



**GEOLOGY AND GROUNDWATER
EXPLORATION IN LIMESTONE USING
ELECTRICAL RESISTIVITY IMAGING (ERI) AT
KAMPUNG STAR BARU, GUA MUSANG,
KELANTAN**

by

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

**FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN**

2023

DECLARATION

I declare that this thesis entitled “Geology and Groundwater Exploration In Limestone Using Electrical Resistivity Imaging (ERI) At Kampung Star Baru, Gua Musang, Kelantan” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

“I hereby declare that I have read this thesis entitled “Geology And Groundwater Exploration In Limestone Using Electrical Resistivity Imaging (ERI) At Kampung Star Baru, Gua Musang, Kelantan” and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Applied Science (Geoscience) with Honours”

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In the name of God the Most Gracious and the Most Merciful

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GEOLOGY AND GROUNDWATER EXPLORATION IN LIMESTONE USING ELECTRICAL RESISTIVITY IMAGING (ERI) AT KAMPUNG STAR BARU, GUA MUSANG, KELANTAN

ABSTRACT

The study area lies between coordinates N 5° 2'4.17" to N 4°59'17.27" and E 102° 0'3.37" to E 102° 0'0.38" with an area of 25 km². The study area is rural, consisting of oil palm plantations, a rubber estate and a primary forest. This study aimed to produce a geological map of the area on a scale of 1:25 000 and to investigate the groundwater sources using Electrical Resistivity Imaging (ERI) method. The purpose of geological mapping is to map the lithology, geological structure and geomorphology using the traversing method and collected groundwater potential data using ABEM Terrameter LS. The field data collected was then processed in GIS software platform to generate geological map and Res2DInv software to give pseudo section data of groundwater potential. The lithology in the study area was composed of limestone, quartzite, slate, shale, and interbedded mudstone with siltstone rock. The geomorphology in the study area is surrounded by hilly areas and karst formation with the elevation ranging from 100 metres to 460 metres. Limestone rock were majority found at the study area. The meta-sedimentary rocks like shale, slate and interbedded mudstone with siltstone were found at the East to South of the study area. In structural geology, outcrop found have anticlines features folding, faults, bedding and joints in the study area. Bedding is continuous at several outcrops and hills. The strike and dip data collected were analysed in a rose diagram and stereonet to plot the orientation of discontinuities. The drainage patterns found in the study field are parallel and have minor dendritic patterns. This research is conducted by doing geological mapping and specification resistivity surveys. The Pole-dipole configuration array is used to perform four survey lines of 200 m inside the study area. The processed resistivity data has an RMS error of less than 20%. The study also found that the highest groundwater potential was located within the fractured bedrock of sedimentary rock.

Keywords: Kampung Star Baru, Gua Musang, geological, Electrical Resistivity Imaging, groundwater, potential

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GEOLOGI DAN EKSPLORASI SUMBER AIR BAWAH TANAH DALAM BATUKAPUR MENGGUNAKAN PENGIMEJAN KEBERINTANGAN ELEKTRIK DI KAMPUNG STAR BARU, GUA MUSANG, KELANTAN

ABSTRAK

Kawasan kajian terletak di antara koordinat N 5° 2'4.17" hingga N 4°59'17.27" dan E 102° 0'3.37" hingga E 102° 0'0.38" dengan keluasan 25 km². Kawasan kajian adalah luar bandar, yang terdiri daripada ladang kelapa sawit, estet getah dan hutan utama. Kajian ini bertujuan untuk menghasilkan peta geologi kawasan pada skala 1:25 000 dan menyiasat sumber air bawah tanah menggunakan kaedah Pengimejan Kerintangan Elektrik. Tujuan pemetaan geologi adalah untuk memetakan lithologi, struktur geologi dan geomorfologi menggunakan kaedah terabas dan mengumpul data potensi air bawah tanah menggunakan ABEM Terrameter LS. Data lapangan yang dikumpul kemudiannya diproses dalam platform perisian GIS untuk menjana peta geologi dan perisian Res2DInv untuk memberikan data keratan rentas potensi air bawah tanah. Lithologi di kawasan kajian terdiri daripada batu kapur, kuarzait, batu tulis, syal, dan batu lumpur yang berselang-seli dengan batu kelodak. Geomorfologi di kawasan kajian dikelilingi oleh kawasan berbukit dan formasi karst dengan ketinggian antara 100 meter hingga 460 meter. Batu kapur majoriti ditemui di kawasan kajian. Batuan meta-sedimen seperti batu lumpur, batu tulis dan batu lumpur yang berselang-seli dengan batu kelodak ditemui di Timur ke Selatan kawasan kajian. Dalam geologi struktur, outcrop yang ditemui mempunyai ciri-ciri anticlines lipatan, sesar, peralihan dan kekar di kawasan kajian. Peralihan berterusan di beberapa kawasan luar dan bukit. Data jurus dan derajat yang dikumpulkan telah dianalisis dalam gambar rajah mawar dan stereonet untuk merancang orientasi struktur. Corak saluran yang terdapat dalam bidang kajian adalah selari dan mempunyai corak dendritik kecil. Kajian ini dijalankan dengan melakukan pemetaan geologi dan kaji selidik spesifikasi kerintangan. Tatasusunan konfigurasi Pole-dipole digunakan untuk melakukan empat baris tinjauan 200 m di dalam kawasan kajian. Data rintangan yang diproses mempunyai ralat RMS kurang daripada 20%. Kajian itu juga mendapati bahawa potensi air bawah tanah tertinggi terletak di dalam batuan terkekar batu sedimen.

Kata Kunci: Kampung Star Baru, Gua Musang, geologi, pengimejan keberintangan elektrik, sumber air bawah tanah, potensi

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CHAPTER 1

INTRODUCTION

1.1 General Background

Groundwater is water that exists below the surface of the Earth and fills all or part of the void spaces in soils or geologic strata. It is also referred to as underground water to differentiate it from surface water found in large bodies of water like oceans or lakes, or water that flows overland in streams. It is a part of the water cycle.

The dissolution of calcite, the primary mineral element of limestone, impacts on the chemical structure of groundwater in limestone. Calcite is slightly soluble in water (Appelo & Postma, 2005). The degree of consolidation and development of permeable zones after accumulation determine limestone density, permeability, and porosity. Long-term dissolution can cause pore space expansion, forming karst terrain, sinkholes, caves, and other features, indicating that carbonate dissolution impacts water compositions.

Groundwater is essential for supplementing domestic, industrial, and irrigation water supplies. Electrical resistivity Imaging (ERI) is the most appropriate method for exploring groundwater resources because it shows an excellent contrast between water-saturated formation with other materials.

1.2 Study Area

The study area purposely measured 25 km² including Kampung Star Baru, Gua Musang, Kelantan (Figure 1.1). The study area is a rural area consisting of an oil palm plantation, rubber estate and primary forest.

The geomorphology of the study area is surrounded by hills, plantations, caves, and karst formations, with the elevation ranging from 80 metres to 260 metres. The study area lies between latitude N 5° 2'4.17" to N 4°59'17.27" and longitude E 102° 0'3.37" to E 102° 0'0.38".

As the study area is rural, many unsurfaced roads are connected between the plantation area and villagers. The study area is about 14 kilometres from Gua Musang's central city and is bordered by the Jalan Jelawang- Gua Musang Highway.

1.2.1 Location

The study area is approximately 25.2 km² or 5.2 km x 5 km with a site plantation and village.

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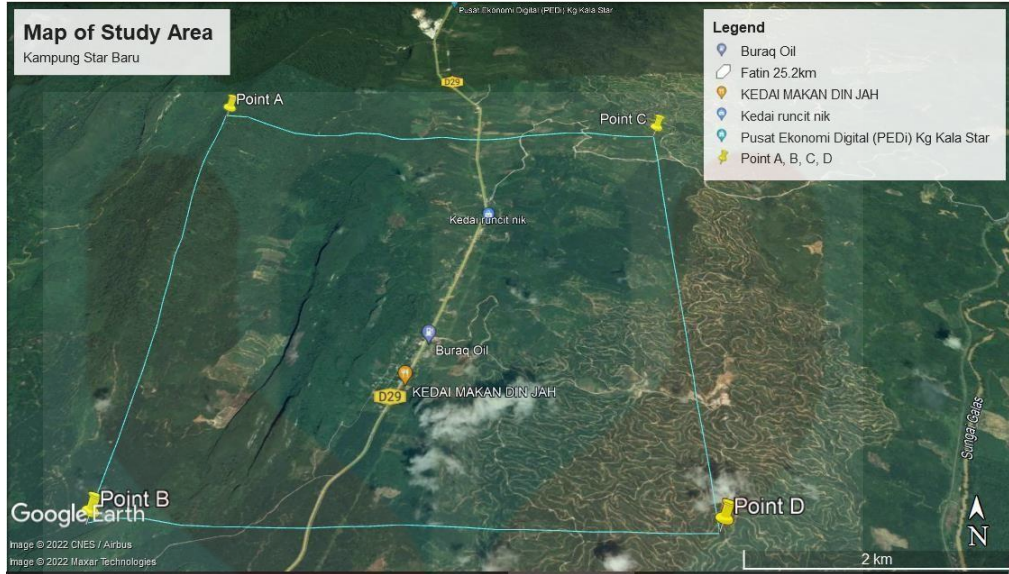


Figure 1.1: Satellite image of the study area (Source: Google Earth Pro, 2022)

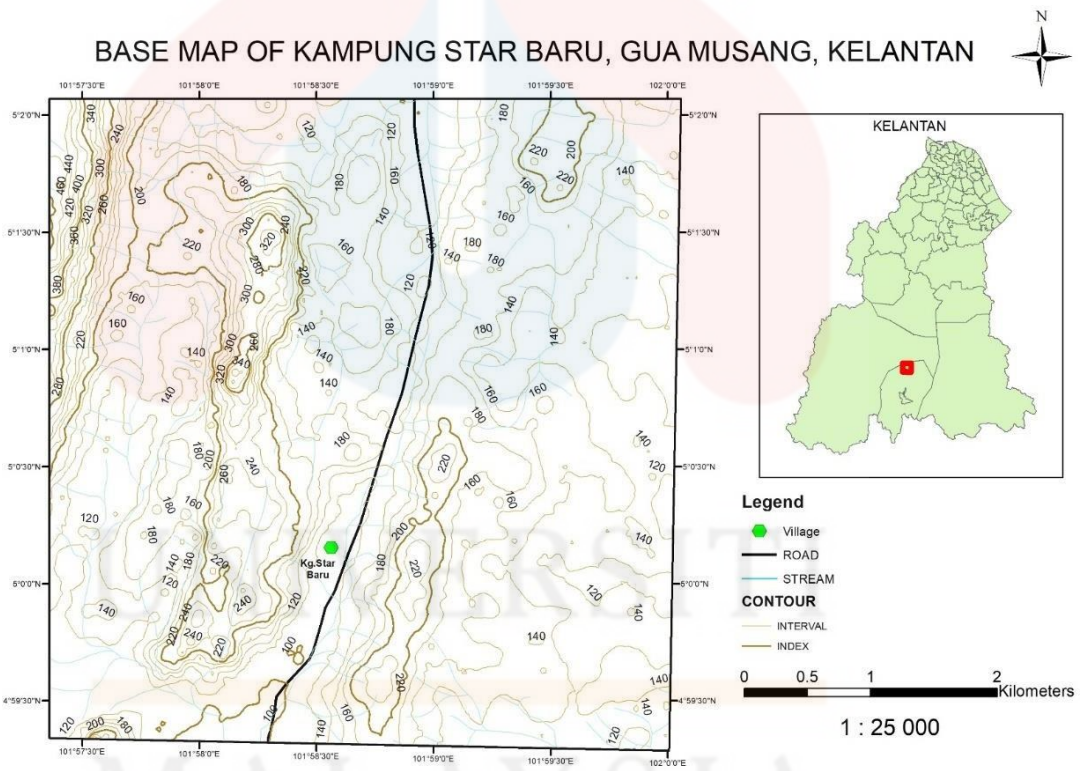


Figure 1.2: Base map of the study area (ArcGIS, 2022)

Table 1.1: Coordinate of the study area at Kg. Star Baru, Gua Musang

Point	Coordinate
Point A	Latitude: 5° 2'1.81"N Longitude: 101°57'22.44"E
Point B	Latitude: 4°59'19.58"N Longitude: 101°57'21.93"E
Point C	Latitude: 5° 2'4.17"N Longitude: 102° 0'3.37"E
Point D	Latitude: 4°59'17.27"N Longitude: 102° 0'0.38"E

i. Road connection

In the study area, the main road connecting Jeli with Gua Musang is overlaid in the middle of the map, also known as Jalanraya Jelawang-Gua Musang (Figure 1.2).

Jalan Sena and Jalan Marani are two additional short asphalt roads that link Kampung Star Baru to the main road. As for other types of roads, they include non-bituminous roads, which are gravel roads and are not suitable for using a car but are instead used by plantation workers with lorries and four-wheel drives. In banana farms, there are also non-bituminous, grass-covered roads that are only suitable for motorcycle or foot traffic.

ii. Demography

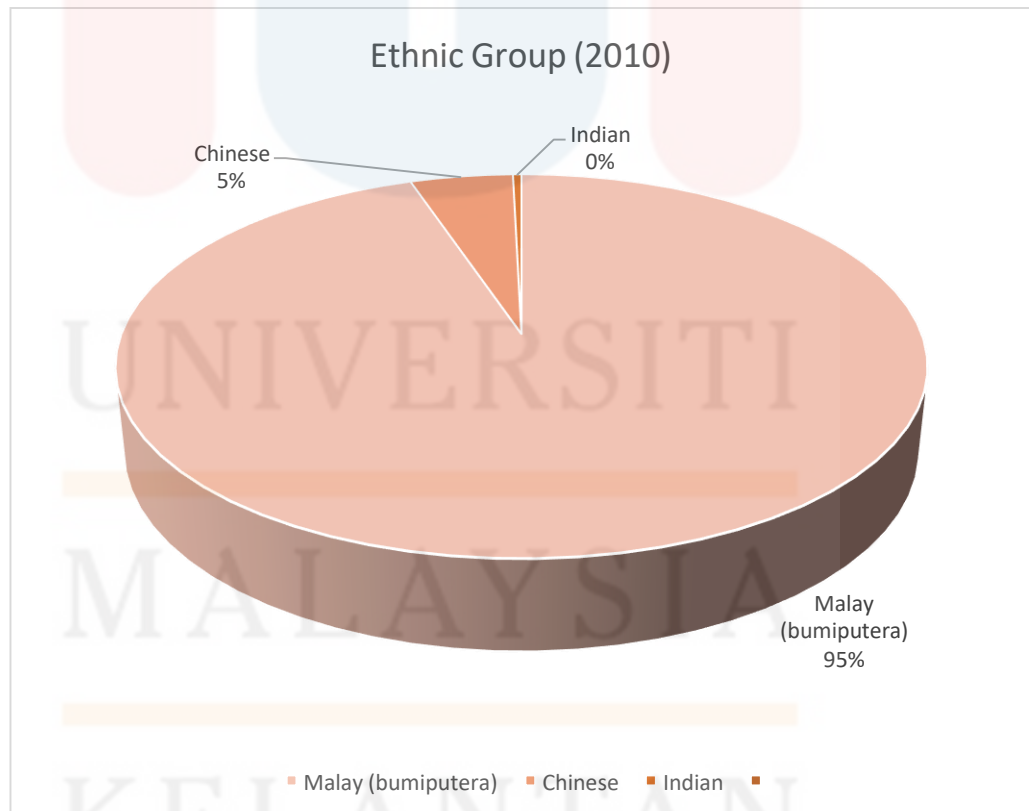
The Gua Musang region spans 6,430 km². The population of Gua Musang is increasing, (as shown in Table 1.2), from 74 988 in 2000 to 86 189 in 2010 and 1,894 in 2020. This quick increase demonstrates the area of Gua Musang's population growth. In addition, a pie chart in Figure 1.3 depicts Gua Musang's population in 2010, with 94.6 percent of the population being Malay and other indigenous people, followed by 4.8 percent of Chinese people and 0.4 percent of Indian people.

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Table 1.2: The population development of Gua Musang(Source: Department of Statistic Malaysia)

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



iii. Landuse

There are significant seasonal variations in population because Gua Musang is the largest district in Kelantan, covering an area of 821,430 hectares. The main factor affecting land use in Gua Musang is an increase in population. Natural or protected forests cover the majority of the land in Gua Musang. A reserve or natural forest covered the district in 2010, 538 kilo hectares. Gua Musang lost 12.6 kilo hectares (km²) of its natural forest in 2019 due to the district's high demand for land use, creating an opportunity for the development of other sectors like agriculture, urban development, and mining. Based on a review of the literature, it has been determined that various distributions of land uses exist in the study area. Plantations grew to be the primary industry in the study area, operating there actively for about 95 percent of the time. The two plantation activities that can be separated are palmoil and rubber tree plantations. Other industries, including agriculture, groves, grottos, road building, and natural forests, use the remaining 5% of the land.

iv. Social economic

The state's domestic output and a location's social and economic conditions are related to social economic. According to the Department of Statistics' 2019 economic report for the state of Kelantan, a few industries, like plantations, manufacturing, mining and quarries, services, and construction, all made

contributions. According to the report, Kelantan's economy grew by about 5.3% in 2019. According to the Kampung Star Baru study area, plantations have emerged as the main economic and social contributor. Two major organisations, KESEDAR and FELDA, typically oversee and manage the economy of the plantation sector in Gua Musang. The development of the rubber tree and palm oil plantations in Gua Musang, including the plantation in the study area, is managed and controlled by both agencies. Because plantations predominate in the study area, most locals work primarily as farmers and manufacturing workers involved in plantation production.



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1.3 Problem Statement

There is always a state of deterioration of water stability in Kelantan throughout the year. The record proves that the state government has failed to protect their natural treasures and, in the coming decades, will experience water- related catastrophes that will haunt the people of Kelantan, such as the lack of raw water, lower groundwater levels and the intrusion of sea water into natural water areas due to excessive groundwater extraction. The state faces water problems like the lack of clean water resources yearly. This study is to work out geological features and find groundwater sources for water utilisation with the increasing population in Kampung Star Baru. The groundwater exploration will be used for domestic use, clean water supply and irrigation for agriculture in the Kampung Star Baru villagers and other societies.

1.4 Objectives

Objectives of this research as follows:

- i. To produce a geological map of the study area on a scale of 1:25000.
- ii. To investigate the groundwater sources using Electrical Resistivity Imaging (ERI) method

1.5 Scope of Study

This research area covered an area of 25.2 km², which is five km² from east to west and 5.2 km² from north to south. This aims for geological mapping in that area and identifying the potential of groundwater sources at Kampung Star Baru, Kelantan. In this study, the aspect covered geological mapping, geomorphology, lithology, and structural geology. For searching the potential of groundwater sources is discovered using electrical resistivity imaging.

1.6 Significance of Study

Groundwater is used for various purposes, including drinking, bathing, cooking, and washing. The current research will benefit for community because they will be able to use this study as a reference and gain information for future research on geology and groundwater exploration at that site. This study is also helpful in producing an updated geological map in small scale area of the study area and geological information that other researchers can use in plans. The discovery of geologic features like faulting, folding, and bedding can provide insight into how geological processes occur in the study area. The groundwater is significant as there is a greater demand for the villagers in Kampung Star Baru, society, and the surrounding area to have safe and clean drinking water. This study can meet the community's need for fresh, clean groundwater for health and other activities. This study may help decide the construction of new wells, drainage, and pumping systems. Overall, this research will benefit the people who live in the area.

Geological mapping is one of the most proficient ways to present geological data and is used for various tasks, including scientific research and the exploration of natural resources. The significant study for geological mapping will update Kampung Star Baru's geological features and beneficiaries to the villagers and society.



