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**GEOLOGY AND DETERMINATION OF POTENTIAL GROUNDWATER
SOURCES USING ELECTRICAL RESISTIVITY IMAGING (E.R.I) AT KAMPUNG
SUNGAI TERAH, GUA MUSANG, KELANTAN**

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

FACULTY OF EARTH SCIENCE

UNIVERSITY MALAYSIA KELANTAN

2023

DECLARATION

I declare that this thesis entitled General Geology and Groundwater Sources Identification in Limestone using Electrical Resistivity Imaging (E.R.I) at Kampung Sungai Terah, Gua Musang, Kelantan is the result of my own research expert 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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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient
interms of scope and quality for the award of the degree of Bachelor of Applied
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Date :



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Geology and Determination of Potential Groundwater Sources Identification Using Electrical Resistivity Imaging (E.R.I) at Kampung Sungai Terah, Gua Musang, Kelantan

ABSTRACT

Geological mapping of 25 km² with the scale of 1:25,000 were conducted in Kampung Sungai Terah, Gua Musang, Kelantan. This area located at 4° 59' 15.27" to 4° 56' 02.10" North latitude and 101° 55' 3.97" to 101° 58' 56.84" East longitude. The objective of this research are to produce updated geological map and to identify the groundwater potential in limestone using Electrical Resistivity Imaging (E.R.I). Unit lithology in the research area can be divided into three main units. It is composed with limestone, shale, and slate from Gua Musang formation with age ranging from Permian to late Triassic. The geomorphology of the study area, Kampung Sungai Terah can be divided into two units of morphology which is medium and low relief morphology unit. In the study area, the main geological structure that occurred in the area is lineament features and joint structure. For the Electrical Resistivity Imaging (E.R.I), a pole dipole configuration array was used with 41 electrode and 200 meters spread length through four lines in the study area. The data of the survey recorded using ABEM Terrameter LS-1. The groundwater potential is based on resistivity value and chargeability value of pseudo section that has been process with RES2DINV software that give a two-dimensional (2D) resistivity data. The result from the E.R.I survey of groundwater potential shows that the area has a good potential source for groundwater where all pseudo section for all four line has a high value of resistivity but low in chargeability.

Keywords: Kampung Sungai Terah, geology, Electrical Resistivity Imaging, groundwater, two-dimensional(2D)

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**Geologi dan Pengenalpastian Sumber Air Tanah yang Berpotensi
Menggunakan Pengimejan Kerintangan Elektrik (E.R.I) di Kampung Sungai
Terah, Gua Musang, Kelantan**

ABSTRAK

Pemetaan geologi seluas 25 km² dengan skala 1:25,000 telah dijalankan di Kampung Sungai Terah, Gua Musang, Kelantan. Kawasan ini terletak pada 4° 59' 15.27" hingga 4° 56' 02.10" latitud Utara dan 101° 55' 3.97" hingga 101° 58' 56.84" longitud Timur. Objektif penyelidikan ini adalah untuk menghasilkan peta geologi yang dikemas kini dan mengenal pasti potensi air bawah tanah dalam batu kapur menggunakan Pengimejan Kerintangan Elektrik (E.R.I). Unit litologi di kawasan kajian boleh dibahagikan kepada tiga unit utama. Ia terdiri daripada batu kapur, syal, dan batu sabak dari pembentukan Gua Musang dengan umur antara Permian hingga Triassic lewat. Geomorfologi kawasan kajian, Kampung Sungai Terah boleh dibahagikan kepada dua unit morfologi iaitu unit morfologi relief sederhana dan rendah. Di kawasan kajian, struktur geologi utama yang berlaku di kawasan tersebut ialah ciri garisan dan struktur kekar. Untuk Pengimejan Kerintangan Elektrik (E.R.I), tatasusunan konfigurasi *pole dipole* telah digunakan dengan 41 elektrod dengan panjang hampan 200 meter melalui empat garisan di kawasan kajian. Data tinjauan direkodkan menggunakan ABEM Terrameter LS-1. Potensi air bawah tanah adalah berdasarkan nilai kerintangan dan nilai kebolehasan bahagian pseudo yang telah diproses dengan perisian RES2DINV yang memberikan data kerintangan dua dimensi (2D). Hasil tinjauan E.R.I terhadap potensi air bawah tanah menunjukkan kawasan tersebut mempunyai potensi sumber air bawah tanah yang baik di mana semua bahagian pseudo untuk keempat-empat talian mempunyai nilai kerintangan yang tinggi tetapi kebolehasan rendah.

Kata kunci: Kampung Sungai Terah, geologi, Pengimejan Kerintangan Elektrik, air bawah tanah, 2-dimensi(2D)

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LIST OF ABBREVIATIONS

GIS	Geographic Information System
GPS	Global Positioning System
E.R.I	Electrical Resistivity Imaging
msec	Millisecond
N	North
S	South
W	West
E	East
Km	Kilometer
Km ²	Kilometer per square
P.P.L	Plain polarized light
X.P.L	Cross polarized light

LIST OF SYMBOLS

° Degree
Ω ohm



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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysia has a humid climate all year long, especially in Peninsular Malaysia's eastern section, sometimes referred to as the East Coast. One of the states impacted by the northeast monsoon that occurs from November to March along Peninsular Malaysia's East Coast is Kelantan which causes the state to be unusually humid and have a high rate of rainfall distribution near the end of each year.

Rain and surface water may naturally produce groundwater. The possibility of groundwater potential in Gua Musang, Kelantan, may be influenced by the high rate of rainfall dispersion in the region. Groundwater is water that naturally accumulates and exists under the surface of the earth. Sedimentary, igneous, or metamorphic rocks may contain groundwater. Sedimentary rocks with high porosity and permeability have pore spaces between the grains that collect groundwater.

Meanwhile, igneous, and metamorphic rock fracture zones may contain groundwater. Through a space opening in the fracture, groundwater can flow and accumulate in the gap along the rocks' fracture. By naturally seeping through the pore spaces between grains and fissures in rocks under the surface and reaching the aquifer's water tables, rain and surface water will replenish groundwater.

The geophysical method is the most suitable method to find groundwater sources. This geophysical method conducts Electrical Resistivity Imaging (E.R.I) to detect the source of groundwater identification in limestone. Electrical resistivity is one of the methods that can be used in surveying for the potential resource in an area with complex geology compared to other geophysical techniques that are ineffective for producing comprehensive data (Mohamaden. et al., 2016; Sobhy, 2017). Due to a population that is expanding by two years faster than average, Kelantan's primary water supply is under great demand for daily uses for domestic, agriculture, and safe drinking. Groundwater exploration needs to be increased for future use, especially in Kelantan.

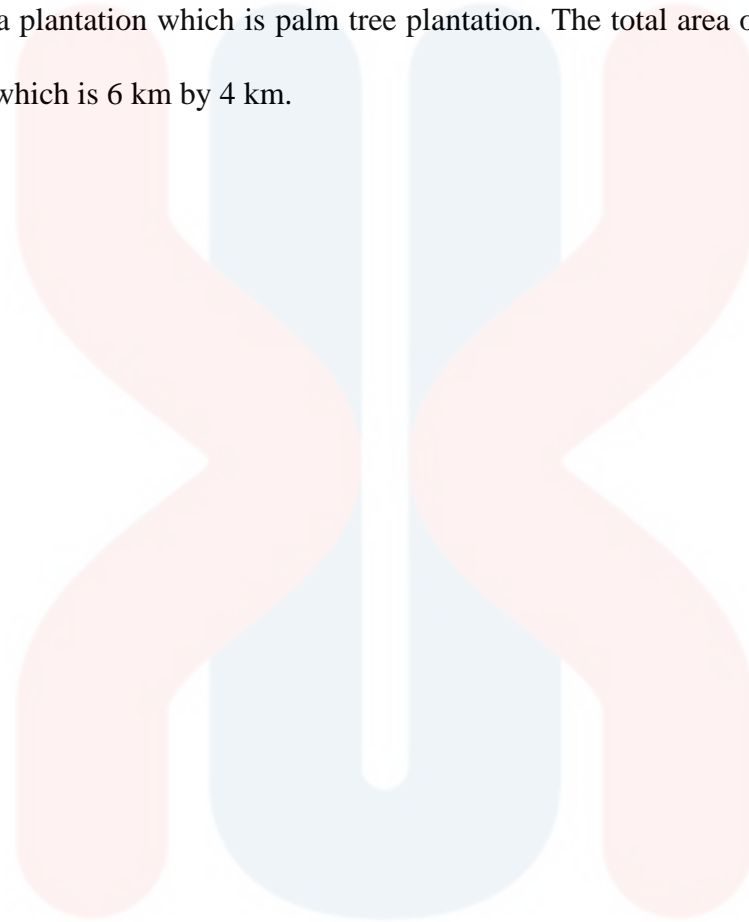
In addition, the geological mapping of the study area is updated with the geology in the study area. The study conducted a geological mapping. Geological mapping shows the distribution of various rock and surficial deposits and geologic structures like faults, folds and joints. The general geology of the study area can be guaranteed through geological mapping.

1.2 Study Area

1.2.1 Location

Kelantan is a state in Peninsula Malaysia located in the north-eastern of Malaysia. It encompasses a total of 15,022 km². Kota Bharu stands as the capital of Kelantan. Gua Musang is one of the ten districts in Kelantan . It is the biggest district in Kelantan. Pahang, Terengganu, Perak, and the Kelantanese districts of Kuala Krai and Jeli are on Gua Musang's southern, eastern, and western borders, respectively. The area of the research study is in coordinate of 4 °59' 27.59" N – 101 °56'40.65" E (Figure 1.1), which within Jelawang-Gua Musang major road. The study area stated in figure

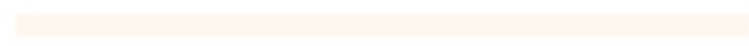
1.1 is in the Gua Musang area, near Kampung Sungai Terah. There is a housing area, school, mosque, and near the Ladang Kelasa office. Along the road of the study area, there is a plantation which is palm tree plantation. The total area of the study area is 25 km² which is 6 km by 4 km.



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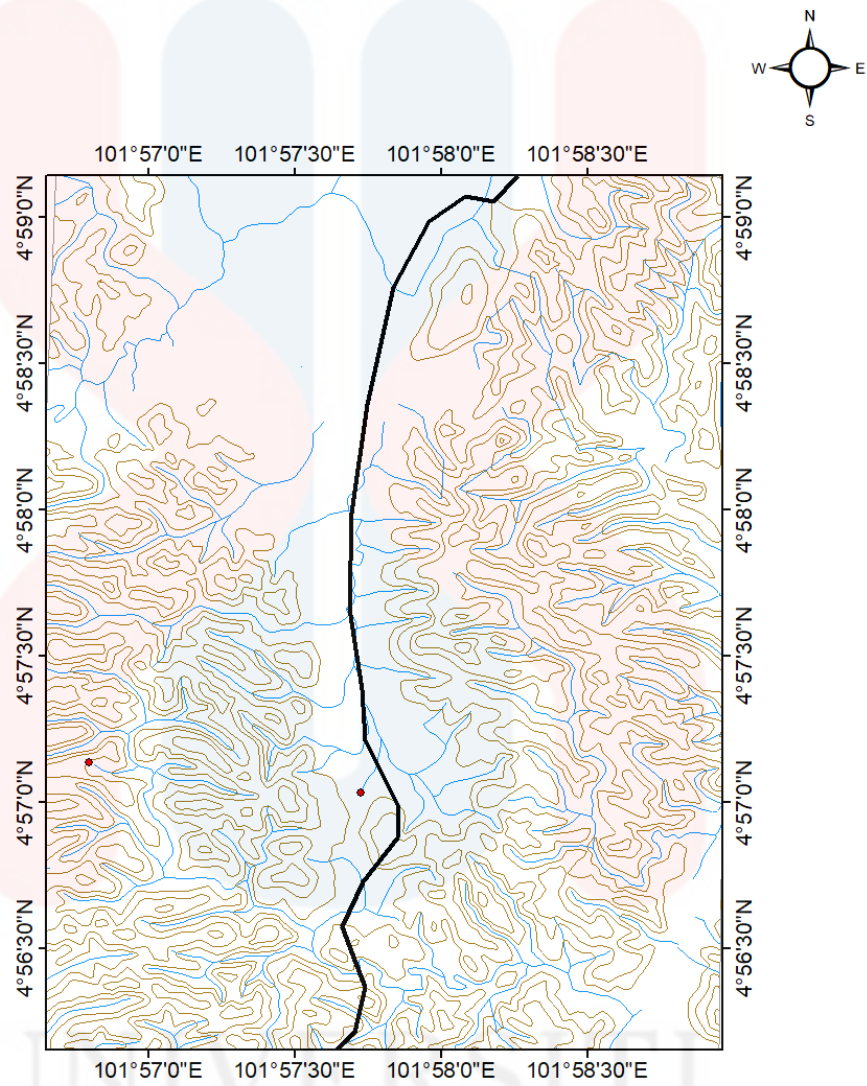


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BASEMAP OF KAMPUNG SUNGAI TERAH, GUA MUSANG, KELANTAN



Legend

- Village
- Main Road
- Countour
- Stream

1:25,000

0 0.5 1 2
Kilometers

Figure 1.1: The base map of the study area

1.2.2 Road/Accessibility

Gua Musang is a small town deep in the jungle of central Kelantan, and the district is a rural area. However, the major road is Jelawang-Gua Musang road to the study area. The highway is connected all the way direct to the town in that area. Moreover, along the central route is a plantation area where the villagers work. There is merely a public transport, such as a taxi, uber or transit bus, that get through the highway since the road is in a rural area. Regardless, private carriers or other types of light or heavy transportation can access the road since the road is wide but with some patchy roads.



Figure 1.2: The picture labelled A and B is the major road to the study area, which is Jelawang-Gua Musang road

1.2.3 Demography

Gua Musang area has a total area of 6,430 km². From the table below (Table 1.1), the population of the community of Gua Musang shows an increasing data which 74,988 in 2000 to 86,189 in 2010 and 101,894 in 2020. This rapid increase shows the population growth in the Gua Musang area. Moreover, a pie chart of figure 1.3 indicates the percentage of the population in Gua Musang in 2010, which is monopolised by Malay and other indigenous with 94.6%, followed by Chinese, 4.8%, and Indian, 0.4%.

Table 1.1: The population development of Gua Musang

Name	Status	Population 2000	Population 2010	Population 2020	Annual population change (2010-2020)
Gua Musang	District	74,988	86,189	101,894	1.7%

(Source: Department of Statistic Malaysia (2022))

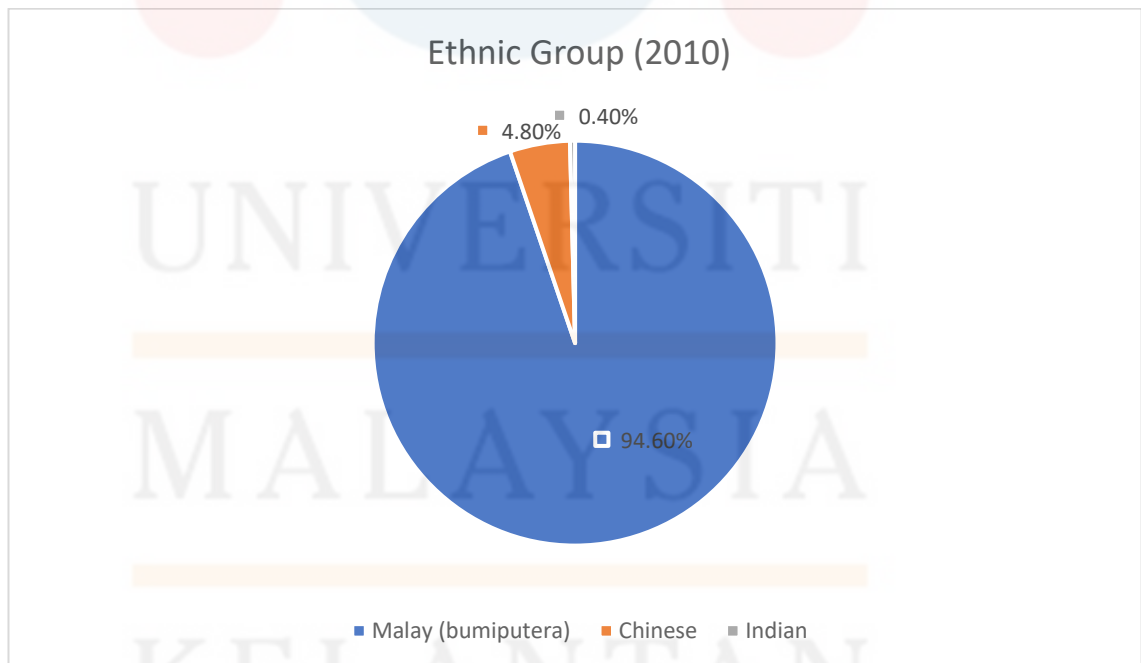


Figure 1.3: Pie chart of an ethnic group of Gua Musang in 2010

1.2.4 Land use

Syafiq Haidar et al. (2022) concluded that the land use of Gua Musang changed from 2017 until 2019. The area shows the difference by year and land use class. Differentiation by year and land use class can be seen in the area. It was demonstrated among the four courses that the percentage of land use in this area, which is still at 88.12 percent, has not changed significantly. However, due to the region's history and current conditions, there are still unavoidable changes in the landscape. These changes can be seen because of logging operations, changing the forest and water bodies slightly.

Logging activities have an increasing tendency of 5.95 percent, affecting other features and destroying the rich plant and fauna-filled forest landscape. Due to the highlands surrounding Gua Musang, things could get worse if rising deforestation continues. The primary cause of deforestation is the conversion of tropical forests into commercial and non-commercial agricultural fields, which impacts water bodies (0.36 percent). Many rain catchment areas in the forest in Hulu Kelantan have been destroyed due to the situation, and the hills have been exposed to rain and hot weather.

