GEOLOGY AND ROCKFALL POTENTIAL ASSESSMENT USING GIS AT GUA MUSANG, KELANTAN

by

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

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DECLARATION

I declare that this thesis entitled "Geology and Rockfall Potential Assessment using GIS at Gua Musang, Kelantan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ………………………………

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APPROVAL

"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 (Geosciences) with Honours".

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Geology And Rockfall Potential Assessment Using GIS at Gua Musang, Kelantan

Nur Natasha Husna binti Abdul Halim[1]

ABSTRACT

This research was conducted at two study areas within the Gua Musang, Kelantan. The study areas were overlaid to one another about 25%. The aims of the study are to update the geological map of the study area, to evaluate the parameters of rockfall at karst area, and to produce rockfall potential zone map for limestone karsts at Gua Musang town area. Geological mapping was focused at the first study area that expends up to 25km^{2}from Kampung Kundur at latitude 4°56'34.00"N to 4°53'51.91"N and longitude 101°59'45.76"E to 101°57'4.02"E. An updated geological map of Kampung Kundur with the scale of 1:25,000 was produced. Permian – Tertiary rock units comprised of metasedimentary, limestone, rhyolite, and granite were discovered in this study area. Besides, rockfall potential assessment was carried out within the second study area that expends up to 26km^{2}around the Gua Musang town at the latitude 4°53'49.22"N to 4°51'05.13"N and longitude 101°54'58.60"E to 101°57'41.26"E. Nine selected limestone karsts, including Gua Musang, Gua Serai, Gua Batu Boh, Batu Neng, Batu Machang, Batu Papan, Gua Madu and two karsts at KESEDAR Etnobotany Park were observed during the drone mapping. Buffer analysis is the tool in Geographic Information System (GIS) that was used in generating the rockfall potential zone map for this karstic area. Five rockfall parameters, including rainfall intensity, slope density, height, vegetation density, and discontinuities and karst features were weighted, and overlaid to determine the rockfall potential for each slope zone at the limestone karsts. The resulting rockfall potential map classified three zones of rockfall potential, from high potential zone (16%), medium potential zone (71%), and low potential zone (13%).

Keywords: GIS, geological mapping, Gua Musang karst, rockfall potential, multi weighted buffer analysis.

Geologi Dan Potensi Runtuhan Batuan Menggunakan GIS Di Gua Musang,

Kelantan

Nur Natasha Husna binti Abdul Halim[1]

ABSTRAK

Kajian ini telah dijalankan di dua lokasi berbeza di daerah Gua Musang, Kelantan. Kedua-dua kawasan kajian ini bertindih antara satu sama lain kira-kira 25%. Tujuan kajian ini adalah untuk mengemaskini peta geologi kawasan kajian, menilai parameter batuan di kawasan bukit batu kapur, dan menghasilkan peta zon potensi runtuhan batuan bagi bukit batu kapur di kawasan bandar Gua Musang. Pemetaan geologi tertumpu di kawasan kajian pertama yang berkeluasan sehingga 25km^{2}dari Kampung Kundur pada latitud 4°56'34.00"N ke 4°53'51.91"N dan longitud 101°59'45.76"E ke 101°57'4.02"E. Peta geologi Kampung Kundur yang dikemaskini dengan skala 1:25,000 telah dihasilkan. Unit batuan berusia Permian hingga Tertiari yang terdiri daripada batuan metasedimen, batu kapur, riolit, dan granit telah ditemui di kawasan kajian ini. Selain itu, penilaian potensi runtuhan batuan telah dijalankan dalam kawasan kajian kedua yang berkeluasan sehingga 26km^{2}di sekitar bandar Gua Musang pada latitud 4°53'49.22"N ke 4°51'05.13"N dan longitud 101°54'58.60"E ke 101°57'41.26"E. Sembilan bukit batu kapur terpilih termasuk Gua Musang, Gua Serai, Gua Batu Boh, Batu Neng, Batu Machang, Batu Papan, Gua Madu dan dua bukit di Taman Kesedar Etnobotany telah dinilai semasa pemetaan dron. Analisis penampan adalah salah satu ciri dalam Sistem Maklumat Geografi (GIS) yang digunakan untuk menghasilkan peta zon potensi runtuhan batuan untuk kawasan batu kapur ini. Lima parameter batuan runtuh, termasuk intensiti hujan, kecerunan cerun, ketinggian bukit, kepadatan tumbuh-tumbuhan, dan ketakselanjaran dan ciri-ciri khas bukit batu kapur telah diberi penilaian, dan nilai keseluruhan berat parameter itu digunakan untuk menentukan potensi runtuhan batuan bagi setiap zon cerun di setiap bukit batu kapur. Peta potensi runtuhan batuan diklasifikasikan kepada tiga zon, dari zon berpotensi tinggi (16%), zon berpotensi sederhana (71%), dan zon berpotensi rendah (13%).

Kata kunci: GIS, pemetaan geologi, bukit batu kapur Gua Musang, potensi runtuhan batuan, analisis penampan pelbagai berat.

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LIST OF ABBREAVATION

BM Batu Machang

BN Batu Neng

BP Batu Papan

DEM Digital Elevation Model

DID Department of Irrigation and Drainage Malaysia FELDA

Federal Land Development Authority

GBB Gua Batu Boh

GIS Geographical Information System

GM Gua Madu

GMS Gua Musang

GPS Global Positioning System

GS Gua Serai

JMG Department of Mineral and Geoscience Malaysia KEP

KESEDAR Ethnobotany Park

KESEDAR South Kelantan Development Authority

pH Potential of Hydrogen

UAV Unmanned Aerial Vehicle

USGS US Geological Survey Earth Resources and Science Centre

LIST OF SYMBOLS

% Percentage

> Greater than

< Less than

ºC Degree Celsius

º Degree

‘ Minutes

“ Second

× Multiple

Σ Sum

Ϭ Sigma

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The description background of study for this research were divided into two parts which are updating the general geology information and mapping of Kampung

Kundur, Gua Musang, and rockfall potential assessment for limestone karsts around the town area of Gua Musang, Kelantan.

1.1.1 General Geology of Kampung Kundur & limestone karsts, Gua Musang.

Gua Musang is one of the districts located in the southern part of Kelantan state (Dony et al., 2014). It is known for its stunning karst topography, along with other several areas in Malaysia including Kinta Valley in Perak, Batu Caves in Selangor, Kilim Karst Geoforest Park in Kedah, and Gunung Mulu National Park in Sarawak. The district comprises of Gua Musang Formation which ranges from Middle Permian to Upper Triassic (Mohamed et al, 2016). The oldest lithology of Gua Musang composed of phyllite, slate and shale unit from Gua Musang Formation, followed by Gua Musang Formation Limestone in Lower Triassic, Semantan Formation siltstone in Upper Triassic and the youngest lithology unit is last granite intrusion in Tertiary Period (Seik, 2017). In term of sedimentology, this area consists of the three (3) major facies: (i) Argillaceous; (ii) Carbonate; and (iii) Volcanics/pyroclastic (Mohamed et al., 2016).

1.1.2 Rockfall History in Malaysia

Rockfall is a natural event which occur due to the geological processes which involve the process of detachment, falling, rolling, and bouncing of rock fragments which can happen singly or in clusters (Hantz et al., 2021). In Malaysia, there have been various cases of rockfall that have resulted in fatal accident and property loss (Simon et al., 2015). One of the historical rockfall disaster occurred in 1973 where 40 people were killed when a limestone rock slab measuring 33 metres in length and weighing 23, 000 tonnes toppled from Gunung Cheroh's full cliff face and crashed on top of a longhouse housing ten families (Shu & Lai, 1980). Another Malaysia's largest rockfall event occurred at Mount Kinabalu in 2015 when a granite pillar that constituted one half of Mount Kinabalu's iconic 'Donkey's Ears' summit collapsed due to a 6.0 magnitude earthquake causing in a death of 18 people (Lai et al., 2017).

1.2 Problem Statement

1.2.1 Lack of Geological Data

Geological data of Kampung Kundur, Gua Musang are very limited. The previous geological research at this study area was conducted by Mohammad Ameer (2021), however, the study did not cover all Kampung Kundur area. In addition, the geological data of the study area from Mineral and Geoscience Department of Malaysia (JMG) was not updated since 2003. Hence, new geological mapping was done in order to update and to complete the existing data.

1.2.2 Incomplete data of rockfall potential zone of limestone karsts For the past few decades, there was a rockfall tragedy that happened at limestone karsts, Gua Musang, Kelantan. Due to the tragedy, Mineral & Geoscience Department of Malaysia (JMG) conducted a rockfall risk analysis and produced rockfall buffer zone maps for three limestone karsts, which are Gua Musang, Gua Serai and Gua Batu Boh. However, there are six other limestone karsts which also located within the same area that had not been studied yet for the same purpose. The composition and properties of the limestone karsts are eventually the same, hence those limestone karsts can be considered as hazardous too. Therefore, the rockfall potential zone map was generated in this study for all the limestone karsts in order to provide sufficient geological data to prevent other rockfall tragedy from happening within the study area.

1.3 Research Objectives

The objectives of the study are:

i. To update the geological map of study area with the scale of 1:25,000.

ii. To evaluate the parameters that contribute to the rockfall at limestone karst area.

iii. To produce a rockfall potential zone map of the limestone karsts at Gua Musang town area.

1.4 Scope of Study

The study was carried out at Kg Kundur, Gua Musang, Kelantan to map the general geology of the area and to assess the rockfall potential of nine selected limestone karsts which are Gua Musang, Gua Serai, Gua Batu Boh, Batu Neng, Batu

Machang, Batu Papan, Gua Madu and two limestone hills at KESEDAR Ethnobotany Park. This study was done by conducting the fieldwork including rock sampling and geological mapping in the study area. Aerial imageries for all limestone karsts were collected on site using by using a drone. Other secondary data such as geospatial dataset for this project was obtained by the reliable government bodies such as Department of Mineral and Geoscience (JMG) and Department of Irrigation and Drainage (DID), and also online applications, such as Google Earth Pro and

Outdooractive Application. The data of previous geological map and latest aerial imagery of the study area were used as well to produce the updated geological map of the study area. This research includes the assessment of the rockfall contributing parameters such as lithology, slope density, vegetation, rainfall distribution, height of rock mass, discontinuities, karst features, and any other possible factors. Buffer analysis was used to present the total weightage of the parameters in ArcGIS Pro Software and rockfall potential zone map was generated. The map of limestone karsts was categorised into 3 classification zones: high, medium, and low rockfall potential.

1.5 Significance of Study

The significance of conducting this research study is to provide the latest and updated geological map with the scale of 1:25,000 for the area of Kampung Kundur, Gua Musang, Kelantan. The updated geological map with the data of lithology and structural geology can be useful for the geologist, researchers and/or geology students to conduct their geological mapping activities within the study area in future.

Other than that, it is significant to provide data of the rockfall potential zone within the limestone karsts, including the parameters that can trigger the rockfall in the

study area. The data of rockfall potential can be useful for the development planning team to figure out which areas are suitable for development or otherwise. This study also significant for the community who live within or nearby the study area to beware about the future rockfall potential hazard to protect their safety, reduce property loss and avoid damage to infrastructure.

1.6 Study Area

This research study was conducted at two different study areas within the district of Gua Musang, Kelantan.

1.6.1 Kampung Kundur, Gua Musang, Kelantan

Kampung Kundur is the centre of the study area for the geological mapping which expends up to 25km^2(5km × 5km) within the area that lies on a latitude 4°56'34.00"N to 4°53'51.91"N and a longitude 101°59'45.76"E to 101°57'4.02"E (Figure 1.1). The lithology of this area dominated by Gua Musang Formation rocks that ranging from Permian to Triassic. There is also the presence of rocks from acid intrusive unit that aged Tertiary.

1.6.2 Limestone Karsts, Gua Musang, Kelantan

For rockfall potential assessment, Batu Neng is the centre of the study area which expends up to 26km^2(4km × 6.5km) within the area that lies on a latitude 4°53'49.22"N to 4°51'05.13"N and longitude 101°54'58.60"E to 101°57'41.26"E (Figure 1.2). There are nine selected limestone karsts were studied including Gua Musang, Gua Serai, Gua Batu Boh, Batu Neng, Batu Machang, Gua Madu, Batu Papan, and two limestone karsts in KESEDAR Ethnobotany Park.

