GEOLOGY AND SUBSURFACE VOID RISK MAPPING USING ERI AT PPMS KESEDAR SEJAHTERA, GUA MUSANG, KELANTAN

By

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

FACULTY OF EARTH SCIENCE UNIVERSITI MALAYSIA KELANTAN

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DECLARATION

I declare that this thesis entitled Geology And Landslide Potential using resistivity method in Paloh , 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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"I/ We hereby declare that I/ we have read this thesis and in my/our opinion this is sufficient in terms of scope and quality for the award of Bachelor of Applied Science (Geoscience) with Honors"

Signature : ……………………………….

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LIST OF ABBREVIATION

No.	Abbreviation	Word
1	GIS	Geological Information System
2	GPS	Geographic Positioning System
3	HCl	Hydrochloric acid
4	JMG	Department of Geoscience and Mineral
5	m	Meter
6	Qtz	Quartz
7	ERI	Electrical Resisitivity Imaging
8	GS	Gua Serai
9	GBB	Gua Batu Boh

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GEOLOGY AND SUBSURFACE VOID RISK MAPPING USING ERI AT PPMS KESEDAR SEJAHTERA, GUA MUSANG, KELANTAN

Abstract:

The study area covers 25 km^2 from the total area of Gua Musang which is 7979.77 km^2. The coordinate of the study area ranging for latitude from 4°48'36.38" N to 4°50'59.17" N and the longitude from 102°00'52.78 E to 101°56’51.09” E. meanwhile the specification area is between Gua Batu Boh and Gua Serai. The objective of the study is to update the geological map of the study area to 1:25000 scale to identify the potential of subsurface void using ERI and to determine limestone karst’s subsurface condition. The methods that have been used in order to update the geological map are preliminary study, sample collection while geological mapping, and field observation such as geomorphology features, land use, and drainage pattern. There were three sample of rock that selected to make a petrographic analysis. The lithology of the area mostly dominated by limestone following by phyllite sandstone interbedded with siltstone and acid intrusive. A variety of the landform makes a difference in the elevation which ranging from 100m to 500m. Geological map that has been updated using Arcgis Software. Specification in this study was involving a secondary data carried out in between and around Gua Batu Boh and Gua Serai. The data was trimmed using Res2dinv Software. Based on result from interpretation shows that there are some areas where subsurface void happened. But the areas were filled with sand and water in the void spaces. Nevertheless, the areas were still unsafe for any development activities to be carried out. Subsurface void was determined to happen in the Gua Batu Boh area.

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GEOLOGI DAN PEMETAAN RISIKO RUANG KOSONG SUBPERMUKAAN MENGGUNAKAN ERI DI PPMS KESEDAR SEJAHTERA, GUA MUSANG, KELANTAN

Abstrak:

Kawasan kajian meliputi 25 km2 daripada keseluruhan kawasan Gua Musang iaitu 7979.77 km2. Koordinat kawasan kajian berjulat untuk latitud dari 4°48'36.38" N hingga 4°50'59.17" N dan longitud dari 102°00'52.78 E hingga 101°56'51.09” E. manakala kawasan spesifikasi adalah antara Gua Batu Boh dan Gua Serai. Objektif kajian adalah untuk mengemas kini peta geologi kawasan kajian kepada skala 1:25000 untuk mengenal pasti potensi lompang bawah permukaan menggunakan ERI dan untuk menentukan keadaan bawah permukaan karst batu kapur. Kaedah yang telah digunakan untuk mengemaskini peta geologi ialah kajian awal, pengumpulan sampel semasa pemetaan geologi, dan pemerhatian lapangan seperti ciri geomorfologi, guna tanah, dan corak saliran. Terdapat tiga sampel batuan yang dipilih untuk membuat analisis petrografi. Litologi kawasan tersebut kebanyakannya didominasi oleh batu kapur diikuti oleh batu pasir phyllite berselang-seli dengan batu lodak dan penceroboh asid. Kepelbagaian bentuk muka bumi membuat perbezaan dalam ketinggian antara 100m hingga 500m. Peta geologi yang telah dikemas kini menggunakan Perisian Arcgis. Spesifikasi dalam kajian ini adalah melibatkan data sekunder yang dijalankan di antara dan sekitar Gua Batu Boh dan Gua Serai. Data telah dipangkas menggunakan Perisian Res2dinv. Berdasarkan hasil tafsiran menunjukkan terdapat beberapa kawasan yang berlaku kekosongan bawah permukaan. Tetapi kawasan itu dipenuhi dengan pasir dan air di ruang kosong. Namun begitu, kawasan tersebut masih tidak selamat untuk sebarang aktiviti pembangunan dijalankan. Ruang kosong subpermukaan telah ditentukan berlaku di kawasan Gua Batu Boh.

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CHAPTER 1

INTRODUCTION

1.1 General Background

Due to the fact that limestone is easily eroded, the town of Gua Musang is currently in danger from geohazards. A geohazard is a geological and environmental condition in which there is a high probability that damage will be caused to the local population as well as the economy of the surrounding region. The karst region is home to a number of geological hazards, including rockfalls, sinkholes, and cavities within the limestone bedrock. Other geological hazards may also be present. One of the geohazards that many of our people overlook is the sinkhole that forms as a result of the subsurface void created in Gua Musang.

Several studies have been conducted in the surrounding area, the most recent being Nurul Asyikin's study of karst formation in 2020. Using GIS, she discovered that there are places in her area that have the potential for limestone geohazards to occur. She did not, however, investigate the possibility of geohazards involving subsurface voids.

Most previous studies were conducted within and around Gua Musang's urban area. Several studies have been conducted in this research area, but only in broad terms. As a result, the purpose of this research is to update the geological information in that specific area which that area is under development to be as urban area.

This study area can be divided into two distinct study areas: the geological mapping study area and the specification study area. The electrical resistivity imaging (ERI) method was used to identify the state of voids in the specification area's subsurface in order to conduct a study on it. Recent events have brought to our attention a limestone karst geohazard that exists in the Bukit Bintang road and took the form of a sinkhole. As can be seen in Figure 1.1, the sinkhole that developed had a massive size and a depth when it first appeared.

The examples that were discussed took place in karstic areas, and some of them pose a significant risk to those who live nearby or in karstic areas themselves. It was essential to conduct this analysis in order to locate any possible subsurface voids in the area under investigation.

Figure 1.1: Sinkhole That Occurred at Bukit Bintang

(Source: Astro Awani, 2015)

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1.2 Problem Statement

1.2.1 Non-updated Geological Map

This research area is located to the south of Gua Musang Town. As a result, this is still a developing area. Nurul Asyikin's 2020 study covered only 30% of the study area. So, the purpose of this study is to update the study areas that he has covered and has not covered.

1.2.2 Incomplete Data About Subsurface Void in Study Area

A detailed data collection is required to ensure that any potential subsurface voidsin the specification area may be identified earlier. The same can be said for geological mapping. Gua Musang has entered a rapidly expanding new phase. However, the data on the subsurface voidis still limited. Based on previous study conducted by Irfan Afid in 2016, he was studied about the potential of limestone geohazard and more focusing on potential of sinkhole occurred in that area. However, he did not study about the void on the subsurface. As a result, this might lead to an unforeseen subsurface void in the future. The ERI was utilized in this study in order to make an interpretation of existence of subsurface void in that particular area.

1.3 Study Area

The coordinate of the study area is cover 25km2 with the coordinate area ranging for latitude from 4°48'36.38" N to 4°50'59.17" N and the longitude from 102°00'52.78 E

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to 101°56’51.09” E. (Figure 1.3). This research area is separated into two parts: the geological mapping study area and the specification area utilized for a study of probable subsurface voids.

Due to the predominance of limestone in the surrounding region of Gua Musang, the study location is appropriate for this investigation. The region of Gua Musang is surrounded by several limestone hills, and the potential for the formation of a limestone karst system under Gua Musang is quite high.

In addition to the possibility for geohazards in the Gua Musang area, limestone karst may also cause issues for engineering developments. This is the significance of employing electrical resistivity imaging to avoid geohazardous regions.

The main road used by most of the people in the study area is Gua Musang Town Road or in highway at kilometre eight. There also a river in the study area which is Sungai Ketil.

1.3.1 People Distribution

According to the Kelantan Department of Population Statistic, the number of people living in the state of Kelantan has been steadily increasing from the year 2010where the local population was estimated to be 1,641,900 to the year 2020, when it reached its current total of 1,792,501. Kota Bharu was the most populous municipality within the state of Kelantan. This was to be expected given that Kota Bharu is the state capital of Kelantan. In comparison to other districts, Kota Bharu offered a greater variety of jobs and businesses than any other location. The population of Kota Bharu in the year 2020 is 555,757 people.

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The town of Gua Musang served as the primary focus of the investigation. The population of the Gua Musang district has been continuously growing from the year 2010 until 2020. The district had a population of 86,189 people in 2010, and the number increasing to 101,894 people in 2020. There is a possibility that the swift growth of the area's economy is to blame for the burgeoning population in Gua Musang. More mining area were opened in Gua Musang town, which resulted in more job opportunities within the area and made it possible for individuals to establish a life there. As a result, more people moved there. The rising number of people in the area can make the occurrence of limestone geohazards more likely.

1.3.2 Land Use

This research site is along the Kuala Lumpur-Gua Musang highway. In the middle of the study area, the government has built public housing for residents. There is an oil palm plantation in the northeast study area. The remainder is undeveloped land that is utilized for farming by the nearby population.

1.3.3 Social Economy

Local inhabitants in the study region are more likely to work as laborers in oil palm farms in the northeast. Because there is also a highway that is frequently the focus for the usage of the people and the surrounding residents, there are many employment possibilities that are utilized as a source of income by the surrounding locals, such as working at petropumps, grocery stores, and car wash businesses.

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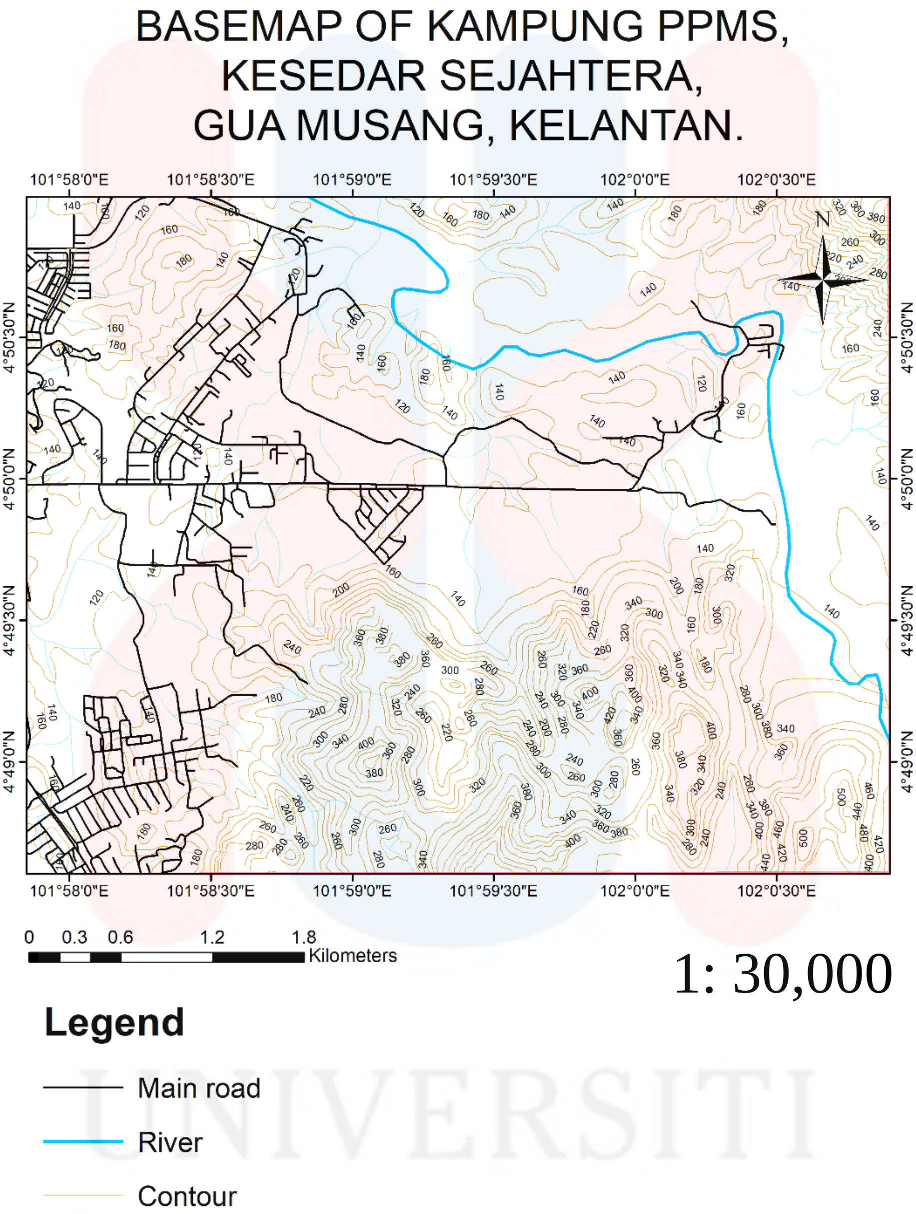

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Figure 1.2: Base map of PPMS Kesedar Sejahtera, Gua Musang, Kelantan.

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1.3.4 Geography

In the state of Kelantan, there is a period known as the monsoon during whichthe rate of precipitation increases dramatically; this natural phenomenon is one of the causes of flooding in Kelantan. In order to monitor and regulate the movement of water drainage in the subsurface of the Kelantan area, hydrological stations have been erected across the region.

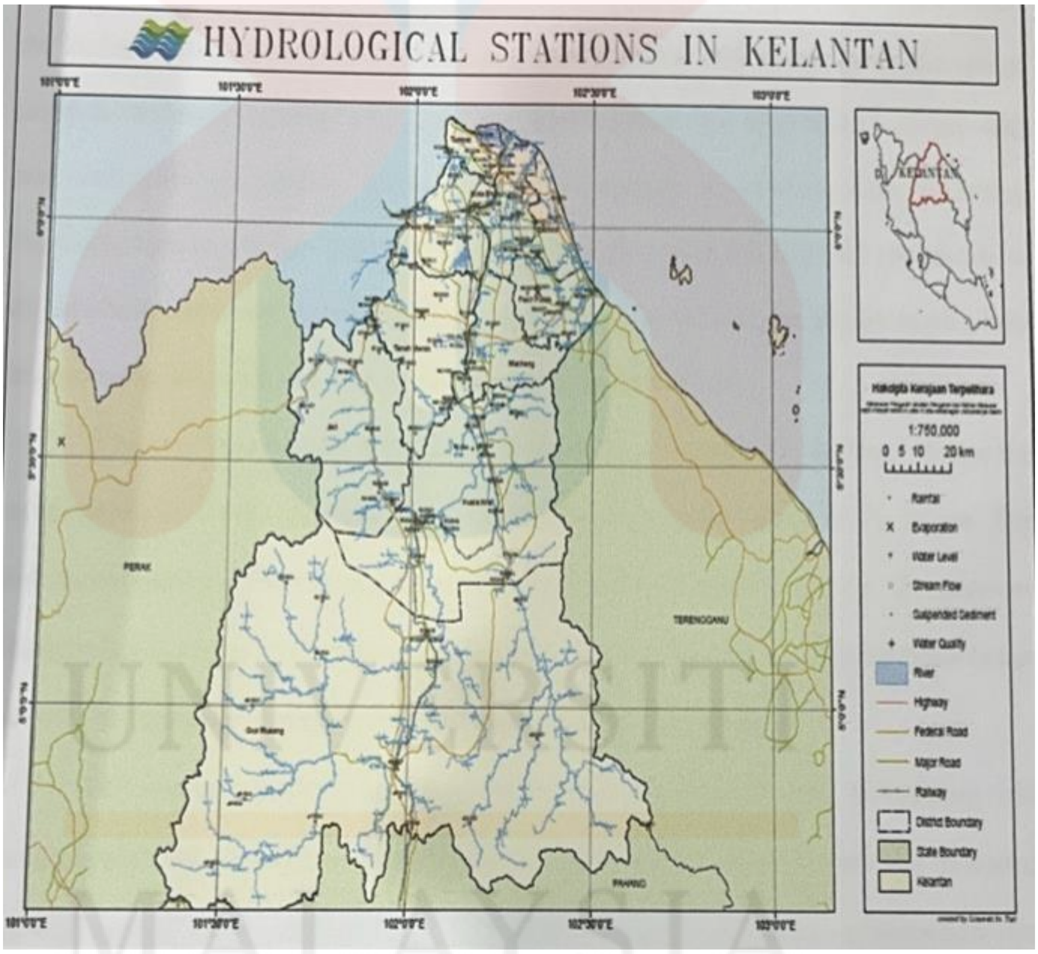

Figure 1.3: Hydrological Stations in Kelantan

The monsoon season is a large-scale sea breeze that arises when the temperature of the land is slightly warmer or colder than the temperature of the ocean.The pressure differences between the land and water also cause the sea

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breezes to blow from the ocean to the land, transporting the ocean's moisture to the land.

The second component is rain dispersion; the rate of rain distribution will grow with the rates of transpiration and evaporation. Before the monsoon season, there is typically a dry season that causes the water evaporation rate process to grow dramatically, and the water will condense in the sky prior to falling as rain during the monsoon.

In relation to the case study, the rate of dissolution of limestone will rise as rainfall dispersion increases. Due to the increase in water precipitation, groundwater penetration, and runoff, the likelihood of limestone bedrock deteriorating during the monsoon season is quite high. Limestone is easily impacted by water due to its mineral composition, which consists mostly of carbonate and calcium. As a result, data on the rainfall distribution in the study area, which is at the Gua Musang station, has already been collected in order to determine the amount of frequency of rainfall in Gua Musang.

Referring to tables 1.1, the distribution of precipitation is most concentrated near the conclusion of each year. In 2010, for example, July has the largest rainfall distribution. Based on the year 2011 the highest rainfall distribution occurs in March, on the basis of the year 2012, it occurs in May, on the basis of the year 2013 it occurs in August, on the basis of the year 2014 it occurs in September, and on the basis of the year 2015 it occurs in August. For 2016 and 2017, the highest rainfall distribution were December and January respectively. However, in 2018, the highest rainfall distribution was recorded in September and for 2019 was in November. Lastly, in 2020 and 2021 was recorded in May and April respectively for the highest rainfall distribution.

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Table 1.1: Rainfall Distribution at Gua Musang from year 2010 to 2021

Months	Rainfall Distributions (mm)											
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
January	67.0	300.0	254.0	107.0	136.0	-	145.0	397.0	279.5	72.0	115.0	266.0
February	63.0	5.0	174.0	196.0	3.0	0	149.0	80.0	29.5	39.0	94.0	22.0
March	74.0	336.0	177.0	57.0	196.0	42.0	2.0	136.0	135.5	226.0	47.0	260.0
April	188.0	151.0	327.0	152.0	169.0	85.0	153.0	216.0	66	52.0	80.0	414.0
May	117.0	58.5	331.0	239.0	225.0	290.0	99.0	336.0	7	218.0	420.0	170.0
June	310.0	178.0	28.0	141.0	215.0	108.0	291.0	181.0	79	165.0	237.0	143.0
July	357.0	127.0	230.0	208.0	90.0	93.0	152.0	151.0	150	169.0	262.0	39.0
August	104.0	281.0	254.0	248.0	618.0	301.0	150.0	344.0	94	222.0	164.0	87.0
September	105.0	264.0	189.0	161.0	489.0	209.0	198.0	277.0	402.5	276.0	257.0	126.0
October	123.0	280.0	128.0	451.0	313.0	210.0	206.0	396.0	305.5	278.0	293.0	131.0
November	284.0	269.0	258.0	216.0	175.0	260.0	244.0	347.0	274	419.0	332.0	234.0
December	268.0	239.0	253.0	178.0	591.0	201.0	288.0	291.0	317.5	169.0	207.0	-
Average	171.67	207.37	216.91	196.16	268.33	149.90	173.08	262.66	178.3	192.08	209.00	157.66

1.4 Research Objective

The objective of this research:

i. To update the geological map of study area to 1:25,000 scale.

ii. To identify the potential subsurface void using Electrical Resistivity Imaging (ERI) data.

iii. To determine the limestone karst's subsurface condition.

