aragonite. These minerals have calcium carbonate in its chemical compound but with different crystal arrangement. Limestone is soluble in acidic water which can result in karst features on the subsurface. The acidic water can break down the surface of bedrock of limestone or dolostone near its crack or bedding planes which tend to get bigger as the bedrock continues to break down.

Other mineral that associates with limestone is dolomite is a mineral that has calcium magnesium carbonate with a chemical composition of $CaMg(CO_3)_2$. Limestone that contains some dolomite is known as dolomitic limestone. Diagenesis is a process that transforms soft sediments such as carbonates mud and grains into all grains together and become more stable. (Adenan, 2014).

2.3.1 Limestone Karst

Limestone is sedimentary rock mainly composed of minerals calcite or aragonite. These minerals have calcium carbonate as its chemical compound but with different crystal arrangement. Limestone is soluble in the acidic water which can result in karst features on the subsurface. This acidic water can break down the surface of bedrock of limestone or dolostone near its cracks, or bedding planes which will tend to get bigger as the bedrock continues to break down.

Karst systems are complex due to variations of geological and hydrological characteristics, they can be included among the most fragile and vulnerable environments in the world. Complexity of karst is observed by the different karst that exist in different regions (Brinkmann, 2012).

Limestone normally made up of allochems, matrix and cement, the component that bind rock together. Limestone can be discriminate into ferroan calcite, non-ferroan calcite and dolomite (Ali, 2013). Limestone can undergoes physical, chemical and mineral changes called diagenesis such as cementation and silification. The word ‘karst’ refers to a type of terrain, known for its distinctive topography in which the landscape is largely shaped by the dissolving action of meteoric water on carbonate bedrock (Al-Fugara, 2014).

In other words, karst topography is geological features formed due the dissolution of soluble rocks underlying underground water systems, sinkholes and caves. It is usually associated with carbonated rock. Rainwater seeps downward through the soil and through fractures in the rock responding to the force of gravity and water becomes weakly acidic because it reacts chemically with carbon dioxide that occurs naturally in the atmosphere and the soil. The carbonic acid in the moving ground water dissolves the bedrock along the surfaces of joints, fractures and bedding planes, eventually forming cave passages and caverns (Alpha, 1997).

These karst can resulting into stalagmite, stalactite, caves, water drainage and many other in the subsurface. These are the few factors that resulting the geohazard phenomenon such as sinkhole and landslide. Limestone bedrock or formations are not as hard as other geological formations as it has air and water cavities which causing low earth pressure balance. Limestone bedrock always forms an irregular surface due to geological fractures, sinkholes, cavities and karst features.

The dissolution processes of bedrock usually caused peculiar morphologies and change the surface landforms. Pure karst landscapes exist all around the the world but the landscapes are often shaped by a multitude of processes (Waele, 2008).

2.3.2 Limestone Potential Geohazard

Limestone geohazard usually depended on few factors such as intact rock strength, weathering, joint spacing, orientation and width, continuity of joint, and outflow of water. Mechanical weathering such as widening of joint due in-growth roots of vegetation and dissolution of carbonate rock by rain water along the joint opening may increases the susceptibity of limestone geohazards (Simon, 2015).

The soil properties are correlated with the resistivity result. Hence subsurface may be identified by comparing the processed resistivity value with the standard known soil. With these identified soil or rock, the failure plane can be interpreted (Goh, 2014). Geophysical methods such as seismic, microgravity, self-potential, electrical resistivity, electromagnetic, and ground-penetrating radar are more advantageous for geohazard investigations because of their nonintrusive nature and cost effectiveness (Bakhshipour, 2013).

. Region of karst imposes some unique environmental hazards to humans, particularly in urban areas where heavy structures are built on cavernous limestone.

Collapse of limestone ccasionally occurs; damaging building with little warning, due to the rapid movement of groundwater from place to place in large cavern passageway (Abu-Shariah, 2002).

The dissolution of limestone bedrock in subsurface will creates voids such as cave and cavern which lead to collapses that influences the geology and environment of that area by inducing severe damage, property loss, and disruptions to daily life (Brinkmann, 2012).

Malaysia has reported many cases of cavities and sinkholes. Kuala Lumpur and Ipoh, are underlain extensively by carbonate rocks (Abu-Shariah, 2002). For example, hill view building collapse was reported due to the intensive geological fractures formed by insatiability of the bedrock steep slope and buried stream networks and that incident killed seven people in Kuala Lumpur (Chow, 1996).

2.4 Electrical Resistivity Imaging (ERI) application on Geohazard Mapping

Electrical Resistivity Imaging (ERI) is a geophysical technique that rapidly produces high-resolution profiles of the subsurface under the most field condition. ERI uses measurements of the ground's resistance to an electrical current to develop a two-dimensional model of the subsurface (Baines, 2002). Profiling and areal mapping are recording techniques for mapping lateral variations in resistivity at approximately constant depths.

ERI uses direct or low frequency alternating current source. Rocks are electrically conductive as a result of ionic migration in pore water space and although rare, conduct electric through metallic minerals (Hoover). Different rock can produced different resistivity based on the mineral composition and soil condition.

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
Soil and Water		
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	$6.998x10^{16}$	$1.429x10^{-17}$

Table 2.1: Resistivity of common rock and chemical.

2.4.1 Electrical Resistivity Imaging (ERI)/ERI array

Electrical methods utilize what from a functional viewpoint may be considered as direct current (DC). Two electrodes are used to inject current into the ground, and two electrodes are used to measure the voltage caused by the current. A number of different electrode configurations have been invented but only a few are commonly used. These are five types of array commonly used in field practice: Gradient, Dipole-dipole, Pole-dipole, Schlumberger and Wenner as shown in Figure 2.1.

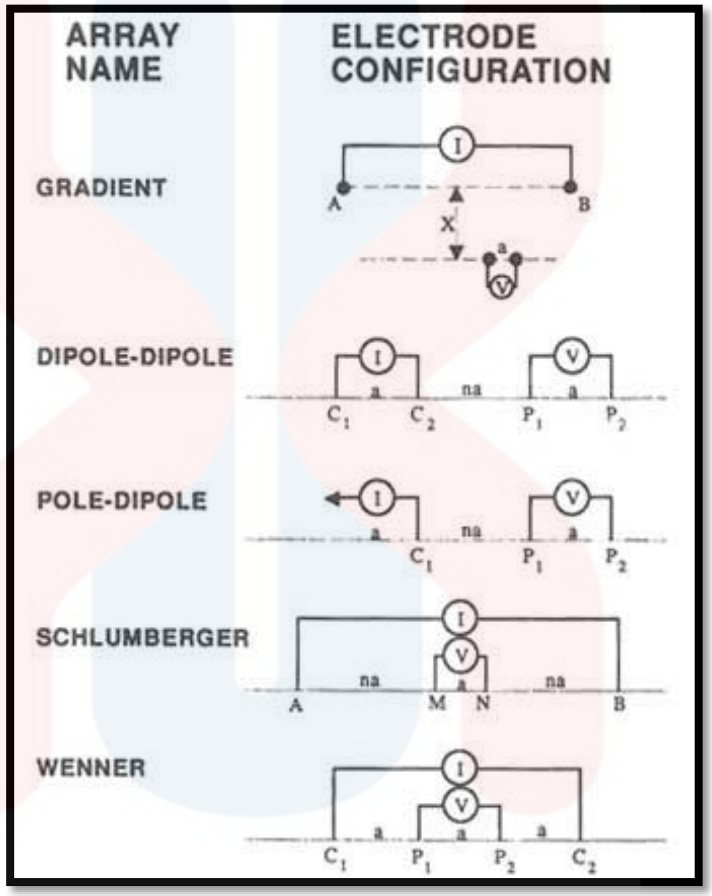

Figure 2.1: Commonly used electrode array arrangement.

A 2D electrical resistivity imaging method with Gradient array were used to measure the subsurface apparent resistivity data during the survey (Ridzuan, 2011). It is the most suitable for studying lateral variations in resisitivity of the ground.

Pole-dipole and Pole-Dipole protocols produced the best image of the man-made hole with very good horizontal and vertical coverage (Nordiana, 2011). The advantage of these arrays is that the current and potential dipole cable are well separated from one another, which effectively reduce noise due to electromagnetic coupling.

In this research, the type of array used is Schlumberger array because it is especially well suited for profiling and areal mapping due to the equidistant spacing between electrodes determine depth of bedrock, overburden and near surface structures such as faults and cavities. (Stummer, 2003). Wenner array are able to provide fast profiling but not suitable for use because it provide too little information for detail research.

ERI method is to measure the apparent resistivity of the subsurface including effects of any or all of the following: soil type, bedrock, contaminants and ground water. Variations in 2-D resistivity may indicate changes in composition, layer or contaminant levels (Rosli, 2011). It is better than borehole drilling that provides the subsurface depth, but it is only at the sampling location. The data in between the boreholes need to be interpolated and the result was in an assumption data but ERI provides sub surface data (Kamil, 2011).

ERI survey allows for a cost and time effective tool to precisely map the terrain factors that contribute to the natural hazard and predict these events (Elmahdy, 2013). By using a combination of resistivity data to establish targets, most of the required information can be mapped and the results verified, thus maximizing the efficiency of the engineering and environmental work (Power, 2014).

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Introduction

This chapter shows the materials and methodology used throughout this research. The material and equipment that are required to carried out the researches smoothly are listed and the methodologies includes preliminary researches, data collection, field investigation and laboratory analysis, data interpretation and discussion, and report writing.

The main equipment used in this research is Electrical Resistivity Imaging (ERI). It has the ability to characterize the subsurface based on the resistivity and thickness of that particular soil. Besides that, it can determine the waterway in subsurface and the transportation of solid matter. It can be used as an assessment to determine the effect of the soil conditions in subsurface on the environment. The data that ERI collected can be integrated to improve the imaging of the subsurface.

Besides that the methodology of geological mapping of the study area is done to analyses the general geology of the study area.

3.2 Materials and Equipment

Hydrochloric Acid (HCL)

HCL is used to determine the existence of carbonate minerals such as calcite and dolomite in the rock, which will show reactions by forming bubble if it comes in contact with the acid. The different reaction speeds can also help to identify the type of mineral. For example, limestone react more vigorously compared to dolomite.

Sample Bag

Sample bag is required to collect the sample and prevent contamination from the surrounding area. This material is important to prevent or reduce the changes on the rock minerals and structure.

ABEM Terrameter S4000

ABEM Terrameter S4000 is the equipment that used innate electrical resistivity of the soil and rock to construct the survey of the subsurface. It used electrical output from the battery to run the program set in the Terremeter as shown in Figure 3.1.

Multimeter, Electrodes and Multi-core wires

Multimeter is used to measure the electric current, voltage, and resistance over several ranges of value. Electrode is the conductors used to allow the electrical current to flow through the ground while multi-core wires are a cable with a number of independent wires. It is used during the Electrical Resistivity

Imaging (ERI) survey. This equipment is required to run the ERI survey on the field as shown in Figure 3.1.

Figure 3.1: ABEM Terrameter S4000 and related equipment for ERI survey

Handheld Global Positioning System (GPS)

GPS is required to determine the location of study area during field investigation to ensure the correct data are collected. It is collecting the data such as latitude, longitude, elevation and time.

Figure 3.2: Handheld Global Positioning System (GPS)

Brunton Compass/Suunton Compass

The compass can be used to measure and collect geological data such as the dip-direction, plunge-direction and dip/strike of the strata lineation/foliation.

Figure 3.3: Brunton Compass

Geological hammer

This hammer is required to collect fresh sample easily on the field for the research by breaking the outcrop. The sample is required to identify the minerals, compositions and origin of the outcrop.

Figure 3.4: Geological hammer (pointed tip)

Hand lenses

Hand lenses are useful in assisting the observation of the features of the rock with the range from 5x to 20x.

Thin section

Thin section is acquired by cutting the sample collected and thinning the sample until it is thin enough to be observed under microscope.

RES2DINV.

It is computer software that converts the survey data collected by ABEM into 2-D image. The image produced can be used to study the subsurface condition of the study area such as lithology and karst.

1:25,000 geological map of Merapoh

This map is required to selecting the suitable study area and show the general geology of the Gua Panjang, Kelantan. It is also used to compare the current geology with previous map for any changes.

ArcGIS

It is computer software that uses geological information system used to produce or update a map. It is used to produce the geological map by collecting the geographic data and updating the database to study the general geology of study area.

3.3 Methodology

The methodology in this research involves all steps done during the completion of this thesis, including preliminary study, field investigation and survey, lab analysis and report writing. This methodology including both procedure for general geology and Electrical Resistivity Imaging (ERI) survey for probability of limestone geohazard.

3.3.1 Preliminary Study

Preliminary researches or the desk study is the previous researches, materials, literatures and data collected before going to the field. It is required to form general ideas and methodologies to ensure that the research conducted is successful and achieved the objectives that are set. The literature reviews and analysis is one of the preliminary researches.

In this research, a 1:25,000 geological map of Merapoh WHICH include the area of Gua Musang, Kelantan is prepared to obtain the general geology of the studies area.

The literature review is conducted to obtain previous data and investigation to guide this research. These literature reviews, journals, articles and news reports in Chapter 2 are used as reference to conduct this experiment which discussed about the general geology of Gua Musang, Electrical Resistivity Imaging (ERI), limestone and geohazard that caused by limestone karst.

