GENERAL GEOLOGY AND PREDICTION OF LIMESTONE GEOHAZARD AT KG. TAMAN RUSA USING ERI, GUA MUSANG, KELANTAN

by

MUHAMMAD SAFIQ BIN MOHD ZAHEL

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DECLARATION

I declare that this thesis entitled "General Geology and Prediction of Limestone Geohazard at Kg. Taman Rusa using Electrical Resistivty Imaging (ERI), 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.

Signature : ______________________________

Name : MUHAMMAD SAFIQ BIN MOHD ZAHEL

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General Geology and Prediction of Limestone Geohazard using Electrical Resistivity Imaging (ERI) at Kg. Taman Rusa, Gua Musang, Kelantan

ABSTRACT

This study is about general geology and prediction of limestone geohazard using electrical resistivity imaging at Kg. Taman Rusa, Gua Musang, Kelantan at coordinate N 04°46’15” to N 04°48’30” and E 101°57’0’ to E 101°59’40” in south of Gua Musang’s city. The purpose of this study is to update geological map of study area. In meantime, there have a change of geological structure whether from natural behavior or artificial action. For completing this study, site investigation and taken rock sample were used. Three sample were taken to undergo petrography analysis. Sample was used to determine the mineral composition and to know the unit of rock at the study area. This process included preparing a slide to observe under microscope. For this specification research, resistivity method was used. Three line profiling data were taken in different location. Result of this study shows that the possibilities can occurred for limestone geohazard in the future. It is because some are located at weak zone or high water content.

Geologi Am dan Ramalan Geobencana Batu Kapur Menggunakan Pengimejan Rintangan Elektrik di Kg. Taman Rusa, Gua Musang, Kelantan

ABSTRAK

Kajian ini adalah mengenai geologi am dan ramalan geobencana batu kapur menggunakan pengimejan rintangan elektrik di Kg. Taman Rusa, Gua Musang, Kelantan. Kawasan kajian terletak diantara koordinat N 04°46’15” ke N 04°48’30” dan E 101°57’0’ ke E 101°59’40” iaitu di bahagian selatan bandar Gua Musang. Tujuan kajian ini adalah untuk mengemaskini peta geologi di kawasan kajian yang telah ade sebelum ini. Perubahan struktur geologi mungkin berlaku dari semasa ke semasa tidak kira secara semula jadi ataupun perbuatan manusia. Untuk menghasilkan peta ini, proses yang perlu dilakukan adalah dengan kerja kajian lapangan dan mengambil sampel batuan. Tiga sampel telah diambil untuk menjalani proses penelitian mineral bawah mikroskop. Sampel ini digunakan untuk mengetahui unit batuan di kawasan kajian. Proses yang perlu dilakukan adalah dengan meneliti keratin nipis bagi mengenalpasti kandungan mineral. Untuk menilai geobencana batu kapur pula, kaedah geofizik pengimejan rintangan elektrik telah dipilih. Tiga garisan data berprofil telah diambil di kawasan yang berbeza. Hasil kajian ini telah menunjukkan kebarangkalian geobencana di kawasan kajian mungkin berlaku di masa hadapan disebabkan terdapat beberapa bahagian dalam permukaan bumi yang berada di dalam zon lemah atau lebih zon kandungan air yang tinggi.

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LIST OF SYMBOLS

Ω	Ohm
°	Degree

LIST OF ABBREVIATION

ERI	Electrical Resistivity Imaging
JUPEM	Jabatan Ukur dan Pemetaan Malaysia
JPS	Jabatan Pengairan dan Saliran

CHAPTER 1

INTRODUCTION

1.1 General Background

The study area at Kg Taman Rusa, Gua Musang. It located at southeast's Gua Musang, Kelantan. Roughly, this area still in development. It has residential area, quarry, school, plantation and restaurant. In geologically, this area provided a few magnificent geological view such as limestone cave, hills and river.

In this study area, limestone cave known as Gua Gagak located at west. It covered in a big area. Gua Gagak formed in porous limestone so that erosion dissolve away the limestone, leaving cavities with grow of time. Reaction weak carbonic acid in water over a time with chemical in the rock produced hollow cavities. Generally, limestone is a sedimentary rock that are formed from small particles of rock or stone that have been compacted by pressure and heat composed by primarily calcium carbonate ($CaCO_3$) in the form of mineral calcite.

Although limestone cave has awesome view and beautiful structure, it also can cause geohazard such as subsidence associated with sinkhole. Many cases that have been reported from around the world such as in Indonesia. In 2013, mining limestone hill Desa Banyuurip, in district of Ujungpankah, Gresik have been occurred rubble limestone resulted in several injuries. This incident occurred during drilling process.

There were also reported in Malaysia news related to this geohazard. Example at highway road near to Gua Tempurung, Ipoh. Road debris caused some users killed and injured. This incident occurred in 2004. Some researcher assumed this incident occur because of sinkhole. Poor subsurface structure lead to this incident happened.

Many cases occur due to rubbles also at Gua Musang itself in 1998. However, karst area may also pose danger for human and properties due to the presence of extensive joint and fractures within this area. Some human activities nowadays are not concern with geological information such as construction, mining process, plantation, build a railway road and others. This area must undergo investigation before running a development.

For subsurface investigation, there are many method researchers will use such as resistivity, gravity, magnetic and seismic method. Suggestion method for this site investigation will use resistivity method. Uses of this method to determine in this karst area whether it have some potential geohazards or not. This geophysical method also used to determine anomalies to underground cavities, gaps, underground bodies or aquifers in this area.

1.2 Problem Statement

This study area has an outdated map published by the Director of National Mapping, Malaysia 1993. It has been 13 years since the last updated. This map was irrelevant nowadays because some geological changes occurred during this period time. Along these year, some area filled with residential area, school and quarry.

Karst area was covered by limestone rock. It is carbonate rock that can be dissolved if exposed to acidic water. Acidic water formed from acid rain or carbonic acid. Too many amount of acidic water can cause development of cavities. Through the time it will or can cause collapse or sinkhole. Generally, many researchers doing investigation around Gua Musang area but not in geohazard especially at this study area. Hopefully with this data and information can be as reference for other person about this area.

1.3 Research Objective

i. To produce and update the geological map at this study area at scale 1:25,000.
ii. To identify subsurface condition of study area using Electrical Resistivity Imaging.
iii. To identify potential limestone geohazard in the study area.

1.4 Study Area

In this chapter will explain about general information about the study area based on the geological mapping process and other resources such as web and journal.

1.4.1 Location

The location of Kg. Taman Rusa located at latitude: N 4°47’01.00”, longitude: E 101°58’19.79”. Based on the base map provided in figure 1.1, the average elevation in the study area is around 425 meters (1,394 feet). Some of the localities in this area are Kampung Badar Tanah Puteh and Kampung Lepan Jaya. It is also near to the Bukit Gong and Mount Rabong.

The study area has 25 kilometers per square (5kmx5km). This site is also surrounded with moderate elevation. The highest elevation is 600m while the lowest elevation is around 0m to 140m. This study area also has streets, school and village. The landform is a quarry granite. Some type of soil use are palm plantation and rubber plantation.

Gua Gagak located at west of the study area. River are connected by each other around this study area. The river area not more than 20 meters indicate there are a small river. The main road at the center map connected Gua Musang to Merapuh, Pahang.

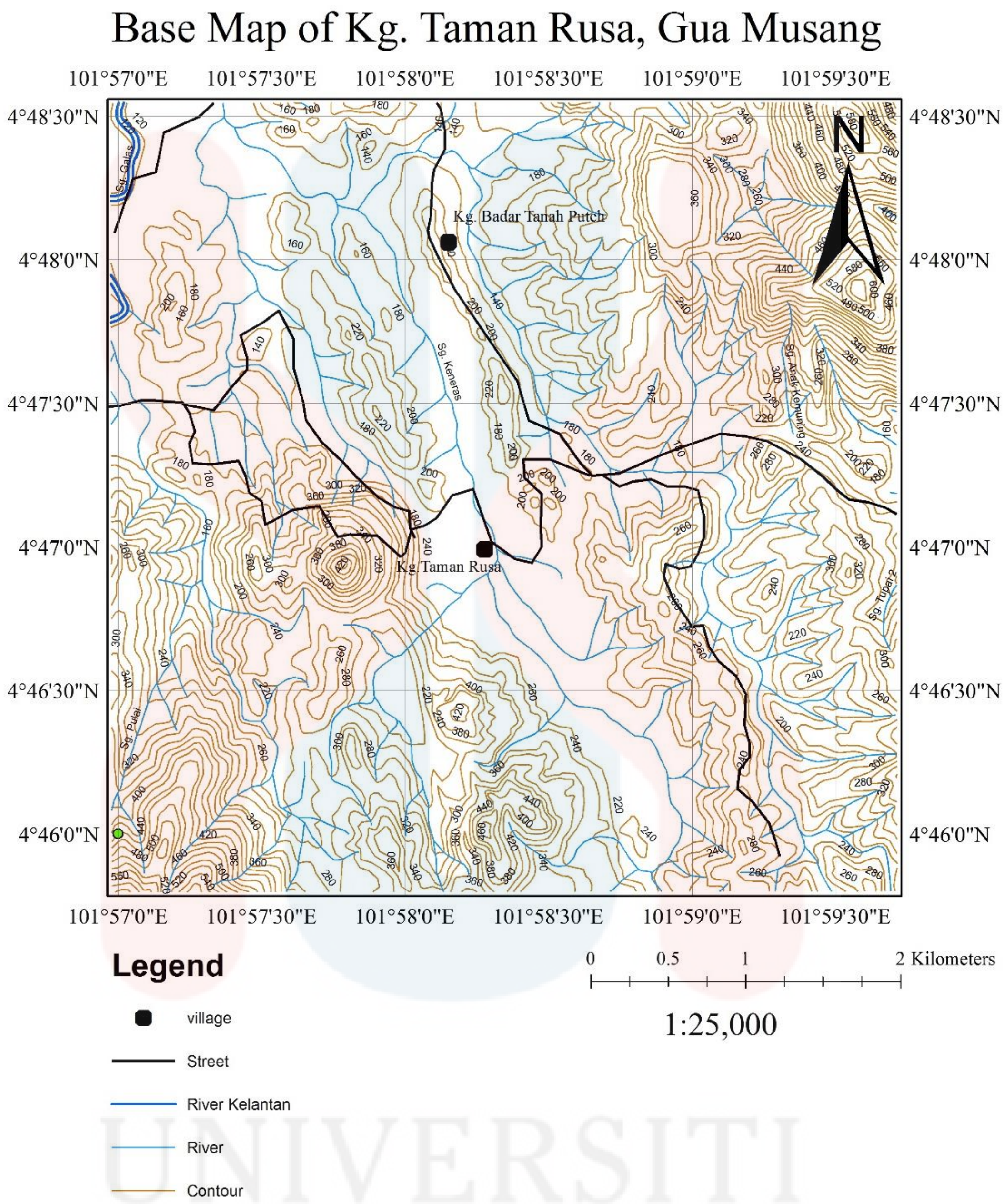


Figure 1.1 Base map of the study area

1.4.2 Demography

The total people in Kelantan state is 1,459,994. It stated by Department Of Statistics, Malaysia. In Table 1.1 below shows Gua Musang, the total people distribution at 2010 is 85,677. According to figure 1.2, Gua Musang percentage population around 6% only same with Machang's district. This is due to the Gua Musang's district still in a development level and mostly covered by forest. The immensity of Kelantan state is 15,028km². Source of this data are from Department of Statistic Malaysia and Government and The Department of Survey.

Table 1.1 Total population in Kelantan in year 2010 (Source: Department of Statistic Malaysia)

State and Administrative District	Population in year 2010
Bachok	125 755
Kota Bahru	461 804
Machang	89 044
Pasir Mas	180 465
Pasir Puteh	113 069
Tanah Merah	116 880
Tumpat	146 595
Gua Musang	**85 667**
Kuala Krai	101 370
Jeli	39 335
Total population	1 459 994

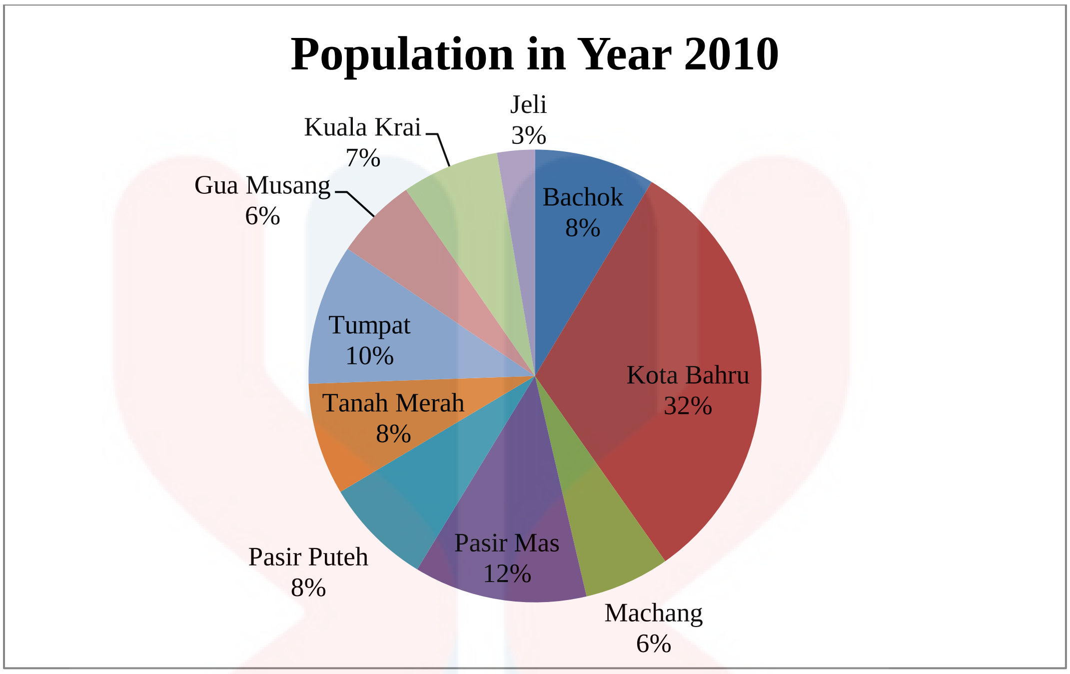
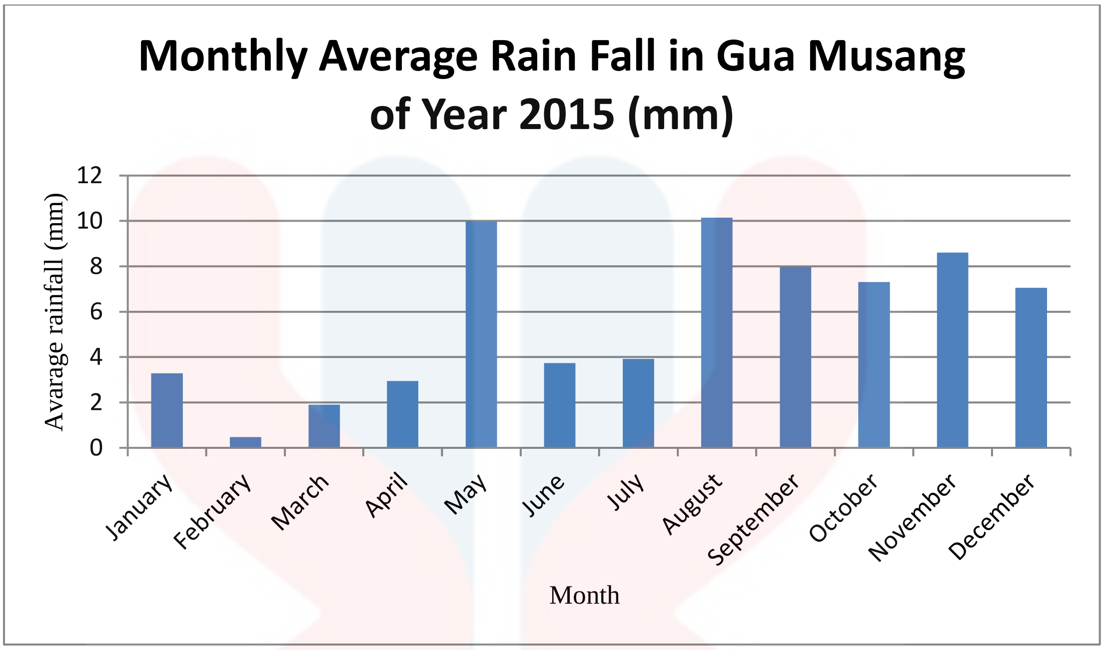


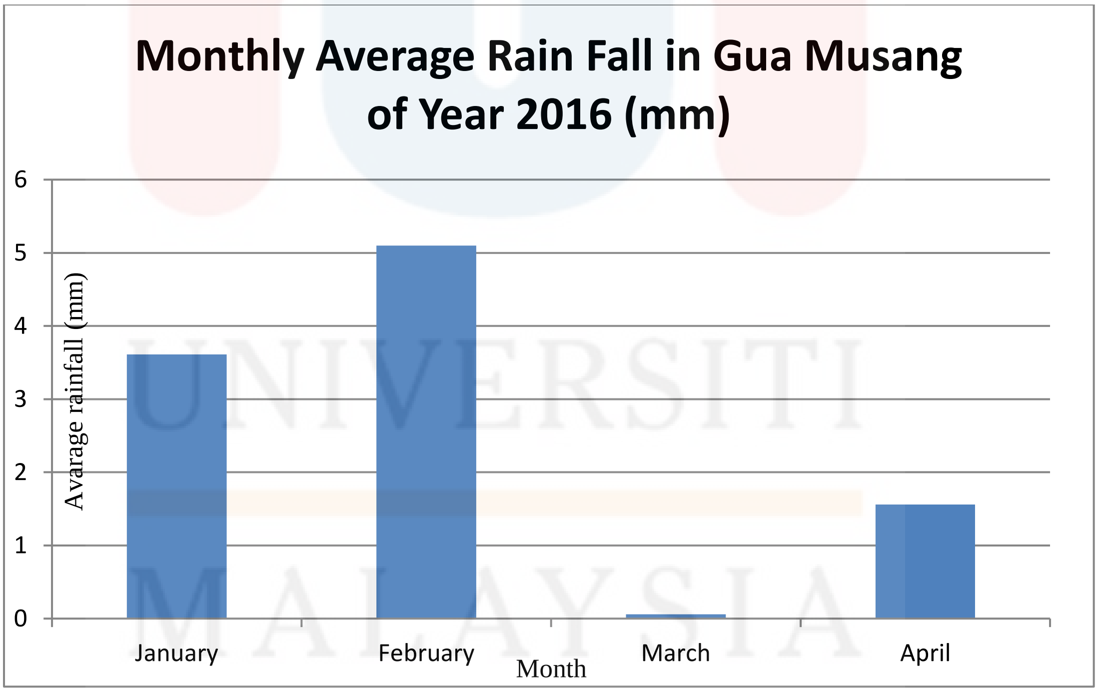
Figure 1.2 Total population in Kelantan in year 2010 (%) (Source: Department of Statistic Malaysia)

1.4.3 Rainfall

The rain distribution is measured at a station in Gua Musang area and the code name for this station ID is 4819027. Graph 1.1 shows the monthly average fall in Gua Musang of year 2015. Its shows that in month of may and august has the highest average that are 10mm. The lowest average in february around 0.5mm. Graph 1.2 shows the monthly average fall in Gua Musang of year 2016 from january to april only.



