GEOLOGY AND SEQUENCES OF METAMORPHIC ROCKS MINERAL ASSEMBLAGES IDENTIFICATION IN GERIK ECOLOGICAL CORRIDOR, GERIK, PERAK

By

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A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Geosciences) with honors.

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2023

DECLARATION

I declare that this thesis entitled "GEOLOGY SEQUENCES OF METAMORPHIC ROCKS MINERAL ASSEMBLAGES IDENTIFICATION IN GERIK ECOLOGICAL CORRIDOR, GERIK, PERAK" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

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

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Date ……………………………………………………….

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GEOLOGY AND SEQUENCES OF METAMORPHIC ROCKS MINERAL ASSEMBLAGES IDENTIFICATION IN GERIK ECOLOGICAL CORRIDOR, GERIK, PERAK

ABSTRACT

The Gerik Ecological Corridor is part of the Baling Formation and is positioned between Jeli, Kelantan, and Ulu Perak, Perak. The study area is approximately 25km2 which is aligned along latitude 05° 33' 48" N to 05° 35' 33" N and longitude 101° 24' 15" E to 101° 28' 33" E. This research aims to update the geological map of the Gerik Ecological Corridor area with a scale of 1:25000. The method that has been used at the beginning of this research is a preliminary study of the previous research and a literature review that has been conducted surrounding the study area. The geological mapping and collecting of rock samples in the research area are done during fieldwork mapping. The lithologies found in the study area are schist and gneiss which in metamorphic rock types. Based on the petrographic analysis, schist contains more mica groups such as muscovite, while gneiss is dominated by quartz and biotite. The transition of metamorphic rock sequences in the study area towards the east is from low-grade to high-grade metamorphic rocks. For the geomorphological aspect, the landform that has on the study area can be classified into two types which are high relief morphology and medium relief morphology. Besides, the transition of metamorphic rocks mineral assemblages of the study area was correlated by this research. The hand specimen collected from the study area then has been processed by the Scanning Electron Microscope (SEM) analysis and X-Ray Diffraction (XRD) analysis. The analysis shows that the mica schist sample and gneiss sample has a high amount of sillimanite mineral rather than kyanite mineral and staurolite mineral. So, the rock mineral assemblages of the study area can be determined in the sillimanite zone of regional metamorphic rocks.

Keywords: mineral assemblages, metamorphic rocks, Gerik, low-grade metamorphism, gneiss

GEOLOGI DAN PENGENALAN URUTAN BATUAN METAMORFIK HIMPUNAN MINERAL DI KORIDOR EKOLOGI GERIK, GERIK, PERAK

ABSTRAK

Koridor Ekologi Gerik adalah sebahagian daripada Formasi Baling dan terletak di antara Jeli, Kelantan, dan Ulu Perak, Perak. Kawasan kajian adalah lebih kurang 25km2 yang diselaraskan di sepanjang latitud 05° 33' 48” N hingga 05° 35’ 33” N dan longitud 101° 24’ 15” E hingga 101° 28’ 33” E. Penyelidikan ini bertujuan untuk mengemas kini peta geologi kawasan Koridor Ekologi Gerik dengan skala 1:25000. Kaedah yang telah digunakan pada awal penyelidikan ini ialah kajian awal terhadap kajian lepas dan tinjauan literatur yang telah dijalankan di sekitar kawasan kajian. Pemetaan geologi dan pengumpulan sampel batuan di kawasan penyelidikan dilakukan semasa pemetaan kerja lapangan. Litologi yang terdapat di kawasan kajian ialah syis dan gneiss iaitu dalam jenis batuan metamorf. Berdasarkan analisis petrografi, schist mengandungi lebih banyak kumpulan mika seperti muscovite, manakala gneiss didominasi oleh kuarza dan biotit. Peralihan jujukan batuan metamorfosis di kawasan kajian ke arah timur adalah daripada batuan metamorf gred rendah kepada gred tinggi. Bagi aspek geomorfologi, bentuk muka bumi yang terdapat di kawasan kajian boleh dikelaskan kepada dua jenis iaitu morfologi pelepasan tinggi dan morfologi pelepasan sederhana. Selain itu, peralihan himpunan mineral batuan metamorf di kawasan kajian telah dikaitkan dengan penyelidikan ini. Spesimen tangan yang dikumpul dari kawasan kajian kemudiannya telah diproses oleh analisis Scanning Electron Microscope (SEM) dan analisis X-Ray Diffraction (XRD). Analisis menunjukkan bahawa sampel syis mika dan sampel gneiss mempunyai jumlah mineral sillimanit yang tinggi berbanding mineral kyanit dan mineral staurolit. Jadi, himpunan mineral batuan kawasan kajian boleh ditentukan dalam zon sillimanit batuan metamorfik serantau.

Kata kunci: himpunan mineral, batuan metamorfik, Gerik, metamorfisme gred rendah, gneiss

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LIST OF ABBREVIATIONS

CFS	Central Forest Spine
DEM	Digital Elevation Model
PPL	Plane Polarized Light
XPL	Crossed Polarized Light
GIS	Geographic Information System
XRD	X-Ray Diffraction
SEM	Scanning Electron Microscope
N	North
S	South
E	East
W	West
Km	Kilometre

LIST OF SYMBOLS

°	Degree
‘	Minute
“	Second
µ	Micro
σ	Sigma
%	Percentage
>	More than
<	Less than

CHAPTER 1

INTRODUCTION

1.1 General Background

This research aims to study the geology and sequences of metamorphic rock mineral assemblages in Gerik Ecological Corridor, Gerik, Perak. This study focuses on the Earth's history, rock distribution, and rock types linked to the area's regional geology, stratigraphy, and structural geology. This data information is necessary for this research and future research. The geology study of the research area is done to study the morphology, lithology, and structural activity to obtain and update the changes of findings of the study and information on the existing map.

Metamorphic rocks are created when rocks are exposed to extreme temperatures, high pressures, hot mineral-rich fluids, or, more frequently, some combination of these conditions. The process of metamorphism changes the rocks into denser, more compact rocks rather than melting them. New minerals are produced by rearranging mineral constituents or through chemical reactions with fluids entering the rocks. Even rocks that have already undergone a metamorphosis might change due to pressure or temperature.

Mineral assemblages to the various types of minerals that make up a rock, and their relative abundance, in the study of geology and the branch of mineralogy. A few factors that occur on the rock during metamorphism affect its characteristics. The study of mineral assemblages is about any minerals in a rock that undergoes pressure and temperature changes representing the stable chemical equilibrium.

1.2 Study Area

The study area of this research comprises the geology of the location, road connection, demography, land use, and social-economic. Additionally, this section will include the Perak map (Figure 1.1) and the base map of the study area (Figure 1.2).

Figure 1.1: The map of Perak, the study area where red circled was the study area.

(Source: Google Image)

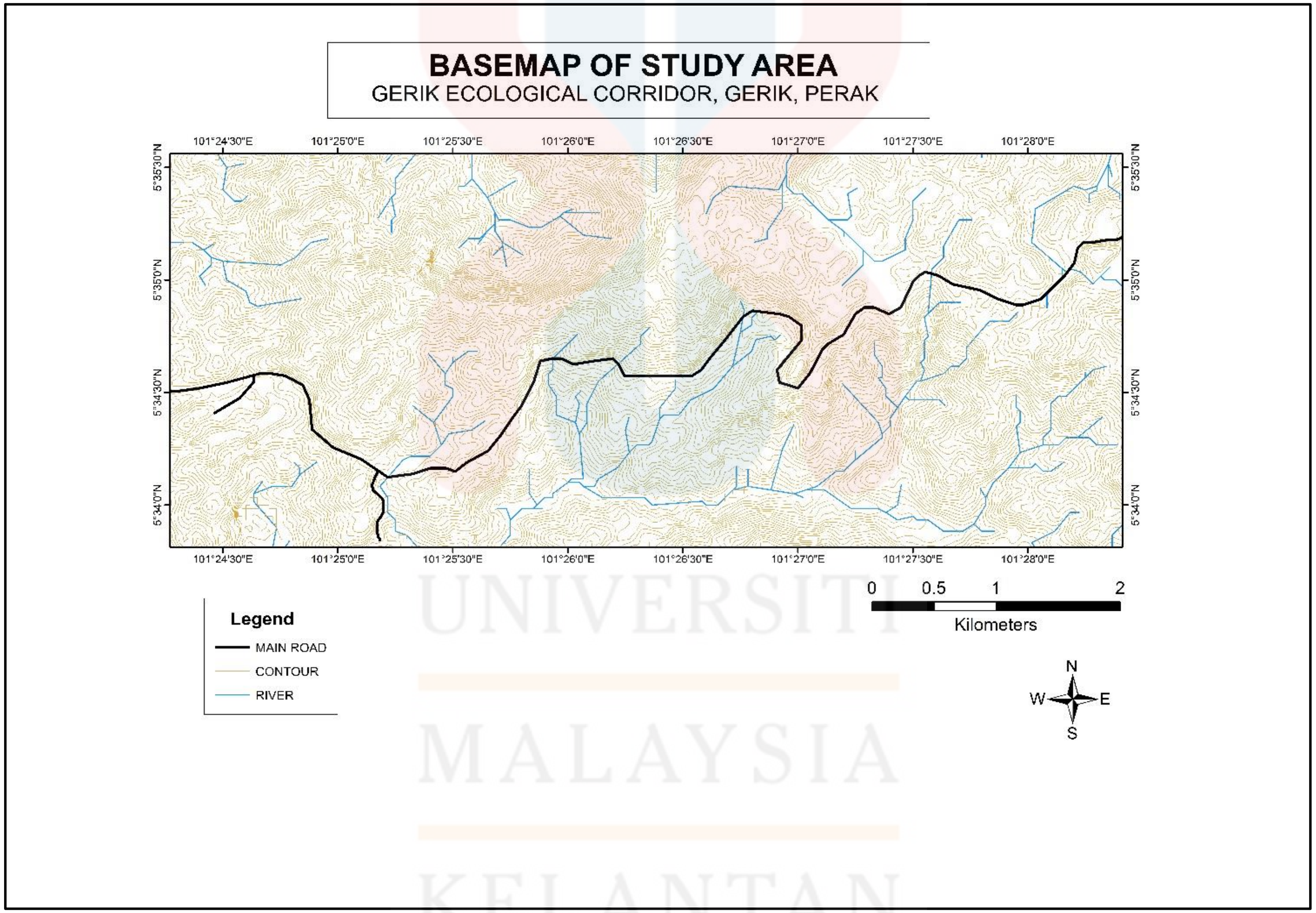


Figure 1.2: Basemap of the study area at Gerik Ecological Corridor, Gerik, Perak

1.2.1 Location

This research focused on Gerik Ecological Corridor, Gerik, Perak. It is on East-West Highway. The study area covers approximately 25km^2 with a scale of 1:25,000, which comprises between latitude 05° 35' 33.75" N to 05° 33' 47.25" N and longitude 101° 24' 15" E to 101° 28' 36.75" E. The high vegetation covered the research area as it was the area of Belum Temenggor Forest of Gerik, Perak. Based on the geological base map, only one major road can access the research area. The research area, located along East-West Highway, is positioned between Ulu Perak, Perak, and Jeli, Kelantan.

Figure 1.3: The study area at Gerik Ecological Corridor, Gerik, Perak. (Source: Google Earth)

1.2.2 Road Connection

Road connection in the study area is only the main road of the East-West Highway that connected Perak and Kelantan. The total length of the main road, East-West Highway, is about 215.5 KM. Main Road East-West Highway, through the study area road, is used by the residents and tourists from Gerik or other states such as Penang and Kedah to go to Kelantan. The route runs through two large mountain ranges, the Bintang Range and the Titiwangsa Range. The access to East-West Highway from the East is at Kulim, Kedah, while for Jeli, Kelantan, it can access from the West area.

Figure 1.4: Road Connection between Gerik, Perak and Jeli, Kelantan.

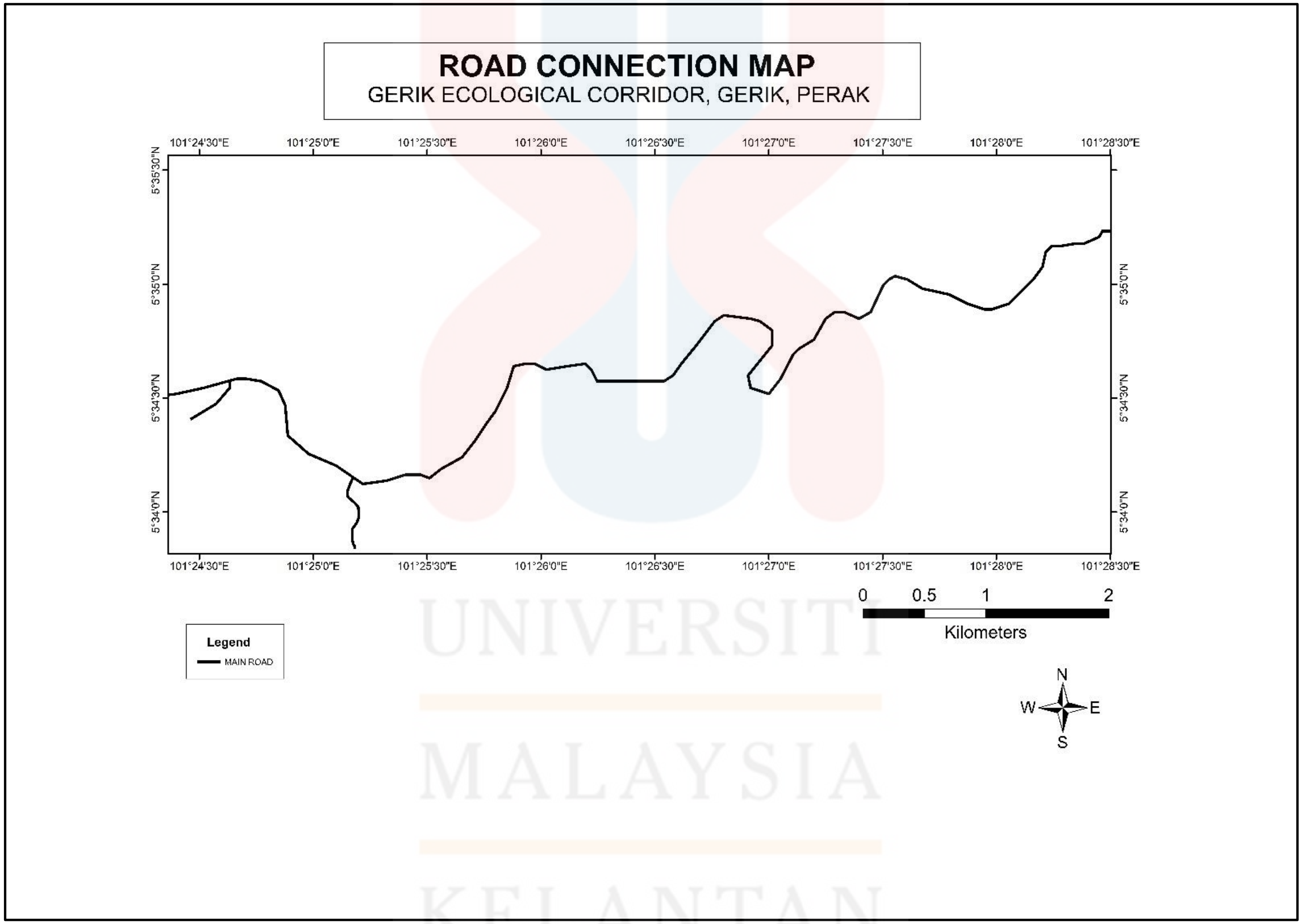


Figure 1.5: The figure shows the road connection map on the study.

1.2.3 Demography

According to the latest development population of the Gerik area, the total population is 29,390 people in the year 2010. Malay and other indigenous Bumiputera are about 24,080, Chinese 4,214, Indian 507, and other groups 74 people. The population statistics show that the male population is more than the female population. The male population is 15,213 people, but the female is 14,177 people in Gerik, Perak. Based on the Nationality of Gerik, 28,875 is from Malaysia, about 98.2% of the total population. For other nationality is only 515 people, about 1.8% of the Gerik population.

Table 1.1: Distribution of people in Gerik, Perak according to gender population and nationality.

