# GEOLOGY AND GROUNDWATER POTENTIAL AT FELDA CHIKU 05, PALOH, GUA MUSANG, KELANTAN.

By

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**DECLARATION**

I hereby declare that this thesis entitled Geology and Groundwater Potential at Felda Chiku 05, Paloh, Gua Musang, Kelantan is the result of my own research except as cited in the references. The thesis has not been accepted in any degree and is not concurrently submitted in candidature of any other degree.

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Date: 18/2/2023

**Geology and Groundwater Potential at Felda Chiku 05, Paloh, Gua Musang, Kelantan.**



## ABSTARCT

Research entitled Geology and Groundwater potential was carried out at Felda Chiku 05, Paloh. The research area was located at Gua Musang district. Since the demand of groundwater had increased for agriculture activity and drinking source, exploring groundwater potential areas for new extraction wells are extremely important to meet the demand of water. The purpose of the research is to update the geological map of the study area with scale of 1:25,000 and to identify the groundwater potential using Electrical Resistivity Imaging (ERI) method. The main lithology of the study area was marble. In exploring groundwater potential area, 3 survey lines were used. For the first and second survey line, Gradient electrode arrangement was used while for third line was Pole - Dipole array with electrode spacing 5 meters for 200 meters line spread for survey. The ABEM Terrameter LS was used to obtain resistivity and induced polarisation data. Following data collecting, the operation moves on to data processing and inversion with the RES2DINV programme. By projecting the resistivity and IP values on a 2 D profile and analysing the processed data, the potentially shallow groundwater exists along survey line 1. The potential for shallow groundwater was shown to be impacted by coarse-grained sand along survey line 2. Survey line 3's model section results shows that the groundwater may be present at a depth of 20 and 45 metres below sea level. It has been demonstrated that geophysical surveys and geological mapping are effective ways to identify groundwater potential zones. The development of the water supply in the future is greatly aided by this study effort.

**Keywords:** Geological map, groundwater potential, lithology, electrical resistivity imaging, survey line.

**Geologi dan Potensi Air Bawah Tanah di Felda Chiku 05, Paloh, Gua Musang, Kelantan.**




## ABSTRAK

Penyelidikan bertajuk Potensi Geologi dan Air Tanah telah dijalankan di Felda Chiku 05, Paloh. Kawasan kajian terletak di daerah Gua Musang. Memandangkan permintaan air bawah tanah telah meningkat untuk aktiviti pertanian dan sumber minuman, penerokaan kawasan berpotensi air bawah tanah untuk telaga perahan baharu adalah amat penting untuk memenuhi permintaan air. Tujuan penyelidikan adalah untuk menggemas kini peta geologi kawasan kajian dengan skala 1:25,000 dan mengenal pasti potensi air bawah tanah menggunakan kaedah Pengimejan Kerintangan Elektrik (ERI). Litologi utama kawasan kajian ialah marmar. Dalam penerokaan kawasan berpotensi air bawah tanah, 3 garisan ukur telah digunakan. Bagi garis ukur pertama dan kedua, susunan elektrod Gradient digunakan manakala bagi garisan ketiga ialah susunan Pole - Dipole dengan jarak elektrod 5 meter untuk hamparan garisan 200 meter untuk tinjauan. ABEM Terrameter LS digunakan untuk mendapatkan kerintangan dan data polarisasi teraruh. Selepas pengumpulan data, operasi bergerak ke pemprosesan data dan penyongsangan dengan program RES2DINV. Dengan mengunjurkan kerintangan dan nilai IP pada profil 2 D dan menganalisis data yang diproses, air bawah tanah yang berpotensi cetek wujud di sepanjang garis tinjauan 1. Potensi untuk air bawah tanah cetek telah ditunjukkan terjejas oleh pasir berbutir kasar di sepanjang garis tinjauan 2. Garisan tinjauan Keputusan bahagian model 3 menunjukkan bahawa air bawah tanah mungkin terdapat pada kedalaman 20 dan 45 meter di bawah paras laut. Telah ditunjukkan bahawa tinjauan geofizik dan pemetaan geologi adalah cara yang berkesan untuk mengenal pasti zon potensi air bawah tanah. Pembangunan bekalan air pada masa hadapan banyak bantu untuk usaha kajian ini.


**Kata kunci:** Peta geologi, potensi air bawah tanah, litologi, pengimejan kerintangan elektrik, garis tinjauan.

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## LIST OF ABBREVIATIONS

| No | TITLE |
|---|---|
| ERI | Electrical Resistivity Imaging |
| JRC | European Commission's Joint Research Centre |
| GHS | Global Human Settlement |
| BRSZ | Bentong – Raub Suture Zone |
| NE | Northeast |
| SW | Southwest |
| NNW | North – northwest |
| SSE | South – southeast |
| NNE | North - northeast |
| SSW | South – southwest |
| VES | Vertical Electrical Sounding |
| DCR | Data Collection Recorder |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of study

### 1.1.1 General Geology of Felda Chiku 05

Research is conducted in Kelantan, Malaysia, which is located in the north-eastern part of Peninsular Malaysia. Kelantan has a tropical climate, with temperatures ranging from 22 to 33 degrees Celsius (Ros, 2016). Felda Chiku 05 is near by the Gua Musang formation where it is dominated by limestone. The geomorphology of Felda Chiku 05 is consists of a small resident area, police station, masjid, hills and forest area.

### 1.1.2 Groundwater Demand in Malaysia

Groundwater is a natural water source that is found in the underground between the soils, rock and sand. Groundwater can be found in the type of rocks such as igneous and sedimentary or metamorphic rocks (Pressbooks, 2015). Groundwater is found in fracture zones in igneous and metamorphic rocks, whereas in sedimentary it will be stored in the space between the sand grains. The porosity and permeability of the rock that holds groundwater are generally high.

Since groundwater is in underground, we need technologies to extract the water. Modern technologies as drilling and pumping have made it simpler to access the groundwater, allowing people to exploit the storage capacity of very deep aquifers. Groundwater could also recharge naturally by absorbing the water out of rain into the pore spaces and crack of rock beneath the earth surface until it reaches the water table level of the aquifer (The Groundwater Foundation, 2022).

Groundwater is a second or alternative source of drinking especially in rural areas because there are no pipe water supplies over there. The advantage of groundwater is it is low turbidity where it contains more nutrient and it is way much cheaper than treated drinking water (Carrard et al., 2019). Groundwater also got be used for agricultural irrigation, domestic usage, industrial activities and for drinking. Hence, the demand for groundwater resources increases towards the population in Kelantan state.

## 1.2 Study area

### 1.2.1 Location

This research on identifying the groundwater potential will be carried out at Felda Chiku 05, Paloh, Gua Musang, Kelantan with the coordinate of 4°58'17.5''N, 102°12'0.6''E. Felda Chiku 05, Paloh is located at Southeast of Gua Musang district. This study area is surrounded with Masjid Al-Ghufran Felda Chiku 05 & 06 and Balai Raya Felda Chiku 5. The highest elevation that can be found at Felda Chiku 05 is 200 m and lowest will be 80m from sea level. The main river at Felda Chiku 05 area is called Sungai Chiku and Sungai Gasing.

a)
b)
c)
d)
e)

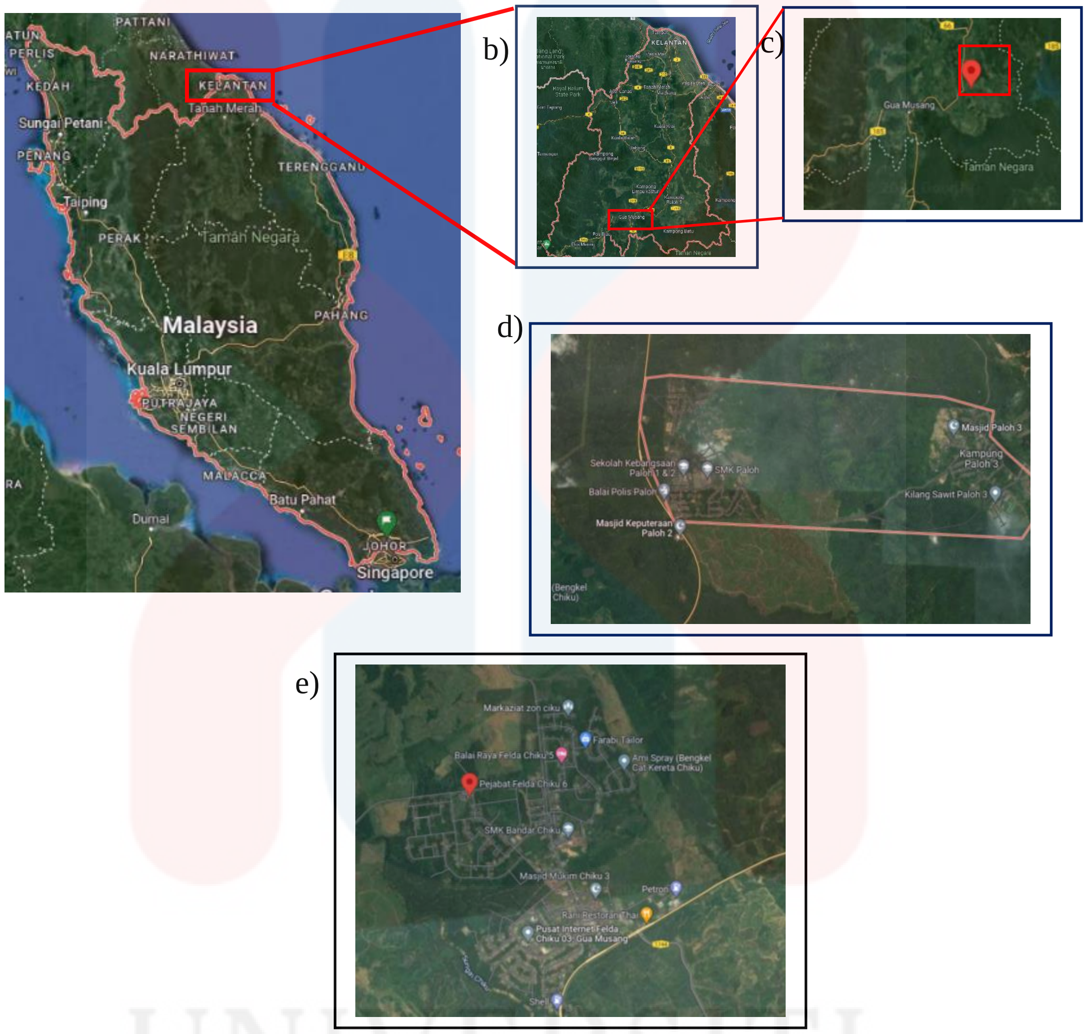





**Figure 1.1**: Satellite image of a) Malaysia map, b) Kelantan map,c) Gua Musang , d) Paloh and e) Felda Chiku 05.

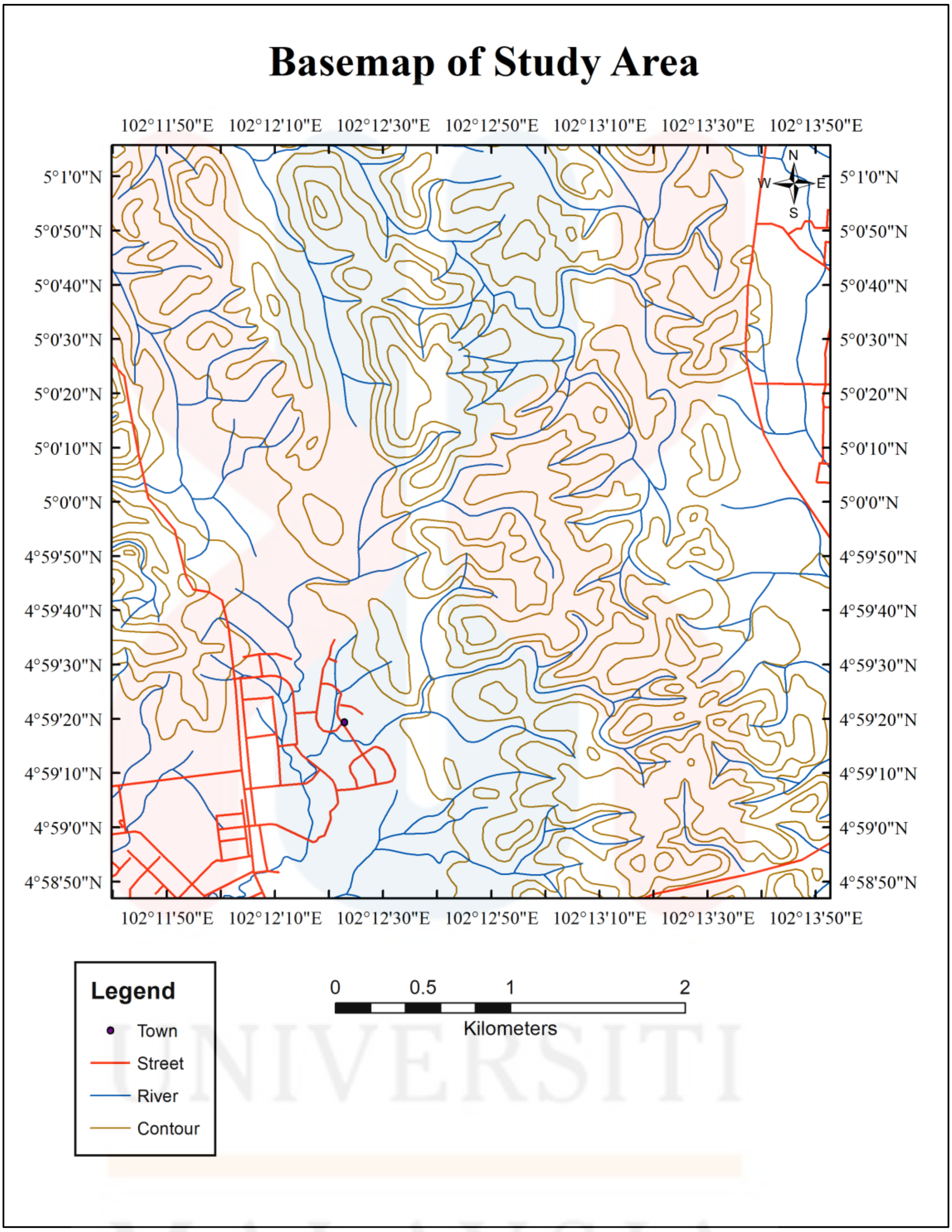



**Figure 1.2**: Basemap of study area.

### 1.2.2. Road Accessibility

Paloh area can be accessed via either Gua Musang or Kuala Krai, both of which are considered valid entry points (Figure 1.4). Approximately 58.1 kilometres separate Gua Musang and Paloh from one another while from Paloh to Felda Chiku 05 is 44.4 kilometres. Travellers coming from either direction must go via the Lebuhraya Kota Bharu - Gua Musang route. The distance of Felda Chiku 05 from UMK Jeli is 139km (Figure 1.5).

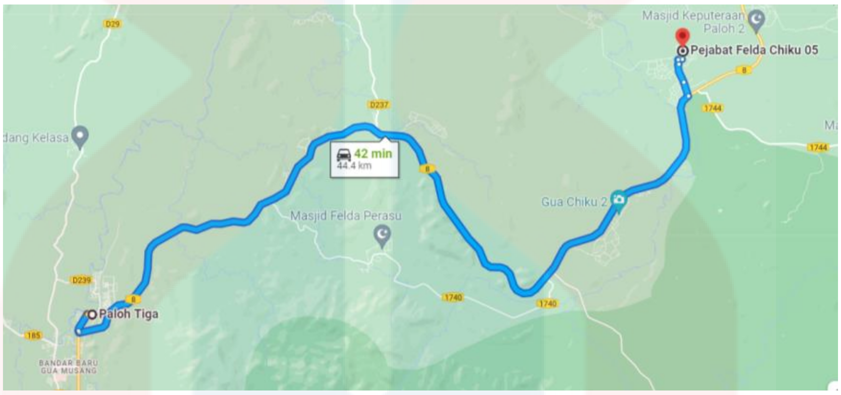



**Figure 1.3**: Road route from Paloh to Felda Chiku 05.


**Figure 1.4**: Road route from UMK Jeli to Felda Chiku 05.

1.2.3. Demography

The population of Gua Musang District on 2015 shows 90, 755 people with population density of 11.1/ $km^2$. In Gua Musang town, where most people work, there are a lot of people living close to each other. But Felda Chiku 05, Paloh area is thought to be an area with small population since it is mostly surrounded with plantation and forest.


| Data | 1975 | 1990 | 2000 | 2015 |
|---|---|---|---|---|
| Population | 48,364 | 66,353 | 79,673 | 90,755 |
| Population Density | 5.92 / $km^2$ | 8.12 / $km^2$ | 9.75 / $km^2$ | 11.1 / $km^2$ |

**Figure 1.5**: Population at Gua Musang area (City-facts, 2019) (Sources: JRC work on the GHS built-up grid)

1.2.4 Land use

Paloh is an agriculture area which is developed by the South Kelantan Development Authority (KESEDAR). It is composed of three distinct plans, which are referred to as Paloh 1, Paloh 2, and Paloh 3. The research site Felda Chiku 05 is located next to Paloh 2, which has an oil palm plantation of 1113.80 hectares and a rubber plantation covering 480.86 hectares. The remainder consists of protected areas of forest. (Hussin & Abdullah, 2012). Other than plantation land use such as residence area, shops, police station and mosque.

### 1.2.5 Social Economic

The majority of residents in the Felda Chiku 05, Paloh region make their livings, financially speaking, via agricultural labour and other estate-related jobs. The palm plantation is the most extensive plantation and estate in the region under consideration. The villagers are responsible for operating a variety of other little enterprises.

## 1.3 Problem statement

The first problem statement that need to be emphasize is the geological mapping. The information about the lithologies and geomorphological at the study area is insufficient. Recent construction at Paloh, Gua Musang might expose hidden rocks.

In Malaysia, Kelantan is one of the states that gives most priority to groundwater. Since 1930s, almost 70% of water supply in Kelantan is supported by groundwater (Hussin, 2020). Since the demand of groundwater is increasing for agriculture activity and drinking source, exploring groundwater potential areas for new extraction wells are extremely important to meet the demand of water (Wada et al., 2010).

## 1.4 Objectives

The main purpose of this research is:

1. To update a geological map at Felda Chiku 05, Paloh, Gua Musang at 1: 25 000 scale.
2. To identify the groundwater potential at Felda Chiku 05, Paloh, Gua Musang using Electrical Resistivity Imaging (ERI) method.

## 1.5 Scope of study

The primary focus of our investigation will be to produce an update geological map at Felda Chiku 05, Paloh area with range of 25 $km^2$. The geological map produced will provide sufficient information such as 1lithologies, geomorphological, structural geology and sampling of outcrop. Geological features at the study area will be observed during traversing. The specification of this research is to identify the groundwater potential using geophysical method is Electrical Resistivity Method (ERI). The software that will be used for mapping and specification are ArcGIS, GeoRose, RES2DINV and Terrameter LS Toolbox Software.

## 1.6 Significant of study

This research is very significant in providing information such as geological structures, drainage system and lithology by producing the geological map of study area. Updated geological map can be a useful guidance for future researcher. Furthermore, observation during mapping process, could also help us to determine the earth movement from past to present.

The output of this study will benefit the residence of Kampung Felda Chiku 05 area and the government by locating the area which has potential of groundwater resources. New location of groundwater resources could be helpful for the residence for domestic usage, agricultural and industrial activities. Therefore, we can overcome high water demand issues especially during dry season and due to pipe damage and breakage during flood season which makes them to utilise river water as their alternative water resource. This research on determining the groundwater potential area could also be a guidance to explore groundwater resources or used as a reference in future studies in the field.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This chapter mainly summaries the literature review from previous study which is related to the study area and identification of groundwater potential. Literature review basically provides significant information such as stratigraphy, structural geology and historical geology of Malaysia.

## 2.2 Regional geology and tectonic setting

Kelantan is a northern Malaysian state (Fig. 1.2). The main waterway is Kelantan River. The Kelantan River basin covers 923 km2, or 85% of the state. Along Kelantan, volcanic, sedimentary, and metamorphic rocks are dispersed north-to-south (Pour & Hashim, 2017). The region has granitic, sedimentary/metasedimentary, extrusive (volcanic), and unconsolidated deposits. Western and eastern state borders have granitic rocks. Main Range Granite reaches north to Thailand from the BRSZ's boundary. Lebir Fault Zones are one of Peninsular Malaysia's primary lineaments (Fig. 2.1).

