GEOLOGY AND HYDROGEOLOGICAL CHARACTERIZATION IN PALOH, GUA MUSANG, KELANTAN, MALAYSIA

BY

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Report submitted in fulfillment of the requirements for the award of the degree of Bachelor of Applied Science (Geoscience) with Honor

FACULTY OF EARTH SCIENCE

UNIVERSITI MALAYSIA KELANTAN

2022

DECLARATION

I declare that this thesis entitled "**GEOLOGY AND HYDROGEOLOGICAL CHARACTERIZATION IN PALOH GUA MUSANG**" is the result of my own research except those 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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Name :

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APPROVAL

I hereby declare that I have read this thesis entitled and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Applied Science (Geoscience)

Signature	:	……………………………........
Name of Supervisor	:	
Date	:	……………………………….

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GEOLOGY AND HYDROGEOLOGICAL CHARACTERIZATION IN PALOH, GUA MUSANG, KELANTAN, MALAYSIA

Abstract

The present work is a part of a final-year undergraduate research project which aims to map the hydrogeological characteristics of the Felda Chiku, Paloh, Gua Musang area in Kelantan, Malaysia. The study area, covering 25 square kilometers, is defined by latitudes between 05°O1'09" E to 05°03'50" E and longitudes between 101°l'43N. The main goal of this study is to produce an updated geological map on a scale of 1:25,000 for the area. The methodology applied for this research includes fieldwork, collection of samples from fresh outcrops, recording structural trends in rocks, and making observations of geomorphological features and drainage patterns. All of the field-related data is processed in GIS, including petrographic studies, to generate geological and thematic maps. Based on field observations, the study area is classified into four different types of lithologies: limestone, shale, and sandstone, with the majority of the area covered by karst limestone landforms.

GEOLOGI DAN PENCIRIAN HIDROGEOLOGI DI PALOH, GUA MUSANG, KELANTAN, MALAYSIA

Abstrak

Kerja ini merupakan sebahagian daripada projek penyelidikan ijazah sarjana muda yang bertujuan untuk memetakan ciri-ciri hidrogeologi di kawasan Felda Chiku, Paloh, Gua Musang di Kelantan, Malaysia. Kawasan kajian yang meliputi 25 kilometer persegi, ditakrifkan oleh latitud antara 05°O1'09" E hingga 05°03'50" E dan longitud antara 101°l'43N. Tujuan utama kajian ini adalah untuk menghasilkan peta geologi terkini dengan skala 1:25,000 untuk kawasan tersebut. Metodologi yang digunakan untuk penyelidikan ini termasuk kerja lapangan, pengumpulan sampel dari luaran segar, merekodkan trend struktur dalam batuan, dan membuat pemerhatian ciri-ciri geomorfologi dan corak saliran. Semua data berkaitan lapangan diproses dalam GIS, termasuk kajian petrografi, untuk menghasilkan peta geologi dan tematik. Berdasarkan pemerhatian lapangan, kawasan kajian diklasifikasikan kepada empat jenis litologi yang berbeza: batu kapur, shale, dan batu pasir, dengan majoriti kawasan ditutupi oleh bentuk tanah batu kapur karst.

CHAPTER 1

INTRODUCTION

1.1.Background of Study

Both a Base map and a geological map are necessary for geological study since the include a wealth of geological information. Tectonic structures, as well as fossil and mineral deposits, are significant elements of geological maps. In this study of geology and hydrogeological characterization involved the use of rock samples from geological maps. The rock samples were collected and analyzed to determine the composition and structure of the earth's crust, as well as the potential for groundwater resources.

The geological map provided a visual representation of the earth's surface and allowed geologists to identify different rock formations and their distribution. By examining rock samples from these formations, geologists could determine the geological history of the area and make predictions about the types of rocks and minerals that might be present in the subsurface.

Hydrogeological characterization involved the study of groundwater resources and their potential for extraction. By analyzing rock samples, geologists could determine the porosity and permeability, which are important factors in the movement and storage of groundwater.

Overall, the use of rock samples from geological maps played a critical role in the study of geology and hydrogeological characterization. These samples provided valuable insights into the composition and structure of the earth's crust, as well as the hydrogeological properties, and helped guide the development of important natural resource management strategies.

1.2. Problem Statement

geologists and hydrogeologists faced a challenge in understanding the composition and structure of the earth's crust and identifying potential groundwater resources. To address this challenge, they relied on the use of rock samples from geological maps to study geology and hydrogeological characterization.

At the time, the geological map was a critical tool in providing a visual representation of the earth's surface and identifying different rock formations. By examining rock samples from these formations, geologists could gain insights into the geological history of the area and make predictions about the types of rocks and minerals that might be present in the subsurface.

Hydrogeological characterization was an important focus of study, which involved understanding the movement and storage of groundwater resources. The analysis of rock samples using only hand specimens and measurements of porosity and permeability was the key method used to determine the hydrogeological properties of the surface. By analyzing the rocks in this way, the study was able to gain a detailed understanding of the hydrogeology of the area and make informed decisions about the management of groundwater resources

Despite the importance of rock samples in the study of geology and hydrogeological characterization, challenges existed in their collection and analysis. The process of collecting rock samples could be time-consuming and expensive, and their analysis required specialized equipment and expertise. Nevertheless, the use of rock samples from geological maps played a critical role in the development of important natural resource management strategies in the past.

1.3. Objectives of the Study

The objectives of the research are as follows:

1. To produce an updated geological map of Paloh, Gua Musang
2. To identify hydrogeological characterisation in Felda Chiku Paloh.

1.4. Scope of Study

This research will be conducted in Gua Musang district, Kelantan especially the Paloh area. the scope of study for hydrogeological characterization involved the use of rock samples from geological maps to identify potential groundwater resources and to develop models of groundwater flow. This involved analyzing the physical properties of the rock samples, such as their porosity and permeability, which were important factors in the movement and storage of groundwater.

In Addition, the study also included the identification of potential locations for drilling wells, based on the analysis of rock samples and models of groundwater flow. This was critical for the development of effective groundwater management strategies and for ensuring that adequate water resources were available for human use and fresh water services.

1.5 Significance of the Study

The importance of this study is that it provides an update on the existing geology map of the study area. Other than that, the study of hydrogeological characterization can give an insight for the people whether their place has the potential in becoming a source of freshwater that can be used in times of need. This study is important, not only because it serves as guidance but also as a proper reference for future studies which can help in avoiding disasters that may or may not happen. These findings will be useful as a baseline study to better understand how water gets into the ground (recharge), how it flows in the subsurface (through aquifers), and how groundwater interacts with the surrounding soil and rock (the geology) through the study area.

1.6. Study Area

This research will be carried out in Paloh, Gua Musang, Kelantan which is 50 km from Gua Musang town. Kelantan is one of the states in Malaysia that is in the northeast of Peninsular Malaysia. The study area is in the western part of Gua Musang. Gua Musang is located at the southern part of Kelantan and it is the largest district in Kelantan with a total area is 7,979.77 km2. This study will be conducted in a position of the southern part of Gua Musang which is covered 25 km2 of the total area which is at Paloh.

The study area is marked with latitude between 05°O1'09" E to 05°03'50" E and longitude in between 101°l'43N which covers 25 km square area. Figure 1.1 shows the base map of the study area.

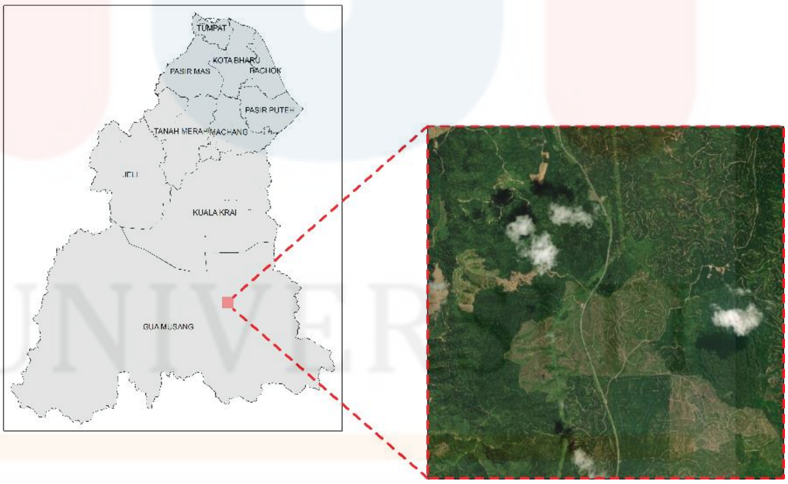


Figure 1: the location map

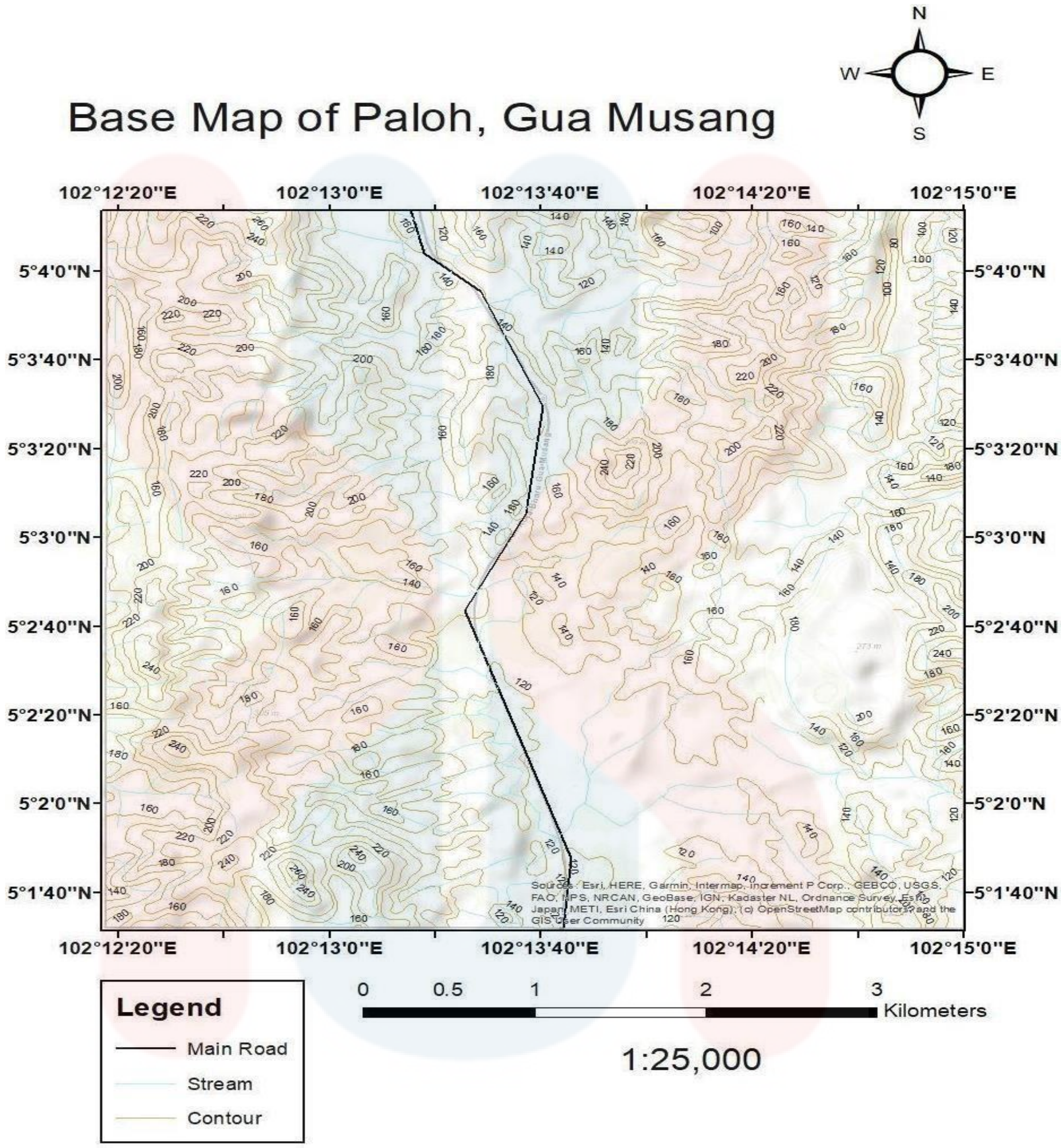


Figure 2: Basemap of Paloh,Gua Musang, Kelantan

1.6.1. Road Connection/Accessibility

LOCATION: in Paloh, Gua Musang, Kelantan
Size of study area: 25km
latitude between 05°O1'09" E to 05°03'50" E
and longitude inbetween 101°l'43N

Map of study area PALOH GUA MUSANG, Kelantan
(source: Google Earth Pro, 2022).

Route from Gua musang city to the study area via driving
(Source: Google Maps, 2022)

oute from Universiti Malaysia Kelantan to the study area via driving
ource: Google Maps, 2021).

1.6.2. Demography

Based on 2020 statistics, the population of Gua Musang is 101 894 people who are still living in the area of 6430km^2.

Name	Status	Population Census 2000-07-05	Population Census 2010-07-06	Population Census 2020-07-07
Gua Musang	District	74,988	86,189	101,894
Malaysia	Federation	22,198,276	27,484,596	32,447,385

Gua Musang

101,894 Population [2020] – *Census*

6,430 km² Area

15.85/km² Population Density [2020]

1.7% Annual Population Change [2010 → 2020]

Gua Musang District: human settlement in Malaysia

Figure 3: Population of Gua Musang people (Department of Statistics Malaysia)

1.6.3. Land Use and development

There is a wide variety of land uses in Kelantan, however, the limited forest still occupies a large portion of the state. Figure 1.4 shows that the research region comprises oil palm, rubber, and forest, however, the study area is dominated by forest (M Hashim et., al 2017). Three systems are used to describe it: Paloh 1, Paloh 2, and Paloh 3. Paloh 3 is the location of the research area. Rubber and oil palm plantations comprise 1420.14 and 942.86 hectares, respectively. Reserved woodland covers the rest (Fauzi Hussin & Hussin Abdullah, 2012). Figure 6.31 will show land use in Kelantan

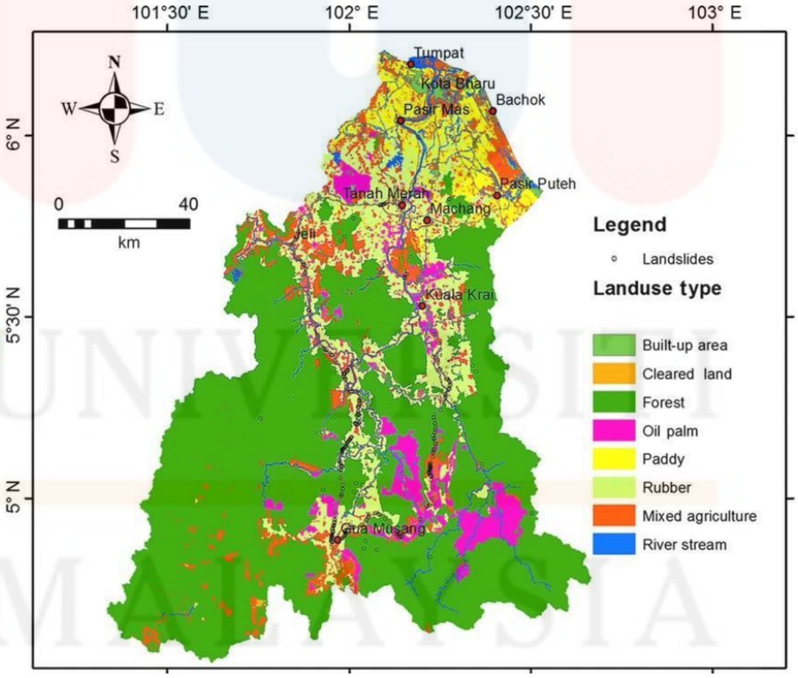


Figure 4: Map of land use type in Kelantan state.