Graph 1.1 Monthly average rain fall in Gua Musang of year 2015. (Source: Department of Irrigation and Drainage Kelantan)



Graph 1.2 Monthly average rain fall in Gua Musang of year 2016. (Source: Department of Irrigation and Drainage Kelantan)

1.4.4 Landuse

Based on landuse map in figure 1.3, it has several places that contain some potential can be develop and make profit such as rubber plantation, palm oil plantation and quarry. They can export rubber and palm to factory. They can develop many products with manufacturing it such as with manufacturing rubber can produce tire for transportation and palm can produce oil for cuisine. The cultivator also can get income by that. There also has granite quarry. The fresh granite at this quarry will distribute to the other factory to produce useful thing.

1.4.5 Social Economic

In the study area, there are many areas that have been built. So many jobs are open to people inside and outside this district. Schools have been opened and provide job opportunities for the teachers and staff related. The plantation can be divided to two type such as rubber and palm oil. It is run by the local cultivator. This area also has stall and restaurant so that people can find what food they want rather than cook by themselves.

In the study area, mostly still covered by forest. This area still not develop well due to the lack of basic thing such as clinic and public administration. Maybe it is because of the amount of resident still in enough when using basic thing. However, some of the basic thing still are not here, they can go to the main district, Gua Musang. It about 10km from this area.

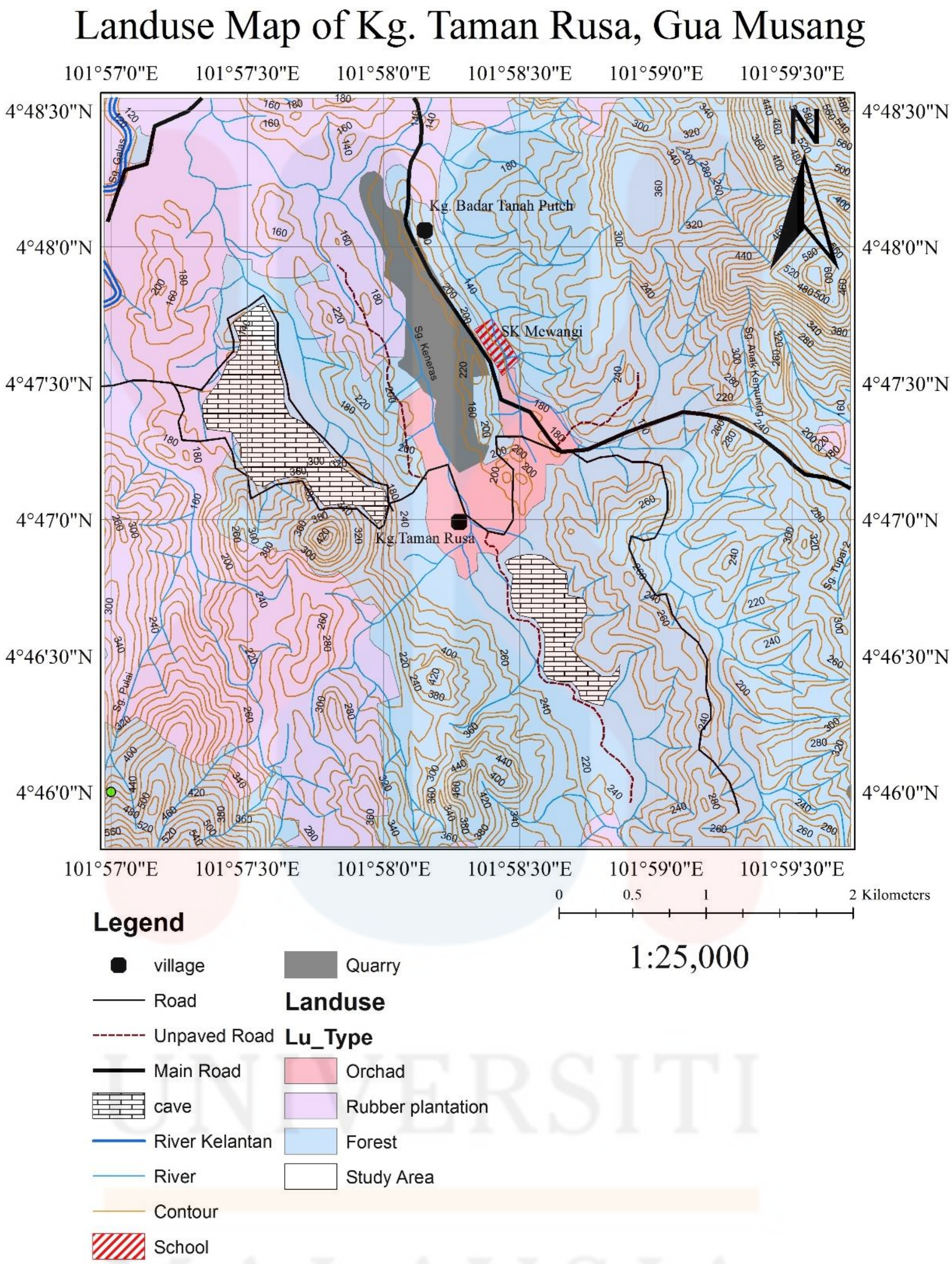


Figure 1.3 Landuse map of study area

1.4.6 Road Connection

Gua musang is located at the south Kelantan border with Merapoh, Pahang. Gua Musang connected by several main roads such as from Dabong, Kuala Krai and Merapoh, Pahang. It also can be access from Lojing's road which is at west part of Gua Musang.

1.5 Scope of the Study

The scope of this study are to find the possibilities the geological event according to karst formation occur such as sinkhole in the future. Geological mapping is used to find sample of rock and do a thin section to know the past occurrence of these geohazards and identify the possibilities. This study only focused about limestone area at Kg Taman Rusa, Gua Musang.

The geological method that are used in this project are electrical resistivity imaging (ERI). In geophysical technique, we have many methods to interpret data such as by using resistivity, gravity, seismic and magnetic. Resistivity method have been chosen for this research because sedimentary rock especially limestone tends to be most conductive due to their high content of fluid cavity. So electrical charges can flow through this holes due to its porosity and permeability. This data is processing by using software called 'RES2DINV'.

1.6 Research Importance

The importance for conducting this research is to establish the new updated geological maps at this area. Some changes maybe occur over a time so it will be useful for the future. So with the scale 1:25,000, it will provide more geological information such as geomorphology, rock boundary, drainage patterns and others. The oldest geological map was from 1997. So through these year maybe some are the place are being changes. To update this map, process mapping must be doing.

Karst is often seen in limestone and typically associated in geohazard. From the research, the data provided can be useful in future development. It also to predict whether the area is suitable for construction development.

This data and information are very useful for certain agencies. Example, data about subsurface investigation can be useful for developer when construction. The road map can help Public Work Department Malaysia in road maintenance. Public awareness also can be published through locals about dangerous geohazard.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Previous research is very useful to get the idea about this research. Many journal and article give information not exactly direct to this research but some are related to the key point such as about the general geology, limestone geohazard and geophysical technique that will be used.

Limestone formation are numerous in Malaysia such as at Klang Valley (K.L area), Kinta Valley (Ipoh area), Kedah-Perlis (including Langkawi islands), and especially Gua Musang, Kelantan area. Limestone formation at this area are being metamorphosed into marble. Limestone formation had many disadvantage to the development of urbanization production if the research is not conducted at that area. When geohazard such as sinkhole, weathering, dissolving and erosion, hydrological contamination and quality problem occur during developments it can highly cost the preservation and maintenance (Al Kouri,2010).

Geohazard are the very serious concern to all engineer and development worker. Due to the karstic environments damage related to sinkholes is not limited to properties and environmental resources, creating pathways for draining surfaces water such as streams, and lakes directly into the underlying aquifers (Bakhshipour,2013). Very challenging factor facing by engineer for this problem are identification and delineation underground cavities. One of the methods are by geological mapping to identify geomorphology area. But it is unpredictable due to limitation of information for underground phases.

So it come one more solution to overcome this problem by using geophysical method, resistivity. This method can identify presence of subsurface cavity formation and voids. Besides that, this method shows the relationship between resistivity of rock sample and their porosity to develop a data of subsurface resistivity distribution via 2D electrical resistivity profile (Bakhshipour,2013). Hence, information of using this method and geology of study area are important.

2.2 Regional Geology and Tectonic Setting

Kelantan is located at the west Malaysia and recent studies have considerably extended the pre-tertiary stratigraphy range in West Malaysia. The sediments in Kelantan were divided into two main groups which is calcareous quartzite and shale series. The age of the former is from Carboniferous to Permian, while that of the latter to Triassic. The exact relation of the chert to these two series is still undecided (Roslan,2012).

The Paleozoic formation in Kelantan was found in the central belt of Peninsular Malaysia. The bulk of the Upper Paleozoic sediments consist of marine Permian strata that occur as linear belts flanking Mesozoic sediments in the Central Belt. The Upper Paleozoic rock consists of Gua Musang Formation in the south of Kelantan while it is the Taku Schist in eastern of Kelantan. The Upper Paleozoic formation is dominated by argillaceous and volcanic facies while the rest belong to calcareous and arenaceous facies.

The depositional environment is typically shallow marine with intermittent active submarine volcanism starting in the Late Carboniferous and reaching its peak in the Permian and Triassic (Lee,2004). The Mesozoic formation are dominant in the central belt that form continuous north – south trending belt extending beyond the international boundaries with Thailand (the Gua Musang Formation) in the north and Singapore (the Jurong Formation) in the south.

The Permian – Triassic of the Gua Musang, Aring and Gunung Rabong formations in Kelantan is dominated by shallow marine clastics and carbonates with volcanic interbeds. Towards the south, deeper marine turbiditic sediment is more dominant in the Telong Formation. These turbidites are commonly tuffaceous in nature with volcanic interbeds (Leman, 1984). The plutonic rocks in Kelantan comprised of Eastern Belt and Cretaceous plutonic rocks (Ghani, 2009). The Eastern Belt granite has been dated as Permian to Triassic age.

Peninsular Malaysia is a part of Sundaland, which is part of the Eurasian Plate. The Sunda Shelf is the extension of the peninsular eastwards and southwards, Sumatra, Natuna, and Western Borneo that belong on the same plate (Hutchison, 2009). Due to convergence at Sunda Trench, the Sumatra Island is dominantly by dextral wrench faults.

Also, a dextral wrench fault occurred at Andaman sea marginal basin resulting in southward movements called as Sumatran Fault System and northward movement called as Sagaing Fault. The Malaysian peninsular is different to Sarawak tectonically and stratigraphically, but is similar to Indonesian Island of Bangka (Hutchison, 2009).

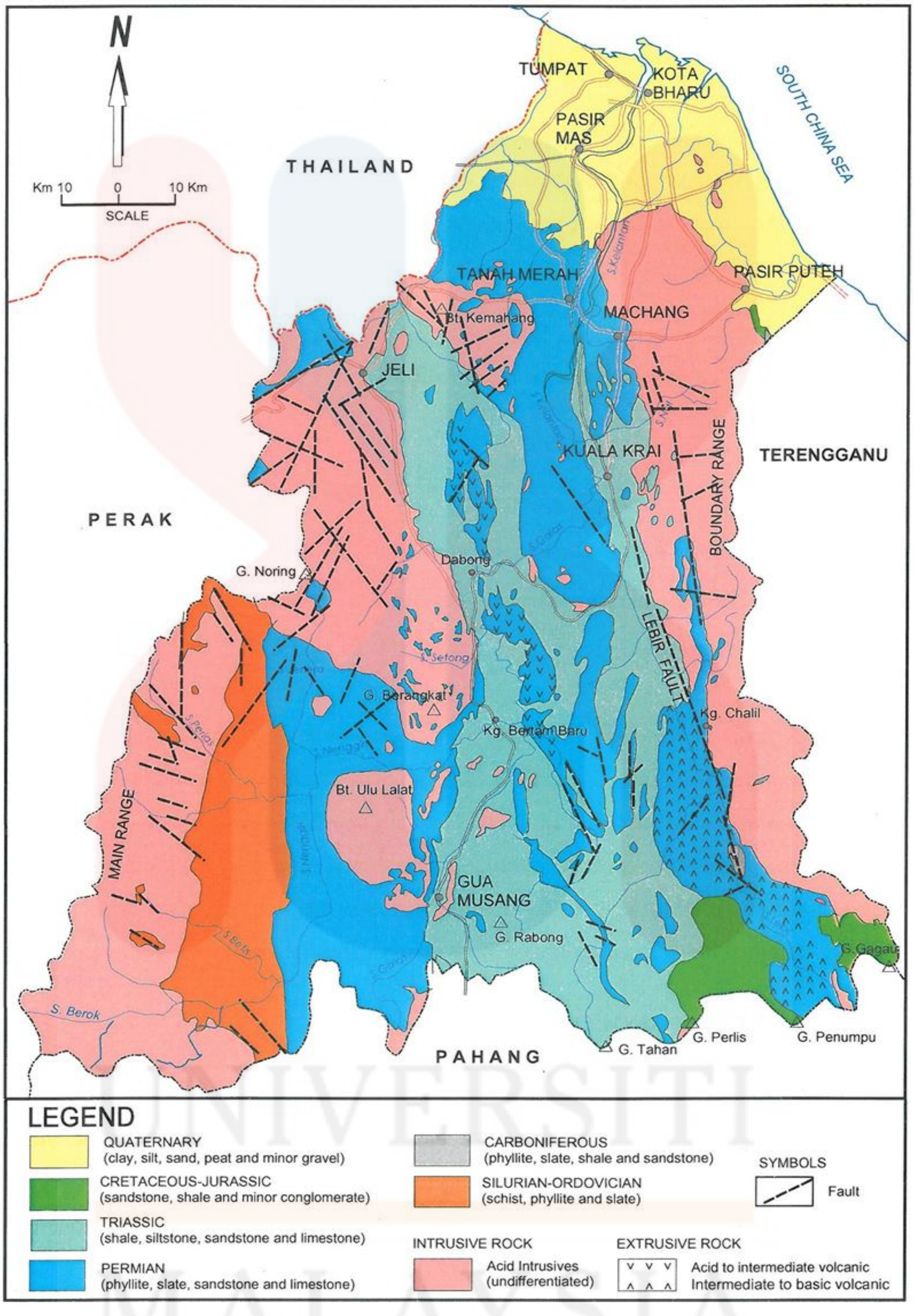


Figure 2.1 General geology map of Kelantan (MacDonald, 1967)

2.2.1 Stratigraphy

Gua Musang Formation was introduced informally for a predominantly argillaceous and calcareous sequence interbedded with volcanic and arenaceous rocks in the Gua Musang area of south Kelantan (Yin, 1965). The unit extends to north Kelantan and southwards to north Pahang. Fossils of ammonoids and pelecypods indicate a middle Permian to middle Triassic age.

It is unconformably over1ain by the Gunung Rabong Formation and named after Gua Musang town in south Kelantan. In the north of the axial belt the Telong Formation is correlated to the Gunung Rabong Formation and the top part of the Gua Musang Formation with the Aring Formation to the rest of the Gua Musang Formation. At the central portion of the axial belt, most of the Lipis Group is correlated to the Kaling Formation which should be a better term considering that the former cannot be divided into formations.

2.2.2 Structural Geology

Gua Musang composed of five types of lithologies which are limestone unit, interbedded sandstone, siltstone and shale unit, phyllite. Slate and shale with subordinate with sandstone and schist unit, felsic unit and also alluvium unit. All of these lithologies are grouped in Paleozoic and Mesozoic era.

As the Triassic period ended, a new regional pattern of sedimentation was established in the aftermath of tectonic disturbances and widespread plutonism that formed the Main Range, Central Belt and the Eastern Belt plutons. These new basins were infilled rapidly by red, ferric-rich, siliciclastics that were deposited in diverse terrestrial settings, ranging from alluvial fans, braided rivers, flood plains, lakes and deltas. These red beds, named in reference to their colour, were likened to molasse deposits and marked the end of marine (Abdullah, 2009).

2.2.3 Historical Geology

The study area, Gua Musang is a formation that are develop during the Permian-Triassic transition (Simon, 2013). This area within the Central Belt of Peninsular Malaysia. The bulk of the Upper Paleozoic sediments consist of marine Permian strata that occur as linear belts flanking Mesozoic sediments in the Central Belt. The Upper Paleozoic rock consists of Gua Musang Formation in the south of Kelantan while it is the Taku Schist in eastern of Kelantan. The Upper Paleozoic formation is dominated by argillaceous and volcanic facies while the rest belong to calcareous and arenaceous facies. The depositional environment is typically shallow marine with intermittent active submarine volcanism starting in the Late Carboniferous and reaching it is peak in the Permian and Triassic. This area mostly covered by limestone.

Gua Musang Formation is predominantly calcareous and argillaceous, subjacent to triassic sedimentary rocks of the Gunong Rabong Formation. Downstream areas of Kelantan Basin (Pasir Mas and River View) are characterized by clay, silt and gravel of Quaternary age. The lithology of Taku Schist is mainly pelitic, consisting of quartz-mica-schist, quartz-micagarnet schist and garnet-mica-schist. Narrow bands of amphibolite schist and serpentinite are also present (Lim, 1983) .The geological structure that is commonly found in the study area is joints, where they divide the rock body into large, roughly angular blocks, which is called as brecciation. The potential geohazard in the study area is landslides, where some of them are composed of soil only and others are mixtures of rock and soil (Simon, 2015).

2.3 Resistivity

Electrical measurements of various types are made at the surface of the earth to investigate subsurface conditions in an area.

2.3.1 Resistivity array

There are five type of array using for resistivity method which are Wenner array, Gradient array, Schlumberger array, pole-dipole array and dipole-dipole array. Each array has their own benefits and limitations. Pole-dipole array is the best advantages for depth penetration and signal amplitude. For the field set up, Wenner and Schlumberger array are the best.

Wenner array are very widely used, and supported by a vast amount of interpretational literature and computer packages. The standard array against which others are often assessed (Milson,2003). Pole-dipole array produces asymmetric anomalies that are consequently more difficult to interpret than those produced by symmetric arrays. Peaks are displaced from the centers of conductive or chargeable bodies and electrode positions have to be recorded with special care. Values are usually plotted at the point mid-way between the moving voltage electrodes but this is not a universally agreed standard (Milson,2003).

Schlumberger array are the only array to rival Wenner in availability of interpretational material, all of which relates to the ideal array with negligible distance between the inner electrodes (Milson,2003). Gradient array is widely used for reconnaissance. Large numbers of readings can be taken on parallel traverses without moving the current electrodes if powerful generators are available.

Dipole-dipole array popular in induced polarization (IP) work because the complete separation of current and voltage circuits reduces the vulnerability to inductive noise. A considerable body of interpretational materials is available. Results are usually plotted as pseudo-sections. Figure 2.2 shows the electrode arrays and their geometric factors.