Peninsular Malaysia is divided into four structural zones: northwest, west, central, and east. Throughout the Palaeozoic, the Northwest structural domain contains NE striking structures, contact aureole, and continuous deposition (Kasim et al., 2020). The structural trend in the Western domain is NNW and N, with major tectonic movement westward, while the structural grain in the Central domain ranges between North and NNW. The Bentong-Raub line to the west and the Labir Fault zone to the east define the Central extensional graben. The regional structural trend in the Eastern domain is NW to NNW.

In the Western Belt, most of the rocks are clastic and carbonate sediments, with a few volcanic rocks here and there. The Main Range is made up of granitic rocks from the Triassic, and the belt is made up of rocks from the Palaeozoic., margin sequence that was linked to the northwest Australian portion of Gondwana until the early Permian (Metcalfe, 2000). Palaeozoic sediments are found in the majority of locations with Mesozoic rocks scattered throughout Kedah and northern Perak. The Kinta Valley has carbonate limestones ranging from the Silurian to the Permian epochs, but other sites have metasediments and lower Palaeozoic limestones.

The major rocks of the Central Belt, which is an extensional graben limited to the west by the Bentong-Raub suture zone and to the east by the Lebir Fault Zone, are deposits of Palaeozoic and Triassic rocks, with some Jurassic and Cretaceous rocks in small amounts. Marine carbonate sediments, shales, volcanic-clastic, and andesites are among the deposits found here. North of the band, shallow marine sediments from the Permian to Lower Triassic. There are marine Permian strata from the Gua Musang Formation, Aring Formation, and Kepis Beds in the Paleozoic and Mesozoic periods, as well as carbonaceous rocks from the Semantan Formation and the red siliciclastic Paloh Formation in the latter period (Kasim et al., 2023).

The Eastern Belt contains two primary depocenters: Permian clastic marine sediments south of West-northwest-east-southeast (WNW-ESE) striking Lepar fault and Carboniferous metasediments north. Palaeozoic sediments unconformably overlie Jurassic-Cretaceous continental deposits. Carboniferous sediments (Kuantan Group, Kamning and Seri Jaya beds) and Permian conglomerates dominate (Linggui and Dohol formations). (Kasim, Suhaili, & Salim, 2020).

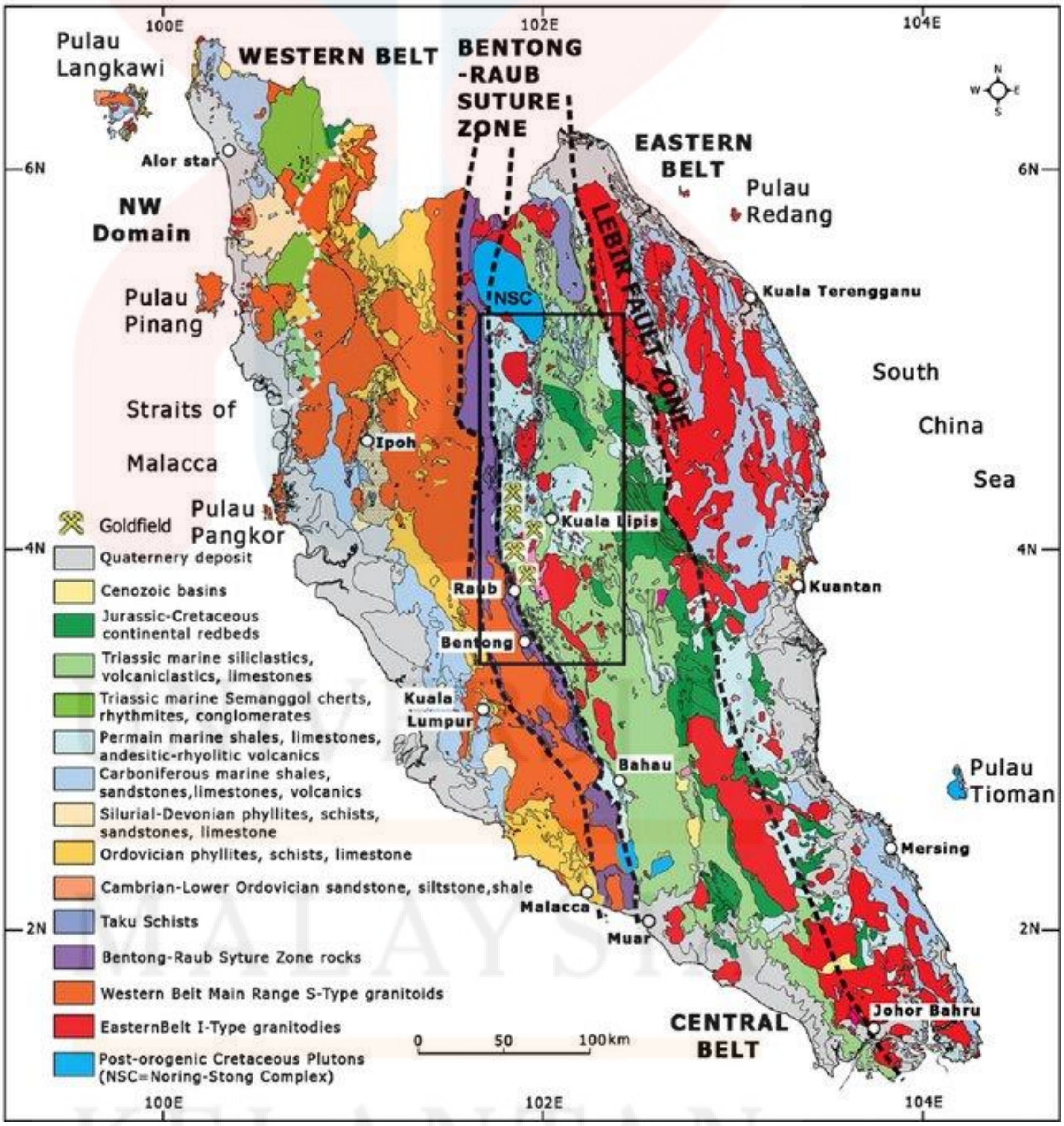



**Figure 2.1**: Geologic map of the Peninsular Malaysia (Hashim, 2013).

## 2.3 Stratigraphy

Gua Musang, Kelantan is part of Peninsular Malaysia's Central Belt, which spans from Kelantan to Johor. In the western half of the Central Belt, you can find the Upper Palaeozoic Gua Musang and Aring Formations in south Kelantan and the Taku Schist in east Kelantan. The Gua Musang Formation is made up of crystalline limestone that is thought to be 650 metres thick (Sulaiman, 2021). Thin layers of shale, tuff, chert nodules, and subordinate sandstone and volcanics are mixed in with the limestone. Calcitic limestone is hard, doesn't have pores, breaks easily, and has sharp edges with a light grey colour. Limestone that has been recrystallized often has a grey to black colour and contains minimal levels of carbonaceous, argillaceous, and pyroclastic impurities (Mah, 2018).

At a scale of 25, 000, determine the accretion environment for a sedimentary unit in Gua Musang's Paloh area In the Paloh region, four distinct lithological units may be found. Tuff, mudstone and andesite units make comprise the metasediment unit of the Middle Permian period. The metasediment unit is the oldest rock unit. A tuff unit from the Early Triassic period has been deposited above the unconformity. The Middle Triassic mudstone unit lies on top of the unit's conformity. Mudstone and siltstone make up the mudstone unit. Unconformity on mudstone unit is overlain by the youngest Late Triassic andesite unit (Xin, 2018). Andesite lava and tuff make up the majority of the structure. Hit-slip faults strike the research region from the NNW-SSE and NNE-SSW directions. (Mah, 2018).

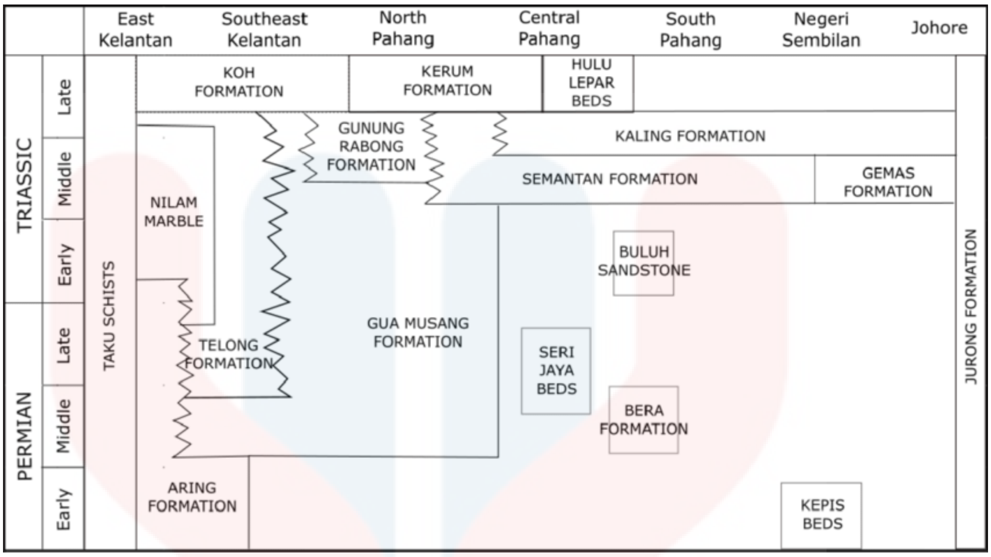



**Figure 2.2**: Permo-Triassic stratigraphic correlation chart of Central Belt Peninsular Malaysia. Modified from Metcalfe & Hussin (1995) (Mohamed et al., 2016).

## 2.4 Structural Geology

Structural geology is the study of how rock units are arranged in three dimensions based on how they have changed over time. The main goal of structural geology is to use measurements of the shapes of rocks today to learn about the history of deformation (strain) in the rocks and, ultimately, to figure out the stress field that caused the strain and shapes that are seen today. This knowledge of how the stress field changes can be linked to important events in geologic history. One common goal is to understand how the structure of a certain area has changed over time in relation to regionally widespread patterns of rock deformation caused by plate tectonics, such as mountain building and rifting.

Taku Schist, and Gua Musang Formation is geologically present in Negeri Kelantan. Granite, diorite, andesite, ignimbrite, and dolerite are igneous rocks in Negeri Kelantan. (Yao, Oludare Idrees, & Pradhan, 2017).

Granite intrusion and diorite pop hire towards NE-SW characterise the northern portion of this major fold. Dextral faults are the most common in the Gua Musang Formation. Gua Musang Formation created the compact and firmly folding in the area border by igneous granite intrusion and near the main fault. To follow this diorite intrusion, the major fold of the Gua Musang Formation has been named. The major compression that caused the Gua Musang Formation to fold and fault (Yao, Oludare Idrees, & Pradhan, 2017).

The primary faults in the Gua Musang Formation are the sinistral fault, which has a strike of N330-340o E and dips 60-80o to the ENE-WSW, and the dextral fault, which has a strike of N30-45o E and dips 60-70o to SE. Gua Musang Formation created a compact and highly folding region in the vicinity of the major fault and in the zone bounded by igneous granite intrusion. The major fold of the Gua Musang Formation must be termed to follow this intrusion of diorite pophire. The Gua Musang Formation's folding and faulting were mostly caused by compression that occurred between the WNW-ESE and ENE-WSW (Meetings of the Society, 2017).

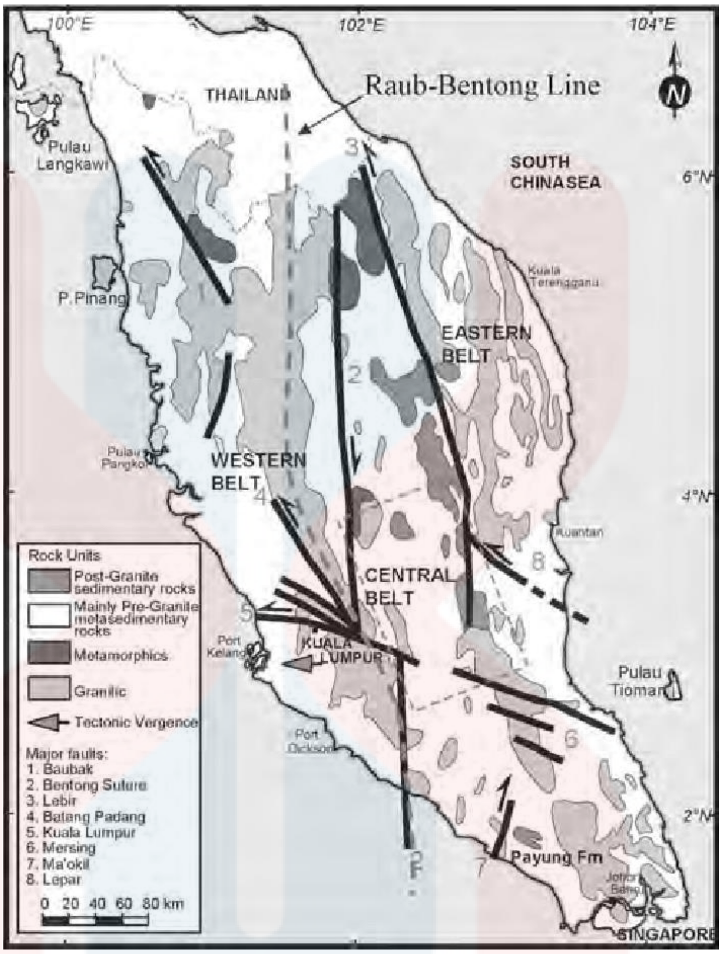



**Figure 2.3**: Geological map of Peninsular Malaysia, showing the main rock groups and faults (Hutchison, 1989).

2.5 Historical Geology

During the period of Carboniferous, East Malaya was attached with Indochina plate and Sibumasu attached with Gondwana; become a part of Cimmerian plate (Jasin, 2013). But from the Devonian to the Permian, an ocean called the Palaeo-Tethys kept the Sibumasu and East Malaya blocks apart.

Middle Permian-Middle Triassic sediments from the Gua Musang Formation are comprised of crystalline limestone interspersed with thin layers of shale, tuff, and chert nodules (Mohamed et al., 2016). The Gua Musang Formation stratigraphic model, burial history, and geothermic model were developed by examining three outcrops of the formation. Sandstone and conglomerate make up the first outcrop, followed by limestone and shale and siltstone in the next two (Folk & Bissell, 2022).

## 2.6 Hydrogeology/ groundwater

Groundwater is the water existing under Earth's surface in rock and soil pore spaces and in the cracks of rock formations. About 30 percent of all easily accessible freshwater in the globe is groundwater. When an unconsolidated deposit or a unit of rock may provide useable water, it is referred to be an aquifer. The water table refers to the depth at which soil pore spaces or rock cracks and voids are totally saturated with water. Groundwater is replenished by rainfall, and it may be discharged naturally at springs and seeps, forming oases and wetlands in the process.

Groundwater is also commonly removed for agricultural and industrial usage by building and running extraction wells. Although shallow aquifers are often associated with groundwater, technically, it may also include soil moisture, permafrost (frozen soil), immobile water trapped in bedrock with very limited permeability, and deep geothermal or oil formation water, among other things. Groundwater is theorised to offer lubrication that might potentially impact the movement of faults.

The stores of Pleistocene and Holocene primarily comprise of unconsolidated to semi combined rock, sand, mud, and sediments that possess in the north of Kelantan state and along the stream valley. The initial 13 to 15 m store is late in age and made out of silty to earth. Towards the coast, the thickness of alluvium might arrive at up to in excess of 200 m and it frames a shape like a thick wedge towards the ocean.

This silt is convoluted and comprised of interstratified and intercalated store with marine and non-marine layers The combinations of marine and non-marine dregs work of because of ocean level changes during the Quaternary age.

A confined aquifer, according to hydrogeology, is always located under water-saturated terrain. Layers of impermeable material lie both above and below the aquifer, causing it to be under pressure such that when the aquifer is pierced by a well, the water will rise over the top of the aquifer. An unconfined aquifer has a water table that rises beyond the level of the surrounding water. As a result, it may rise and decrease with changes in air pressure. Water table aquifers are generally closer to the Earth's surface than confined aquifers are, and as such are influenced by drought conditions sooner than confined aquifers (Hussin, Yusoff, & Raksmey, 2020).

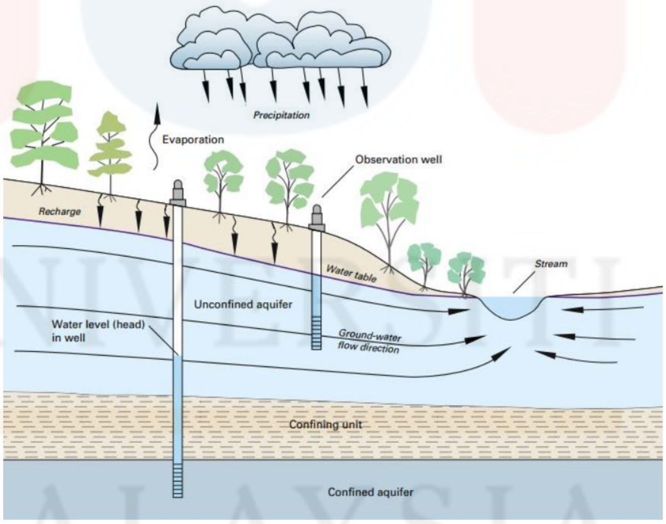



**Figure 2.4**: Hydrogeological section with confined and unconfined aquifer 1 (Montoya, 2017).

Groundwater is a vital natural resource that plays an essential part in the economy. It is the primary water supply for agriculture and the food sector. In general, groundwater is a dependable supply of water for agriculture and may be utilised in a flexible manner: when it's dry and there's a high demand, more groundwater can be drawn; when the rain fall satisfies the needs, less groundwater must be removed. Groundwater is critical to the ecology because it maintains the water level and flow into rivers, lakes, and wetlands. It feeds the environment with groundwater movement via the bottom of these water bodies, which becomes crucial for the wild animals and plants living in these surroundings, especially during the dry months when there is minimal direct recharge from rainfall.

Groundwater plays an important role among the residence especially during the dry and flood season. During the dry season, the residence tends to use river water as their alternative usage while during flood, problems such as damage, breakage and leakage of pipes often happens. This causes the residence to depend on groundwater sources for their basic essential needs.

## 2.7 Research specification/ ERI

To determine the groundwater potential of the research region, geological and geophysical studies were carried out (Nazaruddin et al., 2016). It is also used for determine the earth subsurface condition such as the subsurface thickness, rock structure, groundwater flow and aquifer, groundwater salinity and mineral exploration (Reynolds 1997). In the resistivity method, there are five types of electrode configurations for the resistivity method such as Wenner, Schlumberger, Dipole-dipole, Pole-dipole, and Pole- pole (Muzamil et al., 2016).

| Material | Resistivity (Ohm–m) | Conductivity (Siemen/m) |
|---|---|---|
| *Igneous and Metamorphic Rocks* | | |
| Granites | $5 \times 10^2 - 10^3$ | $10^{-6} - 2 \times 10^{-4}$ |
| Basalt | $10^3 - 10^6$ | $10^{-6} - 10^{-3}$ |
| Slate | $6 \times 10^2 - 4 \times 10^7$ | $2.5 \times 10^{-8} - 1.7 \times 10^{-3}$ |
| Marble | $10^2 - 2.5 \times 10^8$ | $4 \times 10^{-9} - 10^{-2}$ |
| Quartzite | $10^2 - 2 \times 10^8$ | $5 \times 10^{-9} - 10^{-2}$ |
| *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 x 10 – 0.1 |
| Groundwater(Fresh) | 10 – 100 | 0.01 – 0.1 |
| Salt Water | 0.2 | 5 |
| *Chemicals* | | |
| Iron | $9.074 \times 10^{-8}$ | $1.102 \times 10^7$ |
| 0.01M Potassium Chloride | 0.708 | 1.413 |
| 0.01M Sodium Chloride | 0.843 | 1.185 |
| 0.01M acetic acid | 6.13 | 0.163 |
| Xylene | $6.998 \times 10^{16}$ | $1.429 \times 10^{-17}$ |

**Figure 2.4.1:** Resistivity range of different rock types, soil and chemicals (Andrade, 2011).

Among the four cathodes utilized with the resistivity meter, two are utilized to go the current through while the other two measure the adjustment of potential. The disadvantage of Wenner array is, in order to obtain the reading all, the 4 electrodes should be moved while advantage is fewer sensitive voltmeters are utilised because the spacing of potential and voltmeter is directly proportional. Wenner array is basically used in soil testing or in profiling exploration of ground. (Cubbage, Noonan, & F Rucker, 2017).