1.6.4. Rainfall

According to Table 2, Gua Musang will receive 3234.5mm of rainfall overall in 2021. At the conclusion of the year, December had the greatest recorded rainfall distribution with 955.5mm, followed by November with 591mm. The month of June has the lowest rainfall distribution in Gua Musang, with only 63.5 mm.

Table 6.1.4.1: Rainfall distribution in 2021 at Gua Musang area (Source: Department of Irrigation and Drainage)

Months	**Rainfall distribution, mm**
January	116
February	156.5
March	72.5
April	116
May	275
June	63.5
July	307.5
August	217
September	125.5
October	191
November	638.5
December	955.5

Chapter's Summary

This research shows the investigation of the general geology and the Hydrogeological Characterization at Paloh, Gua Musang, Kelantan, Malaysia. This research is shown towards hydrological Characterization, whether the study area can provide a source of water for that specific area. Based on the investigation also, the data that have been collected in this beginning chapter are people distribution, rain distribution, land use, social-economic, and road connection.

This chapter also introduced the study area that will be conducted using the geological map to complete the general geology and acknowledge the research objectives that need to be achieved. Besides the study area and objectives, this chapter explains the importance of this research which is generally to educate the people to become more aware of their surroundings and help in giving knowledge about the study area.

Moreover, the problem statement that needs to be overcome in this research is also mentioned to manage the outcome and ways to overcome the problem that has to face.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discuss about the general geology and hydrogeological Characterization

Ever since the creation of life man, animals, and plants are dependent continuously on a few precious commodities among which water constitutes the primary importance. Other vital commodities such as food and oxygen are by-products of water. Man's relationship with water has been vital, complex, and varied from the earliest times. It is for this reason that the Holy QURAN verses signifying The importance of water have been explained in many verses of the Holy Quran. Similarly, every living thing has been created from water by Almighty Allah: "And we made every living thing from water" **(Al Anbiya 21:30)**

This dependence of man's life on water compelled him to choose his settlement locations at positions where water was easily available. Therefore, early settlements are invariably either along rivers or next to lakes or springs, all of which provide natural water resourcesAs a result, the initial human activities were focused on harnessing water for irrigation, growing domestic cattle, defending oneself, and communicating. In order to increase or change the available water storage throughout time, humans began to intervene with the natural occurrence and movement of water by building dams, dikes, or leves. However, each component will have distinct attributes and meanings based on the resource. For instance, the hydrological cycle, which supplies water through a catchment and subsequent infiltration process, is entirely responsible for the source component of groundwater, which is utterly dependent on it. Hence, investigation of the source requires hydrological knowledge only. Because the reservoir is underground, the subsurface geology becomes the dominant media for its existence. Finally, the abstraction phase is an indicator of man's direct or indirect interaction with the groundwater through man-made structures such as wells. (Sen, 1995).

2.2. Regional Geology and Tectonic Settings

Peninsular Malaysia is a land area of 130,268 km2 that is part of Sundaland, which includes Borneo, Java, and Sumatra, as well as the surrounding seas which include smaller islands. It has a maximum length of 750 km and a breadth of 330 km and is elongated in a general NNW-SSE direction. It is separated from Singapore Island by the narrow Johor Strait to the south and from Sumatra Island by the Strait of Malacca to the west. The southeast and east of the South China seas separate the Peninsular from Borneo Island. According to Hutchison The Peninsular is subdivided into three types of belts: the Western belt, Central belt, and Eastern belt, each with its distinctive stratigraphy. The Kelantan state is located in the Central and Eastern belts. The Western part of the Central belt includes upper Paleozoic rocks of the Gua Musang and Aring Formation in the south

Kelantan and the Taku Schist in the east of Kelantan. Several major fault zones have occurred in parts of the state in Peninsular Malaysia, such as the Bentong-Raub Suture zone that can be seen along Gua Musang to Cameron Highlands, Galas fault zone that strikes from the NNW-SSE cutting the Strong Complex, Lebir fault zone along Sg. Lebir near Manek Urai in Kelantan, and Kemahang Granite and Tahan Range (Tan, 2009). Figure 2.1 refers to the geological map of Kelantan.

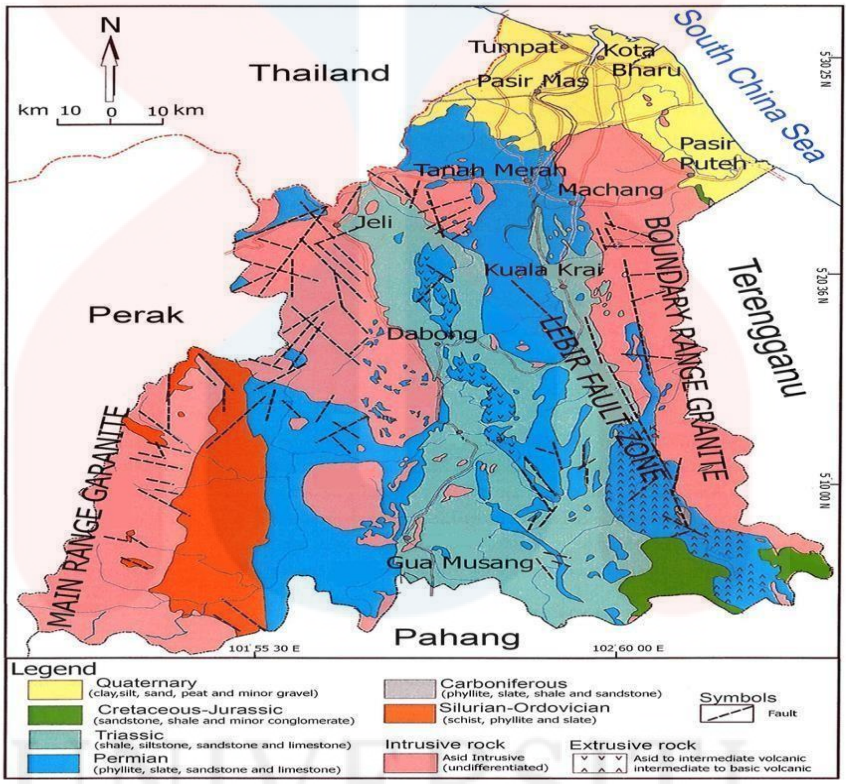


Figure 5: Geological Map of Kelantan Source: Department of Mineral and Geoscience

Kelantan is in Peninsular Malaysia's north-eastern corner. West Perak, south Pahang, and east Terengganu are three Malaysian states with which this state shares borders. The state of Kelantan also has a common border with Thailand. Tumpat, Pasir Mas, Pasir Puteh, Kota Bharu, Bachok, Tanah Merah, Machang, Jeli, Kuala Krai, and Gua Musang are the 10 districts that comprise Kelantan.Sedimentary rock, unconsolidated sedimentary rock, metamorphic rock, metasedimentary rock, volcanic rock, and granitic rock are among the six principal types of rocks found in this state, according to the Department of Minerals and Geosciences (2021). The flat Kelantan alluvial plain of the Quaternary age is found in the northern section of Kelantan, which has Unconsolidated sedimentary.

2.2.1. Aring Formation

The Gua Musang formation in South Kelantan - North Pahang was described by Yin (1965) as comprising of Middle Permian to Late Triassic argillite, carbonate, and pyroclastic/volcanic facies. Now, the term is loosely used for nearly all Permo-Triassic carbonate-argillite-volcanic sequences in the northern part of Central Belt Peninsular Malaysia.

The Aring Formation, named after Sungai Aring in South Kelantan, is composed mainly of pyroclastic rocks and includes lava, dolomitic marble, and argillite. The formation is 3000m thick, with a 270-meter-thick dolomitic marble layer discovered on top. The formation is covered by argillite and tuff, and the Paloh Member, a 1000-meter-thick argillo-tuffaceous limestone unit, is located above the formation. The Aring Formation is composed of interbedded fine to coarse pestiferous tuff, rhyolite to andesitic lava, argillite and limestone. Bivalves were used to determine the age of the formation, it is the stratigraphic equivalent of the calcareous-argillaceous Gua Musang Formation in northwest and west Pahang, according to Fooo (1983) and Hutchinson (2009).

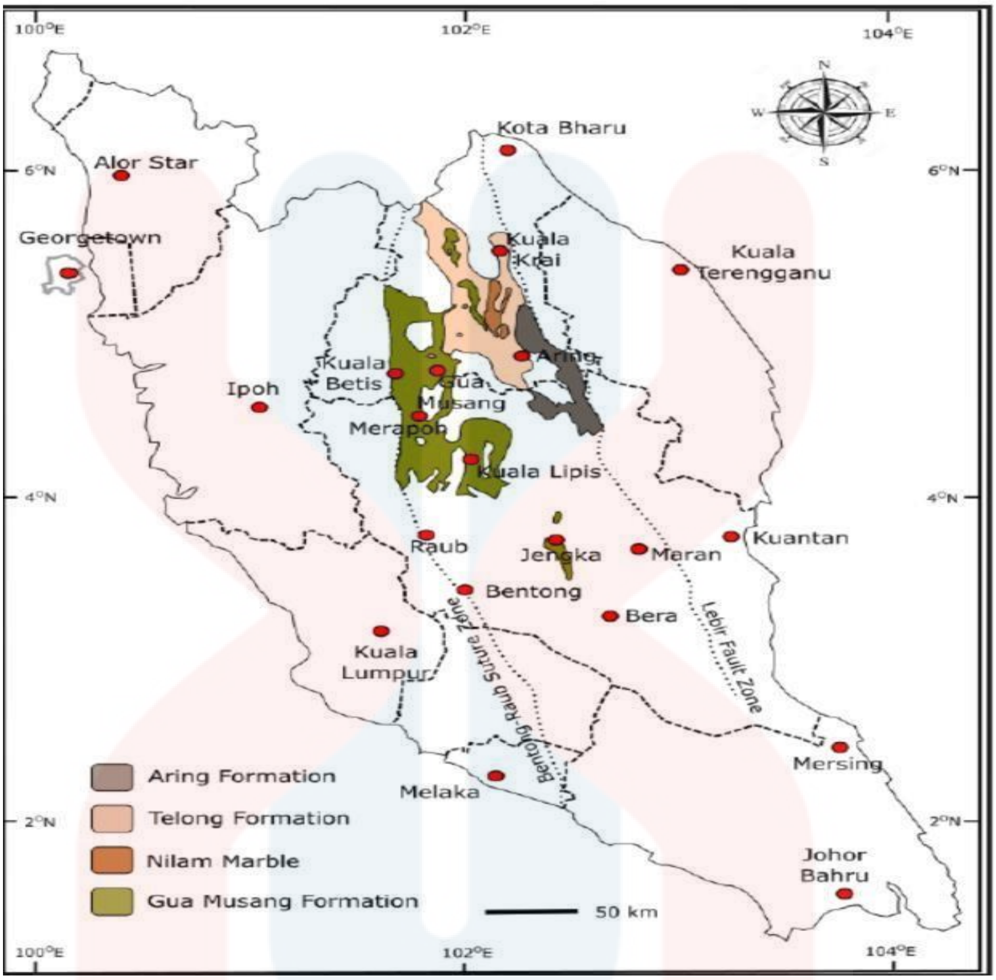


Figure 6: shows the the location of Aring Formation In Kelantan.(Mohamad K.R,2017

2.2.3 Stratigraphy

The Central Belt of Peninsular Malaysia stretches from Kelantan to Johor and is defined by its boundaries, the eastern foothills of the Main Range to the west, the Lebir Fault to the east in the north, and the western boundary of the Dohol Formation to the south. The Paleozoic rocks in this belt are primarily composed of Permian classics, with rare outcrops of Carboniferous limestone appearing as linear bands bordering the Mesozoic strata on either side of the belt. The western half of the Central Belt is home to upper Paleozoic rocks such as the Gua Musang and Aring Formation in south Kelantan, Taku Schist in east Kelantan, the Raub Group in west Pahang and Kepis Beds in Negeri Sembilan. The correlation and categorization of these rocks are shown in Figure.7

The Carboniferous-Permian Raub Group has been correlated with the Kepis Formation in the south and the Gua Musang Formation in the north. The Raub Group is composed of limestone, calcareous shale and pyroclastic rocks (Hutchison, 1989). Some of the rocks identified as belonging to the Raub Group may be part of the Bentong-Raub suture zone rocks and therefore, may not form part of the Central Belt stratigraphy.

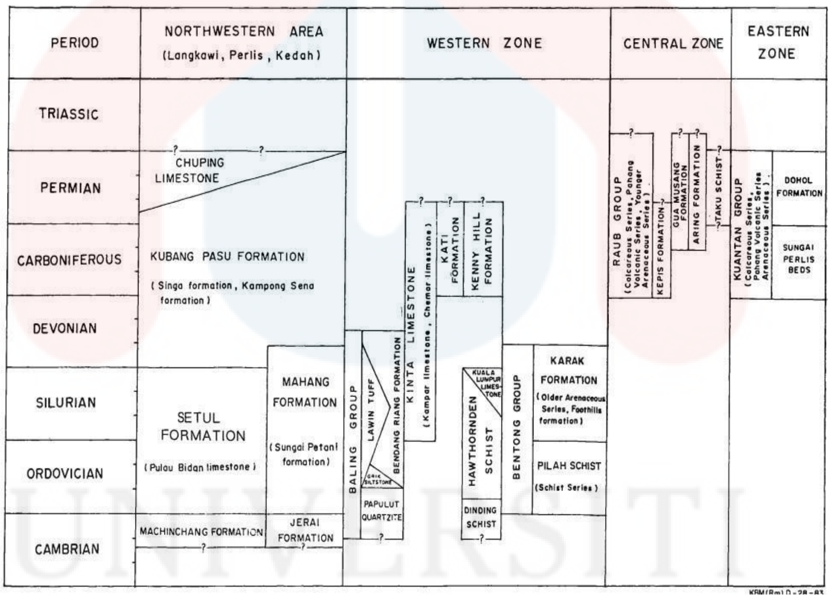


Figure 7: show the Schematic classification and correlation of sourcesource: Foo Khong Vee Perak, Malaysia