3.3.2 Electrical Resistivity Imaging Survey

This procedures involves both field survey and data analysis. The field survey use ABEM Terrameter S4000, electrodes and others related tools to collect data. Then, these data is converted using RES2DINV software into image for analysis.

3.3.3 Geological Mapping

The geological mapping requires the investigation on the study area. It includes the coordinates, elevation, drainage, type of rock exist, landuse and other data. The sampling is also done for the laboratory work. This is done with the help of GPS, compass, geological hammer, hand lenses and other equipment.

The lithology and geological structure in the study area are done by traversing the study area with GPS. By marking the geological structure such as fault, fold, bedding and other in the study area, the change in the geology in the study area can be detected by comparing it with original or previous map.

The geographic information collected can be used to observe the changes that occurs in geology of the study area. These changes can resulting in different lithology compared to previous map and can be used to update the database. With the geological mapping, causes and effects of the changes can be study. Besides, it also help us to study the geomorphology (origin and evolution of topography) of the study area. All the data is used to produce a map in the computer using ArcGIS.

3.3.4 Sampling

Sampling is done by collecting the fresh rock sample (not weathered) on the study area with the suitable size.

3.3.5 Thin Section Preparation and Petrographic Analysis

Thin section is prepared by cutting the rock sample into smaller size. Then, the sample will be thinned until it is observable under a microscope.

Petrography analysis is done to analyses the minerals properties of the rock. This is to compare the mineral composition of the rock sample and the minerals in previous studies.

3.4 Electrical Resistivity Imaging (ERI) Analysis

The survey data collected by Electrical Resistivity Imaging (ERI) can be convert to the 2-D imaging using the software RES2DINV. With the 2-D image, the lithology and karst features can be determine in the subsurface of the study area. Usually limestone bedrock has high resistivity compared to soils which can be determined based on the color of the image.

With the 2-D imaging, the lithology and karst feature can be identifying which can be used to determine the potential geohazards in the study area.

3.4.1 Data Analysis and Interpretation

The Electrical Resistivity Imaging (ERI) equipment is set up on the study area for the data to be collected. The ERI required a wire to be set up in straight line for it to function correctly. Thus, it is essential to secure a good location in the study area. For the report, the coordinates that ERI is set up is recorded using the handheld GPS.

The resistivity surveys use four or more equidistant electrodes in a standard configuration. Pairs of electrodes is set up in a straight line. Then, a low current is applied across the electrodes which allowed the voltage along the electrodes to be measured. The voltage measured can be converted into a resistivity value to represent the subsurface resistivity between the electrodes.

The resistivity value can be used to measures bedrock, water table depth and detects sinkholes to imaging the subsurface of the study area. This can be used to profile landslip geometry, fractures and discontinuities.

Data is collected by profiling along the line at different electrode separations. The spacing between the electrodes fixed and moves the pairs along the line until the last electrode is reached. The maximum depth of field studies is determined by the spacing between the electrodes and the number of electrodes in the array. This is repeated until all the data in the study area is collected. The data then is converted to 2D imaging using the computer.

The research flowchart is shown in Figure 3.5 to produced organized research.

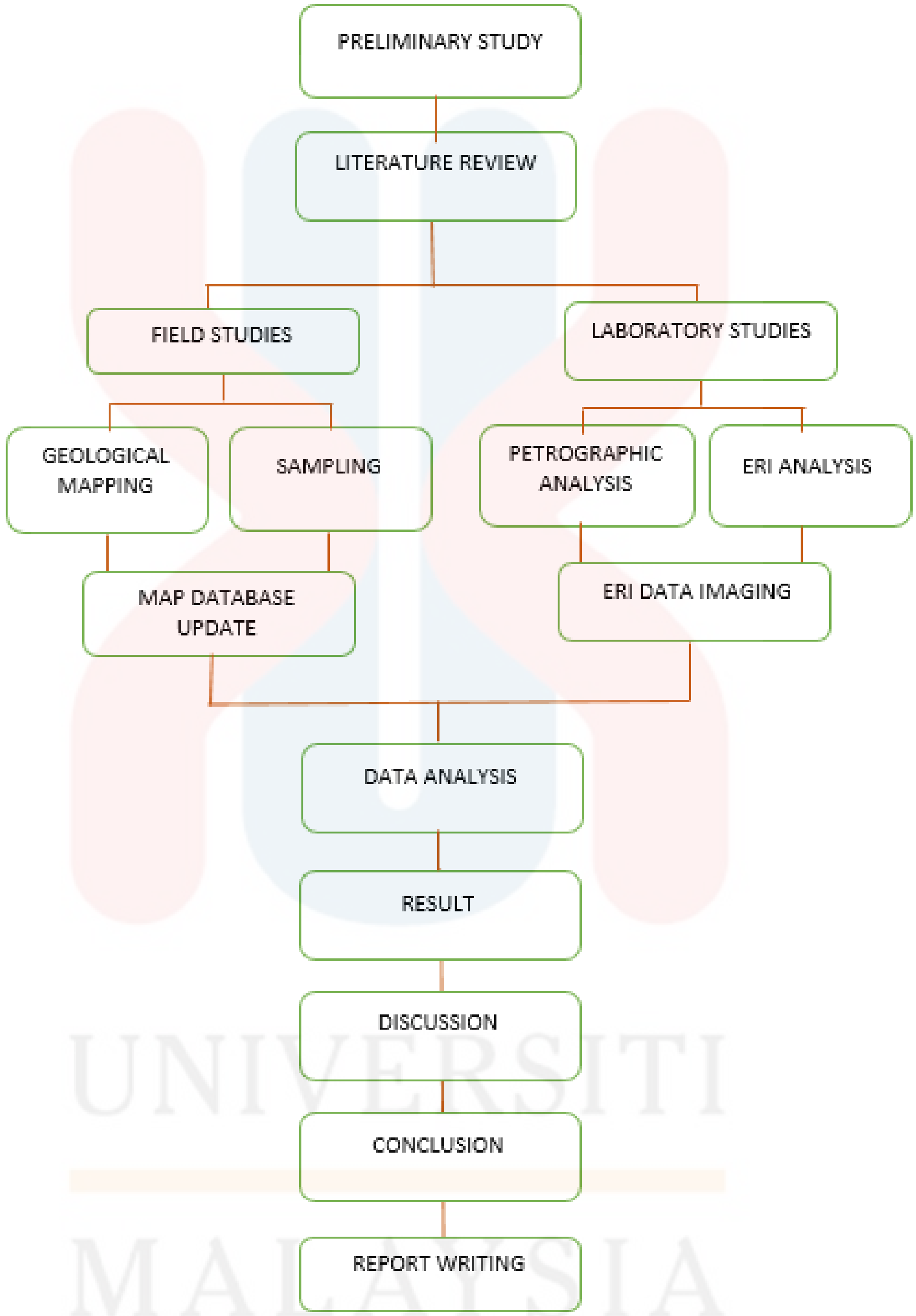

Figure 3.5: Research Flowchart

Chapter 4

General Geology

4.1 Introduction

Chapter Four discuss about the general geology of the study area. General geology provides the information of rock and soil to the geologist. This include the geomorphology of the study area which study the topography, drainage system and the weathering of the rock formation, lithostratigraphy, structural geology and historical geology of the study area. These information is important for planning the development and activities in the study area such as the list and placements of rocks exist, strength of the rock and soil, the weathering activities on the rock formation and geological structures that formed in the rock formation.

For chapter Four, General Geology, mapping is conducted at Kampung Lepan Jaya, in 25 km^2 area. During mapping, the information of the geological structure, lithology, drainage pattern and geomorphology of the study area are observed and recorded. The analysis of the joint and dip direction of lithology also recorded.

The transverse map shows the tracking done during the mapping. The tracking in the center area of the map is done due to easy access to those location. Transverse has been done at the north area, west area and southwest area of the map to find the structure and to observe the lithology of the study area.

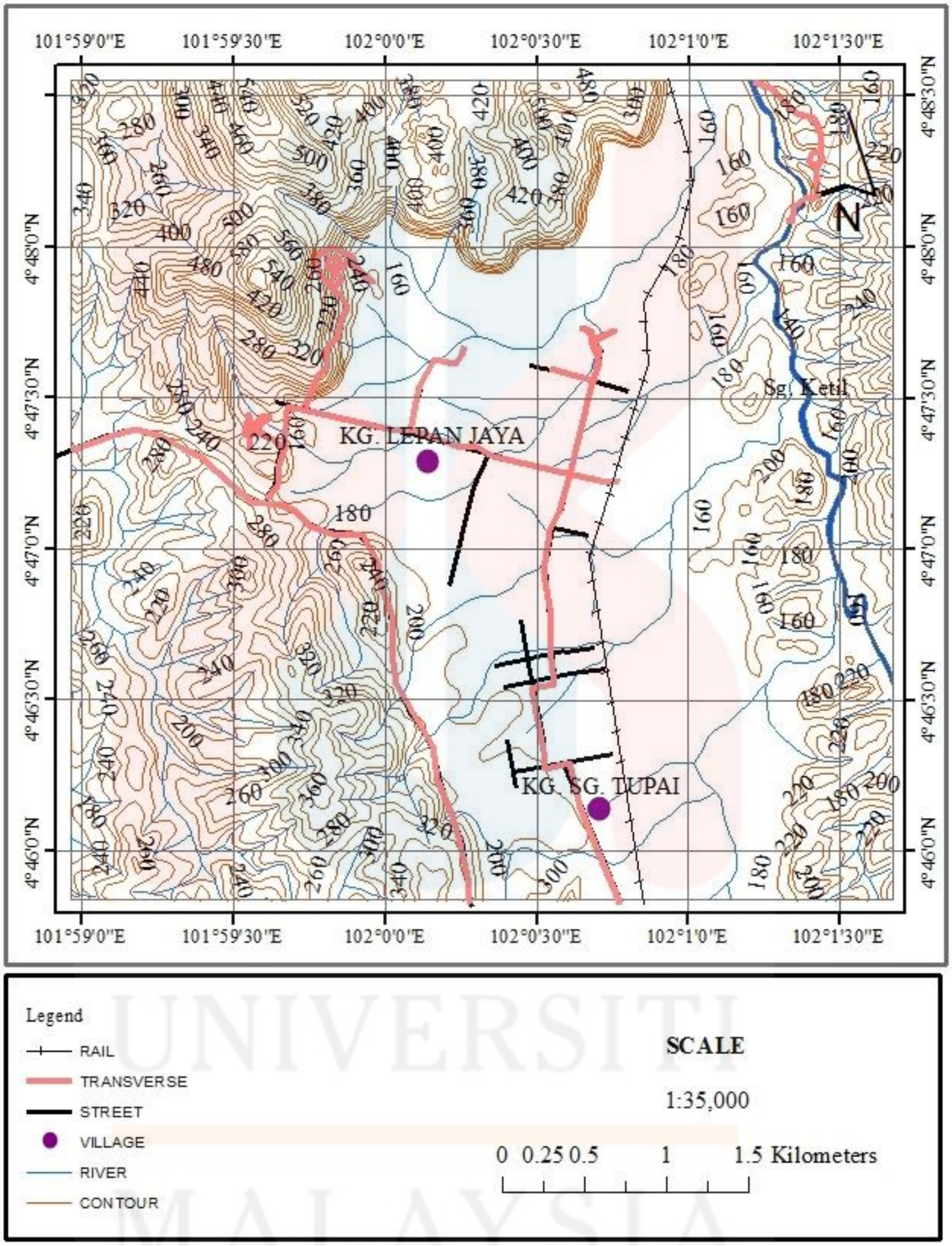

Figure 4.1: Transverse map of the Kampung Lepan Jaya

4.2 Geomorphology

Geomorphology is the study of landform and the processes that involves in the formation of the landform. The processes incudes tectonics and regional structure, fluvial sequences, fluvial processes and landforms, mass movement, slopes processes, hillslopes and soil erosion, weathering, karst and soils.

Geomorphology can be divided into endogenic process and exogenic process. Endogenic process is geological process that occur beneath the surface of Earth. It is associated with energy originating in the interior of solid Earth. Endogenic processes consist of plate tectonic, Earthquake and volcanic activities. Exogenic process also known as gradational process consist of aggradation and degradation processes. Example of aggradation process is deposition while examples of degradation processes are mass wasting, weathering and erosion.

Different landform will be produced depending on the geomorphological activities on the area. The topography, drainage pattern and weathering in the study area are observed to study the geomorphic change in Kampung Lepan Jaya. Few specimens are taken for microscopic observation on the mineral contents.

4.2.1 Topography

A topography map is a detailed map or chart of the features of a relatively small area, district, or locality. It includes the mountains, hills, creeks, and other bumps and lumps on a particular hunk of earth. A topography map can be shown as a graphic representation of the surface features of a place or region on a map, indicating their relative positions and elevations with descriptions or analysis of the relations among its components such as relation between contour, drainage patterns and social activities in the area.

Karst is the landscape underlain by limestone that has been eroded by dissolution including dolomite, and gypsum which producing ridges, towers, fissures, sinkholes, and other characteristic landforms. Figure 4.2 is the example of karst geomorphology. Karst regions also capable to contain aquifers which area providing large supplies of water.

