



**Petrography of The Main Range Granite
Characterization in Titiwangsa Rest Stop, Perak,
Malaysia**

By,

JOSHUA A/L WILLIAM

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

**Faculty of Earth Science
Universiti Malaysia Kelantan**

2023

APPROVAL

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

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Name of Supervisor : _____

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DECLARATION

I declare that this thesis entitled ‘‘ Geology and Petrography of Volcanic Rock at Kampung Bukit Besi, Temangan, Kelantan’’ is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Petrography of the Main Range Granite Characterization in Titiwangsa Rest Stop, Perak, Malaysia

ABSTRACT

The Main Range Granite intrudes the country rock which includes metamorphic rocks during the Triassic period after the merging of two continental plates. The rock in the focused region entirely consists of plutonic rocks which are biotite granite and metamorphic rocks. Those metamorphic rocks include gneiss and mica-schist. The area of interest is in the middle between the Titiwangsa Rest Stop, Perak dispensed along the longitudes and latitudes of five°36'34.39"N to 5°35'31.74"N and 101°29'59.52"E to 101°35'20.08"E with roughly 25km² in terms of surface area. This paper introduces petrography onto finding biotite granite that interfered and intruded metamorphic rocks based on the observations on the rock's mineral surfaces. Geographical mapping procedure was utilized to observe the selected region and the rock samples were gathered from outcrops that can be detected around the area as well. In view of the petrography analysis, the hand sample of the biotite granite shows phaneritic and holocrystalline surfaces. The biotite granite is coarse-grained and shows an exceptionally minor of alkali feldspar as phenocryst. The minerals that comprise in the biotite granite are overwhelmed with alkali feldspar, with normal rate of plagioclase and quartz, while biotite is more dominant in the rock contrasted with hornblende. The focused region extends from the Titiwangsa Rest Stop towards the Gerik-Jeli highway is found straightforwardly on the Bentong-Raub suture zone.

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**Petrografi Pencirian Granit Rentas Utama di Berhenti Rehat Titiwangsa,
Perak, Malaysia.**

ABSTRAK

Granit Rentas Utama meresap batuan negara yang termasuk batuan metamorf semasa zaman Triasik selepas penggabungan dua lempeng benua. Batuan di kawasan yang difokuskan terdiri daripada batuan plutonik iaitu granit biotit dan batuan metamorf termasuk gneiss dan mika-sist. Kawasan yang diminati terletak di tengah-tengah antara Berhenti Rehat Titiwangsa, Perak dengan penyebaran di sepanjang bujur dan latitud $5^{\circ}36'34.39''\text{N}$ hingga $5^{\circ}35'31.74''\text{N}$ dan $101^{\circ}29'59.52''\text{E}$ hingga $101^{\circ}35'20.08''\text{E}$ dengan kira-kira 25km^2 dari segi luas permukaan. Kertas kerja ini memperkenalkan petrografi untuk mencari granit biotit yang mengganggu dan meresap batuan metamorf berdasarkan pemerhatian pada permukaan mineral batuan. Prosedur pemetaan geografi digunakan untuk mengamati kawasan yang dipilih dan sampel batuan dikumpulkan dari keluaran batuan yang dapat dikesan di sekitar kawasan tersebut. Berdasarkan analisis petrografi, sampel tangan granit biotit menunjukkan permukaan faneritik dan holokristalin. Granit biotit berbutir kasar dan menunjukkan sedikit feldspar alkali sebagai fenokristal. Mineral yang terdiri dalam granit biotit dikuasai oleh feldspar alkali dengan peratusan biasa plagioklas dan kuarsa, manakala biotit lebih dominan dalam batuan berbanding hornblende. Kawasan yang difokuskan membentang dari Berhenti Rehat Titiwangsa ke lebuh raya Gerik-Jeli terletak secara langsung di zon sutur Bentong-Raub.

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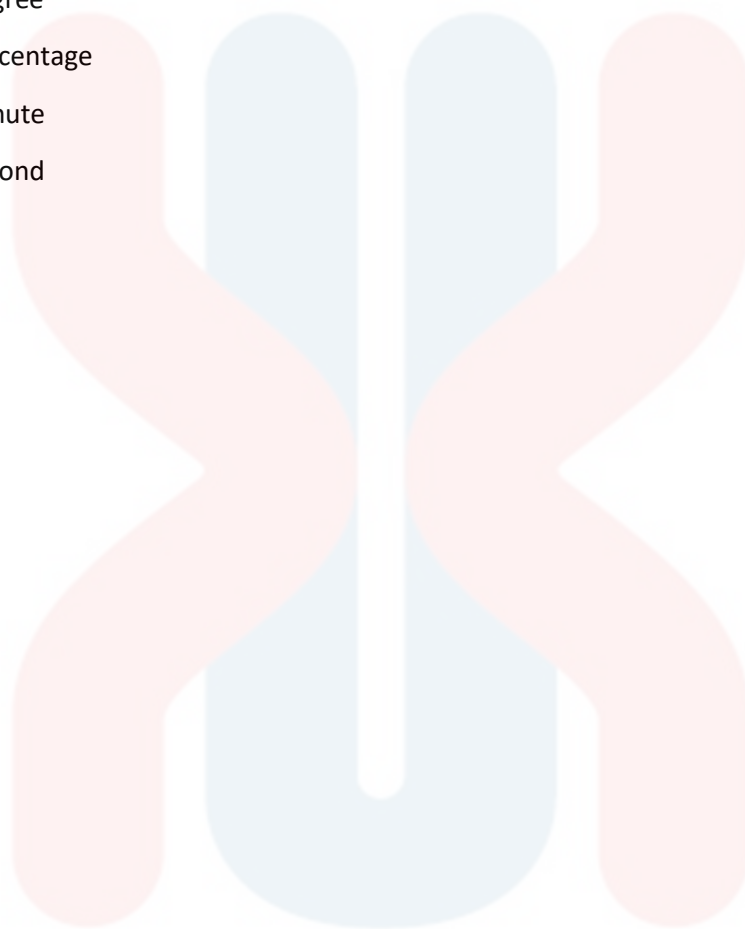
LIST OF ABBREVIATIONS

GPS	Global Positioning System
GIS	Geographic Information System
Ort	Orthoclase
Bt	Biotite
Plg	Plagioclase
Qtz	Quartz
N	North
S	South
E	East
W	West
km	kilometre
PPL	Plane Polarized Light
XPL	Cross Polarized Light

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LIST OF SYMBOLS

- ° Degree
- % Percentage
- ' Minute
- " Second



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CHAPTER 1

INTRODUCTION

1.1 General Background

Petrography analysis is a field of research that examines the physical characteristics of rocks utilising hand specimens to describe them in detail. By determining the mineral composition, texture, provenance of the rock, and recrystallization rate on the research area, one may define the kind of rock under a polarised microscope.

Geological mapping is required in the field of geology to display the geological terrain. Geological mapping must be completed to depict the research area's geological characteristics and to differentiate between the distribution of those features' lithologies on the map, which is represented by locations, lines, symbols, and colours (Coe et al., 2010). Geological mapping is done to gather and update the differences between research findings and the data on the current map.

Granite is classified as an intrusive igneous rock originating beneath a pluton or a volcanic region on the surface of the Earth. A granite rock will be commonly used in manufacturing and construction processes in a consumer's life as it has a dense silica content on the rock itself. Moreover, this type of felsic rock has a 77% percentage of silica, and this rock can be categorized into its types based on the crystallization rate. Such granitic-based rocks include leucogranites and many more. The classification of the granite rocks created by Chappel and White (1974) suggests the development of I-type granite and S-type granite. This classification signifies the composition of the granitoid composition and the felsic magma recrystallization. Peninsular Malaysia

contains one of the largest granitic batholiths, specifically at the Western Belt Terrane of Peninsular Malaysia. Moreover, S-type granites can be found occurring in the Triassic-Central Range of Peninsular Malaysia. Hence, the Main Range has a dominant biotite-granite rock mineral and characterizes the tin provinces around the area.

The geological aspects that are focused on this research are towards the Main Range granite characterization of igneous rocks in the Titiwangsa area located in Perak, Malaysia. Igneous rocks are rocks formed by the solidification and recrystallization of molten lava originating from volcanoes worldwide (Anthony, 2011). The geology and petrography of igneous rocks in the area of Titiwangsa had been taken and studied and petrographic examination of hand specimens were collected. The research area is situated near the Royal Belum resort, and it is along with the Titiwangsa Rest Stop on the Gerik-Jeli Highway. This research focused on metamorphic rock mineral assemblages and the ranges of granite characterization in the area around the Titiwangsa Rest Stop in Gerik, Perak.

1.1 Study Area

1.1.1 Location

This research is focused on the area around Titiwangsa Rest Stop between the Gerik-Jeli Highway. The study area has been measured in the dimension of 5km x 5km and the total area uncovered from this area of interest is 25km². This research area is located at the longitude 101°30'5'' E and latitude 5°35'48'' N in the world's map with coordinate position of selected area. This research area was predicted to have a transition between granites towards into a metamorphic rock based on previous researchers (Mohd Raji,1990).

In terms of its economical use, this area is categorized as a part of the Amanjaya forest reserve and there is a rest stop centre for drivers who are travelling in the Gerik-Jeli Highway. Based on geological base map, there are only few streets, there is no civilization use and this area of research is fully covered with forest. The research area is also between the border of Perak and Kelantan, specifically in Gerik and Jeli. The highest elevation in the base map are meters and the lowest elevation is meters. There is a minor drainage system as Figure 1.1 shows the location and base map of the research study area.

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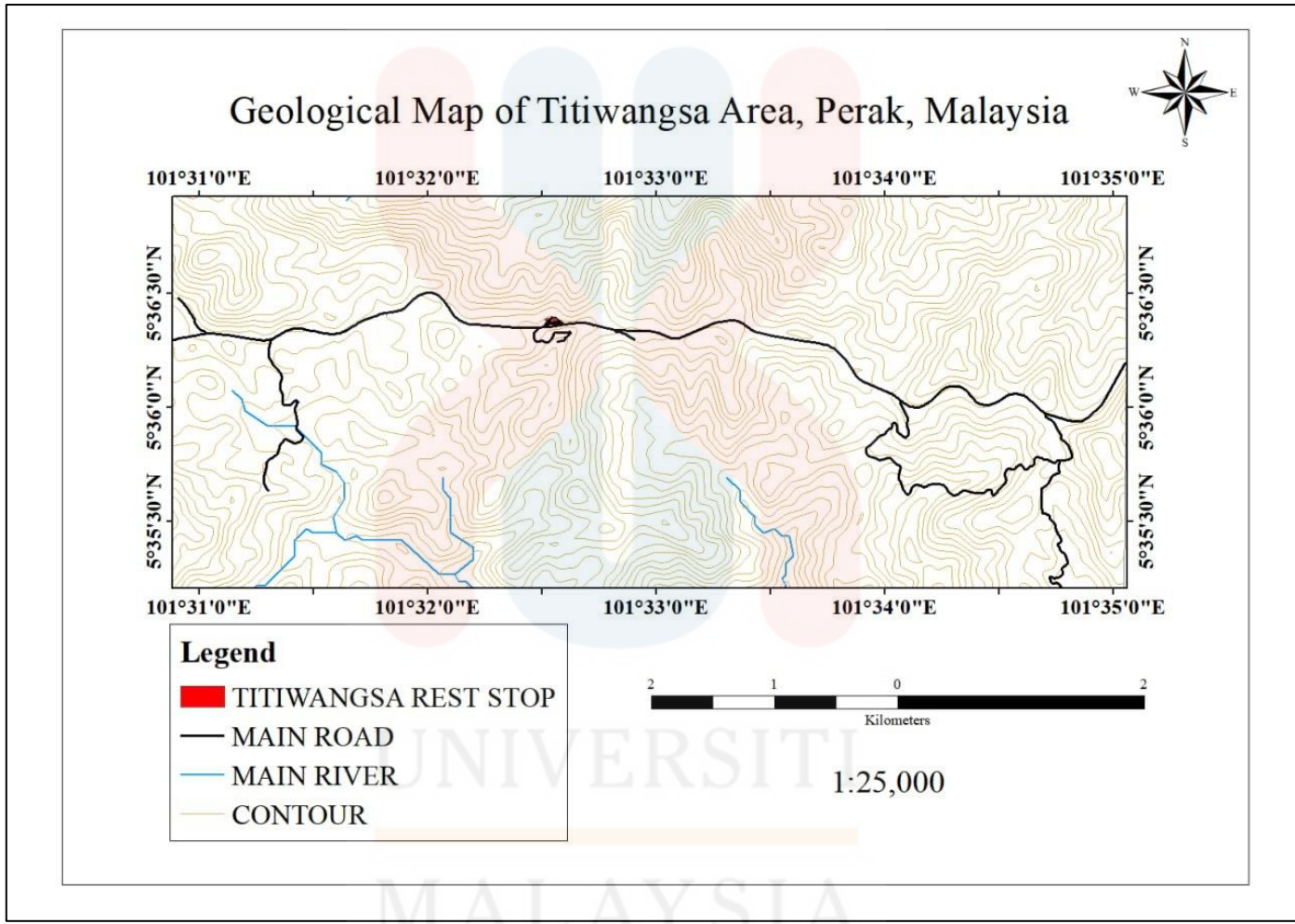


Figure 1.1: Base map of the study area

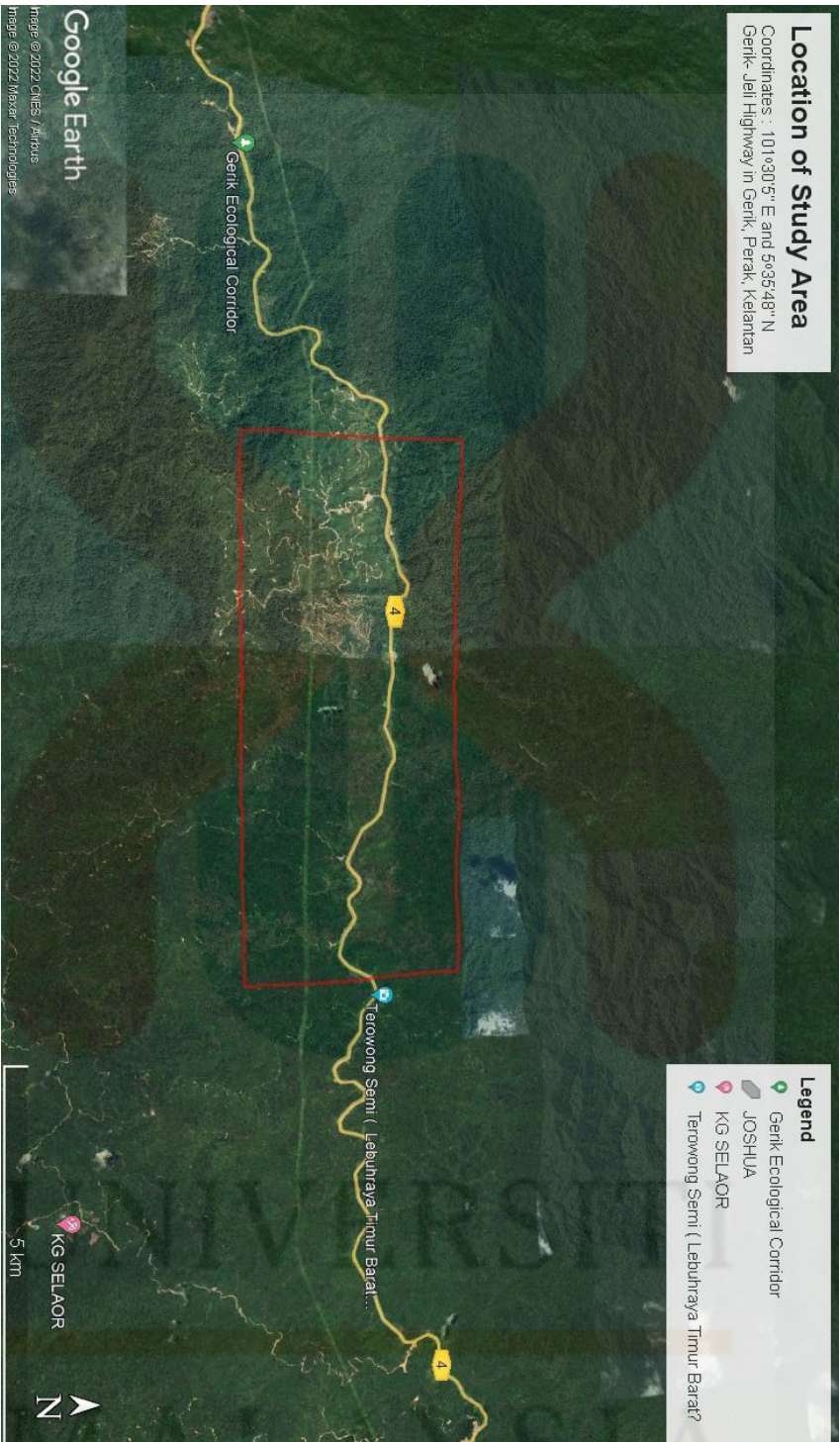


Figure 1.2: The aerial view Earth of the study area (highlighted in red)

1.2.2 Road Accessibility

Accessibility of the road on the study area is divided by the main highway, Amanjaya forest reserve, the Titiwangsa rest stop and the several drainage systems. Generally, the road used in the study area is an extension of the Westcoast highway of Jeli, Kelantan towards Gerik, Perak. The main road as figure 1.3 shows that the road are connected to the highway and towards Gerik, Perak. The Titiwangsa rest stop locates at the highest elevation of the highway in the middle of the Gerik-Jeli highway. Besides, the only way to cross the study area is by a vehicle as the other areas of the location is covered by dense and thick forest from the forest reserve in Amanjaya.



Figure 1.3: The connectivity of the road towards Gerik, Perak from Jeli, Kelantan covered by a dense and thick forest surrounding the highway.

1.2.3 Demography

According to the latest information from the Department of Statistics Malaysia, total population in Hulu Perak is around 95,076 people in year 2010. Gerik is the main town of Pengkalan Hulu in Perak. In the terms of ethnicity, the Malays along with other indigenous people (Bumiputera) are about 76,773 peoples, 8430 Chinese people, 1626 Indian peoples, 1367 of other ethnicities. In terms of gender population, males are 46,657 meanwhile females are 43,359 citizens. In age terms, 18,929 people are basically infants (0-9 years), 19,846 kids ranging from 10 to 19 years old, 13,201 teens ranging from 20-29 years old, 30-39 years old citizens with a number of 9862 residents, 10,130 residents ranging from 40-49 years old and 17,955 people in the elderly category. The figures and tables below are the results exhibited in a pie chart form.

