GEOLOGY AND POTENTIAL LIMESTONE GEOHAZARD USING ELECTRICAL RESISTIVITY IMAGING IN KAMPUNG LAMBOK, GUA MUSANG, KELANTAN.

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

FACULTY OF EARTH SCIENCE
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2019

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APPROVAL

"I/ We hereby declare that I/ we have read this thesis and in our 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"

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DECLARATION

I declare that this thesis entitled "Geology and Potential Limestone Geohazard using Electrical Resistivity Imaging in Kampung Lambok, Gua Musang, Kelantan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Geology and Potential Limestone Geohazard using Electrical Resistivity Imaging in Kampung Lambok, Gua Musang, Kelantan.

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Abstract: This study was focus about geology and potential limestone geohazard in study area in Kampung Lambok, Kuala Betis, Gua Musang. The objectives of this study are to produce the general geological map of study area on a scale 1:25,000 and to study the presence of cavity and potential of sinkhole in subsurface condition of study area by using Electrical Resistivity Imaging. Geological mapping was conducted in order to collect surface geological data such as the rock distribution, structural geology and geomorphology. Rock samples were collected for petrography analysis, mainly for identification of the rock types. Geological map shows the locations where rocks are exposed at the Earth's surface. The geology of the area is covered by limestone, tuff, mudstone and metasediments. Besides, geological map also shows geological feature such as faults and strike dip of rock. The study area is covered by hilly and mountainous. The drainage patterns is dendritic pattern. Electrical resistivity imaging technique was chosen for investigate the presence of cavity instead of other geophysical techniques. The three electrical resistivity lines were done in limestone. Pole-Dipole and Wenner-Schlumberger array configuration were used with electrode spacing distance of 5 m and the length of 200 m. The resistivity imaging measurement was carried out using an ABEM Terrameter LS 1, which electrodes were arranged in a straight line with constant spacing and connected to ABEM LUND cable. The resistivity data were processed by using RES2DINV and the result displayed as pseudosection. The 2D profile showed the zone of alluvium and hard rock zone.

Keywords: Carbonate rocks, cavity, Geophysic application, Malaysia.

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Geologi dan Potensi Geobencana Batu Kapur menggunakan Pengimejan Keberintangan Elektrik di Kampung Lambok, Gua Musang, Kelantan.

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Abstrak: Kajian ini memberi tumpuan tentang geologi dan potensi geobencana batu kapur di kawasan kajian di Kampung Lambok, Kuala Betis, Gua Musang. Objektif kajian ini adalah untuk menghasilkan peta geologi umum kawasan kajian pada skala 1: 25,000 dan untuk mengkaji kehadiran rongga dan potensi sinkhole dalam keadaan bawah permukaan kawasan kajian dengan menggunakan Pengimejan Pengawalan Elektrik. Pemetaan geologi dilakukan untuk mengumpulkan data geologi permukaan seperti pengedaran batuan, geologi struktur dan geomorfologi. Sampel batu dikumpulkan untuk analisis petrografi, terutamanya untuk pengenalpastian jenis-jenis batu. Peta geologi menunjukkan lokasi di mana batuan terdedah di permukaan bumi. Geologi kawasan itu diliputi oleh batu kapur, tuf, batu lapis dan metasediments. Selain itu, peta geologi juga memperlihatkan ciri geologi seperti kerosakan dan pemogokan batu. Kawasan kajian ditutup dengan berbukit dan gunung. Corak saliran adalah corak dendritik. Teknik pengimejan resistensi elektrik dipilih untuk menyiasat kehadiran rongga selain teknik geofizik lain. Ketiga talian rintangan elektrik telah dilakukan di batu kapur. Pole-Dipole dan Wenner-Schlumberger pelbagai konfigurasi digunakan dengan jarak jarak elektrod adalah 5 m dan panjang 200 m. Pengukuran pencitraan resistif dilakukan dengan menggunakan ABEM Terrameter LS 1, yang elektrod disusun dalam garis lurus dengan jarak tetap dan disambungkan ke kabel ABEM LUND. Data resistiviti diproses dengan menggunakan RES2DINV dan hasilnya dipaparkan sebagai pseudosection. Profil 2D menunjukkan zon aluvium dan zon batu keras.

Kata Kunci: Batu karbonat, rongga, Aplikasi geofizik, Malaysia

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LIST OF SYMBOLS

Ω.m	Ohmmeter (measures resistance)
%	Percentage
ft	Feet
<	Less than
>	Greater than

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

According to Reed (2007), geology is defines as not only about the earth but also including the study of the planets and moons in our solar system and also he divided geology into two main studies which is physical geology and historical geology in which physical geology refer to the studies about the earth materials such as minerals and rocks, process operating within the earth on its surface while the historical geology refer to the origin and evolution of the earth, its continent, atmosphere, oceans and life and also can be refer as recitation of the past event.

While according to Roy (2010), geology is divided into three part which are physical geology, dynamic geology and geology and man. Physical geology is describe about the Earth's nature, its basic constituent and the understanding about the causes that make the changes in the Earth's surface morphology while dynamic geology is about understanding the physical theory and geological process that change the Earth's crust by the Earth's internal energy sources. Lastly is geology and man which is mean that the growth of

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human civilization with the knowledge of using naturally occurring Earth's material in a daily life.

General Geology and the Potential of Limestone Geohazard using Electrical Resistivity Imaging (ERI) Kampung Lambok, Kuala Betis is a study carried out to distinguish the potential of geohazard in Kampung Lambok. This study area consists of forest, hills, road, and small town. Some parts of study area is high elevation due to mountain structure and low elevation is river with 20 metre high from the sea level.

The limestone outcrop in Kampung Lambok is called Gunung Chenarut. The estimated terrain elevation above sea level is 369 metres. It is in a form of hill formation where it have beautiful structure with cave inside the hill. Limestone karst look beautiful on the outside of its shape but it is fragile towards its surrounding and vulnerable to weathering processes. The formation of limestone may consist of structures that can make a strong massive limestone to become fragile such as void, fracture, air-filled in subsurface of earth that only can be discover through a research study.

Geohazard can be defined is geological process or phenomenon that can effect natural environment, risk human life and property, and can destroy resources and environment which are needed to human survival and development.

Limestone is sedimentary rock that build up from calcium carbonate. This mineral content calcite mineral tend to dissolve when react with water. Carbonic acid act as agent acid help the water to erode the limestone. Carbonic acid formed when carbon dioxide dissolves in water, known in the form of its salts and esters, the carbonates. When exposed to the air it attracts humidity and carbonic acid.

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1.2 Study Area

1.2.1 Location

The study area was covered by hills, rivers and plains. The hills are formed from the limestone rock. Most of the physical`s landscape from due to the surrounding environment and also the contribution from past environment. The total study area is 25 km^2. This study area shows in Figure 1.1. It can be assessed through Lojing-Kuala Betis highway.

Kuala Betis is a settlement in the southern state of Kelantan. It located approximately 28 kilometres from Gua Musang town. We can found the earliest settlement in Gua Cha since the Mesolithic period are lies in the area. Orang Asli Temiar was the largest settlement in Kuala Betis.

1.2.2 Road Connection or Accessibility

The road connection or accessibility within the study area is connected by the main road from Gua Musang Town and Cameron Highland. From Gua Musang to Kuala Betis, it takes around 30 minutes to reach there by driving. While from Cameron Highland to Kuala Betis, it takes almost 2 hours.

People need to travel via the East-West Highway to Kuala Betis if they are driving from Kuala Lumpur, which connect Kuala Lumpur- Gua Musang Highway Route 8. The distance approximately 345 km. This route connects Kelantan with Pahang district before reached Gua Musang with distance 255 km. Besides driving we can also use public utilities such as train services. Keretapi Tanah Melayu Berhad (KTM) operated every day to Gua Musang through two main rails which is Ekspress Wau and Ekspress Timuran.

1.2.3 Demography/ People Distribution

Majority of Kelantan's population is Malay and Islam as the official religion of the state. In the Tumpat, the Thai ethnic mostly stayed over there with approximately 200 temples exist. Kelantan Chinese also part of Kelantanese as they live while maintaining their own culture. Besides, indigenous people or known as Orang Asli had been live for thousand years in Kelantan and Perak's forest which mainly consist of Temiar tribe.

The study area is located at the southern part of Kelantan, one of the Gua Musang district. Gua Musang then had divided into three different region which are Chiku, Galas and Bertam.

There are five villages located within the study area which are Kampung Chenarut, Kampung Lambok, Kampung Ladang Melayu, Kampung Betis, and Kampung Bawid. The minority malay people lives in Kampung Betis, while others villages are dominated by indigenous people. In term of religion, there are two types of religion that had been practiced by the population which is Islam and Christian.

1.2.4 Landuse

Gua Musang is one of the districts that contribute in economic source for Kelantan. The land use in Kuala Betis is covered by agriculture plantation such as rubber tree and palm oil tree, it also one of the important settlements in Gua Musang area. The plantation become major source of income for some population in this area to support their family.

Most villagers believed that is the logging activities on a significance area had been contribute to the contamination and subjected for the changing of the characteristic of

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main river, Betis River. The others part of the study area is the thick forest which covered by different morphology and lithology.

1.2.5 Social Economic

The main activities in my study area in order to generate incomes by plantations activities and some logging activity. They work as the labour in the palm and rubber plantation area. Due to the low level of education and live far from the town they had to choose that kind of work. This area also known as rural area that isolated from the development and main attraction.

Other than that, there is also mining and logging activities organized by a few companies. Most of the companies using heavy vehicle that lead to damage of the roads surface. Some of the villagers also serve at the government agencies like schools, regional health clinic and Jabatan Kemajuan Orang Asli (JAKOA).

For educational purposes, there is only one primary school known as Sekolah Kebangsaan Kuala Betis located in Kampung Betis. This school basically give the basic educational background to the native people. If they want to further their study in secondary school, they need to go outside the village. However, some of them decided to stay in their village without the intention to further study due to cost of life.

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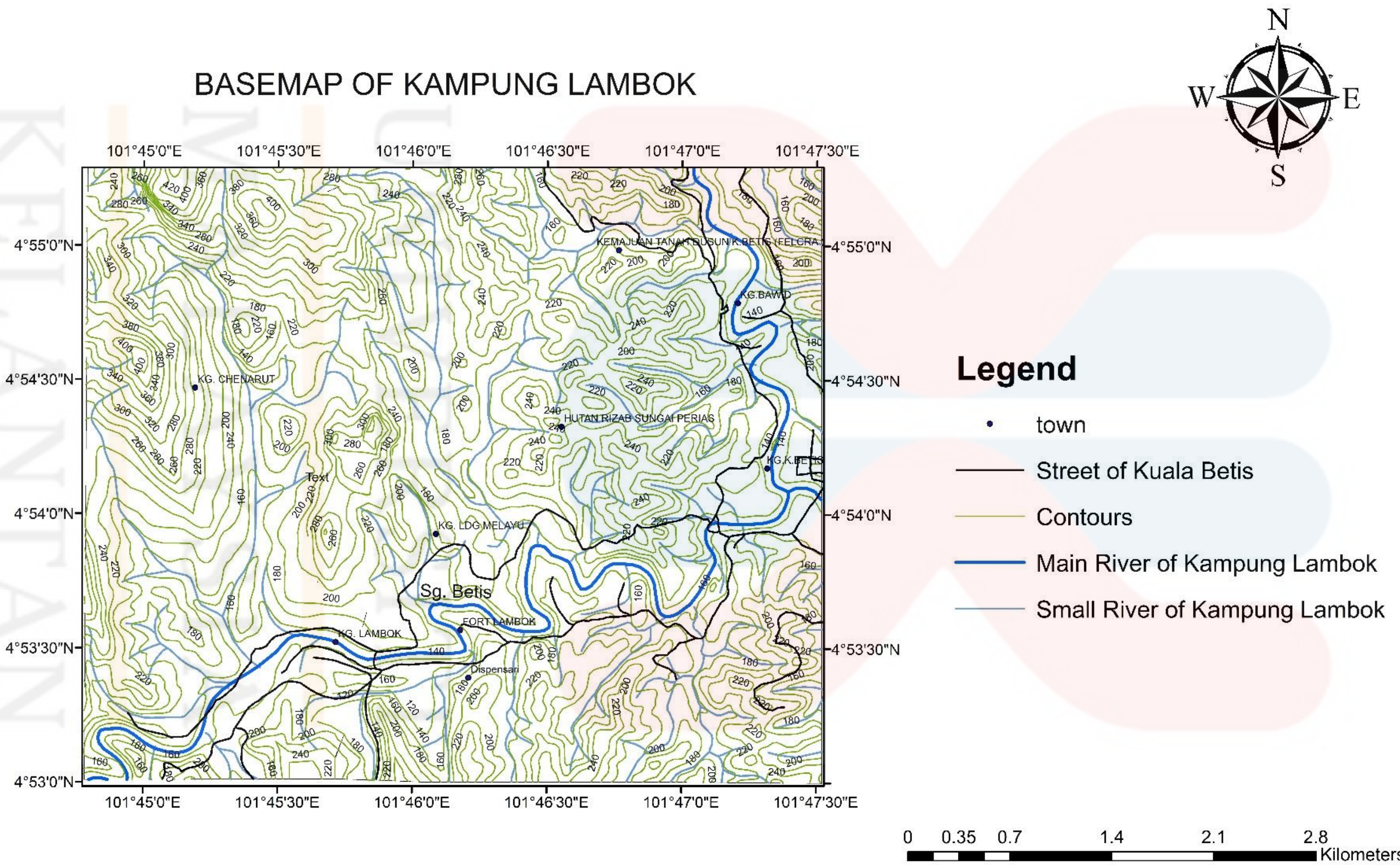

Figure 1.1: Base map for study area.

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Figure 1.2: Kuala Betis dominated by plantation area.

Figure 1.3: Route from Kuala Lumpur to Kuala Betis.

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1.3 Problem Statements

Kampung Kuala Betis is developed small native village where it had their own school, police station, mosque and housing. Building and housing in Kampung Lambok, Gua Musang may located on limestone area with groundwater filled that cannot be determine by the naked eyes due to the bedrock is located at the subsurface of earth.

There is no study on limestone hill in Kuala Betis on potential geohazard in limestone karst. Kampung Lambok was gateway to the Kuala Betis as the study area is covered by limestone karst. Most of previous research that conducted basically on geoheritage area and tourism. But there is no study involved in geophysic method specific on resistivity survey.

Previous investigation focus in the study area is the application of geophysic in magnetic and gravity in Kuala Betis on 1994 by Abdul Rahim Samsudin and friends. Thus, there is no recent 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. On geology aspects, no specific geological map had been produced with definite information regarding the lithology and structural about the study area.

1.4 Objective

1. To produce general geological map of the Kampung Lambok, Kuala Betis, Gua Musang in the scale of 1: 25,000.
2. To determine the presence of cavity and potential of sinkhole in subsurface condition of study area by using Electrical Resistivity Imaging.

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1.5 Scope of the Study

The scope of study area related to geology and geophysic application. Scope in geology involved geomorphology, structural geology and petrology. Geomorphology is the study of the characteristics, origins and development of landforms. While structural geology is the branch of geology that dealing with the structure, distribution and mechanism of the rock. For petrology, it is study of rocks that deal with the content, texture and structure; their existence and dispense; and their lineage in relation to origin and formation of the rock and geologic processes. All the data can be get in field mapping and traverse to collect data in the study area. It is conducted by collecting sample from the outcrop each area that have potential to be investigate. All sample is used for the mineral identification under a microscope. It also includes the regional geology and stratigraphy from preliminary study. While lithology and geomorphology can be study by traverse in study area. Existing geological map is updated through the examination samples under a microscope test for exact rock data. A geological map had been updated by combining recent study and provided.

While for geophysic techniques, this research studied 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 resolves the usage, applicability and efficiency of ERI in imaging the subsurface condition of limestone to analysis the possibilities of geohazard.

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1.6 Significance of the Study

The importance of the research on this research is to update geological map of Kampung Lambok. The geological map will help new researchers to access the place easily in future, which development and geological features changes may take place there.

Next, the geomorphological significance is discovering both past and present action of geomorphological process occur in the study area and showing relationship between landform and the rock type.

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.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is focused on understand about the general geology of the area and the limestone karst characteristics by revision of some previous research and reports. On other hand, to advance in application of geoscience in geophysics method which is electrical resistivity imaging toward Kampung Lambok and limestone karts hill. This geophysics method used to identify potential of geohazard in study area. Besides, the literature review used as a guideline in producing data and information that related to the study area. Study of literature review is primary method before mapping. By referring to the sources that were used for this study, it helped the researcher to gain and expand their knowledge related to the study.

2.2 Regional Geology and Tectonic Setting

Peng (2009) states that Gua Musang Formation estimated to be 650 m thick made up of crystalline limestone, interbedded with thin beds of shale, tuff, chert nodules and subordinates sandstone and volcanic. The properties of light grey calcitic limestone is non-

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porous and hard. Recrystallized limestone often has small amounts of carbonaceous, argillaceous and pyroclastic impurities are present in the grey to black varieties.

The conglomerate in Gua Musang Formation is unconformable on Palaeozoic metamorphic rocks (Abdullah, 2009). The basal conglomerate is hidden and the westernmost of the formation is delimited by the Bentong-Raub Suture, where it is in fault contact with or is unconformable on older rocks.

For Bentong Raub Suture, Hutchison (2009) said that limestone clasts in melange are of Lower and Upper Permian Age. In the Lower Devonian the Palaeo-Tethys was opened, caused by segregation of Sibumasu from Gondwanaland, and closed in the Triassic, caused by the Indosinian orogenic collision with Indochina Block that was earlier sutured to Eurasia.

2.3 Stratigraphy

In the Merapoh-Kuala Lipis and Kuala Betis-Lambok roadcuts can be seen tuffaceous sandstone and tuffaceous shale interbeds that described by Mohamed, et al. (2016). The tuff layers are colored greenish grey and dark brown in the field. More rhyolitic composition represented volcanism within this region on the western side.

Kuala Betis village is situated in south west Kelantan about 40km west of Gua Musang town. Based on Leman, M. S. (1995), fossiliferous localition was discovered from Kuala Betis area. Some of them have Permian flora and fauna included Triassic fauna.