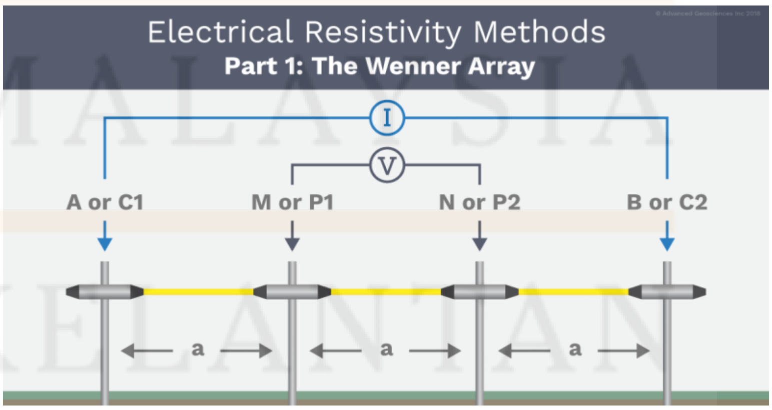



**Figure 2.5:** Wennery array arragement (Hasan, 2017).

With the Schlumberger array, just the external two anodes (the cathodes providing and getting the current) are moved. The benefit of this is that it is a lot quicker because only the main two anodes must be moved but a highly sensitive voltmeters are used because the potential spacing is smaller compared to current electrode. The Schlumberger array is used for vertical electrical sounding (VES) finding in groundwater (Rahmani, Sari, Akmam, Amir, & Putra, 2020).

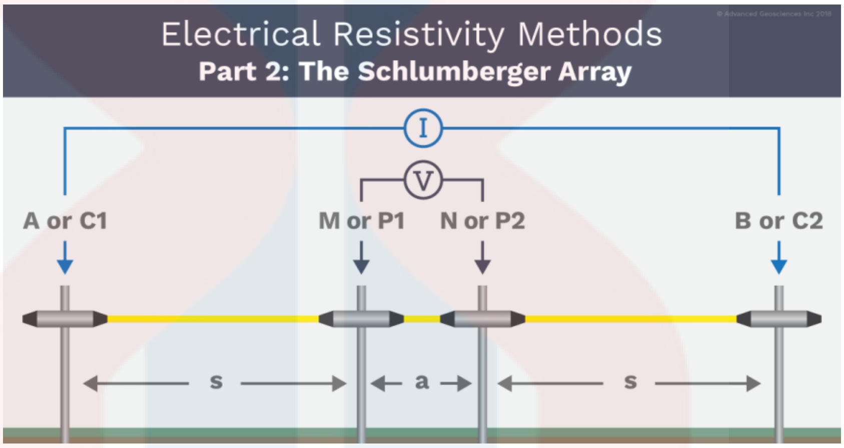



**Figure 2.6**: Schlumberger array arrangement (Hasan, 2017).

The dipole-dipole array comprises of an ongoing anode pair An and B and a potential cathode pair M and N. The primary advantages of the dipole-dipole array are its high resolution where it produces detailed image. If the dipoles are set too widely apart, the signal will be lost and the array will be unable to look further into the ground. (Hasan, 2017a).

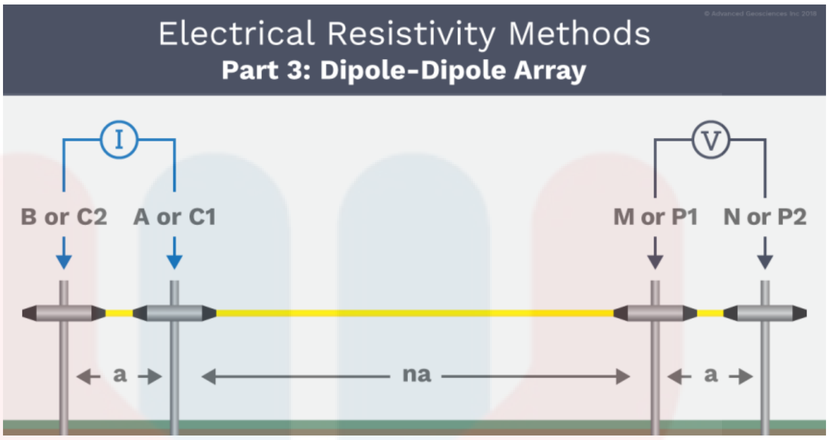



**Figure 2.7**: Dipole-dipole array arrangement (Hasan, 2017).

A pole is a solitary communicating cathode, and a dipole is a pair of oppositely charged terminals that are so near one another that the electric field looks like single electrode instead of 2 different ones. Pole-dipole provides a clearer picture of the cross section of the earth (Hasan, 2017b).

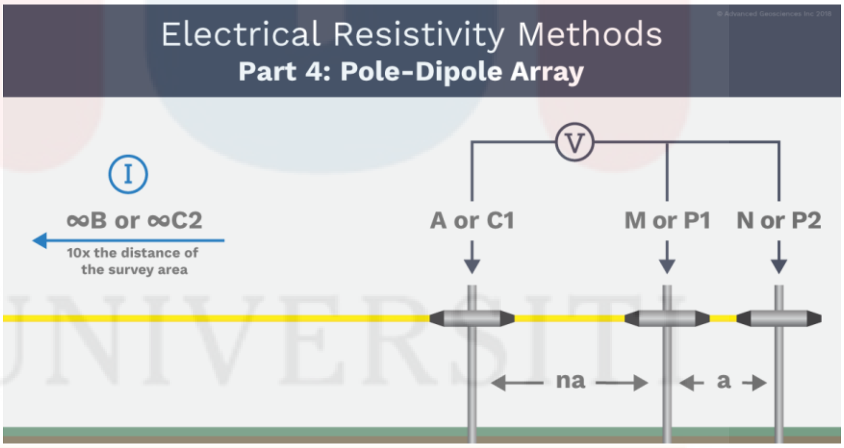



**Figure 2.8**: Pole-dipole array arrangement (Hasan, 2017).

Additionally, one of the potential electrodes is shifted to infinity in the opposite direction as the reception electrode in a pole-pole survey. In a pole-pole array, each side of the survey area has a stationary infinity electrode. (Hasan, 2017c).

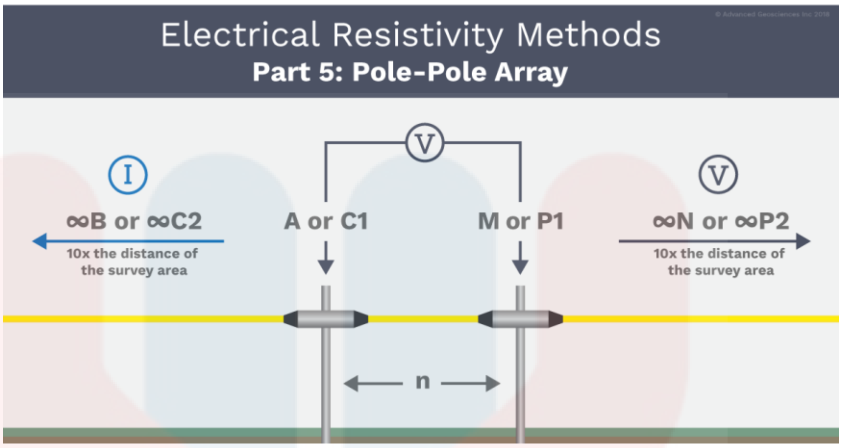



**Figure 2.9**: Pole-pole array arrangement (Hasan, 2017).

The potential energy between two adjacent current electrodes is read to obtain a measurement using the Gradient Array. The transmitter dipoles A&B are used to measure the lateral variations in the Gradient Array's potential field. The process of profiling is sometimes referred to as recording lateral changes (Sean, 2019). Gradient array is something similar to Schlumberger array but Schlumberger only records the receiver from center dipole compared to Gradient, it measures all adjacent dipoles.

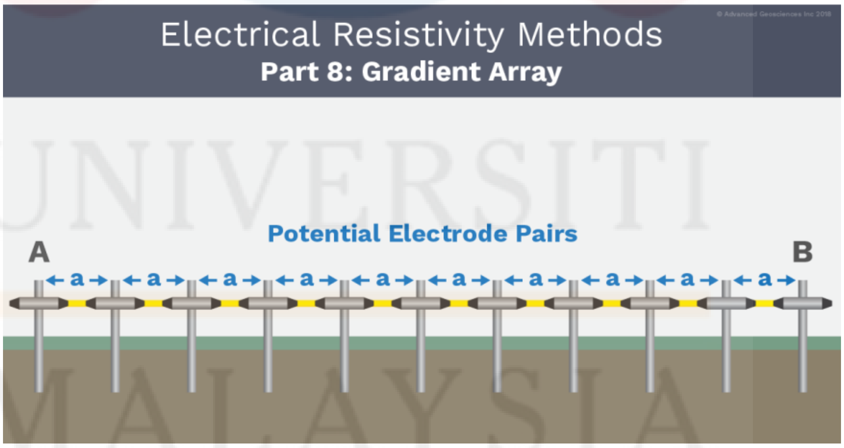



**Figure 2.10**: Gradient array arrangement (Sean, 2019).

**Table 2.10**: Advantages and disadvantages of gradient array.

| Advantages | Disadvantages |
|---|---|
| Use 56 electrodes with spacing of one metre which produces a stronger signal. It is ideal for multichannel data collection | Difficult to be visualised. |

The dipole array has the potential to provide better resolution compared to the other arrays, and the Wenner-Schlumberger combination has the potential to provide greater depth of investigation. Therefore, out of the five Electrical Resistivity Imaging (ERI) arrays, the dipole-dipole array and the Wenner-Schlumberger combination are the ones that are chosen (Naveen Kumar T, Rama Rao P, & Naganjaneyulu K, 2015). It is clear that the system that utilises the dipole array is only capable of scanning to a depth of around 22 metres, while the Wenner-Schlumberger system is capable of scanning to a depth of approximately 60 metres.

# CHAPTER 3

# MATERIALS AND METHODOGY

## 3.1 Introduction

This chapter's objective is to explain the materials and methods used in this study, along with the part that each one played in reaching the study's objectives. Both the materials and the technique used in the research play a vital part. Methodologies include in a wide variety of forms, including material, preliminary studies, sampling, traversing, laboratory investigation, data processing, and data analysis.

## 3.2 Materials and Equipment

Geology mapping and the specification of groundwater potential are the two primary categories into which the material might be placed. To accomplish the goal of our research, we had required a few different types of materials such as Global Positioning System (GPS), compass, geological hammer and software as ArcGIS and Georose. The following is a list of the necessary materials and equipment that had been utilized.

**Table 3.2**: Materials needed for mapping and geophysical survey.

| Materials | Function | Picture |
|---|---|---|
| Geologist Hammer | To collect rock sample from outcrop |  |
| Brunton Compass | Identify strike and dip value. |  |
| Global Positioning System (GPS) | Shows direction and navigate us with information as coordinate and elevation. |  |
| Camera | To capture pictures of outcrop around us as evidence or for more information. |  |

| | | |
|---|---|---|
| Hydrochloric Acid (HCL) | To identify the presence of calcite in the outcrop. |  |
| Hand Lens | To observe the mineral grains of the hand specimen. |  |
| Sampling plastic | Store rock sample collected. |  |
| Microscope | To analyze mineral composition in thin section. |  |

| | | |
|---|---|---|
| Thin Section Machine | To precise thin section cutting. |  |
| Electrical Resistivity Imaging (ERI)<br>a) ABEM Multi Core Cable<br>b) ABEM Terrameter LS<br>c) Electrodes<br>d) Battery<br>e) Clips | To conduct geophysical survey. |  |

## 3.3 Methodology

This research is carried out by adhering to a set of protocols, processing the data, and creating it in software. It is necessary to use software in order to generate the geological mapping and to determine the region that has the potential to contain groundwater.

### 3.3.1 Preliminary study

Preliminary research was a main data gathering from journals, publications, reports and prior studies regarding both geological mapping and specification of groundwater exploration. Preliminary study was a step that needed to be done before beginning the field work in order to get ourselves ready for all of the potential outcomes and surprises that may show up at the conclusion of the research.

### 3.3.2 Field studies

Field study was a must in order to generate the geological mapping. Observation through traversing process at the study area and collecting rock sample for further study.

a) Sampling

Sampling was a process of obtaining rock samples from the outcrops located at the research area. When collecting rock samples, make sure they were in fresh condition and not weathered. It was necessary to break the exposed rock up into tiny pieces in order to get the fresh section of the rock. The size of the rock sample ought not to be too little or excessively large.

b) Traversing

Traverse was a method of surveying the study area by walking along the route and plotting the geology observed on the way. Observation such as taking note on the river channel, geomorphology, outcrops and lithology of the area. Traversing helped us to collect all sort information to generate a complete geological mapping.

c) Geophysical survey

This survey was carried out to identify the groundwater potential resource at Felda Chiku 05, Paloh area. The geophysical method used was Electrical Resistivity Imaging (ERI) with suitable electrode array configuration. There are several types of electrode arrangement such as Wenner, Schlumberger, Pole-pole, Dipole-pole, Dipole-dipole and Gradient. The electrode arrangement which had been used was determined based on the objective of the study.

Different electrode arrangement covers different in depth. Wenner covers less depth compared to Schlumberger while Pole-dipole results the greatest depth. Wenner array provides information about the structure trace whereas Pole-dipole array was more to exploration of groundwater potential. Reading from 3 survey lines were collected using Gradient and Pole-dipole array with electrode spacing 5m for 200m lines.

### 3.3.3 Laboratory investigation

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 a igneous, sedimentary or metamorphic rock. So, microscope was the important tool during this analysis.

### 3.3.4 Data processing

Data processing method involves usage of software as ArcGIS, Terrameter LS Toolbox, RES2DINV and GeoRose to update geological mapping and to process geophysical survey. This method basically uses software.

a) ArcGIS Software

The construction of a map requires the use of software that enables the user to generate, update, analyse, and share information. The topographic data from the Department of Mineral and Geoscience Malaysia was included into the software that was used for field investigations. This results in the creation of a base map. Additionally, a geological map of the Paloh region may be generated using the programme.

b) Terrameter LS Toolbox Software

Terrameter LS Toolbox was a software by ABEM Instruments, that may be used to calculate IP as well as pre-process raw DCR data that has been obtained by Terrameter LS. It provided the user the ability to access raw field data acquired with Terrameter LS, display it in a variety of different ways, and export it into a preferred format that could be read by inversion software (Palo, 2021).

c) RES2DINV Software

RES2DINV software was known as a 2D inversion software. The software worked very easily where it imported data for inversion and visualization. It supported all electrode configurations and cross-borehole surveys ("Geotomo Res2DInv," 2020).

d) GeoRose Software

Software for determining the joint's alignment and force direction. The programmer was updated with information on the structure's orientation. Rose diagrams, stereonet diagrams, and dip direction and angle diagrams may all be generated.

### 3.3.5 Data Analysis and Interpretation

The data that had been obtained will be examined with the guidance of the supervisor. After seeing the study area, the results of this analysis will be connected with the lithology. The data will be analyzed using specialized software in accordance with the resistivity table that was unique to the situation.

# CHAPTER 4

# GENERAL GEOLOGY

## 4.1 Introduction

The content this chapter is about geology which includes geomorphology, petrography, structural geology, historical geology and stratigraphy. Moreover, geomorphological research evaluates the study area's landform, drainage, contour pattern, and weathering. In addition, the evaluation of the strata took into consideration the details and contents of the rocks and minerals through the studies of lithology, lithostratigraphy, and petrography. The geological structures discovered in the research region were then discussed and analysed for structural geology, and the history of that particular place was examined for historical geology. These components were studied before mapping and during the mapping activity. For future research on the general geology of the subject region, this chapter is vital.

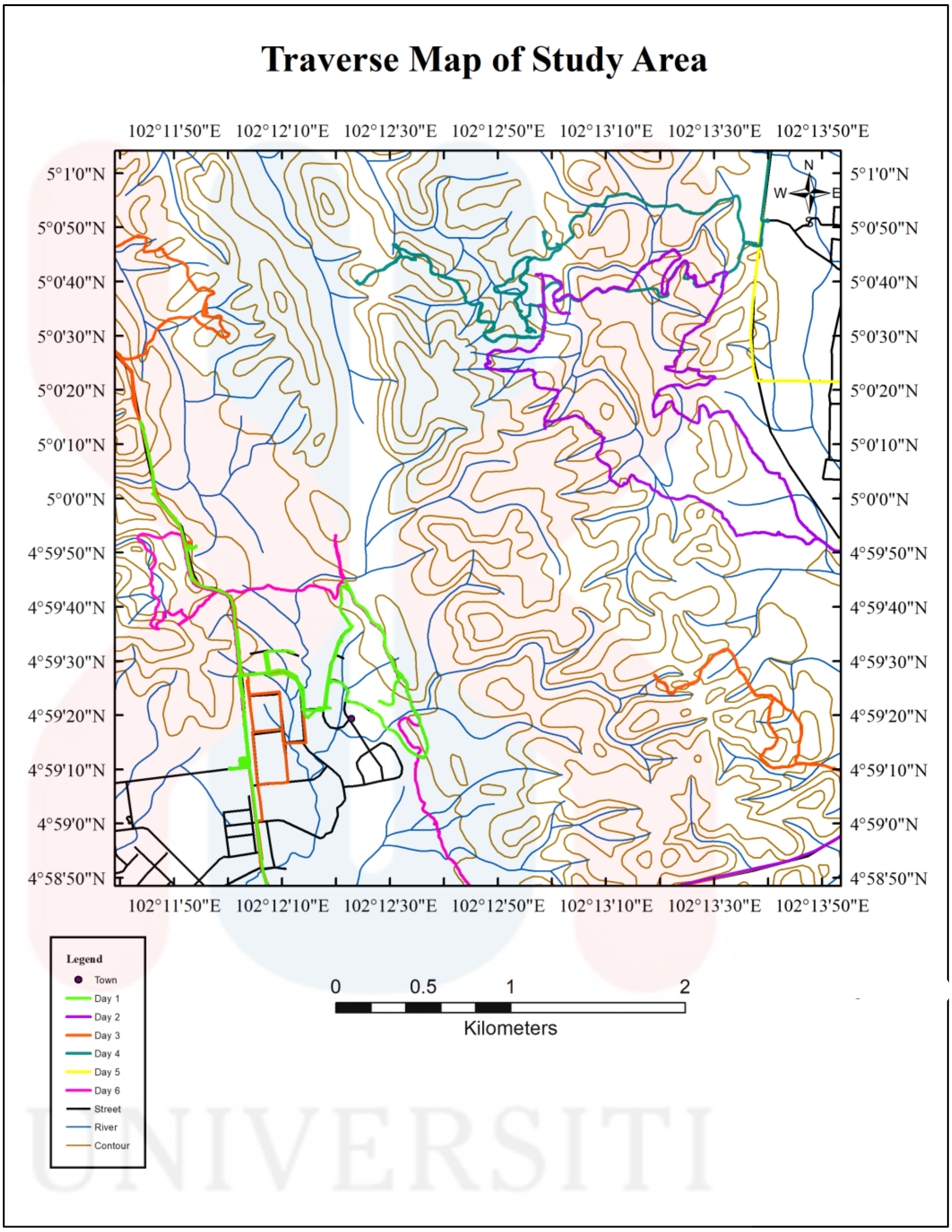



**Figure 4.1**: Traverse map of the study area.

## 4.2 Geomorphology

The study and description of the morphology of the Earth in terms of its geometry and in relation to the process of the creation and evolution of landforms in each region are the primary objectives of the scientific discipline known as geomorphology. It is also the scientific study of scenery, which is concerned with the study of landform and the nature of the land surface as a whole and of it as distinct parts such as mountains and valleys, rifts, hills, plains, and alluvium.

The geomorphology at my study is river and hilly area. Since the area is mostly covered with oil palm plantation water resources through river system is important and it has the hilly and mountainous area.