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This part will discuss the geological component including regional geology, plate tectonic setting, stratigraphy, structural geology and potential groundwater exploration in limestone. This section might come from journals, previous thesis, articles and internet sources.

2.2 Regional Geology and Tectonic Setting of Gua Musang, Kelantan, Malaysia

According to the geological map of Kelantan provided by the Department of Mineral and Geoscience (2003), unconsolidated sediments, extrusive rocks (volcanic rocks), sedimentary or metasedimentary rocks, and granitic rocks make up 6%, 10%, 51%, and 33%, respectively, of the state's 105 022 sq km of land.

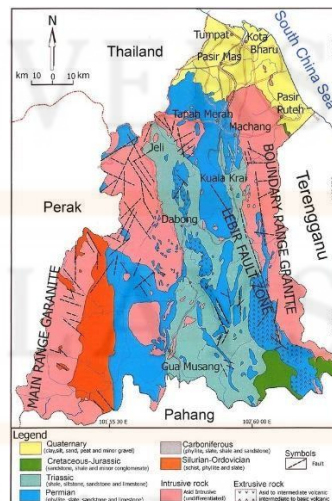


Figure 2.1: Geological map of the Kelantan state (modified from Department of Minerals and Geoscience Malaysia, 2003).

The sediments in the Kelantan region are from the Quaternary period and represent an alluvial plain that lies on top of granitic bedrock. Sediments made of marine clay are present along the coast. On the other hand, further inland in Kelantan, the sediments are made of coarse gravel, silt, or mixtures of these two substances.

Two formations, the Gua Musang Formation and the Gunung Rabong Formation, are located in Gua Musang. The Permian sedimentary rocks cover the sedimentary and metasedimentary rocks in the study area, which is a part of the Gua Musang Formation.

2.3 Geology of Peninsular Malaysia

The Sunda Shield tectonically encompasses Peninsular Malaysia. The Triassic fold-mountain belt of the Peninsula stretches eastward from eastern Burma through Thailand, Peninsular Malaysia, the Banka and Billiton Islands, and into Indonesian Borneo. Peninsular Malaysia is home to all geological periods, from the Cambrian to the Quaternary. The Triassic and earlier strata are mostly marine, whereas the post-Triassic rocks are mostly non-marine (*Environment – Geology – About Malaysia*, n.d.). information Malaysia yearbook 1997.

Throughout the Palaeozoic and Mesozoic periods, sedimentation took place continuously. Significant breaks within and between the Palaeozoic, Mesozoic, and Cainozoic rock groups are visible because of the basin's instability. Nearly half of the Peninsulas are covered in granitoids, which frequently form topographic highs, especially in the Main Range. The main granitic emplacement episode corresponds to the late Triassic orogenic event that folded and deformed all older strata.

2.4 Geology of Kelantan

In Peninsular Malaysia, Kelantan state is located in the country's north east. The Kelantan River is the region's main river. It emerges near Kuala Kari at the confluence of the Galas and Lebir rivers and meanders across the coastal plain until it eventually empties into the South China Sea.

The Kelantan River basin covers 923 km² or about 85% of the state's land area. In the north, it consists of flat to moderately sloping measurements, while in the south, it consists of steep scraps and high slopes (Pradhan et al., 2009). The state of Kelantan has a north-south trend with a diverse range of rocks, including igneous, sedimentary, and metamorphic rocks. Granitic rocks, sedimentary/metasedimentary rocks, extrusive rocks (volcanic rocks), and unconsolidated sediments are the four major types of rocks that can be found in the region.

Localised geological features include granitic faulting and jointing and sedimentary folding, faulting, and jointing. The state's western (Main Range granite) and eastern (Boundary Range granite) borders are covered in granitic rocks. (Rahman & Mohamed, 2001; from Department of Minerals & Geoscience Malaysia, 2003; Heng et al., 2006).

The Main Range Granite can be found in western Kelantan and stretch to the state borders of Perak, Pahang, and Thailand. Kelantan's dominant structural trend, derived from the post-orogenic phase, is from N-S to NW-SE (Ghani, 2009). The Bentong-Raub Suture Zone (BRSZ) runs along the western edge of the Main Range Granite and extends north to Thailand. (Schwartz et al., 1995; Met-calfe, 2000).

The North-south axis of the Bentong-Raub Suture (approximately 13 km wide) runs from Thailand to east of Malacca, Peninsular Malaysia, via Raub and Bentong. The BRSZ is distinguished by parallel topographic north-south trending lineaments and small bodies of serpentinised mafic to ultramafic rocks (Tan, 1996). The Lebir Fault Zone is located in the eastern part of Kelantan state and is one of Peninsular Malaysia's major lineaments. It is a sinistral strike-slip fault thought to be post-Cretaceous (Tjia, 1989; Harun, 2002).

Mountainous, hilly, plain and coastal areas make up Kelantan's landscape (Unjah et al., 2001; Raj, 2009). Mount Chama is Kelantan state's highest point (2171 m), located in the Gua Musang district in the state's western part, close to the Perak state border (Nazaruddin et al., 2014).

Alluvium deposits and unconsolidated sediments make up Quaternary deposits. Other sedimentary rocks in Kelantan include Triassic marine siliciclastics, Volcaniclastics, Sandstone, and Limestone (Nazaruddin et al., 2014).

2.5 Stratigraphy and Lithology Setting of Gua Musang, Kelantan, Malaysia

The Gua Musang Formation comprises crystalline limestone with thin interbedded shale beds, tuff, chert nodules, and subordinate sandstone from the Middle Permian to the Middle Triassic. Three outcrops of the Gua Musang Formation were studied, and a stratigraphic model of the formation, complete with burial history and a geothermic model, was created. Sandstone and conglomerate make up the first outcropping, limestone makes up the second, and shale and siltstone make up the third. In comparison to the reservoir of an effective petroleum system, the porosity of sandstone and silt is moderate to good, according to the model.

The maximum temperature to which the Gua Musang Formation was subjected ranged from 1300C to 1400C, during which the katagenesis process occurred. The knowledge and study of the Gua Musang Formation basin analysis can be improved by understanding the temperature structure.

2.6 Structural Geology

Structural geology refers to structural changes produced by physical and chemical processes. Kelantan's geological features include the west Kelantan Olistostrom, Taku Schist, and Gua Musang Formation. Granite, diorite porphire, andesite, ignimbrite, and dolerite are igneous rocks found in Kelantan. Kelantan is structurally limited by the olistostrom in the west and the Lebir Fault Zone in the east. Thus, these processes are deformation processes.

Deformation is a term used to describe the structural alterations that occur in body of rock's original location, orientation, shape and volume (Davis et al, 1984). Structural geology can be defined as the analysis of the three-dimensional distribution of substantial rock bodies and their surface, including the recognition of positive and negative line reading in the study area (Citra et al, 2012). It is possible to identify the structural geology present in the study area from the lineament reading. For instance, a linear feature of the landscape contains a fault structure. In addition, additional structures like dykes, fracture zones, shear zones, and igneous intrusions can also be used to interpret a lineament. Typically, a line comprises of a series of hills that can be divided along a fault or fold alignment.

2.7 Historical Geology

Gua Musang Formation was included in many forms during the Mesozoic Era. Malaysian Mesozoic Era formations were traditionally grouped in different geographical and paleoenvironment settings. Hence the correlation between other regions was established based on fossil occurrences. Gua Musang Formation belongs to the central belt of Peninsular Malaysia. The rock formations under the Mesozoic are a continuous north-south trending belt, extended beyond the international boundaries with Thailand, where the Gua Musang formation is in the North and Singapore where the Jurong Formation is in the south (Mohamed, K.R., Mohamed Joearry, N. A., Leman, M. S., & Ali, C. A. 2016).

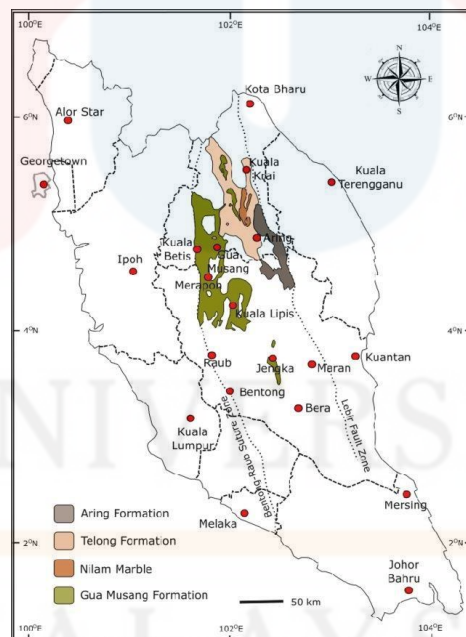


Figure 2.2: Distribution of the Gua Musang Group. Modified from Mohamed (1995).

2.8 Groundwater in Gua Musang

In Bandar Gua Musang, Kelantan, some research has been conducted on the potential for groundwater resources using similar techniques, such as resistivity surveys in chosen locations based on the accessibility. The research used geological mapping to identify the geomorphology, lithology, and geological structures of the study area.

2.8.1 Formation of Groundwater

Ground water is water found underground in saturated zones beneath the land surface. Groundwater does not form underground "rivers," contrary to popular belief. It plugs pores and fractures in underground materials like sand, gravel, and rock. If groundwater flows from saturated rock materials or can be removed from them, by pumping, aquifers are rock materials that contain generous amounts of water. Groundwater moves slowly in an aquifer, typically at 7 to 60 centimetres per day. As a result, water in an aquifer could last hundreds or thousands of years. Groundwater provides approximately 40% of the water in the United State is used for public supply and about 38% of the water used for agriculture is recycled. (USGS, 2013). Kelantan uses both groundwater and surface water treatment as its water resources for daily uses. In metropolitan areas, groundwater resources are utilised more than in rural areas, which favour surface water resources (Sulaiman, N., Saliman, N. S., & Sulaiman, N. (2021).

2.9 Groundwater in Hard rock

Rock fracture systems are heterogeneous and anisotropic due to their heterogeneity and anisotropy. Groundwater resources in crystalline bedrock are limited and difficult to predict. Significant lineaments often indicate fracture zones (Voeckler & Allan 2012) and potentially significantly impact the hydrogeological characteristics of hard rock terrains (Chandra et al. 2005; Henriksen & Braathen 2005; Solomon & Quiel 2006; Courtois et al. 2010).

Sander (2007) discusses the potential limitations of using lineaments as a basis for groundwater studies, such as unconsolidated material coverage and the potential contribution of intense lineaments to drainage, implying that other factors should be considered when forecasting spatial water supply. Because the effects of multiple attributes, such as lineaments and soil-covered valleys, overlap, it's difficult to distinguish between them, even with statistical tools. Soil layers play an important role in water supply in these areas because their kinematic porosity values are often higher than hard rock increasing storage and infiltration capacity in valleys (Freeze & Cherry 1979; Singhal & Gupta 1999).

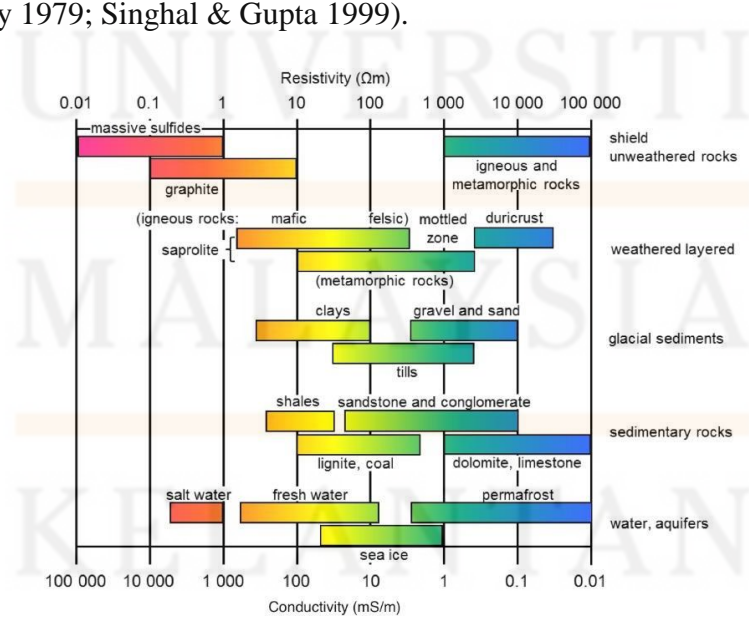


Figure 2.3: Standard value of resistivity and conductivity for various types of materials. (Source: Placky, 1987)

2.10 Groundwater Exploration

Groundwater exploration is developed by the history of India & Egypt in water resources. About 6 000 years ago, irrigation purposes and drinking water were everyday used in Mahabharata in India by getting from an open well. The modern lines of groundwater exploitation were started in 1935. There was the first tube well sunk in that year in Uttar Pradesh. The development of method and techniques of groundwater exploration based on several types: Aerial, Surface, Sub-Surface and Esoteric (Badrinarayanan, 2009). The amount of groundwater in North Kelantan is governed by the kind of landform, which is alluvium. In comparison to the study region, alluvium has the properties of unconsolidated materials and may with stand water. Groundwater can be discovered only in fractured areas of hard rock, where there is an opening in the rock that may gather and store water. Groundwater may be monitored by conducting a geophysical survey utilising the Electrical Resistivity Imaging (ERI) technique. Because each material has a distinct resistivity value, the ERI technique may determine the underlying material and condition by using the resistivity value (Sulaiman, N., Saliman, N. S., & Sulaiman, N. (2021).

2.11 Electrical Resistivity Imaging in Groundwater Exploration

Geophysical methods are the most appropriate for groundwater exploration because they have been used extensively in geotechnical and geo- environmental investigations. For many years, geophysics has played an essential role in such studies by improving instruments and developing new ones to achieve better results and broaden their applications. Electrical Resistivity Imaging (ERI) is a geophysical method used as the first step in groundwater exploration.

ERI measures and maps the resistivity of subsurface materials (Asry et al., 2012). It also refers to a survey in which an electrical current is passed through various paths. The resulting voltage is measured to obtain an image of the subsurface electrical properties (Abidin, 2011). ERI is based on the interaction between the earth and electrical current flow. It is sensitive to changes in subsurface electrical resistivity as measured by Ohm metres. The resistivity is measured by passing an electric current through two current electrodes (C1 and C2) and measuring the resulting voltage at two potential electrodes (P1 and P2). Groundwater resistivity values range from 10 to 100 ohm-m based on the concentration of soluble substances present (Keller, 1996).

Several factors, such as porosity, a degree of water content, and dissolved salt concentration, influenced the interchange value resistivity of various water classes.

Table 2.1: Water resistivity values of various typeSource: Keller and Frischknecht (1996)

Water Type	Resistivity (ohm – m)
Precipitation	30 – 1000
Surface water (igneous rock)	30 – 500
Surface water (sedimentary rock)	10 –100
Groundwater (igneous rock)	30 – 150
Groundwater (sedimentary rock)	> 1
Sea water	0.2
Freshwater	10 – 100
Drinking water (max. salt content 0.25%)	> 1.8
Water for irrigation and stock watering (max salt content 0.25%)	> 0.65

In an electrical resistivity survey, electrode configuration, generally known as the array, will bring high resolution, reliability, and good imaging (Aizebeokhai, 2010). Several studies on the performance of various arrays have been carried out. Many different types of arrays can be used in data acquisition. Wenner array, Schlumberger array, Dipole-dipole array, Pole-pole array, and Pole-dipole arrays were the most commonly used in investigating the subsurface layer. The array configuration significantly impacts the resolution, sensitivity, and depth of investigation.

Table 2.2: Array configuration characteristics (Source: Samoeulian, 2005)

	Wenner	Schlumberger	Dipole-dipole	Pole-pole	Pole-dipole
Sensitivity of the array (horizontal structures)	++++	++	+	++	++
Sensitivity of the array (vertical structures)	+	++	++++	++	+
Depth of investigation	+	++	+++	++++	+++
Horizontal data coverage	+	++	+++	++++	+++
Signal strength	++++	+++	+	++++	++
The labels are classified (+) to (++++), equivalent at poor sensitivity to high sensitivity for the different configurations					

ERI is one of the most influential and cost-effective groundwater research techniques. This is due to the aquifer's electrical properties being closely related to some of its hydrogeological properties (Diat, 2013).

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

The specialisation of this research study is to determine and explore the potential groundwater sources in the identifying sedimentary rock such as the limestone area. Besides, searching for groundwater exploration in that particular area, this research will update the regional geology formation in the study area by producing an updated geological map containing new or remaining data. The method that will use is a geophysical method, the 2D Electrical Resistivity Imaging (ERI).

3.2 Material/Equipment

Table 3.1: List of material and equipment

No	Materials And Software	Uses
1.	ArcGIS Software	It is used to produce the elevation map, contour, and lithology in the study area.
2.	Microsoft Excel	It is used for data tabulation and report writing.

3.	Google Earth Pro	Determination of the geological map and ERI survey line of study area using satellite image.
4.	RES2Dinv	It is used to process the survey line data regarding resistivity, topographical and IP

3.3 Methodology

The methodology is an important technique that must be included in a research study. In order to investigate the research problem, specific actions must be taken, and those actions will be described. In order to better understand the research problem, the method used to identify the methods includes choosing the procedure, being aware of how the data is gathered, and having that data analysed. Generally, there are components of research methodologies that had been run in this research:

- i. Preliminary studies
- ii. Field studies
- iii. Laboratory work
- iv. Data processing
- v. Data analysis and Interpretation
- vi. Report writing

3.3.1 Preliminary Studies

The first stage is a preliminary study of the geological conditions of the research area based on a literature review. The concepts of groundwater exploration by previous research studies include journal articles, books, newspapers, and magazines, the formations of limestone and the method of using a geophysical survey using ERI to conduct the exploration. Analysing the literature review will help understand some aspects of the study area, such as general geology history and tectonics setting, the method used, structural geology, and stratigraphy.

3.3.2 Field Studies

Field studies encompass two types that are geological mapping and groundwater exploration.

The traversing method was applied during field mapping in a box area of 25 km². Materials and equipment used in geological mapping are a geological hammer, a global positioning system (GPS), a compass, a hand lens, plastic samples and a bottle of Hydrochloric Acid (HCL).

The activities during field mapping are observation of outcrop such as its geological structure, lithology, or the weathering condition and collecting rock samples. The image of geological features or information at the outcrop will be captured with a digital camera. These pictures will visualise geological features, landforms, landscapes, lithology, rock formations, and minerals. For structural geology, discontinuities were observed in every outcrops or boulders found in the site. In lithology segments, the observation identified the types of rock found and decided

the age of rock stratigraphy. Weathering grade observed by some techniques like using hand or fingers pressure into constituent grains, by doing comparison of its discolouration and fresh rock, or use a geological hammer to hear either have slight ringing sound when struck. When collecting sample for hand specimen, it is need to get the best fresh or slightly weathered sample from outcrops found by using geological hammer.

For groundwater exploration, 2D Electrical Resistivity Imaging was used onsite. It involved some equipment that will be used such as ABEM Resistivity Terrameter, electrodes, power supply, 200m of Electrical cable, and Clips that will act as a connector. The Pole-Dipole array will be used in the groundwater survey. The survey lines will be set up in 200m length and a maximum of 41 electrodes with an electrode spacing of 5 metres. Pole-Dipole array is used to get approximately five to ten times the survey depth and it has consistency of geological distortion.



Figure 3.1: Tools & Equipment use for ERI Survey

3.3.3 Laboratory Work

All rock samples taken from field mapping will be prepared for petrography analysis.

The rock samples will be cut to produce a thin petrographic section. A thin section is a slice of mineral rock mounted on a microscope with a thickness of about 30 micrometres.