The topography map of the study area has variety in elevation as shown in Figure 4.2 and Figure 4.3. The highest elevation value is 580 m in the northwest area of the map. The geological structure of the highest point is limestone karst tower. The lowest elevation value in the map is 140 m which is the palm oil plantation in the west. The average elevation value is 200 m that covers mainly the center area of the map. This area is used for residential area, palm oil plantation.

Figure 4.2: Limestone karst tower

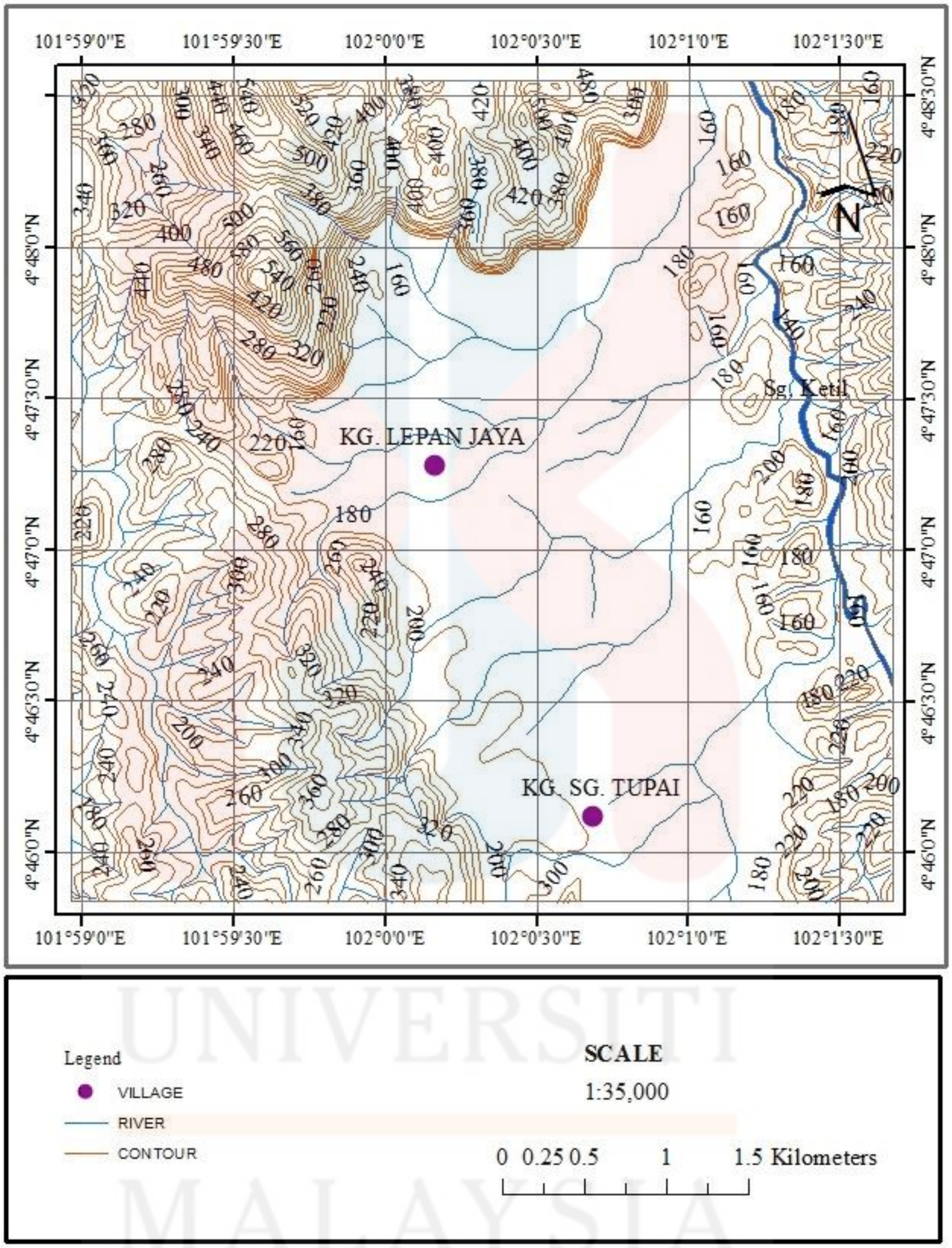

Figure 4.3: Topography map of Kampung Lepan Jaya

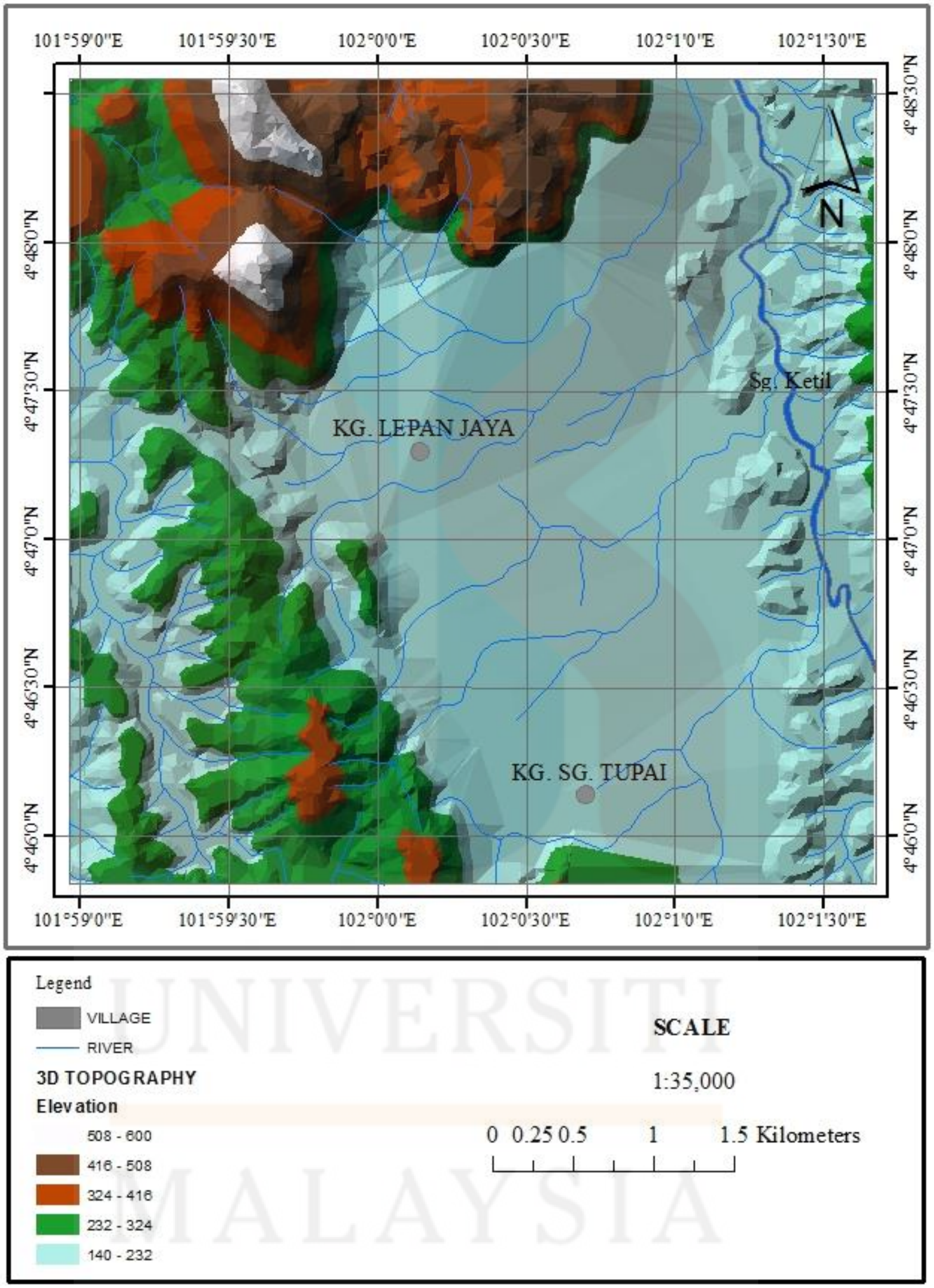

Figure 4.4: 3D topography map of Kampung Lepan Jaya

4.2.2 Drainage pattern

River drainage pattern is the pattern formed by the streams, rivers, and lakes in a particular drainage basin. They are influenced by the topography of the land, hardness of rocks and the gradient of slope. There are six drainage patterns for river which are annular, dendritic, parallel, radial, trellis and rectangular drainage patterns as shown in Figure 4.4.

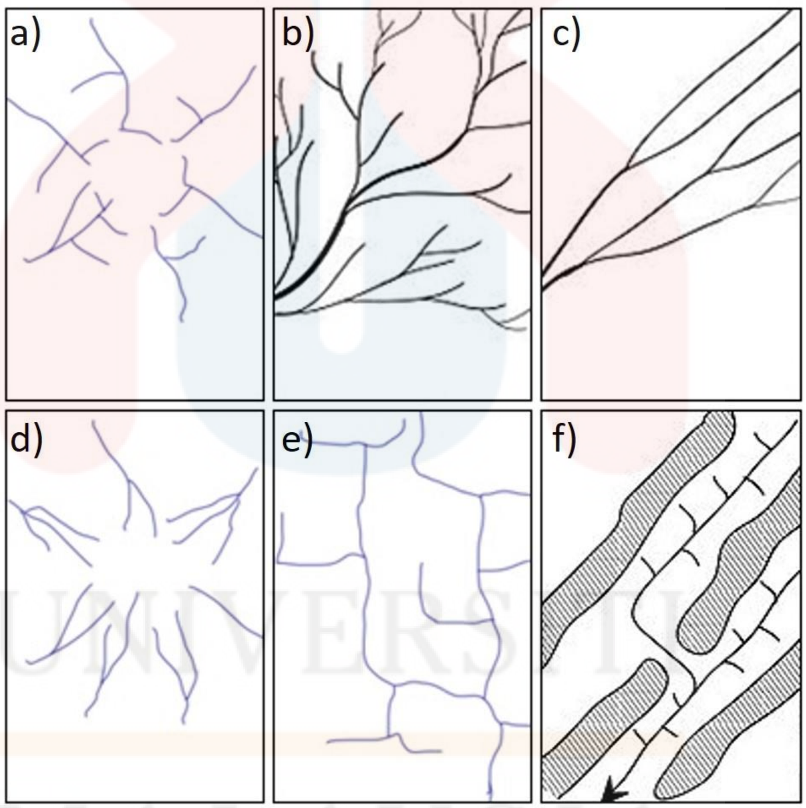

Figure 4.5: Drainage patterns; (a) Annular, (b) Dendritic, (c) Parallel, (d) Radial, (e) Rectangular and (f) Trellis drainage patterns.

The annular drainage pattern is a drainage with ring-like pattern usually present in dome or basin structures, running through the belt of weak rock. It is usually displayed by tributaries running along a dissected structural dome or basin where sedimentary rocks with different degrees of hardness are exposed due to erosion.

Dendritic drainage pattern are the most common drainage pattern. A dendritic drainage pattern occurs when the tributary systems subdivides headway like the limbs of a tree. This pattern of flow of streams and rivers develops in an area which comprises rocks with a uniform structure. The direction taken by the river and its tributaries is largely dependent on the slope. Dendritic systems form in V-shaped valleys resulting the rock types to be impervious and non-porous (Press and Siever, 1982).

Parallel drainage pattern is the pattern in which small rivers flow almost parallel to one another. The sloping surface usually consisted of rock with uniform resistance and exist mostly in steep slope. Because of the steep slopes, the streams are straight and all flow in the same direction which resulting in few tributaries.

A radial drainage pattern occurs when the tributaries flow radially outward and downward from a central topographic high. The water channels flow from around the top if a hill or the top of a dome type feature in numerous directions like the spokes of a wheel. This type of pattern is typical of volcanic cones, isolated hills, and elevated domes. An antiradial pattern develops in a basin where all tributary streams flow radially inward toward a common low area (Press and Siever, 1982).

Rectangular drainage pattern is the pattern that have two directions of stream joining at approximately right angles. It usually formed at rocks that have similar resistance to erosion. It is a pattern influence by faults or joints that intersect at high angles and similar to the trellis pattern.

A trellis drainage pattern occurs where subparallel streams erode a valley along the strike of less resistant formations. It is a rectangular shaped drainage pattern that develops where bands of rocks vary in resistance. The flowing water can erode the soft rocks and thus flows along the bands of soft rock. These beds are usually steeply dipping and may be part of a fold system (Press and Siever, 1982).

In the Kampung Lepan Jaya, there are three observable drainage patterns. There are antiradial, dendritic and parallel drainage patterns as shown in Figure 4.5. The drainage pattern that form in the northwest of the study area formed the antiradial drainage pattern as the tributaries flow from surrounding higher topography into central lower topography. In the southwest of the study area, dendritic drainage pattern is formed due to variation of slope elevation. Parallel drainage pattern that form in the west of study area is tributaries running through due to steep slope.

Based on the contour and drainage pattern, the water catchment area is marked in Figure 4.6. Water catchment area is the area that collect rainwater and forms the tributaries to flow into the river.