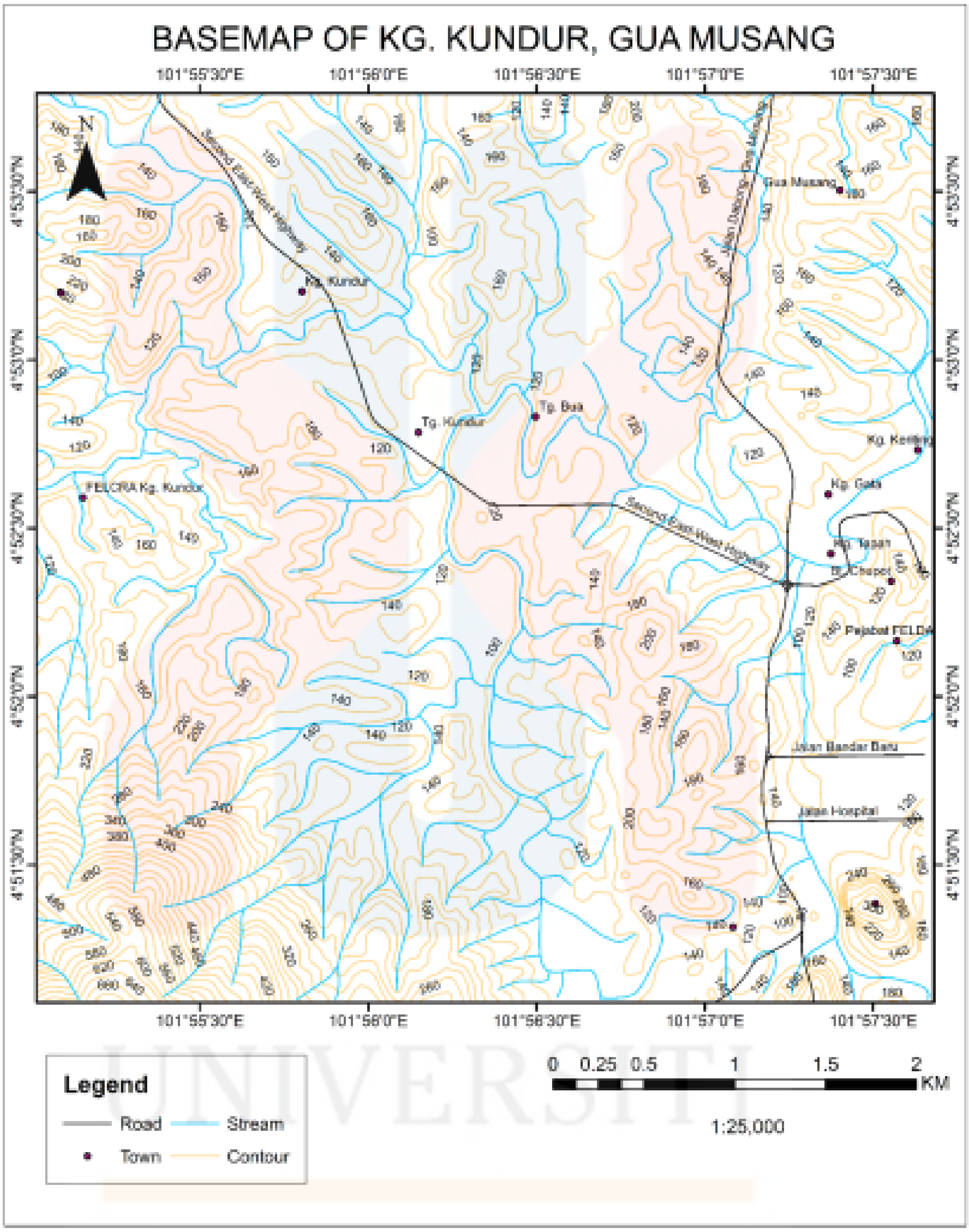


Figure 1.1: Base map of study area for geological mapping.

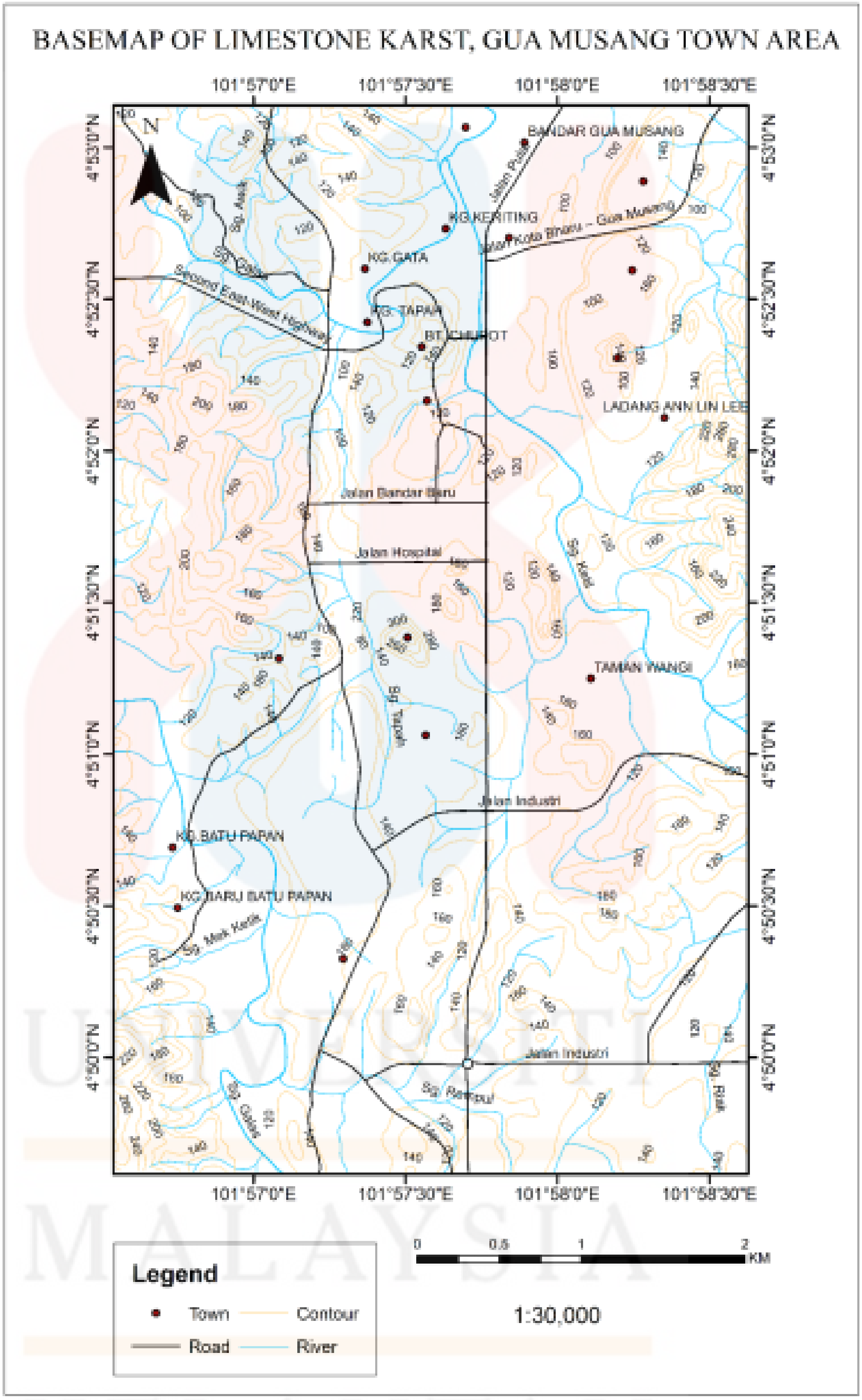


Figure 1.2: Base map of selected limestone hills.

1.6.3 Accessibility / Road Connection

For the study area of geological mapping, there is a good accessibility because there are two main roads: (1) Kota Bharu-Gua Musang Highway that lies on the south east part; and (2) Jalan Jelawang-Gua Musang that lies on the north-western part of the study area. The area also can be assessed by a train as there is a railway station known as Pan Malayan Railway Station within the study area which connects to Kota Bharu Railway Station.

For rockfall specification study area, the study area can be accessed because there is a main road known as Jalan Persekutuan 8 along the northern to southern part of study area. The road is connected to the Kota Bharu-Gua Musang Highway from the northeast, and connected to Merapoh, Pahang from the southeast. Along the road, there are many other connected roads that can be used to access the Gua Musang Town, residential area and most importantly to access the location of the limestone karsts.

1.6.4 Demography

According to the Malaysian Department of Statistics, the population of Gua Musang district is 101,894 people at the year of 2020. The population of Gua Musang is dominated by Malay, Indigenous, Chinese, and Indian. The majority of the population is Malaysian (94.6%), and the rest is other nationality. In addition, the dominant gender of the district is male with approximately 53.8% (Dep. Stat. Malaysia, 2022).

1.6.5 Landuse

Based on the primary observation of aerial imagery obtained from Google Earth Pro, the study area for the geological mapping is mostly covered by vegetation and agriculture such as palm plantation. Due to low resolution of the aerial imagery map, the types of plantations were difficult to distinguish, hence a proper geological mapping was conducted to observe the vegetation types on field. Other than plantation, there is also infrastructure such as road and railway within the study area. Residential areas, and town also contribute to the use of land in the study area.

For the specification study area, the distribution of landuse consists of city centre, industrial and residential area, infrastructures such as hospital, veterinary, school, district police headquarters, road, railways, and mosque. Geomorphology, these buildings, and facilities are surrounded by multiple of limestone karsts. There are also areas of palm plantation that occupied the landuse distribution within the study area.

1.6.6 Social Economic

The social economy in Gua Musang, Kelantan is mainly from farming practices as there are many plantation areas, such as palm and rubber plantation that developed by the Federal Land Development Agency (FELDA) and South Kelantan Development Authority (KESEDAR). Since this district is dominated by the forest, the logging activities is also one of the sources of economy for the society in this area. The communities are also served as a public servant since there are many government agencies are located within the study area. As this area is a rapidly developing district in various sectors, businesses such as restaurants, supermarkets, hardware store and laundry are also one of the economy sources of the society.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section discusses on the geology of the study area that focusses on the regional geology and tectonic setting, stratigraphy, structural geology, historical geology, and rockfall potential assessment for limestone karsts in the study area.

2.2 Regional Geology and Tectonic Settings

According to the geological map of Department of Geoscience Malaysia (2003), the regional geology for Kampung Kundur and the limestone karsts in Gua Musang is dominated by the Permian (phyllite, slate, sandstone, and limestone) to Triassic (shale, siltstone, sandstone and limestone) rocks. Based on the geological map, the geological feature that can be seen is fault. The tectonic belts of Peninsular Malaysia map which issued by Basori et al., (2016) shows that majority of Kelantan state is located at the Central Belt. The Central Belt expands from Kelantan to Johor, with the eastern foothills of the Main Range bounded on its west and the Lebir Fault forming its eastern boundary in the north, and the Dohol Formation forming its southern boundary (Hutchinson & Tan, 2009). According to Tjia & Almashoor (1996), the evidence that the granitoid bodies of the Eastern Belt were part of the Titiwangsa granitoid complex and were separated by more than a hundred kilometres by the rifting was used to interpret the Central Belt as an aborted rift.

2.3 Stratigraphy

Kamal et al., (2016) classified the southern part of Kelantan into four areas according to its stratigraphy which are Kuala Betis, Gua Musang, Aring and Gunung Gagau. Aring is considered a member of the Gua Musang Group due to the similarity of age and lithology of the rock units (Dony Adriansyah & Ahmad Rosli, 2014). Lee et al., (2009) stated that from the Upper Carboniferous to the Permian to the Triassic, the Upper Palaeozoic rocks are primarily composed of argillaceous strata and volcanic rocks, with subordinate arenaceous and calcareous sediments and intermittent submarine volcanism. Gunong Rabong Formation unconformably overlies Gua Musang Formation in the west. The thick limestone sequence at the top of the Gua Musang Formation was dated as Late Scythian. As a result, evidence from Gua Musang and Aring suggests that there was a period of non-deposition during the Anisian (Lee et al, 2004).

2.4 Structural Geology

According to Tjia & Almashoor (1996), the rocks between the Bentong-Raub Suture can be segmented into at least seven tectonic parts that formed structures. Because the Gua Musang Formation is located between the Bentong-Raub Suture and the Lebir Fault Zone, research indicates that all seven tectonic units are in high-angle fault contact with one another. The Bentong-Raub Suture is believed to have strike slip movement, which resulted in the formation of numerous splays along the western margin of the Central Belt.

According to Irfan (2016), stalactite and stalagmite, caverns, and pinnacles are common structural geology which found in Gua Musang limestone hill aged around Permian. The dissolution and weathering processes had affected the limestone karsts,

and structural analysis indicated that the stability of each limestone had been affected. Irfan (2016) also stated that due to faulting and granite intrusion, certain parts of the lithology in the Gua Musang area had made contact or were affected by the contact metamorphism process.

2.5 Historical Geology

The thickness of the Gua Musang Formation is estimated to be 650m where crystalline limestone is interbedded with thin beds of shale, tuff, chert nodules, and subordinate sandstone and volcanics to form the formation (Yin, 1965). The presence of bedding, cross-lamination, and oolites can still be found in the Gua Musang Formation. Poorly preserved fusulines from Gua Musang give a Permian age to parts of the limestone, and Lower Triassic ammonoids have also been reported by limestone nearby. A massive limestone with traces of oolitic structure has been reported to have Upper Carboniferous fossil content. The ammonoid assemblage dates from the Middle-Late Triassic period (240-220 million years ago) and was found in the Tethyan Province. Some bivalves and crinoids were discovered alongside these cephalopods. Mollusc and brachiopod fossils have been discovered in this area (Mohamed et al., 2008).

2.6 Rockfall

2.6.1 Rockfall Definition

Rockfalls are a natural geologic process that involves rapid downward motion of a detached block or a series of blocks with a small volume (Lai et al., 2017). Geomorphologists categorise rockfalls into two types which is primary rockfalls that occur when the rock separates from the host bedrock and falls downslope immediately, and secondary rockfalls which transport previously separate materials downslope (Rapp, 1960).

