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GENERAL GEOLOGY AND CHARACTERIZATION OF CLAY IN GUA MUSANG, KELANTAN

by

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DECLARATION

"I hereby declare that I have read this thesis and in our opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Applied Science (Geoscience) with Honours."

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Signature

Name of supervisor:

Date:

APPROVAL

I declare that this thesis entitled "General Geology and Characterization of Clay in 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 candidate of any other degree.

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Date:

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Praised to Allah S.W.T, I finally finished my FYP's thesis entitled "General Geology and Characterization of Clay in Gua Musang, Kelantan" in a given time. While completing this thesis, it had taught and gave me more experienced and new knowledge that very useful for me in the future.

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GENERAL GEOLOGY AND CHARACTERIZATION OF CLAY IN GUA MUSANG, KELANTAN

ABSTRACT

The study area is located in Gua Musang, Kelantan within 4°47'55.92"N, 101°54'12.21"E coordinates. This 5x5km^2 study is surrounded by plantation like palm plantation and rubber plantation and heavy forest. The lowest elevation of the study area is 95m while the highest is 491m. The study focuses on the general geology to produce a geological map at a scale 1:25000 and characterization of clay properties of Pulai for industrial purpose. The geological mapping was conducted to collect the data to determine the geology of the area and some from previous research. There are three types of lithology found which are limestone, sandstone, and shale. For geological mapping, go to field for traversing and collecting the data, then produce the map using GIS software. In this study, X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF) and Scanning Electron Microscopy (SEM) is used in the sample analysis to determine mineralogy and elemental composition clay in the study area. The XRF analysis revealed SiO_2, Al_2O_3 and K_2O as the major element while the other element shows in minor quantities. Element in all samples in XRD analysis ranges from 30% to 36% for Si, 8% to 12% for Al, and 5% to 6% for K. In the thin section AIN11 mineral feldspar is present which it can be weathered by chemical weathering to form clay minerals. AIN1 also present mineral feldspar in SEM EDS shows mineral anorthoclase and albite with same element but different in percentage.

GEOLOGI AM DAN CIRI-CIRI TANAH LIAT DALAM GUA MUSANG, KELANTAN

ABSTRAK

Kawasan kajian terletak di Gua Musang, Kelantan dalam koordinat 4°47'55.92"U, 101°54'12.21"E. Kawasan kajian seluas 5x5km^2 ini dikelilingi oleh ladang seperti ladang kelapa sawit dan ladang getah dan hutan lebat. Ketinggian terendah kawasan kajian ialah 95m manakala yang tertinggi ialah 491m. Kajian memfokuskan kepada geologi am untuk menghasilkan peta geologi terkini kawasan kajian di Gua Musang pada skala 1:25000 dan pencirian tanah liat untuk menentukan ciri-ciri sifat tanah liat di Pulai, Gua Musang untuk tujuan perindustrian. Pemetaan geologi dijalankan unutk mengumpul data bagi menetukan geologi Kawasan tersebut. Terdapat tiga jenis litologi yang ditemui iaitu batu kapur, batu pasir, dan syal. Dalam kajian ini, bagi pemetaan geologi, pergi ke tempat tersebut untuk merentasi dan mengumpul data, kemudian menghasilkan peta menggunakan perisian GIS. Bagi analisis X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF) dan Mikroskopi Elektron Pengimbasan (SEM) digunakan dalam analisis sampel untuk menentukan mineralogi dan komposisi unsur tanah liat di kawasan kajian. Analisis XRF mendedahkan SiO2, Al2O3 dan K2O sebagai unsur utama manakala unsur lain menunjukkan dalam kuantiti yang kecil. Sama seperti analisis XRF, elemen dalam semua sampel dalam analisis XRD dalam lingkungan dari 30% hingga 36% untuk Si, 8% hingga 12% untuk Al dan 5% hingga 6% untuk K. Dalam bahagian nipis AIN1 terdapat mineral feldspar yang boleh diluluhawa oleh luluhawa kimia untuk membentuk mineral tanah liat. AIN1 juga menunjukkan feldspar mineral dalam SEM EDS dimana terdapat anorthoclase dan albite unsur yang sama tetapi berbeza dalam peratusan.

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LIST OF ABBREVATIONS

Al	Aluminium
Ca	Calcium
E	East
Fe	Ferum
GIS	Geographic Information System
GPS	Global Positioning System
K	Potassium
KM	Kilometre
M	Metre
Mg	Magnesium
N	North
Na	Sodium
S	South
O	Oxygen
Si	Silicon
W	West

LIST OF SYMBOLS

%	Percentage
′	Minutes
″	Second
°	Degree
θ	Theta

CHAPTER 1

INTRODUCTION

1.1 Background of Study

This study is about general geology and clay characterization in Gua Musang, Kelantan. This research area is located in Gua Musang, Kelantan and the selected area is a place where the clay can be found. This study will help characterize the mineralogy of clay in the region.

Clays has been mined since long time ago and is mainly found on or near the surface of the earth. Clays is formed in soils and sediments, by diagenesis and hydrothermal alteration of rocks. Chemically, clays are hydrous aluminium silicate and, usually contains small number of impurities such as sodium, calcium, potassium, magnesium, and iron. Clay applications are becoming more popular due to their environmentally friendly materials that do not pollute the environment at the time of disposal, their abundant world reserves, and their low cost. The ability to chemically modify clay allows applications to be developed in a wide range of technical applications, adding to the value of this abundant natural resource.

The mapping has been done throughout the survey since a certain period. Mapping is required to create and form maps that represent the features that are physically found on the surface of the earth. Geological maps and models can be created through systematic surveys of geological surveys and the correlation between mapping activities and geology. Geological survey is a systematic and detailed study of the physical structure of the rocks that form the top layer of the crust. Field mapping was performed as a tool to properly locate different types of formations. Mapping methods for outcrop and landform studying the classic traverse walk on survey and satellite imagery photo. Samples were collected from study area for further analysis in the laboratory.

1.2 Problem Statement

The geological data and information required for this study is limited. There is not much information that can be matched, and it is not possible to compare data from previous surveys on the topography of the survey area in Gua Musang, Kelantan. The difference in geological map existed can be seen very well compared to field mapping. This is most likely due to the numerous developments that are growing today. At present, a few people know very little about the characterization properties of clay in daily life and have thought that clay is not comparable to clay on the market.

1.3 Objectives

1. To produce a geological map of the study area in Gua Musang at a scale of 1:25000
2. To determine the characteristic of clay properties in Pulai, Gua Musang for industrial purposes.

1.4 Scope of Study

This study will be conducted in the Gua Musang and focuses on general geological and regional clay. The purpose of the study is to create and update the geological map of a study area. The materials and tools to be used are basic geological map needs such as the Global Positioning System (GPS), compass, hammer, and ArcGIS software for creating geological maps. This research explored Gua Musang, Kelantan to obtain the data and information about regional clay and used X-ray diffraction (XRD), X-ray fluorescence (XRF) and Scanning Electron Microscope (SEM) to determine the characterisation of regional clay.

1.5 Significance of Study

Current research focuses on regional clay from several areas in Gua Musang, Kelantan. X-ray diffraction (XRD), X-ray diffraction (XRD) and X-ray diffraction (XRD) will be used to characterize the mineralogy of the clay samples. The study also focuses on creating an up-to-date geological map of the study area in Gua Musang, Kelantan. The data obtained may also be useful to other future researchers, or past research serves as a guide for academic purposes.

1.6 Study Area

Located in the southern part of Kelantan, Malaysia, and Gua Musang is the largest district in Kelantan. Gua musang is in the middle of Pahang to the south, Terengganu to the east, Perak to the west, and the Kelantanese of Kuala Krai and Jeli to the north. Gua Musang has an area of 7,979.77 km^2 with population is about 90,057. The base map of the study area will be in Gua Musang, and the area is 5 kilometres times 5 kilometres. The area of this study is in Pulai, Gua Musang, Kelantan. The coordinate of this area is 4°47'55.92"N, 101°54'12.21"E.

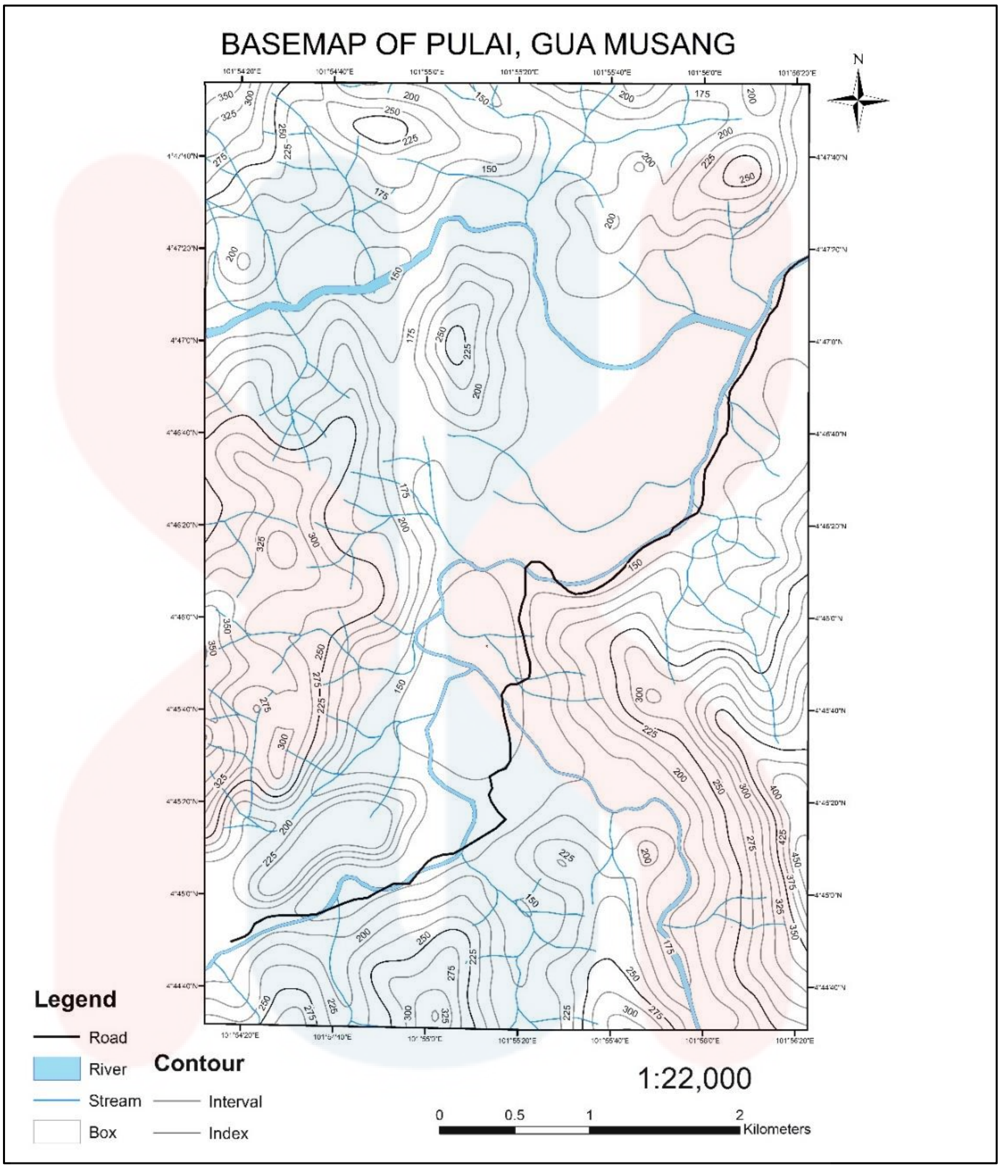


Figure 1.1: Map of Pulai, Gua Musang

1.6.1 Location

Geography is the study of the physical features of the earth and its atmosphere, and of human activity as it affects and is affected by these, including the distribution of populations and resources, land use, and industries. The examples of historical traditions in geographical research are spatial analysis of the natural and the human phenomena (geography as the study of distribution), area studies (places and regions), study of the human-land relationship, and research in the Earth sciences. Stratigraphic formation that can be found in the study area are a few formations from Gua Musang

Group, which is Gua Musang Formation, Telong Formation, Koh Formation and Gunung Rabong Formation.

1.6.2 Demography

According to research from the State Department of Statistics showed the number of people the total population from the year 2010 in every district in Kelantan. Total resident of Gua Musang is 90,057. In 2014 the total population increased to 114,500 people. The latest population count of Gua Musang is in 2014. The total increment of population in Gua Musang from 2010 to 2014 is 24443.

1.6.3 Land use

According to the Department of Statistics, Kelantan's total land area is 15,012 km2, accounting for over 4.6 percent of Malaysia's total land area. Gua Musang's land use is largely focused on plantation areas, such as palm, rubber plantations. Normally, an increase in population leads to a shift in land usage in the region.

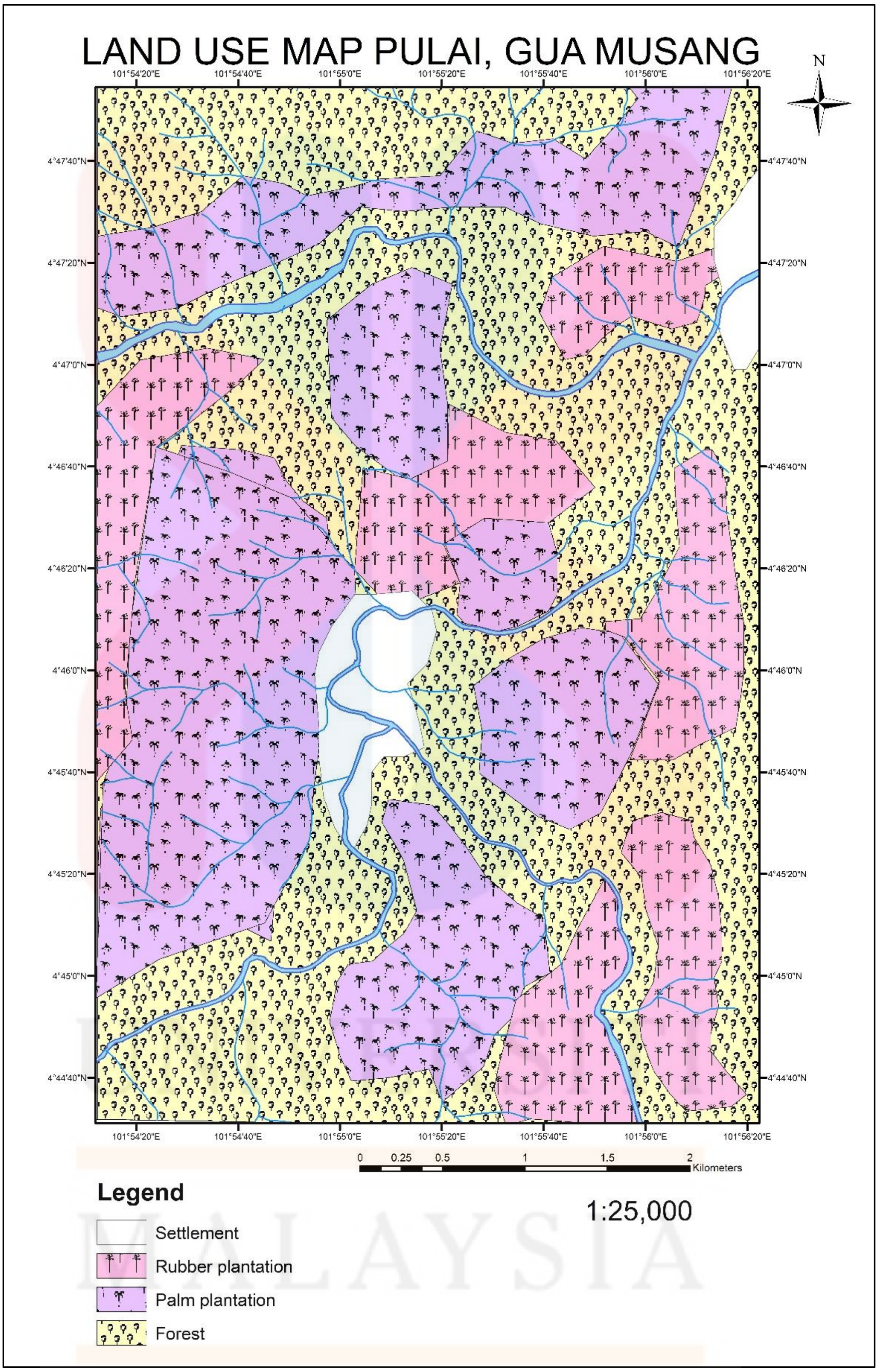


Figure 1.2: Map of land use in Pulai, Gua Musang.