Table 1.2: Percentage of land use from the year 2017 to 2019

Land use class (2017-2019)	Area (ha)	Percentage (%)
No changes	83241.97	88.12
Deforestation	5613.66	5.95
Due to logging	5264.73	5.57
Forest	5264.73	5.57
Water bodies	341.82	0.36
Total	94462.18	100

(Source: Syafiq Haidar, 2022)

1.2.5 Social Economic

Gua Musang area is covered with many open lands that are usually used for plantation activity, such as rubber trees and oil palm trees. This plantation activity has been a work for the villagers there. Furthermore, there is also a town which been a place for attractive community spots and has many job opportunities for the residents around the area.

1.3 Problem Statement

The updated geological information of the study area is still not mapped on a small scale. The information provided in the present time is very general, such as land use, lithology, drainage pattern and topography. In this study, the geological mapping will be updated and generated on the the1:250000 scale using G.I.S.

Furthermore, Kelantan continues to face water shortages due to low-quality surface water supplies, and the demand for groundwater is rising (Abdullah.,2010). This water problem has a lousy effect on the nearby residential area, including some rural areas in Gua Musang. The water shortages are also affecting the vegetation activity in the study area. This research in some rural areas is vital to identify the groundwater sources identification in limestone for daily usage by receiving it from shallow-dug wells.

1.4 Objective

The objective of the research is as below:

- i) To update a geological map of the research area.
- ii) To identify the groundwater potential in limestone using Electrical Resistivity Imaging (E.R.I).

1.5 Scope of Study

This study is conducted on 6 x 4km Jelawang - Gua Musang, which is 25 km in total. The map is on a scale of 1:25,000. The map provides information on the scale area's geomorphological mapping, structural geology, and lithology.

Meanwhile, the groundwater source identification fulfilled by using the geophysical method. The groundwater sources identification of limestone is using Electrical Resistivity Imaging which uses the pole-dipole array. On top of that, knowledge to evaluate the survey data is necessary for the geophysical study before finalising the survey findings and the scale of the data observed to determine the actual data obtained during the field.

1.6 Significance of Study

The study's the updated geological map of the area achieved. This updated geological map bring benefit to the other researcher as they can use and refer to this map as information about the geology of the study area. The study also provides new findings on the geological features of the study area and can give a further understanding of how the geological processes occur in the area.

Furthermore, groundwater resources account for less than 10% of total water use in Malaysia. In rural and remote locations where, piped water is unavailable. So, groundwater is mainly used for domestic reasons. The state of Kelantan is the only exception, with groundwater providing more than seventy percent of the state's public water supply. Therefore, this study can help find groundwater resources in Gua Musang. This study can also help fulfil the requirement or demand for clean

groundwater for the community around the area. This research help or give an idea to build a new well with the agreement and approval from the higher-ups.

In addition, using Electrical Resistivity Imaging (E.R.I) for groundwater sources is the best method for searching for groundwater in limestone. It is because resistivity imaging can be utilised to provide detailed information about the potential groundwater.



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will focus on the previous study of the researcher that has done the research relating to the study. Sources such as papers, articles, and previous research publications will be used as a reference for this present work.

2.2 Regional Geology and Tectonic Setting

2.2.1 Peninsular Malaysia

Peninsular Malaysia is a core part of the Eurasian Plate, also known as Sundaland in South-East Asia (Hutchison,1996). Sumatra, Natuna, and western Borneo are all a part of the same plate, and all comprise the Sunda Shelf, which reaches eastward and southward and has a water depth of fewer than 200 metres. The Sunda Shelf's northern and southern edges meet slightly east of Vietnam, bending to the east until they reach the West Baram Line (Hutchison, 2004, 2005). The continental slope-rise, composed of continental crust that weakens even more to the east, is located east of the Shelf's margin. This deep-water area with numerous reefs is designated as "Dangerous Grounds" on navigational charts.

The Sibumasu Terrane in the west and the Sukhothai Arc (East Malaya Block), which the Late Triassic brought together, are the two tectonic blocks/terranees that form Peninsular Malaysia. Peninsular Malaysia is an essential part of Sundaland's Southeast

Asian continental core (Metcalf, 2013). Sibumasu and East Malaya are divided by the Bentong-Raub Suture Zone, which is composed of ribbon-bedded cherts, schists, and tiny ophiolites that reflect Palaeo-Tethys remnants (Hutchison, 2009).

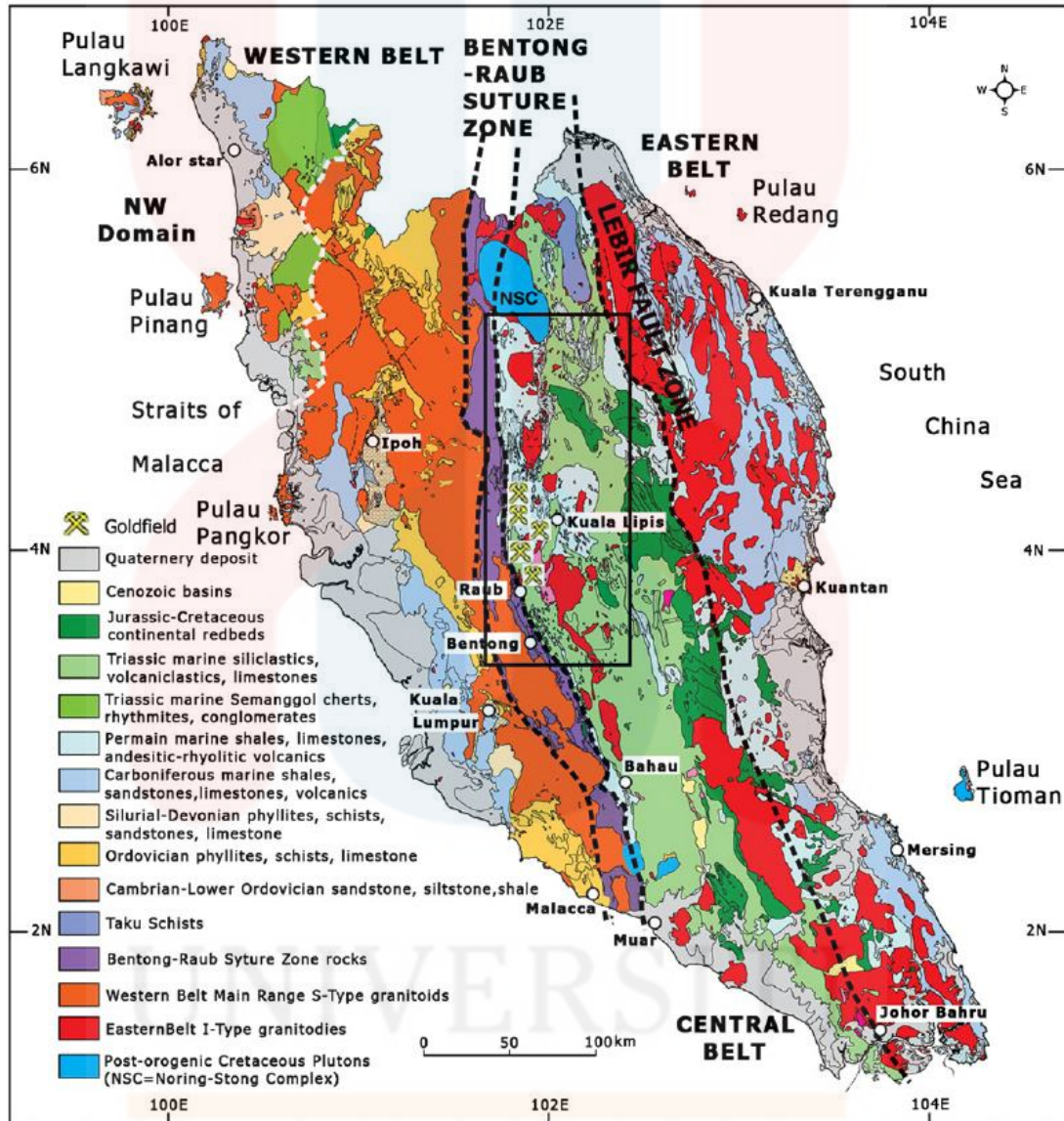


Figure 2.1: The simplified geological map of Peninsular Malaysia (source: modified map by Metcalfe (2013))

The state of Kelantan is located in north-eastern Peninsular Malaysia. Igneous, sedimentary, and metamorphic rocks, among others, are scattered in a north-south trend throughout the state of Kelantan. The four major types of rocks in the area are granitic rocks, sedimentary/metasedimentary rocks, extrusive rocks (volcanic rocks),

and unconsolidated sediments (figure 2.2). Folding, faulting, and jointing in sedimentary rocks, as well as faulting in granitic rocks, are examples of localized geological features. Granitic rocks may be found along the western (Main Range granite) and eastern (Boundary Range granite) edges of the state of Kelantan (Rahman and Mohamed, 2001; Department of Minerals and Geoscience Malaysia, 2003; Heng et al., 2006).

2.2.2 Gua Musang

The largest district in Kelantan, Peninsular Malaysia, known for its gold mineralization, is called Gua Musang. As a result of the location's mix of forest and sparsely vegetated land cover, rock exposure is quite minimal. Gua Musang is situated in the core geological formation, south of the state, which is characterized by Triassic and Permian sedimentary rocks. a metamorphic rock outcrop in the southwest and an igneous rock outcrop in the north-central area. (Kouame Yao et al.,2017)

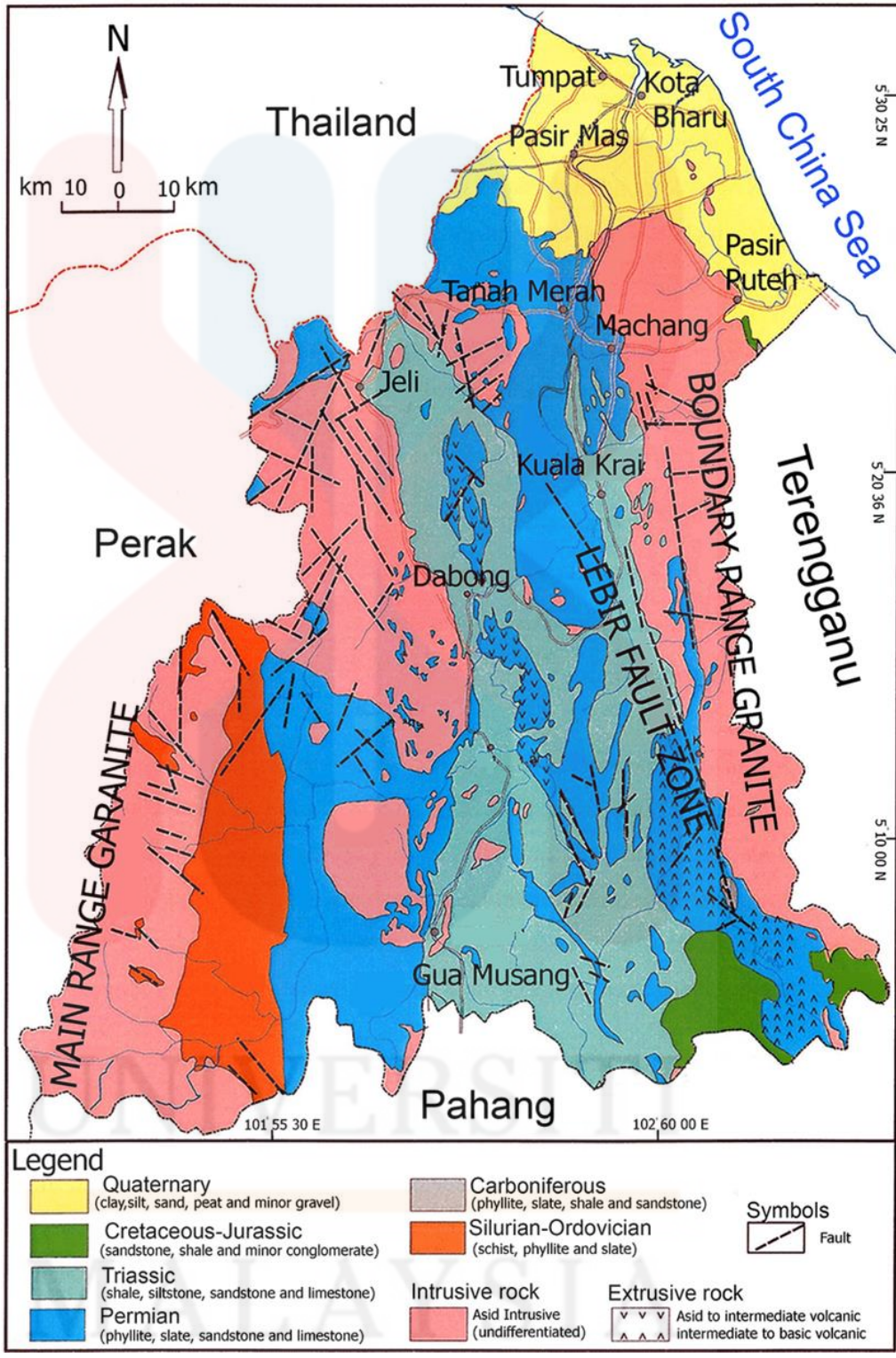


Figure 2.2: The geologic map of the Kelantan state (modified from Department of Minerals and Geoscience Malaysia, 2003)

2.3 Stratigraphy

Gua Musang, Kelantan, is part of Peninsular Malaysia's Central Belt, spanning from Kelantan to Johor. The western portion of the Central Belt contains upper Palaeozoic rocks from the Gua Musang and Aring Formations in south Kelantan and Taku Schist in east Kelantan (Hutchison & Tan., 2009).

A large segment of the Peninsula's newly formed landmass was uplifted during the beginning of the Mesozoic Era and remained subaerially exposed. Marine sedimentation was concentrated in the Koding-Semanggol depocentre in the northwest and the Gua Musang-Semantan depocentre in the Central Belt. The former was the only remnant of a large expanse of marine deposition that existed throughout the Late Palaeozoic and was formed on the Upper Palaeozoic Sibumasu continent. The Gua Musang-Semantan epicentre, which emerged on East Malaya's Upper Palaeozoic shelf, was geographically more extensive.

The Gua Musang-Semantan depocentre's extensive occurrences of tuff and related lava, tuffaceous siliciclastics, and conglomerate throughout the Triassic period show volcanic activity and basinal instability were active during the basin's lifespan. Geologists refer to the rocks in the deeper regions of the Gua Musang-Semantan depocentre as flysch because of dense accumulations of turbidites (Nuraiteng Tee Abdullah, 2009)

According to Yin's (1965) , the thin layers of chert nodules, subordinate sandstone, and volcanic are interbedded with the crystalline limestone of the Gua Musang Formation, which is thought to be 650 meters thick. Calcitic limestone has a light grey color and is hard, non-porous, brittle, and splintery. Recrystallized limestone is often grey to black in colour and has only trace amounts of carbonaceous, argillaceous, and pyroclastic impurities.

A conglomerate-sandstone sequence constantly lies beneath rocks and identified as the Gua Musang Formation to the west of Gua Musang town in the Kuala Betis region. According to estimates, limestones in Gua Musang compensate for around 80% of all the exposed rocks in the Gua Musang-Merapoh region. However, their abundance declined as one moved north and south.

2.4 Structural Geology

According to Dony et al. (2015), tectonic activities in Peninsular Malaysia throughout the Paleozoic and Mesozoic eras mainly affected the formation of faulting and folding, which in turn had an impact on the land mass. In sedimentary and igneous rock, faulting and folding have been found to be confined structures that combine folding, jointing, and faulting.

Within continents, on island arcs, and at continental edges, strike-slip faults can locally create compression or extension. Sedimentary basins will form along strike-slip faults when the fault kinematics diverge from the plate vector (Noda,2013)

Major faults are the main structural geological feature in Gua Musang. The two classes of this major fault are the Terrane-crossing faults and the Terrane-bounding faults, which include the Lebir Fault Zone and the Bentong-Raub Suture Zone (Galas fault Zone).

The faults that divided the Peninsular to create a terrane are known as the terrane-bounding faults (Mustafa, 2009). The Bentong-Raub Suture Zone is a 20 km broad fractured rock that may be seen along the Gua Musang-Cameron Highlands route. Within this suture, there are seven tectonic units, and as a result of their recurrence, an imbricate structure was created (Tjia & Almashoor, 1996). The Taku Schist extends 10 km to the east of the Lebir fault zone, which is located close to Kuala

Krai (Mustafa, 2009). In relation to the other major faults in Peninsular, this Lebir fault Zone is regarded as the dextral strike-slip terrane-bounding fault. The Galas fault Zone, which extends from Thailand to the Tembeling region with trends from 300° to 340° , is the next set of terrane-crossing faults. These faults control the Kemahang granite and the Stong Complex.

In addition, the Gua Musang region has a structure that like folding. For instance, a refolded fold was discovered in the Gua Musang-Pulai junction, where the Permian to Middle Triassic age sequence of well-bedded tuffaceous siltstone, sandstone, and small lenses of limestone are revealed.

2.5 Historical Geology

East Malaya joined the Indochina plate during the Carboniferous, whereas Sibumasu joined Gondwana and joined the Cimmerian plate. Sibumasu and East Malaya blocks, on the other hand, were divided by an ocean from the Devonian to the Permian, becoming the Palaeo-Tethys. The Palaeo-Tethys were sealed off during the Triassic period. However, the Gua Musang Formation began in the Middle Permian and continued until the Upper Triassic (Mohd Shafeea Leman, 1994 and 2004).

According to Mohammad et al. (2016), during the Early Permian, thick argillite and volcanic deposits were laid down close to the Indochina volcanic arc. The accretionary complex was formed as a result of the Paleo-Tethys subduction event. The Middle-Late Permian thick argillite and volcanics produced the shallow marine habitat of Gua Musang.

The development of the benthic fauna and carbonate systems are related to this environment. Early Triassic forearc sinking in the Gua Musang platform increased, providing more space for the deposition of carbonate-argillite-volcanics. As Sibumasu anchored in Indochina, the Paleo-Tethys Ocean underwent total subduction. The deep

Semantan-Gemas basin was formed in the Middle-Late Triassic as a result of the oblique subduction of Sibumasu, which aided the process of basin segmentation on the subsiding Gua Musang Platform.