GENDER POPULATION	
MALES	15,213
FEMALES	14,117

NATIONALITY	
MALAY & OTHER INDIGENOUS	24,080
CHINESE	4,214
INDIAN	507
OTHER GROUP	74

1.2.4 Landuse

The total land area of Perak is about 2097600Ha. 52% of the land area in Perak is covered by natural forest, which is about 1.09Mha. Plantations and non-forest areas cover another 48% of the land area. In Perak, the most landuse for plantation is oil palm plantation, representing about 473kha. The second of most landuse for plantations is rubber mix which is about 219kha. Next is oil palm mix 47.2kha, rubber 44.6kha, fruit mix 11.4kha, and unknown 28.1kha.

1.2.5 Social Economic

The social economy mainly focuses more on ecotourism as the study area is located on the East-West Highway, which surrounds by the Belum forest. Such ecotourism is at Gerik Ecological Corridor because that place has the potential for ecotourism development as it can increase the social economic of Gerik areas. Also, the area has been logged. Logging can help the communities with further development opportunities.

Figure 1.6: The figure shows the logging area in Gerik, Perak.

1.3 Problem Statement

There were little and restricted data about the petrography and sequences of metamorphic rock mineral assemblages at Gerik Ecological Corridor, Gerik, Perak, from the study region. The latest study on Gerik Ecological Corridor, Gerik, Perak, is about the landslide susceptibility assessment using the frequency ratio model. The journal was written by Abdul Ghani Md Rafek and published in 2010. For this reason, more research is needed to provide a systematic description of the metamorphic rocks found in the study area. Also, there is a correlation between the transition of metamorphic rock mineral assemblages and petrography analysis. Metamorphic rock research is linked to rock genesis and production, necessitating a geochemical inquiry. As a result, this research can aid in completing data on metamorphic rock based on the petrography of the sample collected from the study area.

1.4 Objectives

The objectives for the research of this thesis are:

- To produce and update a geological map with a scale of 1:25000 in Gerik Ecological Corridor, Gerik, Perak.
- To determine the type of metamorphic rock and the sequences of mineral assemblages associated with metamorphism in the study area.

1.5 Scope of Study

The scope of study in this research concentrates on geology and sequences of metamorphic rocks mineral assemblages in the research area will be carried out at Gerik Ecological Corridor in Perak. The total area for this research is 25 km^2 along the East-West highway of Gerik, Perak. Additionally, this study will focus on metamorphic rocks. The study of geology focuses on identifying the research area's geology consists of stratigraphy, geomorphology, and structural geology. Geological mapping will analyze the geological structure observed in the research area, producing and updating the geological map of Gerik Ecological Corridor, Gerik, Perak. The study of the sequences of metamorphic rock mineral assemblages will be identified by petrographic analysis. The petrographic analysis will determine the types of metamorphic rocks and minerals contained in them by thin section analysis. For further rock analysis, it will utilize analysis tools such as X-Ray Diffraction (XRD) and Scanning Electron Microscope (SEM) to determine the study area's mineral paragenesis.

1.6 Significance of Study

The research is carried out to identify the geology in Gerik Ecological Corridor, Perak. This research will produce the latest and updated geological and geomorphological part of the study. The data collected by geological mapping will be gathered to produce the latest geological map of the study area. Governments and local communities can use this updated geological map as part of their efforts to study and plan for environmental development. Moreover, the research purpose is also to determine the distribution of the metamorphic rock, and its correlation to mineral assemblages contain in the metamorphic rock from the study area. The result will be significant for the educational institutions and government sectors as it can help understand the tectonic environment, the origin, and the equilibrium relationship of the rock distribution of the study area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section will focus on the geology of the study area, including regional geology and tectonic setting, stratigraphy, structural geology, historical geology, metamorphic rock research specifications, mineral assemblages, and geochemical analysis, and structure of metamorphic rocks in the study area.

2.2 Regional Geology and Tectonic Setting

Peninsular Malaysia is in the South-East Asian part of the Eurasian Plate known as Sundaland (Hutchison & Tan, 2009). The Malay-Thai Peninsula forms from part of Sundaland and is an elongated NW trending southern tip (Kasim. S, et al, 2020). The Sibumasu Terrane, the Sukhothai Arc, the Indochina Block, the West Sumatra Block, the West Burma Block, the SW Borneo Block, and the Semitau Block make up the continental core of Sundaland.

The Sibumasu Terrane, which was generated from the NW Australian Gondwana border in the late Early Permian, includes the Western Belt. The Sukhothai Arc, which was built in the Late Carboniferous and Early Permian on the edge of the Indochina Block, is represented by the Central and Eastern Belts (derived from the Gondwana margin in the Early Devonian). When back-arc spreading occurred in the Permian, this arc was eventually cut off from Indochina.

The Sibumasu Terrane (Western Belt) and Sukhothai Arc (Central and Eastern Belts) are separated by the Bentong-Raub suture zone, which also preserves remnants of the main Palaeo-Tethys ocean basin that was destroyed by subduction beneath the Indochina Block/Sukhothai Arc and gave rise to the Permian-Triassic andesitic volcanism and I-Type granitoid found.

Peninsular Malaysia can be divided into three north-south trending zones based on the difference in stratigraphy, mineralization, and structure (Ramli, S & Samsudin, R, 2014). The divided zones are named Central Belt, Eastern Belt, and Western Belt. In addition, the "North-West Domain" located within the Western Belt has been proposed by some authors (e.g., Hutchison & Tan, 2009).

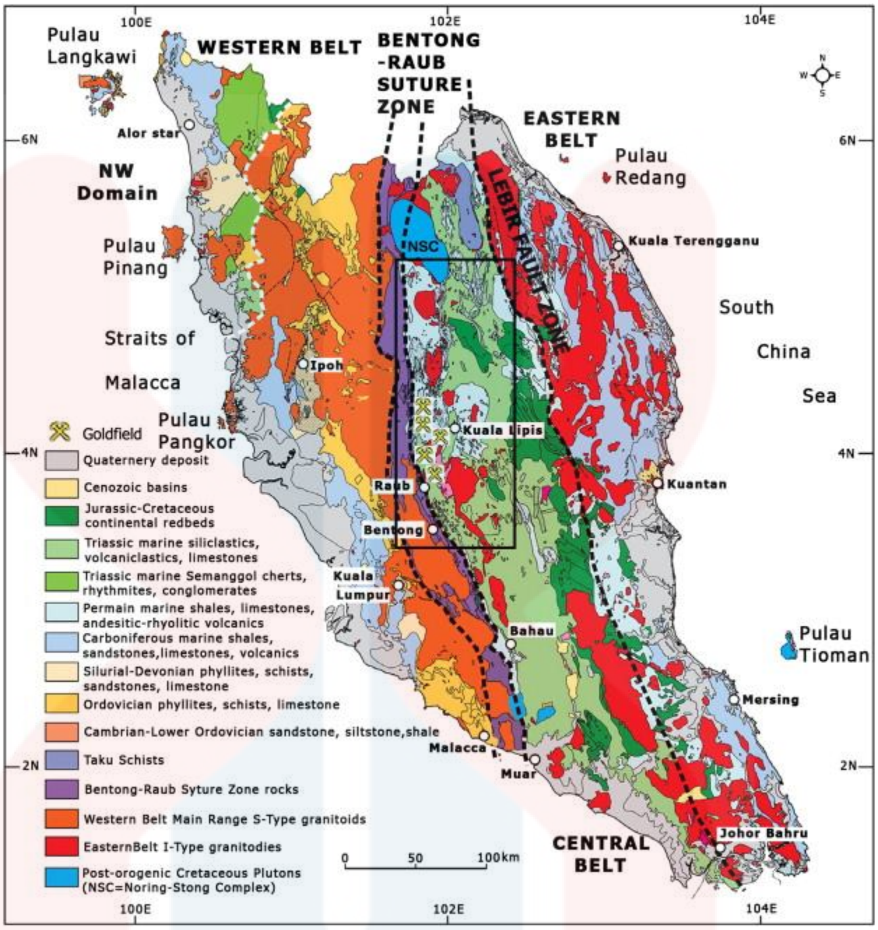


Figure 2.1: The figure shows the map with a divided belt zone.

The Central Zone is the band that runs from Kelantan in the north to Johor in the south, from the eastern foothills of the Main Range to the Lebir fault's eastern boundary to the western boundary of the Dohol formation in the south (Lee. C. P, et al, 2004). The Eastern Zone runs from east Kelantan in the north to east Johor in the south, passing via Terengganu and east Pahang (Lee. C. P, et al, 2004). The Western Zone is the area close to the flanks of the Main Range granite batholith that runs from the Perak – Thai border southwards to the state of Malacca. The Northwestern Zone encompasses the states of Kedah, Perlis, and Langkawi.

The Palaeozoic, Mesozoic, and Cenozoic rock formation periods can be used to categorize the general geology of Perak. The Papulut Quartzite and Gerik Siltstone from the Baling Group, the Trolak Formation, the Belata Formation, the Lawin Tuff, the Kinta Limestone, the SalakBaharu Beds, and the Kati Beds make up Perak's Palaeozoic rock formations. Semanggol Formation is the sole Mesozoic rock formation found in Perak, while Enggor Coal Beds, Boulder Beds, Old Aluvium, Simpang Formation, Simpang Formation, Young Aluvium, Cula Formation, Lawin Basin Deposit, and Beruas Formation are all Cenozoic rock formations.

Perak is in the western belt of Peninsular Malaysia. The baling group is one of the group formations on the Western Belt of Peninsular Malaysia. The formation that makes up Baling Group are the Bendang Riang formation, Gerik Formation, Lawin Tuff, Papulut Quartzite, and Kroh Formation. The study area's formation is found to be in Gerik Tuff or known as Gerik Formation.

Figure 2.2: Geological map of Perak state. (Source: Lee et al.)

The pyroclastic strata are part of the pre-granitic sedimentary rocks that make up the Baling Group, which is present throughout the Main Range. The Grik pyroclastic member is the name given to these pyroclastic facies. The strata at Baling, Kedah, are being extended south-east by the sediments. The group has several facies, including calcareous, argillaceous, and arenaceous facies. Pyroclastic facies are also present in this formation however, it is challenging to pinpoint where the sedimentary and volcanic facies meet since tuffaceous elements are increasingly contaminating the detrital deposits. The sequence as a whole has undergone both thermal and dynamic metamorphism.

2.3 Stratigraphy

The location of study area is on the East-West Highway of Gerik, Perak, which lies on the Western Belt of Peninsular Malaysia. Two main stratigraphic groups in the western zone are the Baling group of Cambrian to Permian age, consisting of Papulut quartzite, Gerik Siltstone, Lawin tuff, and Bendang Riang formation in north Perak, and the Bentong group (Lee. C. P, et al, 2004). It also consists of the Pilah schist and its correlatives and the Karak formation, which is distributed as an unbroken belt along the eastern foothills of the Main Range (Lee. C. P, et al, 2004). The formation of the study area is found to be a part of Gerik Siltstone. According to Lee. et al (2004), the age of Gerik Siltstone from Upper Ordovician to Upper Silurian. Lithology that is distributed on Gerik Siltstone is Carbonaceous Siltstone.

2.4 Structural Geology

Structural Geology is the study of the change in rock structure due to force applied which forms tectonic activities of the Earth. Baling group shows a rather constant that lies on the NE strike, which is approximately perpendicular to the overall trend of the Malay-Thai Peninsula (Burton, 1986). The common structures seen were limestone and calc-silicate, and argillites in the Kroh formation (Burton, 1986). The geological structure of Gerik, Perak is largely consistent with the Malay Peninsula's regional tectonic tendencies (Kee. S, et al, 2014). The complex evolution of structures has resulted from the deformation of Lower Palaeozoic rocks. The Gerik area of Lower Palaeozoic rocks folds into a sequence of structures with steeply descending limbs. On top of the core structures, little folding may be seen. The synclinal axis going southwards is the most notable structure. Argillaceous rocks make up the core of this syncline (Kee. S, et al, 2014).

2.5 Historical Geology

The Malaysian Working Group introduced the term Gerik formation, previously known as Grik tuff (Jones, 1970 & Burton, 1986). Gerik town (Malaysia), located in the southern section of the Transect area, is fairly developed (Amnan. I, et al., 2009). The formation is made up of rhyolitic to rhyodacitic tuffs metamorphosed on occasion. These tuffaceous rocks contain clastic limestone deposits and calcareous shale lenses in varying proportions. Tuff, limestone, and calcareous shale interbeds are also present (Amnan. I, et al., 2009). The Gerik formation overlies both the Kubang Pasu/Yaha Formation and the Kroh formation. Anisopyge sp. and Phillipsia sp. (trilobite) in calcareous shale interbedded with tuff and sandstone at Kampung Batu 2, Gerik, suggests that the Gerik formation is Permian in age (Amnan. I, et al., 2009). This rock unit also contains chonetids (brachiopods) (Amnan. I, et al., 2009).

2.6 Petrology

Petrology of metamorphic rocks is the study of the composition, microstructure, and texture of crystalline rocks. It has undergone chemical, mineralogical, or microstructural changes under high pressure and temperature conditions. Metamorphic rocks can be classified based on their texture and mineral composition. If the sample has fine-grained mineral composition, further studies need to be done, such as petrography analysis and geochemical analysis, to identify its metamorphic rock types.

2.6.1 Metamorphic Rock

Metamorphic rocks are classified on the characteristic of texture and composition, which usually is related to determining the rock type. Metamorphic rock can be distinguished into two types foliated and non-foliated metamorphic rocks. Foliated and lineated metamorphic rock refers to rock's planar and linear fabric elements and has no genetic connotations.

2.6.2 Metamorphism

Metamorphism is a rock-changing process that involves changes in mineral composition and microstructure. Metamorphism is usually in a solid-state under the conditions between diagenesis and large-scale melting (Winter, J. 2014). The exposure of rock to the physical and chemical environment causes metamorphism. A few metamorphic agents that result in the metamorphism process are temperature, pressure, the nature of the fluid, and the state of stress. IUGS/SCMR recommends that metamorphism can be classified into five types of metamorphism (Winter, J. 2014). Contact metamorphism, regional metamorphism, hydrothermal metamorphism, fault-zone metamorphism, and impact or shock metamorphism are the different types of metamorphism.

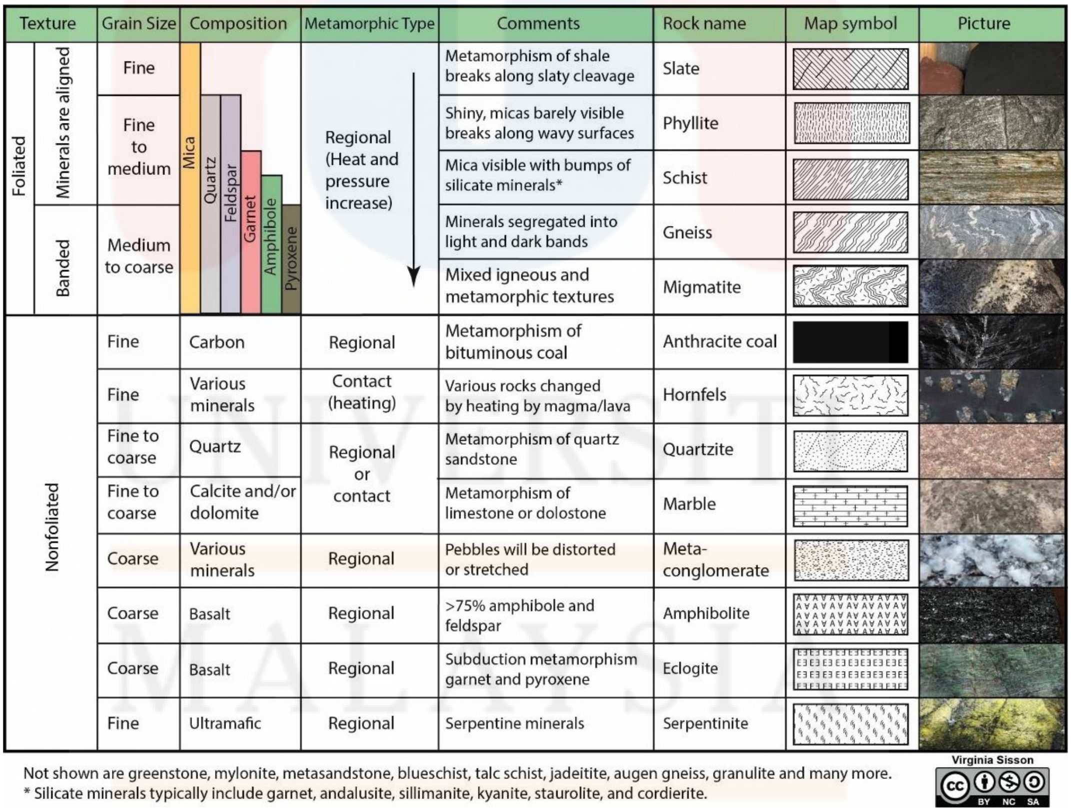
Thermal and dynamic metamorphism has also had an impact on the pyroclastic-sedimentary succession. Low grade metamorphic rocks have been created via thermal metamorphism. Dynamic metamorphism led to the development of cleavage and foliation, as well as the transformation of shale into phyllite. The platy structure of limestone strata is the result of mineral grain elongation. Despite these modifications, the Gerik pyroclastic member continues to be the one most severely impacted.