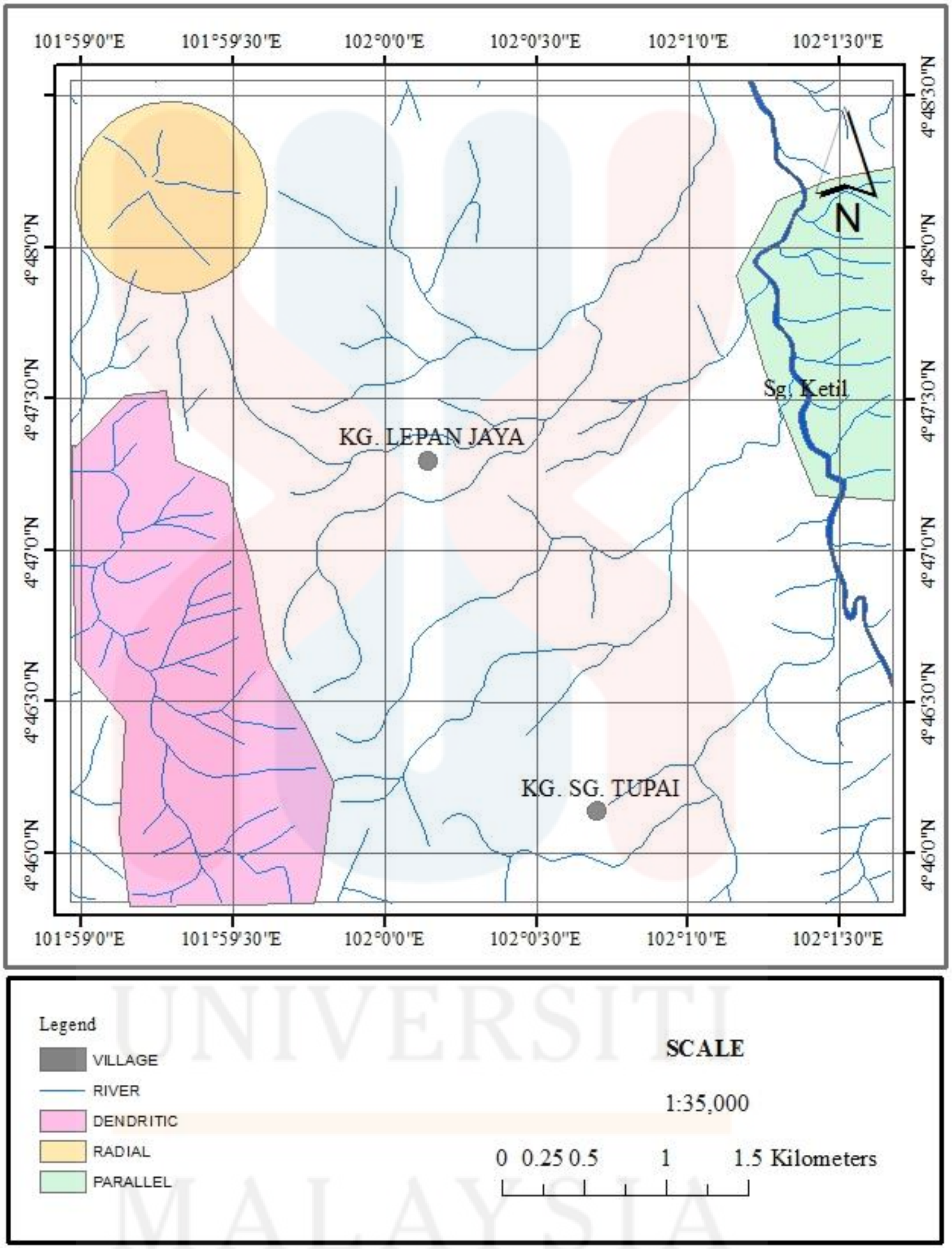

Figure 4.6: Drainage map of Kampung Lepan Jaya

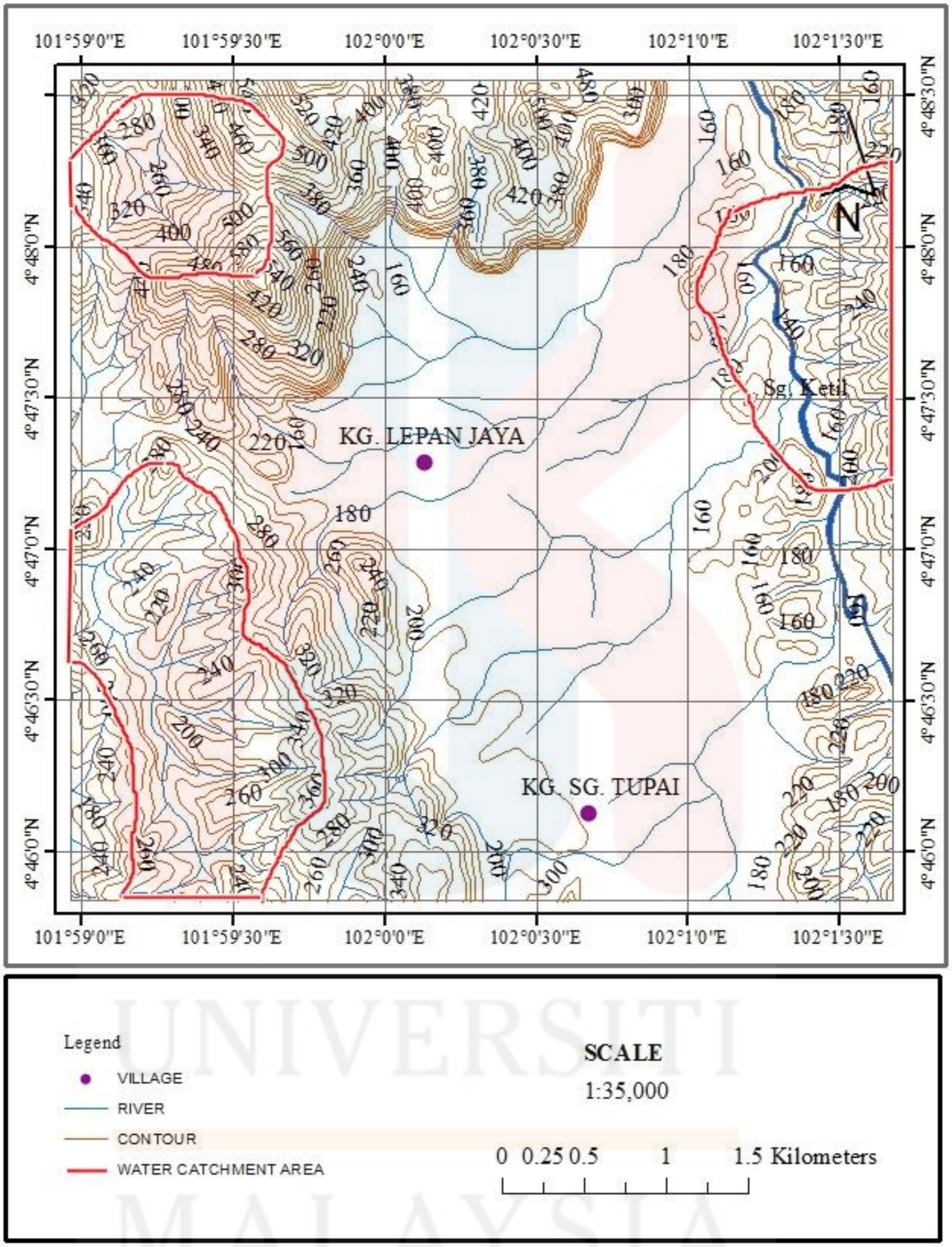

Figure 4.7: Map of water catchment area of Kampung Lepan Jaya

4.2.3 Weathering

Weathering process is the mechanical, chemical and biological processes of breaking down and decomposition of the rock. Mechanical weathering is the weathering process that cause physical disintegration of exposed rock without any change in the chemical composition of the rock. Chemical weathering cause the exposed rock to undergo chemical decomposition which change the chemical and mineralogical composition of the rock. The biological weathering is the weathering process resulted by biological actions either by plants or animals.

In the study area, results of physical and chemical weathering process are observable as shown in the Figure 4.7. The tributary that enter the limestone karst shows weathered area around the water channel. The geomorphology formed on the limestone is caused by the actions of water movement that seep and infiltrate the joint in the limestone karst.

Figure 4.8: Infiltration of tributary into limestone karst

The next weathering evidence occurred at north of the study area. The biological weathering is identified on the plant activities as it burrow it trunk and roots into the limestone karst (karst tower). These activities caused cracks to appear on the karst as the limestone become weak. The weakening of the limestone increase the weathering activities on the karst and the potential of limestone geohazard as shown in Figure 4.8.

Figure 4.9: Example of biological weathering showing a tree burrowing into the limestone karst causing the breaking down of the rock.

4.3 Stratigraphy

The study area mainly consisted of limestone as it dominated 60% of the study area. These limestone consisted of karst tower, interbedded of limestone and mudstone, and interbedded of mudstone and sandstone.

The Figure 4.10 shows the stratigraphy of a karst tower. Based on the stratigraphy of the karst tower, geomorphological process that occurred is an uplift with the limestone located above the interbedded of limestone and mudstone. With this, it can be assumed that limestone is younger than mudstone according to the superposition law.

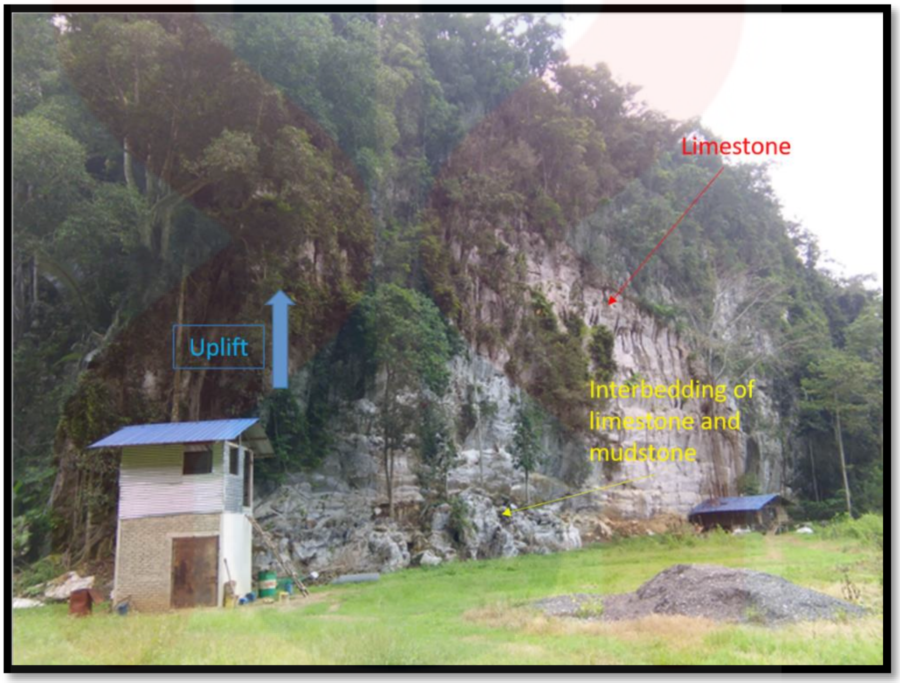

Figure 1.10: The karst tower shows the lithology of limestone (top) and interbedded limestone and mudstone (bottom)

Figure 4.11 shows the lithology on the study area. On the upper-left area of the research location, it mainly consisted of interbedded of sandstone and mudstone. On the west of the study area is consist of mudstone while the rest of the study area is limestone karst. Marble are discovered in few places northeast of the study area. Fluvial lithology is discovered along the main river.