The Malay Basin experienced sinistral strike-slip fault activity during the Permian epoch, which led to the crustal extension (Tija,1994). This causes graben, also known as pull-apart basins or Central Basin, to form. During the Triassic period, sediments were first deposited in the basin. Only fine-grained marine sediments are deposited during the early stages of deposition; later, coarser continental sediments are created throughout the Jurassic to Cretaceous periods (Metcalf I., 1982).

2.6 Research specification

2.6.1 Groundwater

Groundwater is a widely used and significant water source to meet the rising demand for water for industry, agriculture, and industrial needs. Groundwater is naturally occurring water that forms under the surface due to surface water interacting as a recharging agent. Groundwater makes up around 97 percent of all the liquid freshwater available for human use and roughly 22 percent of the total freshwater on Earth (Foster, 1998). Groundwater is a crucial source of water supply for both rural and urban areas in any nation due to its consistent availability and good natural quality (Todd and Mays, 2005)

Natural water supply must include groundwater as a vital component. Groundwater is subsurface liquid that seeps through cracks in rock formations and soil pore spaces. It is regarded as an alternate water supply for all living things. (Muchingami et al.,2012). Only 0.61 percent of the total distribution of the world's

water supply is made up of surface water, which is around 50–70 times more abundant (Fetter, 1980).

Clean water has become a significant demand in these recent years. Identifying potential groundwater, especially in rural areas, is crucial. Groundwater is found beneath the ground and is significantly more extensive and better in quantity and quality than surface water sources such as lakes and rivers. One of the most important reasons for locating a groundwater resource is that groundwater is the ideal option when surface water is running low or is of poor quality (Muhammad Haziq Razak et al., 2020).

Both groundwater and surface water were utilised as water resources in Kelantan. Compared to rural areas, where surface water resources are preferred, groundwater resources are exploited more frequently in urban areas. Both resources are utilised to preserve water supplies. While other states like Terengganu, Pahang, Sarawak, and Sabah used groundwater as a supplemental water resource, Kelantan and Perlis made extensive use of it as a source of freshwater (Nazri Ebrahim et al., 2020)

Due to its excellent natural ability to recharge groundwater, groundwater can be found in alluvial plains. A large expanse of flat land surfaces known as an alluvial plain is formed when sediments like sand, silt, and clay are deposited there. The highland sediments that have eroded as a result of weathering are transferred to the lowland by water flowing there, where they are slowly deposited over time until the sediment amount increases and alluvial soil is formed (Sulaiman, 2021)

2.6.2 Electrical Resistivity Imaging (E.R.I.)

The 2-D resistivity method is a survey that determines potential differences caused by current flowing through the ground. Two current electrodes conduct current

into the background, allowing another two potential electrodes to measure the potential difference (Muztaza et al., 2012)

In many geological situations, 2D electrical imaging surveys can provide information that complements that obtained by other geophysical methods. Conventional arrays, such as Wenner, Schlumberger, or dipole-dipole arrays, are often utilised in 2D electrical imaging surveys (Figure 2.2). The depths of investigation, lateral and vertical resolution and signal-to-noise ratios of these arrays are frequently well understood. Currently, 2D surveys are the most cost-effective compromise between obtaining accurate data and keeping survey costs low. (Hussein, 2015).

The resistivity value is divided into three layers or zones. Topsoil is defined as the first zone with a moderate to high resistivity value (100–1000 Ωm) and a colour of orange to purple near the surface. Resistivity values below topsoil are exceptionally high, ranging from 300 to 2000 Ωm. The third layer is 100 metres below the surface and has a low resistivity profile (10–100 Ohm metres). The colour of this stratum ranged from brilliant green to yellow (Suryadi et al., 2019).

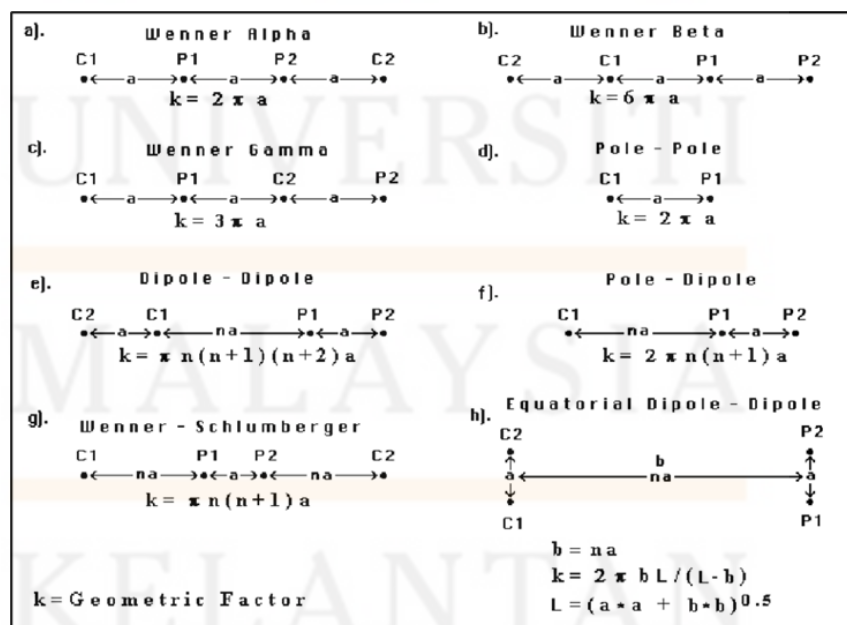


Figure 2.3: Common arrays used in resistivity surveys and their geometric factors. (Source: Loke,1999)

2.6.3 Electrical Resistivity Imaging (E.R.I) in Groundwater Exploration

Geophysical studies of groundwater frequently employ the electrical resistivity approach. It is due to the apparent relationship between electrical properties, geologic formations, and fluid content (Flathe, 1955, 1970; Zohdy, 1969; Zohdy et al., 1974). Engineers must pinpoint the exact position of the groundwater accumulation zone in the subsurface layer to solve the problem. The 2-D resistivity approach is a type of geophysics employed as the first step in any groundwater investigation. Groundwater information can be produced with the help of supporting borehole data and 2-D resistivity inversion (Muhammad Haziq and Nordiana., 2020).

The study used Wenner, Schlumberger, and a pole-dipole array configuration and was based on earlier research by N. Sulaiman et al. (2017) in Lojing, Gua Musang. The data collection indicates that although the location is not in a broken zone, it has a significant groundwater potential based on the low resistivity value for each line survey, that presence in the 2-D profile from all the line surveys.

The resistivity method is one of the geophysical survey techniques that has been shown to locate the possibility of groundwater occurrence (Oseji et al., 2005). This approach included the subsurface composition, layering, and interpretation of the soil characteristics, structure, and cavities or bodies of different geological contexts based on the physical attributes found underground (Dor et al., 2011). It may also establish the depth, border, and thickness of an aquifer (Omosuyi et al., 2007). Sulaiman (2021) makes an evaluation of the existence of groundwater in the hard rock area.

In North Kelantan, the type of landform that includes alluvium controls the quantity of groundwater. In contrast to the studied area, which has hard rock, alluvium

has unconsolidated material properties and can withstand water. Groundwater in hard rock can be found where there are fractures and pores in the rock that can store and accumulate and store water. Electrical Resistivity Imaging (E.R.I.) can be used to detect the presence of groundwater. Since each material has a different resistivity value, the E.R.I. method could be used to ascertain the subsurface material and condition.

Dony et al. (2016) research combining geology and geophysical methods has successfully identified potential groundwater zones in their study area. These combination methods are reliable and suitable for groundwater exploration.

CHAPTER 3

MATERIAL AND METHOD

3.1 Introduction

All the information and methods adopted to carry out the research have been thoroughly covered in this chapter. The research's methodology is explained and was a crucial component demonstrating how the study progressed adequately. The information used in the research to accomplish the objectives is shown in Figure 3.1, and it also includes a flowchart outlining the general methodology used for this study.

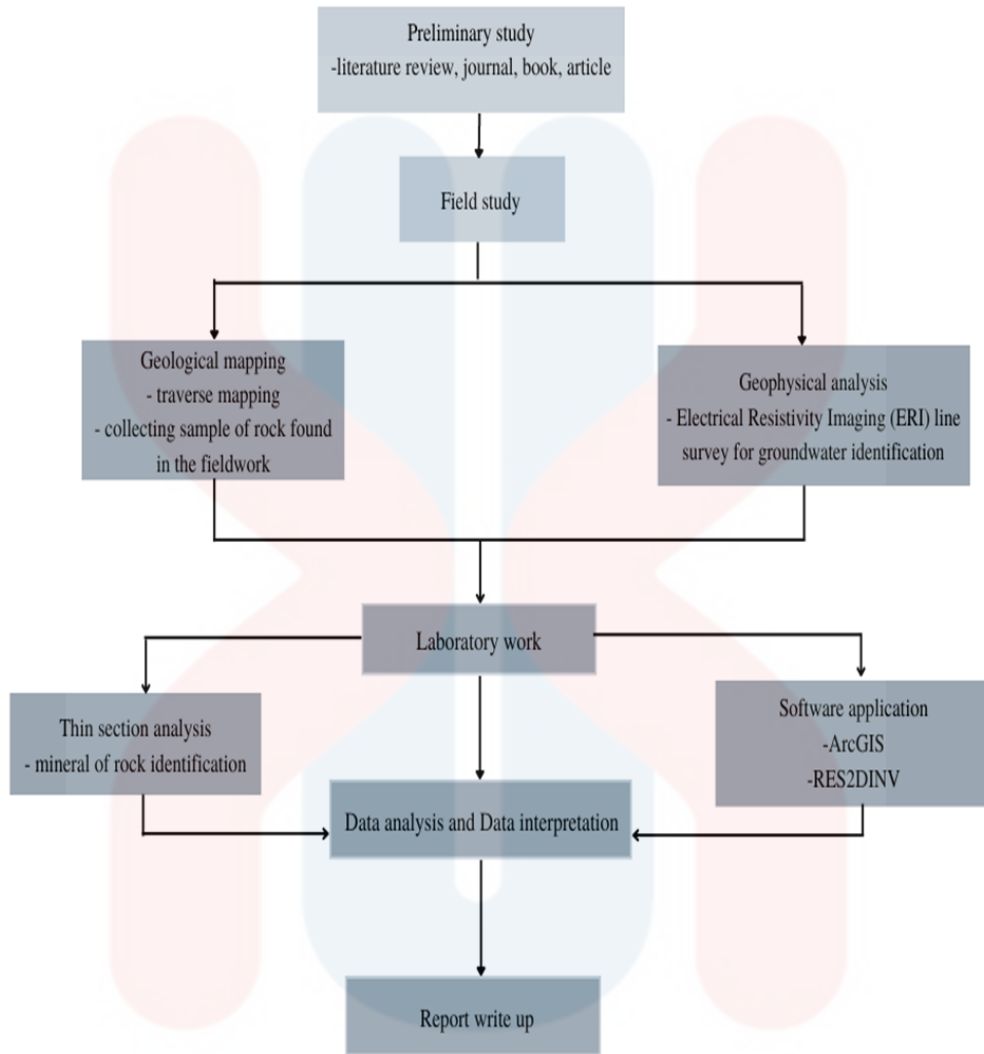







Figure 3.1: The research flowchart

3.2 Material/Equipment

Table 3.1: The table of the material and equipment used in the study

Material and equipment	The use of the materials and equipment	Picture
Global Positioning System (G.P.S.)	Use to measure the longitude, latitude, altitude, velocity and time. This equipment is used when conducting geological field mapping for finding the place, storing sampling points, tracking structures	
Brunton compass	Use for measurement of strike and dip of geological features such as fault, fold and sedimentary strata	
Hand lens	Use to find the mineral crystal that cannot be observed by the naked eye.	
Geological Hammer	This equipment is to collect the rock sample.	
Geophysical equipment <ul style="list-style-type: none"> - ABEM LS-1 terrameter - Electrode and Clip - Battery - ABEM multi core cable 	This equipment is for conducting the geophysical analysis in the study area	
Hydrochloric Acid (HCl)	This quick field test used to distinguish the most common carbonate rocks, dolomite, and limestone	

3.3 Methodology

3.3.1 Preliminary Study

This research done by doing a preliminary study, which is getting the information through internet sources, books, and journals. This preliminary study aims to get information on the existing geology of the study area from the previous research. The base map is also being prepared to use during the fieldwork.

3.3.2 Field Studies

a) Geological Mapping

During the fieldwork, mapping and groundwater source identification has been conducted. The mapping tools such as compass and G.P.S. used to traverse. It includes studying the study area's lithology, morphology, structure, and stratigraphy. To observe and determine the lithology in the field, H.C.L. is used to identify the existence of calcite in limestone carbonate. The rock sample are marked on different minerals found in the field mapping and brought to the laboratory. The outcrop from in the study area are being observed for weathering classification.

b) Electrical Resistivity Survey

The Electrical Resistivity Imaging (E.R.I.) technique is being used in the geophysical method to locate groundwater sources. The survey used multi-electrodes with a 5-meter electrode spacing. The centre of the line survey is the resistivity meter ABEM. The line survey spreads 200 meters with 4 line survey from the study area when it is put out in a straight line. The pole-dipole array, which collects more information about the subsurface throughout the survey, is the type of array employed

in the study. Therefore, during data processing, very accurate data can be created. The ABEM electrical current injected into the ground from the electrode planted into the surface. The resistivity reading then appeared on the ABEM. The data obtained from the ABEM then be generated in 2-dimensional imaging. To create this imaging, the software that is RES2DINV must be installed. The values of the interpreted resistivities from the software show a colour scale and depths. Figure 3.2 shows the equipment for electrical resistivity imaging (E.R.I).

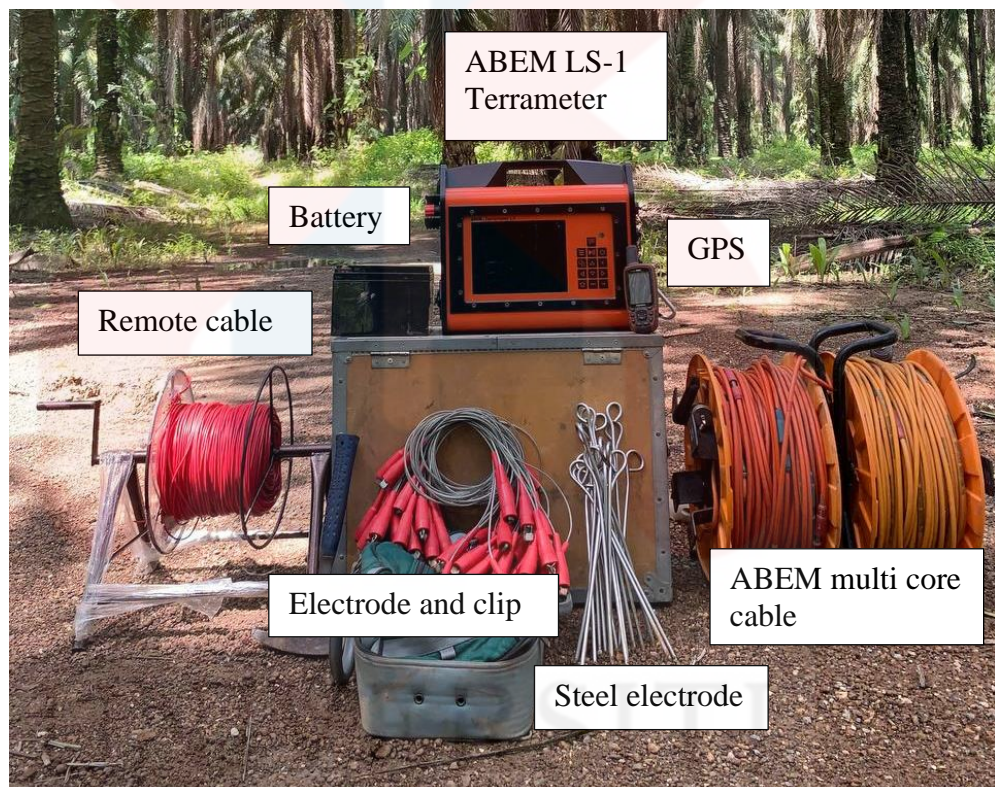


Figure 3.2: The equipment for electrical resistivity imaging (E.R.I).

3.3.3 Laboratory Work

The hand sampling of the rock was sent to the laboratory to get the rock's components and minerals from the rock's specimen. The rock is first polished into fine particles to see if the rock particles can be in thin sections. A thin section, petrography analysis, and software analysis to conduct the laboratory investigation. Petrography

analysis on the rock sample is determine the mineral content and textural relationship within the rock.

The thin section was observed under the microscope, observed the mineral under plane polarised light (P.P.L.) and cross polarised light (X.P.L.) to identify the type of mineral in the different light of the microscope.

3.3.4 Data Processing

All the geological mapping data is then processed using RES2DINV, ArcGIS, GeoRose, and Stereonet to provide the intended results. Based on the strike and dip information collected in the field, GeoRose and Stereonet are utilised to analyse the structural geology to describe the direction of the force acting on the research region. The updated geological map of the research region was created using ArcGIS. To determine the groundwater potential zone, the pseudo section of the research area's apparent resistivity was displayed using RES2DINV.

3.3.5 Data analysis and data interpretation

The data obtained from the fieldwork and laboratory interpreted as the general geology in the study area. Geomorphology, structural, and lithology combine and are generated into a map using ArcGIS software. All the information on the geology of the study area and the rock found in the study area are being interpreted as new information.

Data from the geophysical method of Electrical Resistivity Imaging (E.R.I.) are being generated into 2-dimensional imaging using RES2DINV. The E.R.I. value interpretation is based on inversion and forward modelling. The data collected from the survey line was measured, computed, and inverted using RES2DINV software to

obtain a more accurate groundwater potential. Resistivity value from Loke, 2015. Table 3.2 and Figure 3.3 are being observed as a guide to some common rocks, minerals, chemicals, and metals. Meanwhile, figure 3.3 shows the electrical conductivity and resistivity of common rocks.