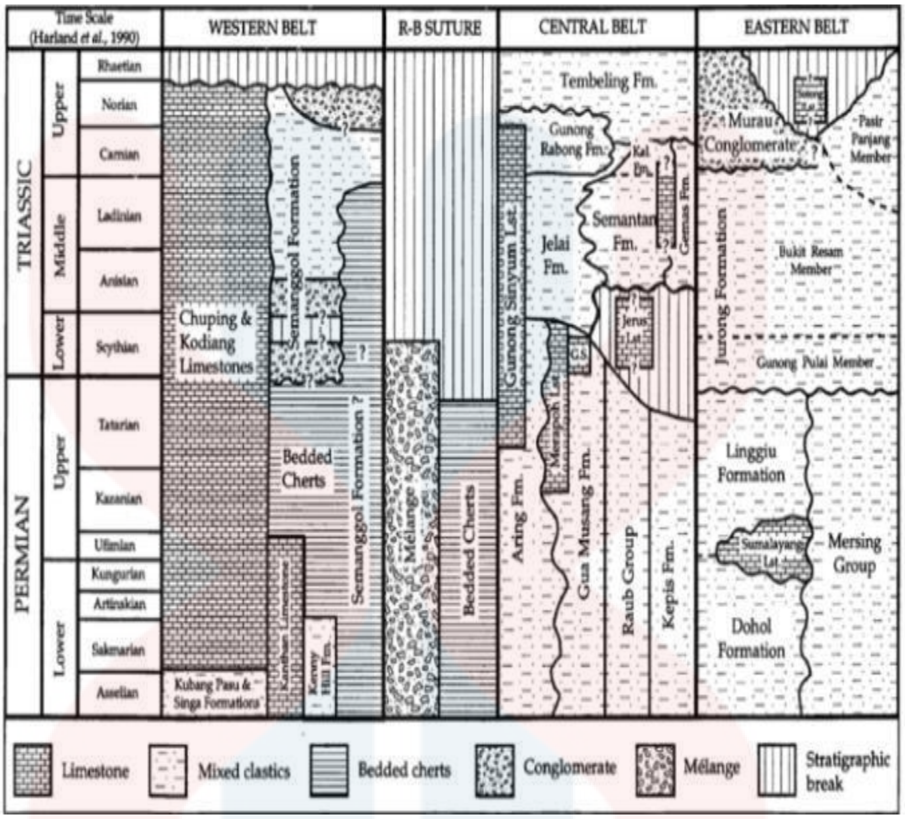


Figure 8: chart for the Permian and Triassic of Peninsular Malaysia (Liew J.E.,2019)

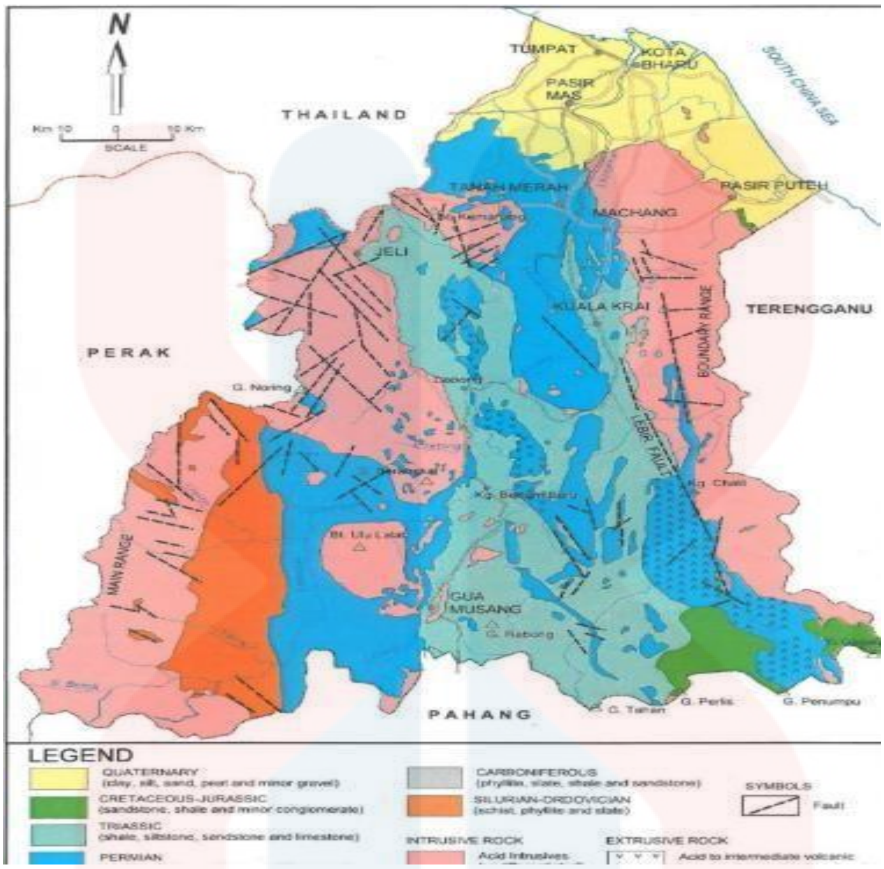


Figure 9: distribution of rocks in Kelantan state. (Department of Minerals and Geoscience)

Kelantan is in Peninsular Malaysia's north-eastern corner. West Perak, south Pahang, and east Terengganu are three Malaysian states with which this state shares borders. The state of Kelantan also has a common border with Thailand. Tumpat, Pasir Mas, Pasir Puteh, Kota Bharu, Bachok, Tanah Merah, Machang, Jeli, Kuala Krai, and Gua Musang are the 10 districts that comprise Kelantan. Sedimentary rock, unconsolidated sedimentary rock, metamorphic rock, metasedimentary rock, volcanic rock, and granitic rock are among the six principal types of rocks found in this state, according to the Department of Minerals and Geosciences (2021). The flat Kelantan alluvial

plain of the Quaternary age is found in the northern section of Kelantan, which has Unconsolidated sedimentary.

2.4.Structural Geology

Pre-orogeny sedimentary successions in the Transect area are generally folded into a series of synclines and anticlines. These structures are caused by the compression and deformation of rock layers as a result of tectonic activity. The dominant strike and fold axis direction of Peninsular Malaysia is South to Southeast, which controls the overall shape of the peninsula. This direction is particularly evident in the mainly Carnian-Norian Semantan and Gemas Formations of the Central Basin.

The tectonic activity that led to the formation of Peninsular Malaysia also caused a variety of other structural features in the region. Faulting is widespread throughout the area, with faults varying in width and characterized by fractured, sheared, or even mylonitic rocks. These faults are the result of movement along the plate boundary and can be used to infer the direction of plate movement and the history of deformation.

One important structural feature in Peninsular Malaysia is the Lebir fault zone, which is at least 10 km wide and spans the gap between Sungai Lebir and the eastern margin of the Taku Schist near Kuala Krai. According to Singh, on the geological map, Triassic Rock boundaries are shown displaced sinistrally for about 20 km along the Lebir Fault. Slicken-sides on the fault surfaces, exposed along road-cuts, indicate sinistral slip. Being deformed metasediments, granite and mylonite were the rocks within the fault zone. (jia 1969) showed that, based on tension fracture and drag fracture, the fault zone has a sinistral slip. Evidence for the sinistral movement along the fault zone in Sungai Aring area was found, (Aw, 1990)

The pre-orogeny sedimentary successions in the Transect area of Peninsular Malaysia are generally folded into a series of synclines and anticlines. The dominant strike and fold axis direction of Sumatra is southeast, which controls the shape of the island. The folding is characterized by tight, asymmetric, and open folds, which cause a repeated and overturned sequence in the older sedimentary rock. These folds are sub-parallel to the long axis of the Malay Peninsula and have various dip angles, with most bedding planes dipping towards the east.

2.5.Petrography

Petrography is a branch of petrology that focuses on the detailed description of rocks. The mineral content and the textural relationships within the rock are described in detail. The petrography analysis is done after the thin section process, where the mineral of the rock can be observed and identified through the microscope. Through this process, the name of the rock can be identified, and the study area can be classified into which the dominant rock takes place.

The petrographic description started with the field notes at the outcrop and include a macroscopic description of hand specimens. The most important tool for the petrographer is the petrographic microscope. The detailed analysis of minerals by optical mineralogy in thin sections and the micro- texture and the structure are critical to understanding the origin of the rock.

2.5.Hydrogeology/ Groundwater

The study of underground water's distribution, flow, and chemistry is known as hydrogeology. Hydrogeology includes the study of aquifer systems. Aquifers are geologic units that allow water to be safely stored and transferred to a well ((Fetter, 2001).

Hydrogeology is the study of water in the broadest sense. Water is life to us and all living things and a unique natural resource to the planet Earth.

Groundwater is the next most significant source after discounting the volumes represented by the ocean and polar ice (Willis, 2001). Groundwater makes up only 0.61% of the total distribution of the world water supply and is approximately 50 to 70 times more plentiful than surface water (Fetter,1980). To achieve a large-scale development of groundwater, it must have a reliable estimate of groundwater potential (Singh, 1984).

The aquifer is a formation, part of a formation, or a group of formations that contain sufficient saturated permeable material to yield a significant quantity of water to wells or springs (Willis, 2001). A layer that contains and transmits groundwater and can be divided into two, that is confined and unconfined aquifer. Confined aquifer, overlain by an impermeable layer of rock such as aquiclude or aquitard(Fetter, 2001). The more productive aquifers occur in sedimentary geologic formation rather than the weathered and fractured crystalline rocks and yield smaller quantities of groundwater in many environments. The hydrogeological map of Kelantan in the Year 2008 is shown in Figure 2.5.1

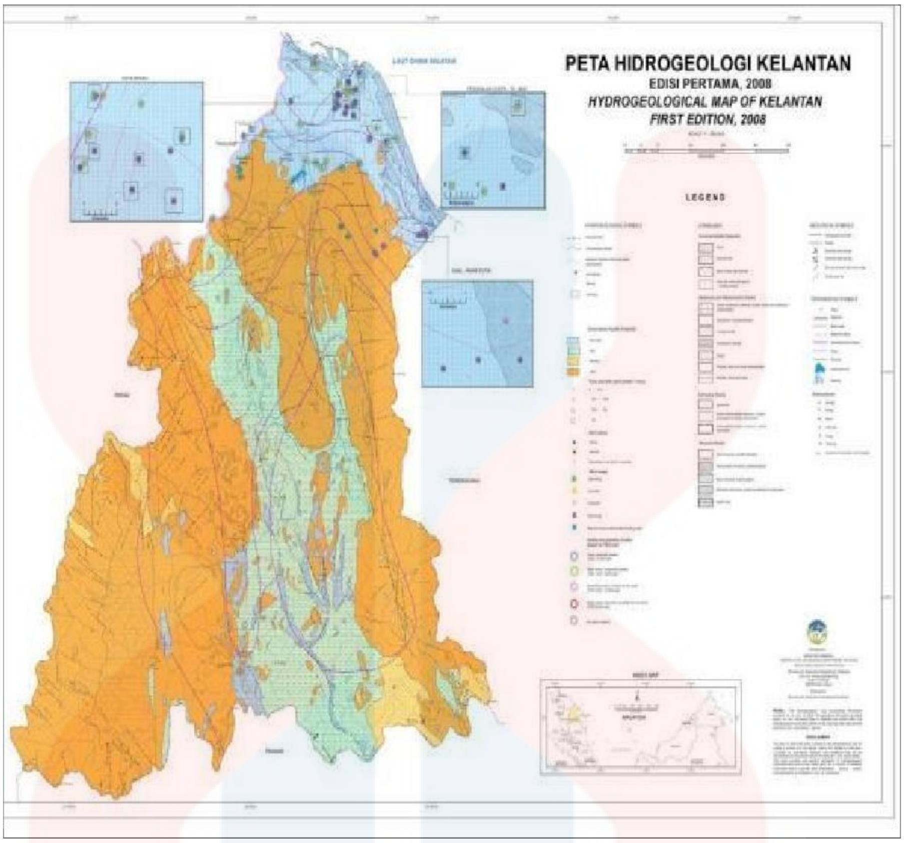


Figure 10*:* Hydrogeological Map of Kelantan 2008 Edition
Source: Ami Hassan Md Din12, Mohd Nadzri Md Reba

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

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

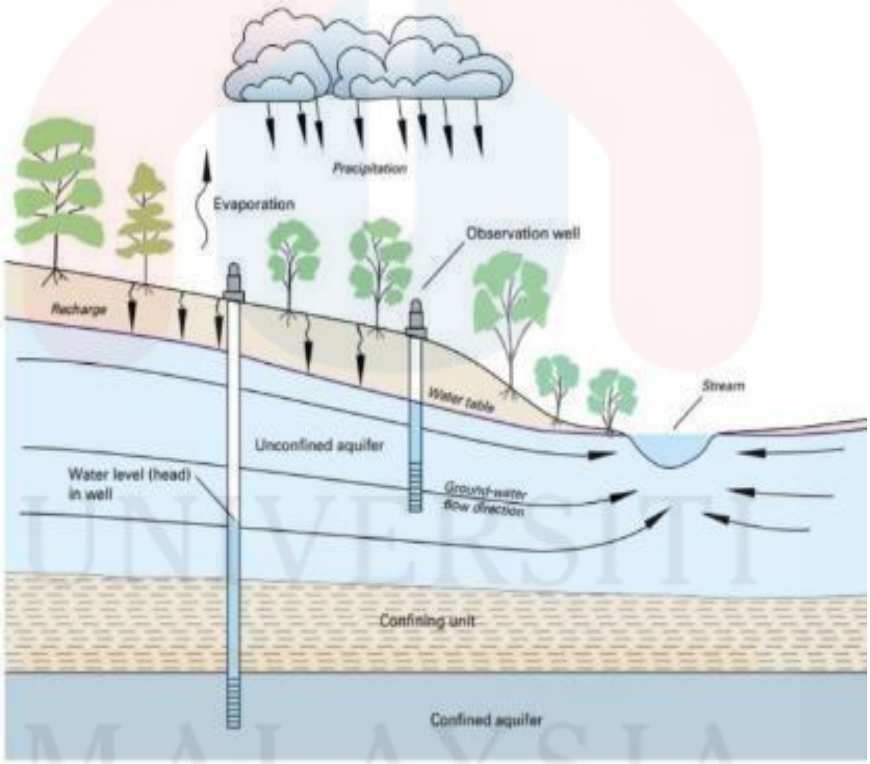


Figure 11: Hydrogeological section with confined and unconfined aquifer 1 (Montoya, 2017)

FYP FSB

CHAPTER 3

MATERIAL AND METHODS

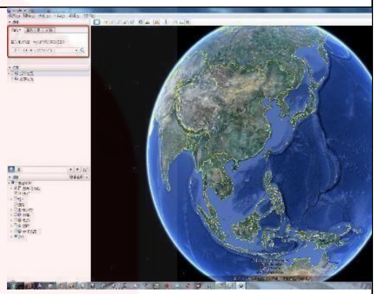
3.1 Preliminary Study

This is an initial study for gathering general information about the research and study area. The material that is used such as articles, journals, and other publications are collected to determine the level of research and development that was done in Malaysia and around the globe. The sources of this material are from the library and the Geology of Mineral and Geosciences Department, Kelantan, and also the website. The purpose of this research is to obtain the initial overview of the geological setting, morphology, and topography of the study area, including the knowledge about topographic maps within the scale of 1:25000. to help in the production.

Table 3.1 several equipment that will be used in geological mapping. the equipment was used:

Table 3.1: Equipment that used for geological mapping

Tools	Uses	Image
1. (GPS)	The purpose of obtaining coordination of specific places in real-time	
2. Geological Hammer	Use for splitting and breaking rocks into small pieces for sampling purposes	
3. Burton Compass	To measure the directional degree measurements (azimuth) through the use of Earth's magnetic field and taking strikeand dip measurements	
4. Measuring tape	Usage of measuring the outcrop atthe field and keeping the sample safe.	

5.ArcGIS 10.3 software	This software allows us to create several geological maps of the study area, such as topography, drainage, and land use.	
6. Base map	Basemaps areused as a starting point for overlayingdata from layers and visualising geographic data.	
7. Google Earth software	It used a computer program that renders a 3D representation of Earth based primarily on satellite imagery of the study area	

3.2.Data porocess

The geological map was processed using ArcMap software, with the GPS track of the field study area recorded and imported into the program. ArcMap tools were used to process the geological map, as well as to determine the strike and dip. The major force that distorted the rock samples were identified by examining the joint measurements. Additionally, rock samples were collected and examined to identify any weathered zones.