2.6.2 Rockfall Triggering-Factors

Land use and development have increased rapidly in this karst topography, leading to substantial changes in landform and geomorphology which consequently may lead to geohazard potential within the area (Putri, 2016). Discontinuities within the rock mass, weathering susceptibility, drastic climate change, widening/enlargement of fissures, increase in slope gradient, vegetation, and tectonic stresses are all factors that contribute to rockfall events (Simon et al., 2015). Earthquakes, rainfall, freeze-thaw cycles, or the progressive weathering of rock material and discontinuities in suitable climatic conditions can all cause rockfalls (Agliardi & Crosta, 2003). Simon et al., (2015) reported that the major causes of limestone karsts rockfall at Gunung Lang, Perak is due to structural failure where many rock blocks detached from the cliffs caused by intersected faults.

2.6.3 Rockfall Potential Assessment

Agliardi and Crosta (2003) stated that rockfall hazard assessment refers to the probability of rockfall occurrence and intensity. There are many techniques suggested by the researchers to study the rockfall potential assessment. Hellmy et al., (2019) suggested that scanline measurement technique to assess the rockfall potential. Rock Mass Strength (RMS) method introduced by Selby (1980) is another method to assess the condition of rock slope in the field based on the presence of discontinuities in the rock mass. Even so, these methods are time consuming and depends heavily on the researchers' site observation and skills.

Nowadays, advance technology which is GIS method is more convenience to study the rockfall potential. The multi-index weighted overlay analysis is an example of GIS tools that can be used. This method can overlay several rasters which represent by the parameters of the rockfall using a common measurement scale and weights (Awawdeh, 2018). After all of the weight was classified, all of these rockfall parameters were overlaid in ArcMap using the weight overlay tools to generate the rockfall potential map (Shit et al., 2016).

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Introduction

This section discusses on the materials and methodologies used in the study of geological mapping and assessment of rockfall potential. The material and equipment are listed including the descriptions of their functions.

3.2 Material & Equipment

3.2.1 Geological Mapping

a) Global Positioning System (GPS)

GPS was used to locate the coordinate of the study area and to provide the positional data such as determination of the precise coordinate, and also to collect structural data such as elevation and joint data.

b) Geological Hammer

Geological hammer was used to break the outcrops into hand specimen during rock sampling. This material is really important especially during geological mapping to obtain fresh sample of rock in order to identify the lithology of the rock.

c) Brunton Compass

Brunton compass was used to navigate the degree of direction (azimuth) over the Earth's magnetic field. It was usually implied to orient a map to identify the magnetic

north for locating any particular point on the map. It was also important to determine the slope gradient.

d) Measuring Tape

Measuring tape was used to measure the large-scale measurements such as the dimension of the rock outcrop and the width of a stream. In this research, the glass fibre type of measuring tape with a minimum 10-meter length was used.

e) Hydrochloric Acid

Hydrochloric acid (HCl) with the concentration of 0.1 was used to identify the presence of carbonate in a rock sample. The carbonate rock reacted when HCl was dropped onto it by producing bubbles. It is important to distinguish between limestone and dolomite at the limestone karsts.

f) Magnification Lens

Magnification lens (hand lens) was used for magnifying the rock sample to observe its mineral composition and textures. This tool was usually used at the field for primary observation of rock samples in hand specimen analysis.

g) Polarized Light Microscope

Polarized Light Microscope was used to observe the mineral texture and composition of rock sample thin sections during thin section analysis.

3.2.2 Rockfall Potential Assessment

a) Drone

Drone is an unmanned aerial vehicle (UAV) that has been utilized to capture the aerial imageries of limestone karsts.

b) Rainfall intensity

Rainfall distribution data is one of the materials used for generating rockfall potential map. It was obtained from Department of Irrigation and Drainage Malaysia (2023) and the rainfall intensity of the area was calculated.

c) Slope Density

The slope data for this research study was obtained from the Digital Elevation

Map (DEM) from USGS. The slope then was identified based on its steepness.

d) Height

The height of the limestone karsts was measured by using the tool in the Google Earth Pro. The heights were measured from the ground surface.

e) Vegetation Density

The vegetation density was observed during the fieldwork and based on the drone aerial imageries. The percentages of vegetation covered the karst was observed and classified into 5 classes: very high, high, medium, low, very low.

f) Discontinuities and karst features

Discontinuities (e.g.: fault and joint), and karst features (e.g.: flowstone and pothole) were observed during the fieldwork and also from the UAV aerial imageries.

3.2.3 Application and Software

a) ArcGIS Pro 10.8

This software was used to generate a base map of study areas, and to evaluate the multi-index weighted overlay analysis for the parameters of the rockfall.

b) Google Earth Pro

This application was used to obtain the aerial imagery of the study areas, and to generate the kml file before converted it into a layer in ArcGIS Pro.

c) Outdooractive

This application was functioned as the mobile GPS where it can navigate, plot, track, locate and record on the map of study area.

d) GeoRose

This software was functioned to generate a rose diagram, and to plot the stereonet program. Rose diagrams are used in structural geology to plot the orientation of joints and dykes.

e) Microsoft Excel

This application software was used to organize input data in rows and columns systematically, and also functioned to generate a Gantt chart.

3.3 Methodology

This section is divided into preliminary studies, data collection of fieldwork and secondary data, data processing, data analysis and interpretation, and report writing. Detailed explanation and procedures are presented in each division parts for this research study. This includes the methodology for both geological mapping and rockfall potential assessment.

3.3.1 Preliminary Studies

Preliminary studies were conducted by reading and reviewing the reference materials that related to the research keywords. The reference materials, specifically research papers were obtained from journal articles, books, students' thesis, and websites such as Academia, Google Scholar, Research Gate, and Open Athens. The literature review was done by referring to all these materials, followed by the identification of research problems for the research study.

3.3.2 Data Collection

Data collection is divided into two parts:

i. Fieldwork

Rock sampling was conducted during the fieldwork to collect the data of lithology and mineralogy of the study areas. Other than rock sampling, geological mapping was also conducted to study the structural geology. For limestone karst area, the drone mapping was conducted to observe the karst features in detailed as well as to observe the parameters that contribute to the rockfall in the study area. The topography base map was used as an observation and reference tool for this study. The

mapping data collection process includes two steps: surveying or reconnaissance and a comprehensive observation study.

ii. Secondary Data

There are two types of secondary data collected which are spatial data and statistic data. The spatial data including the slope density, aspect, morphology, lineament, and drainage. All these data were generated from DEM by United States Geological Survey (USGS) and aerial imagery from Google Earth Pro. Data of GIS and geological map of Kelantan with a scale of 1:1,000,000 were collected from the Mineral and Geoscience Department (JMG). Besides, the statistical data involves the data of rainfall or precipitation distribution of the study area obtained from the Department of Irrigation and Drainage (DID) by determining which rainfall stations were located within or near to the study areas. Table 3.1 shows the data of inventories that are used for this research study.

Table 3.1: Data inventories of the study

No.	Data Type	Data	Data Description
1	Spatial	DEM	Source: United States Geological Survey (USGC) Year: 2018 Resolution: 1 meter
		Aerial/Satellite Imagery	Source: Google Earth Pro Year: 2015 Resolution: 30 meters
		Data of GIS Kelantan	Source: Department of Mineral and Geoscience Malaysia (JMG) Format: Shapefile (shp)
		Geological Map of Kelantan	Source: Department of Mineral and Geoscience Malaysia (JMG) Scale 1:1,000,000
2	Statistic	Rainfall Distribution	Source: Department of Irrigation and Drainage (DID) Year: 2013 – 2022 Format: CSV

3.3.3 Data Processing

i. Updating Fieldwork Data

The data which obtained from the geological mapping at fieldwork are utilized to update the maps of topography, geology, drainage, geomorphology, folds, and lineament using the ArcGIS 10.8 software.

ii. Thematic Map Preparation

For the secondary data processing, the data were utilized to prepare various thematic maps such as slope density, geomorphology, drainage pattern, and rainfall density.

All of the geological mapping data, as well as data from the shapefile, were stored in a database. The rockfall potential parameters would be assigned to each thematic map. The locations in this study area that were linked to a rockfall potential were ranked and weighted. Each weighting value contributes to the level of hazard.

3.3.4 Data Analysis & Interpretation

a) Petrography Analysis

Petrography analysis involves the laboratory analysis to determine the types of rocks that collected from the fieldwork during rock sampling.

The hand specimen analysis was conducted by observing the textures and mineral composition of the rock samples using a magnification lens and were sent to laboratory for thin sections production.

The thin section analysis includes the preparation for thin section production by cutting and thinning the rock sample into a glass slide until it reaches 30µm after polished. The thin sections then were observed using polarized light microscope for better observation of texture and mineral composition of the rock samples.

b) Update Geological Map

The geological map was updated by comparing the previous geological map to the thematic maps which generated during the data processing. The primary data from the fieldwork which includes lithology border, river, main road, structural data, strike and dip data, and other associated data, were compiled and exported into the ArcGIS Pro 10.8 software. The geological map was generated at a scale of 1:25,000 and interpreted based on the geological data provided. The real geological attributes were depicted in the base map using conventional colours and features. This geological map was employed to interpret geological situations in the study area, such as rock units, bedding thickness, faulting, and folding.

c) Multi-weighted buffer analysis

Multi-weighted buffer analysis was used to generate the rockfall potential zone map. All of the rockfall parameters were observed and weighted according to its classifications. After all of the parameters have been weighted, the total of the weightages was calculated. The rockfall potential map was generated using buffer analysis tools from ArcGIS Pro 10.8 software.

3.3.5 Conclusion & Report Writing

Conclusion and report writing was the final stage in conducting this research study. All of the findings and results from the preliminary studies, data collection, data analysis and interpretation, and overall discussion were gathered and presented visually in the research report.

Research Flowchart

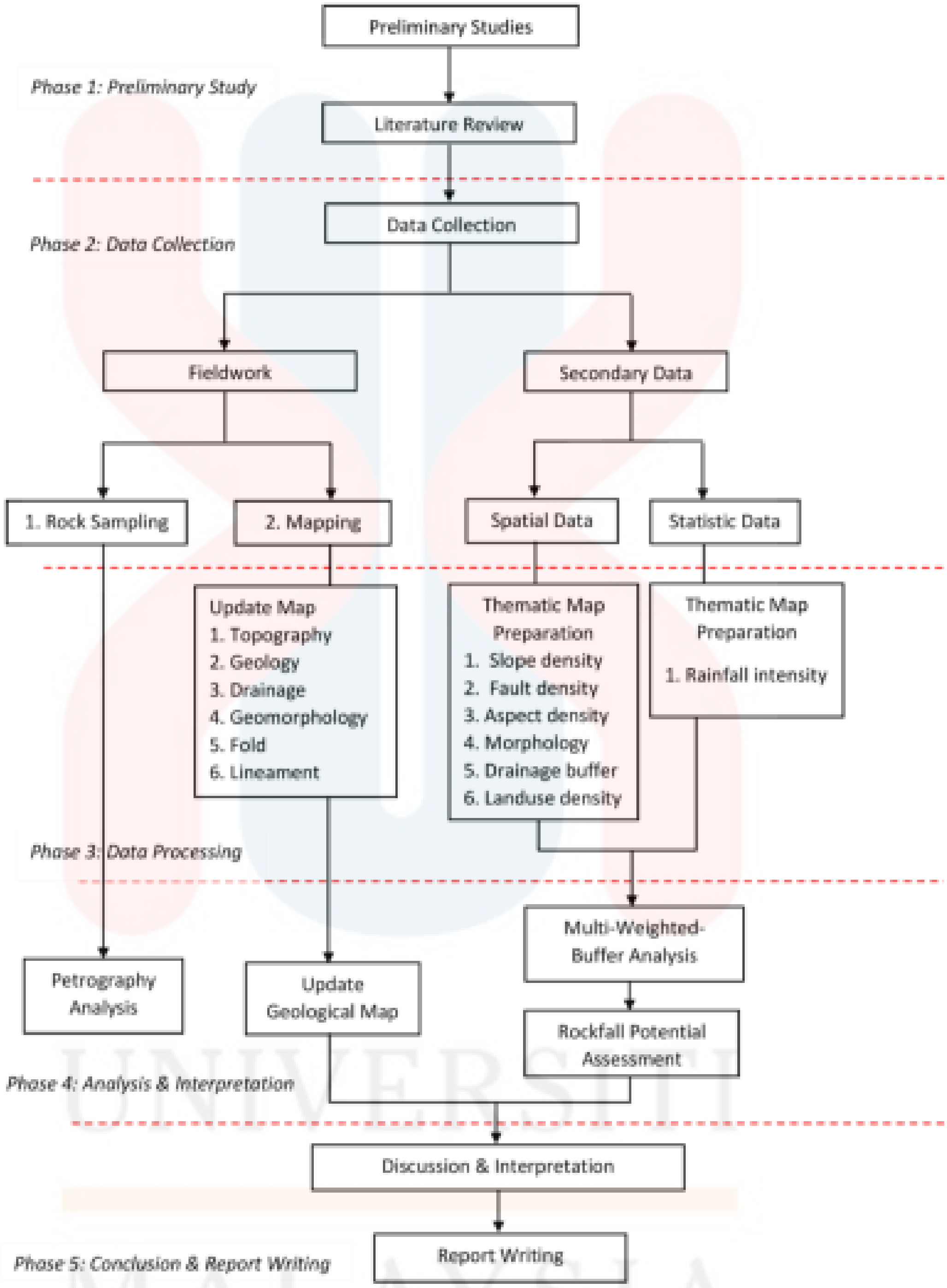


Figure 3.1 : Flowchart of the study

CHAPTER 4

GEOLOGY OF KG KUNDUR, GUA MUSANG, KELANTAN

4.1 Introduction

4.1.1 Brief Content

This chapter discusses the general geology of the study area that is concerned with the study of geomorphology, lithostratigraphy, structural geology and historical geology. All of the data that obtained from geological mapping and field observation were discussed in detail including the analysis of data in the laboratory. The study area has been accessed and observed by traversing during the geological mapping.