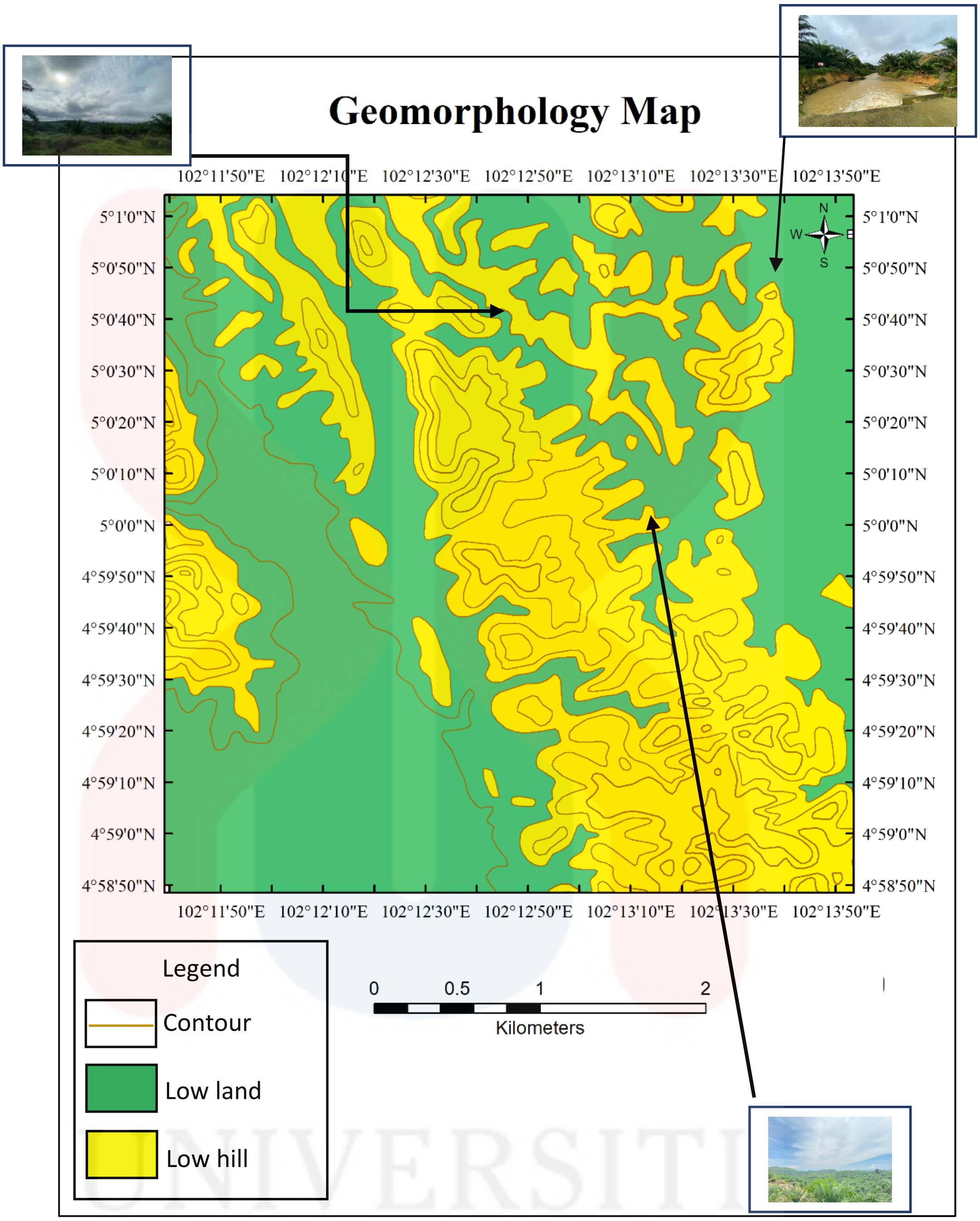



**Figure 4.2**: Geomorphology map of the study area.

### 4.2.1 Landform

The elevation, slope, orientation, stratification, rock exposure, and soil type are some of the basic physical qualities that are used to classify different types of landforms. There are four primary categories of landforms, which are mountains, hills, plateaus, and plains. In general, the landform in the region under study may be broken down into two categories: hilly areas and mountainous areas. These are the two categories. There are several lithologies to choose from, each one suited to a certain landform. Typically, sedimentary rock or metasedimentary rock may be found in steep places. Igneous rocks are often present in regions with hilly terrain. As can be seen in Table 4.1, various types of landforms produce an assortment of lithologies and elevations.

According to the study area there are 2 types of landforms identified low land and low hill. Low land is basically more to flat area with elevation below 100m while low hill is known as small hill area with elevation 100m – 200m.

**Table 4.1**: Types of landforms and elevations (Hutchison, C. S, 2014).

| LANDFORM | ELEVATION (m) |
|---|---|
| Low land | < 100 |
| Low hill | 100 - 200 |
| Hill | 200 - 500 |
| High hill | 500 – 1500 |
| Mountain | 1500 - 3000 |
| High Mountain | > 3000 |

**Figure 4.3**: River at study area.

**Figure 4.4**: Mountainous area.

**Figure 4.5**: Geomorphology view.

### 4.2.2 Drainage system

A drainage system is a pattern generated by the streams, rivers, and lakes in a given drainage basin. This pattern is studied in the geomorphology discipline. They are influenced by the topography of the land, the gradient of the land, and whether or not a specific location is dominated by hard rocks or soft rocks. A drainage basin is a geographical area from which a stream receives runoff, through flow, and groundwater flow.

. In general, the drainage pattern of the study area can be broken down into two distinct patterns: the first pattern is a pinnate pattern, the second pattern is a rectangular pattern, and the third pattern is a dendritic pattern of the stream. Each of these patterns is described in more detail below. The three patterns of drainage that may be seen in the research region are shown in Figure 4.7. The pattern of drainage known as pinnate is represented by the yellow colour, the pattern known as rectangular drainage is represented by the red colour, and the dendritic pattern of the drainage system is represented by the green colour.

Pinnate pattern is developed in a narrow valley flanked by steep ranges. A rectangular pattern is a pattern that originated at a site where there was minimal topography, as seen in Figure 4.6 below. This pattern may be recognised by its rectangular shape. The changes in drainage pattern are the results of geological structure such as major lineament and faults found in my area.

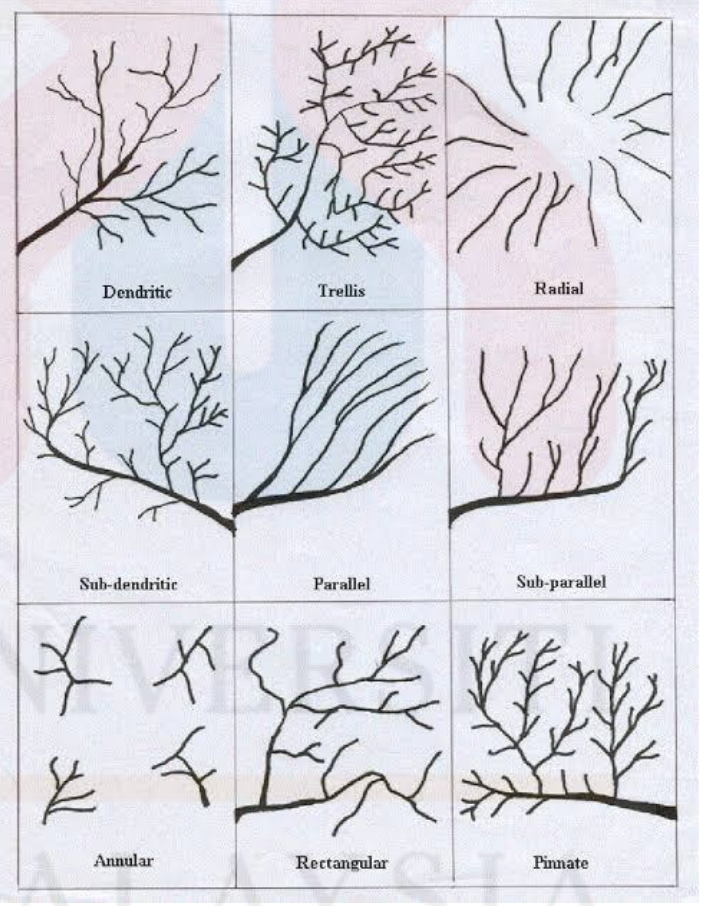



Figure 4.6: Types of drainage pattern (Singh, 2019).

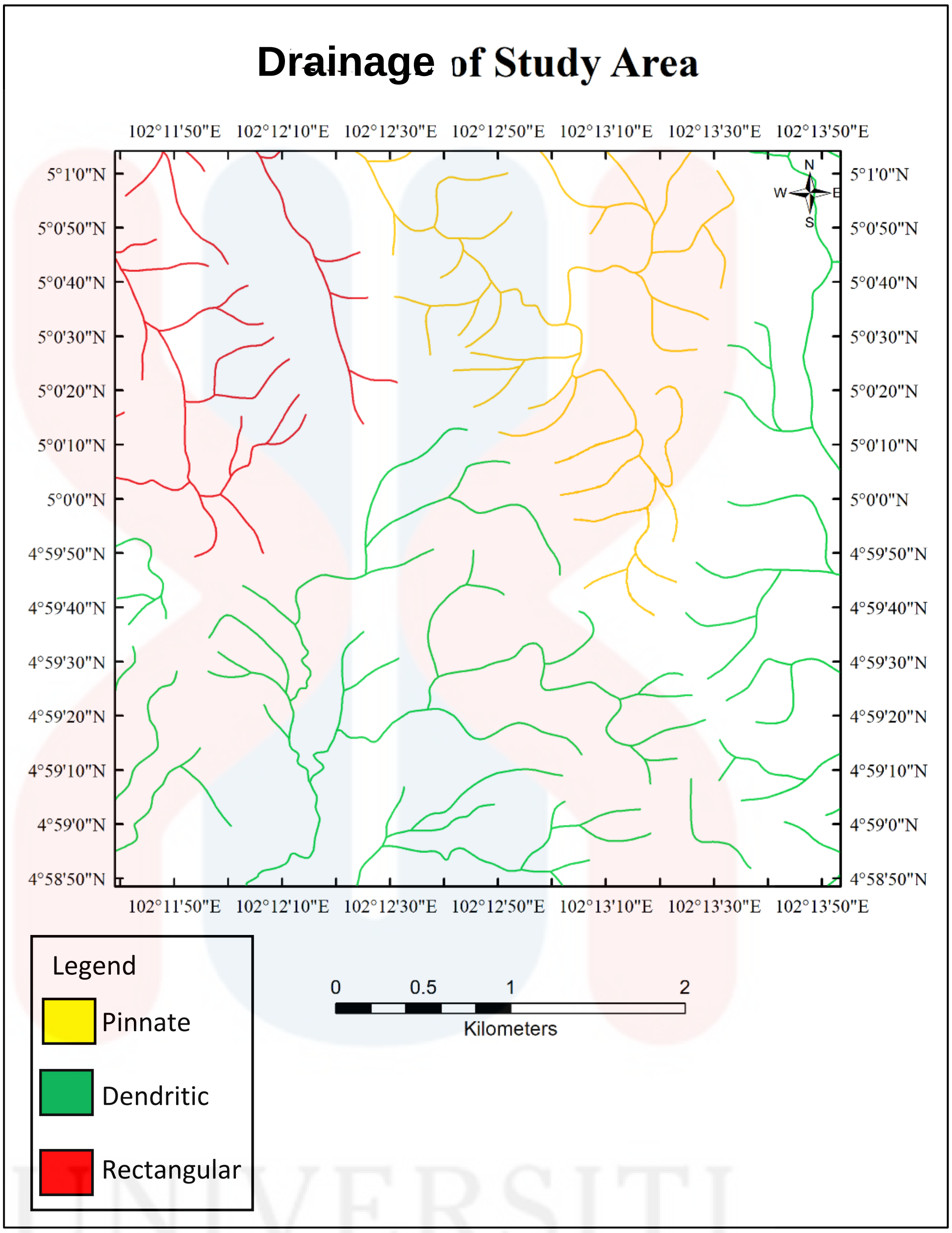



**Figure 4.7**: Drainage pattern in my study area.

4.2.3 Watershed

A watershed, often referred to as a catchment area, is a region of land that collects all of the water that flows into it from rivers, streams, and other tributaries, and then releases it into a larger body of water, such the major river channel in the area under study. The border of a watershed is often determined by the section of the watershed that has the highest point, such as ridge tops. Watersheds are typically split at this region. The topography will affect both the path that the water takes and how it gets there.

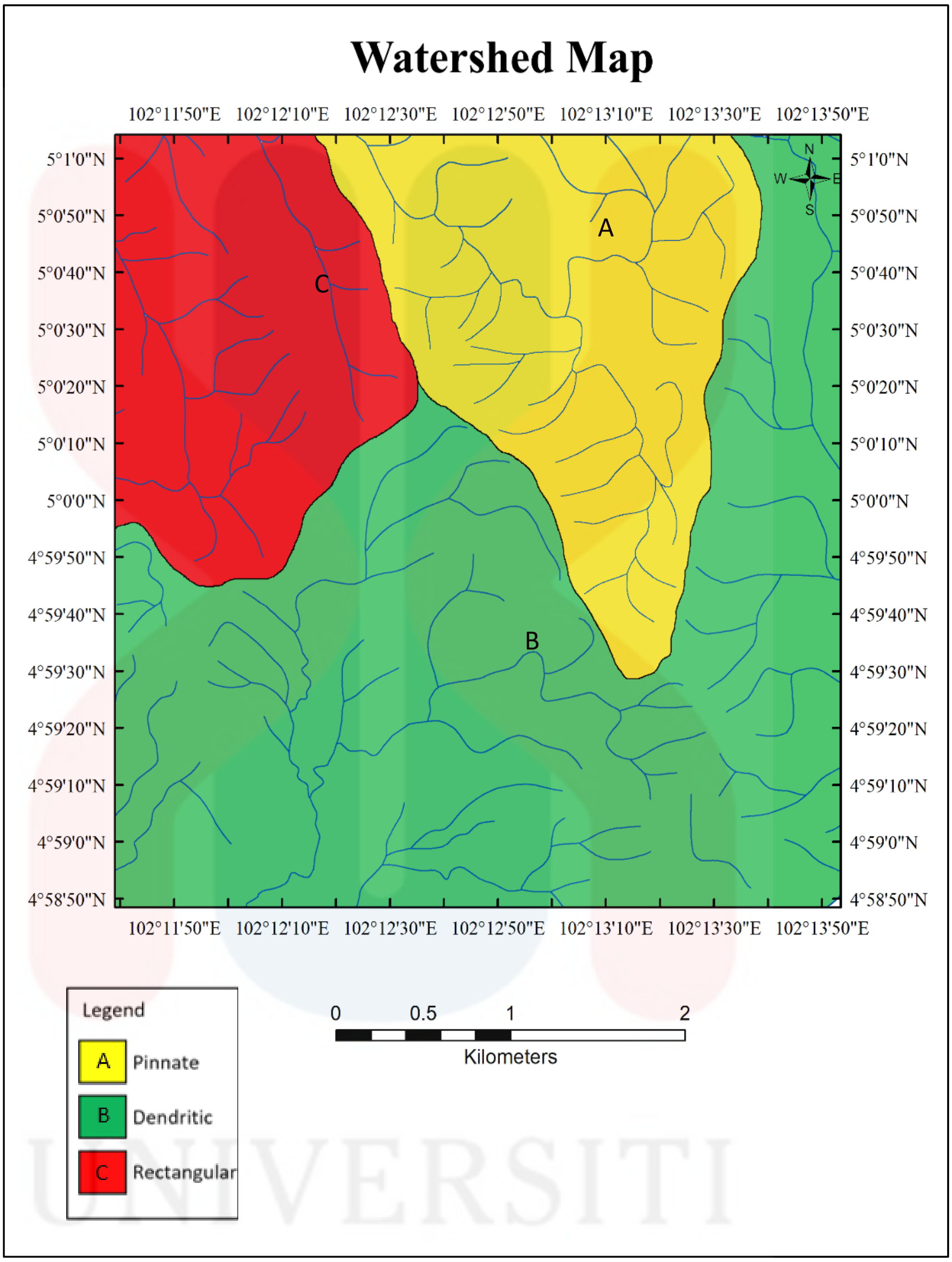





**Figure 4.8**: Watershed map.

### 4.2.4 Weathering

Weathering is the process by which rocks break down because of biological, chemical, and mechanical forces that don't move the rocks. It makes a lot of wasted rock. The weathered mantle may stay where it is or move down hillslopes, rivers, or slopes under the sea. This movement downslope is caused by gravity and fluid forces (Huggett, 2011).

a) Physical weathering

As opposed to the chemical alteration that occurs during biological weathering, the mechanical breakdown of greater rock size into smaller size is the only event involved in physical weathering. Temperature, pressure, frost, wetness, and thermal stress all have a role in accelerating the physical weathering process. Mechanical forces can be generated by frost wedging, thermal expansion, salt crystal formation, and abrasion.

Physical weathering is a major reason for presence of discontinuities such as fractures, joints, fault and folding on rock. The pressure applied on rock during weathering results in creating discontinuities on rock which reduces its strength.

In the area of research, abrasion is the most typical kind of physical deterioration. When water and wind erode rock, a process known as abrasion occurs. Over time, the exposed surfaces of rocks will be reduced in size as these processes occur repeatedly. Figure 4.8 shows an example of physical weathering abrasion.

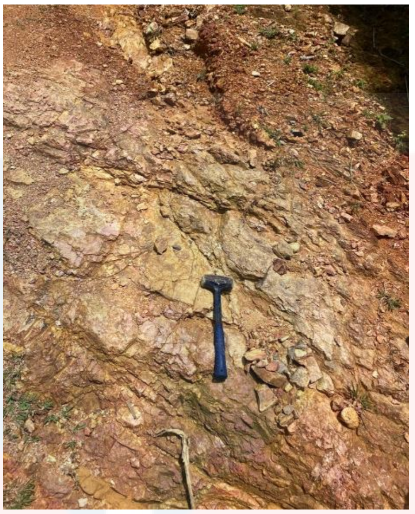


**Figure 4.9**: Physical weathering at study area.

b) Chemical weathering

Chemical weathering is a chemical reaction that involves a change to the initial chemical composition as a result of the processes of dissolution, hydrolysis, carbonation, and oxidation. This can happen over the course of many years. In order for the process of chemical weathering to be successful, the presence of moisture and air are both absolutely necessary. These chemical reactions take place when water and air have a chemical reaction with the minerals and rocks, which causes the original chemical composition of the minerals and rocks to change, resulting in the formation of new chemical contents. Figure 4.9 represents the oxidation process on the outcrop by producing Iron ore and changes the colour of the outcrop from greyish to brown.

**Figure 4.10**: Oxidised outcrop with human scale.

c) Biological weathering

Animals and plants are what cause biological weathering to happen. In the study area, most biological weathering is caused by plants that grow around outcrops and on the tops of rocks. This process is called leaching, and it changes the colour of the rocks' surfaces. Plants that grow on the top of outcrops tend to be hostile to other plants, bacteria, and organisms because they keep most of their water content. Because the rock layer is acidic, the rate at which living things break down the rock will speed up. In the study area, biological weathering is shown in Figure 4.10.

**Figure 4.11**: Biological weathering at study area.

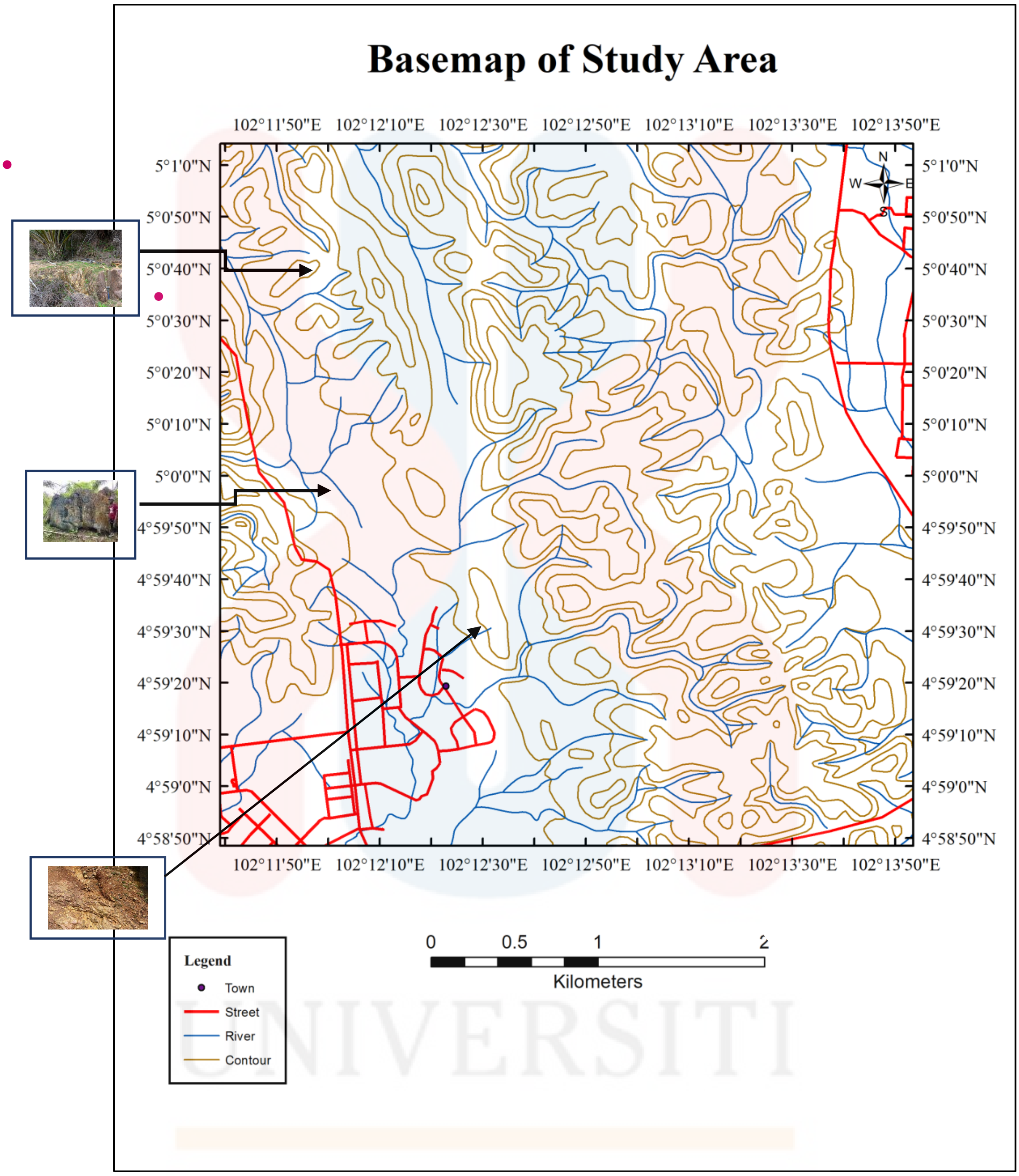



**Figure 4.12**: Location of weathering outcrops in map.

## 4.3 Stratigraphy

The term "lithology" comes from the word "map," and it refers to the study and description of the physical characteristics of rocks, particularly those observed in hand specimens and outcrops. Characteristics of lithologies include colour, form, mineral make-up, and grain size. As long as these characteristics vary, even slightly, we can say that the lithology is different. The line where two different lithologies meet is known as the lithology border or contact. Each edge has the potential for a wide variety of contacts, including sharp contacts, gradational contacts, interfingering contacts, and many others.