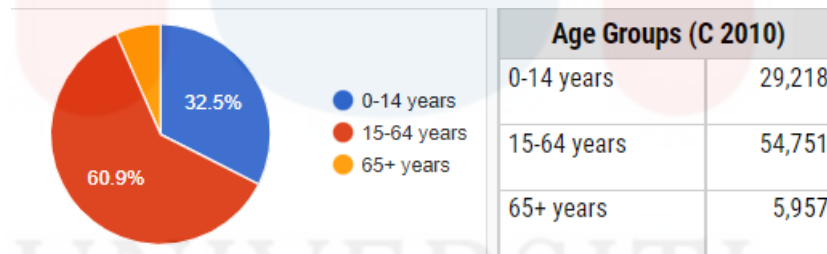


Figure 1.4: The age groups of Pengkalan Hulu according to the Department of Statistics Malaysia in

2010

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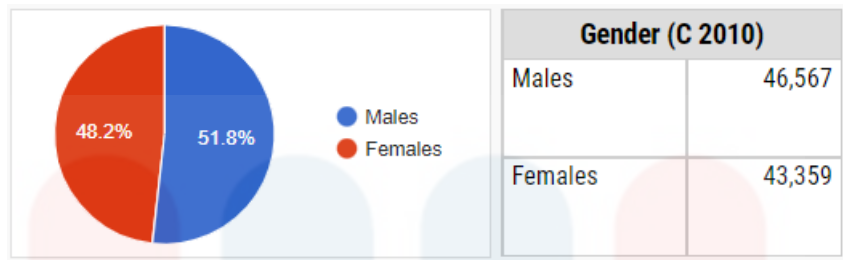


Figure 1.5: The gender classification of Pengkalan Hulu according to the Department of Statistics Malaysia in 2010

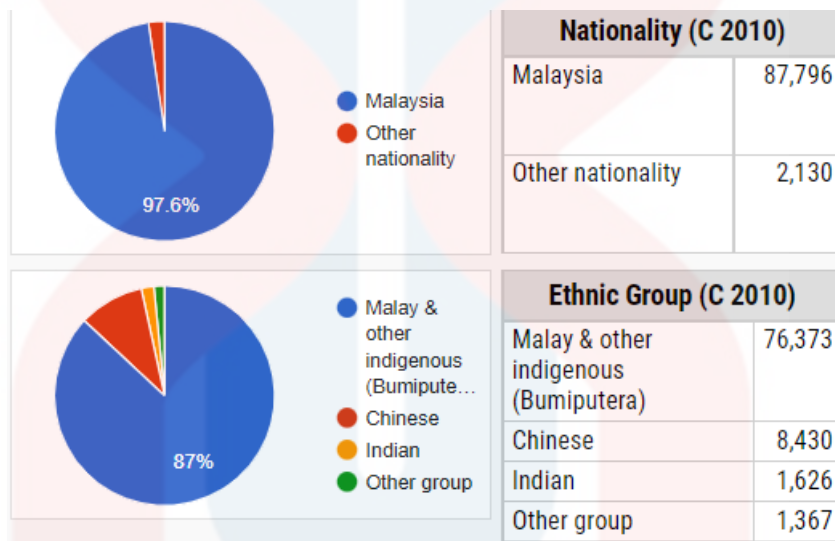


Figure 1.6: The classification of Pengkalan Hulu residents according to nationality and ethnic group

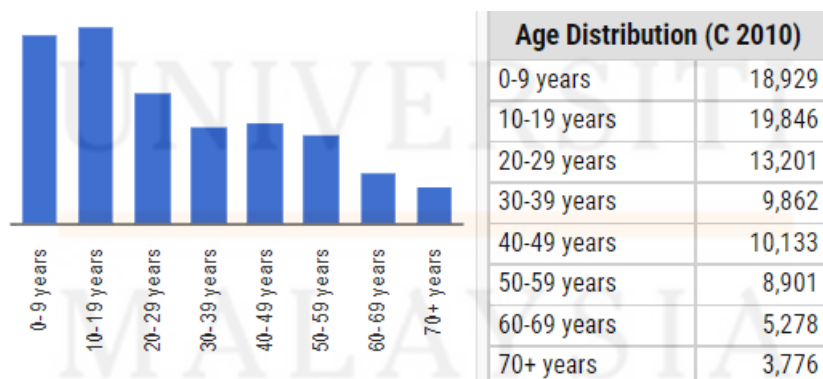


Figure 1.7: The classification of age in Pengkalan Hulu based on the Department of Statistics Malaysia in 2010

1.2.4 Social Economic

The social economic factor used in this study area is only the Titiwangsa Rest Stop which is located along the Gerik-Jeli highway. This rest stop consists of a restaurant for cuisine purposes especially for the drivers who passes by in this particular highway. The rest stop is also having toiletries and a rest zone for drivers to take a break at there. The rest stop is solely on the business field and there are not any economical purposes around the area as this area is surrounded by a forest reserve. The nearest village away from the study area is Kampung Salor, which are fully dependent into the agricultural field.



Figure 1.8 : The Titiwangsa Rest Stop located in the Grik-Jeli Highway

1.2 Problem Statement

There are many limitations on researching this study area. First, a detailed geological map was not generated in this area consisting of the lithology and drainage aspects of the area. This can be solved by traversing methods in the study area in order to obtain the lithological aspect and other geological aspects that can be collected in the area for a geological map basis.

Apart from that, one of the issues is that this area has a lesser geological information as lack of research has been done focusing on the coordinates of this area, especially on the Main Range Granite characterization on the area. The latest research on the area has been done by the Malaysia-Thailand Border Joint Geological Survey Committee (MT-JGSC) only on the year 2012. Referring to this MT-JGSC research on 2019, both parties have come to an agreement on investigating the geology of the Belum-Hala area which includes the area of interest as well, in conjunction to the Sixth Meeting of the Malaysia-Thailand Border Joint Geological Survey Committee held in Kuala Lumpur on June 11, 2009. Since then, geoscientists from Malaysia's Minerals and Geoscience Department and Thailand's Department of Mineral Resources have worked on the project in 2010 and 2011. This can be solved by extracting more information through the ArcGIS method in order to survey the area through satellite imagery.

1.2 Objectives

1. To update a scaled geological map according to the study area in a ratio of 1:25,000.
2. To investigate the Main Range granite characterization throughout the study area.
3. To analyse the petrographical aspects of the plutonic and metamorphic rocks in the research area.

1.3 Scope of the Study

The present project's geological mapping component will mostly rely on fieldwork inputs, such as sampling from recently formed outcrops, noting structural trends in rocks, and making other field observations including drainage patterns and geomorphological characteristics. In order to create a geological and other thematic map, all of these field-related data sets, together with petrographic investigations, will be processed in a GIS-based platform. The main extent of the study is to focus on the geology of the plutonic and metamorphic rocks in the Titiwangsa area in Gerik, Perak. The area scope dimensions are 5km x 5km, circulating about $25km^2$ in terms of its study area.

The rock samples from observed outcrops were investigated, sliced and separated into thin sections and was interpreted with a polarized microscope. The rock nomenclature made by the International Union of Geological Sciences (IUGS) was applied and used to obtain to classify the igneous plutonic rock sample taken according to its categorization. The analogy of the rock process and the rock distribution will be evaluated in detail in this research. This study would be further enhanced by using ArcGIS software for its application in satellite image.

1.5 Significance of Study

The purpose of this study is to produce a geological map in accordance with the study area. This research will be able to provide updated data and fresh findings at the end of this research. Prior to the existing one from the previous research, a thorough and reconstructed geological map of the subject region can be developed. Furthermore, the discovery of more specified and detailed granitic rocks can be added to the research area's geological data. Furthermore, the granitic rocks discovered can be used in a variety of ways, including as a crucial component in construction materials.

The goal of this research is to learn more about volcanic rock, including its distribution, the mechanism by which it forms (petrogenesis), the circumstances under which it does so, and the fact that these questions have not yet been satisfactorily answered by earlier studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Regional geology and tectonic context, regional stratigraphy, and structural analysis are all significant considerations in geology before doing study in a specific location. Furthermore, because the research focuses on petrography and volcanic rock, more research and detail are required to perform and complete this project in the area of Titiwangsa and the Gerik-Jeli highway. As a result, various publications, journals, prior theses, reports, and conferences in conjunction with the research were cited as references.

2.2 Regional Geology and Tectonic Setting

Peninsular Malaysia is categorized into three main ranges of belts that extends towards the Peninsular Malaysia. Those ranges include Western, Eastern and the Central Belt (Khoo & Tan, 1983). The uppermost part of the Western Belt in Peninsular Malaysia underlain by clastics, limestones and volcanics. The Western Belt underlain chiefly by Paleozoic rocks from the Kinta Valley Southwards towards Malacca. In the NorthWestern part, the stratigraphic history that consists of states such as North of Perak, Kedah and Perlis including formations such as the Machinchang formation, Setul formation, Singa formation, Chuping Limestone and Jerai Formation.

As for the Central Belt, the Mesozoic and Permian based rocks dominates the zone. The Bentong Group are the eldest part of the rocks of the eastern extension of the Main Range Granite alongside with Carboniferous rocks that are exposed in Kuala Lipis. Taku Schist which are also made up in the Carboniferous era are older than the eastern flanks in that zone. There are marine-based Permian and Triassic rocks that are accumulated in the zone with the Takai Group ranging from Jurassic to Cretaceous age. The Eastern Belt comprises of older sediments with the Carboniferous age and Permian based clastics, volcanic rocks and limestone along with low grade-schists.

Gerik District, which is located in Perak, Malaysia situated in the Central Belt of the Peninsular Malaysia. It is at the bottom range of the Main Range Granite of the Eastern Belt of Peninsular Malaysia. The lithology of the Main Range Granite consists of several granitic rocks with few portions of sedimentary and metasedimentary rocks around this granitic embodiment. The Main Range Granite is located at the Western part of Kelantan which extends at the Eastern part of the state until the North of Perak and Pahang as well. Outcrop extensions are along the northeast towards southwest directions. Figure 2.1 shows the geological map of Kelantan in Peninsular Malaysia which consists of the three belts of Malaysia, which includes the age as well.

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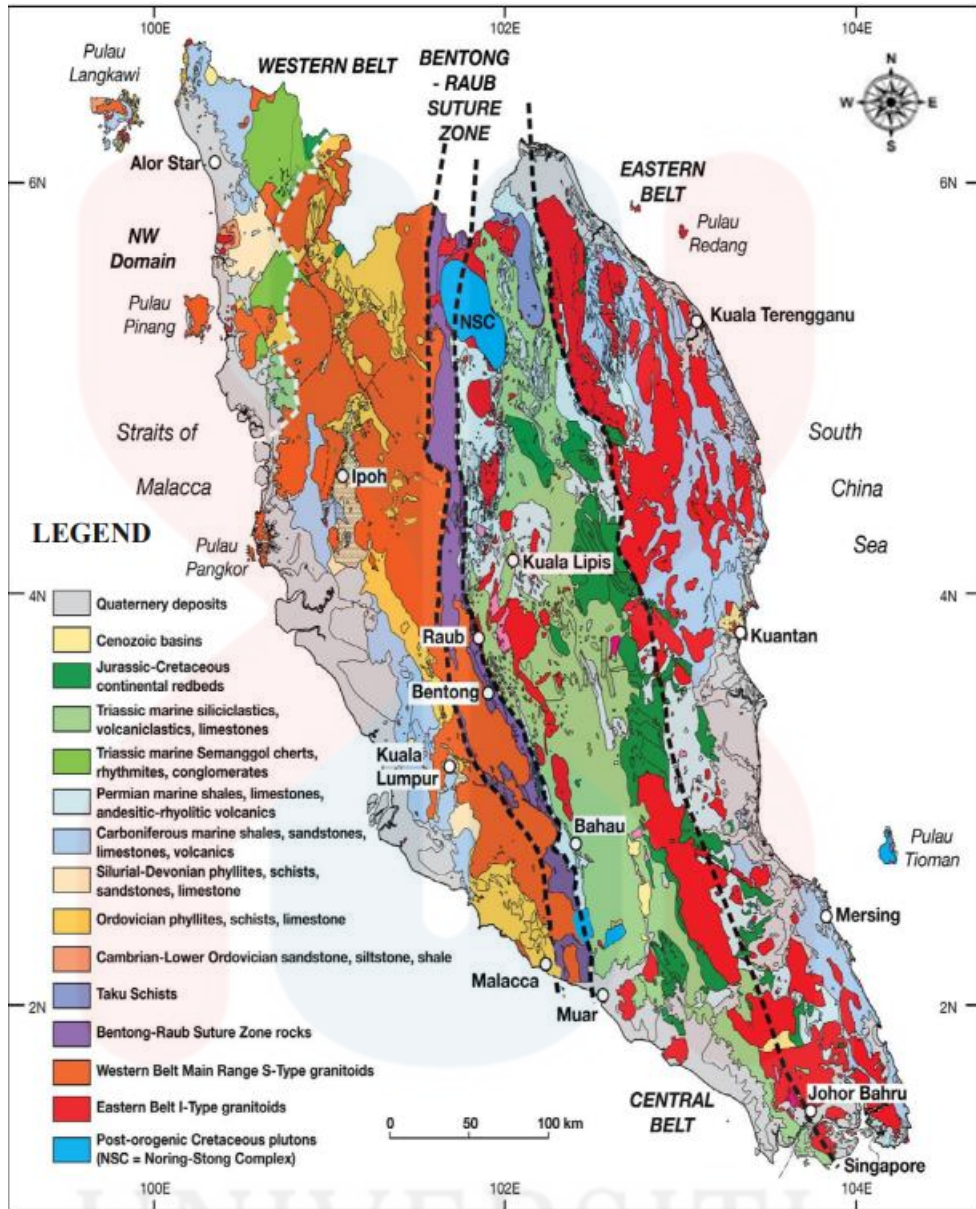


Figure 2.1 Simplified geological map of the Malay Peninsula, modified by (Metcalf, 2013)

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Focused on the research made by Hutchison (1978), 90% of the igneous compositions are made up of granitic bodies in Peninsular Malaysia. They are formed into extended belts from the coast of Thailand to Southern Malaysia. The belts are extended into the Western, Eastern and Mid-Range Province, separated by the Bentong-Raub Suture (Hutchinson & Taylor, 1978; Beckinsale, 1979; Cobbing et al., 1986). The Main Range Granite covers almost the whole of Peninsular Malaysia, and it has more silica content than the other Ranges. The two distinct types of granitic bodies in Peninsular Malaysia, S-Types, and I-type granite, were formed by tectonic collision and crystallization from meta igneous rocks. The Tertiary Tectonic Event, which formed Peninsular Malaysia, affected the granitic intrusion to crystallize from batholiths and secondary minerals such as K-Feldspar and biotite around 251-254 million years ago. The Main Range granite is primarily directed through the effects of an uplift process between tectonic plates and the orogenic granitic trends (De La Roche et al., 1980). Unconsolidated, sediments in alluvium, igneous extrusive rocks, sedimentary or meta-sedimentary rock, and granitic rock are the four types of rock that can found in Kelantan's geology (Nazaruddin et al., 2015).

2.3 Stratigraphy

Western zone, central zone, and eastern zone are the three zones that make up Peninsular Malaysia. The argillaceous, volcanic, calcareous, and arenaceous facies make up the central zone. According to Burton's 1970a system of stratigraphic nomenclature, the Baling Group is categorized into Kroh Formation, Grik Tuff and Papulut Quartzite. The geographic inspiration for this name came from the east Kedah town of Baling, which is located in the middle of the outcrop of this rock type at 5°40'35"N and 100°55'00"E. Based on the geological map of Northern Malaysia and Southern Thailand (Brown et al. 1951), several accumulation of this group were identified to specific stratigraphic units with respect to time which were believed to range in age from Cambrian to Jurassic. Further analysis shows that rocks associated with the Baling group are focused in southern Thailand more than in Malaysia (from Gerik to Kedah). It was discovered that this succession extends into the Grik region to the southeast and contains a significant volcanic and plutonic component. The Baling outcrop produces another intrusion into the Main Range granite batholith to the south, parallel to that of Grik, and is continuous eastward for about 50 kilometres from Baling, which defines as Kabut Granite. The Transect area's northern and southern regions are covered by the Kabut Granite/La Sa granite (Trgrkt/lS). The granite is in contact with the Kubang Pasu/Yaha Formation (Ckp/Yh), Merah/Budo Granite (Trgrmr/bd), Chantarat Granite (Trgrch), and Betong Formation in the northwest (SDBt). When in the southeast, it comes into contact with the Tiang schist and Merah/Budo Granite (Trgrmr/bd) (Cts).

2.4 Structural geology

Based on the research made by Wong (1974), the Main Range Granite intrudes suture zone rocks more extensively. Metasedimentary rocks in the West-Coast highway in Gerik have a higher grade of metamorphism in this south. The grade metamorphism ranges from upper greenschist to lower amphibolite facies. Mohd Raji (1990) also detailed the area by describing several different metamorphic facies such as muscovite-quartz schist and biotite-hornblende dominated gneiss biotite-hornblende schist. Moreover, he suggested that gold mineralization occurs in quartz veins within the muscovite quartz-schist. Biotite gneiss extends on the east of Kampung Batu Melintang; meanwhile, gneiss foliation derived from Kemahang Granite intrudes towards the Northern edge of Taku Schist. This occurrence is due to the argon outgassing during the Cretaceous tectonic event near the Peninsula of Malaysia. However, it is doubtful whether biotite gneiss has a bearing age of rocks originating from Bentong- Raub suture. Main Range Granites are more concentrated in the Potassium-Calcium alkali field (Hutchinson,1984).

2.5 Historical Geology

MacDonald (1953) suggested that there was a unconformity containing rock lenses such as schist and hornfels dominantly around the black limestone. In this location, Wong (1974) found a series of upper greenschist to lower amphibolite schist metamorphic grades, which are prevalent in the suture zone. Muscovite, biotite, andalusite, and garnet are found in the schists and gneiss rocks. The pelitic schist conforms lower to hornblende amphibolite. Tjia (1989a) and Tajul Anuar (1989) suggested the zone as the Transect area's expansion of the Bentong-Raub Suture Zone. In addition, muscovite-quartz schist, garnet-muscovite schist, sillimanite-muscovite schist, biotite-hornblende schist, hornblende-epidote schist, and biotite-hornblende gneiss were found by Mohd Raji (1990), who researched the geology of the Batu Melintang area in depth.

Based on the lithology and petrochemistry of the granite, Hutchison and Taylor (1978) postulated three geographical granite belts throughout the Malay peninsula. The I-type, magnetite-series granitoids that intruded the Palaeozoic host rocks throughout the Permo-Triassic era make up the majority of the Eastern belt granitoids. The S-type, ilmenite-series granitoids dominate the Main Range granitoids (in the centre belt area), with modest intrusions of I-type, magnetite-series granitoids. In the Permo- 13 Triassic period, they also encroached over Palaeozoic country rocks. On the Thai side, the western belt granitoids include both I-type magnetite series granitoids and S-type ilmenite series granitoids from the Cretaceous period. The Silurian-Devonian rocks were also dubbed the Ban to and Betong Formations by Muenlek et al. (1979). Recrystallised limestones to marble, quartzite, phyllite, phyllitic schist, and mica schist make up the former, whereas *Tentaculites elegans*, cherts, siliceous shales, metatuff, carbonaceous

shales, argillite, mudstones, sandstones, and bedded recrystallised limestones make up the latter.

2.6 Research Specification

This research focuses on the petrology of the Main Range Granite that extends from Central Belt of Malaysia, in terms of determining the mineral composition and characteristics of the granite assemblages in the area of interest. The research also emphasizes on the nomenclature of the identified rock samples based on International Union of Geological Sciences (IUGS) classification in order to determine the lithological rock unit of the area. Plus, the textural characteristics will also be studied in order to deduce the geological processes that occur which contributes to the accumulation of the Main Range Granite around the Titiwangsa area. The granitic rocks will also be investigated in terms of its geochemistry to predict the other assemblages around the area.

The core methods used in the research are basically by determining the petrographical characteristics of the mineral in the thin section of the rock sample obtained. This method is significant because the mineral characteristic of the thin section determines the geological processes and the type of granite characterization in the area of interest itself. Previous research made by the MT-JGSC committee at 2012 which focuses solely on the traversing and observing point did not cover fully on the study area that they previously intended. This causes the study area of interest not fully explored geologically hence this core method is vital for a further detailed approach.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

The methods of the study have been executed in several different procedures in order to obtain the data systematically according to the research flowchart. Methods and materials are important to extract the geological information that can be obtained in a more precise and specific way.