Geomorphology includes the study of landform types, topography, slope density, and drainage pattern of the study area, and the processes that are related to the origin of the Earth and its evolution. Geomorphology map is included in this chapter to show the different types of geomorphology units in the study area.

In lithostratigraphy, the assessment includes the study of stratigraphy position, lithology units, and petrographic study of the rocks. The thin sections of different rocks are presented with the interpretation and analysis. It was used in identifying the type of lithologies, and minerals composition which indicate the formation of the rocks itself. It was also used to construct the updated geological map in the study area.

For the structural geology, the geological structures that have been found in the study area were discussed after field observation, including lineament analysis, and folds on the outcrops. By doing the analysis of the geological structures, the mechanism and direction of forces can be determined.

Other than that, the historical geology of the study area was discussed as well, and it includes the historical formation, lithology, and deformation of Earth during the formation of the area.

4.1.2 Accessibility

The accessibility in the study area of Kampung Kundur is considered fair. Some areas, such as Bandar Baru Gua Musang and residential areas could be easily access via paved road of Jalan Dabong – Gua Musang, Jalan Lojing – Gua Musang, and Jalan Merapoh – Gua Musang by using a car. However, the off-road areas (e.g.: palm oil plantation) were accessed via 4-wheel drive (4WD) vehicle. Area that has no road facilities, such as forest, could be accessed via walking except for some areas that has very dense vegetation and steep slope.

Figure 4.1 : The main road access to Kampung Kundur via Jalan Gua Musang from Lojing. (Coordinate N 4° 53’ 45.56”, E 101° 55’23.07”).

4.1.3 Settlement

Kampung Kundur is the dominant settlement in the study area. There are also residential areas known as Taman Tropika, Taman Wira Perdana, and a part of Kampung Kerinting. Bandar Baru Gua Musang is located at the northern part of the study area, where Gua Musang Hospital, Gua Musang District Police Headquarters, and many other Gua Musang government department offices are located.

Figure 4.2 : Settlement at Kampung Kundur near to the main mosque of the village. (Coordinate: N 4° 52’ 38.50”, E 101° 56’ 15.63”)

4.1.4 Forestry and Vegetation

The major forestry and vegetation of the area study area are covered by plantations, such as palm oil and rubber plantation that developed by the local and agencies. There are also many of areas, such as high hills that are dominated by very dense vegetation and have not been developed or explored yet for economical purposes.

Figure 4.3 : The rubber plantation at the hilly area in the study area.
(Coordinate: N 4° 51' 40.85", E 101° 55' 57.33")

4.1.5 Traverses and Observations

Figure 4.4 shows the traverse map of the study area, and Table 4.1 shows the units that stated on the map and its descriptions.

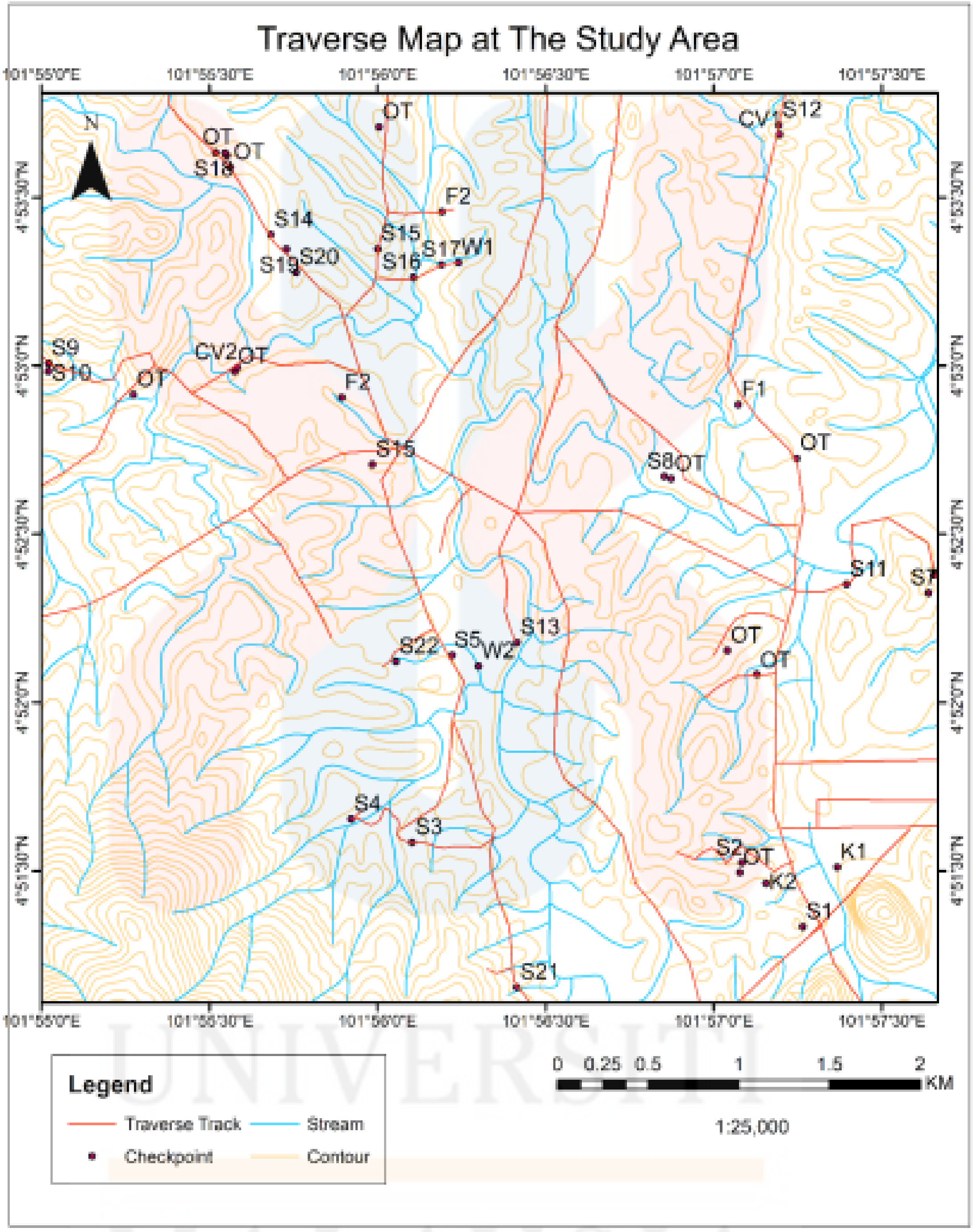


Figure 4.4 : Traverse map of the study area.

Table 4.1 : Unit of the checkpoint in the traverse map.

No.	Checkpoint	Unit	Description
1	S	Rock Sample	Location where rock samples were collected.

2	OT	Outcrop	Location of outcrops were found. No rock sample was taken due to the similarity in term of properties with the nearby outcrop where rock sampling has been done.
3	F	Folds	Location where folds were found.
4	W	Weathering	Location of weathered outcrops found.
5	CV	Collovium	Location of colluvium areas were found.

4.2 Geomorphology

4.2.1 Types of Landforms

The geomorphology of the study area consisted of many types of landforms including karst, hilly, fluvial, alluviul and colluvial areas. These different types of landforms are the products of the endogenic and exogenic processes, or tectonic activities that happened in the past events during the formation of the earth.

a) Karst

The distribution of karst in thi s study area is about 3%. One of the karst landforms that were discovered is this study area is a limestone karst, known as Batu Neng. It is located behind the Hospital Gua Musang, Kelantan. The elevation of the karst is approximately 285 metres above the sea level, and it is moderately to highly covered by vegetation. Another limestone karst discovered in this study area is Batu Tapah. The elevation of the karst is about 120 metres above the sea level.

Figure 4.5 : Image of Batu Neng karst limestone.

b) Hilly area

The hilly area made up about 90% of the study area. The elevation of the area is ranging from 85 metres to 650 metres. Figure 4.6 shows the highest hill that was discovered in the study area. The photo was taken from the elevation 200 metres from the sea level. Due to dense vegetation and extremely steep, the peak of the hill was unaccessible during the geological mapping traverse.

Figure 4.6 : The landscape view of the highest hill in the study area.

c) Fluvial area

The fluvial in Kampung Kundur consists of the sub-river basins of Kelantan river (main basin), which are Galas river, Seting river and Ketil river that flow towards the northward.

Galas river is the major fluvial system in the study area, and it is wider and deeper compared to Seting and Ketil river. Galas river flows northward from Kampung Batu Papan, to the centre of study area at Kampung Kundur, and towards the east at Gua Musang old town. According to Marinah Muhammad et al. (2022), the normal water level of Galas river is between 79 to 95 meters depth. They also added that the water level was reached higher than 97 metres on December 2014 and caused the flood event in the district of Gua Musang.

In the contrasy, Seting river lies on the left upper part of the study area, while Ketil river flows at the right part of study area from Kampung Gata northward, and intersect with Galas river at Kampung Kerinting.

Figure 4.7 : View of Galas River at the coordinate N 4° 51’ 44.17, E 101° 56’ 17.53.

d) Alluviul plain

Another landform discovered in the study area is alluviul. The alluvium deposits were discovered along the Galas, Seting and Ketil rivers, and the sub-streams that linked to the rivers. The alluvium deposits composed of silt, clay, sand, and rock boulders.

(a)

(b)

Figure 4.8 : (a) Alluvium deposits at Ketil River, Kampung Kerinting; (b) Close-up image of the alluvium deposits.

e) Colluvial area

The colluvial areas were discovered within the area of hillslopes. The colluvium deposits composed of the similar materials of alluvium deposits. The difference between alluvium and colluvium is the location where the materials are deposited. Figure 4.9 shows the colluvium deposit that was discovered at the roadside of Jalan Dabong – Gua Musang, and at the roadside of unpaved road near to Galas River.

(a)

(b)

Figure 4.9 : Colluvium deposits at (a) roadside Jalan Dabong – Gua Musang; and (b) unpaved road near to Galas River.

Figure 4.10 : Geomorphological map of the study area.

4.2.2 Topography

In general, the topography of the study area is divided into 5 unit according to the classifications issued by Van Zuidam (1985), as in Table 4.2. The topography classification were classified by the mean of elevation that measured from the sea level in the unit of metre. The elevation of the study area is ranging from 83 to 650 metres, which indicates that the topographic units are vary, starting from slightly sloping plain, sloping hills, steep hills to high steep hills. The distribution of topography of the study area is as shown in the Figure 4.11.

Most of the low land and low hill area, where the mean elevation is lower than 200 metres, are distributed by the residential areas, infrastructures and town. Whereas, the hill and high areas, where the mean elevation is more than 100 metres are mostly covered by the palm plantations that are developed by KESEDAR, FELDA, and private parties.

Table 4.2 : The topography unit based on the mean elevation.

NO.	Topographical Unit	Type of Landforms	Mean Elevation (From sea level) (m)
1	Slightly sloping plain	Low Land	83 – 100
2	Sloping hills	Low Hill	100 – 200
3	Steep hills	Hill	200 – 500
4	High steep hills	High Hill	500 – 650

(Source: Van Zuidam, 1985)

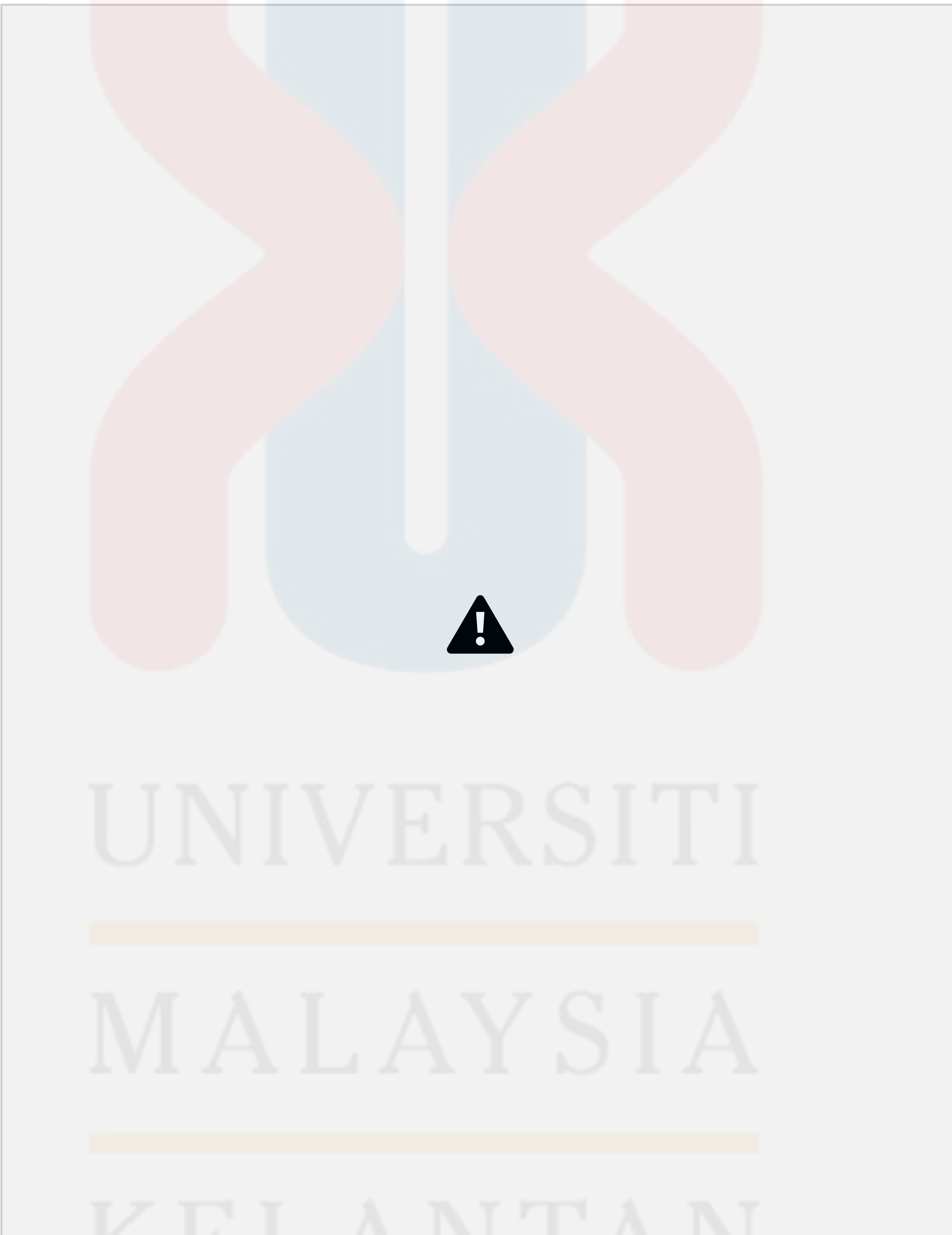


Figure 4.11: Topography map of the study area.