1.6.4 Social economic

Kelantan's business sectors primarily focused on agriculture, production, the agro-industrial sector, and even the tourist industry. Large numbers of residents are involved in the Gua Musang plantation field sector. There are two main agencies that are the Federal Land Development Authority (FELDA) and the South Kelantan Development Authority (KESEDAR) developing and shaping the landscape in Gua Musang district. The FELDA agency has planted about 84.7 percent of the palm oil that made up a large part of Gua Musang's land schemes while the rest were planted with rubber trees. In the meantime, many of the property projects under KESEDAR were harvested with rubber (67 %) whereas the rest were harvested with palm oil trees. Most of the community in the area works under both FELDA and KESEDAR agencies.

1.6.5 Road connection/ Accessibility

Gua Musang is a district that is located at the end of Kelantan state. This district is bordered by three states, mainly by eastern of Terengganu, southern of Pahang and western of Perak. In Kelantan, this district relates to the neighbouring district called, Kuala Krai and borders with another neighbour, Jeli which is located on the northern side.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the study is about the geology and specifications of clay in the area obtained from previous research. All information is collected from journals, articles, books, and case studies, primarily to provide a detailed understanding of the geology of Kelantan, especially the study area of Gua Musang.

2.2 Regional Geology Setting

The longitudinal belt in Peninsular Malaysia is divided into three which is western, central, and eastern (Khoo & Tan, 2009). The western belt is divided into the northwest part and the Kinta-Malacca region. The northwest part is covered by clastic, calcareous, and minor volcanic activity, but in the Kinta-Malacca region, has the deposition of clay and limestone (argillaceous and calcareous) sediments in the early Palaeozoic. Permian-Triassic clastic, volcanic, and limestones are found under the Central Belt. The Permian is found under the Central Belts, Volcanoes, and Central Limestone. The Main Range Granite is made up of pre-early Devonian deposits of coarse clastic, argillaceous sediments, chert (shale), and other forms of rock. Volcanoes and clastic (limestone) from the Carboniferous and Permian periods cover the Eastern belt. Granites, which form extended north-south bodies, are common in the Eastern Belt. It's mostly biotite granite, although there's also hornblende on occasion. Kelantan is a Malaysian province in the north-western 3region of the peninsula. The state is bordered on the north by Thailand, on the east by Terengganu, on the south by Pahang, and on the west by Perak and Kedah.

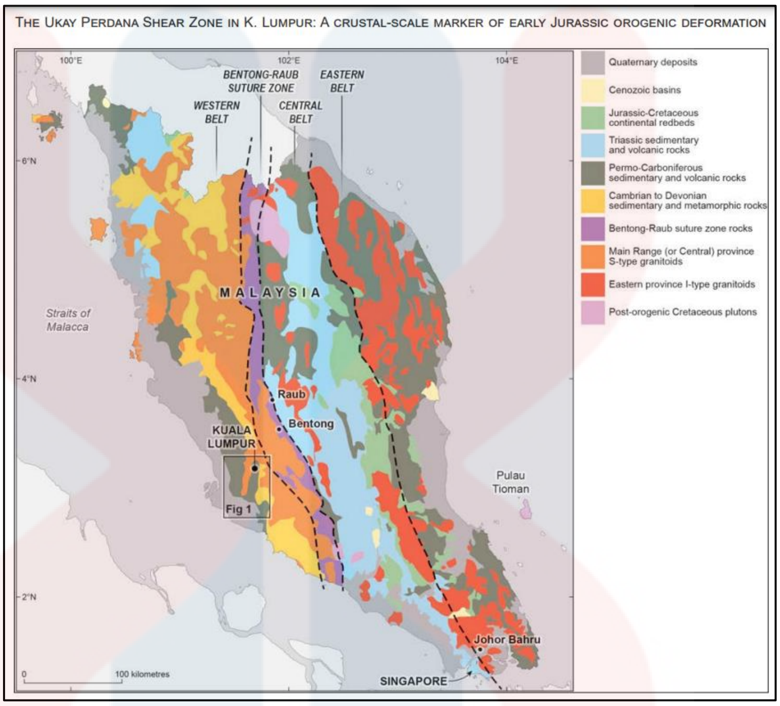


Figure 2.1: Simplified regional geological map of Peninsular Malaysia (Leslie et al., 2020)

Gua Musang is located in the Malaysian Peninsular's middle belt, with latitudes ranging from 4.45° to 6.25° north and longitudes ranging from 101.30° to 102.40° east. The Gua Musang group, of which Aring was a member, was formed in the Malaysian Peninsula's Central Belt. The western and eastern sedimentary and sedimentary rocks, which are main range and border range granites, respectively, are found in the geological core of the Kelantan area (Heng et al. Al. 2006). Kelantan's main rocks include metasedimentary rocks (51 percent), granite (33 percent), volcanic rocks (10 percent), and unconsolidated sediments (6 percent) (Asborne and Chappel, 2003). Claystone is substantially more frequent than calcareous (limestone) and may be found from the Gua Musang Formation's southern end to the Merapoh area. The Gua Musang group sedimentary environment is composed of shallow marine bed sediments which generate active volcanic activity during accretion (Lee, 2004)

Table 2.1: Formations included within Gua Musang Group. (Mohamed et al., 2016)

Name	Gua Musang formation	Telong formation	Nilam marble	Aring Formation
Origin of Name	Gua Musang, South Kelantan	Sungai Telong, South Kelantan	Sungai Nilam (of Sungai Chiku)	Sungai Aring, south Kelantan
Age	Middle Permian to Late Triassic	?Permian to Late Triassic	?Permian to Late Triassic	Carboniferous to EarlyTriassic
Boundary	Unknown lower boundary; Upper boundary overlain by Koh Formation	Lower boundary overlie Gua Musang formation; top boundary overlain by Koh Formation	Unexposed bottom and top boundary	Lower boundary unexposed. Tectonized upper contact with Telong formation and Koh Formation.
Correlation	Upper part of Gua Musang formation interfingers with Semantan Formation, Telong formation, and Gunung Rabong formation	Lateral equivalent to Gunung Rabung formation and Semantan Formation	Lower part coeval with Aring Formation, upper part coeval with Telong formation	Lateral equivalent to Gua Musang formation in Kelantan, metasediments in SE Pahang, Volcanic Series in NW Pahang
Lithology	Argillaceous and calcareous rocks interbedded with volcanic. Minor presecne of arenaceous rocks	Sequence of predominantly argillite associated with some tuff; turbidites	Calcitic marble interbedded with tuff and argillites	Basal dolomite marble, tuff, calcareous argillite, pyritiferous tuffs, subordinate lavas, argillo-tuffaceous limestone
Type Area	Gua Musang area (extended to north Kelantan and Pahang)	Sungai Telong, the upper reaches of Sungai Aring in south Kelantan	Upper reaches of Sungai Nilam	Sungai Aring, south Kelantan
Depositional Setting	Shallow marine shelf deposit, with active volcanic activity	Shallow marine environment with occasional pyroclastic	Open marine for growth of shelly fauna	Neritic with volcanic input

2.3 Stratigraphy

The Aring Formation consists primarily of a volcanic (tuff) series and a thin layer of argillite and marble interbeds throughout the Lebir River, lower reaches of Sungai Aring and Sungai Relai in southern Kelantan (Aw, 1976). The ages of the Aring Formation vary from the Late Carboniferous to the Early Triassic as evidence of the discovery of brachiopod and fossils. The formation is about 3000 meters thick and the Paloh member at the top of the formation is about 1000 meters and is hosted by shale or tuffaceous limestone.

South Kelantan the Gua Musang formation in North Pahang to describe Middle Permian to Late Triassic argillite, carbonate, and pyroclastic / volcanic facies in the Gua Musang area (Yin, 1965). The term has now been loosely used for almost all Permo-Triassic carbonate-argillite-volcanic sequences in the northern part of the Central Belt Peninsular Malaysia. The widespread distribution of argillite-carbonate volcanic rocks in the northern Central Belt has causes problems with the currently assigned names. For example, similar lithologies to the Felda Aring Gua Musang formation are called Aring Formation.

The Telong Formation age Permian to Upper Triassic as evidenced by the fossils of bivalves, ammonites, gastropod, and brachiopods found. Ammonite aggregation was an indicator of the Middle to Late Triassic age (240 – 220 million years ago) and belonged to the Tethyan Province (Hussain et al, 2018). The rock sequence of this formation consists mainly of argillite and thin pyroclastic interbedded marble with minor tuff and andesite. The rock sequence of this formation is mainly composed of argillite and thin pyroclastic marble and contains a small amount of tuff and andesite. In the middle reaches of Sungai Relai and upstream of Sungai Aring, there is extensive, partially tuff and locally carboniferous argillite consisting interbedded tuff and occasional formation and lenses of marble and limestone.

2.4 Structural geology

The Telong Formation of the axial belt is correlated to the Gunung Rabong Formation and the upper part of the Gua Musang Formation with the Aring Formation to the rest of the Gua Musang Formation, (Aw, 1967). Lipis groups correlate only with the Kaling Formation in the central portion of the axial belt This is a good concept given that the former could not be separated into formations.

Semantan Formation and Gemas Formation are homosaxial even though Semantan's limestone facies are not found in the Gemas Formation, but both have a common, predominantly argillaceous chert characteristics (Ying, 1965).

There are one main geological structure that recorded found in Pulai, Gua Musang which is fold . Fold occurs and joint occurred in sedimentary rock. The fold is occurred because of the regional compression in the focal belt of Peninsular Malaysia.

2.5 Historical geology

The range of geological formation in Kelantan start from Lower Palaeozoic until Quaternary. The Palaeozoic, Mesozoic, and Cenozoic are the three main chronologies.

Most of the Upper Palaeozoic was composed of Permian marine sediments that occur in the Central Belt as sequential belts that manipulates Mesozoic sediments. The Upper Palaeozoic lithology is composed of the Gua Musang Formation as well as Aring Formation throughout the south of Kelantan whereas the Taku schist is within the east of Kelantan. Argillaceous and volcanic facies are dominant in the Upper Palaeozoic Formation, with the rest consisting of calcareous and arenaceous facies. Beginning in the late Carboniferous, the sedimentary environment of this formation is shallow, with periodic aggressive underwater volcanic activity peaking between the Permian and Triassic (Lee, 2004).

Mesozoic is certainly dominant throughout the central belt which the Gua Musang formation extends north across the border with Thailand, and Jurong Formation South to Singapore. Shallow marine clastic rocks and carbonate rocks predominate in the Permian-Triassic Gua Musang, Aring and Gunung Rabong. Telong Formation s much more dominant to the south, with deeper marine turbidite deposits. These turbidites are often tuffs with volcanic interbeds (Leman, 2004).

Finally, Quaternary sediments are deposited in the Cenozoic formation. Completely unconsolidated to unconsolidated rocks, sand, gravel, silt, and clay in northern Kelantan is part of the quaternary sediment that undermines the coastal and inland plains.

2.6 Regional clay

Clay is a term early fine-grained material in geological formations by Agricola in 1956 or soils by De Serres in 1600. Clay is not limited to one definition because clay a universal material (Murali.K, 2018). Clay is a soft, freely bounded, fine grained natural rock or soil material less than 0.005 mm in diameter and essentially composed of clay particles. Clay minerals are stable and are an important component of soil in cool, dry, or warm climates and it act as sponges capable of retaining water and dissolved phytonutrients weathered by other minerals.

2.6.1 Clay Properties

Clay can be divided into two types: primary clay and secondary clay. Primary clay form as residual sediments on the ground and remains in the parent or host rock (granite). Primary clay also known as residual clay, is grainy and lack the smoothness required for workability. These clays are non-plastic because they are not easy to mold or shape easily. These clays are carried (transported) by water, wind, and ice deposited away from the source material are called sedimentary or secondary clays (Murray, 2002). Secondary clay deposits are usually associated with very low energy depositional environments such as large lakes and marine basins (Foley,1999). Secondary clay also called as sedimentary clay, is more plastic and has smaller particles more uniform, and is more mixed with other materials compared to residual clay.

Clay minerals including kaolinite, smectite (montmorillonite, saponite), chlorite, and mica (illite) are the principal components of clay raw materials and are formed in the presence of water (Kumari & Mohan, 2021).

Kaolin or China clay is the name given to kaolinite-rich rocks (Perry, 2011). The formation of soft, generally white, earthy minerals results from the chemical weathering of aluminium silicates, such as feldspar (dioctahedral phyllosilicate clay). $Al_2Si_2O_5(OH)_4$ is the chemical formula for this sort of clay.

Smectite (montmorillonite, beidellite, nontronite, saponite, and hectorite) is a group of phyllosilicate (layered silicate) minerals (Odom 1984). Weathering of basalt and gabbro produces smectite. Smectite, also known as swelling clay, has a negative charge that is balanced by the weakly bound exchangeable cations present in the smectite interlayer between the silicate structure (Altaner, 1978). Most smectites have a chemical formula that falls somewhere between montmorillonite $(Na, Ca)_{0.33}(Al, Mg)_2$ and the three endmembers of beidellite and nontronite (Schulze, 2004). (Si_4O_{10}).

Chlorites are a group of phyllosilicate (layered silicate) minerals found in low-grade metamorphic rocks and altered igneous rocks. Chlorite is a common product of weathering and is widely distributed in sedimentary rocks containing clay minerals (Nesse, 2000). Chlorites occur in pelite (metamorphosed fine-grained sedimentary rock) with quartz, albite, sericite (very fine, ragged (irregular) grain and aggregates of white or colourless mica), and garnet, and is also found in association with actinolite (amphibole silicate mineral) and epidote (calcium aluminium iron sorosilicate mineral) (Hurlbut & Klein, 1993). The chemical formula of the chlorite group is $(Mg, Fe)_3(Si, Al)_4O_{10}(OH)_2 \cdot (Mg, Fe)_3(OH)_6$.

Micas is very fine-grained and usually has variation in ion content and water content called clay micas. Mica is a member of the phyllosilicate group which is found in all three major rock types (igneous, sedimentary, and metamorphic) (Dietrich, 2021). Illite is a group of mica clay minerals that are widely distributed in marine shale and related sediments. Illite contains more water and less potassium than true mica (Britannica, 2017). The chemical formula of illite is (K, H_3O) (Al, Mg, $Fe)_2$(Si, $Al)_4O_{10}[(OH)_2$, $(H_2O)]$.

Kaolinite is the most common type of clay where it can be easily found worldwide, extracted from rocks that are rich in kaolinite and it identified as kaolin clay. Kaolin used for the first time in manufacture of ceramics because of the nature of plasticity, has easily shaped and smoothed, no shrinkage time dries and produce good colour after burning (R Dewi, 2018). Kaolinite can be identified with colourless or brown under PPL and grey in XPL. Kaolinite also has low relief and cleavage but hard to see the small size of crystal. **Table 2.2** shows the standard kaolin for the ceramic industry where SiO_2 range at 47% to 48% for 3 types of kaolin. Si element is obtained from quartz and also can obtained from the mica and talc (MEC, 2022). Al element is the third most common element in the earth's crust, which relatively rich in clay, alunite, and mica mineral. In **Table 2.2** also shows Al_2O_3 with range 37% to 38% for three samples. Ti or titanium is obtained from the mineral's rutile, ilmenite and rarely from anatase. **Figure 2.2** shows SEM image of kaolinite with sheet layer of silicate that form lines.

Table 2.2: Composition of Ceramic Grade Kaolin (R. Dewi, 2018)

Compound / Type	ECC Super Standard porcelain	ECC grolleg, Eartware	ECC Rembleend, sanitaryware
	Percentage (%)		
SiO_2	47	48	48
Al_2O_3	38	37	37
Fe_2O_3	0.39	0.7	1.0
MgO	0.22	0.30	0.3
K_2O	0.8	1.85	2.0
CaO	0.1	0.06	0.07
Na_2O	0.15	0.10	0.10
TiO_2	0.03	0.02	0.05

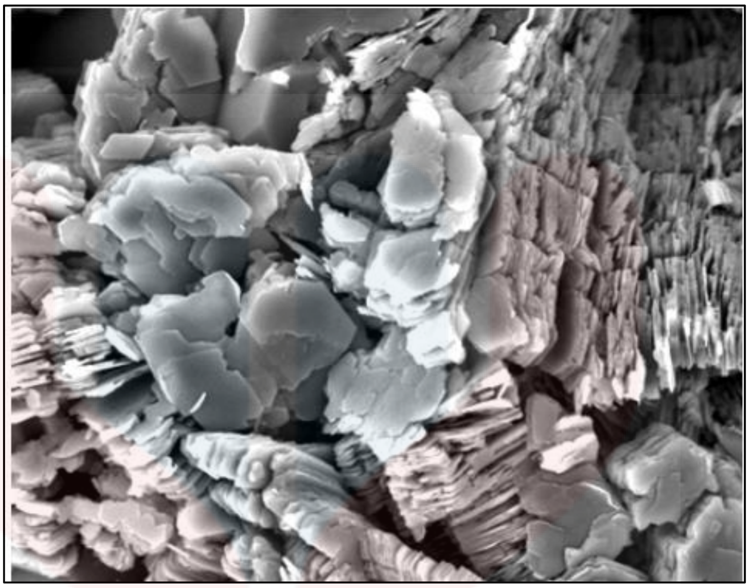


Figure 2.2: Kaolinite with sheets stacked that form lines. (Nazile Ural, 2021)

Smectite is a mineral mixtures of various swelling sheet silicates and mainly consist of montmorillonite, also can contain secondary minerals such as quartz and calcite. Smectite are more commonly called bentonite. Based on **Table 2.3** show the chemical composition of bentonite, show SiO_2 with range from 48% to 49% which obtain from mineral quartz and mica. Al_2O_3 show range from 14% to 15% and Fe_2O_3 show range from 4% to 5% in bentonite. Also, TiO_2 show range from 0.9% to 0.8%. Based on **Figure 2.3** show the shape and texture of smectite which is honeycomb texture.