The method of this study was executed in several different steps, which includes preliminary study, fieldwork research, data collection and petrographically analysis. Preliminary research was done to obtain the lithology of the study area, and fieldwork traversing, and mapping were done throughout the Gerik-Jeli highway. The significance of the method used was to locate the type of lithology rock units in several different locations along the highway route and to determine the nature of the type of rocks embedded in outcrops throughout the area of interest. The outcrops were remarked on their texture, colour, structural analogy, and foliation. The dip and strike measurements were obtained from those outcrops discovered to obtain the lithology and the extension of the rock minerals throughout the area. Rock samples were taken from the outcrop for further petrographically analysis.

3.2 Materials/ Equipment

There are many materials that been used during the excavation of the study area. These materials will be used in order to obtain geological data and also to assist in locating outcrops and the lithology of the area of interest. Rock samples will be split and broken using a geological hammer. The Brunton compass is used in geological mapping to obtain strike and dip, fold, hinge line, axial trace data, azimuth, North declination and detailed measuring of geological objects. Moreover, a GPS (Geographic Positioning System) is a satellite-based navigation system that consists of three fundamental components: a satellite in orbit, monitoring stations on Earth, and GPS receivers. Some GPS systems need altitude calculations in addition to providing latitude and longitude data. The GPS was used to obtain the coordinates of the outcrop and the location of the study area as well. It also tracks the traversing of the study area by tracking the coverage area after traversing.

Plus, hand lens is a crucial piece of equipment to use while identifying minerals on a unidentified rock out in the open. This is to ensure that the minerals are carefully analysed on a rock sample before categorizing the rock samples by its nomenclature. Adding on to the context, the composition of the rock's minerals can be identified even further before even sending it into lab for a detailed petrographical analysis. Then, dolomite and limestone, the most prevalent carbonate rocks, are distinguished from calcite and chlorite by observing how the rock reacts to hydrochloric acid (HCL). Only limestone reacts to hydrochloric acid by producing a fizz sound as it is made up of calcite. Sixth, a measuring tape is necessary for accurate measurements of structures and lithologies. This is to identify the thickness of the structures and the bedding layer of lithologies.

Plastic sample is also used during fieldwork traversing. The function of this material is storing a rock sample in order to keep the rock safely and it can be analysed by sampling it into thin sections in laboratory. The plastic sample should be named with several aspects during the traversing itself which includes the name of the one who took the rock sample, date of the rock sample taken, locality of the sample taken, coordinates of the outcrop and the rock type based on observation itself.

The table below shows the list of materials, equipment and software used throughout the research in order to obtain primary and secondary data.

TABLE 3.1: List of materials, equipment and software used in this research

MATERIALS	
Geological Hammer	A hammer used to obtain rock samples from an outcrop
Global Positioning System (GPS)	A tool used to provide positional and tracking data of a locality in the study area.
Compass	To navigate, obtain strike, dip, declination, azimuth, fault, fold, hinge lines and orientation data in a locality.
0.1M hydrochloric acid	Used as an indicator to detect any carbonate presence. Typically used to differentiate limestone rock with others.
Magnification Lenses (x10)	Used to examine the mineral texture of the rock and the overall mineral composition in order to identify the name of the rock by observation.
Equipment	
Petrographic Microscope	To analyse thin sections of rock samples prepared in order to identify the characteristics of the minerals in the rock sample itself.
Software	
ArcGIS 10.8	To manage geospatial data with the help of satellite imagery and to combine all the data obtained into a geological map.
Georose	This software is used to plot stereonet and rose diagram data obtained from the strike and dip measurement taken from the localities.

3.3 Methods

3.3.1 Preliminary Study

This research initiated since March 2022 and the study area can be identified and supported by several references such as journals, books, papers, and previous thesis. These resources helped to fill in some basic knowledge on the research in order before conducting the fieldwork study as it exposes the geological aspects of the study area to the individual.

For instance, a base map derived from Google Earth and ArcGIS software was created and investigated about the characteristics of the study area in terms of geology and petrography before traversing into the study area. Based on this method, the genesis of a lithology can be identified by determining its line characteristics of the contour lines and the fault and fold presence as well. Moreover, literature review is essential in order to obtain the known data taken by previous researchers so that new data can be identified and published in this research. Previous researchers have concluded the study area generally and this might help to boost the data collection during traversing later on. Furthermore, the formation that intrudes the study area can be identified from previous hypothesis of researchers around the study area itself. Sources of the journals and previous thesis was used from the database of University of Kelantan Malaysia (UMK) and Google Scholar.

3.3.2 Field Studies

One of the methods used to finish this research is geological mapping by traversing. Geological mapping is a method of observing the environment that includes information on the sample's lithology and morphology. The lithology of the area can be precisely identified by observing the outcrops around the study area and determining the characteristics of the Granite Range around the location of interest. Geomorphology is also vital during traversing as it helps to identify the major landforms that occur in the study area. Drawings and sketches can be done in order to have a bigger picture on the characteristics of the major landform. Faults, folds, and major geological characteristics can also be identified by those drawing itself.

For any structural analysis, data gathering will be measured. In general, bedding, foliation, linear characteristics, cleavage, and fold will be used to record and observe structure and structural history. For outcrop analysis, strike and dip will be employed. The direction of a line on an orientation horizontal plane intersecting with an incline rock bed is known as strike. The dip is the angle formed between the horizontal plane and the sloped bed, which is perpendicular to the strike line. Furthermore, data can be acquired by structure investigations, specimen collecting, and mapping images.

3.3.3 Laboratory and Petrography Analysis

Laboratory analysis will be executed through thin section preparation and the categorization of hand specimens obtained from the outcrop around the area of interest. After the rock sample obtained from the outcrop of the area, the rock sample will be identified and categorized based on its physical characteristics such as colour, texture, grain size and hardness.

After investigating the physical characteristics of the hand specimen, the specimen is then analysed in more detail in a laboratory by slicing the hand specimens into thin sections. After obtaining several thin sections from the hand specimens, the thin sections are then observed in a light microscope to observe the mineral composition of the rocks and the rocks will be classified according to the rock nomenclature by IUGS igneous classification diagrams. The evidence obtained would be in terms of identifying the rock's mineral composition and observing the characteristics of the mineral in the thin section. This could help to identify the geological history that occur based on the characteristics of the minerals alone and indirectly identify the granitic contents that originate from the Main Range Granite characterization.

According to their manner of occurrence, texture, mineralogy, chemical composition, and geometry of the igneous frame, the granitic based rocks are classified. Important details can be learnt about the circumstances surrounding their formation from the types of different igneous rocks. The mineral makeup of the rock and particle length, which is heavily influenced by cooling records, are two key factors used to define the category of igneous rocks. Almost all igneous rocks are formed from feldspars, quartz or feldspathoids, olivine, pyroxenes,

amphiboles, and micas, which are all crucial minerals in the production of these rocks.

S-I-A-M classification is the classification made by Chappel and White (1980) to identify the granitic embodiment of the granitic rocks by their mineral composition. The classification table can be done by determining the type of granite initially. The I-type granitoids are hornblende-rich rocks that are either mildly peraluminous or meta luminous. Chemical analysis indicates that they are the result of partial melting of mafic mantle-derived igneous source material; this source material is likely sub-crustal underplated lithospheric, while earlier high-level plutons or subducted crust cannot be completely ruled out. In contrast to the granitoids described above, the S-type granitoids are invariably peraluminous. The biotite content of the rocks is high, and cordierite is usually present. They could also contain garnet, sillimanite, muscovite, andalusite. According to the chemical makeup, they were created by the partial melting of sedimentary source rocks that were peraluminous and had been weathered at the Earth's surface (S. Iwan, 2017).

3.3.4 Data Processing

The data processes had been done by two different methods, one through the Arc-GIS based platform and the laboratory work analysis. As data such as strike, dip and lithology have been taken, the data will be then processed in the ArcGIS platform for further analysis with satellite imaging and overall approach on the study area. Moreover, the data obtained would be joined together with the base map to obtain a complete geological map of the study area. ArcGIS software also can be used in order to extract geospatial information from the study area based on the data obtained from the observation by the traversing method itself.

Rock sample data will be processed in the laboratory to obtain a petrographical approach on the study area as well. As the rock is broken into slices around the desired area to be made into a thin sample, approximately 15cm in size. Next, the rock slice is cleansed using dry coarse silicon carbide fed on a wet lap on a rotating cast-iron lathe until one side has a smooth surface free of organic residue. Using a fine silicon carbide, grinding is continued on the rock sample to create a smooth surface on a fine grinding lap after thoroughly cleaning the rock slice. It is imperative that the final surface be exactly flat, and the easiest way to do this is to grasp the rock slice with the thumb while applying equal pressure to each of the rock slice's corners. This produces an even grind on the rock slice and tends to use more silicon carbide before the action throws it out of the lap. The type of rock being crushed determines how much pressure and silicon carbide are utilised during this form of grinding on both the coarse and fine grinding laps.

During the cutting and grinding process, many changed and friable rocks will crumble, therefore such specimens need to be handled carefully. Allowing the rock samples to soak in a 90 percent xylene solution for a day is an efficient way to cement such items. The cover glass can then be mounted to the thin part. A cover glass is delicately pushed into place with the rubber end of a pencil after one drop of mounting balsam has been placed on the centre of the rock slice from the end of a glass stirring rod. If any bubbles form between the rock slice and the cover glass, they may often be eliminated by applying pressure with the pencil's rubber end close to the bubbles and moving the bubbles outward. If this approach fails to get rid of the bubbles, slide the cover glass away from the glass slide.

3.3.5 Data Analysis and Interpretation

The data then would be analysed into two different ways, which are geological analysis and petrographical analysis. Geological analysis is by determining the structural aspects, stereo net analysis and many more in order to investigate the tectonic processes that occur in the study area. This analysis could help in order to identify the origin of the embedded mineral in the rocks itself.

Petrographical analysis is to identify the mineral compositions of the rock and to categorize their distinct characteristics from a thin section analysis. The rock would be also investigated in order to find its rock category based on the IUGS nomenclature of a rock. When studied more closely, a thin section viewed under a microscope could reveal an almost infinite number of details, including grains with varying sizes, overgrowths on those grains, overgrowths of different clays, each with varying designs and habits, pore areas between the grains, pores that were partially crammed, grains that were partially dissolved, etc. The majority of the information will be of interest to one or more of the expert geoscientists responsible for establishing an early exploratory evaluation of an opportunity, developing a good potential, or utilising a field that is already recognised.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter will discuss and analyse about the aspect of geology of the area of interest in Titiwangsa Rest Stop located along the Gerik-Jeli highway in Gerik, Perak. Geological mapping method was used and executed in order to observe and identify the lithology, structural geology, economic development, drainage patterns, and geomorphic perspectives throughout the area. The data which contributes to the rock unit of the area, the characteristics of the landscapes, the geological structures that forms on the outcrop, and weathering intensity of the outcrop were observed and recorded for further analysis and finally used to produce different types of geological maps. On the other hand, the data on the certain area of the study area could not be obtained due to the limitations of the outcrops and the high risk of accessibility of the area of interest as the area is surrounded by dense forest in proportion to the forest reserve area that has been permitted by the government.

The parts of the chapter include the preliminary desk study analysis of geological mapping pre-conducting the fieldwork. The early analysis has been done regarding on the interpretation of the topographic map of the study area such as linear intervals formed on the topographic map. These intervals found in the topographic map were interpreted as geologic structures, lineaments, and the types of lithology. On the other hand, due to the hard accessibility towards the study area, further evaluation was done based on satellite imaging and a comparison on the previous literature review. Next, this chapter also encompasses about the observation made on the geomorphological context of the area. Furthermore, geomorphology is considered as an essential feature in acknowledging the characteristics of the earth surfaces in conjunction with time and space evolution due to biological and physiochemical factors (Perillo, 1995).

Moreover, the type of lithology can be extracted based on the characteristics of the landscapes according to its weather-resistant factor. This section will be further analysed by the mineral content within the rocks and petro-genesis of the rock as well. The QAP classification of the rock gives a much-detailed analyses of the type of granite formed from the Main Range Granite. Structural geology can be discussed by the type of discontinuities in major or minor form such as foliation, joints, lineaments, faults and many more. Finally, the data collected will be further gathered and its used to compare and contrast with the historical geology, which is the continuance formation of the study area based on previous researchers.

4.2 Geomorphology

Geomorphology is the study based on the characteristics of the landform and the processes that relates to them. It also concerns on the endogenic and exogenic process that makes up those landforms. Endogenic process is process that occurs beneath the Earth's surface which brings to subprocesses such as convection, magmatism, volcanism and epeirogeny. Exogenic process is a type of process that occurs on the surface of the Earth which relates to subprocesses such as weathering, exfoliation, frost wedging, deposition, and transportation. The difference between endogenic and exogenic processes is that endogenic process includes large-scale landforms that builds and transforms related processes that creates relief meanwhile exogenous process (gradational process) that modify relief. The type of landforms that can be discovered in this area are mainly hills and river areas.

Based on the area of interest, the topography, drainage system and weathering processes area the essential subgroup that can be deduced in a geomorphological perspective. Based on the theory made by Van Zuidam (1985), the geomorphological map can be observed by categorizing the landforms onto describing the characteristics of relief and the morphogenesis (origin) process that occurred throughout the landforms in the area.

4.2.2 Geomorphology classification

Geomorphological analysis of the study area is done by in-situ observations and terrain analysis. On the upper hand, geomorphological study had been done by predicting the outcomes based on the contour intervals on the topographic map of the study area. These observations operate to identify the elements of landforms with the process relating to them. The method used to indicate the geomorphological classification of the area during the field study is photographing and eye observation. The landforms are categorized into four main groups, mainly steep mountains, steep hills, sloping hills and slightly sloping plain. The highest elevation peak of the hillsides is 1200m and the lowest is 550m. The majority of the study area are mountainous area, which is highly orogenic towards the northwest section, ranging from 1000-1200m. The type of landforms that can be vastly found are steep hills ranging from 850-1000m.

a) Topography

Topography can be derived from the contour lines from the topographic maps, landform characteristics, relief types and the contour intervals from each landform. As mentioned, the topography of the study area includes a scale of 1:25,000 and a surface area of 25km^2 with a contour interval of 50 metres. The topography depends on mainly the river networks and the hilly areas of the area of interest. The altitude values of the contour intervals brings a indistinguishable relationship with the morphology of the hills located in the study area as shown in the table below.

ABSOLUTE ALTITUDE (METRES)	Morphology/ Relief
Slightly Sloping Plain	>500
Sloping Hills	500-850
Steep Hills	850-1000
Steep Mountains	1000-1200

Table 4.1: The equivalent relationship between the morphological characteristics and the absolute altitude of the Titiwangsa Rest Stop located in the East-West Highway in Gerik, Perak.

In a nutshell, the landform characteristics brings the statement that the landforms have a distinguish hilly area ranging from 500-1200m. This indicates that the landforms are a result from a high tectonic uplift and orogenesis. Hills on research area generally covered with thick and dense forest acknowledging the fact that the area is surrounded with a forest reserve. The river landform is due to the recharge area from those high and steep hills towards a lower lying plain.

Moreover, the high tectonic ridges which are mostly concentrated on the northwest side of the study area are made up of strong and highly weather resistant rock units. This can be proved further based on the high slope and steep elevation values based on Table 4.1. Therefore, the valleys that trends towards northwest can be seen distinctly. The mountain ridges at the northwest region of the study area were believed to be produced because of high orogenic processes whereby the uplift of rock happened due to compressive forces from tectonic activity that occurs on the region, forming those mountain ridges as mentioned. As most of the rocks in the study area originates from the Main Range Granite, the rocks are composed mainly of plutonic rocks. Hence, intrusion of acid intrusive rocks could be also another factor which forms high and steep mountain ridges throughout the north-western side of the region.



Figure 4.1: The hills of the study area ($5^{\circ} 35'3''N$, $101^{\circ}34'58''E$)

KELANTAN



Figure 4.2: The high elevated steep and high mountains in Titiwangsa Rest Stop ($5^{\circ} 36' 22''\text{N}$ $101^{\circ} 32' 33''\text{E}$)



Figure 4.3: Steep hills nearby the Titiwangsa Rest Stop in Gerik, Perak ($5^{\circ} 35' 52''\text{N}$ $101^{\circ} 30' 45''\text{E}$)

