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**General Geology and Sequences of Metamorphic
Rocks Mineral Assemblages in Pulau Banding,
Gerik, Perak, Malaysia.**

By :

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**A report on the completion of the prerequisites for a Bachelor of
Applied Science (Geosciences) degree with Honors .**

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DECLARATION

I declare that this thesis entitled General Geology and Sequences of Metamorphic Rocks Mineral Assemblages in Pulau Banding, Gerik, Perak, Malaysia is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently. submitted in candidature of any other degree.

Signature :.....

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APPROVAL

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

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ABSTRACT

Banding island and its surrounding are dominated by low-grade regional metamorphism which originated from East Malaya Block that dated from Ordovician to Permian age. This paper presented new study on the mineral assemblages and the compositions on the rocks protolith. The study area is situated at longitudes of $101^{\circ} 22' 25''\text{E}$ to $101^{\circ} 22' 35''\text{E}$ and latitudes at $5^{\circ} 33' 47''\text{N}$ to $5^{\circ} 32' 95''\text{N}$. The metamorphic rocks consist of phyllite, mica schist, and metasandstone interbedded with slate. Majority of the phyllite are highly weathered with visible joint and contains quartz veins with thickness varies from 0.5 cm to 6 cm, which following the direction of rock foliation. Phyllite is dominated with mica group and clay minerals, and the mica is mostly muscovite. While the mica schist is also dominated with mica group with muscovite mineral. The direction of the regional metamorphism is lowest from the west of the Banding Island, to slightly moderate metamorphism toward the east of the study area, which supported by the changes of the metamorphic facies from phyllite to schist according to the petrographic analysis. Regionally, Perak state especially in Gerik area are dominated by rocks from Paleozoic era as Perak is located in Western Belt of Peninsular Malaysia.

Keywords: Metamorphic rocks, Banding island, Metamorphism, Petrographic analysis, Gerik.

ABSTRAK

Pulau Banding dan sekitarnya didominasi oleh metamorfisme serantau gred rendah yang berasal dari Blok Malaya Timur yang bertarikh dari zaman Ordovician hingga Permian. Kajian baru ini membentangkan tentang himpunan mineral dan komposisi pada batuan asal. Kawasan kajian terletak pada longitud $101^{\circ} 22' 25''\text{E}$ hingga $101^{\circ} 22' 35''\text{E}$ dan latitud pada $5^{\circ} 33' 47''\text{U}$ hingga $5^{\circ} 32' 95''\text{N}$. Batu metamorf terdiri daripada filit, mika syis, dan batu pasir meta berselang seli dengan batu loh. Majoriti filit sangat terluluhawa dengan kekar yang jelas kelihatan dan mengandungi telerang kuarza dengan ketebalan berbeza dari 0.5 cm hingga 6 cm, yang mengikut arah foliasi batuan. Filit didominasi dengan kumpulan mika dan mineral tanah liat, dan mika kebanyakannya muskovit. Manakala shist mika juga didominasi oleh kumpulan mika dengan mineral muscovite. Arah metamorfisme serantau adalah paling rendah dari barat Pulau Banding, kepada metamorfisme sedikit sederhana ke arah timur kawasan kajian, yang disokong oleh perubahan fasies metamorf dari filit kepada syis mengikut analisis petrografi. Secara wilayah, negeri Perak terutamanya di kawasan Gerik didominasi oleh batuan dari zaman Paleozoik kerana Perak terletak di Jalur Barat Semenanjung Malaysia.

Kata kunci : Batuan metamorfik, Pulau Banding, Metamorfisme, Analisis petrografik, Gerik.

CHAPTER 1

INTRODUCTION

1.1 General Background

Petrography is a field of geology that focuses on describing rocks in detail. Petrography is a subset of petrology, which is a science of geology concerned with the creation of rocks. Studies of rock composition, mineral arrangement, and systemic description are also one of petrography work scope. Microscopic investigations and thin sectioning are one of a good method for this kind of research. The main idea of the study is to figure out the type of lithology, to understand the petrography of the rock around the study area and to identify the sequences of metamorphic rock and mineral assemblages of the study area. Study area would be in Banding island and the East-West Highway surrounds the island which located at Gerik, Perak. Perak state has numbers of Paleozoic formation such as Baling group that situated at the study area. According to Burton (1986), the rock exposure along the East-West highway can be clearly seen dominated with metamorphic rock with

few composition of tuff features. This research will be conducted to deep further knowledge about the information obtained from previous research.

1.2 Study Area

1.2.1 Location

Having location coordinate of $5^{\circ} 33' N$, $101^{\circ} 20' E$, the study area range is 25 km^2 that focuses on Banding island and its surrounding along the East-West Highway. In order to achieve the main objectives of conducting the analyses of petrographic of metamorphic rocks and to evaluate the metamorphic evolution through identifying the type of rock in the study area. Low-grade regional metamorphic rock originated from the East Malaya block during the Ordovician to Permian era is the main type of rock that formed the Banding island. The Paleozoic formation is predicted in the study area is believed to be included in Baling group as the island is placed as in northern part of Perak state. Banding island's was observe in having the highest elevation of 410 meters, while the lowest would be 270 meters above mean sea level. The lithologies of Banding island that can be determined by hand specimens mainly consist of slate interbedded with metasandstone, mica schist and phyllite. Since most of the outcrops are located along Perak East-West Highway, they are easy to locate and access.

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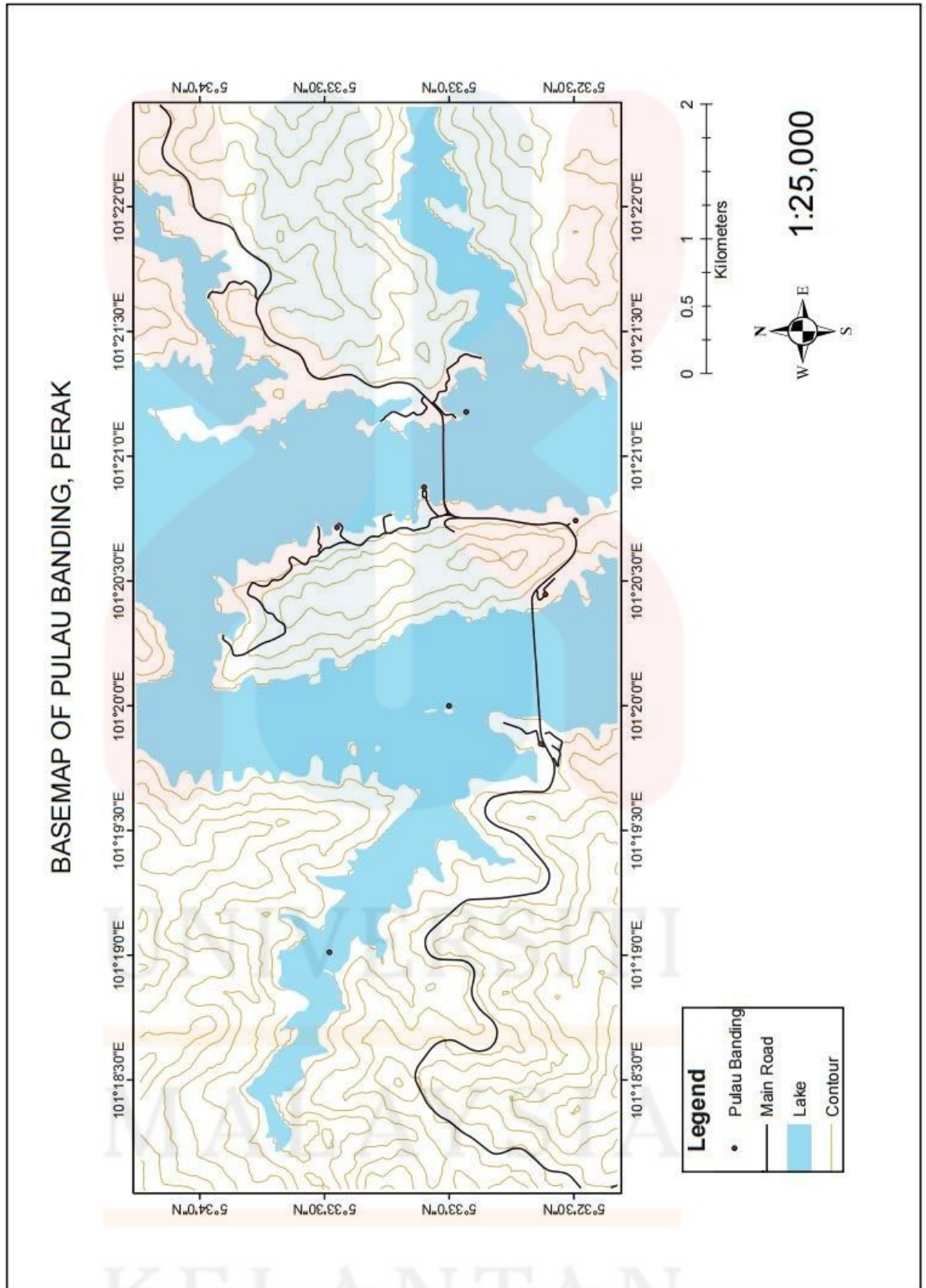


Figure 1 The base map of the study area.

1.2.2 Road connection

Banding island area easily accessible as the island was placed advancing the East-West highway heading to Gerik town which are mainly using road as the main connection. Banding island are connected by two road bridges which the main entrance are from the east while the exit bridge heads to the west side of the Gerik highway. This route serves as the primary connection for the majority of locals and visitors to the Banding area as it is the only road that connects the mainland and the island.



Figure 2 The road bridge from East that connects Banding island and mainland.



Figure 3 A road intersection, left heading to Gerik town while left heading to Trace.

1.2.3 Demography

The distribution of people, social and economic conditions, and road connections are all part of the geology of the study area.

- **People Distribution**

According to the latest information from Gerik mukim statistic of population in 2010, there are about 29,390 of people has been reside in Gerik district. Based on this statistic data, the total of male residing in Gerik is 15,213 while the remaining 14,177 people are female.

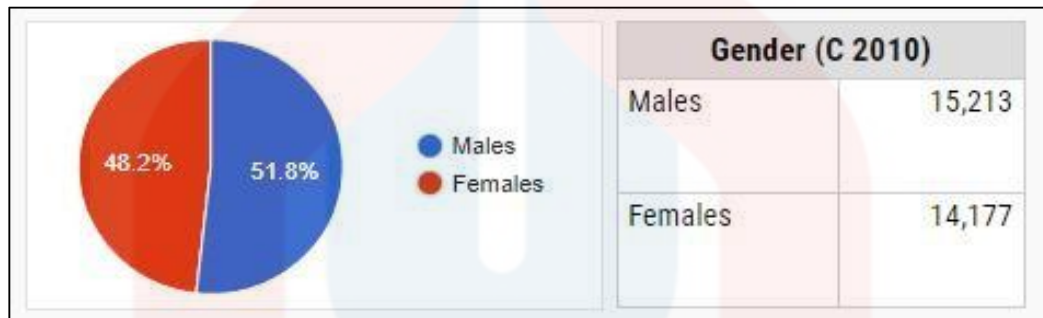


Figure 4 A pie chart of gender statistic of Gerik district.

Statistic by age group, a total of 9,689 of people age from range 0-14 years, a total of 18,093 are age from 15-64 years old while 1,608 people are from the range age 65 and above.



Figure 5 A pie chart of age group statistic of Gerik district.

To breakdown the ethnicity, Malay and other bumiputera ethnic dominantly residing in the area taking the total of 24,080 from the actual total of people, Chinese are 4,214 total of people, Indians are 507 of people while the other 74 people are belongs to other group.

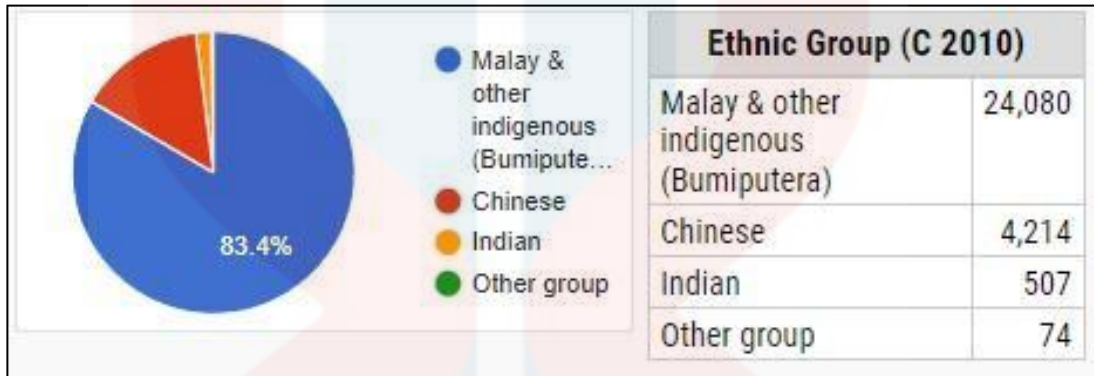


Figure 6 A pie chart of ethnic group statistic of Gerik district.