Table 2.3: Composition of bentonite (Abdullah S.L & Audu A.A, 2017)

Compound / Type	GA (Ashaka)	GT (Tango)
	Percentage (%)	
SiO_2	48.16	49.87
Al_2O_3	14.86	14.98
Fe_2O_3	4.80	5.12
MgO	2.08	2.08
K_2O	1.60	1.76
CaO	1.16	1.81
Na_2O	1.66	1.43
TiO_2	0.94	0.87

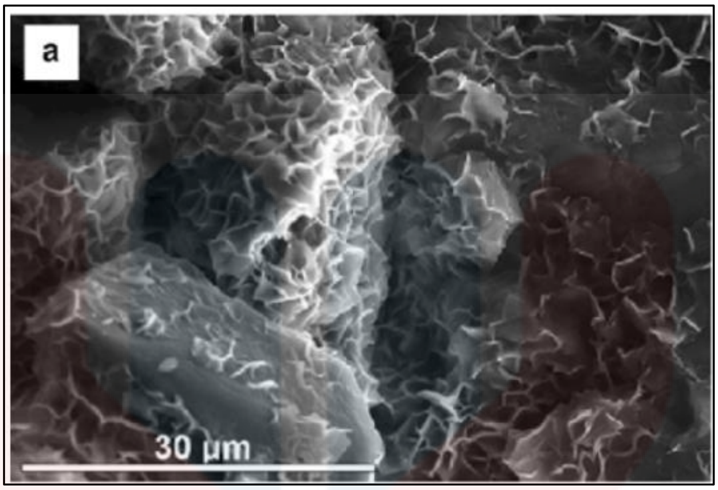


Figure 2.3: Smectite with honeycomb texture. (G.E. Christidis, 2011)

Illite contains more water and less potassium than true mica, but it has a sheet structure like a mica and poorly crystallized. It may form a chemical series with both muscovite and montmorillonite, it is a weathering product of muscovite and alters to montmorillonite under humid conditions. **Table 2.4** show, illite component consist of element SiO_2 with 58.68% percentage which is the highest amount other type of clay mineral kaolinite and bentonite.

Table 2.4: Composition of Mineral Illite (Okashah et al., 2021)

Compound / Type	Illite Percentage (%)
SiO_2	58.68
Al_2O_3	19.25
Fe_2O_3	5.04
MgO	2.50
K_2O	6.12
CaO	1.29
Na_2O	0.19
TiO_2	-

Chlorite does not have any specific industrial uses of any importance. Chlorite minerals often form in clay-rich sedimentary rock, where usually associated with biotite, muscovite, garnet, andalusite or cordierite. Chlorite in PPL is colourless to pale green and greenish or green with low to moderate in relief. Chlorite also has pleochroism and perfect cleavage. While under XPL, chlorite is anisotropic with multiple twinning. In **Figure 2.4** show chlorite mineral appear under SEM image.

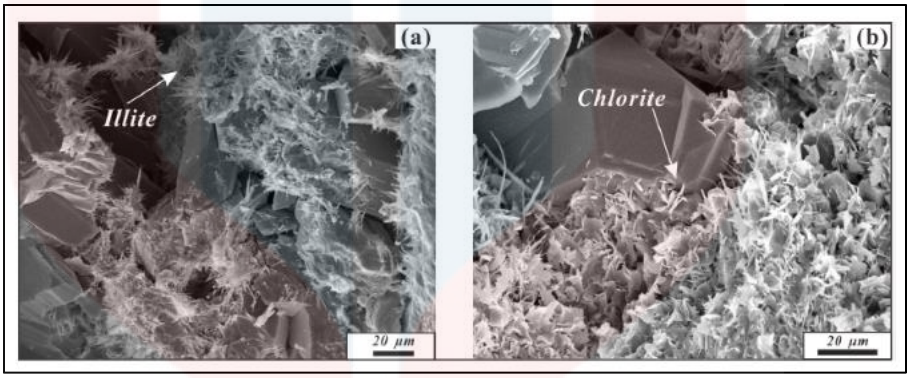


Figure 2.4: SEM image of a) Illite associated micro intergranular pore and b) slit pores among schistose layers of acicular chlorite (Luo, Y.-F. et al, 2019)

2.6.2 Application of Clay

Clarification, absorption, and adsorption materials made of clay minerals are good. Because of their flexibility, abundance, and low cost, they are utilised in a variety of industrial applications including paper, paints, petroleum, ceramics, cement, adhesives, asphalt, and the food and health industries (Murray, 1999).

In the construction industry, clay was used in construction because of its excellent properties. Clay can be made into sun-dried bricks by sun-drying or baking in the fire. The bricks are then assembled with another component of clay, mortar, to build a house (Khanam). Brick clay is rich in silica, alumina, iron oxide, calcium, magnesium, and organic matter. The interrelationship of these components determines whether they are suitable to produce high-quality bricks for construction (Constro Facilitator, 2020). In the case of clay in agriculture, clay minerals are widely used in soil conditioners and fertilizer products as carriers, additives, binders, and coatings (Kozicki & Carlson, 2022). Clays may promote sustained or controlled release of the active ingredient when used as a granular carrier or coating. Clays bentonites are recognized for their ability to improve water retention when used in fertilizer. Bentonite and kaolin may also act as a diluent for fertilizers, reducing the concentration of elements. It can also be used as a fluidity improver for products such as ammonium nitrate.

Ivana Savic, Stanisa Stojiljkovic, Ivan Savic, and Dragoljub Gajic (2014) shown that bentonite may be used in agricultural, food processing, textile manufacturing, and biomedical applications. In agriculture, bentonite is utilised in soil fertilisation because its presence in the soil enhances soil dryness and pH, all of which are beneficial to plants. Because of its adsorption capabilities, bentonite is utilised as storage equipment in the food sector (Al-Arfaj et.al., 2014). In the textile sector, bentonite used in paints boosts emulsion stability due to its large specific surface area and adsorption capacity, and bentonite is utilised as a tanning agent for the dye. In biomedical application, bentonite used as suspending agent because it provides the suspension of fine particles in aqueous system.

2.6.3 Occurrence of Clay

Clay is made up of crystalline rock that has been weathered, transported into the sedimentary environment, buried, heated in the diagenetic-hydrothermal environment, and then recrystallized during metamorphism (Erberl et al., 1984). Climate, drainage, initial rock type, vegetation, and weathering duration may all influence the sort of clay mineral that forms from crystalline rock in the weathering environment. Clay minerals are layer silicates that develop at the earth's surface as chemical weathering products of other silicate minerals. They're typically found in shale, which is the most frequent sedimentary rock type. The presence of imbalanced electrical charges on the surface of clay grains allows it to store water and behave as a sponge. Clay mineral's capacity to attract water molecules is known as adsorption.

Kaolinite is a clay mineral that forms when feldspar weathers. It has a powdered white look. Illite is a weathering result of feldspar and felsic silicates that has a mineral composition like muscovite. Chlorite is a stable weathering result of mafic silicates in cool, dry, or temperate climates. It may be found in metamorphic rocks like chlorite schist.

CHAPTER 3

MATERIALS AND METHOD

3.1 Introduction

Materials and methods used in this study for geological mapping and specification of the study were described accordingly in this chapter. Global Positioning System (GPS) is combined with Geographic Information System (GIS) to locate the tracks and complete the geological map. Besides that, the instruments such as X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF) and Scanning Electron Microscope (SEM) with Energy Dispersive X-ray (EDX) analysis are used to determine the chemical composition of clays.

3.2 Materials

Materials were used to support the methods during field works and laboratory works are as follows.

Table 3.1: Instruments for field works and laboratory works.

Material	Description	Image
Rock hammer	It used for splitting and breaking rocks.	
Brunton compass	To take the bearing and know the direction	
Global Positioning System (GPS)	Used in geological mapping to locate the location of samples	

Sample bag	To store the sample soil and rock	
Hydrochloric acid (HCL)	Used to observe on the reaction of rocks on HCL to differentiate between calcite and chlorite.	
Measuring tape/ ruler	To measure the length and height of outcrop	
Hand lens	Used to make the first analysis of rock samples in the field	
Field notebook	For note the information at the field	
X-ray Diffraction	To identify the crystal structure of clays	
X-ray Fluorescence	To determine the chemical composition of clay	
Optical microscope	Uses visible light and a system of lenses to magnify images of small samples	
Scanning Electron Microscope	To determine texture, mineral composition and crystalline structure of clay and rock.	

3.3 Methodology

3.3.1 Preliminary Research

Preliminary study takes place at the beginning of an event, often as a form of preparation by referring or study of past research such as journal or book which contain information that related with topic research and location of study area. Based on preliminary study, knowledge and better understanding of the research area and the area of study was gathered. This information was obtained from new types of sources such as journal, thesis, test book, and geology private sector. This information was obtained from a new type of sources such as journal, thesis, test book, and private sector of geology. The geomorphology is a major part, and the characterisation of regional clay is a main objective of this research.

3.3.2 Field studies

Field studies involve collecting data outside of an experiment or lab setting that involves observation in the study area. It includes geological mapping, rock sampling and site visit.

a) Traverse

Traverse was performed during geological mapping and used topography map, geological and GPS to records the journey along field mapping activities. Traverse map also used to mark outcrop, hazard, land use, geomorphology and any structure found during traverse mapping in the area before producing map for each specification. Along the traverse of the study area, primary data can be obtained directly from the observation made in the field. Sample of rocks and clays has been collected from several points around Gua Musang.

b) Rock and clay sampling

Rock sampling is conducted by taking the rock or outcrop in the study area by using geological hammer. The fresh and unweathered sample is taken for analysis and put in the sample bag. the location of the sample is marked on the sample bag.

c) Soil sampling

Several soil samples is collected in the same area with the rock sample have been collected. The soil is taken from the depth 20cm from the surface about 300g by using mini shovel. The soil sample is put into sample bag and dries by using oven. Then, the sample undergoes laboratory by using XRD, XRD and SEM to analyse the mineral composition in the samples.

3.4 Laboratory investigation

a) Petrography

The laboratory investigations for this study include thin section analysis. Thin section was used for determining the lithology and the rock unit in the area. Thin section is the microscopic examination is to identify the minerals and the structural aspect such as cleavage, fracture, and rock textures. Thin sections are thin, flat material prepared for examination with a microscope, in particular a piece of rock. Although this thin section is thin in size, it preserved the actual size and shape of minerals of rocks. Hard rock samples found in the study area were examined in thin section. The rock sample should be cut from larger size using diamond saw and the reduce the size by cut the chip. Then, the rock needs to polish until the sample thickness of only 30µm thick. **Figure 3.1** is the flowchart for the thin section preparation.

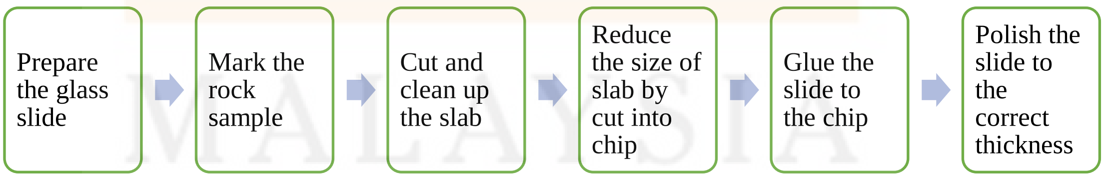


Figure 3.1: The flowchart for the preparation of thin section

b) XRD and XRF analysis

For XRD and XRF analysis, the clay sample should be in powder form. The preparation was conducted by drying the samples in laboratory oven for several hours until it was completely dry. Then, grinding the dry clay samples into fine powder. The clay sample can be up to 1 - 2 mm or less than 10mm thick. The prepared clay samples should be split into three packages for XRD, XRF and SEM but only the XRD and XRF package sample sent to laboratory to proceed for the test.

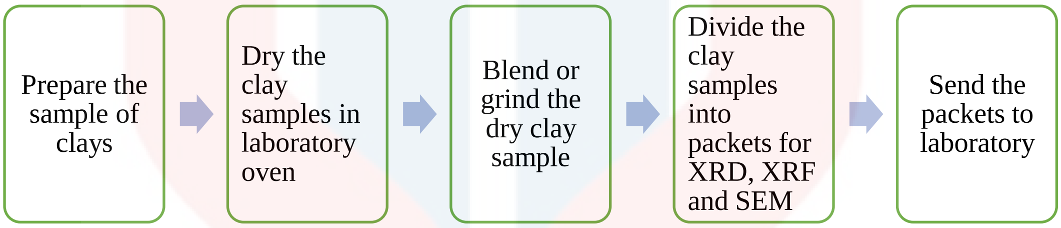


Figure 3.2: The flowchart for the preparation of sample for XRD and XRF tests.

c) SEM analysis

Preparation of the rock's samples collected for the EDX, and SEM analysis included the required amount of cutting, polishing, and cleaned with a high air pressure cleaner before mounting on the machine stands. The sample must be clean to avoid contamination from other substances. Next, the rock sample needs to be dried. The rock sample are cut into thin section size. The surface was polished before mounting. Then, the sample send to laboratory for test. **Figure 3.3** shown a flowchart for preparing SEM rock sample.

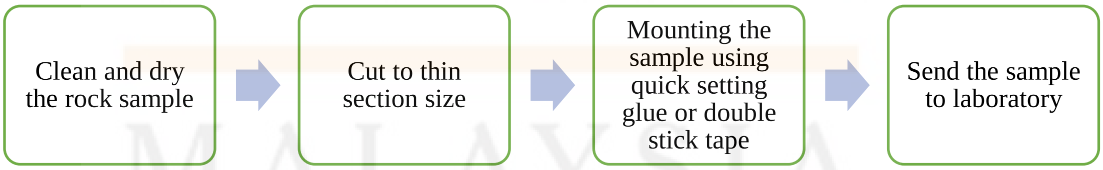


Figure 3.3: The flowchart for the preparation of rock sample for SEM

Preparation of clay samples for SEM test is proceed from XRD and XRF preparation method by the placing the carbon adhesive tape and place it over stud. Since it needs to be a very thin layer, sprinkle with dry clay sample powder and fan out the excess clay powder. Next, place the studs for gold / platinum plating. After that, it will be able to observe with SEM.

Figure 3.4: The flowchart for the preparation of sample for SEM

3.5 Data processing

Data processing is the step where the data is processing to gain the result. Data processing needs some software such as ArcGIS and Georose.

a) ArcGIS software

All the maps, including the geological map, base map, terrain map, and drainage map, were created using the Geologic Information System (ArcGIS) software. Geological map is produced as a reference for the other researcher and for the residence. Base map generally shows the study area consisting of road, contour, river, lake and other geomorphology including town or village distribution. The geological mapping is done using the base map as a guide. The varied types of rock on the study area are then presented on a geological map.

b) GeoRose software

GeoRose software is software that used to analyse the joint data. From thus software we can determine the direction of major force of the area that have applied to the rock units or outcrop. Before used this software the joint data is collected in the field.

3.6 Data analysis and Interpretations

Data analysis and interpretation is the process of assigning meaning to the information collected and determining the conclusions, significance, and implications of the findings.

a) Laboratory analysis

X-ray diffraction (XRD), X-ray fluorescence (XRF), and scanning electron microscopy (SEM) are used for laboratory analysis. The structure of crystalline materials can be determined using XRD analysis, the total elemental composition of soil samples can be determined using XRF, and the structure, texture, and shape of clay can be determined using SEM.