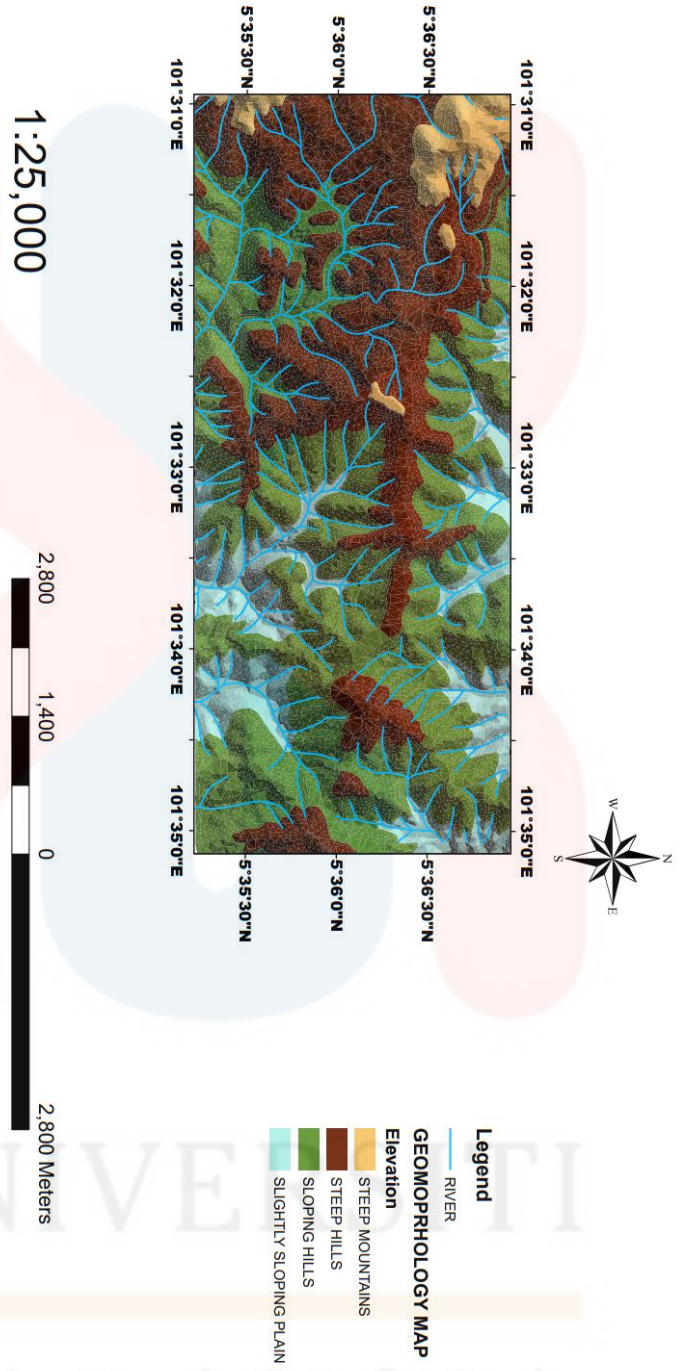


Figure 4.4 : The geomorphological map of the study area

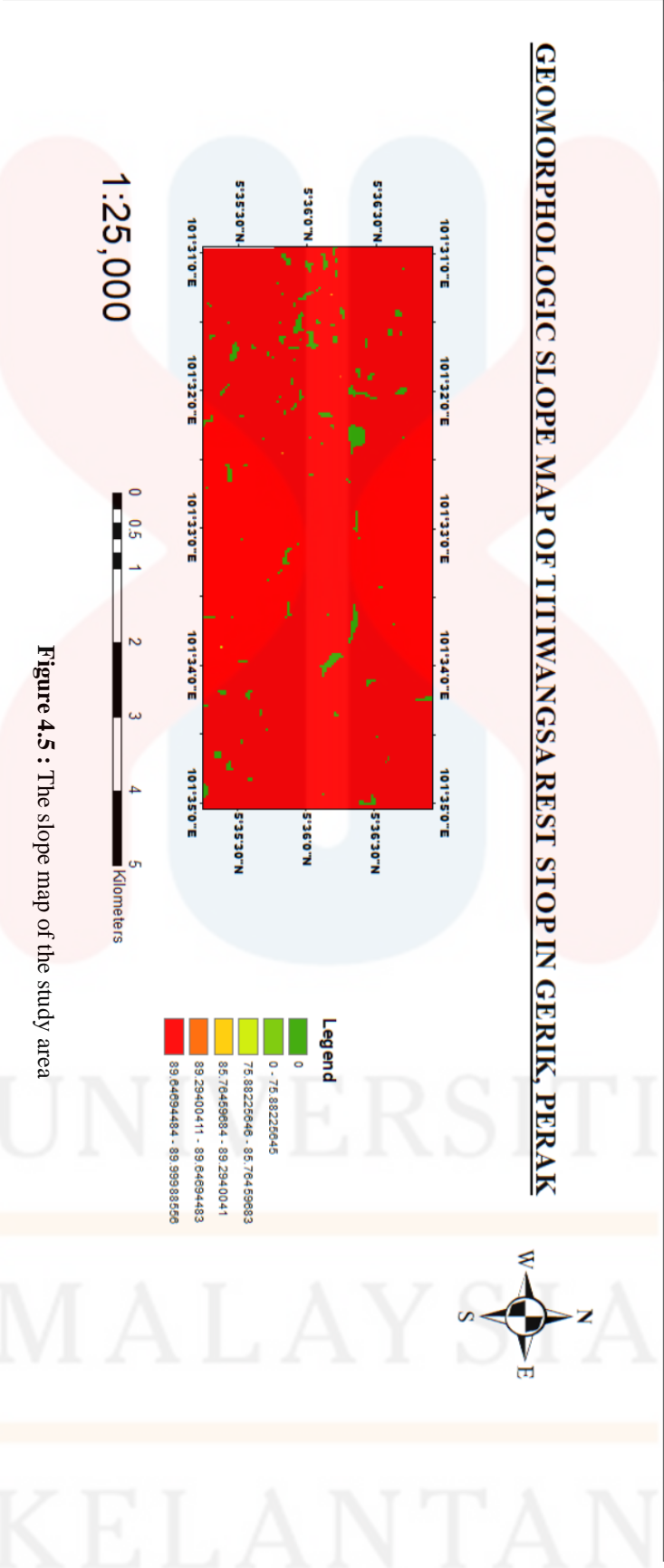


Figure 4.5 : The slope map of the study area

4.2.3 Weathering

The weathering aspects in Malaysia is mainly due to several factors; Malaysia is situated at the equatorial line on the Earth's surface, tropical weathers, and climate changes. These mentioned seasons would bring a humid environment in the country which could accelerate exogenic processes of the rock in Malaysia.

Physical weathering is the main factor that contributes to the weathering rate in the study area. The possible physical weathering agents that could contribute to the types of weathering processes includes water, wind, and heat. Weathering agents mentioned could be main factors of mechanical disintegration and chemical decomposition which physically alters the strength and hardness of the rock.

Generally, most of the outcrops that can be found in the Titiwangsa-Rest stop are moderately weathered. The minerals embedded in the rock can be seen with a naked eye along with some signs of rock disintegration within the rock sample itself. However, several major fractures and cracks can be seen in outcrops which shows signs of mechanical disintegration. These cracks indicate the rapid expansion and cooling from temperature changes throughout the area.

The rate of weathering in general occurs more rapidly compared to other areas based on observation because the region has a higher elevation which makes the outcrops are more susceptible towards the weathering agents. The weathered colours of the rocks are mostly in the range of dark brown to dark grey, indicating that the weathering grade of the outcrop's ranges from Grade 2 to Grade 3. Discontinuity aspects also can be observed in the outcrops in general basis. Discontinuities such as joints, fissures, foliations, fractures, and minor faults can be seen in outcrops throughout the region.

4.2.4 Drainage

Drainage system is defined by the patterns formed by rivers originating from high elevated hills and mountains, forming a network-like systems of different river patterns. These network-like streams would flow along weak zones of rock structure. The weak zones of rock structures include the parts of rocks which can be easily eroded. The drainage patterns shows and exposes the original slope mechanism of the rock unit that has been intruded or uplift as the streams originated from the recharge area of water in the highest elevation flows along the slope of the study area (Zhang & Guilbert, 2012).

Based on the drainage map of the study area, the drainage pattern is dominated by parallel and dendritic streams. Moreover, almost 75% of the river streams are dominated by the dendritic and parallel streams, especially in the low lying landform areas such as sloping and steep hills. Mainly on the edges of the study area, several radial river streams can be observed especially in high elevated areas.

Dendritic drainage patterns in the study area defines as the uniform bedrock for unconsolidated materials such as granite, gneiss, and other volcanic rocks. To add on, dendritic patterns will flow in an area where bedrock has an proportionate amount of resistance towards erosion, moderate velocity and free from geology structures such as faults and folds which alters the drainage pattern of a stream. So, with the presence of dominant dendritic stream patterns around the study area, it can be concluded that the rock unit of the bedrock surrounding the region is more weathering-resistant rocks. This gives a clear indication that the rock that allows a uniform bedrock in order for stream patterns to flow could be acid intrusive.

The parallel drainage patterns located mostly towards the south of the area of interest indicates the presence of geological structures such as faults and folds. Geological structures could alter and be a basis for orogenesis formation of mountain ridges around the study area. Parallel also forms in steep slope which also could indicates rock subjected to high heat and pressure, mainly metamorphic and volcanic rocks. This is because that the metamorphic rocks can be exposed to the surface of the earth due to the mentioned geological structures.

Radial pattern is defined as the direction of river moving outwards along the slope direction from a high point of elevation from a steep mountain. Radial pattern is also known as a recharge unit as water will be collected at the highest point of the hill by rainfalls. Radial patterns also develops on isolated cones or dome-like structure on landforms. This dome-like structure occurred mainly due to high tectonic activity and regional uplift. Due to tectonic activity, volcanic rocks are often exposed in the area which contains radial stream movement due to intrusive nature beneath the Earth surface. The radial pattern is also the basis structure for other river streams network in general. Three distinct radial patterns can be seen based on the drainage pattern map; located on the north western region, north eastern region and the south western region of the study area.

DRAINAGE MAP OF TITWANGSA REST STOP IN GERIK, PERAK

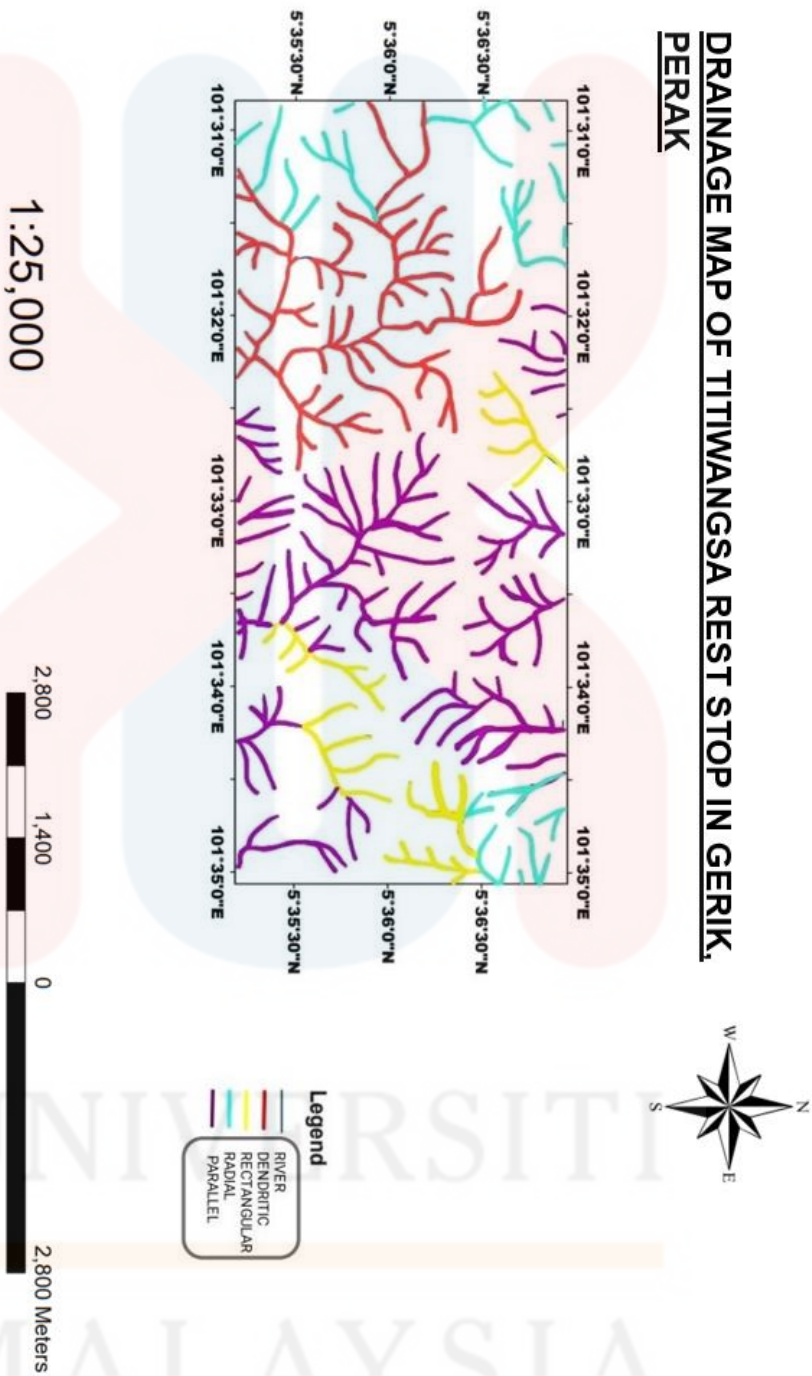


Figure 4.6 : The drainage pattern of the study area.

4.3 Lithostratigraphy

Based on the content of the geological map, the lithology of the study area mainly comprises of schist and granitic acid intrusive. This granite can be categorized as Kabut Granite originating from the Main Range Granite and Tiang Schist originating from Tiang formation. The Kabut Granite of the area contains a specific feature of porphyry involving alkali feldspar and has larger grain size which can be visibly seen. The rock samples which were collected on the field were observed and will be described in macroscopic and microscopic terms. This section involves the description of the granitic embodiment and also the schist rock samples based on its texture, composition and also the grain size of the rock itself.

LITHOLOGY	UNIT	DESCRIPTION	PERIOD	ERA
	SANDSTONE	Mainly compromises of siltstone and shale. A product of Kubang Pasu formation	CRETACEOUS-JURASSIC	MESOZOIC
	GRANITE	Unit contains dominant biotite porphyry, contact with Kubang Pasu formation and Betong formation	TRIASSIC	MESOZOIC
	SCHIST	Product of high tectonic activity and pre- collisional rocks	CARBONIFEROUS	PALEOZOIC

Table 4.2: The explanation and categorization of rock units according to its distribution in the geologic map of Titiwangsa Rest Stop in Gerik, Perak as shown.

4.3.2 Macroscopic View

a) Outcrop 1

Based on the rock samples obtained from the outcrop, the greyish coloured rock is coarser in texture and the grain size of the rock are large; approximately 2mm-4mm in length. The rock also shows a porphyry characteristic whereby biotite minerals act as a phenocryst in the rock sample. This is because that the rock sample shows biotite mineral which acts as a coarse-grain crystal embedded into a finer grained silicate-rich groundmass. The rock sample also shows dominant minerals such as quartz, feldspar, mica and biotite in the naked eye. Quartz can be seen in a clear and translucent colour, plagioclase is white in colour, biotite which shows a black colour in nature and mica which shows a reflective crystal in nature. The rock outcrop itself has been moderately weathered and the parts that exhibit this feature are mainly dark brown to blackish in colour. The rock sample obtained exhibits the weathered parts of the rock outcrop. The colour is mainly yellowish particularly from plagioclase minerals which can be observed in the rock sample.

Hence, based on the overall observation, this rock can be classified as an igneous volcanic intrusive rock, namely biotite-granite porphyry. Major minerals that were identified under polarized microscope are quartz, alkaline feldspar, plagioclase, and biotite. Texture of the rock can be categorized in crystallinity, fabric, and granularity terms. The outcrop is composed of holocrystalline structures as it is made up of wholly crystalline particles in the mineral composition itself. Rock granularity of the outcrop and hand samples are big and coarser in nature as the majority of the rock crystals are approximately 5mm or more in length. Alkali feldspar phenocrysts can be seen in finer groundmass of the rock nature as it tends to have a larger diameter

compared to the other crystals in the rock. Hence, this rock can be classified as porphyritic in terms of its fabric texture.



Figure 4.6: The outcrop that has been found along the East-West Highway nearby the Titiwangsa Rest Stop in Gerik, Perak (Location = $5^{\circ} 35' 48''\text{N}$, $101^{\circ} 30' 5''\text{E}$)

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Figure 4.7: The rock sample obtained from the outcrop shown above.

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Figure 4.9: The grain size of the rock sample by observation based on the naked eye during field mapping in the study. The grain size can be clearly seen and coarse in nature

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b) Outcrop 2

The second location of the outcrop is located in $05^{\circ} 36' 22''\text{N}$, $102^{\circ} 32' 33''\text{E}$, which is the opposite of the Titiwangsa Rest Stop in Gerik, Perak with a slightly higher elevation of 1060m. The orientation of the outcrop is 185°S . The size of the outcrop is approximately six metres in height and 70 metres in length. The rock units include a mica-schist unit based on the IUGS classification as the mineral orientation of the platy minerals are parallel to one another and the abundance of minerals in the rock.

Based on the rock sample obtained from the rock outcrops, the grains of the rock sample can be clearly seen which includes minerals such as biotite, muscovite, quartz, feldspar and some alteration of chloride. The biotite minerals are almost aligned into a foliation which depicts that the outcrop of the surrounding area is a transition between schist and subjected gneiss. The fresh sample of the rock sample is dark grey in colour meanwhile the weathered sample is blackish in colour. There is a presence of quartz dyke interlaying the biotite minerals and there is a presence of deformation in the outcrop of the rock itself.

Moving on to the analysis of the thin section, the types of minerals composition that can be seen includes muscovite, albite, biotite, alkali feldspars and quartz. Muscovite in this sections appears to be pinkish-orange in colour and they appear to have a low relief. Muscovite also has a high birefringence, and they tend to have flakes with 1 perfect cleavage. They appear to have a clear resemblance under Plane Polarized Light (PPL) with a perfect cleavage.

Albite, which is a representation of plagioclase appears to be in a low birefringence and this mineral has a colour range from black to white. This mineral also has a low relief as there is a lesser refractive index emitted on this mineral. Carlsbad twinning exists in this mineral which differentiates from the other mineral composition as twinning of plagioclase is common in the composition of an igneous rock. Perthite also can be seen in the feldspar replacing the original plagioclase mineral. This occurrence exists as an intergrowth state among albite mineral due to unmixing from crystallization.

Biotite also can be seen in this thin section, ranging around green to brown. The biotite in this thin section emits a high pleochroism and a moderate relief. The birefringence is high and most of the minerals are masked by the deep colour of the mineral itself. Biotite exhibits a perfect mica cleavage and it appears darker in the North-South direction. Minor chlorite alteration can be seen indicating a propylitic alteration in this rock mass. This indicates that hydrothermal alteration occurs commonly in this rock outcrop.

Alkali feldspars also can be detected in the thin section as well. Sanidine, which is a type of alkali feldspars has a low relief and birefringence. This mineral also has a low and pale grey in colour throughout the thin sections. The extinction of the alkali feldspars are parallel to the cleavages as well. Alkali feldspars also shows a Carlsbad twinning and there are some minor perthite alterations as well. Several inclusions also can be seen in the majority of sanidine as well.

Muscovite is another noticeable mineral in this section. It has a low relief and has no extinction at all. The birefringence is high and distinctive. There is a perfect cleavage that can be seen along with the orientation of the mineral. The colour of the minerals are also in the second order which ranges from pinkish to greenish in colour.



Figure 4.11 : Figure 5. shows Outcrop 1 located in $05^{\circ} 36' 22''$ N, $102^{\circ} 32' 33''$ E with the elevation of 1060 metres in Titiwangsa Area, Gerik, Perak.

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Figure 4.12 : The intrusion of quartz from Outcrop 2, ranging around 8-10cm, in between outcrop lines.

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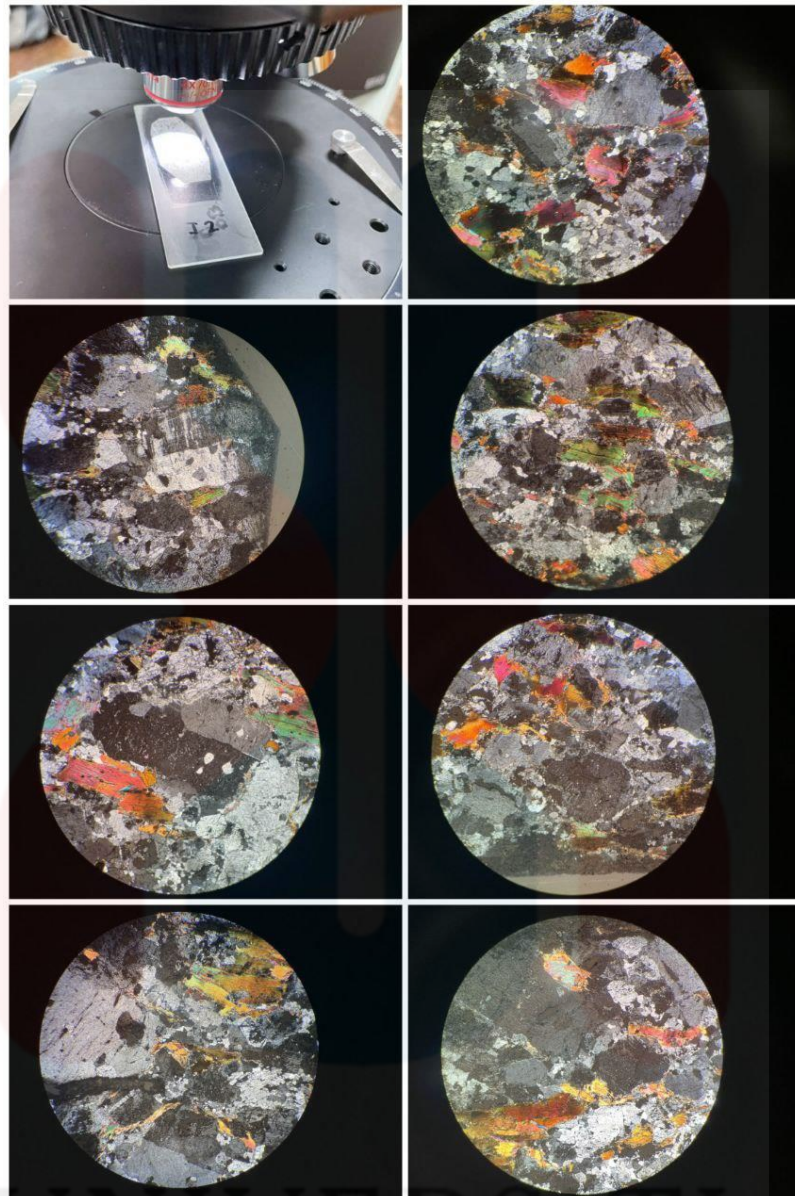


Figure 4.13 : The thin section from the outcrop labelled J2 contains several presences of muscovite and characteristics such as inclusions and exsolution (perthite) can be seen in the alkali feldspar phenocryst. Sample J2 exhibits twinning with phenocryst characteristics. Sample J2 also has Albite Twinning seeping besides the presence of biotite and muscovite.

c) Outcrop 3

The location coordinates of this outcrop is around $05^{\circ} 36' 3''\text{N}$, $102^{\circ} 34' 59''\text{E}$, which is the slightly further from the Titiwangsa Rest Stop in Gerik, Perak with a slightly lower elevation of 920 metres. The orientation of the outcrop is 62°NE . The size of the exposed outcrop is approximately five metres in height and 50 metres in length. The rock units include a highly foliated schist which can be derived as gneiss unit based on the IUGS classification as the grains of the rock matrix are visible by observation and there are alternating bands of light and dark minerals aligning (foliation) with a lesser amount of schistosity. The outcrop is also coarser in nature and contains minerals such as quartz, mica and feldspar. Quartz can be seen as a translucent mineral; mica contains a reflective structure meanwhile feldspar has a glassy lustre embedded in the rock. Quartz veins can be seen intruding and recrystallizing along the rock units in the outcrop. This is due to the intrusion of magma from the mantle due to the tectonic collision as mentioned in Chapter 2. This proves a regional metamorphism process to be an origin of the outcrop as well. The vein from the outcrops extends in a diameter of 2.5-3.5 cm wide towards the outcrop and the grains are greyish in colour. Distinct discontinuities of the outcrop include minor faults and slickensides.