1.5 Scope of Study

This study was carried out in the Gua Musang area, and more particularly, in the public housing neighbourhood of PPMS KESEDAR SEJAHTERA. In terms of the lithology and geological structure that can be found in the region, the mapping that has been done in the study area serves the aim of updating the geological data that is scaled at 1:25000 around the area.

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In addition, the location of Batu Boh Cave and Serai Cave, both of which can be found in Gua Musang Town, serve as the specification area for the purpose of this study. Around this location, as many as five different survey lines have been employed to collect data from the subsurface. After the data were collected, the Res2Dinv programme was utilized to do an analysis on the data, and lastly, a 2D resistivity image was able to be generated and interpreted in order to determine whether the research region has any subsurface voids.

1.6 Significance of Study

The significance of performing this research in Gua Musang is to benefit these five aspects: the community, the government, the private sector, which includes businessmen and engineering contractors, other Malaysian universities, and another research from across the world.

1.6.1 Community

To begin with, it can aid the Gua Musang community by raising awareness of the surrounding area's plight. All information pertaining to the current state of events in the region can be transformed into various information systems, whether digital or non-digital.

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1.6.2 Government

Second, the government could address any issues that may arise in the region by implementing ways that will avoid any dangerous situations from affectingthe Gua Musang population. For example, the data can be use by Jabatan Perancangan Bandar Dan Desa.

1.6.3 Private Sector

Third, in order to proceed with the development of buildings and other structures in Gua Musang, urban planner, geotechnical and engineers must be well informed about the area's structure.

1.6.4 Malaysians Universities

Fourth, by broadening their scopes of study, other Malaysian universities can learn more about this research for example students who take geology and engineering.

1.6.5 Researcher from Around the World

Finally, this study will be able to draw international researchers to our country so that they may work directly on the study location. This research will help to give information about the subsurface condition for them to study.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter examined the prior studies that were conducted on limestone karst and the geohazards that were imposed by it. It is possible to take and enhance the studies by reviewing the research done by other researchers from around the world. The techniques that are going to be utilized in this research can also be referred to from previous research studies for utilization. A researcher can benefit throughout the entirety of their studies from conducting a literature review, as well asimprove the quality of their research as a result.

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2.2 Regional Setting

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This study area is in the middle of Kelantan which is above Gua Musang Formation. In summary, most sedimentary rocks have been found in the study area. this proves that the rocks found are the same as discussed by Goh et. al (2006). Goh et. al (2006) stated that the central zone of Kelantan is made up of sedimentary and

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metasedimentary rocks, both of which make up the region's geology. Granites from the Main Range and the Boundary Range can be found to the west and east of these mountains, respectively.

Peninsular Malaysia is a part of the East Eurasian Plate, as stated by Ariffin (2012). It can be found in the Sunda arc's active subduction zone areas. Kelantan is a state in Malaysia that may be found on the west coast of Peninsular Malaysia. Granitic intrusive rocks can be found in the central zone, particularly in Du Lalat (the Senting batholith), the Stong Igneous Complex, and the Kemahang pluton in Pahang (Goh et al, 2006). The belts that go across the middle and western parts of Kelantan lead directly into the southern part of Thailand.

To the east of the Boundary Range is a flat area of Sungai Kelantan that is composed of coastal alluvium, over which granite has been deposited. Lower Paleozoic sedimentary rock in Kelantan is thought to be the oldest rock in the region. It has been documented that amphibolite and serpentinite are both rather uncommon minerals (Goh et al., 2006). On the eastern half, Permian volcanie-sedimentary rocks are present, and they are overlying an unconformably lower Paleozoic sequence that can be found in the southwest of Kelantan.

The majority of the Taku Schist may be found in the middle and northern parts of Kelantan. In addition, the Boundary Range Granite and the Triassic deposits in the Gunung Gagau region contain a continental rock that dates to the Jurassic and Cretaceous periods. The lithology was made up of conglomerate, which was covered by sandstone and had intercalations of volcanic material (Goh et al., 2006)

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2.3 Stratigraphy

This study area is dominated by limestone rocks and there are also areas where the rocks have turned into marble. This is because the limestone rock has gone through a very long metamorphic phase that changes the minerals found in the rock. Generally, Gua Musang Formation is characterized by a predominance of argillaceous and calcareous sequences, which are in turn interbedded with volcanic and arenaceous rocks. This formation may be found all the way to the north of Kelantan and all the way to the south of North Pahang.

Limestone can be found in the form of cliff-bound ridges, lenses, and isolated tower-like hills originating from the granite block that surrounds Bukit Raja Muda and extends porthward to Gua Musang. The age of the Gua Musang Formation falls between between the Middle Permian and the Upper Triassic (Leman, 2004). The Gua Musang Formation was formed on a shallow maritime shelf that was also home to an active volcanic environment around the time of its deposition (Leman, 2004).

Rock formations that date back to the Mesozoic era in Malaysia can be categorized according to a variety of factors, including geography and paleoenvironment. The areas of Northwest Peninsular Malaysia and the Central Belt of Peninsular Malaysia, as well as West Sarawak, include geological formations that date back to the Mesozoic era. The portion of Malaysia that comprises the peninsula. There are three distinct belts that contain Mesozoic sedimentary rocks. These belts are referred to as the Western Belt, the Central Belt, and the Eastern Belt (Khoo & Tan, 1983).

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Belt, the Central Belt, and the Eastern Belt (Khoo & Tan, 1983). The Mesozoic rocks predominate in Peninsular Malaysia's Central Belt, which is located in the middle of the peninsula. They reach all the way to Thailand (the Gua Musang Formation), which is located in the north, and Singapore (the Jurong Formation), which is located in the south. Together, they makeup a belt that always trends north to south.

In general, the marine Triassic sediments that were deposited in the Central Belt are more tuffaceous than those that were deposited in the Western Belt at the same time. The Gua Musang, Aring, and Gunung Rabong Formations in Kelantan and northern Pahang date back to the Permo-Triassic period. These formations are characterized by shallow marine clastic and carbonate sediments with interbeds of volcanic ash.

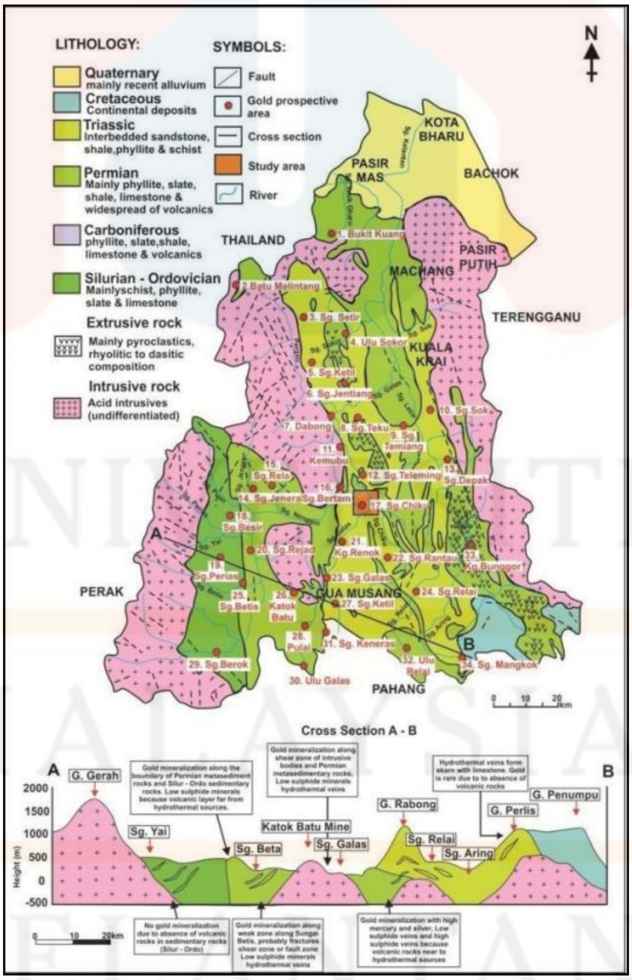

Figure 2.1: The Geological Map of Kelantan

(Source: Mohd Hariri Ariffin et. al, 2018)

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2.4 Historical Geology

The study area is located in Gua Musang formation. Most of the rocks found in this study area are sedimentary rocks which are dominated by limestone and marble. The majority of Triassic rocks can be found in the middle and southern parts of Kelantan. These rocks are composed of argillo-arenaceous sediments intercalated with volcanic and limestone (Goh et al., 2006). The Gua Musang

Formation lies in an unconformable position atop the Gunung Rabong Formation. Crystalline limestone makes up the majority of the formation, which has a thickness of around 650 meters and is interbedded with thin strata of shale, tuff, chert, subordinate sandstone, and volcanic materials. There are also granite rocks around the study area.

This pluton can be found in the portion of Peninsular Malaysia's Central Belt that is the furthest to the north. The Gua Musang Formation serves as the natural border for this region (MacDonald, 1968). It has a laterally continuous relationship with the Stong Complex to the west and it has intruded into the most northwestern part of the Taku Schist. It was once known as the Noring Granite, and it stretches in a westerly direction all the way to Perak. In Malaysia, it encompasses the mountains of Bukit Jeli, Bukit Kemahang, and Bukit Kusial, in addition to a number of other, smaller hills.

Granite, in most cases, takes the form of a mountain range that extends in a generally north-to-south direction and reaches all the way from Narathiwat Province, which is located on the eastern coast of the Thai Peninsular, to Sukhirin District, which is located in the most southern part of the range. Following that, it continues on its journey until it reaches the town of Jeli, which is located on the Malaysian side of the border.

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This granite is characterized by coarse-grained porphyritic granodiorite, which gives it its distinctive appearance. Granite underwent shearing deformation, which led to the emergence of augen textures in the area surrounding the Strong Complex plutons. Quartz crystals are known to splinter and partially recrystallize when there is metamorphic foliation present in the rock. This is also demonstrated by the micrograniteth that can be found in the most western part of the unit. This microgranite has extremely schistose fibers in its composition (Burton, 1973). According to Khoo (1983), the development of a shear or fault zone in the rock that followed the original emplacement of the granite is what leads to the formation of clastic granite gneisses.

2.5 Limestone

2.5.1 General Limestone

According to Bund.P, (2009), Limestone and other carbonate rocks, such as dolomite and marble, have a particularly distinctive reaction to precipitation; they tend to be quite soluble. Due to the presence of dissolved carbon dioxide in precipitation, precipitation is a powerful acid known as carbonic acid, which dissolves carbonate rocks. Researchers can see this effect through the discovery of decked caverns, pristine water springs, and breath-taking tower karst landscapes. When limestone bedrock is eroded, it typically develops cavities. The building process has become challenging for engineers. Depending on the structure of fractures and faults in the limestone bedrocks, different sized cavities can emerge at varying depths and altitudes.

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The most prevalent type of rock on the surface of the Earth is limestone. 10% of the Earth's land area is composed of limestone, 25% of the world's population utilizes limestone as a water supply, and some individuals build their homes on the bedrock. Additionally, limestone can serve as a carbonate storage for underground oil and gas. The mineral calcite or aragonite makes up the majority of limestone's composition; it contains calcium carbonate (CaCO,). Limestone is also regarded as a unique form of rock for three reasons: first, it is composed primarily of marine microorganisms; second, it has a unique chemical composition; and third, it has a distinct geologic history. Second, it dissolves readily in natural fluids and generates caverns, cavities, shafts, and karst. Finally, lime and cement are essential to agriculture.

According to Bund.P (2009), rainfall may quickly erode limestone since it contains weak carbonic acid and has a propensity to react with limestone. This process produces karst as a result of the erosion of joints and bedding planes in response to precipitation. The rate of weathering on various portions of limestone varies, resulting in the production of sinkholes where rivers seep into the bedrock. The creation of swallow holes is the result of either the ongoing chemical attack of water on the joints of the limestone or the collapse of a cavern under the surface.

2.5.2 Subsurface Void

Subsurface voids are gaps or holes in or beneath concrete slabs. They are a major source of concern for engineers and property owners since they can cause structural failures or catastrophic risks. The first arrival travel-time tomography

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method was successful in calculating a low-velocity anomaly coincident with a known subsurface void (Feigenbaum et. al., 2020). Voids are most typically found on highways, pavements, bridges, and concrete slabs (such as floors or walls). Locating voids and fixing issues is critical for assuring the concrete structure's safety.

Natural limestone subsurface spaces such as washouts or settlement gaps, floor slabs, tunnels, vaults, and caves (karst) or solution cavities and sinkholes These voids are geological and man-made phenomena engineering interests This is because they are possibly hazardous geological dangers. Their presence may cause the deterioration of foundation materials and, in rare cases result in structural defects/failures/collapses.

2.5.3 Karst

According to Bednar (2008), the formation of a karst affluent is dependent on a number of elements, including the kind of climate, the amount of rainfall, the depth of groundwater circulation, the thickness of the soil cover, the rock structure, and the solubility. There are some karst regions that are simple to identify based on the landforms on the surface, but there are also regions that do not display any surface evidence of karst development. However, solution caverns can be found underneath the can. Cone karst, also known as Kegelkarst in Germany, is characterized by residual relief rather than closed depressions. Tropical karst is found in regions with humid tropical climates, which allow for rapid and vigorous solution.

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This led to the growth of dolines, which eventually interfered with each other and led to the destruction of the original land surface. The end result is a polygonal pallem consisting of ridges that encircle individual dolines. There are two identified varieties of cone karst, which are referred to be cockpit karst and lower karst respectively. Cockpits are a type of tropical doline that resemble starfish and are known in Germany as kugelkarst. Tower karst, also known as turmkarst in Germany; remnant hills are called mogote or towers (haystack hills). Lower slopes are extremely precipitous and have overhanging terrain. Depressions with a level bottom and a high prevalence of vegetation are typical of alluvial plains. The remnant hills could have very sharp edges and could be responsible for the formation of pinnacle karst (Huggett, 2007), Because limestone contains a low amount of calcium carbonate, it is easily dissolved by acids produced by natural materials. Human activity in the karst environment can have a variety of negative consequences, including effects on natural resources. For example, water contamination and sinkhole development might have an impact on engineers working on urban building projects.

2.5.4 Sinkhole

According to (Yeap (1997a), there are two basic factors that cause sinkholes. First, there is an upward ravelling of dirt over a hole in the bedrock. Second, the creation of a soil arch. According to Yeap (1997b), the major reason of sinkhole formation is when the surface development is impacted by chemical dissolution of the bedrock in conjunction with mechanical weathering of overlaying soils. The water table fluctuation is the second cause of sinkhole

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development; water provides the basis for soil strength. That is when an abrupt shift in water content causes stress and failures.

2.6 Electrical Resistivity Imaging (ERI)

2.6.1 General Electrical Resistivity Imaging

Conducting subsurface assessments, according to Gregory B. Byer (2006), is to suggest ancient karst limestone formation. Another reason that this approach is problematic is the effectiveness of data collecting (Gregory B Byer, 2006). It provides a good indication of the depth of the bedrock, or it may also indicate the shape of the bedrock surface engineering design can also be affected by variations in soil characteristics; and there are some critical features, such as fracture (pinnacles and grike), caves, voids, and sinkholes. To survey a thinly mantled karst region for foundation design, 2- dimensional resistivity is acceptable; it can operate as a reference for soil boring selection area. The resistivity method is a quick and inexpensive way to determine shallow subsurface conditions with an acceptable outcome. Resistivity research on caves has been conducted in a variety of locations outside of Indonesia, including Yongweol-Ri, South Korea (Farooq et al., 2012). Resistivity imaging in two dimensions is capable of delivering subsurface conditions pictures to clients with no geophysical background. By comparing the average difference to drill data, this approach may also identify the height of the top bedrock.

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According to Sedat YILMAZ (2011), electrical resistivity is used to determine the location of a weathered zone by obtaining the region's characterisation and quantification data. The array utilized in his research for Data Reduction of Electrical Resistivity Imaging was a dipole-dipole array; this information allowed the researcher to map the weathering material at depth and analyze information on the surface's depth. Electrical resistivity imaging is a cost-effective technique that researchers may employ to obtain a continuous subsurface picture and to quantify the ground's reaction along profiles in order to acquire subsurface imaging capabilities. The electrical resistivity approach is sensitive enough to determine the water content of a layer.

The configuration used was the Dipole-dipole configuration. By using this configuration, it was assumed that a more precise subsurface cavity description could be yielded rather than using other types of electrode arrays (Farooq et al., 2012). On-site, the dipole-dipole array might be utilized with a high horizontal resolution. The purpose of electrical resistivity imaging for complex subsurface structures is to get a high-resolution picture of electrical resistivity patterns in the subsurface. In order for scientists to get a two-dimensional image of the subsurface, it is necessary for them to take several measurements in a short period of time.

By getting imaging for electrical resistivity, a researcher is able to do a depth- based mapping of the region of deteriorating material. The advantages of employing electrical resistivity imaging include the ability to get lithological and structural information, the method's simplicity and quick duration, and the fact that gassy sediments do not alter the picture quality. Low resolution and poor

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penetrability are two limitations of electrical resistivity imaging. During the inversion process, it cannot identify minor structures, such as wood, peat, or stone.

2.6.2 Approach to Conduct and Analyse Electrical Resistivity Imaging on Karst Features

Roth (2003) states that electrical resistivity imaging is the most prevalent technique used to locate karst features in a study region. This approach is employed when other methods, such as ground penetrating, are ineffectual due to the ability of the soil layer to transmit the electric current flow. Conductive clays, for example, are the key to this method. According to Roth et al. (2002), electrical resistivity imaging can distinguish between air and soil conductivity when identifying subsurface constituents. Before sinkholes formed, air was able to fill the cavities' voids.

This approach employs electrodes to detect electrical conductivity in order to identify distinct soil types at different depths. After conducting a study, researchers are able to determine the potential for karst characteristics, and geologists can install electrodes in the ground at particular intervals. In accordance with Van Schoor (2002), a probe will be placed at intervals along the survey line to measure the electrical potential between the probes. The probes will then distribute an electric current into the soil and detect the electric potential between the intervals of the electrodes dimensional image of the subsurface, it is necessary for them to take several measurements in a short period of time.

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According to Anderson (2008), due to differences in electrical conductivity between soil types, the analysed data may be used to create a soil profile that serves as a depth indication. Contribute to the comprehension of the soil layers under the surface. This approach employs a grid pattern of electrodes in order to simulate a two-dimensional picture, and the array employed is a dipole-dipole array, which is more sensitive. Dipole-dipole arrays are also useful for determining the form and depth of soil layers as well as the size of sinkholes. The dipole-dipole technique is the optimal array for identifying sinkholes.

2.7 Geomorphic Process and Stream Capture

2.7.1 Relation between Void and Karst Topography

When a region is underlain with soluble rock, the aboveground tends to experience a side consequence when a depression of a given position begins to form, commonly known as sinkholes. Large void formation in a karst environment may lead to sudden and catastrophic pavement failure, whilst one particle's slow migration from the sub-base may cause gradual ground subsidence.

There are two ways that sinkholes can arise, and void can be of varied sizes. The first is when the soluble rock beneath the soil is dissolved as a result of

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the water process movement seeping through the earth, and the gaps in the rock are filled with the soil above.

If the process is still ongoing, groundwater will tend to dissolve the rock, and the soil will be totally eliminated, leaving behind shallow depressions with gently sloping edges. It will be surrounded by a network of enormous, irregular depressions known as solution valleys, which will be formed by sinkhole. Sinkholes can also be formed by the collapse of a cave's ceiling, which creates a crater with steep sides. This approach has the potential to result in communal deaths. Geoscientists are required to study the site's development to guarantee that the underlying rocks are of sufficient thickness to sustain the intended constructions.

Karst topography, mostly shaped by groundwater erosion in many regions with soluble rocks as substratum. Numerous caves, springs, sinkholes, solution valleys, and vanishing streams serve as characteristics for determining the topography of karst terrain.