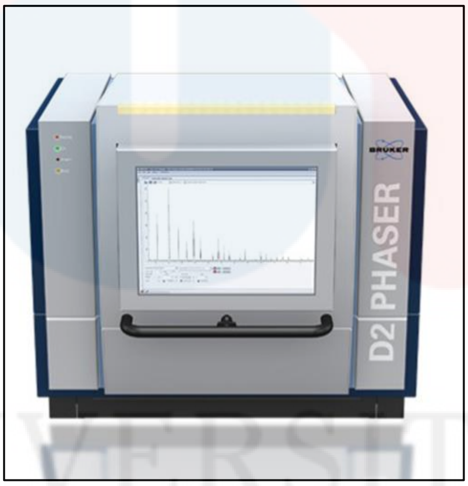


Figure 3.5: Bruker D2 phaser X-ray powder diffraction (XRD)

Figure 3.5 displays the results of an XRD investigation using a Bruker D2 Phaser diffractometer, which produced a graph of the diffraction pattern with peak intensities plotted against 2θ degree. Mineral phase identification was analysed by using DIFFRAC EVA 5.2 software by comparing experimental XRD pattern from sediment sample with theoretical XRD pattern from Crystallography Open Database (COD).

Figure 3.6: Bruker S1 Titan 800 X-ray fluorescence (XRF)

XRF analysis was performed using Bruker S1 Titan 800 X-ray shown in **Figure 3.6**. The S1 TITAN 800 use a large area detector to give incredibly fast analysis times and accurately report the elemental analysis of the sample.

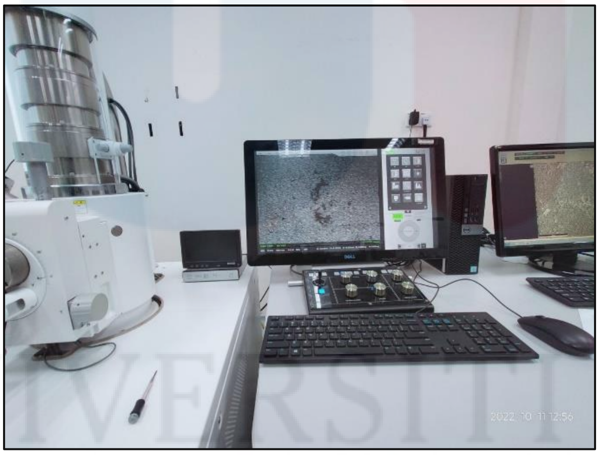
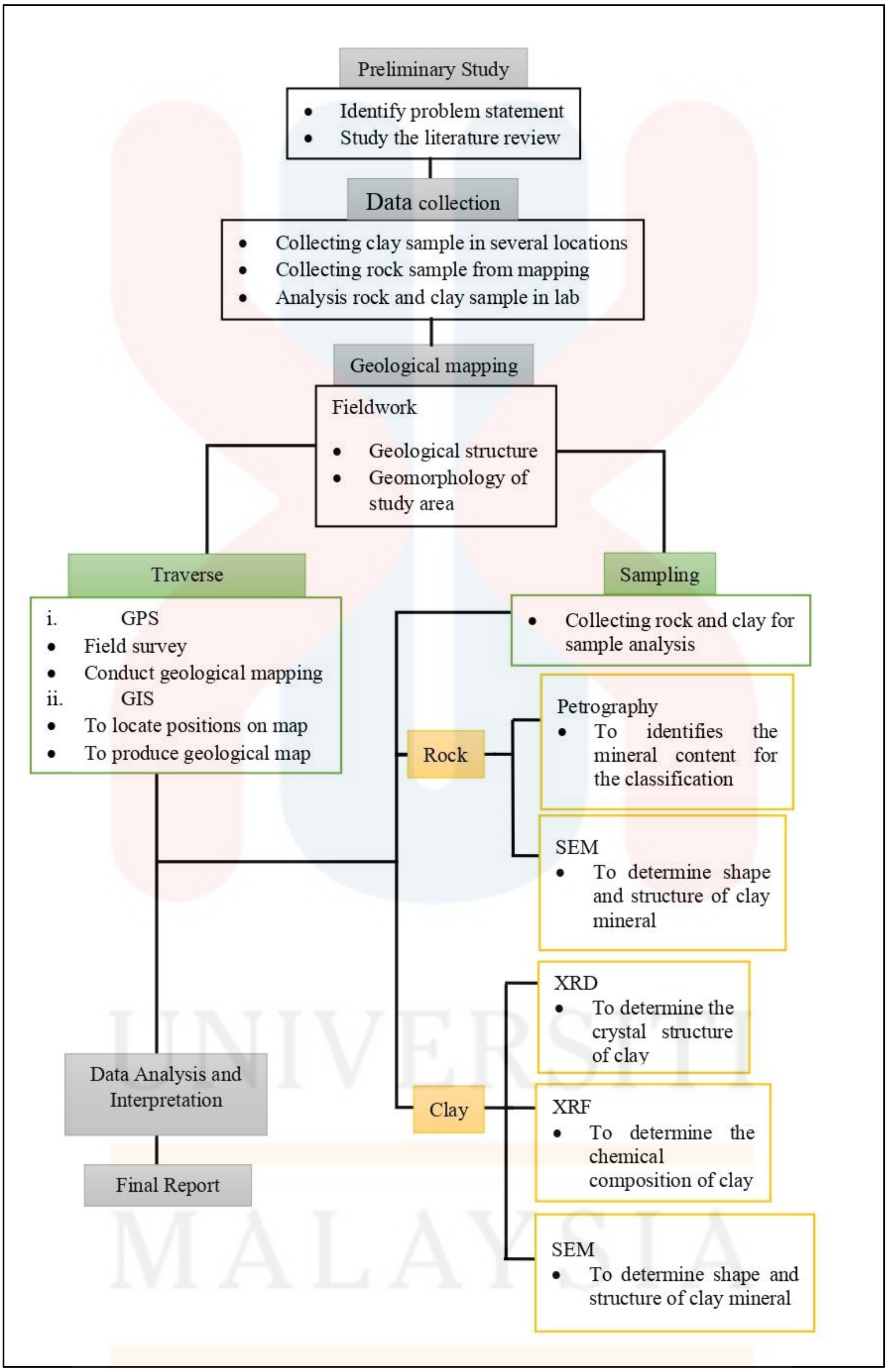


Figure 3.7: Jeol JSM-IT100 Scanning Electron Microscope

Figure 3.7 shows the results of SEM examination using the Jeol JSM-IT100 scanning electron microscope. The large chamber and mechanically eccentric stage provide a platform for easy sample navigation, whether working on large objects or with many samples for labs that need high throughput. Advanced electron optics and high sensitivity detectors make this SEM ideal for imaging a wide variety of sample types.

3.7 RESEARCH FLOW CHART



CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

Stratigraphy, structural geology, field observations, geomorphological processes, and geography are all parts of general geology. The study area has undergone changes and events, which are described using all these factors.

Population distribution, land use, socioeconomics, and road connection are all aspects of the studied area's geography. The topography, drainage system, and geomorphological processes of the research area are all covered. On the other hand, geological mapping of the study region can be accomplished through field observation and mapping. Structured geology includes the investigation of bedding, fractures, and lineaments. These crucial elements have been found in the study area. Field deformations are exposed by structural geological studies, and the lithology of the research area is described using lithostratigraphy.

4.1.1 Accessibility

The location of the study area is located at Gua Musang, which is more than 126km from UMK Jeli. The Gua Musang-Merapoh highway connects Gua Musang to the rest of Kelantan in the south. The Gua Musang-Lojing highway connects the transportation network with the study area. The road for entering the study area is covered by unpaved road. Unpaved road is also being used by logging, mining, and agriculture activity around this area. Hilux is the only good and suitable transportation that have been used to cover up this study area because the unpaved road is too extreme and along the way to cover up the study area there are fully covered with nature of flora.

4.1.2 Settlement

The settlement at the study area is Kampung Pulai and these areas are villages where have residents. There are still residences even though the majority of the study area is made up of limestone karst, palm and rubber plantations.

4.1.3 Vegetation or forestry

Forestry, palm and rubber plantations are the mainland uses in the study region. Most land use activities and economic transformations in Gua Musang are dominated by rubber and palm plantations. The research region is dominated by palm plantations, and the majority of the forest has irrigation.

4.2 Geomorphological Process

Geomorphological process is that enhance the development of the landform, the physical, morphological, and structural characteristics of the landform that shape the landform process. Landforms consist of different elements, such as mountains and valleys, rifts and scraps, lake basin and profile of water courses and vegetation pattern. Geomorphology is also practiced within physical geography, geology, engineering geology, archaeology, and geotechnical engineering.

4.2.1 Geomorphological classification

The geomorphology of the study area is discussed based on geomorphological conditions such as topography, drainage patterns, river structure and vegetation of the research area. Many techniques were used to assess the geomorphological of the study area including field observation, topography map analysis and satellite imagery. In Kelantan, there are four types of geomorphology landscape which are mountainous area, hilly area, plain and coastal area.

4.2.2 Topography

Topography may be characterized as the natural development of the surface of the earth or its physical characteristic. It also contains several different features or landforms. The characteristic and type of landform can be described by the study area contour pattern. It can be described as slightly sloping plain, sloping hills and steep hills based on observation in the study field.

Figure 4.1 represents the contour lines featured on topographic maps. The height above sea level of these joint points is similar. The slope is more gradual the farther apart the lines are. The contour interval is the height difference between each contour line. Some landforms are easily recognized due to the patterns that contour lines produce because each landform feature has quite a unique appearance. The study area contains a variety of landforms, including hills, steep slopes, and gentle slopes.

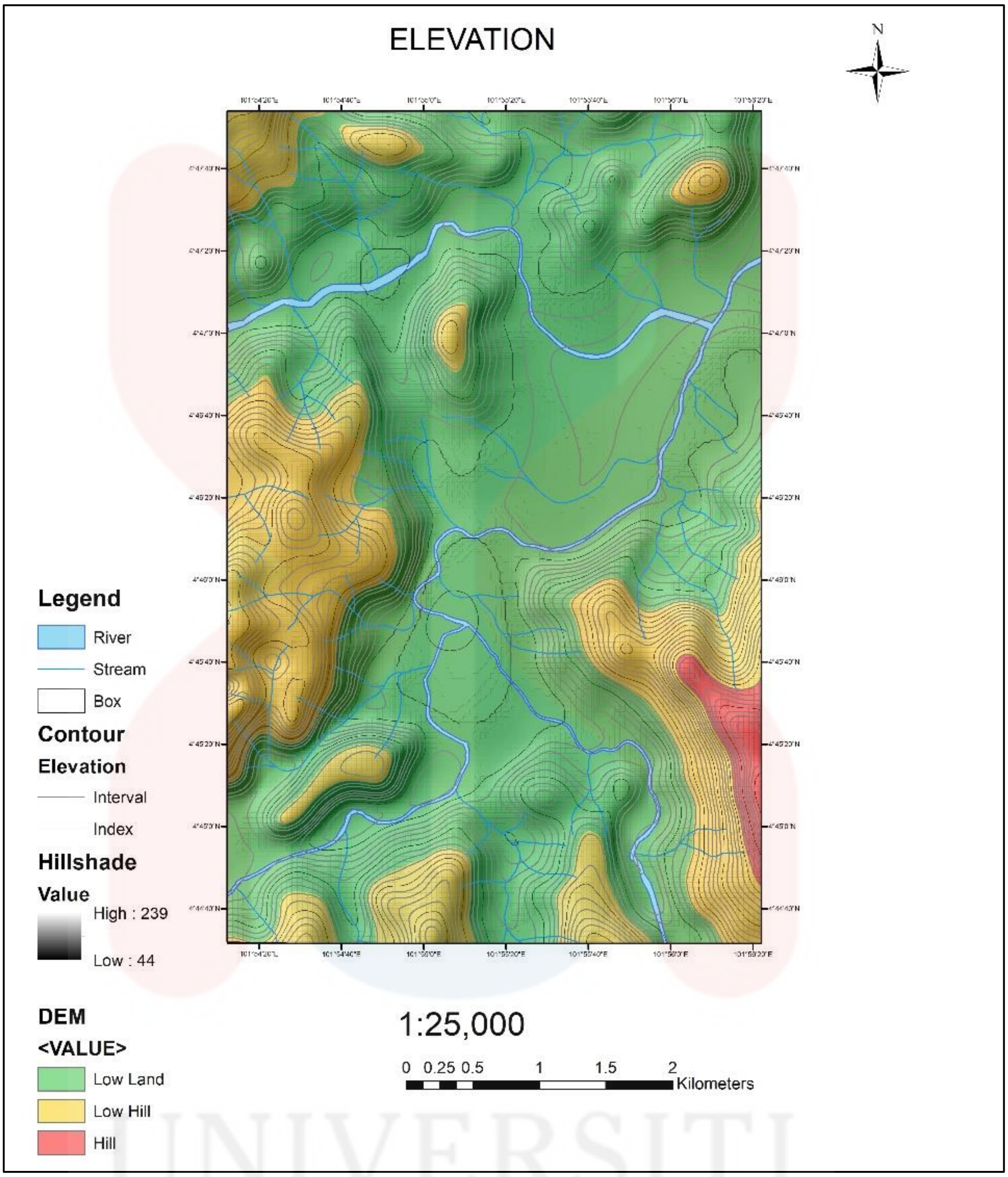


Figure 4.1: Contour line represents landform in study area.

The lowest contour value of the research area as it also has a river that passes down through it. **Table 4.1** shows the relationship elevation and morphology element. The north section in study area whereas the slightly sloping plain or gentle steep, the contour lines is far apart which the elevation is between 95m to 227m. Several hills can be found in the study area with elevation 227m to 359m. At south-east in study area where the highest elevation steep slope with peak elevation 400m.

Table 4.1: Elevation and morphology element relationship in study area

Absolute altitude (Meter)	Morphology Element
95-227	Slightly sloping plain
227-359	Sloping hills
359-491	Steep hills

4.2.3 Landform

The study of the shape of the earth's surface and its features is known as landform. This included features on the earth's surface such as mountains, hills, and streams. Roads, buildings, urban developments, railroads, airports, place names, geographic features, administrative boundaries, states, borders, reservations, and other cultural features are examples of these features. Lakes, rivers, streams, swamps, and coastal plains are also hydrographic features. Mountains, valleys, contours, and cliffs were among his relief features. Wooded glades, vineyards, and orchards were among the vegetation features.

Compared with the study area, the elevation range was between 80m and 440m, and from topographic maps, the selected study area included lowland plains, low hills, and hilly terrain. The given topographic map clearly shows the elevation difference of the study area using different colors and contour lines. **Figure 4.2** show the landform of the study area.

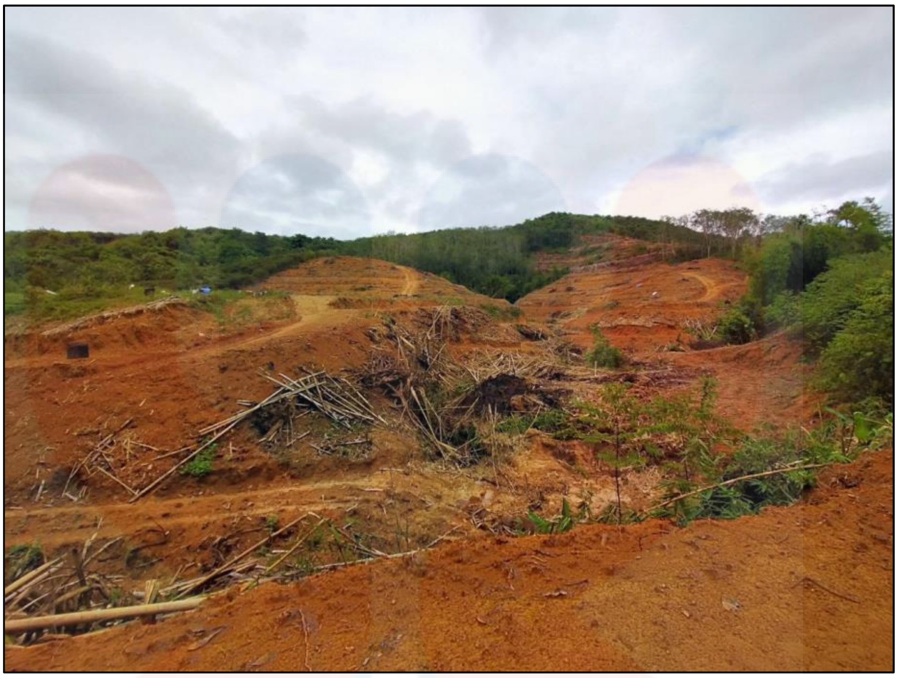


Figure 4.2: Hilly landform in study area

4.2.4 Weathering

Weathering is the proses of disintegration of rock, soil and mineral. Weathering process has the relationship between atmosphere, hydrosphere, lithosphere and also biosphere. The rock that has low resistance can easily weathered which is the process come from the erosion and transportation of the losses particle from the rock after being weathered. The transportation process needs the agents which area water, wind and ice. Time, climate, exposure area, particle properties and mineral composition are the factors that can affect the rate of weathering.

The weathering process is the breakdown of rock into fragments. The weathering process is classified into three types: chemical weathering, biological weathering, and mechanical weathering.