A microscope will identify the thin petrographic section and analyse the rock sample to determine the rock's mineral content and texture. One classic yet essential mineralogical analysis method is investigating materials such as minerals and rocks in transmitting and reflecting light.

The steps in creating the thin petrographic section included cutting the samples into glass size and then frosting the glass slide, followed by the cement part, which cemented samples to the slide. Then, grind the section and hand grind it using a thin section machine. The next step is to examine the sample on the slide under a microscope to see if the mineral can be seen through. Once the mineral has been identified and seen under a microscope, examine it under the microscope mineral will be observed by cross polarise light (XPL), and plane polarises light (PPL). The magnificent 30x, 10x, and 4x is used for mineral observation to obtain a clear image of the mineral.

3.3.4 Data Processing

Data obtained from fieldwork will then be processed in the software application. These data will be processed into RES2DInv software, ArcGIS Software, GeoRose software, and Stereonet Software. GeoRose and Stereonet were used to analyse the geological structures like joints, bedding, fault and fold based on the field data of strike and dip to explain the direction of the force acting on the study area. The drainage and topography map was generated by using ArcGIS software based on contour elevation that extracted from Digital Elevation Model which is the representation of topographic surface and topographic features analysis. The lithology map generated by analysing the distribution of rock and differentiate boundary of rock by lithologic legend based on USGS standard colour. RES2DInv were used to generate the pseudo section of the apparent resistivity of the study area. This processing data will then be interpreted for groundwater potential.

3.3.5 Data Analysis and Interpretation

All software will incorporate information gathered in the field, such as fault and fold analysis based on strike and dip data, to produce an updated geological map of the study area. The rose diagram represents the force direction that acted on the research area. The following chapter goes over the deformation history of the study area in greater detail. The mineral observed under a microscope in petrography provides information about the type of rock. It began with field notes that described the outcrop in macroscopic hand specimens. Observing the grains' colour variation under plane polarised light, refractive index, optical symmetry, and fracture characteristics under a microscope. Based on inversion and forward modelling, the ERI interpretation of the value pseudo data will be interpreted using the resistance value

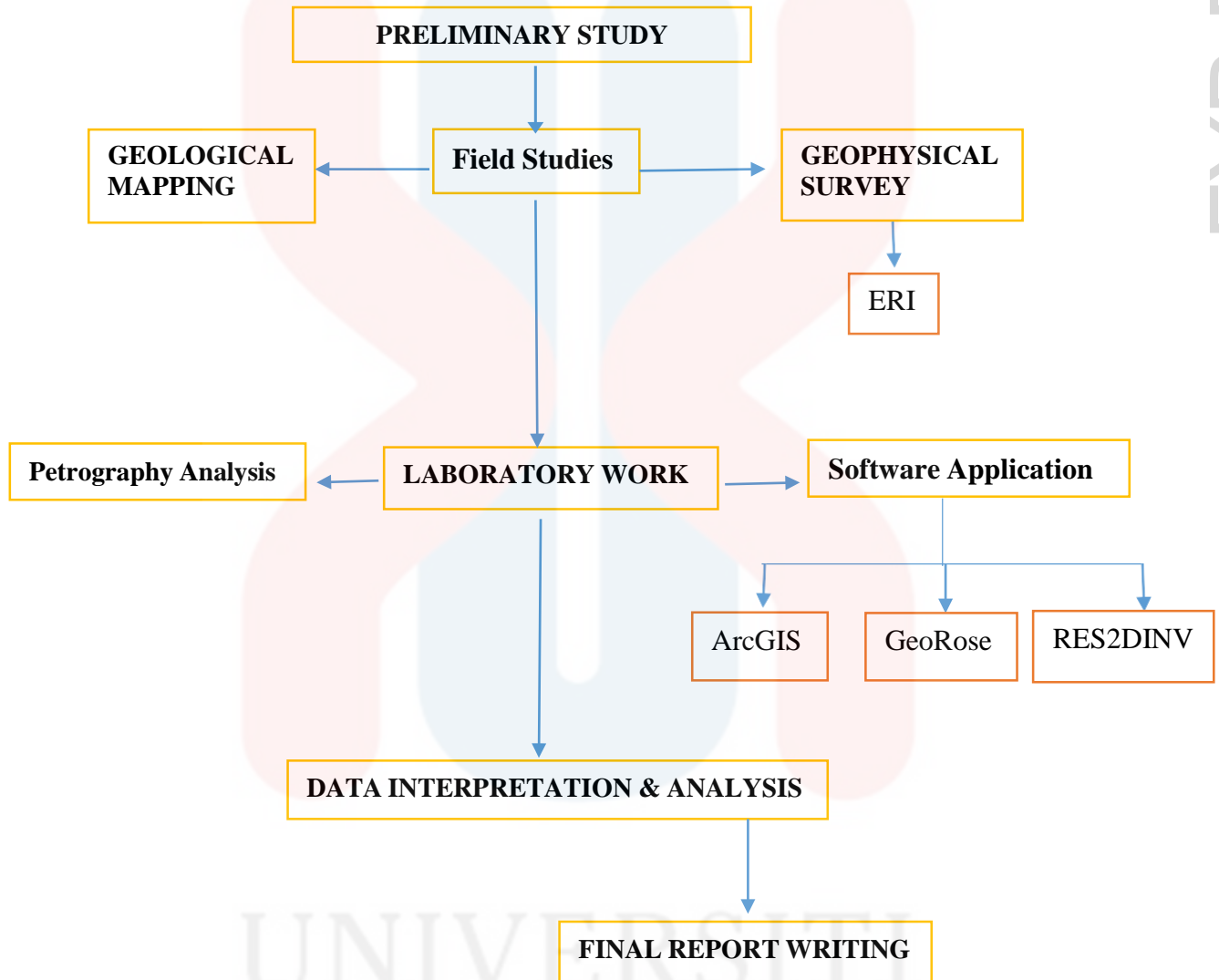
suggested by Keller and Frischknecht, (1996) in (Table 2.1). The study area's geological map was updated and created.

3.3.6 Report Writing

All data that are analysed and interpreted will be collected and documented in a report such as the preliminary study, field findings, data processing, and research interpretation will be documented in a report.



3.4 Research Flow Chart



CHAPTER 4

GENERAL GEOLOGY

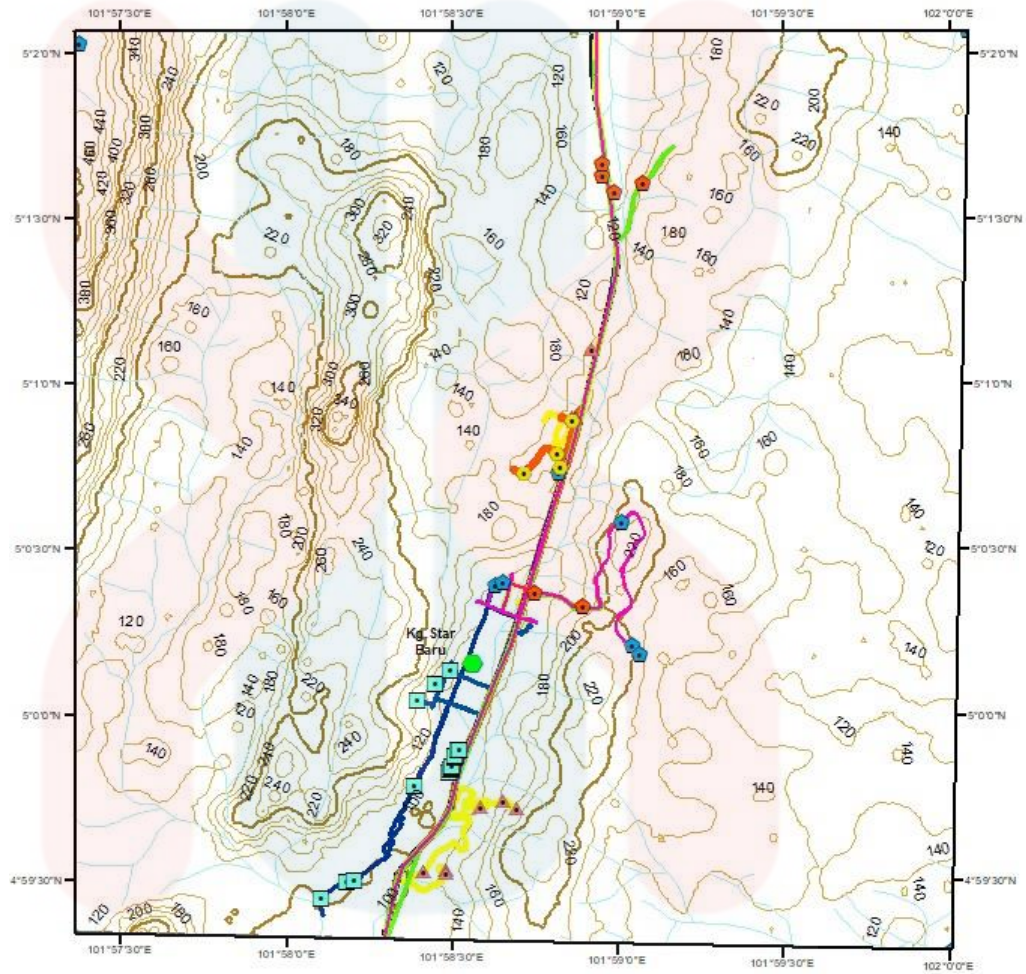
4.1 Introduction

This chapter will cover all geological aspects of the studied area, including geomorphology, stratigraphy, lithostratigraphy, structural geology, and historical geology. The mapping process begins with preliminary research from earlier journals, online sources, and other sources. To better understand historical geology, all of the data from geological mapping and interpretation undertaken in the study region is observed.

4.2 Traverse and observation station

Based on Figure 4.1 below shows the traverse and observation station. The map consists of 5 days of traverse in the study area and 42 checkpoints that have been marked in the map. Marked checkpoints in the map are consist of localities, outcrops, boulders, streams, landform, land use and sample collected.

TRAVERSE AND OBSERVATION STATION MAP OF KAMPUNG STAR BARU, GUA MUSANG, KELANTAN



Legend		
— TRVERSE DAY 1	LOCALITY DAY 1	Village
— TRVERSE DAY 2	LOCALITY DAY 2	Stream
— TRVERSE DAY 3	LOCALITY DAY 3	Road
— TRVERSE DAY 4	LOCALITY DAY 4	
— TRVERSE DAY 5	LOCALITY DAY 5	

CONTOUR
 — INTERVAL
 — INDEX

1 : 25 000



Figure 4.1: Map of traverse and checkpoints stations in the study area

4.3 Accessibility

From Jeli to Gua Musang, destination to the study area were done by route of Jalan Sungai Sam – Dabong – Jeli/Route 66 and Jalan- Jelawang Gua Musang. In this study area, Jeli and Gua Musang are connected by a single main road that runs over the centre of the territory as seen on the base map. The name of this street is Jelawang-Gua Musang road. Two additional, brief asphalt roads, Jalan Sena and Jalan Marani, connect Kampung Star Baru to the main road. Non-bituminous roads are gravel roads that are not appropriate for town people, but are instead utilised by plantation workers who use lorries and four-wheel drives. Non-bituminous, grass-covered roads that are only appropriate for motorbike or foot traffic can be found on oil palm plantations, banana farms and rubber plantations.



Figure 4.2: The only main road in the study area



Figure 4.3: One of the gravel road at study area leading to oil palm plantation



Figure 4.4: Non-bituminous road at rubber plantation in study area



Figure 4.5: Gravel road at between banana's farm and oil palm plantation



Figure 4.6: Small bituminous road in village

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4.4 Settlement

Kampung Star Baru is located in the Gua Musang district. This study area comprises of villages such as Kampung Limau Kasturi and Kampung Keldong.



Figure 4.7: Buraq Oil the only petrol station in this area



Figure 4.8: Food stall named Kedai Makan Din Jah

4.5 Forestry or Vegetation

Gua Musang's total tree cover in 2001 was 66% primary forest. 17% of Gua Musang's tree cover was intact forest as of 2016. A forest still in its natural state, with all its habitat-plant community components present, is referred to as an untouched forest. Rubber represents the most significant plantation type in Gua Musang, with 96.4kha and 12% of the total land area. The primary occupation for the first generation of inhabitants of Gua Musang for a living is rubber tapping and other types of plantations.



Figure 4.9: Rubber plantation at study area



Figure 4.10: Oil Plantation at study area



Figure 4.11: Banana farm at study area

4.6 Geomorphology

Analysis of the physical attributes of the earth's surface and their link to its geological structures is known as geomorphology. In terms of geology, flood plains, drainage patterns, and watersheds, which are created by the passage of rainwater, geomorphology shows how landforms change through time. It also includes topographic analyses and features due to the diverse landforms and the physical,

chemical, and biological processes that affect the surface or the landscape. The undulating hills present in the study area's eastern and western portions are included in the area's geomorphology. Dendritic and parallel drainage patterns, are the two main varieties seen in the research area.

4.6.1 Geomorphologic Classification

The overall topographic features of the study area, Kampung Star Baru, Gua Musang are presented in the elevation map (Figure 4.14). In the map, it is seen that the elevation of the study area ranges from 100 metres to 500 metres. Most of the study area is covered by elevation ranging from 120 to 200 metres. The study area covered one highest hills with an elevation of 320 metres and second high hill with elevation 220 metres. There are geomorphological unit based on the mean elevations known as slightly sloping plains, sloping hills, steep hills, and high steep hills. The table below (Table 4.1) shows the geomorphological unit with its mean elevation respectively.

Table 4.1: The geomorphological unit with its mean elevation (Source: Van Zuidam, 1985)

Elevation	Geomorphological unit
< 50 meter	Plains
50 meter - 100 meter	Slightly sloping plain
100 meter - 200 meter	Sloping hills
200 meter - 500 meter	Steep hills
500 meter - 1.500 meter	High steep hills
1.500 meter - 3.000 meter	Mountain
> 3.000 meter	High Mountain

Since the study area is covered by elevation ranging from 100 metres to 500 metres, this concludes that the study area is major covered by two geomorphological units: steep hill and sloping hill. Its landform for steep hills are hill while landform for sloping hill is low hills. A slope map was generated to study the steepness of the slope of the study area. The slope is the results of erosion that affects the landform of a specific area. As seen on the map, the study area is covered dominantly by sloping hills about 60%. According to further reading and study of the slope map generated by the contour lines, the landform of the study area is classified as youth. This is because the landform can be described as having no flood-plain or fast-flowing streams, and vertical erosion is compared to lateral erosion.



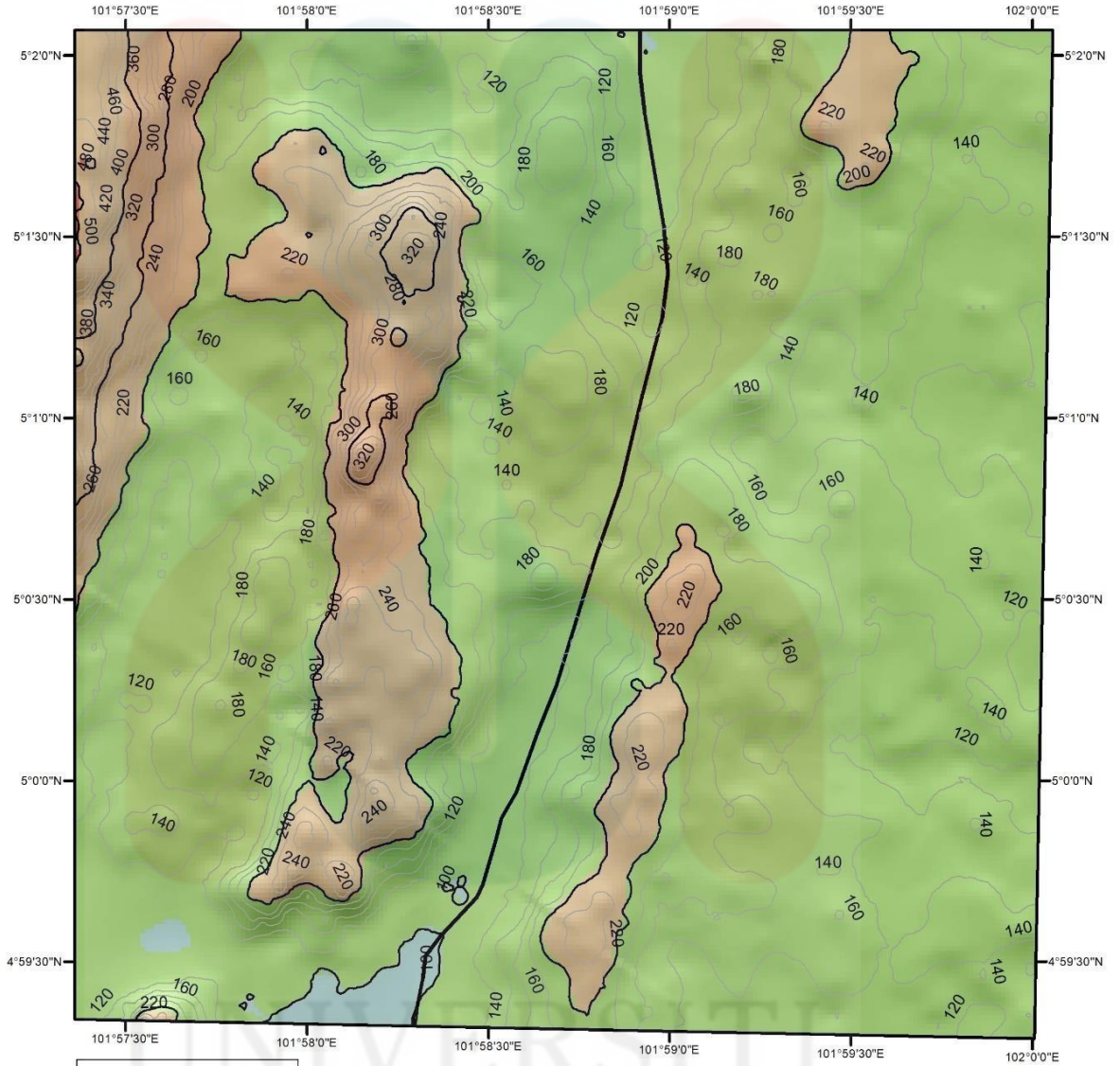
Figure 4.12: Geomorphology sight at locality N 04 59 43.26, E 101 58 35.23



Figure 4.13: Geomorphology sight at locality N 05 00 35.10, E 101 59 00.91

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ELEVATION MAP OF KAMPUNG STAR BARU, GUA MUSANG, KELANTAN



Legend

- BOX
- ROAD

CONTOUR ELEVATION

Type

- INTERVAL
- INDEX

HILLSHADE

Value

- High : 229
- Low : 0

DEM

<VALUE>

- 92.18080139 - 100
- 100.00000001 - 200
- 200.00000001 - 500
- 500.00000001 - 1,500



1 : 25 000

Figure 4.14: Map of elevation in the study area

4.7 Topography

Topography is the study of the land surface. It is the arrangement of natural and artificial features in the world. The mountains, rivers, valleys, or craters on the surface refer to the topography. The land surface of the study area, by physical characteristics, is hilly with the elevation ranging from 200 metres to 480 metres above sea level at the eastern and western parts of the site. The highest hill can be found in the east part of the study area with elevation of 500 metres. Also, the lowest land can be found at the southern of the study area with elevation 100 metres. The low hill area ranging from 120 metres to 180 metres above sea level, is located at the centre from north to south of the regional province. This low hill is a flat area containing villages, small grocery shops, mosques, petrol stations and food stalls. Based on the investigation of the contour pattern, the karst-covered forest's characteristics were determined. The contour line spread apart from the concentric circle denotes a mild slope, whereas the concentric circle denotes hills and karst terrain. The narrow spaces signify the steep hills. Where there is carbonate bedrock, karst landscapes develop. Because of a uniqueness of soil acidity, chemistry, and temperature, bedrock is exposed to a slow disintegration process over time. Sinkholes, caverns, and springs are just a few of the characteristics frequently formed due to this process.