Streams that normally flow for a short distance on the surface before disappearing into a sinkhole are found based on their features. The water flows underground through fissures or caverns until it reaches the surface at a spring or other stream.

2.7.2 Formation of Caves and Cave Deposit

Caves are the greatest illustration of the combination of the impacts of weathering and erosion by groundwater. Due to the mechanism by which

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groundwater percolates through carbonate rocks, it dissolves and enlarges cracks and enlarges the holes to produce a complex, interconnected system of fissures, caves, caverns, and underground streams. A cave is distinguished by its naturally occurring, underground entrance that is often connected to the surface and is large enough for a person to enter.

Due to a network of interconnecting caves, a cavern is considerably bigger than a cave. The creation of caves and caverns is caused by the dissolving of carbonate rocks by groundwater that is only slightly acidic. The percolation of groundwater via the zone of aeration dissolves and enlarges the cracks and bedding planes of carbonate rock. When reaching the water table, the groundwater migrates towards the region's surface streams. As groundwater passes through the zone of saturation, it continues to dissolve carbonate rock and construct a system of horizontal pathways via which the dissolved rock is delivered to the streams.

Due to the lower height of the streams when deeper valleys are eroded by surface streams, the water table tends to fall. The horizontal channels that conveyed the flow of water through the system percolate to the lower water table, when a new network of channels forms. The formerly utilized canal has been abandoned and now serves as an interconnecting system and collapse, leaving the floor littered with falling debris.

There are several unusual formations in caves, such as dripstone. As water seeps into the cave, a little quantity of dissolved carbon dioxide escapes and calcite precipitates. Due to the procedure, numerous dripstone deposits are generated. There are also stalactites, which are icicle-shaped formations that hang from cave ceilings as a result of water condensation. Each water droplet deposits a small

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coating of calcite over the preceding layer, forming a cone-shaped projectile that descends from the ceiling. When water falls from the roof of a cave, a little quantity of calcite precipitates on the floor. When excess calcite is deposited, an upward-growing protrusion known as a stalagmite develops.

If the deposition process continues, the stalactite and stalagmite will meet and create a column if the deposition continues. Groundwater seeping through a gap in a cave's roof may generate a vertical formation, whereas groundwater running over the cave floor may build travertine terraces.

2.7.3 Subsidence

When excessive volumes of groundwater are extracted from a region that is mostly composed of weakly cemented sediments and sedimentary rocks, subsidence may result. It occurs when the water pressure between the grains decreases and the weight of the material on top is more than what the underlying soil can hold. This condition makes this area prone to subsidence. Caves below the subsurface at this location with ample space are the product of tectonic activities (Farooq et al., 2012. The grains will tend to pack closer together, causing the soil to sink and become deeper. Subsidence will be frequent if the groundwater extraction operation continues. In certain big regions, groundwater is extensively used for irrigation. The only option to combat the sinking process is to replace the water that was drained from the region; if the area reaches equilibrium, the subsidence will effectively cease.

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CHAPTER 3

MATERIAL AND METHODOLOGY

3.1 Introduction

The identification of the problem, the condition and sample area, sample preparation, data collection, and data analysis will be described in detail in this chapter. These are the procedures that must be done in order for a researcher to complete the process of gathering vital data and informational details for this study.

3.2 Materials

3.2.1 Fieldwork Equipment

a) Geology Hammer

The goal of utilising a geologist's hammer is to collect a fresh sample surface of a rock in order to identify its composition, mineralogy, nature, and where it originated from the Earth. It can also indicate a rock's strength. It may also aid in the acquisition of a fossil and minerals, and it is used to reveal the fossils therein.

b) Hydrochloric Acid (HCL)

The geologist's method of using acid is to put a drop of dilute hydrochloric acid HCL (5% to 10%) on an outcrop or mineral and watch the carbon dioxide gas bubbles form. Carbonate minerals such as calcite and dolomite are represented by the bubble. We needed to use a hand lens to see the bubbles slowly forming in the drop of HCL or becoming so powerful that a fast effervescence was formed when the acid started to react with the rock surface. The type of carbonate minerals present, their quantity, and the particle size of the carbonate all influence the effervescence strength.

For example, a limestone rock sample will create more powerful bubbles than a dolostone rock sample because limestone has more calcite whereas dolostones include more dolomite.

c) Global Positioning System (GPS)

It's a technology that uses latitude, altitude, longitude, velocity, and time to locate your location with extreme precision. It relies on 24 GPS satellites in orbit around the Earth to function. Each satellite transmits a microwave signal that a GPS almanack may use. The data it sends is coded uniquely for each. The satellites provide the length of time it takes for the signal to reach the receiver, allowing it to calculate its location geometrically.

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d) Bruton Compass

To determine the dip and dip-direction of the surface, foliations, and the plunge and plunge-direction of lines, lineation, a compass is employed. To capture dip and dip direction data using a compass. Plunge and plunge direction may also be obtained by aligning the edge of the compass's lid with the line's orientation.

The compass is generally used to determine foliation and lineation in metamorphic rock, as well as faults and joints.

Figure 3.1: Materials that will be use during Geological Mapping.

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3.2.2 Updating Geological Mapping

a) ArcGIS

A geographic information system, often known as a GIS, is what is employed in the processes of developing new maps and maintaining existing ones. It is used to build maps by gathering geographic data and analyzing mapped information before releasing it in order to uncover geographic information. This process is done in order to uncover geographic information. In addition to this, it is able to maintain geographic data in the form of a database and give this data for use in a number of different applications.

In addition to this, the system contributes to the establishment of an infrastructure for the production of maps. Throughout the process of developing and maintaining the foundation map for my thesis, I relied heavily on ArcMap and ArcToolbox. The ArcMap interface has two primary areas that correspond to the layers on the map, and the ArcToolbox has tools for geoprocessing, data conversion, and analysis. Both of these areas can be accessed using the ArcMap menu.

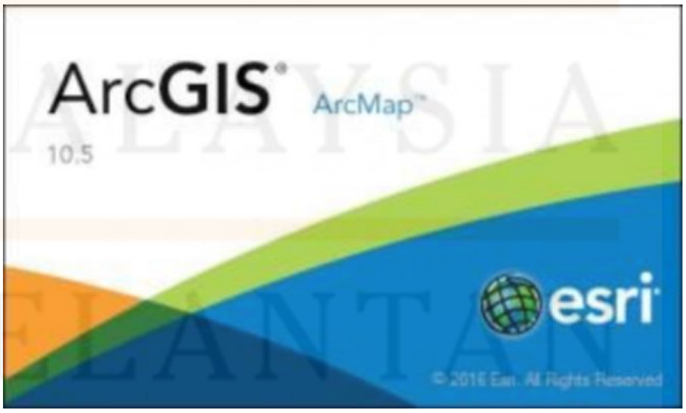

Figure 3.2: ArcGIS software that is being used for map generation.

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b) Abem

It is utilized in resistivity surveying mode, and it contains a battery-powered, deep-penetration resistivity meter with an output adequate to conduct a survey for 2000 meters under ideal conditions. It features discriminating circuitry and programming that isolates incoming signals from DC voltages, self-potentials, and noise. If array geometry data is provided, apparent resistivity can be presented in addition to voltage. The Terrameter SAS 4000 can measure four channels at the same time, which applies to resistivity and IP measures as well as voltage measurements, which can be conducted up to four times quicker.

c) Electrode and Cable

The aim of an electrode in Electrical Resistivity Imaging (ERI) is to conduct electricity into the ground; 64 electrodes are typically utilized connected by a multi core wire. The current and potential electrode pairs are triggered automatically by a laptop and a control module attached to a ground resistivity meter, which displays an output current.

The greatest depth of electrical penetration is determined by the space between the electrodes and the number of electrodes in the array. However, when the distance between the active electrodes increases, fewer points are gathered at each depth level until the lowest level, where just one reading is taken.

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3.2.3 Thin Section Preparation

Laboratory work was basically the process that was carried out in the laboratory involving the thin section and petrography analysis. Electronic microscope was used to observe the rock samples collected in thin section form using different magnifications. This process was carried out to identify the mineral composition of the rock.

a) Thin Section

The rock samples collected during field study were gathered to make thin section. Thin section of rock specimen was prepared using glass slide, frost the glass slide, cutting and grinding the slide to a correct thickness which was suitable to be used as thin section. Finally, the thin section was ready to be analyzed under microscope.

b) Petrography Analysis

Petrography analysis was observing the mineral composition, color, shape and cleavage of the minerals in the thin section. This analysis helped to identify the origin rock whether it is an igneous, sedimentary or metamorphic rock. So, microscope was the important tool during this analysis.

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3.2.4 Software and Mobile Apps

a) Google Earth

Google Earth allows users to view precise satellite photos of most areas on the planet on their computer displays. These maps may be merged with numerous overlays provided by other firms and individuals, such as street names, weather patterns, crime figures, coffee-shop locations, real-estate values, population densities, and so on (Britannica, 2022).

Figure 3.3: Google Earth Software.

b) Res2Dinv Software

The RES2DINV program was a 2D inversion software. The program was quite simple to use when it came to importing data for inversion and visualization. All electrode combinations and cross-borehole surveys were supported ("Geotomo Res2DInv," 2020).

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Figure 3.4: Res2Dinv Software.

3.3 Methodology

3.3.1 Preliminary Study

The preliminary study is the research desk or study completed before to travelling to the field. The preliminary study is carried out by reading from various case studies that have been conducted in the subject region or nearby. Before the following phase, various case studies from other countries with the same geological structure as the relevant area were employed as references and reading materials.

A solid foundation, such as the research area, background, and so on, should be known since this helps ensure that no time is lost during fieldwork. More time spent in the field implies more money lost. Careful preparation was required to ensure that adequate time was available to cover all of the research area in the allotted period.

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3.3.2 Geological Mapping

Geological mapping is also being carried out in order to learn more about the lithology and structure of the research region. Geological mapping is a procedure in which geologists traverse the research area using a geological information system (GPS), identifying the exact site or place that has an important feature, such as a fault, a fold, bedding, or a large fracture. The geological structure capable of altering the terrain or displacing lithology's initial position.

3.3.3 Data Collection

Data collecting may be separated into two categories: primary data and secondary data. Primary data are information gathered during geological mapping Secondary data was information gathered from the government or the private sector. Rain distribution, population statistics, and many other examples are examples of secondary data.

a) Data Inventories

Data inventories are a method of organizing data that has been acquired or gathered in a systematic table. The data inventories are shown in Table 3.1.

b) Field work

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The goals of the field work were to undertake geological mapping. Samples will be collected for future research. Fieldwork is essential for taking a detail look at the research region as well as conducting geohazard assessment. The research area's topography will be examined and document.

c) Lab work

In this investigation, lab labour will be done to create the thin slice. The petrography of the rocks/samples are required for the designation of the rock. The whole site's sample need to inspect and categorise for rock description. This method can help to minimize confusion during lab work.

Table 3.1: Data Inventories

Data type	Data	Data description
Spatial Data	Geological Map of Gua	Source: JMG
	Musang	Scale: 1:1,000,000
	DEM	Source: USGC Resolution: 30 meters
	Data Gis Kelantan	Source: Department ofMineral and Geoscience Malaysia (JMG) Format: Shapefile (shp)
Statistic Data	Rainfall Data	Source: Malaysia Meteorological Department (MetMalaysia) Year: 2019

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3.4 Interpretation Secondary Data

Interpretation for secondary data Electrical Resistivity Imaging (ERI) is done to identify if there is a subsurface void in the specification area. The data found needs to be improved first to reduce the errors in the data. the data has been improved until the error is less than 10%. this is because it is compatible with the settings made for the learning level.

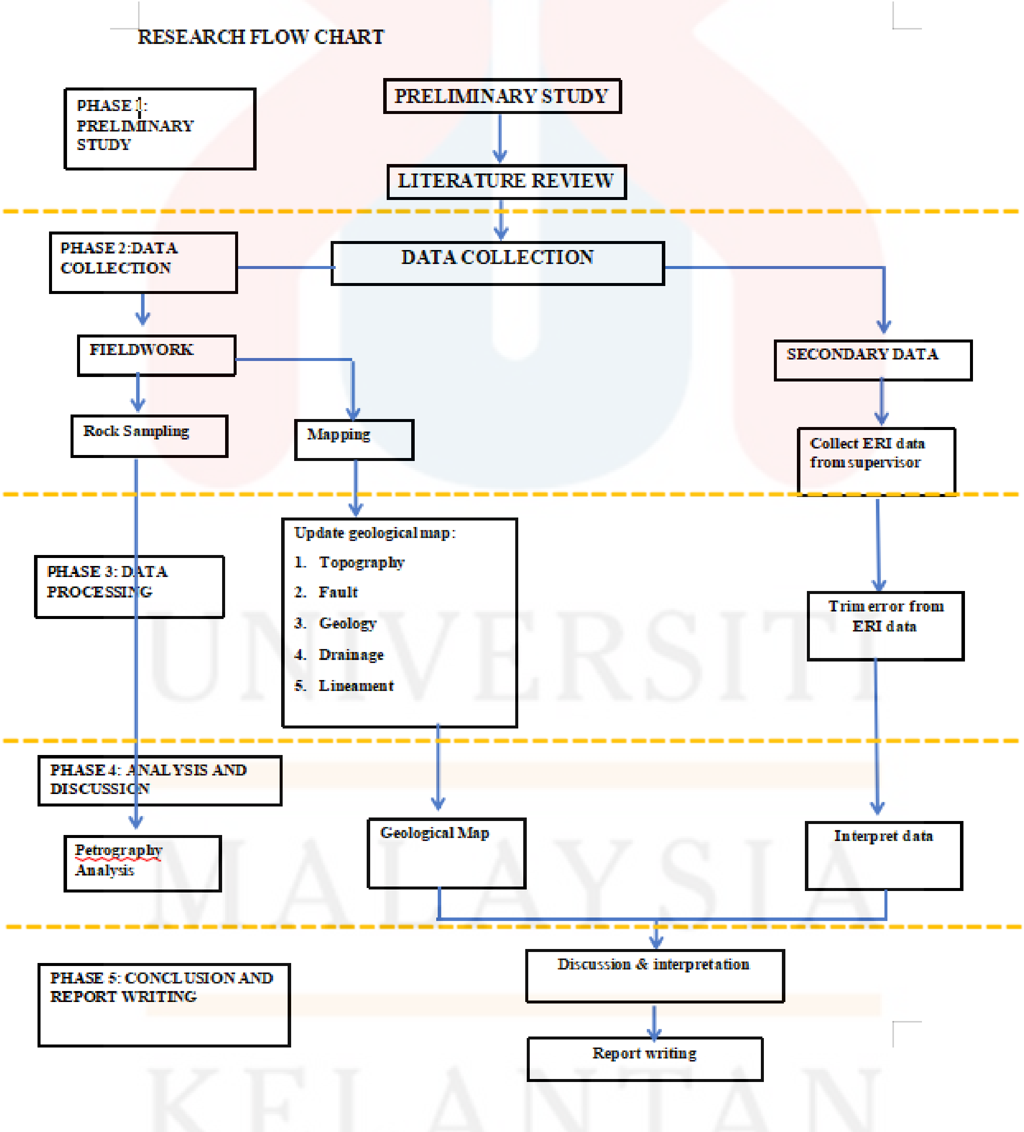

Figure 3.5: Flowchart for methodology

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CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

4.1.1 Introduction

This chapter will be discussing about the geology in PPMS KESEDAR SEJAHTERA region in Gua Musang, Kelantan. Due to the limitation of gathering the information from other sources namely ArcGIS software, internet and so on, thus, the result that are being analysed will be validated with the help from the past research as a guide to interpret the study are precisely.

Generally, this chapter will be discussed on the general geology which related to basic geology, stratigraphy, geomorphology, structural geology and also history geology in the study area. This chapter also will show the geological map, cross section of the lithology and the petrography analysis that was conducted in order to determine the rock type within the study area.

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4.1.2 Traverse and Field Observation

The fieldwork was conducted for four days. During the fieldwork, traversing within the study area cover along the main road and the villages. Fifteen samples were gathered during the observation in the research area (OL 1 - OL 15) to be transferred to the campus for the purpose of selection to be utilized as a thin section (Figure 4.1). From fifteen outcrop that have been found, seven rocks sampling (S1 - S7) were taken to bring to campus for further action. The samples were then separated into numerous groups based upon the type of rock, and the total number of rock samples acquired was three.

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TRAVERSE MAP AT PPMS KESEDAR SEJAHTERA, GUA MUSANG, KELANTAN

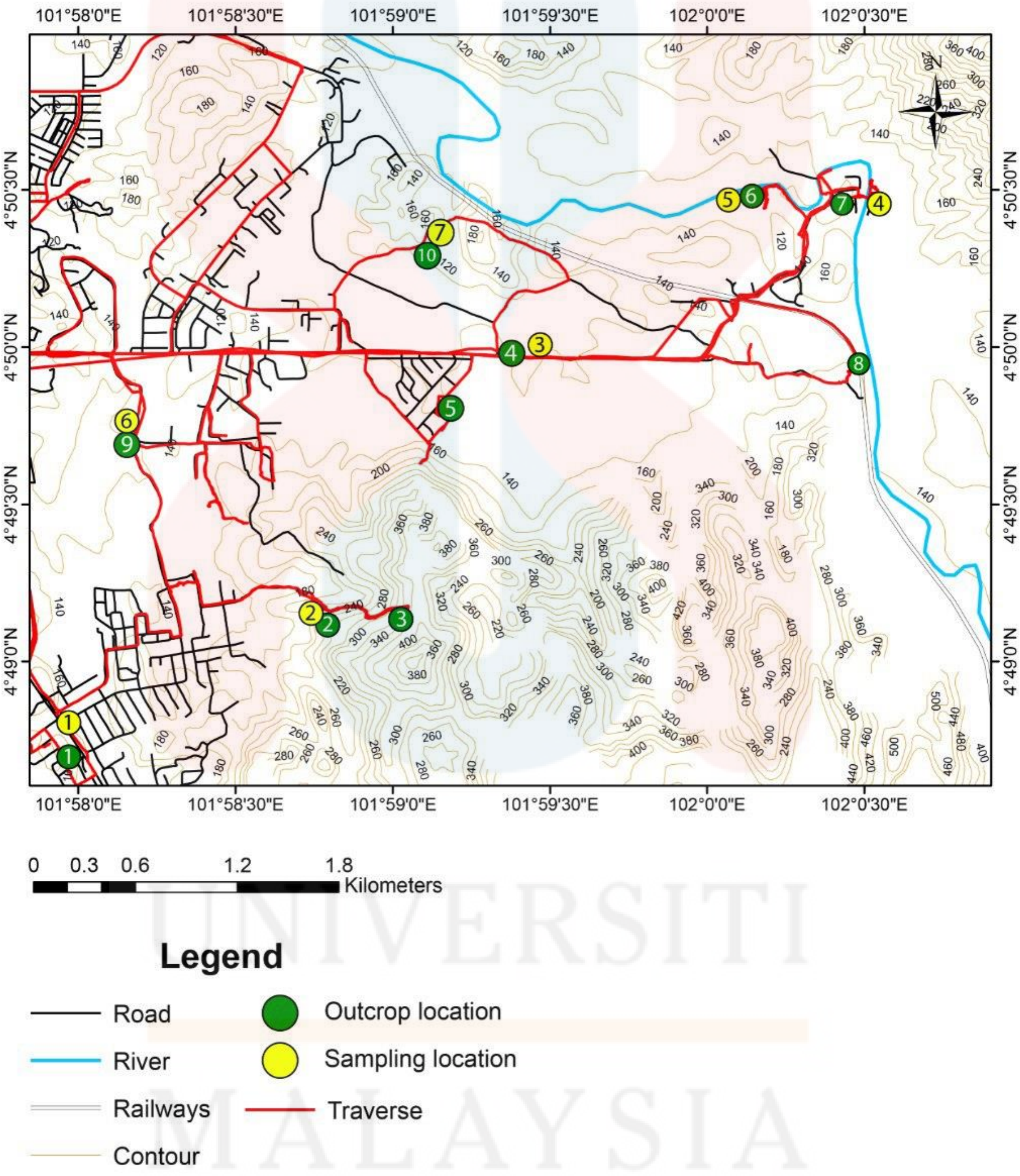

Figure 4.1: Traverse Map in The Study Area

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4.1.3 Accessibility

The main road that can be used to get into the study area is the Federal Route 8 which connecting Kuala Lumpur and Kota Bharu highway. Although there are not much main roads to access study area, this study area can be access through Jalan Industri (Orange arrow). by using the main road, some main areas can be accessing such as industrial area, PPMS Kesedar Sejahtera and also Chin Teck Farm. Some areas need to traverse by walking at the north-east area near to Chin Teck Farm. To get to village that indicate by no.3 in the map, the main highway can be used.