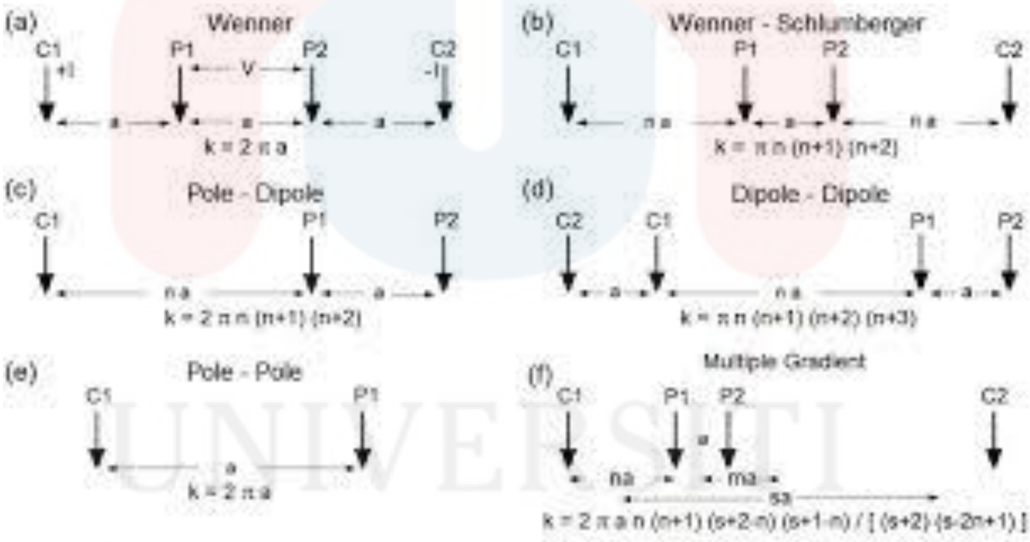


Figure 2.2 Electrode array and their geometric factors (Milson,2003)

2.4 Limestone Geohazard

Limestone is a sedimentary rock that are formed from small particles of rock or stone that have been compacted by pressure and heat composed by primarily calcium carbonate ($CaCO^3$) in the form of mineral calcite. Another common mineral is dolomite (Kong,2002). Limestone are very soluble. Because of that can formed karstic feature such as cavities, caves, solution slots, pinnacled bedrock, stalagtites or stalagmites, basal notches overhang cliffs.

According to (Abdeltawab, 2013) most karst cave and sinkhole are structurally controlled by major faults and joint. Detection of karst limestone foundation bedrock (cave, sinkhole and open fractures). It is because limestone is a sedimentary rock that are consist mineral calcium. Limestone is such a unique rock because it can soluble to acidic water due to the mineral formed. So the reaction between this mineral and acid water can formed karstic features such as cavities, caves, pinnacled block, stalagmite and stalagtite that are can formed a sinkhole or subside this area to the deep (Kong,2002).

2.3.5 ERI application on Geohazard Mapping

Electrical resistivity imaging or we called it as ERI used to perform measurement in the field and ability to detect the vertical changes, horizontal structures and strong signal strength. Injecting DC current into the ground using 2 electrodes (c1 and c2) to read potential difference reading between this two (p1 and p2) that are shown in Figure 2.3 (Fadli,2015). The sequence of measurement used to build up a pseudo-section (R.D., 1993). This method included a formula to get a data, "pa = k V / I". Where k is the geometric factor use for arrangement 4 electrodes. I is current, V for voltage and *pa* is an apparent resistivity (Loke,1999). The image is developed using an algorithm (Win,2011).

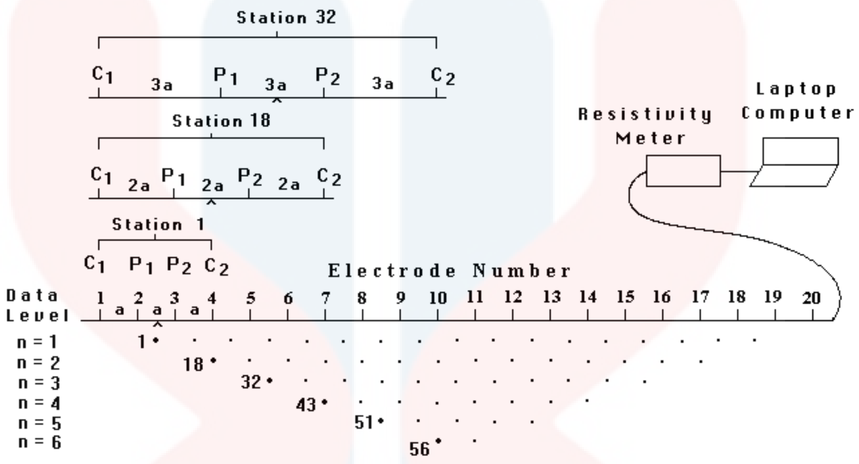


Figure 2.3 The arrangement of electrode (Loke,1999)

This method actually depends on ionic content of pore fluids. The increasing of this content depends on the reduction in resistivity (Khaki,2014). A Wenner electrode arrays shows that the suitable between electrode are range around 5m to get better good resolution images in total length around 300m-400m depending on suitable field's surface (Khaki,2014). There are different factors that affect the movement of current in the subsurface and therefore the performance of the ERI such as temperature, water content, ions (their concentration and mobility), porosity, clay content, permeability and skin depth (Doyuran, 2012)

From the Table 2.1, it shows that specific rock has their own value of resistivity also same like electrical conductivity. This can be the guide when we do the investigation as a reference. Clay shows that have very lower value of resistivity.

For the lower value in electrical conductivity goes to groundwater due to very good conductor.

Table 2.1 Resistivity of some rock and sediments (Loke,1999)

Rock type	Resistivity range (Ωm)
Granite porphyry	4.5×10^3 (wet) – 1.3×10^6 (dry)
Feldspar porphyry	4×10^3 (wet)
Syenite	$10^2 - 10^6$
Diorite porphyry	1.9×10^3 (wet) – 2.8×10^4 (dry)
Porphyrite	$10 - 5 \times 10^4$ (wet) – 3.3×10^3 (dry)
Carbonatized porphyry	2.5×10^3 (wet) – 6×10^4 (dry)
Quartz diorite	$2 \times 10^4 - 2 \times 10^6$ (wet) –1.8×10^5 (dry)
Porphyry (various)	$60 - 10^4$
Dacite	2×10^4 (wet)
Andesite	4.5×10^4 (wet) – 1.7×10^2 (dry)
Diabase (various)	$20 - 5 \times 10^7$
Lavas	$10^2 - 5 \times 10^4$
Gabbro	$10^3 - 10^6$
Basalt	$10 - 1.3 \times 10^7$ (dry)
Olivine norite	$10^3 - 6 \times 10^4$ (wet)
Peridotite	3×10^3 (wet) – 6.5×10^3 (dry)
Hornfels	8×10^3 (wet) – 6×10^7 (dry)
Schists (calcareous and mica)	$20 - 10^4$
Tuffs	2×10^3 (wet) – 10^5 (dry)
Graphite schist	$10 - 10^2$
Slates (various)	$6 \times 10^2 - 4 \times 10^7$
Gneiss (various)	6.8×10^4 (wet) – 3×10^6 (dry)
Marble	$10^2 - 2.5 \times 10^8$ (dry)
Skarn	2.5×10^2 (wet) – 2.5×10^8 (dry)
Quartzites (various)	$10 - 2 \times 10^8$
Consolidated shales	$20 - 2 \times 10^3$
Argillites	$10 - 8 \times 10^2$
Conglomerates	$2 \times 10^3 - 10^4$
Sandstones	$1 - 6.4 \times 10^8$
Limestones	$50 - 10^7$
Dolomite	$3.5 \times 10^2 - 5 \times 10^3$
Unconsolidated wet clay	20
Marls	3 – 70
Clays	1 – 100
Oil sands	4 – 800

2.3.7 Res2DInv Software

Data that we obtained will be converted to know the true depth resistivity imaging using RES2DINV software. This software is designed to interpret the 2D data of geophysical method, resistivity. This software can handle any data from many type of array such as Wenner, Schlumberger, dipole-dipole, pole-dipole, Wenner-Schlumberger and others. The data can be obtained from many geophysical instruments such as ABEM, AGI, PASI, IRIS and others.

CHAPTER 3

MATERIAL AND METHODOLOGY

3.1 Introduction

The materials and methodology are explained in this chapter. For materials for this study can be divided to four types such as at field, in the lab, spatial data and software. For methodology part, can be divided into five type which is preliminary research, literature review, field studies, laboratory investigation and lastly analyses and interpretation.

3.2 MATERIALS

Figure 3.1 shows some of the geological parts tools. For geological mapping, we use software ArcGis to digitize base map this area and sampling tools such as geological hammer, GPS (Geological Positioning System), hydrochloric acid and hand lens.

All this material have their own function such as compass. Compass was used to measure the orientation of geological planes and lineation with respect to north and the angle of dip of the geological features with respect to the horizontal. Besides that, geological hammer used during field work need to bring at least one hammer which used to break rocks. Basically a hammer weighing less than ¾ kg is for very soft rock. 1kg is probably the most useful weight.

Other, the hand lenses also important during fieldwork. A magnification of between 7 and 10 times is probably the most useful lenses to use during the field work to identify the samples that had been observed. This lens contains a magnifying glass enclosed in a circular piece of plastic and a handle to hold it.

Global Positioning System (GPS) is use to locating our positions on a map. GPS is a hand held device which is collecting radio signals from orbiting satellites that continuously transmit the exact time and their position.

Other than this equipment, camera also useful during fieldwork. A camera use to take some photo of outcrops exposures or any other feature in the field. From the photo, we can identify and describe topographic features. Photo that we take also can be as proven that we do the fieldwork at that study area. We do not need to waste our time to visit our site twice because we can use from that photo as a reference.

The most important part, for geophysical method, we will use ABEM Terrametes SAS4000. Example like Figure 3.2. It is for Electrical Resistivity Imaging (ERI).

Table 3.1 Equipment use for geological mapping

Figure	Name
	Software ArcGIS
	Brunton Compass
	Hand lens
	Geological hammer
	Global Positioning System (GPS)
	Camera
	ABEM Terramter SAS4000

3.2.1 Data Inventory

Table 3.2 shows data inventories.

Table 3.2 Data Inventories

No.	TYPE OF DATA	DATA DESCRIPTION	SOURCE
1.	Topographic map	Map of Merapuh, Kelantan	Directorate National Mapping of Malaysia
2.	Field data	GPS location	Garmin
3.	Statistic data	Population distribution for Kelantan	Department of Statistic Malaysia
4.	Rain distribution	Annual rainfall trend in East Peninsula	Ministry of Science, Technology and Innovation
5.	Hydrological data	Map of Hydrological Station in Kelantan	Department of Irrigation and Purpose

3.3 Methodology

3.3.1 Preliminary Research

Preliminary researches are very important to get an idea and information before going to the field. Related information and geological data of the study area can be obtained from references of previous study to get the basic idea in understanding its geology. This study is focusing in research of Gua Panjang area. The references data are gathered from all the websites of geology, University

Malaysia Kelantan (UMK), Geoscience Department Malaysia (JMG) and Mapping and Measurement Department Malaysia (JUPEM).

Many previous research or journal are related to this study so that can gather the information and problem statement and possible outcome to form literature review. More than 20 journal from around the world related to this study being collected.

3.3.2 Field Studies

For this field study, it can be divided into two part which is geological parts and the specification of this research. Firstly, geological part included mapping process such as traversing, taking a rock sample and design base map to show the lithology and geomorphological pattern. It could be done to confirm the type of lithology and the drainage pattern at this study area. The coverage area has the limit according to our procedure that is 25 kilometre per square. Sketching and take coordinates also must be done to make a traverse map.

Secondly, this research focused only on specification using ABEM Terrameter SAS4000 at limestone area, Gua Panjang. This method going to be done at 200 metres or 400 metres according to surveying using satellite imagery. The choosing of profiling line based on the satellite imagery, ability to accommodate the desired length and accessibility. Array type is considered to each pro and cons. The dipole–dipole is the most penetrative, while the wenner is the least penetrative array with Schlumberger at intermediate (Milsom, 2003). But, Wenner have the best vertical resolving power, compared to the others.

3.3.3 Laboratory Work

This topic focused on petrography section. Petrography is a geological process by doing thin section. During mapping, rock or outcrop we collected must be undergoing thin section process to determine the mineral constituents, porosity and other factor that are influenced dissolution of the rock. The important tools use for this section is petrographic microscope. The technique in preparing thin section involves three step:

i. Sectioning and cutting

The rock sample is cut into the certain size with the given thickness. The sectioning process used to provide the exposed surface of interest rock.

ii. Grinding

First, the rock sample must be ground smoothly using a horizontal diamond impregnated diamond wheel. Grinding is performed to remove deformation induced in sectioning and to planar grind. Remove the saw marks while doing as little grinding to get a flat surface before it is cemented and gluing into a glass slide.

iii. Lapping

The sample will be moved on rotary motion with a glass slide. The sample will be examined by using transmitted light before it undergoes polishing session. Polishing will remove the final deformation during grinding process. Lastly, view the sample under polarized microscopy to observed the mineral composition.

3.3.4 Data Processing

For the specification research, the ERI method use ABEM Terrameter SAS4000. This machine is specific use only for resistivity subsurface investigation. Data can be interpret using software 'RES2DINV'.

3.3.5 Data Analysis and Interpretation

Geological mapping is the important method to create geological map. Geological map is a special-purpose map made to show geological features. Rock units or geologic strata are shown by colour or symbols to indicate where they are exposed at the surface. Bedding planes and structural features such as faults, folds, foliations, and lineation are shown with strike and dip or trend and plunge symbols which give these features three-dimensional orientations. Stratigraphic contour lines may be used to illustrate the surface of a selected stratum illustrating the subsurface topographic trends of the strata.

CHAPTER 4

GENERAL GEOLOGY

4.0 GENERAL GEOLOGY

This chapter will tell about the general geology of the study area. The information in this chapter is gathered by geological mapping and literature review. The general geology of the study area is divided into geomorphology, stratigraphy, structural geology and historical geology.

4.1 Introduction

Geomorphology is study about the landform and its process related to origin and evolution especially in study area. From geomorphology study, we can know the process that led to the earth changes. Stratigraphy is study about rock strata, their relatives and absolute age and relationship between strata. In this research, lithostratigraphy is used to use identify relationship between strata. For naming the rock, petrography analysis is used by thin section process.

Structural geology concerned on rock formation, rock geometries to know about the deformation history. The information gathered are important to understand the past events. All information from geomorphology, stratigraphy and structural geology is combined to reveal the historical geology events.

Mapping has been done through traversing the study area and the traverse route is mapped on figure 4.1. Outcrop station are taken along the research area when there are important outcrop and geology structure is found. Samples are taken in different station with different lithology. These sample is used for lithology identification through petrography analysis. There are four sample station in the study are labelled as red circle. Table 4.1 shows the locations of sample station and observation sample.

Table 4.1 Location for Station Sample and Observation Sample

Sample Station	Observation Station
1) N 04°47'05", E 101°58'17"	1) N 04°48'10", E 101°57'41"
2) N 04°47'15", E 101°58'39"	2) N 04°48'01", E 101°57'43"
3) N 04°47'12", E 101°58'56"	3) N 04°48'05", E 101°57'43"
4) N 04°47'42", E 101°57'38"	4) N 04°46'27", E 101°58'11"
	5) N 04°46'26", E 101°58'08"
	6) N 04°47'50", E 101°57'19"
	7) N 04°47'28", E 101°57'01"
	8) N 04°47'47", E 101°57'36"

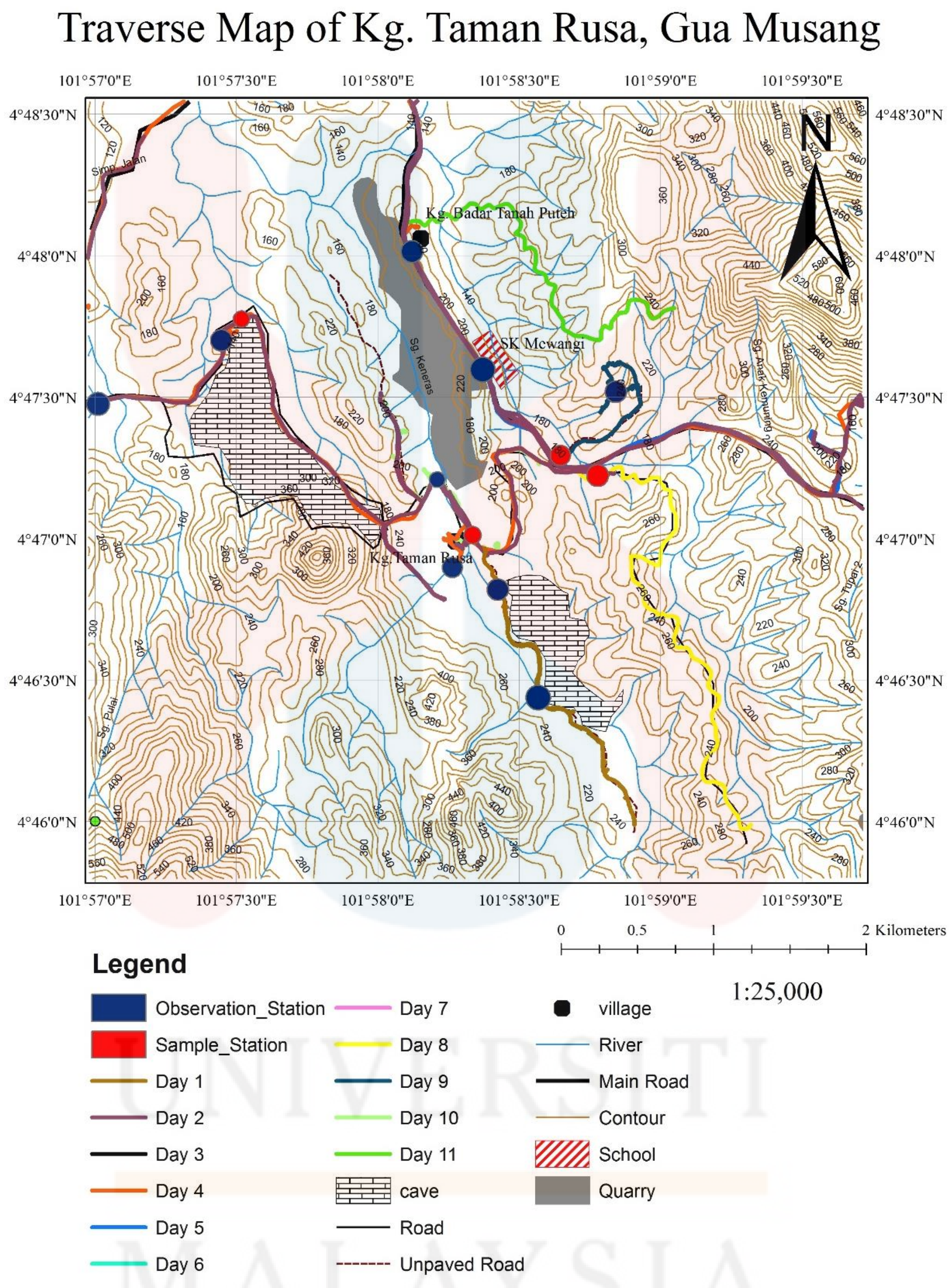


Figure 4.1 Traverse map of study area

4.2 Geomorphology

This study focused on the geological mapping and karst geomorphologic of Gua Gagak and nearby area. At Kg. Taman Rusa and nearby area, it consists of flat and hill part. It still surrounded by forest. It is because some area develops as industrial area such as factory, workshop and residential area. Geological map in figure 4.2 shows the lithology unit in study area. Mostly this area covered by limestone unit such as limestone hills and cave.