Based on the microscopic thin section, the minerals that can be seen in the is quartz, mica and feldspar and several opaque minerals. Quartz can be seen with a white to cream birefringence and has a low relief. The quartz appears in isotropic shapes due to intense pressure and temperature from the subsurface of the Earth. The quartz appears clear in nature, and it shows a strained extinction. Moreover, most of the thin sections shows an irregular shape which shows an igneous trait. This is because that the crystallization in the rock is slower in certain areas. Quartz, feldspar and many

other minerals are aligned in a linear arrangement which forms the white bands of the rock samples. Anorthite shows a milky and cream colour with several twinning characteristics such as Carlsbad twinning together with a low relief.



Figure 4.13 : Outcrop 3 located in $05^{\circ} 36' 3''\text{N}$, $102^{\circ} 34' 59''\text{E}$ in the Titiwangsa area, Gerik, Perak.

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Figure 4.14: The rock sample obtained from Outcrop 3 in the Titiwangsa Area in Gerik, Perak

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Figure 4.15 : Quartz intruding the gneiss rock unit as mentioned in outcrop 3

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Figure 4.16 : The presence of aplite in the outcrop sample intruding from the Southwest to Southeast direction

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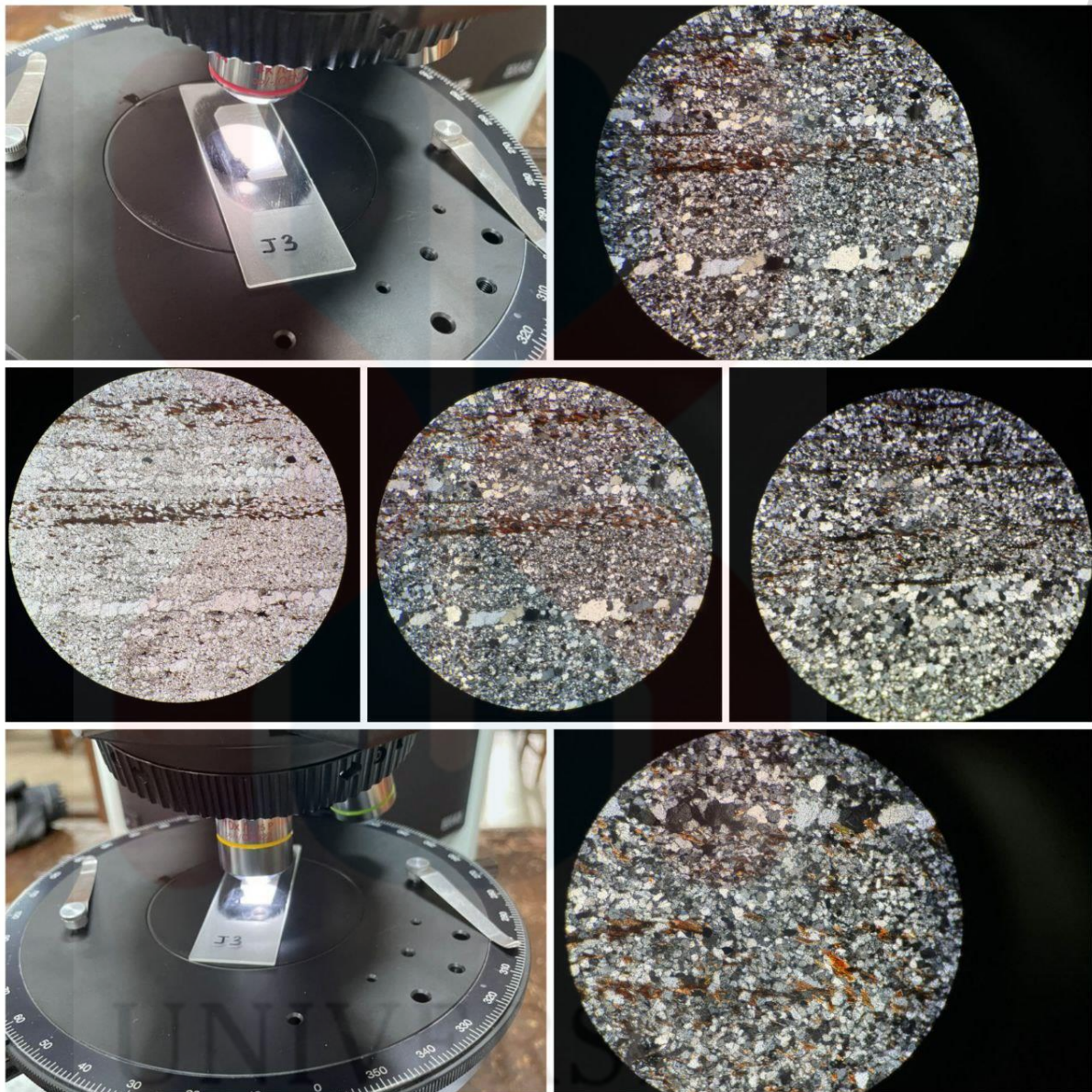


Figure 4.17 : Thin sections labelled J3 which has mineral compositions such as quartz, anorthite, sanidine and certain alterations to weathering. Felsic minerals such as quartz and feldspar aligns in a linear texture to show light bands subsequent to the dark bands (foliation) on the rock sample.

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4.4 Structural Geology

The study of the geological structures was initiated with the deduction of the linear structures from the topography map. Geologic linear structures such as the lineament and faults are present in the topographical map. Lineaments are defined as the weak zones or landforms formed by tectonic activity such as ridges and valleys. They expose the types of rock structure and the zone of weaknesses in a rock. The structural map shown a handful of lineament concentrations that were trending highly to northwest. These lineaments were detected by analysing the weak zones of the mountainous ridges with the aid of contour lines. The lineaments can be hypothesized as fracture zones granitic embodiment in the study area were fractured open by the uplifting of magmatic intrusion. High tectonic activity especially towards the north-western side of the study area exposes more weak zones and high steep slopes of the granitoid itself. The mountainous ranges which is a by-product of the mentioned process forms the Main Range Granite. Hence, landscapes of mountainous ridges with steep valley forms vastly with a high elevation in the study area.

The geological structures that can only be observed at the study were joints, fractures, veins, and faults. Two major faults can be indicated in the study area as there is a displacement between two different terranes as shown in the hill shade map shown. During field mapping, joints data was taken from each outcrop in order to analyse the orientation of the rock units in the study area.

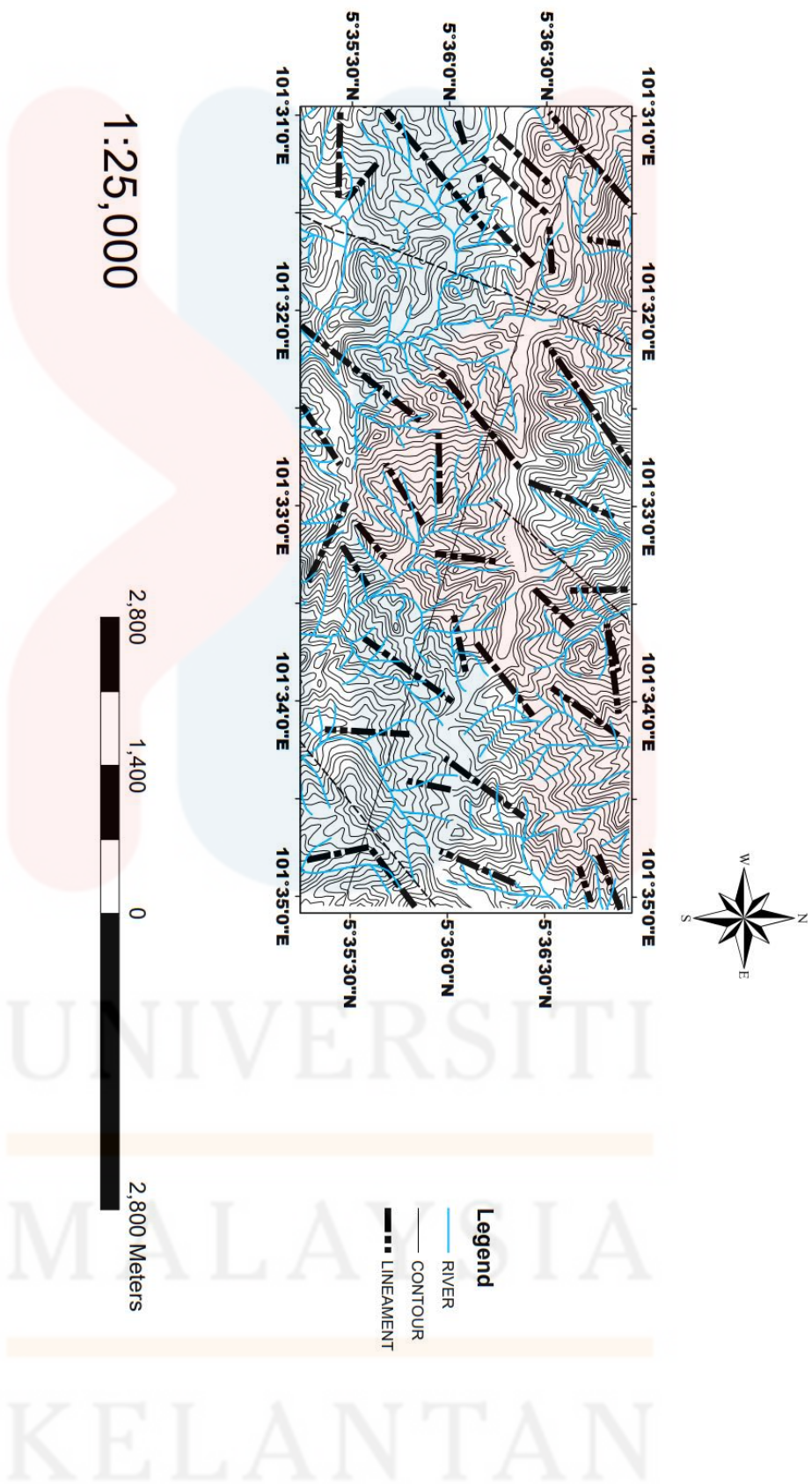


Figure 4.18 : The negative lineaments based on the contour lines of the study area

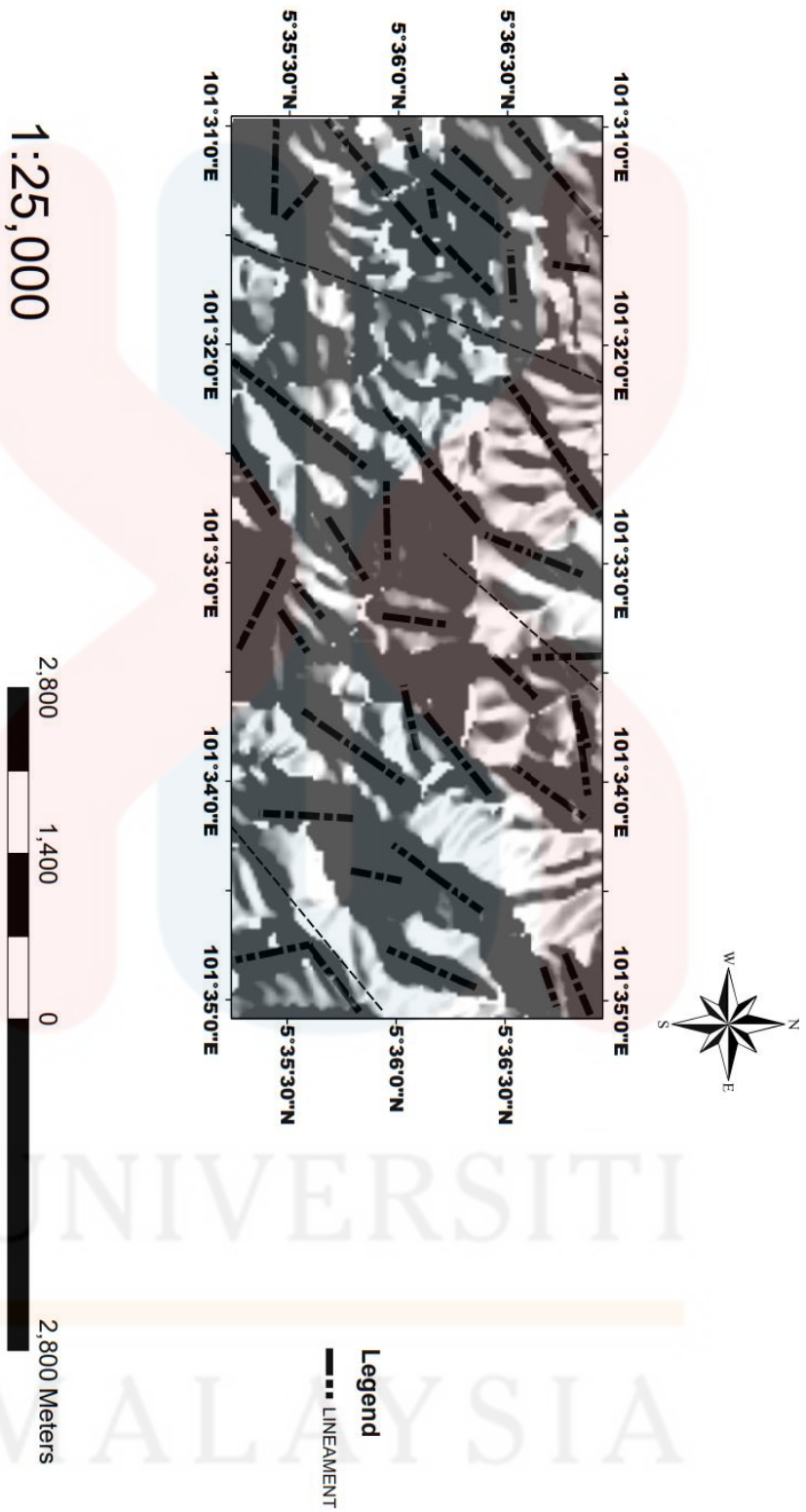


Figure 4.19: The negative lineaments based on the combination of hill shade and slope map

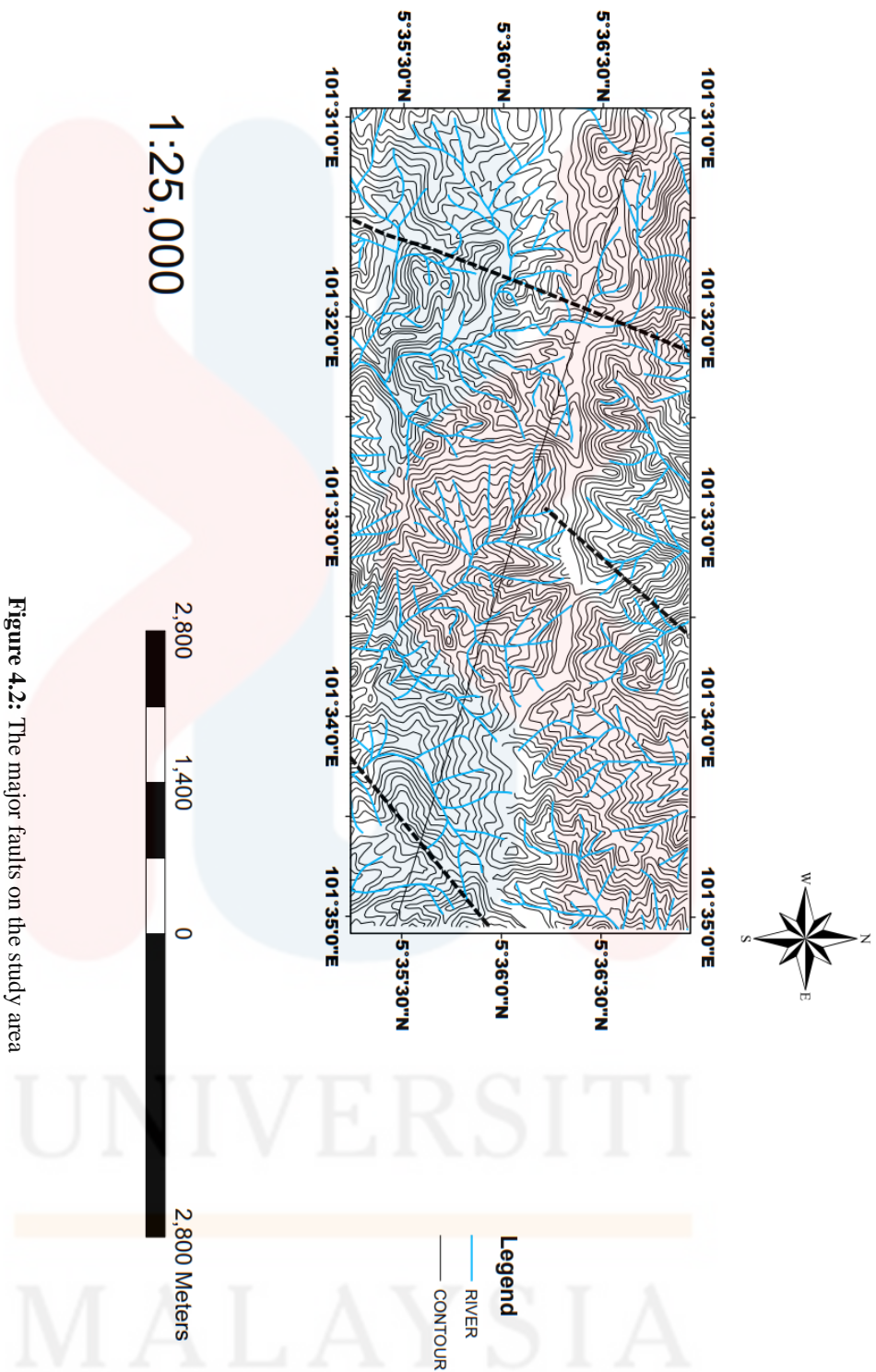


Figure 4.2: The major faults on the study area

4.4.2 Mechanism of structures

The discontinuity data was taken, and the orientation of the outcrop was identified based on the data in the form of rose diagram and plane plot graph. Based on the rose diagram, most the discontinuities are categorized into four data sets, two sets ranging from 340° - 350° and 310° - 325° in northwest direction: 145° 160° and 170° - 185° towards southeast. This factor implies that the principal stresses directed from the NW-SE region. Hence, compressive stresses derived from the mentioned direction from high tectonic activity causes the rocks to brittle and deform in that manner. Based on the data obtained by the plane plot diagram, the planes of weakness from the joint analysis indicates that the planes intersect at regions in both northwest and southeast region further proving that compressive forces from the fault activity had cause high deformation and orogeny among the rock units in the study area.