Statistic shows that Malaysian nationality is 28,875 people while the remaining 515 people are other nationality.



Figure 7 A pie chart of nationality statistic of Gerik district.

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1.2.4 Social Economic

Aside from using East-West Highway as the main road connection, there are other routes that has been used by the locals which are the river. Basically it is because the main income sources of the locals in the area are fishing and house boat. The locals also gain their income by renting the boat for eco-tourism purpose such as island hopping and as tourist transportation for sightseeing. The locals also sell honey and handcraft at Banding public jetty as one of the income sources.



Figure 8 The situation at Banding public jetty.



Figure 9 The road entrance to Banding public jetty.

1.2.5 Landuse

Banding island is surrounded by the artificial lake of Temenggor lake or known by locals as Temenggor dam which is situated near the Belum rainforest. Most of the land was covered with Belum rainforest as it is the oldest world's rainforest that is believed to have existed for 130 million years ago. Belum rainforest is home to many species of flora and fauna from the common species, until to the most endangered species such as hornbill and Malayan tiger as well as Rafflesia. Banding area is also one of the tourist attractions due to its geological setting thus some parties decided to build resorts around the island for accommodation for tourists.

1.3 Problem Statement

The insufficient data or information about petrography of the rock of the study area and to confirm the regional history of the study area to identify mineral assemblages that leads to the implementation of the research. The latest research that was conducted in area of interest was made in 2009 by the Malaysian-Thailand Border Joint Geological Survey Committee (MT-JGSC) in Belum-Hala Transect project. Next problem is, there are no previous specific Banding island lithology map that been created by any previous researcher.

1.4 Objectives of Study

- I. To update the geological map of the study area with scale of 1 : 25000.
- II. To determine the mineralogy of metamorphic rock and sequences of mineral assemblages in the study area.

1.5 Scope of study

The research will take place at north of Perak state which are part of Western belt of Peninsular Malaysia. The area covers the whole Banding island with its surrounding which is East-West Highway. Banding island is surrounded by the artificial lake of Temenggor Lake, situated near the Belum rainforest. The scope of the research study is related to petrography of Banding island and its surrounding and to determine the sequences of metamorphic rock and mineral assemblages of rock of the study area. The metamorphic rocks on Banding Island are based on field research and petrographic study of specimen data gathering. The primary focus is on Banding Island, which is located 41 km from Gerik town southwest of Perak and its surrounding along the East-West Highway.

1.6 Significant of study

The significant study of this research is to identify the sequences of metamorphic rocks and mineral assemblages of Banding island as well as in providing latest geological map. This research will be up to provide updated information and new findings which previous research are unable to. Aside that, a reconstructed geological map can be develop by using previous research as a reference to implement this new research study. Geological mapping will be conducted by using main road which is East-West Highway as medium for traversing. All data such as structural data will be recorded to develop latest map. Thin sectioning, petrographic microscope, X-Ray Diffraction (XRD), Scanning Electron Microscope (SEM) would be use for data analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Before conducting any research, geologists must evaluate regional geology, tectonic background, regional stratigraphy, and structural analysis of a specific place. Furthermore, this research focuses on petrography and sequences of metamorphic rock, conducting and completing this project on Banding island and along the east-West Highway route will necessitate more investigation and details than previous research. As a result, many papers, journals, past theses, reports, and conferences will be referred to as references in conjunction with the research.

2.2 Regional Geology and Tectonic Setting

Peninsular Malaysia can be divided into three main belts: Eastern Belt, Central Belt, and Western Belt. The Eastern belt that forms in the Carboniferous to Cretaceous period consists of Terengganu, Pahang, and Johor states. Kelantan is known consist of some part of the Central belt along a few part of Pahang and Johor state are included during the Mesozoic to Permian era. The Western belt during the Paleozoic

period was formed by the most state in Malaysia as Perak, as well as Kedah, Selangor, Negeri Sembilan, and Melaka. The location of the northern part of Perak is a part of the Western Belt, or Sibumasu block, in Late Triassic which once had collided by the two different tectonic plates name as Indochina plate that placed in the eastern part of Peninsular Malaysia. The other part of the plate is Sibumasu plate which was located as the part of western part in Peninsular Malaysia. According to Jones (1973), the area that was extend in the western zone from the border of Perak-Thai proceeding towards the southwards of Melaka state, which the area was occupied by the Lower Paleozoic geanticline and eugeosyncline and is part of miogeosyncline. Baling group situated in north Perak is one of the main stratigraphic groups that formed as an unbroken belt down through the eastern part of the foothills of the Main Range.

The general geology of Perak can be divided into the Paleozoic, Mesozoic, and Cenozoic eras. The Papulut Quartzite and Gerik Siltstone are from the Baling Group, the Belata Formation, the Lawin Tuff, the Trolak Formation, the Kinta Limestone, and the Kati Beds also make up the Paleozoic rock formations that forms in Perak. The Boulder Beds, Simpang Formation, Cula Formation, Enggor Coal Beds, Old and Young Alluvium, Lawin Basin Deposits, and Beruas Formation are all part of Cenozoic rock formations, while the Semanggol Formation is the sole Mesozoic rock formation found in Perak.

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 that was given to this pyroclastic facies. The strata of sediment found in Baling, Kedah are being extended to south-east. The group has a number of facies which includes 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.

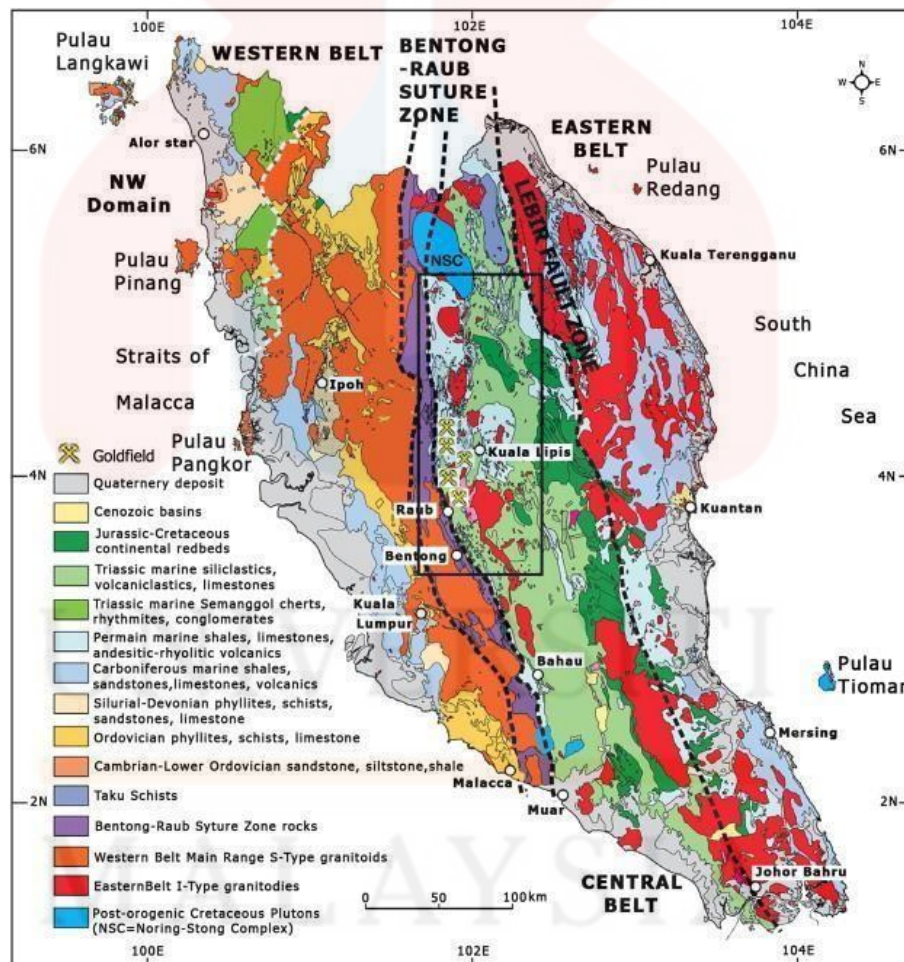


Figure 10 Peninsular Malaysia 3 divided belt (Source : Tate et al. 2009).

2.3 Stratigraphy

The area of interest is located in the western belt. According to Jones (1973), the western zone encompasses the territory between the Perak-Thai border to the state of Malacca. The two main stratigraphic groups that exist in the western zone are Baling group and Bentong group. The other significant unit should be the Lower Palaeozoic formations of Dinding schist, Hawthornden schist, and Kuala Lumpur Limestone in Selangor. Since the area of interest is situated in north Perak, it is included in Baling group stratigraphic unit. Calcareous, arenitic, and argillite sedimentary rocks make up the Baling group, formerly known as the Baling formation. These rocks have already undergone metamorphism. Most of the rocks in these formations are carbonaceous. Clay facies, limestone facies, calc-silicate facies, and arenite facies are the four divisions of the Baling formation (Burton 1970). It can be difficult to determine the relationship between each facies because of the numerous faults and the fact that these facies change both vertically and horizontally. According to Jones (1970), he claimed that the Gerik area's folding, potential faulting, and lateral discontinuity make it difficult to calculate the thickness of the sedimentary section of the group. However, the maximum thickness of the arenaceous, argillaceous, and calcareous strata between 8,000 and 9,000 feet does not account for any potential effects of localised fractures.

Rapid lateral and horizontal sediment fluctuations can be seen in the Baling Group. Typically, the group is composed of argillaceous rocks in the top section and arenaceous strata in the bottom part. The argillaceous component of the group also experienced stronger development of the calcareous facies. In the Gerik area, the sequence is composed primarily of quartzite lenses of shale and limestone in

the lower half, and phyllite and shale with thin lenticular developments of limestones in the top section. The upper portion of the series contains quartzite, schist, and siltstone as well. Gerik formation are believed to be a shallow marine depositional environment due to the location are mostly made up of pyroclastic origin due to the tuff's well-bedded characteristics, the presence of chilled magma and epiclastic elements, as well as the fact that the tuff occasionally interbedded with argillaceous and calcareous materials. Volcanism may take place subaerobically, although the erupted materials were deposited in a marine environment (Jones, 1970). According to Sia (1989), fossilised algae have been found in the calcareous rocks of the tuff, which may also be a sign that the deposition took place in a shallow marine environment.

2.4 Structural Geology

Study areas are believed to be included in Gerik's formation since the location of the research area is located in north Perak. This is supported by the research project conducted by Malaysia-Thailand Border Joint Geological Survey Committee (MT-JGSC) in Belum-Hala Transect project. The name of Gerik formation was taken from the nearby town named Gerik located in north Perak, which was previously named Gerik tuff (Jones, 1970 & Burton, 1986). According to Burton (1986), the rock exposures from this formation can be seen well exposed along the East-West Highway that binds Perak to Kelantan state. The Gerik formation is primarily made up of rhyolitic to rhyodacitic composition and tuffs of pyroclastic rocks that form during previous volcanic activities. The Gerik formation's tuffs are occasionally metamorphosed. According to Burton (1986), The tuffs reveal grey to green speckled bedded rocks made of quartz, potassic feldspar, and plagioclase grains and

fragments up to 5 mm in diameter set in a fine or cryptocrystalline matrix of quartz, mica, chlorite, and siliceous materials and iron oxides in thin sections. It's possible that the matrix came from volcanic ash. These tuffaceous rocks also contain clastic limestone deposits and calcareous shale lenses in varying proportions. Foliation usually occurs in the tuffs' groundmass as a result of regional metamorphism. Schistose texture can be seen in the most altered rocks. He also suggested that it is possible that the matrix came from volcanic ash. These tuffaceous rocks also contain clastic limestone deposits and calcareous shale lenses in varying proportions.

The regional tectonic trends of the Malay Peninsular are typically consistent with the geological structure of Gerik. The Lower Palaeozoic rocks' deformation has resulted in the intricate evolution of structures. The Lower Palaeozoic rocks in the Gerik area are first folded into a sequence of formations with steeply dipping limbs. Primary structures can be seen overlaid with minor folding. The synclinal axis extending south is the most significant structure in Gerik area. The argillaceous rocks are the one that make up the syncline's core.