Moreover, conformance lithology and unconformity lithology are the two main types of layered lithologies. The lithological stratum is said to be in a state of conformity if there are no geological elements, like features, that break up the stratum. When a lithological layer is disrupted by geological features like faults, cracks, fractures, and joints, this is known as an unconformity. The study area was found to be predominantly composed of three different lithologies, limestone, meta mudstone, and meta quartz wacke. Figure 4.3.19 is a map depicting the lithology of the study area with plotting of the position of outcrops collected 1, 2, 3, 4, 5 and 6.

a) Meta mudstone

The sample of meta mudstone was collected at the coordinate of N 04° 59’ 26.1 E 102° 12’ 31.1 and N 05° 00’ 31.5” E 102° 12’ 58.6”. The meta mudstone was found at the SSW and NNE of my study area. The meta mudstone was highly weathered. The surrounding of the outcrop was oil palm plantation and river area.

**Figure 4.3.1**: Meta mudstone outcrop 1.

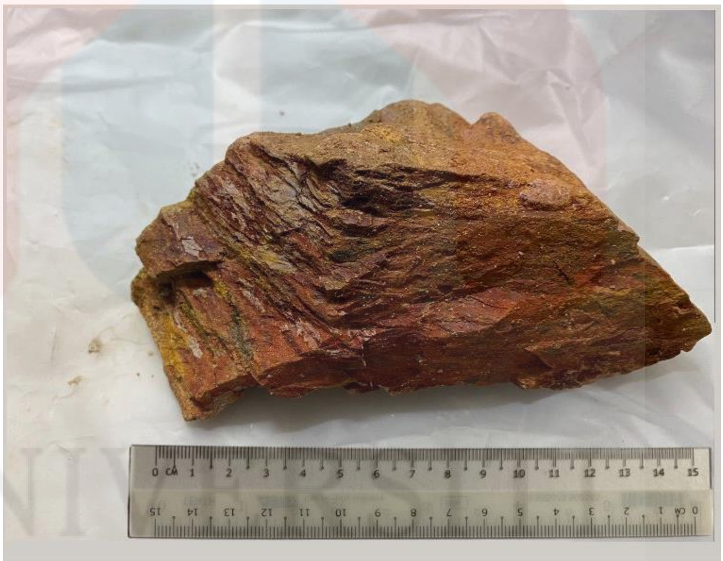


**Figure 4.3.2**: Meta mudstone sample 1.

**Figure 4.3.3**: Meta mudstone outcrop 2.

**Figure 4.3.4**: Meta mudstone outcrop 2.

**Table 4.2**: Mineral composition for meta mudstone.

| Mineral composition | Percentage for sample 1 (%) | Percentage for sample 2 (%) | Cross polarizes light (XPL) | Plain polarizes light (PPL) |
|---|---|---|---|---|
| Quartz | 15% | 10% | Colour: Greyish to white order 1<br>Twinning: No | Colour: Colourless<br>Relief: Low<br>Pleochroism: No<br>Shape: Anhedral<br>Cleavage: Absent |
| Clay Oxide | 48% | | Colour: Brown<br>Relief: Low<br>Crystal form: Anhedral<br>Cleavage: Absent | Colour: Brown<br>Twinning: No |
| Silica clay | 30% | 86% | Colour: Dark grey to black | Colour: Colourless to brown |
| Opaque mineral | 7% | 4% | Colour: Black order 1<br>Twinning: No | Colour: Black<br>Relief: Low<br>Pleochroism: No<br>Shape: Euhedral to Anhedral<br>Cleavage: Absent |

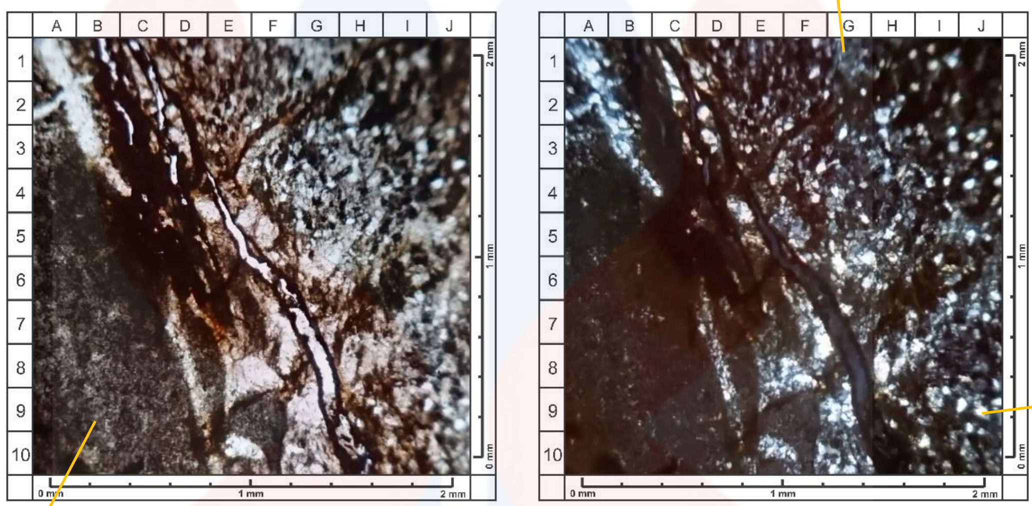



**Figure 4.3.5**: The photomicrograph of meta mudstone sample under plain polarized light (PPL) on the left and cross polarized light (XPL) on the right.

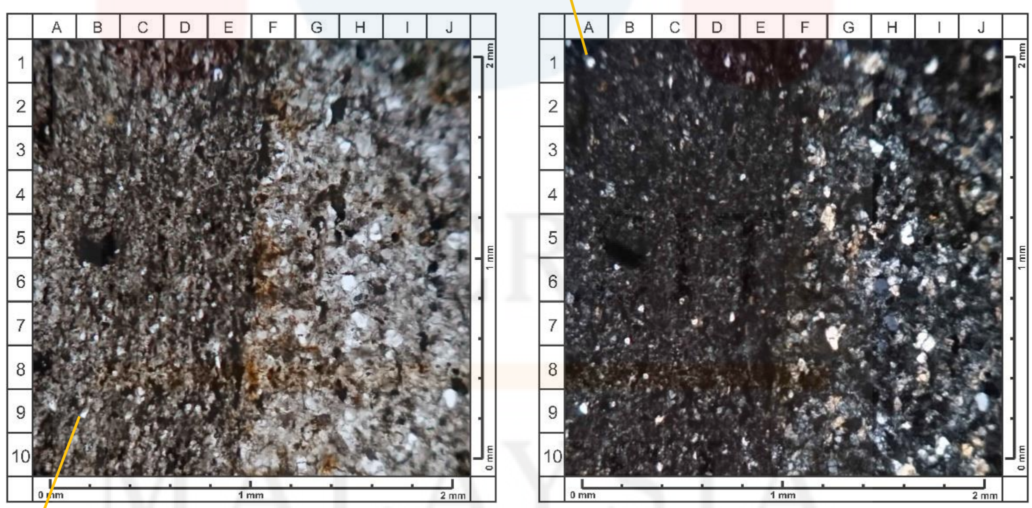



**Figure 4.3.6**: The photomicrograph of second meta mudstone sample under plain polarized light (PPL) on the left and cross polarized light (XPL) on the right.

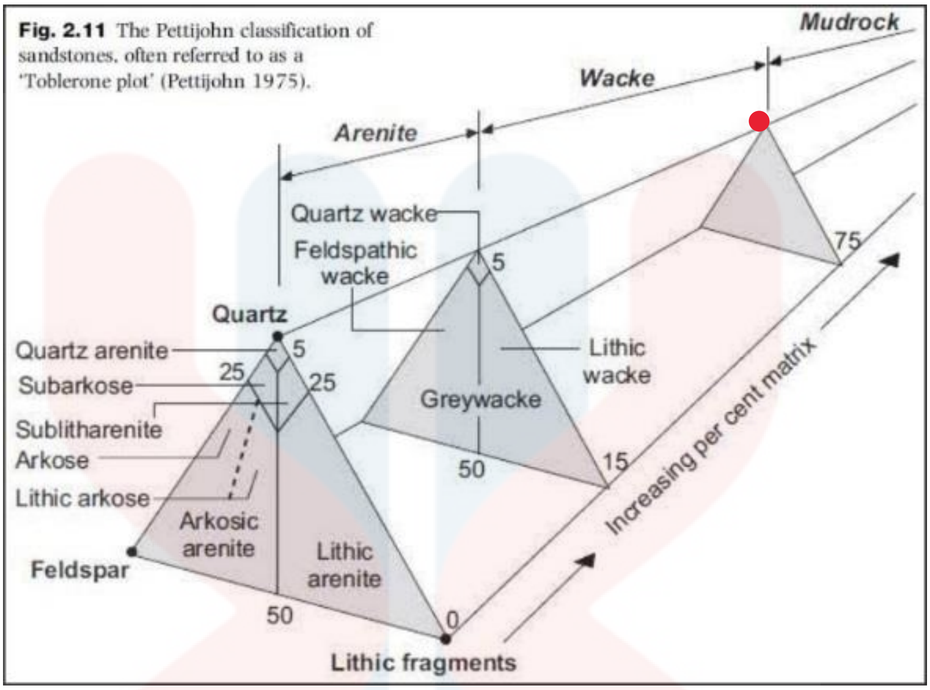



**Figure 4.3.7**: QAP triangle classification (Pettijohn, 1975).

a) Marble

Marble is formed due to metamorphism process from the parent rock limestone. Limestone is a sedimentary rock composed mostly of calcium carbonate (CaCO3), most often in the forms of calcite and aragonite. Sandstone is often layered, and it may include substantial amounts of magnesium carbonate in addition to the more common constituents of clay, iron carbonate, feldspar, pyrite, and quartz. In general, limestone has a gritty texture. You may find grains as tiny as 0.001 mm (0.00004 inch) and as big as particles visible to the naked eye among them. In many cases, the grains are really fragments of ancient shells or skeletons.

Though most limestone was formed in shallow marine environments like continental shelves and platforms, it was also formed in much smaller amounts in a wide variety of other places. Almost all dolomite is secondary, formed when limestone is chemically altered. There are large swaths of the Earth's surface that have lost their protecting mantles, revealing the fragile limestone underneath. These exposures often deteriorate into karst topographies due to the solubility of limestone in precipitation. Most caves are made by excavating limestone.

Marble was found at the direction of W, EES and S with respective coordinates N 04° 59’ 53.5” E 102° 13’ 41.9”, N 04° 59’ 11.6” E 102° 13’ 50.5” and N 04° 59’ 00.3” E 102° 12’ 38.4”. The outcrop is surrounded with oil palm plantation.

**Figure 4.3.8**: Marble outcrop 1.

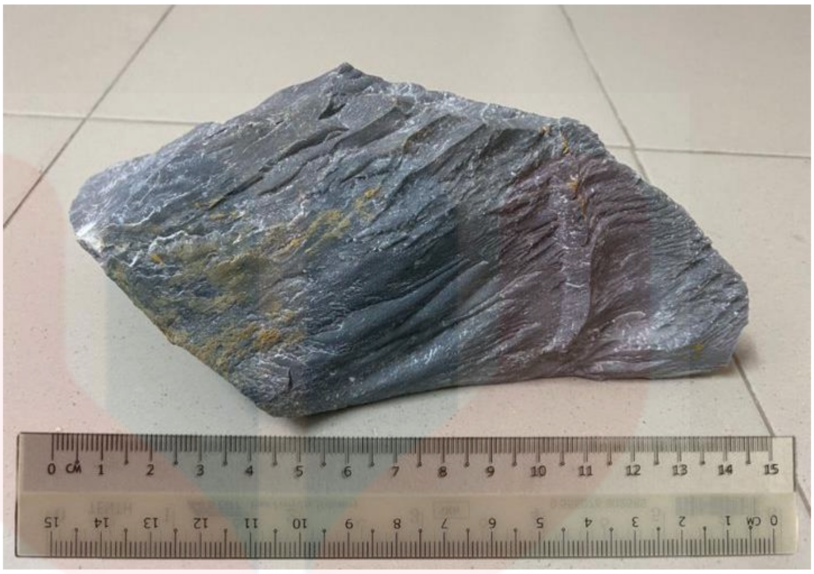


**Figure 4.3.9**: Marble sample 1.

**Figure 4.3.10**: Marble outcrop 2.

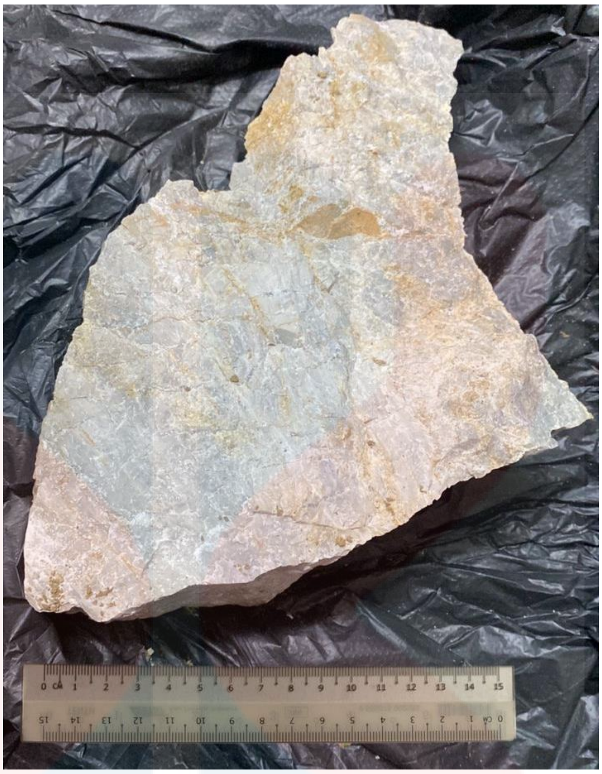



**Figure 4.3.11**: Marble sample 2.

**Figure 4.3.12**: Marble outcrop 3.

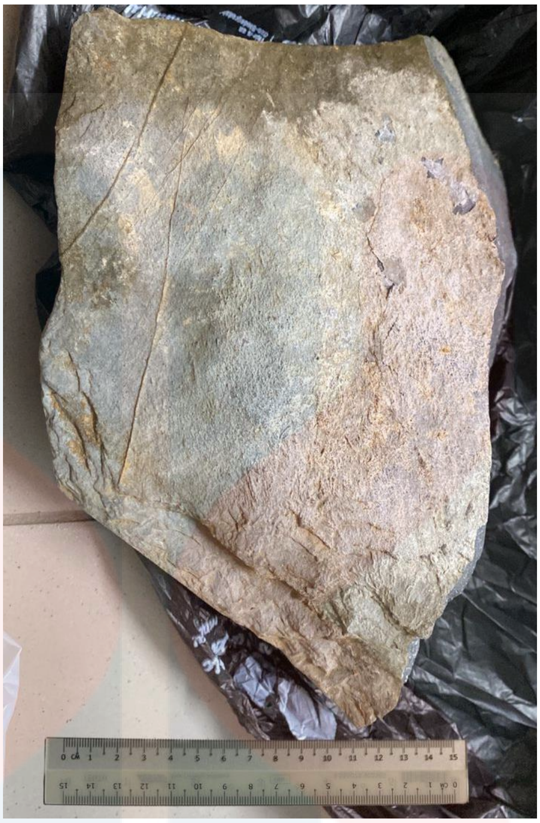


**Figure 4.3.13**: Marble sample 3.

**Table 4.3**: Mineral composition for marble.

| Mineral composition | Percentage for sample 1 (%) | Percentage for sample 2 (%) | Percentage for sample 3 (%) | Cross polarizes light (XPL) | Plain polarizes light (PPL) |
|---|---|---|---|---|---|
| Calcite | 100 | 80 | 100 | Colour: Pink to green (order 4 to 5)<br>Twinning: Polysynthetic | Colour: Colourless<br>Relief: Low to moderate<br>Pleochroism: No<br>Shape: Anhedral<br>Cleavage: Two direction |
| Calcite veinlets | | 20 | | Colour: Pink to green<br>Twinning: Polysynthetic | Colour: Colourless<br>Relief: Low to moderate<br>Pleochroism: No<br>Shape: Anhedral<br>Cleavage: No |

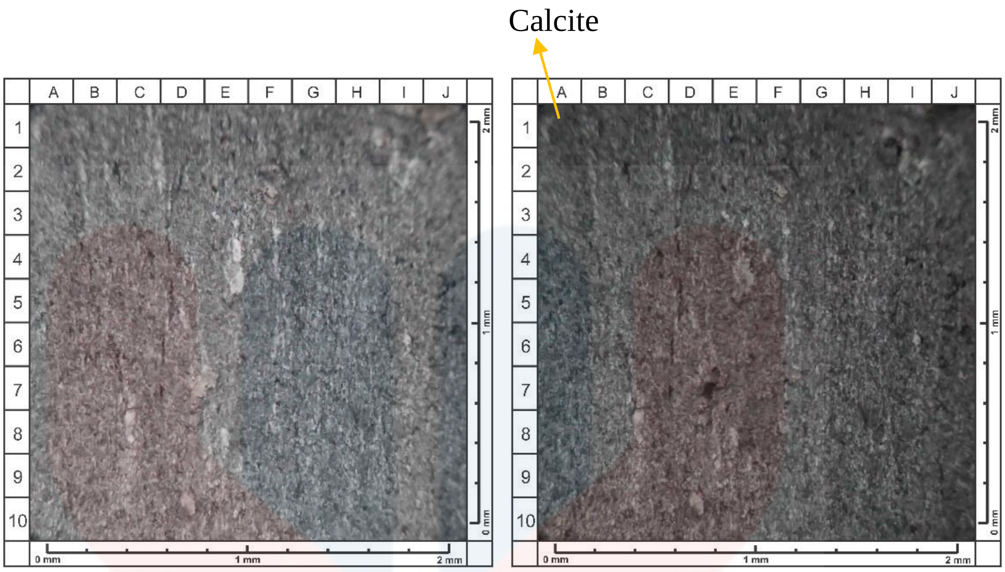



**Figure 4.3.14**: The photomicrograph of marble sample under plain polarized light (PPL) on the left and cross polarized light (XPL) on the right.