Physical weathering was caused by changing temperatures on the rock, which caused the rock to break apart and was aided by water. There are two types of physical weathering caused by freeze. That happens when water gets into a crack, the temperature drops, and the water freezes, causing it to expand and break apart the rock. Exfoliation is another type of physical weathering that occurs when a crack develops parallel to the surface because of pressure reduction during uplift and erosion. **Figure 4.3** shows the mass movement that happen due to the erosion and weathering.

Figure 4.3: Mass movement by physical weathering

Chemical weathering is the process by which rocks are broken down through chemical reactions. There are four types of chemical weathering, such as oxygen, which can cause the production of rust, which can soften and turn rock reddish. This type of weathering primarily affects rocks containing iron minerals. Carbonic acid is produced by carbon dioxide and can weather carbonic rocks and living organisms. Another type of chemical weathering occurs when a living organism produces weak acid through its urine. The most common type of chemical weathering is caused by acid rain, which when combined with another pollutant can hasten the weathering process. **Figure 4.4** shows the limestone exposed to chemical weathering by rainwater eroded the bedding planes.

Figure 4.4: Limestone bedding planes exposed to rainwater.

Biological weathering is a process that occurs when a plant's root grows on a rock and exerts stress on the rock, causing it to crack. Biological weathering is also a process in which plants, animals, and microbes weaken and disintegrate rock. Plant roots can invade on rock joints, and as they thicken, they push fissures open and cause them to enlarge and deepen. Chemical change is also a component of some biological weathering. For instance, variations in the soil's moisture content can be caused by the respiration of animals or biological degradation. **Figure 4.5** shows a root penetrating a joint or fissure in a rock and undergoing biological weathering.

Figure 4.5: Root penetration in rocks (biological weathering)

4.2.5 Drainage Pattern

Drainage systems can also be defined in terms of geomorphology as the patterns formed by the streams, rivers, and lakes in a specific drainage basin. They are governed by the land's topography, whether a particular region is dominated by hard or soft rocks, and the land's gradient.

A drainage basin is a topographic region that receives runoff, through flow, and groundwater flow from a stream. The number, size, and shape of drainage basins found in an area varied. Overall, the more information about the drainage basin is available, the larger the topographic map.

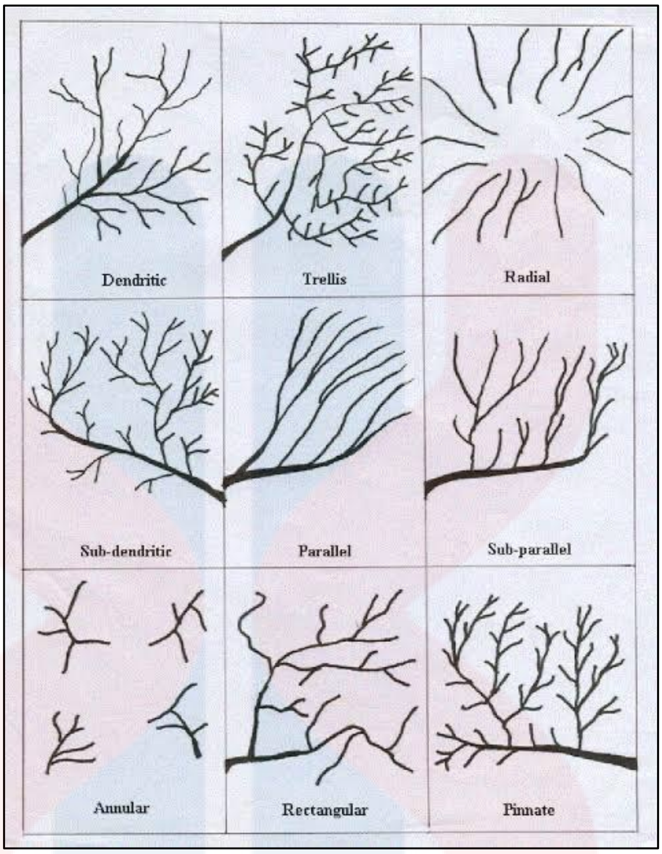


Figure 4.6: Type of drainage

There are seven types of drainage which are dendritic, trellis, radial, sub-dendritic, parallel, sub-parallel and annular based on **Figure 4.6**. A pattern of rivers caused by steep slopes with some relief. It is formed where there is a slope. The tributaries run parallel to each other in a uniformly sloping region. A dendritic drainage pattern is the most common form and looks like the branching pattern of tree roots. It develops in regions underlain by homogeneous material. **Figure 4.7** shows the map of the distribution of drainage pattern.

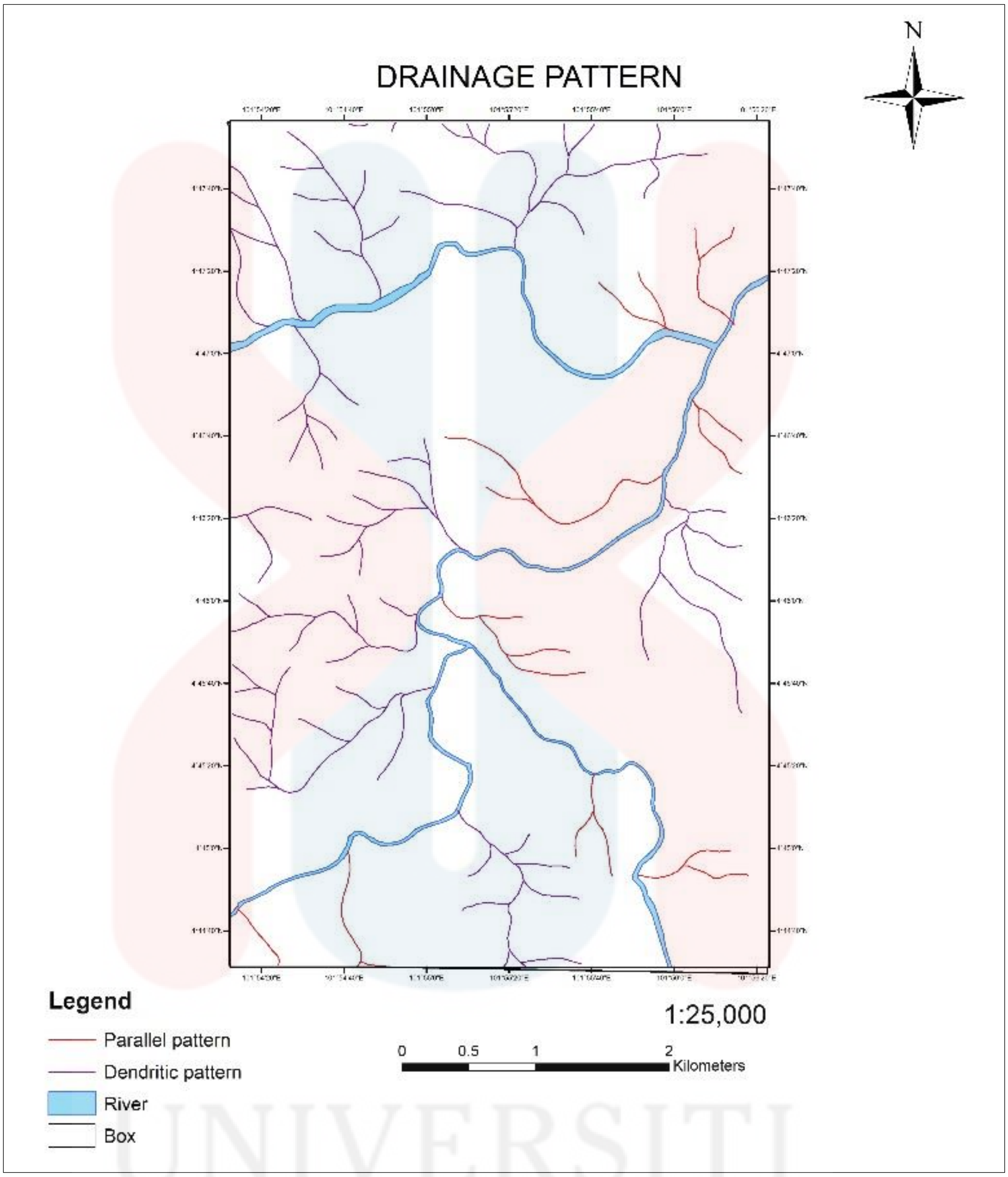


Figure 4.7: Map of drainage pattern in study area

a. Dendritic

Dendritic drainage pattern looks like the tree branches and common form that can be seen. In the study area, the dendritic drainage pattern is dominant where it is in the northwest. The direction in which water flows is eastward in areas where the rock under the stream has no specific fabric or shape and can be eroded equally easily in both directions, the dendritic pattern is by far the most frequent. The dendritic pattern originated in terrains that are covered by sedimentary rocks, massive igneous or metamorphic rocks.

b. Parallel

The second dominant pattern of river in study area is parallel. The pattern of drainage with some relief caused by steep slope is the parallel drainage system. Because of the steep slopes, with a few tributaries, the streams are fast and straight and all flow in the same direction. Where the surface has a pronounced slope, parallel drainage patterns form. A parallel pattern also develops in regions of parallel, elongated landforms such as outcropping resistant rock bands. By observing the study area, the parallel pattern is located mostly at the center of the study area.

4.3 Lithostratigraphy

Lithostratigraphy is subtopic of stratigraphy which study about strata or the layer of rock. Lithostratigraphic units are rock bodies, which are described and classified based on their lithological characteristics and stratigraphic relationship. Lithostratigraphic units are the basic units of geological mapping, by using interpretation of the secondary data and previous research to recognize the distribution of rock types in the study area. The rocks are defined as a unit of limestone, a unit shale/ slate and a unit of sandstone.

The geological map reveals the rock lithology, structural geology, cross section, and column of stratigraphy that helps to explain the study area's geology. The rocks units are identified by its characteristics such as colour, mineral composition, colour, grain size texture, hardness and other information that related. The rocks unit or lithologies that have been recognized in the study area is from Gua Musang

Formation which consist of limestone, shale unit and sandstone unit. **Figure 4.8** show the lithology map of the study area.

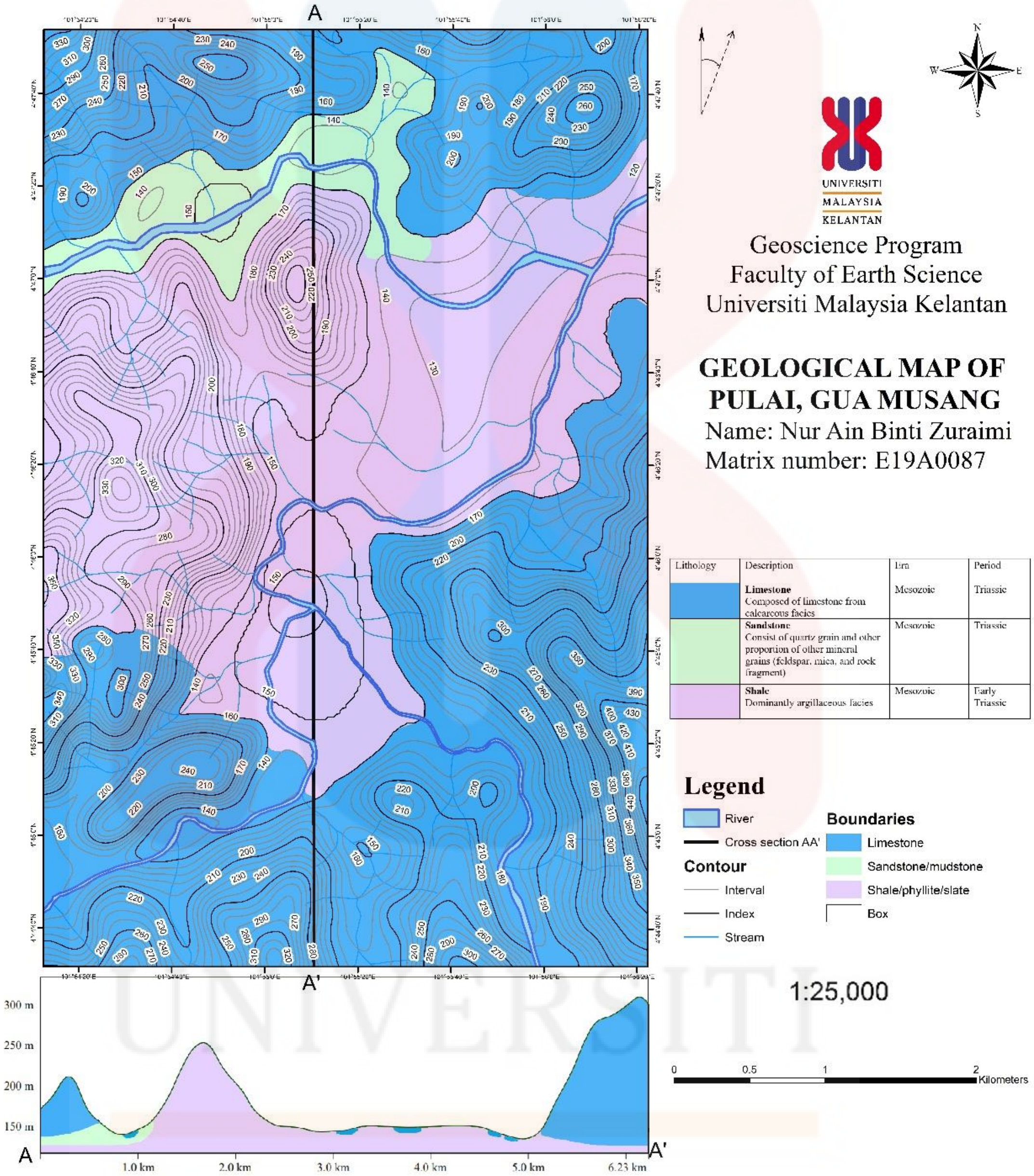


Figure 4.8: Geological map of Pulai, Gua Musang

4.3.1 Stratigraphy Column

Based on interpretation of secondary data and previous research the research area consists of three types of lithology which are limestone, sandstone, and slate. **Table 4.2** shows stratigraphy column of Pulai, Gua Musang, Kelantan. Slate deposit is the oldest rock that was discovered at the study area followed by sandstone and the youngest rock is limestone deposit. Shale in the Early Triassic period while sandstone and limestone in the same period which is Triassic.

Table 4.2: Stratigraphy column of study area

Lithology	Description	Era	Period
	Limestone Composed of limestone from calcareous facies	Mesozoic	Triassic
	Sandstone Consist of quartz grain and other proportion of other mineral grains (feldspar, mica, and rock fragment)	Mesozoic	Triassic
	Shale Dominantly argillaceous facies	Mesozoic	Early Triassic

4.3.2 Petrography

Hand specimen of limestone

Figure 4.9: Hand specimen of sample AIN1

Thin section AIN1

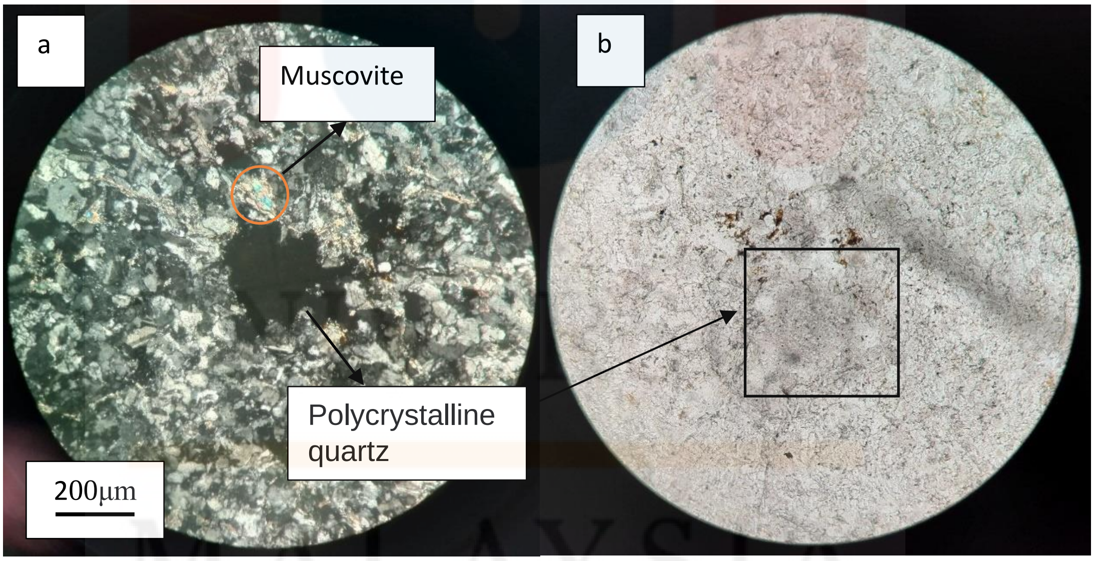


Figure 4.10: Thin section AIN1 a) under XPL b) under PPL

Figure 4.9 shows the petrographic image, microscopic observations were carried out at 10x10 magnifications. This thin section consists of mineral quartz and muscovite. Quartz is colorless under PPL but can be black in XPL because of extinction. It also lacks cleavage, twinning, and anhedral form. Muscovite is pale green under XPL with relief low to moderate and appears colorless under PPL. Pleochroism in muscovite is absent but has very perfect cleavage. Muscovite is well formed tabular crystal with a roughly hexagonal outline. Under XPL muscovite is anisotropic with extinction and twinning. The **Figure 4.10** is fine grained in size, whitish in colour and the sample is reacted to HCL which has calcite in the composition.