2.3.1 Limestone

Based on Ford and Williams (2007), calcium carbonate can accumulate in almost environment. However, most limestone survived as consolidated older rocks was formed

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in shallow environments. Original limestone materials are aragonite or calcite precipitated by marine animals for shells and skeleton buildings, expelled as faeces or precipitated in tissue or algal plants.

Monroe et al. (2007) stated that calcites in limestone dissolves rapidly in acidic water, but the chemical reactions leading to dissolution is reversible. So, under some circumstance calcite and thus limestone form by inorganic chemical precipitation.

There are three phases involved in formation of limestone. First phase is genesis of calcareous ooze, the ocean is the habitat for small life's form for example plankton and foraminifera. This life's form absorbs chemicals from the sea to create its skeleton or shells. The skeleton is continually being replaced for a long period of time and the residue of the old material is pinched out into the ocean. As a result, it will create repeatedly rain of calcium carbonate debris settling onto the ocean floor.

Slow accumulation process will occur clumping the calcium carbonate debris on the seafloor, then, include also dying organism as well, the process known as calcareous ooze. Limestone also a mixture of dedritus includes sand and muds that are expel from an organism. The dedritus had been relocated from higher parts of the seabed or washed away from the land in river flows. Limestone has varieties of colour due to presence of dedritus. Dedritus give the limestone a grey or brown color.

Second phase the ooze will be condensed. The ooze settling at the bottom of the sea is empty space for the moment. Until more ooze is dispersed down from the higher part s of the seabed, the accumulation load forces the sediments at bottom to compact, the process known as diagenesis. It includes large force that the particles will dissolve, until it recrystallizes with little space. The narrow bends of limestone is filled with dedritus that is forced into it, making the limestone look flaggy.

Third phase is the limestone is uplifted out of the sea due to the tectonic force beneath the Earth's surface. As the seawater withdraw out at the bottom, fresh water flow in the rock and the native material is dissolved and redeposit as cement. When the limestone is exposed to the weathering activity, it starts to erode away the limestone, leaving karst landscape of caves, gorges, depression and rock outcrop.

2.3.2 Karst Features

Karst refers to a characteristics topographic features that is developed by dissolution made by downward percolating meteoric water (Benito et. al, 1995). Ford and Williams (2007) define karst also used to describe a special type of landscape containing caves and extensive underground water systems that is developed on especially soluble rocks such as limestone, marble and gypsum.

There are a few of characteristics of karst that we can see clearly. The presence of a number of basins (depressions) of varying shapes and sizes, the basin is flooded or waterless with different depths and distances. Second, small amounts of hills that are the sides of erosion due to chemical dissolution of limestone, thus forming hills (conical hills). The rivers do not develop on the surface. The rivers in the Karst region are generally discontinuous, lost into the soil and just emerge from the soil. The presence of rivers below the surface, the presence of limestone caves on the surface or above the surface. The presence of sediments of red sludge (terrarosa) sediment deposits that are deposited by limestone weathering. The open surface has a rough, cracked appearance or even tapered

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holes. The number of stalactites and stalagmites resulting from water entering the holes (doline) then down to the cave and dripping from the roof of the cave to the base of the cave that turned into rock.

Sinkhole developed as a result of dissolution of limestone through there are action with acidic polluted water (Al-Zarah, 2007). Groundwater penetrated through weak zone in limestone after a certain period will developed channels and voids (Elawadi, 2003). Schoor (2002) states that cavities can be partially or completely water filled and depending on the composition of the water, have a resultant conductivity ranging from conductive to relatively resistive compared to host rock.

Each type of karstic rock presents a different type and severity of karstic geohazard which are related to the rock solubility and geological settings. Typical karstic features with records of sinkholes, cave entrances, stream sinks, resurgences and building damages. Groundwater abstraction also has the potential to trigger subsidence in karst area (Anthony et al., 2011).

Based on Moore (2013), the most significant hazard is karst. The karst landscape is characterized by features such as sinkhole, caves and cave entrances, sinking streams and outcroppings and weathered carbonate rocks. There have been incidences of sudden sinkhole collapse as well as flooding of sinkhole basin crossed by roads or buildings. The possible impacts from the proposed road alignment (or any other structure, building and subdivision) on the karst environment include sinkhole collapse, sinkhole flooding, groundwater contamination and negative effects on the cave and subsurface dwelling wildlife.

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Natural erosion processes acting on the limestone bedrock could give rise to cavities which subsequently could lead to formation of sinkhole. The formation or emergence of a sinkhole is usually very sudden and unpredictable and its development can be catastrophic. A'kif Al- Fugara, et al (2014) explained that Inherent karst features of the limestone bedrock (such as pinnacle profile, cavities and linear trenches) all contribute or provide the geologic setting for the development of sinkholes man made factors or activities such as dewatering of groundwater trigger the formation or emergence of sinkhole occurrences, rockfall and soil erosion.

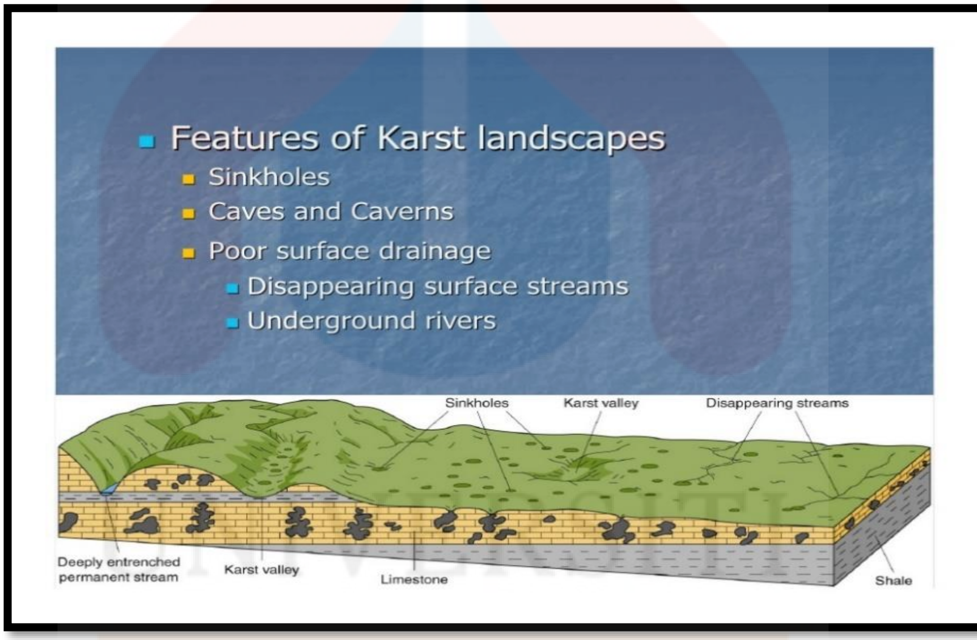

Figure 2.1: Karst topography

2.4 Structural Geology

Generally, according to Dony Adriansyah Nazaruddin, et al. (2015), Gua Musang has lot of geomorphological features, mountainous areas which mostly consists of a mountain ridges and valleys. Comprised of granitic rock largely porphyritic granite,

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coated by superficial quaternary precipitate. While joints is the geological morphology that common can be found. Hilltop areas in Peninsular Malaysia are developed by long erosional record through successive uplifts during Cenozoic. Rock type and structure will affect this morphology.

Generally, the drainage pattern in this area explained it has been affected by structural controls like joints and faults (Dony Adriansyah et. al., 2014).

2.5 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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2.6 Geophysical Method

Geophysical method responds to the physical properties of the subsurface media like rocks, sediments, water, voids and others and can be classified into two distinct types based on Reynolds (2011). First, passive methods are those that detect variations within the natural field associated with Earth. Contrast to that, active method are artificially generated signals are transmitted into the ground which then modify those signals in ways that are characteristics of the materials.

2.6.1 Electrical resistivity

It offers a quick and cost-effective imaging of the shallow subsurface with acceptable resolution (Mohamed Metwaly and F. AlFouzan, 2013). It also consists of the application of constant direct current imposing into the ground via two current electrode and measuring the resulting voltage at two potential electrodes. Each electrode configuration has specific advantages and disadvantages, based on the penetration depth and the horizontal resolution.

Abdul Rahim Samsudin (1994) states that the main purpose of a resistivity survey is to determine the horizontal boundary (horizontal and vertical) within the earth. He also said that the advantage in the use of alternating current is able to eliminate the polarization ability of the electrode and its ability due to the telluric flow.

2.6.2 Types of electrical resistivity array

There are a few types of electrical array. Each of them has their own particular advantages, disadvantages and sensitivities. Four types that provided in ABEM is dipole-dipole array, Wenner array, Schlumberger array and pole-dipole array.

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Dipole-dipole array has the ability to identify the location that had been under weathered zone by obtained the characterization data and quantification data of the area. This type of array authorises the researchers to mapping the weathering material at depth and analysis the information on the depth of the surface (Yilmaz, 2011). Usually dipole-dipole array resolves complex structure and can be applied at great horizontally resolution at site.

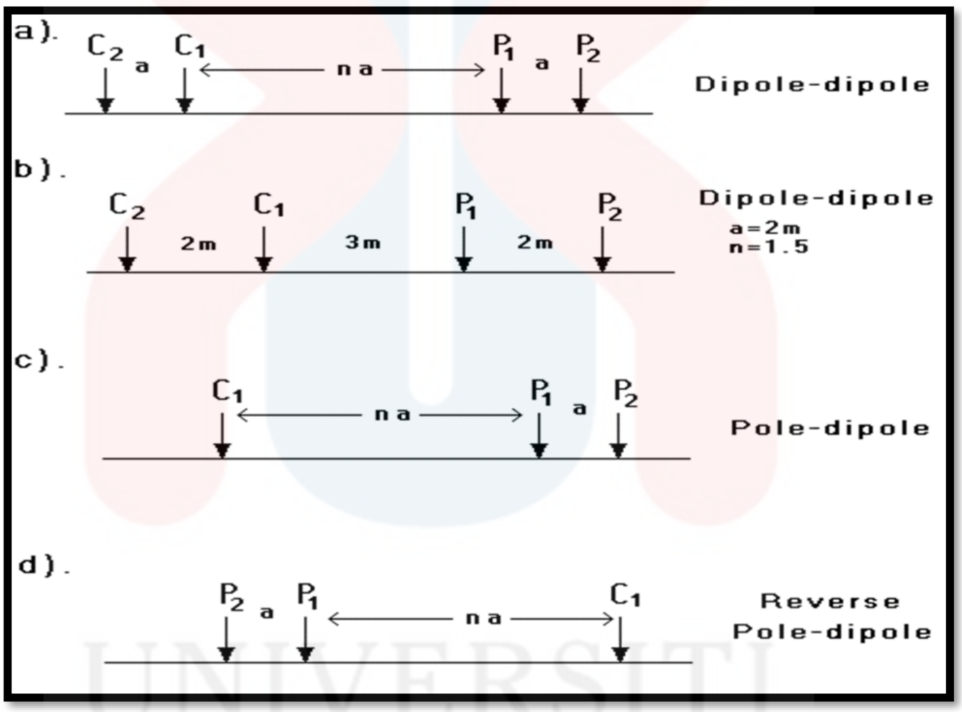

Figure 2.2: Various arrangement for dipole-dipole and pole-dipole array type.

Wenner array consist of four collinear, equally spaced electrodes. Based on EPA (2016), this array easily determined in the field and the sensitivity of devices is not as vital as other array geometries. Wenner also have small current magnitude are needed to produce measureable potential differences. The problems for Wenner array are all the electrode must be moved to a new position for each sounding. Gasperikova (2012) states

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that it is necessary to use longer current cables in order to image deep into the earth. This array also sensitive to near surface heterogeneities which may screw deeper electrical response.

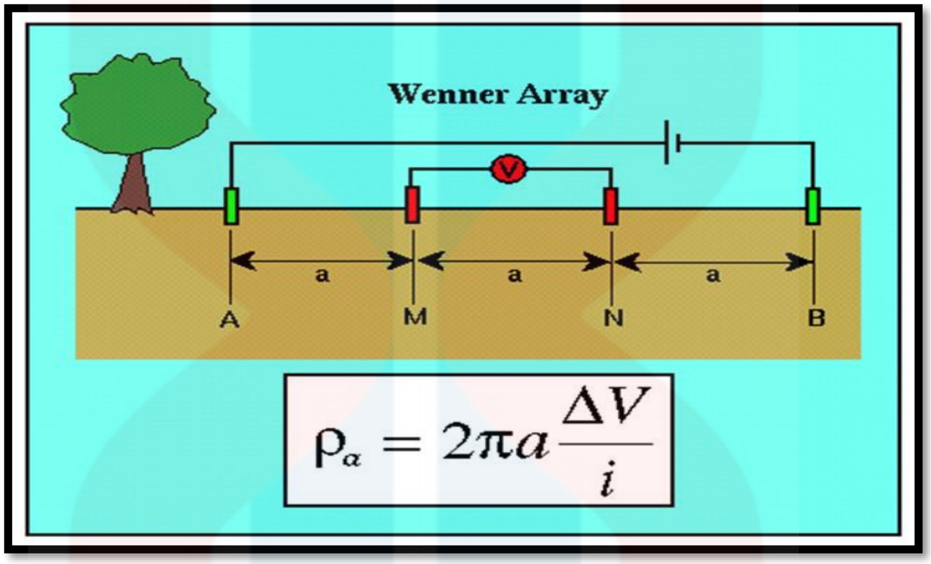

Figure 2.3: The arrangement of Wenner array.

Schlumberger array having same arrangement with Wenner array which is consist four electrodes. But it gives more advantages. Fewer electrodes need to be moved for each sounding and the cable length for potential electrode is shorter. Schlumberger also have better resolution, greater probing depth, less time-consuming field deployment than the Wenner. The deficiency of Schlumberger is the recording instruments needed to be very sensitive and their array itself may be difficult or confusing to coordinate amongst the field crew.

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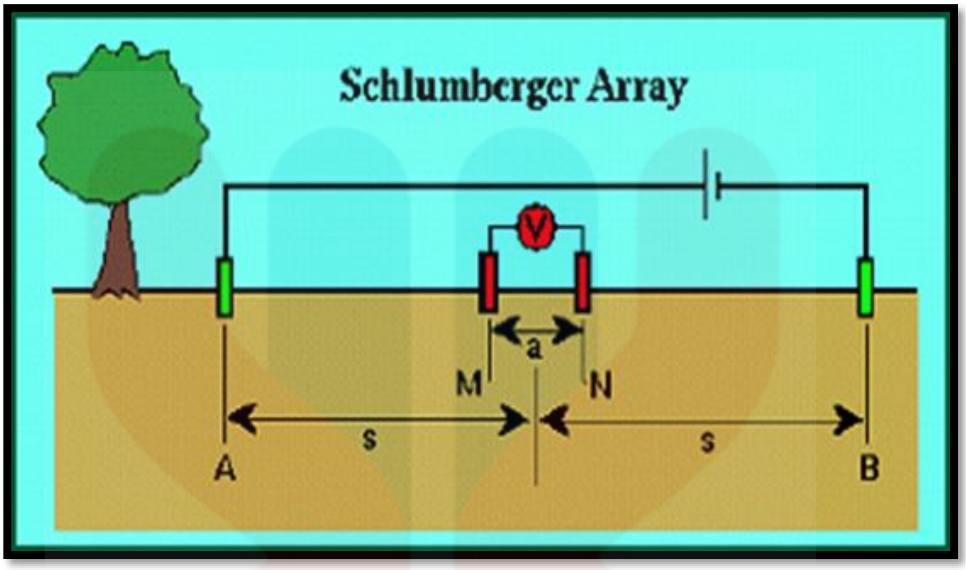

Figure 2.4: Electrode configuration for Schlumberger array type.

CHAPTER 3

MATERIALS AND METHOD

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

Some materials are used according to the method that apply for the studies according to the needs. The previous journals and articles and project reports will be going to use which that can be obtain from library. For the field observations, sample of an outcrop will be going to use for the further analysis in the laboratory.

1. Geology Hammer

Usually this hammer used to crack the fresh outcrop. After cracking out the outcrop, if there is a presence of fossil normally geology hammer will help to take out the fossil. By using geology hammer, the strength of outcrop or sample will be determined. Other than that, it is important in analyse mineral, composition and origin of outcrop.

Figure 3.1: The geological hammer that researcher usually use in fieldwork.

2. Hydrochloric acid

Reactivity of mineral of an outcrop can be test by using dilute HCl. The main purpose in using HCl is to determine the existence of carbonate minerals such as calcite and

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dolomite in the rock which will show the reactions by forming bubble if it gets contact with the acid. The type of minerals can be identified by the different reaction speeds.

Figure 3.2: Dilute Hydrochloric acid that will helps in know reactivity of the rocks or minerals.

3. Hand lens

Hand lens are provided quick and easy to perform the work in field. It is important in examining the minerals, see the size and shape of grains in the rock and look for small fossil or crystal. It can be enlarging the image of rock mineral and fossil range.

Figure 3.3: Hand lens makes easier to see the small features.

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4. Sample bag

Sample bag necessary in doing fieldwork to collect the sample and prevent contamination from the surrounding area. It is required to avoid and lessen the changes on the rock minerals and structure.

5. ABEM Terrameter S400

Abem Terrameter S400 is main equipment that used deep-seated 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 Terrameter.

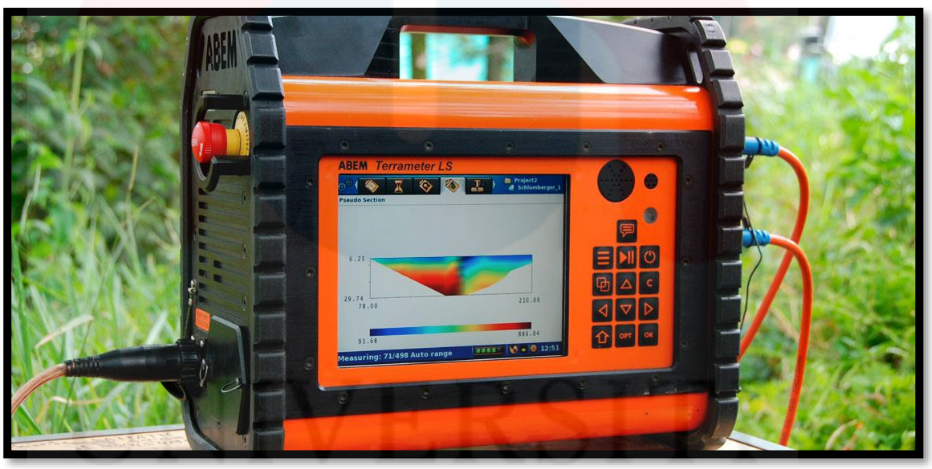

Figure 3.4: Abem Terrameter S400 can show multiple data from various array.