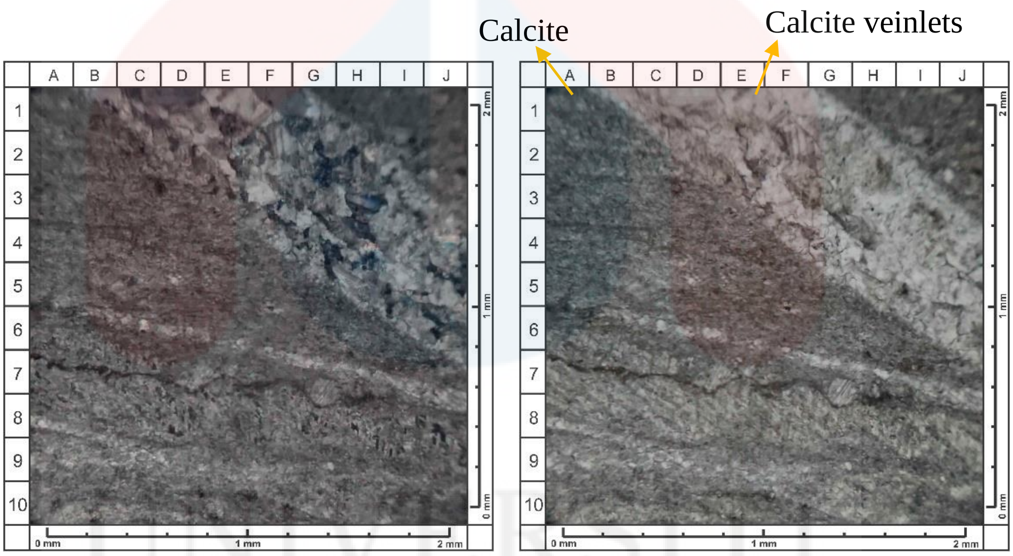
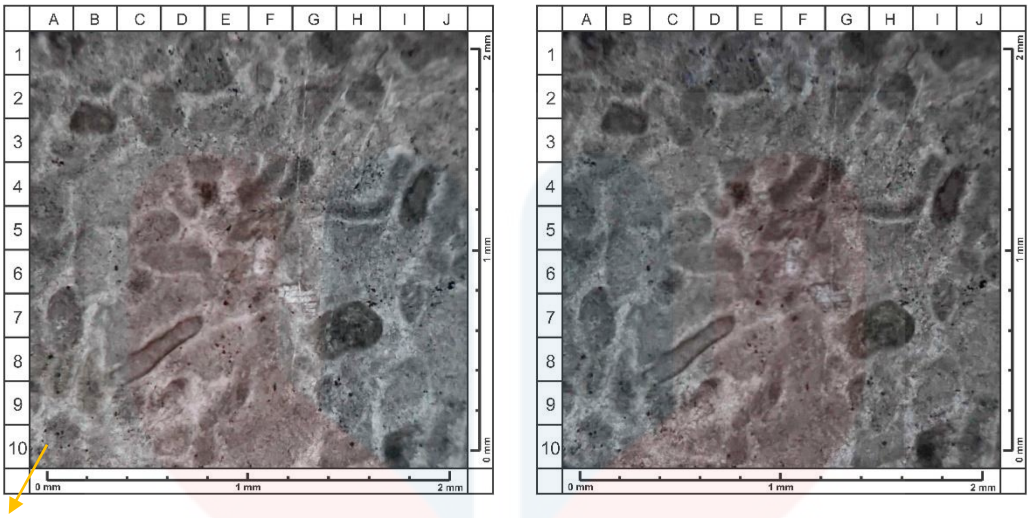



**Figure 4.3.15**: The photomicrograph of second marble sample under plain polarized light (PPL) on the left and cross polarized light (XPL) on the right.



Calcite

**Figure 4.3.16**: The photomicrograph of third marble sample under plain polarized light (PPL) on the left and cross polarized light (XPL) on the right.

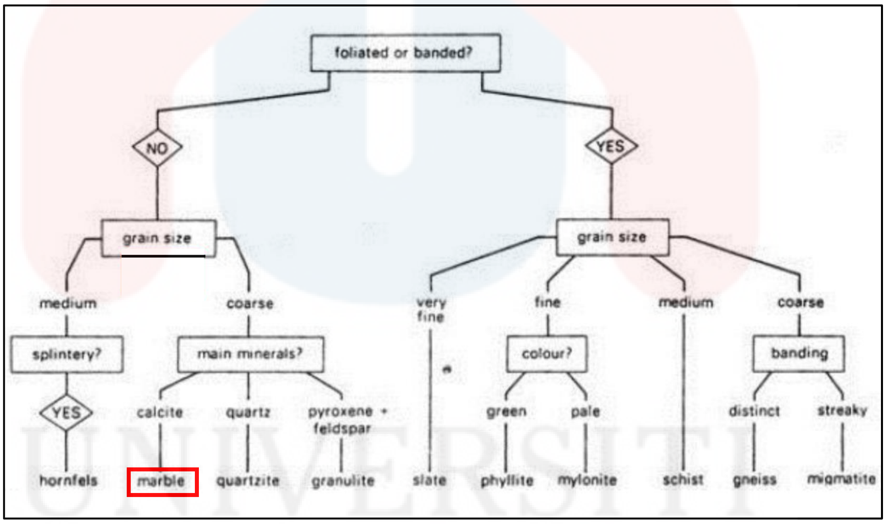



**Figure 4.3.17**: Rock classification (Gillen,1982).

b) Meta Quartz Wacke

Greywacke forms when silty, fine sand is deposited in very deep water, such as the ocean. The sediment (unconsolidated loose particles) responsible for the sand and mud may be traced back to rivers and glaciers that carried them to the ocean.

Erosion of bare rock is the source of the sediments. The granite is eroded and the fragments are carried away by the weather. Fine particles are less likely to sink to the seafloor and may be carried further. Greywacke is made up of sediments like this.

It is hypothesised that greywacke forms when muds and sands wash down the continental slope and collect over aeons on the deep-sea bottom. These sediments are buried at great depths, where they are transformed by compression and cementation. The fossils and sedimentary strata also pointed to a formation at sea floor deposits.

**Figure 4.3.18**: Meta Quartz outcrop.

**Figure 4.3.19**: Meta Quartz sample.

**Table 4.4**: Mineral composition for meta quartz.

| Mineral composition | Percentage (%) | Cross polarizes light (XPL) | Plain polarizes light (PPL) |
|---|---|---|---|
| Quartz | 35% | Colour: grey to white<br>Twinning: No | Colour: Colourless<br>Relief: Low<br>Pleochroism: No<br>Shape: Anhedral<br>Cleavage: No |
| Silica Clay | 63% | Colour: Dark grey to blackish | Colour: Colourless to brown |
| Opaque Mineral | 2% | Colour: 1st order black interference<br>Twining: No | Colour: Black<br>Relief: Low<br>Pleochroism: No<br>Shape: Euhedral - |

| | | | |
|---|---|---|---|
| | | | Anhedral |

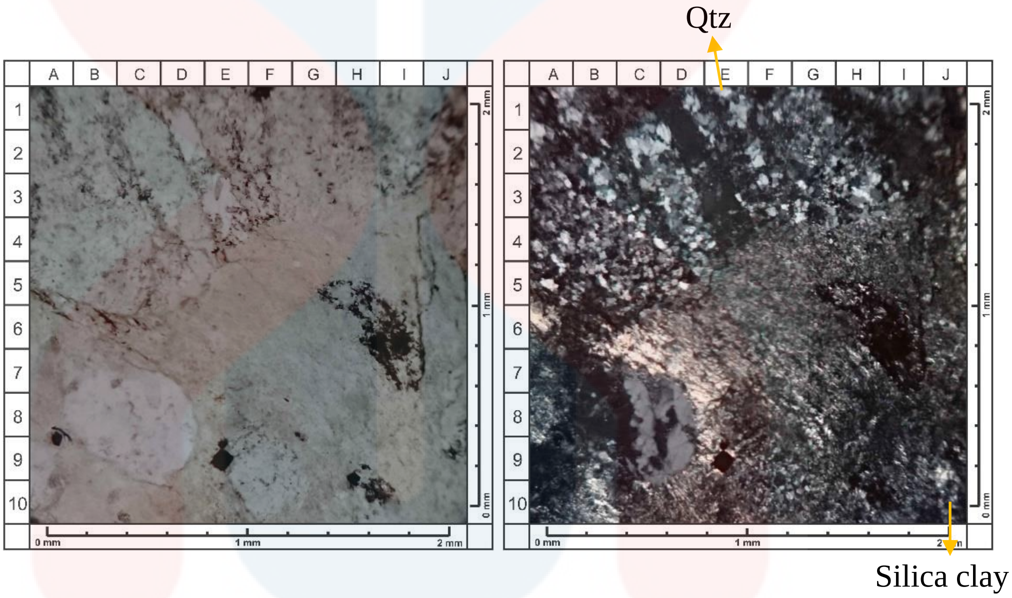



**Figure 4.3.20**: The photomicrograph of meta quartz sample under plain polarized light (PPL) on the left and cross polarized light (XPL) on the right.

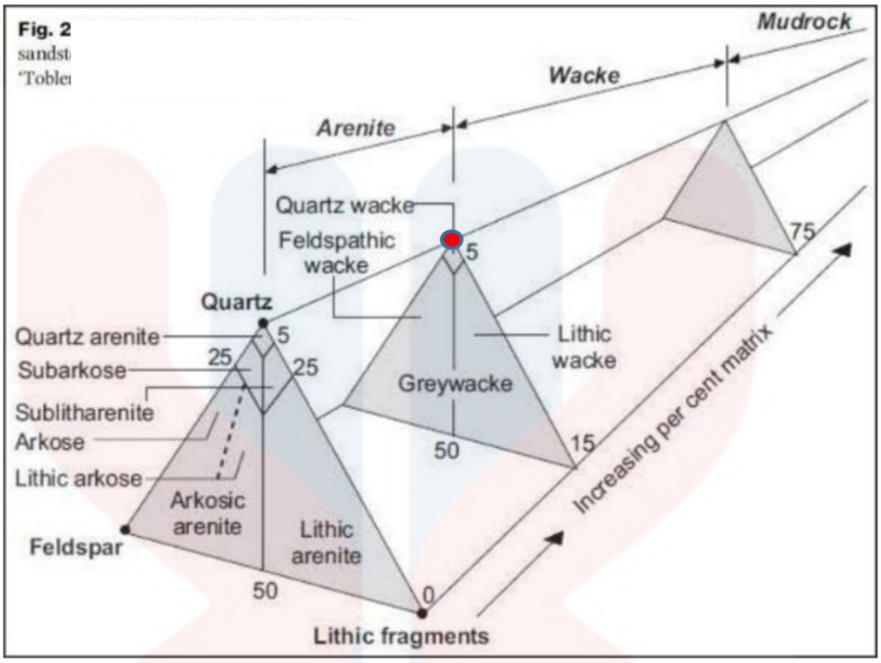



**Figure 4.3.21**: QAP triangle classification (Pettijohn, 1975).

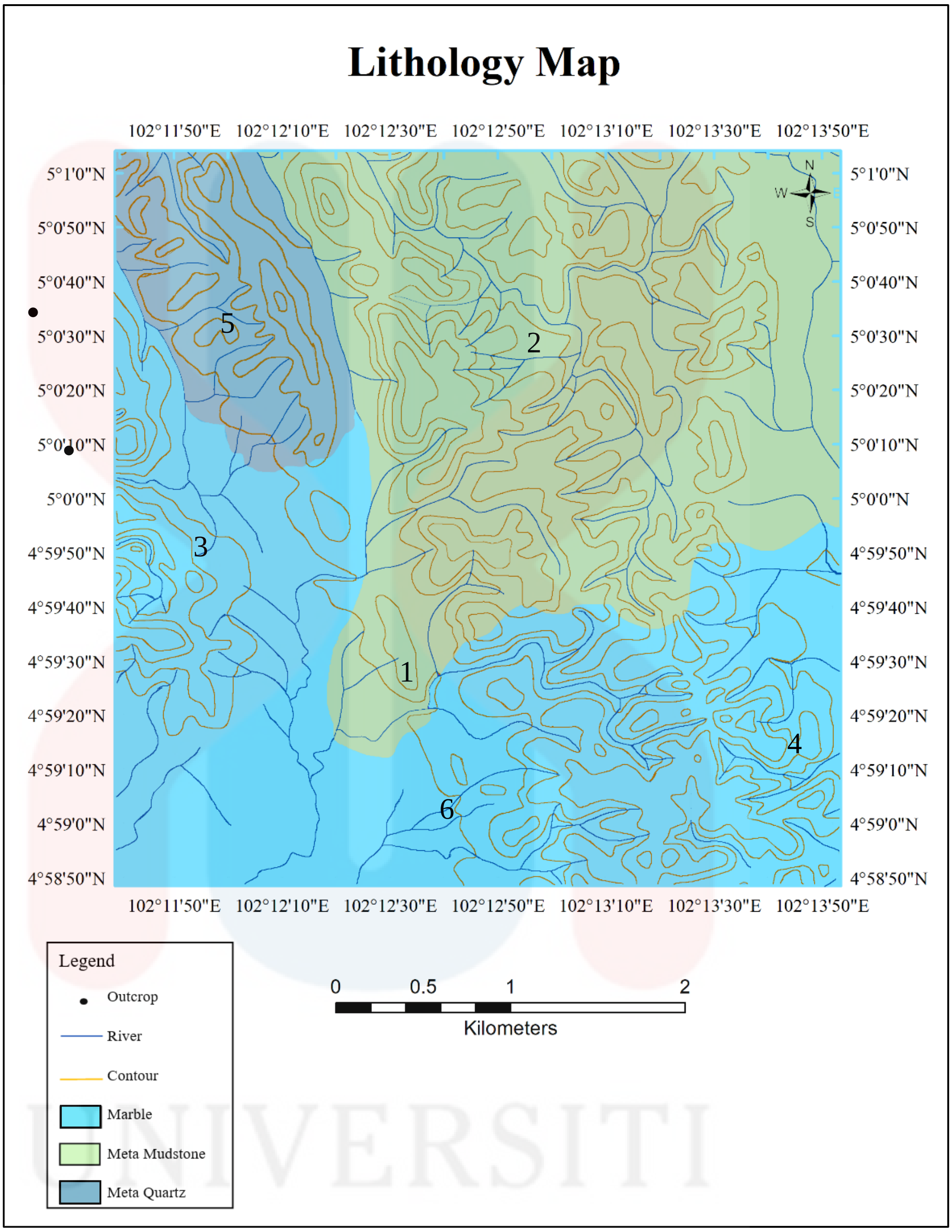



**Figure 4.3.22**: Lithology map of study area.

## 4.4 Structural geology

### 4.4.1 Lineament

Lineament is a pattern or linear features that can be seen on a map of the land. Lineament is one way to find geological structures in the area under study. In order to find geological structures like faults, fractures, and joints, the topography map's linear or straight features were studied. Geomorphic lineaments can also be used to talk about fracture zones, shear zones, and igneous intrusions like dykes. Lineament mapping is usually done based on geomorphological features like aligned ridges and valleys, the movement of ridge lines, scarp faces, and river passages, straight drainage channel segments, clear breaks in crystalline rock masses, and aligned surface depression.

According to the lineament map shown in figure 4.4.1, there are a number of straight lines that can be seen. Not only do the lineaments show things like faulting, but they can also show things like rivers and roads. We looked at the directions of the lineament to figure out the general direction of the forces acting on the study area. The force is coming from the north to the south, which is the same direction as the faulting in the study area.

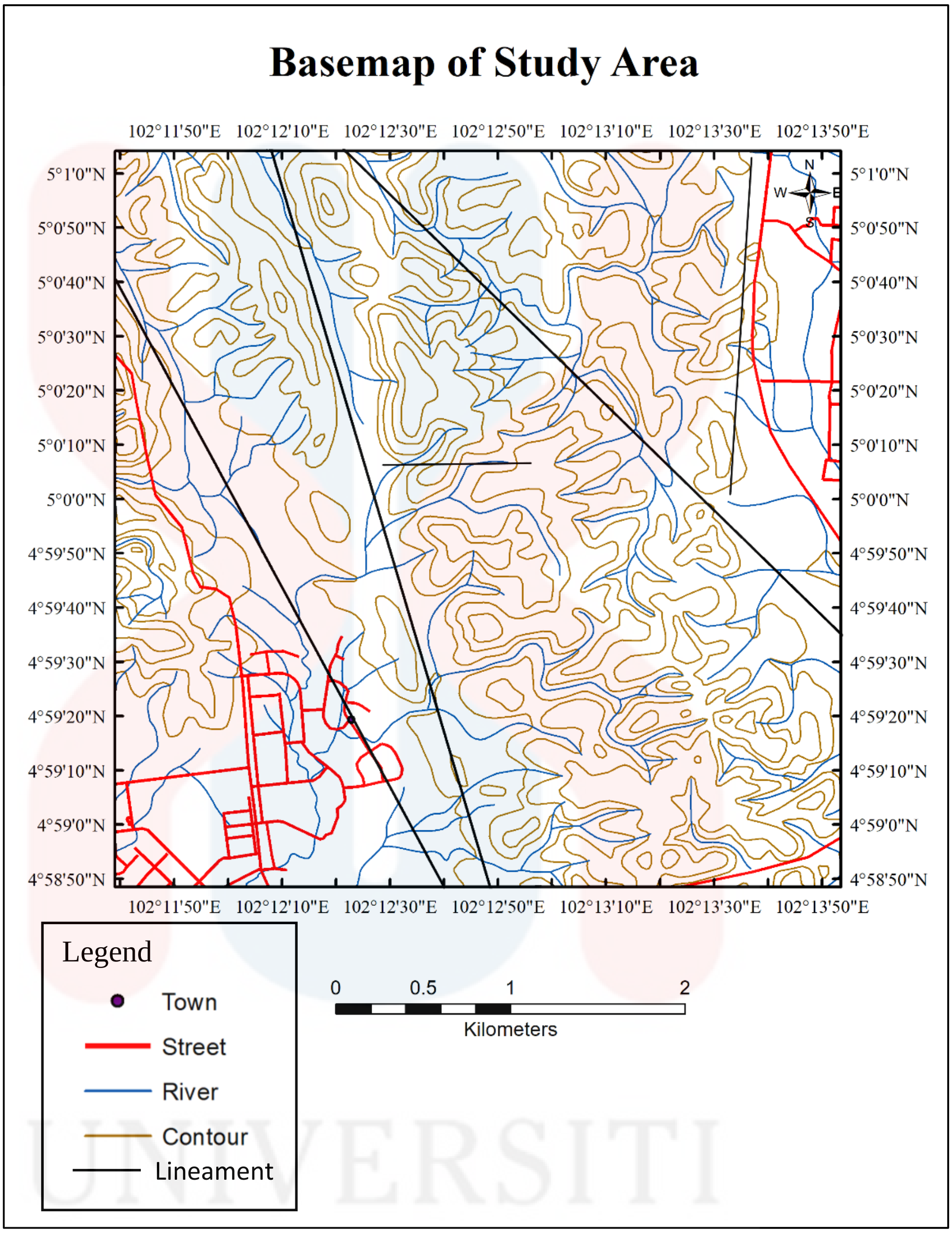



**Figure 4.4.1**: Lineament map of study area.

### 4.4.2 Joint Analysis

A joint is a fracture or crack in rock that has a measurable displacement. A joint is a geological feature that evolved as a result of tectonic plate motion. A joint is any minor break in a surface that may be made either along or across. Shear joints and extensional joints are the two common kinds of joints. The type of joint found in my study area is shear joint which is formed due to movement of rock in 2 directions. The rock cracks in this plane are perpendicular to the least principal stress and parallel to the stresses acting on the rock.

**Table 4.5**: Joint reading.

| Bearing° | Frequency |
|---|---|
| 101 – 110 | 10 |
| 121 – 130 | 4 |
| 131 – 140 | 17 |
| 141 – 150 | 18 |
| 151 – 160 | 13 |
| 171- 180 | 5 |
| 181 – 190 | 6 |
| 191 – 200 | 16 |
| 211 - 220 | 4 |
| 221 – 230 | 4 |
| 311 - 320 | 3 |

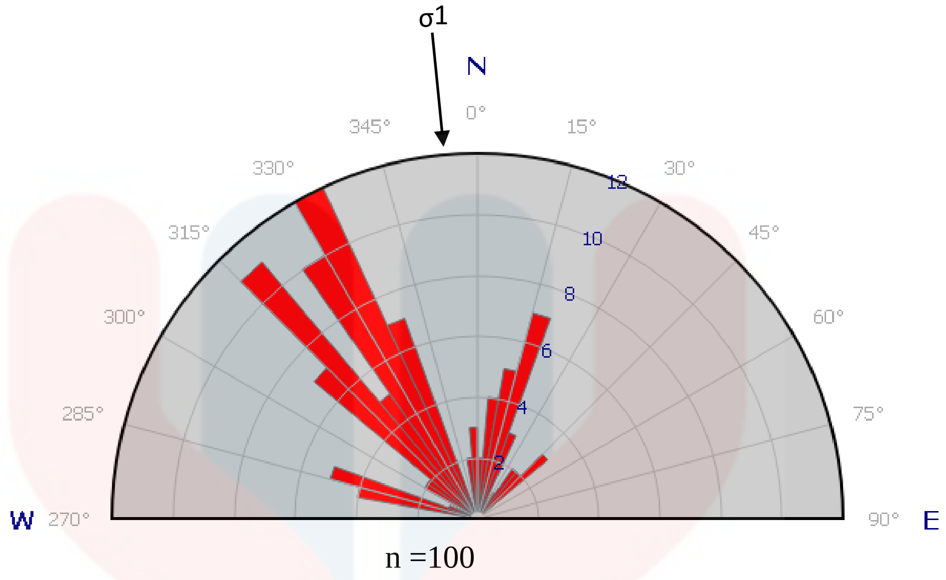



**Figure 4.4.2.1**: Rose diagram for the joint reading.

**Figure 4.4.2.2**: Joint outcrop.

Referring to figure 4.4.2.1 the highest compressive stress, or Sigma 1 is located at north-north west (NNW) direction. Accordingly, two primary stresses are perpendicular to and in the plane of the Earth's crust, whereas one principal stress is always vertical. The highest compressive stress is referred to as sigma 1, the intermediate stress as sigma 2, and the least main stress as sigma 3. When a rock is under stress, three forces are at work. There were three forces: $\sigma^{l}$, the strongest $\sigma^{2}$, the average and $\sigma^{3}$ the weakest.