Table 4.3: Description thin section AIN1

Rock	Mineral	Description
Limestone	Quartz (Qtz)	White in PPL, colourless in XPL extinction at certain angle which cause blackish or greyish, no twinning, low relief
	Muscovite	Brown or silver sometime with a tint of yellow, green in colour, with perfect cleavage

Hand specimen phyllite

Figure 4.11: Hand specimen of sample AIN3

Thin Section AIN3

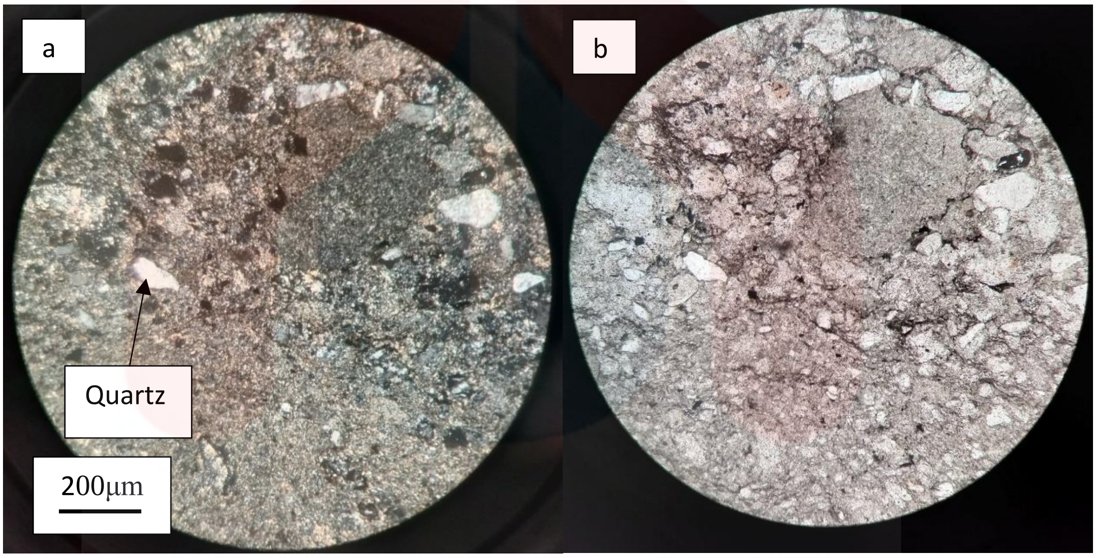


Figure 4.12: Thin section a) under XPL b) under PPL

Figure 4.12 shows the petrographic image, microscopic observations were carried out at 10x10 magnification. This thin section consists of the mineral quartz, and matrix fill the thin section. Quartz is colourless under PPL but can be black in XPL because of extinction. It also lacks cleavage, twinning, and anhedral form. Matrix is the finer-grained mass of material in thin sections such as clay or silt. **Figure 4.11** shows fine grained in size and consist with iron. The colour is white to grey.

Table 4.4: Description thin section AIN3

Rock	Minerals	Description
Phyllite	Quartz	White in PPL, colourless in XPL extinction at certain angle which cause blackish or greyish, no twinning, low relief
	Matrix	Fine grained sedimentary material (clay/silt), larger grains is embedded

Hand specimen sandstone

Figure 4.13: Hand specimen of sample AIN6

Thin section AIN6

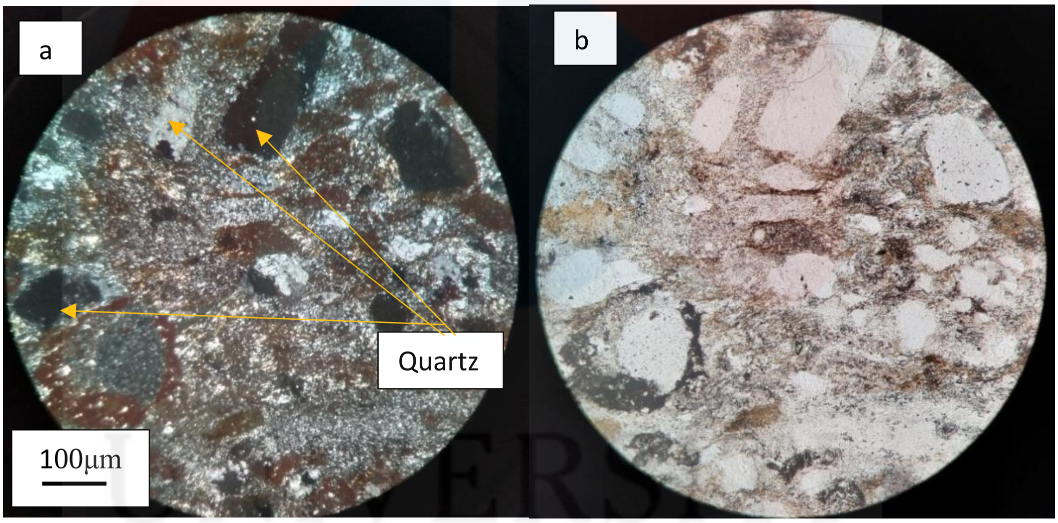


Figure 4.14: Thin section a) under XPL b) under PPL

Figure 4.14 shows the petrographic image, microscopic observations were carried out at 10x magnification. This thin section is quartz sandstone with iron. Quartz is colourless under PPL but can be black in XPL because of extinction. It also lacks cleavage, twinning, and anhedral form. Quartz is moderately well-rounded with hematite and overgrowth of quartz in optical continuity with the original grain.

Table 4.5: Description of thin section AIN6

Rock	Minerals	Description
Sandstone	Quartz	White in PPL, colourless in XPL extinction at certain angle which cause blackish or greyish, no twinning, low relief

Hand specimen

Figure 4.15: Hand specimen of sample AIN11

Thin section AIN11

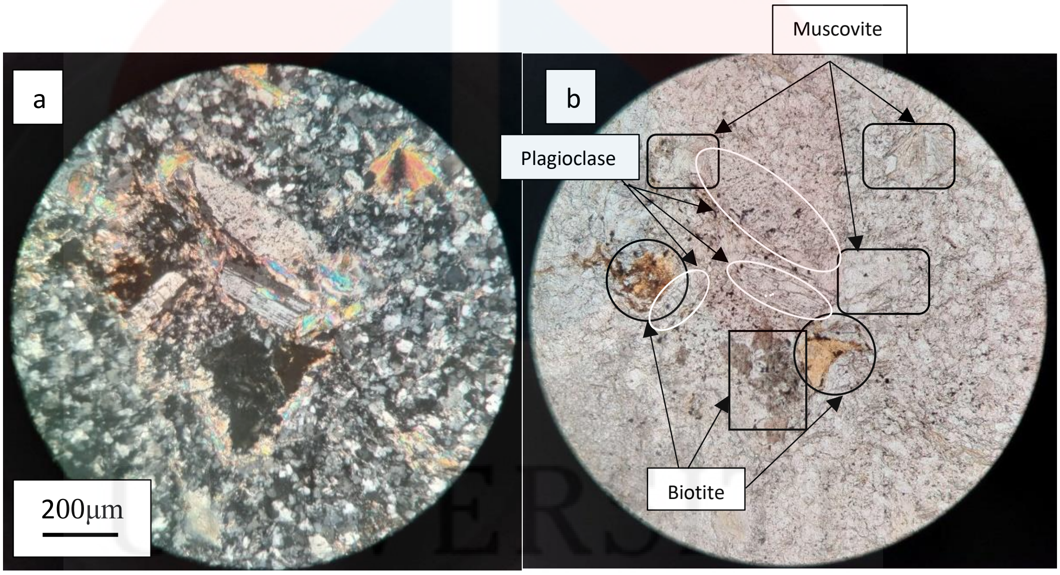


Figure 4.16: Thin section a) under XPL b) under PPL

Figure 4.16 shows the petrographic image, microscopic observations were carried out at 10x magnification. This thin section consists of quartz, plagioclase, biotite, and muscovite. Plagioclase is colourless but may appear grainy or greyish in PPL. Twinning is visible under XPL giving a zebra strip appearance. Plagioclase has low to moderate relief, a subhedral shape, and two cleavages. Muscovite is pale green under XPL with relief low to moderate and appears colorless under PPL. Pleochroism in muscovite is absent but has very perfect cleavage. Muscovite is well formed tabular crystal with a roughly hexagonal outline. Under XPL muscovite is anisotropic with extinction and twinning.

Table 4.6: Description of thin section AIN11

Mineral	Description
Quartz	White in PPL, colourless in XPL extinction at certain angle which cause blackish or greyish, no twinning, low relief
Plagioclase	White or grey in colour, white to grey in pleochroism, perfect two direction cleavage, low relief
Biotite	Brown in PPL with pleochroism and has cleavage
Muscovite	No pleochroism, pale green in XPL, colourless in PPL

4.4 Structural Geology

The study of the three-dimensional distribution of rock units in relation to their deformational histories is known as structural geology. It acts as a present-day geometric measurement to uncover information about the history of deformation of the earth's surface at the study area. Two major analyses were performed in this study to determine the geological event and surface occurrence. Lineament analysis and joint analysis were described and analyse by using GeoRose software for the joint analysis.

4.4.1 Joint Analysis

A joint is a break (fracture) of natural origin in the continuity of either a layer or body of rock that lacks any visible or measurable movement parallel to the surface (plane) of the fracture. Joint analysis aims to study the propagation of crack in material. It was used to calculate the driving force on a crack and it's resistant toward fracture. About 230 reading (**Table 4.7)** were taken and the collected data was interpreted using GeoRose software as result **Figure 4.18. Figure 4.17** is where the outcrop of the data was taken.

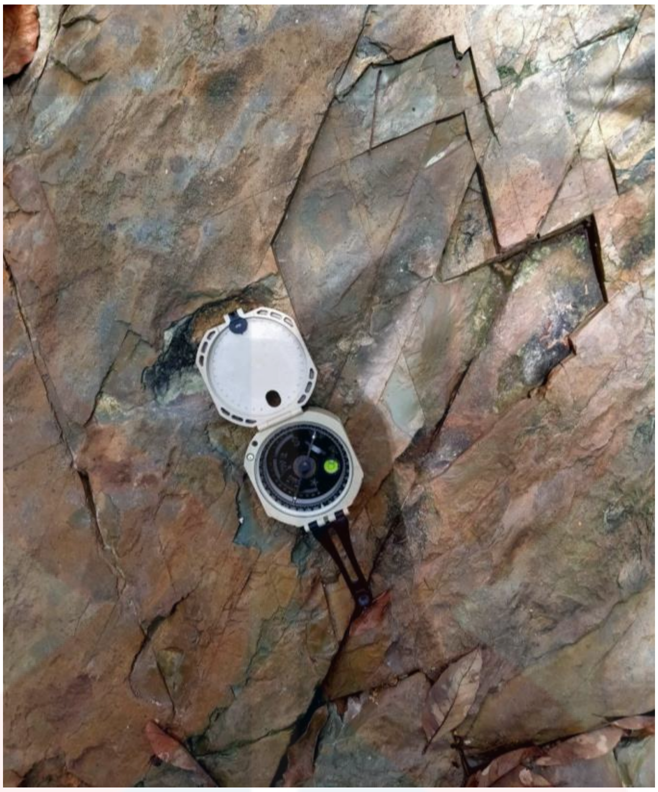


Figure 4.17: Cross cutting joint could be seen on the outcrop.

Table 4.7: Joint direction data

238	251	247	245	249	260	222	232	216	222
237	266	256	262	266	218	227	219	225	225
256	252	260	246	267	225	228	235	225	220
231	269	255	255	269	214	226	219	225	214
245	261	250	260	225	227	226	220	232	225
244	264	258	260	220	222	231	220	225	230
236	255	254	259	234	220	235	225	226	224
255	270	266	265	230	218	218	227	232	255
266	250	270	256	219	206	235	215	226	257
268	261	265	249	225	227	227	220	220	260
258	220	214	216	218	225	225	262	232	230
242	225	274	222	218	210	222	230	218	244
218	256	260	224	255	263	224	208	220	264
220	227	271	227	262	225	230	232	221	225
244	260	269	225	265	264	225	236	225	234
256	235	271	211	265	222	226	233	257	200
260	230	269	214	261	223	268	234	226	221
265	235	266	222	266	236	267	238	265	231
218	212	265	228	230	220	266	235	224	225
225	216	231	220	228	221	220	231	220	223
224	235	216	224	235	216	224	235	216	224
216	255	217	216	255	217	216	255	217	216
214	240	215	214	240	215	214	240	215	214

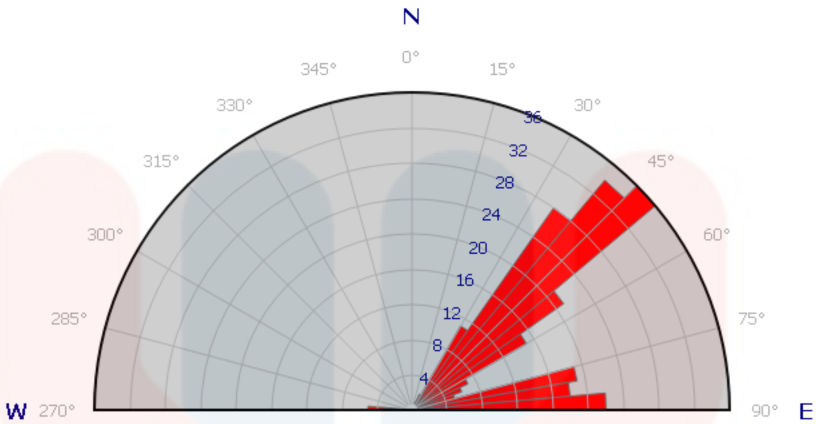


Figure 4.18: Rose diagram of joint analysis

4.4.2 Lineament Analysis

Lineament analysis refers to a linear feature that is displayed as an expression of an underlying geological structure, such as a fault. This study was conducted to determine the force direction that resulted in the current geological surface that can be seen today. Lineament analysis was performed using satellite imagery of the study area and the surrounding area because it could provide information about the direction of force acting on the area. This result can also predict what will happen if the force direction changes, which could endanger the study area.

The lineament can be analysing by using the terrain mapping. From the terrain map, the linear features such as the stream and ridges. Terrain map with the help of topographic map by using GIS method can be produced. The topographic data is a very crucial as they complement each other to make lineament interpretation to characterize the regional area. **Figure 4.19** shows the terrain map with the lineament line.