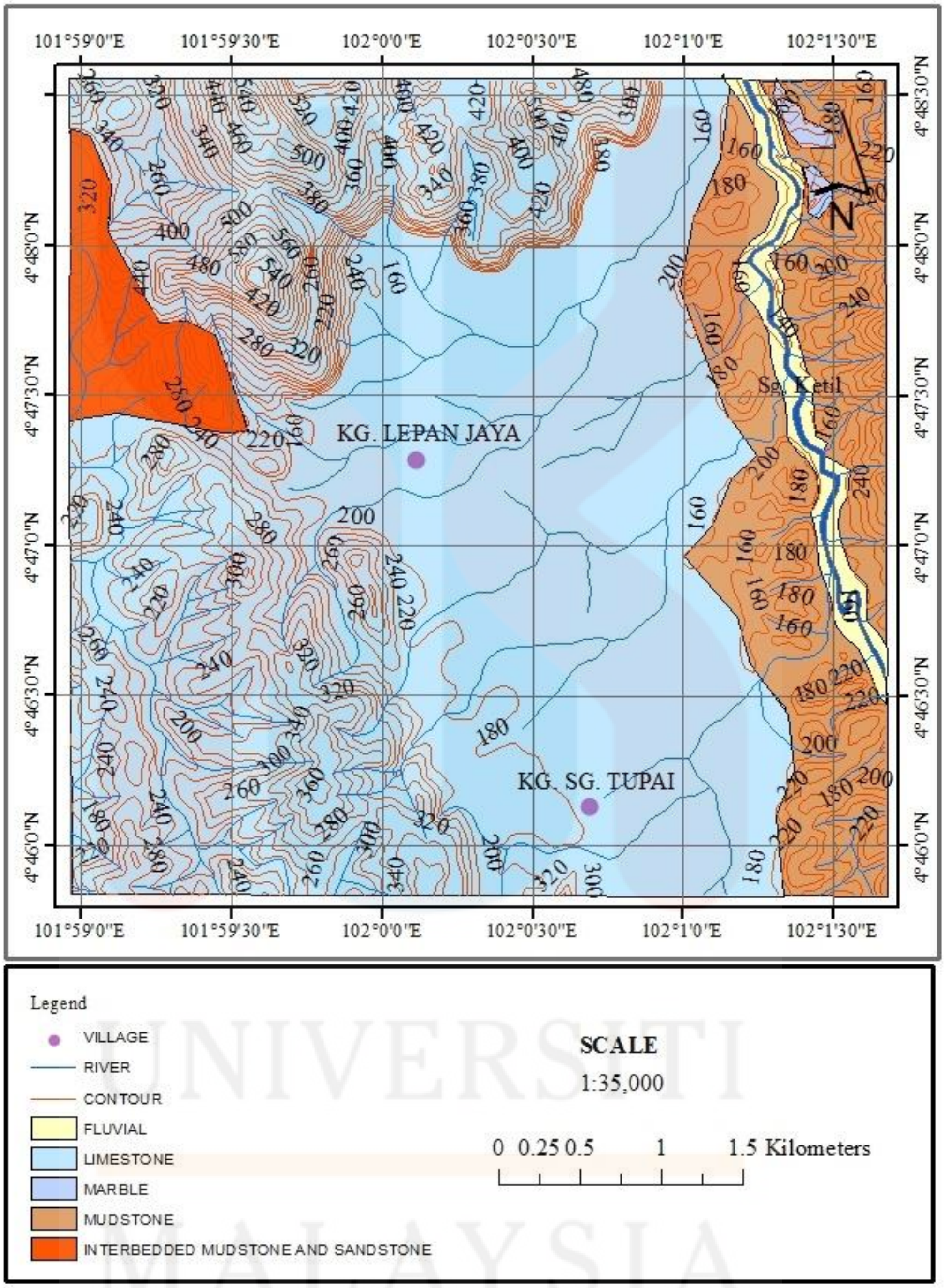

Figure 4.11: Geological map of Kampung Lepan Jaya

The lithology found in Kampung Lepan Jaya is recored in the Table 4.1. There are four lithology found which are limestone, marble, sandstone and mudstone. Figure 4.12 shows the image fluvial located at N 04^{O} 48’ 04.7”, E 102^{O} 01’ 20.7” with elevation of 193 meter.

Table 4.1: Lithology of Kampung Lepan Jaya

ERA	PERIOD	ROCK UNIT	DESCRIPTION	LITHOLOGY	
Cenozoic	Quartenary	Sedimentary	Quaternary sediments	Fluvial deposits	
Paleozoic	Permian	Gua Musang Formation	White, black or grey in colour with fine crystalline texture	Limestone	
			White colour with crystalline texture	Marble	
			Reddish to brown colour with fine grain size	Mudstone	
			Reddish to brown colour with coarse grain size	Sandstone	

Figure 4.12: Fluvial

4.3.1 Petrography Analysis

Sample 1

The rock sample in Figure 4.13 is taken at coordinate N 04^{O} 47’ 26.0”, E 102^{O} 00’ 04.7”. The outcrop is located at small rubber plantation. When tested with hydrochloric acid (HCl), the rock shows intense reactions and forming bubbles. Thus is can be interpreted that this rock is limestone.

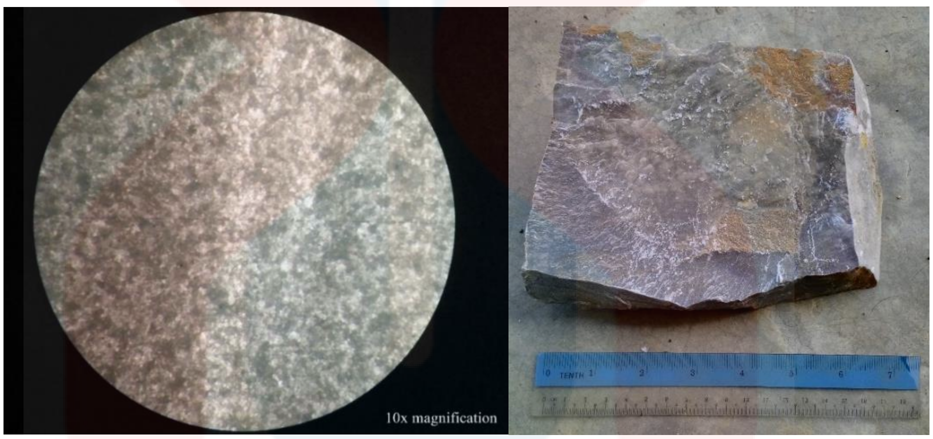

Figure 4.13: Thin section (cross-polarized) and hand specimen of Sample 1

Under microscope, the sample shows greyish white crystalline texture which shows twinkling effects. The interference color also high which is white. Adding to the fact that this rock reacts to HCl, it can be conclude that this mineral is calcite and the rock sample is limestone.

Sample 2

The rock sample in Figure 4.14 is collected at palm oil plantation with coordinate N 04^{O} 48’ 10.5”, E 102^{O} 01’ 22.4”. This sample is white in color with crystalline texture and shows little to none reaction to the HCl. By observation, this rock is interpreted as marble.

Under the microscope, the rock sample consist of the mineral calcite with greyish colour and clear crystalline texture which shows twinning effects and high interference color. It also shows white quartz mineral that has glassy luster and hexagonal crystal shape. Olivine mineral can also be seen. It is the mineral with vitreous luster, conchoidal fracture and granular texture.

Figure 4.14: Thin section (cross-polarized) and hand specimen of Sample 2

<u>Sample 3</u>

This sample is collected at coordinate N 04^{O} 47’ 24.3”, E 102^{O} 59’ 33.1”. The location of this outcrop is karst tower. Moreover, when this rock is tested with hydrochloric acid (HCl), it shows intense reactions and forming bubbles. Thus is can be interpreted that this rock is limestone.

Under the microscope, the rock sample shows the composition of mineral calcite, greyish crystalline texture with high interference color. It also shows white mica mineral that has Pearly to vitreous luster. Small olivine mineral can also be seen located which shows colorful and vitreous luster. Based on the reaction of rock sample to HCl, it is interpreted as limestone.

This limestone in Figure 4.15 shows few differences in mineral contents may be due to this outcrop located near the lineament compared to Sample 1 limestone.

Figure 4.15: Thin section (cross-polarized) and hand specimen of Sample 3

4.4 Structural Geology

Structural geology is the study of the three dimensional distribution of large bodies of rock, their surfaces, and the composition of their inside in order to try and learn about their tectonic history, past geological environments, force and events that could have changed or deformed them.

In structural geology, the strike and dip of various outcrops are recorded but most of the outcrop in the study area did not show clear beds or strata. Strike is the direction of the line that is formed by the intersection of the plane of the rock bed with a horizontal surface while dip is the direction in which the steepest angle is formed between the plane of the rock bed and the horizontal surface. Moreover, the existence of lineament on the map is marked and joint analysis is done to study the structural geomorphology in the study area.

Most of the study area is made up with lime stone karst structure such as karst tower and limestone cave such as sown in figure 4.16.

Figure 4.16: Karst features in study area.

4.4.1 Lineament

A lineament is a linear feature or detail of a face, body, or figure, considered with respect to its outline or contour which is an expression of an underlying geological structure such as a fault. It is used as distinguishing features to reflect underlying crustal structure. Figure 4.17 shows the lineament in Kampung Lepan Jaya while Figure 4.18 shows the lineament in the study area.

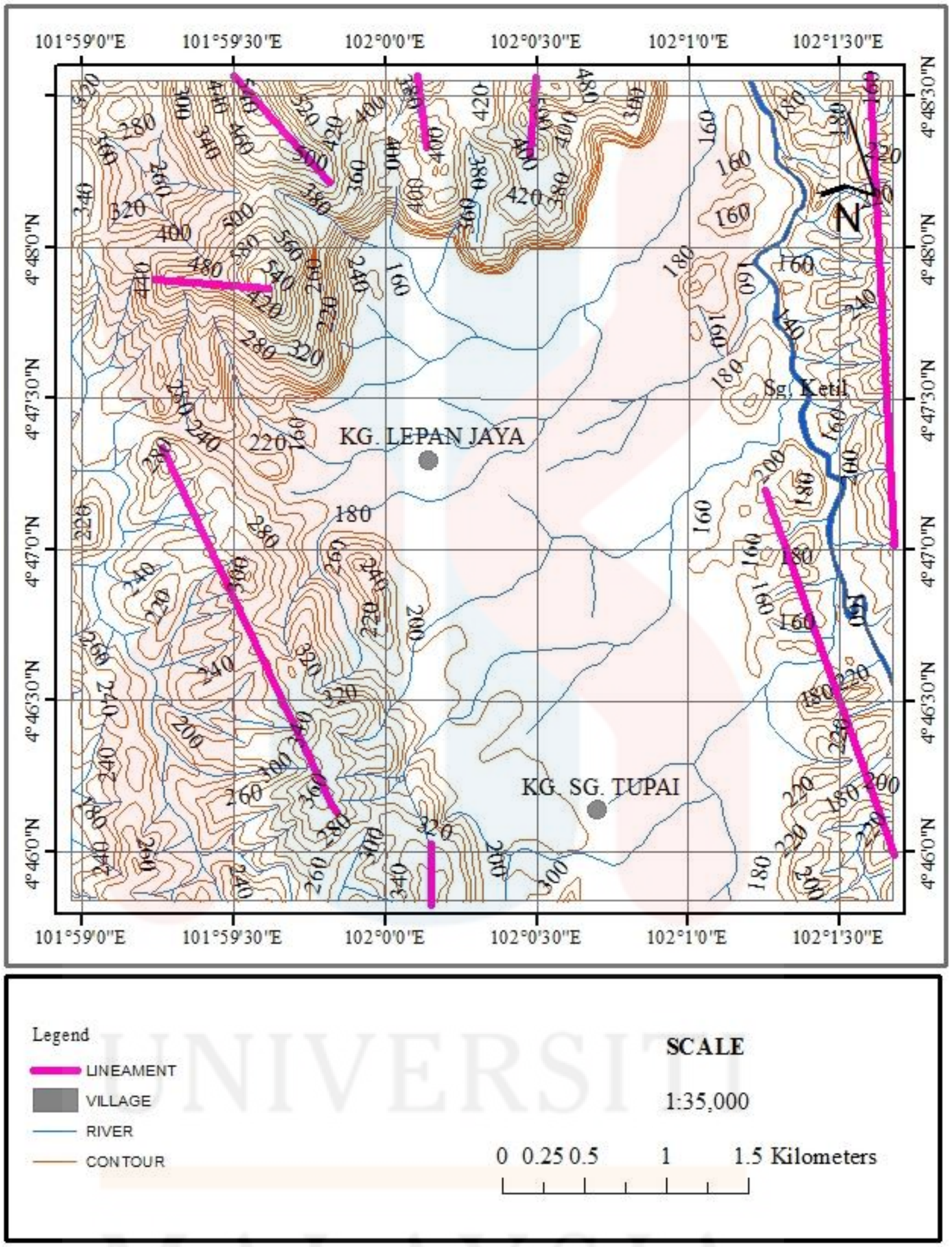

Figure 4.17: Lineament map of Kampung Lepan Jaya

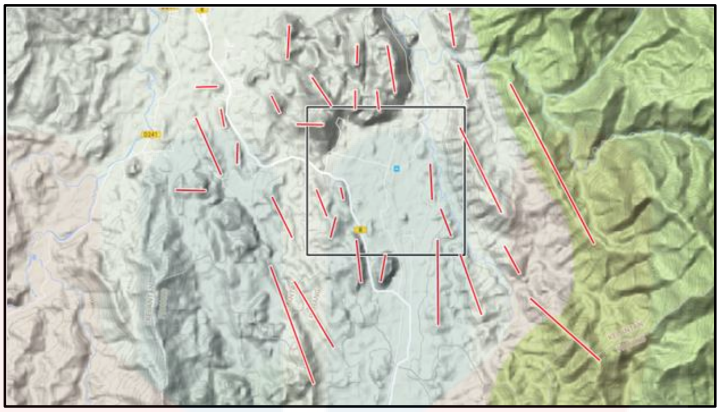

Figure 4.18: Lineament of study area. Source: Google Earth.

4.4.2 Joint analysis

A joint is a fracture of natural origin in the continuity of either a layer or body of rock that lacks any visible or measurable movement parallel to the plane of the fracture. A joint is created by the movement of rock body.

The joint analysis is used to analyses and projects the direction of movement or forces in the rock body. It can be integrated with lineament existed to find the structural geology in the rock body such as fault. Three joint analysis are conducted around the study area.

In Figure 4.19 of Locality 1, the joint analysis show that the direction of $\sigma1$ force is N 340^o W which is the northwest direction of the locality. Then, the $\sigma3$ force is in the direction of N 70^o E. Then, Figure 4.20 of Locality 2 shows that the force is diverging with the highest $\sigma1$ force in the direction N 5^o E and $\sigma3$ force in the direction N 275^o W. Lastly, Figure 4.21 of Locality 3 shows the $\sigma1$ force is in direction of N 65^o E. The perpendicular $\sigma3$ force is in the direction of N 335^o W of Locality 3.