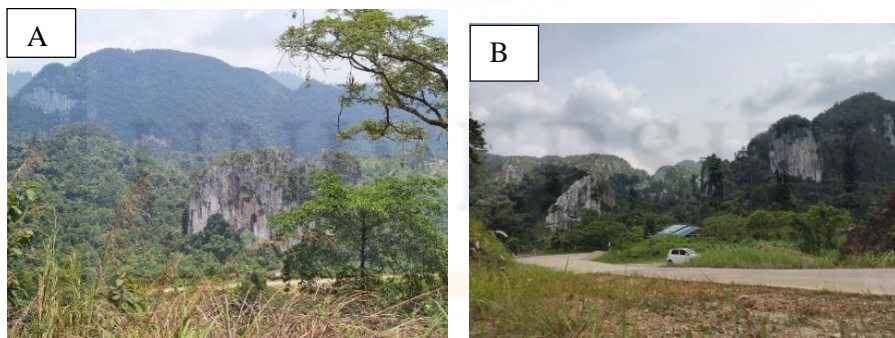


Figure 4.15: Limestone karst at study area with elevation 260 metres (A) and 320 metres (B)



Figure 4.16: Karst at the study area with elevation 240 metres

TOPOGRAPHY MAP OF KAMPUNG STAR BARU, GUA MUSANG, KELANTAN

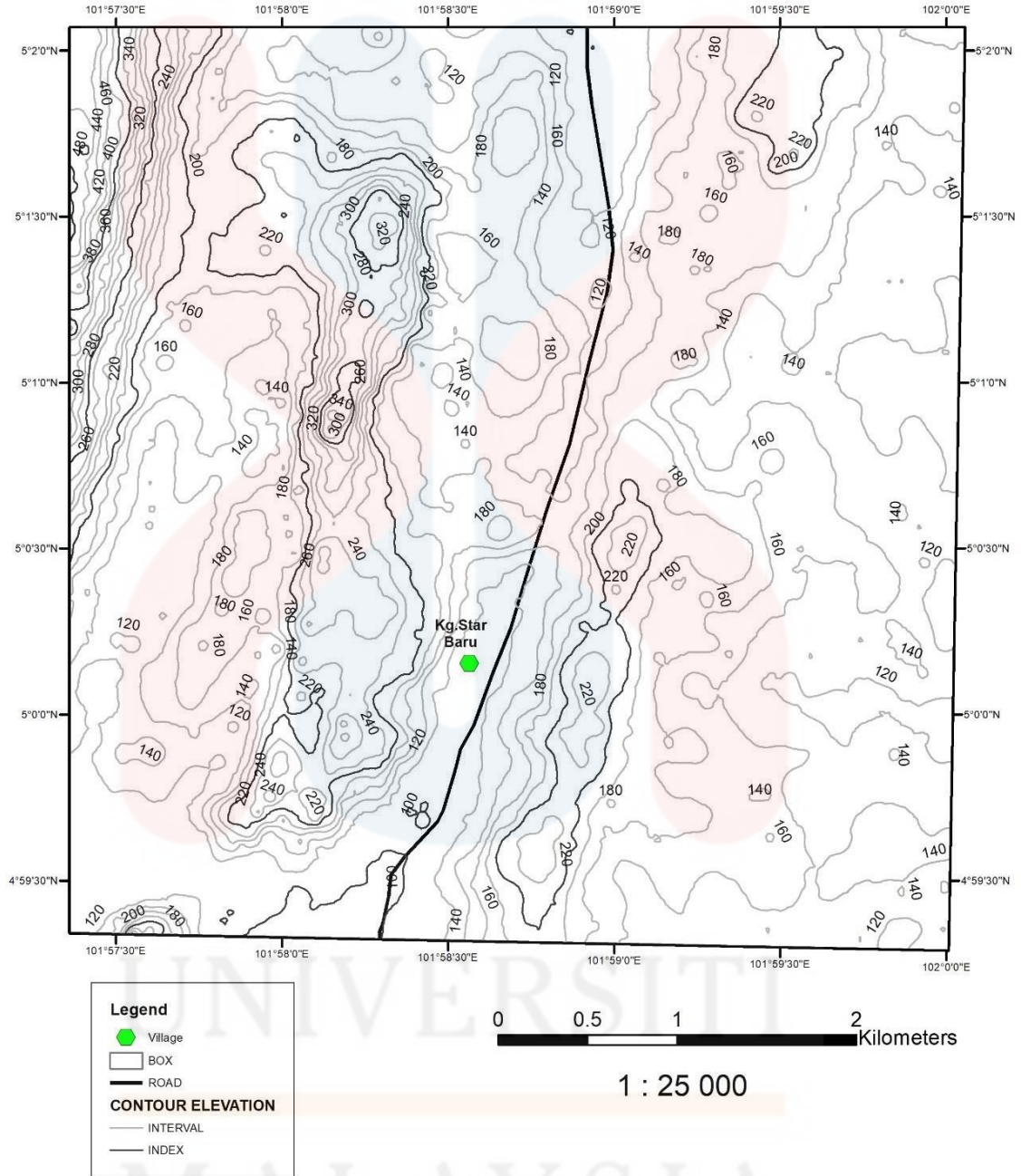


Figure 4.17: Topography map of the study area

4.8 Drainage Pattern

A drainage pattern is defined as concordant if it correlates to the topology and geology of the area. The topography and river slope significant impact the river's flow. The most typical drainage patterns are those that are concordant and can be divided into many different sorts.

A drainage basin of streams, rivers, and lakes typically produces drainage patterns. The features of different rock types, recharge areas, and the potential state of a place are primarily determined by drainage patterns. There are several drainage patterns such as dendritic, parallel, rectangular, trellis, contorted, and angular. The rock's hardness, the land's gradient, and the subsurface's geology can be interpreted by drainage pattern. When the runoff surfaces are increased, the earth materials have low erosion resistance, which can create drainage channels.

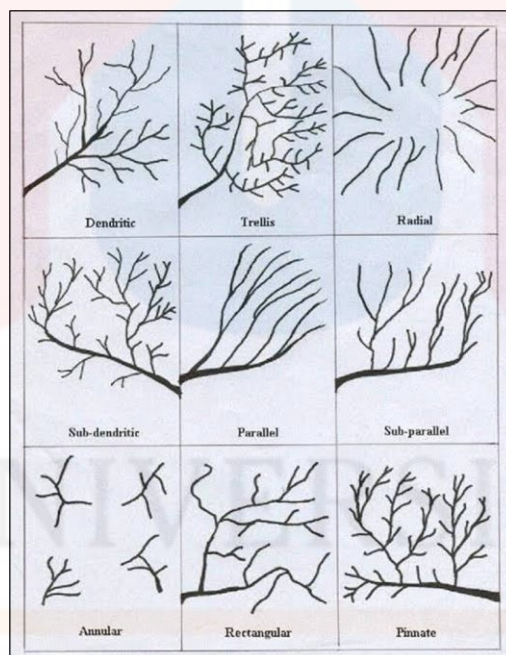


Figure 4.18: Type of drainage patterns

According to the drainage map below Figure 4.23, there is no primary river in the research region. Various streams in the study area are connected to other waterways. There are two types of drainage patterns in this research area, with the parallel pattern being the major and the dendritic being the minor ones. According to Figure 4.13, the green colour of the legend denotes a parallel drainage system. A parallel drainage system is a river pattern formed by steep slopes with some relief. Because of the steepness of the hills, the streams become rapid and straight, with few

tributaries flowing in the same direction. This system arises on surfaces with a consistent slope. Tributary channels tend to follow the slope of the surface in a parallel-like pattern. A parallel pattern can occasionally suggest the presence of a large fault that passes across a highly folded section of bedrock. Any type of transition between parallel and dendritic can occur. According to Figure 4.13, the dendritic pattern is shown by the red colour of the legend. The dendritic drainage pattern is the easiest to recognise since it resembles tree branches. There are several contributing streams in a dendritic system, which then grow where the river channel follows the slope of the ground. Dendritic systems arise in V-shaped valleys, requiring impermeable and low-porous rock types. Most of the study area's streams are episodic and periodic rivers. It is because a streams that only runs after a specific occurrence (or episode), such as significant rainfall or swelling runoff channels from other rivers, is appear along the oil palm plantation site in this study area. In contrast to perennial and periodic rivers, they typically lack a stable source, have no groundwater below them, and are virtually entirely dependent on climatic circumstances for their water.



Figure 4.19: Periodic river at the oil palm plantation



Figure 4.20: Episodic river found mostly at rubber plantation and boundary of oil palm plantation of study area



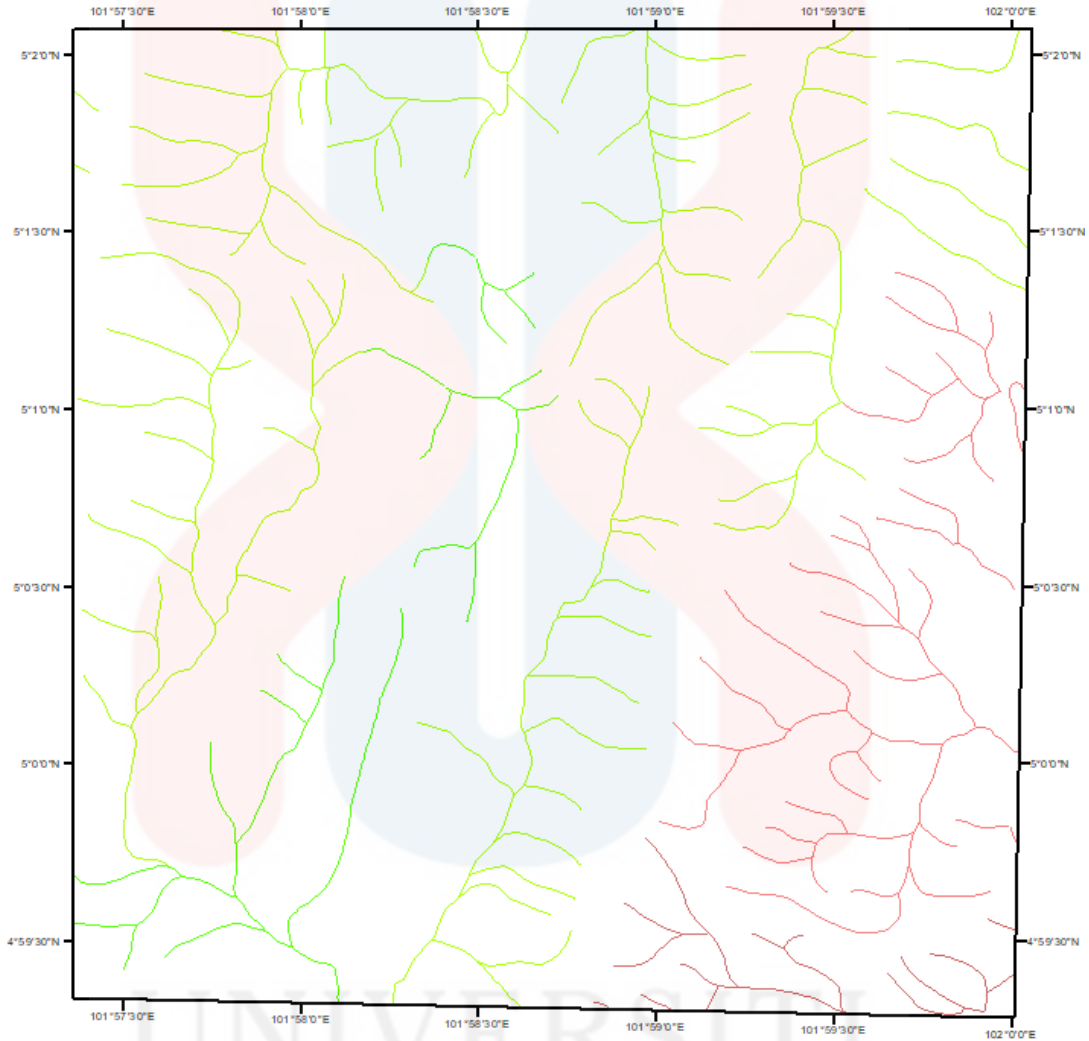
Figure 4.21: The streams at locality N 05 00 23.55, E 101 58 37.91

KELANTAN



Figure 4.22: Streams beside oil palm plantation at locality N 04 59 49.51, E 101 58 29.61

DRAINAGE MAP OF KAMPUNG STAR BARU, GUA MUSANG, KELANTAN



Legend

-  Stream
-  Parallel Pattern
-  Dendritic Pattern



1 : 25, 000

Figure 4.23: Map of drainage pattern in the study area consist of parallel and dendritic pattern

4.9 Weathering

Chemical weathering was the most prevalent weathering event in the studied region. It has had an impact on the outcrop's stability. The majority of the sandstone outcrops are almost completely transformed into topsoil and will shortly be totally transformed into soil. Because of the temperature and humidity in the research region, chemical weathering is quite active. Malaysia is noted for having a tropical climate with frequent rain and humidity on the earth's surface. Water from the stream and rain is the primary cause of chemical weathering in this location. Due to strong chemical weathering, a part of an outcrop that was thought to be interbedded mudstone and siltstone has turned into topsoil. The brown colour denotes topsoil. It is thought that the arrangement of the outcrops is not systematic, since there were originally shattered rocks that were more durable that were deposited on the surface in-situ by weathering process before this surface was buried by another layer of weathering products.

The majority of the outcrops were oxidised, resulting in reddish brown rocks. This is due to the presence of iron in mafic minerals, such as pyroxene and olivine. The amount of oxygen in the atmosphere chemically attacks those minerals causing rusting. This explains the presence of iron which reacted with oxygen producing insoluble iron oxide such as limonite and hematite.



Figure 4.24: Oxidised soil on the study area due to weathering.

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Figure 4.25: Weathered outcrop at locality N 05 00 22.15, E 101 58 45.5

4.10 Lithology

In the studied area, limestone predominates among other rocks, including interbedded mudstone and siltstone, shale, slate, and quartzite. Rock samples taken by hand are examined with the naked eye. A comparison between a hand-based observation and a microscope-based observation. Observing hand specimens helps provide a general understanding of the rocks. When observing rocks or any rocks with visible grains, observations of their colour, how they respond to acids and their point value are taken.

4.10.1 Limestone Unit

Most of the study area is covered with limestone. Locations of limestone outcrops and limestone boulders are seen in the figures (Figures 4.26, 4.32 & 4.37). Most of the limestone found in outcrop and boulder size is believed to have been transported from the nearest limestone hills. When a few drops of hydrochloric acid touched the hand specimen's surface, it gave a fizz reaction indicating the presence of calcite. Calcite is very reactive towards acid as it dissolves in contact with acid. The formations of crystals are visible to the naked eye.

One of the limestone outcrop is just at the east of study area at the house that surrounds with all limestone rock. This limestone outcrop forms a huge cavity forming a shallow hole inside it by solution with rain water of stream in the paleo-environment. These limestones are grey and have flow bands that appear in black. Azimuths for this outcrop are 02 NE and 174 SE.



Figure 4.26: Limestone outcrop at locality N 05 01 34.80, E 101 58 59.38

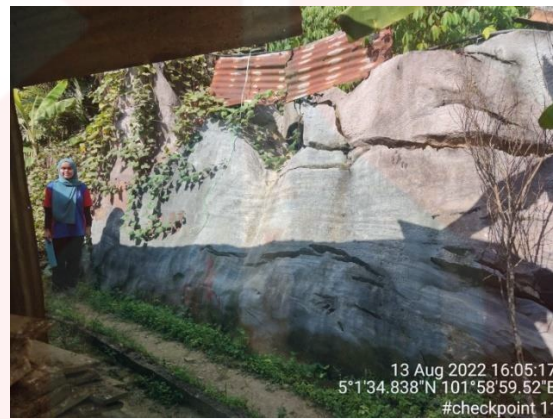


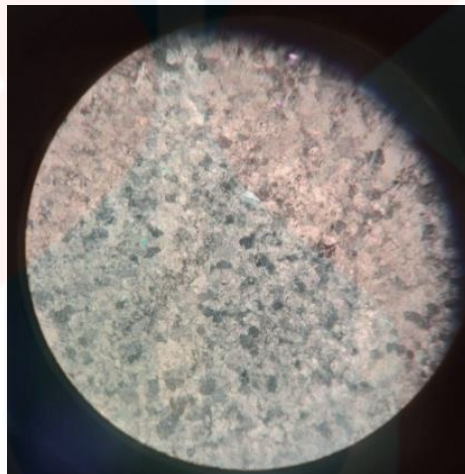
Figure 4.27: Limestone around the house



Figure 4.28: Sample collected at locality N 05 01 34.80, E101 58 59.38

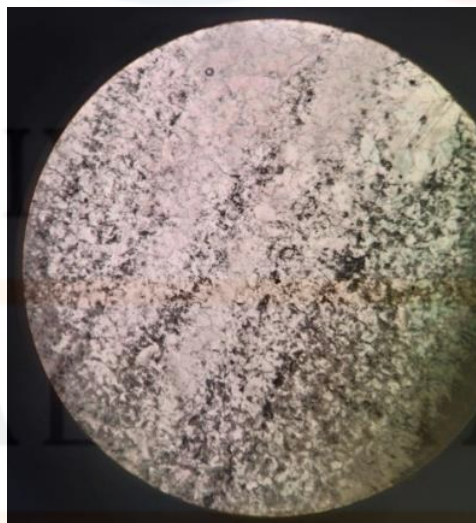


Figure 4.29: Hand specimen of Limestone



Scale: 2mm

Figure 4.30: Thin section of limestone in 10x Cross Polarized XPL



Scale: 2mm

Figure 4.31: Thin section of limestone 10x Plane Polarized PPL

Table 4.2: Mineral composition of Limestone

Sedimentary Rock: Limestone		
<p>Non-Foliation structure (granulose), crystal plastic texture (nematoblastic), with mineral size $<1/256 - 1/8$ mm, good sorting</p> <p>The mineral grain size is more compact and small</p> <p>The granular texture contains crystalline silica and a composition of Calcium carbonate (CaCO_3)</p>		
Description of mineralogy		
Composition of mineral	Amount (%)	Description of optical mineralogy (Magnification 10X)
<ul style="list-style-type: none"> • Calcite 	99	<p>Absorption colourless in PPL, low relief, no pleochroism, Anhedral shape crystal, no cleavage,</p> <p>Interference colour Soft red – green in XPL, dark symmetry, no twinning (polysynthetic)</p>
<ul style="list-style-type: none"> • Opaque mineral 	1	<p>Absorption colour Black in PPL, low relief, no pleochroism, Euhedral - Anhedral Crystal shape</p> <p>Interference colour Black in XPL, no twinning</p>

Next, one of the limestone outcrops found just at the west study area at the hill karst surrounding bushes at the bottom. Azimuth at this outcrop is 202 SW, 25 NE. These limestones are mix colour between Greyish and white and crystalline. These limestones are slightly metamorphosed and formed by the recrystallisation of limestone undergoing metamorphism and will form marble later. It is because some minerals are seen like grand blast texture but in minor quantity.