6. Multimeter, electrodes and Multi-core wires

Electric current, voltage and resistance are measured by using multimeter over several ranges of value. The conductor to allow the electrical current to flow through the ground while multi-core wires are a cable with a number of independent wires.

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Figure 3.5: Shows a set that always come together in using Abem Terrameter.

7. Compass

There are two types of compass, Brunton and Suunto. It is used to measure and collect all the readings and data such as dip direction and strike and dip of bedding features.

Figure 3.6: Suunto Compass

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8. Global Positioning System (GPS)

It is a system that give the exact of latitude, longitude, altitude and time. GPS required in doing field investigation for determining the location of study area especially if the area was remote area.

Figure 3.7: Handheld Global Positioning System

9. Res2Dinv

It is one of the types of software that are used for interpretation of Electrical Resistivity Imaging (ERI) data and to get the data approximately ERI calibration also will be used. After the data was collected by Abem Terrameter, the survey data will be converted into 2D image. The image produced are necessary in order to study the subsurface condition of the study area such as lithology and karst.

10. ArcGis

ArcGis is important in producing or updating the map. All the geographic data that had been collecting entered in this software for update purpose.

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3.3 Methodology

3.3.1 Preliminary study

The researcher collected data and information based on the various type of sources. Include primary and secondary sources. Five section involved in preliminary research steps and planning; first is introduction- researchers must know and clear their research problem and background. Second, literature review- it can be found at library sources and internet. Next, research design- the way the data collected, methodology used has related with the research plan. Besides, expected outcome- the result from data gathering and analyse. Lastly, timeline- the phase involved in data collection and testing. Research Design is data acquired from geology and geophysic method aspects before further collection and analysis of data proceed.

3.3.2 Field study

Tools and equipment used in geological field mapping: geological map, compass, GPS, hammer, hand lenses, field notebook, camera. The research work involved the method of basic geological mapping within the study area. Rocks were collected and analysed during this fieldwork for various parameters as well as the geological conditions. Basic geological mapping skills was conducted in field exploration. For example, traverse and field measurement techniques to determine the attitude of planar structures such as bedding.

Geophysical field mapping done by selecting an area of interest and identifying all the geophysical aspects of the area with the purpose of preparing a detailed geophysical report. Before any survey is undertaken, objectives of the study must be well defined and attainable. Since there are numerous geophysical methods the geophysicist must be able

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to choose the methods that are applicable in the area, cost effective and are able to give a solution to the problem at hand. There are various reasons why we carry out geophysical surveys and they include water resources (surface and ground water), geo-hazard assessment (seismic) and environmental issues.

For line survey of Electrical Resistivity Imaging (ERI) there are needed around three to five lines must be done at different location. This location are chosen near the lineament and steep contour because it is easier to investigate the different stability of subsurface. For each line average length is about 150m to 250m. Each line can be parallel but also have the option to not parallel.

3.3.3 Laboratory work

Digitization of maps could be done by use two important things, Global Positioning System (GPS) and Geographic Information System (GIS). It involves before and after mapping phase. All data in GPS will transfer into the computer after complete the mapping for digitize the map. Planning for updating the geological features in the study area can easily readable and usable. GIS also functioning in editing the data for completing general geology and potential of limestone geohazard analysis for the study area.

For sampling, rock sample important in doing petrography aspects. The samples of fresh rock were taken for thin section preparation. The samples include different localities represent the lithology in the area. The objective for doing petrography is to establish a baseline information about the petrology variability observed in sample taken to compare with the previous research or work. This can be done by characterizing the minerals, rocks fragments, and other components identified in standard size petrographic

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thin sections rocks. The sample were taken by using geological hammer and labelled by their localities. The location also are marked on the GPS for reference.

For thin section procedure it was done after collecting the sample. The rock are cut to smaller shape. The instruments that are used are abrasive cut off machine, precision sectioning saw, thin section system, grinder polisher machine, beaker, spatula and glass slide while for the materials are Silicon Carbide Powder 400 (P600) Grit, Epoxy Hardener and Epoxy Resin with ration is 2:1 and Silicon Carbide Powder 320 (P400) Grit in order to produce thin section.

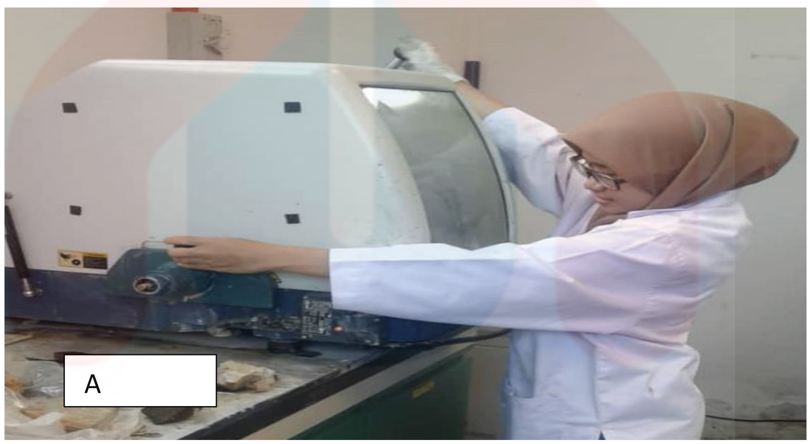

Figure 3.8: Process of cutting (A) using cut off machine and thinning (B) use thin section system.

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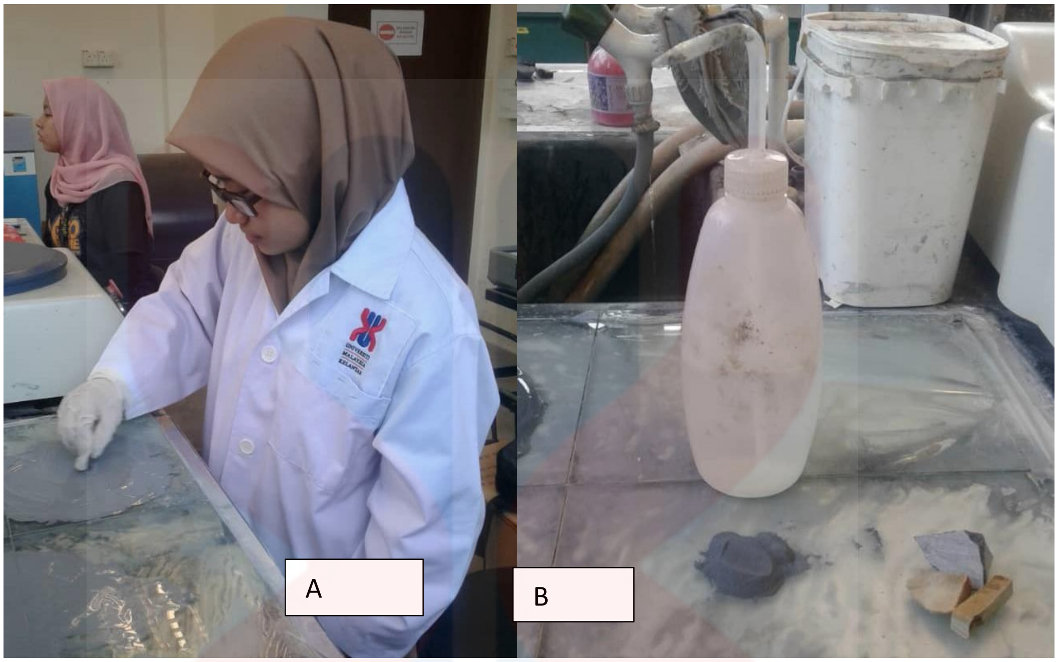

Figure 3.9: Process of rubbing (A) by using the (B) Silicon Carbide Powder 320 (P400).

First step is by cutting the sample of rock. This step is using a machine which is abrasive cut off machine. The size of the rock must be small as size of glass slide and the ground of the rock sample are optically flat. Second step is by rub the surface of the rock sample that have been cut and the glass slide at the place provided until the rock sample is flat and the glass slide become blurry or cloudy. This step is done by using the Silicon Carbide Powder 400 (P600) Grit. Third step is drying the sample. Samples can be dried at a room temperature followed by drying in a furnace with temperature level 4 or 5. The surface of the sample and glass slide that have been rub must face above.

Fourth step is while waiting for the rock sample and glass slide to dry, the mixture of the Epoxy Hardener and Epoxy Resin with ratio is 2:1. These materials is are mixing in a beaker and stir for 10 minutes or until the bubble disappear. Next step is put the

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mixture at the sample of rock. This is done after the rock sample and glass slide are in hot and dry condition. Put the glass slide on the rock sample. After this step is done, the samples are left for one day or until the glue is truly drying. Then, after the glue is already dry, the next step are proceed. The sample are cut again until it thickness as thick as a paper. This step is done by machine which is thin section system. The sample will be place on the side of the machine in which that part are like a vacuum to hold the sample and wait until the pressure value of the machine rose until 20 and above, then the cutting are started.

The last process to prepare the thin section are sawing and grinding. After hardening of the resin, a slab is sawn from the block by using a diamond studded sawing blade. The slab is ground with a grinding machine and finally by hand with korund powder or papers until scratches are removed. Then, the slab is mounted with the resin on an object glass which is 1 mm thick. When it is fully cured, the slide is placed in a special jig and the slab is sawn to a thickness of 1-2 mm. After this slide ground and polished by a machine and then proceed by the land to a thickness of 20 micron. The final thickness is reached when the quartz grains are white to grey in colour in cross polarized light. After cleaning, the slide is covered with a cover glass. During all the treatments oils should be used as lubricating agent instead of water in order to prevent swelling of clays and dissolution of salts. Last step are using Silicon Carbide Powder 320 (P400) Grit by rubbing the sample at the place provided or by using the machine which is known as grinder polisher machine. This step must be done slowly to prevent the sample from broken into a piece.

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3.3.4 Data processing and interpretation

Two data analysis is done in this study which are geological analysis and geohazard potential data using ERI method. Geological analysis will be investigate based on petrography analysis. On petrography analysis, the accurate type of rock is determined based on its dominant mineral followed by other mineral in the thin section.

Meanwhile ERI was used to determine geohazard in the area. This analysis was done using ERI instrument which is known as ABEM Terrameter. It can be operated on three modes; resistivity, induced polarization (IP) and self-potential (SP). In the resistivity survey mode, it comprises a battery powers, deep penetration resistivity meter with an output sufficient for current electrode separation with good survey condition. While for IP measured the transient voltage decay in number of time intervals. The length of time intervals can be either constant or increasing with time. For SP it usually measured natural direct current potential and the result will be displayed in Voltan.

The profile is important to the Res2Dinv software for processing and 2D pseudo-section is generated for the interpretation. By using Res2Dinv, it can interpret the subsurface of earth.

3.3.5 Report writing

Writing are followed the standard rubric for the researcher. It must contain all the section and include the findings and their outcomes. It must been analyse and interpret are written in the report with simple language as the references in the future.

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3.4 Approach need to be taken before conducting the method

A researcher needs to firm their information that sinkholes is present at the site and established that an undulating bedrock surface was present, indicative to karst activity. Conduct a reconnaissance mapping with terrain conductivity, the purpose is to create a basic understanding of the soil and bedrock relationships in term of apparent conductivity or resistivity, appropriately to conduct a few metres deep.

Next, a researcher needs to interpret the potential air or fluid filled voids and solution enhanced features. Lastly, researcher can process and interpreting the terrain conductivity and 2-dimensional resistivity data by developed final geological model.

3.5 Approach to conduct and analyse electrical resistivity imaging on karst features

To identify the different soil at different depths in this method, it uses electrode to measure the electrical conductivity. When a survey has been conducted, researcher is able to identify a potential for karst and are able to place the electrodes in the ground with the specific space intervals. The intervals are placed a probe along the survey line, in order to measure the electrical potential between the probes taken. Then, the probes will disperse an electric current into the soil and the measure the electric potential between electrodes interval. (Schoor, 2002).

Due to the different electrical conductivity based on different type of soil, the analyse data can form a soil profile to act as indicator for depth. It can contribute in understanding the soil layers settling beneath the surface. This method applies grid pattern electrodes set up, in order to get a 2 -dimensional image modelled and the array used for this method is dipole-dipole array because it more sensitive. Others than that, dipole-dipole also great in determining the shape and depth of soil layer and size of the sinkhole.

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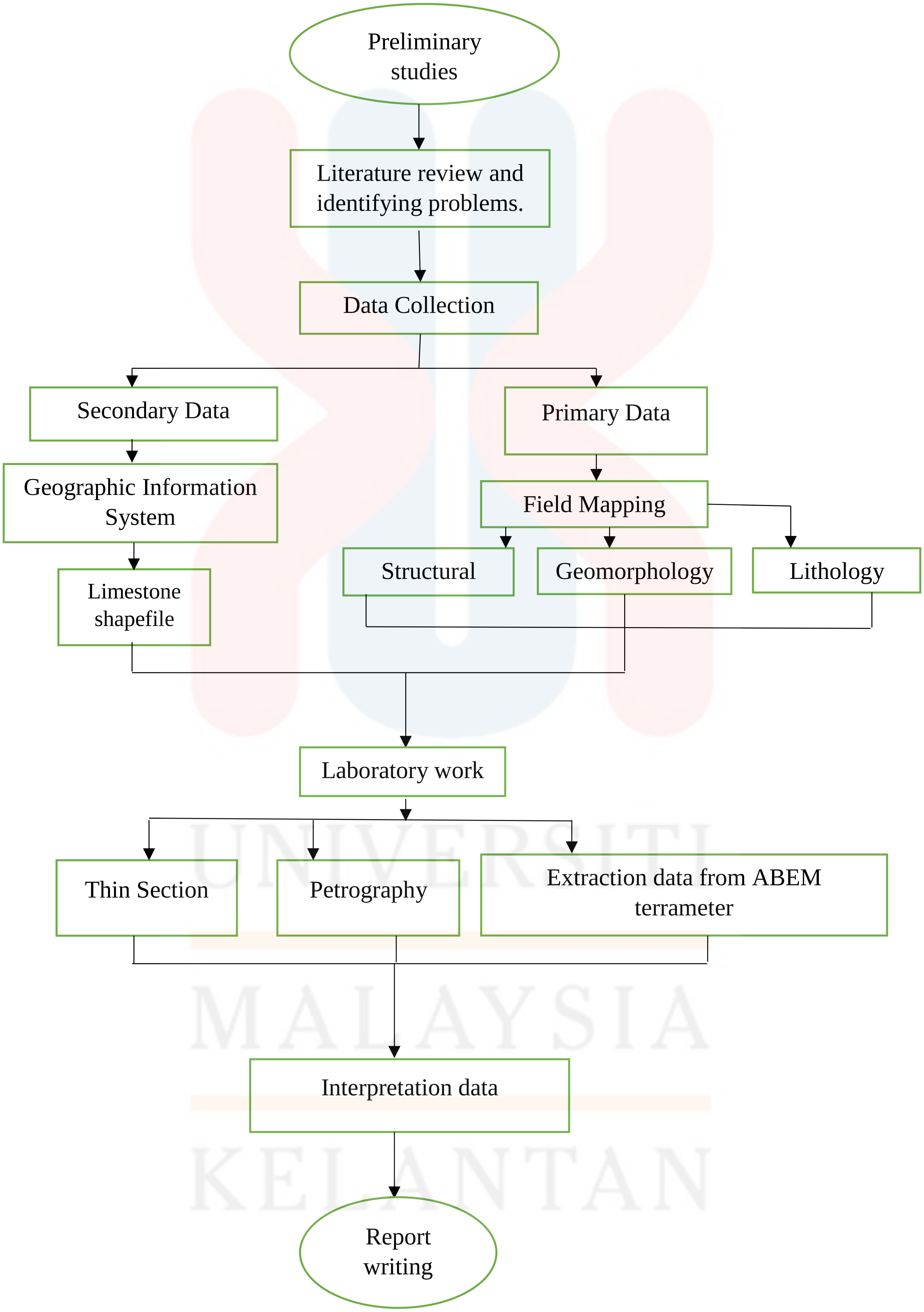

Figure 3.10: The research flowchart

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

General geology usually is the result from field observation and mapping as well as structural geology. This is important to update new information or data that the researcher gained during field observation and mapping. It also for update the current geological map which might not be accurate. The information obtained is important to proceed the next step which is research specification.

General geology of study area is distributed into geomorphology, petrography, stratigraphy, structural geology and historical geology. It provides many geological information which cover geography parts of the area, geomorphologies processes, field observation and mapping and any extra information that are necessary to be discussed in this chapter.

Geomorphology is a science that concerned with understanding the form of the Earth's surface and the processes which it was shaped, both at the present as well as the

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past. While, basic topography is the reviews on the lineaments, beddings, cracks and fault analysis. The formation of these structure were mostly due to tectonic movement.

Stratigraphy is the knowledge about rock strata, their relative and absolute ages, and the relationship between strata. Stratigraphy used to correlate the past environment with what have been seen today by analyzed from the physical characteristics of rock itself.

4.1.1 Accessibility

By using Jalan Gua Musang, people get to access study area by continue straight follow the road of Jalan Gua Musang- Kuala Betis. Study area also can access through via Jalan Gua Musang- Cameron Highland then take the right exit passing through Jalan Gua Musang- Kuala Betis. By using paved road that function as main road to the villagers, people can access to oil palm plantation and rubber plantation.

Figure 4.1: The main road that have been used by villagers.