4.2.3 Slope

The degree or percentage of slope is used to classify slopes, according to Van Zuidam (1985). The slope categorization and its characteristics are shown in Table 4.3. Figure 4.7 depicts the slope map of the study area.

The slope classes in the study area are ranging from flat to extremely steep slope. According to the slope map, the distribution of slightly steep slope is highest, followed flat, gently slope, steep slope, sloping, very steep slope and the lowest is extremely slope.

Table 4.3: Slope classification and its characteristics

NO.	Characteristics	Slope Class (°)
1	• Flat or almost flat. • No meaningful denudation.	0 – 2
2	• Gentle Slope. • Low speed ground motion.	2 – 4
3	• Sloping. • Low speed ground motion with a higher magnitude compared to 2° - 4°.	4 – 8
4	• Slightly Steep Slope. • A lot of ground movement.	8 – 16
5	• Steep Slope. • Ground movements are common. Intensive denudation processes	16 – 35
6	• Very Steep Slope. • Very intensive denudational process. Rocks begin to unfold	35 – 55

7	• Extremely Steep Slope. • Very strong denudational process. Prone to falling rocks	>55

(Source: Van Zuidam, 1985)

Figure 4.12 : Slope map of the study area.

4.2.4 Drainage Pattern

Drainage pattern is the arrangement of stream on the surface of Earth by drainage system that defined by the rock beneath the Earth's surface, geological structures, erosion, and the shape of the Earth itself (Van Zuidam, 1985). He also classified the basic drainage patterns into 7 types: 1) dendritic, 2) parallel, 3) trellis, 4) rectangular, 5) radial, 6) annular, and 7) multibasinal.

The drainage pattern of the study area is divided into two types, dendritic and trellis. The different of these two drainage patterns is as shown in Figure 4.13. Regionally, the dendritic pattern develops on relatively uniform bedrock, and high weathering resistance rocks. This type of drainage creates spreading branches pattern that resemble shady trees. The dendritic drainage lies on metasediment and granitic rocks of the study area.

In contrast, the trellis drainage commonly develops on folded sedimentary rocks, volcanic rocks or low-grade metasedimentary rocks exhibiting distinct weathering changes. This drainage pattern usually faces sideways along the successive stream. In this study area, the trellis pattern could be observed in the area of folded metasedimentary rock.

Dendritic

Trellis

Figure 4.13 : Drainage pattern of the study area.

4.2.5 Weathering

Weathering is a natural process that occurs within rocks with no movement involved. Distinct rocks imply different weathering processes and grades. Weathering is most active in soggy conditions and environments that have been exposed to air and sunshine. Weathering can be classified into three types: chemical, biological, and physical weathering.

The weathering of rocks caused by the action of living organisms is known as biological weathering. This process happens when living organism, such as plant roots develop within the fracture of outcrop forming the voids and gaps and causing the physical and chemical weathering to occur. Figure 4.14 represent one of the examples of biological weathering of limestone outcrop in the study area.

Chemical weathering was also discovered in the study area. It is the chemical disintegration and alteration of rock through the processes of oxidation, hydration, hydrolysis, and carbonation. Figure 4.15 shows the example of metasedimentary outcrop that has exposed to chemical weathering. The outcrop changed its mineral composition as well as the colour of the rock from lighter grey to dark grey.

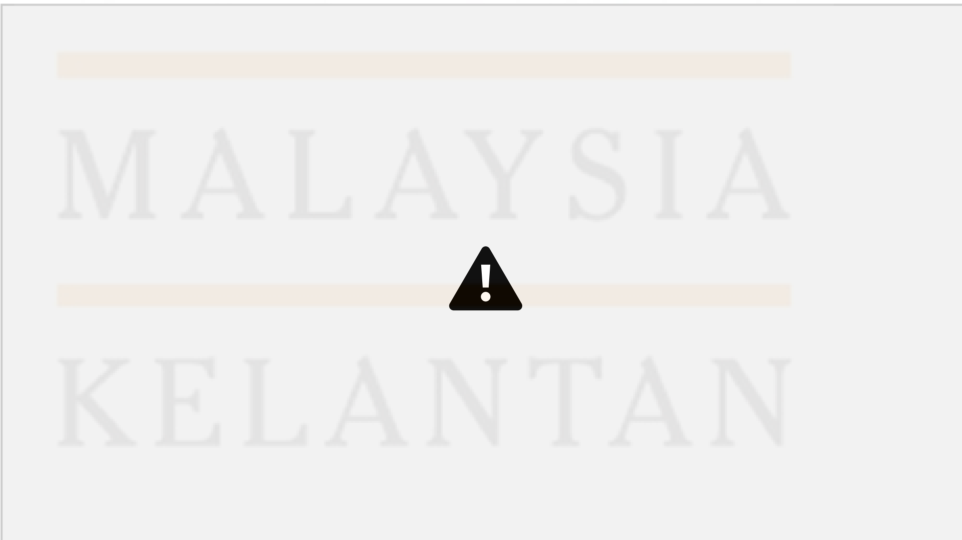


Figure 4.14 : Limestone outcrop exposed to biological weathering at the study area.

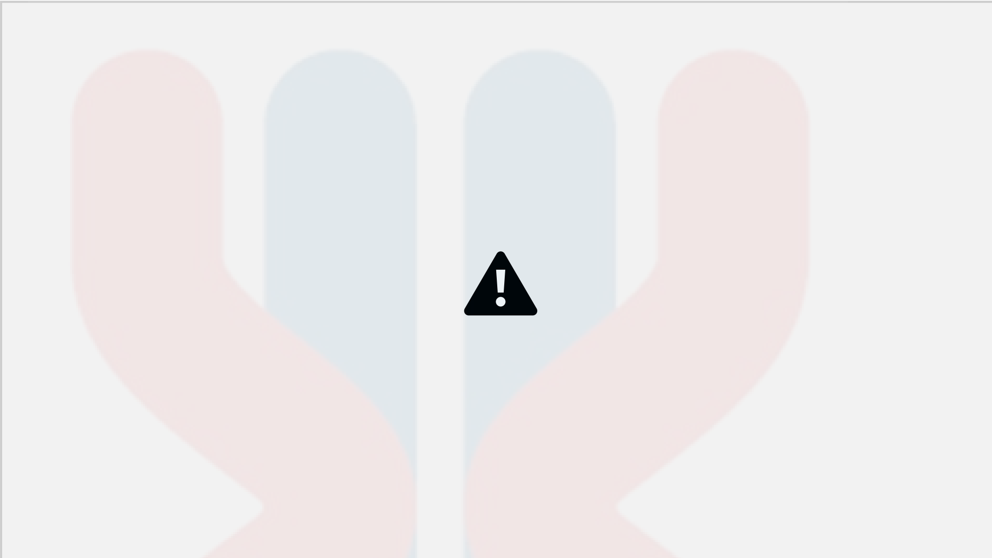


Figure 4.15 : Metasedimentary outcrop exposed to chemical weathering at the study area.

4.3 Lithostratigraphy

There is 4 types of lithologies in this study area: granite, rhyolite, limestone and metasedimentary rock units which ranging from Permian to Tertiary. The rock units are defined in the following order from youngest to oldest.

4.3.1 Lithology Unit

a) Granite

The distribution of granite in this study area is approximately 30%. The granite is also known as an acid intrusive rock unit. The outcrops of granite were identified on the field, by observing the mineral composition on the outcrop that mainly composed of coarse-grained quartz, and alkali feldspar. The granites of the Eastern Province are characterised by equigranular to weakly porphyritic texture and contain orthoclase to intermediate microcline alkali feldspar (Hutchison, 1977). The identification of granite outcrop was also due to the higher landform features and drainage patterns that flow from the top to the bottom of the river. In term of weathering, the grades of the granite outcrops are varied, from fresh outcrop to completely weathered, as shown in the Figure 4.16 and Figure 4.17, respectively.

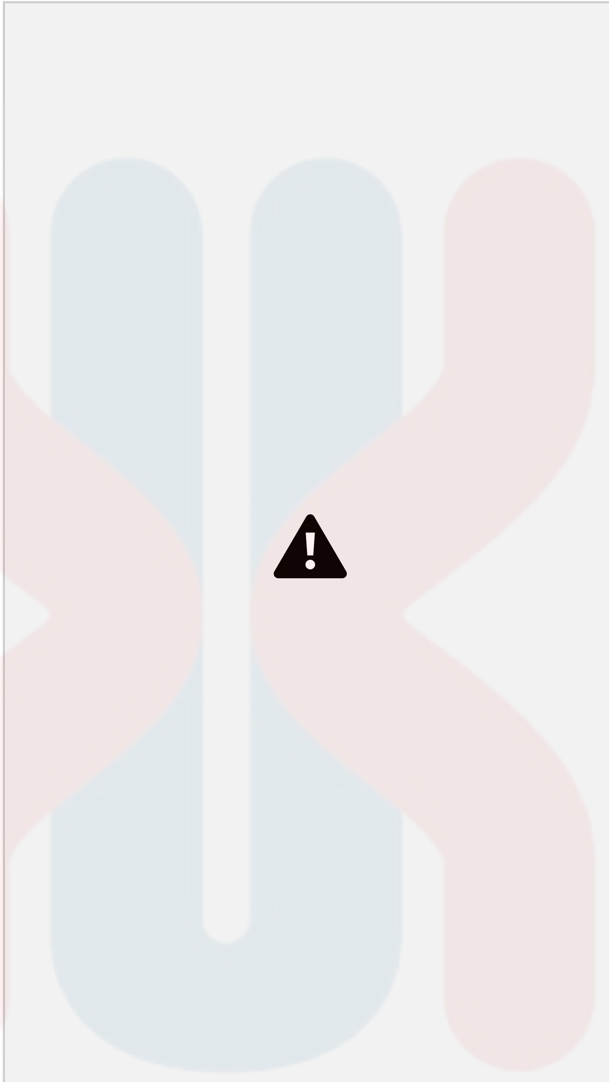


Figure 4.16 : Outcrop of grade II granite found in a stream.

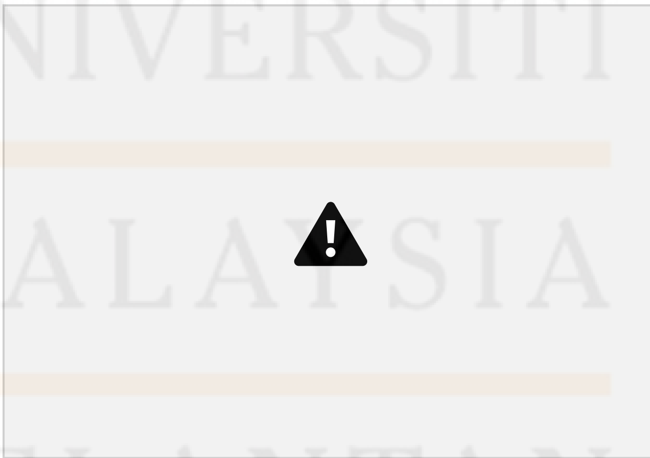


Figure 4.17 : Outcrop of grade VI granite found at a roadside.
(Coordinate: N 4° 53’37.844”, E 101 55’33.030”

Heng et al. (2006) stated that there is a granite intrusion, or batholith found in Kampung Panggong Lalat, which about 8 km away from the study area of Kampung Kundur. The body of the batholith that was mentioned by the researchers is as shown in the Figure 4.18. The granite intrusion found in the Kampung Kundur area can be consider as part of the batholith because in general, the features of the batholith are known to be large, and usually over 100 km^2. Moreover, batholith is known to be massive molten pluton deposits that experienced metamorphism process to produce high resistant igneous rocks. When the older layer erodes, the dense batholith body will be exposed to the Earth's surface.