3.3.Data analysis

Data Mapping operations were conducted to collect data, and stratigraphy and structural analysis were performed. Associated software and self-interpretation were used to interpret the data and reflect the overall geological features and needed information of the study region.

Hydrogeological data was utilized to confirm petrographic data in terms of rock names and classifications, by analyzing porosity and permeability.

Petrographic analysis was one of the data analysis processes and went through two steps. The first step involved macroscopic observation through hand specimen analysis, with the microscope used as equipment to observe the mineral. The petrography process continued with thin section analysis, where the rock sample was cut and thinned on a glass slide.

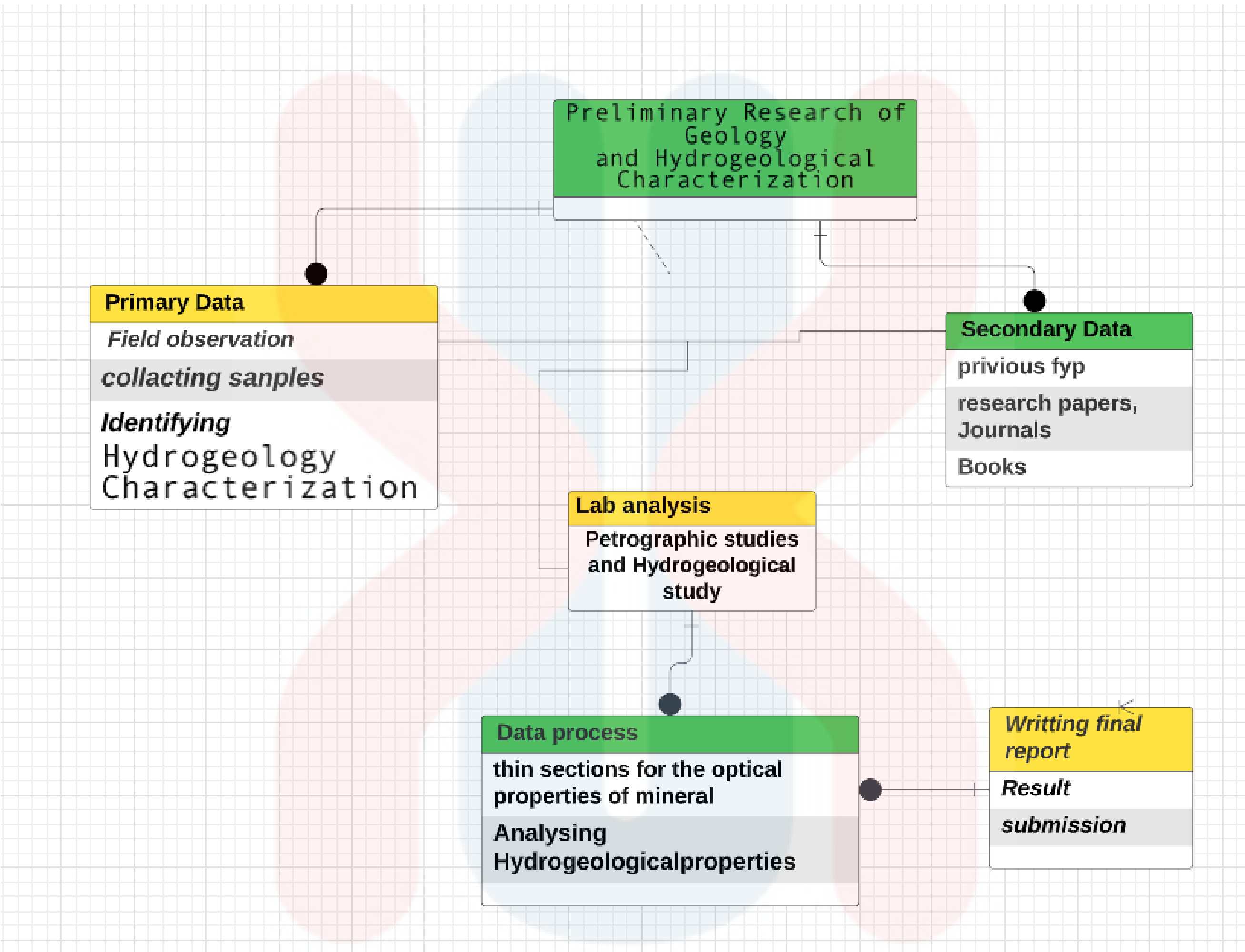


Figure 12: Flow chart of the research

3.4. Field Studies

I. Mapping

In the field study of mapping, the first step was traversing. This involved walking along the road and river and observing the study area. All the information gathered during traversing was recorded in the field notes, along with ground photos taken throughout the study area. This method provided an overall view and precise details about the area, which was necessary for the next phase of detailed mapping and to complete the geological map.

During traversing, the coordinates of the outcrop were recorded, and any sedimentary and tectonic structures such as bedding, faulting, folding, fracture and joint were observed. The dip and strike readings of all these structures were taken using a compass. The fracture and joint readings were used to produce a rose diagram.

Moreover, this method can also help study land use, topography, and drainage patterns. It can also be useful in identifying the location of hydrological features such as aquifers.

3.5.Laboratory Investigations

Laboratory investigation for this research project was divided into two parts which are general geology which include the thin section and the identification of minerals under the microscope. Thin section process is needed in order to the types of rocks for the samples taken in the field based on its mineral content.

I. ArcGIS software

In the steps of producing a complete and detailed geological map of the study area, all information obtained from mapping is inserted in ArcGIS software. Thus, all the information about the geological features was plotted on this new map. The software also has a complete tool that can help researchers to insert any geological data to represent the map. In addition, the potential map for the hydrological potential location will be produced based on the map produced.

II. Thin Section

Using the rock sample that has been taken from the field, a thin section slide is done for analysis and interpretation under the microscope to proceed to the next step. The process of making thin sections is explained in the next section.

a. Prepare the glass slide

The rock sample will be glued to the glass slide to be flatten for the rock section to end up with a constant thickness. To achieve this, the slide must be ‘frost’ which two goals can be accomplished, that are: remove the thick spot on the slide and the face slide is adjusted to be parallel to the grinding whell’s face.

b. Frost the glass slide

'Frost' or grind the glass slide is for the purpose to flatten out and roughen the surface so that the epoxy can bind well together. The slide is placed on the grinder in the same orientation to achieve the flat and rough surface.

c. Mark the sample

For rocks that have fabrics, decision must be made on where to cut the rock sample. Usually, the rock sample is cut on the perpendicular plane for any planar fabric. However, for particular purpose, other orientation might be preferable. A line should be marked on the rock for guidelines.

III. Petrography Analysis

From the thin section that has been done in the laboratory investigation process, the finished thin section is interpreted. This process is crucial to determine the type of rock, the minerals content that made up the rock mineral is at the study area to name the rock, what its parent rock and others. By observing igneous rock under the petrographic microscope, a specific interlocking texture with slow crystallization from a melt can be seen. Without knowing how to recognize, describe, organize and analyze the textures, the origin of the rocks cannot be studied.

Petrography analysis is important to identify the type of rocks accurately.

IV. HYDROGEOLOGICAL CHARACTERIZATION

The hydrogeological characterization analysis was conducted using a hand specimen of rock and measurements of porosity and permeability. The study involved the collection of rock samples from the study area, and subsequent laboratory analysis to determine the porosity and permeability of the rocks. The findings of the study revealed that the rocks in the area had varying degrees of porosity and permeability, which could have significant implications for the movement of water through the subsurface. The use of hand specimen analysis and laboratory measurements allowed for a detailed understanding of the hydrogeological properties of the rocks, which could be used to inform groundwater resource management decisions. Overall, the study demonstrated the importance of detailed laboratory analysis in hydrogeological characterization studies.

Chapter 4

GENERAL GEOLOGY

4.1 Introduction

This research has been conducted in Paloh, Gua Musang, Kelantan which is 50 km away from Gua Musang town. The study area covers 25 km^2 of the total area, located in the southern part of Gua Musang. The study will focus on describing the geomorphology, stratigraphy, structural geology, and historical geology of the area. This chapter will provide an overview of the general geology of the research area. The base map of the study area is shown in Figure 4.1.

4.2 Geomorphology

Geomorphology is the scientific study of landforms and the processes that shape them. The processes that shape landforms include erosion by wind, water, ice, and the depositional process of laying down material that has been eroded. Understanding geomorphology and its processes is crucial for understanding physical geology. The geomorphology that will be discussed in this research includes the topography, drainage system, and weathering processes of the study area.

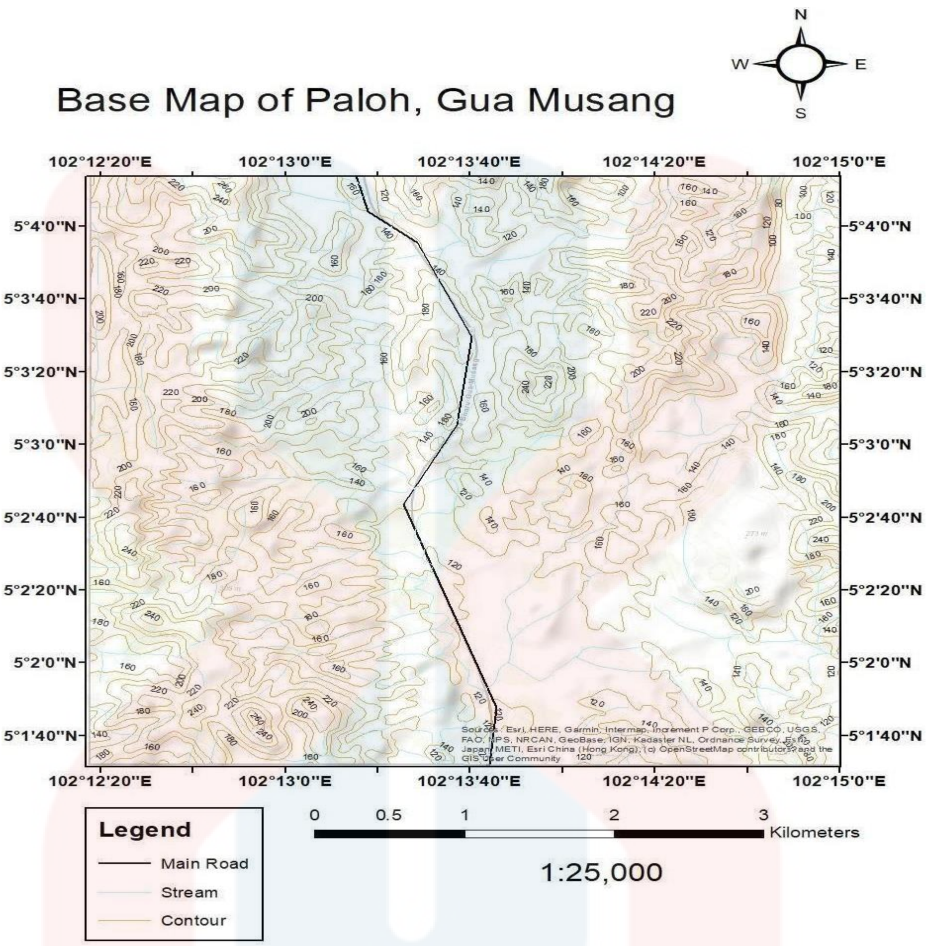


Figure 4.1: Base Map of gua musang paloh

4.2.1 Topography

Topography refers to the physical features of a surface area, including relative elevations and the position of natural and man-made features. It is a field of earth science that studies the surface and features of the Earth and other observable astronomical objects like planets, moons, and asteroids. It involves recording the relief of the terrain, the three-dimensional (3D) quality of the surface, and identifying specific landforms.

The study area is characterized by small hills located in the western and eastern parts of the study area, with elevations of 280 meters and 140 meters respectively. Most of the residential areas are concentrated in the northwest, northern, and northeast of the study area, and the houses are mostly built along the roads for easier access. The main roads extend from west to east. The topography map of the study area is provided in Figure 4.2, and the geomorphology map is displayed in Figure 4.3. The geomorphology map describes the elevations of the hills in the study area.