Gerik formation consists of pyroclastic, calcareous, arenaceous, and argillaceous facies (Kee, S., Ismail, M & Kadir, A, 2014). The pyroclastic facies are mostly made up of rhyolitic to rhyodacitic tuffs (Kee, S., Ismail, M & Kadir, A, 2014). Tuffs, limestone, and calcareous shale interbeds are also found. These tuffaceous rocks contain clastic sandstone, limestone, and calcareous shale lenses in varying proportions. As a result of regional metamorphism, foliation can be visible in the groundmass of tuffs in some areas.

2.6.3 Mineral Assemblages

Metamorphic rocks are characterized by a complete change in mineral assemblage or a shift in the compositions of pre-existing mineral phases. The resulting mineral assemblage will reflect the original rock's chemical makeup and the new pressure-temperature conditions it is exposed to.

As the temperature and pressure on the rock rise, progressive or prograde metamorphism takes place. A rock with a certain chemical composition is anticipated to experience a continual sequence of chemical reactions with any fluid phase present as the pressure and temperature rise, resulting in several new mineral assemblages that are stable at higher pressures and temperatures.



Texture	Grain Size	Composition	Metamorphic Type	Comments	Rock name	Map symbol	Picture
Foliated – Minerals are aligned	Fine	Mica, Quartz, Feldspar, Garnet, Amphibole, Pyroxene	Regional (Heat and pressure increase)	Metamorphism of shale breaks along slaty cleavage	Slate		
Foliated – Minerals are aligned	Fine to medium			Shiny, micas barely visible breaks along wavy surfaces	Phyllite		
Foliated – Minerals are aligned	Fine to medium			Mica visible with bumps of silicate minerals*	Schist		
Foliated – Banded	Medium to coarse			Minerals segregated into light and dark bands	Gneiss		
Foliated – Banded	Medium to coarse			Mixed igneous and metamorphic textures	Migmatite		
Nonfoliated	Fine	Carbon	Regional	Metamorphism of bituminous coal	Anthracite coal		
Nonfoliated	Fine	Various minerals	Contact (heating)	Various rocks changed by heating by magma/lava	Hornfels		
Nonfoliated	Fine to coarse	Quartz	Regional or contact	Metamorphism of quartz sandstone	Quartzite		
Nonfoliated	Fine to coarse	Calcite and/or dolomite	Regional or contact	Metamorphism of limestone or dolostone	Marble		
Nonfoliated	Coarse	Various minerals	Regional	Pebbles will be distorted or stretched	Meta-conglomerate		
Nonfoliated	Coarse	Basalt	Regional	>75% amphibole and feldspar	Amphibolite		
Nonfoliated	Coarse	Basalt	Regional	Subduction metamorphism garnet and pyroxene	Eclogite		
Nonfoliated	Fine	Ultramafic	Regional	Serpentine minerals	Serpentinite		

Not shown are greenstone, mylonite, metasandstone, blueschist, talc schist, jadeitite, augen gneiss, granulite and many more.
* Silicate minerals typically include garnet, andalusite, sillimanite, kyanite, staurolite, and cordierite.

Figure 2.3: Metamorphic rock classification by texture, protolith, mineralogy and type of metamorphism. (Source: Sisson, 2018)

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

This chapter will be discussed several materials and methodologies that will be used in this research. There is a list of the equipment and materials that will be listed providing the method description, which includes the data collection, data processing, and data interpretation. Also, several methods that used to complete the study of geological and the specification of the study area. A few methodologies initially decided to conduct the investigation. Additionally, it will allow the other parties to carry on this analysis utilizing the mentioned law as well as enable the examination to collect information to examine information.

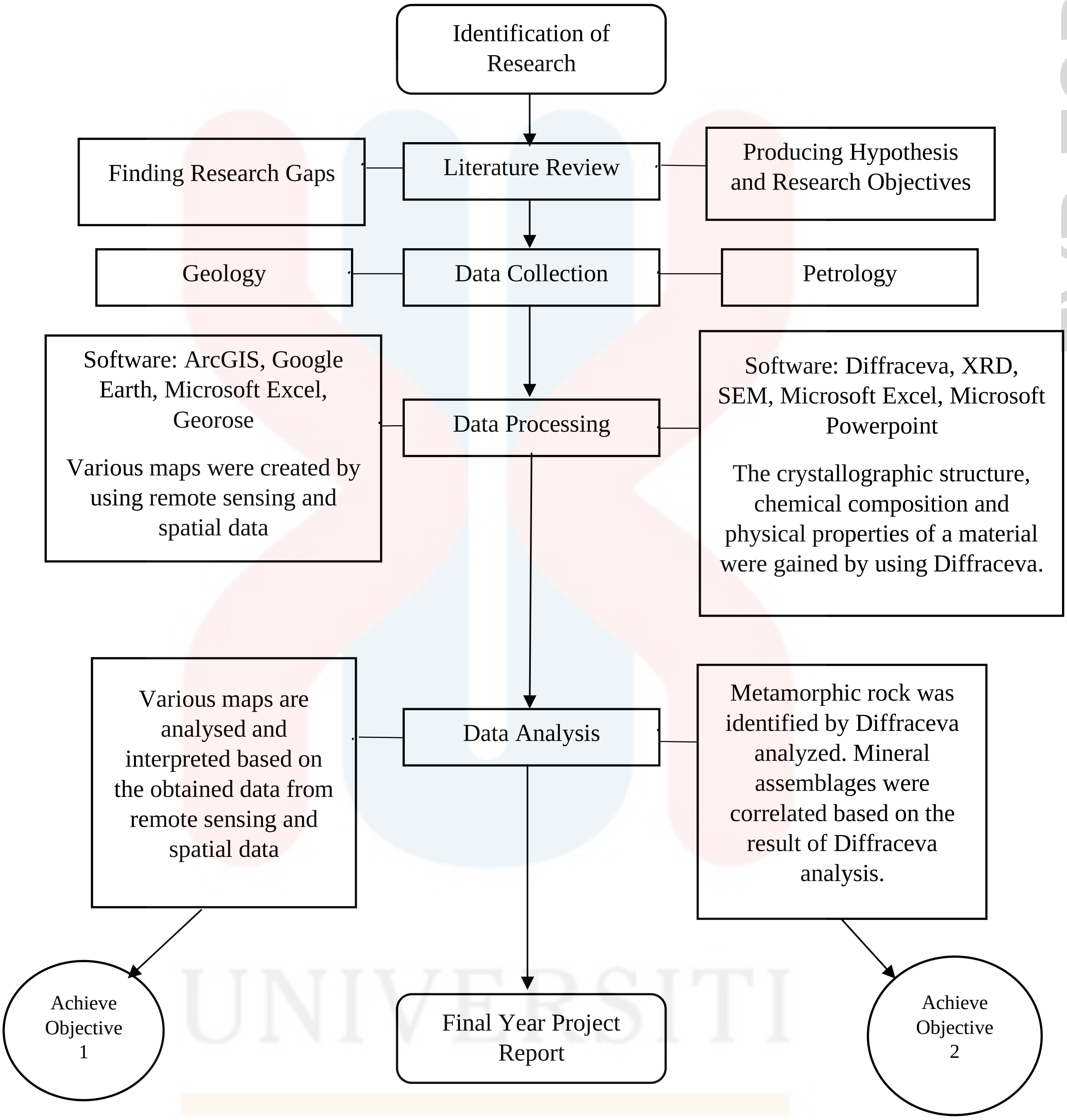


Figure 3.1: Research Flow Chart of Primary data

3.2 Materials / Equipment

Material and equipment to do mapping also collect the sample are important things for a geologist. GPS, also known as Global Positioning System, is a satellite-based navigation system. It is used to mark the study area's location as it can provide information such as latitude, longitude, and elevation. Second, geological hammer. This hammer is used for splitting and breaking the rock from the outcrop. Third, Brunton compass. Brunton compass is used to measure detailed geological mapping, such as measuring strike and dip, determining the magnetic declination, and measuring the bearing of a geological structure.

Fourth, a magnification lens is an important piece of equipment to identify the mineral with the naked eye on the field, making the first field analysis before undergoing the petrographic analysis. Fifth is a notebook, which is used to write the data collected while mapping. This notebook is important as it will store the data securely. A few applications and software will use to generate data from this research, such as Google Earth, Microsoft Excel, ArcGIS, GCDKit, Georose, and DiffracEVA. Google Earth applications will help obtain the aerial image of the study area. The data collection will organize using Microsoft Excel. ArcGIS software will be used to manage and extract the spatial data. GCDkit or Geochemical Data Toolkit software is a system for calculating whole-rock analysis. Georose software for producing a rose diagram was obtained by plotting the data of structural geology collected in the study area. Lastly, DiffracEVA is a software that will evaluate x-ray diffraction.

3.3 Methodology

This section will be divided into five parts which include preliminary studies, field studies, petrology analysis, data processing, and data analysis and interpretation. Comprehensive interpretation and procedures will be presented for every methodology in this research. This part also includes the methodology used for taking primary data.

3.3.1 Preliminary Studies

The preliminary study is important before conducting a field study. It is used to know the research project viewpoint of the study area, such as rock types and distribution, formation, geomorphology, and geological condition. This preliminary study includes reviewing literature papers, journals, and books. Reviewing literature review to identify research issues related to the metamorphic rock mineral assemblages to gain extra information from the research. Reviewing the journal and book was referred to identify the details about metamorphic rock mineral assemblages.

3.3.2 Field Studies

Field study relates to primary data collection. These involve part of geological mapping to record the geological information of the study area. Geological mapping is required for obtaining geological information such as lithology, geomorphology, stratigraphy, petrology, and mineralogy. Field activities include taking the strike and dip data, joint systems, outcrop sketching, and collection of rock samples. A field study usually takes about two weeks to complete geological mapping of the study area.

3.3.3 Petrology Analysis

The sampling approach was collected in the study region to better analyze petrology and petrography aspects. At least ten samples must be collected to generate a decent result and analysis of metamorphic rocks. The samples were then gathered before being processed in the lab to create thin-section specimens.

1. Petrography

a) Hand specimen

The rock sample collected from the study area must be fresh from the outcrop. If the weathered samples were collected, it would affect the analysis of rock. The hand specimen analysis is observed by a magnification lens to determine the mineral composition and rock structure.

b) Thin Section

A thin section is performed to determine the collected samples' mineral composition and texture characteristics. The Polarized Light Microscope was used to examine thin sections. Numerous procedures must complete by producing high-quality thin sections. Sectioning, impregnation, precision sectioning, bonding, resection, and grinding and polishing are procedures that need to do for producing the thin section.

Thin Sections Procedure:

i) Verify that the glass slide is frosted, flat, and of a consistent thickness.

ii) Next, the rock sample's area must be chosen before being sliced into a thin section.

iii) The third step involves cutting a slab. A drill core or chunk of rock is chopped to the right size for installation on a slide using a diamond saw.

iv) The slab's initial lapping follows. The slab has labels on one side, and the other side has been lapped flat and smooth using 400 grit carborundum on a cast-iron lap, followed by 600 grit carborundum on a glass plate.

v) An epoxy adhesive is used to secure a glass slide to the slab's lapping face after it has dried on a hot plate.

vi) The slab is cut off close to the slide after being divided into sections using a thin section saw. On a thin section grinder, the thickness is further decreased.

vii) Final lapsing is required before polishing. The section is lapped by hand with 600 grit carborundum on a glass plate to a final thickness of 30 microns. Before polishing, fine grinding with 1000 grit is optional.

viii) The slice is then set in a holder and spun on a polishing machine using nylon cloth and diamond paste until the polish is appropriate for SEM or microscopy examinations.

c) XRD Analysis

The sample was processed by X-Ray Powder Diffraction (XRD method) where this method is used to analyze the properties like phase composition, structure, and texture (Ermrich & Opper, 2013). For experimental analysis, each sample was pounded until it becomes powder. The optimal particle size of powder diffraction samples is 1 to 5 µm (Ermrich & Opper, 2013). A 0.2g to 0.7g amount of sample powder is needed use for analysis. This analysis will provide the result of the structure materials, such as grain size and crystalline orientations.

Figure 3.2: X-ray Powder Diffraction instrument.

d) SEM Analysis

Scanning Electron Microscope (SEM Method) is another method to process data used in this research. The SEM analysis will provide data on crystallographic structure and elemental composition. The SEM sample is obtained by gently breaking the rock with a small rock shopper or X-acto knife (Lorenz, J. 2003). The optimal size for the final sample is generally around 5 by 10 by 10 mm. The sample will then be coated with a conductive material to obtain a clear image of a rock sample.

Figure 3.3: Scanning Electron Microscope (SEM) instrument.

3.3.4 Data Processing

To produce a new geological map and additional supportive map of Gerik Ecological Corridor, Gerik, Perak, geological data obtained by fieldwork studies, remote sensing, and spatial data were transferred to ArcGIS software. Petrological data were obtained by the petrology analysis which will be transferred to excel before plotting for determining whole rock analysis.

3.3.1 Data Analysis and Interpretation

Using the Arc GIS program, the data analysis from this study is being used to create the most recent geological map. It is a geographic information system (GIS) for making and utilizing maps and geographic data. Following the completion of the thin section examination for mineral identification, the petrographic analysis will be conducted. The relative mineral phase composition of the kind of rock can be estimated using XRD and SEM.

CHAPTER 4

GEOLOGY

4.1 Introduction

This general geology chapter will be discussed the specific geology information of Gerik, Perak area which includes geomorphology, lithology, structural geology and historical geology based on interpretation results from the field study. Geological mapping was done to collect all the data needed for this chapter's analysis. ArcMap was mainly used in this chapter to interpret the field data into the map. Maps such namely topography, drainage pattern, and lithology will be created to understand more about the study area. Also, some structural applications are used to analyze the structural data that have been collected in the study area. In addition, the data that have been collected in the field were used to create a geological map of the study area with a scale of 1:25,000.

4.1.1 Accessibility

The accessibility that has on study area is the main road of East-West Highway which connected three states which are Kedah, Perak and Kelantan. The total distance of East-West Highway is about 215.5 km. The access to the study area from Universiti Malaysia Kelantan is using the main road. It takes about an hour to go there by car. While from the study area to Gerik town, it also takes about an hour trip to go by car. Both routes have the same total distance which is 60 km.

Figure 4.1: The main road that can be accessed to the study area.