2.5 Historical Geology

Perak state has identified limestone caves and hills as its main geological features. It has a number of Paleozoic era formations, such as Baling Group, including Bendang Riang, Papulut Quartzite, Lawin Tuff, Kroh Formation, and Gerik formation. The study area, Banding island, was included in Baling group at Gerik, located in the northern part of Perak, which is the island formed in the middle of an artificial lake widely known by locals as Temenggor lake or Temenggor dam. Banding island is mostly majorly built up with low-grade regional metamorphic rock, which originated

from the East Malaya block during the Ordovician to Permian age. Baling group was once named as Baling formation are the sequences of rock that spread along the east of Semanggol formation with Mahang formation. The lithology from Baling group can be found in its original place, such as Baling in Kedah and around Gerik in Perak. According to the Malaysia-Thailand Border Joint Geological Survey Committee (MT- JGSC) (2009), both the Kubang Pasu/Yaha Formation and the Kroh Formation are covered by the Gerik formation.

The Malaysian Working Group has formally recommended the word Gerik formation to replace Burton's (1970, 1972, and 1986) term for Grik tuff for the pyroclastic rocks that are primarily composed of tuffs with rhyolitic to rhyodacitic composition. The occurrence of *Anisopyge* sp. and trilobite in calcareous shale interbedded with tuff and sandstone at Kampung Batu 2, Gerik, suggests that the Gerik formation is Permian in age. A brachiopod can also be found in this rock section.

2.6 Metamorphic Rock

This research aims to study the petrology of the Banding island, which is located within the Western belt Peninsular of Malaysia, with the goal of determining the characteristics of the mineral assemblages and mineral composition in the study region. In order to define the lithological rock unit of the area, the research also highlights the nomenclature of the discovered rock samples based on the International Union of Geological Sciences (IUGS) classification. In addition, textural characteristics will be investigated in order to determine the geological processes that contribute to the sequences of metamorphic rock on Banding Island and its surrounding.

By determining the petrographical characteristics of the minerals present in the thin section of the resulting rock sample is also one of the the research main methodology. This technique is significant because the thin section's mineral characteristics itself explained how the rock in the area of interest behaves and how the geological process behaves. The MT-JGSC Committee earlier conducted a study in 2009 that was primarily concerned with traverses and stations but did not entirely cover the original study area. Due to the fact that the area of interest has not been well examined geologically, this core method is crucial for a more complete approach.

2.7 Petrography

To identify the mineral assemblages in the sample for the particular research area, the petrography analysis is carried out more thoroughly. as it is frequently use as standard method in studying provenance. Petrographic analysis establishes mineral composition as well as a rocks origin whether it was igneous, sedimentary, or metamorphic. It is anticipated that the petrography of the Gerik Formation will primarily consist of sedimentary rocks like sandstone, limestone, mudstone, and shale. However, several research also claim that the study region contains the metamorphic rock type such as phyllite and metasedimentary rock. In order to compare the petrographics to earlier point count data, the thin section attempts to illustrate the fundamental petrography obtained. (Dickinson et al.,19.83).

2.8 Mineral Assemblage

Complete changes in mineral composition or modifications to the composition of pre-existing mineral phases define metamorphic rocks. The chemistry of the original rock and the new pressure-temperature conditions to which it is exposed are both reflected in the result of mineral composition. Progressive or prograde metamorphism happens when the rock is subjected to higher temperatures and pressures. As pressure and temperature increase, it is anticipated that rocks with a given chemical composition will go through a series of ongoing chemical reactions with the liquid phase, producing a number of new mineral aggregates that are stable at greater pressures and temperatures.

CHAPTER 3

MATERIAL AND METHOD

3.1 Introduction

Data collecting, data processing, data analysis, and data interpretation were all part of the approach that was used, along with preliminary research, materials, and equipment for field studies and laboratory work. The research's methods can be broken down into two categories: field studies, which involve geological mapping, and laboratory work, which involves the preparation of thin sections.

3.2 Materials/Methods

To implement this research, a few materials are needed to achieve the success of the research. The vital materials or equipment needed in samples collection and geological mapping should be GPS, notebook, stationaries, hammer, sample bags, compass, and camera. Aside from that, internet sources are crucial to create maps using Arcgis and to get aerial images using Google Earth which are conveniently in providing general image of the research area that includes settlement, main river,

streams, main road, and geomorphology of the study area as well as the topography. The method used for this study mostly covers the analysis purpose. By using these methods, the implementation of the research is effortless with the aid of materials. Methods used would be a preliminary survey, geological mapping, thin sectioning, microscope study, X-Ray Diffraction (XRD), Scanning Electron Microscope (SEM), and Arcgis Map to create maps.

3.2.1 Preliminary Survey

Preliminary survey was held to investigate or explore the study area conditions and infrastructure availability including the facilities' accessibility. The major goal is to conduct a survey of the study area's meteorological conditions, the village geological map, geomorphology, and terrain. The survey is also used to calculate the amount of earthwork that needs to be done in the study.

3.2.2 Geological Mapping

Geological mapping is the process of a geologist going out into the field and physically capturing geological data from the rocks that outcrop on the surface. Materials such as GPS, compass, sample bag, stationaries, notebooks, and hammer are crucial in mapping. GPS were used to locate the coordinates while compass were used to measure structural reading. Stationaries and notebook act to record every reading and labeling while hammers are used to chip away small rocks from outcrops and the sample bag function is to store them.

3.2.3 Thin Sectioning

7-10 samples are taken from the study area for the thin sectioning process. Thin sectioning is basically to cut the samples according to the glass slide size. By using a diamond saw, a thin silver of rock is lacerate from the sample and is optically flattened. Then the samples will be put on a glass slide and smoothed out with finer abrasive grit until the sample is only 30 micrometers thick. The interference colour chart (Michel-Lévy chart) will be used in the procedure to determine the thickness.

3.2.4 Microscope study

Generally, the use of microscope in the thin section is to analyze the samples mineral under Plane Polarized Light (PPL) and Cross Polarized Light (XPL). Optical mineralogy were used to study rocks and minerals by examining their optical properties. A petrographic microscope or also known as polarising microscope were used and the technique that was used are known as transmitted light microscopy or polarised light microscopy.

3.2.5 X-Ray Diffraction (XRD)

XRD are generally used to identify the molecule shape and geometry using X- rays. X-ray diffraction analysis (XRD) is a materials science technique for determining a material's crystallographic structure and then measuring the intensities and scattering angles of the X-rays that exit the substance. Samples should be crushed and pulverized into powder and the results should have come in graphs interpretation.

3.2.6 Scanning Electron Microscope (SEM)

SEM is a method that is used to scan and projects the image of a focused electron stream over the sample surface depending on the scales needed. SEM is also used to further corroborate the existence of certain mineral identified by XRD.

3.2.7 GIS

Using GIS software to produce lithology map as the software programme is capable of saving data entry and storing data properties in attributes. From this perspective, the primary objective which is to provide information and produce maps with scale of 1 : 25000 can be achieved in hardcopy or softcopy form.

3.3 Methodology

This research has been completed using a variety of methodologies, including preliminary studies, field studies, laboratory work, and data processing. The research flow chart for this study is shown in Figure 3.1.

3.3.1 Preliminary Studies

In order to choose the appropriate method to be employed in this research for the examination of petrographic and mineralogy, it was necessary to review a number of preliminary studies. Study the types of rocks that are produced by volcanoes, as well as the types of rocks on Banding Island and in the vicinity of the East-West Highway, by using the regional geological map. Additionally, based on the research area base map, the geology of the study area includes its geomorphology, structural geology, and lithology has been roughly identified.

3.3.2 Field Studies

The structure, lithology, stratigraphy, and other elements that are related to geology within the selected study region must be mapped and documented using the geological map. In geological mapping, it is important to observe and measure the feature of study area geomorphology, lithology, stratigraphy, weathering evidence, structural indication, and other characteristics. Geological mapping needs to include data collecting and field observation in order to study the geological feature.

Any structural analysis will be measured through data collecting. Basically, bedding, foliation, linear features, cleavage, and fold are used to record and observe structure as well as structural history. Measuring structural analysis was done by using strike and dip. The direction of a line on an orientation horizontal plane that met an inclined rock bed is known as the strike while the dip is the angle formed when the strike line and the inclined bed are perpendicular to one another. Additionally, data collecting can be accomplished by structure investigation, specimen collection, and mapping-related photography.

The process in geological mapping also involves sampling rocks and the rock sample must be taken as fresh sample since weather samples are unsuitable for petrography analysis as it might already decayed or turned into soil. By utilising a geological hammer to break the outcrop, all samples will be collected. The petrography and data analysis study must be conducted using the sample.

3.3.3 Laboratory work

Hand specimen preparation, thin section analysis, XRD and SEM were used in the laboratory work. The samples undergo thin section preparation after it has been collected, followed by petrographic analysis. When there are two or more minerals in the sample, XRD are used to determine the composition or structure of the minerals while SEM was used to support the XRD's result.

- **Thin Sectioning**

Petrography is the use of a microscope to investigate rock and minerals. The sole purpose of petrography was to identify rocks, minerals, and ores and there are several steps to do so. The thin section must be prepared using six steps which are sectioning, impregnation, precision sectioning, bonding, resectioning, and finishing with grinding and polishing (Buehler, 2006).

At least 10 to 12 samples was taken around study area to run the thinsection for petrographic analysis. From the collected samples, a few rock samples are chosen and thinly cut using diamond saw for petrographic analysis to identify the mineralogy and the type of rock.

The mineral composition and textural characteristics of the collected samples are evaluated using thin sections. Examining thin section are done by using polarized microscope. A high-quality thin slice needs to be produced using a variety of techniques to get the best cut.

- **XRD Analysis**

X-ray diffraction (XRD) tests are carried out on hand-selected rock samples from the study area to more precisely identify the mineral components and analyse the properties like structure, phase composition, and texture (Ermrich, M. & Opper, 2013), while also to determine the composition of the rock and the amount of clay in it. For X-Ray Diffraction (XRD) analysis, samples were sent to the Faculty of Bioengineering and Technology in University Malaysia Kelantan to run the analysis in the lab provided. For sample preparation, rock samples for XRD were ground and pulverized into powder for the analysis. The X-Ray Diffraction (XRD) instrument was used to determine the samples' mineralogical characteristics.



Figure 11 The image of XRD instrument.

- **SEM Analysis**

SEM analysis offers information on the elemental composition and crystalline structure. Rock was gently crushed to obtain SEM samples using a tiny rock hopper or an X-acto knife (Lorenz, J.2003). To gained project image using SEM, samples was sent to the lab at University Malaysia Kelantan for SEM analysis. In preparation, samples for SEM were crushed into small pieces with measurement of 0.5cm x 0.5 cm or 2cm x 2cm. SEM is a technique that scans and projects the image of a focused electron beam over the sample surface. Additionally, SEM was employed to support the discovery of certain minerals discovered by XRD. By employing this technique, it is easy to interpret the results of XRD analysis in greater detail and determine the mineralogy, particle texture, and pore structure of polished rock samples.



Figure 12 The image of SEM instrument.

3.3.4 Data processing

All of the data taken from the sample and observation checkpoints during geological mapping was processed in terms of lithology, geomorphology, geological structure, mineralogy and petrology, sedimentology, stratigraphy, depositional environment, and other geological aspects. The ArcGIS programme is then were used to process all the data and create the geological map. Additionally, the sample was examined utilising petrography analysis to obtain the specifics of the petrology data.

3.3.5 Data analysis and interpretation

Using the Arc GIS programme, 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 utilising maps and geographic data. Following the completion of the thin section analysis for mineral identification, the petrographic analysis will be conducted. The relative mineral phase composition of the kind of rock can be estimated using XRD while result from SEM can support the result of XRD.