Table 3.2: Resistivity value for some common rocks, minerals, chemicals, and metals

Material	Resistivity ($\Omega \cdot m$)	Conductivity (Siemen/m)
Igneous and Metamorphic Rocks		
Granite	$5 \times 10^{-3} - 10^6$	$10^{-6} - 2 \times 10^{-4}$
Basalt	$10^{-3} - 10^6$	$10^{-6} - 10^{-3}$
Slate		$2.5 \times 10^{-8} - 1.7 \times 10^{-3}$
Marble	$6 \times 10^2 - 4 \times 10^{-7}$	$4 \times 10^{-9} - 10^{-2}$
Quartzite	$10^2 - 2.5 \times 10^8$ 2 - 8 10 - 2×10	$5 \times 10^{-9} - 10^{-2}$
Sedimentary Rocks		
Sandstone	$8 - 4 \times 10^3$	$2.5 \times 10^{-4} - 0.125$
Shale	$20 - 2 \times 10^3$	$5 \times 10^{-4} - 0.05$
Limestone	$50 - 4 \times 10^2$	$2.5 \times 10^{-3} - 0.02$
Soils and waters		
Clay	1 - 100	0.01 - 1
Alluvium	10 - 800	$1.25 \times 10^{-3} - 0.1$
Groundwater (fresh)	10 - 100	0.01 - 0.1
Sea water	0.2	5
Chemicals		
Iron	9.074×10^{-8}	1.102×10^7
0.01 M Potassium chloride	0.708	1.413
0.01 M Sodium chloride	0.843	1.185
0.01 M acetic acid	6.13	0.163
Xylene	6.998×10^{16}	1.429×10^{-17}

(Source: Loke, 2015)

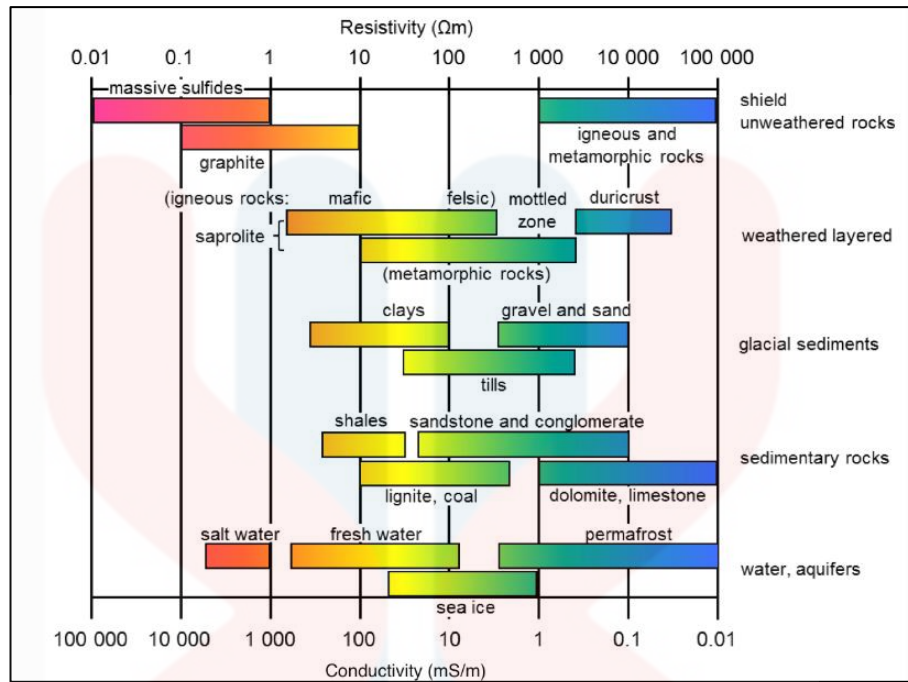


Figure 3.3: The electrical conductivity and resistivity of common rocks.

(Source: EM, Geosc.xyz (2018))

3.4 Report

The research report writing consists of chapters 1, 2, until 6. The information on the research study consists of the background study, introduction, scope, and significance until the study area is written up in chapter 1. Chapter 2 of the research study consists of a literature review of the previous research related to this study. This literature review helps to collect the information to conduct the investigation. Chapter 3 is a write-up of material and method that provides information on the methodology and the material used to succeed in the study. The updated map of the study area including the data of general geology will be in chapter 4. Chapter 5 discussed about the research specification with the result of study.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter cover the general geology of the study area. All geological factors include geological mapping, geomorphology, structural geology, and historical geology of the study area. A field survey at the study area, Kampung Sungai Terah, conducted the mapping. This chapter will gather all the data about the general geology of the study.

4.1.1 Accessibility

Accessibility defined how approachable and ease it is to get to a location in comparison to another location. Accessibility is also determined by people and has an impact on regional growth, transportation regulations, and infrastructure. The land use system and road network are directly related geographically in the Kampung Sungai Terah area. All of the destinations are connected by the roads. There are two different sorts of roads: the main paved ones, which large cars may use, and the unpaved ones, which only small vehicles like motorbikes or four-by-fours can use. The primary paved road connecting Gua Musang town in the south to the Kampung Sungai Terah area is known as Jalan Jelawang-Gua Musang. The palm oil and rubber plantation area is accessible via the unpaved road. The research area's communications infrastructure is

very accessible, but it still relies on local factors, and there may be some areas there that have poor coverage.



Figure 4.1:The trail in the palm oil plantation area with high vegetation.



Figure 4.2:The Major Road of Jelawang – Gua Musang.

4.1.2 Settlement

Settlement includes the locations and areas that are populated by a community of people. The Kampung Sungai Terah, which is in the east, is one of the primary settlements that is covered and situated in the research area. The site is covered with palm oil plantations which are Ladang Sungai Terah. There is a village area surrounded by a school and a mosque. Ladang Kelasa office and factory also manage the plantation activity in that area.



Figure 4.3: Picture of the school in the study area (S.K. Sungai Terah)



Figure 4.4: Picture in front of the palm oil factory in Sungai Terah.

4.1.3 Vegetation

Gua Musang is a small town deep in the jungle of central Kelantan, and the district is a rural area. The total area of Gua Musang is about 7980 km². Gua musang is a town that is covered with plantation and vegetation activity. Most villagers or communities in that area do plantation activities such as palm oil plantation, rubber

tree plantation and logging activity. There is also another settlement in the small town of Gua Musang. The land use in Gua Musang is at 88.12%, which has not changed significantly from 2017.



Figure 4.5: Picture of vegetation in the study area.

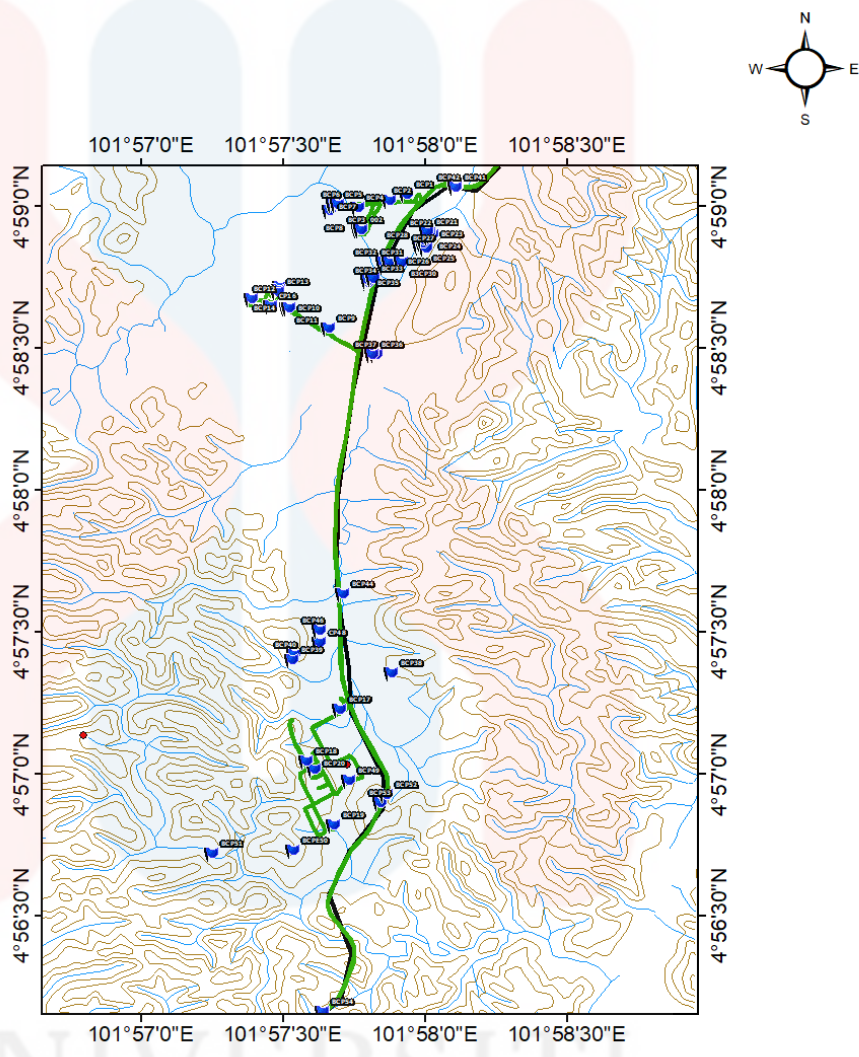
4.1.4 Traverse and observation station

During the mapping process, traversing and observing techniques are used to gather geological information, sample rocks, and measure them. Before entering the field, a well-planned traverse path was established to ensure the success and effectiveness of the geological mapping processes. For the research region, the entire geological fieldwork procedure takes about 4 days to complete and collect the geological data.

Observations were made while traversing by observing out for any changes from the lithological and geological formations' set patterns. A field notepad was used to record every observation, and a GPS device was used to follow the traverse path. Following that, the traverse route was plotted on the map in Figure 4.6.



TRAVERSE MAP OF KAMPUNG SUNGAI TERAH, GUA MUSANG, KELANTAN



Legend

• Village	Points
— Main Road	Waypoint
— Countour	check point
— Stream	

1:25,000

0 0.5 1 2
Kilometers

Figure 4.6: Traverse map of the study area

4.2 Geomorphology

Geomorphology studies the physical characteristics of the earth's surface and how it relates to its geological structures. The study of geomorphology explains the landform changes in geology, floodplain area, drainage pattern area and watershed, which formed from the rainfall flow. It also includes topographic analyses and features because of the different landforms and the physical, chemical, and biological processes that influence the surface or the landscape. Geomorphology in the study area includes the undulating hill and drainage pattern.

4.2.1 Geomorphology classification

The categorisation and definition of the landforms' existence, origin and growth is a geomorphic classification. The geomorphological classification is based on the type of landform that exist in the study area. A landform is a surface feature that is a part of the terrain. Plains, plateaus, mountains, and hills are the four main types of landforms.

From the map in figure 4.8, the area consists of different elevations. The study area covered by high hill with high elevated area which the highest peak is at 276 m above sea level. Meanwhile, the lowest elevation in the study area is at 77 m above the sea level. The stream that exists in that area are in dendritic and trellis pattern. Table 4.1 depict the elevation range with the colour in elevation map of the study area. Meanwhile, figure 4.7 shows a picture of morphology from the hill area in the study area.

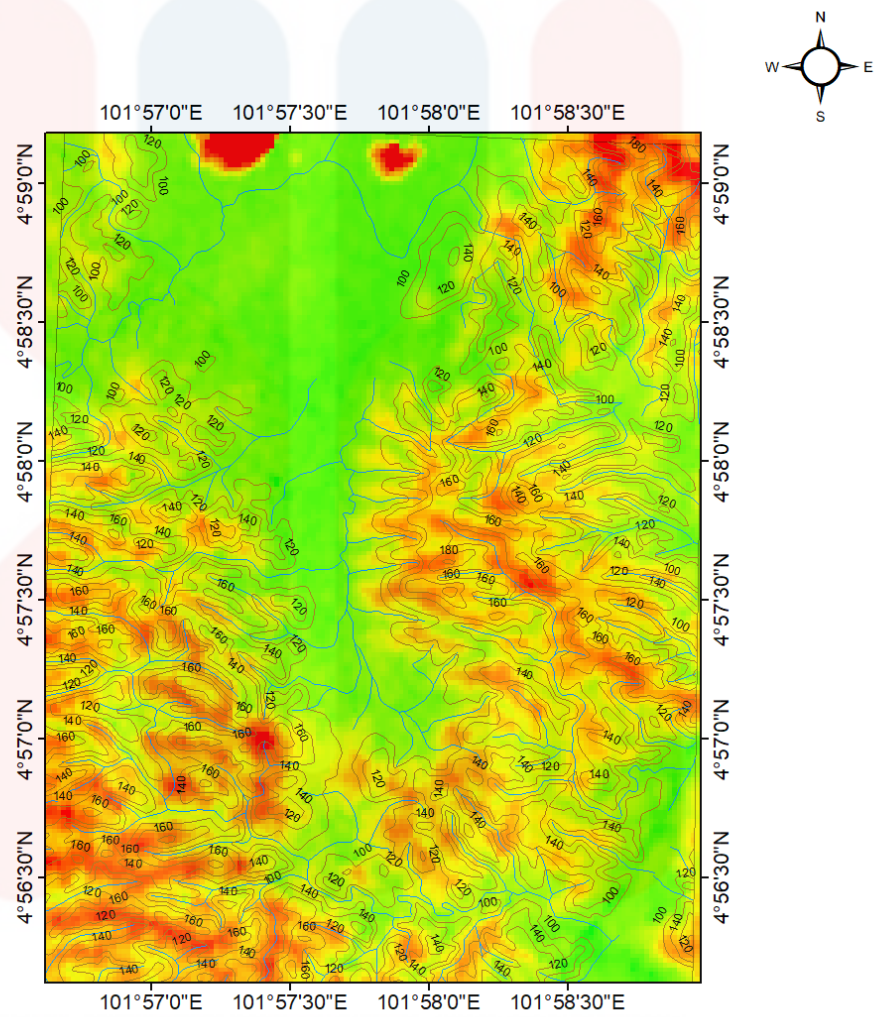


Figure 4.7: Hill morphology at station 38 of the study area

Table 4.1: The table indicating the landform base on the elevation map of the study area.

NO	GEOMORPHOLOGICAL UNIT	SYMBOL	LANDFORM	ELEVATION (m)
1.	Peak		Hill	180-276
2.	Steep hills		Low Hill	130-170
3.	Sloping hills		Low-lying plain	100-129
4.	Slightly sloping plain		Lowland	75-99

ELEVATION MAP OF KAMPUNG SUNGAI TERAH, GUA MUSANG, KELANTAN



Legend

	Countour	Elevation (meters) Value
	Stream	
		High : 276 Low : 75

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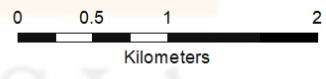


Figure 4.8: The elevation map of the study area.

4.2.2 Weathering

Weathering is a breaking down or dissolving process of rock and minerals on the earth's surface. Water, ice, acids, salts, plants, animals, and temperature changes are weathering agents. Weathering processes transform the physical and chemical characteristics of the original rocks into soils or smaller fragments of rock known as sediment. Chemical weathering, biological weathering, and physical weathering are the three forms of weathering. When erosion promoters and other weathered elements are removed, which exposes them to additional weathering, weathering can weaken and make rocks more porous, increasing their vulnerability. Malaysia is generally on the equator line, with a humid and warm temperature all year round. The factors influencing the weathering rate include material, climate, chemical composition, and surface area. Table 4.2 shows weathering grade used as reference to interpret the weathering classification.

Table 4.2: The weathering grade

Grade	Terms	Description
I	Fresh	No visible sign of rock material weathering; perhaps slight discolouration on major discontinuity surfaces.
II	Slightly weathered	Discolouration indicates weathering of rock material and discontinuity may be somewhat weaker externally than in its fresh condition.
III	Moderately weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as a core stones.
IIII	Highly weathered	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as a core stones.

V	Completely weathered	All rock material is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact.
VI	Residual soil	All rock material is converted to a soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported

(Source: Agnese Kukels, 2011)

From the observation in one of the outcrops found in the study area, the weathering grade are in grade 5 and 6 (figure 4.9). The upper part of the outcrop are in grade 6 while the outcrop in the below part of the outcrop is grade 5. The outcrop graded as in grade 6 because the material is completely covered with soil. When use a hammer to hit the outcrop, it just a residual soil without any existent of rock. Meanwhile, the grade 5 is completely weathered where the rock material has decomposed into soil. However, the original mass structure is still largely intact.

The outcrop in figure 4.9 going through a physical weathering or mechanical weathering it refers to process of shattering large rock into small ones. The rocks may fracture and break due to the various climatic conditions, such as hot days and cool night. The human activity such as excavation, speed up the process of weathering. The excavation activity can be proof as it has left a trace on the outcrop at the below part of the outcrop.