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4.1.2 Settlement

Kuala Betis is a settlement in the southern state of Kelantan. It located approximately 28 kilometres from Gua Musang town. The earliest settlement can be found in Gua Cha since the Mesolithic period are lies in the area. Orang Asli Temiar was the largest settlement in Kuala Betis.

More than 2,000 Orang Asli residents in 14 villages around Kuala Betis under Rancangan Pengumpulan Semula (RPS) Kuala Betis, Gua Musang. The establishment of the RPS Kuala Betis, Gua Musang is a strategy to gather cottage villages and indigenous people into a reconstructed area of their origin. All facilities provided by the government to enhance their economic and social status.

4.1.3 Forestry

In study area, land is used mostly for agriculture. Firstly, it is used for plantation. The land with high elevation usually used for oil palm plantation, whereas, at low elevation or flat area, land is used for rubber plantation. *Elaeis Guineensis* known as African oil palm is estimate approximately in range about 5 years above. This is because the plant already matured and grown. Rubber tree or their scientific name is *Hevea Brasiliensis* also are in matured stage. Villagers also use land for residential. They built houses, groceries and other building for their activities.

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Figure 4.2: Scenery of oil palm plantation in study area.

4.1.4 Traverse and observation

Traverse map in Figure 4.3 show distribution track, sampling, resistivity line location and observation. During traversing, all geological data are collected with the picture of surrounding. As can see in Figure 4.2, at western part of study area is not been explored because that part is covered by abandoned palm oil plantation which no road connection to access. The samples collected for thin section from outcrop were fresh and not weathered.

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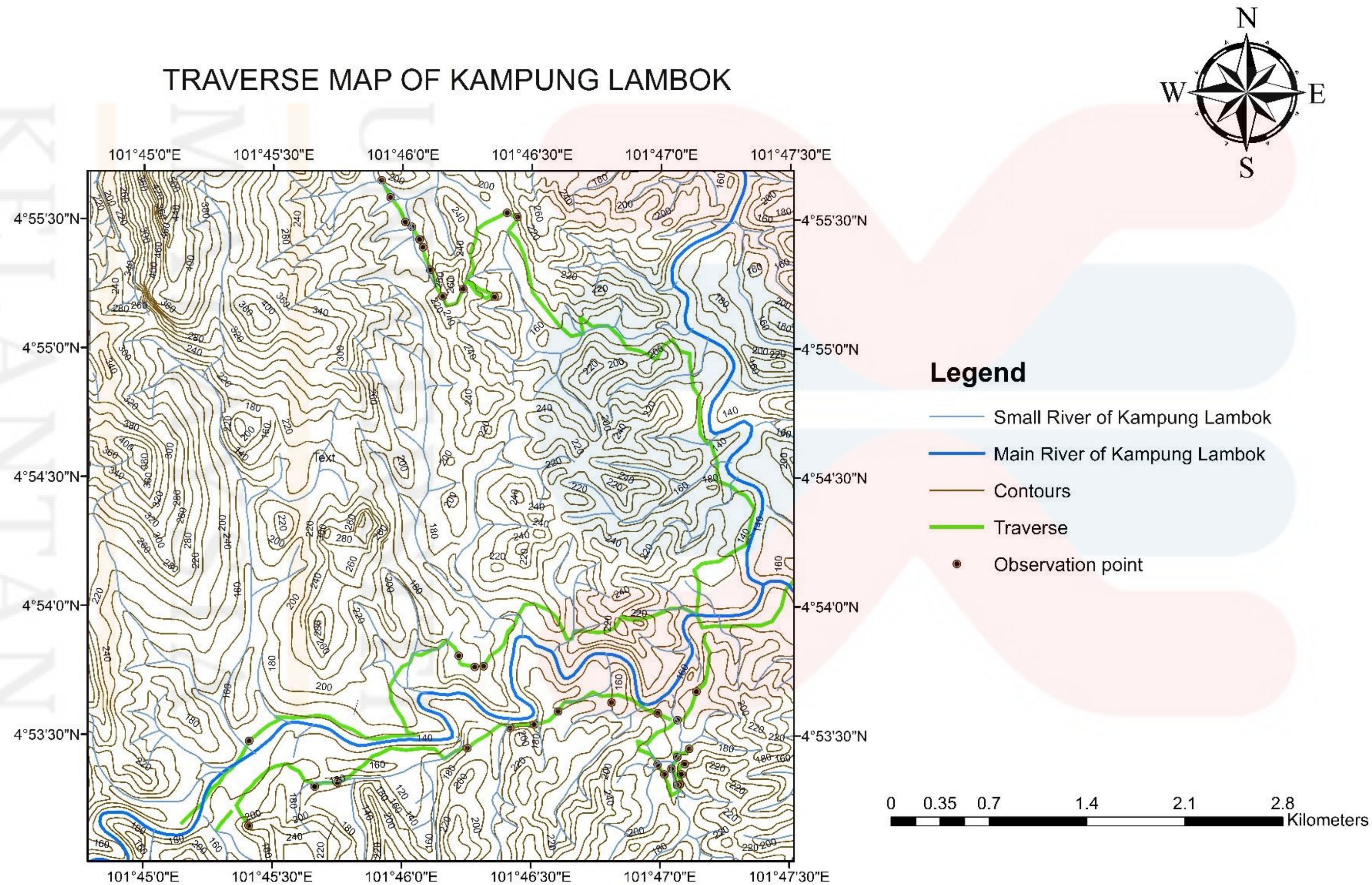

Figure 4.3: Traverse and station map.

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4.2 Geomorphology

The study of landform and the processes that involves in the formation of landforms we called as geomorphology. It can be divided into exogenic and endogenic processes. Endogenic processes is geological processes that occur beneath the surface of the Earth. It is associated with energy originating in the interior of solid Earth. Endogenic processes consist of plate tectonic, earthquake and volcanic activity. Exogenic process also known as gradational process consist of aggradation and degradation processes.

4.2.1 Geomorphologic Classification

Different landform will be produced depending on the geomorphological activities on the areas. The topography, drainage pattern and weathering in the study area are observed to study the geomorphic change in Kampung Kuala Betis. Topography is the investigation of the earth science involving the investigation of surface shape and features of earth. The elevation of study area is discussed and analyzed in this part. Topography is the main criteria to class the geomorphological unit either in physical criteria, hydrology criteria and also any hazard susceptibility zone in the study area. The classification of the mean elevations is divided into 5 units;

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Figure 4.4: Landform in study area.

Table 4.1: Landscape classification based on topographic relief.

Class	Landform classification	Mean elevation (above sea level, m)
1	Low lying	<15
2	Rolling	16-30
3	Undulating	31-75
4	Hilly	36-300
5	Mountainous	>301

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Karst applies to a distinctive type of landscape that develops from the dissolving action of water on soluble bedrocks. Karst landscape are characterized by fluted and pitted rock surfaces, sinkholes, sinking streams, spring subsurface drainage system and caves.

Figure 4.5: Karst tower in the study area.

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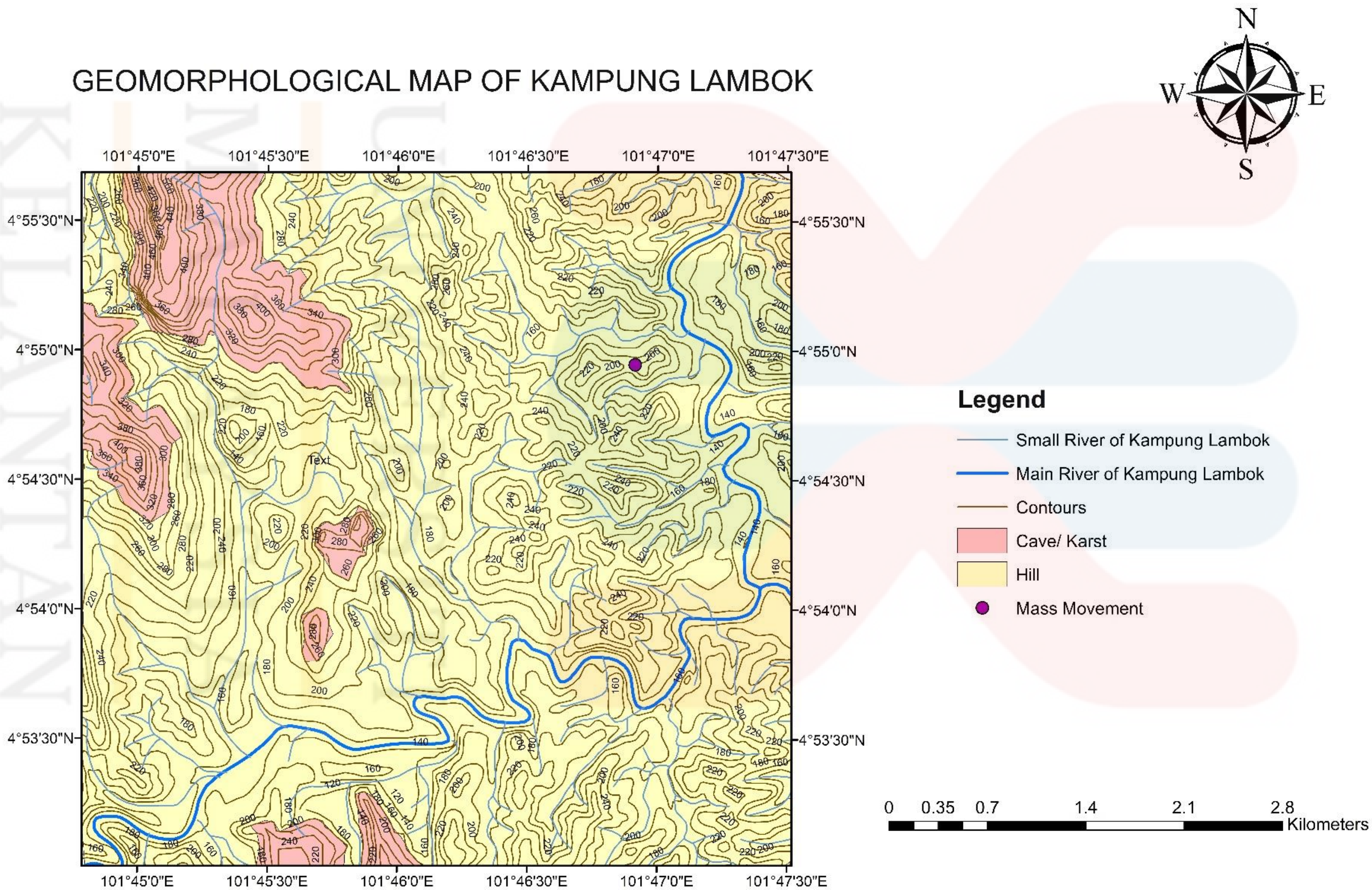

Figure 4.6: Geomorphology and landform map.

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4.2.2 Weathering

The closely related processes with geomorphology is weathering which can be divided into three types, namely biological weathering, chemical weathering and physical weathering and then the subsequent process which is erosion. This process usually happens at the Earth's surface as well as near the Earth surface.

Weathering is the breaking down or dissolving of rocks and minerals on Earth surface. Water, ice, acids, salts, plants, animal and changes in temperature are all agents of weathering. Once the rock has broken down, a process called erosion transports the bits of rock and minerals away. Erosion is the movement of particles broken down by weathering process by agents. The agents will transport the weathered rocks until the particles are deposited.

Mechanical or physical weathering takes place when physical forces break minerals and rocks into smaller pieces that retain the composition of the parent material. While chemical weathering is the decomposition of rocks by chemical alteration of parent materials. Chemical weathering occurred when the rock is changing chemical properties. Processes that are led to chemical weathering are carbonation, hydration, hydrolysis or oxidation. The effect those process changes the chemical composition of rock. Water, wind and ice are the agents that triggers of this weathering. Based on Figure, formation of limestone stalactite explained the rock undergo chemical reaction by carbonation which affected by temperature and evaporation.

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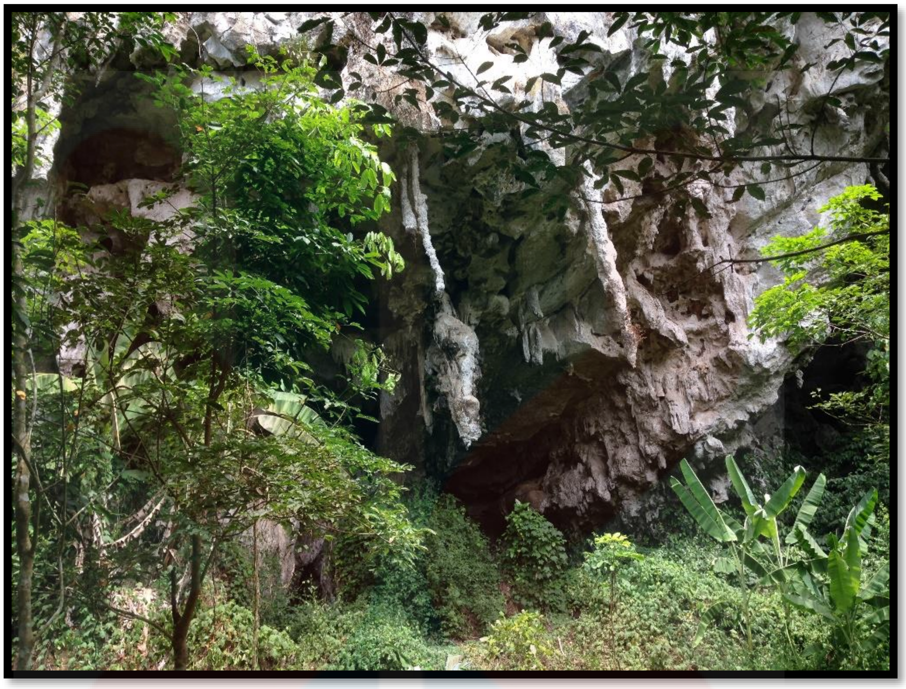

Figure 4.7: Stalactite is the result from dissolution of limestone.

4.2.3 Drainage Pattern

Drainage patterns is the pattern formed by streams, rivers and lakes in a drainage basin. Inside a network, a difference patterns can be observed and related to other geographical factors. Drainage basin can also be known as watershed. It is an area drained by a stream and tributaries. Usually the tributaries developed its own drainage pattern. Catchment area is a basin shaped area of land, bounded by natural features such as hills or mountains from which surface and sub surface water flows into streams, rivers and wetlands. Water flows into and collects in, the lowest area in the landscape. Drainage network will transport water, sediment and other material.

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Drainage pattern are influenced by the topography of the land, hardness of rocks and the gradient of slope. There are six drainage patterns which are annular, dendritic, parallel, radial, trellis and rectangular drainage patterns.

Dendritic drainage pattern usually develops in areas where the rock or unconsolidated material beneath the stream has no particular fabric or structure. This type of drainage pattern can easily be eroded in any direction. Trellis drainage pattern develops when sedimentary rocks had been folded or tilted and then eroded depending on their strength. While rectangular drainage pattern described as develop in areas that very little topography and a system of bedding planes, fractures, or faults that form a rectangular network.

Differ with parallel drainage pattern. It a system look alike pattern of rivers caused by steep slopes with some relief. Due to the steep slopes, the streams are swift and straight, with very few tributaries and flow in all the same direction. Parallel drainage patterns form where there is a pronounced slope to the surface. And it developed in regions of parallel, elongated landforms like outcropping resistant rock bands.

Annular drainage patterns define as the stream follow a roughly circular or concentric path along a belt of weak rock, resembling in plan a ring-like pattern. It developed over a mature and dissected dome mountain characterized by a series of alternate bands of hard and soft rock beds. Others than that, radial drainage pattern. Radial pattern is the streams that radiate outwards from a central high point. Excellent radial drainage usually displayed by volcanoes and commonly develop other geological features are domes and laccoliths.

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In the Kampung Kuala Betis, the observable drainage patterns that dominant is dendritic drainage pattern. It due to randomly developed, tree-like pattern composed of branching tributaries and a main stream. Characterize because of relatively homogeneous rocks and impervious soils.

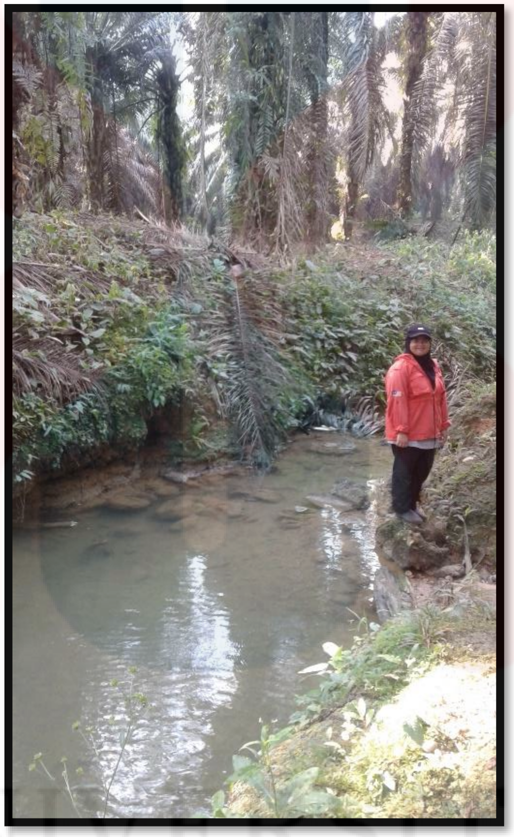

Figure 4.8: One of the tributaries found in Kampung Ladang Melayu.