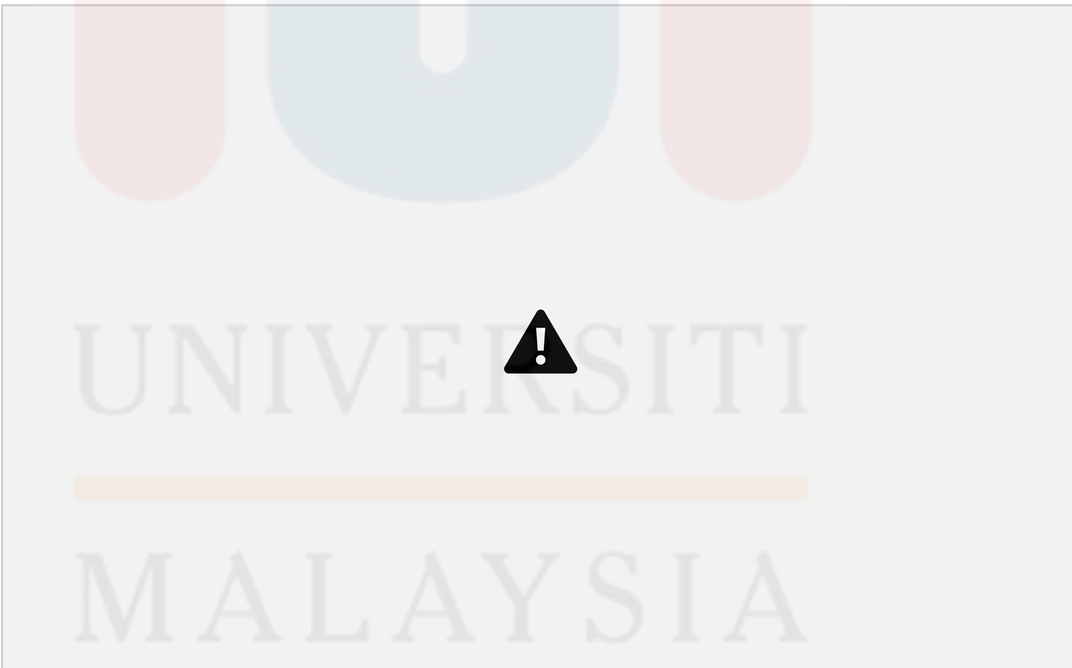
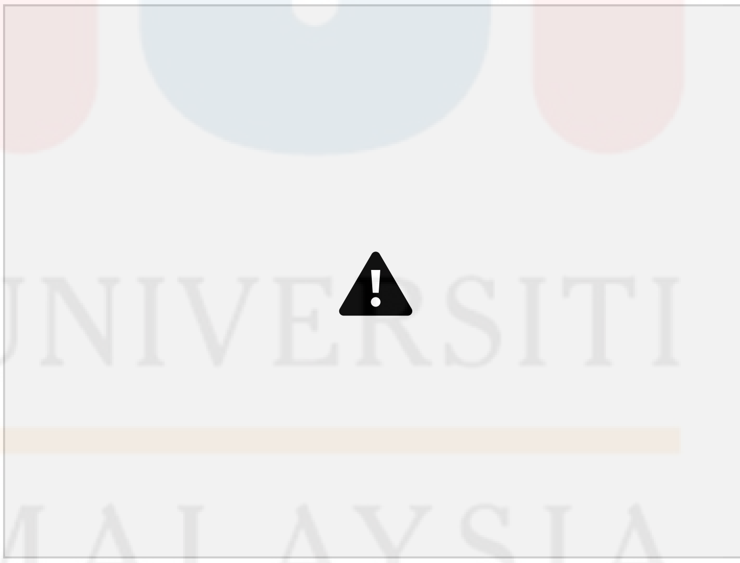


Figure 4.18 : Satellite image of batholith at Gua Musang, Kelantan.
(Source: Google Maps)

The distribution of granite boulders, as shown in Figure 4.19, along the streams that located at the foot hill at the lower part of the study area indicates that the hill is made up granitic rock. The granite boulders can be disintegrated with the rock mass by many factors, including discontinuities and weathering. The breakdown material will be transported down to the slope by the gravity force or can be aided by the wind and waterflows.

(a)



(b)

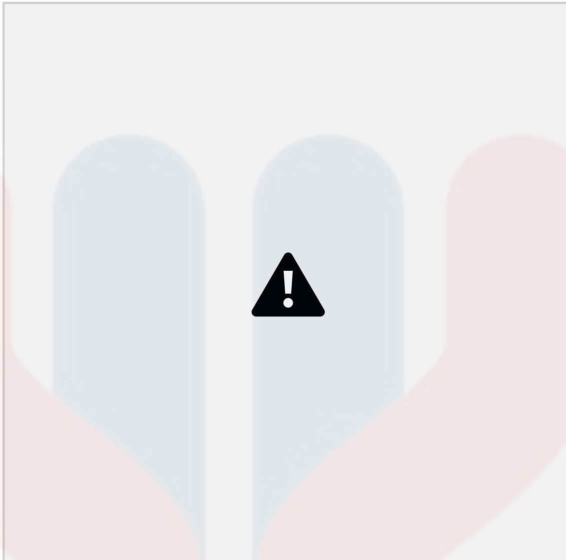


Figure 4.19 : (a) Abundant of granite boulders found in a stream at the foot hill; (b) Close-up image of granite boulder where its mineral composition can be observed using bare eyes.

<u>Petrography Analysis of Granite</u>

The lithology of this unit was identified according to volcanic rock classification issued by Streckeisen (1976).

The microscopic observations were made at 10x ocular magnification and 5x objective magnification under PPL and XPL, as shown in Figure 4.20. The texture is phaneritic, or medium to coarse mineral sizes.

Based on the observation of the thin section, the mineral composed of Microcline (A10) which about 47%. Some of the minerals are converted into sericite. In PPL, the color absorption is colorless, relief is low, pleochroism is absent, crystalline shape is subhedral to anhedral, and hemisphere is one direction. In XPL, the color of the first order is gray to white interference, oblique dark angle, and polysynthetic twin is presence.

Another major mineral that can be observed is Quartz (C1) which about 50%. In PPL color absorption is colorless, relief is low, pleochroism is absent, crystalline shape is anhedral, and hemispheres are absent. In XPL, the color is gray to white interference of the first order, the dark corners are wavy, and twin are absent.

Opaque minerals (A9) also can be found during the observation, which about 3%. In PPL, absorption color is black, low relief, pleochroism is absent, crystalline shape is euhedral to anhedral. In XPL the color of black interference of the first order, and twins are absent.

(a) (b)

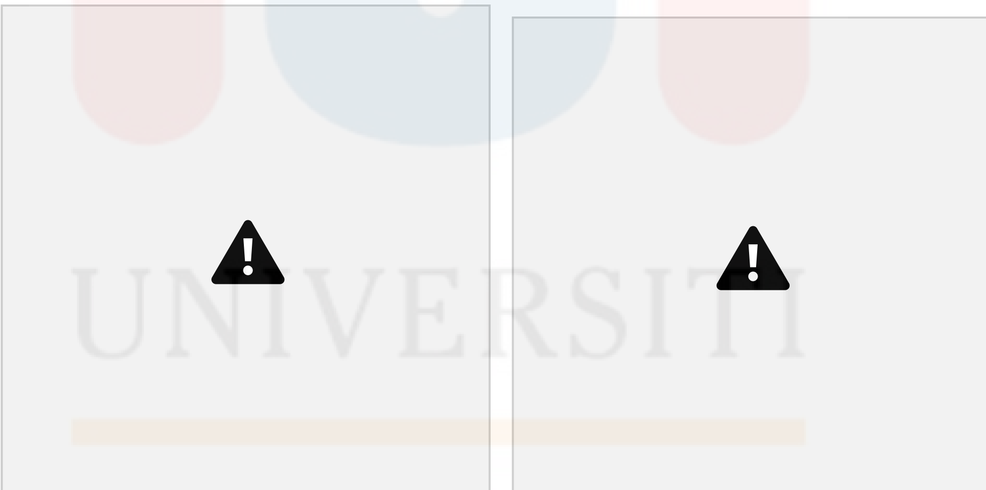


Figure 4.20 : (a) PPL image of granite; (b) XPL image of granite.

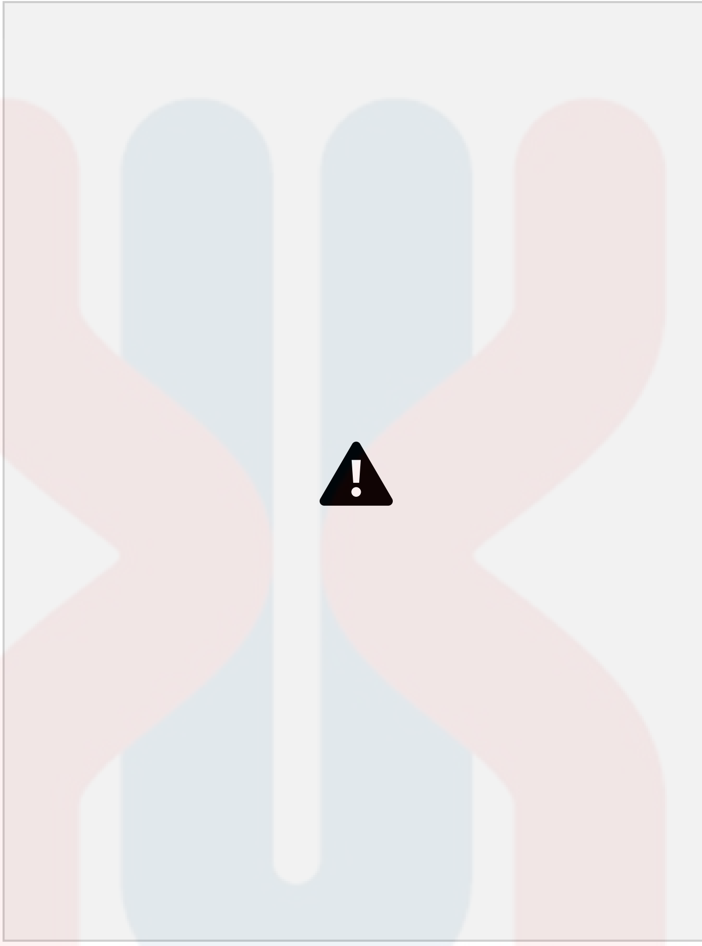
Figure 4.21 : QAPF Diagram of alkali feldspar granite (Streckeisen, 1976).

b) Limestone

Limestone distributed about 10% of this study area. Crystalline limestone is found in the Gua Musang Formation, along with chert nodules, sandstone, tuff, and volcanic rock (Hutchison, 2009). Limestone is a type of chemical sedimentary rock that developed at low temperatures in an aquatic environment. The extensive limestone is believed to be a continuous carbonate platform that was deposited within the Gua Musang platform during the Permo-Triassic period before being exposed to erosion and karstification (Mohamed et. al, 2016). Based on the age of the fusulinacea fossil in the limestone and the Triassic bivalve fossil that Rajah and Yin (1980) suggested, the limestone in Gua Musang is estimated to be Middle Permian to Lower Triassic in age .

Most of the limestone outcrop in the study area area karstic limestone, as shown in Figure 4.22 (a). The identification of limestone rocks was made by observing the reaction of the rock towards hydrochloric acid. The presence of bubble-like reaction indicated that there is high composition of calcite in the rocks. The colour of the limestone rocks was also observed as it indicates the amount of carbon contained within the limestone. Light grey limestone contains the least amount of carbon, and the dark limestone contains the most carbon and oxygen found in the deep sea.