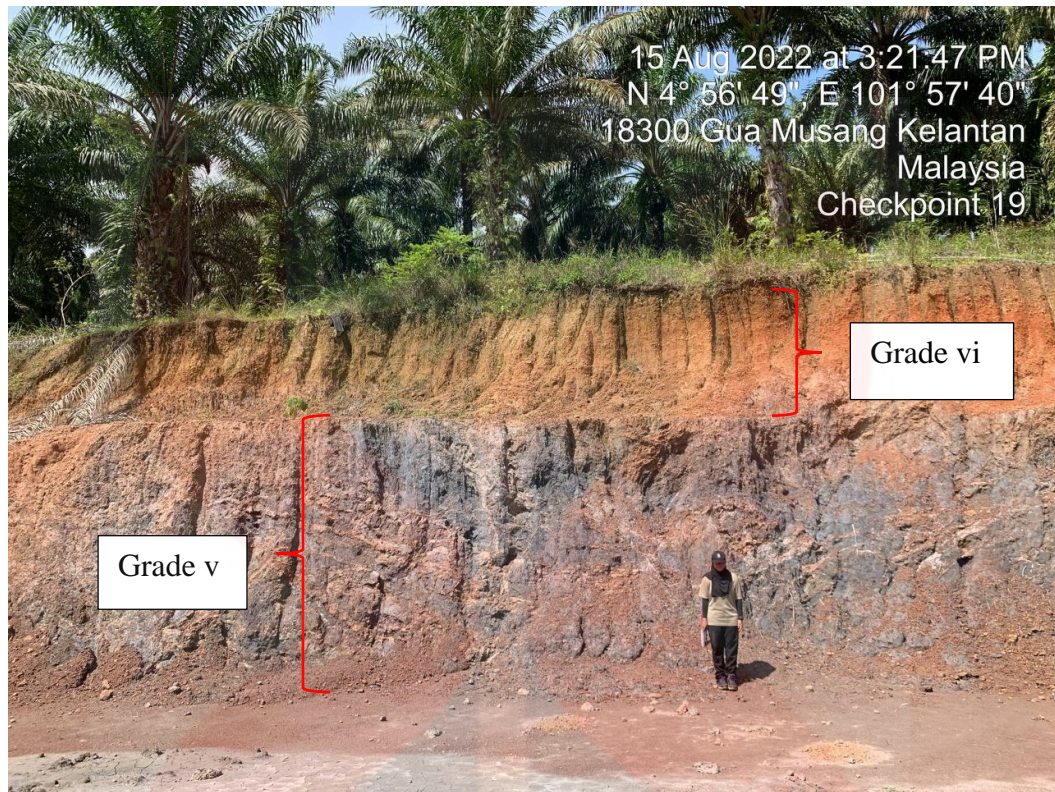


Figure 4.9: The picture of weathering outcrop at station 19 in the study area

There is also a biological weathering in Figure 4.10. Biological weathering may occur with the assistance of the fauna and flora of the landscape. Furthermore, the outcrop got root encroaching on the rocks' surface and securing them.

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Figure 4.10: The outcrop of biological weathering that occur because of the root plant.

Furthermore, chemical weathering is the process of decomposing rock by chemical changes, which changes the composition of the rock. Carbonation is a type of chemical weathering that is present in the studied region (Figure 4.11).

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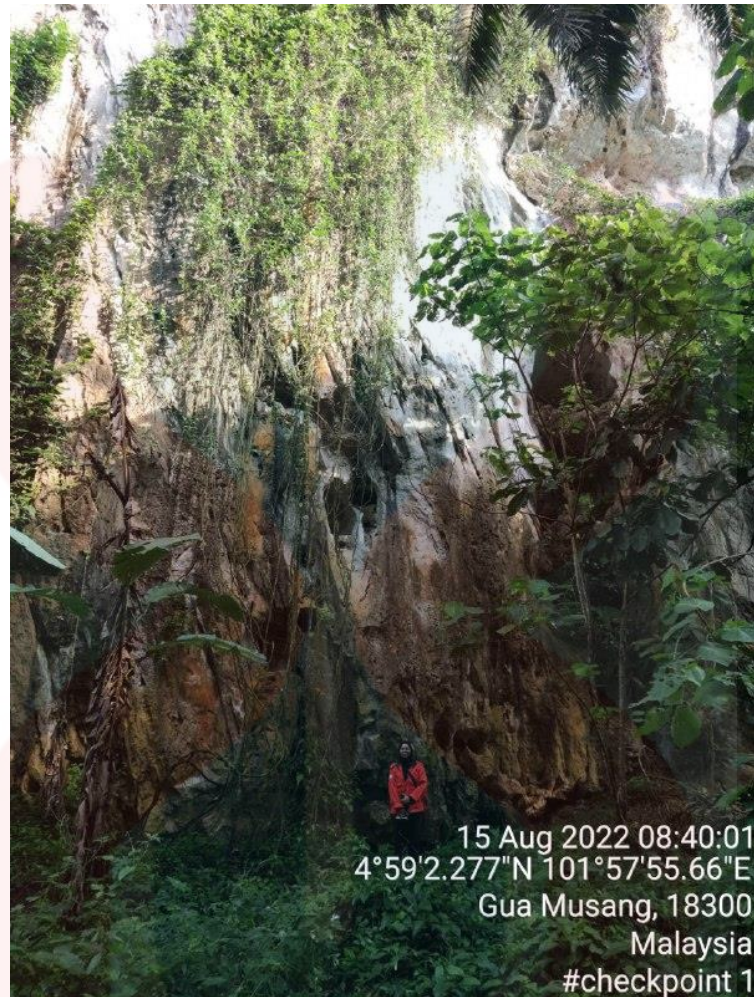


Figure 4.11: The outcrop of chemical weathering because of carbonation.

4.2.3 Drainage

The characteristics of the rocks and geological formations that were present in a landscape region that was drained by streams throughout time by stream erosion are revealed by the drainage pattern. A specific drainage basin's drainage pattern is made up of streams, rivers, and lakes. They are influenced by the topography of the terrain, which includes factors like the dominance of hard or soft rocks and the gradient of the ground.

The trellis and dendritic drainage pattern may be seen on the map of the research region (Figure 4.12). When a valley is eroded along the strike of a less durable formation by a subparallel stream, this results in a trellis drainage pattern. It forms in

folded terrain and shows as parallel troughs of weak rock between ridges of strong rock. Most of the rocks are limestone, and there is joint structural geology in that area.

In the studied region, 30% of the drainage pattern is dendritic. In the drainage area, there is joint structural geology. Shale, limestone, and slate are the types of rock that are present. The branching tree observed in areas with homogeneous material resembles the dendritic drainage pattern. It can form when the rock (or unconsolidated material) underneath the stream lacks any unique fabric or structure, allowing it simple to erode in all directions.

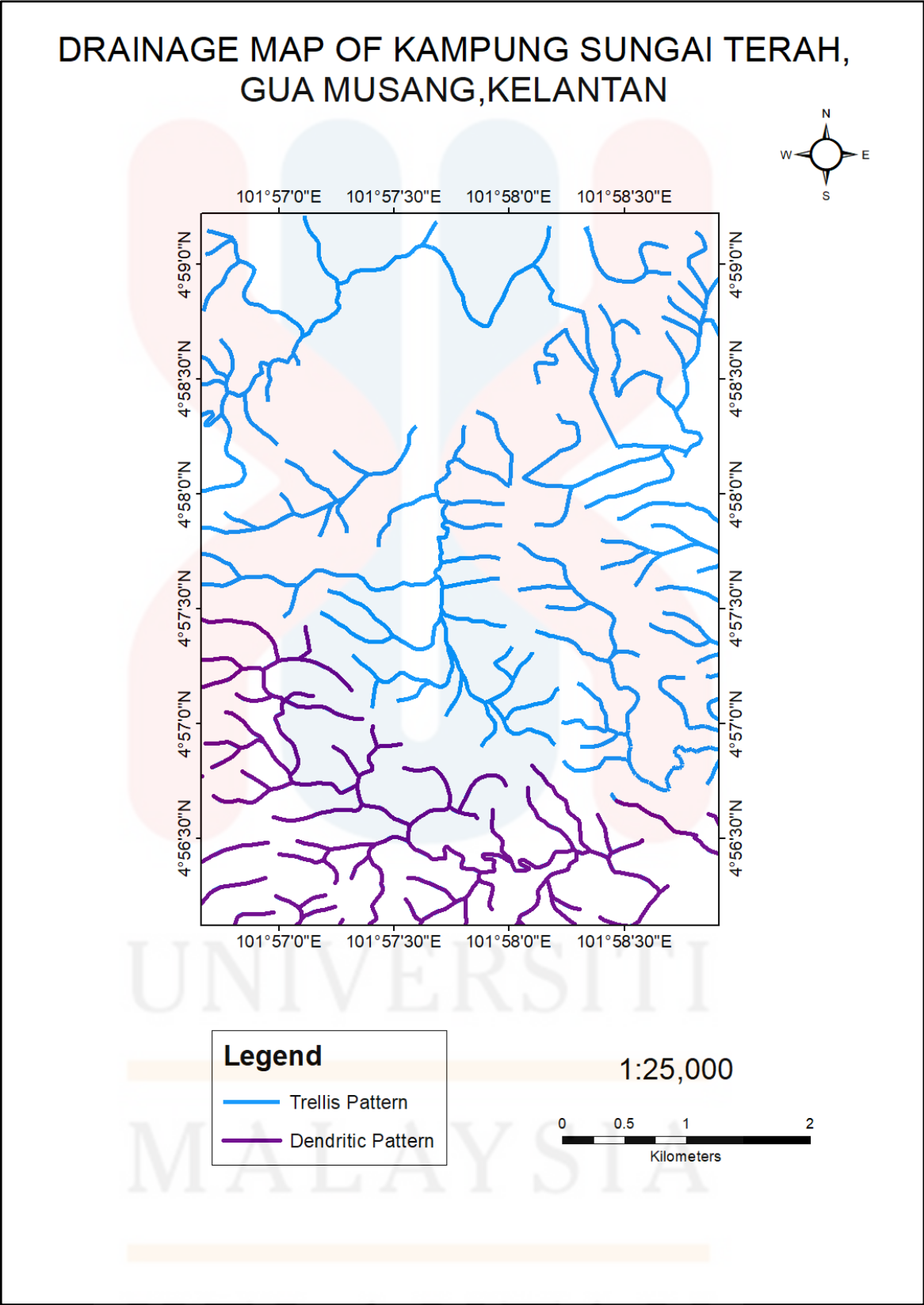


Figure 4.12: The drainage map of the study area.

4.3 Lithostratigraphy

Lithostratigraphy is the geological science related to the formation of strata or rock layers that the physical characteristics of the various rock types may identify. The relative locations of rock units can be assessed by considering their geometric and physical relationships, which indicate which beds are older and which are younger. According to the hierarchical structure of elements, formations, and groups that describe rocks, the units can be classified into lithostratigraphic terminology.

4.3.1 Stratigraphy

Generally, there are four main lithologic units in the study area: limestone, slate, and shale. Based on the lithostratigraphic unit, the stratigraphy is provided chronologically from the oldest to the youngest. The table 4.3 shows the stratigraphic column, which illustrates the relationship between the units in the study area. The slate and shale classified as the oldest units in the study area. The youngest units in the study area are limestone that located at the north of the study area.

Table 4.3: Stratigraphy column

Lithology	Description	Formation Age	Stratigraphy
Limestone	The rock consists of calcite minerals. The rock texture is granular. Their component grains range from visible particles to 0.001 mm (0.00004 inches).	Late Triassic	
Shale	The rock is a fine-grained, clastic sedimentary rock formed from mud that contains tiny bits of various minerals, mainly quartz and calcite, and clay mineral flakes. It is interbedded with limestone.	Permian	
Slate	The rocks are a dark grey colour and have a slaty cleavage that can be divided into a thin, flat sheet form. It formed by low-grade regional metamorphism.	Permian	

4.3.2 Unit explanation of Lithology in the Study Area

The order of the lithologic rock units, from the oldest to the youngest, as well as their horizontal and vertical distribution, are important information to know when discussing lithologic units. The distribution of each lithology, the size of the rock units, and the relationships between the units are also discussed. The identification of the minerals and their compositions depends on the petrographic study of each lithologic unit. The distribution of the lithology unit in the study area is depicted in Figure 4.13.



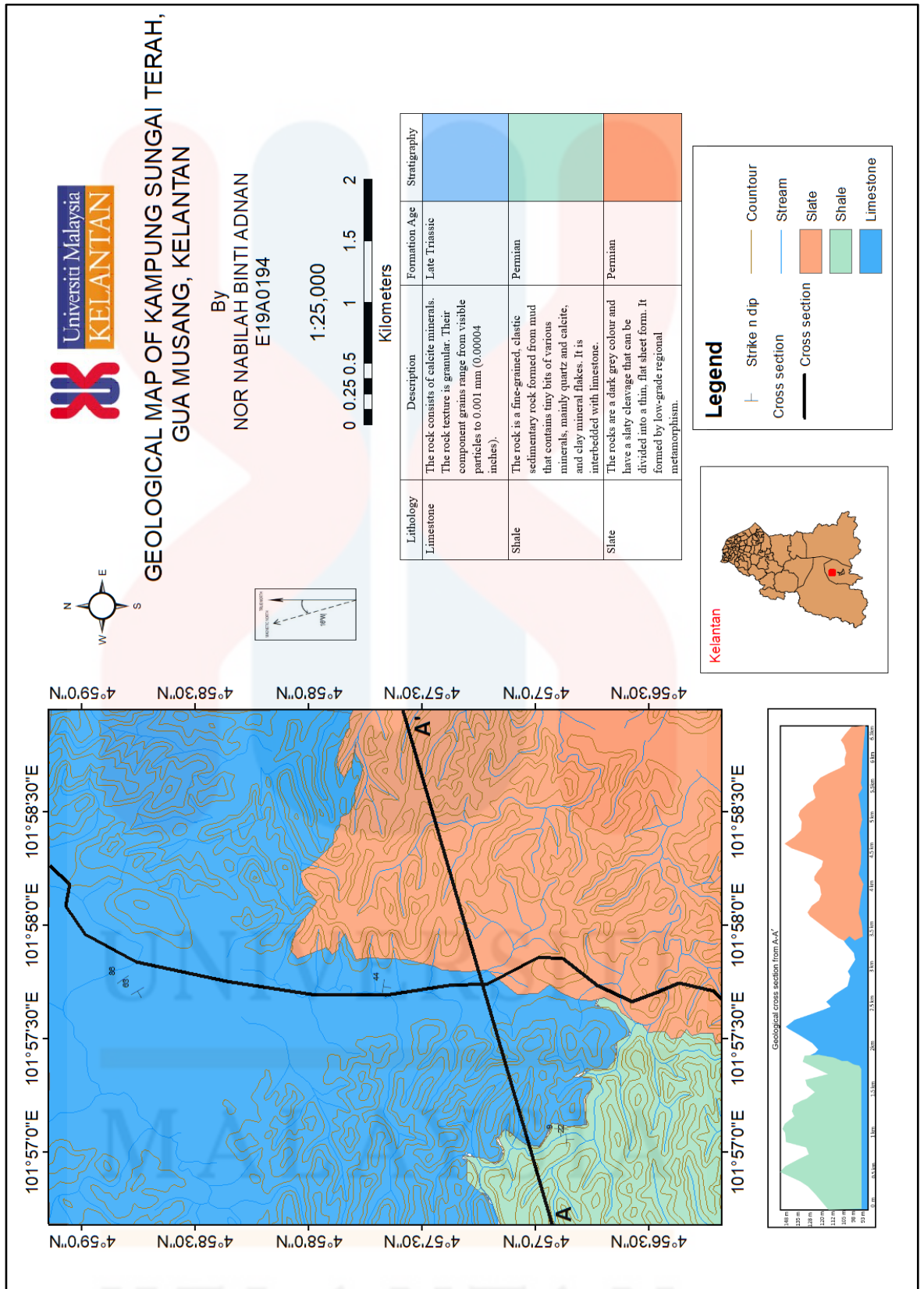


Figure 4.13: Geological map of the study area.

a) Limestone

Limestone was found in the study area (Figure 4.14), with more than 50% of the majority rock type found in the study region. This area also stated that the limestone was a fine grain rock interbedded with meta-sediment. The colour of the limestone is light grey from admixture with carbonaceous content without any trace of fossil appearances. The outcrop also reclaims to have a height in the range of 3 to 7 meters and contain calcite mineral. There is some limestone found that has slightly metamorphosed that have some foliation.



Figure 4.14: The limestone outcrop.

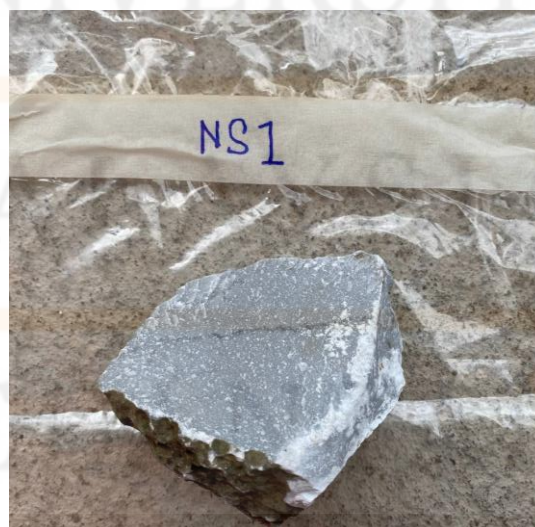
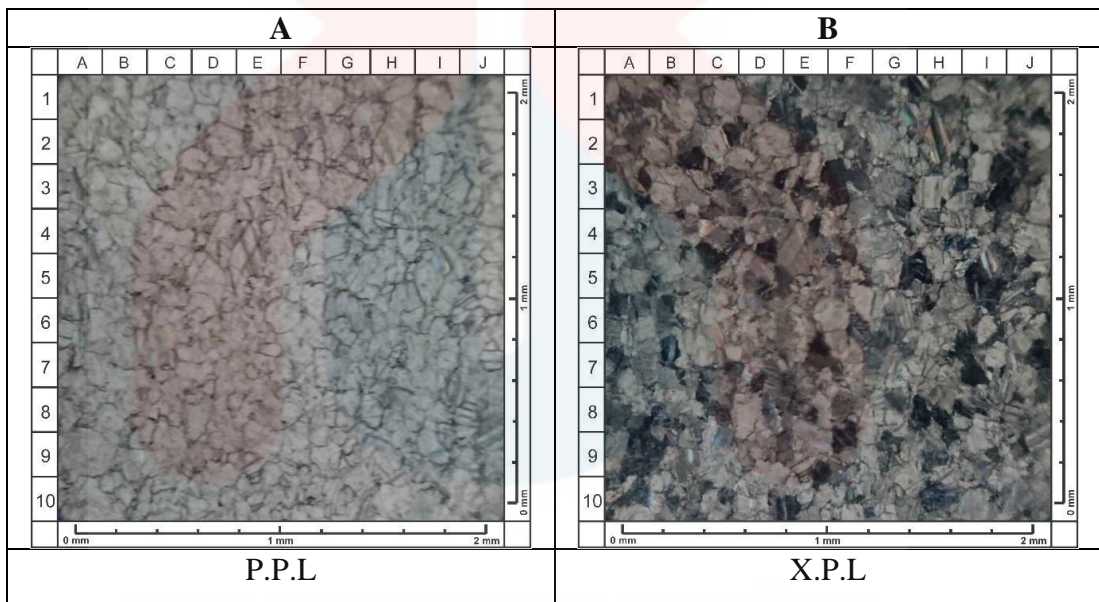


Figure 4.15: The rock sample of limestone in the study area.