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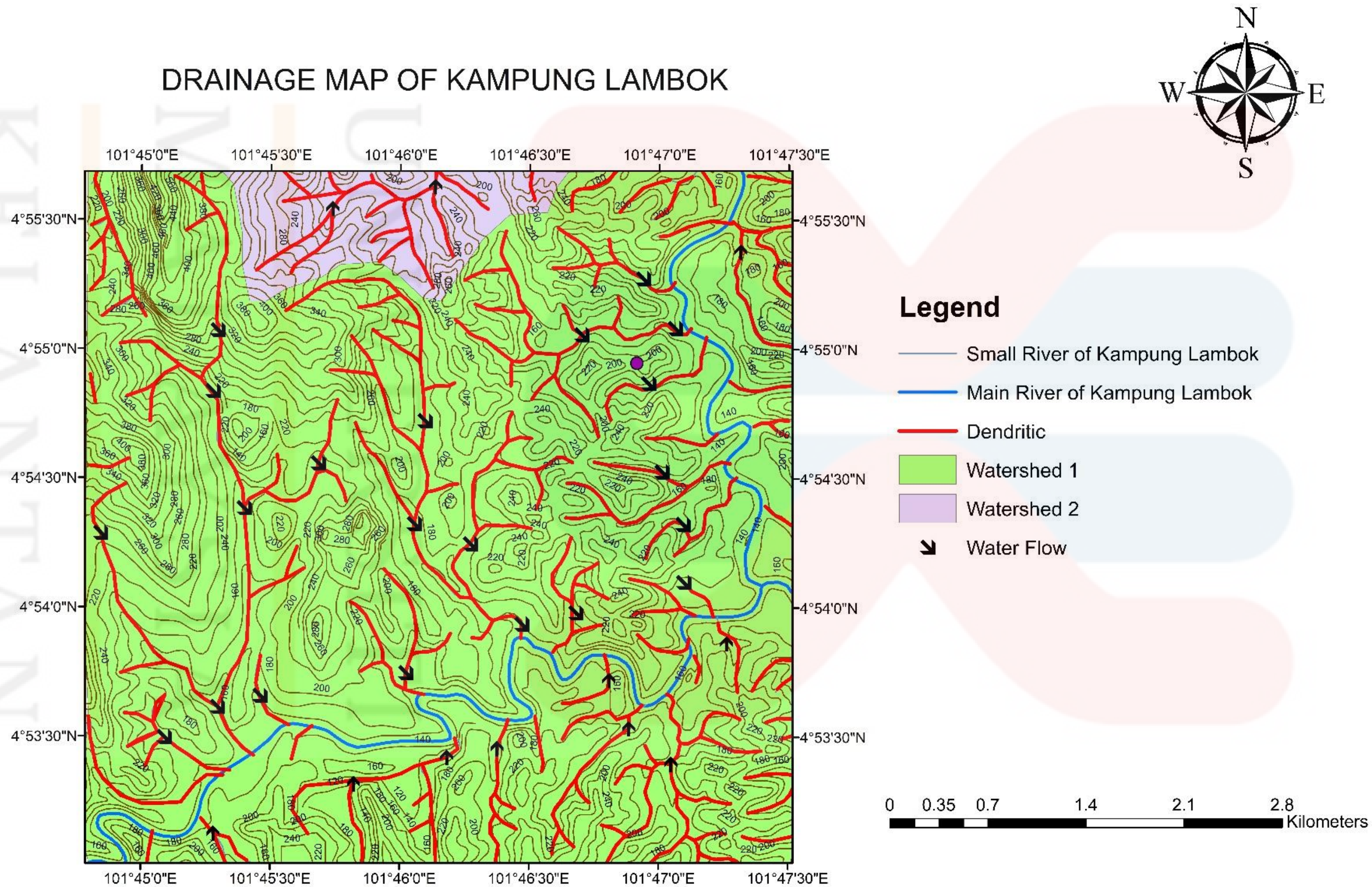

Figure 4.9: Drainage map.

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4.2.4 Mass Movement

Mass movement or mass wasting defined as the downslope movement of material under the direct influence of gravity. Most type of mass wasting are aided by weathering and usually involve surficial material. Mass movement is an important geologic process that can occur at any time and almost any place. A few factors that can lead to mass movement is slope angle, weathering and climate, water content, vegetation and overloading.

Figure 4.10: Landslide is the most common form of mass wasting in study area.

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4.3 Lithostratigraphy

4.3.1 Stratigraphic Position

According to stratigraphy data Figure 4.11, limestone is the oldest rock. Limestone is overlain by tuff and the contact boundary is undefined. After that, slate underlain by mudstone. Metasediment can consider as a product from high pressure and high temperature of mudstone. Alluvium which composed of gravel, sand and silt, which located at main river is the youngest unit in study area. The age is in quaternary period.

The contact between limestone-tuff, tuff-slate, slate-mudstone is unconformity. Unconformity contact was interpreted when a missing interval in geological time occurred because of interruption in deposition or by the erosion during depositional of rock. As conclusion, the age of study area is in Permian period and all lithology is under Gua Musang Formation.

Based on Figure 4.12, the geological map shows the distribution of four type of rocks which is alluvium, limestone, tuff and metasediments. It also shows the indication of major fault which is normal fault.

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Era	Age	Formation	Lithology	Description
Cenozoic	Quaternary		Alluvium	Alluvium located at main river and composed of gravel and sand.
Palaezoic	Late Triassic	Gua Musang Formation	Limestone	Limestone with thick bedded limestone and recrystallize limestone.
Palaezoic	Early Triassic	Gua Musang Formation	Tuff	Mostly dominated by tuff and minor with mudstone outcrop.
Palaezoic	Middle to Late Permian	Gua Musang Formation	Metasediment	Hornfels which is metasediments that have characteristics of mudstone.

Figure 4.11: Stratigraphic column.

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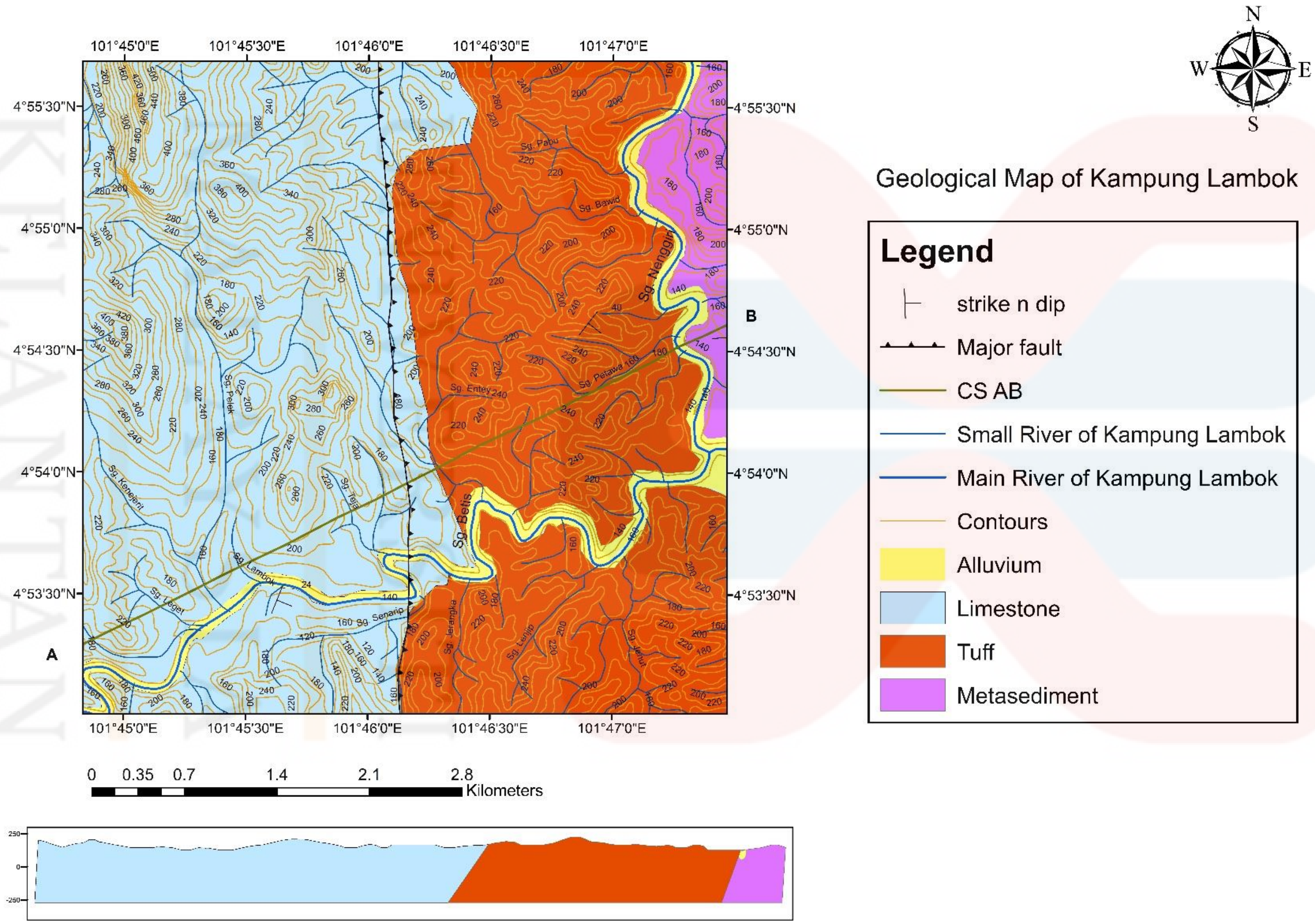

Figure 4.12: Lithological map.

4.3.2 Unit Explanation

4.3.1.1 Limestone unit

Limestone is classified as micrite limestone according to Folk's texture classification of carbonate sediment (Folk, 1959). Micrite limestone also known as mud limestone which abundance with lime mud matrix and not contain organic materials. Outcrop of micrite limestone is around 5 m and above. One of the outcrops shows in Figure 4.13 The micrite limestone is fine grained rock, dark grey in colour and dense.

Mostly, the outcrop is found in palm plantation. This rock is dominated at western part of study area. Under limestone unit, there are also different types of limestone which are crystalline limestone. Crystalline limestone is usually located at river and in the form of travertine as can see in Figure 4.14.

According to Kamal Roslan *et al.,* (2016), limestone in south Kelantan to north Pahang is concluded deposited within the Gua Musang platform during Permo-Triassic. This limestone carbonate platform is deposited before erosion and karstification occur.

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Figure 4.13: One of the limestone found in the study area.

Figure 4.14: Hand sample of marblise limestone or crystalline limestone.

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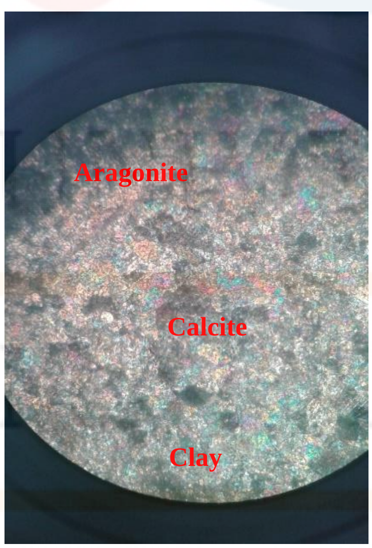
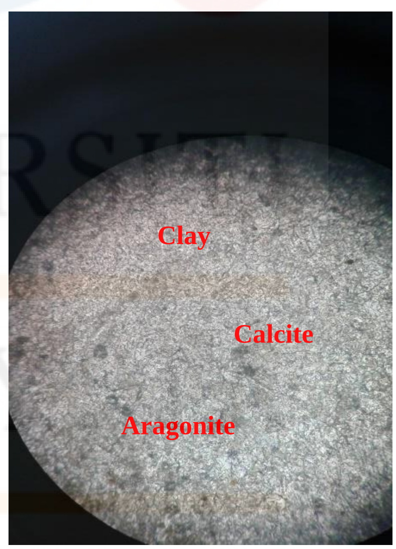
Figure 4.15: Hand sample of limestone.

Table 4.2: Identification and description of limestone

<table>
<tr><td colspan="2">Coordinate: 101°46'17.71"E 4°53'45.783"N</td></tr>
<tr><td>Cross Polarized Light

</td><td>Plane Polarized Light

</td></tr>
<tr><td colspan="2">40× magnification</td></tr>
<tr><td colspan="2">Mineralogy description:</td></tr>
</table>

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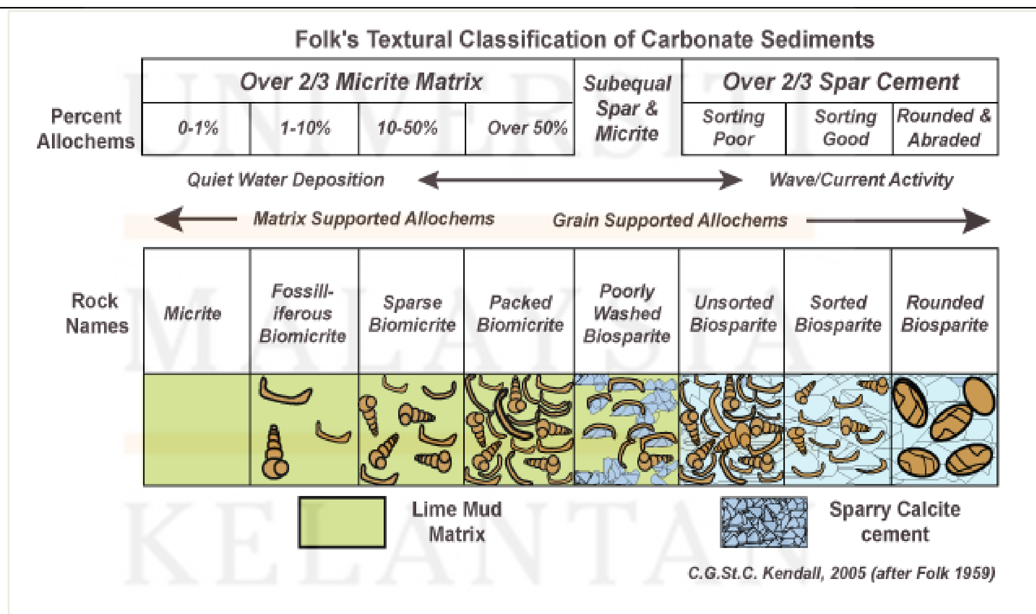
Composition of mineral:	Amount (%)	Description of optical mineral
Calcite	≥ 90	In plane polarized light, calcite is colourless, no peloochroic, high relief and has cleavage. In cross polarized light, calcite has twinning and high interference colours.
Aragonite	5	Colourless, high relief, pleochoism is absence,
Dolomite	5	Colourless in plane polarized light, euhedral shape, no pleochoism, moderate to high relief
Rock name: Micrite limestone (lime mud)		
Rock type: Sedimentary rock		
Classification: Folk’s Texture Classification of Carbonate Sediments		



4.3.1.2 Meta sediment unit

Slate is foliated metamorphic rock with low grade metamorphism. Slate is dark in colour with fine-grained and mainly composed of clay and mica mineral. Slate is formed when the mudstone or shale is undergoing metamorphism with under relatively low pressure and temperature conditions. When the strong compression is acted upon it, causing fine grained of clay is aligned in planes with perpendicular to the compression.

4.3.1.3 Volcanic unit

Volcanic sedimentary rock formed during eruption volcanoes that produce a range of materials which are molten lava flowing from fissures in the volcano and particulate materials (i.e. pyroclastic materials) that is ejected from the vent to form volcanoclastic deposits.

Tuff contains of fine ash which clast size approximately <0.063 mm. The outcrop of tuff shows in Figure 4.16. Volcanic soil has colour reddish brown and white, while, tuff is dark brown in colour. Based on geomorphological map of study area, tuff is only found at southern part of study area which the landform is gentle hill. There is no contact boundary are found between tuff and other rock.

Tuff is under Gua Musang Formation which the age is Early Triassic. The depositional environment of this rock is it comes from volcanic activity. Depositional environment inferred near the volcanic source because the presence of volcanic of all types and sizes of particles i.e. tuffs, lapilli and agglomerate (Kamal Roslan *et al.*, 2016).

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Figure 4.16: Tuff outcrop near to the JAKOA's office.

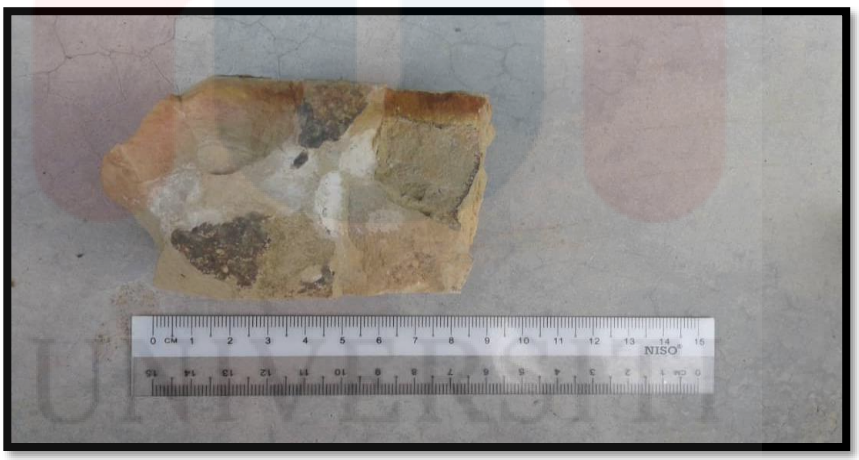

Figure 4.17: Hand sample of tuff.

4.3.1.4 Clastic sedimentary unit

Clastic sedimentary rock is distributed in the eastern part of study area and it is more abundant compare another rock unit. Clastic sedimentary rocks that found in study area are mudstone and sandstone.

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Mudstone is a clastic sedimentary rock made up of mixture of more than one-third of silt and/or clay (Folk, 1974). Mudstone has a fine-grained sedimentary rock. Based on the rock that found in study area, the colour of mudstone is white grey (Figure 4.17). Mudstone is lack of fissility or layering compared to shale. Mudstone is under Gua Musang Formation. The age of this unit been assumed under Middle Triassic.

Figure 4.18: Outcrop of mudstone.

Figure 4.19: Hand sample of mudstone.

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Table 4.3 : Identification and description of mudstone.