Table 4.2: Joint Analysis 1

Joint Analysis 1 (N 04^{O} 47’ 26.0”, E 102^{O} 00’ 04.7”)				
340	293	337	349	343
330	292	335	352	341
334	274	325	350	348
324	333	327	337	350
335	326	318	273	327
340	336	347	274	272
341	335	350	272	334
319	337	348	275	335
227	339	352	272	311
338	334	341	269	308
328	337	338	265	309
326	340	333	259	340
325	336	350	336	61
326	296	346	342	62
335	359	338	339	83
346	343	345	345	80
343	333	338	355	83
280	332	336	343	345
262	182	357	345	337
265	144	340	347	352

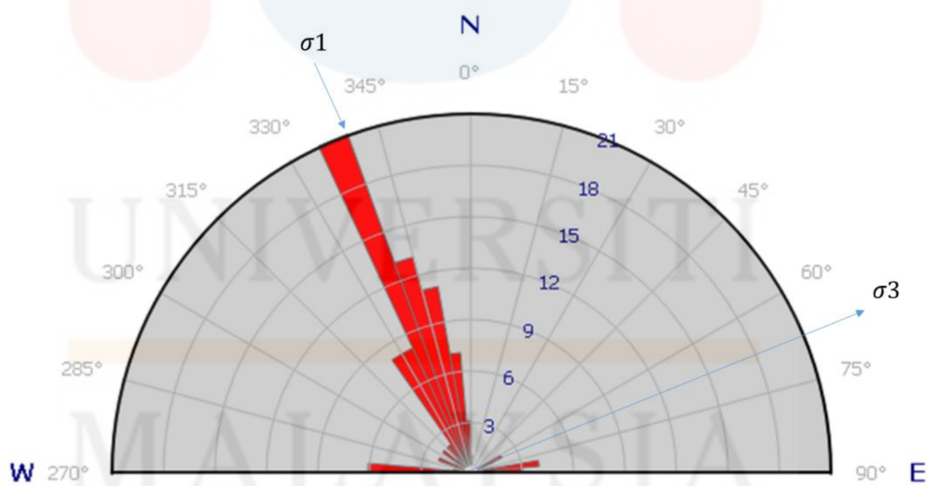

Figure 4.19: Joint Analysis 1

Table 4.3: Joint Analysis 2

Joint Analysis 2 (N 04^{O} 47' 41.5", E 102^{O} 00' 41.2")				
10	282	347	40	255
56	306	343	44	276
5	296	35	50	163
12	27	5	60	82
71	25	9	59	67
4	355	33	28	44
22	356	35	71	38
50	32	116	76	42
70	6	155	0	331
37	354	169	337	350
53	312	96	335	16
39	58	350	346	45
24	51	342	35	41
17	35	329	322	341
20	345	332	330	355
26	311	11	305	245
0	306	321	308	251
10	35	308	344	175
267	350	319	334	158
268	341	313	326	163

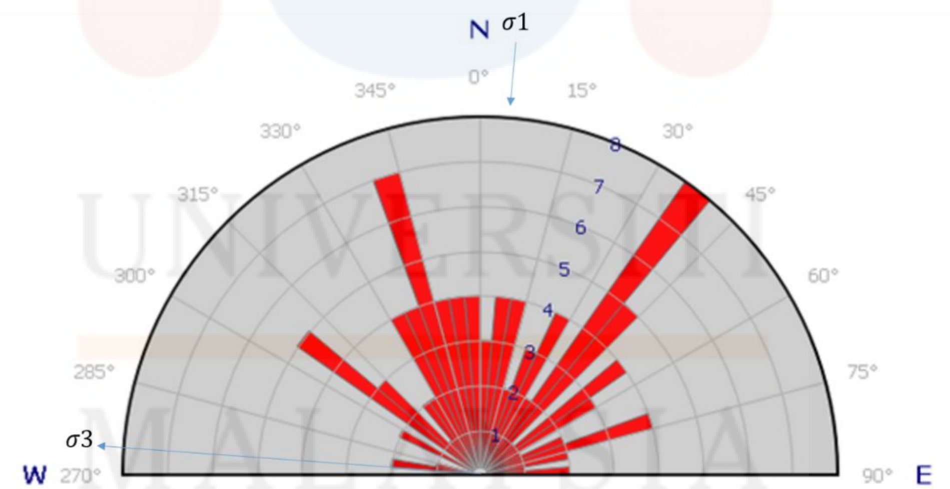

Figure 4.20: Joint Analysis 2

Table 4.4: Joint Analysis 3

Joint Analysis 3 (N 04^{O} 46' 56.7", E 102^{O} 00' 31.4")				
205	152	74	185	243
201	249	60	234	245
210	251	65	155	241
299	171	41	242	245
202	75	52	224	154
17	169	112	173	249
321	184	69	139	240
313	242	82	197	243
255	248	60	199	79
248	150	70	156	77
222	136	78	169	245
251	152	74	204	85
186	73	156	16	60
232	140	152	16	79
244	133	293	348	67
242	49	331	18	89
238	65	207	11	164
200	51	262	11	174
139	19	211	215	135
147	25	254	240	247

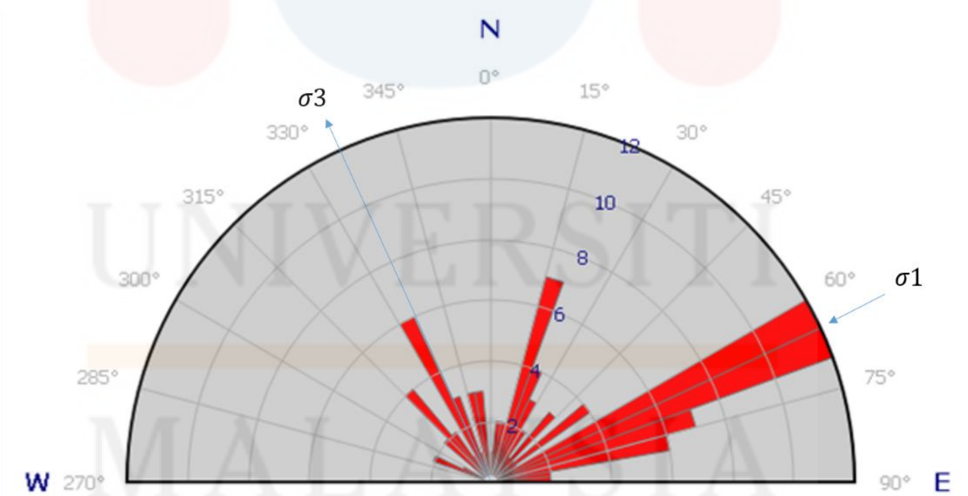

Figure 4.21: Joint Analysis 3

The location of the Joint Analysis 1, Joint Analysis 2 and Joint Analysis 3 are taken is shown in the map of Figure 4.22.

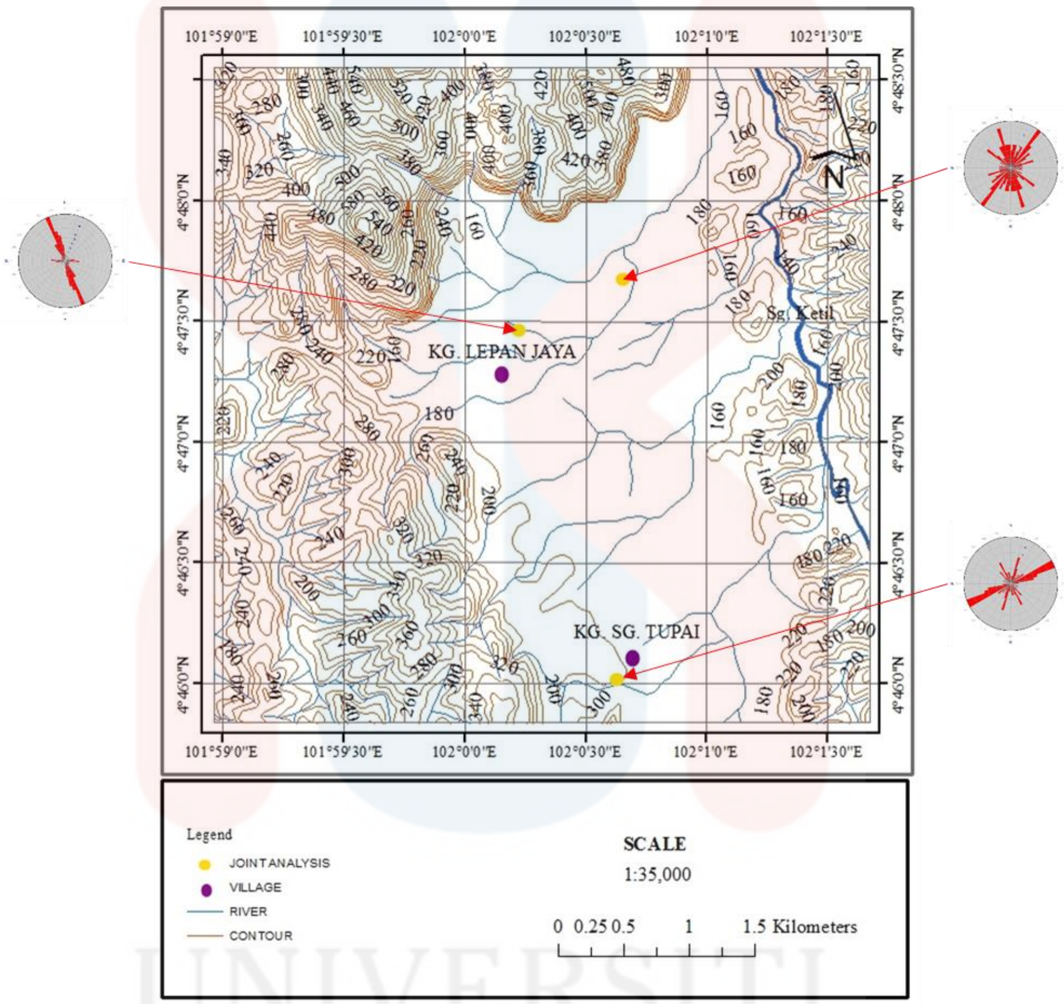

Figure 4.22: Joint Analysis of Kampong Lepan Jaya

4.5 Historical Geology

Historical geology can be identified through the stratigraphy of an area, the structural geology that form on the rock and through the existence of fossil. A fossil is the naturally preserved remains or traces of animals or plants that lived in the geologic past. There are two main types of fossils; body and trace. Body fossils include the remains of organisms that were once living and trace fossils are the signs that organisms were present. Fossils are most commonly found within sedimentary rocks due to the favourable conditions of burial and limited alteration through time. Sedimentary rocks form on the Earth's surface as sediment accumulates in rivers, lakes and on the seafloor in particular.

A fossil of a plant's root is identified on a karst tower north of the study area as shown in Figure 4.24. This shows that the fossiliferous limestone is a land or forest in the past.

Figure 4.23: Body fossil of plant's root (in the box)

CHAPTER 5

PREDICTION OF LIMESTONE GEOHAZARD BY USING ELECTRICAL RESISTIVITY IMAGING (ERI) AT KAMPUNG LEPAN JAYA, GUA MUSANG, KELANTAN

5.1 Introduction

Four line survey of Electrical Resistivity Imaging (ERI) is done at four different location. These location are chosen near the lineament and steep contour because it is easier to investigate the different stability of subsurface. Figure 5.1 shows the equipment used in the ERI field survey.

The survey is done using the ABEM Terrameter S4000 with other field equipment to collect the data of the subsurface and RES2DINV software is used to convert the data to ERI image for analysis. Figure 5.2 shows the location of the first and the last electrodes which formed each survey line.

Figure 5.1: ABEM Terrameter S4000 and related equipment for ERI survey.