Figure 4.2: Accessibility Map from Google Earth

(Source: Google Earth)

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4.1.4 Settlement

According to Figure 4.1, there are few settlements in the research area since most of the land is heavily used for agricultural activities. The palm oil plantation Chin Teck Farm dominates 40% of the low land area in this particular study area.

Table 4.1: Data Inventories

Symbol	Settlement
1	Settlement for PPMS KESEDAR SEJAHTERA
2	Settlement for industrial area
3	Settlement or village
4	Settlement for workers in Chin Teck Farm

The agricultural workers' village accounts for barely 5% of the research area and it is located in the center of the study area at 4°49’52.23"N 101°59’07.51"E. This area is known as Settlement No. 1. In contrast, 15% of the settlement is most likely located in the southeast section of Gua Musang, which is especially designated as the "Industrial Area," as indicated by settlement No. 2 in Table 4.2. however, there also have a village at the southwest of the study area where the people nearby live.

4.1.5 Forestry

In the south-east section of the research region, vegetation covers roughly 30% of the area. It is a high land location with very restricted access, ranging from

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hill to high hill. The highest elevation is recorded as 500m. The land at the south-east is mainly unexplored by people for planting purposes. This is due to the fact that the land is not well-suited for planting. The region in the south-west of the Study Area, on the other hand, is fast developing due to its proximity to the highway. A variety of public amenities are available in the area to help the people who live nearby that area economic growth as well as countries economic.

4.2 Geomorphology

According to Astrid et al., (2020), geomorphology is the study of landforms, the relationship between the process and its production. Geomorphologic processes alter land structure as a result of geological process change.

4.2.1 Geomorphology Classification

The landform in the research region is classified based on its absolute height (Zuidam, 1985). Zuidam divides geomorphology into seven (7) categories. Table 4.3 depicts the link between absolute height (m) and morphology.

According to Table 4.3, terrain having an elevation of less than 50 meters isclassified as low land. Following that, terrain with an elevation of 50 m to 100 m isclassified as inland low land.

Following that, there will be a little hill (100 m to 200 m), a hill (200 m to 500 m), and a steep hill (500m to 1.500 m). A mountain is defined as territory having a height ranging from 1,500 to 3,000 meters.

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Table 4.2: Relationship between Absolute High (m) and is Morphology.

Absolute high (m)	Elevation
<50	Low Land
50 - 100	Inland Low Land
100 - 200	Low Hill
200 - 500	Hill
500 - 1500	High Hill
1500 - 3000	Mountain
> 3000	High Mountain

Figure 4.2 depicts the geomorphology of the PPMS Kesedar Sejahtera area inGua Masang, Kelantan. Within the research region, three (3) primary landforms are observed: low land, low hill, and hill. This is due to the elevation range of the research region is around 120 m to 500 m. The landform categorization in Table 4.2 is based on Zuidam (1985).

The research area's south-east area is prominent, with low hill to hill terrain. It occupies around 40% of the study area and has a maximum elevation of approximately 500 m. The low land region covers approximately 70% of the study area, mostly from the south-west to the north-east.

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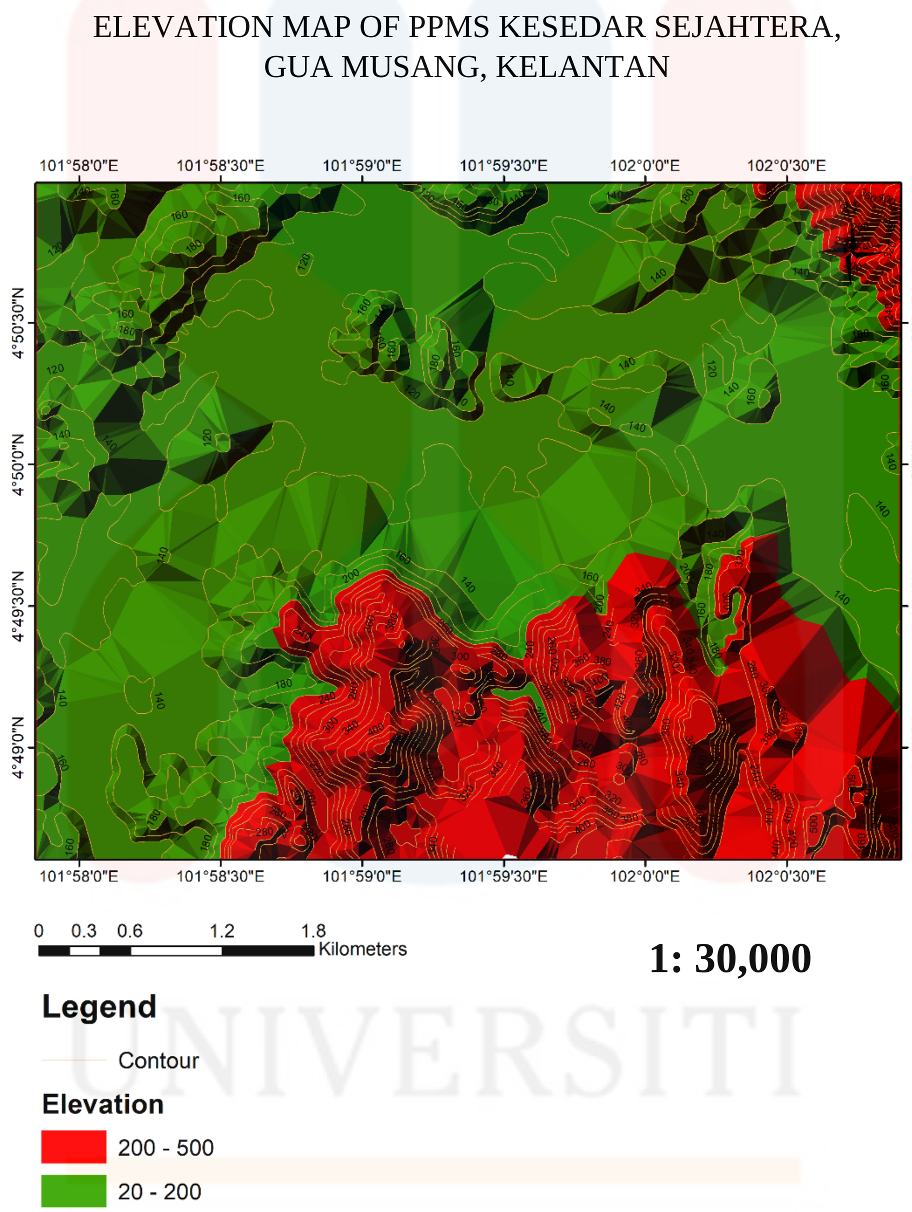

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Figure 4.3: Elevation Map of The Kampung PPMS Kesedar Sejahtera

4.2.2 Weathering

The term "weathering" refers to the process through which minerals and rocks undergo both a physical and a chemical transformation. In the course of time, almost every substance will typically deteriorate.

Depending on their composition, the rates of weathering for each type of rock vary. If the rock's minerals are weak and cannot sustain weathering, the rock erodes quickly, however if the minerals are robust and can endure weathering, the rock erodes more slowly. As a carbonates rock, limestone weathers more easily than other rocks. Limestone is often very soluble when exposed to water.

4.2.3 Drainage Pattern

Figure 4.3 depicts the several types of drainage patterns classified by Howard (1960) and Parvis (1950). In general, there are eight (8) different types of drainage patterns. These include dendritic, pinnate, parallel, radial, rectangular, trellis, angular,and annular.

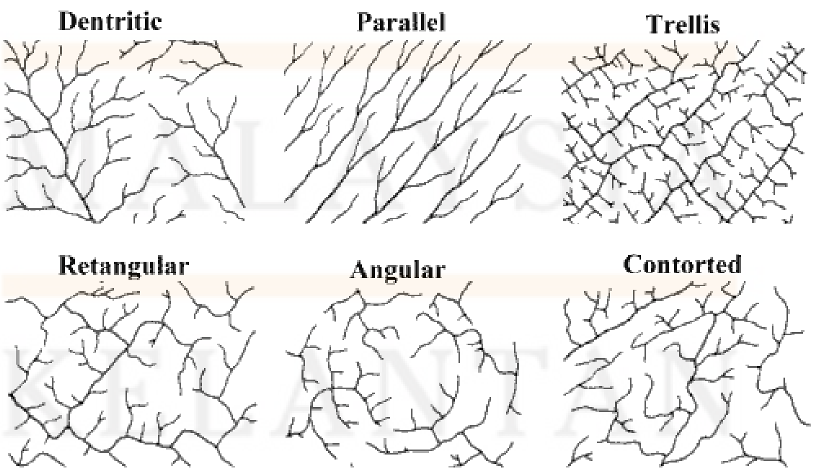

Figure 4.4: Types of Drainage Patterns

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Within the research region, three significant patterns have been observed in Figure 4.4: annular pattern, dendritic pattern, and sub parallel pattern. Yellow color implies an annular design. An annular pattern is generated when an igneous intrusion breaks through sedimentary rocks, which is common in eroded zones. This pattern is frequently encountered in weaker belts.

Then comes the dendritic pattern. This pattern is dominating the flat flying area. This pattern is highlighted in red to represent the type of sedimentary rocks that dominate this region in the center of the research area. The branching pattern with fine branches indicates that this region is prone to eroding and has poor structural control. Finally, the sub-parallel pattern consists of miniature rivers that flow parallel to one another. As shown on the map, the green color pattern shifts from slope to undulating surface. It also involves homogeneous rock resistance.

A landscape's drainage pattern is intimately tied to its topography. Topography relates to the physical characteristics of the land surface, such as height, slope, and landform shape. These topographical factors influence how water flows through the landscape, which influences the drainage pattern.

The slope and relief of the ground define the drainage pattern of a landscape. The slope is the angle of the land surface that controls the flow direction and speed. Rapidly flowing water and the creation of deep valleys and gullies are common outcomes of steep slopes. Flat or moderately sloping regions, on the other hand, have slower-moving water and more widespread drainage patterns.

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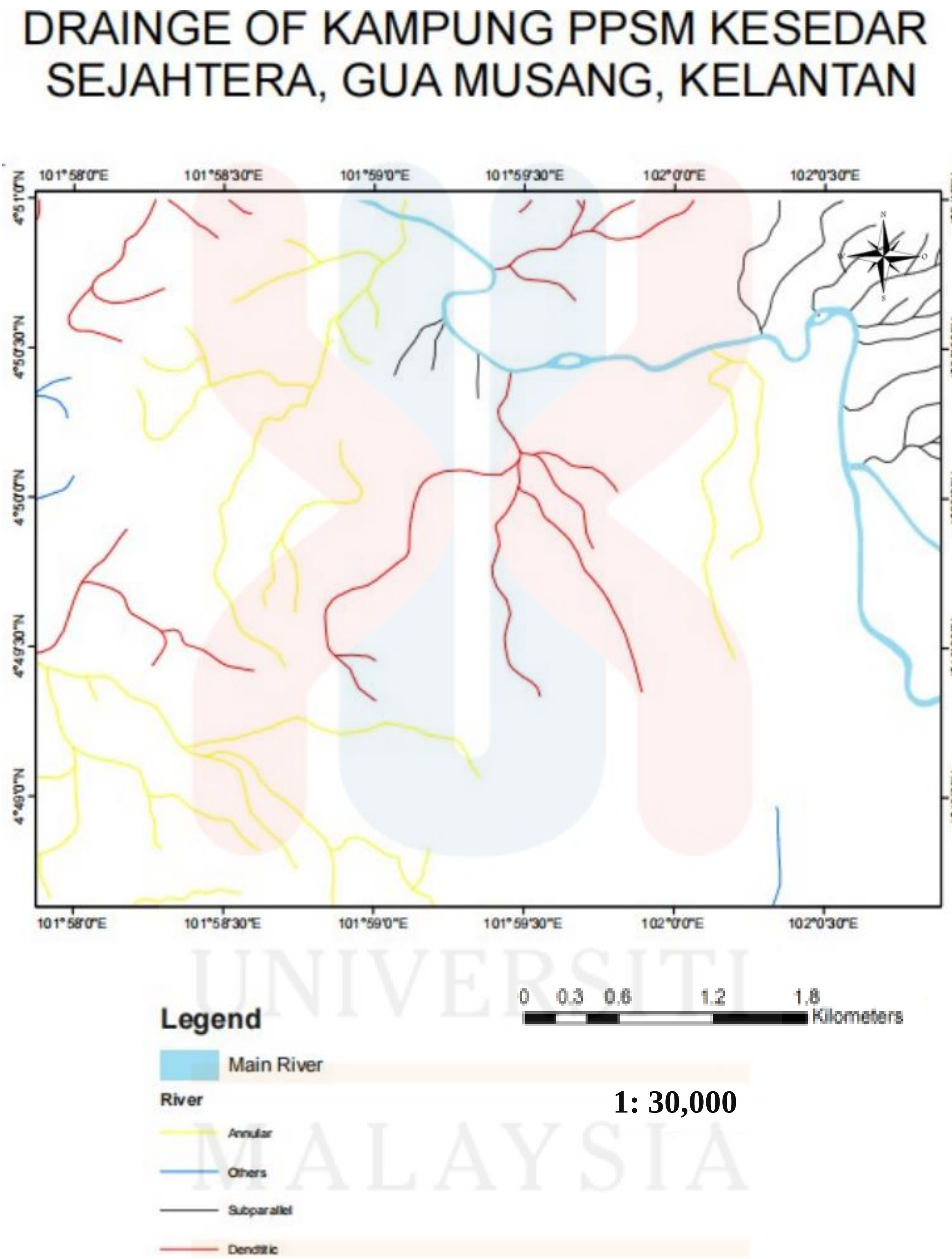

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Figure 4.5: Drainage Patterns in The Study Area

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4.3 Lithostratigraphy

The lithology units are separated into four units in the territory of PPMS Kesedar Sejahtera, Gua Musang, Kelantan. Table 4.4 shows the stratigraphic position in ascending order. The Gua Musang formation includes all of these elements. The oldest unit is the Phylite, which dates back to the Permian era. Next is limestone. Half of the study area is basically covered by the limestone. This kind of lithology is date in Middle Permian. On the third from the table, it is inter-fingering with the following unit, which has evolved from the middle Permian to the late Triassic.

This unit is made up of sandstone, siltstone, and shale. A kind of unconformity layer between the sedimentary layer and acid intrusive rock is denoted by the hiatus sign in the period section during the Middle Permian to Late Triassic and Tertiary periods.

Table 4.3: Stratigraphy Column of The Study Area

LITHOLOGY	DESCRIPTION	UNIT	PERIOD	ERA
	This rock unit is inferred to be located at the region of higher elevation such as from hill to high hill area, withcloser contour and steeper slope.	Acid Intrusive	Tertiary	Palaeozoic to Mesozoic
	Sandstone and siltstone is highly exposed to weathering and easily erode.	Sandtone intebedded with Siltstone	Middle Permian to Late Triassic	
	Type of carbonate sedimentary rockwhich is the main source of the material lime	Limestone	Permian	
	This rock unit is interpreted and beinginferred occupy thelow hill or hill area.	Phyllite	Permian	

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4.3.1 Lithology

The rock's age ranges from Permian to Quaternary. According to the derived lithology map, sedimentary rock which is limestone, dominate the flat flying regions inside the PPMS Kesedar region, Gua Musang. The interbedded sandstone and siltstone cover approximately 20% of the research area.

Following that, a form of metasedimentary rock symbolizes the low hill to hill area, indicating stronger resistance than the sedimentary rocks in the lower portion. A phyllite sample was obtained in this area to corroborate this conclusion. Finally, the south-east hill area is thought to be acid intrusive. This is corroborated by the observation of the drainage pattern in this area, which is annular.

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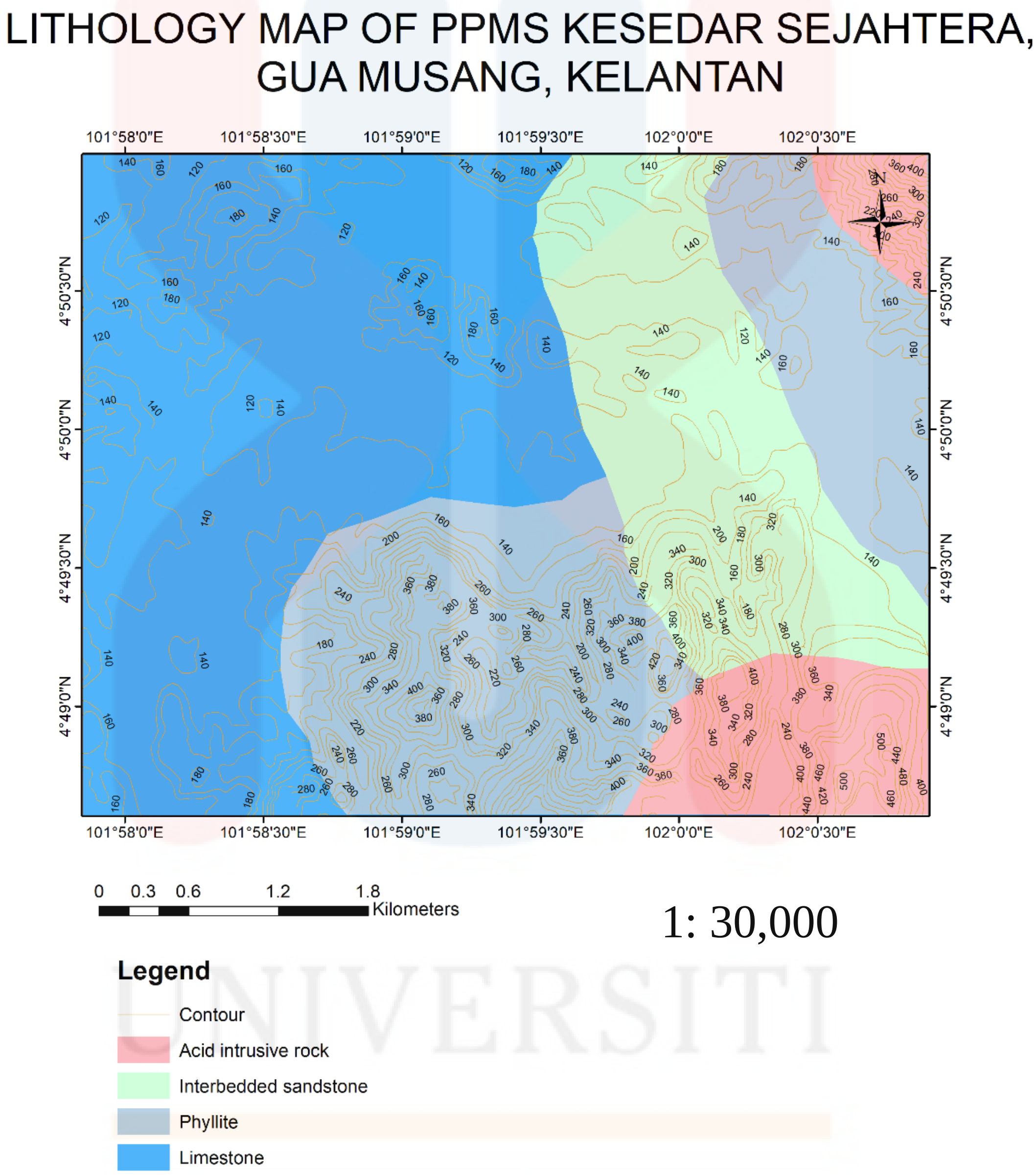

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Figure 4.6: Lithology Map of The Study Area

4.3.2 Unit explanation

Mohamed et al. (2016) explored the lithology unit that spans the Gua Musang area and its relationship to the Central Belt. The lithology units in the study area engaged are phyllite, limestone, sandstone interbedded with siltstone, and acid intrusive.