The study area is prominent with limestone, with some areas of siltstone, sandstone, slate(meta-sediment) and granite. The karst formation formed many occurrences of caves, tower karst and pinnacles. Gua Musang is a city located at the south of Kelantan bordering with Merapoh, Pahang. The local karst, named Gua Gagak cave has unique panorama due to their shape and geomorphologic process. The karst process affected by some condition such as rainfall, rich organic acids, abundant of acid and also a lot of carbon dioxide.

However, the karst process greatly depends on the thickness of the cave, characteristics of the cave, geological structure such as joint, fault and bedding, characteristics, and also the topographic movements such as watersheds area, channels.

The genesis of karst morphology in carbonate rock is process of chemical weathering. The agent of this chemical weathering is acidic water. The acidity of water is caused by many factors. For the acid rain, it is the product of reaction of rain water with sulphur dioxide, carbon dioxide, and nitrogen oxides that is present in atmosphere. The degree of air pollution plays an important factor in influencing the acidity of rain. As a groundwater, it can be attributed to the pollution of the groundwater itself. Also, when water infiltrates from surface into subsurface, it will react with carbon dioxide in the soils to form carbonic acid.

4.2.1 Drainage

Drainage pattern is the pattern formed by the stream, rivers, & lakes in a particular drainage basin. Drainage basins are divided from each other by topographic barriers called a watershed. Based on table 4.2, there are seven drainage pattern which are dendritic, radial, rectangular, trellis, parallel, annular, meandering and others. Dendritic is a randomly developed, tree-like pattern composed of branching tributaries and a main stream. It is the most common drainage pattern and is characteristic of essentially flat-flying or relatively homogenous rock and impervious soils. Radial drainage is composed of streams radiating outward from a central peak, dome, or volcanic cone.

Another drainage pattern such as parallel is characterized by major streams trending in the same direction. Tributaries usually join the main stream at approximately the same angles. Besides that, trellis pattern is a modified version of the dendritic pattern. It formed in area folded rock strata. Furthermore, annular pattern is a primary streams develop in the concentric, circular joints surrounding an uplifted dome of sedimentary rocks.

Based on map in figure 4.2, two drainage patterns are identified in the research area which are dendritic and radial. Dendritic pattern is bounded by black lines in figure 4.3. Dendritic drainage pattern is dominant in the research area. Two main dendritic pattern located at southeast and northwest respectively of study area. The direction of water flow to the south. Dendritic drainage pattern associated with flat and uniform bedrock. radial pattern also found in the research area bounded by red line at the north east of study area. Radial drainage pattern develops surrounding area of high topography to low elevation area.

The main river in the study area is known as Galas river which flows to Kelantan river. There are at least four rivers existed at this study area which are Anak Kemuning river, Tupai river, Keneras river and Pulai river. Based on figure 4.3 and figure 4.4 its shows the water flow. Basically figure 4.3 indicate the slow water flow make the process deposition occurred. Deposition occurred when sediments, rock or soil are added to some area because it loss the kinetic energy to flow further. It can be when the shallow river formed.

In contrast to figure 4.3, figure 4.4 shows difference in the energy flow. Erosion process occurred when water flow in high rate make sediment transport to another area. The rate of the river flow reflects the surrounding environment and the process occur along the river. When the river's pattern is straight, it indicated high energy flow and associated with erosion process.

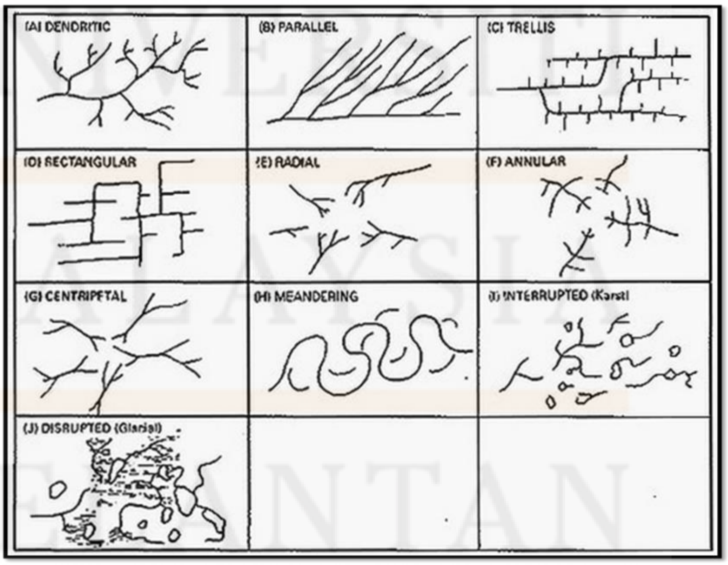


Table 4.2 Type of drainage pattern

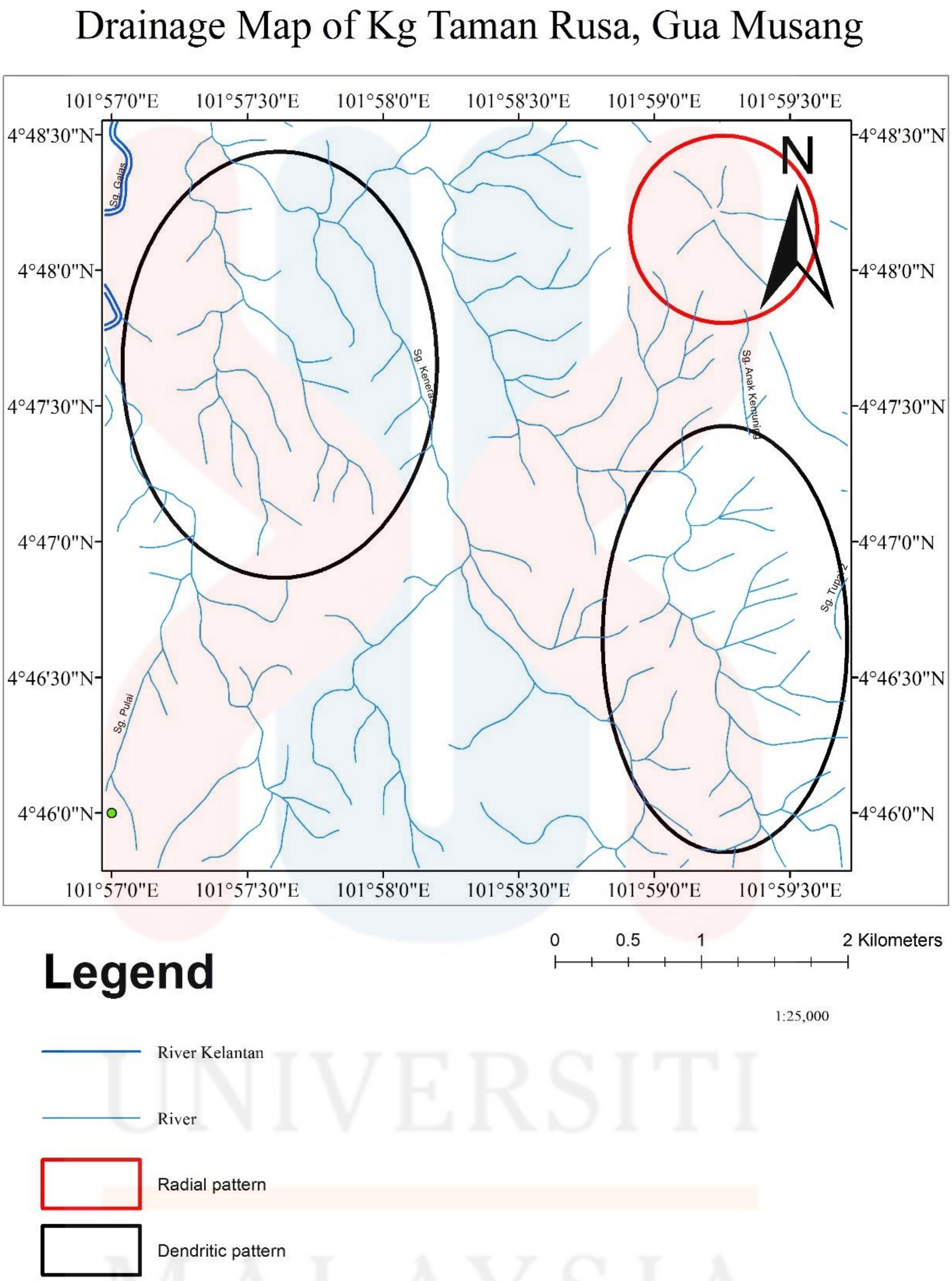


Figure 4.2 Drainage map of study area

Figure 4.3 Slow moving river at study area

Figure 4.4 One of the river exists in the study area

4.2.2 Watershed

A watershed is the area of land where all of the water that is under it or drains off of it goes into the same place. The term watershed is used to indicate an area of land from which all water falling as rain would flow toward a single point. This includes both surface water flow, such as rivers, streams and creeks, and the underground movement of water. The boundaries and the area of such a watershed are determined by first specifying geographic point on land.

Based on figure 4.5, a line is then drawn which connects all of the points of highest elevation immediately adjacent to that point. The watershed area would be the land area within those boundaries. The watershed is thus defined hydrologically, that is, by the specific river or stream. Watershed and drainage basin or catchment are used synonymously and all of them refer to the area of land drained by a river system. In study area consist of three main watershed shows as label 1, 2 and 3.

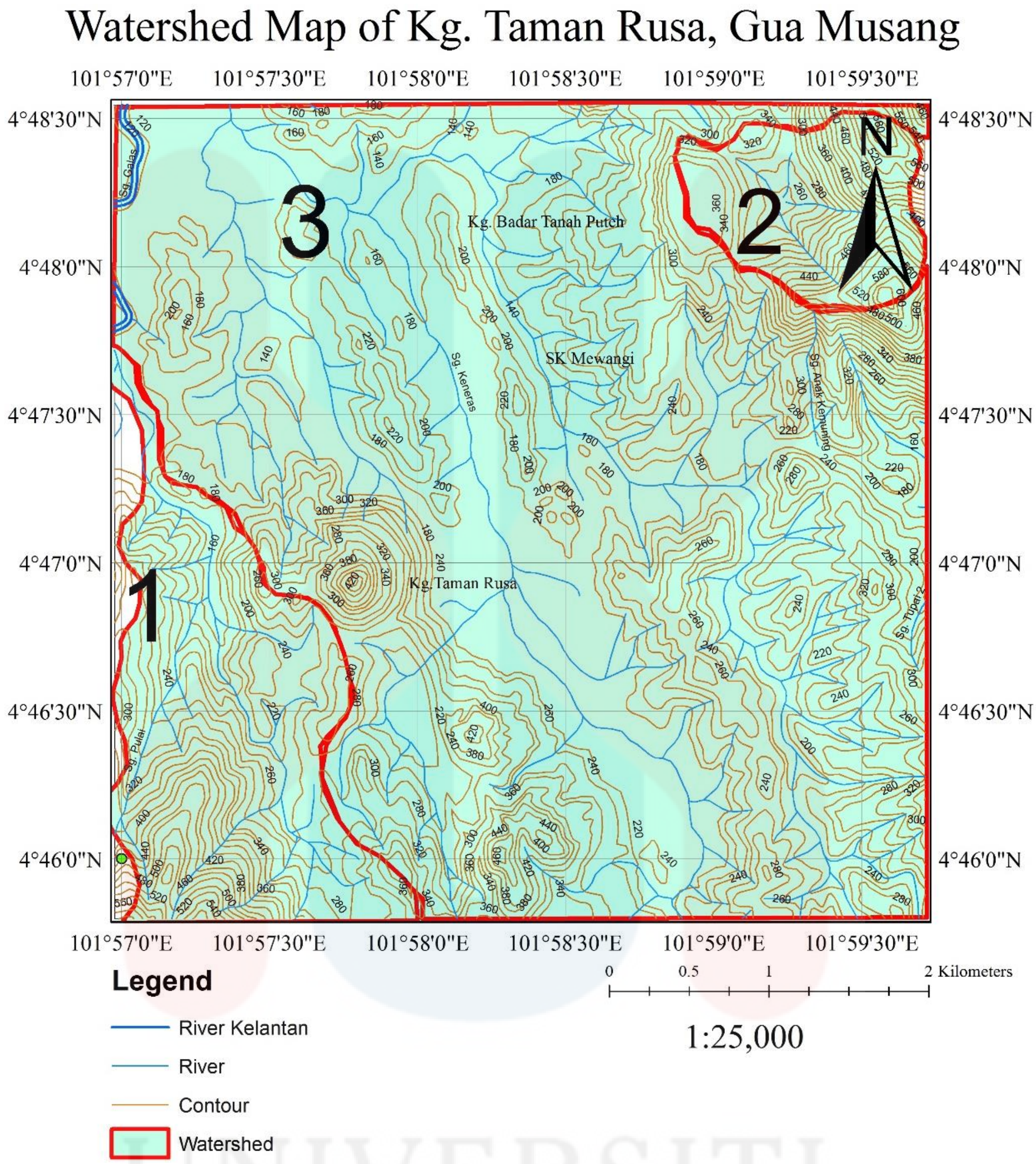


Figure 4.5 Watershed map of study area

4.2.3 Topography

Based on topography map in figure 4.6, it can explain the landform or geomorphology in study area. Area with high contour can be interpreted as limestone hill such as Gua Gagak at west and Gua Sidang at south west in the study area respectively.

Also, the contour groups with relatively uniform contour spacing, indicating uniform steepness can be interpreted as igneous rock, as they are more weathering resistant and they weather uniformly. In this study area, there is one quarry granite located at the south. The quarry still ongoing process.

The mineral quartz from granite is hard enough to resist most abrasion, strong enough to bear significant weight, inert enough to resist weathering and it. This can be proved by Bowen reaction series. Mineral in the lowest part in the series is hard enough to resist weathering. These characteristics make it a very desirable and useful dimension stone.

Based on 2D and 3D topography map in figure 4.6 and 4.7, the highest part is located at northeast and southwest respectively. Its stated around 520 metre to 560 metre from sea level. Also, the flat land stated at the northwest area indicated the lowest part. The flat area refers to the residential area, Kg. Pulai at the study area. It covers around 4% of study area. In the middle of study area, granite quarry is located. From the observation, two of the hill at the quarry actually connected. By the time past, the centre of that hill were excavated to produce open pit quarry.

Based on 3D map figure 4.7, it shows elevation part with colours. The highest elevation, 520-560 metres cover only 4% in study area shown as silver colour. The lowest part cover only 4% too same as highest part with shown as blue colour.