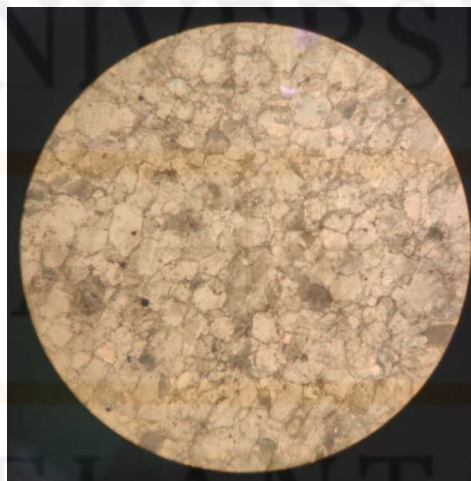
Figure 4.32: Limestone outcrop at locality N 05 00 44.08, E 101 58 49.40



Figure 4.33: Outcrop where sample of limestone collected

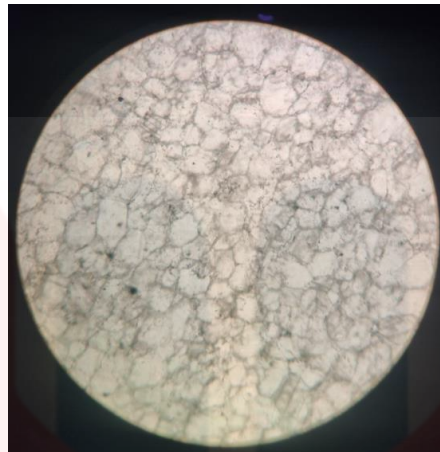


Figure 4.34: Hand specimen limestone



Scale: 2 mm

Figure 4.35: Thin section of limestone in 10x Cross Polarized XPL



Scale: 2mm

Figure 4.36: Thin section of limestone 10x Plane Polarized PPL

Table 4.3: Mineral composition of Limestone

Sedimentary Rock: Limestone		
<p>Non-Foliation structure (granulose), crystalloblastic texture (nematoblastic), with mineral size <math><1/256 - 1/4\text{ mm}</math>, good sorting</p> <p>The mineral grain size in this limestone seems larger than the previous limestone (Figure 4.30)</p> <p>The granular texture contains crystalline silica and a composition of Calcium carbonate (CaCO_3)</p>		
Description of mineralogy		
Composition of mineral	Amount (%)	Description of optical mineralogy (Magnification10X)
<ul style="list-style-type: none"> • Calcite 	99	<p>Absorption colourless in PPL, low relief, no pleochroism, Anhedral shape crystal, no cleavage,</p> <p>Interference colour Soft red – green in XPL, dark symmetry, no twinning (polysynthetic)</p>
<ul style="list-style-type: none"> • Opaque mineral 	1	<p>Absorption colour Black in PPL, low relief, no pleochroism,</p> <p>Euhedral - Anhedral Crystal shape</p> <p>Inteference colour Black in XPL, no twinning</p>

Furthermore, the limestone outcrop and boulder found are just at the South-West of the study area along the streams beside the oil palm plantation. Azimuth at this outcrop is 293 SW, 111 NE. Sample for hand specimens is collected without microscope observation. Their colour is mixed with greyish white. The most extended outcrop found at this stream is 13.4meter length.



Figure 4.37: The outcrop of limestone along streams at locality N 04 59 52.56, E101 58 30.56 and handspecimen collected

4.10.2 Meta-Sedimentary Unit

i. Quartzite

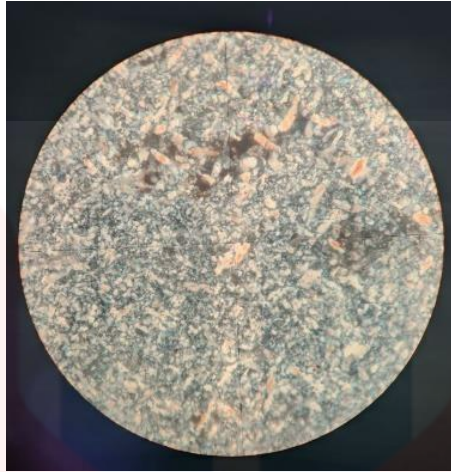
The South-East of the study area, there is composed of meta-sedimentary rocks. In this locality, quartzite is found on hills surrounding oil palm plantations with an elevation of 110 m. This outcrop has 4.3 meters in length, and 2.1 meters in height. The azimuth of this outcrop is 30 NE, 223 SW.



Figure 4.38: Quartzite Outcrop at locality N 04 59 31.57, E 101 58 24.98

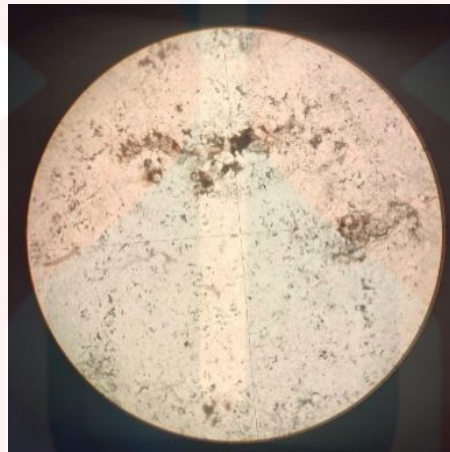


Figure 4.39: Hand specimen Quartzite



Scale: 2mm

Figure 4.40: Thin section of Quartzite in 10x Cross Polarized XPL



Scale: 2mm

Figure 4.41: Thin section of Quartzite in 10x Cross Polarized PPL

Table 4.4: Mineral composition of quartzite

<p>Meta-Sedimentary Rock: Quartzite</p> <p>Hard and originally Pure Quartz Sandstone</p> <p>Non-foliation (Granulose), crystalloblastic texture (granoblastic), size mineral <math><1/256 - 1/4\text{mm}</math>, not so good sorting.</p> <p>Quartz mineral as a major mineral</p>		
<p>Description of mineralogy</p>		
<p>Composition of mineral</p>	<p>Amount (%)</p>	<p>Description of optical mineralogy (Magnification 10X)</p>
<ul style="list-style-type: none"> Quartz 	<p>99</p>	<p>Absorption colourless in PPL, Low relief, no pleochroism, Anhedral shape crystal, no hemisphere</p>

		Interference colour Grey-whitish in XPL, no twinning
<ul style="list-style-type: none"> • Opaque mineral 	1	<p>Absorption colour Black in PPL, low relief, no pleochroism, Euhedral - Anhedral Crystal shape</p> <p>The interference colour is Black in XPL, with no twinning</p>

ii. Shale

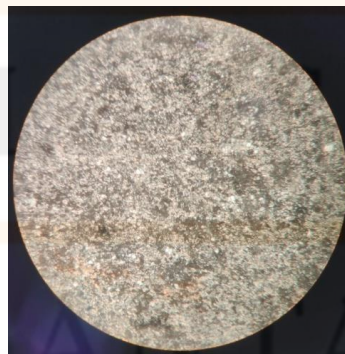
This shale is always found in the area of the east of study area. It is covered with soil on top, and also found the outcrops of shale that is stand alone. Azimuth outcrops are 127 SE and 304 NW. Elevation of hills 194 meters nearest to the oil palm plantation.



Figure 4.42: Shale at locality N 05 00 12.67, E 101 59 02.60

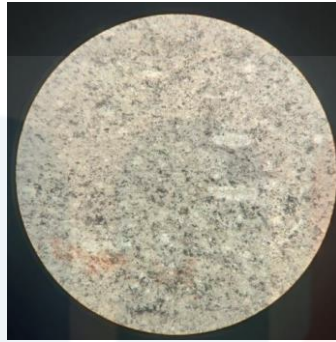


Figure 4.43: Hand Specimen Shale



Scale: 2mm

Figure 4.44: Thin section of Shale in 10x Cross Polarized XPL



Scale: 2mm

Figure 4.45: Thin section of S in 10x Cross Polarized PPL

Table 4.5: Mineral Composition of Shale

<p>Meta-Sedimentary Rock: Shale</p> <p>Fine-grained mixed of clay minerals</p> <p>Massive structure, weak foliation, texture mineral $<1/256 - 1/64$ mm, good sorting,</p> <p>Have parallel mineral arrangement that not occurs structure foliation</p>		
<p>Description of mineralogy</p>		
Composition of mineral	Amount (%)	Description of optical mineralogy (Magnification 10X)
<ul style="list-style-type: none"> Clay Silica 	82	<p>Absorption colourless to brownish in PPL,</p> <p>Interference colour Dark Grey Blackish</p> <p>Micron size silicate material</p>

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• Clay Oxide	15	Absorption colour Brownish under PPL, Interference colour Brown under XPL, Micron size in mixing silicate and oxide
• Quartz	2	Absorption colourless in PPL, Lowrelief, no pleochrisme, Anhedral shape crystal, no hemisphere Inteference colour Grey-whitish in XPL, no twinning
• Opaque mineral	1	Absorption colour Black in PPL, low relief, no pleochisme, Euhedral - Anhedral Crystal shape Inteference colour Black in XPL, no twinning

iii. Meta-Mudrock (Slate)

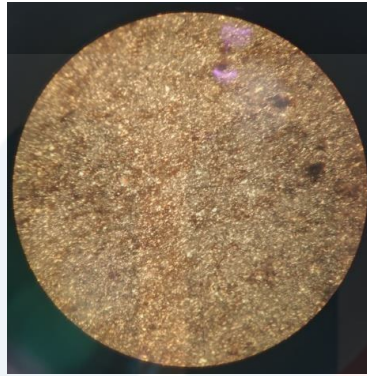
This meta-mudrock is found at the entrance of the hill. This outcrop has 50 meter length, and 3 meter height with folding of layer slate and interbedded mudstone with siltstone. The azimuth of this outcrop is 106 E, 283 W. This rock contains dominantly by mica mineral that is shiny as “speckled extinction” in cross polarized light in microscopic observation and have minor biotite.



Figure 4.46: Locality of N 05 00 22.15, E 101 58 45.5

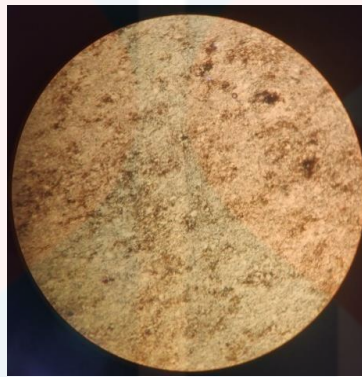


Figure 4.47: Hand specimen of slate



Scale:2mm

Figure 4.48: Thin section of Slate in 10x Cross Polarized XPL



Scale: 2mm

Figure 4.49: Thin section of Slate in 10x Cross Polarized PPL

Table 4.6: Mineral composition of Slate

Meta-Sedimentary Rock: Slate		
<p>Homogenous metamorphic rock derived from shale through low-grade metamorphism</p> <p>Massive structure, weak foliation, mineral size texture $<1/256 - 1/32$ mm, good sorting parallel mineral arrangement that not yet begin foliation and solid substances</p>		
Description of mineralogy		
Composition of mineral	Amount (%)	Description of optical mineralogy (Magnification 10X)
<ul style="list-style-type: none"> Clay Silica 	90	<p>Absorption colourless to brownish in PPL,</p> <p>Interference colour Dark Grey Blackish</p> <p>Micron size silicate material</p>

• Quartz	4	Absorption colourless in PPL, Lowrelief, no pleochrisme, Anhedral shape crystal, no hemisphere Inteference colour Grey-whitish in XPL, no twinning
• Opaque mineral	1	Absorption colour Black in PPL, low relief, no pleochisme, Euhedral - Anhedral Crystal shape Inteference colour Black in XPL, no twinning
• Mica	3	Absorption colour No colour in PPL, , Inteference colour White in XPL,
• Biotite	2	Absorption colour Brown in PPL, low relief, moderate pleochisme, Monoclinic Crystal shape Inteference colour Brown in XPL, no twinning

iv. Meta-mudrock (Siltstone)

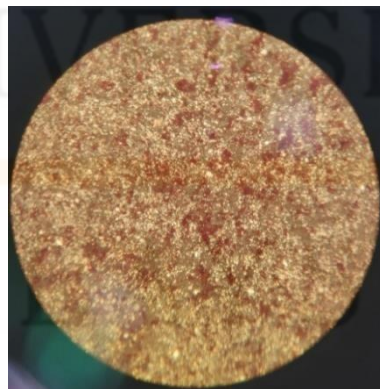
This meta-mudrock is also found at the entrance to the hill. This is the same outcrop that has interbedded rock. This siltstone was interbedded with mudstone. Azimuth for this outcrop is 106 E, 283 W.



Figure 4.50: Locality outcrop of N 05 00 22.15, E 101 58 45.5



Figure 4.51: Hand specimen Siltstone



Scale: 2mm

Figure 4.52: Thin section of Siltstone in 10x Cross Polarized XPL



Scale: 2mm

Figure 4.53: Thin section of Siltstone in 10x Cross Polarized PPL

Table 4.7 Mineral Composition of Siltstone

Meta-Sedimentary Rock: Siltstone		
Form of mudrock which can be distinguished from shale and it is interbedded with mudstone that are distinguished from shale too		
Massive structure, weak foliation, texture mineral size between $<1/256 - 1/64$ mm, good sorting, parallel mineral arrangement not yet formed foliation and solid		
Description of mineralogy		
Composition of mineral	Amount (%)	Description of optical mineralogy (Magnification 10X)
• Clay Oxide	97	Absorption colour Brownish under PPL, Interference colour Brown under XPL, Micron size in mixing silicate and oxide
• Quartz	2	Absorption colourless in PPL, Low relief, no pleochrisme, Anhedral shape crystal, no hemisphere Interference colour Grey-whitish in XPL, no twinning
• Opaque mineral	1	Absorption colour Black in PPL, low relief, no pleochrisme, Euhedral - Anhedral Crystal shape Interference colour Black in XPL, no twinning

4.11 Geological Map of Study Area

This section was giving an updated geological map of Kampung Star Baru, Gua Musang, Kelantan with scale 1: 25 000. It consists of scale, legend, cross section, lithostratigraphy column and other explanations.



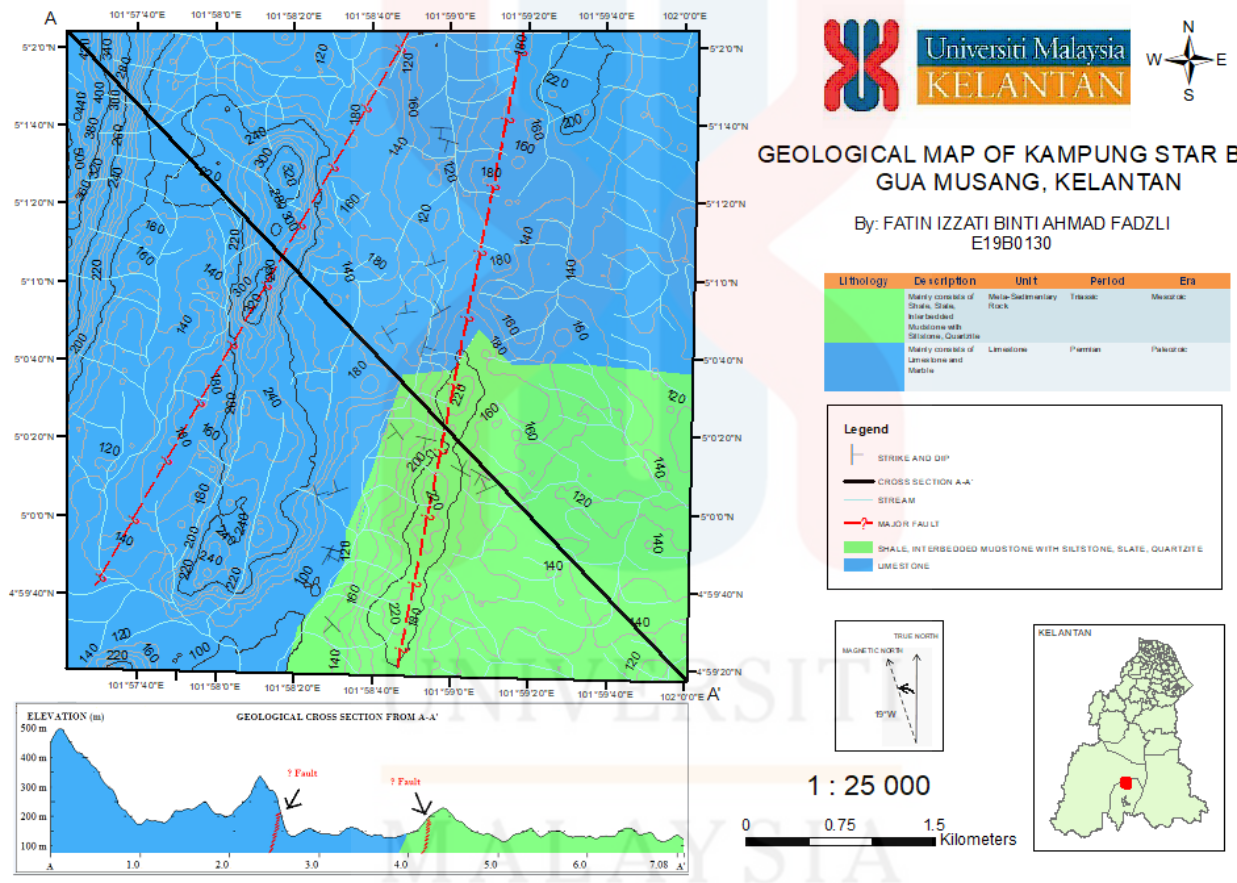


Figure 4.54: Geological map of the study area

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4.12 Lithostratigraphy

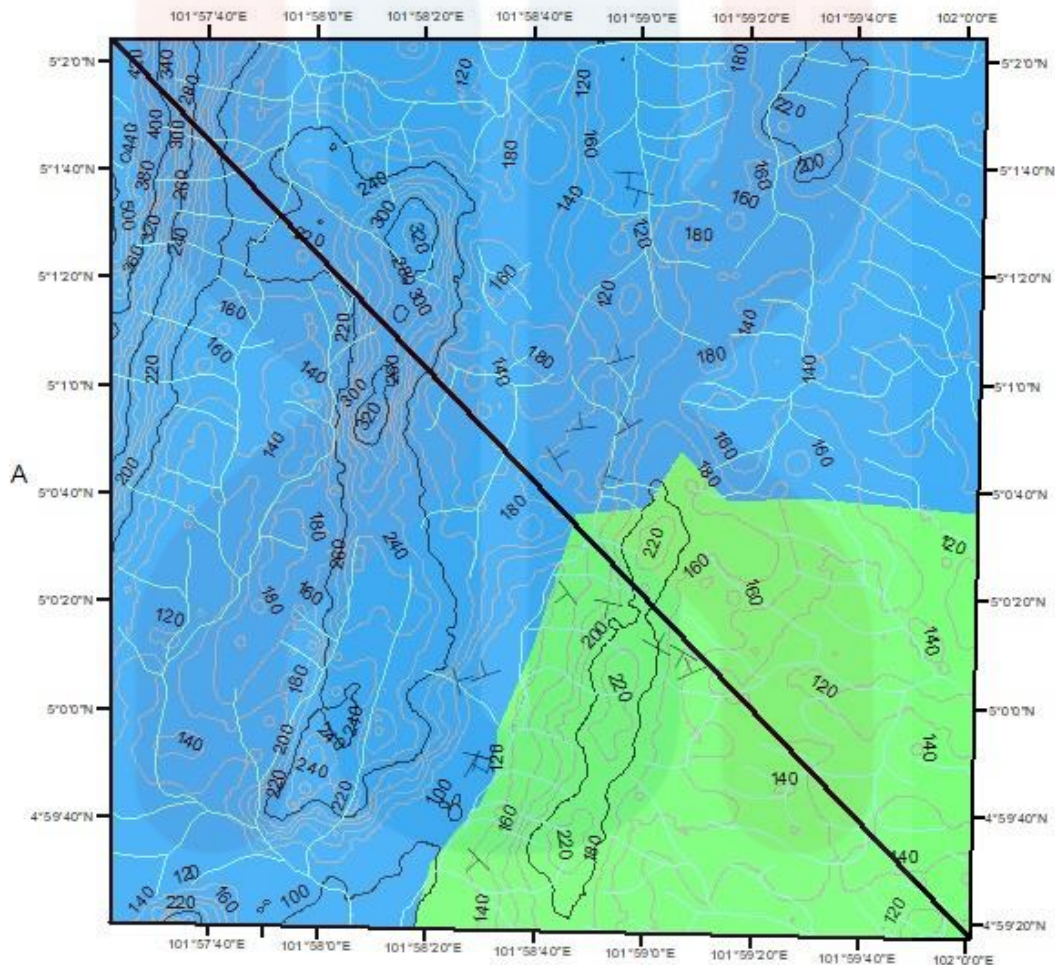
The field of geology known as lithostratigraphy is concerned with creating strata or rock layers that the physical characteristics of the different rock types may recognise. It is possible to ascertain the relative placements of rock units by considering their geometric and physical relationships, which show which beds are older and which are younger. The units are divided into lithostratigraphic terms based on the hierarchical structure of members, formations, and groups that describe rocks.