4.3.2.1 Phyllite Unit

This rock unit is interpreted and inferred to inhabit the low hill to hill area of study area, particularly in the south-east and north-east regions. However, according to Mohamed et al., (2016), Yin (1965), this unit is classified as arenaceous facies.

This arose in a maritime environment. This rock is said to have existed since the Permian epoch. Hazmira (2013) verified her results of the Phyllite unit in the top half of the research region, which ranged from low hill to mountainous. She defines the color of rock as either reddish or brownish.

4.3.2.2 Limestone

Limestone and other carbonate rocks, such as dolomite and marble, have a very distinct behaviour when exposed to rainwater; they tend to be quite soluble. Within this study area, limestone is dated as the Permian. This rock is covered almost of the study area. It also can be found at the low land of the study area.

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4.3.2.3 Interbedded Sandstone and Siltstone

This rock unit evolved from the Middle Permian to the Late Triassic period. Within the PPMS Kesedar Sejahtera region, this lithology unit covers almost 25%. Sandstone and siltstone are particularly exposed to weathering and their structures are quickly eroded. This rock unit is located in the centre of the study area and extends from north to south-east. The majority of the sample collection discovered is yellowish in color (Hazmira, 2013).

4.3.2.4 Acid Intrusive

This rock unit is thought to be at a higher elevation zone, such as from hill to high hill, with a closer contour and a steeper slope. This is due to the fact that an igneous rock has a great resistance to weathering even after being exposed to it for a lengthy period of time. This rock is thought to be Tertiary in age. The formation of acid intrusive inside Gua Musang has resulted in a high marine topography for limestone, which was previously deposited in a shallow marine environment (Mohamed et al., 2016).

4.4 Petrography

In this subtopic, readers will comprehend that the type of mineral found in the research region is dependent on the sample's coordinates. The objective of petrography is to identify the mineral inside a rock sample in order to correlate it

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with the environment around the outcrop, or it can serve as an indicator for geologists to learn about the past history of the rock sample based on its former location or formation process.

A mineral is the building block of a rock, hence a rock could not develop without minerals. As a result of the fact that a rock is an aggregate of minerals that develop when a given process transports the mineral from its source to produce a new material based on its mixing, rocks are the result of the mineral's transformation into a mixture.

a) Sample 1

The geological sample depic was collected in the coordinates 4°50'27.2"N 101°57'45.5"E which nearby to Kuala Lumpur - Kota Bahru highway. When tested with hydrochloric acid (HCI), the rock has a violent reaction and forms bubbles. Calcite vein was seen in the hand specimen rock sample (Figure 4.8).

The color of the hand specimen was grayish and contains some mineral crystals. Using HCI, it was determined if the vein was composed of quartz or calcite. The vein was identified as calcite by testing. Calcite mineral is seen in the thin section of the specimen (Figure 4.9).

Calcite minerals are commonly found in limestone, marble, and similar rocks. In the thin section, the sample was colourless and cloudy grey. The existence of twinning and twinkling shows that sample 1 was composed of limestone. It can be noted that the cleavage is flawless, and the sample displayed moderate relief. The interference colour has a bright white hue. The first sample was determined to be limestone.

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Figure 4.7: Limestone Outcrop Nearby Kuala Lumpur - Kota Bahru Highway

Figure 4.8: Hand Specimen of Limestone

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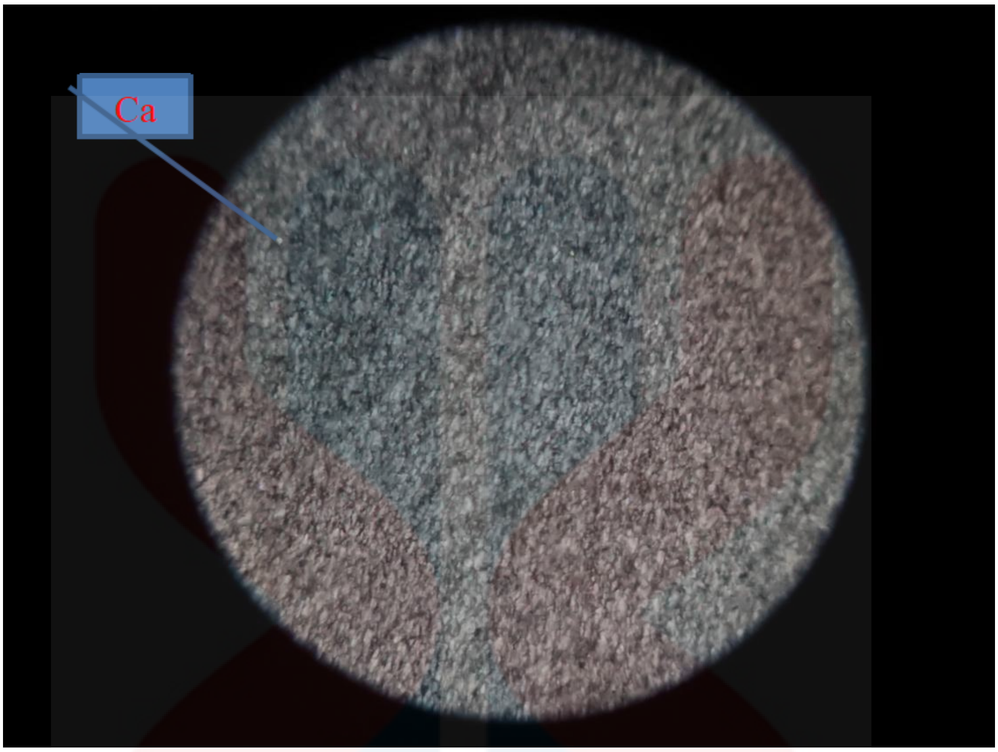

Figure 4.9: Thin Section for Limestone

b) Sample 2

This sample was collected at 4°49'11.3"N 101°58'45.4"E and the number three in traverse map (Figure 4.1) which consists of three different minerals: Quartz, Silica Clay, and Opaque Mineral Quartz comprises 10% of the sample and has a colorless absorption color under plane polarized light (PPL), low relief, absence of pleochroism, anhedral crystal shape, and absence of cleavage. The interference color of cross-polarized light (XPL) is order 1 gray-white, the dark corners are undulating, and there is no twinning. Silica Clay comprises 89% of the sample and has an absorption hue ranging from colorless to brown under PPL and from dark gray to black under XPL. It comprises of silicate material on the micron scale. Opaque mineral comprises 1% of the sample and exhibits a black absorption

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color under PPL, low relief, and euhedral to anhedral crystal shape. In XPL, it has a black interference color of the first order and no twinning. So, it can be determined as phylite.

Figure 4.10: Outcrop for Phylite

Figure 4.11: Outcrop for Phylite

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Figure 4.12: Hand Specimen for Phylite

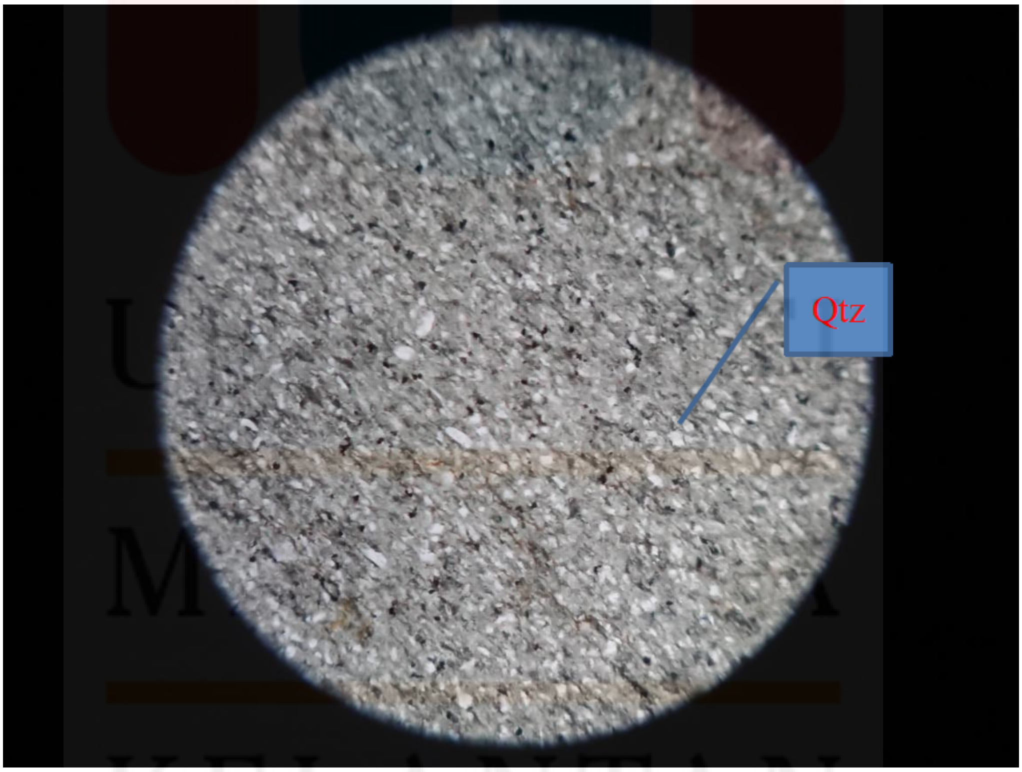

Figure 4.13: Thin Section for Phyllite

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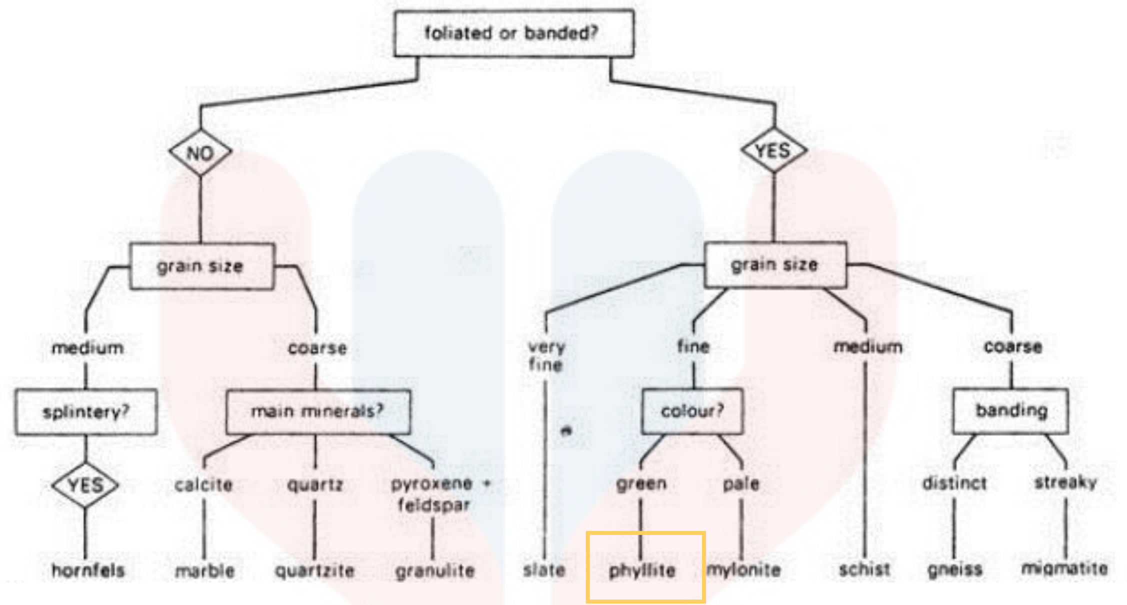

Figure 4.14: flow to determine Phyllite.

c) Sample 3

This sample was taken at 4.8428124 E, 102.0037232 N. from the outcrop it can see was severely weathered. The rock was soft and simple to fracture. The presence of bedding in the outcrop indicates that the rock is sedimentary. When tested with Hcl on the sample, the rock did not respond at all. The specimen's color also indicated that it was severely worn (Figure 4.16). Performing a thin section on the specimen would be challenging.

Figure 4.17 shows thin slice of sample 2 reveals that the bulk of minerals in sample 2 consist of quartz. Quartz is a prevalent mineral in sedimentary rocks. Quartz is often colorless and white to the highest degree.

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Quartz has no cleavage nor twining. The interference colour of quartz is gray. Quartz material has undulating extinction features. It was found that the sample was sandstone.

Figure 4.15: The Outcrop of Sandstone

Figure 4.16: Hand Specimen of Sandstone

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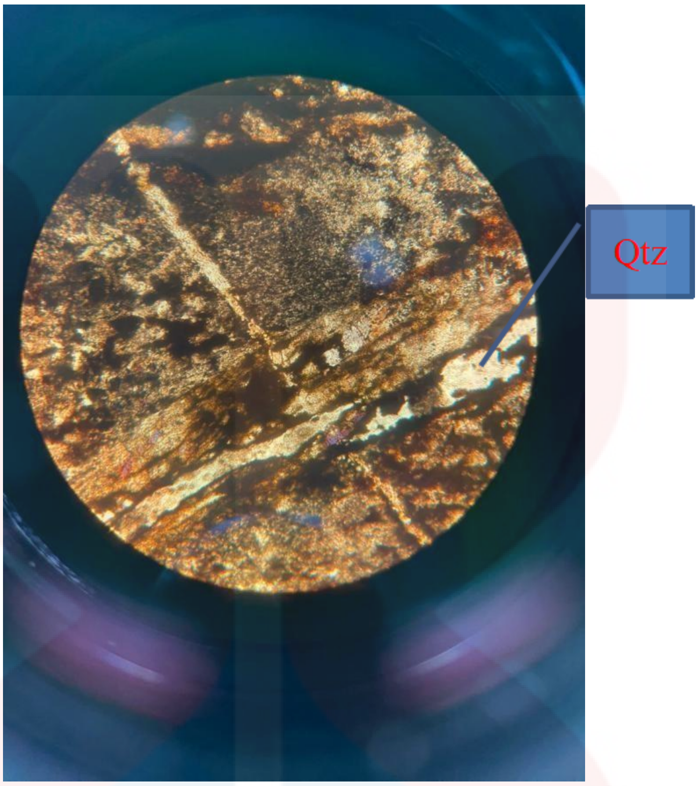

Figure 4.17: Thin Section of Sandstone

4.5 Structural Geology

Primary structures were formed during the development of rock masses, whereas secondary structures were formed as a result of primary structure deformations caused by plate tectonic movement. The structural geology covered in this study includes features such as lineaments and fault lines that may be evaluated using processed satellite imagery.

4.5.1 Fault

Figure 4.18 depicts the structural map of the PPMS Kesedar Sejahtera, Gua Musang area. The assessment of satellite photos like Google Earth revealed two faulting lines within the research region. The interpretation of the contour map, terrain map, and TIN layer map indicates that the blocks are dislocated, implying that it is a fault area.

Next, the Ketil River is a meandering river that most likely developed in a weak lithology unit with little structural control. Different river flow directions indicate that faulting has occurred in that location, and water is flowing through the fissures caused by discontinuities. As a result, the fault occurred at the top of the study area map.

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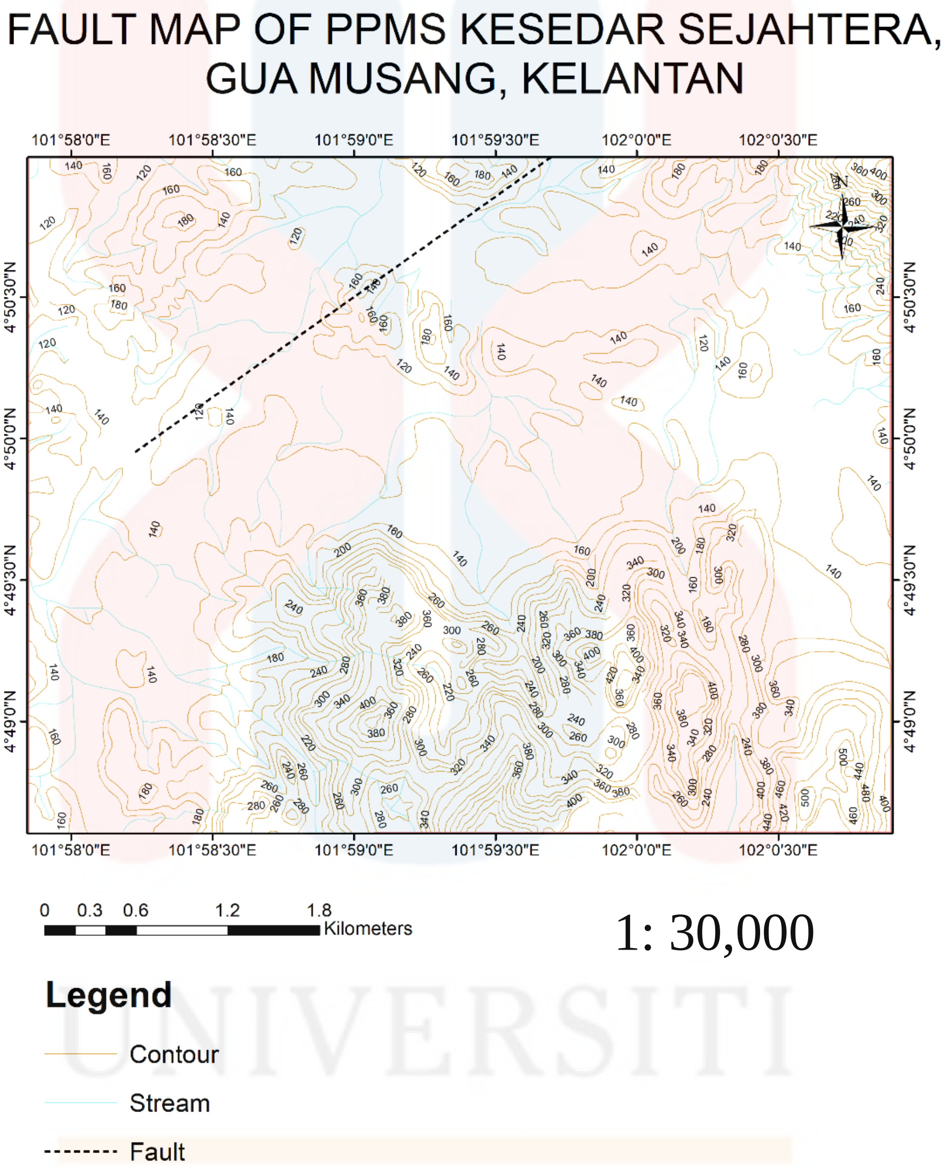

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Figure 4.18: Fault That Occurred at Study Area

4.5.2 Mechanism of structure

Lineament is a landscape feature that is a manifestation of geological structure. O'Leary et al. (1976) defined linear surface characteristics that are distinguishable from the patterns of neighboring features and presumably represent underlying events.

A lineament also a linear feature on the Earth's surface that may be related with fault lines, fractures, or other geological formations in geology. Lineaments can be seen in satellite or aerial imaging, topographic maps, or as physical landforms on the ground. There was several importance of lineament in geology and one of them is they can reveal the presence of faults or fissures in the Earth's crust, which is useful in understanding earthquake activity and tectonic plate movements.

Lineaments can also be used to identify locations that may contain mineral deposits or other natural resources. Certain forms of lineaments, for example, are frequently linked with hydrothermal mineralization. Lineaments can be used to map geological formations and better understand regional geology. This can be valuable in establishing an area's geological history and forecasting future geological occurrences.

The lineament was measured across a broader region than the 25-kilometer research area. On a tiny scale, it was difficult to identify the lineaments. Therefore, a greater scale topography was utilized. Figure 4.19 is a map that depicts lineaments within the PPMS Kesedar Sejahtera area.