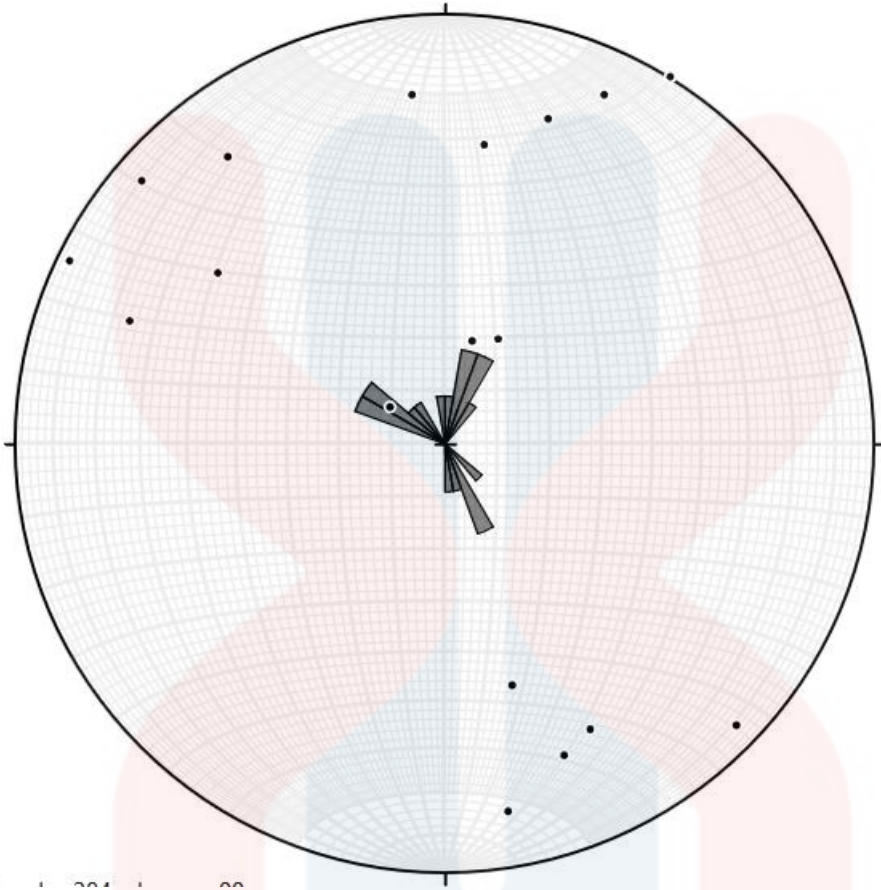


Figure 4.21: Orientation analysis of outcrop J1

Figure 4.21: The orientation analysis of outcrop J1 based on the stereonet plot which includes rose diagram reading and the stereonet plot

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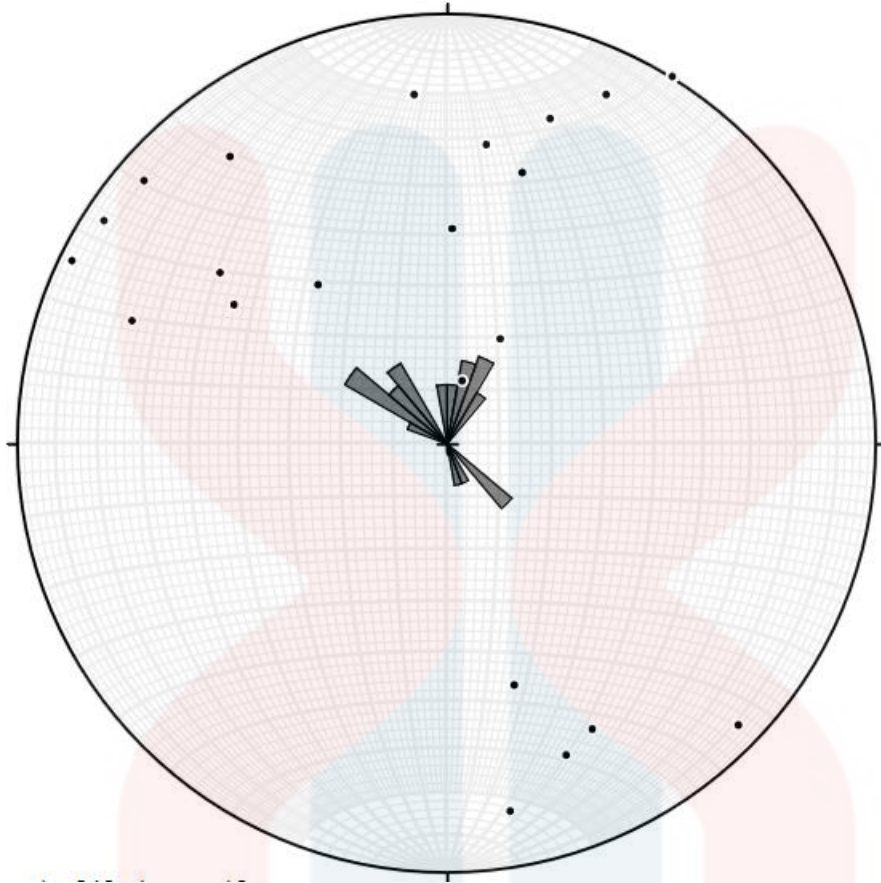


Figure 4.22 : The orientation analysis of outcrop J2 based on the stereonet plot which includes rose diagram reading and the stereonet plot

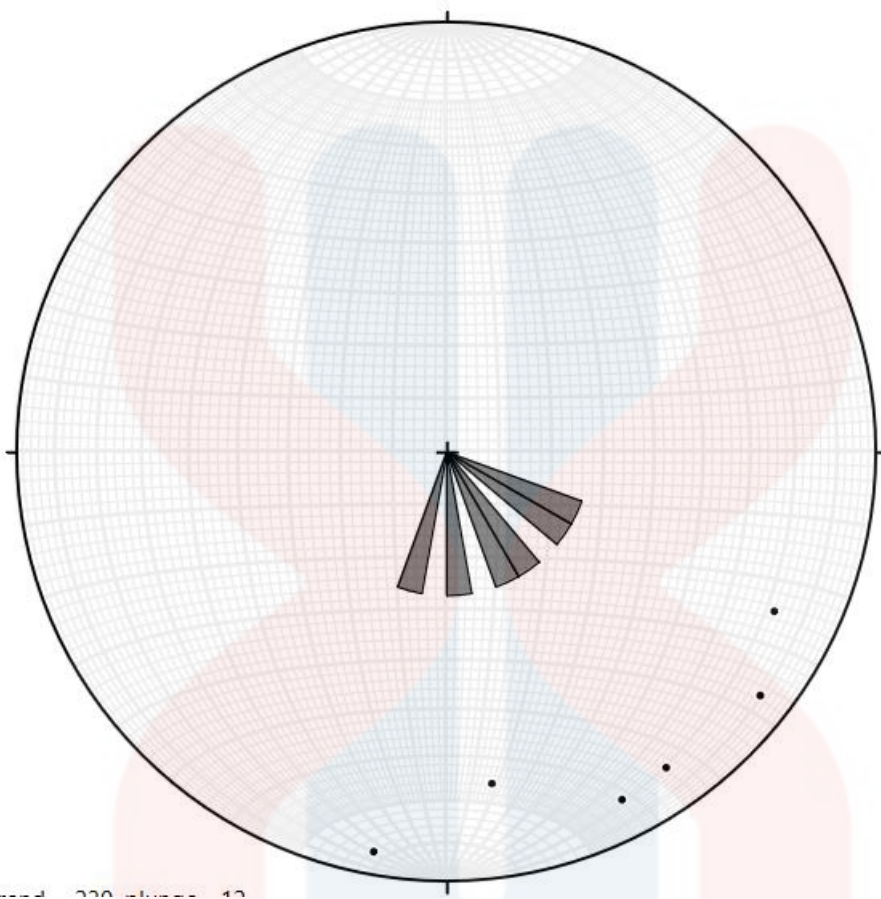


Figure 4.23

Figure 4.23 : The orientation analysis of outcrop J3 based on the stereonet plot which includes rose diagram reading and the stereonet plot

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4.5 Historical Geology

The lithology unit that has been found in the study area comprises of Kabut granite from the Main Range Granite Complex, Tiang Schist and Kubang Pasu sandstone. MacDonald (1953) suggested that there was a unconformity containing rock lenses such as schist and hornfels dominantly around the black limestone. In this location, Wong (1974) found a series of upper greenschist to lower amphibolite schist metamorphic grades, which are prevalent in the suture zone. Muscovite, biotite, andalusite, and garnet are found in the schists and gneiss rocks. The pelitic schist conforms lower to hornblende amphibolite. Tjia (1989a) and Tajul Anuar (1989) suggested the zone as the Transect area's expansion of the Bentong-Raub Suture Zone. In addition, muscovite-quartz schist, garnet-muscovite schist, sillimanite-muscovite schist, biotite-hornblende schist, hornblende-epidote schist, and biotite-hornblende gneiss were found by Mohd Raji (1990), who researched the geology of the Batu Melintang area in depth.

Based on the lithology and petrochemistry of the granite, Hutchison and Taylor (1978) postulated three geographical granite belts throughout the Malay peninsula. The I-type, magnetite-series granitoids that intruded the Palaeozoic host rocks throughout the Permo-Triassic era make up the majority of the Eastern belt granitoids. The S-type, ilmenite-series granitoids dominate the Main Range granitoids (in the centre belt area), with modest intrusions of I-type, magnetite-series granitoids. In the Permo- 13 Triassic period, they also encroached over Palaeozoic country rocks. On the Thai side, the western belt granitoids include both I-type magnetite series granitoids and S-type ilmenite series granitoids from the Cretaceous period. The Silurian-Devonian rocks were also dubbed the Ban to and Betong Formations by Muenlek et al. (1979).

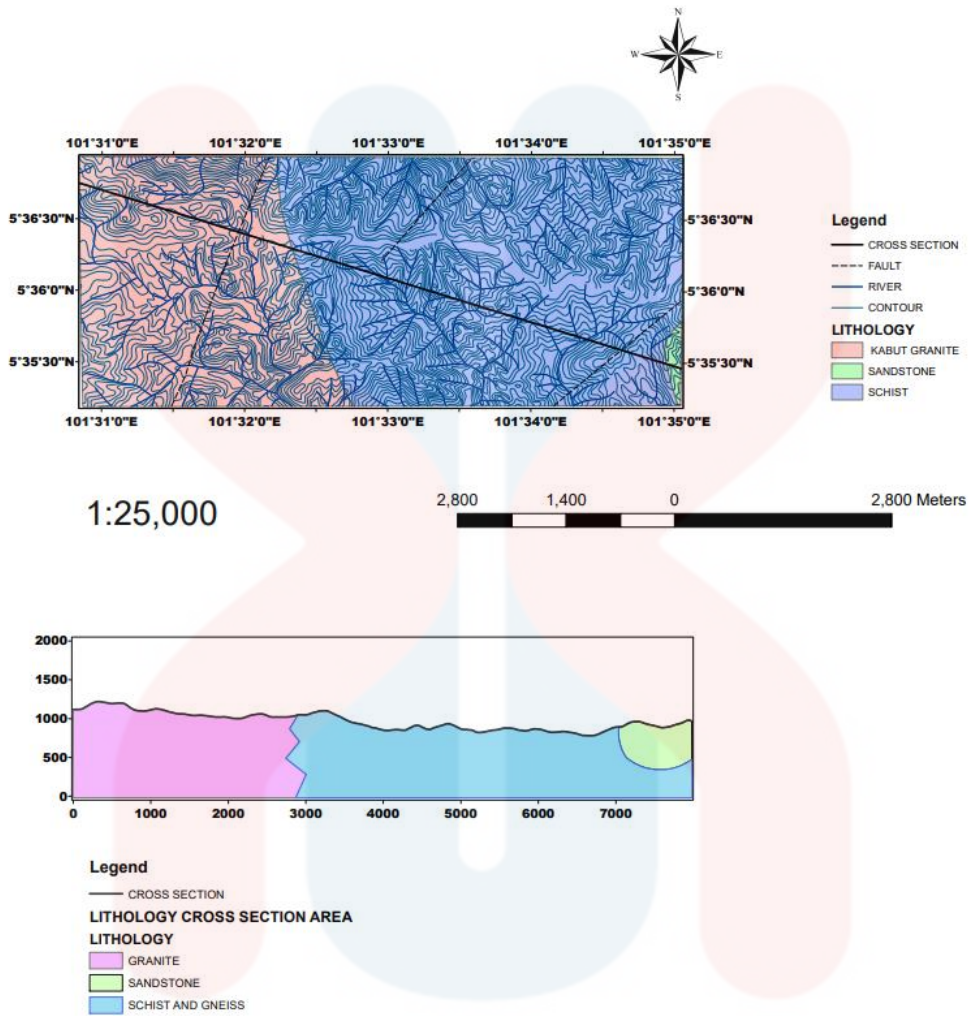


Figure 4.24: The cross section and the geological map of the study area

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CHAPTER 5

PETROGRAPHY OF GRANITE

5.1 Introduction

This chapter will be closely related to the title of the research, which involves the petrology of volcanic rocks and metamorphic rocks in order to determine the nature, texture and the classification of the rock samples obtained. This will be achieved by the QAP (Quartz, Alkali, Plagioclase, Feldspar) classification of rock using the QAP Ternary diagram for volcanic rocks (Streckeisen, 1974). The categorization of the mineral compositions on the thin sections of the rock will be done by point counting method in order to plot in into the Ternary diagram to obtain a appropriate rock name based on its rock classification. Based on physical observation of the rock samples during the mapping of the study area, three rock units can be identified based on the IUGS classification (Le Bas & Streckeisen, 1991). Those rocks are igneous granite porphyry, mica-schist, and gneiss. The purpose of collecting rock samples is to study the characteristics of the rock samples macroscopically and microscopically. The rock samples is then processed into thin section for further mineral identifications and QAP analysis. Three thin sections of the rock samples obtained from outcrop 1 are examined and analysed in terms of its optical properties under the polarized microscope.

5.2 Results

5.2.1 Mineral Composition

Based on the thin sections shown in figure 5.2, the mineral compositions that can be found in the thin section of rock sample J1 are mainly quartz, biotite, olivine and alkali feldspar. The quartz mineral that can be seen in the thin section is highly dominant in this rock sample because it acts as a intrusive igneous rock originated from subsurface mantle. This defines that high silicate content can be observed from the upwelling origin of the rock itself. The quartz minerals contain a first order colour, mainly greyish to milky white. These minerals also has a irregular or a wavy extinction when the stage of the microscope has been rotated as many different sections of the grains extinct in several different orientations. The quartz minerals of the thin section also contain an interlocking texture and several areas of the thin section contains a different characteristic of quartz, whereby the quartz has a hexagonal crystal system compared to the interlocking texture of the mineral. This indicates that the rock unit has an holocrystalline igneous texture as well as a minor metamorphic trait based on the mineral composition.

Plagioclase was white to greyish colour in hand specimen. Plagioclase was identified by its optical properties under polarized microscope. It was colourless under plane polarized light microscope (PPL). It did not change the colour during rotation of stage under plane polarized light. This indicated that the plagioclase was non-pleochroic. It was anhedral to subhedral in shape and its size was about 1 to 7 mm. It was grey first order birefringence. Plagioclase was differentiated from alkaline feldspar by the twinning habits of crystal. Plagioclase had both albite and Carlsbad twinning, but alkaline feldspar can only have Carlsbad twinning. Inclusion of small biotite and sphene can be observed in the thin section of granite.

Alkali feldspar was anhedral in shape and its size is up to 3 cm. It had grey low first order birefringence under cross-polarized light. Alkali feldspar was colourless in under plane polarized light, which means that it is non-pleochroic. Alkali feldspars showed simple and Carlsbad twinning and perthite intergrowth in the thin section. The main types of alkali feldspar were perthitic orthoclase and often showed euhedral outline in hand specimen but sometimes appears to be irregular in thin section. Simple twinning of the alkali feldspar and the presence of small oriented euhedral inclusions usually plagioclase, oriented subparallel to the crystal faces of the host K-feldspar suggested that the minerals were magmatic. Mantling of plagioclase over alkali feldspar are common.

Quartz can also be observed under the microscope. It was anhedral in shape and occurred as sub-grains in the thin section. It was colourless to greyish black under plane polarized light. The quartz occurred as individual mineral and some of them were filling up the space between others minerals especially alkali feldspar and plagioclase.

Biotite can also be observed in the thin section as well. This is because that the biotite exhibits a strong pleochroism as the biotite in figure 5.2 exhibits different colours when it is observed in different angles from the microscope. The colour of this mineral varies from deep greenish brown to pinkish in colour. Moreover, the relief is moderate, and it has a cleavage extinction as a perfect linear mica cleavage can be seen in the biotite minerals originating from the thin section. It also has a high birefringence masked by a deep colour and the cleavage of the minerals can be seen in the East-West direction. A minor chlorite alteration is also present in the thin section as well.

Several olivine occurrences also can be detected in the thin sections of the granite as well. The relief of the mineral is very high as seen in several thin sections with a birefringence up to the second order, ranging around yellow to green in colour. The olivine also has a high retardation and a lack of cleavage and has a abundance of fractures.

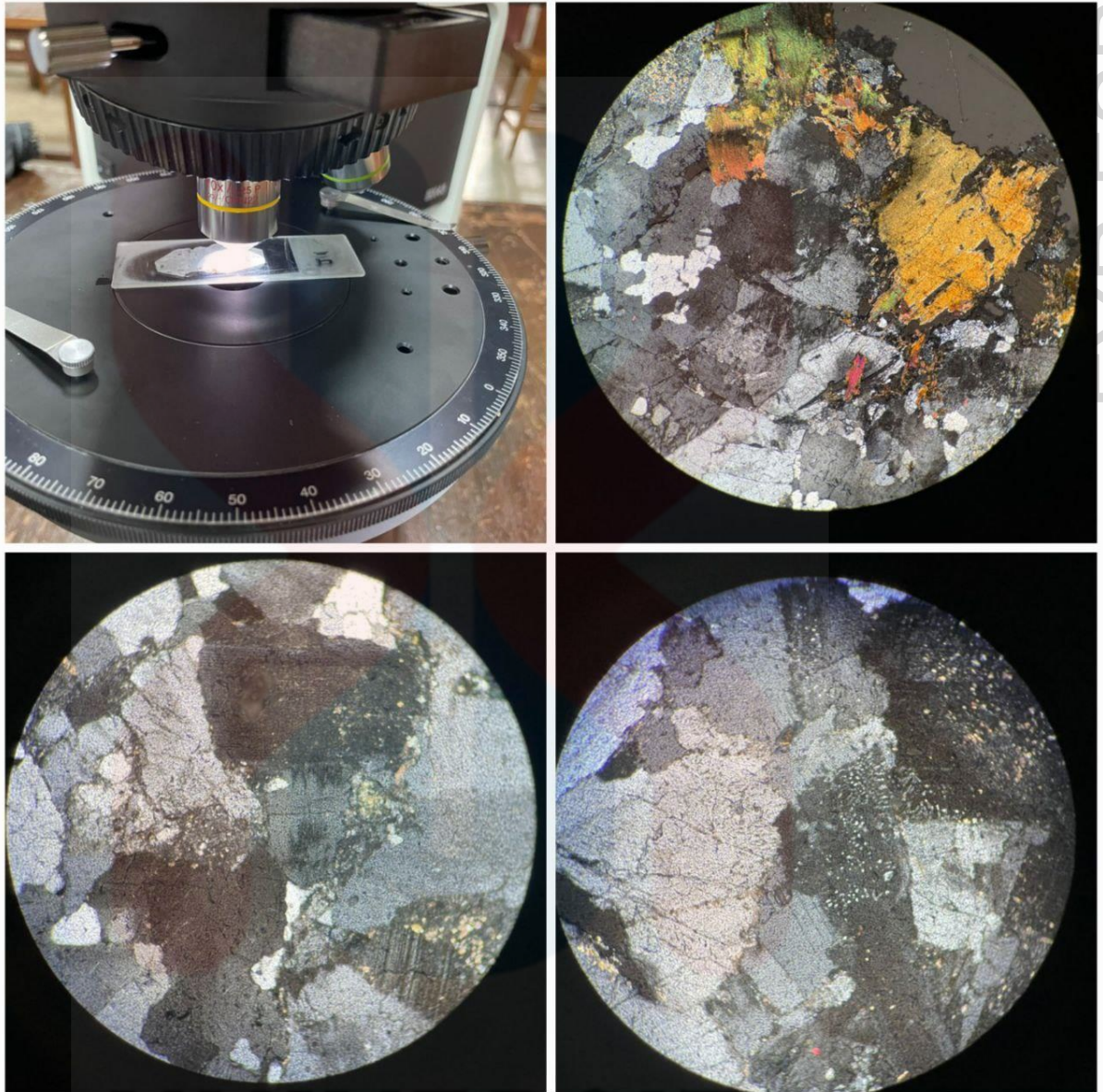


Figure 5.1: Position of the thin section subjected on the East-West orientation on the thin section which shows mineral composition such as biotite, quartz, sanidine microcline, and orthoclase.