4.4.3 Fault and scarp

The region of research might have thrust faults. The geomorphology of the research site is used to pinpoint it. According to the topographical map, the study area's trust fault is concentrated in the region's northern and north-eastern corners, with less fault signs to be seen in the region's southern and western parts. One of the obvious signs of a thrust fault is a sharp change in lithology at the boundary between sedimentary and metamorphic rock. Along what is thought to be a thrust fault, the topographic gradient dramatically rose.

Scarp refers to the stepped appearance of the rock surface that results from fault slide. Displacement of the ground surface due to movement along faults is topographic evidence of faulting and a hallmark of thrust faults. As shown on the outcrop at figure 4.4.3, the vertical erosion of the limestone wall is rather severe. y4 Only at the fault scarp is there no vegetation and the appearance of erosion or a landslide, yet the surface is virtually as smooth as the rest of the limestone.

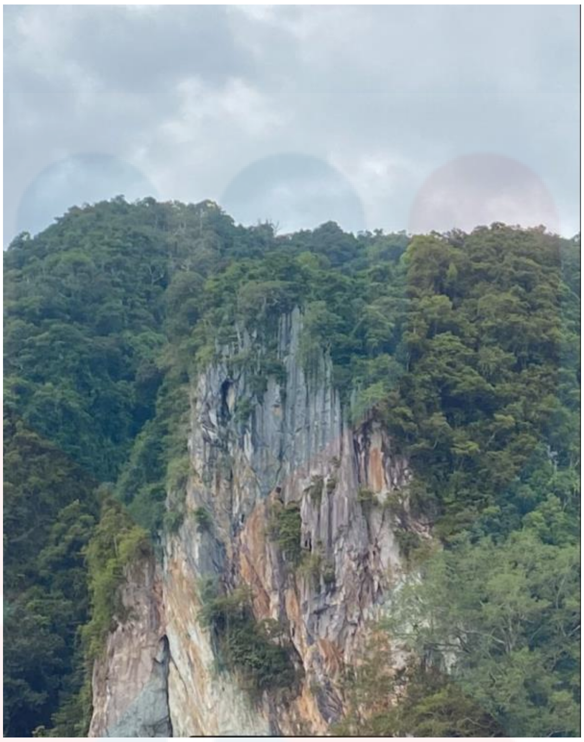


**Figure 4.4.3**: Scarp on limestone karst wall.

## 4.5 Historical geology

The study area was composed of sedimentary rock, which, as a result of the metamorphism process, has begun to transform into metasedimentary rock. In the time period known as the Early to middle Triassic, sedimentary rock limestone was metamorphosed into marble which is mostly to be found in stream and river. However, in the Late Triassic, meta sedimentary rock in the form of meta mudstone and meta quartz was formed. According to the age of the rocks it can be seen that the deposition of marble happened first followed by meta mudstone and meta quartz wacke. The major fault that is located at the middle of my study area is the boundary between the formation of meta quartz wacke and meta mudstone rock.

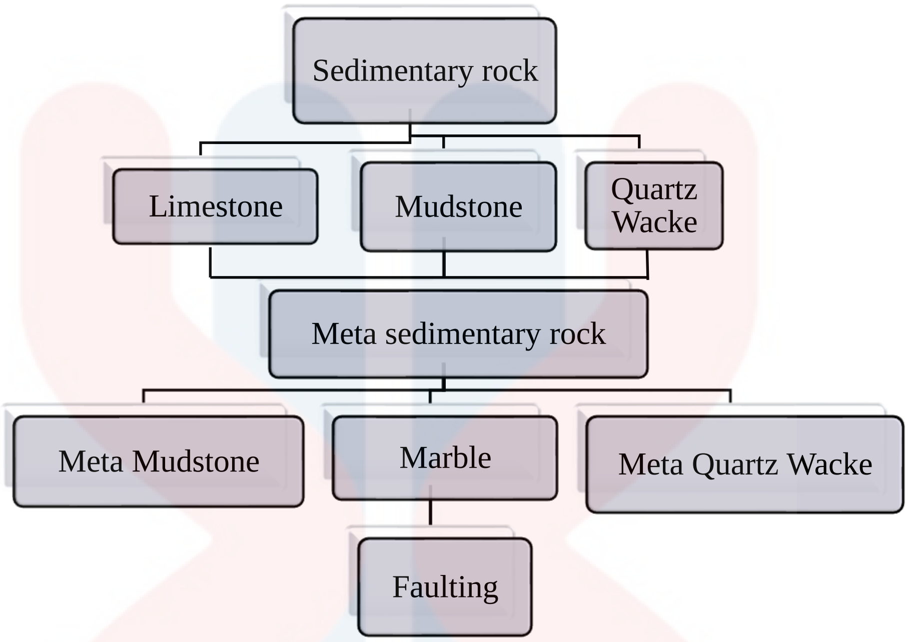



**Figure 4.5.1**: Flow chart of historical geology.

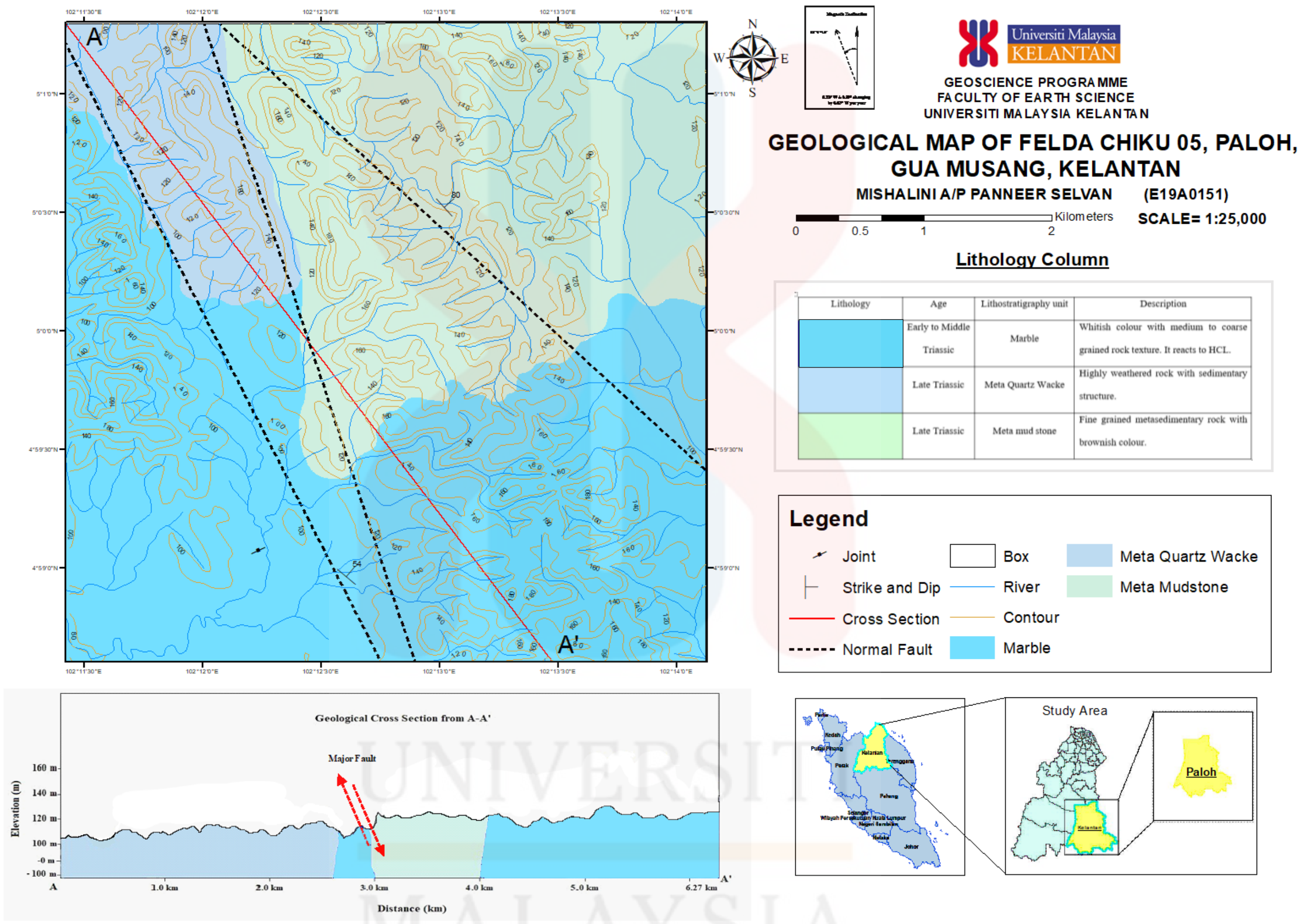



**Figure 4.5.2:** Geological map.

# CHAPTER 5

# RESULTS AND DISCUSSION



## 5.1 introduction

In this chapter, the study provides further information on electrical resistivity imaging, a method for conducting a geophysical survey of groundwater potential. This is where the outcome is interpreted and further discussed.

Essentially, electrical resistivity imaging is the geophysical technique employed in this study (ERI). Through the electrode that has been inserted into the ground surface, it is utilised to measure the subsurface resistivity. Conductivity is the name for the resistivity's mathematical inversion. A 2D cross-sectional model with resistivity values and depth is presented in the Electrical Resistivity Imaging profile. Depending on the electrode array being utilized, the depth varies. During data gathering on the ABEM Terrameter, raw data such as pseudo sections may be examined. RES2DINV software will subsequently be used to process the raw data. As it helps in analysis, the resistivity values scale of earth materials is utilized for comparison.

## 5.2 Electrical Resistivity Imaging Survey Lines

In order to forecast the potential for groundwater in Felda Chiku 5, a total of three survey lines have been selected. Every single line was chosen based on the appropriate circumstances. Several factors, such as the lineaments of the entire region, are known as the basic things that need to be analysed. According to hydrogeology research, the topography of the region may be used to determine the discharge and recharge area. Recharge region is situated in a high-elevation environment, such as a mountain or hill. As a result, the discharge location is considered to be in a plains-like low-elevation area.

Since water flow is constrained to gravitational directions, groundwater typically moves from high elevation regions to low elevation regions. For the purpose of identifying potential layers of rock that may have held water, the survey line's orientation should be parallel to or across the lineament. The three resistivity lines are placed in a flat location, and RES2DINV software is used to measure all the resistivity line data.

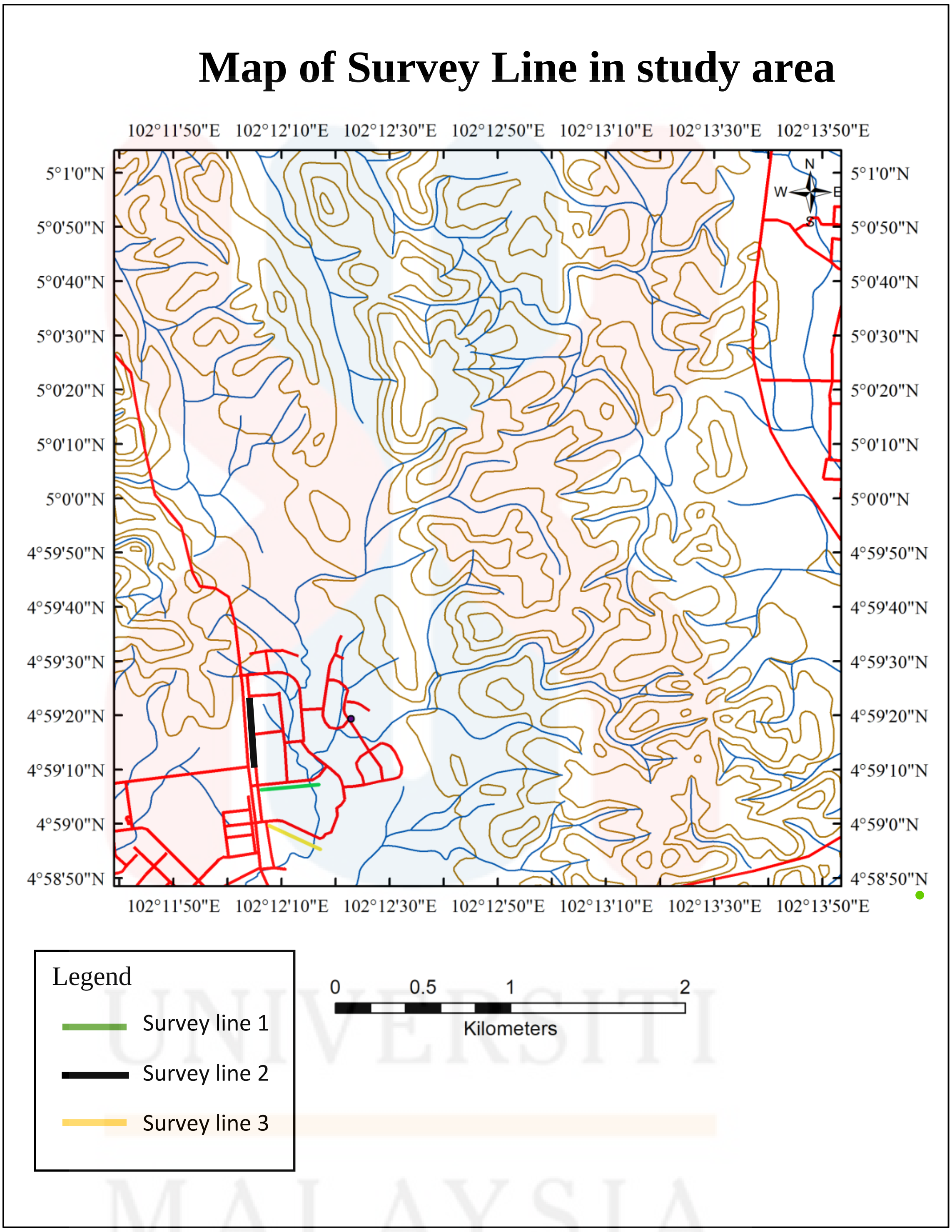



**Figure 5.2.1:** Map of survey line.

5.3 Data processing and inversion

Once the raw data has been collected, it is transferred from the ABEM Terrameter to a computer using the LS Terrameter Toolbox programme, which contains the measured data, spread, and protocol files. Thus, it is possible to examine and export to various formats the project database files, download data files, location of the survey, change the electrode position, and other things related to the data. The filtered data file gives the user the option of excluding or include the poor and negative information before exporting the data. After converting the data to the RES2DINV in (.dat) format, it may be utilised for further process.

Processing and inversion of the data are begun after data collection. Root mean square (RMS) error occur due to the interruption of noise and poor contact of electrode with the ground. In order to overcome this issue, the bad data need to be eliminated as show in figure 5.3.1. The resistivity and induced polarisation are utilised as parameters because, based on the suggested conceptual model, the user will be able to visualise the actual geological conditions in relation to other geological data. It was shown that this would lead to a rise in awareness and understanding, and that the connections between these things are easy to make out.

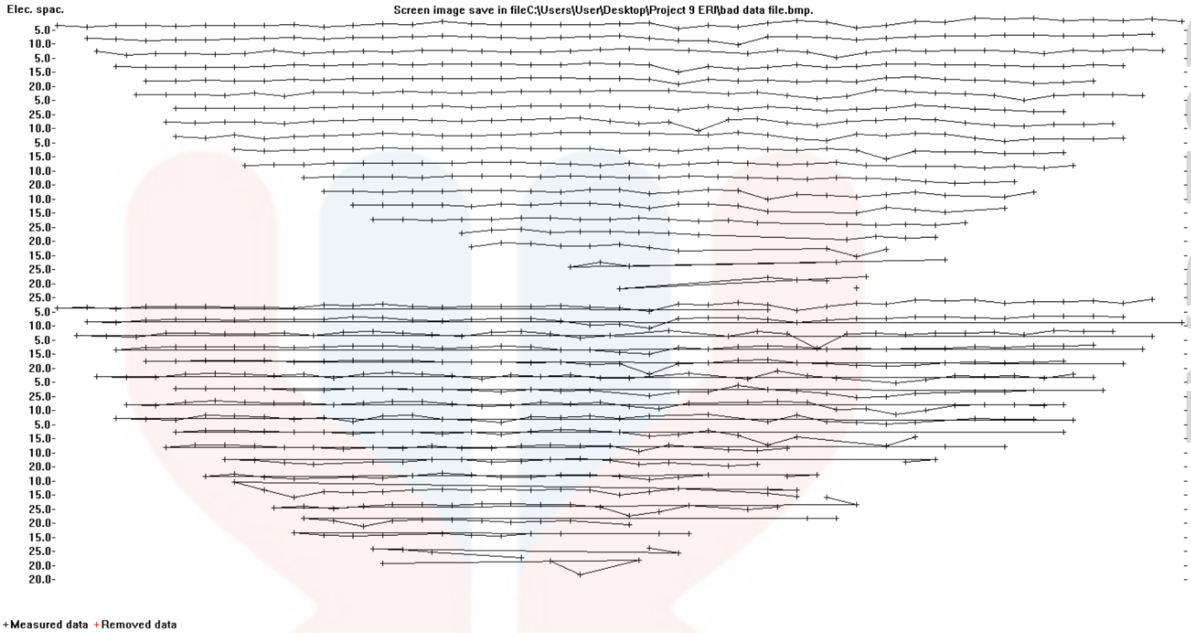



**Figure 5.3.1**: Bad data point.

## 5.4 Data interpretation

### 5.4.1 Resistivity

A model section was used to get the apparent resistivity value, and this model section is referred to as the pseudo section. The apparent resistivity depends on the shape of the electrode hence, it cannot reflect the actual subsurface state. Understanding the subsurface through apparent resistivity reading requires inversion. The resistivity scale operates in the opposite direction in the model portion. The resistivity value, according to the industry norm for earth materials, provides a good approximation of the layer's depth.

If the rock's pore fluid is being displaced, the rock's resistivity value will be high. This is because during lithification, the minerals get compacted and block the passage of electric current. A similar phenomenon occurs when the salinity of the pore fluid is low, leading to an increase in the resistivity value. The quantity of salt that can be dissolved in a given fluid is directly proportional to its saltiness. The activity of ions to carry electricity may be boosted by heavy precipitation of salt.

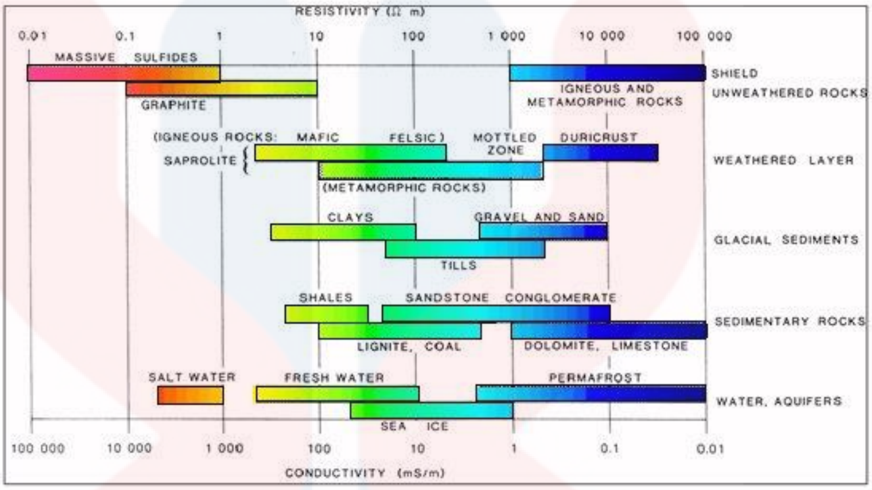



**Figure 5.4.1:** Electrical resistivity and conductivity value (Developers, G. 2018).

### 5.4.2 Chargeability

The tables below provide a very broad overview of the potential chargeability's of materials. Large amounts of mixed materials are used in field measurements, which is one reason why in-situ chargeabilities often look lower than laboratory values.