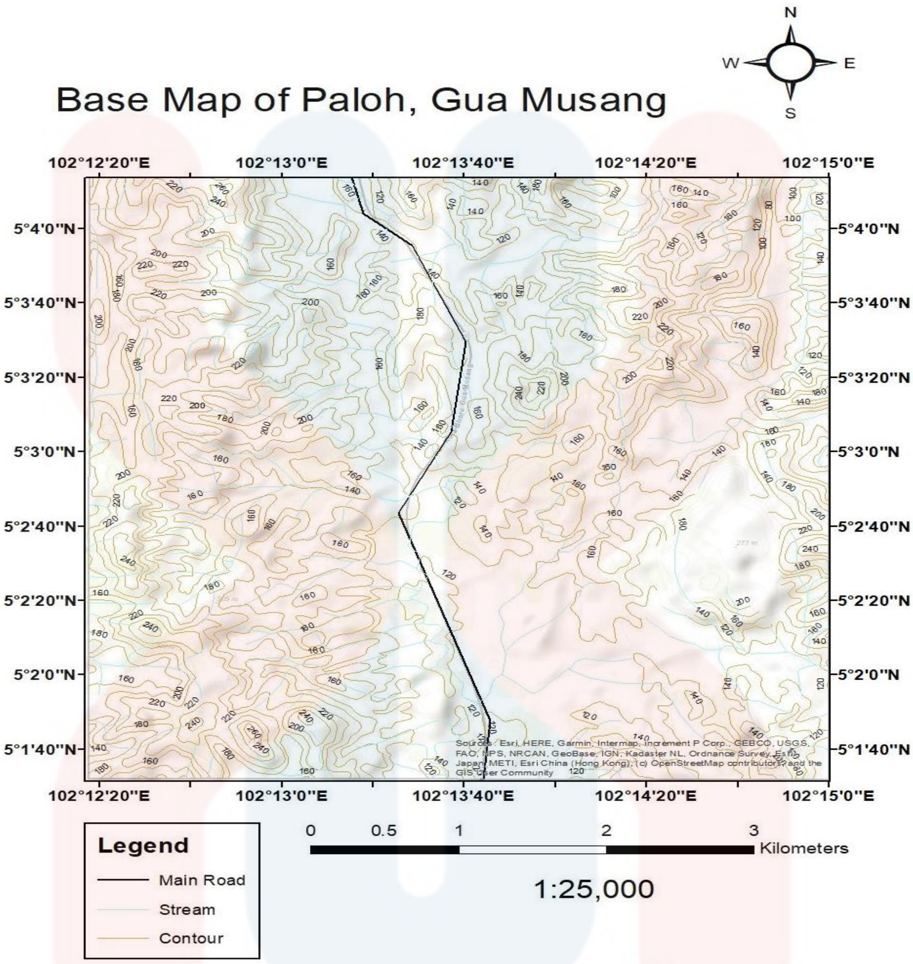


Figure 4.2: 2–Dimensional topography map of paloh Gua musang

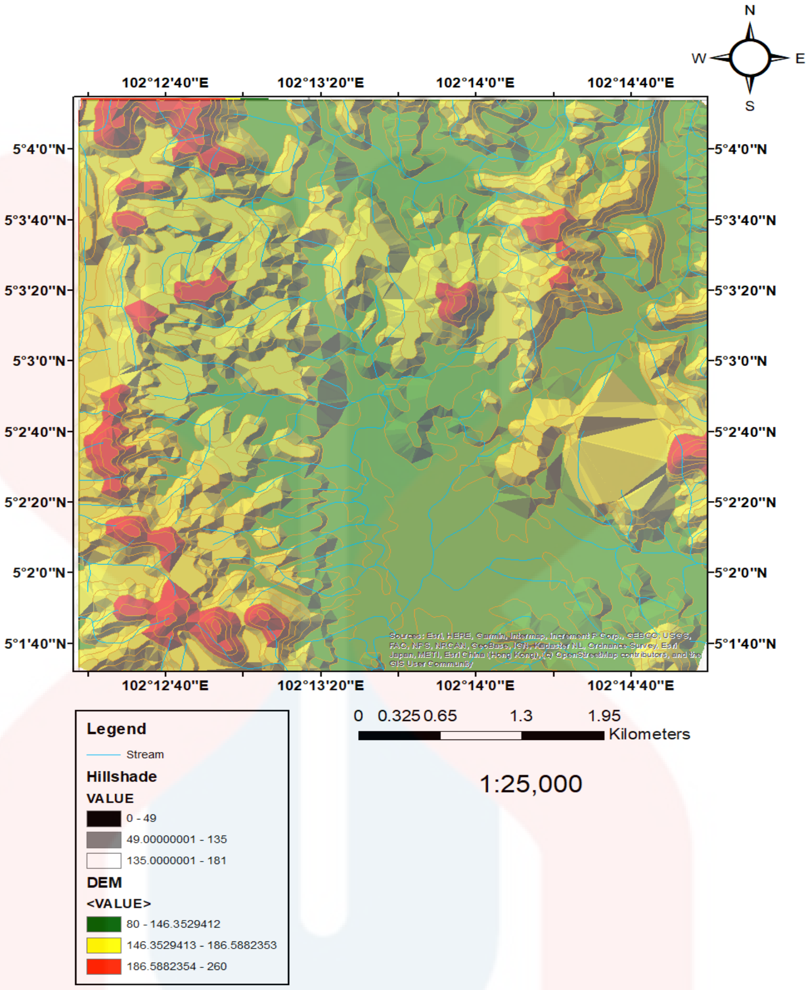


Figure 4.3: Topographic map of Paloh Gua Musang

The highest relief marked at the study area is 260 meters which are located in the western part of the study area. The highest elevation indicates around A GMKL AGRO PARK. The next hills found in the study area have an elevation of 140 meters, are located in the eastern part of the study area and it is Near C Gmkl agro park.

The lowest part of the study area, marked at the study area around 0 – 49 meters as shown in Figure 4.3 indicates the residential area or the urbanization area which is a flat landform indicates that the area is not hilly.

4.2.2 Drainage Pattern

The drainage pattern is an important aspect of geomorphology. A drainage system is the pattern formed by the streams, rivers, and lakes in a particular drainage basin. It is governed by the topography of the land, including the presence of hard or soft rocks and the gradient of the land. A drainage basin is a topographic region from which a stream receives runoff through flow and groundwater flow. According to the configuration of channels, drainage systems can fall into one of several categories known as drainage patterns or systems.

There are several types of drainage systems according to their patterns. They can be classified into several types, such as dendritic, parallel, trellis, rectangular, radial, centripetal, deranged, annular, and discordant depending on the topography and the geology of the land. Different patterns can indicate different geomorphology.

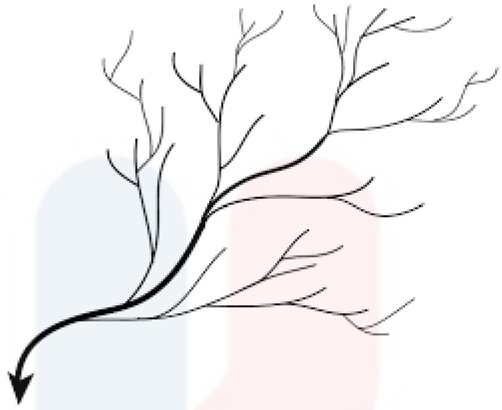


Figure 4.4: Dendritic drainage patterns

Most of the drainage patterns found in the study area are dendritic drainage patterns (Figure 4.4). Dendritic systems are the most common form of drainage systems in the world. They develop where the river channel follows the slope of the terrain and consist of many contributing streams that join together into the main river.

The parallel drainage system is a pattern of rivers caused by steep slopes with some relief (Figure 4.5). Due to the steep slopes, the streams are swift and straight with very few streams flowing into the main river, and all of them are in the same direction. The study area has a sub-parallel drainage system due to the steep slopes of the streams.

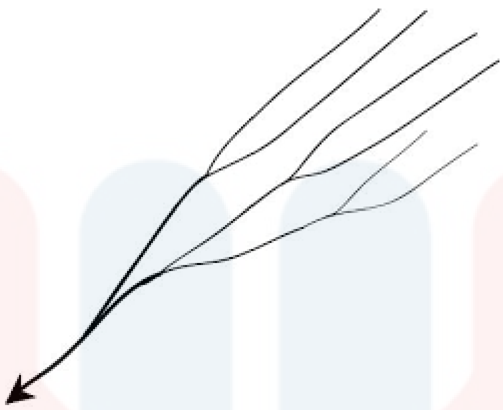


Figure 4.5: Parallel drainage patterns

Two types of rivers can be classified based on the drainage map of the study area (Figure 4.6). Both are recognized as streams. The flow of the river is from the South towards the North of the study area, where water in a river will flow from higher elevations towards lower elevations. This is due to the fact that lower elevations are found in the Northern part of the study area and higher elevations are found in the Southern part of the study area. Many streams can also be found in the study area which are located on the left side, in the South-West of the study area and begin flowing from higher elevations to lower elevations into the main river. Most of the drainage patterns are shown by the streams.

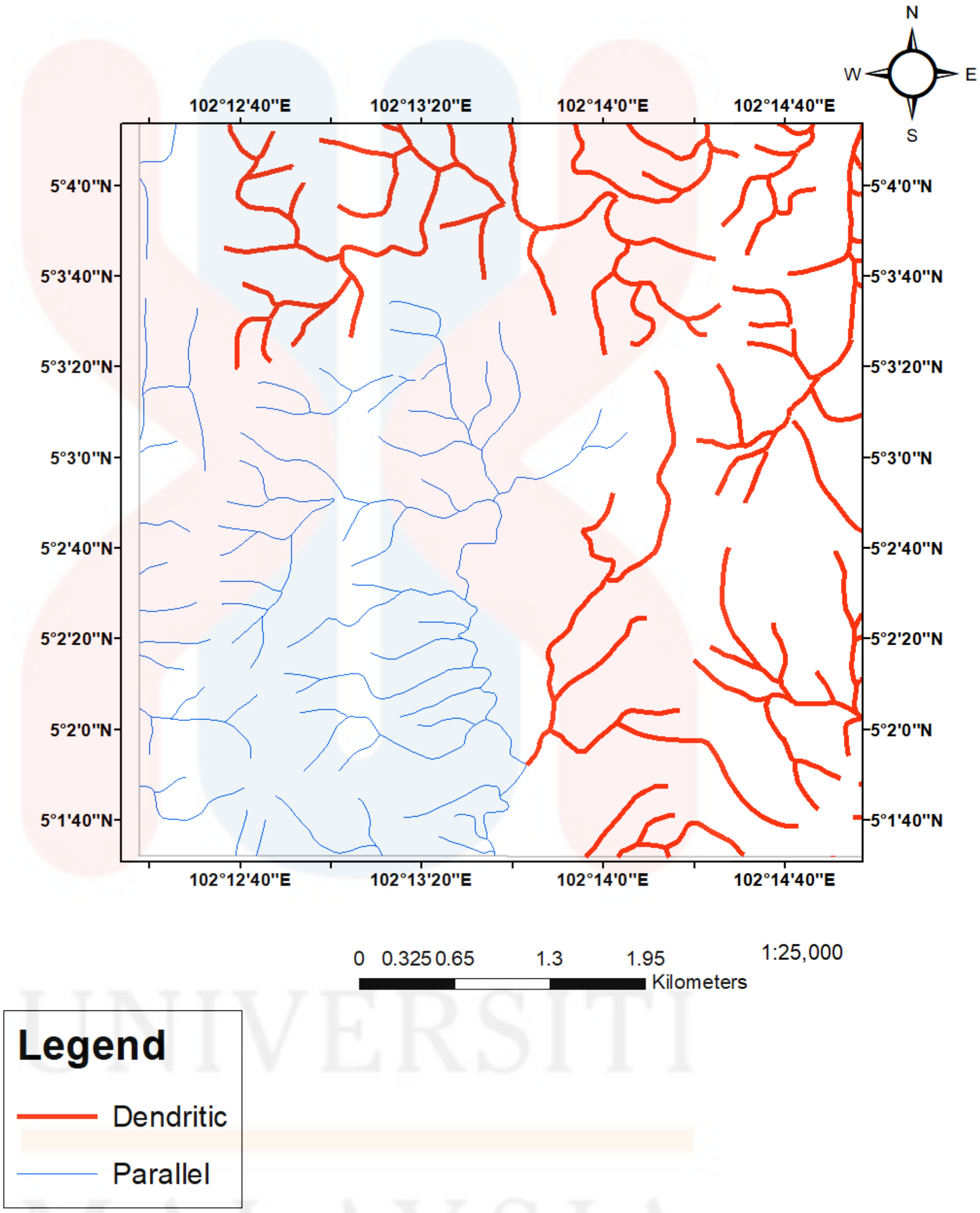


Figure 4.6: Drainage patterns in paloh Gua musang

The dendritic pattern in the study area occurs when the tributary system, such as the tree branches, becomes divided. This pattern is due to the rock's mass being reasonably homogeneous and usually forms in horizontal sedimentary or in intrusive igneous rocks such as granite in the study area. The dendritic pattern drainage tends to become subparallel and join at an acute angle. This type of drainage pattern will be disturbed or interfered with when there is any marked structure such as joints or faulting. The dendritic drainage pattern is characterized by a branching network of streams and rivers that resemble the branches of a tree. This pattern typically develops in areas with homogeneous rock types, such as horizontal sedimentary rocks or intrusions of igneous rocks. In the study area, the dendritic pattern is likely formed in granite rocks. This dendritic pattern is characterized by subparallel streams that join at acute angles. However, this pattern can be disrupted or altered by the presence of structures such as joints or faults in the rock. When these structures are present, they can cause the streams to follow a different path, resulting in a different drainage pattern.

4.2.3 Weathering Process

Weathering is a natural process that occurs over time and is responsible for breaking down rocks, soils, and minerals as well as artificial materials through contact with the Earth's atmosphere and waters. The process of weathering can be divided into three main categories: mechanical or physical weathering, chemical weathering, and biological weathering. It's important to note that weathering should not be confused with erosion, which is the process by which rocks and minerals are moved by agents such as water, wind, ice, snow, waves, and gravity. Weathering can weaken and change the state of the rock, making it easier to erode. Weathering can occur in situ, meaning that the rock is not moved, but the change in the rock's physical and chemical properties can still occur.

Physical weathering, also known as mechanical weathering, is the process by which rocks, minerals, and soils disintegrate without undergoing chemical change. This process can be caused by a variety of factors such as temperature changes, pressure, frost, root movement, and burrowing animals. The most common process in physical weathering is abrasion, which is the reduction of size of clasts and particles.

Physical weathering can increase the surface area exposed to chemical activity, thus accelerating the pace of disintegration. For example, when rocks are exposed to extreme temperatures, they may expand and contract, causing them to crack and break apart. This process can also be assisted by water, whether it is from rain or nearby streams. Physical weathering can be seen in the formation of boulders, gravel, and sand from larger rock formations.

Physical weathering can also cause changes in the shape and texture of rocks. For example, rounded edges and smooth surfaces are often the result of physical weathering caused by water and wind erosion. Physical weathering can also result in the formation of rock formations such as hoodoos and spires, which are shaped by the erosional forces of wind and water. Overall, physical weathering is an important process in the natural breakdown and alteration of rocks and minerals, and plays a significant role in shaping the landscape.

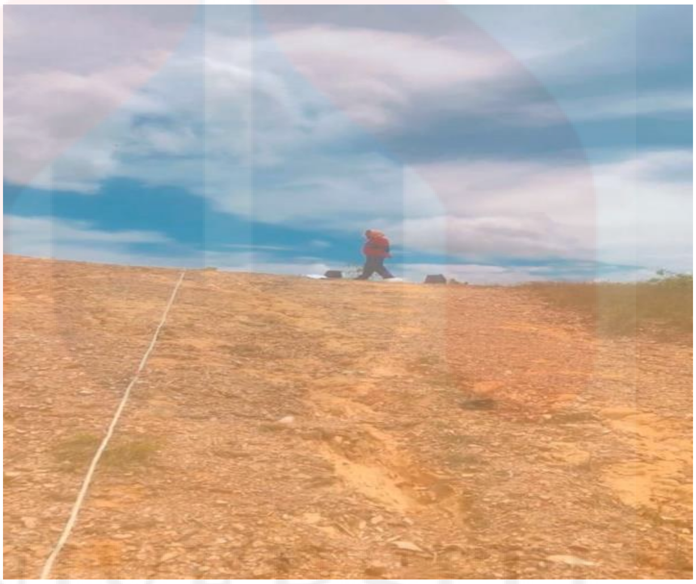


Figure 4.7: Physical weathering that is caused by the change in temperature

Other than that, Biological weathering refers to the breakdown of rock and soil materials by living organisms, such as plants, animals, and microorganisms. In Paloh, Gua Musang, biological weathering can occur through a variety of processes, including the root growth of plants, which can physically break down rock and soil materials as they grow; the burrowing and digging of animals, which can create channels and tunnels through rock and soil; and the action of microorganisms, which can release acids and other substances that can corrode and dissolve rock and soil materials.

Plants can play a particularly significant role in biological weathering, as their root systems can physically break down rock and soil materials and create channels for water and other substances to flow through. For example, tree roots can grow into and break up rocks, and the dead plant material that accumulates around the roots can also contribute to the breakdown of rock and soil materials through decomposition.

Overall, the impact of biological weathering on the geology of Paloh, Gua Musang will depend on the types of plants and animals present in the area, as well as the local climate and other environmental conditions Figure 4.8 and Figure 4.9.

Figure 4.8: Biological weathering that is caused by a plant's root

Figure 4.9: Another biological weathering that is caused by a plant's roots

Figure 4.8 and Figure 4.9 the biological weathering found in the study area. From the photograph, it can be seen that the roots had penetrated into the rock ca the soil to be disintegrated. The roots are moving downwards as it is looking for water and minerals. As time goes by, this action will cause the soil to fall and cause soil flows or landslides.

4.3.1 Structural Geology

In the study area, several structrual have been identified. The Gua Musang Formation is comprising of mainly three members; (i) argillaceous facies, mudstone, and pelitic hornfel, (ii) slate and phyllite, (iii) sandstone and metasandstone rocks. Understanding the structural geology of the study area is essential in understanding the regional geologic past and interpreting the geomorphology and topography of the area.

4.3.2 Lineament Analysis

Lineament is a linear fracture in a landscape which is an expression of an underlying geological structure such as a fault. Fracture zones, shear zones, and igneous intrusion such as dyke can also give rise to lineaments. These lineaments can be appearing obvious in aerial or satellite photographs while in geological maps or topographic maps, lineaments are often seeming apparent. Based on Table 5.1, the strike and dip data that have been obtained from the lineament analysis are used in the GeoRose software in order to obtain the Rose diagram for lineament analysis.