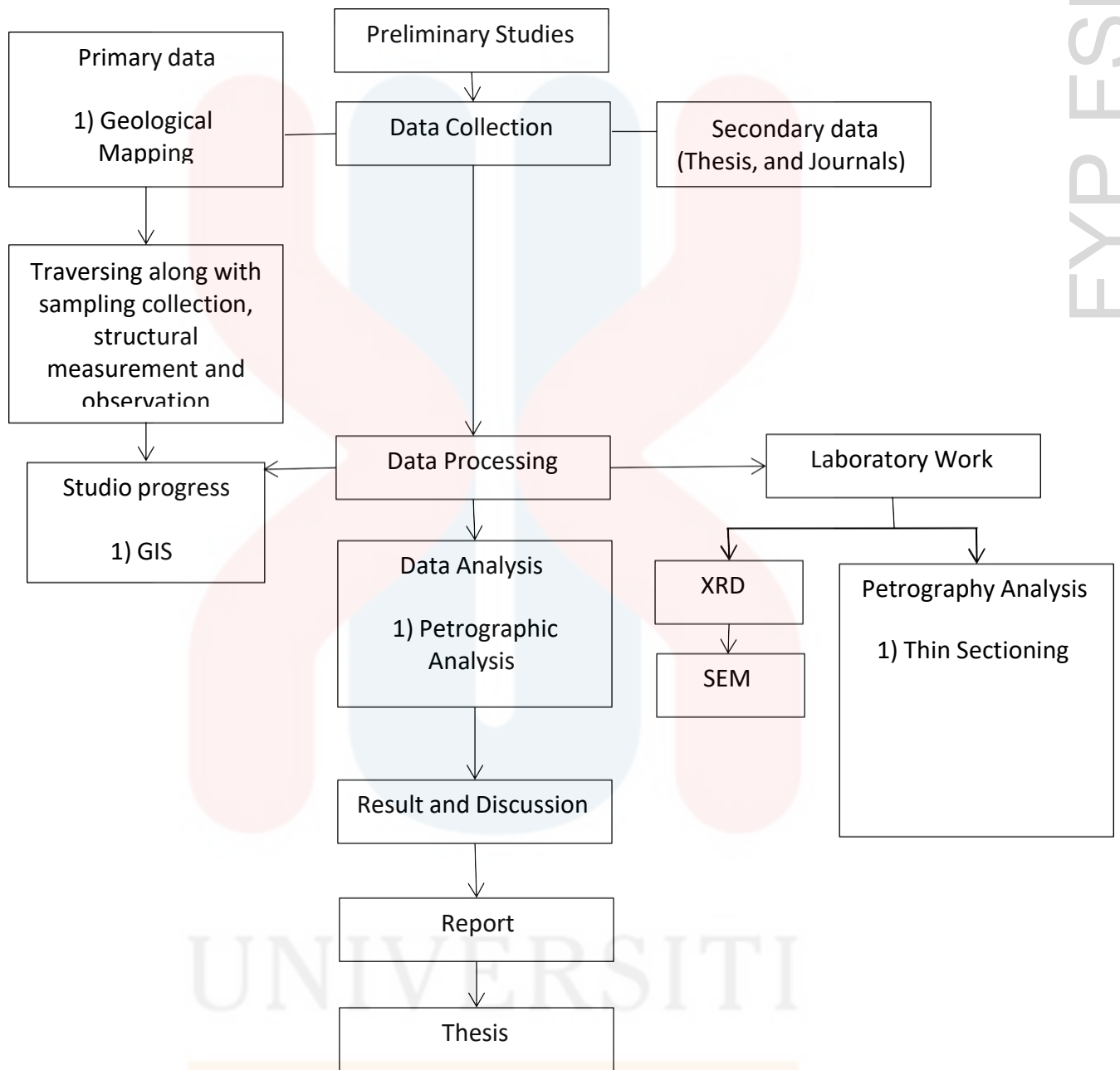


Figure 13 The research flow chart.

CHAPTER 4

GENERAL GEOLOGY

4.1 INTRODUCTION

The chapter will cover the general geology of the research area : Banding island, Gerik, Perak that includes geomorphology, stratigraphy, structural geology, and historical geology.

While conducting the research study, traversing method of data collecting was carried out in the field. The information was gathered in raw details such as outcrop discovery, the state of the outcrop and specimens, observing outcrop morphology, strike and dip reading and by the end will be documented. Geological maps are created after the finding information from the geological mapping has been analysed. The research area's geological features are all depicted on the geological map. The geological map was prepared at a scale of 1:25 000 and covers an area of 5 x 5 km².

B) Accessibility

Accessibility is a road that provides access to a particular place or destination, such as a main highway or a site inside of another town. Banding Island is a conveniently located along the East-West Highway that leads to Gerik Town. The island is connected to the mainland by two road bridges, with the main entrance on

the East and the exit on the West sides of the Gerik Highway. As the only road between the mainland and the island, this route acts as the primary access point for the residencies and tourists in the region.



Figure 4.1 The road bridge from East that connects Banding island and mainland.



Figure 4.2 A road intersection, left heading to Gerik town while left heading to Trace.

C) Settlement

A settlement is a site or a location where people reside, along with the buildings, streets, roads, and other connections between the buildings. It might be anything, from a remote farm to a large city. Depending on the population over time, a settlement may be either permanent or transient. Refugee camps are an example of a

transient settlement. Over time, some of the temporary settlement will change to a permanent settlement. Settlements can be broadly categorised based on their structure, size, and housing density.

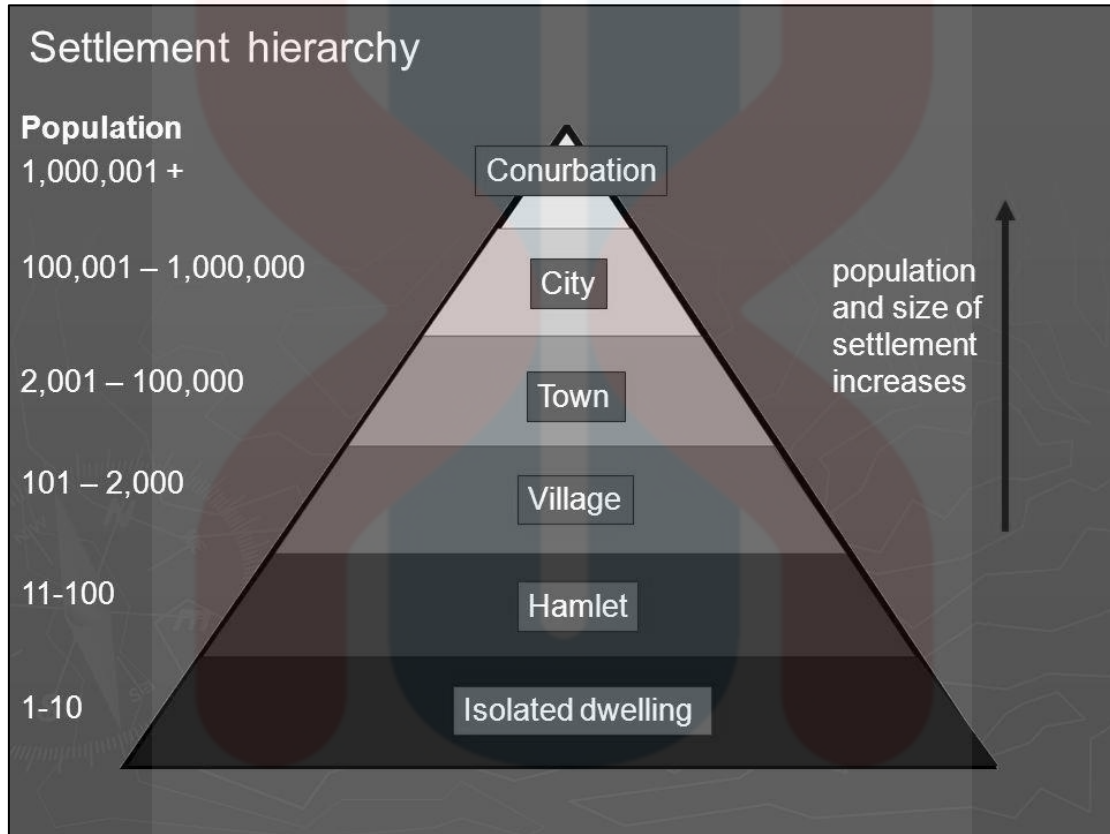


Figure 4.3 The settlement hierarchy.

Figures below show some of the facilities that are located in the study area.

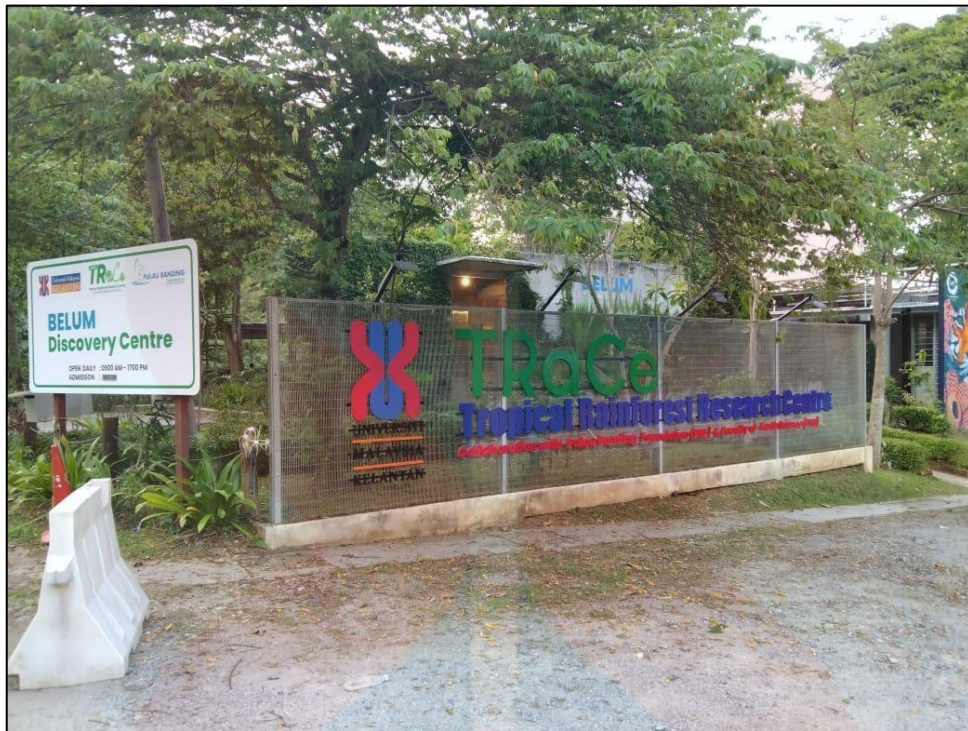


Figure 4.4 The UMK Trace located near to Banding island.



Figure 4.5 The Hentian Rehat Royal Belum located near UMK Trace.



Figure 4.6 Kem Tentera Darat, Pulau Banding..



Figure 4.7 Kompleks Pusat Perikanan Darat, Pulau Banding.

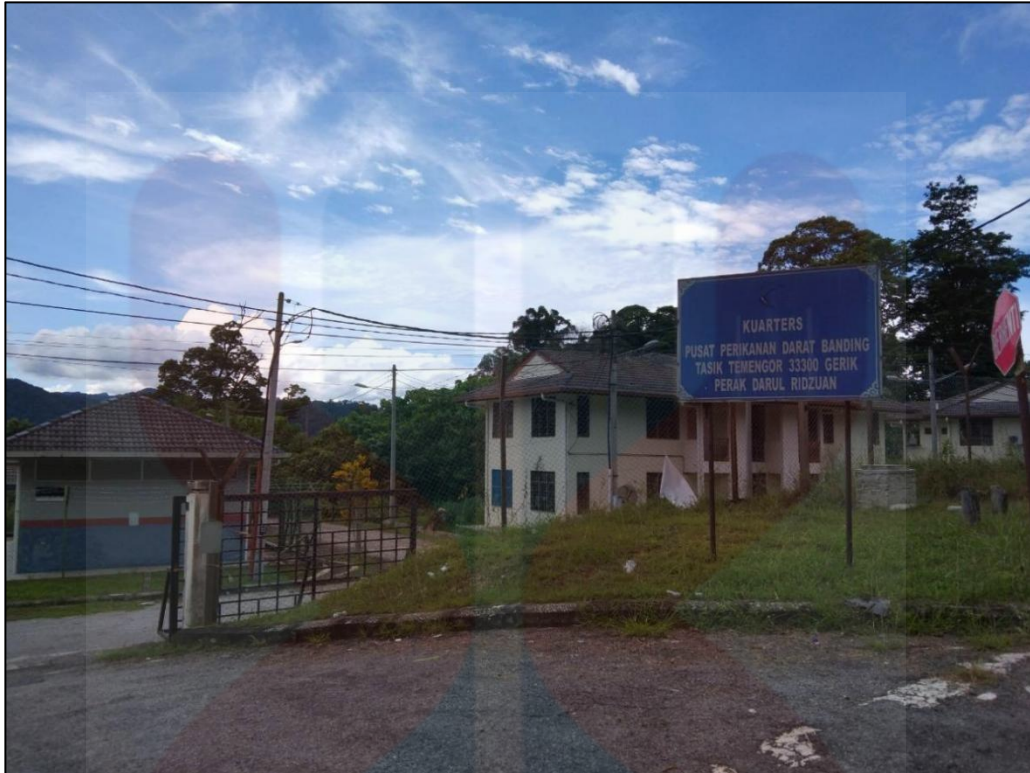


Figure 4.8 Kuarters Pusat Perikanan Darat, Pulau Banding.



Figure 4.9 The Belum Rainforest Resort as on of tourist attraction.

D) Forestry

Temenggor Lake, sometimes referred to as Temenggor Dam by locals are located close in the Belum rainforest surrounds the Banding Island. Belum rainforest are the oldest rainforest in the world and are thought to have existed for 130 million years, covered the majority of the area. Numerous plant and animal species, ranging from the common to the critically endangered resides in the Belum rainforest as habitat including Rafflesia, hornbill, and Malayan tiger. Due to its geological setting, Banding Area is also a popular tourist destination, thus certain parties chose to construct resorts all over the island to provide lodging for visitors.