These examples demonstrate that a broad range of variability may be anticipated, suggesting that it is challenging to precisely identify the kind of rock or material in the ground using values of inherent chargeability in models produced by inversion of IP data.

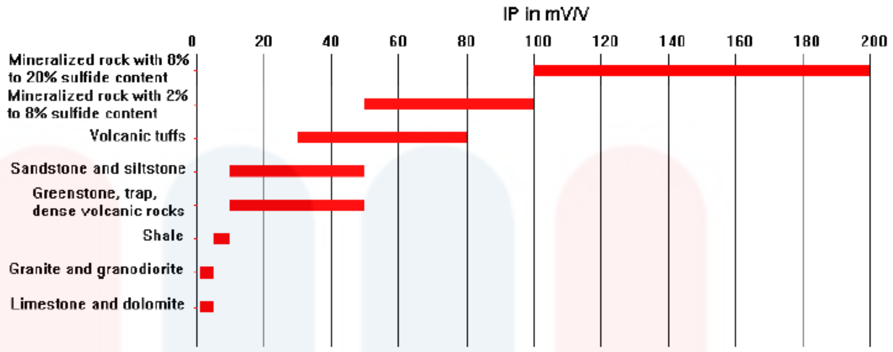



Figure 5.4.2: IP values for some Rocks and Minerals in mV/V (Jegede & Iyoha, 2018).

## 5.5 Survey line 1

The first location of the survey line is located at the respective coordinate as shown in table 5.5.1. The survey is located near to the major lineament in my study area. The type of survey line used is Gradient with point A's azimuth 100° (EES) direction and point B at azimuth of 280° (WWN) direction. Figure 5.5.1 and 5.5.2 shows the set-up of equipment for survey line 1.

**Table 5.5.1:** Coordinates of electrode with elevation.

| Electrode | Latitude | Longitude | Elevation (m) |
|---|---|---|---|
| 1 (A) | N 04° 59' 07.6 | E 102° 12' 12.2 | 99 |
| 21 (C) | N 04° 59' 07.4 | E 102° 12' 08.9 | 97 |
| 41 (B) | N 04° 59' 07.0 | E 102° 12' 05.7 | 98 |


**Figure 5.5.1:** Set up of survey line 1.

**Figure 5.5.2:** Set up of survey line.

Based on Figure 5.5.3, the total RMS error for resistivity is 7.4. In this survey line, the least amount of resistivity is 16.0 Ωm and the most is 2250 Ωm at a depth up to 36 m. Using Figure 5.5.4 as a guide, the pseudosection can be split into three parts: Zone 1, Zone 2, and Zone 3. Zone 1 has a high chance of having groundwater with a low resistivity value that is less than 115 Ωm in the depth of 13.4m to 36.9m and 6.76m to 17.3m from ground level. According to the chargeability value the groundwater potential area value ranges from 9 mv/v to 15mv/v. Based on the IP table on figure 5.4.2 it indicates that the region as sandstone which has a good porosity and permeability. For Zone 2, the chargeability value of 13mv/v to 15mv/v resistivity values range from 200 Ωm to 1500 Ωm, which is the average resistivity value for sedimentary rocks like limestone, sandstone, and shale. Zone 3 is for materials that have a high resistivity value between 1500 Ωm and 4000 Ωm where are hard materials like granite and quartzite that have a high resistivity value are to be found. Since the study are is abundant with marble rock, Zone 3 is classified marble rock region while Zone 2 is known as limestone area because limestone undergoes metamorphism process and formed into marble rock.

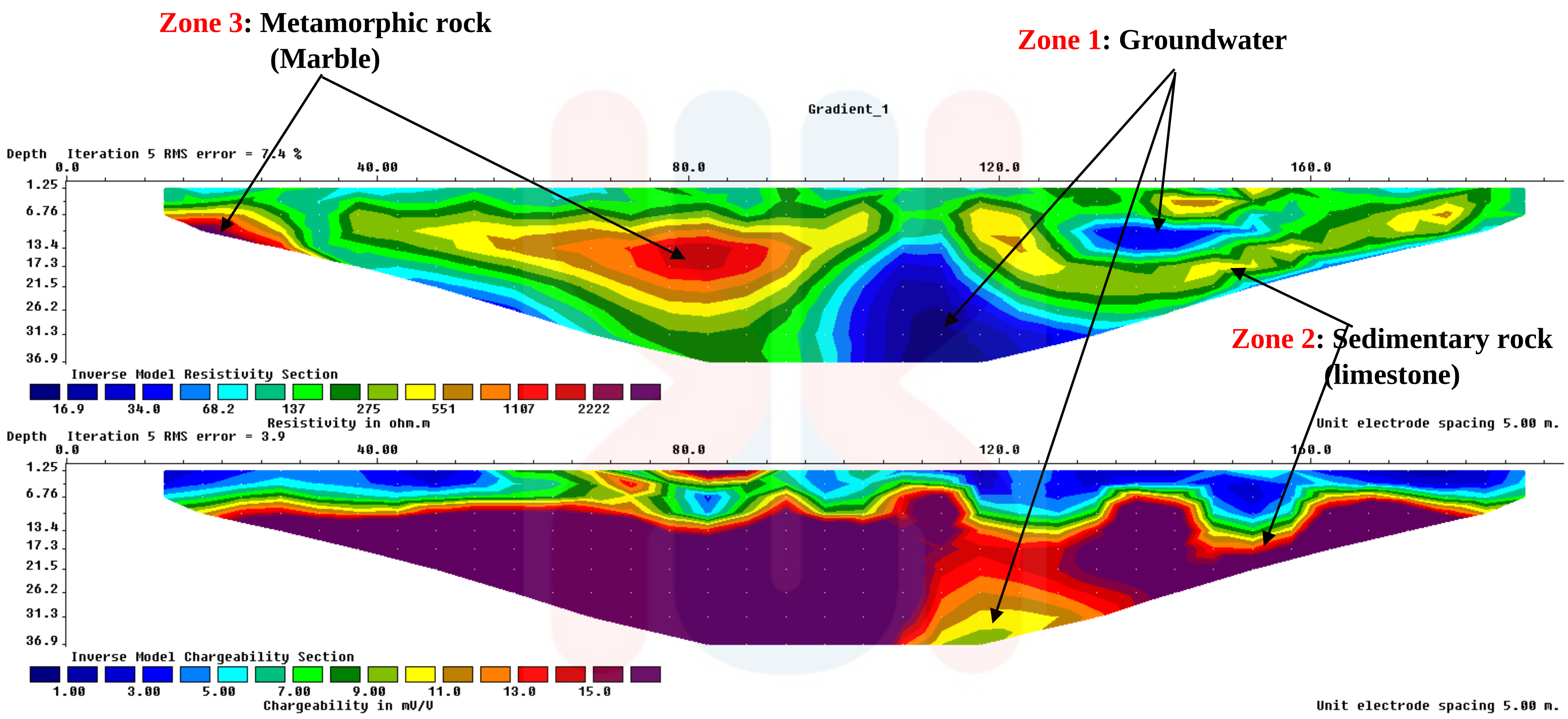



**Figure 5.5.3:** Result of survey line 1

5.6 Survey line 2

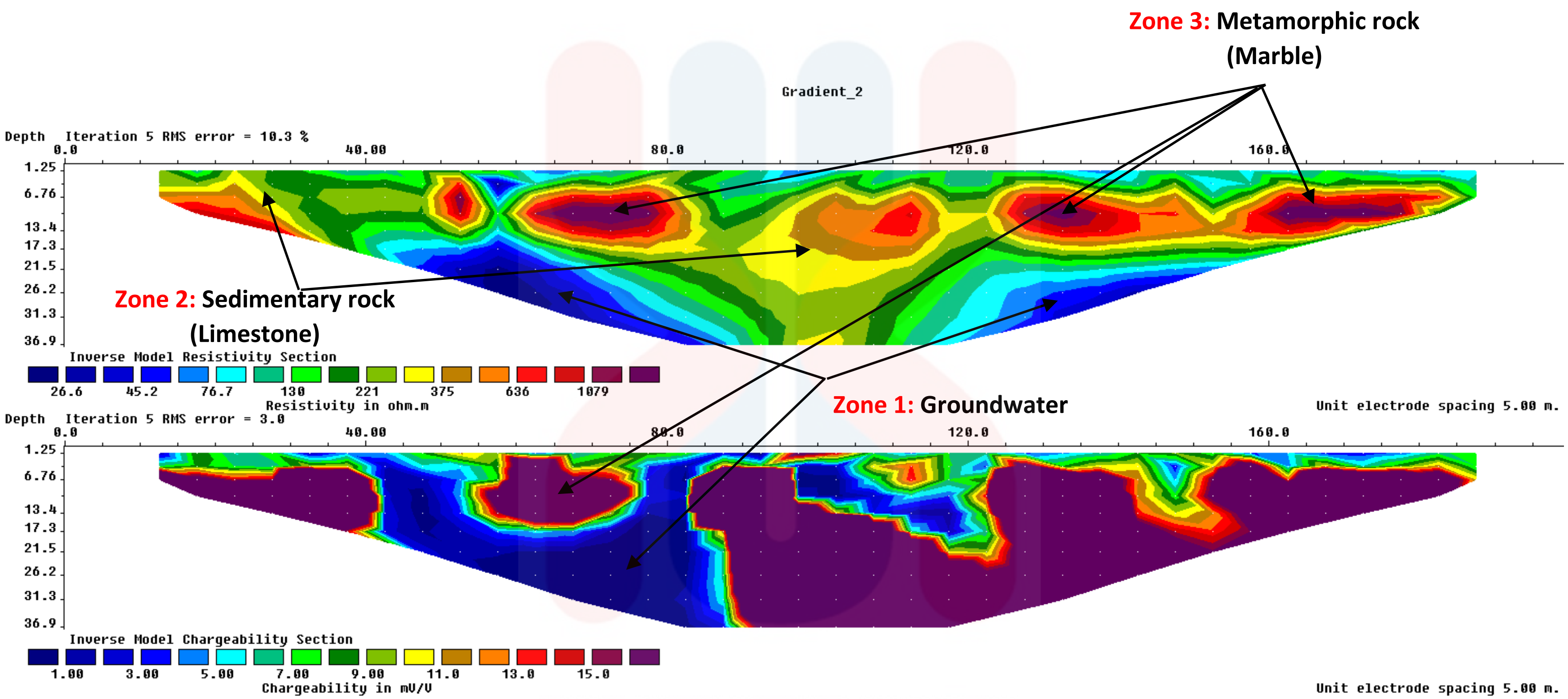
The 2nd survey line has been carried out with 200 meters in length with electrode spacing of 5m. The type of array used is Gradient configuration. The survey line is set up beside the road. Point A was located at azimuth 350° (NNW) direction and point B at azimuth of 170° (ESS) direction. Figure 5.5.4 shows the set-up of equipment for survey line 2.

**Table 5.5.2:** Coordinates of electrode with elevation.

| Electrode | Latitude | Longitude | Elevation (m) |
|---|---|---|---|
| 1 (A) | N 04° 59’ 10.6 | E 102° 12’ 05.1 | 95 |
| 21 (C) | N 04° 59’ 13.8 | E 102° 12’ 04.7 | 96 |
| 41 (B) | N 04° 59’ 07.2 | E 102° 12’ 05.6 | 95 |


**Figure 5.5.4:** Equipment set up for survey line.

Based on Figure 5.5.6, the root-mean-square error (RMS) for resistivity is 10.3%. This survey line has a minimum resistivity of 15 m and a maximum resistivity of 1800 m at a depth of more than 37 m. Based on the contrast of resistivity and chargeability values at 26.6Ωm to 76.7Ωm and 1mv/v to 5mv/v respectively, the potential of groundwater is identified at Zone 1 in the depth 13.4m to 36.9m. Pseudosection 2-D resistivity line 2 indicate that the topsoil at Zone 2 is consists of sedimentary rock that has resistivity value ranges 100Ωm - 500Ωm such as limestone. Since limestone has good porosity and permeability the shallow water at depth 1.25m seeps through the pores and cracks into the aquifer. Zone 3 has the highest resistivity value 600Ωm - 1880Ωm and highest chargeability value of 15mv/v which shows that it consists of metamorphic or metasedimentary rock such as marble.




Z

**Figure 5.5.5:** Result of survey line 2.

5.7 Survey line 3

3rd survey line was carried out beside Mosque of Felda Chiku 5 due to the recharge area as stream flow. The array configuration used in this survey line was Pole – Dipole. Table 5.3 shows the coordinate and elevation of electrodes used. Point A was located at azimuth 293° (WWN) direction and point B at azimuth of 110° (EES) direction. Figure 5.5.6 shows the set-up of equipment for survey line 3.

**Table 5.5.3:** Coordinate and elevation of electrodes.

| Electrode | Latitude | Longitude | Elevation (m) |
|---|---|---|---|
| 1 (A) | N 04° 58’ 58.7 | E 102° 12’ 14.5 | 102 |
| 21 (C) | N 04° 59’ 00.2 | E 102° 12’ 11.6 | 101 |
| 41 (B) | N 04° 59’ 01.0 | E 102° 12’ 08.4 | 104 |


**Figure 5.5.6:** Set up for survey line 3.

This third line employs a Pole-Dipole electrode arrangement. As can be seen in Figure 5.5.9, the overall RMS error is 10%, which is more than the limit at a depth of more than 57m. The RMS error during the usage of pole – dipole is high due to its sensitivity towards sound. This survey line has a minimum resistivity of 7.0 Ωm and a maximum resistivity of 1,600 Ωm. This result's pseudosection has three distinct regions: Zone 1, Zone 2, and Zone 3. The resistivity in Zone 1 varies from 7 Ωm to 30 Ωm.

A large quantity of groundwater may be stored under the surface here in the depth of 21.5m to 43.1m, therefore its potential groundwater is great. Because the river serves as a recharge agent for the groundwater, the survey line that ran directly beside it may be the cause. The Zone 2 resistivity value varies from 40 Ωm to 430 Ωm. limestone, and sandstone are examples of sedimentary rocks that may be present in Zone 2 for this range of resistivity values. It is been proving as limestone because its chargeability value is 1mv/v to 13mv/v. The maximum resistivity value for this survey line is 1630 Ωm in Zone 3, a zone for hard materials with a high resistivity value. Granite, basalt, and quartzite may make up Zone 3, which has the greatest resistivity rating.

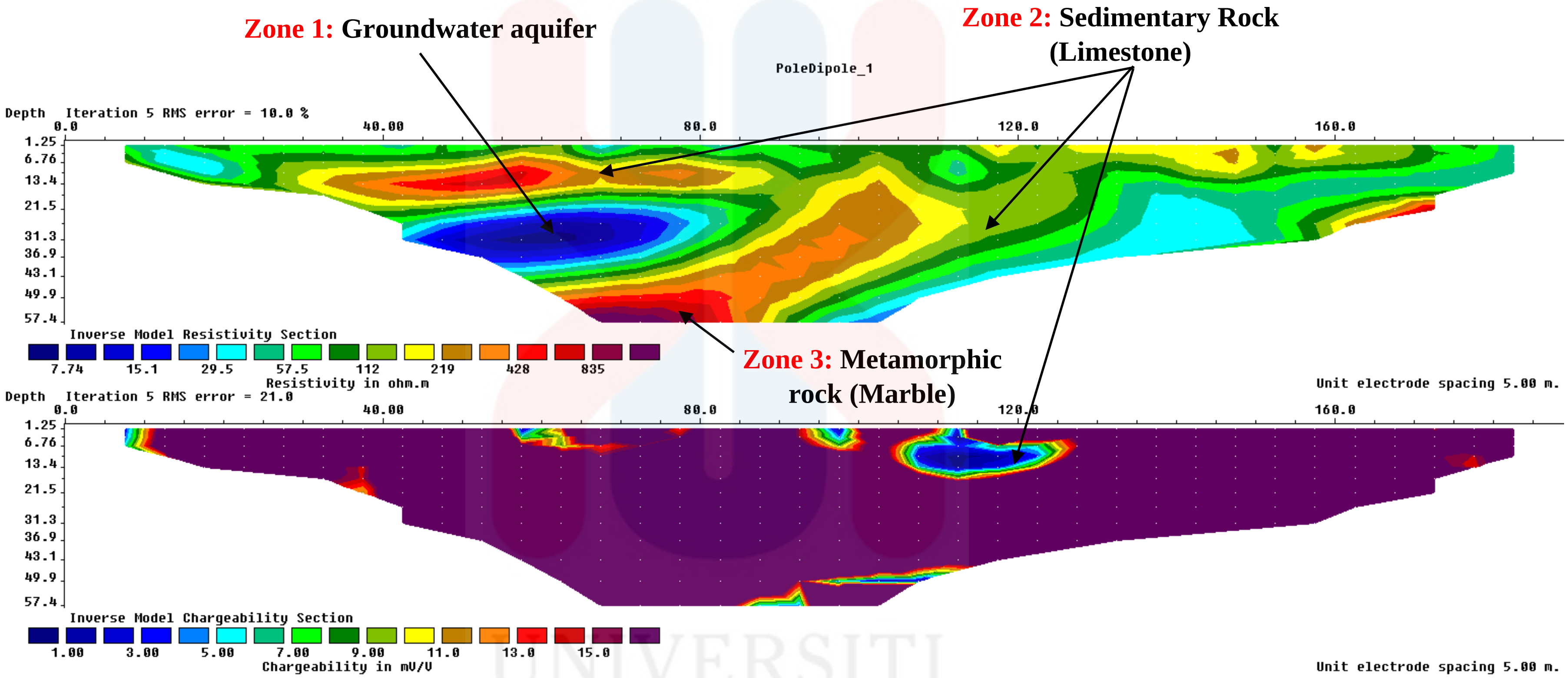



**Figure 5.5.7:** Result of survey line 3

5.8 Discussion

This section expands on the evaluation of the outcome. Three survey lines data clearly demonstrate that a resistivity value and a conductivity value are quite comparable. The conductivity of earth materials with high resistance values is often lower. Water can carry an electrical charge; hence it has become an important factor to assess conductivity. The resistivity, on the other hand, demonstrates how resistant the materials of the earth are to water.

According to the findings, both igneous and metamorphic bedrocks exhibit significant levels of resistivity. This is a result of the bedrock's own insufficient connecting space in its matrix. Additionally indicating conductivity and resistivity is the porosity value. The porosity of igneous and metamorphic bedrock is quite low but the make good aquifers because they have a lot of cracks and gaps which allows the water to pass through.

Survey line 1, 2 and 3 has a good potential of groundwater aquifer at the average depth of 15m to 40m. The aquifer lies below the presence of sedimentary rock layer which is classified as limestone rock according to the lithology of the study area. Limestone rock is neither porous or permeable but the chemical composition calcium carbonate which dissolves easily in water causes the formation of cracks and gaps. This allows the water from discharge from surface water and rainfall to seep through into the aquifer.

**CHAPTER 6**

**CONCLUSION AND SUGGESTON**

6.1 Conclusion

The results of the geological mapping and geophysical survey was concluded in this chapter. The student was able to identify the lithologies present in the study region the marble, meta mudstone and meta quartz wacke surrounded with geological age of Early Triassic to Late Triassic. The geological features identified is 3 major faults.

The geological mapping has resulted in an updated map of my research area. Based on the observations and measurements that have been made, it enables the learner to comprehend how tectonic movement has affected the study region from a past era to the present. The discovered geological evidence supports the invasion and modification of rock bodies as a result of temperature fluctuations.

The findings of the electrical resistivity imaging survey indicate that shallow groundwater potential may exist in my research region, which is in accordance with the subject of the specification. In the interpretation process, combining the resistivity and chargeability values improves knowledge and interpretation of the underlying rock bodies. Due to the presence of sedimentary rock limestone, survey line 1, 2 and 3 has a possibility for good groundwater aquifer at the average depth of 15m to 40m.

## 6.2 Suggestion

The information in this subtopic may be utilised by students or researchers to identify the potential of groundwater. The investigation of Kelantan's groundwater is also aided by this effort. Future groundwater investigation should take further steps as the project's title simply calls for discovering the prospective zone for groundwater. It is necessary to do more research on the suggested drill site and groundwater flow direction. Additionally, extensional subsurface groundwater inquiry includes recording boreholes, examining the quality of the groundwater, conducting pumping tests to determine transmissivity, and covering aquifer storage.

On the other hand, in addition to applying the Electrical Resistivity Imaging approach, another geophysical technique like Vertical Electrical Sounding (VES) should be suggested. This technique will provide information on the thicknesses of aqueous bodies and the water's yield capacities. This will provide a clearer image when identifying the probable groundwater zones.

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