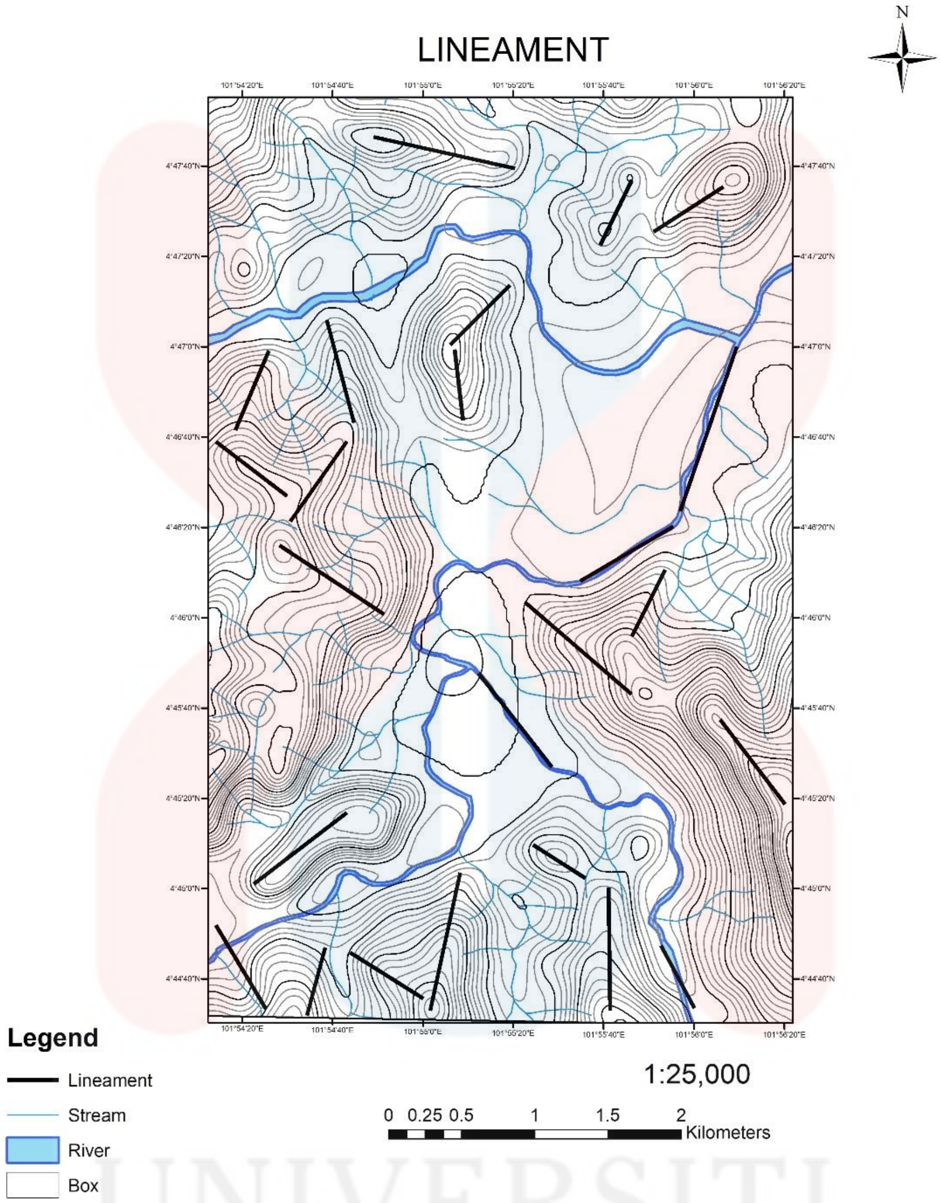


Figure 4.19: Lineament map of study area

4.5 Historical Geology

The study area, Gua Musang is a formation that are develop during the Permian Triassic transition (Simon, 2013). This region is situated within the Peninsular Malaysian Central Belt. The bulk of the Upper Palaeozoic sediments consist of Permian marine strata which occur in the Central Belt as linear belts flanking Mesozoic sediments. In the south of Kelantan, the Upper Palaeozoic rock is the Gua Musang Formation, while in the east of Kelantan it is the Taku Schist. Argillaceous and volcanic facies dominate the Upper Palaeozoic formation, while calcareous and arenaceous facies belong to the remainder. Usually, the depositional climate is shallow marine with occasional active underwater volcanism beginning in the Late Carboniferous and peaking in the Permian and Triassic to meet it. This region is covered entirely by limestone.

CHAPTER 5

CHARACTERIZATION OF CLAY

5.1 Introduction

This study assists in identifying the occurrence and characterization of clay properties including physical properties of clay, chemical analysis of clay by using X-ray diffraction and X-ray fluorescence analysis SEM and microscopy investigation. The results of the analyses for eight locations of clay samples in Gua Musang, Kelantan were described accordingly in this chapter.

5.2 Sample description

The sample is composed of rocks and soil samples. Some soil sample is collected at the same places where the rock sample is collected. The descriptions of the samples that were taken in Pulai, Gua Musang, are shown in **Table 5.1**. Only 12 of the 16 samples (Appendix 1) that were collected have undergone analysis.

Table 5.1: Description of collected sample.

Sample	Coordinate	Description
AIN1 (Thin section, SEM, XRD, XRF)	N 04°46.50 E 101° 56’ 5.9”	The rock and soil sample has been collected at riverside near the road. The hand specimen of the rock sample has a whitish colour on the outside and yellowish in the inside. The soil sample has a yellowish to orange in colour and the grain size s fine to medium grain. The rock sample is coarse grain and consist of k-feldspar.
AIN3 (Thin section, SEM)	N 4 46 6.6 E 101 55 37.5	The rock sample has been collected at the roadside near rubber plantation. The colour of the sample is dark grey with fine grain.
AIN5 (XRD)	N 4 47 14.1 E 101 55 23.7	The soil sample has been collected at cut slope. The colour of soil sample is whitish with orange reddish. The grain size is fine to medium.

AIN6 (Thin section, SEM))	N 4 47 19.7 E 101 55 21.2	The hand specimen has been collected at cut slope which it has dark orange to reddish in colour and fine coarse grain. The sample is undergo chemical and physical weathering because it crumble when hit with hammer.
AIN7 (XRD)	N 4 47 2.2 E 101 54 48	The soil sample has been collected at cut slope and the size grain is medium to coarse. The colour of soil sample is yellow to orange.
AIN8 (XRD)	N 4 46 47.5 E 101 54 56.3	The soil sample has been collected at cut slope and the colour of the soil is yellow to reddish.
AIN9 (SEM)	N 4 46 47.3 E 101 54 56.1	The rock sample has been dug out from the road and the sample is undergo chemical and physical weathering because it crumble when hit with hammer. The colour is orange to reddish with coarse grain.
AIN10 (XRD)	N 4 46 22.6 E 101 55 0.8	The soil sample has been collected at cut slope which has colour greyish with coarse grain
AIN11 (Thin section, XRF, SEM))	N 4 46 25.7 E 101 55 0.8	The rock sample has been collected near the river which the sample has reddish outside and whitish in the inside. The sample is fine to medium grain.
AIN12 (SEM)	N 4 45 08.6 E 101 55 08.1	The rock sample has been collected near the river. The sample has dark grey in colour and fine grain
AIN13 (SEM)	N 4 45 28.4 E 101 55 1.7	The rock sample has been collected near the river and the sample is dark grey in colour and fine grain with vein quartz
AIN15	N 4 45 15.1 E 101 54 26.5	The rock sample has been collected is karst, dark grey in colour and fine grain

GEOLOGICAL MAP OF PULAI,
GUA MUSANG, KELANTAN, MALAYSIA.

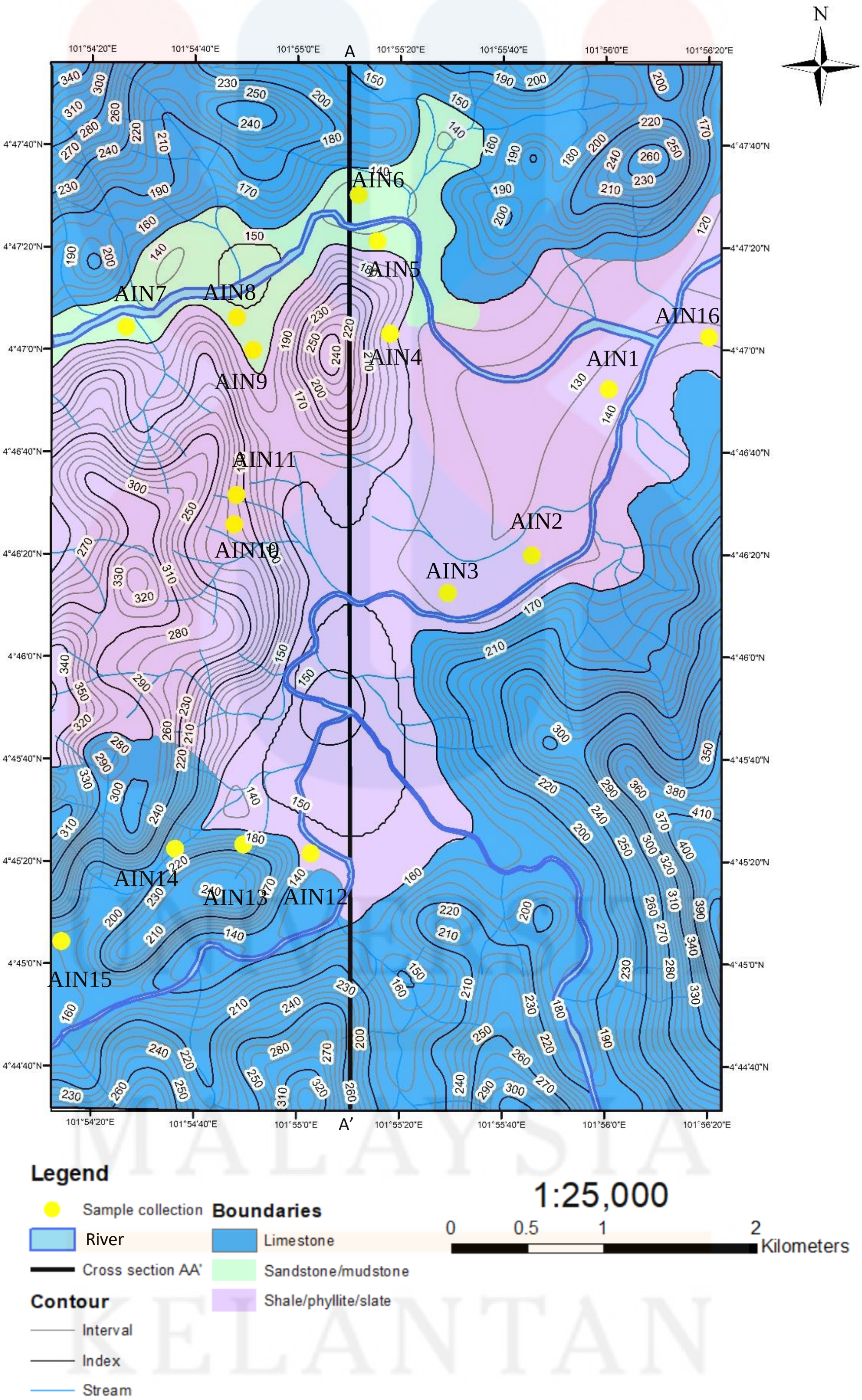


Figure 5.1: Geological map show location of the sample

5.3 Physical Properties

Clay is found on or near the surface of the earth. Based on the study area, clay sample mostly found in the excavation area which give clear view of soil horizon. **Figure 5.2** show clays located in B horizon of soil profile because this zone accumulate of fine materials and material precipitates like as clay, iron, carbonates, gypsum.

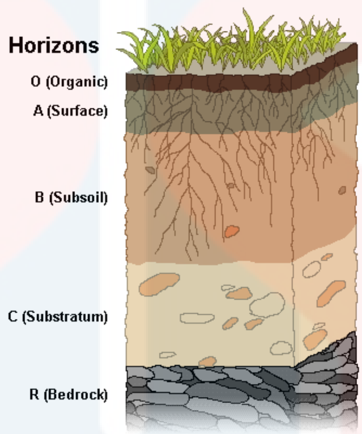


Figure 5.2: Soil horizon of soil profile

Based on clay sample collected, the colour of clay ranging from light brown to brick red colour and whitish. The clay was randomly distributed according to colour. The colour of most clay samples depends on the quantity and oxidation state of iron and other transition element present. The clay feels sticky and clump when wet, can refer **(Figure 5.3 and 5.4)** but feel smooth when dry.

Figure 5.3: Outcrop sample AIN4 show the texture of the clay

Figure 5.4: Outcrop sample AIN7 show the texture of the clay

5.4 Analysis

5.4.1 XRD

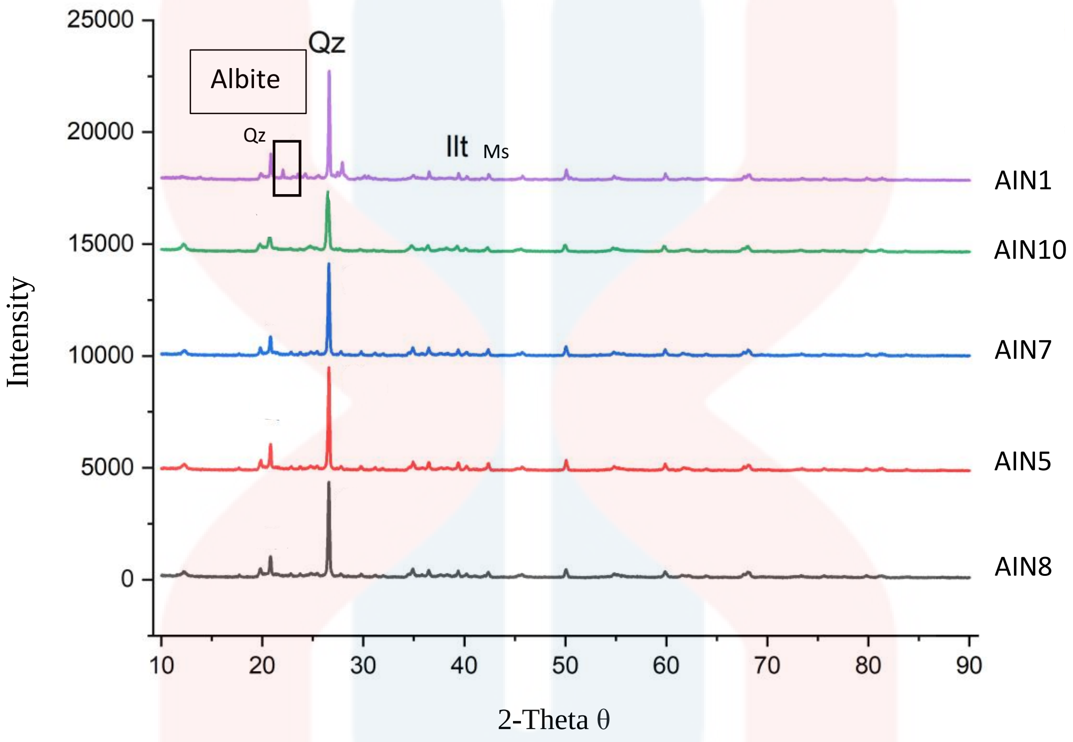


Figure 5.5: XRD graph result

Table 5.2: XRD peak element percentage (%) by Diffract Eva

Element / Sample	AIN1	AIN5	AIN7	AIN8	AIN10
	Percentage (%)				
Si	30.30	35.60	35.60	35.80	35.20
Al	12.80	8.00	8.10	8.00	8.30
Na	1.20	-	-	-	-
K	5.80	5.50	5.90	5.80	5.50

Based on **Figure 5.5**, all five graph XRD result which is AIN1, AIN5, AIN7, AIN8, and AIN10 show almost the same peaks pattern at the range 10 to 70 2-Theta (θ) and element in all the sample has range between 30% to 36% for silicon (Si), 8% to 12% for aluminium (Al) and 5% to 6% for potassium (K) (**Table 5.2)**. Also, the minerals found in the samples are almost the same which are quartz, illite and muscovite minerals. The highest peak is shown in the graph for all samples attributed to mineral quartz at 25 to 30 2θ which has 35.80% of element Si (AIN8), that are mainly mineral quartz. AIN1 in the black box has a little peak attributed to mineral albite at 20 to 25 2θ with 12.8% of element Al. Mineral illite with 5.8% to 6% of K element appear in all sample even with lowest peak in graph. Minor mineral in the sample is muscovite which the peak is low.

5.4.2 XRF

Table 5.3: XRF analysis result comparison with ceramic grade kaolin and illite.

Element / Sample	Ain1	Ain11	ECC Super Standard Oorcelain	ECC Grolleg, Eartware	ECC Rembleend, Sanitaryware	Illite
	Percentage (%)					
SiO_2	100.00	91.91	47	48	48	58.68
Al_2O_3	19.61	18.58	38	37	37	19.25
Fe_2O_3	0.54	0.35	0.39	0.7	1.0	5.04
MgO	-	0.73	0.22	0.30	0.3	2.50
K_2O	4.95	4.40	0.8	1.85	2.0	6.12
CaO	0.15	0.100	0.1	0.06	0.07	1.29
Na_2O	-	-	0.15	0.10	0.10	0.19
TiO_2	0.04	0.01	0.03	0.02	0.05	-

XRF analysis was conducted using a portable XRF Analyzer (S1TITAN800). Previous research stated that Mg is normally found in typical clay. From **Table 5.3**, AIN1 and AIN11 show Si has highest element content 100.0% and 91.9% because when the analysis is conducted using portable XRF, it needs to be direct contact with the sample and it point direct to quartz mineral in rock. Also, in the table is identified that the sample AIN1 and AIN11 containing Al_2O_3 are 19.61% and 18.58%. The data is much different from the standard ceramic grade kaolin. But if refer on literature review chemical composition of illite, Al_2O_3 XRF for the two samples are in the same range which is 19%. Based on the proximity of silicate and alumina compositions obtained between AIN1 and AIN11 with pure kaolin showed that kaolin has silicate aluminate levels near pure kaolin although there are still many impurities it contains such as K2O, Fe2O3, TiO2, MgO, SO.

5.4.3 SEM

Based on **Figure 5.6**, the shape and texture of the mineral clay in the sample are quite rough because it was improperly polished, thus the shape and texture of clay can not be identified.