Lithostratigraphy focuses on analysing the rocks in the studied area, relating them to their ages to create a stratigraphic column. The primary types of rocks in the study region are limestones, although there are also additional types of meta-sedimentary rocks. Rock samples taken by hand and examined with the naked eye are called hand specimens. A comparison between a hand-based observation and a microscope-based observation. Observing hand specimens helps provide a general understanding of the rocks.

Based on the objectives, a geological map of the research area is created at a scale of 1:25 000. It comprises the study region's lithology, stratigraphic column, and structural geology limits. The area study's stratigraphic column for lithology was carried out using the formation the previous researcher had completed.



LITHOLOGY MAP OF KAMPUNG STAR BARU, GUA MUSANG, KELANTAN



1 : 25 000



Figure 4.55: Lithology map of the study area

4.12.1 Stratigraphic position

Table 4.8: The table shows the lithostratigraphic column of the study area. The study area encompasses two types of lithologies that are limestone and meta-sedimentary unit

Lithology	Description	Unit	Period	Era
	Mainly consists of Shale, Slate, Interbedded Mudstone with Siltstone, Quartzite	Meta-Sedimentary Rock	Triassic	Mesozoic
	Mainly consists of Limestone and Marble	Limestone	Permian	Paleozoic

4.13 Structural geology

Structural geology studies of the distribution of rock units, surface areas, and inner structures in three dimensions in connection to their deformation histories, past geological conditions, and events that have induced deformation. All of these can be dated to determine the formation date of the structural features. That occurs due to stress and strain, depending on its measures. The measurements often incorporate lineament analysis, folding analysis, faulting analysis, and joint analysis.

4.13.1 Lineament analysis

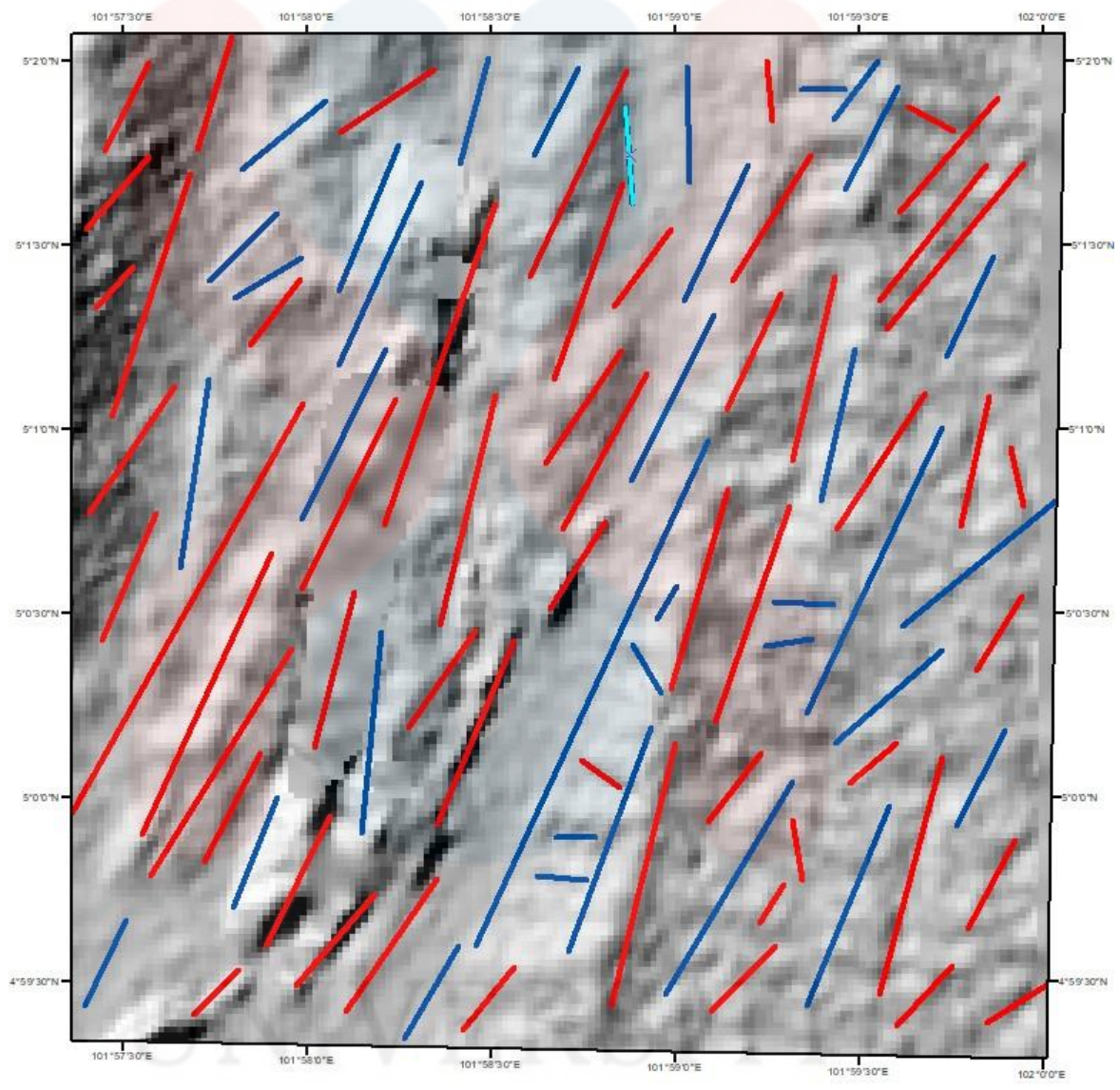
A lineament is any linear feature that may be seen on a topographic map and provides details about the underlying geological structure. Lineament, which is often extracted from enhanced image data visual analysis, is one of the most crucial features for identifying structural weaknesses like faults or subsurface elements. The structural lineament typically manifests as a fault-aligned valley, a fault plane, fold-aligned hills, a straight shoreline, or a combination of these features. There are two types of lineament analysis. First one is known as the positive lineament and secondly is known as the negative lineament. These lineaments are represented in a stereographic projection where there are shown major forces. Using aerial or satellite

images, lines on geological or topographic maps can be located.

Positive lineaments are determined with the help of three dimensional map of the study area. This is in order to help in the process of observations and identification of the fault line on the ridges. The positive lineaments identified are marked with red line as seen on map.

Negative lineaments are determined with the help of drainage map. The negative lineaments are measured according to the line of the drainage available in the study area. The longest line indicates the tensions in the river.

LINEAMENT MAP OF KAMPUNG STAR BARU, GUA MUSANG, KELANTAN



Legend

- Negative lineament
- Positive lineament

1 : 25 000



Figure:4.56: Lineament map of study area

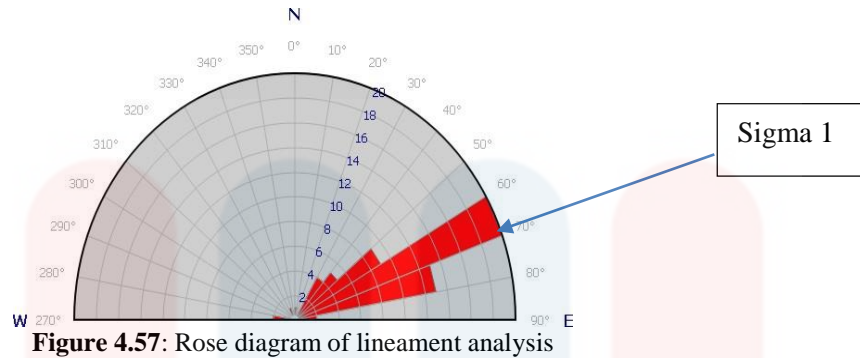


Figure 4.57: Rose diagram of lineament analysis

The rose diagram in the image above (Figure 4.55) shows an investigation of lineaments in the research area. As can be seen, the most significant force which is compressional stress is coming from the NE direction, and the most orientation is on sigma 1, where the distribution of directional occurred.

The lineament analysis in the studied region demonstrates that the principal force is primarily coming from the northeast direction. According to the observation, the rock is subjected to a high pressure that causes it to fracture, connect, or form a fault when the highest force is applied to it.

4.13.2 Fault

In the Earth's crust, a fault is a single fracture or a zone of rupture that has developed parallel to the fracture or area. Due to plate tectonic processes at work on the Earth's surface, which cause the fault line to coincide with the ground's surface along a fault plane, this occurs. The three primary types of defects that various stress situations may cause are strike-slip faults, and thrust faults. A fault may form when various forces pull or push on the crust, causing the rocks to move past or bump up against one another.

Some examples of fault can be found in the study area:

1) Locality: N 05 01 06.36, E 101 58 55.25

Azimuth: 196 S, 19 N

Length: 5.79 meter / Height: 2.61 meter



Figure 4.58: Fault at locality: N 05 01 06.36, E 101 58 55.25

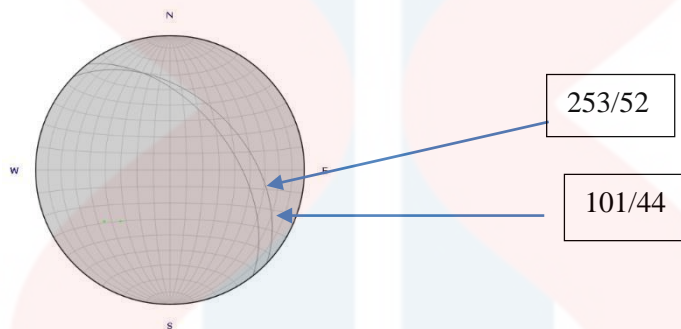


Figure 4.59: Stereonet of fault

From the stereographic projection in Figure 4.59, there was 2 sigma display in the stereonet that show the directions of faults occur.

2) Locality: N 05 00 22.15, E 101 58 45.5

Azimuth: 106 E, 283 W

Length: 50 meter / Height: 3 meter



Figure 4.60: Fault 1 & Fault 2

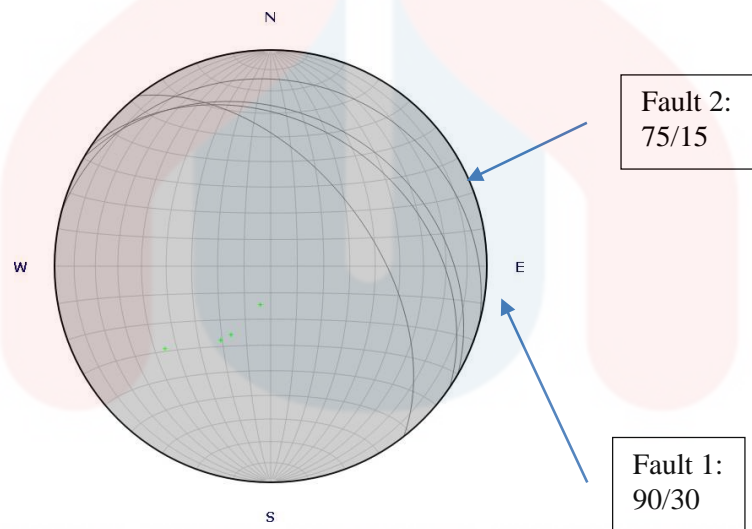


Figure 4.61: Stereonet of fault

There are two fault found in this outcrop like Figure 4.58. This fracture fault can be seen on interbedded mudstone and siltstone rock. This fracture rock can be result in absorption of rainwater through the pore spaces and fractures of rock that will increase the level of groundwater but in minor quantity because of their rock composition.

4.13.3 Folding

Outcrop that have folding and measurement taken. A fold in structural geology is a collection of previously flat surfaces, such as sedimentary layers, that are permanently folded or curled. The scale of rock folds ranges from microscopic crinkles to folds the size of mountains. They can be found in periodic sets or as a single solitary fold (known as fold trains). Folds created by sedimentary deposition are known as synsedimentary folds.

Locality: N 05 00 22.15, E 101 58 45.5

Azimuth: 106 E, 283 W

Length: 50 meter / Height: 3 meter



Figure 4.62: “Anticline” fold at locality N 05 00 22.15, E 101 58 45.5

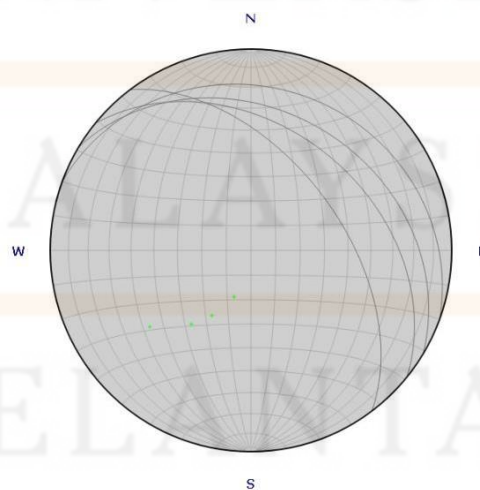


Figure 4.63: Stereonet of Folding

Reading data: 266/31, 238/53, 297/20, 228/39

Based on data strike and dip, the direction shows that this folding are from rock that interbedded mudstone with siltstone. The folding features is anticline that is an arch-like shape. Its develop above thrust faults during tectonic process which is bend bedding.



4.13.4 Joint

For the structural and stratigraphic study, dip and strike readings are straightforward but crucial geological measures. These data are taken for joint and bedding structures at the outcrop. In geology, a joint is a brittle-fracture surface in rocks with little to no displacement.

1) Locality: N 05 00 05.61, E 101 58 26.91

Azimuth: 215 SW, 346 E

Length: 3.89 meter / height: 3.30 meter



Figure 4.64: Joint at locality outcrop in rubber plantation

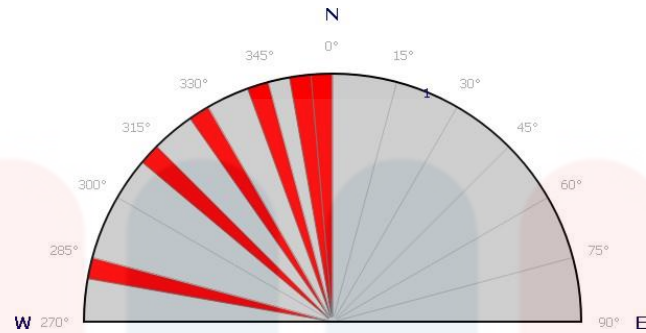


Figure 4.65: Rose diagram for joint

In this data of rose diagram, the orientation show reading sets of joints points towards the West direction. The reading got overall 5 degree of class interval.

2) Locality: N 05 00 08.00, E 101 58 29.87

Azimuth: 205 SW, 32 NE

Length: 13.1 meter / Height: 0.5 meter



Figure 4.66: Outcrop at plantation in locality N 05 00 08.00, E 101 58 29.87

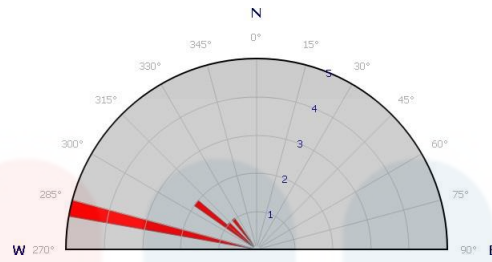


Figure 4.67: Rose diagram for joint

The reading of rose diagram shows the orientation of joints point to West direction. The number of data collected shown as appeared diagram. The reading got overall 5 degree of class interval

4.13.5 Bedding

The layering observed in sedimentary rocks and occasionally in metamorphic rock is called bedding, also known as stratification.

1) Locality: N 05 00 23.55, E 101 58 37.91

Azimuth: 119 SE, 303 NW

Bedding at bottom



Figure 4.68: Bedding plane at nearest karst zone

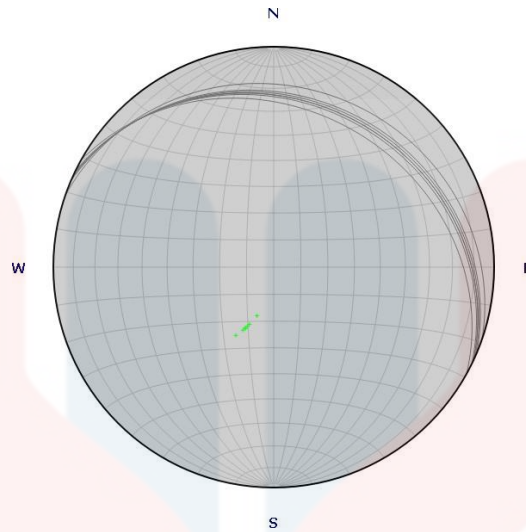


Figure 4.69: Stereonet for bedding

Strike/Dip :215/29, 246/25, 243/20/ 244/21, 219/20, 238/25

The stress of rock and trending of rock is the deformation process. Based on the stereonet and rose diagram result of joint and bedding, it is shown that the force, trending direction for the area over which it is distributed, and deformed rocks are from the West direction. The deformation of rocks comprehends the field stress detected in the strain and geometries that may be connected to some significant geologic event that occurred in the past.

4.14 Historical Geology

The Gua Musang Formation is one of many formations that originate from the Mesozoic era. Because Malaysian Mesozoic rock formations were frequently grouped in different geographic and paleoenvironmental settings, a correlation between the various locations was constructed based on fossil discoveries.

The Gua Musang Formation is part of Peninsular Malaysia's middle belt. The Gua Musang Formation in Thailand and the Jurong Formation in Singapore are two examples of the continuous strip of Mesozoic rock formations that stretch north to south and cross international borders.

Yin (1965) and Mohd Shafeea Leman defined the Middle Permian to Upper Triassic Gua Musang Formation south of Kelantan (1993 and 2004). The crystalline limestone deposit, estimated to be 650 metres thick, is broken up into thin beds by thin strata of chert nodules, shale, tuff, and subordinate sandstone and volcanics.

Calcitic limestone is a light grey material that is hard, non-porous, brittle, and splintery. Trace quantities of pyroclastic, carbonaceous, and argillaceous impurities are present in the grey to black varieties of the occasionally recrystallised limestone.

There are still visible remnants of bedding, cross-lamination, and oolites. The granite bulk's flanks contain lenses of limestone that continue northward to Gua Musang, generating ridges bounded by cliffs and rows of isolated hills resembling towers. Some limestones have been dated to the Permian (Scythian) era by poorly preserved fusulinids, such as *Verbeekina* from Gua Musang. However, nearby limestone has also been found to date to the Lower Triassic age. Upper Carboniferous (Viséan) fossils have been discovered in the massive limestone that forms the hills of Gua Bama and Gua Sae, west-northwest of Kuala Lipis.