E) Traverse

The geological mapping traverse that was carried out throughout the research study is represented in Figure 4.8. There are 4 sampling locations, and a total of 7 samples were collected. The rock sample was taken at the sampling location to be examined in the lab for petrographic analysis, XRD analysis, and SEM analysis. The outcrops throughout the route are mostly made of metamorphic rock and were covered in vegetation. Because it is a part of the Belum rainforest, the research area that located near the East-West highway is densely forested.

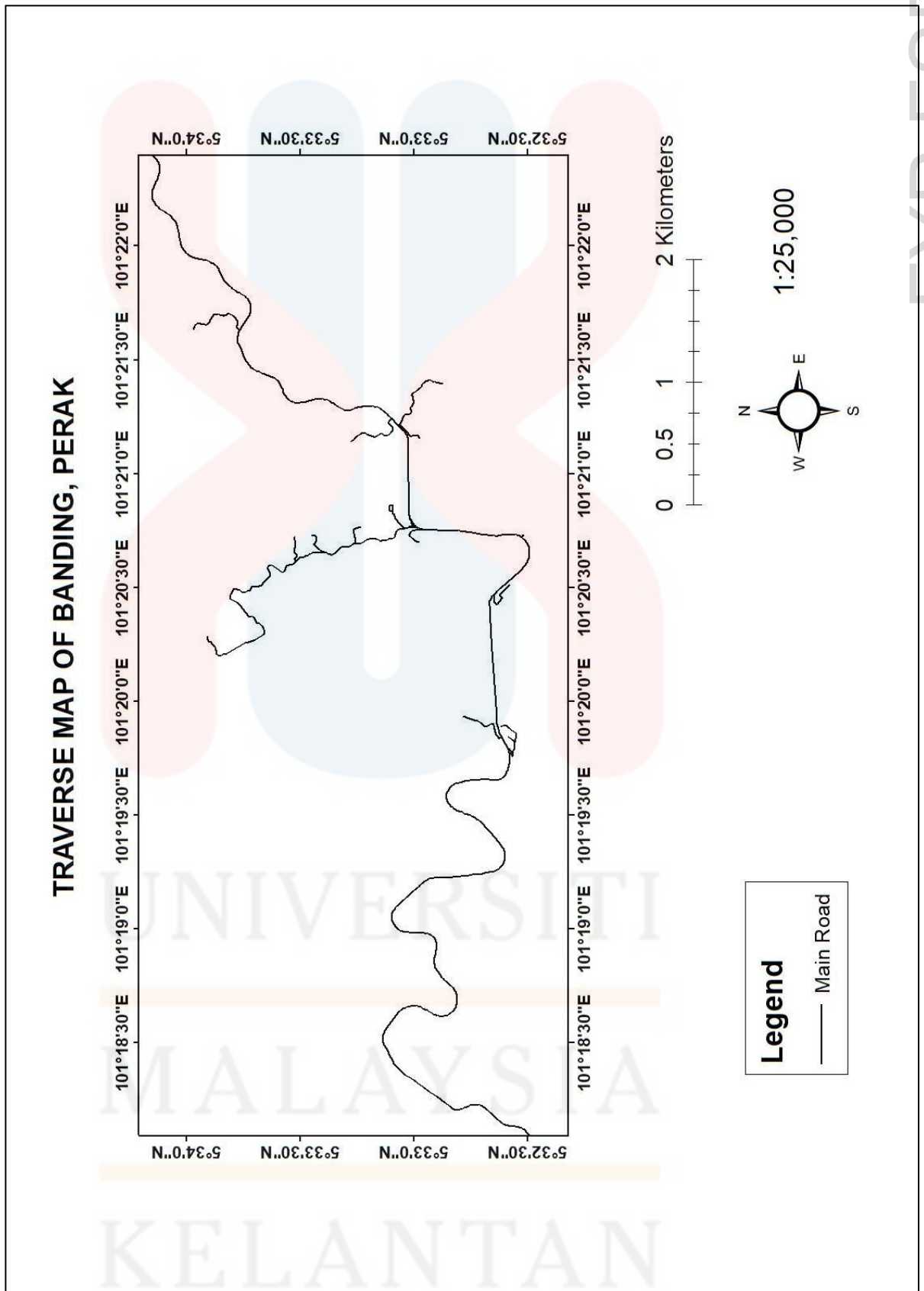


Figure 4.10. The traverse map of the study area.

4.2 GEOMORPHOLOGY

The study of landforms including their formation, processes, and underlying sediment, is known as geomorphology. As rock or sediment breaks down, it is moved to new locations where it is deposited, creating the landforms that are seen today. Different climatic conditions will result in various types of landforms. The majority of the time, geomorphology processes proceed slowly. However, if a significant event such as a flood, landslide, tsunami, earthquake, or volcanic eruption occurs, the environment may change quickly. The research region contains steep mountain units and lakes as types of landforms.



Figure 4.11 The geomorphological structure of Banding island.

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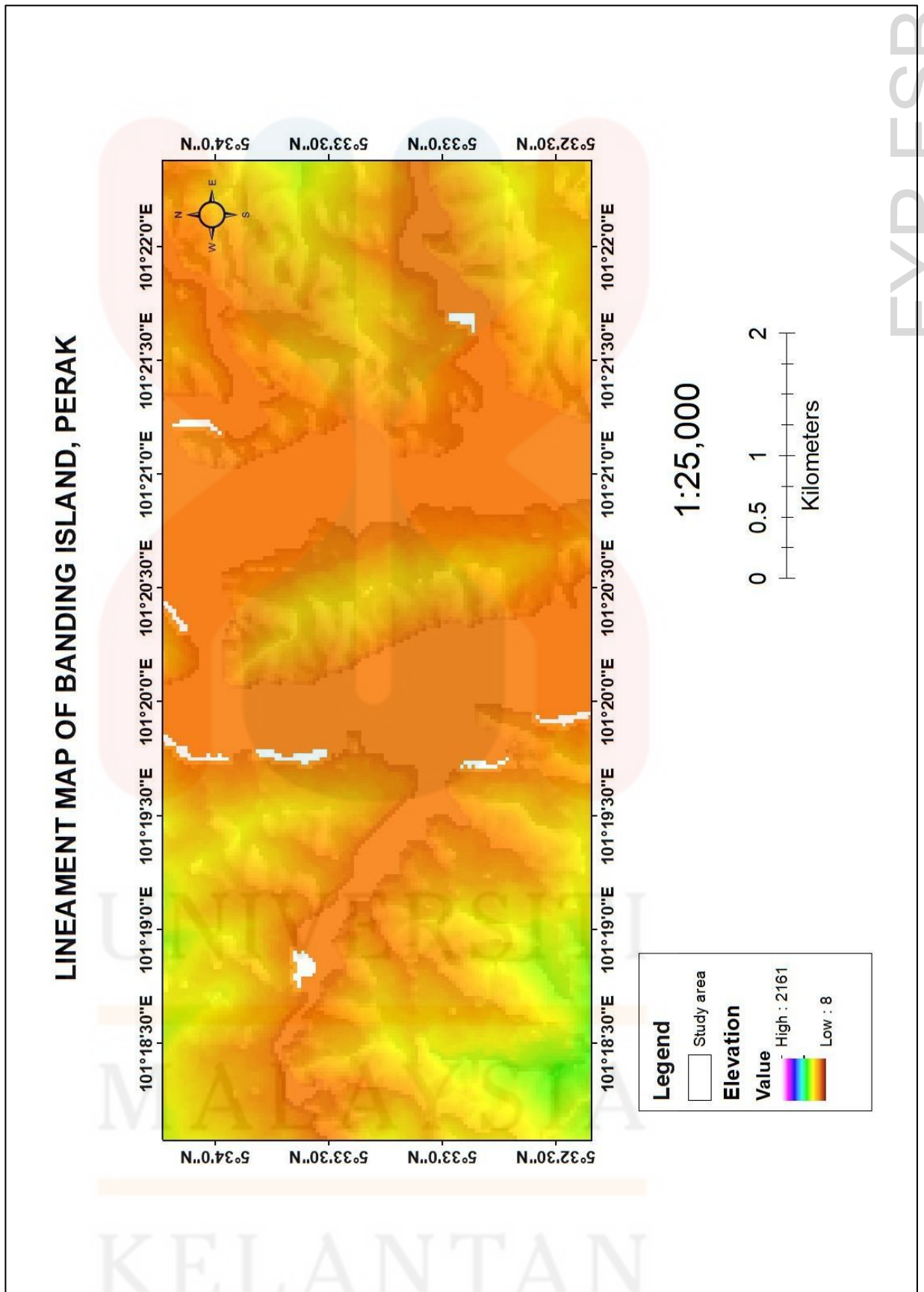






Figure 4.12 The elevation map of banding island.

Table 4.1: The elevation of each geomorphological unit

NO	GEOMORPHOLOGICAL UNIT	SYMBOL	LANDFORM	ELEVATION (M)
1	PEAK		High Hill	561-680
2	STEEP		Hill	421-560
3	SLOPE		Low Hill	361-420
4	LOW		Lake	235-360

A. GEOMORPHOLOGIC CLASSIFICATION

The landform classes by elevation, slope and relief by Chabala (2013) was used to determine the geomorphological classification of the study area. Several geomorphological factors that must be taken into account are :

1. The field of morphology studies relief in general.
 - Morphology - The characteristics of the earth's surface such as hills, ridges, valleys, mountains, plains, and alluvial fans.
 - Morphometry - Quantitative measurement of a certain landform's slope, slope shape, relief, erosion rate, elevation, and drainage pattern.
 - Morphography - The geomorphological extents area.

2. The concept of morphogenesis focuses on the morphological process, which is the process that governs the growth and construction of landforms. Morphogenesis is connected to lithology, geological processes, and structural geology.

- Active Morphostructure - Derived from an endogenous process that involves faulting, folding, and elevation.
- Passive morphostructure - Landforms classified are based on lithology and rock structure.
- Morphodynamic - The exogenetic processes that relate to the forces from glaciers, water, volcanism, and climate.

Table 2 displays the categorised elevation and values by Chabala (2013).

Table 4.2. Shows the elevation class

Elevation classes	Range of elevation(m)
1	<1080
2	1080-1420
3	>1420

(Source : Chabala, 2013)

In numerous research, slope is one of the key inputs in landform categorization systems (e.g., Dobos et al., 2005; Huting et al., 2008; Saadat et al., 2008; Barka et al., 2011; Chabala et al., 2013).

Table 4.3. The slope classes.

Slope classes	Range of slope (m)
1	0-1
2	1-3
3	3-5
4	5-8
5	8-12
6	12-30
7	>30

(Source : Chabala, 2013)

Table 4.4: Landform classes by elevation, slope, relief and curvature.

Class number	Type of landform	Description
1	Hills (summit)	Slopes greater than 12%, convex curvature, elevation greater than 1180 m, and relief intensity between 1180 and 1375m are all characteristics of highland land surfaces.
2	Upper terraces	Concave curves, slopes greater than 8% to 12%, elevations greater than 1180 m, and relief between 1100 and 1180 m.
3	Plateau	Upland regions, often flat surfaces, slopes greater than 3% to 8%, flat curves, and elevations between 1030 and 1180 m.
4	Dambos	Lowest elevation, slopes less than 1%, concave to flat arcs, and elevations between 976 m and 1080 m or 976 m and 1030 m.
5	Lowland	Low gradient, slopes more than 1% up to 3%, flat curvature, and elevation between 976 m and 1180 m.

(Source : Chabala, 2013)

According to Chabala's categorization of geomorphology, the study area consist of elevation ranges from 270 to 440 metres and are classified as a lowland area. The geomorphological classification had been interpreted using the landform classification proposed by Chabala (2013), based on the geomorphological observations made in the field and also the correlation to the topography of the research area.

B. WEATHERING

Weathering is the process by which the physical and chemical characteristics of rocks exposed to climatic change and ultimately weathered and changed into soil. The weathering process was aided by water, wind, gravity, and glaciers. Due to Banding island being part of the oldest rainforest, which is tropical with high temperatures, heavy rainfall, and high humidity, chemical weathering and biological weathering were both discovered in the study region.

Oxidation is the process of chemical weathering that is present in the research field in Figure 4.13. Water serves as an agent that interacts with the oxygen-rich environment around it. When oxygen in water comes into contact with the iron components found in minerals that form rocks, a reaction can take place.



Figure 4.13 The oxidation that took place in study area.

The weakening and subsequent disintegration of the rock by microbial, animal, and plant activity is known as biological weathering. Figure 6 shows how plants grew roots through phyllite rock fissures in search of moisture and room. The roots of the flora progressively break the rock apart as it grows. This rock mass also contains chemical weathering domination.



Figure 4.14 The biological and chemical weathering in one of the location.