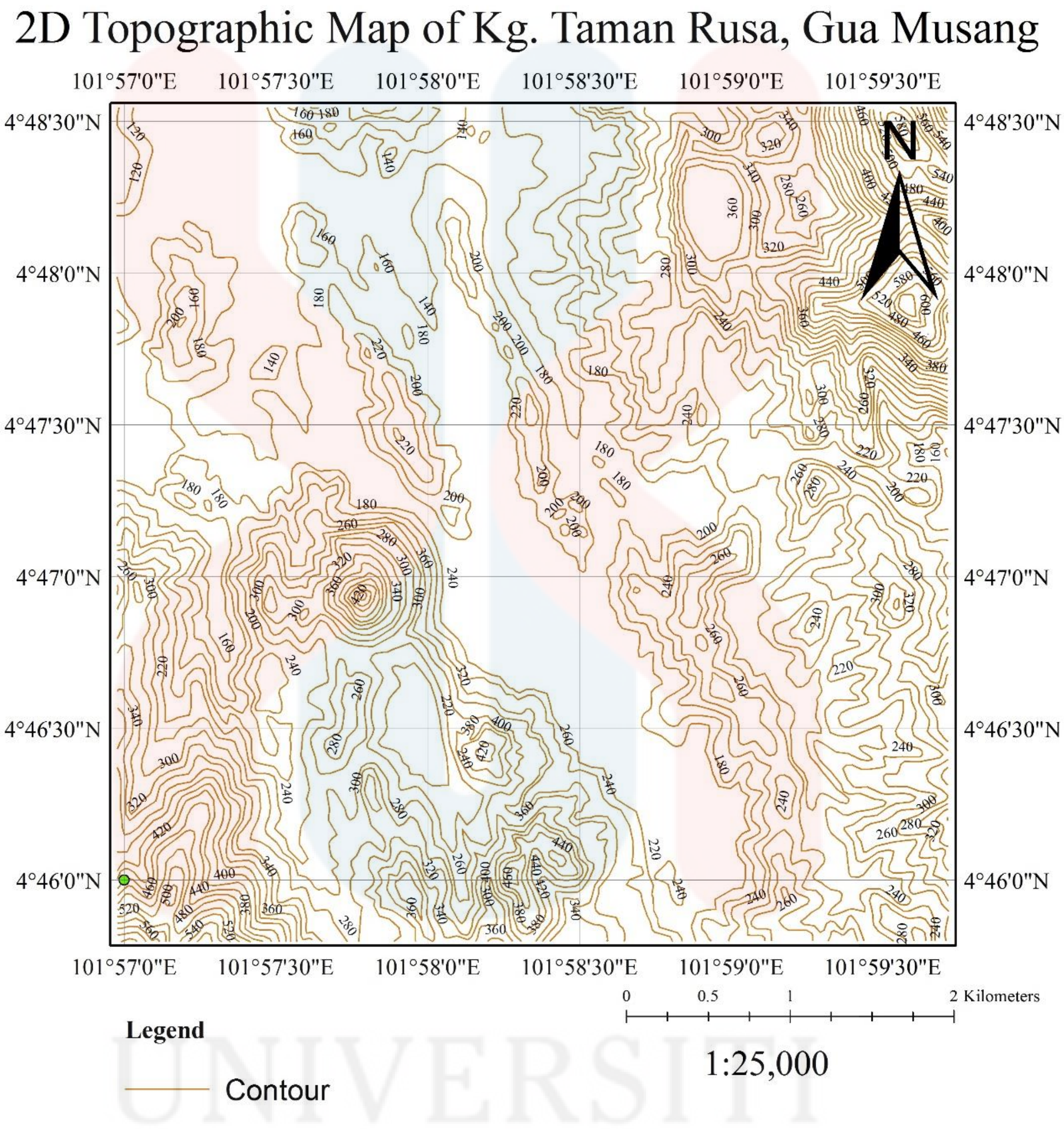


Figure 4.6 Topography map of the study area

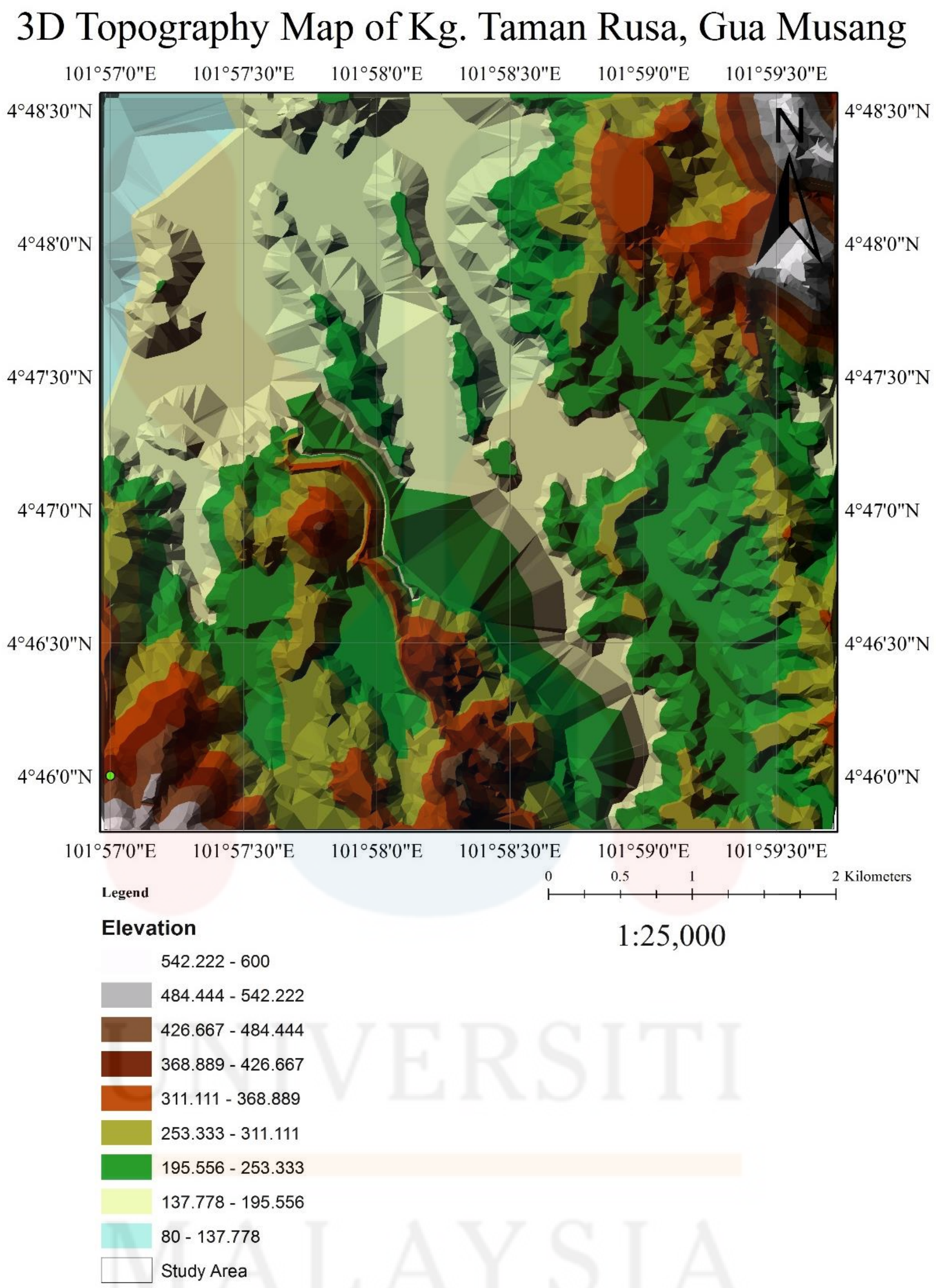


Figure 4.7 3D map of study area

4.2.4 Weathering process

Weathering process was the process where the breakdown of rock into smaller fragments. It has two type of weathering process which is physical and chemical weathering. Physical process occurred where the rock breakdown without chemical reaction process. For chemical process, the changes of rock composition or mineral.

In the study area, two types of weathering process are found. For physical weathering process, there are several agents mechanical weathering such as plant growth, frost wedging, and abrasion by wind, water or gravity. Based on figure 4.8, the physical weathering occurred in one of the location in the study areas and it is identified as the plant wedging. Noticeable that tree send out root system, the fine roots find their way into cracks of the rock.

Another type of weathering is known as the chemical weathering which includes dissolution, oxidation and hydrolysis. Figure 4.9 shows, limestone cave undergo dissolution process where the acidic water dissolved ~~in~~ the mineral from a rock body leaving cavities in the rock. These cavities may generate sinkhole or cave feature such as stalactite and stalagmite.

Figure 4.8 Plant wedging

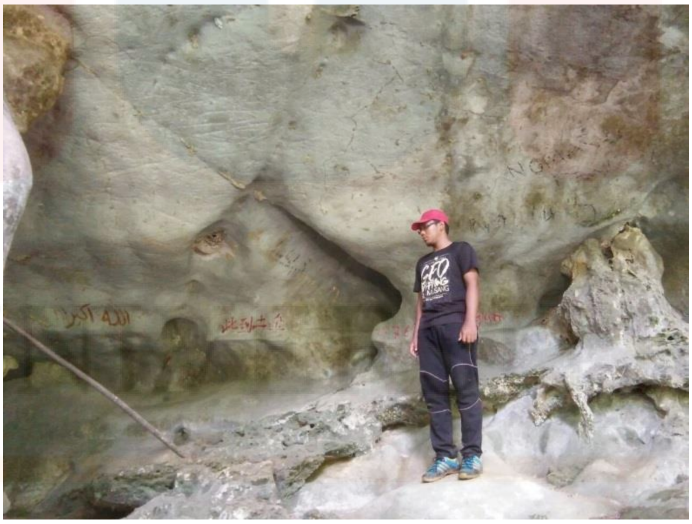


Figure 4.9 Dissolution process

4.3 Stratigraphy

Based on geological map in figure 4.10, it shows the rock unit distribution in study area. The oldest rock unit are limestone followed by granite, clay and lastly sandstone. Mostly area covered by limestone unit and some place are dominant with limestone feature such as limestone hill and cave. The granite can be found obviously at quarry area.

The stratigraphy of the study area can be correlated with lithologic log. The log acquired from the bedding structure. In geology, a bed is the smallest division of a geologic formation or stratigraphic rock series. A measurement collected by bedding plane. A bed is the smallest lithostratigraphic unit, usually ranging in thickness from a centimetre to several metres and can be differentiated by above and below layer. Beds can be identified by their rock or mineral type and particle size.

In the study area in figure 4.11, bedding plane found. Beds are enclosed or bounded by sharply defined upper and lower surfaces of bedding planes. These surfaces are probably the easiest physical features of sedimentary rocks to identify in outcrop.

Bedding planes are surfaces probably formed by the erosion of unconsolidated sediment collected at the sediment surface. The possibilities of sedimentary rock are interbedded sandstone with clay. The log is made using software called 'SedLog' as shown in figure 4.12.

The stratigraphic law of original horizontality is used to determine the age of the rock. The interbedded sandstone with claystone were from Triassic age based on Gua Musang stratigraphy as shown in figure 4.11. It formed in Gua Musang formation. The sandstone is predicted older than clay.

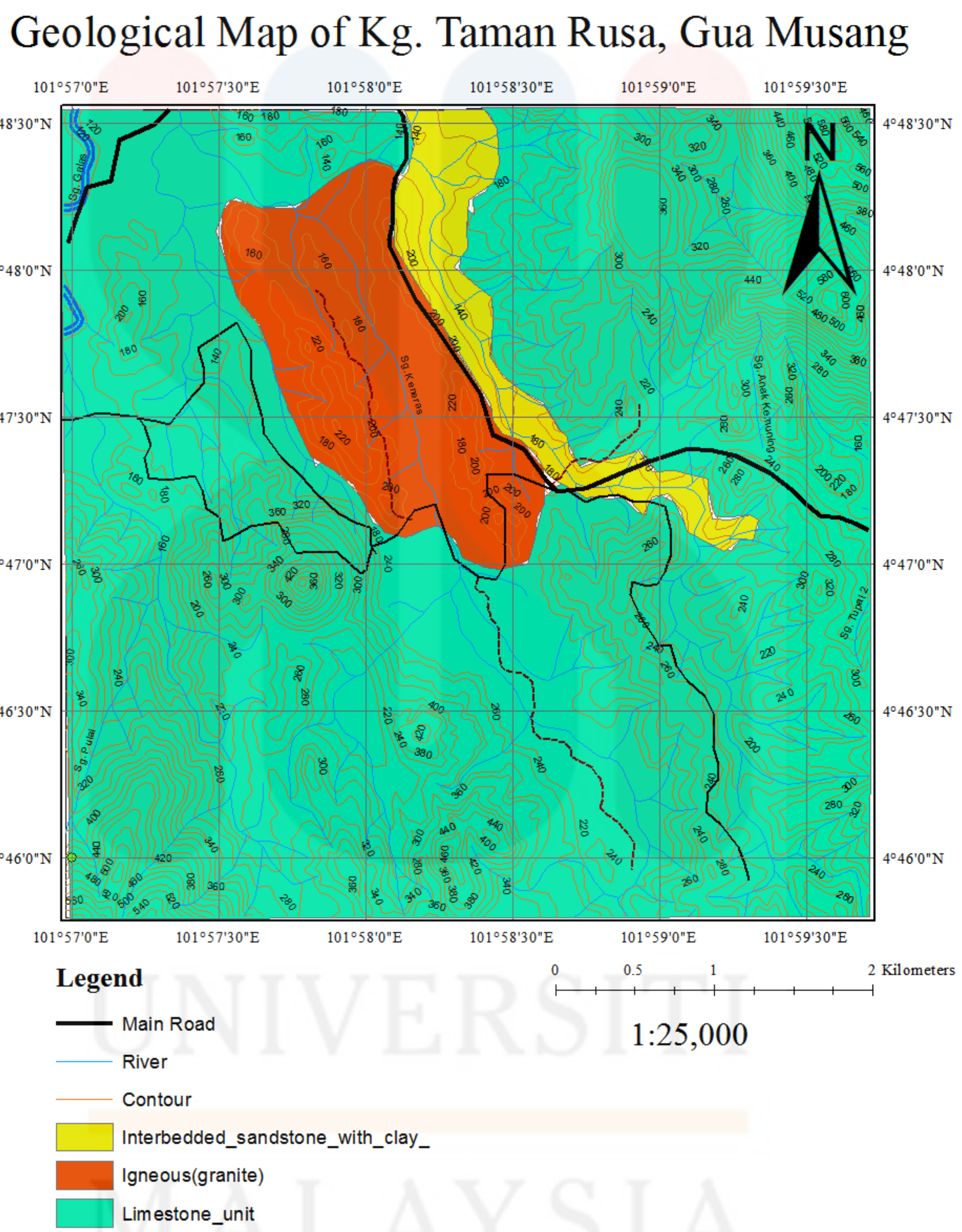


Figure 4.10 Geological map of study area

Figure 4.11 Interbedded sandstone and clay at study area (N 04°48’05.8’’, E 101°58’08.1’’)

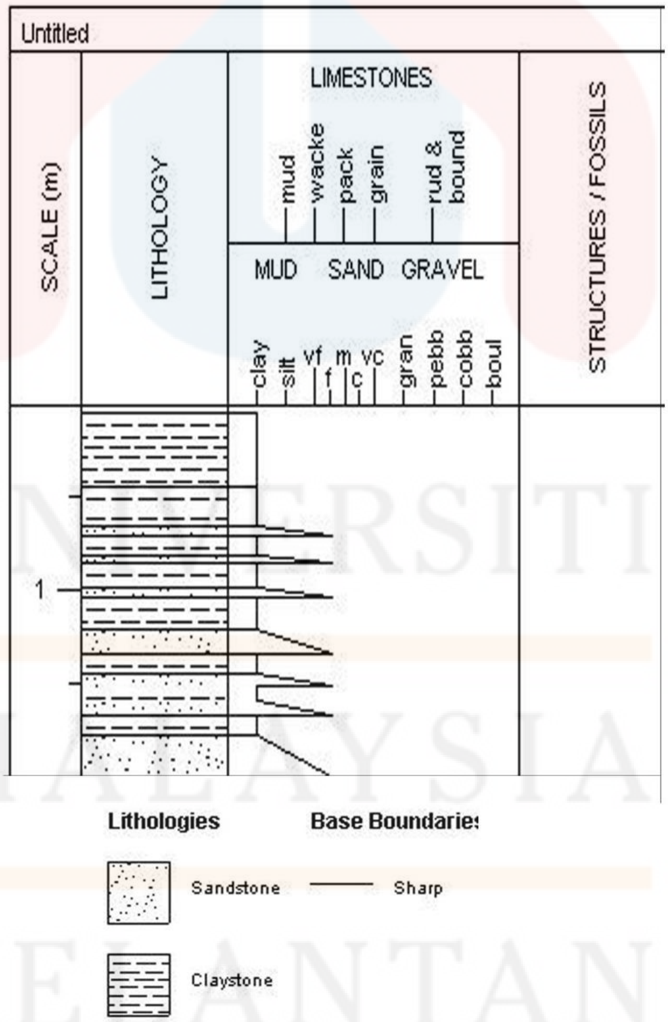


Figure 4.12 Litholog section

4.3.1 Petrology

Petrology is the branch of geology that focused on detailed description of rock, by using microscope. Petrology used to classify composition and texture of the rocks. For this research, three sample of rock from different location were taken for petrography analysis. The location of the sample location is noted in figure 4.13. First location stated as S1 and next same to it.

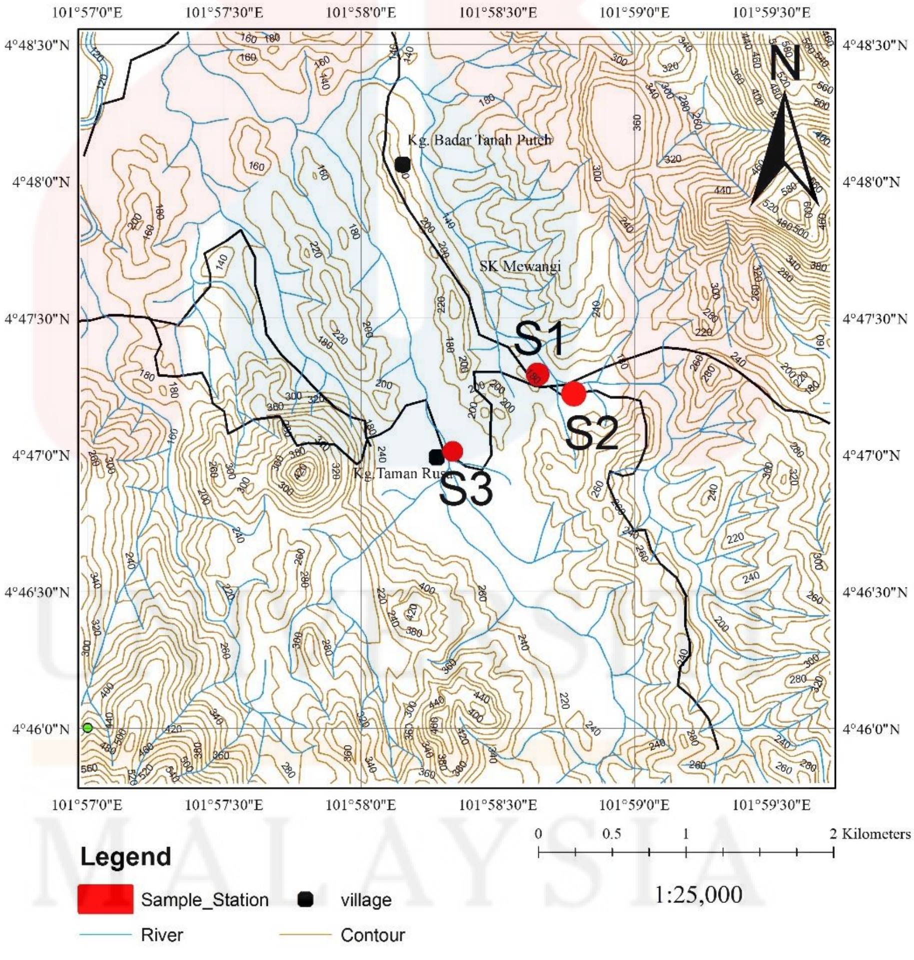


Figure 4.13 Location for each sample

4.3.1a Sample 1(S1)

Coordinate: N 04°47’16”, E 101°58’38”

For sample 1, the location is located at the centre of the study area with coordinate of N 04°47’16”, E 101°58’38”. Figure 4.14 shows the outcrop photography of sample 1. From the outcrop in this figure 4.14, it can be seen that the rock is highly weathered, however fresh rock from the outcrop is taken in photography analysis as in figure 4.15. From the primarily observation using hand lenses, it is predicted that the rock sample 1 is slate.

The fresh sample 1 is then undergo petrographic analysis in the form of thin section for identification minerals. The identification mineral is done using microscope in cross and plane-polarised lenses. Figure 4.16 shows sample 1 under cross-polarised lenses and under cross-polarised lenses.

Figure 4.14 Location sample taken

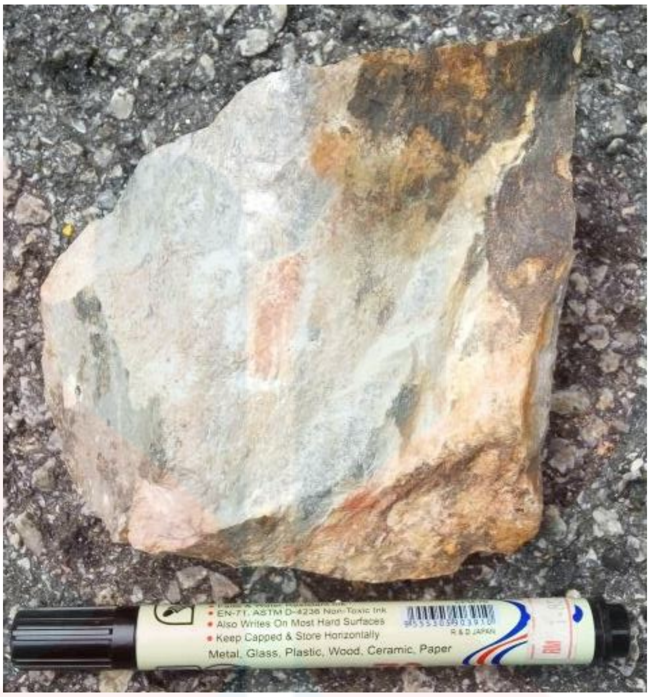


Figure 4.15 Hand specimen sample

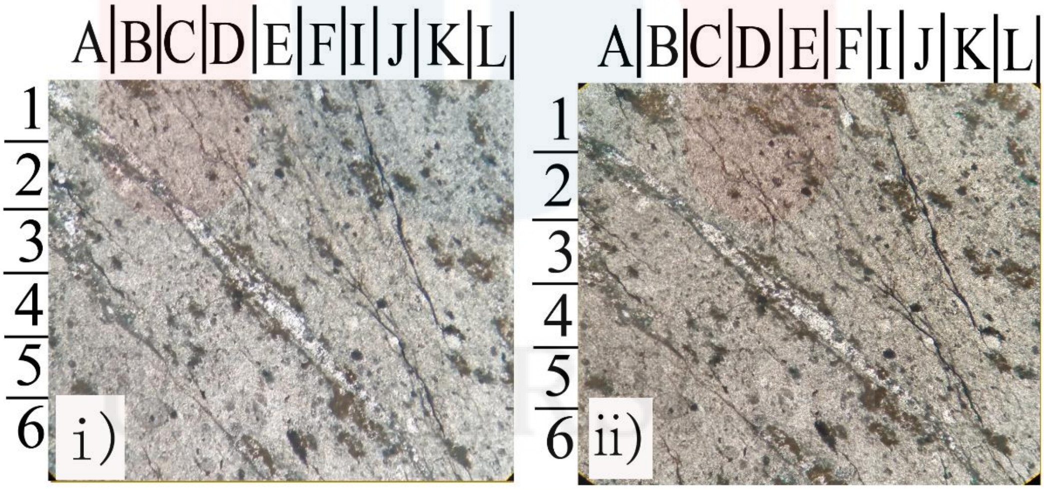


Figure 4.16 showing i) specimen under plane-polarised and ii) specimen under cross-polarised

4.3.1b Sample 2(S2)

Coordinate: N 04°47’13”, E 101°58’45”

For sample 2, the location is located at east of the study area with coordinate of N 04°47’13”, E 101°58’45”. Figure 4.17 shows the outcrop photography of sample 2. From the outcrop in this figure, it can be seen that the rock is located at the river, however fresh rock from the outcrop is taken in photography analysis as in figure 4.18. From the primarily observation using hand lenses, it is predicted that the rock sample 2 is sandstone.