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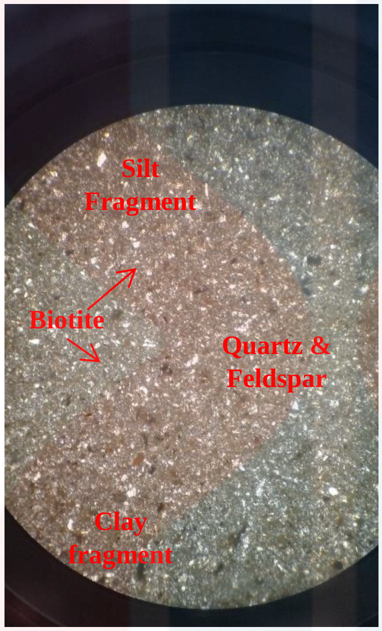

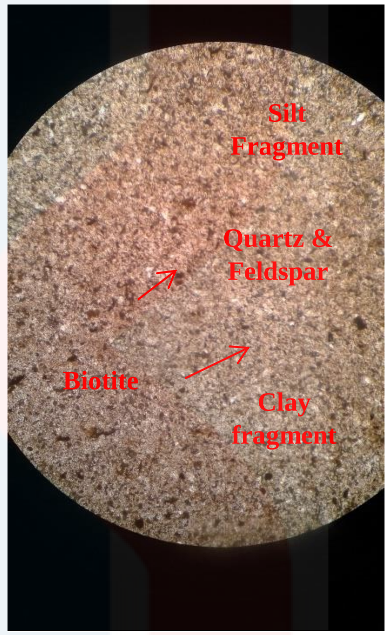

40× magnification</td></tr>
<tr><td colspan="3">Mineralogy description:</td></tr>
<tr><td>Composition of mineral:</td><td>Amount (%)</td><td>Description of optical mineral</td></tr>
<tr><td>Quartz</td><td>25</td><td>Low relief, colourless, no cleavage, pleochroism is not presence.</td></tr>
<tr><td>Feldspar</td><td>15</td><td>Has poor cleavage, colourless, no pleochroic. Grey colour in cross polarized light.</td></tr>
</table>

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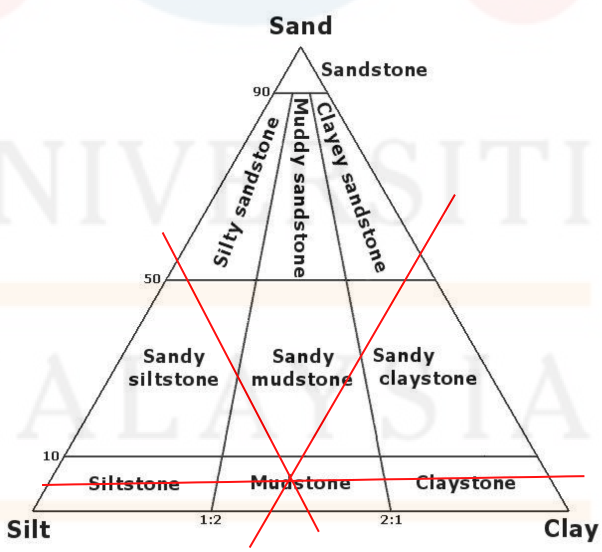
Biotite	5	Biotite in brown colour, low relief, no twinning and high pleochroic.
Calcite		Colourless, pleochroism is absence, high relief, has cleavage and twinning.
Apatite	0.1	Apatite is colourless, prismatic crystal; extinction angle is parallel, high relief and no twinning.
Clay fragment		In clay grained size.
Silt fragment		The grained size larger than clay sized.
Rock name: Mudstone		
Rock type: Sedimentary rock		
Classification: Based on the size of the material by Folk (1974).		



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4.4 Geological structure

In this section, the geological structures, either macro or micro in scale will be described. Geological structures are the results of tectonic forces that occur within the Earth. These structures can be either primary or secondary based on the time of their formation, such as during the rock formation for primary, and after the rock has formed for secondary. Structural geology is actually a study of the processes that result in the development of geologic structures and how these structures give impact to rock.

Therefore, the structural features found in the field can help to get a better understanding about how the rock was formed as well as the deformation processes that happened to it, to be specific, including how these structures affect the rock that led to cavities or sinkhole. The geological structures found in the study area are lineament, joint, folding and fault.

4.4.1 Lineament analysis

Lineament is a regional scale geological structures, displayed by topographic component. This lineament can be split up into two types, positive lineament and negative lineament. The positive lineament demarcated by ridges, whereas negative lineament shown by features like valleys. By using current technologies for instance aerial photographs and topographic map, lineament can be clearly observed. The formation of lineament is ordinarily related to structural deformation that commonly signalises fold or fault zone. But, sometimes, lineament can also exist due to human factors and result of erosion.

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As mentioned previously, lineament can be analysed and interpreted by ridge and river feature. For ridge, basically it was formed because of the deformation processes, like faulting which can produce fault-aligned hill area. Whereas for river feature, it is usually developed as a result of erosion. This erosion can both be destructive at one point and constructive at the other point. However, the constructive usually occur once the river has lose its energy and deposit the load it carries.

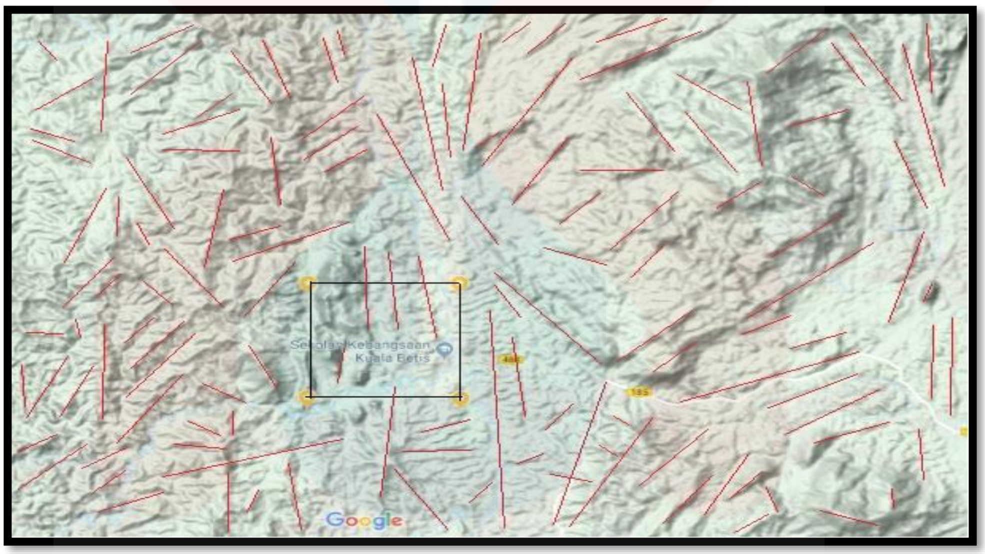

Figure 4.20: Interpretation of regional lineament observed by terrain.

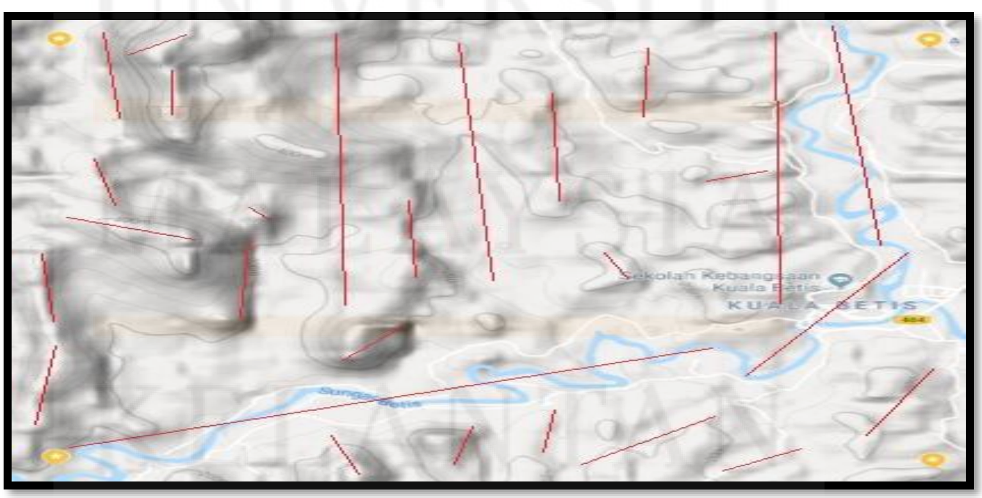

Figure 4.21: Lineament map of study area.

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4.4.2 Fault

The fracture is called a fault when the blocks on opposite sides of a fracture move up, down, or sideways. The fault plane is displaced relative to the rock on the opposite side of the fracture. When movement takes place along a fault, the rocks on opposite sides may be scratched and polished.

Figure 4.22: Fault in limestone.

4.4.2 Joint

Joint is a fracture in rocks along which no visible movement has occurred. Nearly vertical joints that result from reduction during cooling are commonly found in igneous rocks. Similar joints occur in thick beds of sandstone and gneiss, with the sheets similar to the structure of a sliced onion. Deep-seated igneous rocks often have joints almost parallel to the surface, signifying that they formed by expansion of the rock mass as overlying rocks were eroded away. Some joints in sedimentary rocks may have formed as the outcome of contraction during compaction and drying of the sediment.

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In some cases, jointing of the rock may result from the exploit of the same forces that cause folds and faults. In relatively uninterrupted sedimentary rocks, such joints are often in two vertical sets perpendicular to one another. Normally, streams develop along zones of weakness caused by joints in rocks, and thus the regional pattern of joint orientation often applies a strong control on the development of drainage patterns.

Joint analysis is conducted to see if there is a correlation between the joint patterns of the study area.

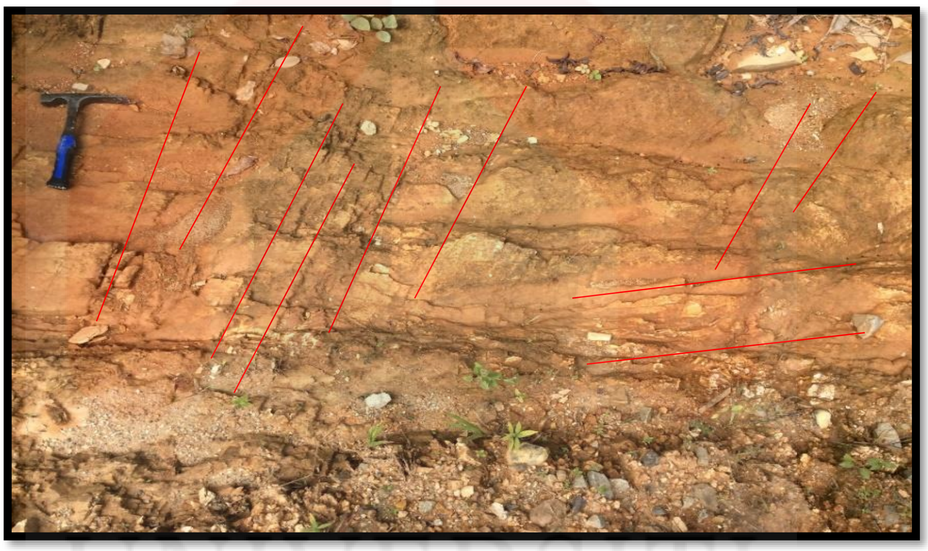

Figure 4.23: Joint that been found normally in ground.

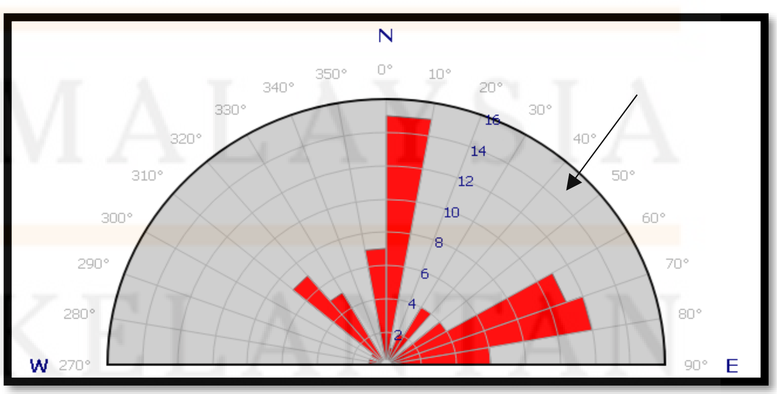

Figure 4.24: The main force comes from N 40° E.

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4.4.3 Fold

Folds known as rock layers have been crumpled and bent are quite common. Most fold forms in response to compression and probably takes place deep in the crust where rocks are more ductile than they are at shallow depth or at the surface. An anticline is an up-arched or convex upward fold with the oldest rock layers in its core, differ with a syncline. Syncline is a down arched or concave upward fold in which the youngest rock layers in core.

Anticline have an axial plane connecting the points of maximum curvature in each folded layer. The axial plane divides fold into halves and each half being a limb. Most fold often found as a series of anticlines alternating with synclines, an anticline and adjacent syncline share a limb. Both are simply folded rock layers and do not necessarily correspond to high and low areas.

Figure 4.25: Folding that forming an anticline.

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4.5 Historical Geology

Along the western margin of the Gua Musang basin, argillaceous rocks are conformable on basal conglomerate indicating that the basin was developed on continental basement. In the central part, there is evidence suggesting that volcanic activities might have created topographic highs allowing for the deposition of some limestone bodies on top of them. Platform or shelf instability must have continued into Early Triassic as evidenced by the occurrence of limestone blocks and conglomerate in shale as well as the presence of emergent features.

Metasediment produced by a few factors for example from intrusion of granite, movement of two plate tectonic between Sibumasu and Indochina and lastly is fault. The sediment itself before turns to metasediment are produce from transportation and deposition of Penyu Basin.

Tuff in Gua Musang Formation under volcanic rocks produced from the eruption of volcanoes around the Sibumasu and Indochina plate. While limestone results from erosion and deposition of collision Sibumasu and Indochina plate.

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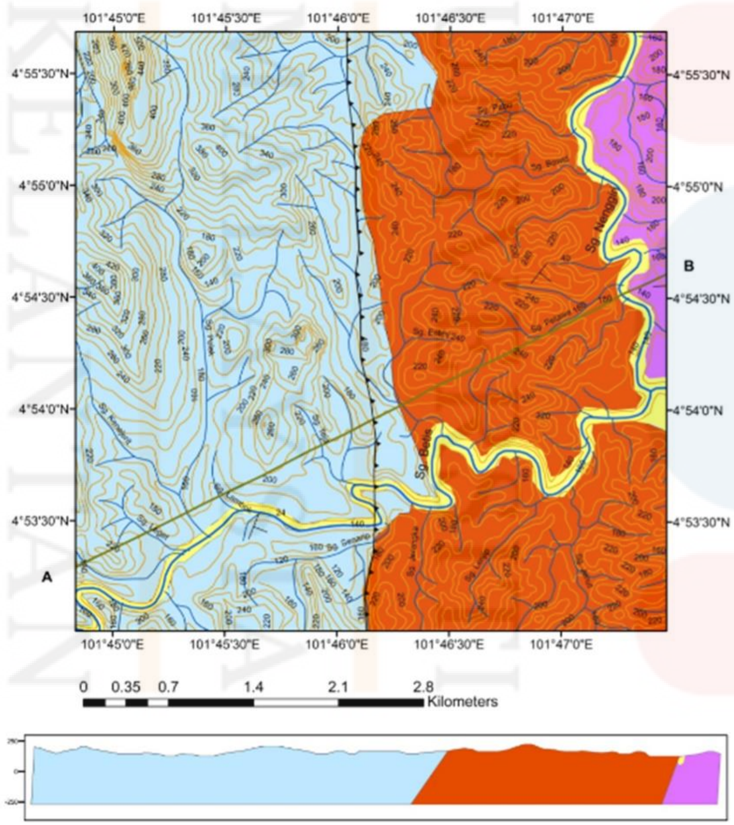
GEOLOGICAL MAP OF GEOLOGY AND POTENTIAL LIMESTONE GEOHAZARD USING ELECTRICAL RESISTIVITY IMAGING IN KAMPUNG LAMBOK, GUA MUSANG, KELANTAN

By:
FATIMAH NAJEEBAH BINTI ILYASAK
E15A0050
2019

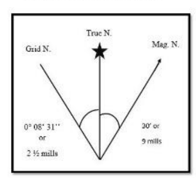


Legend

- strike n dip
- Major fault
- CS AB
- Small River of Kampung Lambok
- Main River of Kampung Lambok
- Contours
- Alluvium
- Limestone
- Tuff
- Metasediment

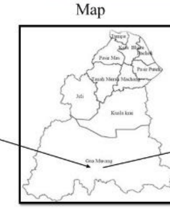
Era	Age	Formation	Lithology	Description
Cenozoic	Quaternary		Alluvium	Alluvium located at main river and composed of gravel and sand.
Palaeozoic	Late Triassic	Gua Musang Formation	Limestone	Limestone with thick bedded limestone and recrystallize limestone.
Palaeozoic	Early Triassic	Gua Musang Formation	Tuff	Mostly dominated by tuff and minor with mudstone outcrop.
Palaeozoic	Middle to Late Permian	Gua Musang Formation	Metasediment	Hornfels which is metasediments that have characteristics of mudstone.

Magnetic Inclineation

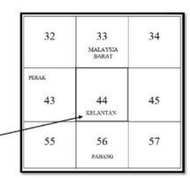


Peninsular Malaysia Map

Administrative Map



Index Map



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CHAPTER 5

POTENTIAL LIMESTONE GEOHAZARD USING ELECTRICAL RESISTIVITY IMAGING IN KAMPUNG LAMBOK, GUA MUSANG, KELANTAN

5.1 Introduction

This chapter is necessary and main focus on potential limestone geohazard in the study area. The resistivity data obtain in field and processed by using RES2DINV software, to produce 2D inversion model. The resistivity value for common materials can be seen in Table 5.1.

The potential of limestone geohazard is determine by the resistivity value of materials at three survey line. Usually, the types of layer contained in geological basement complex terrain are top layer, weathered layer and fractured/fresh basement rock. From the interpretation of data, it provides the lateral distance, elevation, resistivity of subsurface material and also the potential of limestone geohazard.

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5.2 Location of Survey Lines

There are **three** survey lines has been carried out in this survey. The location of lines can be seen in Figure 5.1. All the lines are on the same lithology which is limestone. First line and second line are cross each other. The location is between two caves. While for the third line are chosen based on the location located in the area near to the major fault indication.