The process of weathering that causes rock to disintegrate without any chemical change is known as physical weathering, sometimes known as mechanical weathering or disaggregation. Temperature, pressure, frost, and other factors all have a role in this kind of weathering. These elements will cause the expansion and contraction of the sun-baked rock surface layer as well as the melting and freezing of water to occur again. Later, the rock would develop cracks as a result of this recurring process. The consequence of this operation was a crack, which increased the surface area of the rock. A rock with a large surface area will be more likely to be exposed to chemical activity, which will speed up the rate of disintegration.



Figure 4.15 A boulder that was captured with the netting of outcrop.

C. DRAINAGE PATTERN

Thornbury (1969) defined a drainage pattern as the planimetric arrangement of streams that a drainage system has etched into the surface of the land. The underlying rocks or topography determine the drainage patterns. The drainage system also displays the drainage basin's initial slope, original structure, diastrophism, and regional geological and geomorphological history. The pattern created by streams, rivers, and lakes in a specific drainage basin is known as the drainage pattern. They are controlled by the geography of the ground, the gradient of the land, and whether a particular region is dominated by hard or soft rocks.

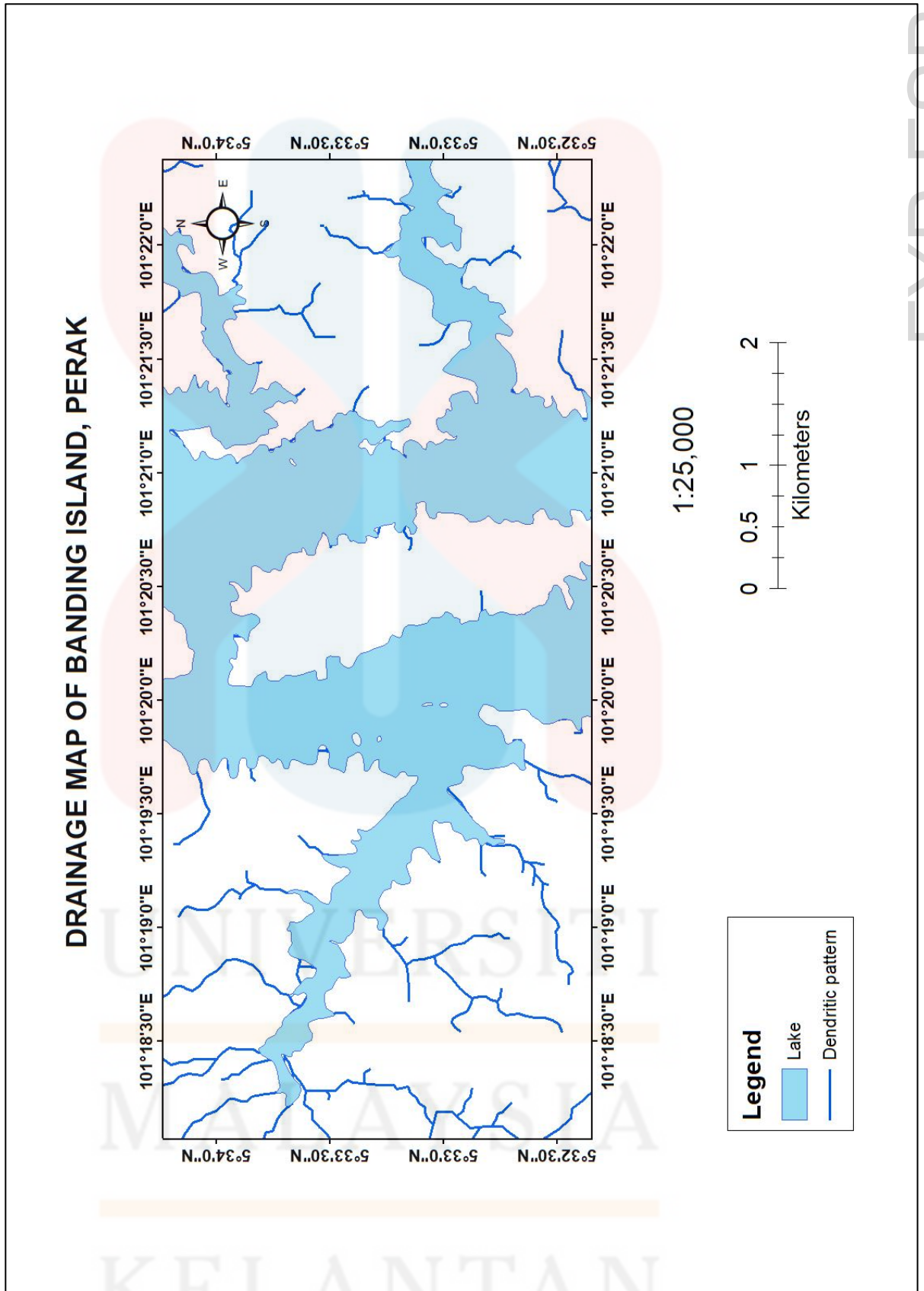


Figure 4.16 Dendritic pattern of drainage of the study area.

The first characteristic of a dendritic pattern is the erratic branching of tributary streams in all directions. The river and its tributaries form a pattern like a tree's branches in this most typical drainage pattern, which is characterised by being largely flat-lying and the direction in which the river and its water channels flow the valleys between the ridge.

The most typical drainage pattern is dendritic, and it develops in regions where the rock can't easily be eroded in all directions. The subsurface geology has the same level of resistance to weathering and erosion as the area where it formed because it is underlain by uniform material. Therefore, it appears that there is no control over the path the stream takes. Acute angles, or angles of fewer than 90 degrees, are formed when streams join a bigger stream. Metamorphic rock phyllite and schist that are not folded are two types of rock that can be found in the area that have dendritic patterns as shown in Figure 7.

4.3 LITHOSTRATIGRAPHY

The study of rocks in the research area that are related to their age and used to build a stratigraphic column is the focus of lithostratigraphy. Additionally, the research area is dominated by metamorphic rock, specifically phyllite and mica schist, and one branch of stratigraphy that deals with the definition of rock units in terms of their geological characteristics. The western zone, according to Jones (1973), includes the area between the Perak-Thai border and the state of Malacca. The Baling group and Bentong group are the two principal stratigraphic groups found in the western zone. The Lower Palaeozoic deposits of Dinding schist, Hawthornden schist, and Kuala Lumpur limestone in Selangor should constitute the other noteworthy unit. Due to its location in north Perak, the area of interest is a part of the stratigraphic unit known as the Baling group. Calcareous, arenitic, and argillite sedimentary rocks make up the Baling group.

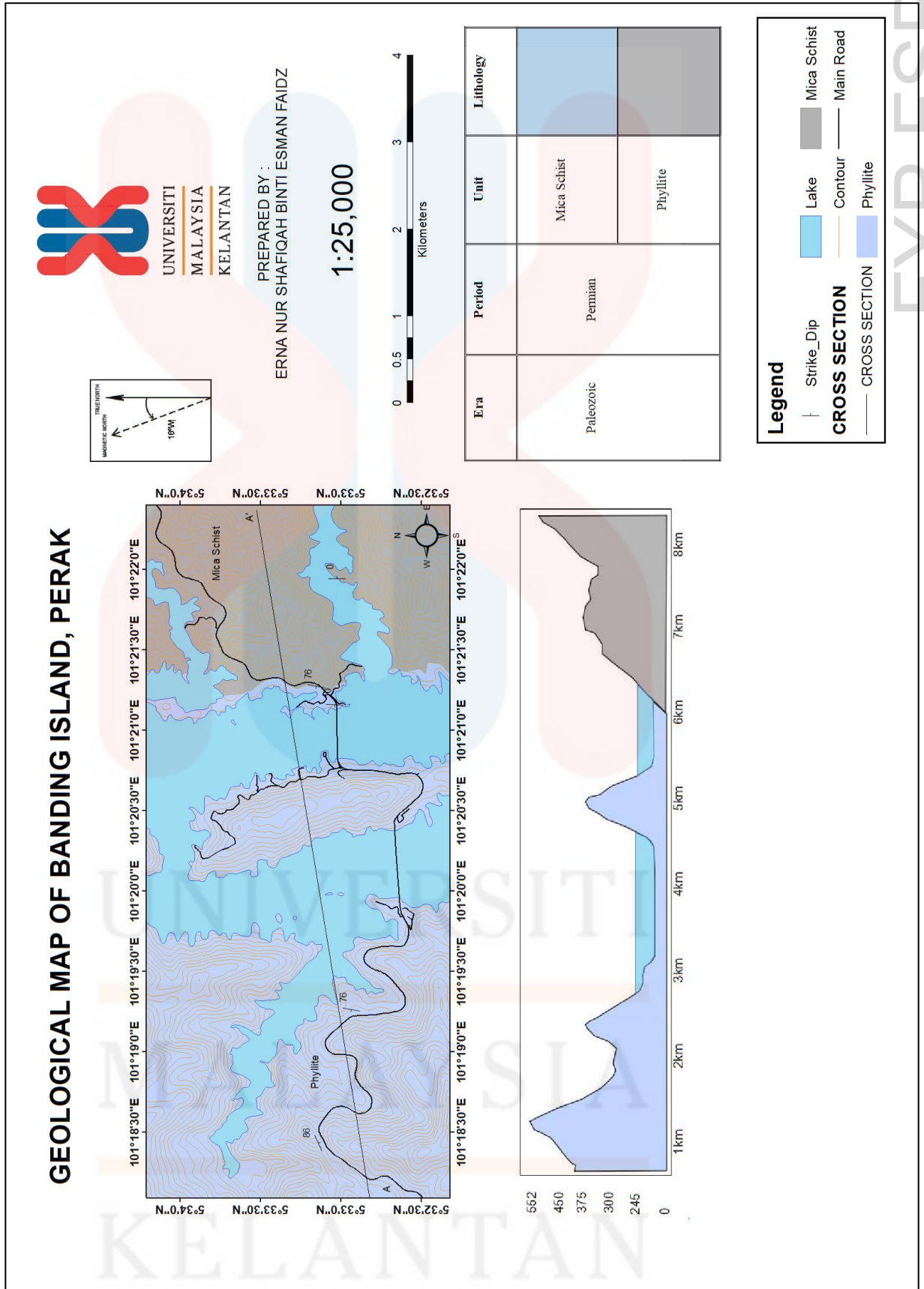


Figure 4.17 The geological map of the study area.

Phyllite unit

Location : N 05° 33' 07", E 101° 18' 27"

The first location was located at N 05° 33' 07", E 101° 18' 27" at the very west of the study area. Figure 8 depicts the outcrop approximately 15 meters height with the length of 12 meters. Interbedded metasandstone was found in this unit. The outcrop morphology is in the hilly area at height 440m shows that it has been "extremely worn" by biological weathering, with the majority of the outcrop being covered by vegetation. This outcrop was covered in net as the physical weathering also took place in this area. Fresh samples were taken as shown in Figure 4.18.



Figure 4.18 The condition of the first location.



Figure 4.19 A boulder that was separated from the rock mass due to physical weathering.

Schist unit.

Location : N 5° 32' 57" N, 101° 21' 80" E

Schist unit location was located at the east part of the study area, exactly at the lake side of Banding island at N 5° 32' 57" N, 101° 21' 80" E. Approximate 1 to 2 meters height of the outcrop with the length of 10 meters long. The outcrop appears to be weathered due to chemical weathering and small amount of physical weathering. This area considered to have high grade phyllite than the upper land which exposed to weathering more than the low land.



Figure 4.20 The schist unit outcrop at the east side of the study area.

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A. STRATIGRAPHIC POSITION

Table 4.5:The description of the formation of the study area.

Period/Epoch	Formation/ Unit	Stratigraphic Column	Description
Permian	Gerik Formation		Mica schist intercalated with layers of quartz
			Phyllite on the other hand has intercalation of dark grey to black

B. UNIT EXPLANATION

Table 4.6. The description of each lithology unit of the study area.

Type of rock	Lithology	Description	Formation Age	Stratigraphy
Metamorphic rock	Phyllite	Majority are highly weathered with visible joint. Contain quartz vein with thickness varies from 0.5 cm to 6 cm. Intensity of the regional metamorphism is lowest (west)	Permian	
	Mica schist	Located at lake side. The east of the study area has experienced moderate metamorphism, which is confirmed by the transition of phyllite into schist as a result of metamorphism.		

4.4 STRUCTURAL GEOLOGY

A) Joint Analysis

L1, L2, and L3 were three of the four areas utilized in the joint analysis. The 4 locations mentioned has collected a total of 200 joint readings for each locality. Figure 4.19 shows a rose diagram for each region where reading was done. L1 and L2 locality has the major force from NE and SW direction while L3 and L4 has major forces from NW and SE. The tectonic event that produced the joint in all of the places exposed it through extensional mineral weathering and 200 readings of the joint strike are being interpreted and measured.