The angular quartz is found in fine- to medium-grained argillaceous sandstone in a matrix of limonitic or carbonaceous clay (Foo, 1983). Among the fossils discovered in the shale facies are Permian productoid and spiriferous brachiopods, *Leptodus* and *Uncinuellina*, lophophyllid corals, fenestellid bryozoa, and crinoid ossicles mixed in with Triassic bivalves. The list of fossils provided by Mohd Shafeea Leman is comprehensive (2004, p. 44-45). The volcanic materials, which range in composition from rhyolitic to andesitic, include tuff, lava flows, and agglomerate. The bulk is crystal lithic tuff, fine to medium-grained, with sporadic interlamination of dark grey tuffaceous shale and black carbonaceous shale.

CHAPTER 5

ELECTRICAL RESISTIVITY IMAGING (ERI)

5.1 Introduction

This chapter primarily discusses the outcomes of utilising the resistivity method to determine groundwater potential in hard rock (ERI). Equipment like the ABEM Terrameter LS Toolbox used to obtain data from ERI mapping and software RES2DInvare used to process each survey line. Four Pole-Dipole survey lines with a 200-metre spread and 41 electrodes spaced 5 metres apart were used in this study.

In order to ascertain the underlying conditions by measuring the ground surface, the Electrical Resistivity Method (ERI), which has been around for a while, is now frequently utilised. According to the apparent resistivity value of the ground surface materials, a 2D electrical resistivity imaging (ERI) pseudo section result is utilised to categorise the probable groundwater in the analysis area. Each line is interpreted following its geomorphology, lithology, and hydrogeologic or subsurface circumstances.

5.2 Map of study area indicates the survey line of groundwater exploration

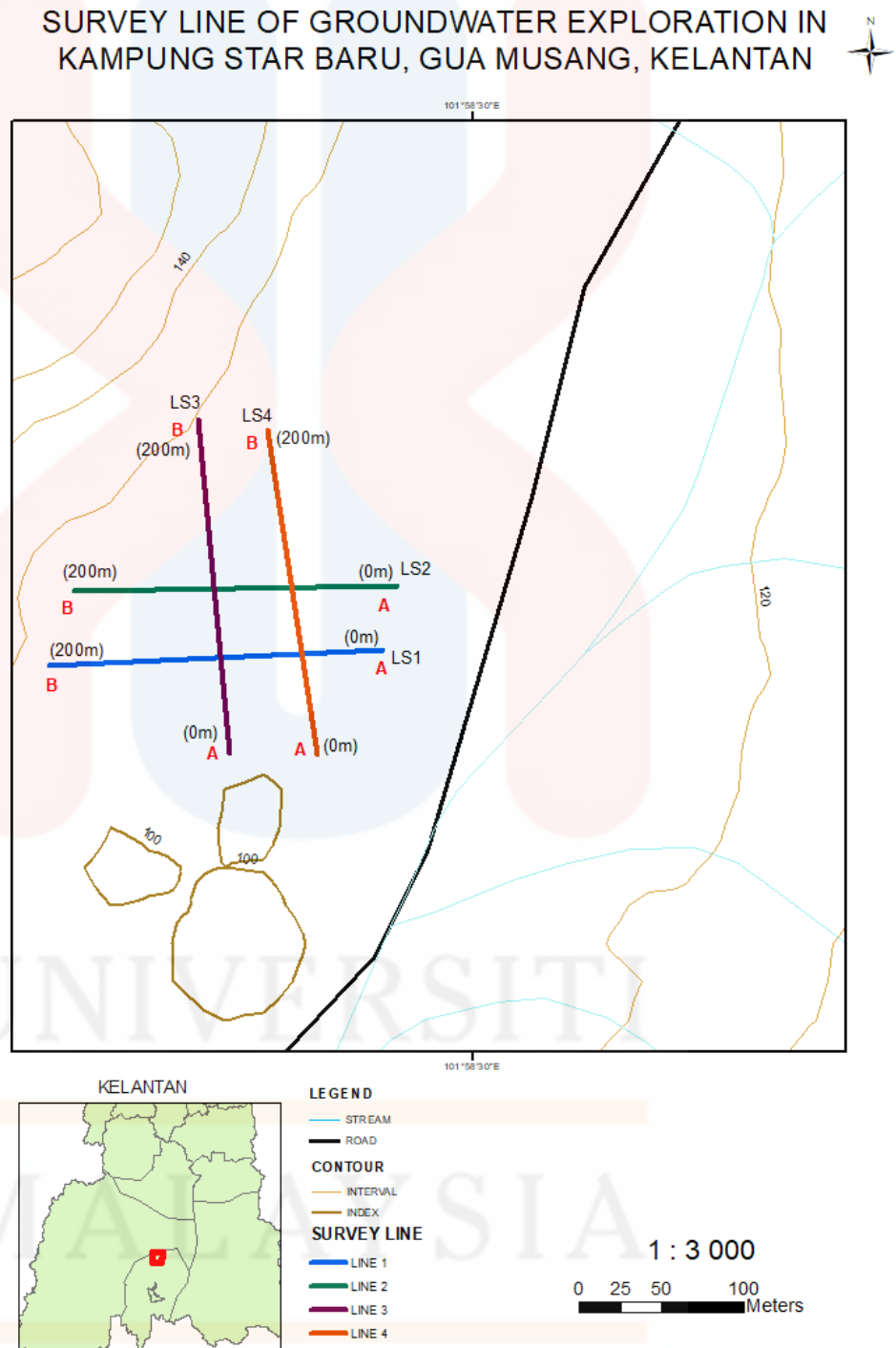


Figure 5.1: Map of specification survey line of groundwater exploration

5.3 Location of Resistivity Survey

Four survey line were conducted in part of Kampung Star Baru's area, located at an oil palm plantation beside the streams of the South-West part in the study area. The terrain formed as undulating at this site. The specification survey covers determining the groundwater in limestone in areas. The figure (Figure 5.1) above shows the location of the survey lines and the direction that had been conducted. Each line is parallel between line 1 and line 2 and also parallel between line 3 and 4.

The resistivity data obtained from ABEM Terrameter LS is processed using RES2DINV software. The interpretation of all survey lines is based on the previous literature review of the resistivity scale that other researchers had done. By contrasting earth material resistivity values with induced polarisation (IP) values reported by earlier researchers, it is possible to determine the resistivity values of subsurface conditions for earth materials. A comparison between resistivity measurements and IP values is conducted to determine the potential groundwater in limestone rock.

5.4 Result

The interpretation is made based on the values of resistivity and chargeability that shown in the pseudo section

5.4.1 Line Survey 1

Line Survey 1 has an electrode spacing of 5 metres and a length of 200 metres. The configuration array is a Pole-Dipole type. The table below displays the location of electrodes first, centre, and last, found at the electrode 1, electrode 21, and electrode 41, respectively. NE-SW is the direction of the line survey.

Table 5.1: Coordinate location for line survey 1

Electrode Number	Coordinate	Elevation (m)
1	N 04 59 47.9 E101 58 33.5	109.65
21 (Centre)	N 04 59 47.6 E 101 58 30.4	112.12
41	N 04 59 47.5 E 101 58 27.1	113.42

Based on the resistivity and chargeability analysis from the figure 5.5 below, resistivity values can be interpreted.

The total percentage of root-mean-squares (RMS) errors observed for linesurvey 1 in the inverse resistivity pseudo section is 7.6 %, while for the inverse model of chargeability section is 0.98%. Minimum resistivity value in this survey line is from 0 Ω m and the highest is 40 000 Ω m with depth 70 m. The highest elevation in this survey line is 120 m. The chargeability values range from 0 msec to about 7 msec.

Based on Figure 4, the pseudosection 2-D profile is divided into three zones – Zone A, Zone B and Zone C. Zone A has a high potential of groundwater with resistivity value below than 200 Ω m. For Zone B the ranges of resistivity value are between

600 Ω until 1,000 Ω m which is for that probably consists of wet fractured or clay in fill and transitional zone consisting of rock fragment limestone and silty sand. Zone C is for the material with high resistivity value that ranges between 7,000 Ω m until 40,000 Ω m. High resistivity value is indicating understood to be the compact or impact limestone to the other not so hard materials such as other sedimentary rocks and shield unweathered rocks such as igneous and metamorphic rock type of rocks. Groundwater potential for this location is stored in two types which are in fractured rocks and in sediments. Zone A at the bottom of the pseudosection is stored in sediments while Zone A at the top of pseudosection is stored in fractured rocks. This zone A on top area can be interpreted as surface areas with stagnant water formed by rainwater for about 20meters depth. Also, groundwater potential can found in depths 70 meters above. The limestone in left side (Zone C) were the ideals of storing fluids based on IP pseudo section interpretation.

For chargeability pseudo section, it shows that low chargeability which means the potential of groundwater is good in this area.



Figure 5.2: Centre of Survey Line 1

When conducting the Electrical Resistivity Survey, many rocks can be seen at the surface. At the surrounding of Line 1, survey line A & B mostly found boulder or rocks from underground. At the end of line survey A, the last electrode is nearest to the stream.



Figure 5.3: Rocks from underground and last electrode that nearest to the stream



Figure 5.4: Boulders at line survey 1

5.4.1.1 Summary interpretation of Survey Line 1

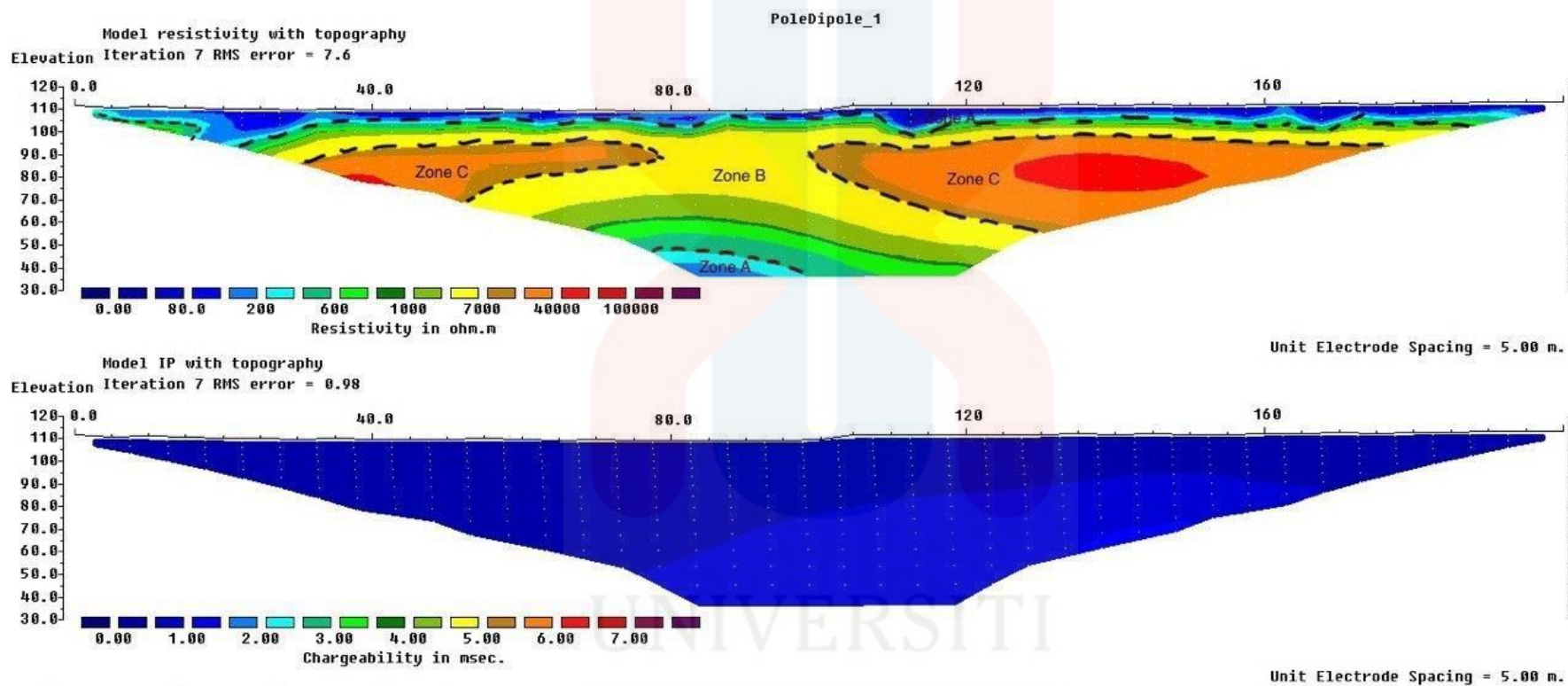
Table 5.2: Summary interpretation of Survey Line 1

Resistivity value	Zone	Interpretation
< 200 Ωm	Zone A	-Potential groundwater Top: stored in fractured rocks (surface areas with stagnant water formed by rainwater = 20m depth) Bottom: stored in sediments (70 m depth)
600Ωm – 1000 Ωm	Zone B	-Wet fractured or clay in fill, transitional zone consisting of rock fragment limestone, silty sand
7 000 Ωm – 40 000 Ωm	Zone C	-Compact or impact limestone or other sedimentary rocks (that not so hard) and shield unweathered rocks

		Left side: were ideals of storing fluids
<p>Good potential of groundwater</p> <p>Low chargeability IP: < 1 msec</p> <p>Rocks seen on surface at Line A & B (boulders and rocks from underground)</p> <p>End of line A nearest to stream</p>		

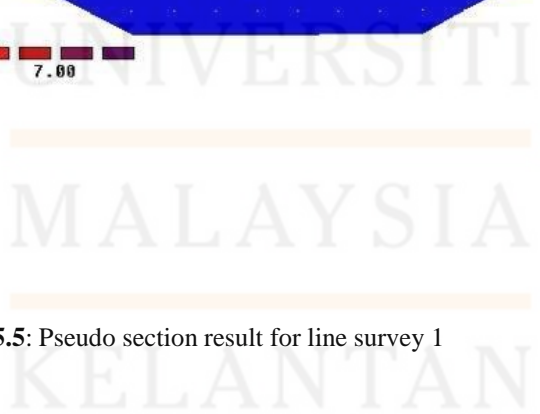
FYP ESD





Horizontal scale is 32.43 pixels per unit spacing
 Vertical exaggeration in model section display = 0.30
 First electrode is located at 0.0 m.
 Last electrode is located at 200.0 m.

Figure 5.5: Pseudo section result for line survey 1



5.4.2 Line Survey 2

Line Survey 2 has an electrode spacing of 5 metres and a length of 200 metres. The configuration array is a Pole-Dipole type. The table below displays the location of electrodes first, centre, and lastly, found at the electrode 1, electrode 21, and electrode 41, respectively. NE-SW is the direction of the line survey.

Table 5.3: Coordinate location for line survey 2

Electrode Number	Coordinate	Elevation (m)
1	N04 59 49.1 E101 58 33.9	119.11
21 (Centre)	N04 59 49.0 E101 58 30.8	119.71
41	N04 59 49.0 E101 58 27.6	121.51

Based on the resistivity and chargeability analysis from the figure 5.8 below, a resistivity pseudo section and chargeability model section for line 2 is shown with a range of resistivity pseudo section between $0 \Omega\text{m}$ to $100000 \Omega\text{m}$ that represented with colour from dark blue to dark purple. The chargeability values range from 0 msec to 7 msec. The depth of pseudo sections is 70 meters from the surface. The root-mean-squares (RMS) error observed for line survey 2 in the inverse resistivity pseudo section is 10.1% while for an inverse model of the chargeability section is 0.12%. the highest elevation on this line survey 2 was 130meters.

From the resistivity pseudo section survey line 2, it can be categorised into low resistivity values, medium resistivity values and high resistivity values. The values with low resistivity are in Zone A around below $200 \Omega\text{m}$. The low resistivity values are shown at the top and bottom of the pseudo-section models represented by dark

blue to turquoise. Thus, this is understood to be Zone A on top are the surface water and the bottom could be a water stored in sediments and gravel. In zone A about 60m above and 20m, there are the potential of groundwater.

The medium resistivity values which is Zone B can be classified from 600 Ωm to 7000 Ωm , represented by from light green to yellow. This section can be interpreted as clay, sand, gravel or wet fractured sediments that clay in-fill. The high resistivity labelled as Zone C have resistivity value range from 40000 Ωm to 120000 Ωm . It shown the bedrock of limestone in the subsurface appear on left about 40 meters on survey line and right side at the 160 meters on survey line. Bothside are looking good at storing fluid in the rock.

The chargeability pseudo section shows low chargeability which means the potential of groundwater is good in the area of survey line 2.



Figure 5.6: Centre of survey line 2

At survey line 2, the surface area flattened and had a specific drainage stream with stagnant rainwater. At this survey line also found a boulder along the lines A & B.



Figure 5.7: Stagnant rainwater and boulders along line survey 2

5.4.2.2 Summary interpretation of Survey Line 2

Table 5.4: Summary interpretation of Survey Line 2

Resistivity value	Zone	Interpretation
< 200 Ωm	Zone A	-Potential groundwater Top: surface areas with stagnant water formed by rainwater (20m depth) Bottom: stored in sediments and gravel (60 m depth above)
600Ωm – 7 000 Ωm	Zone B	-Clay, sand, gravel and wet fractured sediments that clay in-fill

40 000 Ω m – 120 000 Ω m	Zone C	-Bedrock of limestone at left and right side (good storing fluid)
<p>Good potential of groundwater</p> <p>Low chareability IP : < 1 msec</p> <p>Flattened surface area</p> <p>Have specific drainage stream with stagnant rainwater</p> <p>Many boulders found</p>		

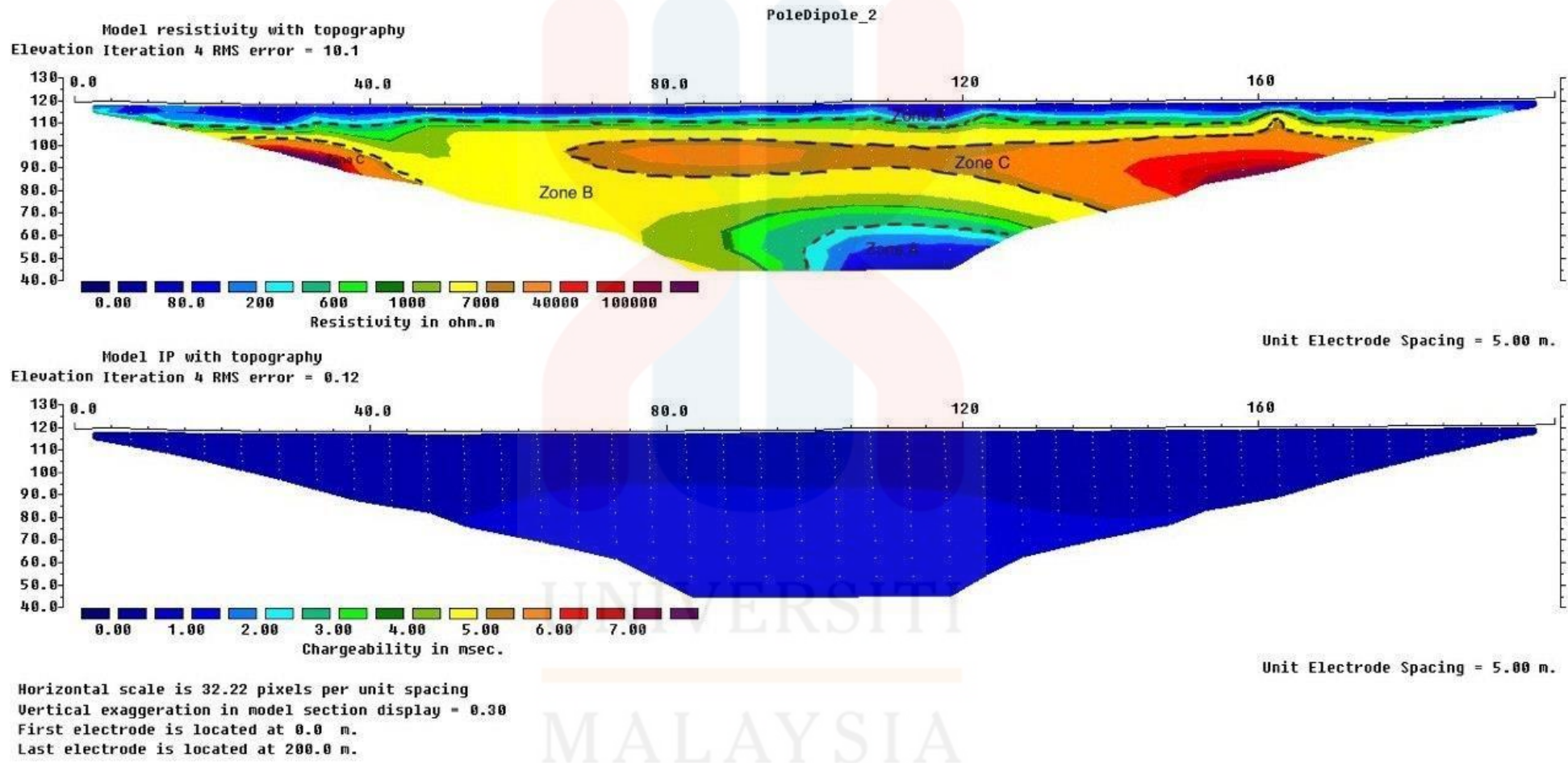


Figure 5.8: Pseudo section result for line survey 2

5.4.3 Line Survey 3

Line Survey 3 has an electrode spacing of 5 metres and a length of 200 metres. The configuration array is a Pole-Dipole type. The table below displays the location of electrodes first, centre, and last, found at electrode 1, electrode 21, and electrode 41, respectively. SW-NE is the direction of the line survey.