Table 5.1 shows the data obtained in the study area

Strike	**Dip**	**Strike**	**Dip**
300	80	276	44
310	64	250	72
226	78	114	76
220	74	12	60
266	50	19	66
86	70	352	66
108	40	274	42
96	70	152	66

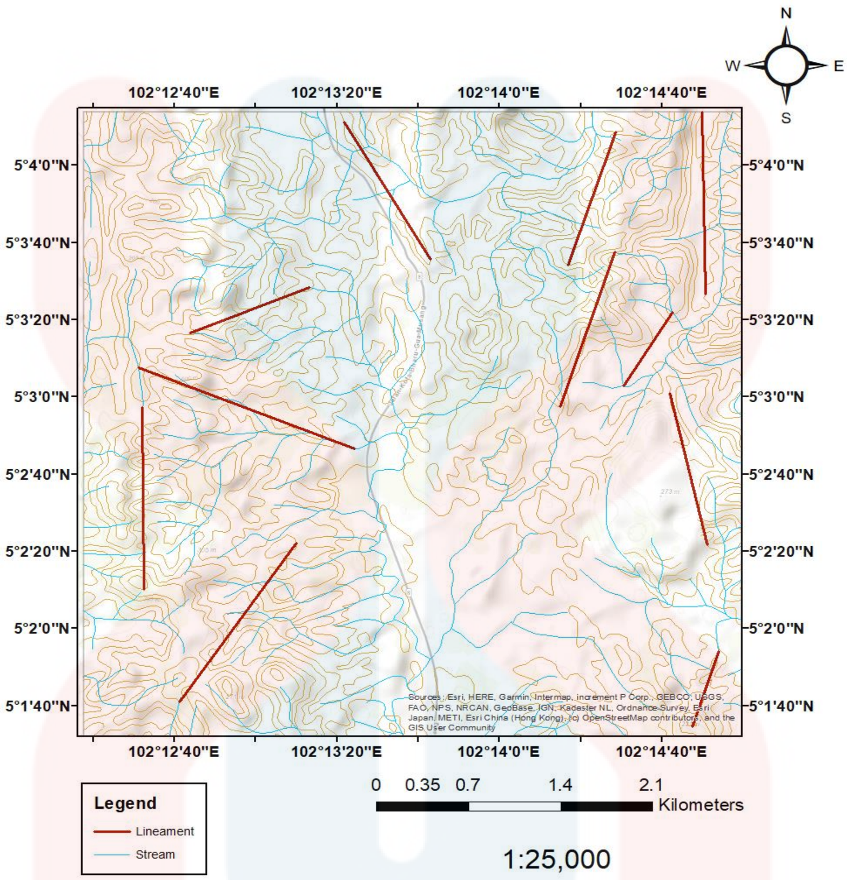


Figure 4.10: Regional lineament of Paloh Gua musang and its vicinity.

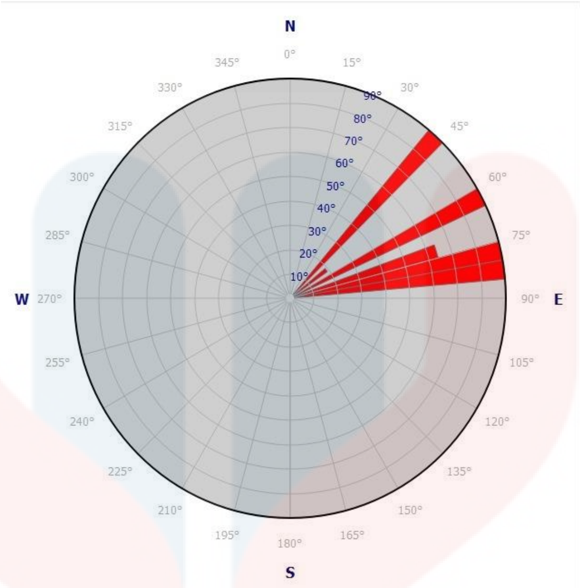


Figure:4.11. show dip direction

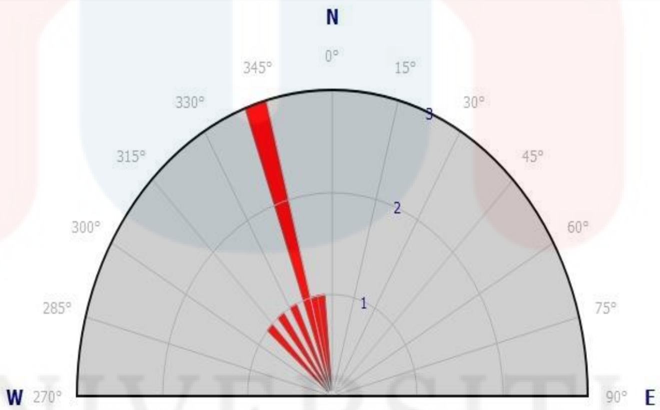


Figure:4.12 shows the Strike Data

The strikes of the rock layers or faults range from 19 to 352 degrees, with the majority falling between 300 and 310 degrees and 220 and 226 degrees. This suggests that the layers or faults are generally oriented in a northwest-southeast direction.

The dips of the layers or faults range from 40 to 80 degrees, with the majority falling between 50 and 74 degrees. This indicates that the layers or faults are generally inclined downward from the horizontal.

The strikes and dips of the layers or faults are fairly consistent, with only a few outlying values. This suggests that the layers or faults are relatively uniform in orientation. The strikes and dips of the layers or faults are not perfectly aligned, but there are some trends in the data. For example, the strikes of the layers or faults that dip more steeply (i.e., those with dips greater than 60 degrees) tend to be closer to 300 degrees, while those that dip more shallowly tend to be closer to 270 degrees. This suggests that the layers or faults may be affected by different tectonic forces or processes.

Overall, these observations helped to understand the orientation and inclination of the rock layers or faults and can provide insights into the geology of the area. However, it is important to keep in mind that these interpretations are based on a limited dataset, and more detailed analysis may be necessary to fully understand the geology of the area.

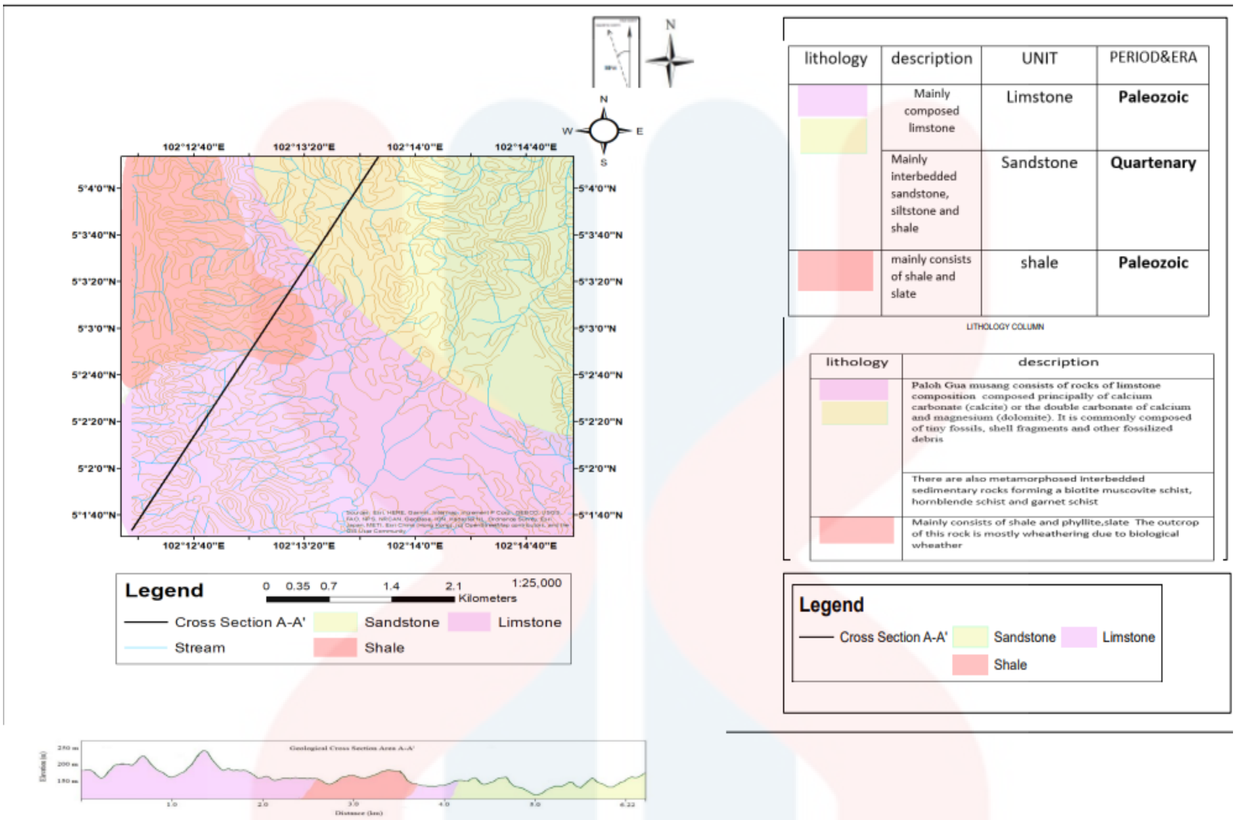


Figure 4.13: Geology map of Paloh Gua musang

4.4 Stratigraphy

In the study area, there are several main types of rock that are present which are limestone, sandstone, and shale, the sedimentary rocks that are present in limestone are majorly found in the study area while the igneous rocks that are present in the study area such a quartz (Figure 4.12).

Limestone is a sedimentary rock that is formed from the accumulation of shells, bones, and other calcium-rich materials. It is often white or light in color, but can also be gray, brown, or black. Limestone is composed of the mineral calcite, a calcium carbonate form.

Sandstone is a sedimentary rock that is composed of small grains of sand that are cemented together. It is usually composed of quartz, but can also contain other minerals such as feldspar and mica. Sandstone can range in color from white to gray to red, depending on the minerals present and the conditions under which it was formed.

Shale is a fine-grained sedimentary rock that is composed of clay and other minerals. It is usually formed from the compacted remains of mud or clay that has been deposited on the floor of a lake or ocean. Shale is often gray or black in color, but can also be brown or green. It is a common rock type and is often found in layers or formations.

Figure: 4.14: Handspecimen of limestone

Figure: 4.14: Handspecimen of limestone located at N05°02’44.36 E102° 14' 29.83 '' this specimen is collected. The color of this hand specimen from the surface is white-gray due to the biological weathering that is algae. The texture is small and the mineral can’t be seen by the naked eye. The outcrop is well-exposed in the cave. It is hard to obtain a fresh specimen due to the biological weathering that is caused by the flow of the water in the streams as shown in Figure 4.15.

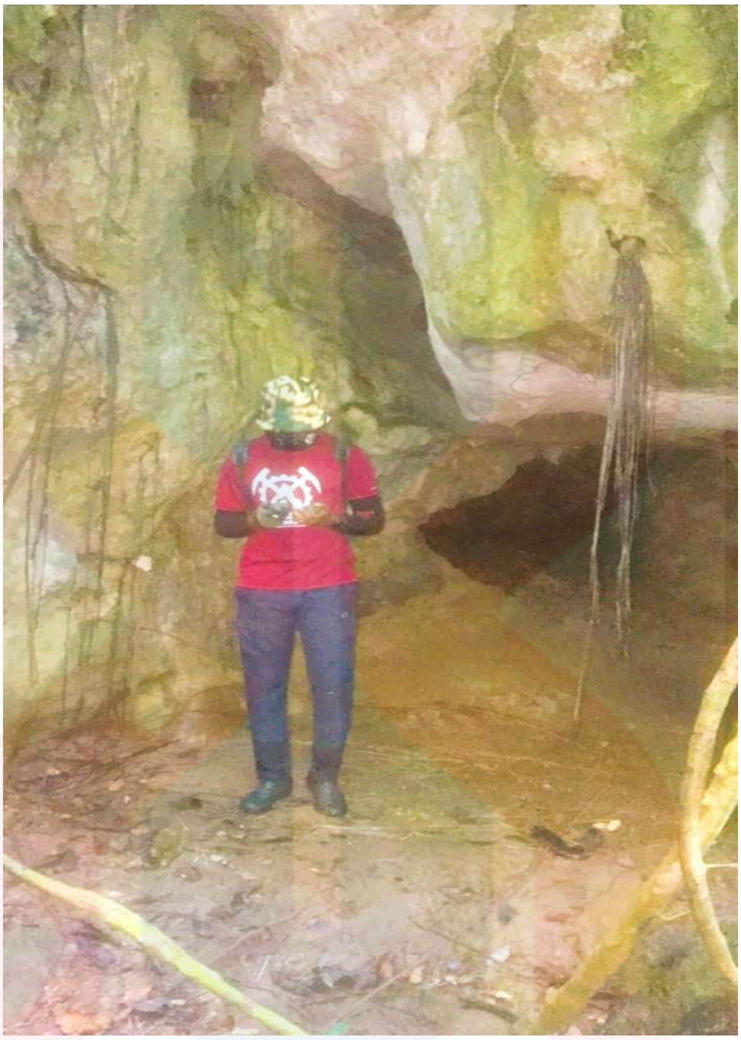


Figure: 4.15: an outcrop of limestone Cave

Thin section 1

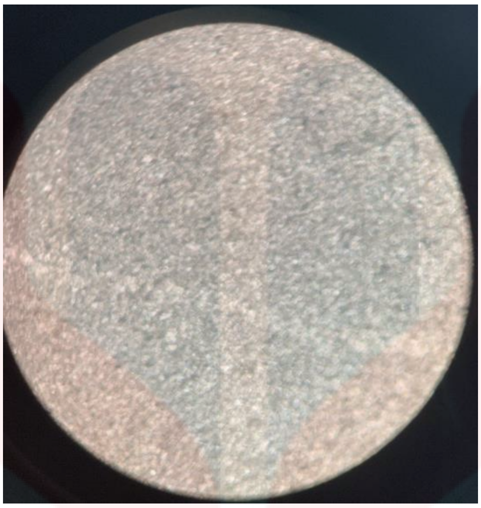


Figure 4.16: Plane Polarized of limestone

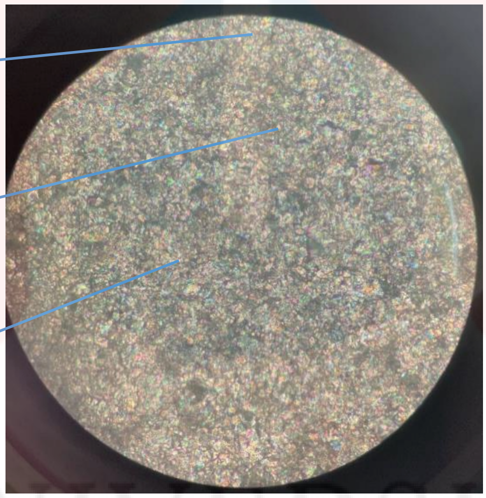


Figure 4.17: XPL Polarized limestone

The dominant mineral in limestone is usually calcite. Limestone is a type of sedimentary rock that is formed from the compaction and cementation of the remains of marine organisms, such as coral, foraminifera, and mollusks. These organisms secrete calcium carbonate, which combines with other minerals to form calcite. Calcite is a common mineral that is found in many types of rock, including limestone and is composed of calcium, carbon, and oxygen. Limestone can also contain other minerals, such as dolomite, quartz, and feldspar, but calcite is usually the most abundant mineral in the rock. The specific mineral composition of limestone can vary depending on the conditions under which it was formed and the types of minerals that were present in the sediment that was compacted to form the rock

Figure:4.17 a hand specimen of shale

Figure 4.17 hand specimen found at N05°02’03.8 E102°14’29.2 Black shale is a type of shale that is characterized by its dark color, which is black or very dark gray. It is a fine-grained sedimentary rock that is composed mainly of clay minerals, as well as small amounts of other minerals such as quartz and feldspar.