The fresh sample 2 is then undergo petrographic analysis in the form of thin section for identification minerals. The identification mineral is done using microscope in cross and plane-polarised lenses. Figure 4.19 shows sample 2 under cross-polarised lenses and under cross-polarised lenses.

Figure 4.17 Location sample taken

Figure 4.18 Hand specimen sample

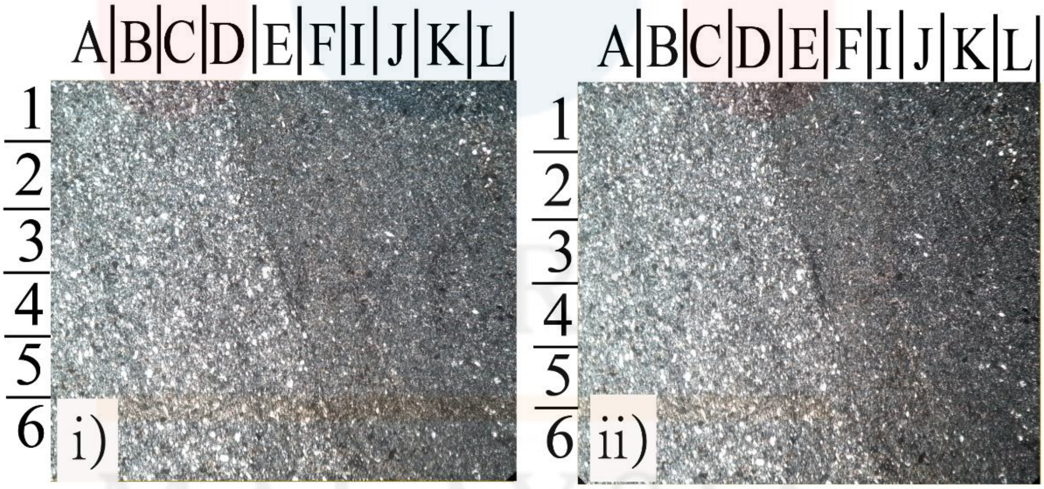


Figure 4.19 showing i) specimen under plane-polarised and ii) specimen under cross-polarised

Due to observation by hand specimen, this outcrop is gritty to touch like a sandpaper. Is also have very clearly lamination. The colour are white, black and mostly brownish. Under microscope shown in figure 4.19, this sample mostly formed by quartz and feldspar. This sample colour are divided by the brightness. The contact of this two part labelled as D1, E2, F3, I6. Part with light brightness indicate fine grained and dark indicate coarse grained. 70% of sample formed by mineral quartz and 30% with feldspar. The colour of quartz are colourless or clear and have weak relief. Feldspar with black colour and streak white.

4.1.3c Sample 3(S3)

Coordinate: N 04°47’02”, E 101°58’19”

For sample 3, the location is located at southwest of the study area with coordinate of N 04°47’02”, E 101°58’19”. Figure 4.20 shows the outcrop photography of sample 3. From the outcrop in this figure 4.20, it can be seen that the rock is located at the quarry and the hand specimen shown as in figure 4.21. From the primarily observation using hand lenses, it is predicted that the rock sample 3 is granite.

The fresh sample 3 is then undergo petrographic analysis in the form of thin section for identification minerals. The identification mineral is done using microscope in cross and plane-polarised lenses. Figure 4.22 shows sample 2 under cross-polarised lenses and under cross-polarised lenses.

Figure 4.20 Location sample taken

Figure 4.21 Hand specimen sample

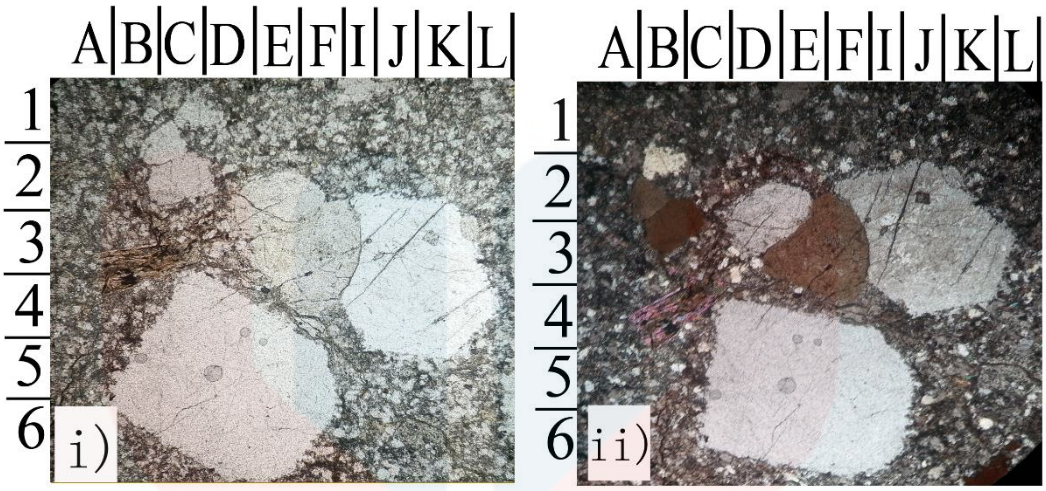


Figure 4.22 showing i) specimen under plane-polarised and ii) specimen under cross-polarised

Due to the observation by hand specimen, this sample expected as granite. It is coarse-grained. The pink colour indicate as an orthoclase feldspar, clear to smoky are quartz or muscovite and black indicate as a biotite or hornblende. This three mineral are the most dominant in igneous rock. From microscope observation, the mineral composition is plagioclase, biotite, alkali feldspar and quartz.

The percentage of plagioclase is 45%, quartz is 30%, biotite is 10% and alkali feldspar is 15%. This percentage are plot in on QAPF diagram. QAPF diagram used for classification the igneous rock. As a result, shown in figure 4.23, the rock's sample name is granodiorite.

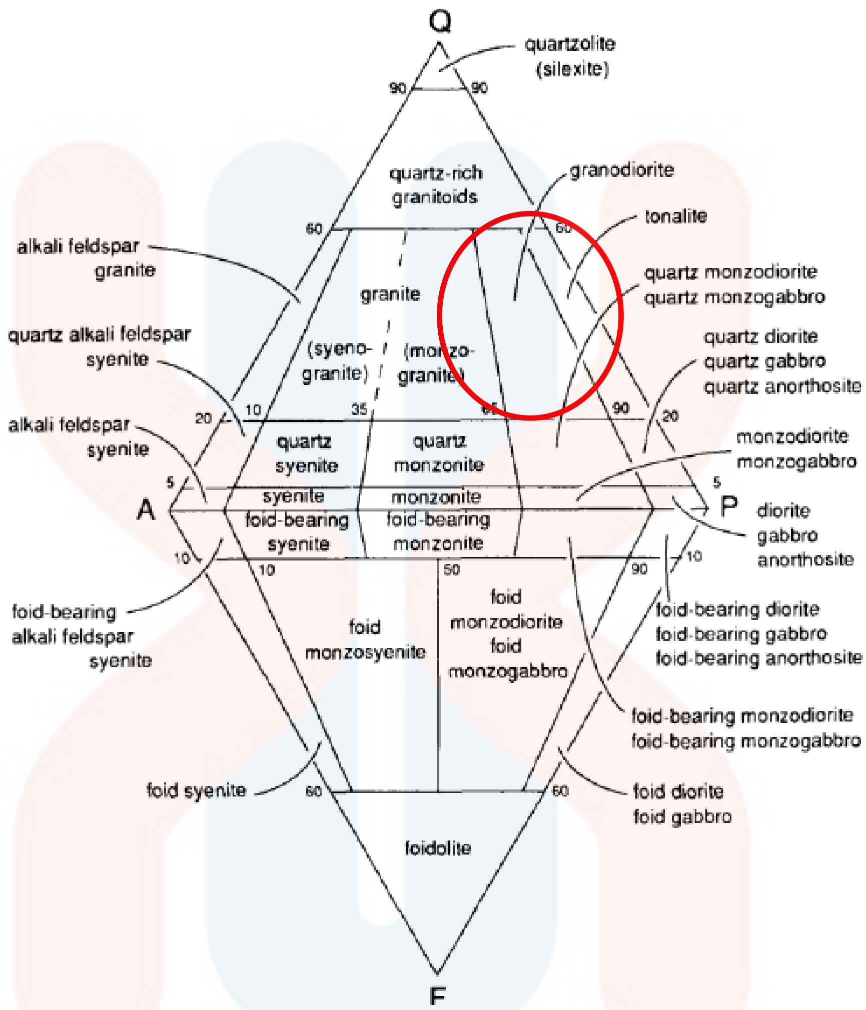


Figure 4.23 QAPF Diagram

4.4 Structural Geology

Structural features such as lineament, joint, fold, fault and fracture are the result of past geological events such as plate tectonic or earthquake. These structure is formed due to the force acting on the rock's bodies or tectonic plate. Under this subtopic, the force of lineament, joint analysis, fold analysis will be interpreted. This research discovered the three-dimensional distribution of large bodies of the rock, their surface and the composition of their inside.

4.4.1 Lineament

Lineaments are well-known phenomena in the earth's crust. Rocks exposed as surfaces or in road cuts or stream outcrops typically show innumerable fractures in different orientations, commonly spaced fractions of a meter to a few meters apart. These lineaments tend to disappear locally as individual structures, but fracture trends persist. We can easily map most of these lineaments in the field of from the limited aerial photos.

The lineament reading for study area is taken from the terrain map of the study area obtained from ArcGis database as shown in figure 4.24. Based on regional lineament map in figure 4.24, this map represented with scale 1:100 000. All the bearing reading data gathered is interpret into GeoRose software to obtain the rose diagram for the lineament interpretation. From the rose diagram in figure 4.25, it can be interpreted that the major force, $_1$ is W 340 N and the minor force, σ_3 is at N 60 E.

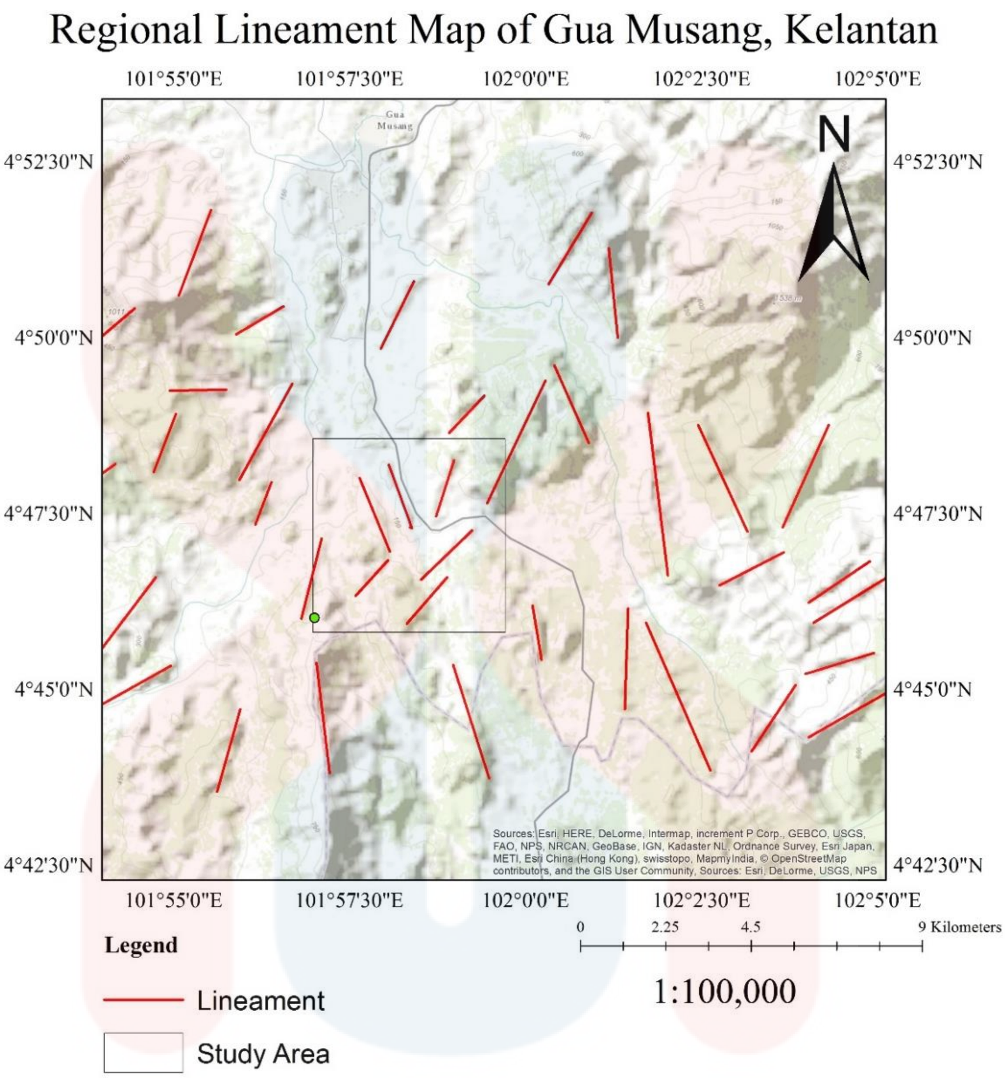


Figure 4.24 Regional lineament of Gua Musang

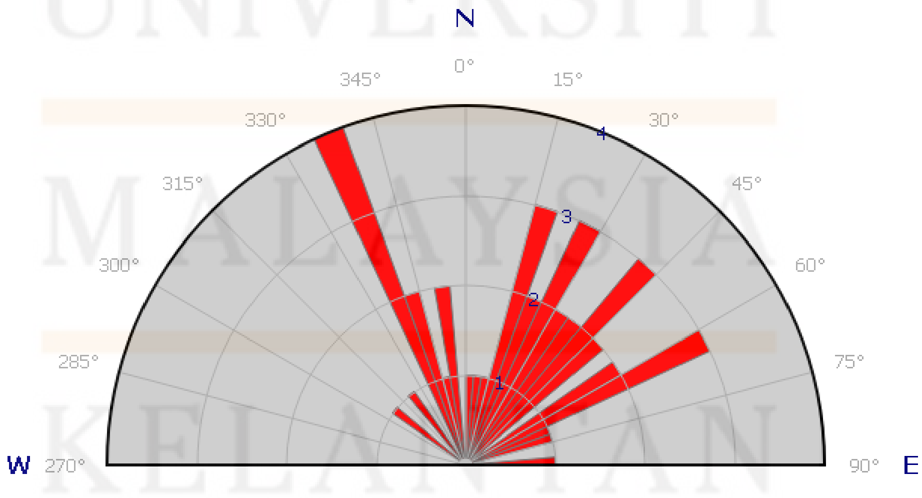


Figure 4.25 Rose diagram for lineament structure

4.4.2 Joint Analysis

During mapping progress, 100 reading of joints value were collected at two different check point. The data collected then were analyzed by using the GeoRose software to produce rose diagram. Joints formed when rock are stretched to their breaking point. This pattern helped in interpreting much precisely the direction forces. It is structure which there has been no appreciable displacement parallel to the fracture and only slight movement to the fracture plane.

At the first station refer to figure 4.26, it located at N 04°48`5.7” and E 101°58`08.1”. The type of joints was nonsystematic because does not share a common orientation and have curved and irregular fractures surfaces. Result of reading taking interpreted by rose diagram. Based on figure 4.27, the maximum force or σ_1 direction come from N 75 E. Minimum force or σ_3 comes from direction N 337 N. At second station in figure 4.28, joint reading was taken on limestone outcrop at coordinate N 04°47`03.2” and E 101°58`18.8”. The maximum force, σ_1 direction come from direction N 65 E and minimum force, σ_3 is W 325 N shown in rose diagram figure 4.29.

Figure 4.26 First station

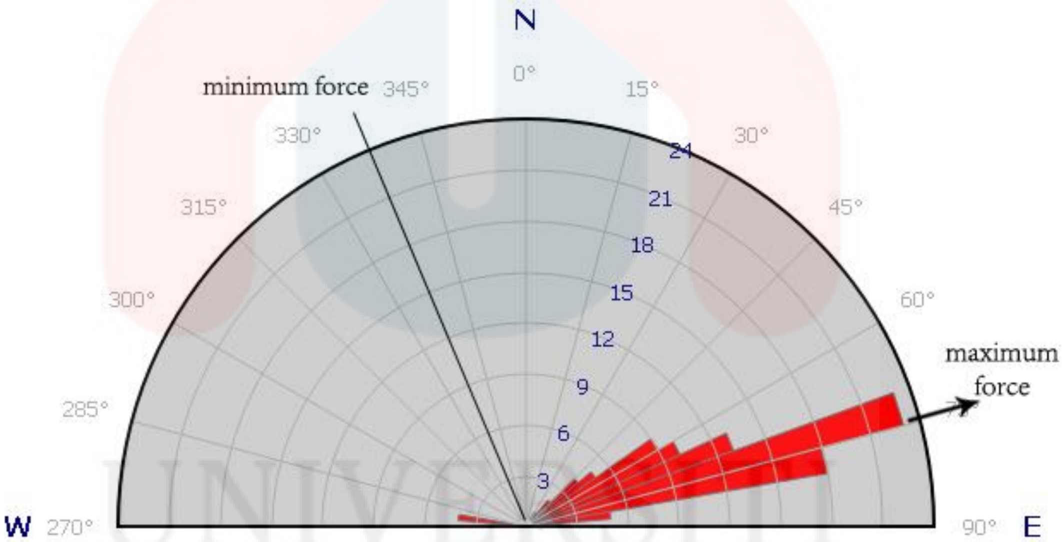


Figure 4.27 Rose diagram for first station

Figure 4.28 Second station

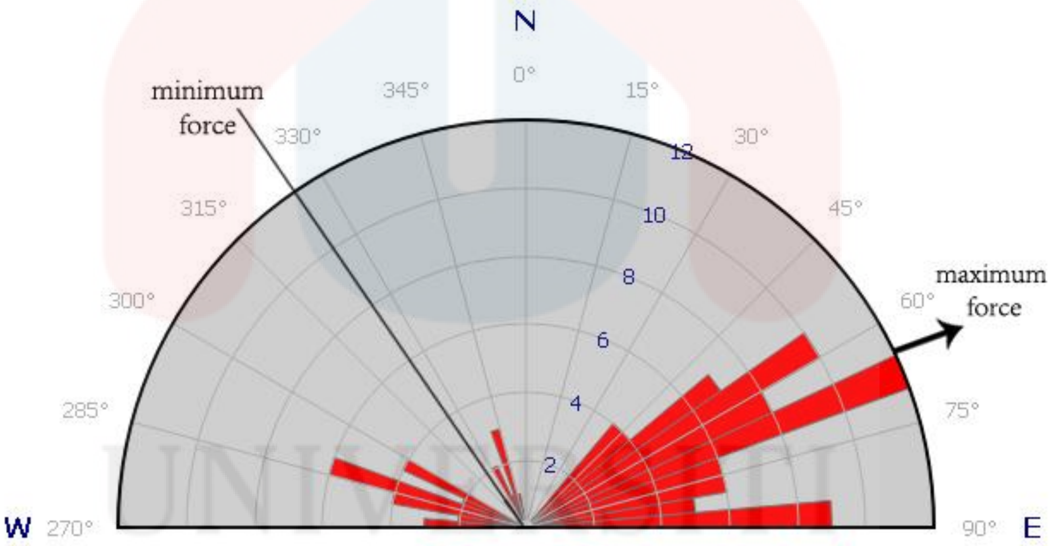


Figure 4.29 Rose diagram for second station

4.4.3 Fault Analysis

Fault is a planar fracture or discontinuity in a volume of rock. Fault occur within the earth's crust from the action of the plate tectonic forces. Sometimes the rapid movement of fault will cause earthquake. There are two type of fault such as normal and reverse fault. To determine this type of fault we have to identify where the hanging wall and foot wall. If the hanging wall move upward and foot wall move downward it will be reverse fault. If in opposite direction will be normal fault.