1. First locality (N 05° 33' 33", E 101° 20' 21")



Figure 4.21 Joint in first location

B) Foliation Analysis

When flat or elongate minerals within a rock are compressed and aligned, foliation process will occur. As pressure is applied, these rocks take on a platy or sheet-like structure that mirrors the pressure direction. Sheety minerals like mica or chlorite are the ones that exhibit foliation the most as shown in the figure below. According to Vernon (2004), foliation is a usual process in rocks affected by the regional metamorphic compression in particular of areas of mountain belt formation. L4 rose diagram recorded the foliation in this location and its showing that its major forces is at NW and SE direction.

2. Fourth locality (N 5° 32' 57", E 101° 21' 80")

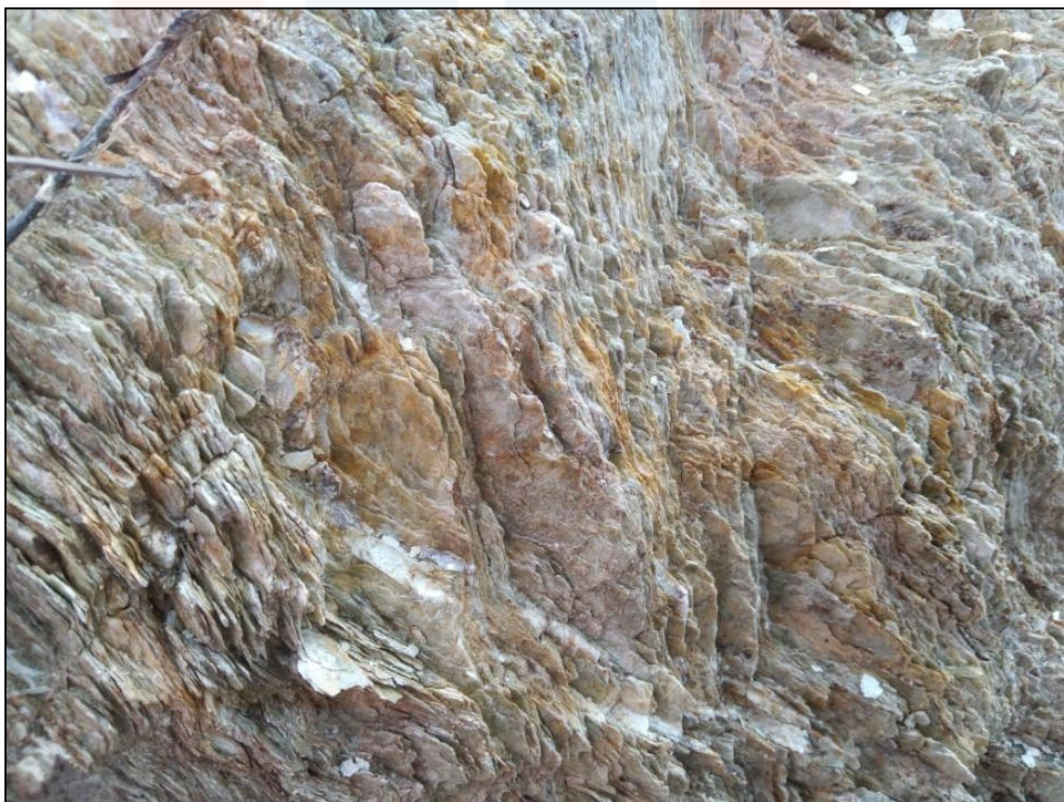
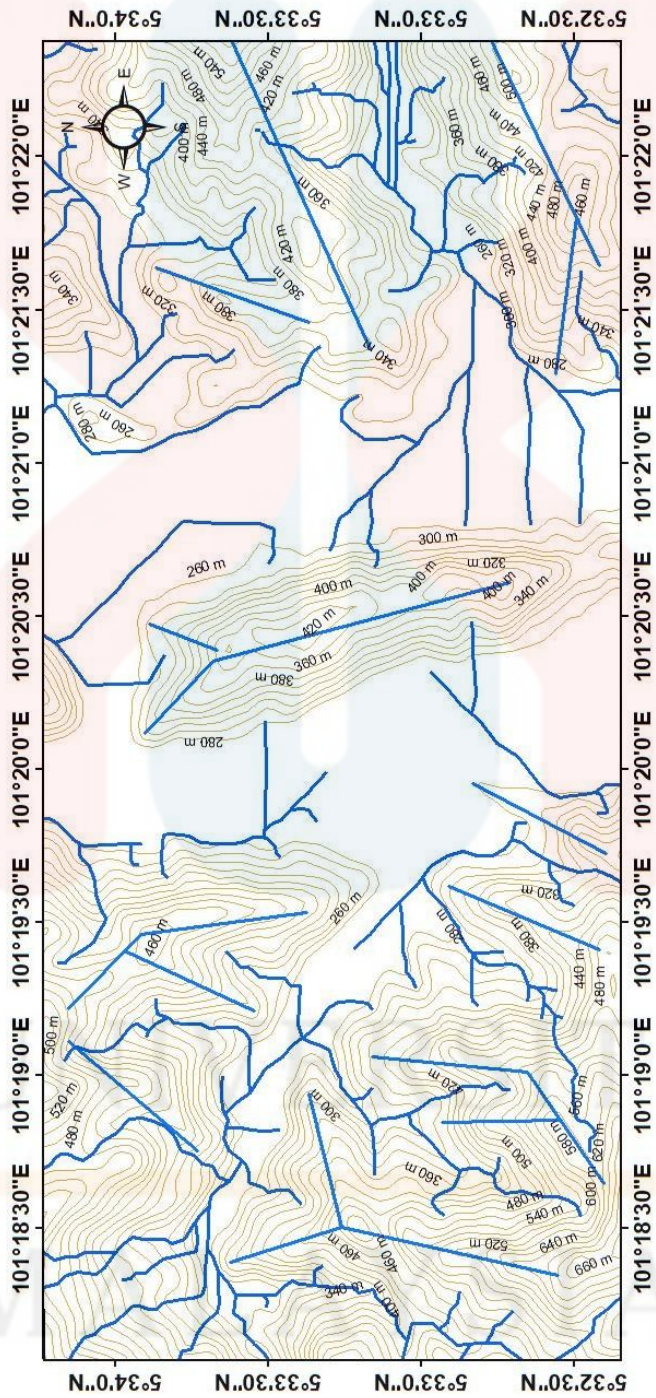


Figure 4.22 The foliation at the study area.

C) **Lineament Analysis.**

Positive and negative lineaments were analysed in lineament analysis. The study area ridges generates the positive lineament, and the rivers produced the negative lineament. To determine the bearing of each lineament, the two lineaments were measured with a protractor after being identified. In order to determine the direction of the forces applied at the river and ridges, all bearings were employed to construct the rose diagram.

POSITIVE LINEAMENT MAP OF BANDING ISLAND, PERAK



1:25,000

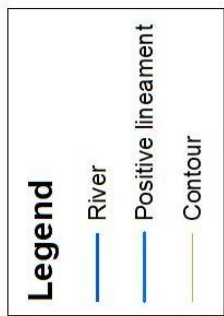
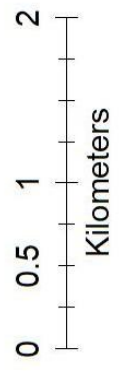


Figure 4.23 The positive lineament of the study area.

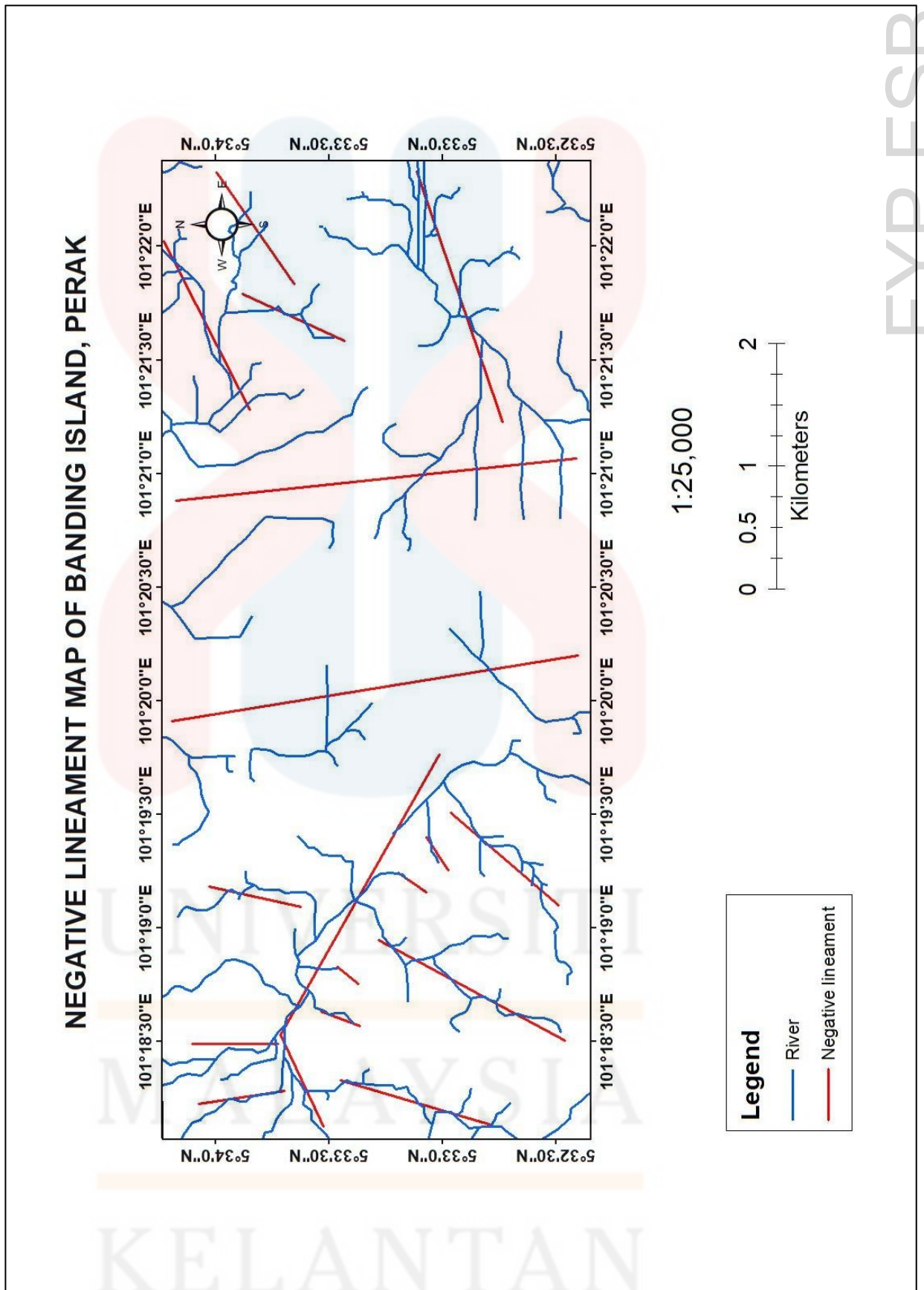


Figure 4.24 The negative lineament of the study area.

Positive Lineament

The lineament are the line that are generated along the topographical features that exhibit the surface characteristics. The positive lineament represents ridges or ranges of hilly area obtained from the study area. The rose diagram shows the forces is at NE and SW while the tension is at NW and SE.

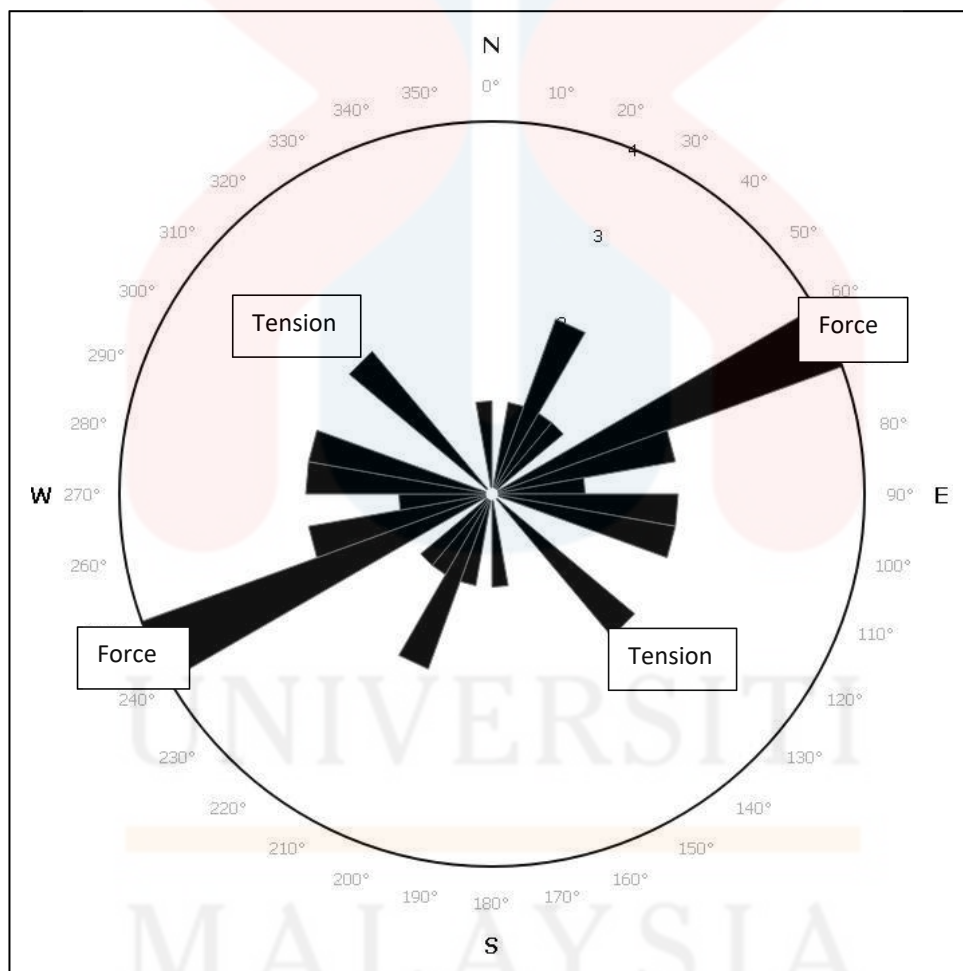


Figure 4.25 The rose diagram of the positive lineament of the study area.