Figure:4.18 shows an outcrop of shale

Figure 4.18 shows An outcrop of shale that has been affected by biological weathering and shows a variety of signs of this process. Some possible features that can be seen include:

Plant roots: Shale that has been broken down by plant roots show visible cracks or fractures, or may have a "swirled" or "rooted" appearance.

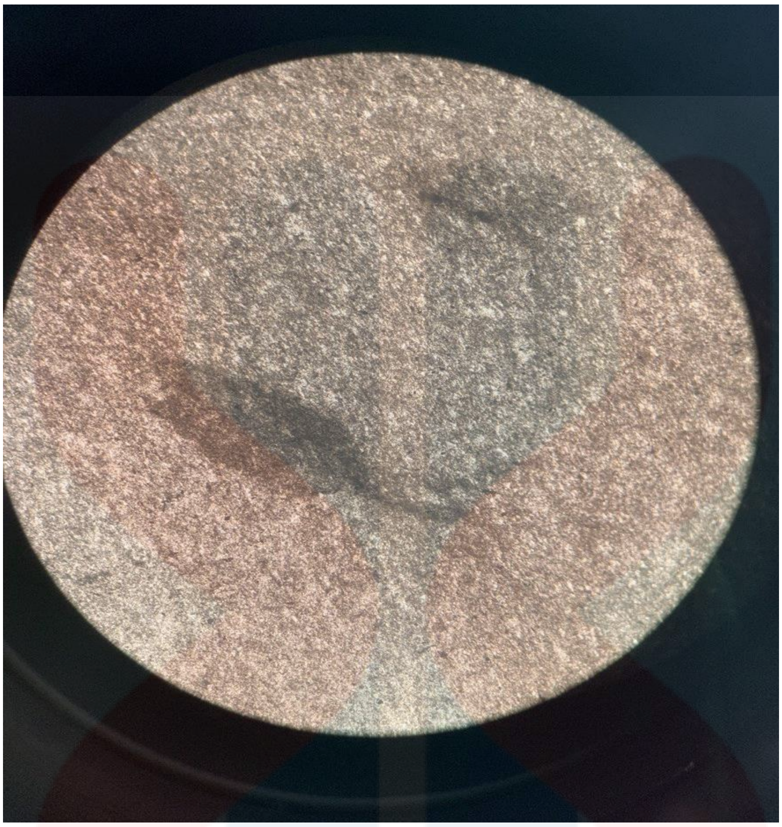


Figure 4.119: Plane Polarized of shale

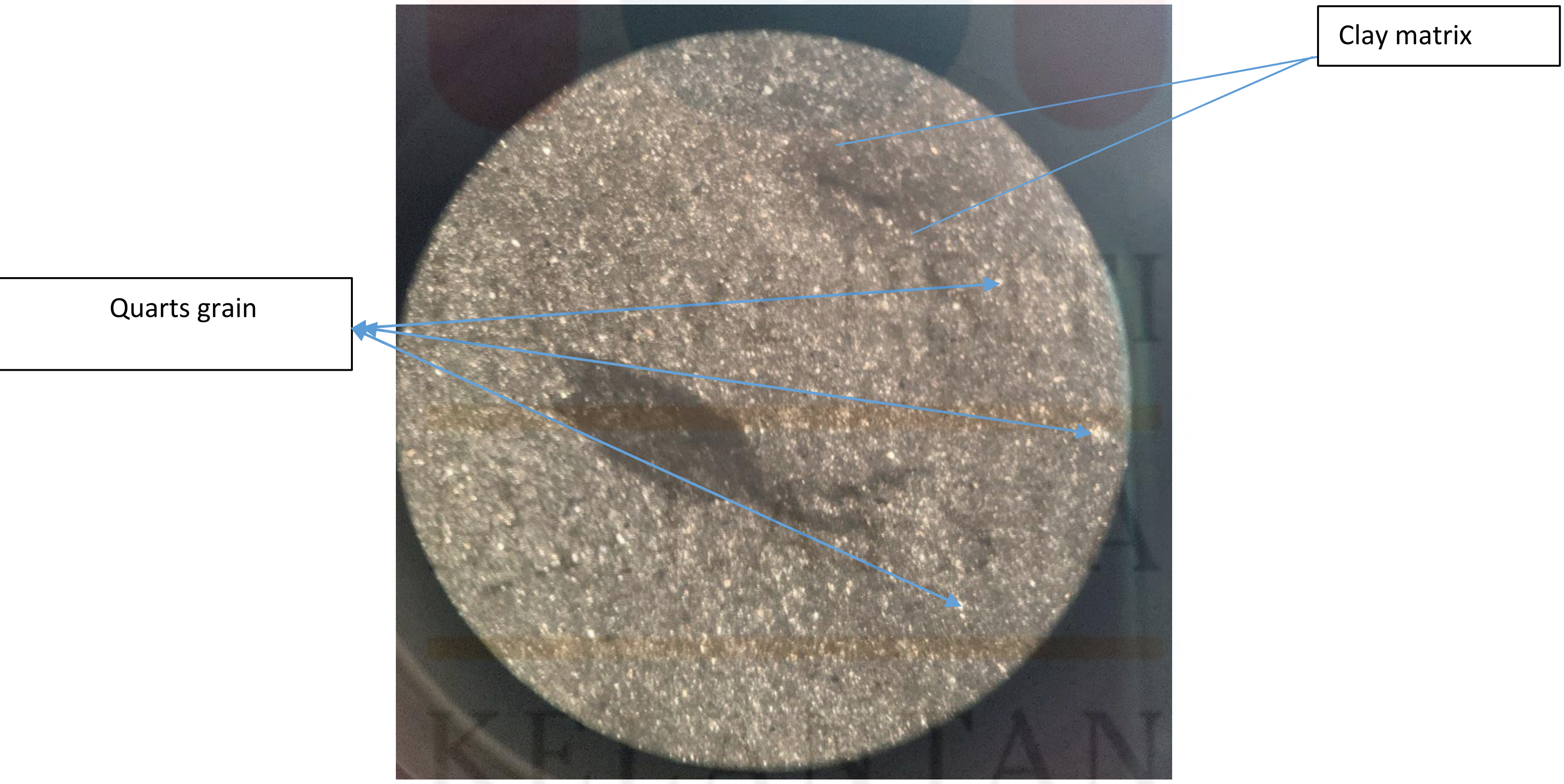


Figure 4.20: XPL Polarized shale

The dominant mineral in shale is typically clay. Shale is a type of sedimentary rock that is formed from the compaction and cementation of clay and other fine-grained minerals. Clay minerals are typically the most abundant minerals in shale, although shale can also contain quartz, feldspar, and other minerals. The specific mineral composition of shale can vary depending on the conditions under which it was formed and the types of minerals that were present in the sediment that was compacted to form the rock.

SAMPLE 3 SANDSTONE

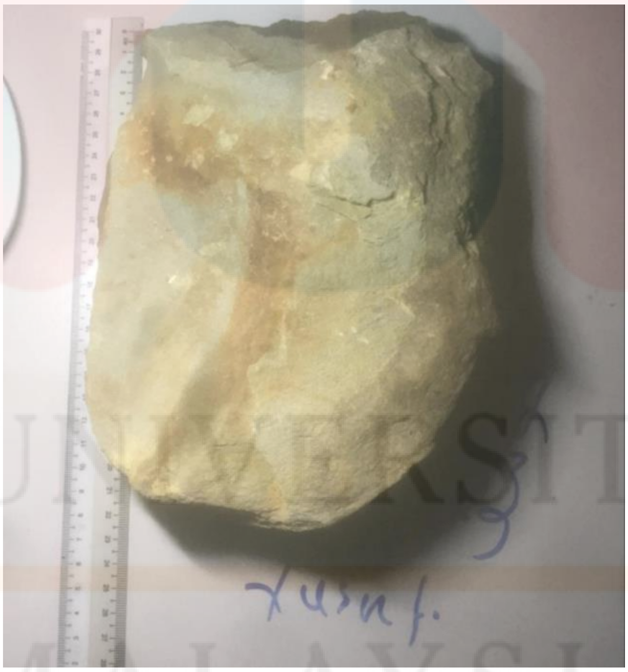


Figure:4.20 shows a hand specimen of sandstone

Figure 4.20 shows the hand specimen of sandstone. Which is composed of sand-sized grains of minerals or rocks. It is typically formed in a range of colors, including white to gray,

White to gray sandstone can be made up of a variety of minerals, including quartz, feldspar, and calcite. It may also contain trace amounts of other minerals, such as clay, iron oxide, and gypsum.

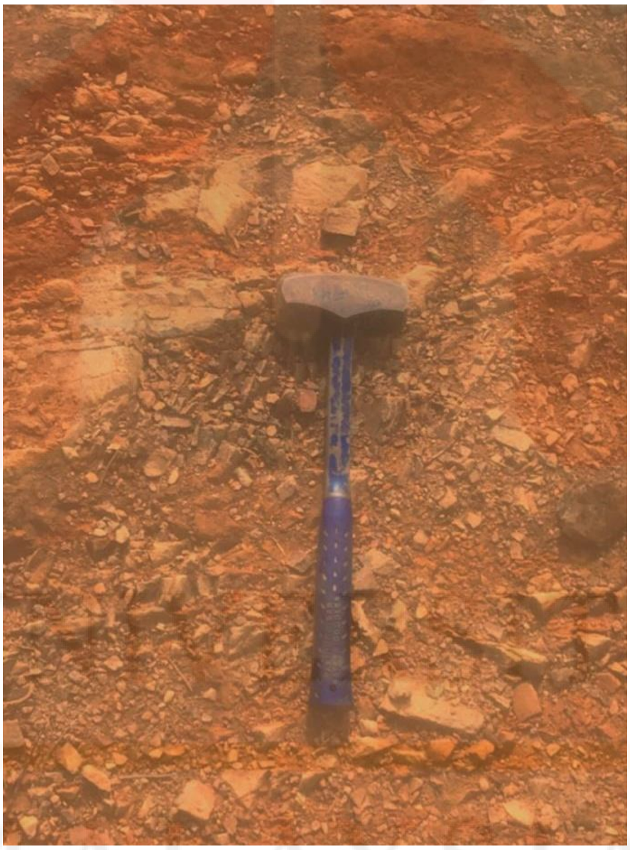


Figure:4.23 shows an outcrop of sandstone

Figure 4.23 shows that this Sandstone is a type of rock made up of sand-sized particles of minerals, rock, or organic material.

In this outcrop, Hot weather is caused to weather more quickly due to the increased temperature and dryness of the air. High temperatures can cause the minerals in the sandstone to expand, leading to cracks and fractures in the rock. Hot and dry conditions can also cause the water in the pores of the sandstone to evaporate, leading to further drying and cracking.

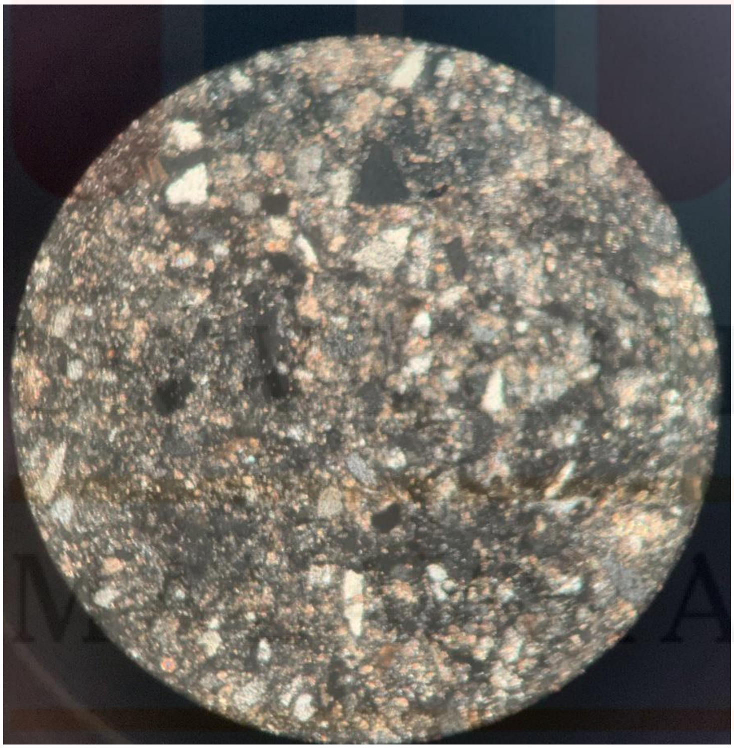


Figure 4.24: PL Polarized sandstone

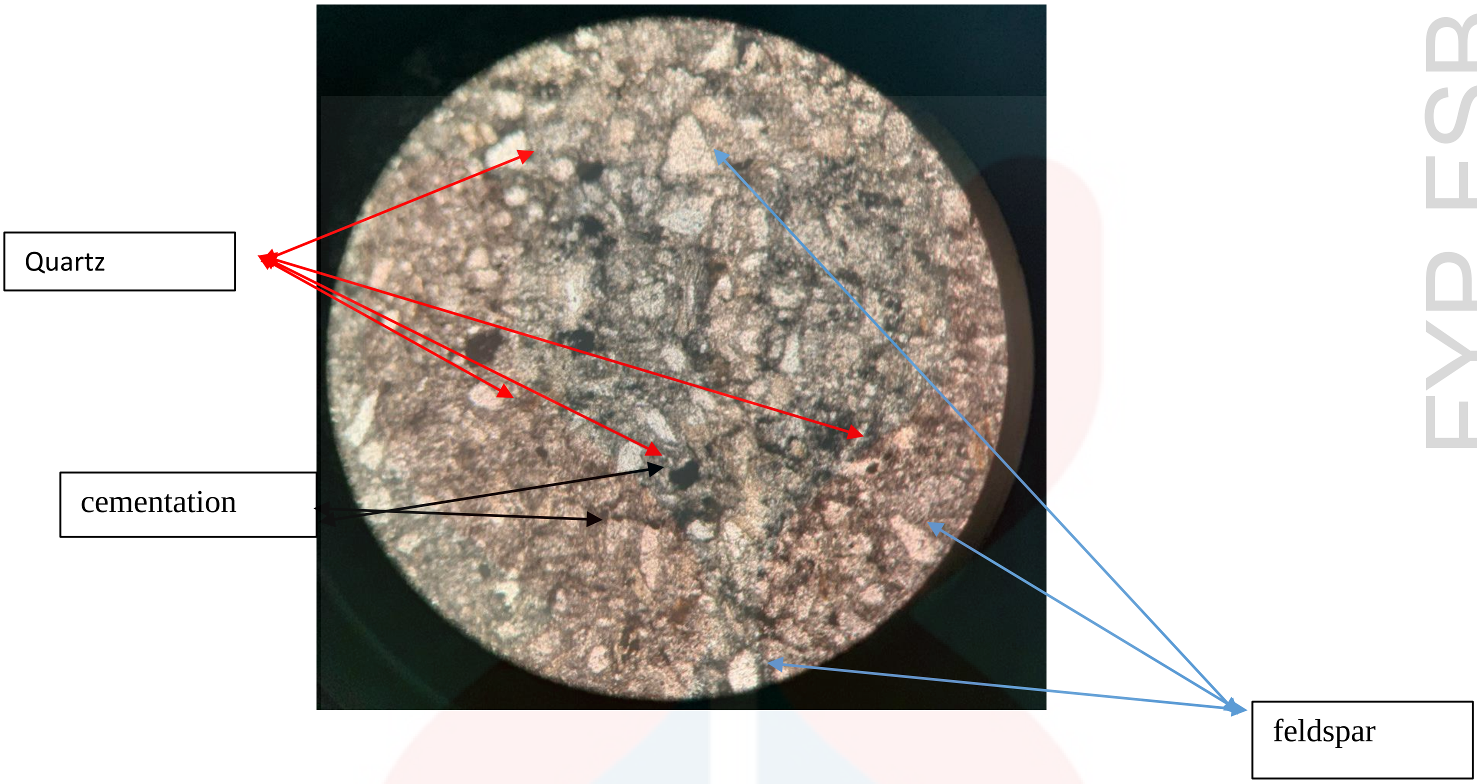


Figure 4.25: XPL Polarized sandstone

The dominant mineral in sandstone is usually quartz. Sandstone is a type of sedimentary rock that is formed from the compaction and cementation of sand-sized particles of minerals, rock fragments, and organic material. Quartz is a hard, crystalline mineral that is resistant to weathering and is commonly found in sandstone. Sandstone can also contain other minerals, such as feldspar, mica, and clay, but quartz is usually the most abundant mineral in the rock. The specific mineral composition of sandstone can vary depending on the conditions under which it was formed and the types of minerals that were present in the sediment that was compacted to form the rock.