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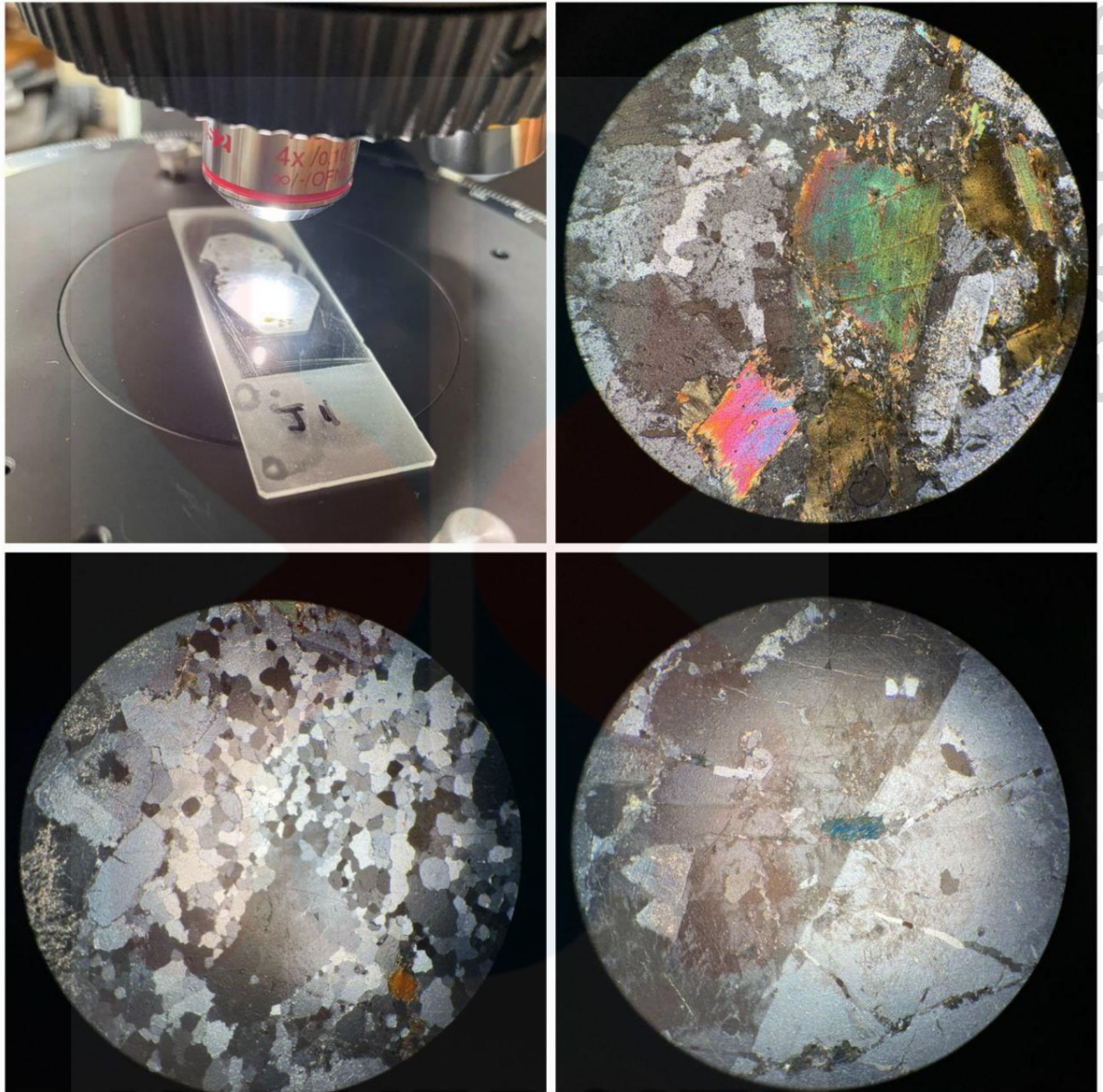


Figure 5.2: The position of the thin section subjected on the North-West and South-East direction on the thin section which shows mineral orientation such as biotite, quartz, orthoclase and chloride alteration.

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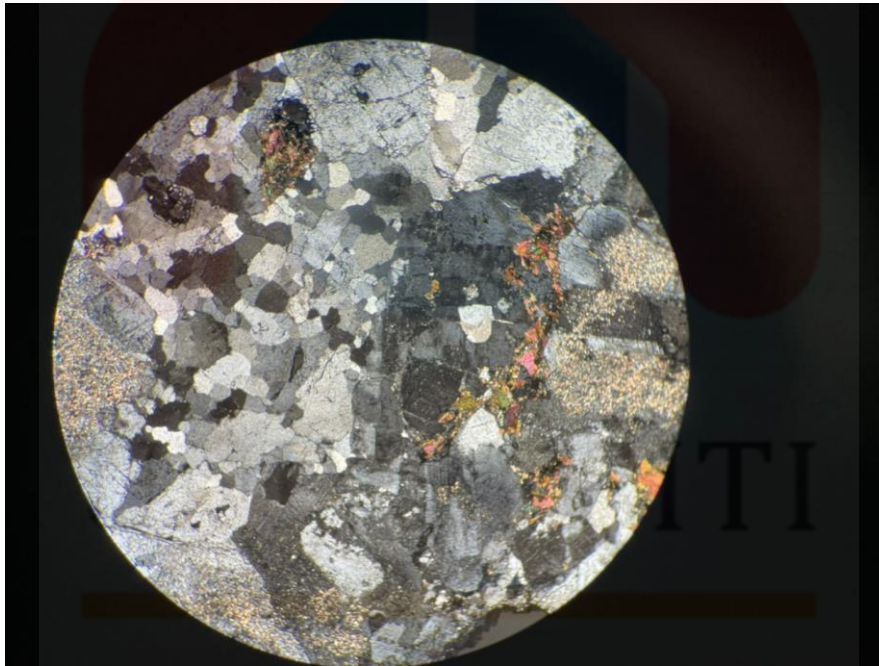
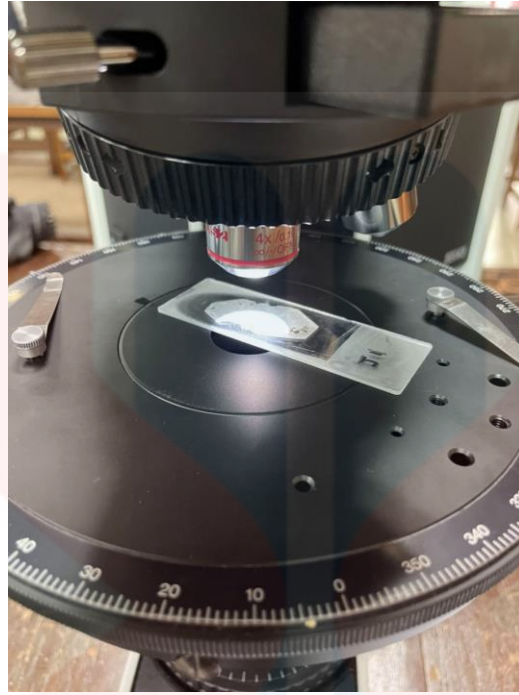


Figure 5.3 : The position of the thin section subjected on 300°N - 160°S direction on the thin section which shows pleochroism of biotite and weathering material.

5.2.2 Textures

Textures in a rock's thin section indicates a constituent relationship with the nature of an particular rock based on its origin. This is because that a rock which has been sliced into the scale of thin section contains many rock characteristics that relates to the origin of the rock formation and the geological history surrounding the rock as well. Moreover, textures also indicate the rate of crystallization especially in the igneous and the metamorphic background. Texture of a rock can be described based on the crystallinity, granularity, and the fabric nature of the rock itself. Based on the thin section of the granite rock sample obtained, several textures which includes igneous and metamorphic traits can be detected in the thin section.

Perthitic structure are dominantly present on several regions of the thin section. Perthite can be defined as a type of exsolution made up mostly of feldspar content. Perthite is made up of brown and white lamellae and it typically grows in an igneous nature which is filled with plagioclase compositions as this structure are superior in mineral texture classifications in the igneous nature. The perthite in this thin section is mainly black and white in colour embedded orthoclase, ranging around 1-2mm in diameter.

Inclusions are a by- product of the recrystallization and the cooling down of lava in a rock embodiment as inclusions are formed when lava flow overlies a rock which has already formed. To add on to the context, high temperature from the lava flow would cause the host rock to melt again resulting the lava flow to mould together with the host rock and solidifying with the host rock itself. Inclusions can be seen in plagioclase mostly from the granite thin section, representing in a cream colour (high silica content) .

The presence of myrmekite can also be observed in the thin section of granite rock sample obtained from the study area. Myrmekite is formed as a result from a slow crystallization rate caused by magma cooling. It is also defined as a intergrowth of quartz in a deformed and a wormy shape infused with plagioclase in the thin section. To be more specific, based on the thin section of the granite sample, the myrmekite appears to have a wormy structure alloyed in a orthoclase mineral, showing a white to cream colour.

Zoning is a distinct feature mainly in plagioclase which can be categorized into two, concentric zones and sector zones. Zoning is basically formed by crystals enlarging its molecules with different growth bands or zones, which in short produces layers encompassing the feature itself. Based on the thin section, the zoning feature, which is greyish black in colour can be seen overlying the alkali feldspar crystal.

Pyrite is a mineral common in metamorphic and igneous rocks which occurs due to hydrothermal veins, magmatic intrusion and contact metamorphic deposits. The pyrite which can be determined in the thin section appears in a granular texture, in tiny inclusions and has a oblique light-brass yellow. Pyrite, which is also known as iron sulphide embedded in the plagioclase crystal altered towards weathering. Iron chloride can be observed also in the thin section as an alteration product due to weathering process of the rock outcrop.

Twinning is a major distinct feature that can be seen in the majority of the thin sections. Twinning is two or more crystals from the same mineral grows in an symmetrical growth even with a different extinction and different interference colours. Lamellar and polysynthetic twinning are common in the thin sections which is made up of feldspar. Polysynthetic twinning occurs when more then three crystals are

twinned on the same plane meanwhile lamellar twinning is defined as the thin planes which consists of lamellae, a distinct feature of an alkali feldspar crystal. Plus, Carlsbad twinning and Albite twinning are dominant in alkali and potassium feldspars in the thin sections as shown in the figure below.

Quartz in the thin sections possesses several distinct features in the thin section which shows both metamorphic and igneous characteristics. To be more precise, quartz crystals has an interlocking crystal arrangement in the thin section. This shows that crystallization process occurs in the thin section resulting in an irregular shape of the crystals itself. On the other hand, signs of intrusion also can be seen in several thin sections in accordance with the intrusion of granitic embodiment of the Main Range Granite. On contrast of the mentioned textural feature, several regions of the thin sections shows that the quartz crystals are in a linear arrangement which would eventually forms foliations (bands) in the rock texture subjected to high pressure and temperature.

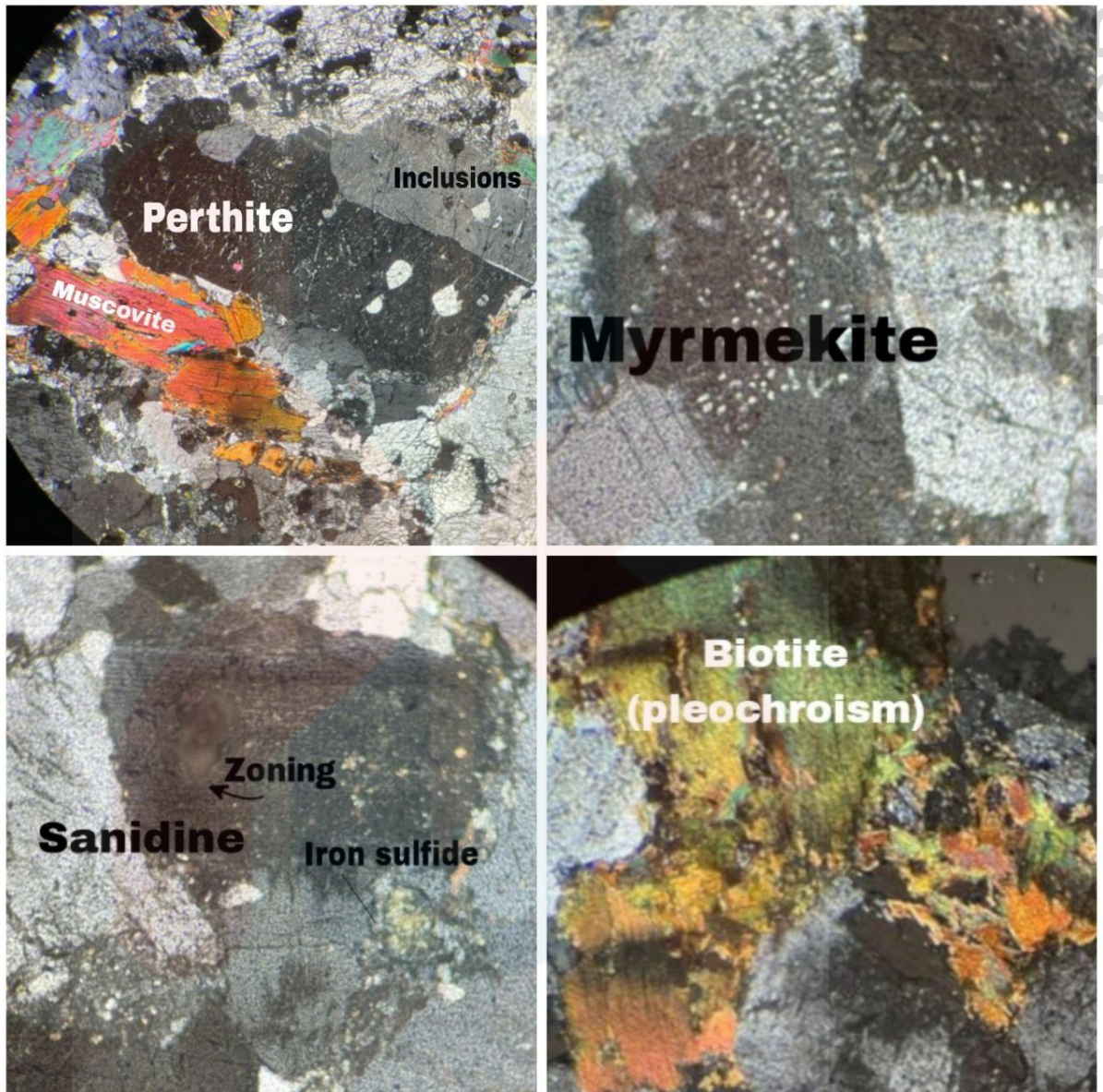


Figure 5.4 : The presence of mineral textures that can be found in the thin sections of granite

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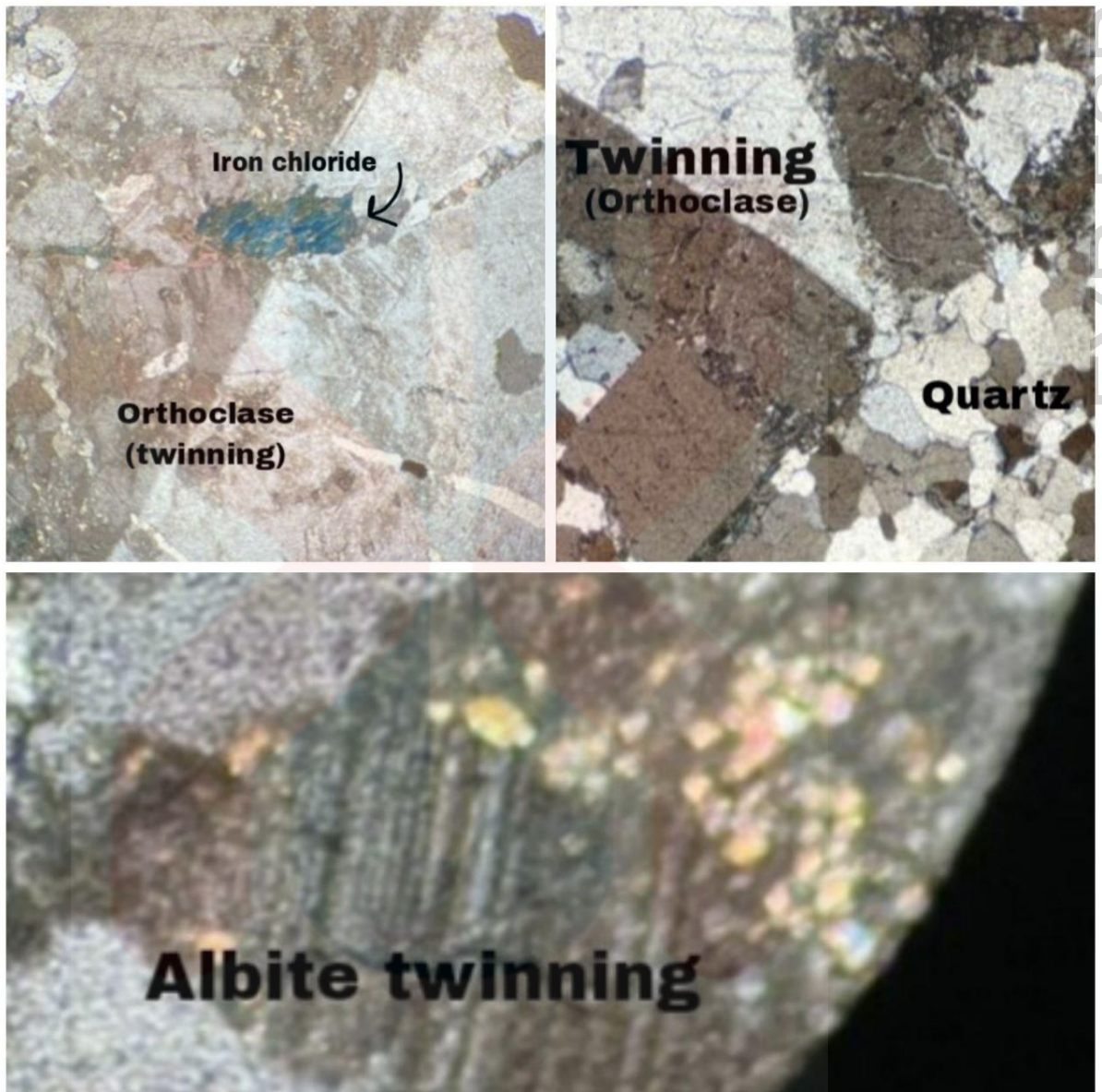