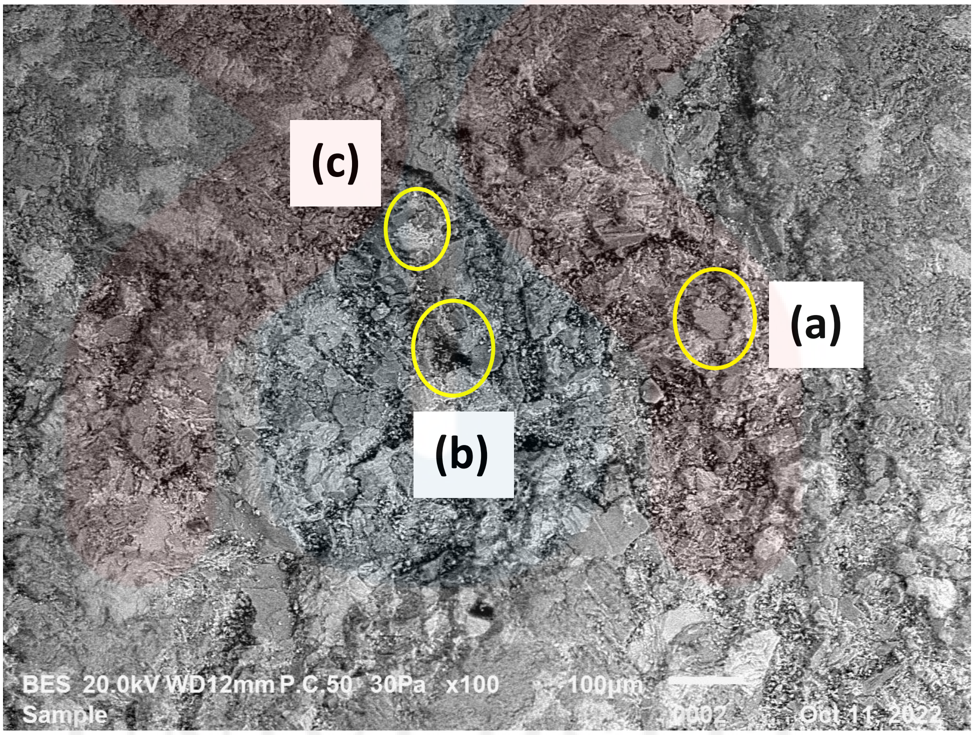
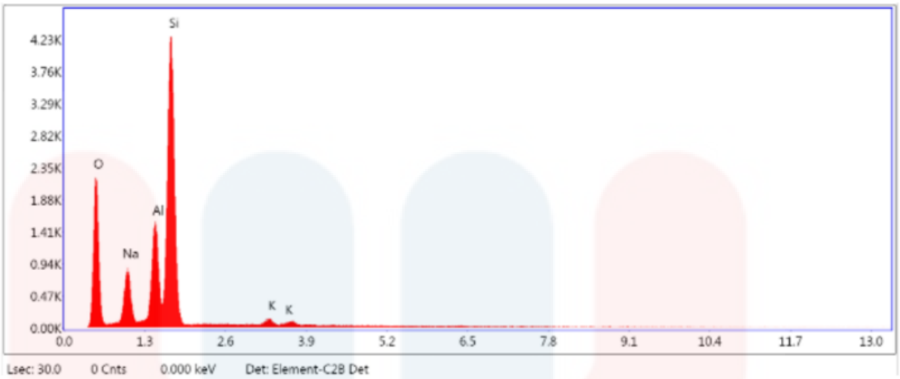


Figure 5.6: SEM images of rock sample AIN1 a) EDS represent anorthoclase, b) EDS represent anorthoclase and c) EDS represent albite



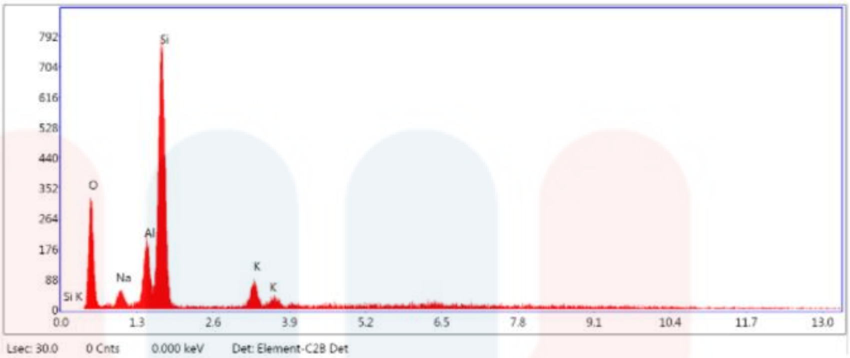
eZAF Smart Quant Results

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
O K	35.08	47.70	697.50	8.60	0.1203	1.0639	0.9705	0.3222	1.0000
NaK	10.66	10.09	308.20	7.55	0.0513	0.9673	0.9968	0.4940	1.0075
AlK	13.18	10.62	631.05	5.05	0.0882	0.9478	1.0116	0.6941	1.0174
SiK	39.95	30.95	1841.75	4.63	0.2655	0.9687	1.0184	0.6841	1.0024
K K	1.13	0.63	37.73	10.84	0.0089	0.8984	1.0468	0.8648	1.0148

Figure 5.7: EDS for point (a) in SEM AIN1

Point (a) in **Figure 5.6** has been spotted using EDS shows that the mineral is anorthoclase mineral. There is element Si with a percentage of 39.95%, element Al with a percentage of 13.18%, Na with 10.09%, and K with 1.13%. There is element Si with 42.60%, Al with 9.62%, Na with 4.035% and K with 5.78% in **Figure 5.7.**

EDS Spot 4

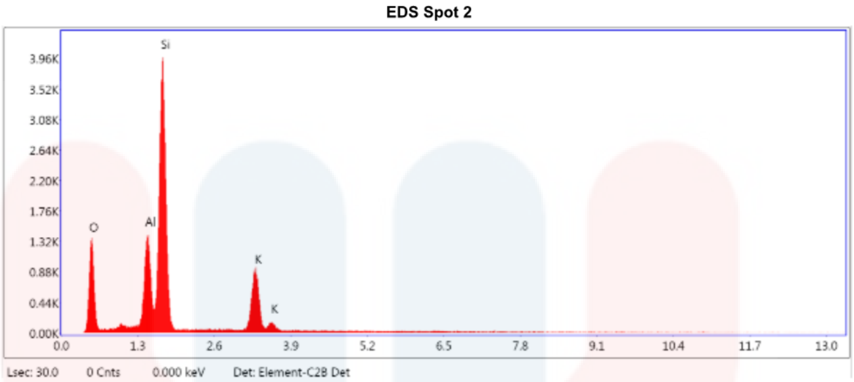


eZAF Smart Quant Results

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
O K	37.78	51.73	103.73	10.79	0.1115	1.0632	0.9683	0.2775	1.0000
NaK	4.03	3.84	17.25	17.08	0.0179	0.9668	0.9948	0.4555	1.0083
AlK	9.82	7.97	79.50	6.90	0.0693	0.9474	1.0097	0.7289	1.0216
SiK	42.60	33.22	340.20	4.80	0.3056	0.9683	1.0165	0.7385	1.0033
K K	5.78	3.24	30.99	10.09	0.0458	0.8983	1.0453	0.8709	1.0133

Figure 5.8: EDS for point (b) in SEM AIN1

Point (b) also has same mineral as point (a) which is anorthoclase mineral with slightly different in weight percentage, Si with 42.60%, Al with 9.82%, Na with 4.03% and K with 5.78% in **Figure 5.8**.



eZAF Smart Quant Results

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
O K	35.42	50.46	427.95	9.84	0.0834	1.0717	0.9630	0.2198	1.0000
AlK	12.35	10.43	570.93	4.58	0.0902	0.9555	1.0051	0.7500	1.0195
SiK	37.85	30.72	1663.63	4.22	0.2712	0.9767	1.0121	0.7297	1.0051
K K	14.39	8.39	433.37	3.45	0.1162	0.9063	1.0415	0.8810	1.0115

Figure 5.9: EDS for point (c) SEM AIN1

Point (c) in **Figure 5.6**, the SEM images represents the albite mineral which has the component element based on **Figure 5.7**, Si with 37.85%, Al 12.35% and K with 14.39%. Albite is the feldspar mineral, a sodium aluminosilicate where it also can be found low grade metamorphic rock.

5.5 DISCUSSION

The results of the XRD analysis in **Figure 5.5**, show the presence of quartz, illite, and albite minerals and thus can be linked to the results of the XRF analysis in **Table 5.3** because they have elements such as Si, Al, Na, and K. XRD shows that the percentage of 30% to 38% for the element Si (**Table 5.2**) is high, and it is likely that the percentage for SiO_2 is also high. So, based on XRF analysis for AIN1 sample, composition of SiO_2 is within the range of standard kaolin (47%-48%). The results of AIN1 sample based on XRD and XRF analyses have shown the composition of illite mineral which are 12.8% of Al element and 19.61% of Al_2O_3 respectively in the range of illite mineral. The Potassium (K) element in XRD result and K2O in XRF results in the same range which is 4.953% and 5.8%.

The mineral feldspar is present in the thin section AIN11 (**Figure 4.11)**, mineral feldspar can be weathered by chemical weathering to form clay minerals. SEM EDS (**Figure 5.6)** shows anorthoclase and albite, two alkaline feldspar minerals with the same elements but different percentages, which are supported by XRD and XRF analysis results. Element in all the sample XRD has range between 30% to 36% for Si, 8% to 12% for Al and 5% to 6% for K.

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

As a conclusion, the interpreted research area's geological map was produced by conducting mapping and using ArcGIS. As a result of interpretation, it is able to identify the rocks in the study area, the majority of which are sedimentary rocks such as limestone, sandstone, and shale.

For the specification of the study area, the result of the analysis sample has clearly shown that the analyzed sample is an illite mineral compound. The XRD demonstrates that illite has a peak with 8% to 12% for aluminium (Al) even if it is modest in each sample, validates the XRF analysis 19.61% and 18.58% of Al_2O_3. The XRD and XRF show the major elements in the sample, which is SiO_2, Al_2O_3 and K_2O, while the other elements show in minor quantities. Based on those analyses, the characteristics of clay mostly in the aspect of element content were determined which was dominated by the element Si for each sample. Clay in Pulai, Gua Musang, Kelantan possesses industrial values.

6.2 Suggestion

For future research, the research about characterization of clay study should be continuing in order to improve this research. Characterization of clay study is one of the studies that least applied and it beneficial especially in exploration for clay deposit and do more sampling for precise results. Furthermore, I suggest that the university repair and improve facilities such as XRF machines, SEM, and machines for thin section for student's research to get accurate results.

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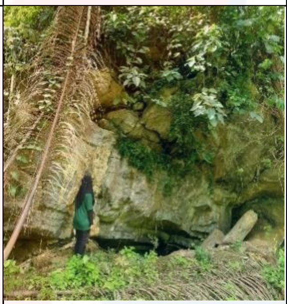
APPENDIX 1

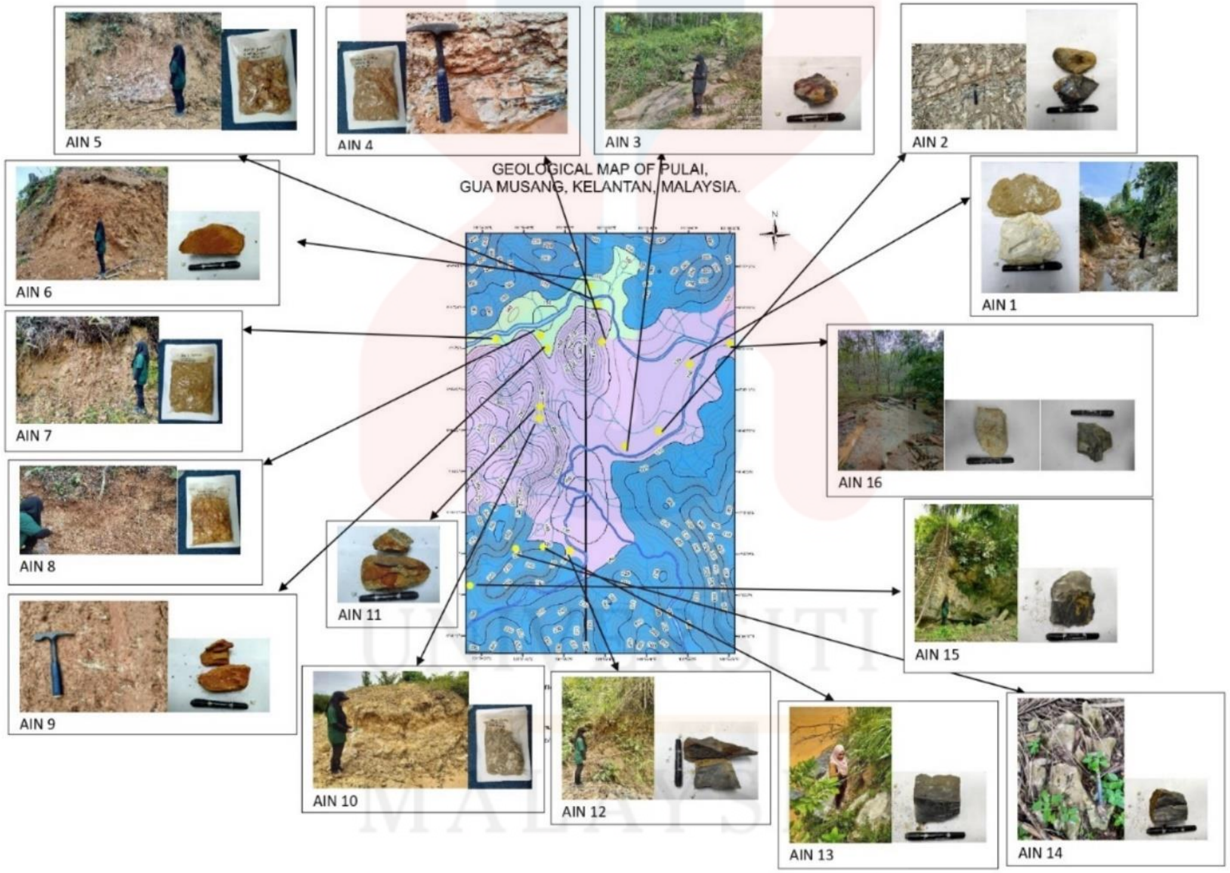
The description of the sample used in this study.

Sample Code	Lithology	Location / Coordinate	Physical characteristic
Ain1 Rock & soil		N 4 46 50 E101 56 5.9 • Near with river • Landslide	Coarse grain, whitish, yellowishand clayey
Ain2 Rock		N 4 46 10 E 101 55 41 • Outcrop exposed on road	Greyish, brownish, Fine gerain
Ain3 Rock		N 4 46 6.6 E 101 55 37.5 • Near hill	Greyish, fine grain
Ain4		N 04 46 55.2 E 101 55 27 • Exposed on road	Orange to dark red, clayey
Ain5 Soil		N 4 47 14.1 E 101 55 23.7 • Cut slope	Whitish orange to redish

Ain6		N 4 47 19.7 E 101 55 21.2 • Cut slope	Yellowish to orange reddish, coarse grain, sandy
Ain7 Soil		N 4 47 2.2 E 101 54 48 • Cut slope	Orange, clay to sandy
Ain8 Soil		N 4 46 47.5 E 101 54 56.3 • Cut slope	Whitish orange to reddish, coarse grain
Ain9 Rock		N 4 46 47.3 E 101 54 56.1 • On the road	Orange to redish, coarse grain
Ain10 Soil		N 4 46 22.6 E 101 55 0.8 • Cut slope	White to greyish, Clay to sand
Ain11 Rock		N 4 46 25.7 E 101 55 0.8	Whitish to greyish, Fine to medium grain
Ain12 Rock		N 4 45 08.6 E 101 55 08.1 • Near the hill • With vegetation • Near river	Dark grey with fine grain

Ain13 Rock		N 4 45 28.4 E 101 55 1.7 • Near river with vegitation	Grey to blakish, fine grain With quartz vein
Ain14		N 4 45 26.9 E 101 54 49.4 • Near the hill	Dark grey with fine grain With quartz vein
Ain15		N 4 45 15.1 E 101 54 26.5 • Karst with cave	Dark grey, fine grain With qquartz vein
Ain16		N 4.78 18 08 E 101.94 03 1 • Near the river	Yellowish, greyish

APPENDIX 2



GEOLOGICAL MAP OF PULAI,
GUA MUSANG, KELANTAN, MALAYSIA.
AIN 1
AIN 2
AIN 3
AIN 4
AIN 5
AIN 6
AIN 7
AIN 8
AIN 9
AIN 10
AIN 11
AIN 12
AIN 13
AIN 14
AIN 15
AIN 16