Based on figure 4.30, this normal fault found at coordinate N 04°47`03.2" and E 101°58`18.8". This area actually Gua Gagak. The strike and dip direction of the fault is 252/62. Also in study area have major fault based on map in figure 4.31. The data obtained from ArcGis software.

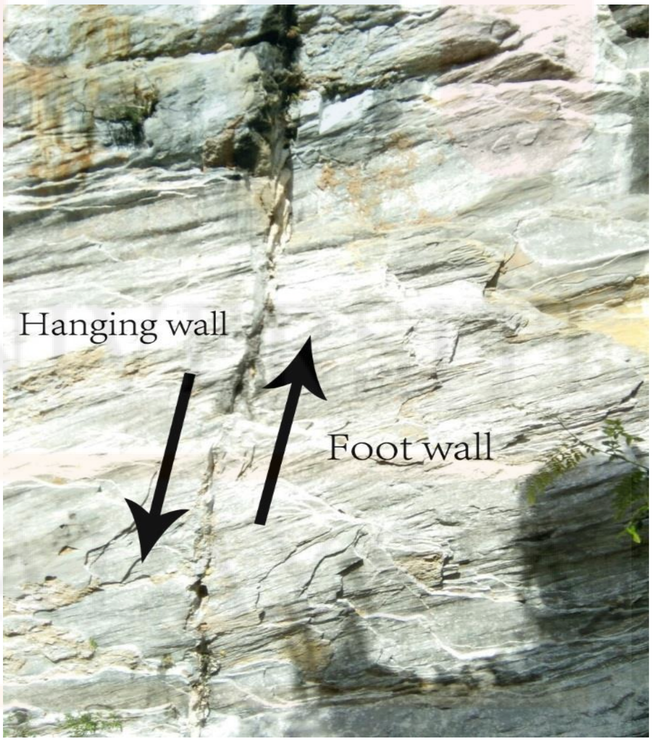


Figure 4.30 Normal fault

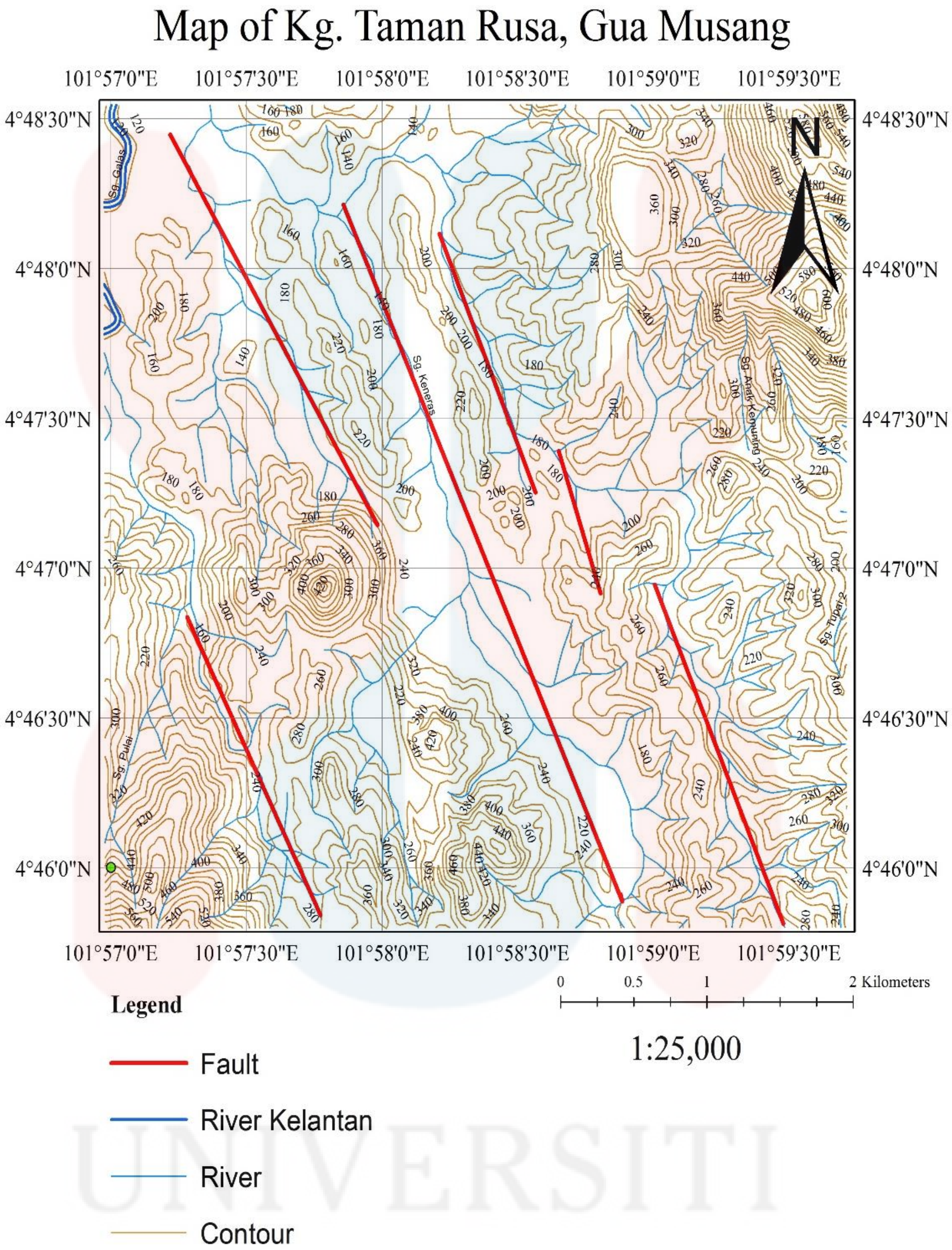


Figure 4.31 Fault distribution in study area

4.4.4 Fold Analysis

Fold is a rock formation that has been made by flat rock becoming deformed due to stress and pressure. Fold are created when two plates that make up the earth collide. As the plates are forced together, it will bend, curve or jagged pattern in the rock. Based on figure 4.32 at coordinate N 04°47’47” and E 101°57’36”, the type of folding is overtuned fold. It happened when one limb has turned completely upside-down with older beds on the top. The strike and dip direction of the folding are 350/56.

Figure 4.32 Folding

4.4.5 Fracture Analysis

Fracture is a surface along which rock or minerals have broken therefore surfaces across which the material has lost cohesion. Commonly caused by stress exceeding rock strength. There are many type of fracture such as extensional, shear, oblique extension, pinnate and gesture fracture. Based on figure 4.33, at wall of Gua Gagak shows many fracture. This are the obvious fracture seen. The type of fracture is shear. It is because the motion parallel to dip parallel plane or dip-slip.

Figure 4.33 Fracture

4.4.6 Gash Vein

Gash vein is a mineral-filled fracture formed along zones of ductile shear in the same orientation as the pinnate fracture. It is a vein resulting from the filling and sometimes enlargements of joint or crack that does not extend beyond the stratum in which it occurs. Based on figure 4.34, the calcite vein has intruded into limestone. This vein of calcite was formed as fluids entered an open space fracture during alteration of the rock.

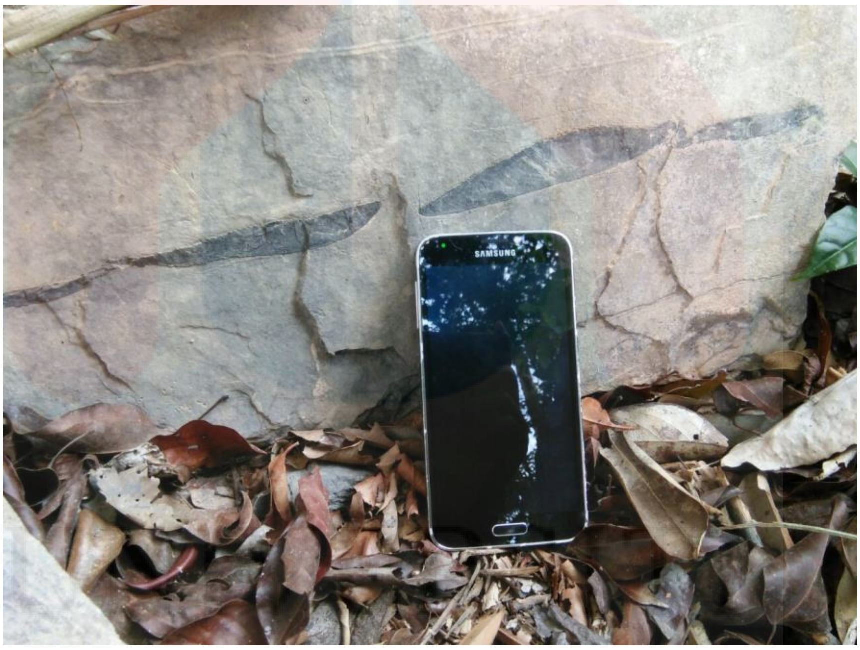


Figure 4.34 Gash Vein

4.4.7 Fossil Analysis

Based on figure 4.36, there are a fossil found which is probably ammonite in study area at coordinate N 04°46’18.4” and E 101°58’44.7”. From the previous research, Gua Musang have numerous on phylum mollusk such as ammonoids, bivalves and gastropods, and on phylum brachiopods. These fossil are very important to determine the age of marine Triassic in rock formation for that area especially in study area. Gua Musang area well known as abundant Triassic fossil within Central Belt in Peninsular Malaysia.

Figure 4.35 shown the age of each fossil due to their age. It also can be as reference to make early interpretation. From the previous paleontology research, mostly fossil found in Gua Musang age from middle Permian to middle Triassic (Dony, 2014). This body fossil might be ammonite in limestone rock.

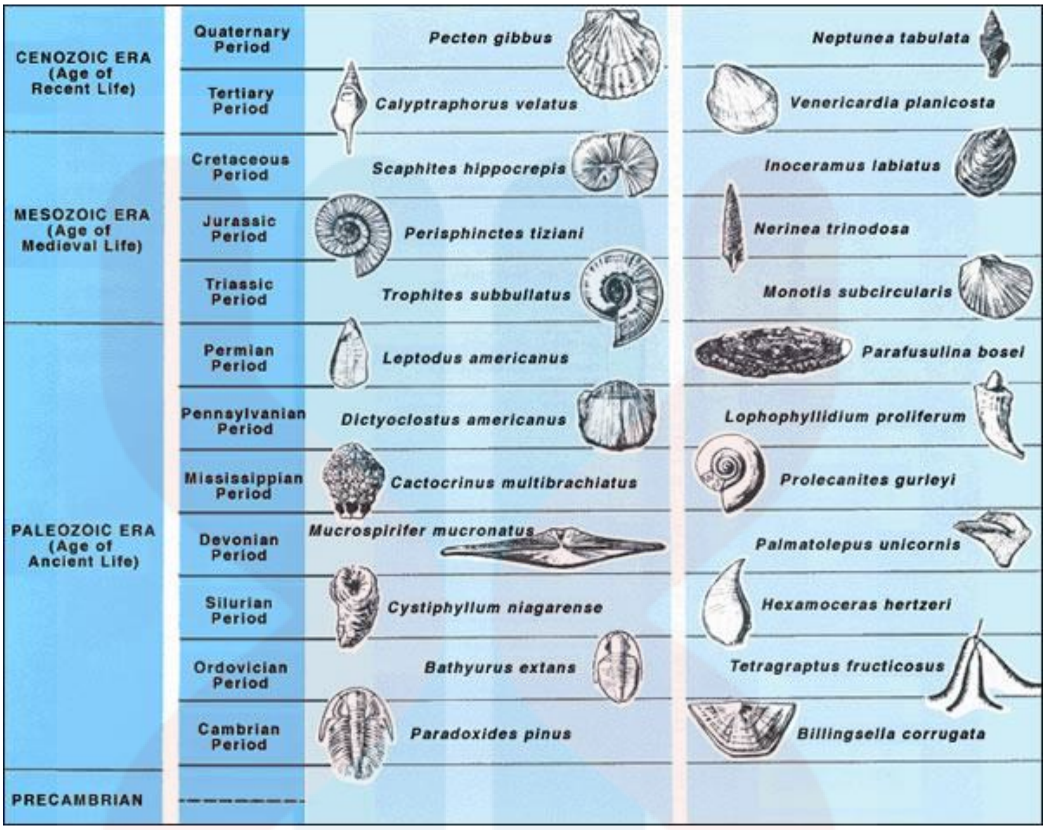


Figure 4.35 Geologic time scale with index fossils

Figure 4.36 Fossil (ammonite)

4.5 Historical Geology

The sediment log of study area can be correlated with Gua Musang formation stratigraphy. Based on lithology section from previous chapter, the sandstone and clay are from Triassic age. Clay was expected to be younger than sandstone. Limestone is the older rock unit in Gua Musang formation. Granite or igneous rock probably not younger than sandstone and clay.

Table 4.3 Stratigraphic column of Gua Musang

Era	Period	Series	Type of rock
Mesozoic	Triassic	Upper	Sandstone
		Middle	Clay
		Lower	Granite
Paleozioc	Permian	Upper	Limestone
		Lower	-

CHAPTER 5

RESULT AND DISCUSSION

5.1 Introduction

The electrical resistivity method is applied at three locations. Two location located to each other and another one at Gua Gagak. The data obtained from the resistivity profiling is converted into visual model by process called inversion. This process is done by using software Res2Dinv. The model from the inversion process is interpreted.

5.2 Electrical Resistivity Profile

There are three survey line of electrical resistivity imaging (ERI) profiling done at the study area. Two profile are located near to each other at area Gua Sidang and the remaining lines at Gua Gagak. Each profile spanning 200 meters. Figure 5.1, its shows the location of profiling. The first station referred as Line 1, second station refer as Line 2 and third station refer as Line 3.

Selection of profile must consider some of the parameters such as length and type of surface. The line must be able in straight line whether it flat or hill area. The length depends on our investigation. In this research study, three survey lines with 200 meters in length is used for electrical imaging resistivity. The line must be in a straight line to avoid disruption in the resistivity results. And the humidity of surface can accumulate more the result.

Two types of array configuration used in this research are Schlumberger and Wenner. Table 5.1 shows the differences on Schlumberger and Wenner array.

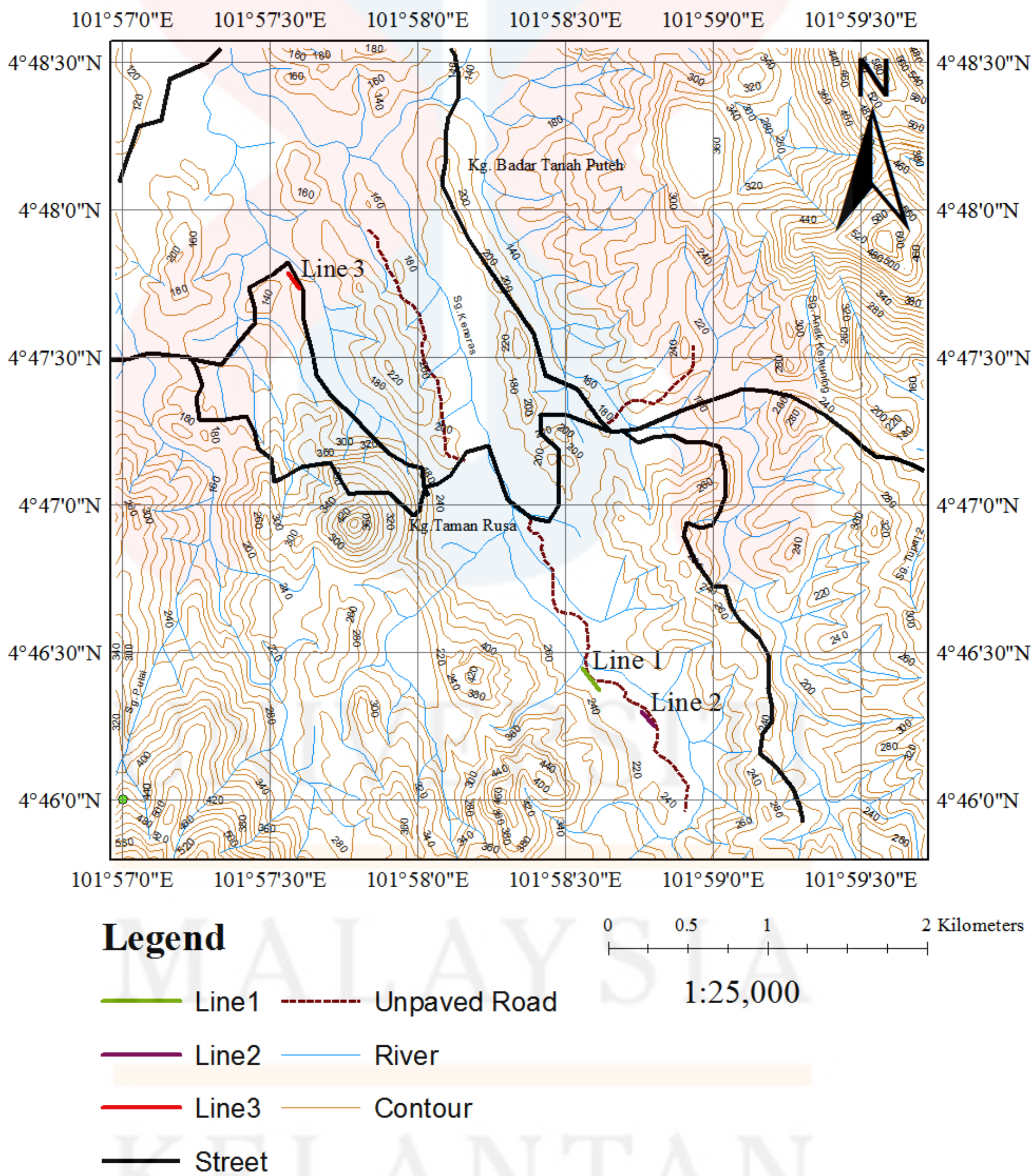


Figure 5.1 Line profiling location

Table 5.1 Advantages and limitations of different array

Sclumberger array	Wenner array
Advantages: 1) When the distance of electrode current increase, the distance of electrode capacity increase.	Advantages: 1) The effect of horizontal resistivity near to surface decrease because the electrode capacity remained at static location.
Limitations: 1) The interpretation limit only to simple and horizontal layer.	Limitations: 1) The interpretation limits only to simple and horizontal layer.