The laboratory result for this sample (Figure 4.15) is that it has 100% calcite mineral. From the plain polarised light (PPL) observation, the absorption colour is colourless. The relief is low-moderate with non-pleochroism existing. It has an anhedral crystal, and cleavage in 2 directions is absent. In cross polarise light (X.P.L.), it has the interference colour of light red to green in the order of 4 to 5 with a symmetrical dark angle (Table 4.4). The test at the field using HCL showing reaction towards the rock showing it has calcite mineral.

Table 4.4: A- PPL view of the thin section. B- X.P.L. view of the thin section



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b) Shale

The characteristics found in the study area are black to dark grey (Figure 4.16). The shale that found in the study area is interbedded with limestone. The outcrop found was ranged from 1 to 3 meters in height. The rock can be fractured into tiny bits just by a little pressure. It is said to be of Permian age, referred to by Kamal Roslan, Nelisa Ameera, and Che Aziz (2016). Shale in the study area is a protolith rock to slate.



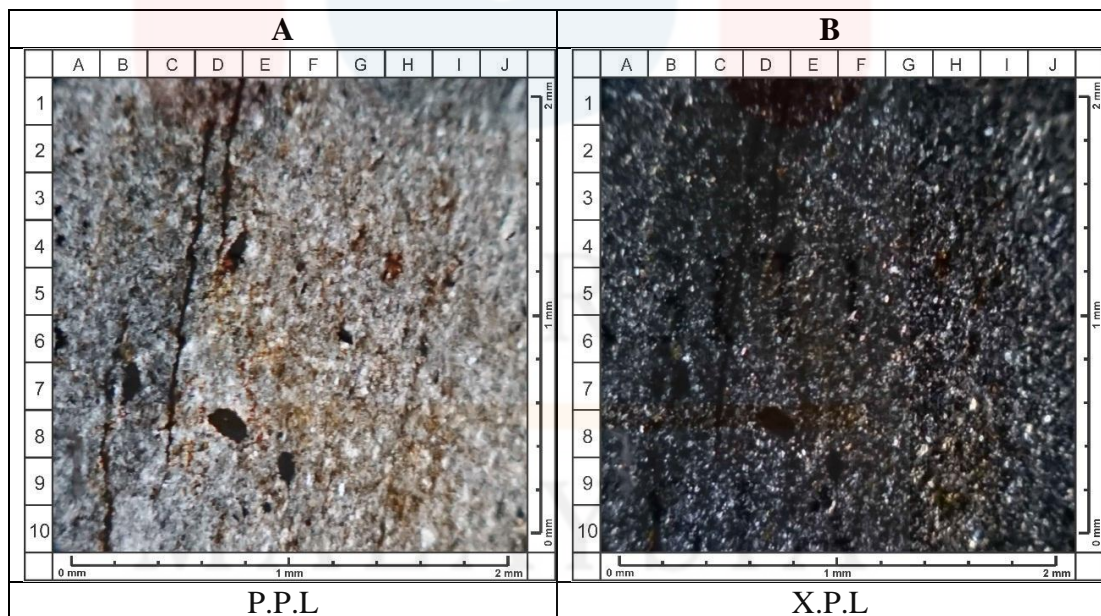
Figure 4.16: The outcrop of shale at station 51.



Figure 4.17: The rock sample of shale

The rock has 3% of quartz mineral, which at PPL the absorption colour is colourless and has a low relief with no pleochroism. It has an anhedral crystal form that has no cleavage. In X.P.L., the interference colour is in order 1, grey to white, the dark corners are wavy, and there is no twinning. It also has 30% silica clay which, at PPL, the interference colour is colourless to brown. In X.P.L., the interference colour is dark grey to black. It consists of micron-sized silicate material. Next, the rock sample has 64% oxide clay. In PPL, the thin section absorption colour appears brown. It consists of a mixture of micron-sized silicate and iron oxide materials. Lastly, there is the existence of opaque minerals, which are recorded at 3%. At PPL, the absorption colour is black and has low relief. Also, there is no pleochroism in the shape of euhedral to anhedral crystal form. In X.P.L. colour of the interference is black, which is in order 1, and there is no twinning.

Table 4.5: A- PPL view of the thin section. B- X.P.L. view of the thin section.



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c) Slate

In the eastern portion of the research region, slate was the oldest unit. According to Kamal Roslan, Nelisa Ameera, and Che Aziz, the shale, slate, phyllite, and siltstone that compensate the metasediment lithology (argillaceous facies) slate unit are Permian in age (2016). Mudstone and shale undergo low-grade regional metamorphism to produce slate, a fine-grained, foliated metamorphic rock. It has a dark grey tone, slatted cleavage, and may be divided into comparatively thin flat sheets. Due to its low pressure and low temperature during formation, slate is a low-grade metamorphic rock.

Shale, mudstone, or volcanic rock rich in silica that serves as protolith rock undergoes regional metamorphism, which affects the development of slate. It is concluded that the protolith of the slate came from the shale in the study region since the mineral compositions of the slate are almost comparable to those of shale. Under low pressure and temperature circumstances, shale eventually undergoes metamorphism to form slate throughout time (Figure 4.18).



Figure 4.18 : The slate outcrop in the study area


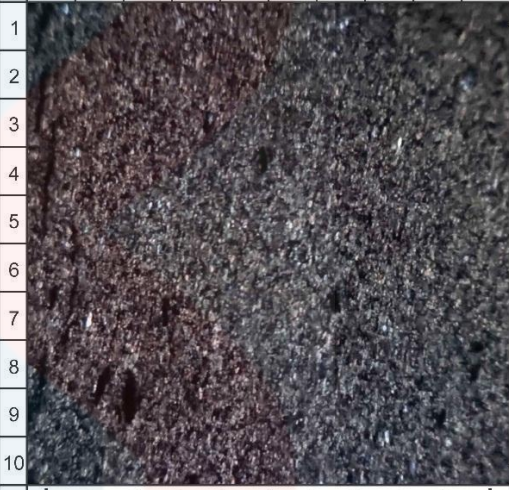


Figure 4.19: The hand sampling of slate

From the laboratory analysis (Table 4.6), the rock consists of 2% quartz mineral. In PPL, the absorption colour is colourless, with low relief and no pleochroism. It has an anhedral crystal and no cleavage. In X.P.L., the interference colour is in order 1, which is grey to white, and the dark corners are wavy. Other than that, there is a silica clay mineral which is 48%. At PPL, the absorption colour is

colourless to brown. In X.P.L., the interference colour is dark grey to black. Consist of micron-sized silicate material. The characteristics of the rock and mineral indicate that the rock is slate and shale is the protolith rock for slate.

Table 4.6 : A- PPL view of the thin section. B- X.P.L. view of the thin section

A											B										
	A	B	C	D	E	F	G	H	I	J		A	B	C	D	E	F	G	H	I	J
1											1										
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					
0 mm 1 mm 2 mm											0 mm 1 mm 2 mm										
P.P.L											X.P.L										

4.4 Structural Geology

Structural geology is a subdiscipline that investigates how rocks change shape in response to forces inside the earth. Rocks and their forming minerals accommodate the forces acting upon them and occasionally create geological structures, such as fractures, faults, joints or folds. Geological structure analysis aims to comprehend the why, how, and when the earth deformed.

4.4.1 Lineament analysis

From the study, the positive and negative lineament of the study area provided in the map. The positive lineament was delineated from the peak, while the negative lineament was from the valley part of the study area. Figure 4.20 shows the lineament analysis of the study area.

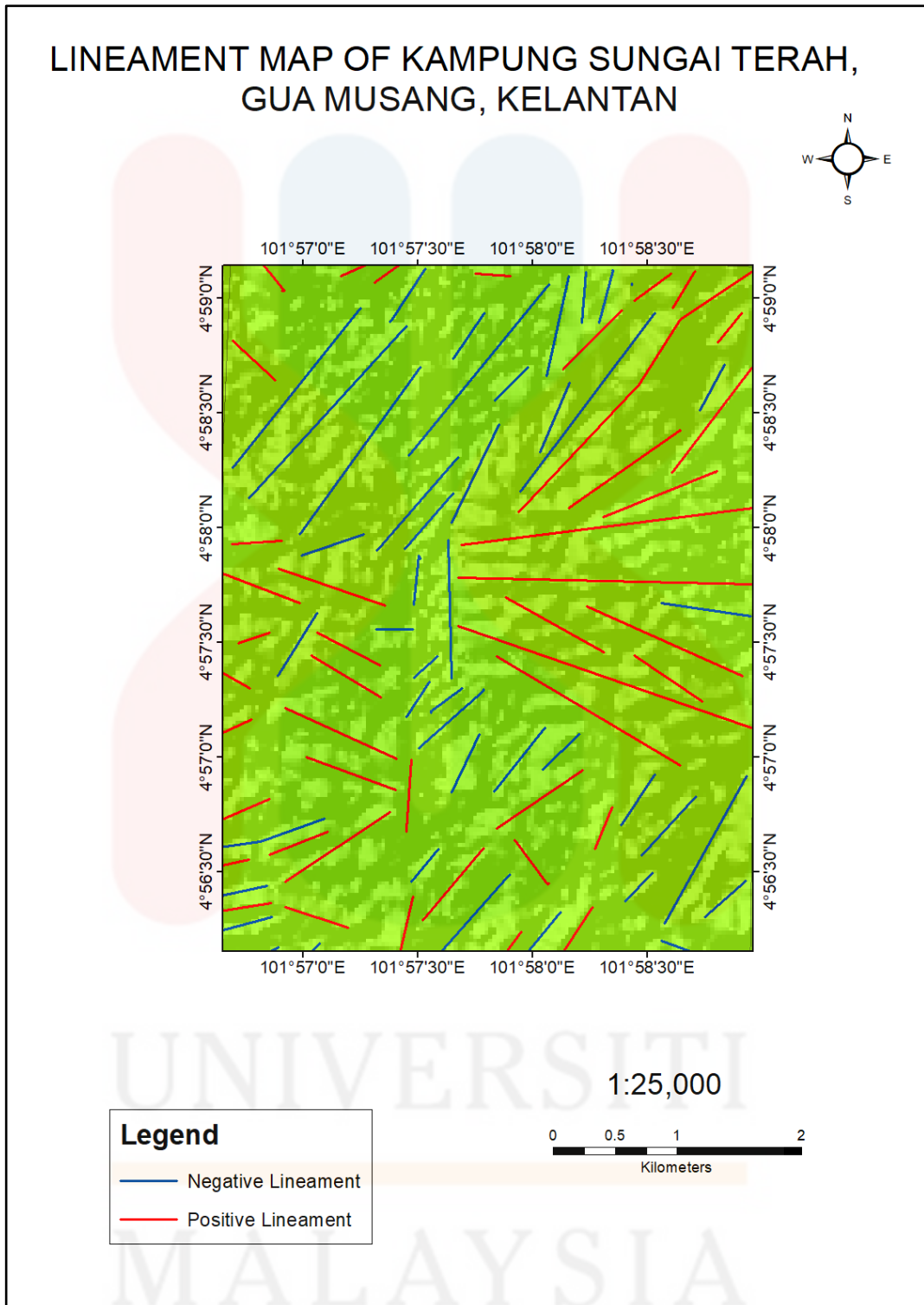


Figure 4.20: The lineament map of the study area

a) Positive lineament

From the rose diagram of the lineament map, positive lineament rose diagram analysis (Figure 4.21) indicate that that the force is orienting in a north-west and south-east direction. While the tension was most apparent in the south-east and north-west directions.

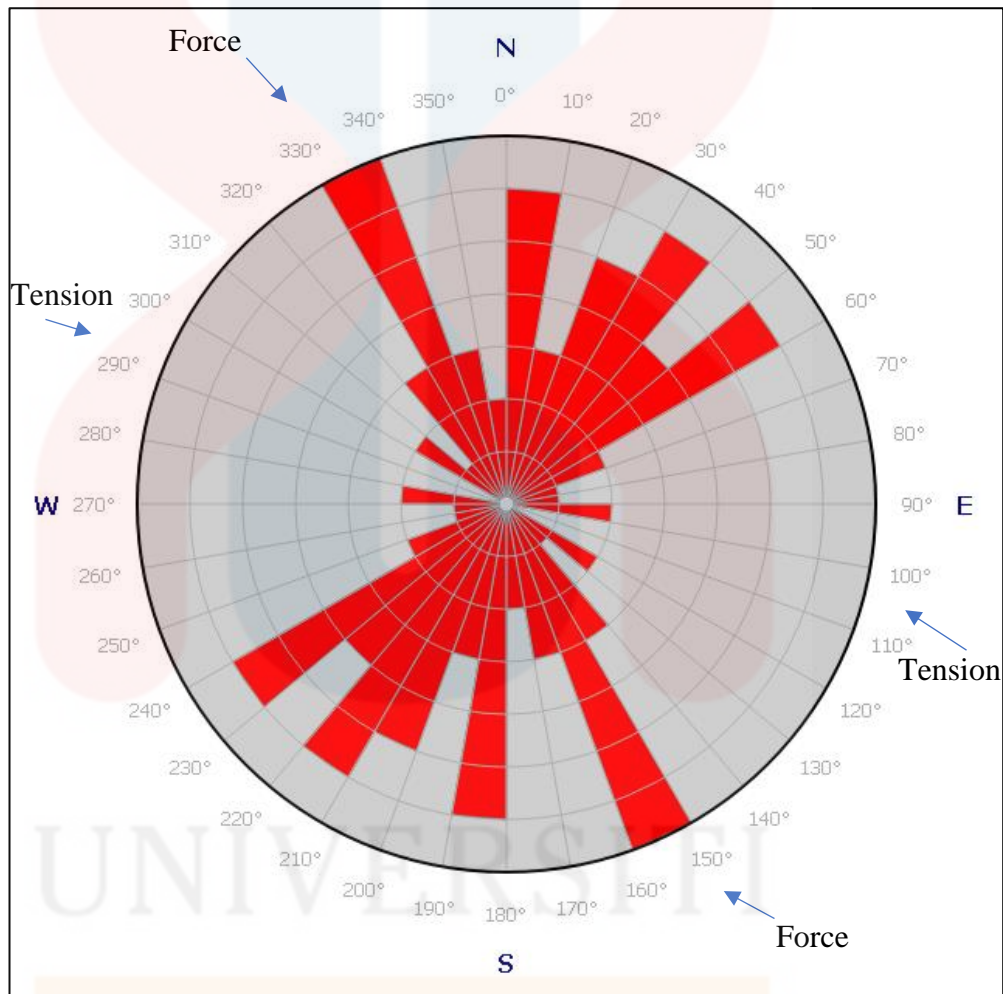


Figure 4.21: Rose diagram of positive lineament.

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b) Negative lineament

The negative lineament analysis plot was shown on the rose diagram as stated in Figure 4.22. The northeast - southwest directions were marked as the force. The directions of the tension were defined as north-west and south-east.

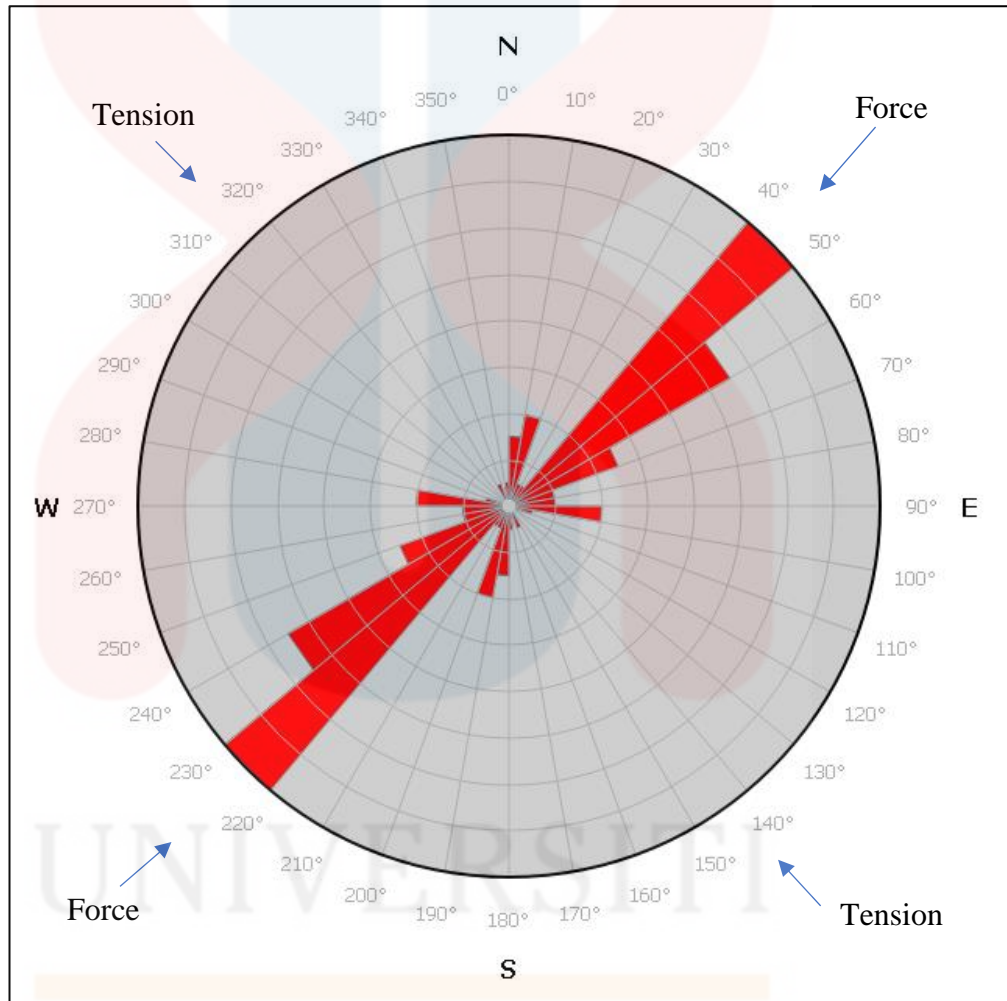


Figure 4.22: Rose diagram of negative lineament.