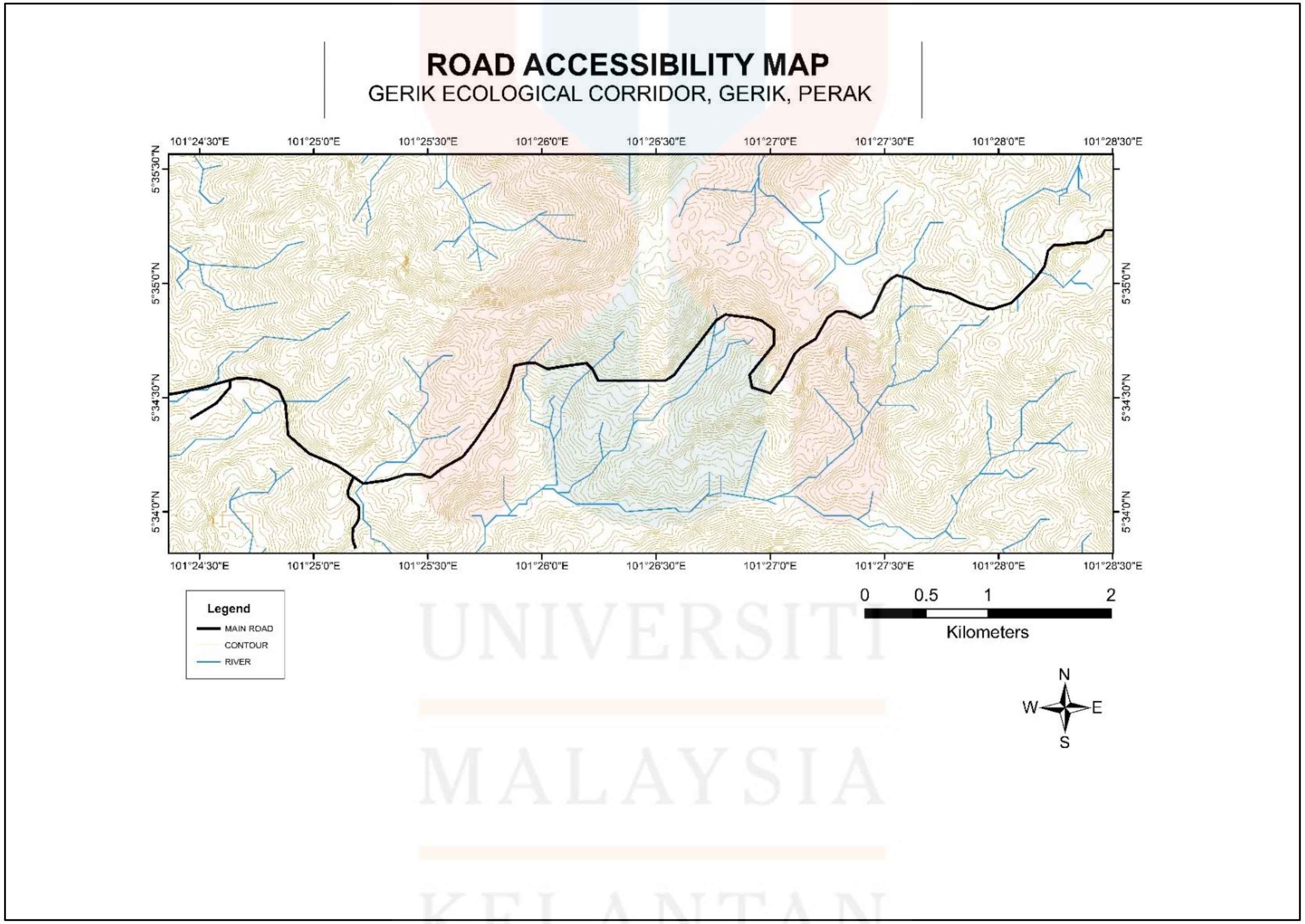


Figure 4.2: The figure shows road accessibility that connected the study area from Gerik, Perak to Universiti Malaysia Kelantan, Jeli.

4.1.2 Forestry (Vegetation)

The study area on Gerik Ecological Corridor, Gerik, Perak is located at the place known as Central Spine Forest (CFS). The CFS is made up of three different forests reserved on Gerik Ecological Corridor, Gerik, Perak. The CFS forest reserved are Temengor reserved forest, Amanjaya reserved forest and Belum reserved forest. This CFS has approximately about 18,866 hectares covering East-West Highway. Figure 4.3 shows the central location of CFS that is located in the study area.

Figure 4.3: The central location of CFS in the study area.

4.2 Geomorphology

Geomorphology is the study of the nature and history of landform and the processes which creates them. It is commonly occurring and created by the physical and chemical processes at the Earth's surface. Geomorphological processes such as endogenic and exogenic processes will form the geomorphological landform of an area.

4.2.1 Topography

Topography is the elevation form and changes in a particular area. The elevation difference is resulting from the processes of erosion and deposition that occur in that area. The process creates different landforms in an area which results in many different contours and elevation lines. As shown in Table 4.1, the contour line's altitude values reveal varied relationships between the morphological components in the study area. It has been characterized according to Van Zuidam (1985) classification.

Table 4.1: Relationship between absolute altitude with morphology (relief).

Absolute Altitude (m)	Morphology/Relief
<5	Lowland
5-100	Low-lying Plain
100-200	Low Hills
200-500	Hills
500-1500	High Hills
1500-3000	Mountains
>3000	High Mountains

Source: Van Zuidam (1985)

Based on Figure 4.4, shows that the study area has three different morphology that covered the study area which are low hills, hills, and high hills. The highest elevation or known as the high hills is 900 m which is located in the Northeastern part of the study area. Besides, the lowest elevation or low hills is 200 m. It is located in the Southwestern part of the study area. The area that covering of hills morphology which is between 200-500 m is located in the center part of the study area. It is covered by the Central Forest Spine (CFS) which includes Temengor reserved forest, Amanjaya reserved forest and Belum reserved forest.

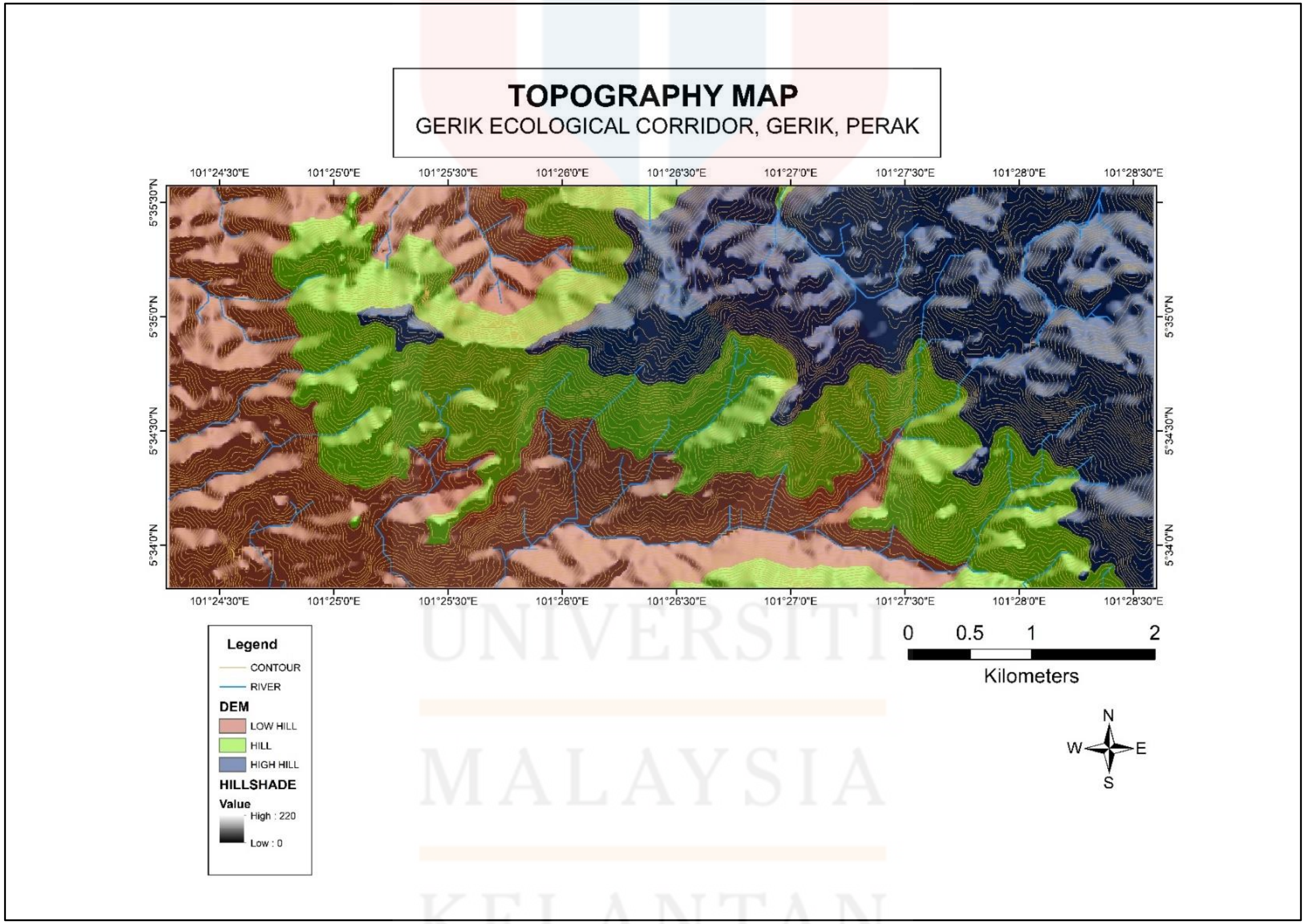


Figure 4.4: The figure shows a topography map of the study area.

4.2.2 Weathering

Weathering is the process of breakdown or dissolution of rocks and minerals on the Earth's surface. According to Xystouris. et al (2021), agents of weathering include water, ice, acids, salts, plants, animals, and temperature variations. After a rock has been fractured, the fragments of rock and minerals are carried away by a process known as erosion. Weathering has three different processes which are chemical weathering, biological weathering, and physical weathering. This process will occur on-site or with little or no movement occur.

Physical weathering is the process of rock disintegration without changing its chemical properties. Due to the temperature changes, physical weathering occurs causing the breakdown of rock into smaller fragments by the process such as contraction and expansion. Figure 4.5 shows the mica schist outcrop that has undergone physical and chemical weathering.

Chemical weathering requires the interaction of rock with mineral solutions to alter the composition of rocks. Chemical weathering is mostly causes by the water flow whether it’s from rainwater or flow water underneath the rock surface. This chemical weathering has four different processes which are carbonation, hydration, oxidation, and hydrolysis.

Next, biological weathering is the process where the plant, animals, and bacteria break down the rock until it influences the landscape formation. This weathering is such the root of the plant extruded the outcrop which will break the rock apart from the original. Figure 4.6 shows the outcrop that has plant intruded on it causing the change in the outcrop appearance, especially in terms of rock structure.

Figure 4.5: The outcrop that undergoes physical and chemical weathering.

Figure 4.6: The outcrop that undergoes biological weathering.

4.2.3 Drainage Pattern

In a particular drainage basin, the drainage pattern will form by the streams, lakes, and rivers. Regional geology controls drainage patterns, which show how structures, local slopes, and bedrock erosional properties are controlled. These geologic factors work together to create patterns that can be recognized. The drainage pattern is formed by the influence of the topography of the land, the gradient of the land, and whether a particular region is dominated by hard or soft rocks.

Based on the drainage pattern from the study area, there are consist of two types of drainage patterns which are dendritic drainage pattern and parallel drainage pattern. The study area mainly is made up of dendritic drainage patterns. The pattern is typical without any apparent structure and appears where there is unconsolidated material beneath the stream. While for the parallel drainage pattern, it appears in the south-western direction in the study area. Parallel drainage patterns develop when there is a steep slope to the surface which sometimes indicates the presence of a major fault that cut across an area of steeply folded bedrock.

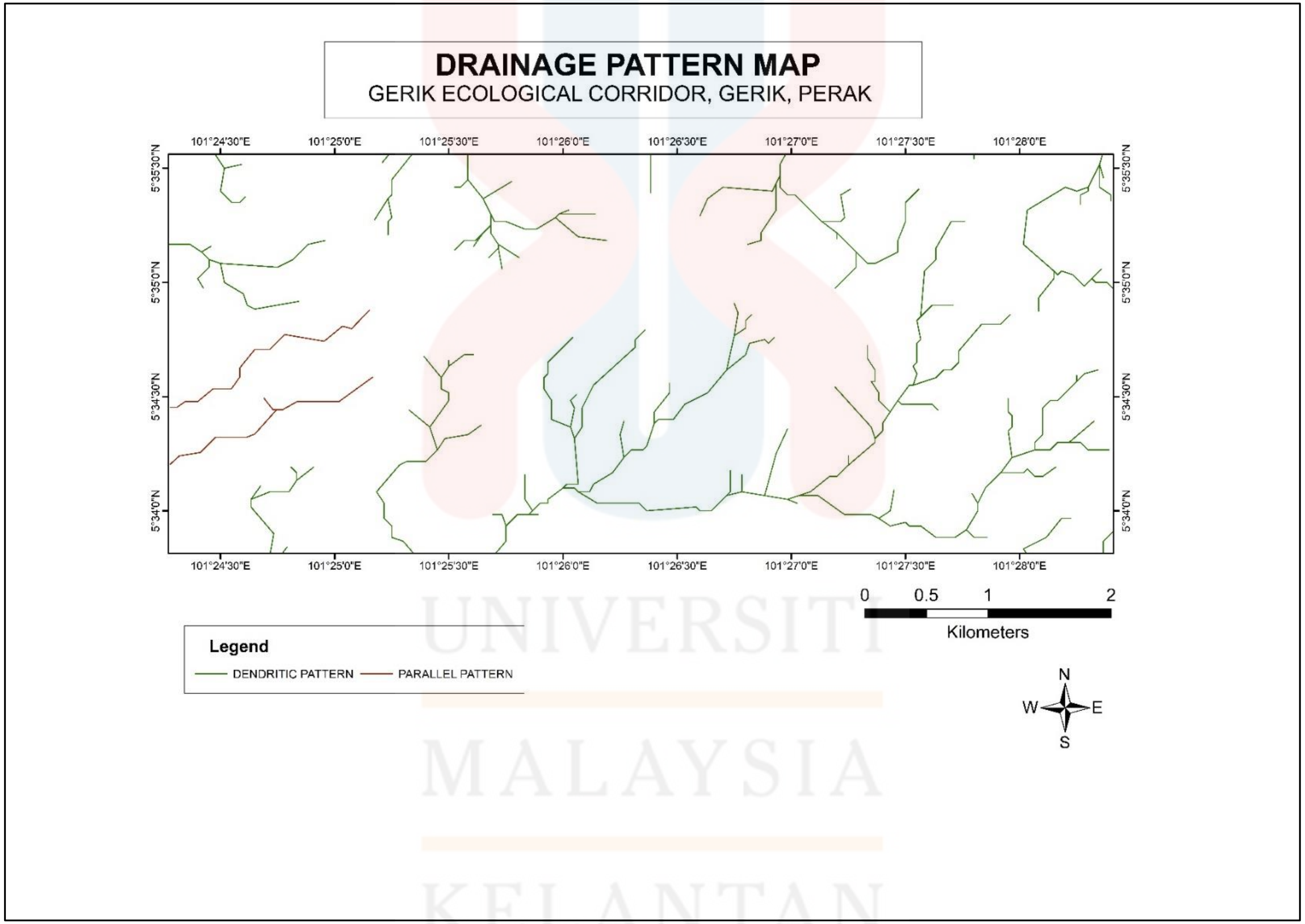


Figure 4.7: The drainage pattern map of Gerik Ecological Corridor, Gerik, Perak.

4.3 Stratigraphy

Stratigraphy is the study of rock layering or as known as strata that already exists in the study area to determine its geological history. Also, it discusses the relationship between the formation of igneous and sedimentary rocks. Lithostratigraphy is one of the sub-disciplines of stratigraphy. It is a study of the categorization of rock bodies based on the observable lithological features of the strata and their respective stratigraphic locations. Based on the study area, it is dominantly consisting of metamorphic rock types such as schist and gneiss. Figure 4.8 shows the map of lithology distributed in the study area.