CHAPTER 5

Hydrogeological characterization in Paloh Gua musang

5.1 Introduction

This chapter explains the Hydrogeological characterization of the study place which involves the study of the hydrogeology of the study area. Rock sampling is a widely-used technique in hydrogeological characterization that enables researchers to obtain valuable information about the geological and hydrological properties of an area. Through the collection of rock samples from different locations within the study area, this thesis conducts laboratory analysis to determine the physical characteristics of the rock formations. This information is essential in understanding the area's hydrogeology, such as its porosity and permeability, and how water is likely to move through the different rock formations. The results of this study contribute to the overall knowledge of the geology and hydrological properties of the area, which can further inform groundwater management and remediation efforts.

Sandstone, limestone, and shale, are all common rock types that have been found in a hydrogeological characterization project in Gua Musang Paloh. these rock types can affect the movement of water in the ground in different ways.

I collected limestone, shale, and sandstone rocks from different locations within the study area to determine their suitability as potential Aquifer, Aquitard, Aquiclude and Aquifuge for groundwater resources. I measured their porosity and permeability hydrological properties using the fallowing laboratory techniques.

Porosity is a measure of the volume of empty spaces (pores) in a material, compared to its total volume.

To estimate the porosity of a rock sample using a beaker and water:

First need to Measure the weight of the dry rock sample and record it as "W1". Fill beaker with a known volume of water, and record the volume as "V1". Next I place the rock sample into the beaker of water, ensuring that it is fully submerged. I allow the rock sample to soak in the water for a 30 minutes to ensure that all the air trapped in the pores is replaced by water. After that i removed the rock sample from the beaker and allow any excess water to drain off and then Measured the weight of the saturated rock sample and record it as "W2".

used this formula to calculate the porosity of the samples:

$$\text{Porosity} = (1 - W2 / W1) \times V1$$

Where:

W1 is the weight of the dry rock sample

W2 is the weight of the saturated rock sample

V1 is the volume of water in the beaker

By subtracting the weight of the saturated rock sample from the weight of the dry rock sample, you can determine the volume of water that the rock sample displaced. Dividing this volume by the total volume of the rock sample gives you the porosity of the sample as a percentage.

After analyzing the porosity and permeability of the rocks the results to assess the hydrological properties of the rocks and their suitability as potential aquifers. I found that limestone was highly porous and permeable, which makes it a good candidate for groundwater storage and extraction. In contrast, shale was found to be less porous and permeable, which makes it less suitable for aquifer development. The porosity and permeability of sandstone were found to be more variable, but it can also be a good candidate for groundwater storage and extraction if the properties are suitable.

In conclusion, measuring the porosity and permeability of rocks is an important step in evaluating their potential as aquifers for groundwater resources, and I was able to provide critical information on how water flows through the rocks and how much water they can hold.

5.2 MEASURING THE PROPERTIES OF THE ROCKS

Figure 5.1: the weight of dry shale sample

Figure 5.2: the samples to soak in the water

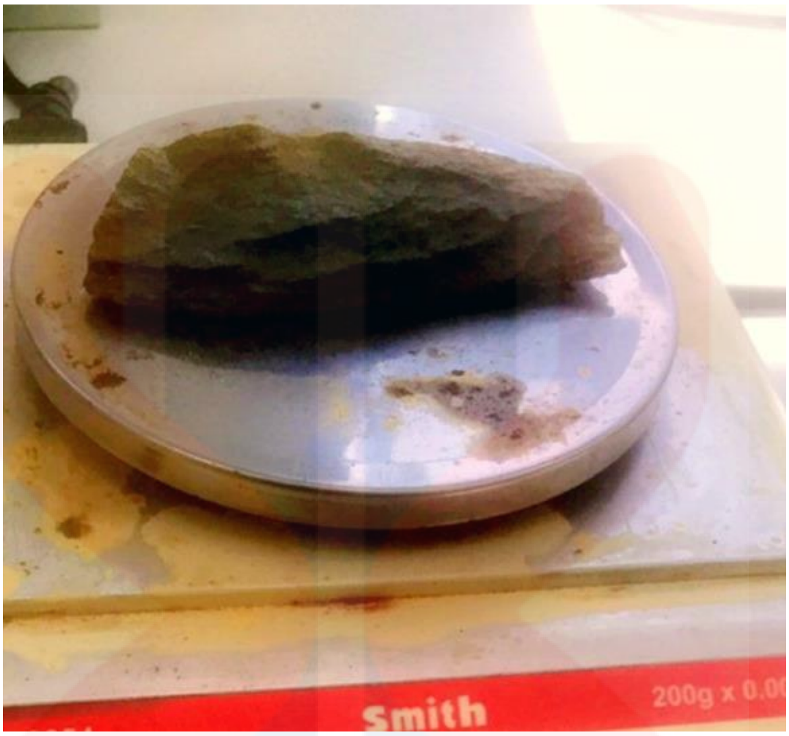


Figure 5.3: the weight saturated shale sample

Based on the laboratory experiment conducted to determine the porosity of a rock sample, the weight of the dry shale before saturation with water was found to be 116.3g. To ensure that all the air trapped in the pores was replaced by water, the sample was left to soak in water for 30 minutes. After the saturation period, the excess water was allowed to drain off and the weight of the saturated rock sample was measured and recorded as 120.7g.

To calculate the porosity of the shale sample, the following formula was used:

Porosity = (1 - W2 / W1) x V1

where W1 represents the weight of the dry rock sample (116.3g), W2 represents the weight of the saturated rock sample (120.7g), and V1 represents the volume of water in the beaker (300ml).

Porosity = (1 - W2 / W1) x V1 Porosity = (1 - 120.7g / 116.3g) x 300ml Porosity = (1-1.038) x 300ml Porosity = 0.062 x 300ml Porosity = 18.6%

Shale is generally considered to have a low permeability, which means that it is less likely to allow water to flow through it easily. Therefore, based on the available information, it is reasonable to consider the fine-grained shale sample as an aquitard, which is a type of rock that has lower permeability than an aquifer but can still store water.

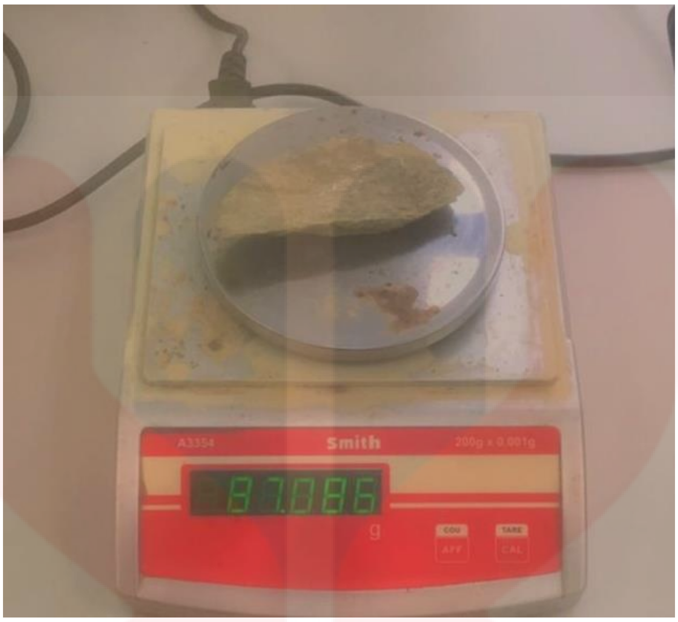


Figure 5.4: the weight of dry sandstone sample

Figure 5.5: sandstone to soak in the water

Figure 5.6: the weight saturated sample sandstone

The porosity of the sandstone sample can be calculated as follows:

Porosity = (1 - W2 / W1) x V1. Porosity = (1 - 88.74g / 87.9g) x 300ml

Porosity = (1 - 1.0096) x 300ml. Porosity = 0.9904 x 300ml Porosity = 29.712%

Therefore, the porosity of the sandstone sample is 29.712%.

It's worth noting that porosity is an important factor in determining the hydrological properties of a rock formation, such as its ability to store and transmit fluids.

In addition, sandstone have higher porosity have greater capacity to store fluids, but also have higher permeability, meaning fluids can flow through more easily.

Figure 5.7: the weight of dry limestone sample

Figure 5.8: the weight saturated limestone sample

Porosity of the limestone sample calculated as follows:

Porosity = (1 - W2 / W1) x V1 Porosity = (1 - 95.8g / 95.5g) x 300ml Porosity = (1 - 1.003) x 300ml Porosity = 0.003 x 300ml Porosity = 0.9%

Therefore, the limestone sample has a very lowest porosity.

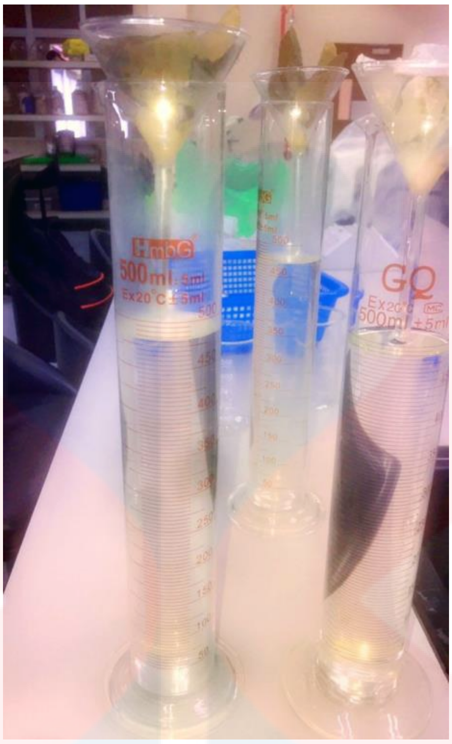


Figure 5.9: measuring the permeability of the samples

Based on the results of the lab tests conducted, that the sandstone sample is highly permeable and porous, indicating that it has the potential to be a good aquifer for storing and transmitting water. On the other hand, the limestone sample had a lower permeability and a very low porosity, which suggests that it would likely function as an aquitard or aquiclude that would impede the flow of water.

The shale sample had low permeability, but its moderate porosity suggests that it may function as an aquitard. In general, aquifers are rock units that have the ability to store and transmit water, while aquitards and aquicludes are rock units that impede water flow. Aquifuges, on the other hand, do not allow water to pass through them. Given the results of the permeability and porosity tests, it is likely that the sandstone sample is the best candidate for a water reservoir rock, while the limestone and shale samples may be more suitable for serving as barriers or seals to water flow.

5.3 Discussion

The lab tests conducted on the rock samples provide important information about their hydrogeologic properties, specifically their permeability and porosity. Permeability is a measure of a rock's ability to allow fluids to flow through it, while porosity is a measure of the volume of open space within a rock.

The sandstone sample has a high porosity of 29.712%, which indicates that it contains a significant volume of open space that could potentially be used for storing and transmitting water. Additionally, the sandstone sample is highly permeable, which means it has the potential to allow water to flow through it. This makes it a good candidate for an aquifer, a rock unit that has the ability to store and transmit water.

In contrast, the limestone sample has a very low porosity of only 0.9%, indicating that it has very little open space that could be used for storing or transmitting water. Furthermore, the low permeability of the limestone sample suggests that it would likely function as an aquitard or aquiclude, a rock unit that impedes the flow of water.

The shale sample has a moderate porosity of 18.6%, and while its permeability is also low, it may still function as an aquitard. This means that it could serve as a barrier or seal to water flow, helping to contain water within a specific area.

Overall, Geologists and hydrogeologists use a variety of techniques to analyze the geologic properties of rock samples, such as petrographic analysis, mineralogical analysis, geophysical surveys and drilling to infer the hydrogeological characteristics of an area. They use this information to identify potential aquifers or oil and gas reservoirs. The study of rock samples can provide information on the porosity, permeability, mineral content, and depositional environment of the rock, which can be used to infer the water storage and flow properties of the rock formation.

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

This study aimed to identify the hydrological characteristics of Paloh Gua Musang Kelantan. The general geology of the area was studied, and it was found that the area is composed of sedimentary rocks, mainly Limestone, sandstone, and shale. The hydrological characteristics of the area were also studied, and it was found that the area has a high permeability and a low runoff rate. The results of this study can be used to inform future hydrological studies in the area.

Based on a study that has been conducted, it was found that the study area of only sedimentary rocks and all the structures. The structure was little to none due to human activity in the study area which is lineaments and strikes and dip in rocks. The drainage pattern in the study area was determined into two types; that are dendritic drainage patterns and sub-parallel drainage patterns. Basically, Gua musang geomorphology is a hilly area that is found in the southwest of the study area with a valley at its center and another one that is nearly at the center of the study area to the eastern part.

6.1 Suggestion

Continuing this research is essential to further understand the hydrogeological characterization of the area. This research has already identified the hydrogeological characteristics of the area, but further research is needed to gain a better understanding of the area and its hydrogeological characteristics. Further research should focus on the hydrological processes that occur in the area, such as the flow of water through the aquifers, the recharge of the aquifers, and the interaction between surface water and groundwater. Additionally, research should be conducted on the geology of the area, including the types of rocks and soils present, and the potential for contamination of the groundwater. In addition, research should be conducted on the water quality of the area, including the levels of contaminants, the presence of pollutants, and the potential for contamination of the groundwater. This research should also include an assessment of the potential for water scarcity in the area, as well as the potential for water contamination due to human activities. Finally, research should be conducted on the potential for groundwater contamination due to climate change. This research should include an assessment of the potential for changes in the hydrological cycle, as well as the potential for changes in the water quality of the area.

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