(a)



(b)

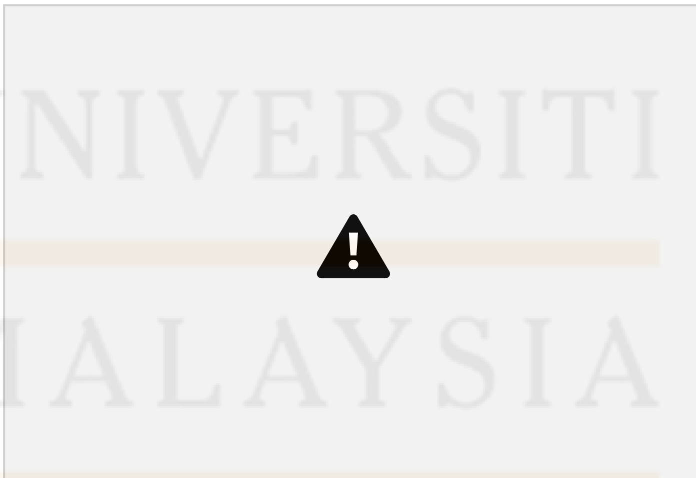


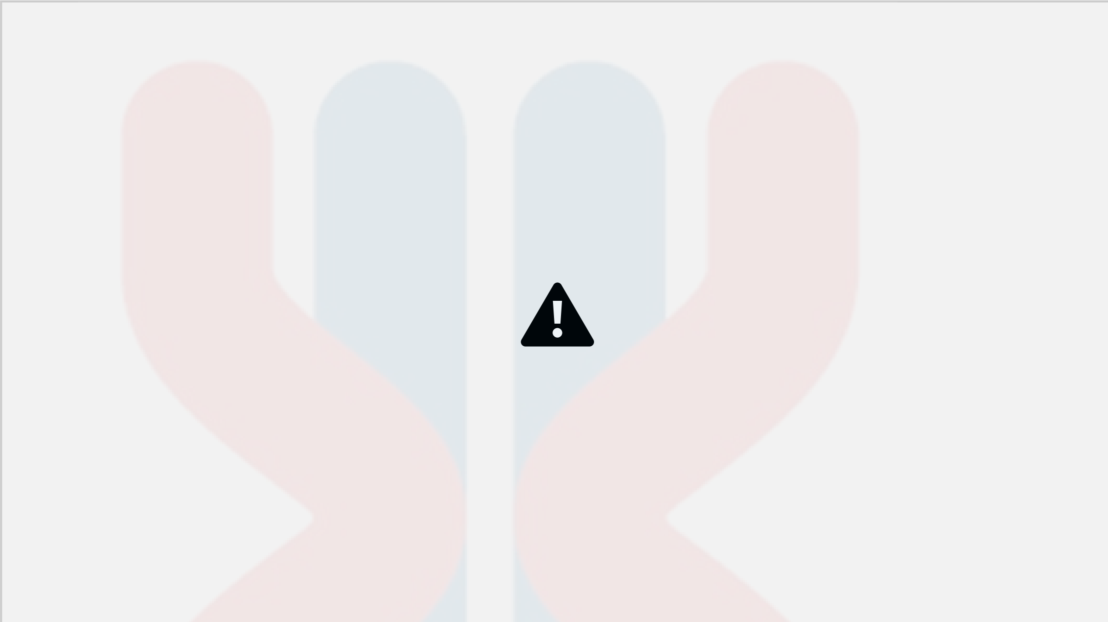
Figure 4.22 : (a) Karst limestone outcrop in the study area, known as Batu Tapah; and (b) Hand specimen of limestone in the study area.

c) Rhyolite

Rhyollite comprised about 5% of the eastern part of study area. Spiller et. al (1998) stated that the Gua Musang formation is composed of argillaceous rocks with interbedded limestone and volcanic pyroclastic rocks (rhyolite). According the Kamal Roslan et. al (2016), the low-lying argillovolcanic Gua Musang formation (including isolated limestone karsts) that age ranging from Middle Permian to Late Triassic is composed of argillite - rhyolitic volcanic rocks that across Lipis district to Gua Musang. These volcanic, or pyroclastic facies created marine topographic highs for limestone deposition in shallow marine environment

According to Nursufiah (2017), the volcanic rocks of the Gua Musang Formation is ranging from rhyolitic to andesitic and comprise tuff, lava flows, and agglomerate. Muhammad Afiq (2018) stated that the rhyolite found in Gua Musang represents the acidic volcanic rocks of the Gua Musang Formation that were unaltered by metamorphism and exposed to the surface of Gua Musang due to a minor NW striking fault that extends toward the lower regions of Galas River along the Taku Schist boundary. The contact between the Gua Musang Formation and the Taku Schist across the Galas Basin is interpreted using lithological alterations from a massive, non deformed rhyolite to quartz-biotite schist in the Galas Basin's east.

(a)



(b)

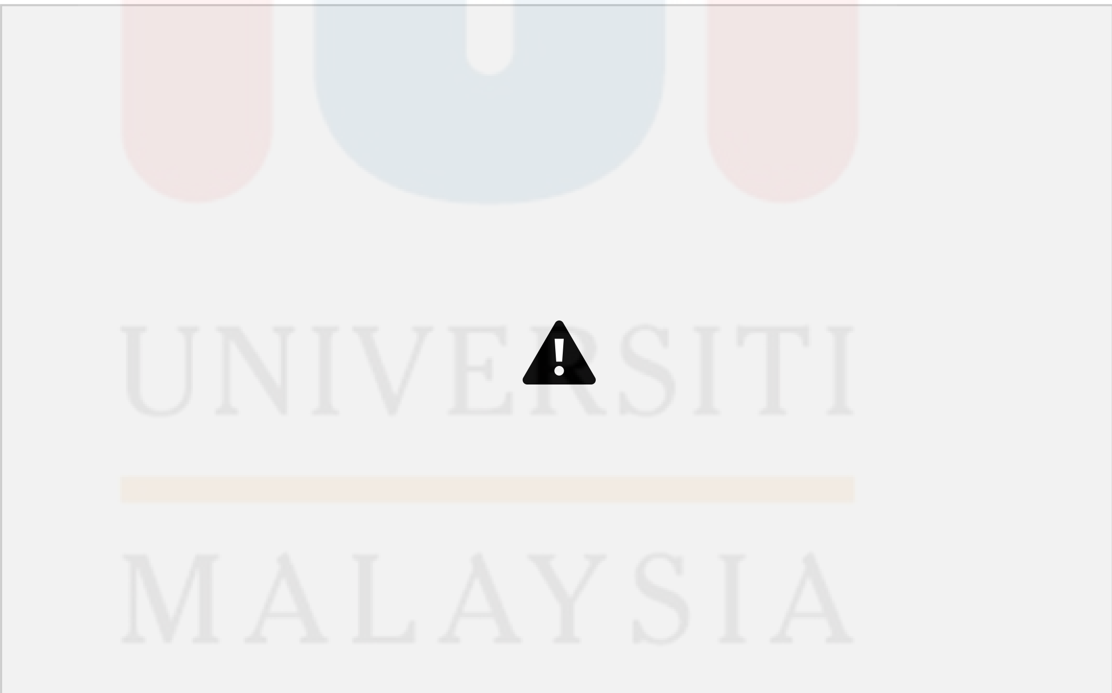


Figure 4.23 : (a) The outcrop of rhyolite at Ketil River ; and (b) Hand specimen of rhyolite.

<u>Petrography Analysis of Rhyolite</u>

The lithology of this unit was identified according to mineral composition and QAPF diagram of volcanic rock classification issued by Streckeisen (1976).

The microscopic observations were made at an ocular magnification of 10x and an objective magnification of 5x under PPL and XPL as shown in the Figure 4.24. Based on the observation, the structure is massive, has aphanitic texture, and fine to medium mineral size.

The abundant mineral composition is Quartz (C1), which about 48%. In PPL, the color absorption is colorless, relief is low, pleochroism is absent, crystalline shape is anhedral, and hemispheres are absent. In XPL, the interference color is gray to white of the first order, the dark angle is wavy, and twins are absent.

The second most abundant mineral is orthoclase feldspar (F10), which about 35%. In PPL, the color absorption is colorless, relief is low, pleochroism is absent, s crystalline shape is subhedral to anhedral, and hemisphere is one direction. In XPL, the color of the interference is gray to white of the first order, the dark angle is parallel to oblique, and the polysynthetic twin is present.

Matrix (J7) or also known as groundmass comprised about 15% in this sample. In PPL, the absorbance color varies from colorless to light gray to brown, and it has high relief. In XPL, the color of interference varies from dark gray to black to brown. It also consists of quartz microlites, and feldspar microlites.

Biotite (A10) is also observed in this sample, but with very small amount, which about 1%. In PPL, the absorption color is brown to greenish, has medium relief, strong pleochroism, crystalline shape is subhedral to euhedral, and hemisphere is one direction. In XPL, the interference color is green to orange of the third order, and the dark angle is parallel, and twins are absent.

Another composition of this sample is opaque mineral (G2), which also comprised about 1%. In PPL, the absorption color is black, has low relief, pleochroism is absent, and the crystalline shape is euhedral to anhedral. In XPL, the interference color is black of the 1st order, and twins are absent.

(a) (b)

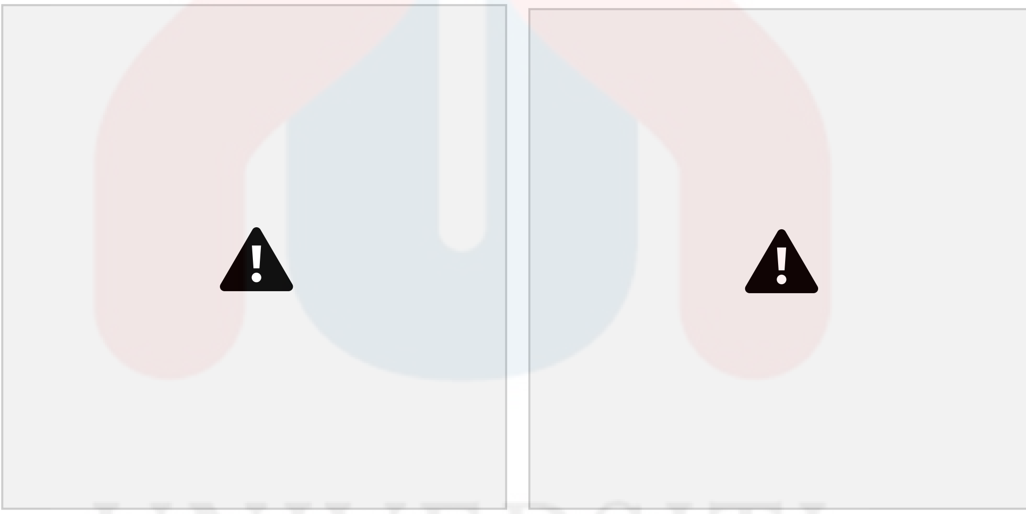


Figure 4.24 : (a) PPL image of rhyolite; (b) XPL image of rhyolite.

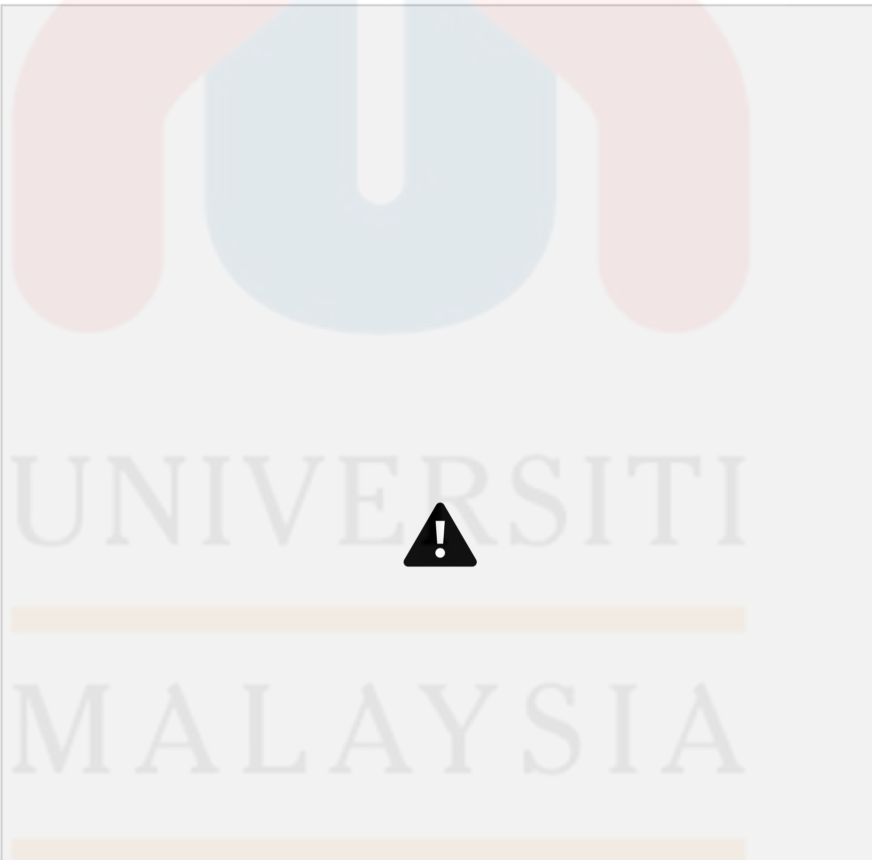


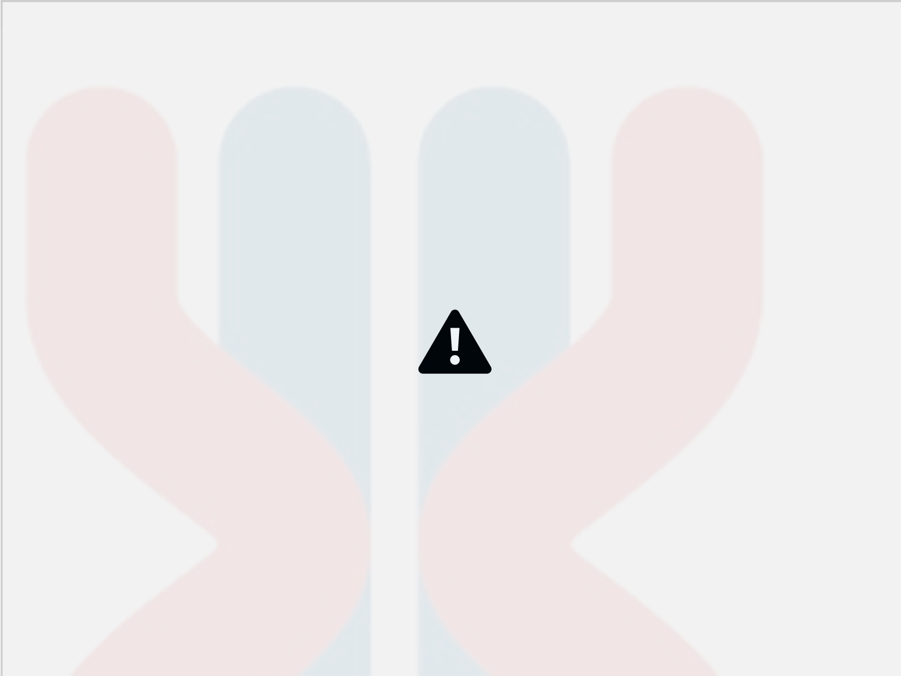
Figure 4.25 : QAPF Diagram of alkali feldspar rhyolite (Streckeisen, 1976).