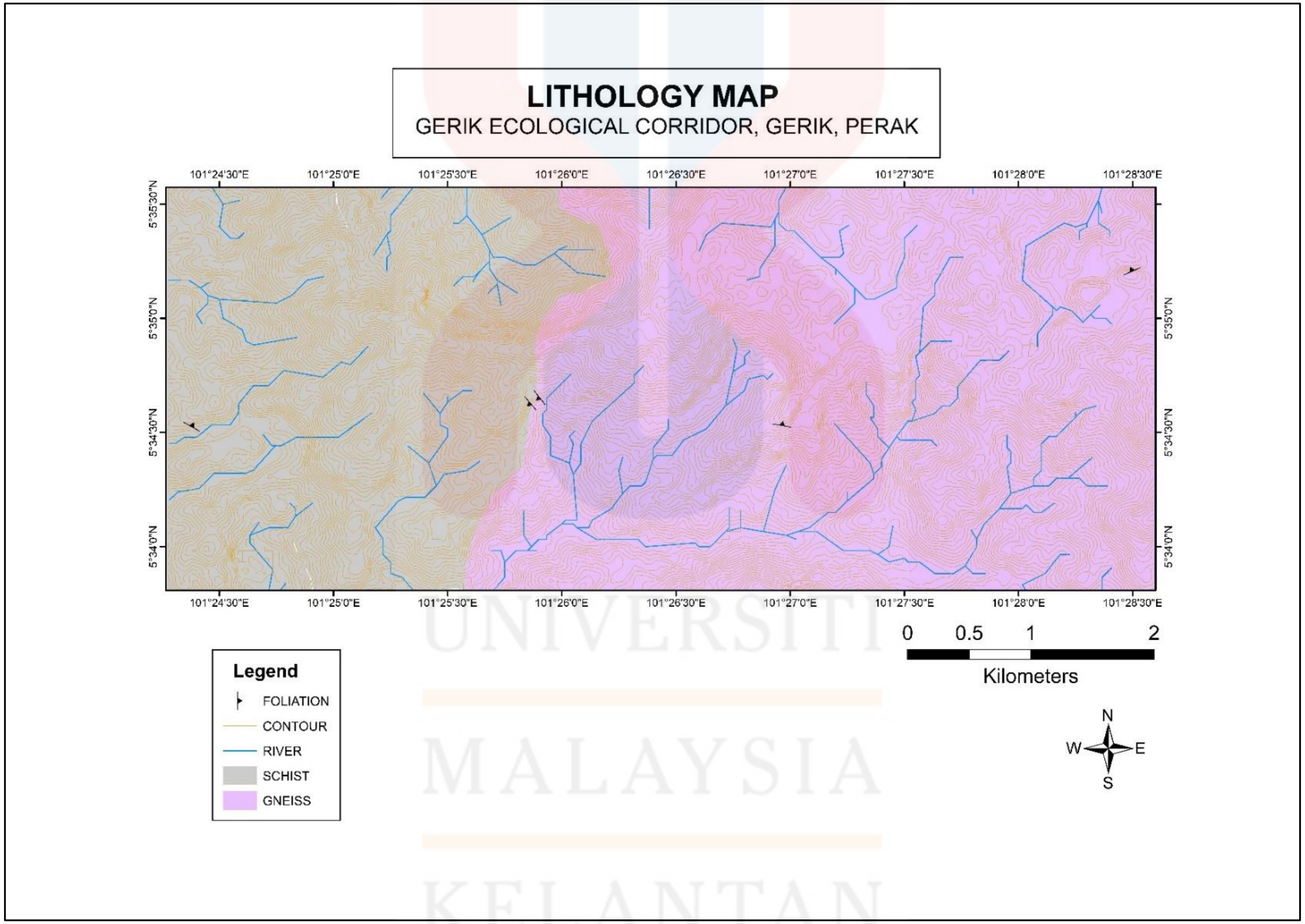


Figure 4.8: The lithology map of the study area.

4.3.1 Lithostratigraphy

Lithostratigraphy is related to the study of the rock sequence. This study also includes about rock age and the stratigraphic column that will be constructed. Apart from that, lithostratigraphy is also one discipline where the characteristic of rock will be studied based on its physical and petrographic features.

Mica Schist unit

Location 1: N 05° 34' 30", E 101° 24' 20"

For sample 1, the outcrop is located at the western part of the study area with the coordinate of the outcrop being 05° 34' 30" N, 101° 24' 20" E. Figure 4.9 shows the approximate outcrop that has been exposed in the study area is about 30 meter long and 10 meter height. The morphology of the outcrop is in a low hill area. Also, the outcrop shows moderately weathered by chemical weathering and physical weathering. This is because most of the part of outcrop has discoloration and the surface of the rock is integrated into the soil. The outcrop was identified as hill cutting outcrop because the area is used to build a road connection between Perak and Kelantan.

Figure 4.9: The outcrop of the Schist.

Based on the hand specimen interpretation in Figure 4.10, the sample is known to be Mica Schist. This is because the sample shows the foliation structure which is made up of plate shaped mineral grains and the grains cannot be seen clearly under the naked eye. The dominant mineral in this schist is mica mineral as it can be seen by the naked eye because physical characteristics show blinking.

Figure 4.10: Hand specimen of schist.

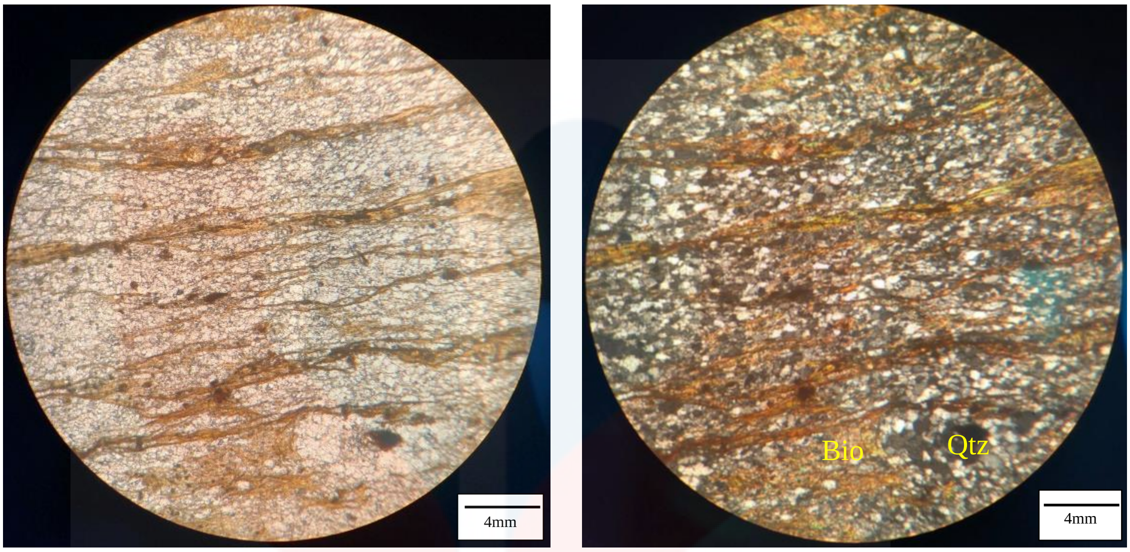


Figure 4.11: The petrography of schist under a thin section with a magnification of 4 x 10.

From the thin section, quartz mineral shows dominantly in this rock. Muscovite is distributed in reddish brown colour in XPL and colourless to brown in XPL. The thin section shows the foliation structure that has on the hand specimen. The rock is known to be schist because of the foliation structure showing clearly on the hand specimen.

Gneiss unit

Location 2: N 05° 34’ 32”, E 101° 26’ 55”

Sample 2 is located in the southern part of the study area with the coordinate of 05° 34’ 32” N, 101° 26’ 55” E. Figure 4.12 shows the outcrop area for sample 2 and the size of the outcrop is 100 meter long and 20 meter height. Morphology of the outcrop at hills morphology and it can see that the outcrop has been moderately weathered by the biological weathering because it is covered by vegetation. The outcrop was identified as hill cutting slope to build a road connection.

Figure 4.12: The outcrop of Gneiss.

From the hand specimen in Figure 4.13, Gneiss shows dark brown coloured when it is weathered, and a fresh sample will have a colour of greyish. The hand sample has a medium size grain. The grain can be seen in brown coloured because it's from the composition of biotite mineral that has on it.

Figure 4.13: The hand specimen of Gneiss.

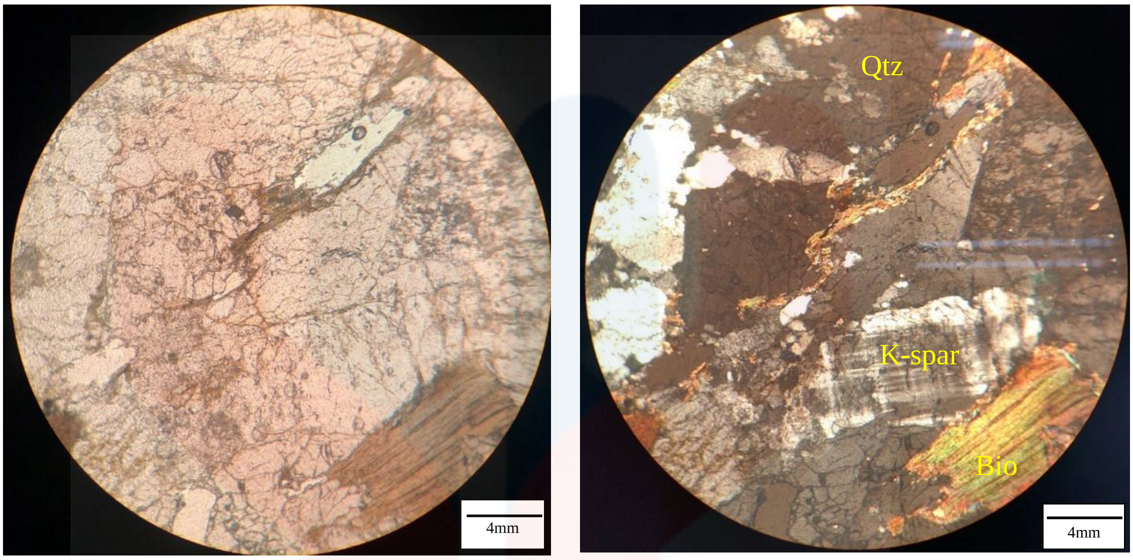
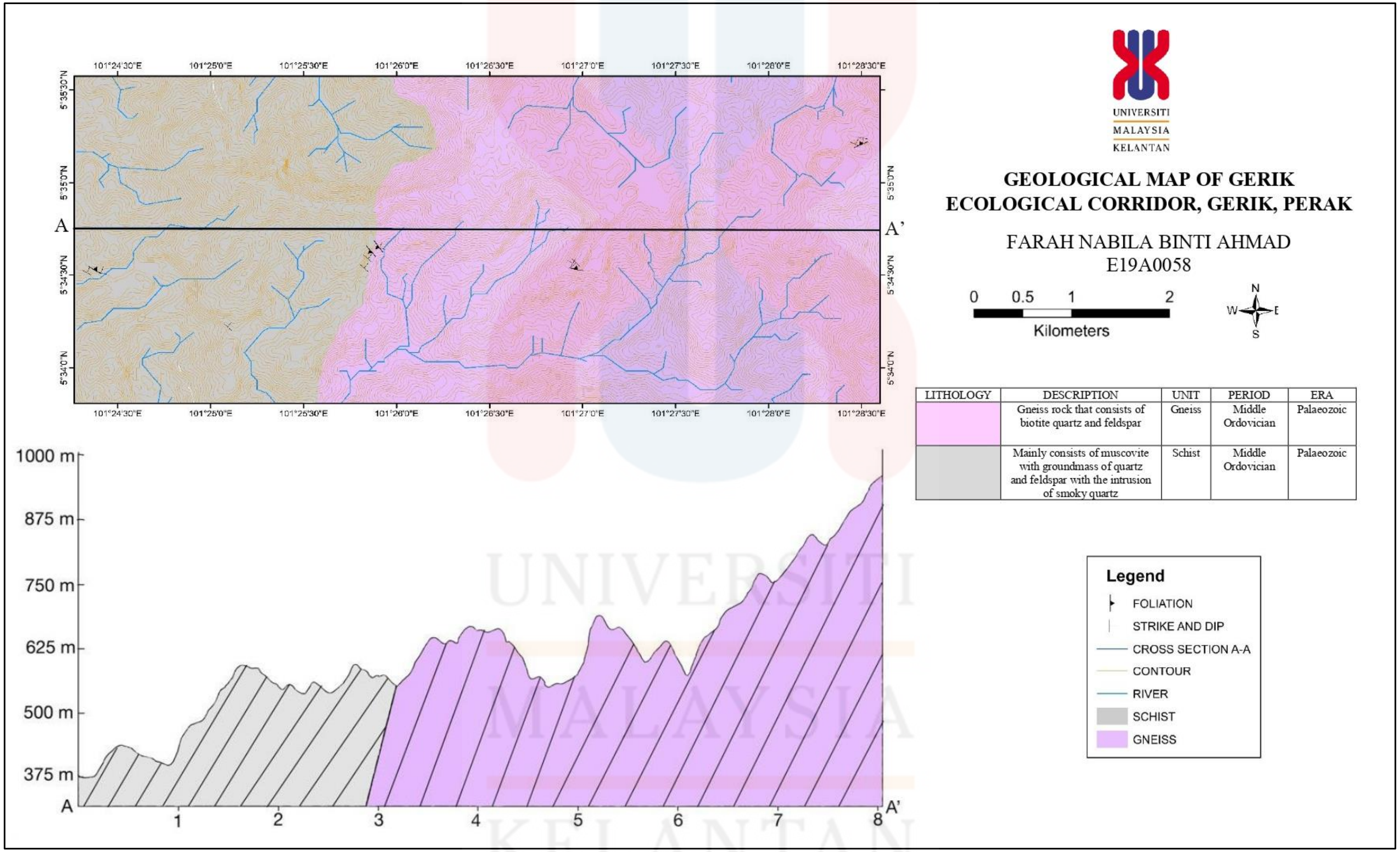


Figure 4.14: The petrography of Gneiss under a thin section with a magnification of 4 x 10.

In the thin section as shown in Figure 4.14, the mineral consists of quartz, plagioclase and biotite with some groundmass of muscovite. The quartz shows colourless in PPL and gray to blackish colour in XPL. While for plagioclase, also shows colourless in PPL and white and greyish in XPL. The plagioclase mineral shows a microcline structure in XPL. The rock is known to be gneiss from this outcrop.



LITHOLOGY	DESCRIPTION	UNIT	PERIOD	ERA
	Gneiss rock that consists of biotite quartz and feldspar	Gneiss	Middle Ordovician	Palaeozoic
	Mainly consists of muscovite with groundmass of quartz and feldspar with the intrusion of smoky quartz	Schist	Middle Ordovician	Palaeozoic

Figure 4.15: Geological Map of Gerik Ecological Corridor, Gerik, Perak.

4.3 Structural Geology

In structural geology, the distribution of rock units in three dimensions concerning their deformational histories is investigated. The main objective of structural geology is to comprehend the stress field that produced the observed strain and geometries by using measurements of the current rock geometries to learn about the history of deformation (strain) in the rocks. A common objective is to comprehend the structural evolution of a specific region concerning regionally widespread patterns of rock deformation (for example, mountain building, rifting) caused by plate tectonics. This understanding of the dynamics of the stress field can be linked to significant events in the geologic past.

4.4.1 Lineament Analysis

Lineament analysis is the information study about the geological structure lying on the earth based on the satellite image of an aerial photograph. The terrain mapping will express the structure such as faulting and others from a large scale. According to S. Hema & T. Subramani (2016), lineament is the weaker zone of bedrock due to the movement of the earth's intersections of lineaments which usually formed a linear, curvilinear, and rectilinear line in the satellite image. Numerous lineaments in the study area were identified from the lineament map produced from the satellite image illustrated in Figure 4.17.

Lineament can be classified into two types which are positive lineament and negative lineament. For the positive lineament, it will show the landform such ridge. While for the negative lineament, it will produce the landform like drainage and valleys. From Figure 4.16, the rose diagram from lineament analysis shows the principal forces in the direction North-East with the value of 50°. The lowest force, in the direction of North-West direction with the value of σ3, is 325°.

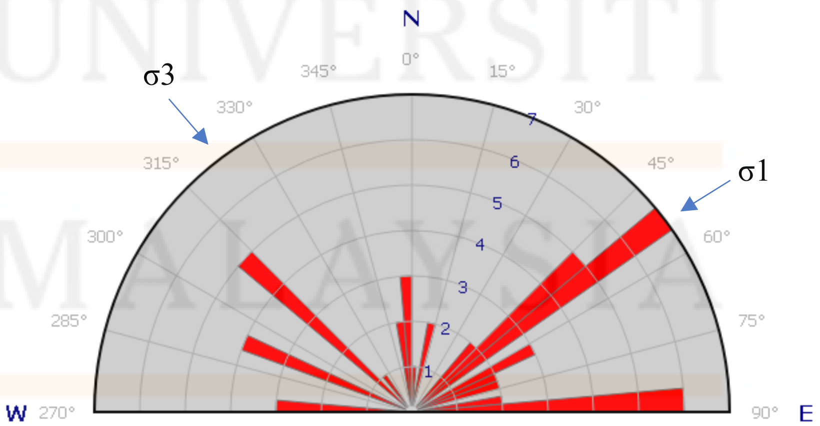


Figure 4.16: The rose diagram for lineament analysis of the study area.