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4.4.2 Joint

Joints are cracks or fractures that separate the rocks into pieces or blocks without relative displacement. Joints are common in almost all surface rocks, spreading in various directions. While joints are generally undetectable in unweathered rocks, they become noticeable after weathering, especially in soluble rocks like limestone. The outcrop in the study area is mainly a joint structure.

From the joint analysis of stereographic projection(Figure 4.24), research is done to display the angular properties of a plane-faced object on a single drawing or diagram. From the stereographic projection in Figure 4.25, there is 3 sigma display in the streonet that show high tension from three directions. The counting area is 42.86% of the net area.

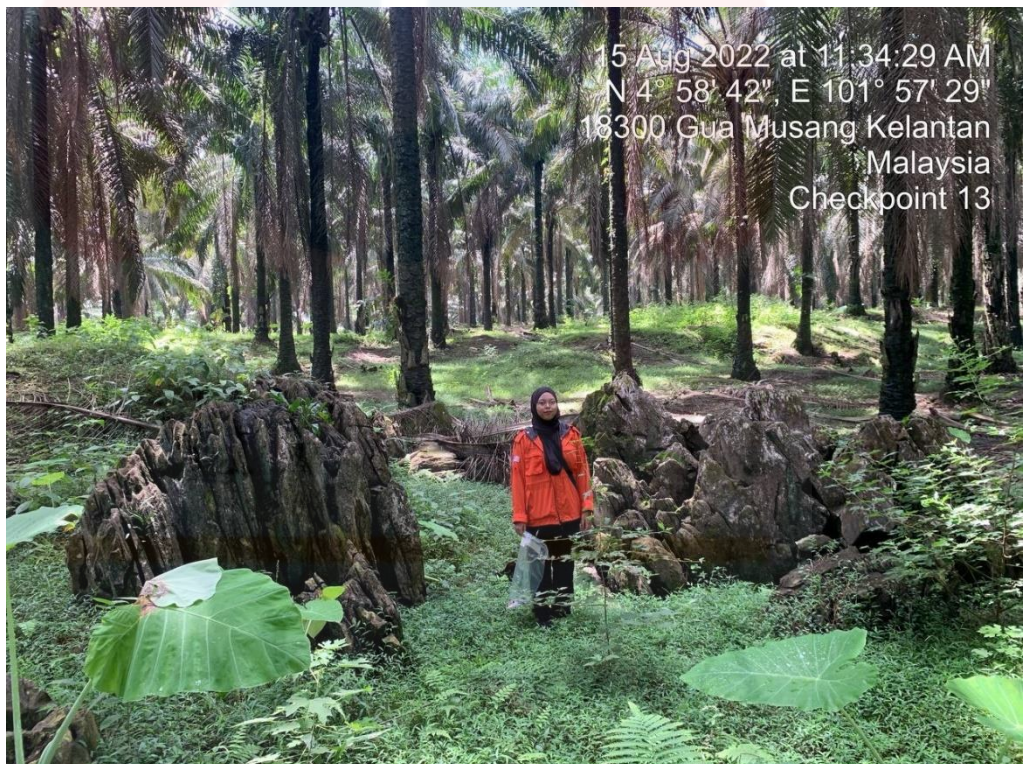


Figure 4.23: The outcrop at station 13

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Figure 4.24: The picture of joint at station 13

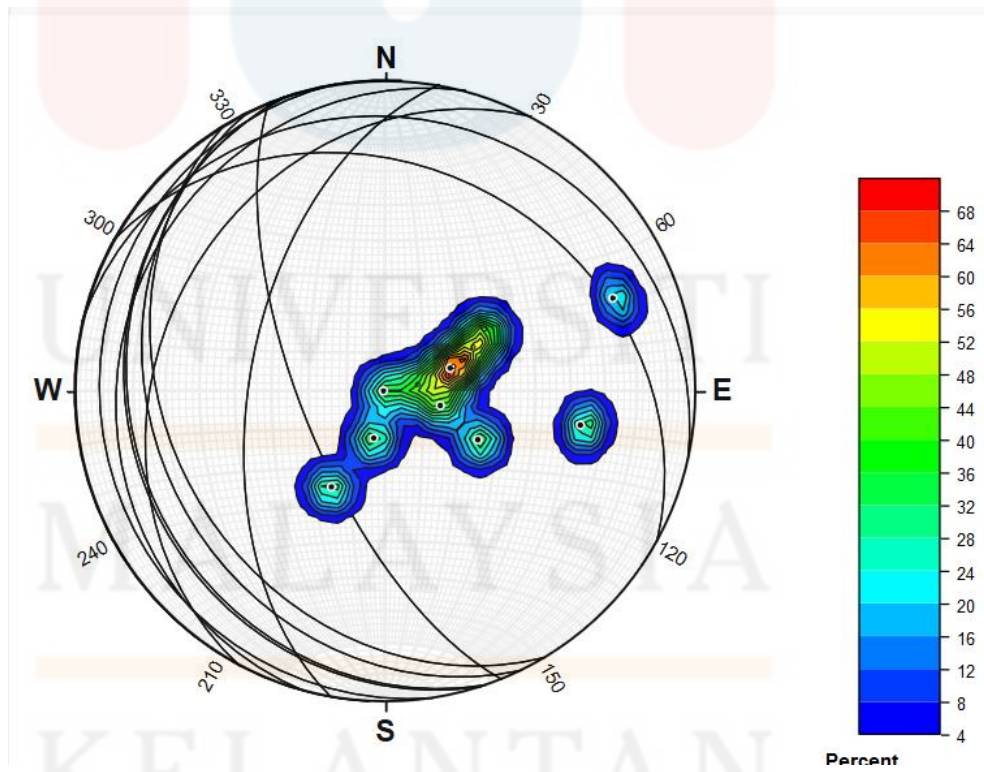


Figure 4.25: Stereographic projection of joint.

4.5 Historical Geology

The Middle Permian to Upper Triassic Gua Musang Formation (Mohd Shafeea Leman, 1993 and 2004) was mapped by Yin (1965) in south Kelantan. In the formation, which is estimated to be 650 m thick, crystallized limestone is interbedded with thin layers of chert nodules, chert nodules, shale, tuff, subordinate sandstone, and volcanics. The calcitic limestone is hard, non-porous, brittle, and splintery, and it is light grey in colour. Significant amounts of carbonaceous, argillaceous, and pyroclastic impurities are present in the grey-to-black varieties of the regularly recrystallised limestone. The metasediment unit is thought to have been deposited in warm, tranquil, shallow marine environments during the pre-Mesozoic era. The argillaceous facies, which is composed of shale, siltstone, phyllite, and sandstone, forms the metasediment unit.

Early Triassic volcanic activity is thought to have occurred in this region. The carbonate cannot be deposited at this time because of the hazy water conditions brought on by the volcanic eruption that interferes with its deposition activities. The formation of carbonate rock has been halted by the volcanic eruption's emission of volcanic material. Following the complete deposition of the volcanic material, the water becomes quiet and clean once more, allowing carbonate to form. The major carbonate distribution in Gua Musang suggests that this region was exposed to a depositional environment near to a volcanic source in a volcanic arc context.

CHAPTER 5

ELECTRICAL RESISTIVITY IMAGING (E.R.I.)

5.1 Introduction

This chapter covers the result of the groundwater potential in limestone using the electrical resistivity (E.R.I.) method. The interpretation of each line is based on software such as RES2DINV. For this research, there are four survey lines of pole dipole configuration to classify the possible groundwater present in the analysis area with 200 meters spread line and 41 electrodes with 5 meters spacing each.

The result of the 2D electrical resistivity imaging (E.R.I.) pseudo section is classified as the potential groundwater in the analysis based on the apparent resistivity value of ground surface materials. Rocks have conductivities and resistances that range over many orders of magnitude.

5.2 Resistivity location

Four survey lines were conducted in a different part of the study area, the palm oil plantation area. Figure 5.1 shows the location of all survey lines executed in Ladang Sungai Terah at the coordinate of N 04° 58' 57.3" and E 101° 58' 05.8". The topography of the conducted E.R.I location is at the plain area which the elevation ranges from 70m above sea level to 120 m above sea level. The area covered with palm oil plantation and dim area which suitable to conduct the survey for Electrical Resistivity Imaging (E.R.I) because error may occur if the survey is do in hot or raining weather.

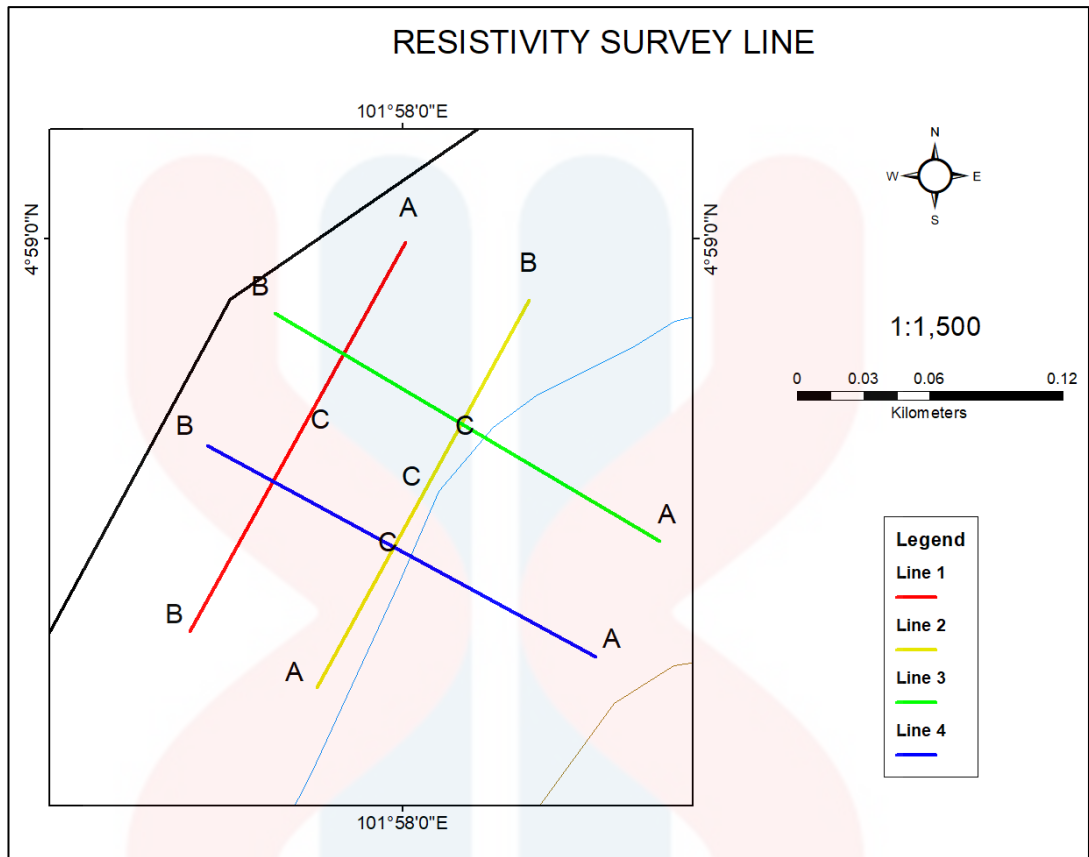


Figure 5.1: The E.R.I. survey line location.

5.3 Survey setup

This section provides setup of the E.R.I survey (Table 5.1). It shows the coordinate and the array used for the survey line. 4 electrode line are used to determine the groundwater potential of the study area using pole dipole array with 200 m length.

Table 5.1:The overall setup for E.R.I survey for groundwater potential

Survey Line	Coordinate			Array	Length
	0m	100m	200m		
1	N 04° 59' 01.0" E 101° 58' 05.4"	N 04° 58' 58.1" E 101° 58' 04.0"	N04°58'55.4" E101°58'02.3"	Pole dipole	200 m
2	N 04° 58' 58.5" E 101° 58' 04.1"	N 04° 58' 57.3" E 101° 58' 05.8"	N04°58'00.2" E101°58'07.2"	Pole dipole	200 m
3	N 04° 58' 56.6" E 101° 58' 09.2"	N 04° 58' 58.3" E 101° 58' 06.3"	N04°59'00.0" E101°58'03.6"	Pole dipole	200 m
4	N 04° 59' 54.9" E 101° 58' 08.2"	N 04° 58' 56.4" E 101° 58' 05.2"	N04°58'57.9" E101°58'02.5"	Pole dipole	200 m

5.4 Interpretation of earth material

The pseudo section of electrical resistivity imaging shown the resistivity value ranging from 0-15000 ohm.m. Based on this value, its divided into three classes, which are low, medium, and high resistivity value. The interpretation of earth material for each resistivity value is shown in Table 5.2.

Table 5.2: The resistivity value and interpreted earth material

Resistivity value	Interpreted earth material
0 Ωm – 80 Ωm	Surface water, alluvium, fresh water
200 Ωm – 2000 Ωm	Weathered limestone, clay
5000 Ωm – 15,000 Ωm	Limestone bedrock

5.5 Result

5.5.1 Survey line 1

Figure 5.2, 5.3, and 5.4 shows the set up of E.R.I survey with the direction N 208° E. – S 28° W. The interpretation is made based on the values of resistivity and chargeability shown in the pseudo section.



Figure 5.2: Set up for Line 1 in the centre



Figure 5.3: Set up for Line 1 cable electrode A

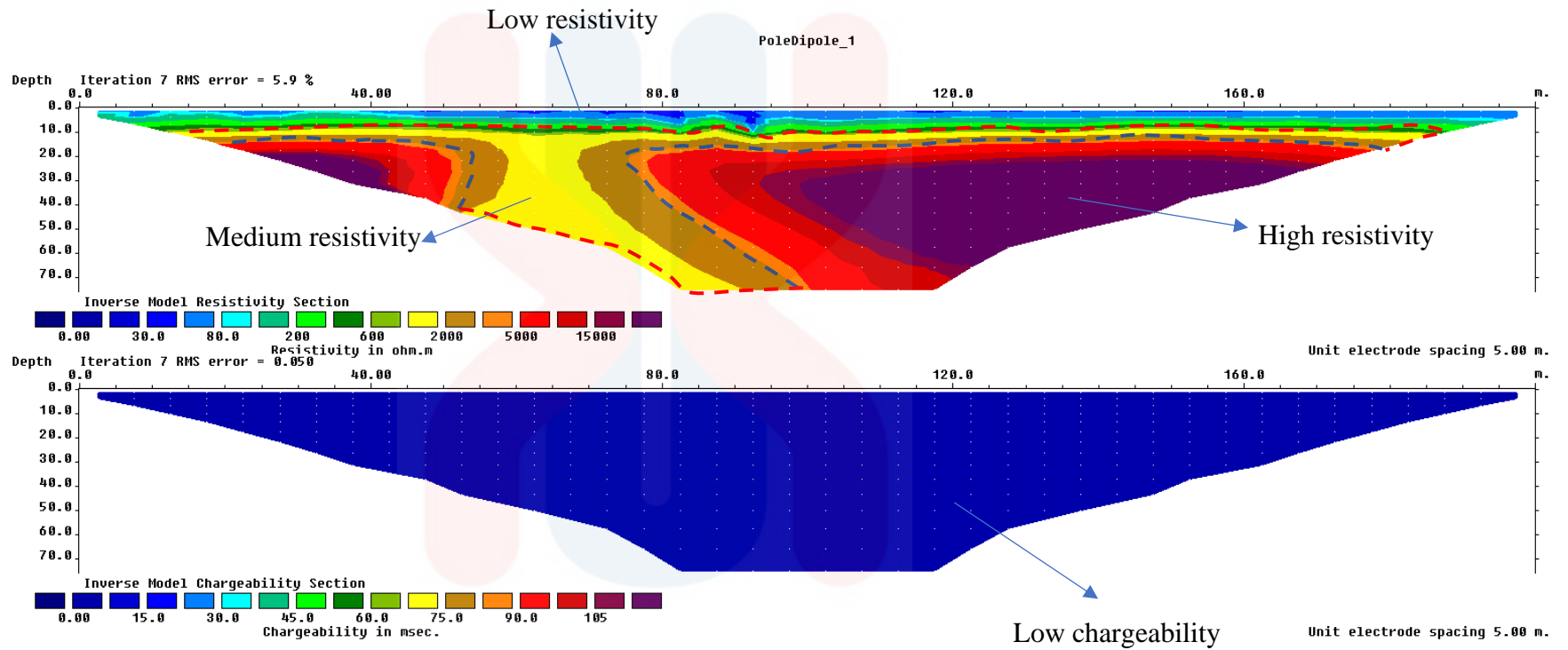


Figure 5.4: Set up for line 1 cable electrode B

Based on the resistivity and chargeability analysis from the Figure 5.5, the earth material beneath subsurface is interpreted. The depth of the pseudo section is 70 meters. The root-mean-squares (R.M.S.) errors displayed from the processed pseudo section for line 1 is 5.9 % in the resistivity section, while for an inverse model of the chargeability section is 0.050%.

The value with high resistivity is classified as approximately 5000 Ωm to 15000 Ωm . The high resistivity values are shown at the right and left parts of the pseudo section models that are presented in. Thus, this is understood to be a hard rock like fresh limestone bedrock in that area. The higher resistivity values mean that the

material in the subsurface has less ability to conduct electricity. The medium resistivity values can be categorised from 200 Ωm to 2000 Ωm , respectively. This section can be classified as clay or weathered limestone which can have a high groundwater potential. Low resistivity values shown at the model section's top layer have resistivity values less than 100 Ωm . This area at the surface is covered with water, which is why the area is interpreted as low resistivity. The chargeability of the of pseudo section show low chargeability which in the range of 0 msec to 15 msec. This can be interpreted as groundwater potential or surface water area.