Figure 5.5 : Major mineral textures that can be found in the thin section

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5.2.3 QAP Classification

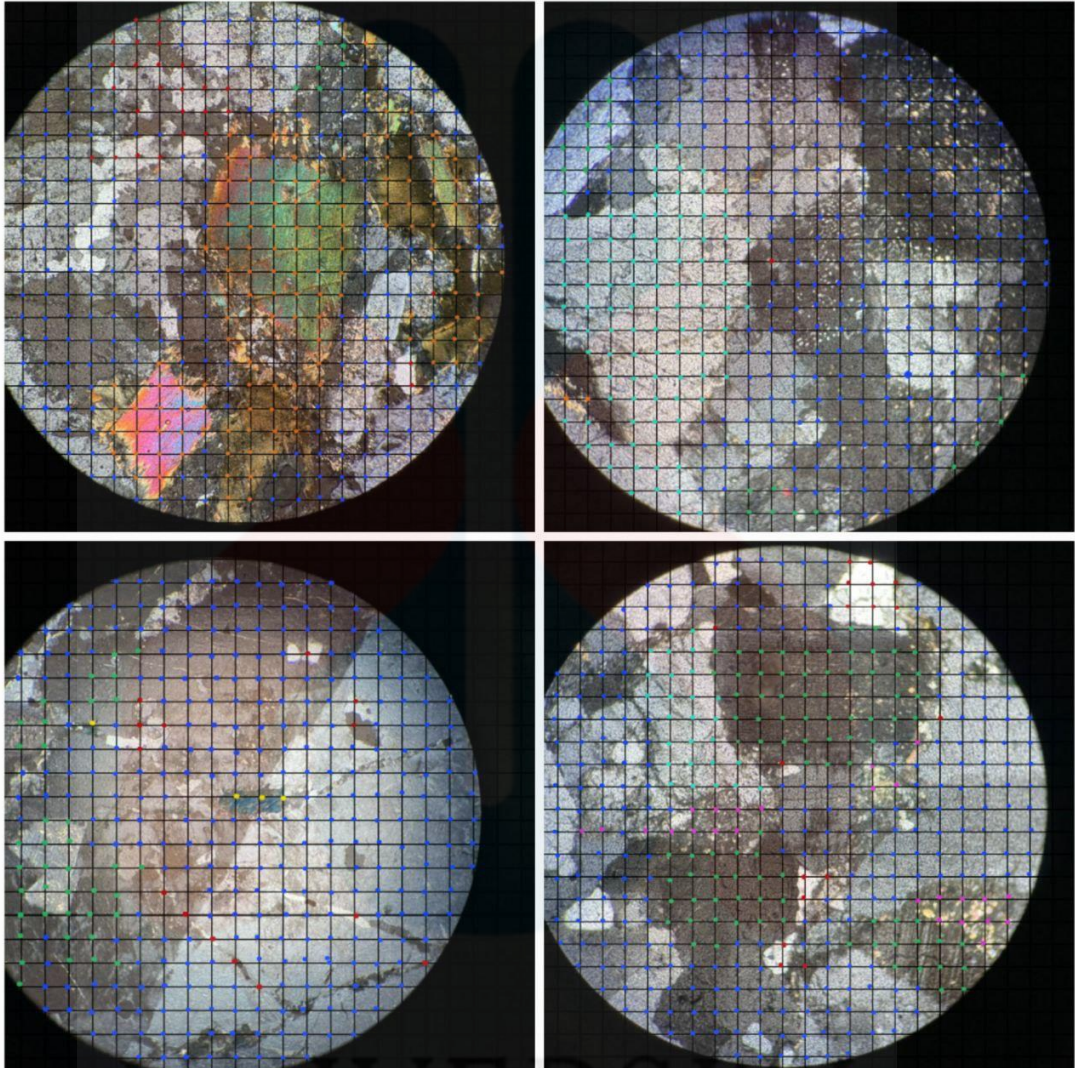


Figure 5.6 : The figure shows the point counting method that has been done for each thin section from the rock sample of granite

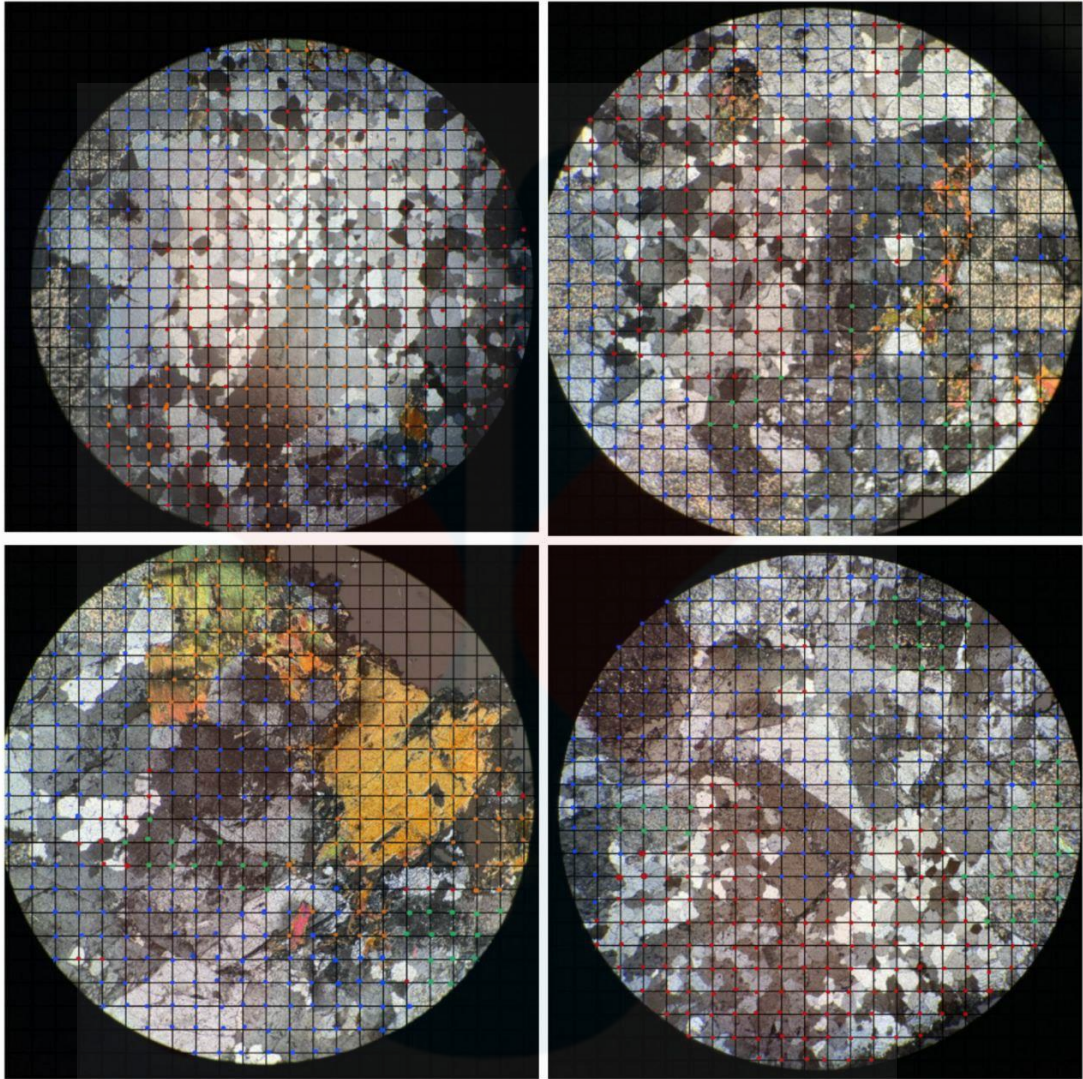


Figure 5.7: The figure shows the point counting method that has been done for each thin section from the rock sample of granite

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Mineral Content	Colour in Thin Section	Point Counting Analysis	TOTAL	Abundancy Percentage (%)
Quartz	Red	412+96+173+16+7+1+17+167	889	25
Alkali Feldspar	Green	67+130+80+25+23+599+81+147+260	1088	71
Plagioclase	Blue	169+253+199+214+302+273	2013	55
Biotite	Orange	246+124+367	737	20
Amphibole	Light Blue	28	28	1
Chloride	Yellow	4	4	0.1

Thin Sections	Percentage of Mineral Content per thin section (%)		
	Quartz	Alkali Feldspar	Plagioclase
T1	32	78	41
T2	19	67	57
T3	18	72	39
T4	22	67	52
T5	24	68	60
T6	0.1	32	-
T7	5	42	64

Table 5.1: Point counting method for each mineral crystals has been collected and generated on the table above

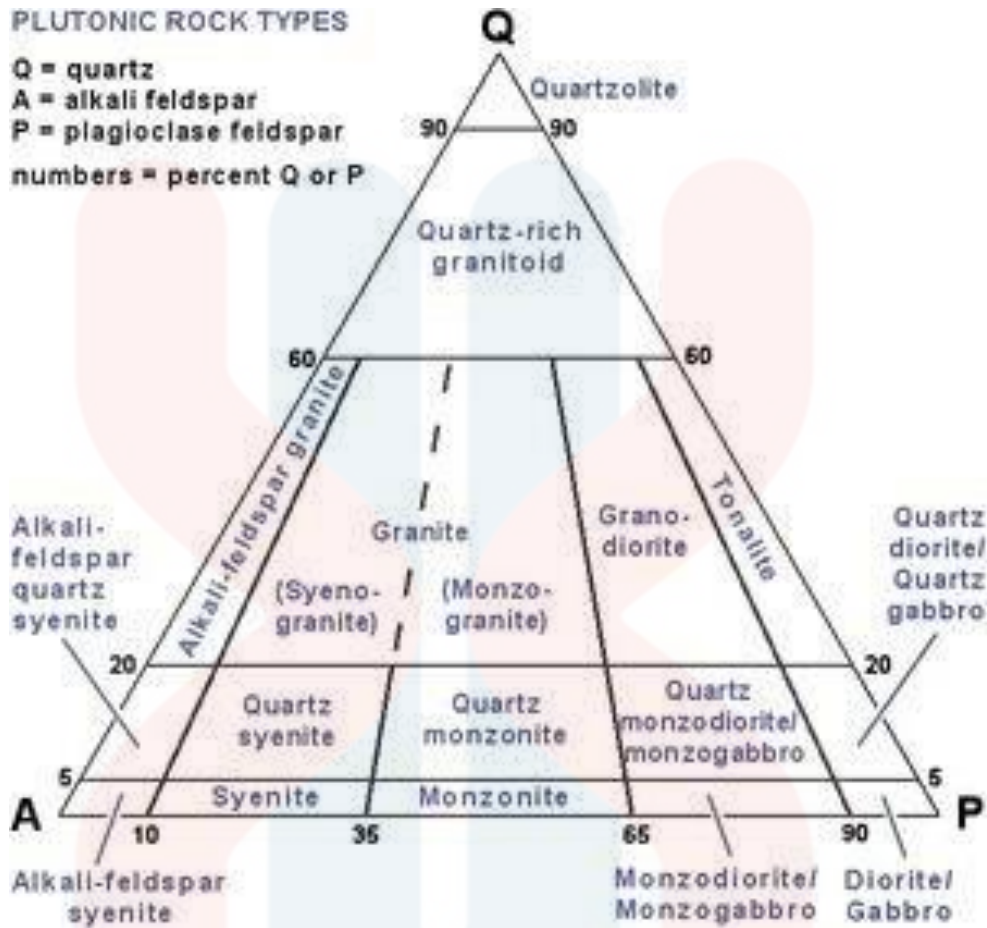


Figure 5.8: The classification of QAP diagram for an igneous origin

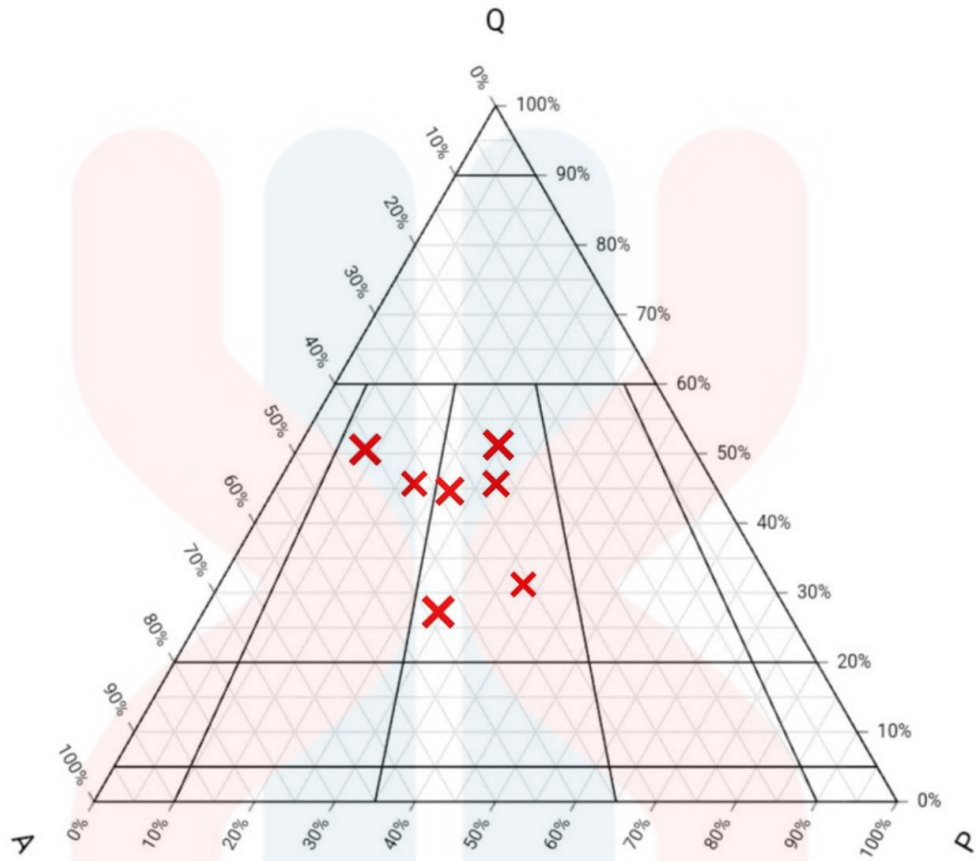


Figure 5.9 : Based on the point counting values of the minerals of Quartz, Feldspar and Plagioclase, the values have been plotted down, resulting for the majority of the point counting plots falling in the Monzogranite column.

5.3 Discussion

Compared to the results of the petrographic analysis and the QAP analysis of the rock sample, the rock sample can be identified as monzogranite. Monzogranite (L.E Maitre,1987) is made up biotite granite rocks that made up of quartz, potassium feldspar and plagioclase. Moreover, the granitic unit of this classification as coarse grains rock mainly made up of I-type granites which are abundant in potassium feldspar.

Hence, the granitic embodiment of the area caused by the igneous intrusive granitic bodies intruding existing country rocks that are abundant in the Western Belt of Malaysia, mainly metamorphic rocks such as the Tiang Schist. Based on the textural characteristics of the thin section, indications of the irregular shapes of the crystals suggests a slow rate of crystallization occurs during the cooling of lava during the intrusion period. This causes several silica-rich textures such as inclusions and myrmekite from a by-product of crystals moulding together under low temperatures by time.

In the Mid-Range Granite terrane, which extends to the East-Coast highway, the rock units have a transitional phase from a igneous rock towards a high-grade metamorphism trait (gneiss); can be observed by the combination of petrological aspects of igneous and metamorphic rock together. This explains the linear alignment of the quartz in the thin section of the granitic rock which has a metamorphic origin. Moreover, the schist also possesses an interlocking trait of crystals together with several foliations of quartz. Hence, the intrusion of granitic embodiment by mantle upwelling based on the tectonic activity occurs during the formation of the metamorphic country rocks in the Western Belt of Malaysia subjected to high temperature and pressure.

As the study area is situated in the Western Province of Malaysia, the geological feature of this study area is that this location is the centre of collision between two tectonic terranes, Sibumasu in the West and Chanthaburi terrane in the East part of Southeast Asia. This tectonic plate had been split into two different terranes by the Bentong-Raub suture. Since the tectonic processes took place in Peninsular Malaysia's Central Belt, the locality of Gerik-Jeli commonly has a variety of meta-igneous melt sources. The spreading of Mesotethys ridge around the Palaeozoic era caused many phenomenon such as the intrusion of metasediments, Z-type granites, and I-type granites throughout the regions in Malaysia. In the Sibumasu plate terrane, this process had resulted to continental subduction, which had generated slab breakoffs and Bentong-Raub suture zones. In accordance with the lithology of the presented map, the granites intruded in the Titiwangsa valley are classified as biotite granite. The pluton in the studied area contains late-stage magmatic features, such as coarse-grained pegmatitic potassium feldspar. The existence of meta supra crustal rocks and biotite-muscovite granite in the region demonstrate that the crustal rocks of the Sibumasu and Indochina tectonic terranes partially melted.

CHAPTER 6

CONCLUSION AND RECCOMENDATIONS

6.1 Conclusion

The Titiwangsa Rest Stop area situated in the Grik-Jeli Highway is known as for its ideal site for environmental exploration. The area is made up geomorphological patterns such as a high sloped hill and a mountainous area. Parallel and dendritic drainage patter makes up the majority of the drainage shape in the study area. Besides, the Titiwangsa area is made up of lithologies such as Kabut Granite and Tiang Schist. The dipping value to the rock varies from 12° to 72° from the outcrop.

As a closure of this research, the geological map of the study area has been studied and updates based upon its geological data. The updated aspects of the geological data include drainage system, lithology, and the mineral characterization of the lithological units. Based on the lithological categorization, the area of interest is made up of biotite-granite, mica schist and gneiss unit. Moreover, based on the hand samples, the characters of the outcrop based on the rock samples are categorized based on the grain size and the mineral composition that the rock samples bring. The mineral crystallization of the thin section consists of different phases of crystallization, including igneous and metamorphic trait together. To be more precise, the characters that can be detected in the thin section includes Carlsbad and Albite twinning, myrmekite, pleochroism, iron chloride alteration, pyrite presence and linear alignment of quartz. Based on the QAP classification and the thin section of the rock, the rock is classified as monzogranite, which had biotite as a porphyry and abundant in potassium feldspar.

Most of the rock unit samples contains presence of intrusion made up of rich contents of silica. This is because that the Main Rage Granite unit, the I type granite which contains a high amount of Potassium Feldspar intruded the metamorphic rock unit which is schist and gneiss whereby forming and intrusion from the mantle during a high tectonic event.

6.2 Recommendations

The first suggestion, due to a lack of accessibility, future researchers are suggested to obtain permits to enter the forest reserve to have a wider view of the lithology. Several landslide susceptibilities can be detected and could be dangerous to the highway surrounding the study area. Hence, future researchers could investigate the study area in terms of landslide risk accordance to the geomorphology of the study area. As the area is bombarded by forest reserves, the aspect of safety should be taken into consideration as animals could interfere with the investigation.

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