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LINEAMENT MAP OF PPMS KESEDAR SEJAHTERA, GUA MUSANG, KELANTAN

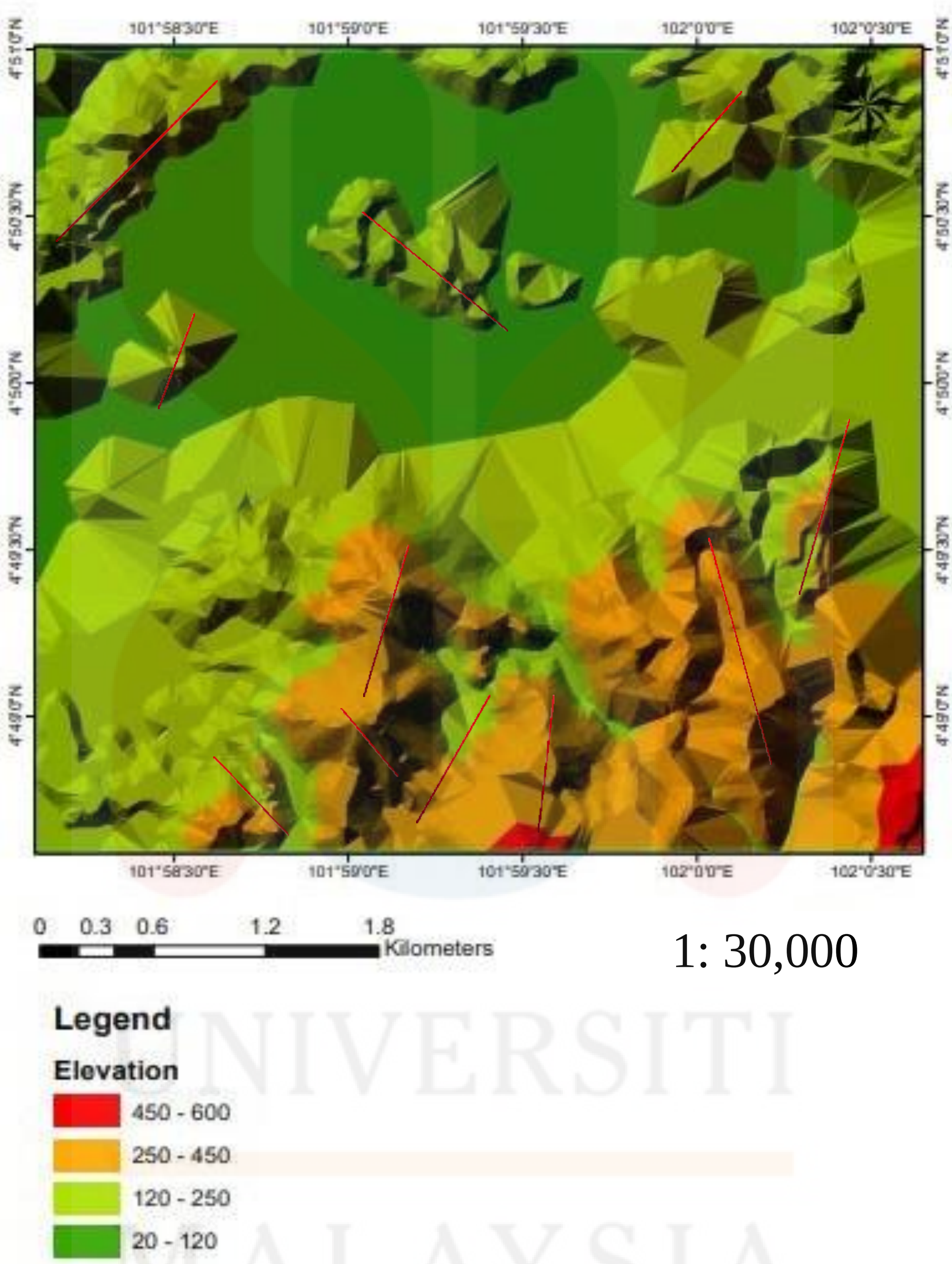

Figure 4.19: Lineament Map of The Study Area

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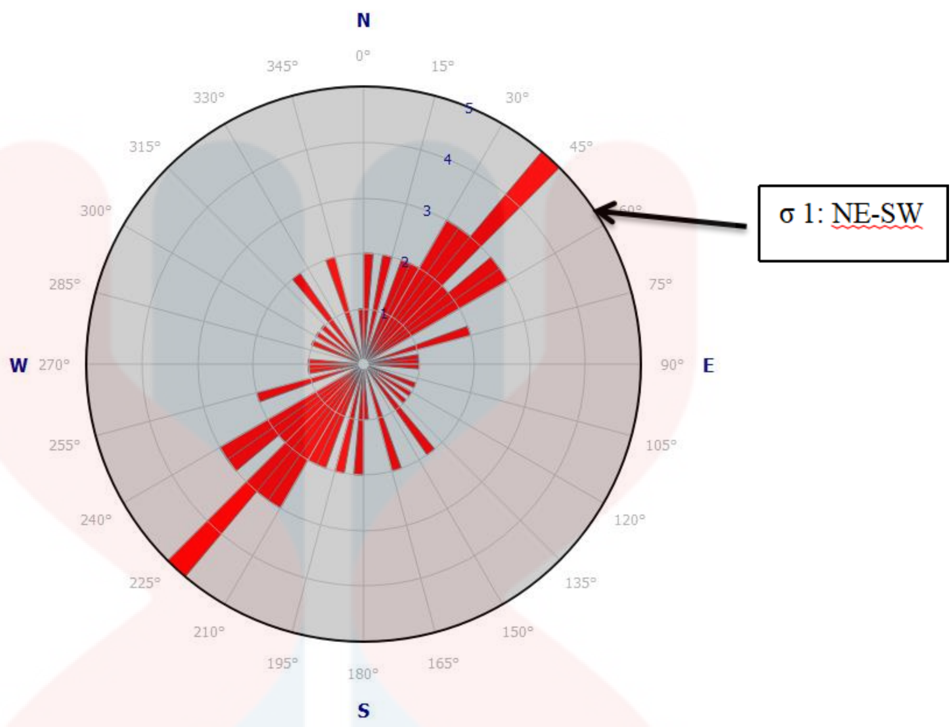

Figure 4.20: Lineament Analysis Compression Force is NE-SW

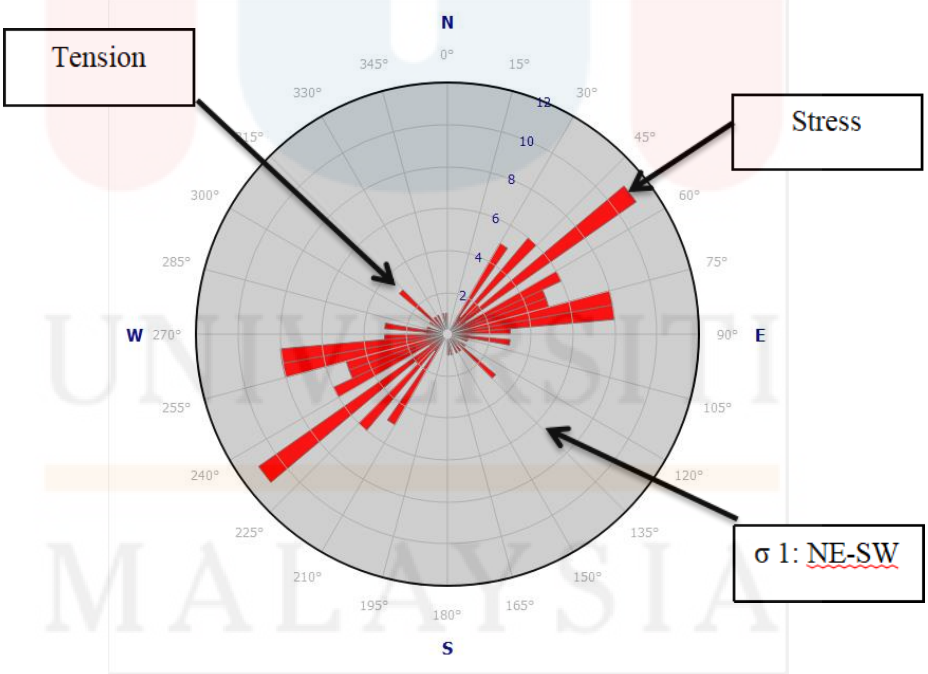

Figure 4.21: Joint Analysis Show Stress and Tension

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4.6 Historical Geology

This research area has seen numerous occurrences, one of which is deposition. Deposition in this research region demonstrates that older rocks are at the bottom and newer rocks are on top. The occurrence of phyllite rocks in the research region demonstrates this. Following that, the presence of limestone rocks in the research region demonstrates the occurrence of deposits. After this research region went through a protracted process in the construction of the area's structure, the occurrence of sandstone rocks occurred. Acid intrusive rocks observed in the research region are caused by intrusion at the bottom and can be found in locations with high elevation in the study area.

A fault is also a geological formation in this area. Minor faults are present in the northern part of this research area. The fault's extent was measured from northeast to southwest. The principal units of the Gua Musang formation from the middle Permian to the late Triassic era were argillite, carbonate, and volcanic facies. The argillaceous series, which includes siltstone, phyllite, mudstone, slate, and shale, is the dominating facies in the study area.

Four (4) kinds of lithology have been found in the PPMS Kesedar Sejahtera area. Acid intrusive unit, sandstone interbedded with siltstone unit, limestone unit, and phyllite unit are among the lithology units embedded within the Gua Musang formation.

The phyllite unit is the oldest unit in this research. The argillaceous facies include the phyllite unit. This phyllite depositional environment is being formed in an area with a warm, calm, and shallow marine environment, which is ideal for the formation of argillaceous faces. The argillaceous faces may also be involved in the sandstone interbedded with siltstone unit.

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4.7 Updating Geological Map

After geological mapping is done in the study area, all the data that has been taken will be collected in one map.Geological maps are significant tools used by geologists to understand the Earth's surface and subsurface. These maps include a lot of information on an area's geology, including the types of rocks and sediments present, the age and structure of the rock formations, and the location of mineral deposits.

There has also been other research done around the study region. The primary goal of updating the geological map is to determine what extra data is available and distinguish it from earlier studies.

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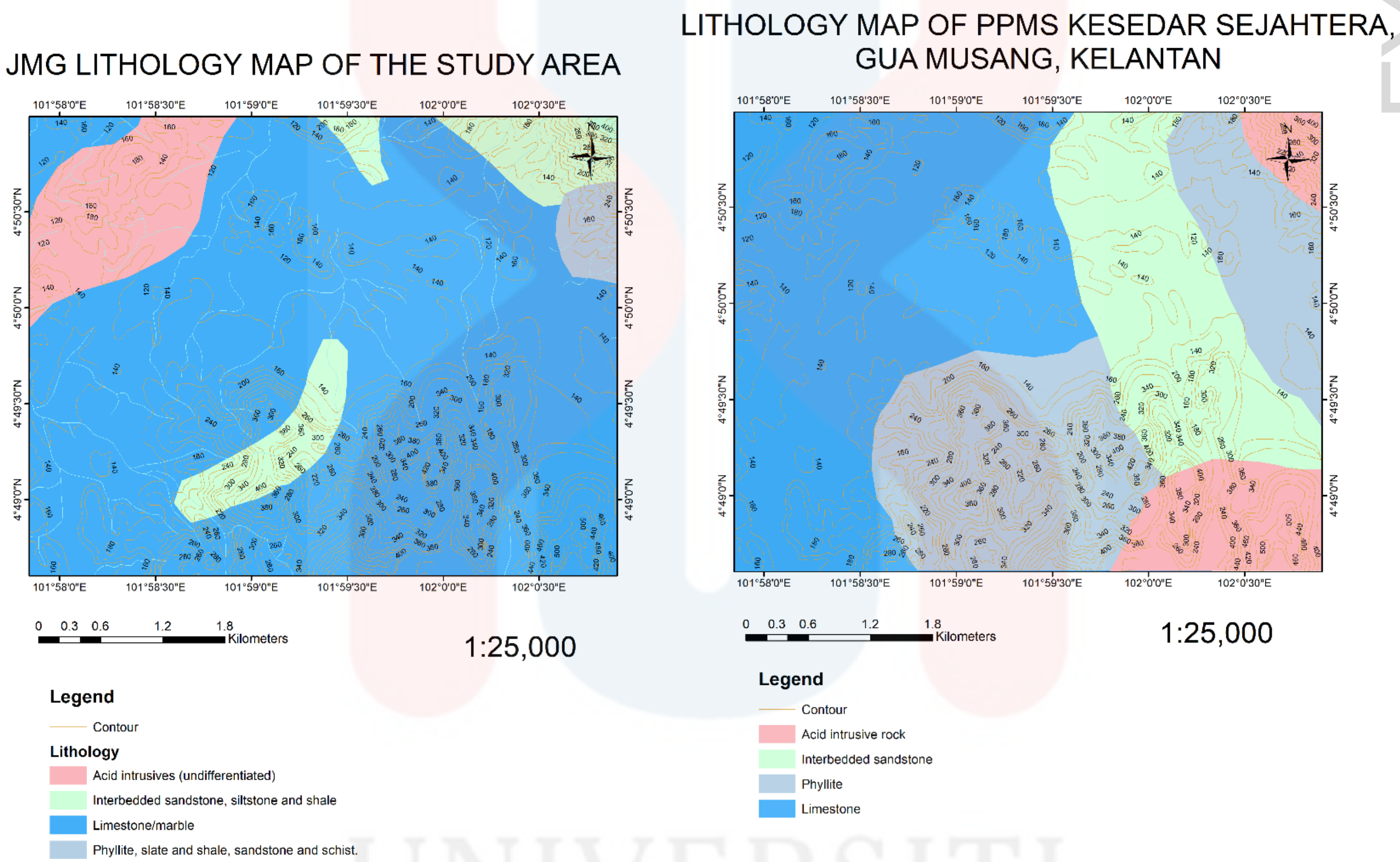

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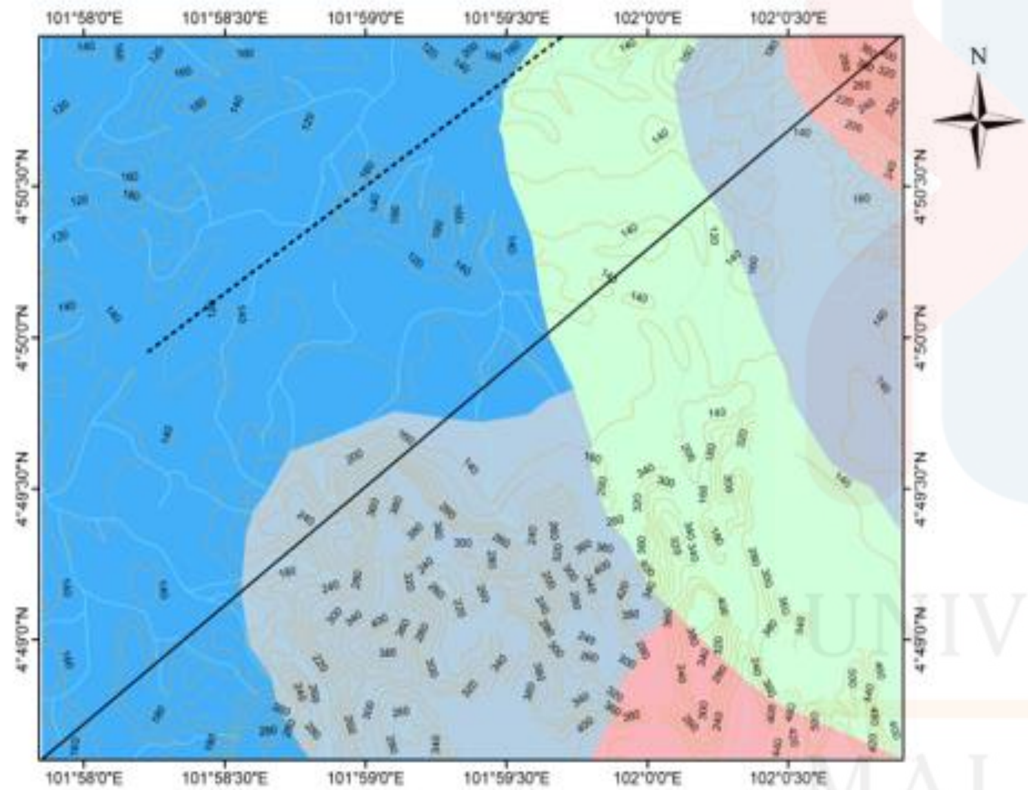
Figure 4.22: Different map between JMG and FYP Mapping



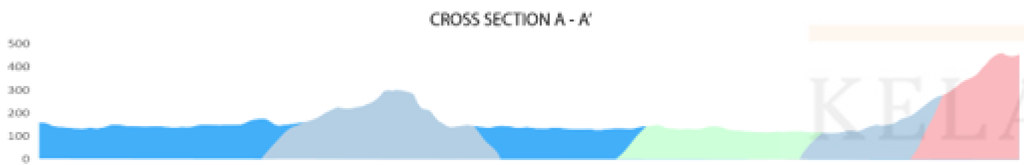
GEOLOGY AND SUBSURFACE VOID RISK MAPPING AT PPMS KESEDAR SEJAHTERA, GUA MUSANG, KELANTAN

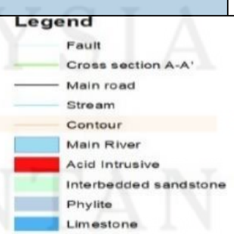
MUHAMMAD HAMDANI BIN HASZLAN

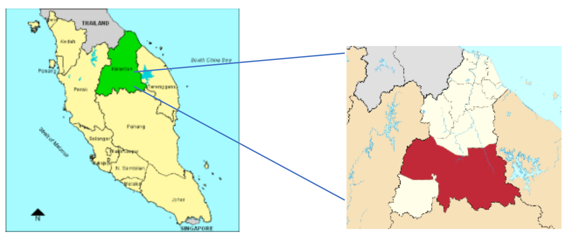
E19A0167

0 0.45 0.9 1.35 1.8 Kilometers

LITHOLOGY	DESCRIPTION	UNIT	PERIOD	ERA
	This rock unit is inferred to belocated at the region of higher elevation such as from hill to high hill area, with closer contour and steeper slope.	Acid Intrusive	Tertiary	Palaeozoic to Mesozoic
	Sandstone and siltstone is highly exposed to weathering and easily erode.	Sandtone intebedded with Siltstone	Middle Permian to Late Triassic	
	Type of carbonate sedimentary rock which is the main source of the material lime	Limestone	Permian	
	This rock unit is interpreted and being inferred occupy thelow hill or hill area.	Phyllite	Permian	







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CHAPTER 5

ELECTRICAL RESISTIVITY IMAGING (ERI)

5.1 Introduction

This chapter will focus on analyzing the fieldwork data collected by using electrical resistivity techniques to the limestone hills. A resistivity technique is one of the oldest ways to perform a geophysical survey. Its primary purpose is to identify the subsurface resistivity distribution by measuring the subsurface resistivity after injecting electrical current. Based on our assumption and the obtained data, this approach will yield the genuine resistivity of the subsurface.

Several geological factors, such as mineral and fluid or water content, porosity, and degree of water saturation in the rock, can relate to the resistivity of the ground. Electrical resistivity survey may also be used for mining, geotechnical, and hydrocarbon exploration, sinkholes, and voids.

Following the collection of data from fieldwork, the data are inverted. In geophysical inversion, the model is based on a mathematical idealization of a region of the earth in order to develop a model that resembles real observed data. The model parameters are physical quantities that may be approximated from observed data; the inversion techniques are attempting to develop a model for the subsurface with limited and constrained parameters using measured data. To invert the secondary data, the

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RES2DINV programs was used, which measure the apparent resistivity values rather than the model resistivity values of the model cells.