ERI SURVEY OF STUDY AREA

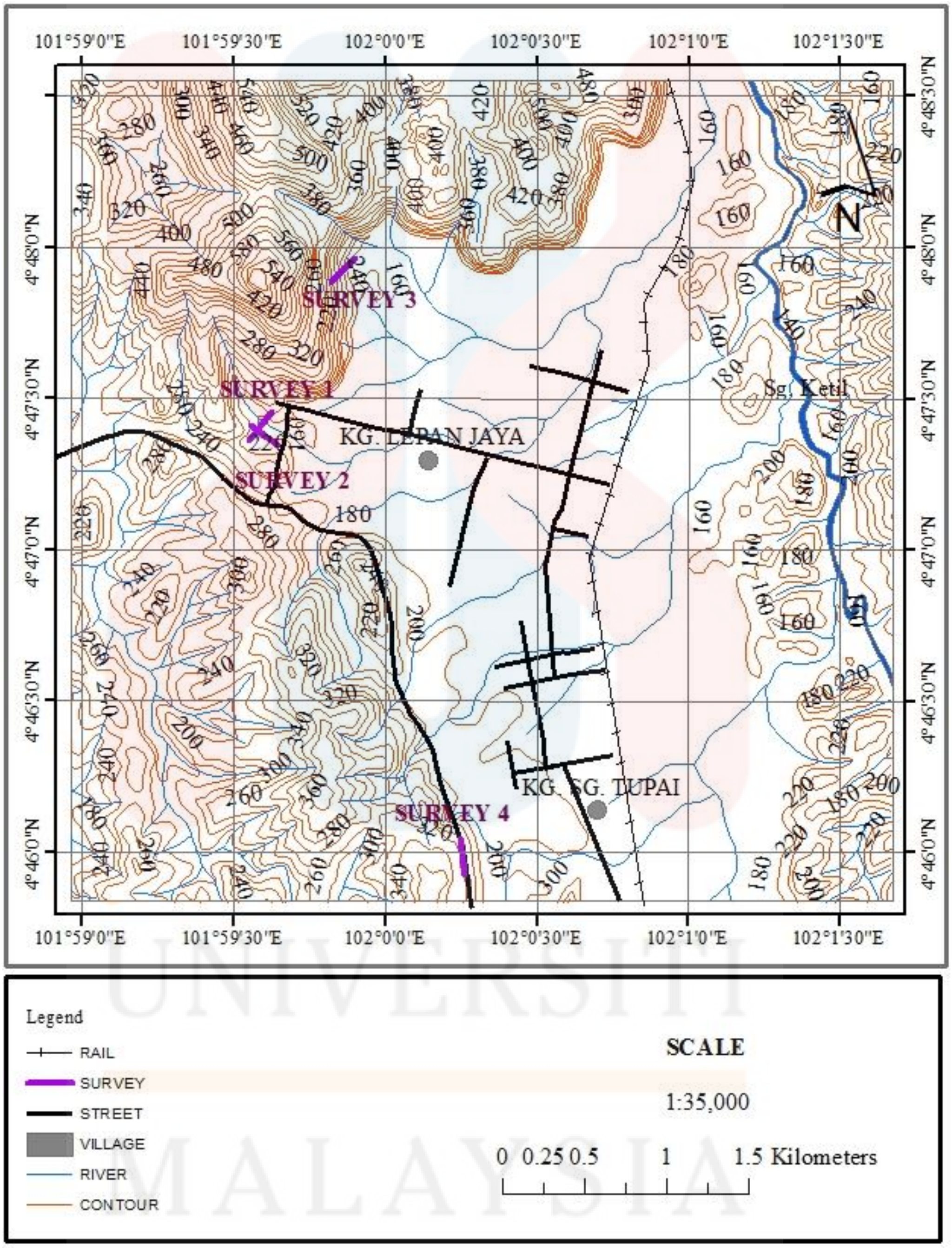

Figure 5.2: ERI survey of study area

In the analysis, the type of rock is determined using the resistivity of the rock based on the Earth Material Resistivity (Palacky, 1988). Table 5.3 shows the resistivity table of rock used as reference.

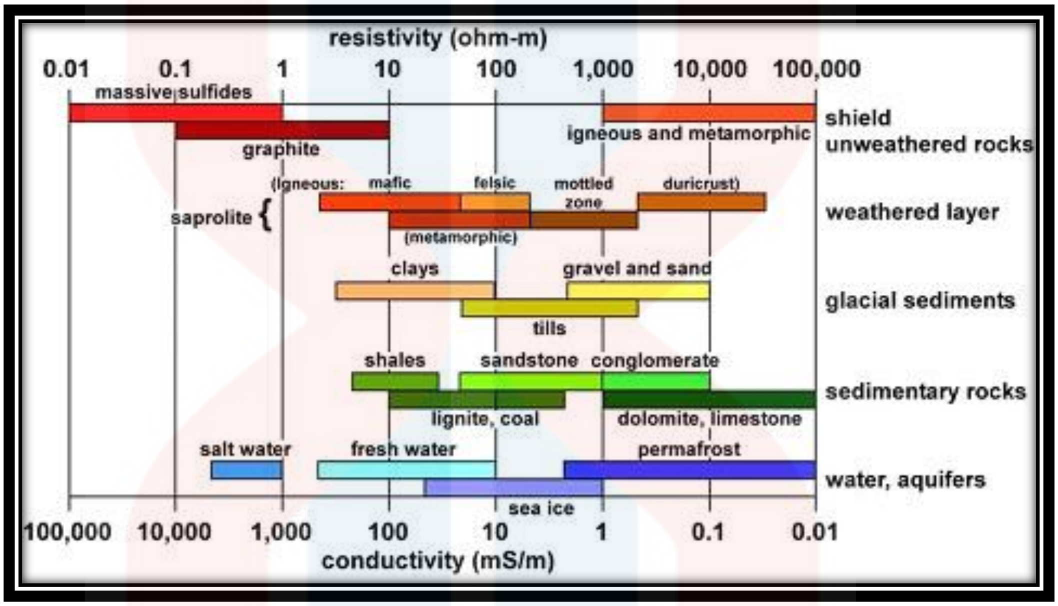

Figure 5.3: Earth Material Resistivity (Palacky, 1988)

The study area is consisted of sedimentary rocks and the ERI survey is done in the limestone lithology area to study the probability of limestone geohazard. The ERI survey is a survey done to investigate the subsurface condition based on the resistivity of rock or soil. The electrical resistivity of each rock is different and also influenced by its dry or wet condition. In this study, ERI survey is used to find the probability of limestone geohazard in subsurface which is sinkhole.

5.2 Interpretation of the ERI survey

Before the interpretation of ERI survey is done, few error points that occur during data collection is removed to ensure smooth image is produced. These error data points occur maybe due to dry condition of the field during survey that caused drastic change of resistivity in the subsurface rock. Thus, it will result in wrong interpretation of the survey. Figure 5.4 shows the example of error data point.

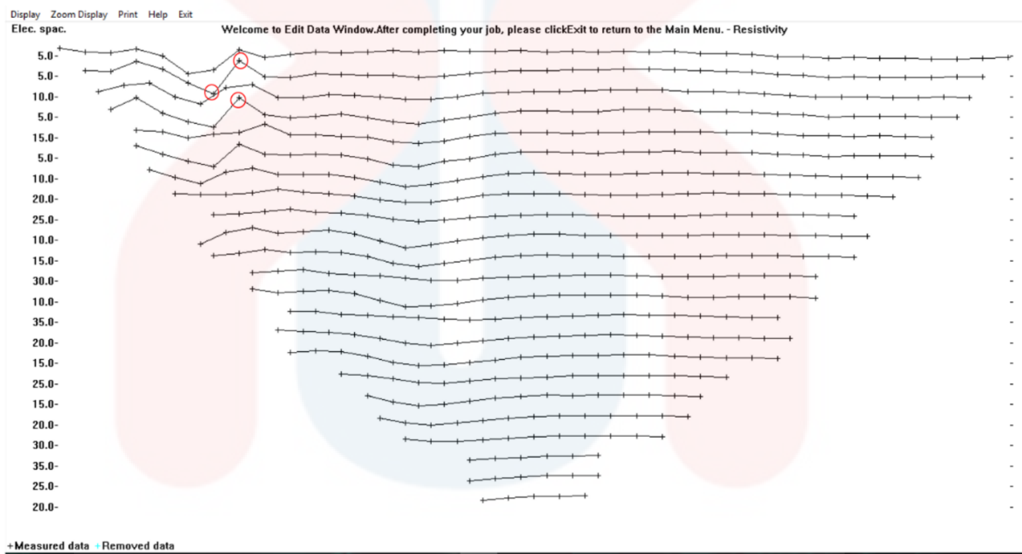

Figure 5.4: Example of error data point (data point in red circle)

After the elimination of the error data point, the data point is expressed as an image using the RES2DINV software. The subsurface is differentiate based on the zones formed by different color and resistivity for easy interpretation of data.

5.2.1 Resistivity Survey 1

The Resistivity Survey 1 is done at the location from N 04º 47' 26.5", E 101º 59' 37.5" to N 04º 47' 23.4", E 101º 59' 33.5". The survey line is 160 m long with 4 m spacing between each electrodes. This ERI survey used the Schlumberger array. Figure 5.5 shows the ERI image of Resistivity Survey 1. That ERI image contains four zones. The zones is named Zone A, Zone B, Zone C and Zone D respectively.

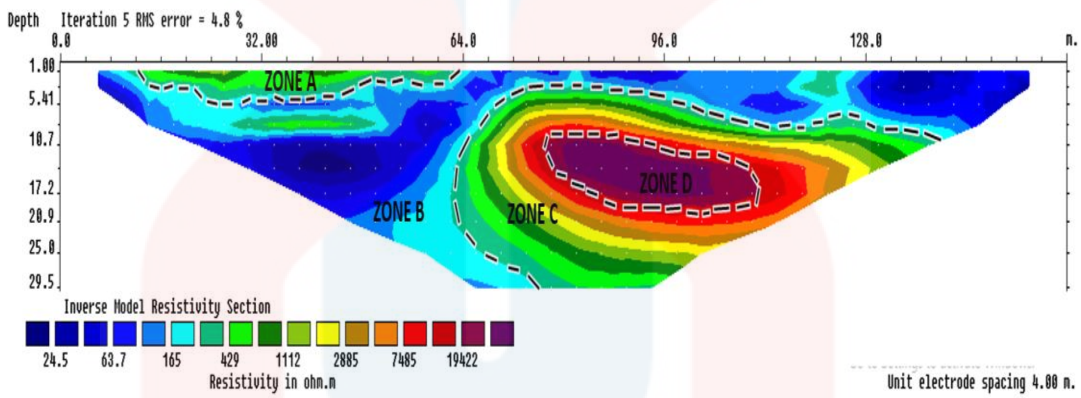

Figure 5.5: Resistivity Survey 1

In Figure 5.5, Zone A represents the rocks with resistivity range around 200 ohm to 1100 ohm. This resistivity usually represent saturated sandstone or sandstone in wet condition. The zone is from electrode point 12m to 64m with the depth from 0 to 5 m. This sandstone has weak strength and heavily influenced with the surrounding water.

Zone B is the areas consisted of the rock with the depth from 5 m to 29.5 m from electrode point 4m to point 64m and the rock with depth of 8 m from electrode point 64m to point 156m. The resistivity of the zone is around 10 ohm to 200 ohm which are the resistivity of fresh water, clay and saturated sandstone. This zone is interpreted as the area of saturated sandstone with weak strength and high water content that is the cause of breaking or sinking of soil. The low resistivity of the top right area of the zone is due to tributary running through the survey line while the low resistivity in bottom left area shows possible existent of water aquifer in electrode point 44m and depth 15 m. These result shows that Zone B has high probability of sinkhole in the bottom left area of the zone.

Zone C is the area with medium resistivity that is colored from green to red. The resistivity of this zone is ranged from 429 ohm to 7,485 ohm. This zone is located from electrode point 64 m to 140 m with the depth from 5m to 29.5 m. This area representing the sandstone, conglomerate, limestone or dolomite. This area formed medium-strong and stable rocks.

Zone D is the area with high resistivity from 7,485 ohm to more than 19,422 ohm as shown in the color range from purple and dark purple. The zone is located from electrode point 78m to 108m with the depth from 10.7 m to 20.9 m. As the study area is consisted of mainly sedimentary rock, this high resistivity area is likely resulted by strong conglomerate, limestone or dolomite which has resistivity range from 1,000 ohm in wet condition to 100,000 ohm in dry condition. This shows that the zone has strong and stable rock.

This survey shows that Zone B has high probability of sinkhole. The existence of possible water aquifer may influence the surrounding Zone A and Zone C. This can cause the weakening of Zone C by dissolving of limestone in water and increase the probability of sinkhole.

5.2.2 Resistivity Survey 2

The Resistivity Survey 2 is done from coordinates N 04º 47' 34.5", E 101º 59' 48.0" to N 04º 47' 40.6", E 101º 59' 49.7". The survey line is 200 m long with 5 m spacing between electrodes. This survey used the Wenner array for ERI investigation. Based on Figure 5.6, the Resistivity survey is separated into five zones, from Zone A to Zone E.

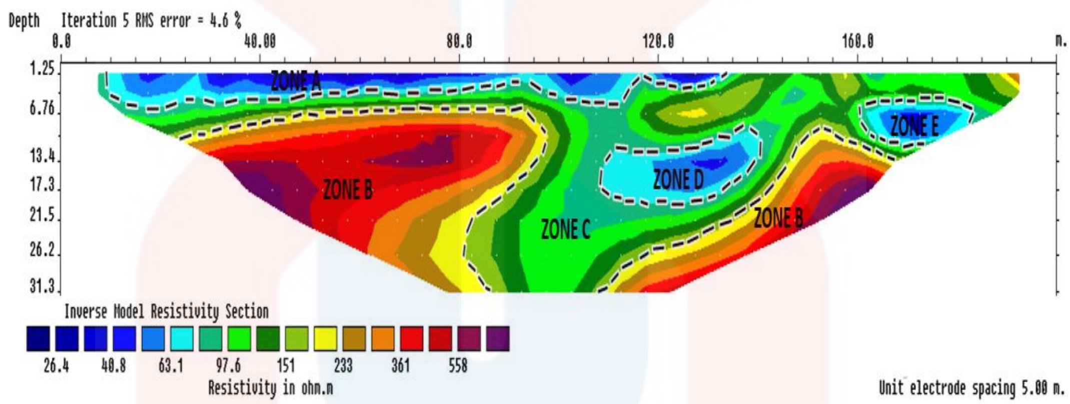

Figure 5.6: Resistivity Survey 2

Zone A is located from electrode point 10m to 135m with the depth of 6 m. This zone has resistivity ranged from 26.4 ohm to 63.1 ohm. This zone is likely consisted of clay, saturated sandstone and fresh water. The low resistivity of this zone may due to the existence of tributary running on the Earth surface. This zone shows that the roc has weak strength.

Zone B has resistivity range from 233 ohm to more than 558 ohm. This zone has depth of 6.76 m to 31.3 m and from electrode point 25m to 165m. This zone probably consisted of dry sandstone and has high strength.