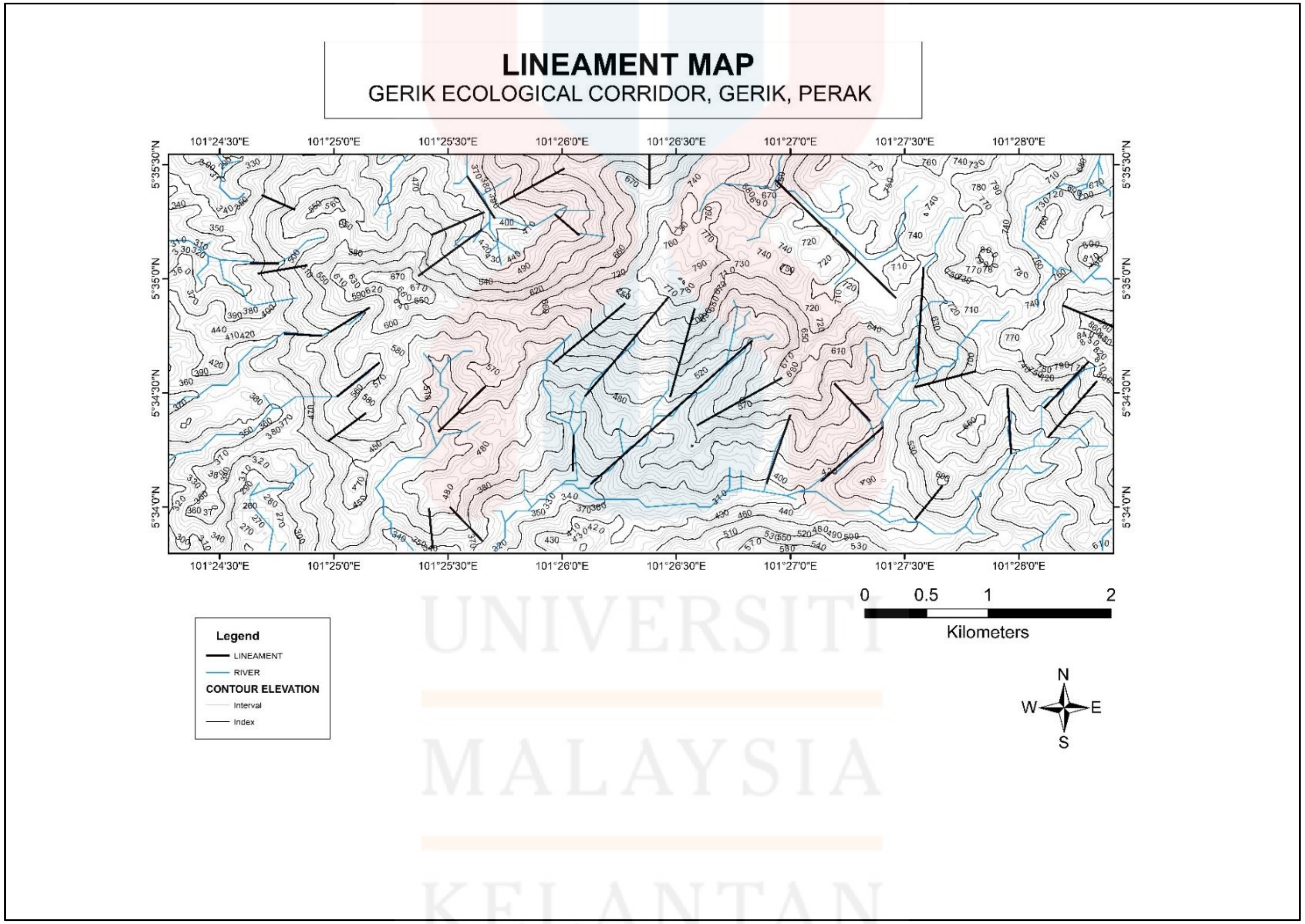


Figure 4.17: The lineament map of the study area.

4.4.2 Joint Analysis

Joints are brittle-fracture surfaces in rocks where little to no displacement has occurred in geology. Also, A joint is a specific kind of extension fracture created when a rock is moved perpendicular to the plane of the fracture.

i) First locality

Coordinate: 05° 34’ 12” N, 101° 25’ 06” E

The joint from the first locality from Figure 4.18 is showing a non-systematic or irregular joint. This irregular joint is formed because of the local or regional stress that is exerted on it when the metamorphism occurs. A reading of 100 strike of the joint is being interpreted and measured. Figure 4.19, shows that the principal force direction is in North-West direction with the value of σ_1 being 315°. The lowest force is in the direction of North-West direction with the value of σ_3, 285°.

Figure 4.18: The outcrop that has joint discontinuities.

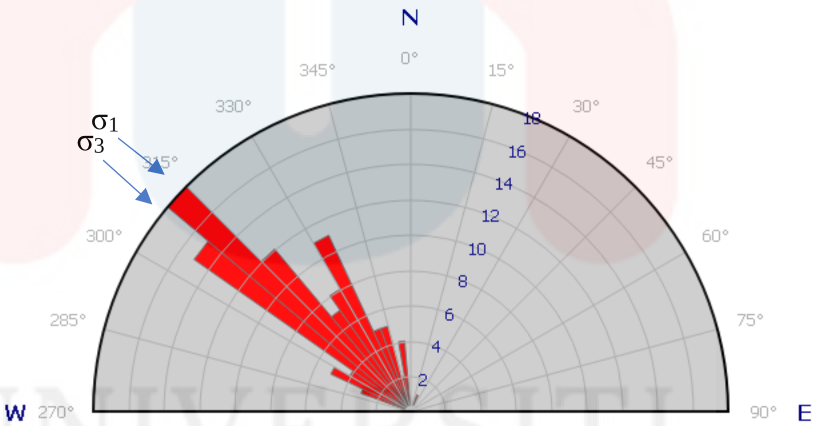


Figure 4.19: The rose diagram for the first locality.

ii) Second locality

Coordinate: 05° 34’ 32” N, 101° 26’ 55” E

The second locality has the columnar joint which forms a vein on the outcrop as shown in Figure 4.20. The columnar joint is filled with quartz that intrudes the rocks while the cooling process occurs. The 100 readings of the strike of the joint are interpreted and measured. Figure 4.21, shows that the principal force is exerted in the direction of North-West direction with the value of σ_1 being 315°. While for the lowest forces, it is in the direction of North-West with the value of σ_3, 270°.

Figure 4.20: The quartz intrusion of the outcrop in the second locality.

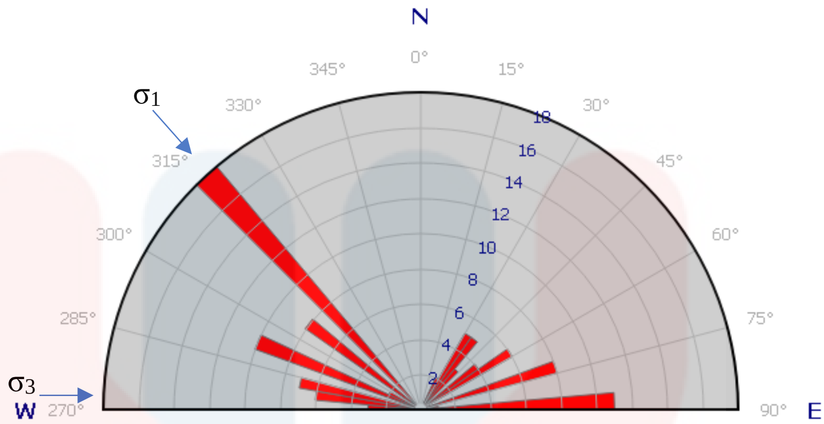


Figure 4.21: The rose diagram for the second locality.

iii) Third locality

Coordinate: 05° 35’ 13” N, 101° 28’ 32” E

From the third locality, Figure 4.22 shows the joint discontinuity that has on the outcrop which is a non-systematic or irregular joint type. This irregular joint must be formed when the protolith of the outcrop has undergone the metamorphism process which causes the rock having exerted pressure. The 100 readings of the irregular joint are measured and interpreted by the rose diagram. From Figure 4.23, the principal force that has on this locality is at the value of σ_1 being 35°, with the direction of North-East direction. For the lowest force which is σ_3, it has a value of 280° with a North-West direction.

Figure 4.22: The outcrop from locality 3 that have a non-systematic joint.

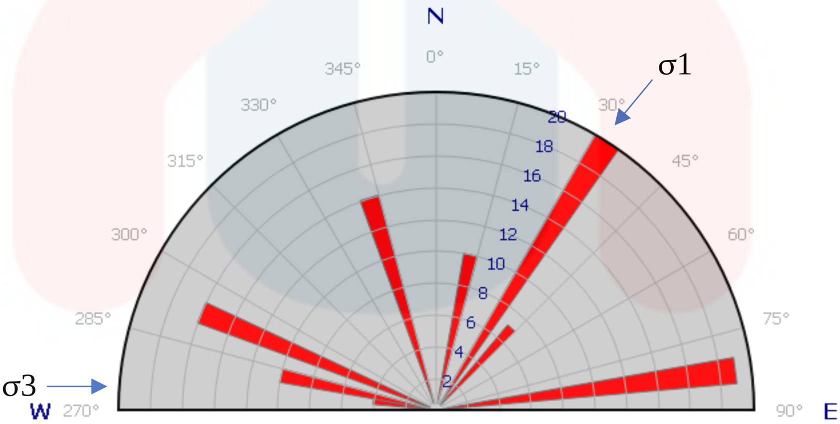


Figure 4.23: The rose diagram for the third locality.

4.4 Historical Geology

Gerik formation is the formation exposed in the study area Gerik, Perak under the Baling Group which consists of Papulut Quartzite, Gerik Formation, Lawin Tuff, Bendang Riang Formation and Kroh Formation (Burton, C., 1986). The lithology of Gerik formation is divided into four main facies: pyroclastic, calcareous, arenaceous, and argillaceous (Amnan, l, et al., 2009). The sub facies of pyroclastic is mainly tuff of rhyolitic to rhyodacitic composition (Amnan, l, et al., 2009). Argillaceous on Gerik formation consists of shale, phyllite, mudstone, siltstone, hornfels and schist sub-facies (Amnan, l, et al., 2009). Calcareous sub-facies are limestone and calc-silicate hornfels (Amnan, l, et al., 2009). Sub-facies of arenaceous are subgreywacke, schist, hornfels and conglomerate (Amnan, l, et al., 2009).

The study area is dominated by the argillaceous facies which can find sub-facies such as shale, phyllite, mudstone, siltstone, hornfels or schist. Gerik formation was formed during Middle Ordovician to Early Silurian. Gerik formation is conformably overlain by the Kubang Pasu formation which consists mostly of low-grade metamorphic rocks.

CHAPTER 5

SEQUENCES OF METAMORPHIC ROCKS MINERAL ASSEMBLAGES

5.1 Introduction

This chapter discussed the sequences of metamorphic rocks mineral assemblages that have been identified based on the data analysis from the study area Gerik Ecological Corridor, Gerik, Perak. The methods used to analyze the sample are petrography analysis, SEM analysis and XRD analysis. The result then will determine the metamorphic rock mineral assemblages that formed in the study area. Mineral assemblages of the rock are the identification of the mineral composition distributed on each rock sample. It can be subdivided into a series of metamorphic zones based on the appearance of a new mineral in metamorphosed pelitic rocks as the metamorphic grade increases. Also, the subdivided zone was characterized based on the new mineral that characterized any particular zone in terms of its index minerals.

5.2 Petrographic Analysis

Petrography analysis is the study of the detailed descriptions of rocks. This study usually involves the study of hand specimens and thin sections. The petrographic analysis starts from the macroscopic description by hand specimen. While for the thin section, the mineral content and textural relationship will be discussed in the microscopic analysis by using a microscope image.

I) Hand Sample Analysis

A total of four samples were gained from the study area. To determine the rock type, hand sample analysis need to study before furthering another analysis.

Figure 5.1: Hand specimen for sample mica schist.

Based on the hand specimen in Figure 5.1, the sample shows foliation or plated structure on it. The hand specimen was taken out from the fresh part of the outcrop. This is because that outcrop is moderately weathered. The mineral observation by hand specimen is hard because its mineral is too small to see by the naked eye. The rock showing brownish colour and shiny minerals can be seen from the hand sample. Shiny minerals are known to be mica minerals. The rock shows the characteristics of low-grade metamorphic rock which is mica schist.

Figure 5.2: Hand specimen for sample schist.

Sample 2 has been taken at the second location with the coordinate of 05° 34' 12" N, 101° 25' 06" E. The hand specimen was taken from the Western part of the study area. The rock has greyish colour if it is fresh rock, but it has brownish colour in weathered rock. The hand specimen has a very fine grain and can't be determined the mineral consists of the naked eye.

Figure 5.3: Hand specimen for sample gneiss.

The third hand specimen was also gained from the second location with the coordinate of 05° 34’ 12” N, 101° 25’ 06” E. The outcrop of this hand specimen is underlain by the outcrop from rock sample schist. This shows the contact between these two outcrops in that location. The outcrop of these samples has greyish colour on the fresh rock and brownish colour on the weathered rock. The hand specimen shows a greyish colour and has a very fine grain. Its mineral cannot be determined by the naked eye.


Figure 5.4: Hand specimen for sample gneiss.

The fourth sample is gained from the Eastern part of the study area. The sample was taken at the coordinate 05° 34’ 32” N, 101° 26’ 55” E. The grain size of the hand specimen shows medium grain size. The hand specimen shows dark brown as the sample has undergone weathering processes. The mineral shown on the rock can be interpreted as quartz, biotite, and alkali feldspar as it shows its physical characteristics of it clearly. The hand specimen the further will look over by the thin section analysis for further knowing about the mineral characteristics. The rock is known to be in high grade metamorphic rocks which is gneiss because it has a medium grain size.

II) Thin section analysis

Thin section analysis is the analysis of rock samples to determine the mineral composition, the structure of a crystal and its texture. The hand specimen is analyzed under the microscope under two different modes which are using plane-polarized light (PPL) and cross-polarized light (XPL).

MICA SCHIST

From the photomicrograph thin section sample analysis, the sample shows mica minerals in platy mineral foliated orientation with the groundmass of minerals quartz and feldspar. The thin section shows biotite which is a mica mineral with a brownish colour in PPL and brown with some blackish colour in XPL. The biotite minerals appear in platy and foliated orientation. For the groundmass of quartz, it is colourless in PPL and greyish to white colour in XPL. The quartz mineral has undergone deformation as most of the quartz has become anhedral crystal faces. Next, is alkali feldspar also known as orthoclase. It has colourless colour with some dirt in PPL and it has first order grey colour in XPL. The orthoclase shows anhedral crystal faces. Scisht has a foliated structure and the texture of mica schist in this thin section shows schistosity texture.

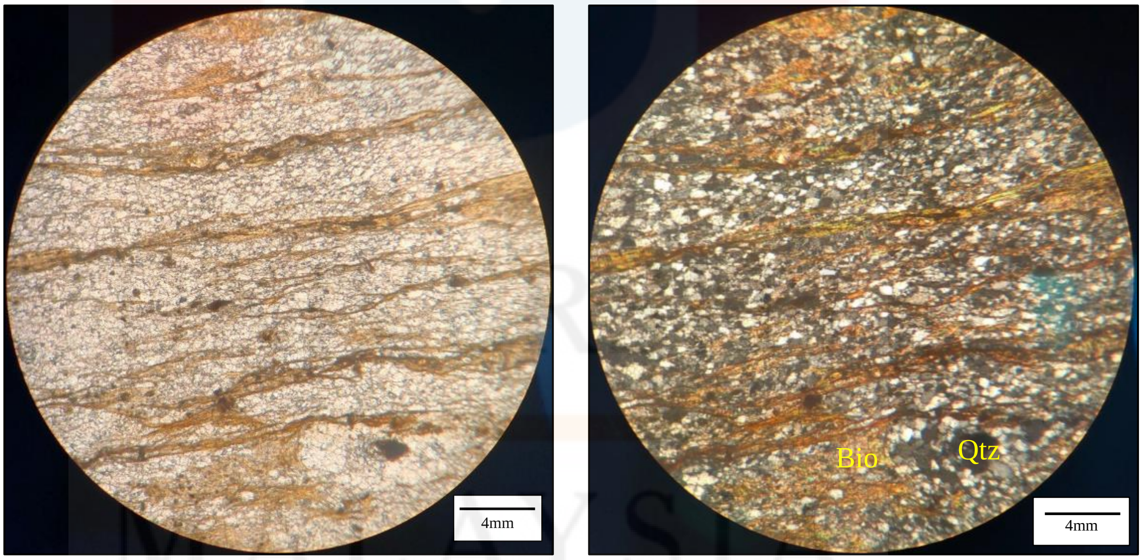


Figure 5.5: The thin section image of mica schist under a microscope between XPL and PPL.

SCHIST

From the photomicrograph of a thin section from sample 2, the sample shows mica minerals oriented in compositional layering surrounded by quartz and feldspar. The muscovite (mica) minerals show brownish in PPL and have third order interference colour in XPL such as green and blue colour. The muscovite mineral shows platty orientation which may cause by the stress that occurs during the metamorphism process. For the quartz minerals, its colour in PPL is colourless and has a greyish to white colour in XPL. The quartz mineral shows anhedral crystal faces on the thin section. The crystal faces orientation may different from the protolith as it will undergo deformation while metamorphism occurs. For feldspar minerals, it shows colourless with some specks of dirt in PPL and greyish in XPL. The schist rock has a foliation structure with the rock texture in this schist rock is schistose.