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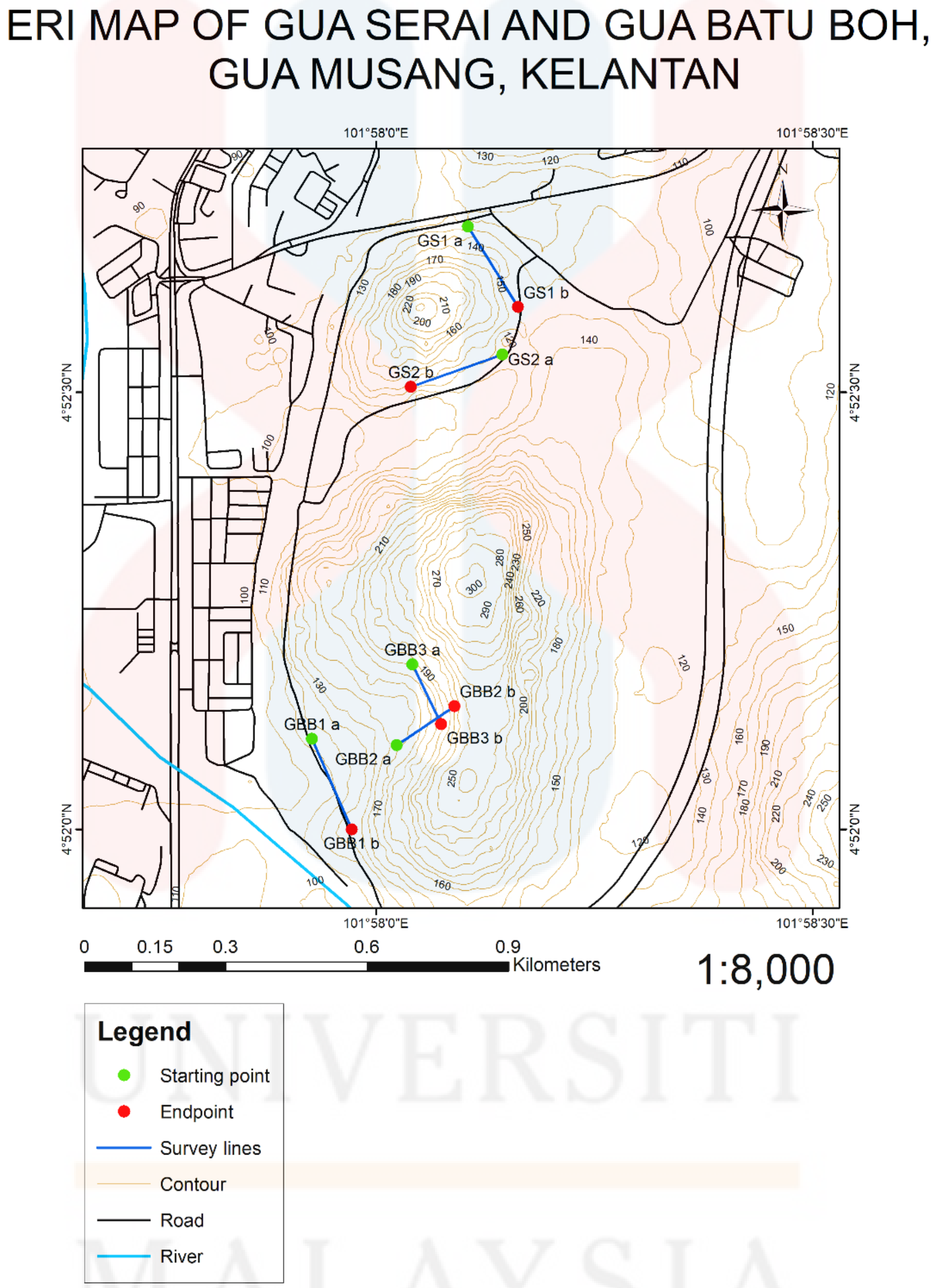

Figure 5.1: Map of Specification Area

Table 5.1: Data Result for All Survey Line

Site	Type of Array	Length of survey (m)	Depth of penetration (m)	Total no data points	RMS error	Number of iterations
GS 1	Dipole - Dipole array	200	25.2	336	17.6%	5
GS2	Pole - dipole array	200	70	724	13.1%	5
GBB1	Dipole - Dipole array	200	25	271	8.8%	5
GBB2	Pole - dipole array	200	70	682	36.2%	5
GBB3	Pole - dipole array	200	70	710	39.1%	5

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5.1.1 Gua Serai 1 (GS 1)

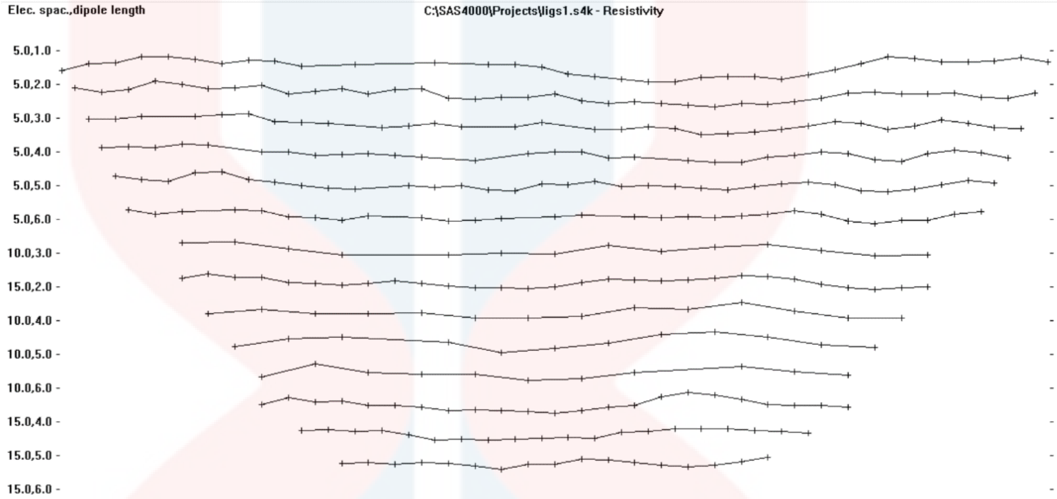

Figure 5.2: Bad Datum Points for GS 1

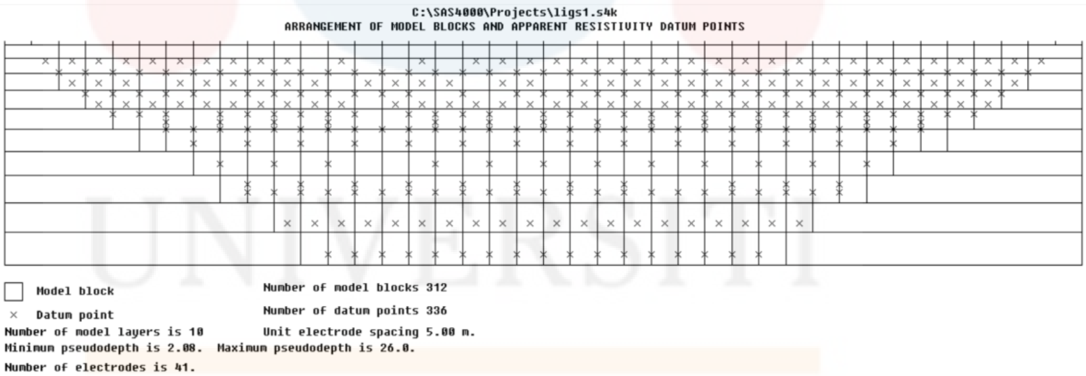

Figure 5.3: Model Discretization for GS 1

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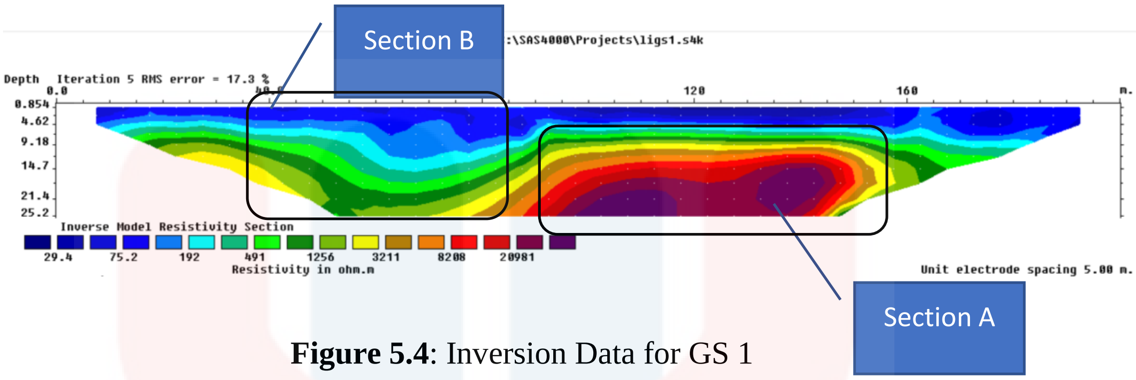

Figure 5.4: Inversion Data for GS 1

C:\SAS4000\Projects\ligs1.s4k
Minimum electrode spacing is 5.0.
Dipole-dipole array
Total number of data points is 336.
Position of mid-point of array is given.
IP values given in terms of chargeability
Minimum electrode location is 0.0.
Maximum electrode location is 185.0.
Minimum electrode spacing is 5.0.
Sorting data points.
Number of data levels is 14.
Number of electrodes is 41.
Reading inversion results.
The model has 10 layers and 312 blocks.
Iteration 1 : RMS error 47.01 17.40.
Iteration 2 : RMS error 27.15 17.07.
Iteration 3 : RMS error 21.73 17.19.
Iteration 4 : RMS error 17.49 17.10.
Iteration 5 : RMS error 17.25 17.55.

Blocks sensitivity information present.
Average sensitivity is 3.136.
Inversion constraints information present.
Reading of file has been completed.

Figure 5.5: Inversion Result for GS 1

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For this electrical resistivity imaging, the line profile is 200 meters long. By using a dipole-dipole array, the electrical current penetration depth for this line profile is 25.2 meters. The model resulted the RMS error of 17.3%. The distance between each electrode is 5 meters, and the total number of data points gathered throughout the 1st run is 336.

Section A

Focus on the 100m until 155m of surface length and the 9m until 25m of depth for this section. The resistivity value in this area is within the range of 3211 ohm.m. to 28981 ohm.m.

Section B

Focus on depths ranging from 0 m to 25 m and surface lengths ranging from 40m to 85m. From 4.62m to 25m in depth and 40m to 85m in length, the surface exhibits a curving decline, suggesting that the foundation cannot support the load.

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5.1.2 Gua Serai (GS 2)

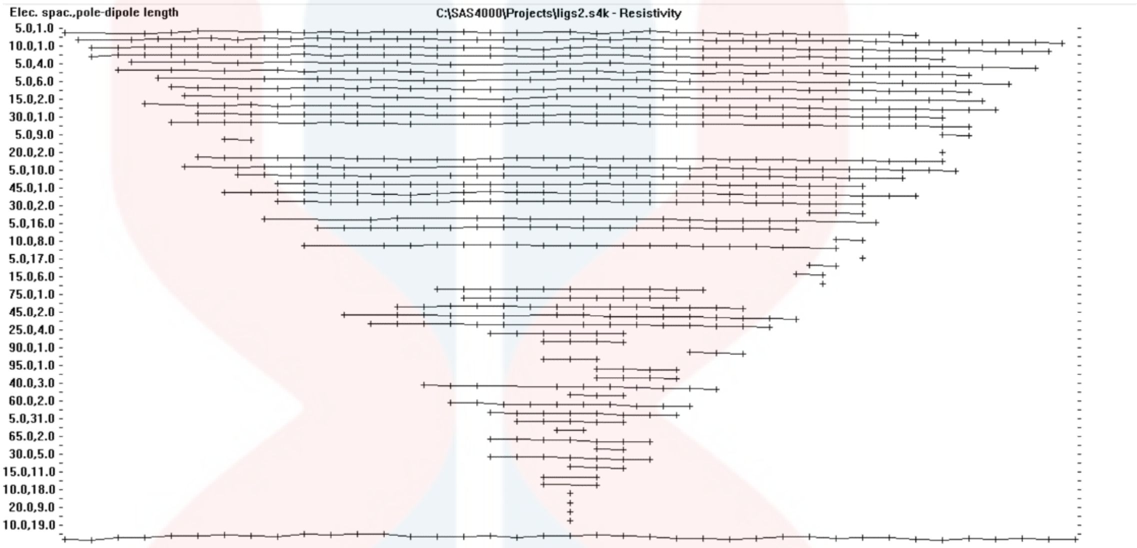

Figure 5.6: Bad Datum Points for GS 2

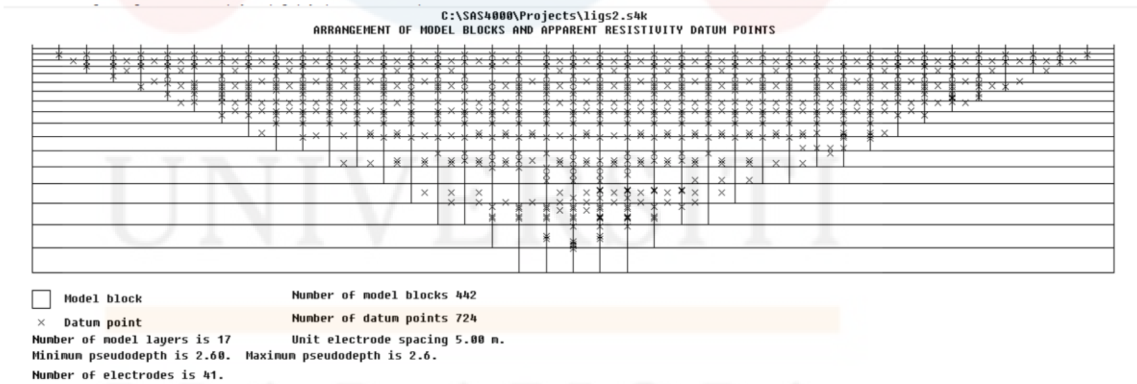

Figure 5.7: Model Discretization for GS 2

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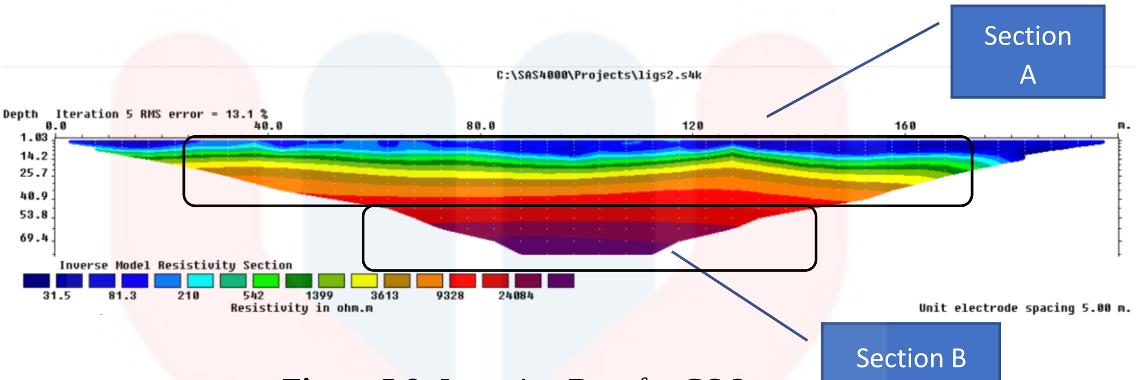

Figure 5.8: Inversion Data for GS 2

C:\SAS4000\Projects\ligs2.s4k
Minimum electrode spacing is 5.0.
Pole-dipole array
Total number of data points is 724.
Position of mid-point of array is given.
IP values given in terms of chargeability
Minimum electrode location is 0.0.
Maximum electrode location is 190.0.
Minimum electrode spacing is 5.0.
Sorting data points.
Number of data levels is 58.
Number of electrodes is 41.
Reading inversion results.
The model has 17 layers and 442 blocks.
Iteration 1 : RMS error 41.30 2.32.
Iteration 2 : RMS error 19.18 2.27.
Iteration 3 : RMS error 14.22 2.26.
Iteration 4 : RMS error 13.57 2.25.
Iteration 5 : RMS error 13.11 2.27.

Blocks sensitivity information present.
Average sensitivity is 3.289.
Inversion constraints information present.
Reading of file has been completed.

Figure 5.9: Inversion Result for GS 2

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When a pole-dipole array is utilized, an electrical current may travel seventy meters along this line profile. The distance between each electrode is five meters, and the total number of data points acquired during the one run was 724. RMS error is 13.1%.

Section A

For this portion of the section, which focuses on the depth at 1.03m until 40.9m and the length on the surface from 25m until 165m, resistivity values can be classified into three layers, which are first, second and third layers.

In the first layer, resistivity value ranges between 31.5 ohm.m to 81.2ohm.m with depth from 1.03m to 14.2m. In the second layer, with the depth at 14.2m gives off resistivity value ranging from 210ohm.m to 542 ohm.m. In the third layer, it comprises the depth at 25.7m to 40.9m resulted in resistivity values ranging from 3613 ohm.m to 9318 ohm.m.

Section B

For this portion of the section, the focus will be on depths of 53.8m to 70m and surface lengths of 60m to 135m, where there is a high resistivity range of 9328 ohm.m to 24084 ohm.m.

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5.1.3 Gua Batu Boh 1 (GBB1)

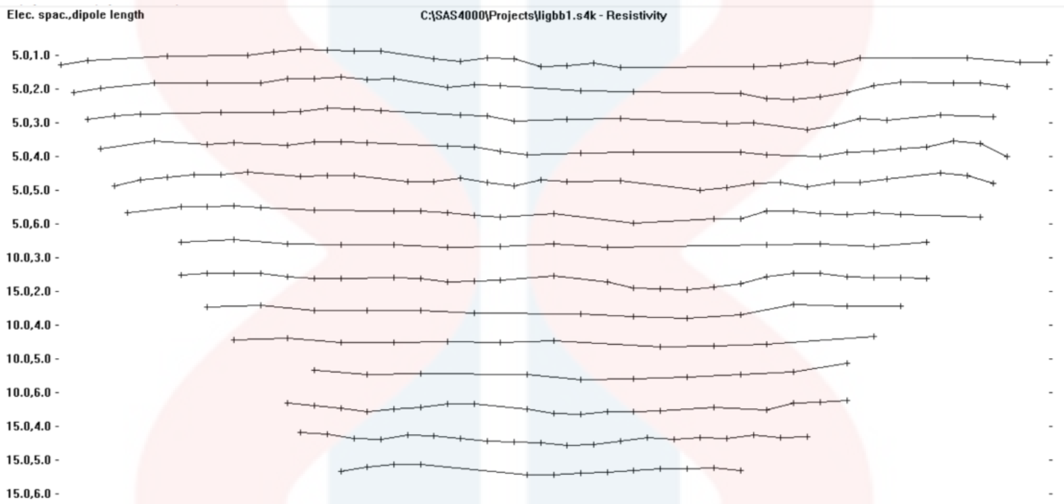

Figure 5.11: Bad Datum Points for GBB 1

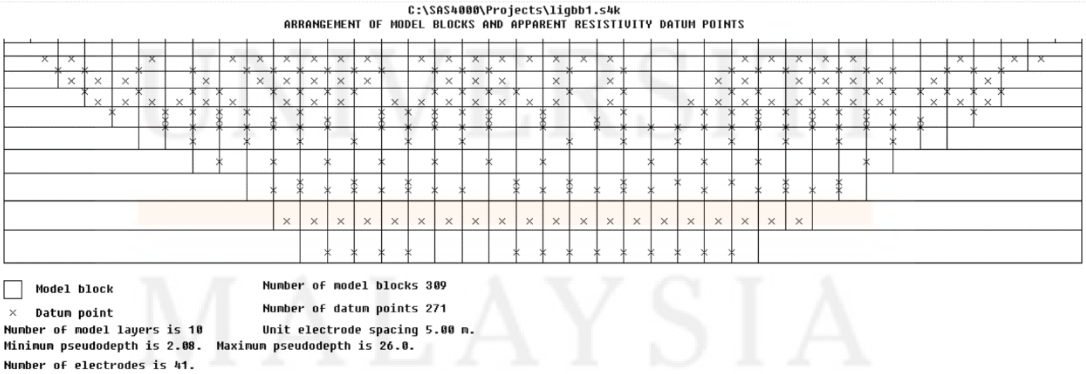

Figure 5.12: Model Discretization for GBB 1

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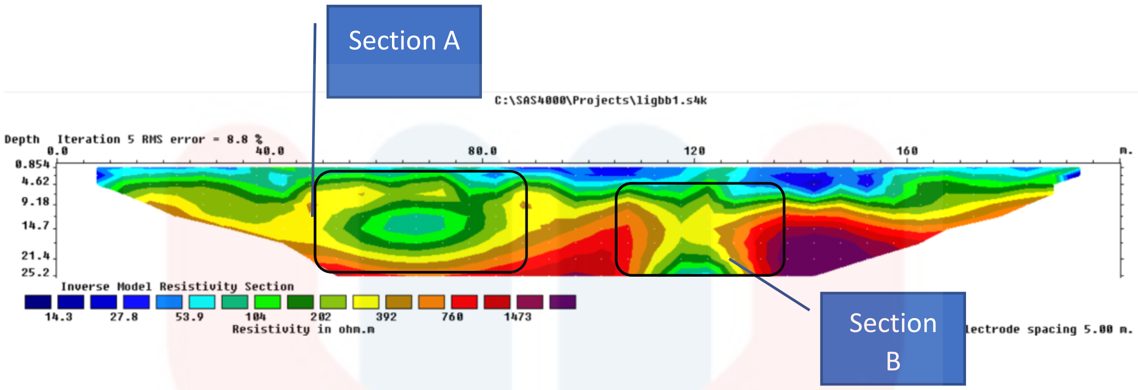

Figure 5.13: Inversion Data for GBB 1

C:\SAS4000\Projects\ligbb1.s4k
Minimum electrode spacing is 5.0.
Dipole-dipole array
Total number of data points is 271.
Position of mid-point of array is given.
IP values given in terms of chargeability
Minimum electrode location is 0.0.
Maximum electrode location is 185.0.
Minimum electrode spacing is 5.0.
Sorting data points.
Number of data levels is 14.
Number of electrodes is 41.
Reading inversion results.
The model has 10 layers and 309 blocks.
Iteration 1 : RMS error 26.51 43.35.
Iteration 2 : RMS error 12.10 44.95.
Iteration 3 : RMS error 8.54 39.70.
Iteration 4 : RMS error 8.67 41.92.
Iteration 5 : RMS error 8.79 40.39.