5.3 Interpretation of Subsurface

The data from ABEM is interpreted by using RES2DINV software where the apparent resistivity is converted to true resistivity. The result is present in pseudosection. The interpretation of result is based on resistivity values some of rocks, waters and chemical by Loke (1997). The reference of resistivity value can be seen in Table 5.1. By using the 2D resistivity method, the cavities or sinkhole can be detected by its low resistivity. Besides, high resistivity indicates the presence of alluvium and hard rock.

The Induced Polarization (IP) is a measure of the soil ability to be polarized when soil is under the influence of an electric field. In this study, Induced Polarization (IP) method is used to differentiate between groundwater and alluvium/gravel beneath the ground. The chargeability of a material affected the grain size of particles, type of minerals present and type of mobility of ions within the pore fluids (Jones, 2007). Induced Polarization gives result in term of chargeability. The chargeability values of materials were determined by (Telford *et al.*, 1976) shown in Table 5.2.

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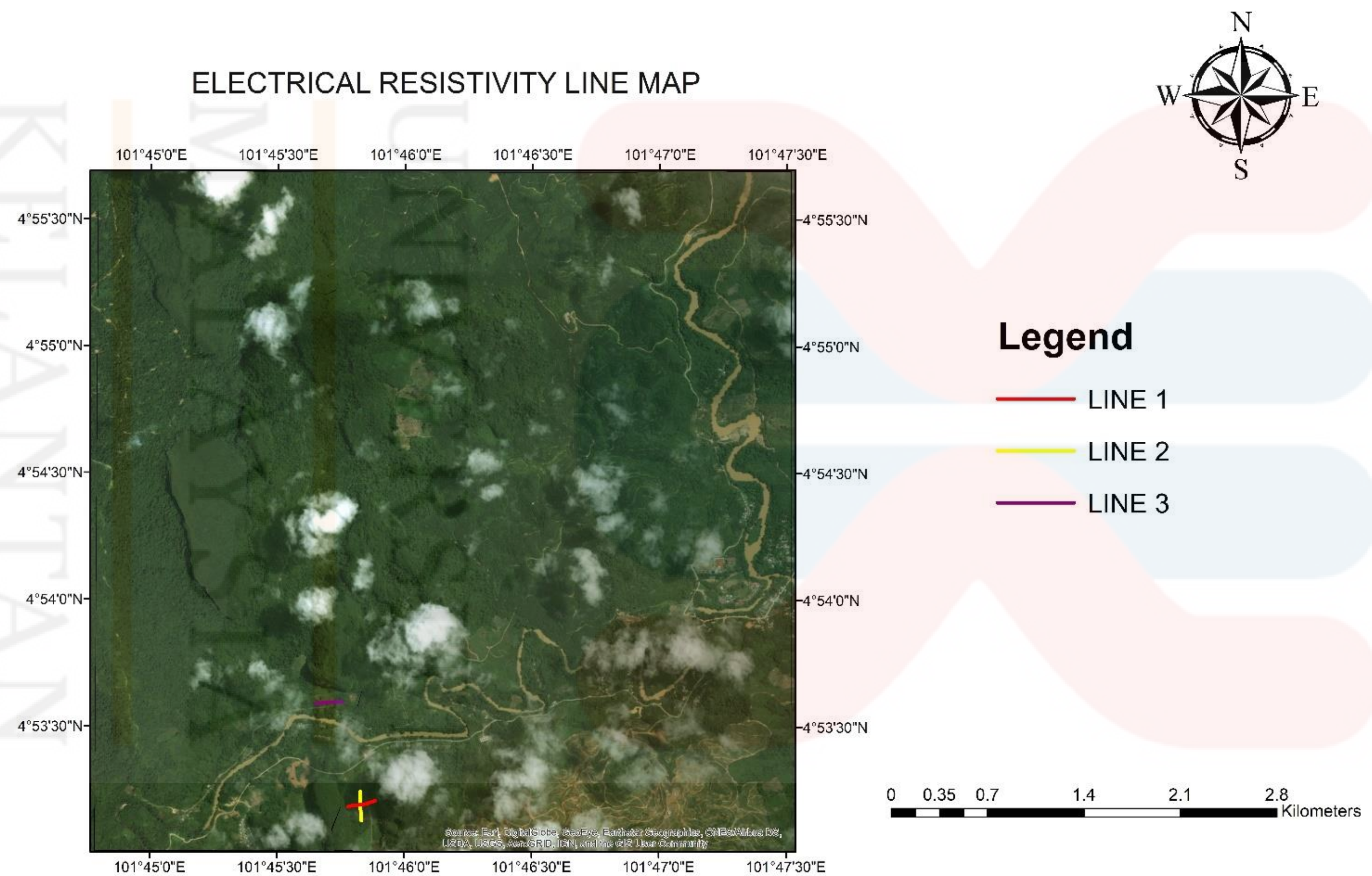

Figure 5.1: Electrical resistivity survey lines map of study area with base map.

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Table 5.1: Resistivity and conductivity of some rocks, waters and chemicals.

Material	Resistivity (Ωm)	Conductivity (Siemen/m)
Igneous and Metamorphic Rocks		
Granite	5×10^3 - 10^6	$10^{-6} – 2 \times 10^{-6}$
Basalt	$10^3 – 10^6$	$10^{-6} – 10^{-3}$
Slate	$6 \times 10^2 – 4 \times 10^7$	$2.5 \times 10^{-8} – 1.7 \times 10^{-3}$
Marble	$10^2 – 2.5 \times 10^8$	$4 \times 10^{-9} – 10^{-2}$
Quartzite	$10^2 – \times 10^8$	$5 \times 10^{-9} – 10^{-2}$
Sedimentary Rocks		
Sandstone	8 - 4×10^3	2.5×10^{-4} – 0.125
Shale	20 - 2×10^3	5×10^{-4} – 0.05
Limestone	50 - 4×10^2	2.5×10^{-3} – 0.02
Soils and Waters		
Clay	1 - 100	0.01 – 1
Alluvium	10 - 800	1.25×10^{-3} – 0.1
Groundwater (fresh)	10 – 100	0.01 – 0.1
Sea water	0.15	6.7
Chemicals		
Iron	9.074×10^{-8}	1.102×10^7
0.01M Potassium chloride	0.708	1.413
0.01M Sodium chloride	0.843	1.185
0.01M Asetic acid	6.13	0.163
0.02 Xylene	8 - 4×10^3	8 - 4×10^3

Source: Loke (1997).

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Table 5.2: The values of chargeability of materials.

Material type	Chargeability (ms.)
Groundwater	0
Alluvium	1 – 4
Gravels	3 – 9
Precambrian volcanics	8 – 20
Precambrian gneisses	5 – 20
Schists	5 – 20
Sandstones	3 – 12
Argilites	3 – 10
Quartzites	5 – 12

Source: Telford *et al.*, (1976).

5.3.1 Resistivity Survey Line 1

The location of Line 1 is based on Table below. The length of the survey line is 200 m and electrode spacing is 5 m. The array that be used during the line survey is Pole-Dipole array and Schlumberger array.

Electrode No	**Longitude**	**Latitude**	**Elevation**
1	101° 45' 52.5"E	4° 53' 12.2"N	121 metre
21	101° 45' 49.7"E	4° 53' 11.5"N	145 metre
41	101° 45' 46.7"E	4° 53' 11.0"N	156 metre

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The survey line 1 site is done at the rubber plantation area of Kampung Lambok that locates between two caves. The survey line is set up of about 200 meters in the direction of NS. A small tributary river is located near the survey line. The weather during the survey line is cloudy and the time conducting the survey is about 12.00 p.m.

Figure 5.2: The orientation of survey Line 1.

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Based on Figure 5.3, the array used is Pole Dipole. The lower resistivity value is ranging between 20 Ω.m – 500 Ω.m. The material was interpreted as limestone cavity that had been filled with water with the thickness between 40m at the centre. This section is indicated by the colour of blue pale to green pale. We can see the water passage at the top of the section. Usually the fracture, joints and bedding plain are pass-ways for waste groundwater and acidic rain. The weathering and chemical dissolution in fractured limestone found to be more aggressive than massive limestone. This fracture pattern in limestone could be the reason of underground streams and multi elevation cavities formation.

On the left of pseudosection, the resistivity value can be seen around 200 Ω.m to 4000 Ω.m. It was indicated by the colour of light green to red. The material was interpreted as stable rock of limestone. The depth is 140m until 110m. While on the right section, it having the highest resistivity value range between 7500 Ω.m until 12000 Ω.m. it can be seen on the 120m until 60m depth. The value usually classifies as limestone that already undergoes a metamorphism process because resistivity tends to increase with the depth.

Based on IP result shows the lower resistivity value zone in Figure 5.3 has interpreted as groundwater zone with chargeability value of 0.1 msec – 0.5 msec. There are potential cavity sources in this layer because the resistivity value is low. IP result are important to differentiate either it is a clay or groundwater.

For comparison purpose to see which array give the best resolution, the Schlumberger array also have been used. Figure 5.4 shows the pseudo for Schlumberger. The higher resistivity value is in range about 750 Ω.m to 3000 Ω.m, which was interpreted as hard rock. The colour represent is brown to purple. This layer covered at the lower part

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of profile at WS direction which this layer was present at lateral distance from 115 m until end of line. This can be considered as limestone undergo metamorphism process or can be newly from marble.

The lower resistivity value is ranging between 45 Ω.m – 500 Ω.m. the resistivity is low due to presence of clay/ alluvium/ fresh water. During the process in run this profile the site was just after raining heavily. Due to this factor, the soil probably saturated with water when the electrodes are implemented into the ground. It can contribute to the saturation of top soil and leads to low resistivity reading.

Unfortunately, interpretation of Schlumberger based on direct current soundings will be limited to simple, horizontally layered structures. The depth for electric current to penetrates also small compared to Pole Dipole that have great penetrations.

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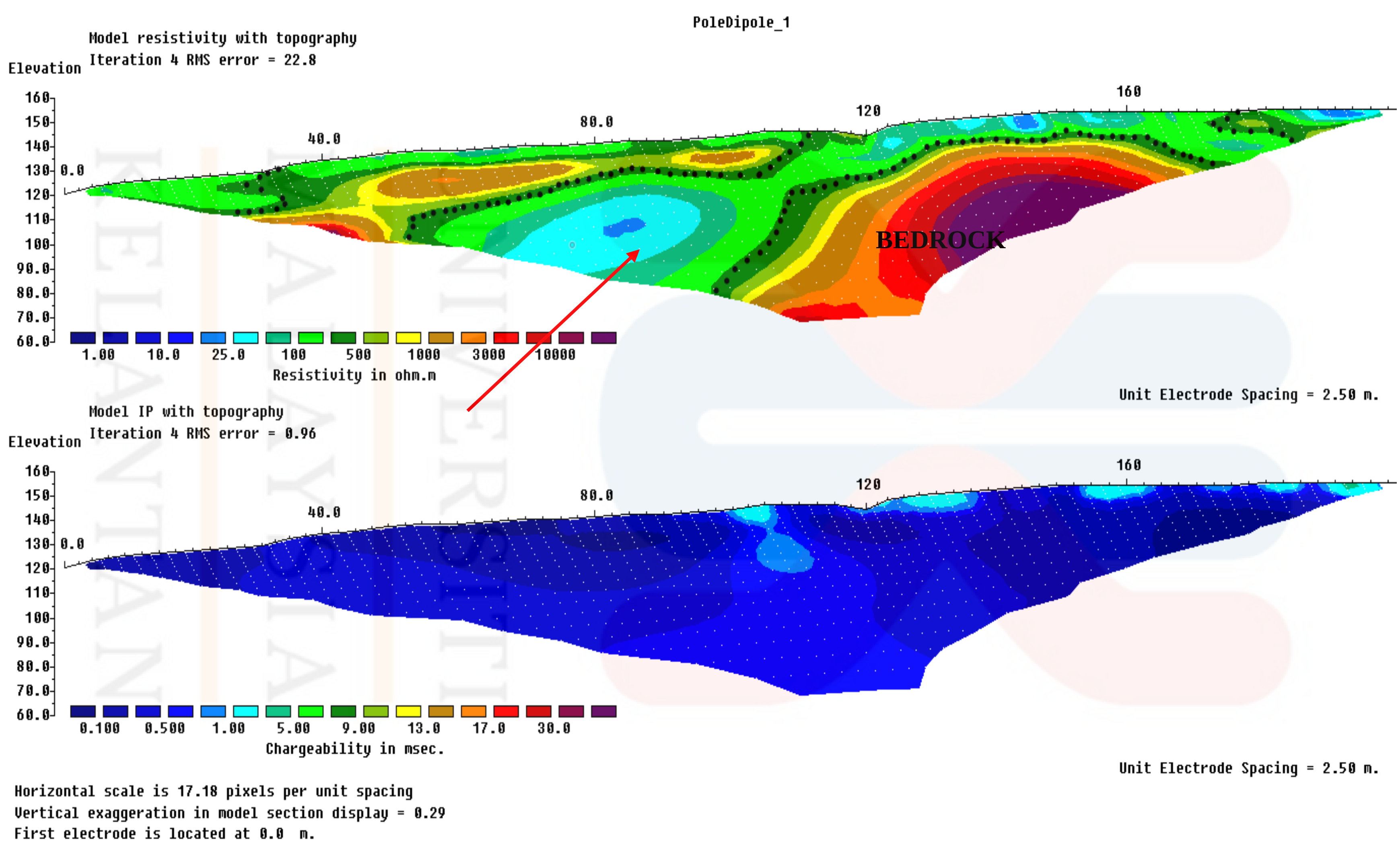

Figure 5.3: 2D Inversion model sections for Line 1 by Pole Dipole array.

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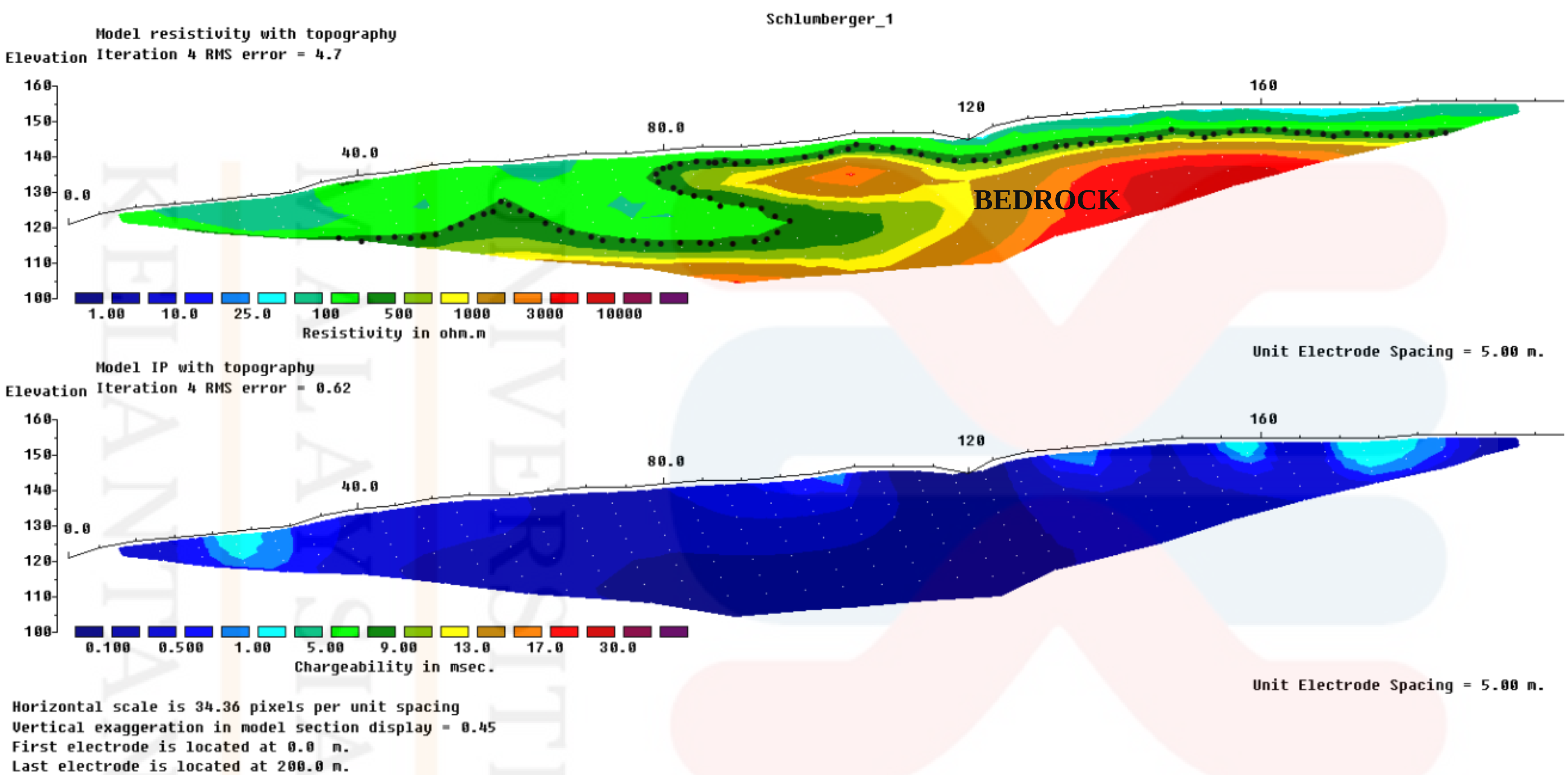

Figure 5.4: 2D Inversion model sections for Line 1 by Schlumberger array.

5.3.2 Resistivity survey Line 2

The location of Line 2 is based on Table below. The length of the survey line is 200 m and electrode spacing is 5 m. The array that be used during the line survey is Schlumberger array and Pole-dipole array.

Electrode No	Longitude	Latitude	Elevation
1	101° 45' 49.6"E	4° 53' 14.6"N	166 metre
21	101° 45' 49.6"E	4° 53' 11.5"N	166 metre
41	101° 45' 50.0"E	4° 53' 8.0"N	168 metre

The survey line 2 is done by cross the survey line 1. The survey line is set up of about 200 meters in the direction of N-S along the rubber plantation and small river. The time the survey is measured at 1.31 p.m. with nice weather. Figure 5.5 shows the set up of second line.