d) Metasedimentary rock unit

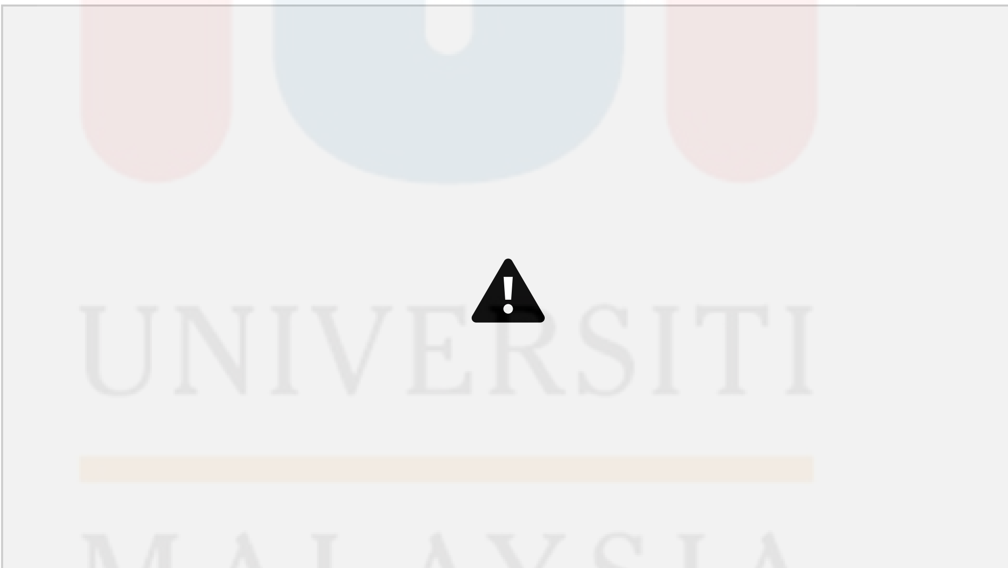
This unit consisted of two rock types including slate and plyllite from Gua Musang Formation aged Permian. This unit is the most abundant lithology in the study area, which comrpised about 55%. The age of metasedimentary is older due to the granite intrusion throughout the unit. Since granite intruded this rock unit, baked zone was created, and sediments that subjected ot metamorphism were altered to form metasedimentary rock.

Phyllite and slate are quite similar in terms of their mineral composition, characteristics and appearances. They were identified during the field by observing its physical characteristics. Moreover, the identification of the rock unit was also made by observing the foliated texture of the rock, and also the fine-grained minerals texture. The metasedimentary rock unit also has a less steepness elevation which lower than granite unit elevation.

. (a)



(b)



(c)

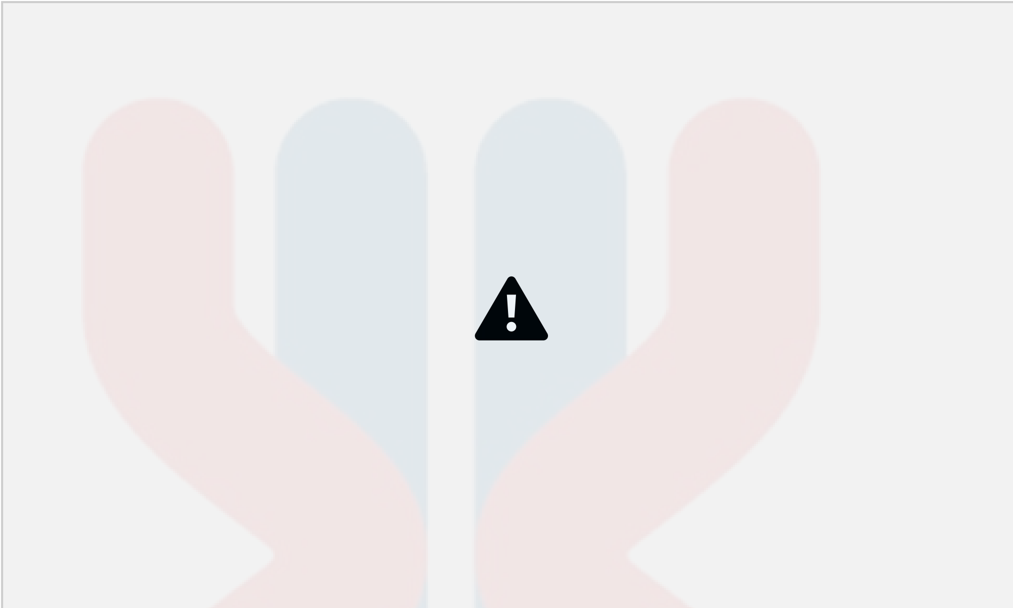


Figure 4.26 : (a) Outcrop of metasedimentary rock at Taman Wira Perdana, Gua Musang; (b) Close up of metasedimentary outcrop at sub-stream of Galas River; and (c) Hand specimen of metasedimentary rock.

Petrography Analysis of Phyllite

This rock sample is identified based on the mineral composition, and flow chart of metamorphic rock issued by Gillen (1982).

Microscopic observations were carried out at 10x ocular magnification and 5x objective magnification under PPL and XPL, as shown in Figure 4.27. Based on the observation, it shows the foliation structure (phylittic), palimpsest texture (blastopellite), and grains size <1/256 to 1/8 mm, that are well sorted.

The higher mineral composition of this sample is clay silica (F10), which is 39%. In PPL, the absorption color is colorless to brown, whereas in XPL , the interference color is dark gray to black, and it consists of micron-sized silicate material.

The second highest mineral content is quartz, which is 30%. In PPL, the color absorption is colorless, relief is low, pleochroism is absent, crystalline shape is anhedral, and hemispheres are absent. In XPL, the color is gray to white interference of the first order, the dark corners are wavy, and twin mineral are absent.

Talc mineral (B3) is also comprised of 30% of the sample. In PPL, the color absorption is colorless, low relief, weak pleochroism, crystalline shape is anhedral, and hemispheres are absent. In XPL the interference color is blue to yellow of the third order, the dark angle is oblique, and twin mineral is absent.

Other than that, there is also 1% of opaque mineral (F6). In PPL, black absorption color, low relief, pleochroism is absent, and crystalline shape is euhedral to anhedral. In XPL, the observed color is black interference of the first order, and twin mineral are absent.

(a) (b)

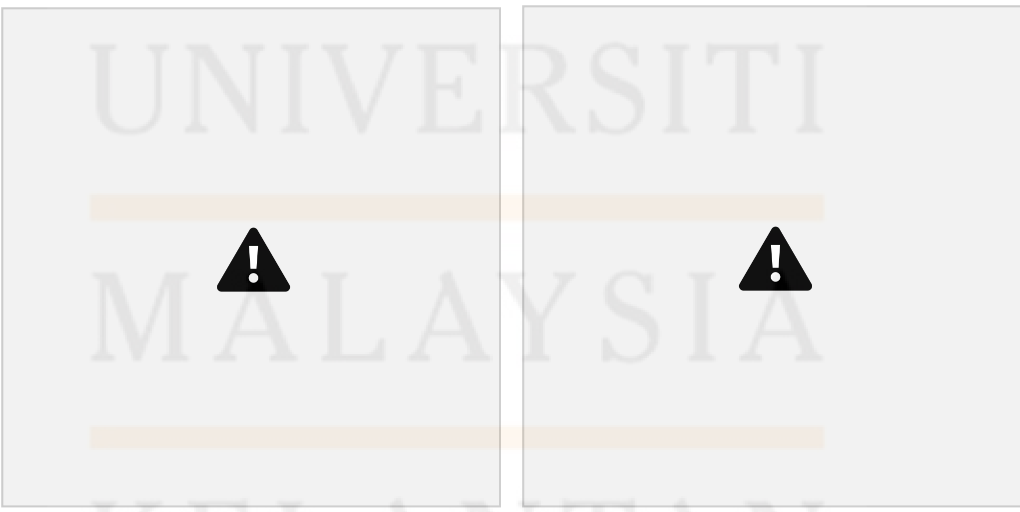


Figure 4.27 : (a) PPL image of phyllite; (b) XPL image of phyllite

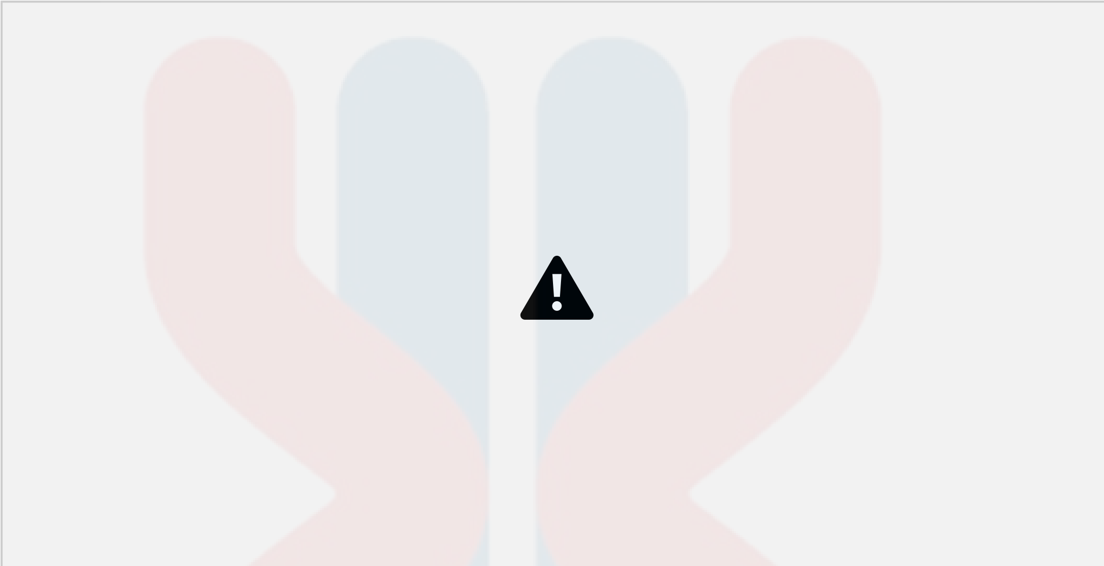


Figure 4.28 : The classification of metamorphic rock shows that the outcrop is phyllite (Gillen, 1982).

4.3.1 Stratigraphy position

Table 4.4 : Stratigraphy column of the study area.

Era	**Period**	**Formation/ Rock Unit**	**Lithology**	**Description**
Cenozoic	Tertiary	Acid Intrusive	Granite	The youngest rock unit that intruded the succession of Gua Musang Formation. It contains of quartz, feldspar, and mica minerals.
Mesozoic	Middle Permian to Late	Gua Musang Fm.	Rhyolite	Acidic volcanic rock that were unaltered by metamorphism. Interbedded with limestone. The texture is fine-grained.

	Triassic		Limestone	Consist of bedding limestone, marl, mudstone, shale, sandstone conglomorate and unconformity with bedded tuff and marble. Some appear as karsts.
				Composed of slate and phyllite. Both rocks have foliated texture. Prominent development of limestone throughout the succession

Figure 4.29 : Geological map of the Kampung Kundur, Gua Musang, Kelantan.

4.4 Structural Geology

4.4.1 Lineament Analysis

There are two types of lineaments: positive and negative. Positive lineament is identified based on ridges and ranges, and it indicates bedding. However negative lineament denotes fault or joint, which can be identified from valleys or rivers (Ibrahim Komoo et. al (1989).

Lineament is a feature indicator of a geological structure, such as a fault, that appears as a linear line on a map composed of aligned valleys, hills, or a combination of the two. Most of the lineament structure that was extracted from the map is all over the part of the study area.

Lineament analysis was done before geological mapping to locate the geological structure such as faulting and folding. Figure 4.30 shows the lineament maps of the study area. The negative lineaments indicate by purple lines, while positive lineaments indicate by yellow lines.

Lineament Map of The Study Area

Figure 4.30 : The lineament analysis map of Kampung Kundur, Gua Musang, Kelantan.

4.4.3 Fold

Fold is a structure that was categorised based on the orientation of its axes and its appearance. It developed as a result of forces acting on the deformed area. A flat surface or other undeformed surface is subsequently distorted. Anticline, syncline, monocline, chevron, plunging, harmonic, and recumbent folds are among the several fold types. A syncline is a fold that is concave upwards, whereas an anticline is convex upwards.

Folds were found in the two different locations in the study area, which both are occurred on the metasedimentary rock. The first location of the folds was found is at the coordinate 04° 52' 52.910''N, 101° 57' 48.04''E. The types of folds are syncline and anticline. Second location is at the coordinate 04° 53' 18.064''N, 101° 56' 11.379''E. The type of folds are also syncline and anticline. The folds are the example of relict discontinuities since they are preserved on the high to completely weathered rock mass. Figure 4.31 shows the outcrop of folding areas. Based on the rose diagram, as in the Figure 4.32, the major force direction of the folding is towards the East – West direction.