Blocks sensitivity information present.
Average sensitivity is 2.737.
Inversion constraints information present.
Reading of file has been completed.

Figure 5.14: Inversion Result for GBB 1

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200 meters is the length of the line profile for this electrical resistivity imaging. Using a dipole-dipole array, the electrical current penetration depth for this line profile is 25.2 meters. The distance between each electrode is 5 meters, the total number of data points gathered throughout the 1st run was 271, RMS error of 8.8%.

Section A

This area covers a length ranging from 50m to 85m and depth at 4.62m to 21.4m. It shows a presence of void that was filled with sand. This is because the resistivity value ranging from 194 ohm.m to 282 ohm.m

Section B

In section B, it covers the length from 105m to 130m with depth ranging from 14.7m to 25.2m. This area shows resistivity value in between 282 ohm.m to 392 ohm.m

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5.1.4 Gua Batu Boh 2 (GBB2)

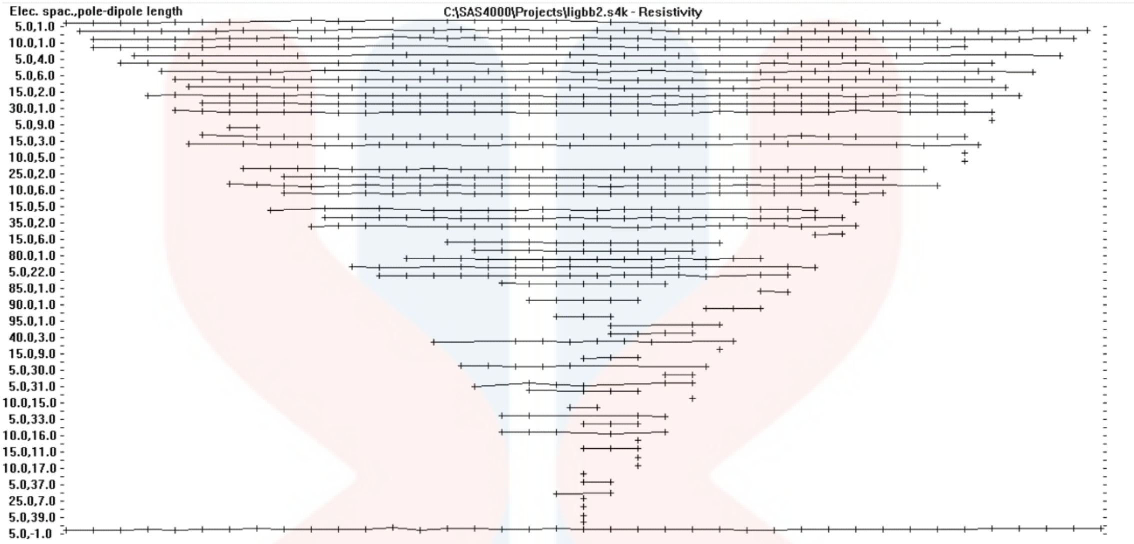

Figure 5.15: Bad Datum Points for GBB2

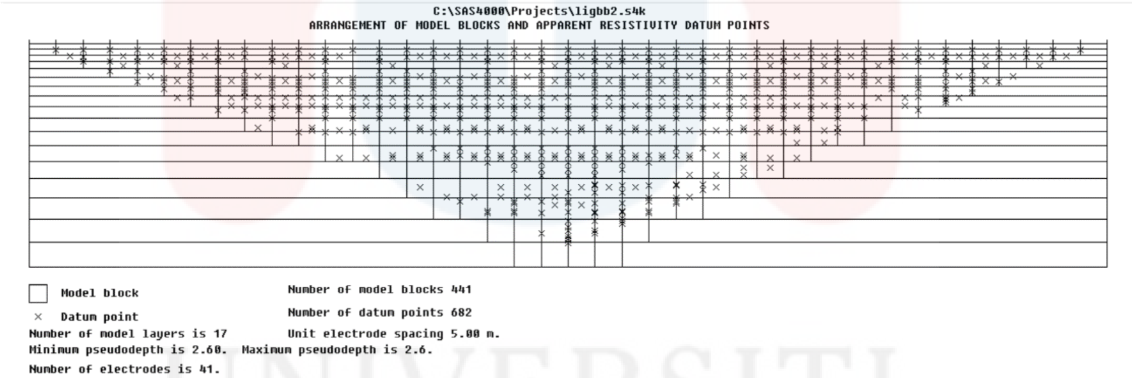

Figure 5.16: Model Discretization for GBB2

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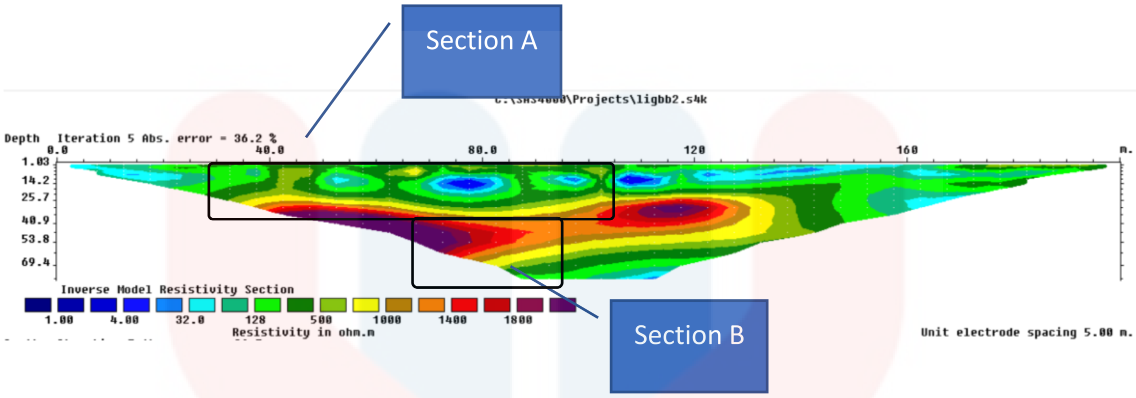

Figure 5.17: Inversion Data for GBB2

C:\SAS4000\Projects\ligbb2.s4k
Minimum electrode spacing is 5.0.
Pole-dipole array
Total number of data points is 682.
Position of mid-point of array is given.
IP values given in terms of chargeability
Minimum electrode location is 0.0.
Maximum electrode location is 190.0.
Minimum electrode spacing is 5.0.
Sorting data points.
Number of data levels is 63.
Number of electrodes is 41.
Reading inversion results.
The model has 17 layers and 441 blocks.
Iteration 1 : Abs. error 46.69 56.52.
Iteration 2 : Abs. error 43.09 29.71.
Iteration 3 : Abs. error 37.72 27.80.
Iteration 4 : Abs. error 37.48 28.94.
Iteration 5 : Abs. error 36.18 26.73.

Blocks sensitivity information present.
Average sensitivity is 4.530.
Inversion constraints information present.
Reading of file has been completed.

Figure 5.18: Inversion Result for GBB2

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200 meters is the length of the line profile for this electrical resistivity imaging. Using a pole-dipole array, the electrical current penetration depth for this line profile is 70 meters. The distance between each electrode is 5 meters, and a total of 682 data points were gathered throughout the first run with 36.2% RMS error.

Section A

For this portion of the section, where the depth is 1.03m to 25.7m and the length on the surface is 45m to 115m. The resistivity value is in between of 1 ohm.m to 1000 ohm.m.

Section B

This portion of the section, centered on depths of 40.9m to 70m and surface lengths of 80m to 100m. This area has a moderate resistivity value ranging from 1000 ohm.m to 1400 ohm.m.

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5.1.5 Gua Batu Boh 3 (GBB2)

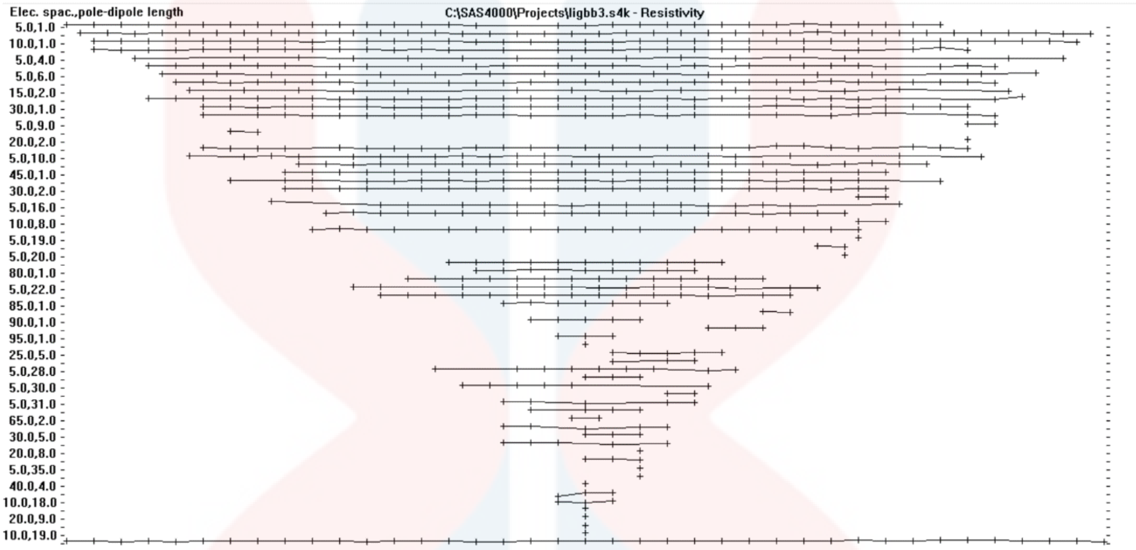

Figure 5.19: Bad Datum Points for GBB 3

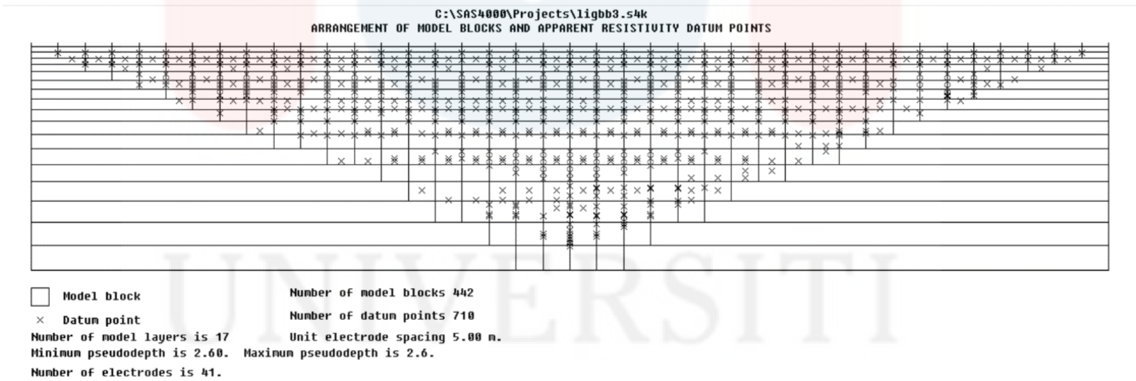

Figure 5.20: Model Discretization for GBB 3

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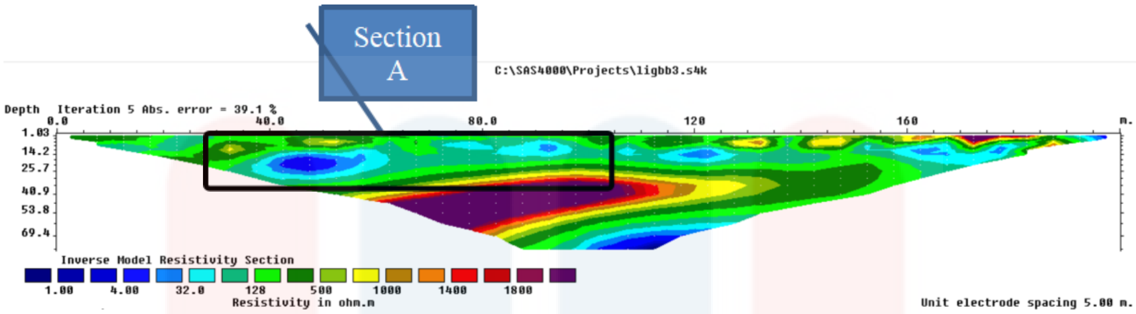

Figure 5.21: Inversion Data for GBB 3

C:\SAS4000\Projects\ligbb3.s4k
Minimum electrode spacing is 5.0.
Pole-dipole array
Total number of data points is 710.
Position of mid-point of array is given.
IP values given in terms of chargeability
Minimum electrode location is 0.0.
Maximum electrode location is 190.0.
Minimum electrode spacing is 5.0.
Sorting data points.
Number of data levels is 64.
Number of electrodes is 41.
Reading inversion results.
The model has 17 layers and 442 blocks.
Iteration 1 : Abs. error 48.63 140.55.
Iteration 2 : Abs. error 40.54 82.67.
Iteration 3 : Abs. error 39.90 70.38.
Iteration 4 : Abs. error 39.49 66.22.
Iteration 5 : Abs. error 39.09 64.35.

Blocks sensitivity information present.
Average sensitivity is 3.712.
Inversion constraints information present.
Reading of file has been completed.

Figure 5.22: Inversion Result for GBB 3

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Using a pole-dipole array, this line profile's electrical current penetration depth is 70 meters. The distance between each electrode is 5 meters, the total amount of data points gathered during the first run was 710 and RMS error 39.1%.

Section A

In this area, the length it covers ranging from 30m to 100m and depth of 1.03m to 25.7m. This area shows a range of resistivity value from 1 ohm.m. to 500 ohm.m.

5.2 Discussion

5.2.1 GS 1 (Section A)

The area depicts the presence of bedrock. Bedrock usually shows a higher resistivity value. The resistivity value is reasonable since as depth increases, temperature and pressure rise, compressing and drying the lithology and soil, making electrical conductivity more challenging. This value also shows that the lithology is completely compressed, and electricity cannot be transported due to a lack of channels, such as pores and water.

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5.2.2 GS 1 (Section B)

For this section, the area appears unstable because most of its foundation is clay and saturated soil with resistivity ranging from 29.4 ohm.m to 1256 ohm.m. Therefore, it is possible that the soil and clay is saturated and tends to loosen and move downwards, resulting in subsidence.

5.2.3 GS 2 (Section A)

In the first layer, it shows low resistivity showing the presence of humidity in the area. In the second layer, the resistivity value is slightly higher than the first layer due to the addition of the depth and pressure. In the third layer, it shows the area has a high resistivity having probability for the area to metamorphed forming bedrock.

5.2.4 GS 2 (Section B)

For this portion of the section, the high resistivity values show the area comprises of highly impermeable rock that cannot contain any water or flow because the pores are compressed, and the pathways are blocked. This will influence the conductivity of electricity, as there will be no medium for the current to move through the layer, and the resistivity in that portion will rise. It

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is observable that as depth decreases, resistivity increases, and it has been demonstrated that pressure and temperature rise with depth.

5.2.5 GBB 1 (Section A)

This area shows a presence of void that was filled with sand. This is because the resistivity value ranging from 194 ohm.m to 282 ohm.m. The image particularly in the area shows forming a circle indicating a void presence. While void spaces that in left unfilled should have a higher resistivity, the resistivity inside was slightly lower showing that the void was already filled with some loose materials such as sand. These materials lessen the resistivity value.

5.2.6 GBB 1 (Section B)

In this area, it can be seen a lower resistivity value located in between of two high resistivity value areas. This is because the void in the area was happened and filled with loose materials. Void in the area goes along fracture and it became larger due to the infilling materials keep increasing and increasing the opening spaces of the fracture thus increasing the size of the void.

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5.2.7 GBB 2 (Section A)

This area indicates a presence of four small voids infilled with water. This can be proven by the lower resistivity inside the void compared to the outside part. There are also certain areas showing higher resistivity because soil have converted to clay due to the presence of water during data collection.

5.2.8 GBB 2 (Section B)

This particular area in the centre has a significant lesser value in between two higher resistivity values. This might be due to the presence of fracture, or the rock tend to have a fresher grade in the area.

5.2.9 GBB 3 (Section A)

At the surface part, it shows that water can flow due to the humidity in terms of the resistivity value. This can facilitate water to flow and infill voids in the subsurface area. At length 45m to 60m, it shows that the soil has converted to clay during data collection. As this area is shallow, the possibility to collapse is higher because water easy to infiltrate and infill void areas due to the humidity factor.

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CHAPTER 6

CONCLUSION & RECOMMENDATIONS

6.1 Conclusion

The purpose of this study is to develop a geological map, evaluate the study region for the likelihood of sinkhole formation by employing the geophysics method Electrical Resistivity Imaging (ERI), and determine the depth of the limestone bedrock.

A geological map was created using reconnaissance mapping, lithology mapping, terrain mapping, and drainage pattern mapping, thereby achieving the first objective. The second objective also achieve by ERI method was applied to two limestone hills in the Gua Musang study area in order to observe the low resistivity, (water saturated soil or void), moderate resistivity (limestone or sandstone), high resistivity (marble bedrock or metamorphosed limestone with extremely high resistivity), and the possibility of a void.

GBB 1, GBB 2, AND GBB 3 have the potential for sinkhole and subsidence development due to the preponderance of resistivity found in loose soil, wet soil, and voids filled with water and silt. By employing ERI, the depth of the subsurface of limestone hills may be detected and interpreted, therefore, the third objective is achieved.

6.2 Recommendations and Suggestions

Recommendation and proposal to enhance the quality of the research may be divided into two components. The first proposal and suggestion are to clarify ERI data and eliminate any ambiguity; study must be conducted using seismic wave technique and drilling in order to get a certain subsurface depth, and then it can be correlated with ERI data. By analysing faults and fractures, the gravity technique may also be used to acquire more precise and comprehensive subsurface geological data. Apply LIDAR and SPOTS to geological mapping then. Second, more time must be allocated to this study if we are to attain superior outcomes

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