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Figure 5.5: Resistivity and chargeability values for survey line 1

5.5.2 Survey line 2

Figure 5.6, 5.7, and 5.8 shows the set-up of line survey 2. The line survey is at N 208°E - S 28°W.



Figure 5.6: Set up of line survey 2 at the centre.

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Figure 5.7: Set up for Line 2, electrode cable A



Figure 5.8: Set up for Line 2, electrode cable B

Figure 5.9 shows the resistivity and chargeability for line 2 ranging from 0 Ωm to 15000 Ωm , which is represented by dark blue colour to dark purple, while chargeability values from 0 msec to 105 msec. The root-mean-square (R.M.S.) for the resistivity pseudo section is 4.8% and 0.100% for the chargeability pseudo section.

The high resistivity values for the survey line 2 pseudo section range from 5000 Ωm to 15000 Ωm . The high resistivity value area can be interpreted as the fresh limestone bedrock with less ability to conduct electricity. The medium resistivity values range from 200 Ωm to 2000 Ωm and can be interpreted as limestone area that can be a high possibility of potential groundwater. This resistivity value colour is distributed in the upper middle part of the layer in a pseudo section with a depth of about 0 meters to 50 meters. The low resistivity values in the range of 0 Ωm to 80 Ωm have a dark blue colour at the surface layer pseudo section, which is covered with water puddles on the surface. For chargeability, all part of the pseudo section is in low chargeability which at range of 0 msec to 15 msec. The low chargeability on the high resistivity data, means hard rock area have water flow within the rock fracture.

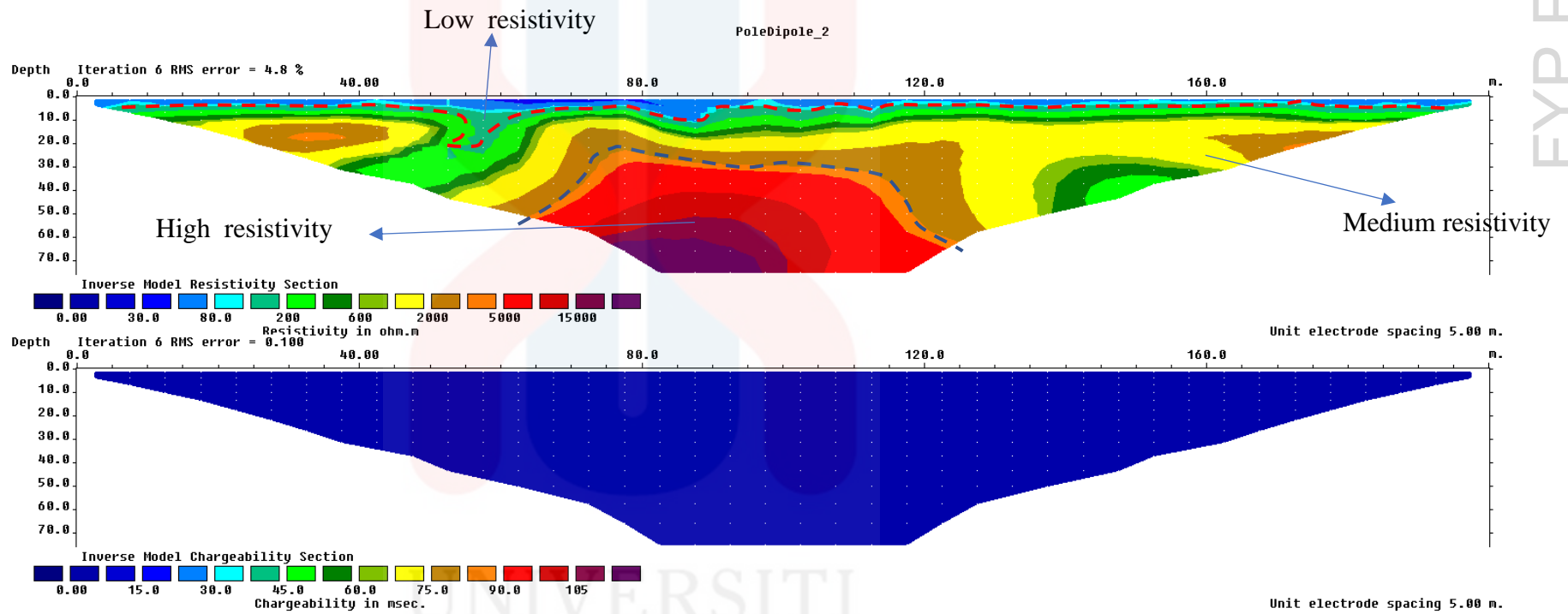


Figure 5.9: Resistivity and chargeability values for survey line 2

5.5.3 Line survey 3

The length of survey line 3 is 200 meters, with an electrode spacing of 5 meters. The array type used is the pole dipole array. Figure 5.8 shows the set-up of line survey 3. The line survey is at S 300° E-S 120° W.



Figure 5.10: The set-up of line survey 3

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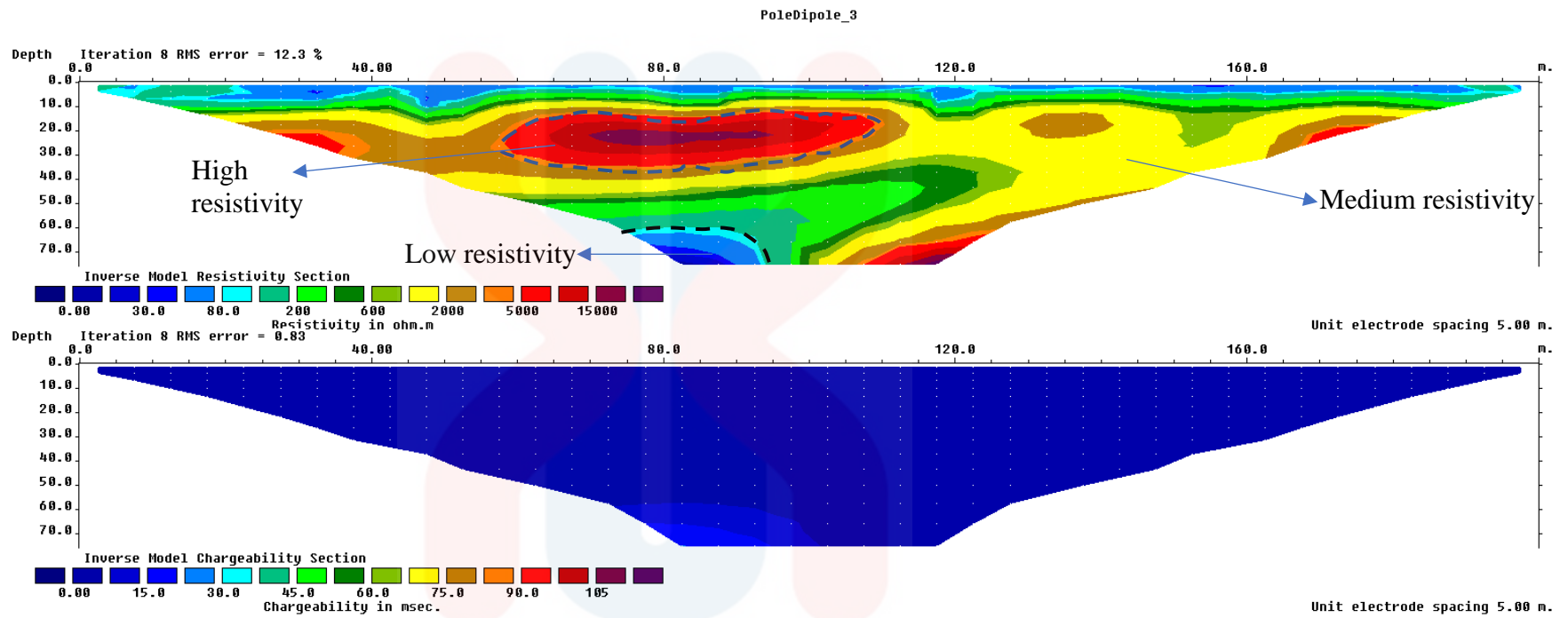
Figure 5.11: Set up for Line 3, electrode cable A



Figure 5.12: Set up for Line 3, electrode cable A

Figure 5.13 below shows the root-mean-square (R.M.S.) for the resistivity pseudo section is 12.3% and 0.83% for the chargeability pseudo section.

The high resistivity value area can be interpreted as the limestone bedrock with less ability to conduct electricity. The distribution of this resistivity value in the pseudo section is in the middle layer. For the medium resistivity values, the values range from 200 Ωm to 2000 Ωm , with the colours light blue to light green and yellow. This medium resistivity value area can be interpreted as weathered limestone, or clay area with a high possibility of potential groundwater. This resistivity value colour is distributed in the upper part and below part of the layer in pseudo. The low resistivity values range from 0 Ωm to 80 Ωm . This low resistivity value in the lower part of the pseudo section can be classified as fresh water while at the upper part of pseudo section it can be interpreted as surface water. For chargeability, it can be interpreted that line survey 3 has a good potential for groundwater because it has most of the low value of chargeability which is 0 msec to 15 msec.



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Figure 5.13: Resistivity and chargeability values for survey line 3

5.5.4 Line survey 4

Figure 5.10 shows the set-up of line survey 4. The line survey is at S 300° W- E 120° S.



Figure 5.14: The set-up of line survey 4 in the centre part of the survey.

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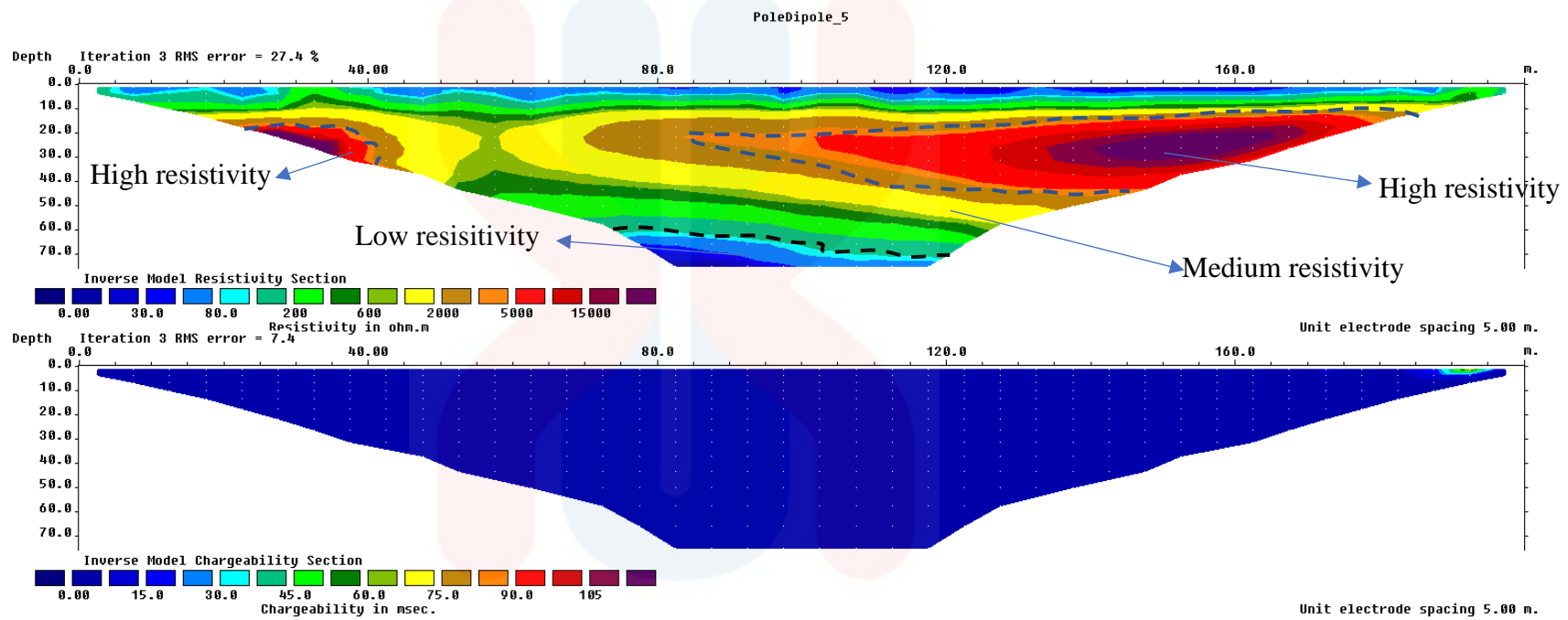
Figure 5.15: Set up for Line 2, electrode cable A



Figure 5.16: Set up for Line 2, electrode cable A

Based on figure 5.17 below, a resistivity pseudo and chargeability model section for line 4 is shown. The root-mean-square (R.M.S.) for the resistivity pseudo section is 27.4% and 7.4% for the chargeability pseudo section.

The high resistivity values for the survey line 4 pseudo section range from 5000 Ωm to 15000 Ωm . The high resistivity value area interpreted as limestone bedrock it stated in the depth of 30 m depth from the surface. The distribution of this resistivity value in the pseudo section is in the left part and middle part of the layer. For the medium resistivity values, the values range from 200 Ωm to 2000 Ωm . This medium resistivity value area can be interpreted as weathered limestone or clay area that can be a high possibility of potential groundwater. This resistivity value colour is distributed in the lower part of the layer in pseudo. The low resistivity values range from 0 Ωm to 80 Ωm . This low resistivity interpreted as surface water at the upper part of pseudo section and fresh water lower part of pseudo section. For chargeability, it can be interpreted that line survey 4 have a low value of chargeability that can be a good potential of groundwater.



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Figure 5.17: Resistivity and chargeability values for survey line 4

5.6 Discussion

Limestone composes most of the study area, especially in the survey area, where limestone represents the whole line survey's bedrock. Groundwater may accumulate in the pore spaces and rock fractures. By comparing the readings between the resistivity and chargeability levels, this can be determined. The groundwater value was inferred from the chargeability range of 0 to 15 msec. Resistivity and chargeability values were compared to one another based on the interpretation of the complete survey line in order to show the presence of groundwater. Low conductivity is present when the resistivity values are high. This can refer as the capacity of the material to oppose the electrical current flow, while conductivity referred to a materials capability to carry electrical current. From the result of resistivity and chargeability value of all survey line, there is groundwater potential from all survey line.

Based on the electrical resistivity survey pseudo section that is represent in the study area, the results showed that the study area is divided into three resistivity classes based on the resistivity values which is high resistivity zone, the medium resistivity zone, and the lower resistivity zone. The hard rock was depicted by a colour ranging from light red to dark purple. The high resistivity range comprises from 5000 Ωm to more than 15000 Ωm . The medium resistivity zone is made up of alluvium and weathered limestone with colours ranging from green to brown and resistivity values between 200 Ω and 2000 Ωm . Less than 30 Ωm are the ranges for low resistivity values, which are depicted by the dark blue colour. From the result of resistivity and chargeability value of all survey line, there is groundwater potential from all survey line.

Weather conditions should be properly considered, as resistivity surveys should not be undertaken on days when it is raining. For the results to be accurately

interpreted, the survey needs to be correctly performed. When a significant rainfall is present during the site survey, water from the downpour will be absorbed by the soil, increasing the soil's moisture content. This will influence the resistivity reading because soil moisture content is one of the main factors influencing the distribution of resistivity. Therefore, the suitable timing and weathering should be thoroughly considered before conducting the survey line. Geomorphology, lithology, and structural geology are additional variables that must be taken into consideration when running the survey line.

5.7 Conclusion

To conclude, the optimum method for determining the potential of groundwater in the subsurface region is the geophysical approach. A geophysical approach is also simple to use and far less expensive than a drill. According to the interpretation of each line's model section, the survey location has the potential for groundwater. The groundwater potential in hard rock is examined for this study using a pole dipole setup. The interpretation is based on the values of the chargeability and resistivity values in the model sections. The presence of groundwater potential can be inferred when the resistivity values increase, and the chargeability values decrease.

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This chapter will cover the conclusion and all of the results obtained from the study area and site survey based on its interpretation from the geological map and geophysical method using resistivity techniques. Generally, there are two units of lithology in the study area that can be identified based on the interpretation of the geological map, which are limestone and metasedimentary rock. The lithology is distributed in different locations in the study area. The limestone unit is distributed in the North-South of the study area and covers about 50% of the total area of the study area. The limestone unit is from the Mesozoic Era and Triassic Period, consisting of calcite minerals and fine-grained rock.

The stratigraphy column of the area of study was developed based on rock lithology correlation with previous researchers. Slate and shale are the oldest unit of rock listed in the research field during the Carbonaceous-Permian under the Gua Musang Formation, and limestone rock also from the Gua Musang formation during the Triassic Period: The tectonic events that have occurred in the past can be understood based on the presence of different structural geology in the study area. In the study region, geomorphology consisted mainly of the hilly area covered in the northern and eastern parts, while the flat area covered the middle of the study area.

The drainage pattern found in the study region consists mainly of a dendritic and trellis pattern.

Based on the interpretation of the geophysical method using electrical resistivity, it can be assumed that the study area consists of groundwater potential that showed in all line surveys. Survey line 1 has potential groundwater at a depth of 20 meters to 70 meters. In comparison, survey line 2 has groundwater potential at a depth of 50 meters from the surface. The groundwater potential for survey line 3 is measured at a depth of 60 meters from the surface layer. Finally, for line survey 4, the capacity for groundwater is 50 meters to 70 meters in depth.

6.2 Recommendations

The purpose of the recommendation is to the potential of groundwater in the Kampung Sungai Terah. For further analysis, the student is recommended to assess water quality in the presence of groundwater potential in Kampung Sungai Terah using suitable methods such as pumping testing. It was shown based on the outcome obtained from the E.R.I. survey process. The groundwater potential can be found at levels ranging from depths of 10 m to 70 m in various locations. However, as the water is often stored in the fractured zone, the amount of water cannot be predicted, and a drilling method is needed to estimate the amount of water in the fractured area. By using more comprehensive subsurface investigations such as logging and pumping tests, vertical electrical sounding, and horizontal profiling geophysical surveys, it is also suggested that the student locate groundwater sources in another section of the study area.

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