Table 5.5: Coordinate location for line survey 3

Electrode Number	Coordinate	Elevation (m)
1	N04 59 45.9 E101 58 30.7	117.19
21 (Centre)	N04 59 49.1 E101 58 30.1	120.11
41	N04 59 52.4 E101 58 30.0	126.70

Based on the resistivity and chargeability analysis from the figure 5.12 below, resistivity values can be interpreted.

The total percentage of root-mean-squares (RMS) errors observed for linesurvey 3 in the inverse resistivity pseudo section is 7.2 %, while for the inverse model of chargeability section is 1.3%. Minimum resistivity value in this survey line is from 0 Ω m and the highest is 40 000 Ω m with depth 70 m. The chargeability values range from 0 msec to about 7 msec.

Based on Figure 4, the pseudosection 2-D profile is divided into three zones – Zone A, Zone B and Zone C. Zone A has a high potential of groundwater with resistivity value below than 200 Ω m. Based on observation, the water in zone A is stored in the fractured rocks about 15metres below ground. For Zone B the ranges of resistivity value are between 600 Ω until 7,000 Ω m which is for that probably consists of wet fractured or clay in fill and transitional zone consisting of rock fragment limestone and silty sand. Zone C is for the material with high resistivity value that ranges

between 40,000 Ω m until 100,000 Ω m. High resistivity value is indicating understood to be the compact or impact limestone to the hard materials such as other sedimentary rocks and shield unweathered rocks such as igneous and metamorphic rock type of rocks. Groundwater potential for this location is stored just in one types which are in fractured rocks on top of pseudo section. However, the limestone in this survey line has it high porosity in storing fluids in it. This zone A on top area can be interpreted as surface areas with stagnant water formed by rainwater also.

For chargeability pseudo section, it shows that low chargeability below than 1 msec, which means the potential of groundwater is higher in this area. At the ove 160 meters length of surveyline, there is a minor accumulation part of clay and shales can be found. It is clay that highly mineralization. These group is impermeable which means the water cannot travel easily through the rock.



Figures 5.9: Centre of survey line 3

The site of line survey three are highly composed of vegetation growing areas. Only a few boulders were found at this survey line which is at Line A from the centre.



Figure 5.10: Boulders found at line A survey line 3



Figure 5.11: Vegetation at survey line 3

5.4.3.3 Summary interpretation of Survey Line 3

Table 5.6: Summary interpretation of Survey Line 3

Resistivity value	Zone	Interpretation
< 200 Ωm	Zone A	-Stored in fractured rocks (<15m depth)
600Ωm – 7 000 Ωm	Zone B	-Wet fractured or clay in-fill and transitional zone consisting of rock fragment limestone and silty sand
40 000 Ωm – 120 000Ωm	Zone C	-Compact or impact limestone to hard materials such as sedimentary rocks and shield unweathered rocks such as igneous and metamorphic rock
Potential groundwater is higher Low Chargeability IP: < 1 msec Above 160m length survey line= minor accumulation part of clay and shales. Clay high mineralization. These are impermeable (water cannot travel easily through rock)		

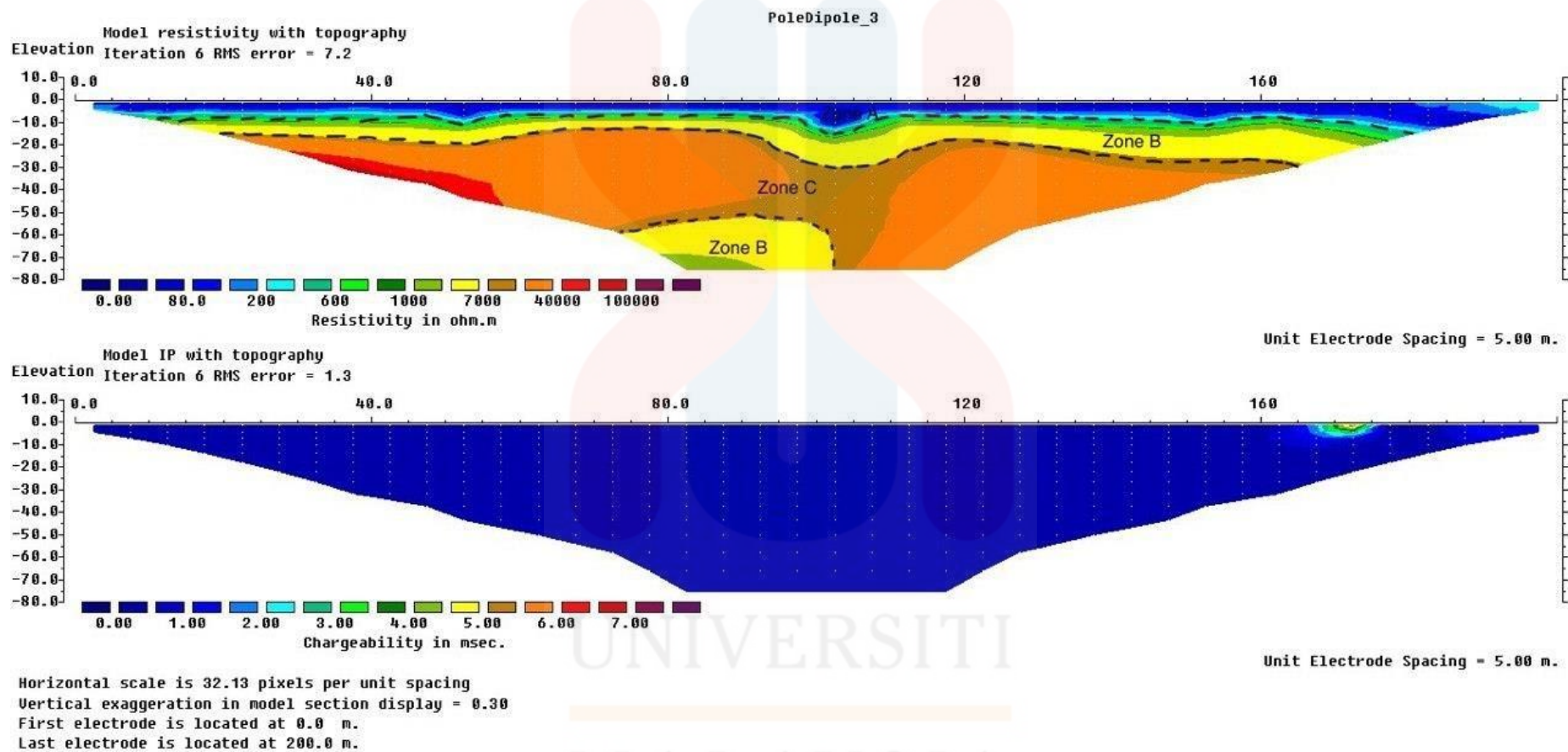


Figure 5.12: Pseudo section result for line survey 2

5.4.4 Line Survey 4

Line Survey 4 has an electrode spacing of 5 metres and a length of 200 metres. The configuration array is a Pole-Dipole type. The table below displays the location of electrodes first, centre, and last, found at electrode 1, electrode 21, and electrode 41, respectively. SW-NE is the direction of the line survey.

Table 5.7: Coordinate location for line survey 4

Electrode Number	Coordinate	Elevation (m)
1	N04 59 45.8 E101 58 32.3	121.23
21 (Centre)	N04 59 49.1 E101 58 31.5	122.04
41	N04 59 52.1 E101 58 31.4	127.48

Based on the resistivity and chargeability analysis from the figure 5.16 below, a resistivity pseudo section and chargeability model section for line 4 is shown with a range of resistivity pseudo section between 0 Ωm to 100000 Ωm that represented with colour from dark blue to dark purple. The chargeability values range from 0 msec to 7 msec. The depth of pseudo sections is 70 meters from the surface. The root-mean-squares (RMS) error observed for line survey 4 in the inverseresistivity pseudo section is 9.5% while for an inverse model of the chargeability section is 18.5%. The highest elevation on this line survey 4 was 130meters.

From the resistivity pseudo section survey line 4, it can be categorised into low resistivity values, medium resistivity values and high resistivity values. The values with low resistivity are in Zone A around below 200 Ωm . The low resistivity values are shown at the top of the pseudo-section models represented by dark blue to turquoise. Thus, this is understood to be Zone A on top are the surface water and mixture of clays with soil and silty sand.

The medium resistivity values which is Zone B can be classified from 600 Ωm to 7000 Ωm , represented by from light green to yellow. This section can be interpreted as sandstone in the subsurface. The high resistivity labelled as Zone Chave resistivity value range from 40000 Ωm to 120000 Ωm . It shown the bedrock of limestone in the subsurface appear on left about 40 meters length on survey line. Limestone are good at storing fluid in the rock.

The chargeability pseudo section shows combination of high chargeability and low chargeability which means the potential of groundwater is lower in the area of survey line 4. It may be high number of clayey particles, gravel, sand and have basement rock, also majority covered by highly mineralized areas which mean red-coloured soil.



Figure 5.13: Centre of survey line 4

Survey Line 4 is along the non-bituminous road in this oil palm plantation. Boulder is found only at line A from the centre, near the streams area.



Figure 5.14: Stream nearest line A and boulder

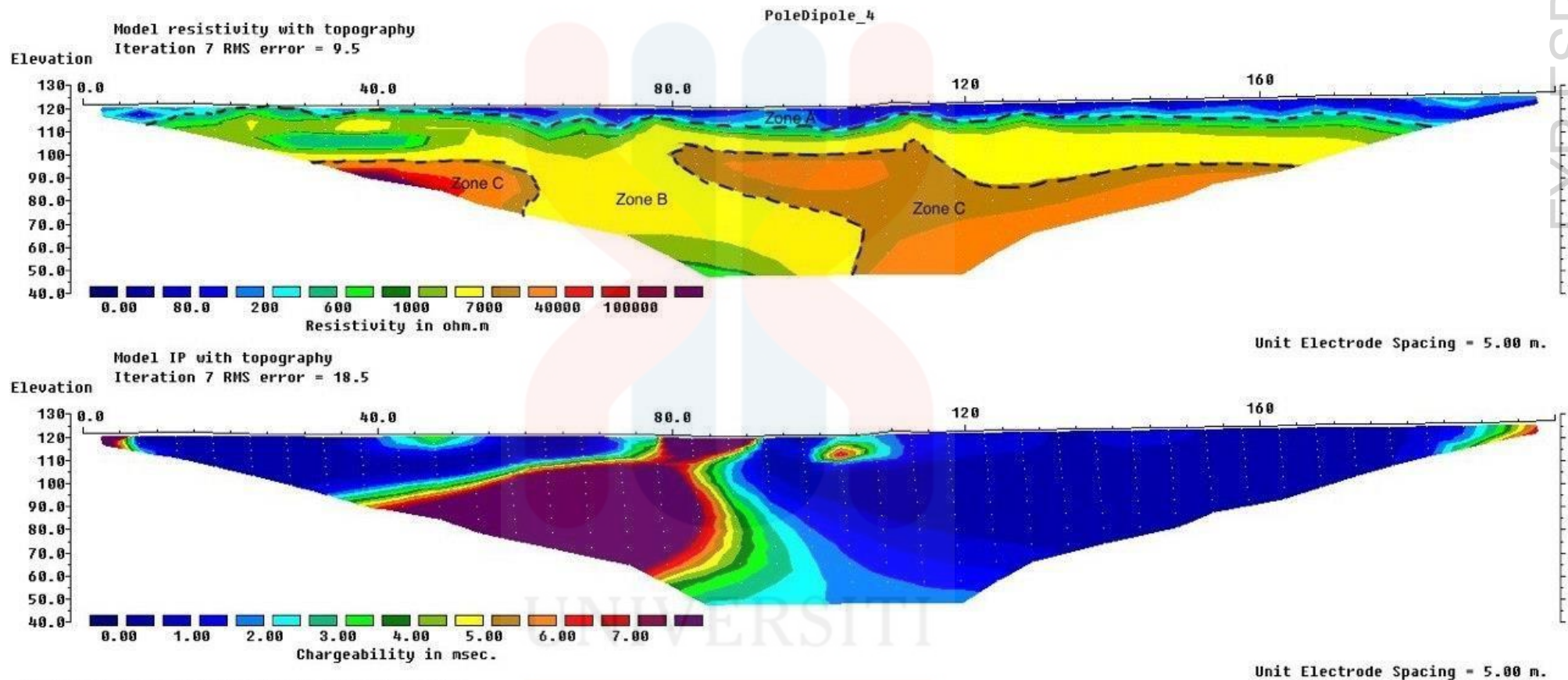


Figure 5.15: Non-bituminous road (red-soil) in this oil palm plantation

5.4.4.4 Summary interpretation of Survey Line 4

Table 5.8: Summary interpretation of Survey Line 4

Resistivity value	Zone	Interpretation
< 200 Ωm	Zone A	-Surface water and mixture of clays with soil and silty sand (<15m depth)
600Ωm – 7 000 Ωm	Zone B	-Sandstone in the subsurface
40 000 Ωm – 120 000Ωm	Zone C	-Bedrock of limestone (appear on left about 40 meters length)
<p>Potential groundwater is lower Chargeability IP: Low + High It may high number of clayey particles, gravel, sand and have basement rock Highly mineralized area</p>		



Horizontal scale is 32.30 pixels per unit spacing
 Vertical exaggeration in model section display = 0.31
 First electrode is located at 0.0 m.
 Last electrode is located at 200.0 m.

Figure 5.16: Pseudo section result for line survey 4

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5.5 Discussion

Most of the study area is covered by a sedimentary rock called limestone, particularly in the Gua Musang region, where all of the line surveys consist of sedimentary rock as its bedrock. In the pore spaces and fractures in the rock, groundwater may accumulate. This can be measured by comparing the reading between resistivity and chargeability values. In order to indicate the presence of groundwater, resistivity values and chargeability values were compared to each other based on the interpretation of the entire survey line. When the resistivity values are high, thus there is low conductivity conducting material. This resistivity refers to the capacity of the material to oppose the electrical current flow, while conductivity refers to the ability to conduct the electrical current.

The results showed that, based on the resistivity value of the high resistivity region, the medium resistivity area and the lower resistivity area, the study area consists of three resistivity classes based on the electrical resistivity system that operates in the study area. The high resistivity range consists of the resistivity range from 40000 Ωm to more than 100000 Ωm , a colour of light red portrayed the hard rock to dark purple. The medium resistivity area consists of a resistivity value ranging from 600 Ωm to 7000 Ωm indicating the colour between green to yellow which is weathered bedrock, sediments and residual soil in this zone. Low resistivity values range less than 200 Ωm , represented by dark blue colour to turquoise. From all the line surveys in the study area, the interpretation from resistivity values shows groundwater potential in the site area.

All survey lines 1, 2, 3, and 4 have groundwater potential when compared to the resistivity and chargeability values. From all the survey line, the water can be assumed to exist as a confined aquifer overlain by a hard layer. Survey lines 1 and 2 have

potential groundwater at depths approximately 60 meters from the subsurface. In comparison, survey line 3 has groundwater potential above 70 meters from the surface layer and the most good aquifers. For survey line 4, the groundwater potential is estimated at the whole section model with 70 meters depth from the surface layer. The majority of groundwater capacity is in the correct portion of the model section at the survey line of 160 meters to 200meters with a depth of 70 meters from the surface layer.

Weather conditions should be considered, as resistivity surveys should not be undertaken on days when it is raining. The survey needs to be correctly excuted for the results to be accurately interpreted. When a significant downpour is present during the site survey, water from the precipitation will be absorbed by the soil, increasing the soil'smoisture content. This will affect the resistivity reading because the soil moisture content is one of the main factors influencing resistivity distribution. Therefore, suitable timing and weathering should be thoroughly considered before conducting the survey. Geomorphology, lithology, and structural geology are additional variables that must be considered when running the survey line. Geomorphologies include rivers or ponds, while lithology such as limestone presented by the fracture, is related to groundwater occurrence.

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5.6 Conclusion

To conclude, the geophysical approach is the best way to assess the capacity of groundwater in the subsurface region. The geophysical method is also easy to handle, and the cost is much cheaper than the borehole. The survey site consists of groundwater potential depending on the interpretation of a model section of each line. For this study, a Pole-Dipole configuration is used to determine groundwater potential in limestone. The interpretation is based on the resistivity values reading and the chargeability values reading in the model sections. When resistivity values increase and the chargeability values decrease, it can be interpreted as groundwater potential in that area. The most groundwater potential in limestone -present is in line survey3, followed by survey line 1 and 2, and the less groundwater potential present in limestone is in survey line 4.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This chapter will cover the part of the conclusion and 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 the different locations in the study area. About 60% of the study area's total area comprises the limestone unit, dispersed on the study area's north-western side. The limestone unit is made of limestone and marble and dates back to the Paleozoic and Permian periods. The final unit is a metasedimentary one, which makes up around 40% of the studied area. The metasedimentary unit, which includes shale, slate, and interbedded mudstone with siltstone and quartzite, was created throughout the Mesozoic and Triassic periods. Geomorphology in the research area comprised a flat area in the centre and a karst and mountainous area that was mainly in the western regions. In the research region, parallel and dendritic patterns make up most of the drainage 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 and 2 has potential groundwater at a depth of 60 meters, while survey line 3 has groundwater potential at a depth above 70 meters. Finally, for line survey 4, the capacity for groundwater is 40 meters in depth but in

the lowest potential.

6.2 Recommendation

For the recommendation, the potential groundwater is located in Kampung Star Baru, Gua Musang, Kelantan. For further analysis, the community is recommended to assess water quality in the presence of groundwater potential in Kampung Star Baru using suitable methods such as pumping testing. It was shown based on the outcome obtained from the ERI investigation. The groundwater potential can be found at levels ranging from depths of 20 m to 75 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.

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