5.3 Analysis

After obtained raw data, it must be processed using RES2DNIV. The pseudo-section field in resistivity inversion model for quantitative interpretation is produced using RES2DINV software. The 2D model used by inversion software made up by several rectangular blocks. It based on data distribution in that pseudosection.

The distribution and size of block will generate automatically by that software used the distribution data by raw guide. The depth of line below the block will be assigned mostly the same with the depth of electrode area.

The result obtained from resistivity survey is processed by RES2DINV to remove bad datum point. Next, the inversion process is done using least-square inversion option in the software. Figure 5.2i and 5.2ii shows the processed of datum points.

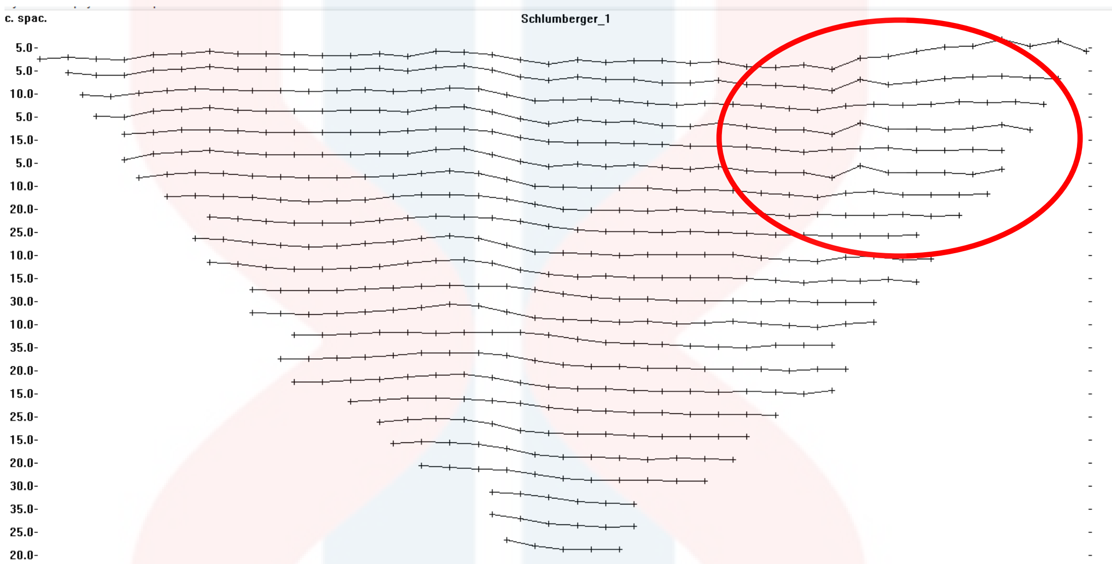


Figure 5.2i Process of removing the bad datum

Figure 5.2ii After remove bad datum

5.4 Result Interpretation

The completed inversion then analysed for subsurface potential. The result of each profile explained in this subtopic.

5.4.1 Survey Line 1

Survey Line 1 is done at coordinates N 04°46’25.8” and E 101°58’33.6” with electrode spacing of 5.0 meter and 200 meter in length. This line using Schlumberger array. The depth of penetration around 36.9 meter. The different zone indicates different value resistivity range reading. The four different zone attribute the type of rock and water content.

For survey Line 1, four zones are identified based on its resistivity value range. For zone A, with depth of 0-6.76 meters shows resistivity value of 8.07-105Ωm. This zone is consisting of the lowest resistivity value. This can be interpreted as saturated sandy clay. For zone B, with the resistivity value range from 4994-17798Ωm and depth from 6.76-31.3 meter can be interpreted as weathered limestone.

For zone C, its shows the highest reading of resistivity value range from 17798-64216Ωm at depth from 6.76-13.4 meters. It stated at distance from 40.0-80.0 meters. This interpreted as massive limestone. For zone D, at the lowest depth from 31.3-36.9 meters shows the reading from 379-1367Ωm. It can be interpreted as saturated sandstone.

5.4.2 Survey Line 2

Survey Line 2 is done at coordinates N 04°46'20.5" and E 101°58'41.9" with electrode spacing of 5.0 meter and 160 meter in length. This line using Schlumberger array. The depth of penetration around 36.9 meter. The different zone indicates different value resistivity range reading. The four different zone attribute the type of rock and water content.

For survey Line 2, four zones are identified based on its resistivity value range. For zone A, with depth of 0-26.2 meters shows resistivity value of 22.2-39.9Ωm. It is located at two part which is from 10.0-90.0 meters and 110.0-140.0 meters. This zone is consisting of the lowest resistivity value. This can be interpreted as saturated sandstone. For zone B, with the resistivity value range from 71.7-129Ωm and depth from surface to 231 meter can be interpreted as saturated sandstone with clay.

For zone C, its shows the resistivity value range from 231-415Ωm at depth from 6.76-26.2 meters. It stated at distance from 90.0-105.0 meters. This interpreted as porous limestone. For zone D, at the lowest depth from 26.2-36.9 meters shows the reading from 415-746Ωm. It can be interpreted as saturated sandstone only.

5.4.3 Survey Line 3

Survey Line 3 is done at coordinates N 04°47'45" and E 101°57'30" with electrode spacing of 5.0 meter and 200 meter in length. This line using Wenner array. The depth of penetration around 36.9 meter. The different zone indicates different value resistivity range reading. The four different zone attribute the type of rock and water content.

For survey Line 3, four zones are identified based on its resistivity value range. For zone A, with depth from surface to 67.6 meters shows resistivity value of 18.5-78.6Ωm stated the lowest resistivity value interpreted as saturated sandstone. For zone B, with the resistivity value range from 318-646Ωm and depth from surface to 21.5 meter can be interpreted as porous weathered sandstone.

For zone C, its shows the resistivity value range from 1315-2674Ωm at depth from 6.76-21.5 meters. It stated at distance from 90.0-105.0 meters. This interpreted as slightly weathered sandstone. For zone D, at the lowest depth from 26.2-31.3 meters shows the reading from 76.8-156Ωm. It can be interpreted as fresh groundwater. Zone D have more water content than another zone. This location suspected have fault due to one low resistivity value formed between the two zone with highest resistivity value.

5.5 Discussion

From all three survey line, it can be concluded that the highest resistivity value located at zone C from survey Line 1. It can be interpreted as massive limestone due to the location nearby with limestone hill. The lowest resistivity value located at zone A also from survey Line 1. It can be interpreted as saturated sand clay. The differences between highest and lowest zone are their water content. When highest resistivity value, the water content become lowest and vice versa.

Survey Line 3 shows has structural feature which is fault. Possibilities for the upper surface sink at the future are high because water can sip through this part and produce high water content below the highest zone stated. As a conclusion, the results shows the possibilities of geohazard happen are high at area survey line 3 because hard rock located above soft bedrocks. In a meantime, water can sip through this fault and increase water content at low resistivity zone.

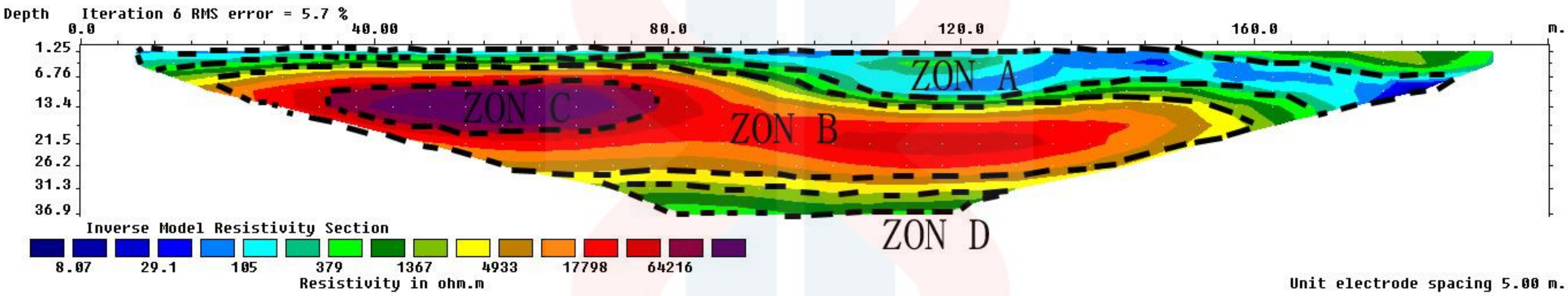


Figure 3.3 Survey Line 1

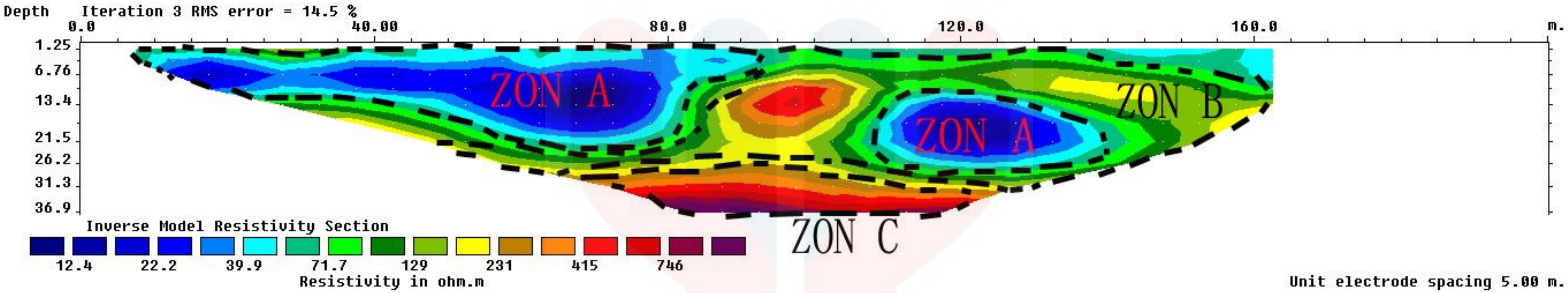


Figure 5.4 Survey Line 2

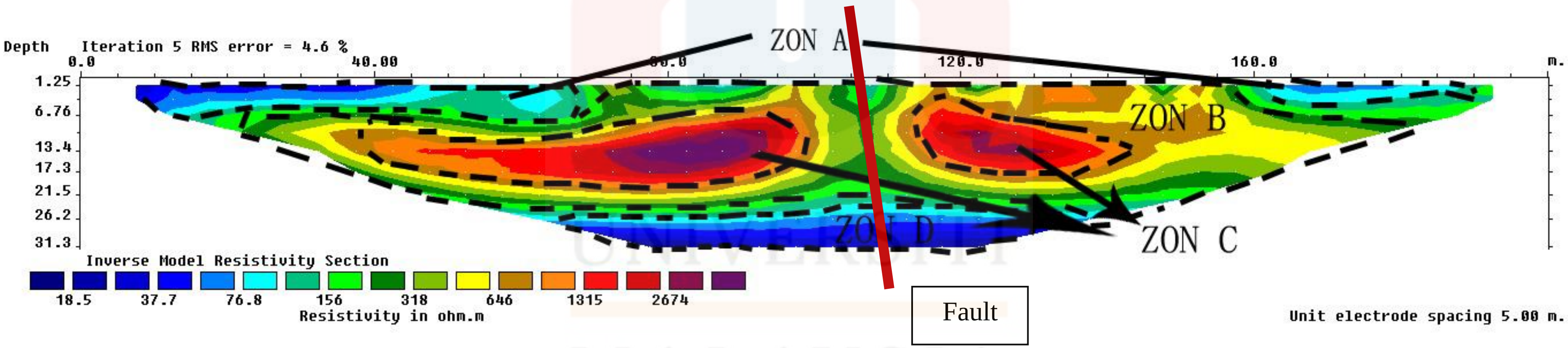


Figure 5.5 Survey Line 3

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

As a conclusion, the objectives stated early in this research was achieved by preliminary research, field mapping, laboratory process and electrical resistivity survey. All of the findings are reported in chapter four and five. The objectives of this research were updated the geological map, identify subsurface condition by using electrical resistivity imaging and predict the limestone geohazard.

The older geological map was produced with existing data obtained from the JUPEM. By process geological mapping, new finding about geological information was added. Its explain in chapter 4. The landform and morphology of study area was explained and illustrated with the help of contour map, drainage map, watershed map, 2D and 3D topography map.

The stratigraphy and petrography analysis detail was stated by explaining in lithology section and thin section process respectively. As the specification research was about prediction of limestone geohazard, it was assessed by using method electrical resistivity imaging. This method used ABEM Terrameter machine to detect the subsurface karst information.

For second objective, the lithology predicted at survey line area are known but not very accurate because did not have borehole data. Resistivity method provide roughly the lithology data. It still need another combination method to obtained more accurately data.

Based on analysis and discussion in previous chapter, it can be concluded that the study area has potential of limestone geohazard due to the profiling data detected the voids by low resistivity sign (lower resistivity than limestone and unconsolidated sediments). This part filled with water, hence become low resistivity value than surrounding rock.

6.2 Suggestion

As the suggestion for the future research, to get a better result must be added with Vertical Electrical Sounding (VES). Borehole data is needed to confirm and to give an accurate result. For the future work, it is suggested to do more research on study area to prevent accidently happened. The location of limestone hill in study area such as Gua Gagak and Gua Sidang provide precious geological information. It is good for the researcher and student come to observe practically.

REFERENCES

Department of Statistic Malaysia,2016

Department of Survey and Mapping Malayisa,2016

Abdeltawab, S. (2013). Karst Limestone Geohazards in Egypt and Saudi Arabia. *International Journal of Geoengineering Case histories*, 258-269.

Abdullah, N. T. (2009). Mesozoic stratigraphy. In *Geology of Peninsular Malaysia.* (pp. 67-131). University Malaya and Geological Society of Malaysia, Kuala Lumpur: In: Hutchison, C.S. & Tan, D.N.K., eds.

Boon-Kong, T. (2002). Environmental Geology of Limestone in Malaysia.

Doyuran, Ö. A. (2012). Soil Profile Identification Around Necatibey Subway Station. *International Journal of Engineering & Applied Sciences (IJEAS)*, 1-14.

Ghani, A. (2009). Structural evidence for a Palaeozoic orogeny in northwest Malaya. 501-520.

Hutchison, C. (2009). Regional Geological Setting. In *Geology of Peninsular Malaysia* (pp. 31-40). Geological Society of Malaysia and University of Malaysia.

Kelantan On-Line Rainfall Data(mm). (2016, May 23). Retrieved May 2016, from Department of Irrigation and Drainage: http://infobanjir.water.gov.my/kelr.cfm

Lee. (2004). Mineral resources, Peninsular Malaysia. . *Rep. Geol. Survey Malaysia*.

Mohd Shafeea Leman. (1984). Tectonic framework and evolution of the Central Belt and its margins, Peninsula Malaysia. In *Bulletin of the Geological Society of Malaysia* (pp. 307-322).

Khoo and Lim (1983). Paleomagnetism,geochronology and petrology on the dolerite dykes and basaltic lavas from Kuantan, West Malaysia. *Bulletin of the Geological Society of Malaysia.*, 71-85.

Loke, M. B. (1996). Rapid least squares inversion of apparent resisitivity pseudosection using a quasi-Newton method. *Geophys. Prospec.*, 131-152.

MacDonald. (1967). Late Paleozoic paleogeography of Southeast Asia: Some stratigraphical, paleontological and paleomagnetic constrains. *Bulletin of the Geological Society of Malaysia*, 153-164.

Mahmoud Khaki, I. Y. (2014). Electrical resistivity imaging and hydrochemical. *Hydrological Sciences Journal*, 5.

Milsom, J. (2003). The Geological Field Guide Series. *Field Geophysics*.

Norbert Simon, M. F. (2015). Assesment of Rockfall Potential of Limestone Hills. *Journal of Sustainability Science and Management*, 24-34.

Omar Al-Kouri, H. O.-S. (2010). Geostatistical Analysis of Karst. *EJGE*, 914.

R.D., G. D. (1993). Two dimensional resistivity imaging and modeling. *Journal of Applied Geophysics*, 211-226.

Simon, K. (2013). Mesozoic Tectonostratigraphy &. 7.

Todd Halihan, S. C. (2007). *Using Electrical Resistivity Imaging to Evaluate Permanganate Performance during.* Oklahoma: University of Nebraska, Lincoln Oklahoma State University.

Wardah, A. (2011 , January). ~ *Snʇnƃuəd ıs ıqlɐb-lɐ ɐʎɥəp* ~. Retrieved from http://watinwardah.blogspot.my/2011/01/suka-sabah-0.html

Yin, J. (1965). A radiometric time scale of the Triassic. *J. Geol. Soc. Australia*, 107-121.

Zaw Win, U. H. (2011). Geophysical investigation using resistivity and GPR: A case study. *Bulletin of the Geological Society of Malaysia*, 20.

Zeinab Bakhshipour, 1. B. (2013). Application of Geophysical Techniques for 3D Geohazard. *The ScientificWorld Journal*, 1.

Zul Fadhli, D. R. (2015). Mapping Subsurface Karst Formation. *EGJR*, 351.

Omar Al-Kouri, H. O.-S. (2010). Geostatistical Analysis of Karst. *EJGE*, 914.

Loke M.H. and Barker R.D.,1996a. Rapid least-squares inversion of apparent resistivity pseudosections using a quasi-Newton method. Geophysical Prospecting, 44, 131-152.

APPENDIX A

Table A.1 Lineament reading at regional map

156	31	155	156	33
62	25	60	71	68
55	140	2	171	168
128	162	8	40	42
15	42	26	39	157
160	172	14	18	28
58	88	20	15	22
47	49	36	60	

Table A.2 Joint reading at Station 1

68	65	72	66	72
60	54	59	77	54
61	81	64	66	74
77	55	96	87	67
72	73	64	60	44
58	52	59	60	72
70	76	81	46	63
55	71	75	70	70
69	65	75	77	96

94	85	81	73	83
79	43	95	70	79
66	69	90	54	59
49	37	99	75	71
58	59	74	77	63
69	80	76	74	79
71	74	75	65	94
45	66	34	47	45
66	34	47	73	75
79	61	55	75	71
70	75	76	63	68

Table A.3 Joint reading at Station 2

43	59	285	87	74
65	66	282	295	71
65	79	65	68	43
289	297	72	60	79
81	89	95	94	81
80	68	66	65	49
292	288	78	71	57
59	74	85	85	284
294	295	286	89	86
93	96	58	52	58

58	52	91	84	56
63	61	60	62	63
61	82	287	283	44
49	51	53	55	58
57	69	77	72	79
344	340	331	339	339
324	330	267	266	341
345	64	77	41	47
48	50	284	232	66
231	245	87	65	45

APPENDIX B

Figure B.1 Coordinate's signboard

Figure B.2 Quarry

Figure B.3 At Gua Gagak

Figure B.4 Visit Wildlife Conservation Centre

Figure B.5 Panoramic view at Gua Gagak

Figure B.6 Setup resistivity machine (Abem Terrameter)