Zone C is the area with resistivity range from around 97.6 ohm to 151 ohm and the depth until 31.3 m. This area represent the saturated sandstone and clay. The low resistivity of this zone is influenced by the fresh water from Zone A, Zone D and Zone E. This zone has weak rock strength but low probability of sinkhole.

Zone D is the area from electrode point 110m to 140m with the depth from 13.4 m to 21.5 m. The resistivity is ranged from 26.4 ohm to 63.1 ohm which consisted of resistivity for clay, saturated sandstone and fresh water. This zone shows the possibility of water channel in the subsurface which is the cause for low resistivity and weakening of rock. This zone shows little possibility of sinkhole.

Similar to Zone D, Zone E is the area with resistivity is ranged from 26.4 ohm to 63.1 ohm. Zone E is located from electrode point 160m to 180m with the depth of 67.6 m. This resistivity of this zone also represent the resistivity of clay, saturated sandstone and fresh water which may shows the existence of water channel in the subsurface. This zone shows higher possibility of sinkhole together with Zone D compared to the other zones.

Based on previous Figure 5.6, the Resistivity Survey of that area shows low probability of sinkhole. Most of the area has moderately high resistivity to electricity which represent stable and strong rock. The ERI survey shows that in the Zone D and Zone E contain weak rocks and probable existence of underground water channels. However, that area is surrounded by stable rock which makes it hard to collapse or sink.

The folding of rock of Zone B usually caused the weakening of the surrounding rocks but the area still stable based on the resistivity of the rocks. The existence of water channels in the subsurface can contribute to weakening of rock and higher probability of sinkhole in the future.

5.2.3 Resistivity Survey 3

Resistivity Survey is taken from coordinate N 04° 47' 56.4", E 101° 59' 51.8" to coordinate N 04° 47' 50.8", E 101° 59' 49.8". The survey is done using the Schlumberger array of 200 m long survey line with 5 m spacing between electrodes. Figure 5.7 shows the ERI image of the Resistivity Survey 3. The ERI survey is marked with three different zones, Zone A, Zone B and Zone C, which represent the zones with different resistivity.

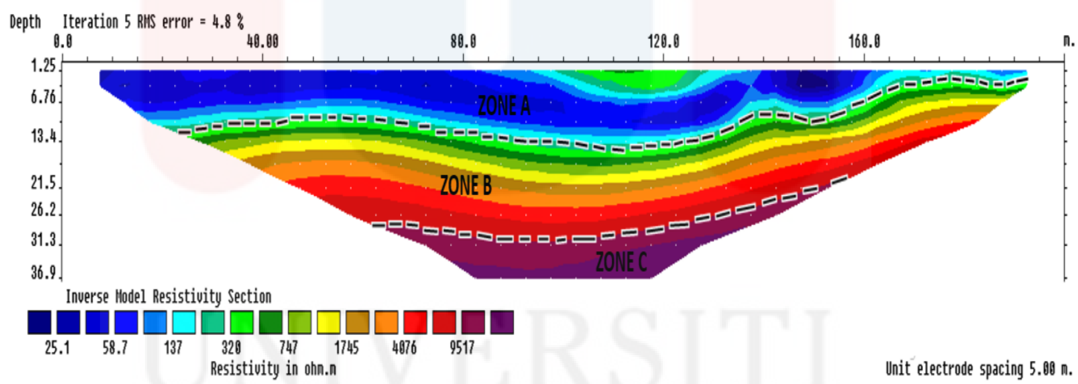

Figure 5.7: Resistivity Survey 3

Zone A is consisted of the rock with resistivity ranged from 25.1 ohm to 137 ohm. This zone covered the depth from the surface until 13.4 m. Based on the resistivity of the rock, this zone is consisted of clay, saturated sandstone and fresh water. The cause for this low resistivity is due to the tributary as well as this location is situated in the water catchment area. The rock in this area is weak due to the water but stable as it is on top of strong layers of rock.

Zone B is located from 6.76 m to 31.3 m in depth and consisted of rock with resistivity from 328 ohm to 4876 ohm. This area represent the layers of sandstone, conglomerate, limestone or dolomite. This zone has strong and stable rock which lowers the probability of sinkhole.

Zone C is the area with resistivity from 4,876 ohm to more than 9,517 ohm. This zone is the rocks with the depth from 31.3 m to 36.9 m. This zone probably shows the existence of conglomerate, limestone and dolomite. This rocks have high strength resulting in stable rocks with very low probability of sinkhole.

The Resistivity Survey 3 shows the typical example of stable rock and soil. Zone C has very high resistivity and stability of its rocks, followed by Zone B that also has stable rocks with high resistivity which serve as solid foundation at the bottom of the survey. Thus, the probability for the sinkhole to occur is very low even for Zone A with high resistivity and weak rocks.

5.2.4 Resistivity Survey 4

The coordinate of Resistivity Survey 4 is taken from N 04^o 46' 01.8", E 102^o 00' 14.4" to N 04^o 45' 55.4", E 102^o 00' 15.5". This survey used the Schlumberger array with 200 m long survey line and 5 m spacing between the electrodes. Figure 5.8 shows the image result of Resistivity Survey 4. The survey image is separated into five zones. These zones with different resistivity is named from Zone A to Zone E.

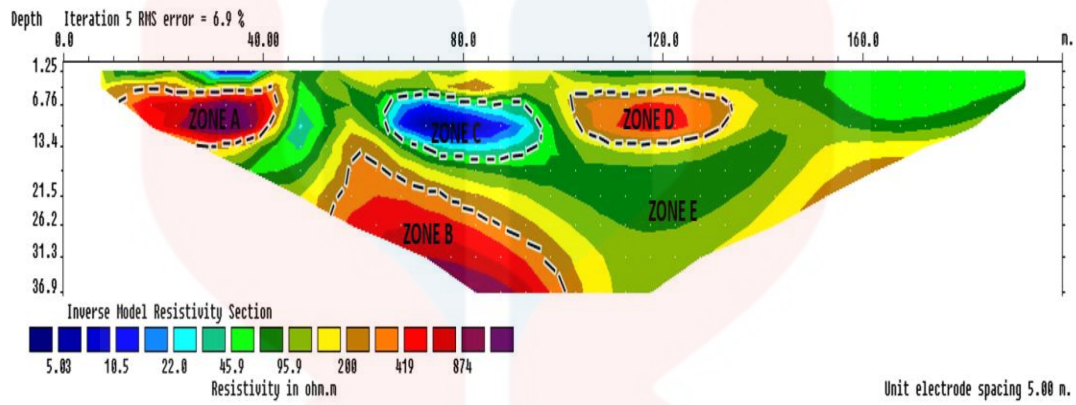

Figure 5.8: Resistivity Survey 4

In the Figure 5.8, Zone A consisted of rock with resistivity from 419 ohm to more than 874 ohm. This area is located at electrode point 10m to 45m and with the depth from 6.76 to 13.4 m. This resistivity represent the resistivity of sandstone. This area has strong and stable rock which lowers the probability of sinkhole.

Zone B is similar to Zone A in which it is consisted with rock that has the resistivity from 419 ohm to 874 ohm. This zone located at electrode point from 55m to 100m and has the depth from 13.4 m to 36.9 m. This zone consisted of stable and strong sandstone with low probability of sinkhole.

Zone C is the area with rock resistivity from 5.03 ohm to 22.0 ohm. This zone is located at electrode point from 65m to 95m with the depth from 6.76 m to 13.4 m. This resistivity shows the existence of clays, saturated sandstone and fresh water. The low resistivity in the subsurface shows possibility of water channel. Thus, this zone has weak rock strength and higher probability of sinkhole compared to other zones.

Zone D is the area with rock resistivity from 200 ohm to 419 ohm which represent the resistivity of sandstone. This zone located at electrode point from 100m to 140m with the depth of 6.76 m. This zone has moderately high rock strength and stability with a low probability of sinkhole occurring.

The Resistivity Survey mainly formed by rock from Zone E which has the resistivity from 45.9 ohm to 200 ohm. This resistivity mainly represented by clays, saturated sandstone, dry sandstone and fresh water. This zone has higher resistivity and rock strength compared to Zone C. the probability of sinkhole to occur in this zone is also lower than Zone C.

Based on ERI image of Figure 5.7, the probability of sinkhole occurring in this area is low. This is due to Zone E that has high rock resistivity and rock strength which prevent the sinkhole from occurring. The existence of Zone A, Zone B and Zone D with high rock resistivity area further increase the stability of the subsurface. Even though the survey shows the possibility of water channel with Zone C which increase the probability of sinkhole, it is too small for it to affect the surrounding areas.

5.3 Overall Resistivity Survey Analysis Summary

Based on the four Resistivity Survey, the study area, Kampung Lepan Jaya has low probability of limestone geohazard to occur because only one survey shows high probability for sinkhole compared to the other three surveys. Moreover, most limestone formed in flat Earth's surface or in karst tower formation which composed of strong and stable rocks.

CHAPTER 6

CONCLUSION

6.1 Conclusion

The geological map of the study area, Kampung Lepan Jaya is able to produce with the scale 1:25,000. This geological map can be used by geologist as a reference to update the map of Gua Musang. It also can be used by other students or researcher as a reference to identify the lithology of limestone in Gua Musang.

The Electrical Resistivity Imaging (ERI) can be used to identify the subsurface condition and also limestone based on the resistivity of the rock. Limestone has rock resistivity of more than 1,000 ohm and it can be used to study the interaction of limestone and other rocks or water channels. The strength and stability of limestone and other rock can also be interpreted based on the resistivity of rock in which higher resistivity resulting in higher rock strength.

The probability for limestone geohazard can be analyze using the ERI survey which resulting to most of the survey are not showing hazardous subsurface conditions. The resistivity and strength of rock in subsurface can be directly related to the probability of sinkhole occurring, thus ERI survey can be used to investigate the subsurface condition.

6.2 Suggestion

From this research project, there are few improvement that can be applied to produce better thesis. The future researchers that want to use Electrical Resistivity Imaging (ERI) to investigate the subsurface for probability of limestone geohazard, it is better to place the survey line near limestone karst such as limestone cave or karst tower to get better result of subsurface limestone.

Future researchers should use longer survey line 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.

Moreover, it is better if the survey line is located near the lineament and slightly sloping area compared to the survey image in flat area. It is because the image produced will have variety and different of survey image that can be used for research.

Lastly, we should be careful while handling and setting the equipment for field survey because the equipment such as ABEM Terrameter S4000 is easy to break which can cause delay in the research.

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APPENDIX

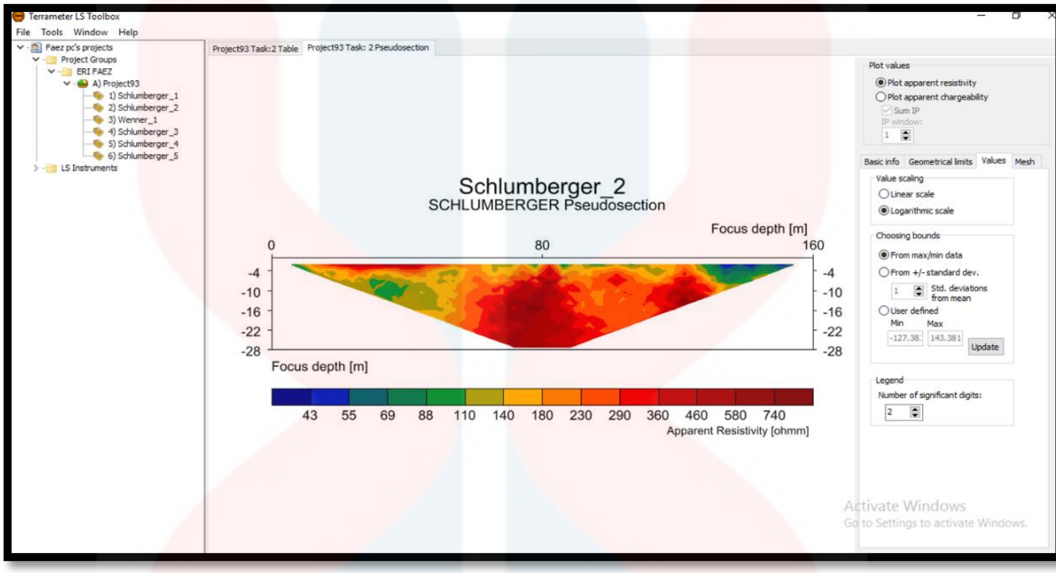

Figure 7.1: Raw data from Terrameter Toolbox

Figure 7.2: Cow herding and palm oil plantation in Kampung Lepan Jaya

Figure 7.3: Procedure for ERI survey. 1) Choose suitable location with straight survey line. 2) Set up the electrode. 3) Connect the wire. 4) Put on the battery. 5) choose the array and let it run until it stop. 6) Record necessary data and pack up.

Figure 7.4: Thin section preparation. 1) Cut the sample into smaller size. 2) Cut the sample into fitting size for the slide. 3) Glue the sample into the slide. 4) Thinning the sample. 5) Smooth the sample surface. 6) Check for observable mineral or repeat Process 4 and 5.

Figure 7.5: Karst tower near SK Paloh

Figure 7.6: Outcrop for Joint Analysis 1

Figure 7.7: Outcrop for Joint Analysis 2