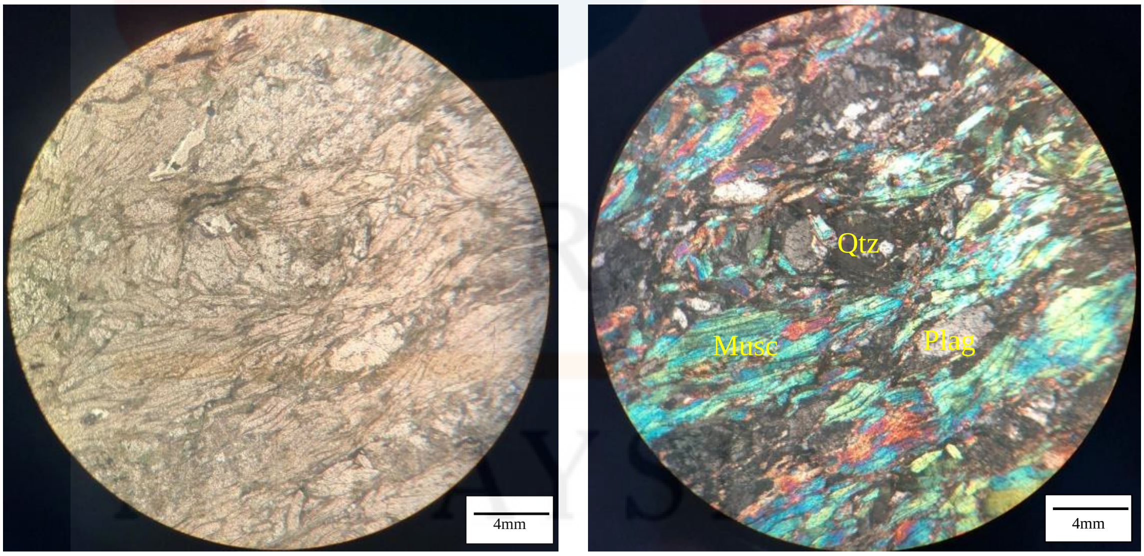


Figure 5.6: The thin section image of schist under a microscope between PPL and XPL.

GNEISS

Photomicrograph thin section of sample 3 in Figure 5.7 showing the major form of quartz and feldspar with surround by olivine minerals, mica minerals and opaque minerals. The thin section has polymineralic textures of contact metamorphism. For quartz minerals, it shows colourless in PPL and greyish colour on XPL. Olivine minerals, it has pale green colour in PPL and a brownish to blackish colour in XPL. Olivine mineral has anhedral crystal faces not showing any cleavage. The Mica mineral that consists in this thin section is muscovite. It has a pale brown colour in PPL and brownish and green colour in XPL. The muscovite shows a perfect cleavage and it is surrounded by major minerals as a platy sheet like structure. Next, opaque mineral. It shows black colour both in PPL and XPL. This opaque mineral is identified to be magnetite as it shows octahedral crystal habit and has very good cleavage. This gneiss rock has the texture of gneissose.

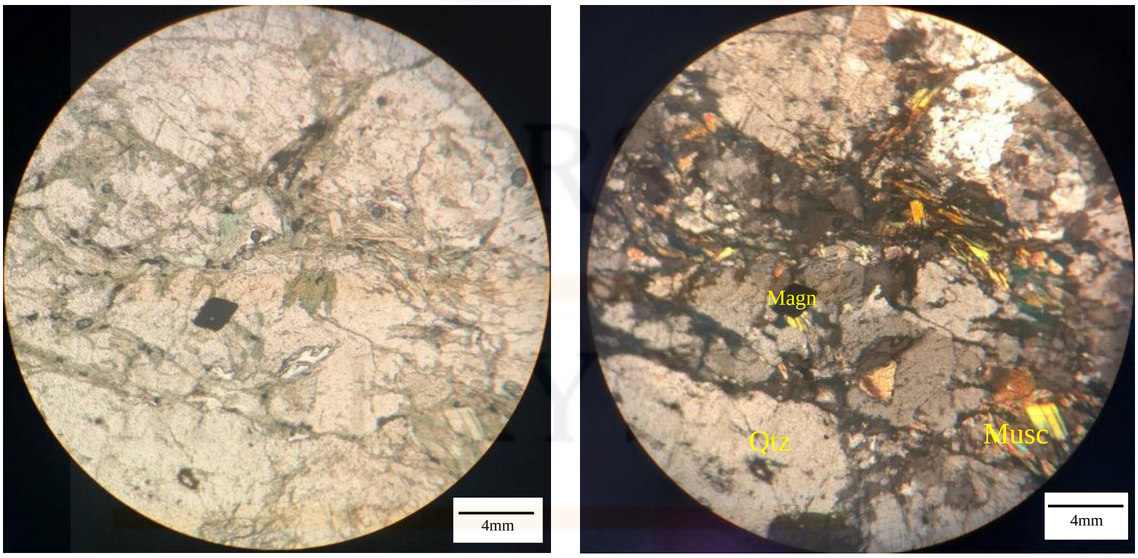


Figure 5.7: The thin section image of gneiss under a microscope between PPL and XPL.

GNEISS

Photomicrograph thin section of sample 4 in Figure 5.8 showing the major form of quartz, biotite and feldspar. The quartz mineral is colourless in PPL and white to greyish colour in XPL. Quartz minerals show anhedral crystal faces which may cause by the deformation of the rock. For biotite mineral, appears brownish in PPL and has second order of green interference colour which is green to brownish in XPL. The biotite has perfect cleavage and appears in tabs and long skinny flakes crystal habit. For feldspar minerals, it shows colourless with some specks of dirt in PPL and white colour with some cross hatching in XPL. This feldspar is perthitic and has a microcline. The crystal faces show subhedral on this thin section. Also, this gneiss rock has the texture of gneissose mineral texture in thin sections.

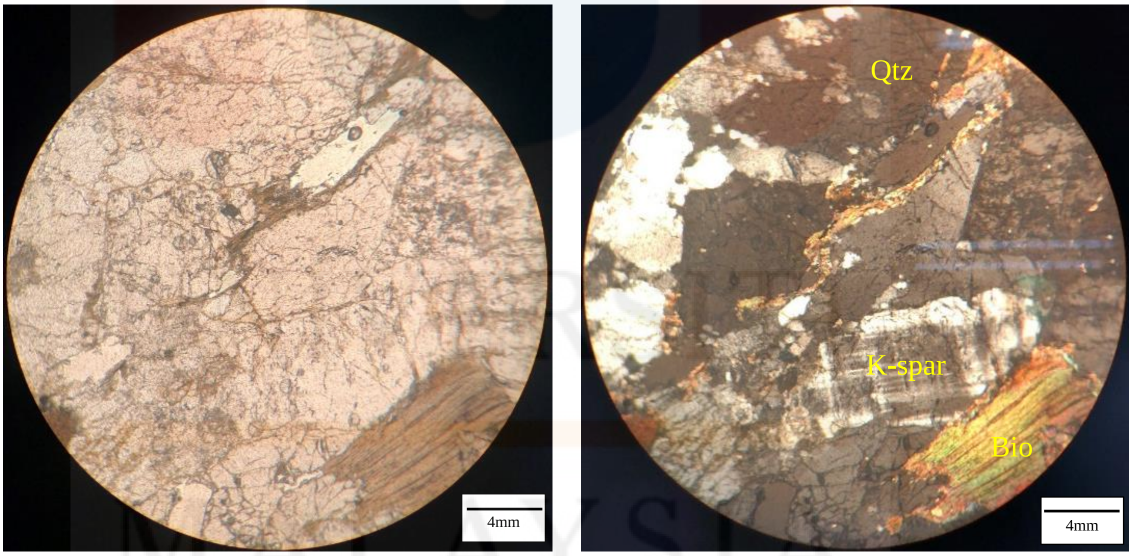


Figure 5.8: The thin section image of gneiss under a microscope between PPL and XPL.

5.3 SEM analysis

Scanning Electron Microscope (SEM) analysis is an acquiring method for producing high resolution images of the sample surface. The image produces by using a focused beam of electrons. Information about the object's composition and physical characteristics can be seen in the photos that are produced.

5.3.1 Mica Schist

From the SEM image of sample 1, the mica schist sample shows quartz minerals showing anhedral crystal faces. This may cause by the deformation of quartz minerals while metamorphism occurs. Biotite (mica) mineral, shows platy in terms of its crystal structure as it usually has a perfect cleavage texture. For feldspar minerals, it appears in small rhombic crystals.

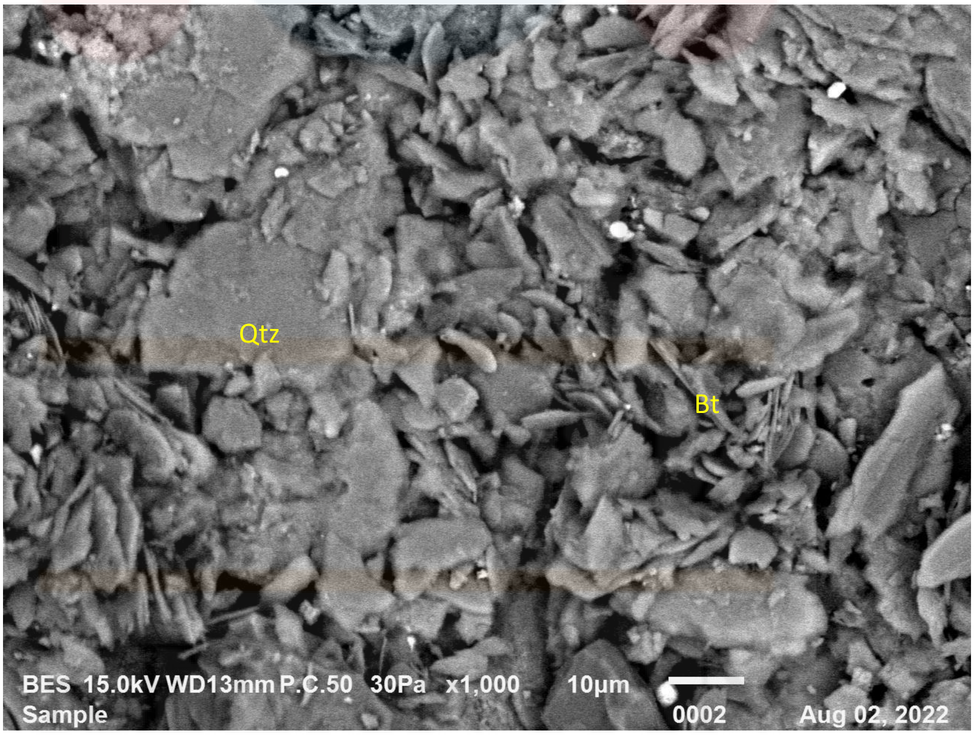


Figure 5.9: The SEM image for sample mica schist showing quartz and biotite minerals.

5.3.2 Gneiss

For sample 2, the gneiss sample shows biotite minerals with perfect cleavage. For quartz minerals, it appears subhedral in crystal faces. This indicates that pressure has been exerted in the rock while metamorphism occurs. For the feldspar, it appears in a rhombic crystal shape with big sizes compared to sample 1.

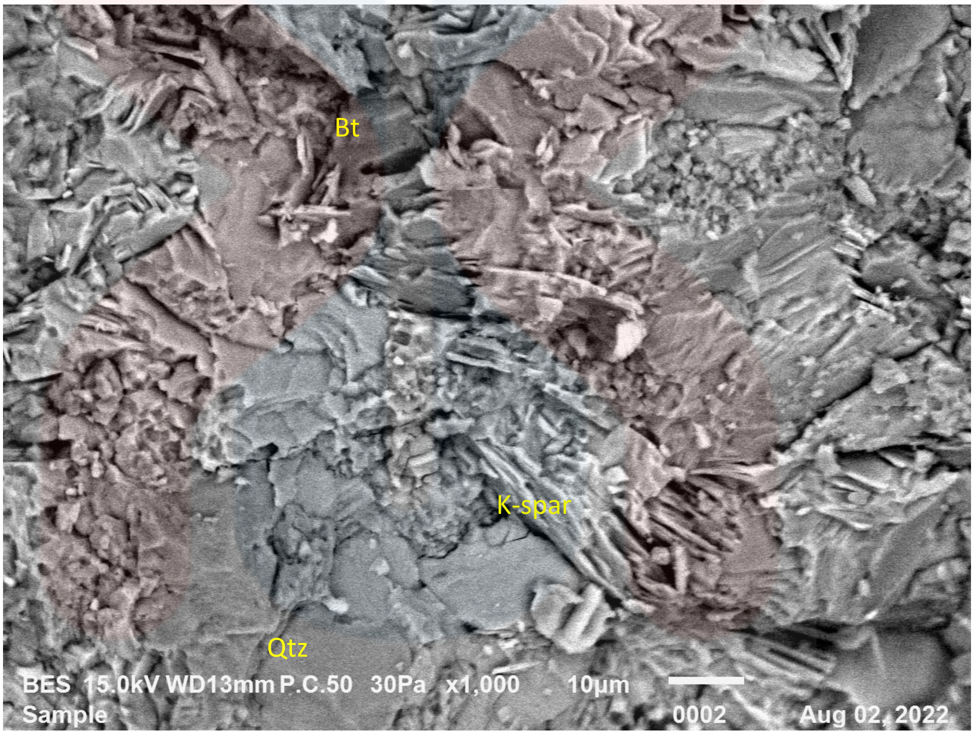


Figure 5.10: The SEM image for sample gneiss showing quartz, biotite and potassium feldspar minerals.

5.3.3 Gneiss

For sample 3 which is gneiss, the quartz shows a subhedral crystal shape on the SEM image in Figure 5.13. Feldspar mineral shows a subhedral crystal shape surrounded by quartz minerals mostly. Biotite (mica) minerals, appear in a flaky structure as it has perfect cleavage texture.

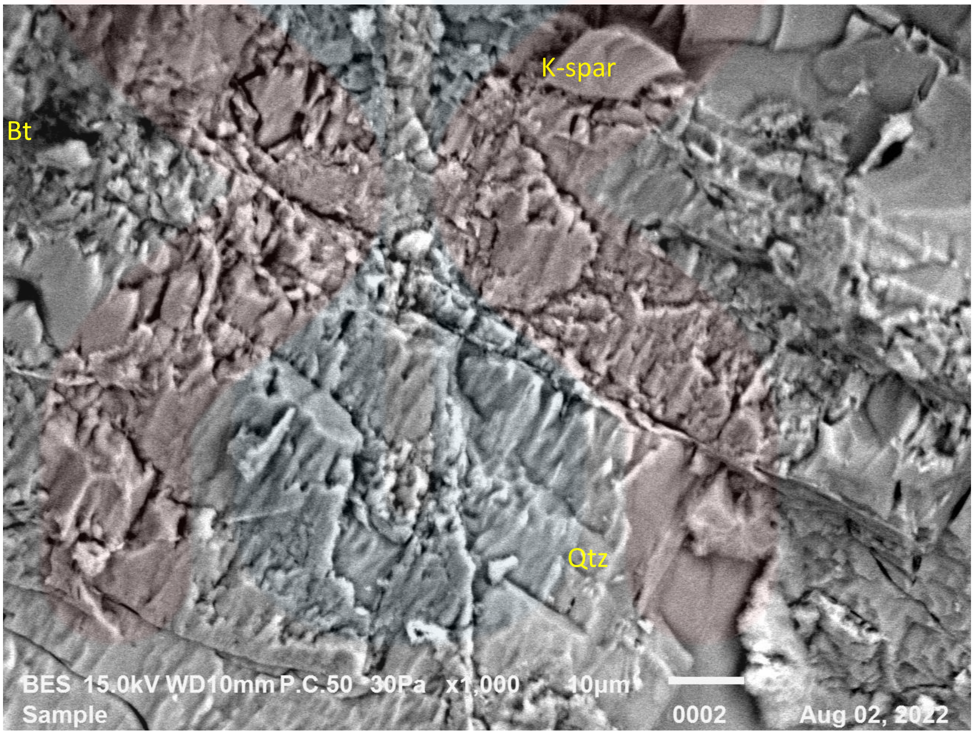


Figure 5.11: The SEM image for sample gneiss showing quartz, biotite and potassium feldspar minerals.