Based on Figure 5.6, the resistivity value is ranging between 1 Ω.m to above 15000 Ω.m. The higher resistivity value from 7500 Ω.m to above 15000 Ω.m is distributed at the NW part of section and SE part of section. This layer is indicated by the colour of red to dark purple. This layer is considered as hard rock.

The intermediate resistivity values are between 250 Ω.m to 2500 Ω.m, which displayed by the colour light green to light brown. This layer is distributed at the centre part of section. This layer is represented as weathered limestone.

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The lower resistivity value re ranging from 10 Ω.m to 250 Ω.m which is indicated by dark blue to light green. This layered considered as old sinkhole that has been filled with clay. The potential sinkhole is located at the top on the left part of section which lateral distance 170m to 140m. the hydraulic pressure of rainwater carried of infilling sediments and dry tree leaves inside the shallow cavities can increase the cavities dissolution and led to sinkhole formation. A water saturated mixture of sand, silt or clay can behave rather like quicksand and become very mobile.

As compared lower resistivity values zone in Figure 5.6 with induced polarization, the zone with chargeability ranging from 0.1 msec – 1 msec and lies at 150 – 140 m of elevation is expected as water and alluvium. As the result in Line 2, there is groundwater source zone and presences of empty void.

Based on Figure 5.7, the second line also been measured by applying a Schlumberger array. The higher resistivity value is above 15000 Ω.m, which was interpreted as hard rock. The colour represent is green to purple. This layer covered at the lower part of profile which this layer was present at lateral distance. It implies highly impermeable rock which unable to water flow. It can be observed that the lower the depth the higher the resistivity.

The lower resistivity ranges from 15 Ω.m to 100 Ω.m, which is indicated by the dark blue to dark green colours. This layer is considered as groundwater potential because groundwater has low resistivity value which is from 10 Ω.m to 100 Ω.m (Table 5.1).

Based on IP result in shows the lower resistivity value zone in Figure 5.7 has interpreted as alluvium zone with chargeability value of 1 msec – 3 msec. Alluvium is

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assumed dominance at top part this profile. As result, this layer is no groundwater sources because the resistivity value is high which is above 100 Ω.m. And that layer was interpreted as alluvium. It also does not indicate any signs of voids.

The interpretations of Schlumberger are based on direct current soundings will be limited to simple, horizontally layered structures. The depth for electric current to penetrate also small compared to Pole Dipole that have great penetrations.

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Figure 5.5: The orientation for Line 2.

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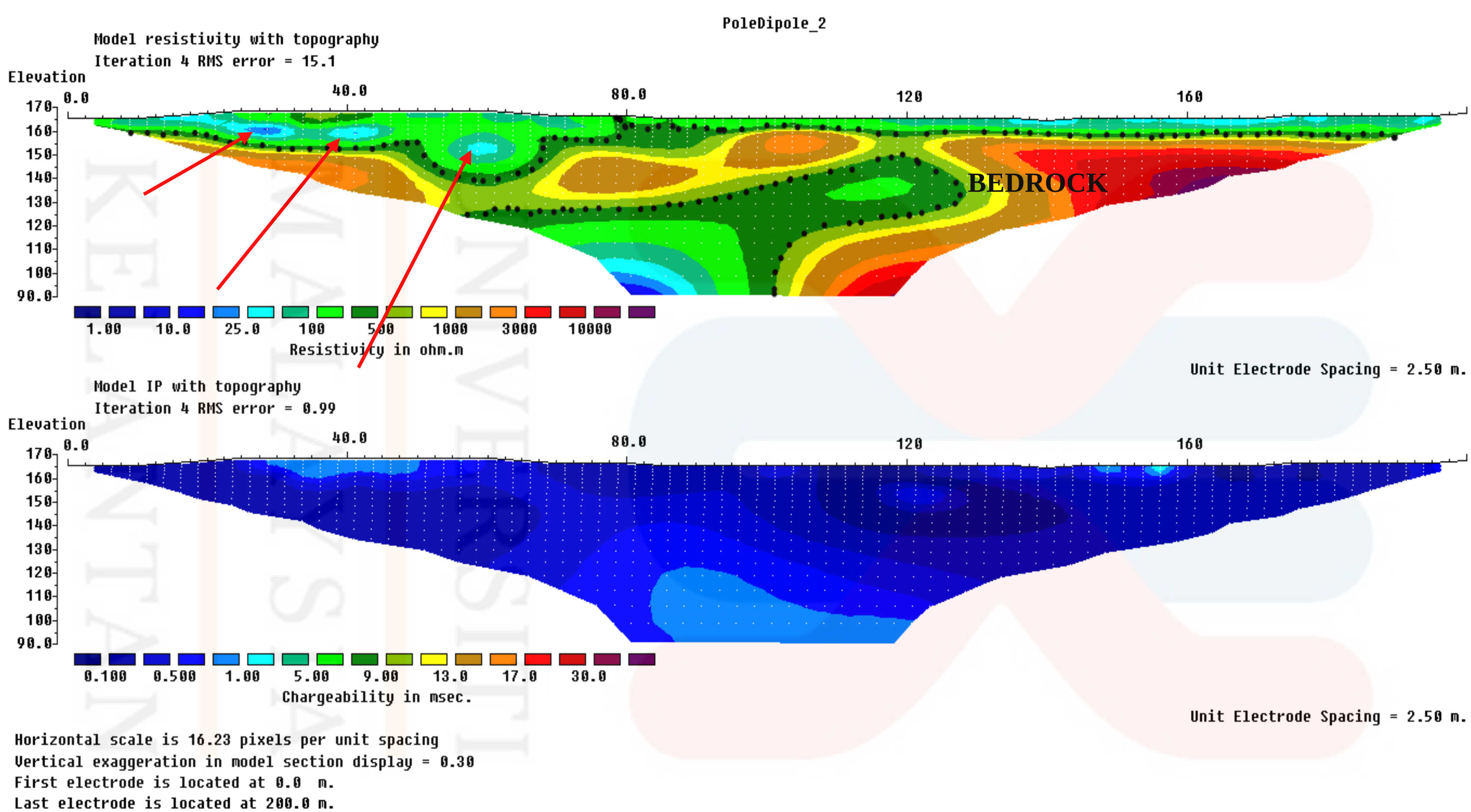

Figure 5.6: 2D Inversion model sections for Line 2 by Pole Dipole array.

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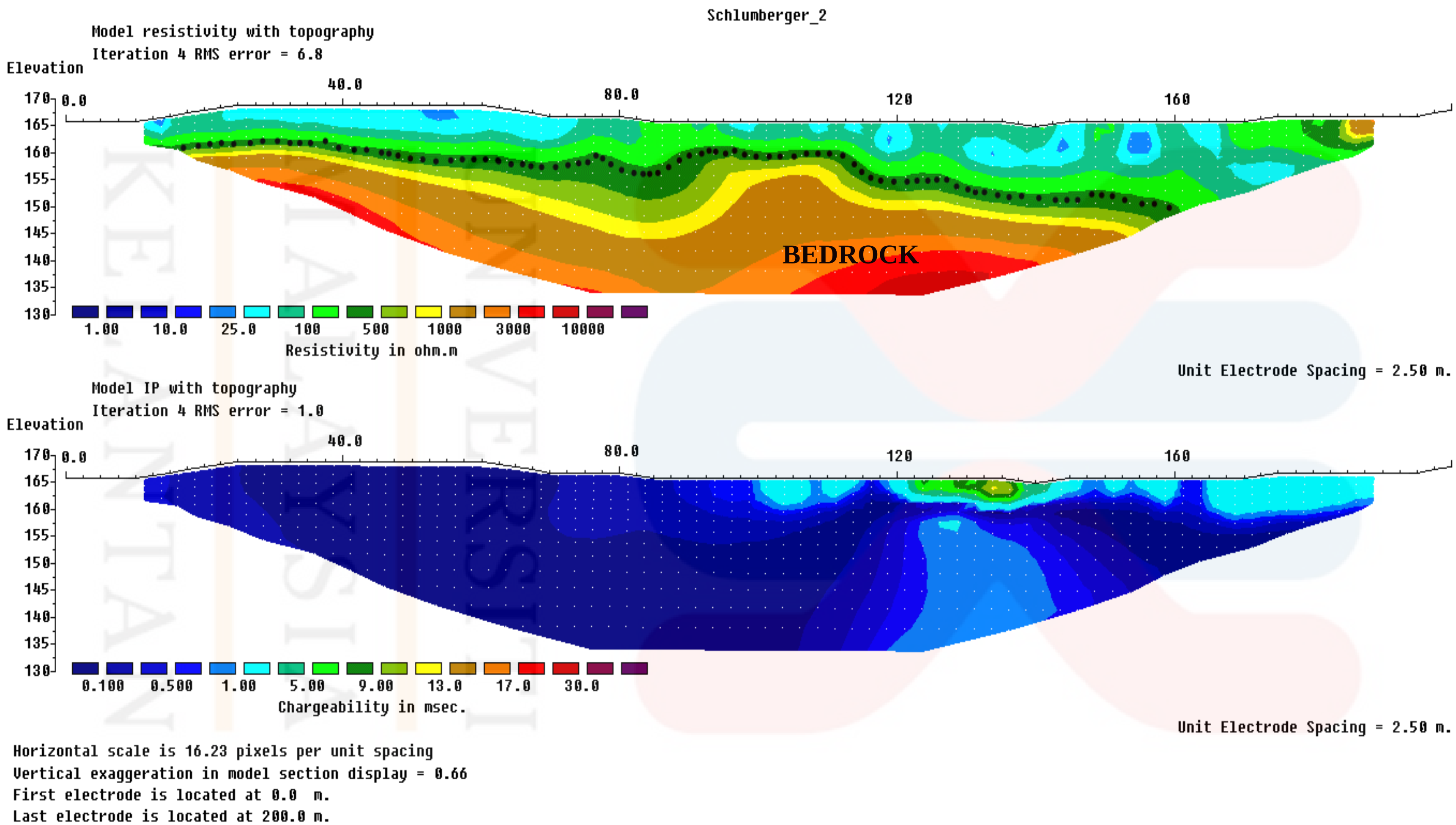

Figure 5.7: 2D Inversion model sections for Line 2 by Schlumberger array.

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5.3.3 Resistivity survey Line 3

The location of Line 3 is based on Table below. The length of the survey line is 200 m and electrode spacing is 5 m. The array that be used during the line survey is Pole-dipole array.

Electrode No	Longitude	Latitude	Elevation
1	101° 45' 45.3"E	4° 53' 35.7"N	152 metre
21	101° 45' 42.2"E	4° 53' 35.8"N	154 metre
41	101° 45' 39.1"E	4° 53' 35.4"N	157 metre

The survey line 3 is located at the Kampung Ladang Melayu. The survey line is set up of about 200 meters in the direction of S-W. The time conducting the survey line is started at 5 23 p.m. The setup for this line shown in Figure 5.8.

Based on Figure 5.9, the resistivity value is ranging between 5 Ω.m to above 10000 Ω.m. The higher resistivity value from 500 Ω.m to above 4000 Ω.m is distributed at the centre part of pseudo. This layer is indicated by the colour of dark green to purple. This layer is can be considered as hard rock with gravel. Limestone probably already undergoes a metamorphism process because resistivity tends to increase with the depth. The depth between 150m until 110m.

The lower resistivity values are between 1 Ω.m to 250 Ω.m, which displayed by the colour dark blue to light green. This layer is distributed at the upper and lower part of section with the 150m until 140m depth and 110m until 90m. This layer is represented

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alluvium/sand/gravel. It also can show the existence of clays, saturated limestone and fresh water. The low resistivity in subsurface show possibilities of water channel.

There are no any indications or sign shows the presence of sinkhole in this area profile.

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Figure 5.8: The orientation for Line 3.

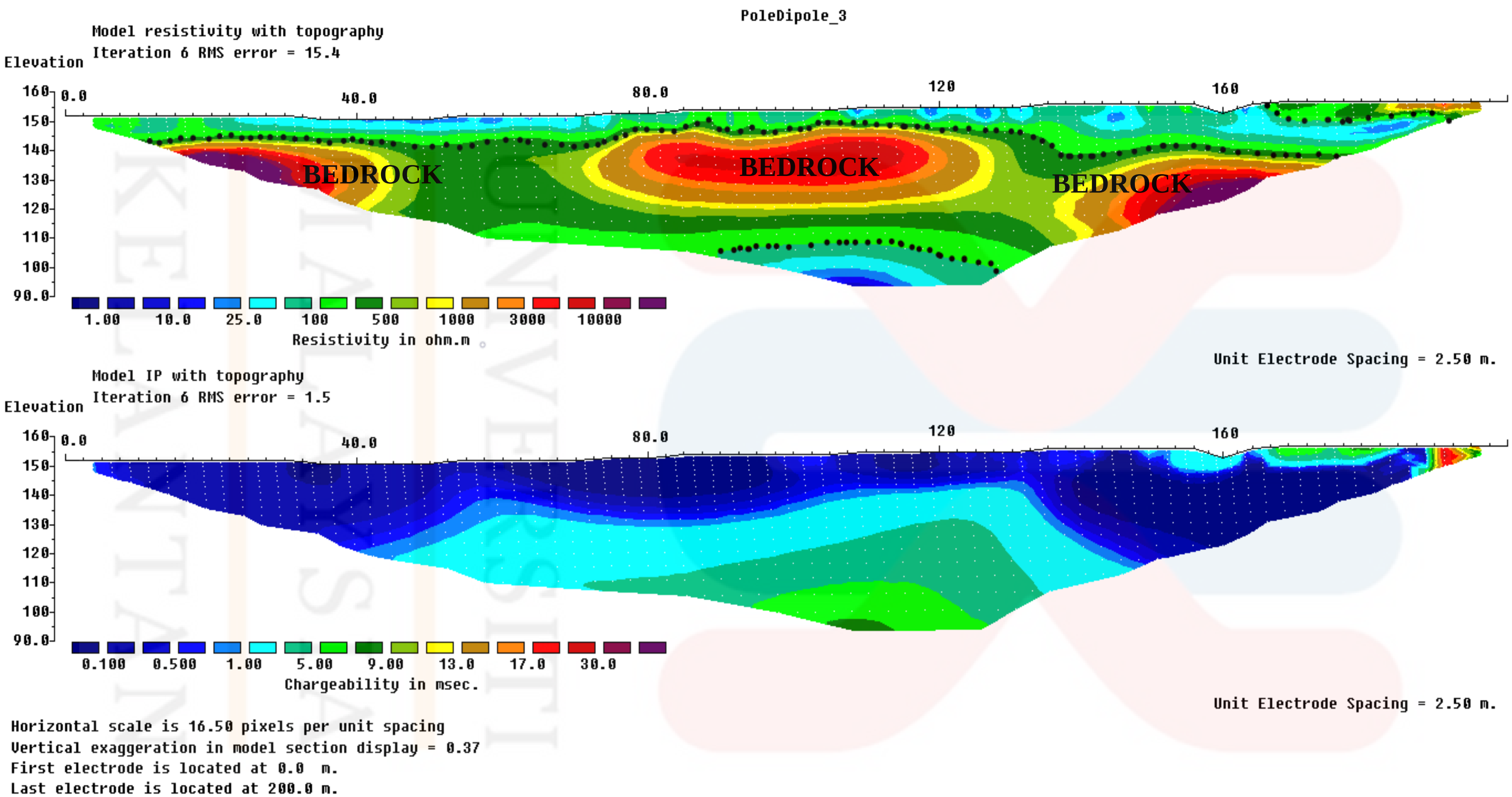

Figure 5.9: 2D Inversion model sections for Line 3 by Pole Dipole array. (**No potential sinkhole**)

5.4 Discussion

Generally, each pseudosection shows the three resistivity zones. Three resistivity zones are divided based on their resistivity values. The higher resistivity zone has the resistivity values are above 800 Ω.m. This layer is represented as hard rock zone. After that, the intermediate resistivity zone has the resistivity value ranging from 100 Ω.m to 800 Ω.m and can interpreted as the alluvial deposits or unconsolidated sediments. Lastly, the lower resistivity zone which the resistivity values are between 1 Ω.m to 100 Ω.m, and it represented by dark blue to dark green colour. This layer zone assumed as water zone.

Line 1 and Line 2 are running by using two types of electrode configuration which is Schlumberger array and Pole Dipole array. This is for comparison to see which options give the best idea about the subsurface conditions. Due to the short of time, Line 3 are only able to running by Pole Dipole array.

Voids or cavity can be predicted by seeing the lineaments or other geological aspects like topography and fault. The possibility of formation of sinkhole can be come from the groundwater movement or turbulation and from the small cavity slowly become a large empty void.

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CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

From geological mapping, lithology can classify into three units which is limestone unit, metasedimentary unit, volcanic unit and clastic sedimentary unit. In limestone unit, the type of limestone is identified as micrite limestone. While meta-sedimentary rock is composed of hornfels rock. Volcanic rock is composed by tuff. And, clastic sedimentary rock is mudstone. Drainage pattern in study area is dendritic pattern most covered in study area. Hill landform is dominant in study area with the elevations between 76 m to 300 m, whereas, at the western part is covered by karst landform. The type of karst landscape is cone karst which is the shape of cave is rounded.

Subsurface condition of the study area is identifying by using electrical resistivity imaging (ERI) method. ABEM Terrameter LS has been used to measure the resistivity. Three resistivity profiles, P1, P2 and P3 have been made and interpret in chapter 5 along with the figure of the resistivity value.

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The prediction of limestone geohazard can be made after the data has been collected by using ERI method. The data is then analyse in chapter 5. Based on the results, Line 1 and Line 2 shows there are potential limestone geohazard because of low resistivity value. This is because underground river and groundwater are present, corresponds to the low resistivity value indicates high water content in the area, and may lead to sinkhole. While Line 3 does not indicate any presence of potential limestone geohazard due to the stable rock of limestone.

6.2 Recommendation

The aim of this study is to investigate the any potential of limestone geohazard by using 2D electrical resistivity imaging technique. While recognizing the limitations of my research, a few suggestions for next researcher to take a look.

1. Use another geophysical method i.e. borehole drilling to calibrate borehole data with electrical resistivity data to the subsurface structure.
2. Choose location based on a few aspects like topography and surrounding environments.
3. Use synthetic models. It designed for confirming the interpretation of the inverted 2D resistivity profiles.

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