5.4 XRD Analysis

In this study, a different approach for mineral quantification utilizing XRD methodology was created. A substantial amount of the material from each sample was powdered and combined in about 100 grams to prevent issues during sampling. For experimental purposes, measuring peak intensity only required a modest amount of material roughly 5 grams. All test settings were held constant throughout this analysis's XRD determination. The mineral mixing ratios were selected based on what the petrographic study revealed. The peaks in the XRD patterns that correspond to each mineral were selected using a database of pattern information. Table 5.1 give information from the XRD analysis such as the mineral content, percentage of minerals and crystal system.

Table 5.1: Mineral content (Wt %), Crystal System for each mineral on the sample by XRD methods.

Sample	Mineral	Percentage (%)	Crystal System	Axis System
Sample 1 (Mica Schist)	Quartz	7.3	Hexagonal	a = 4.92100 c = 5.41630
	Biotite	35.5	Monoclinic	a = 5.33500 b = 9.24400 c = 10.20600
	Muscovite	11.0	Hexagonal	a = 5.21200 c = 29.80400
	Sillimanite	40.4	Orthorhombic	a = 7.37170 b = 7.52430 c = 5.72420
Sample 2 (Gneiss)	Quartz	80.1	Hexagonal	a = 4.98000 c = 5.46000
	Biotite	34.4	Monoclinic	a = 5.31750 b = 9.21200 c = 19.97600

	Muscovite	22.9	Monoclinic	a = 5.18000 b = 9.02000 c = 20.04000
	Sillimanite	49.4	Orthorhombic	a = 7.42180 b = 7.58680 c = 5.74300
Sample 3 (Gneiss)	Quartz	93.2	Hexagonal	a = 4.99640 c = 5.45430
	Biotite	12.9	Triclinic	a = 5.30000 b = 5.30000 c = 60.000
	Muscovite	6.8	Monoclinic	a = 5.18000 b = 9.02000 c = 20.04000
	Sillimanite	41.1	Orthorhombic	a = 7.45370 b = 7.62380 c = 5.75600

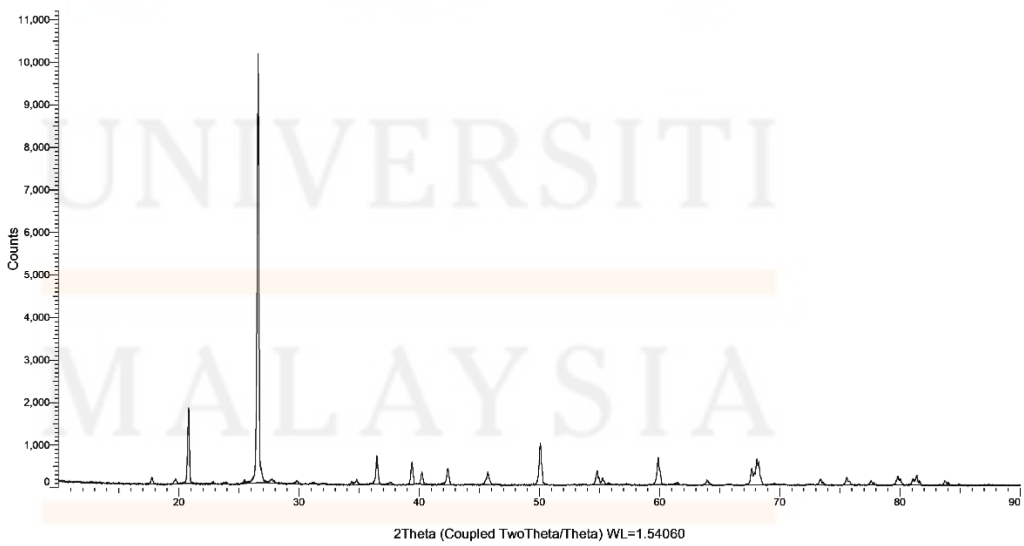


Figure 5.12: The XRD analysis graph for sample mica schist (sample 1).

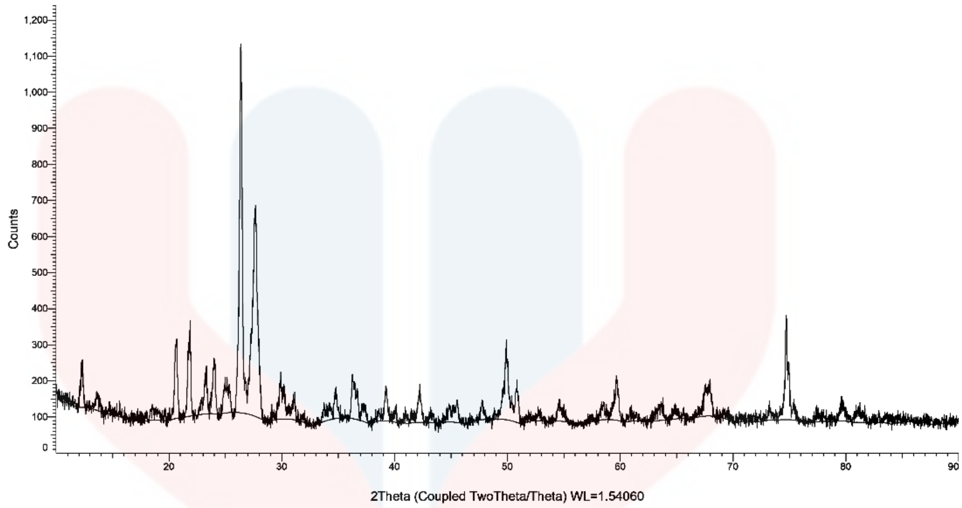


Figure 5.13: The XRD analysis graph for sample gneiss (sample 2).

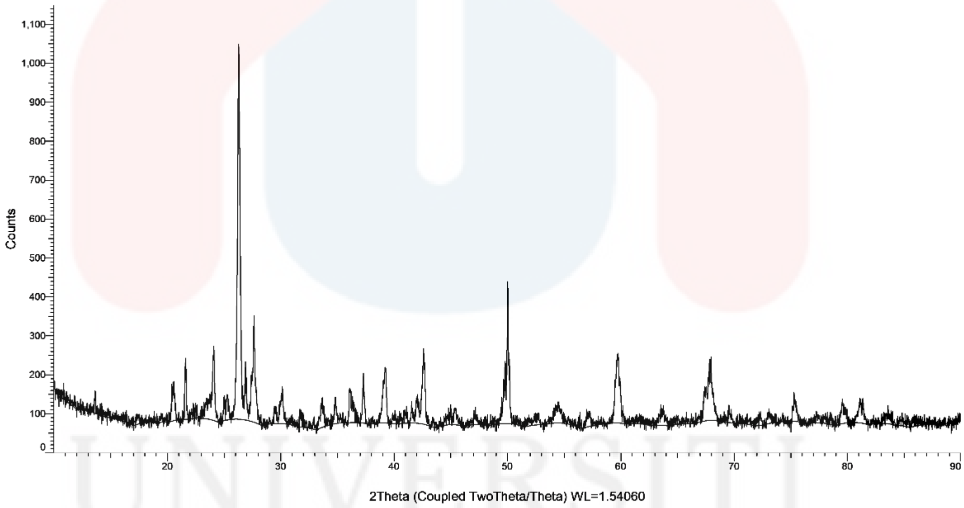


Figure 5.14: The XRD analysis graph for sample gneiss (sample 3).

Based on the finding that there are some variations between the mineral composition estimates from XRD analysis and petrographic determination using both techniques, the minerals present in each sample are listed in the table and the mineral discovery is based on the graph's greatest peak under XRD investigation.

The graph of sample 1 in Figure 5.14, shows that the higher percentage is Sillimanite with 40.0% with the crystal system being Orthorhombic. The second most high percentage is biotite with 35.5% and has a monoclinic crystal system. Next, muscovite and quartz with 11.0% and 7.3% respectively. Muscovite and quartz have hexagonal crystal systems.

For the graph of sample 2 in Figure 5.15, it shows the higher percentage is quartz with 80.1% and has a hexagonal crystal system. It is followed by the mineral sillimanite with 49.4% and has an orthorhombic crystal system. Next, biotite and muscovite with a percentage of 34.4% and 22.9% respectively. Also, biotite and muscovite have the same crystal system which is monoclinic.

The third graph sample is from Figure 5.16, the highest percentage is quartz mineral with 93.2% and it has a hexagonal crystal system. It is followed by sillimanite with 41.1% and has an orthorhombic crystal system. Next, biotite with a percentage of 12.9% and has a triclinic crystal system. Lastly, muscovite with 6.8% of the percentage and has a monoclinic crystal system.

5.5 Discussion

The study of petrology from the study area is needed as it will determine the rock type that has been distributed. Also, the SEM analysis and XRD analysis can determine the mineral assemblages in the rock, especially in metamorphic rocks. From the geological mapping and petrography analysis, the area is having two types of lithology which are schist and gneiss. For schist, it has a foliation structure in the thin section with the mineral content of biotite, quartz and feldspar. While for the gneiss, it has biotite, muscovite, quartz and feldspar.

The SEM analysis and XRD analysis, it is used to analyze the mineral assemblages that have on the rock. The mineral assemblages are determined by the metamorphic rock mineral assemblages zone. According to John Winter, there are 6 typical metamorphic mineral assemblages which are the Chlorite zone, Biotite zone, Garnet zone, Staurolite zone, Kyanite zone and Sillimanite zone. The zone classification is shown in Table 5.2

From the study above, it is classified that the study area is in the Sillimanite zone. This is because the percentage of sillimanite mineral content in each sample is high. Also, sample 1 which is mica schist does not show a high peak percentage mineral of garnet, staurolite and kyanite. So that the schist is in the sillimanite zone. Figure 5.17 below shows the map of regional metamorphic from the study area.

Table 5.2: The rock zone with the mineral assemblages of metamorphic rock.

(Source: Winter, J., 2014)

Rock Zone	Metamorphic Mineral Assemblages
Chlorite Zone	Slates or Phyllites (Contain chlorite, muscovite, quartz, and albite)
Biotite Zone	Slates, Phyllites and Schists (Contain biotite, chlorite, muscovite, quartz and albite)
Garnet Zone	Schists with conspicuous red almandine garnet (Contain biotite, chlorite, muscovite, quartz albite or oligoclase)
Staurolite Zone	Schists (Contain staurolite, biotite, muscovite, quartz, garnet and plagioclase)
Kyanite Zone	Schists (Contain kyanite, biotite, muscovite, quartz, plagioclase, garnet and staurolite)
Sillimanite Zone	Schists and Gneiss (Contain sillimanite, biotite, muscovite, quartz, plagioclase, garnet and staurolite).

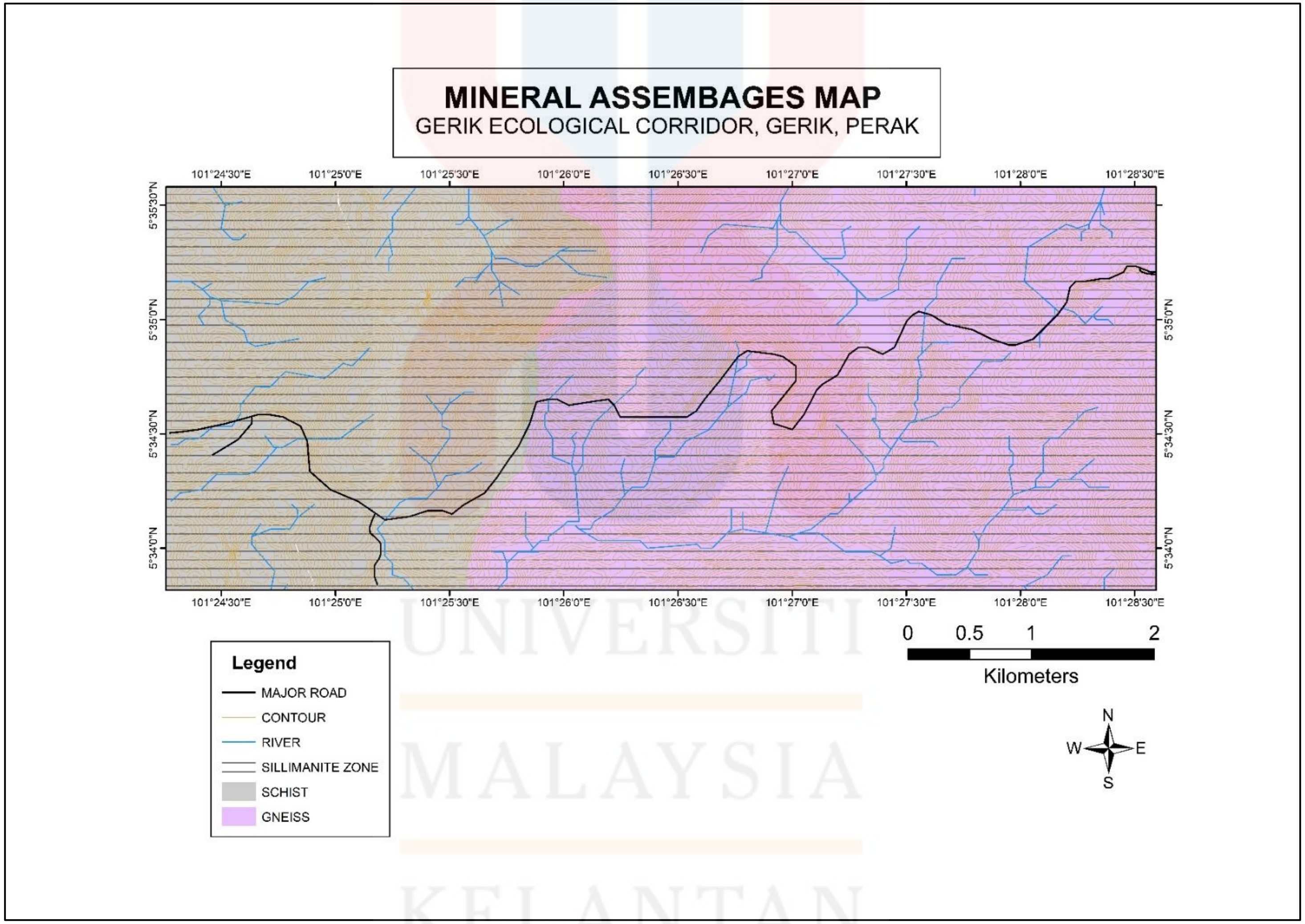


Figure 5.15: Mineral assemblages of metamorphic rock map of Gerik Ecological Corridor, Gerik, Perak.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In the conclusion, the geological map of the study area on Gerik Ecological Corridor is updated and changed with more details on the scale of 1:25000. From the research area are consisting of two types of lithology which are the Schist unit and the Gneiss unit. The rock unit was identified based on the geological mapping and data collection of the research area. On the geomorphology aspect, it can be divided into two units which are high relief morphology (high hill) and medium relief morphology (low hill and hill). For drainage distribution, it consists of two types of drainage patterns which are dendritic pattern and parallel pattern.

For specification, the metamorphic rock is identified by hand specimen based on the characteristic of the rock and petrography analysis. Also, the SEM analysis and XRD analysis are analyzed for determining the regional metamorphic rock zone. There are consists of two types of metamorphic which are schist and gneiss. From petrography analysis, the schist has dominantly mica minerals such as muscovite with the presence of platy structure as it has foliation. Also, quartz minerals are dominant in the schist as the rock groundmass. For gneiss, the rock has dominantly quartz and biotite. This showing that the study area has low grade to high grade metamorphic rock from the West toward the East direction. The SEM analysis gives information about the structural behaviour of each mineral and also the mineral that consists of each sample. XRD analysis, it showing that the mica schist sample collected has a high percentage of sillimanite mineral in it rather than the mineral of kyanite and staurolite. For gneiss, it is grouped in the sillimanite zone because usually, the mineral assemblages that can be found on the transition of mineral is only sillimanite mineral.

6.2 Recommendation

The suggestion for the next research is on the structural geology study. This is because the research area is along the East-West highway, which is the public road for people used to go East Coast states such as Kelantan, Terengganu and Pahang.

Based on the geological mapping from this research, the outcrop exposes mostly discontinuities. The outcrop has undergone many events of weathering and structural activities. So, it will impact the current slope that already exists from the first road has been completed. So, for future studies, they should study the slope stability assessment and how to prevent the slope from failing.

Also, the study area is located in the Central Spine Forest which usually has wild animals around such as the elephant. So, to ensure safety while mapping it is good to go with group members and not survey alone. It is because if go by group, it can be more careful and alert for surrounding.

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