Negative Lineament

Negative lineament on the other hand represent fault or joint which can be identified from the river or valley. The forces occurs at NW and SE while the tension is at NE and SW.

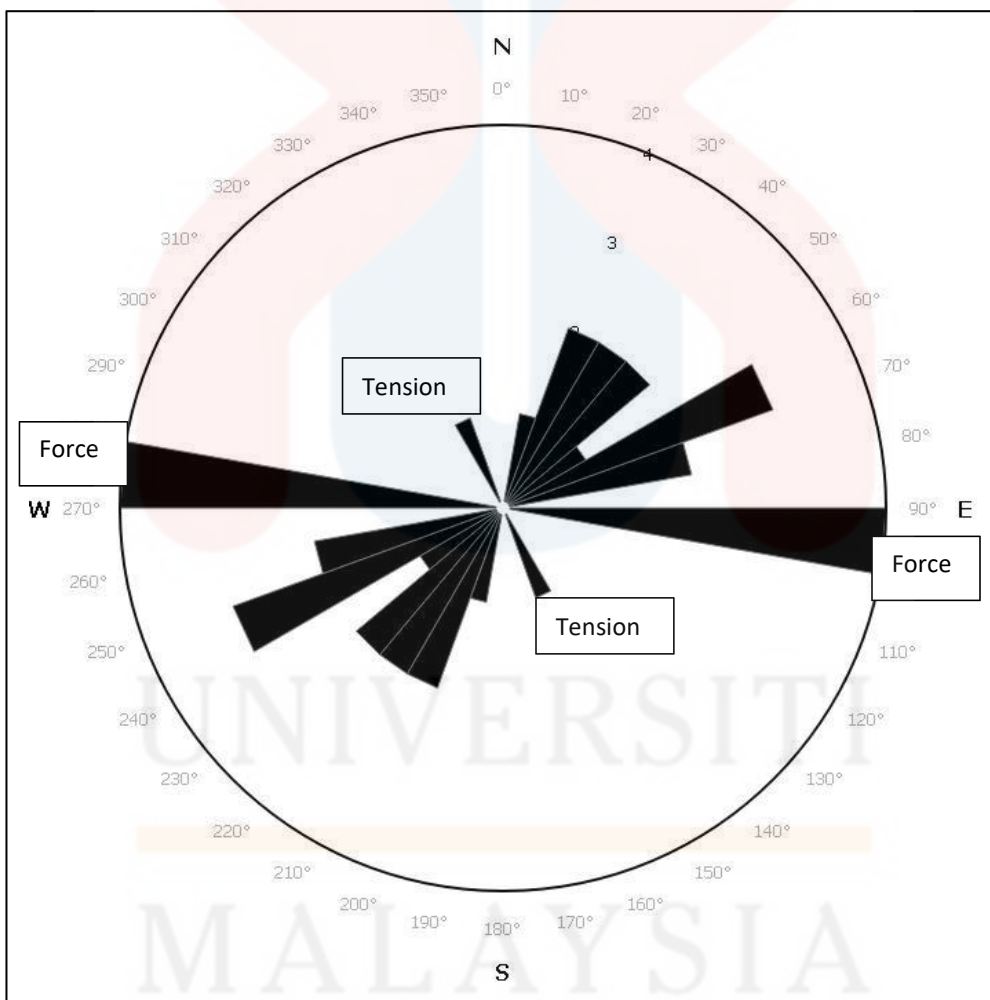


Figure 4.26 The rose diagram of the negative lineament of the study area.

1. First locality (N 05° 33' 33", E 101° 20' 21")

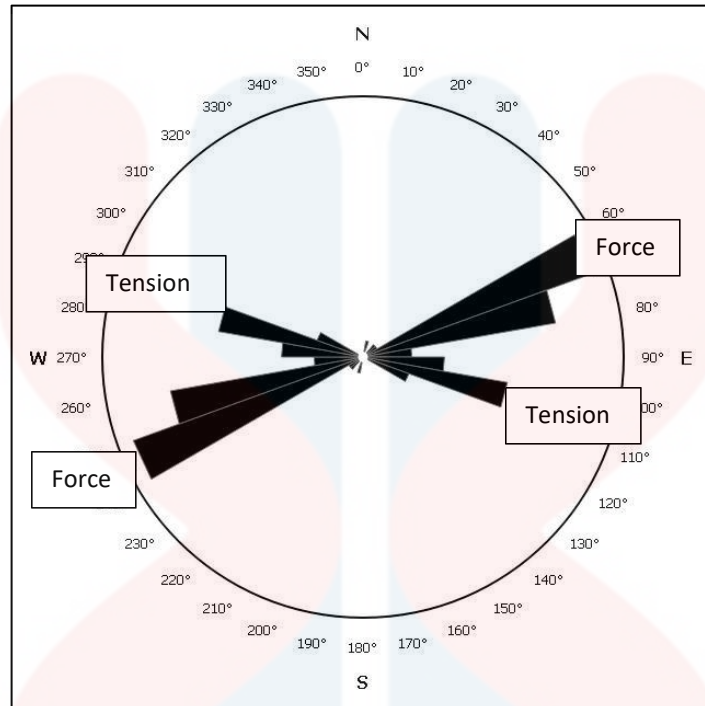


Figure 4.27 The rose diagram L1.

2. Second locality (N 5° 32' 54" , E 101° 19' 14")

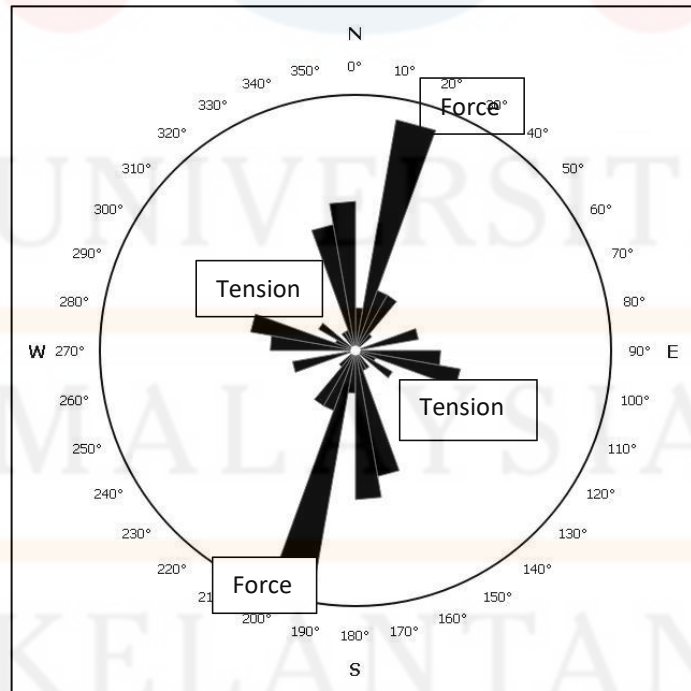


Figure 4.28 The rose diagram L2.

3. Third locality (N 5° 33' 33", E 101° 21' 19")

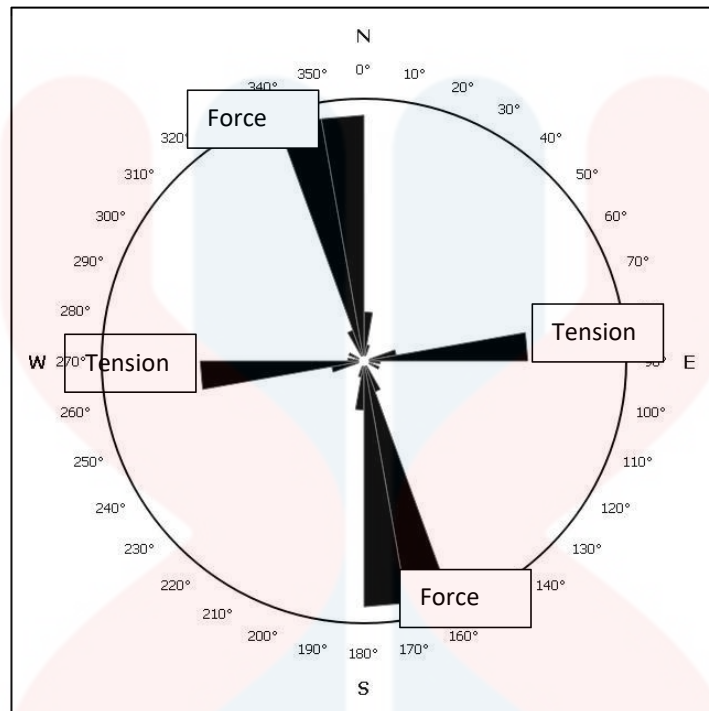


Figure 4.29 The rose diagram L3.

4. Fourth location (N 5° 32' 57", E 101° 21' 80")

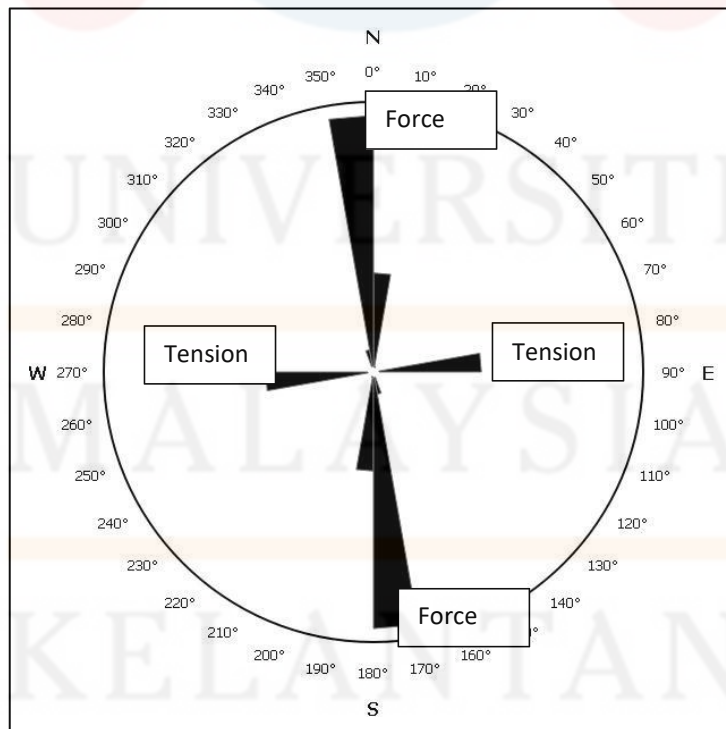


Figure 4.30 The rose diagram L4.

4.5 HISTORICAL GEOLOGY

Hills and limestone caverns are the main geological features of Perak state. The Baling Group which contains Bendang Riang, Papulut Quartzite, Lawin Tuff, Kroh Formation, and Gerik Formation are one of the Paleozoic formations found here. The study area Banding island is an island positioned in the midst of a manmade lake popularly known by the locals as Temenggor lake or Temenggor dam and it is a member of the Baling group located in Gerik, which situated in the western part of Perak. Low-grade regional metamorphic rock that came from the East Malaya block from the Ordovician to Permian era makes up the majority of Banding Island's significant structures.

The western zone, according to Jones (1973), is a region that stretches from the Perak-Thai border southward to the state of Melaka. The Southeast Asian granite belts are divided into the Eastern, Main Range (South Thailand-West Peninsular Malaysia), Northern (Northern Thailand), and Western (Southwest Thailand-East Myanmar) granite provinces (Cobbing et al., 1986, 1992; Ghani et al., 2013). The Eastern granite province, which is situated in the western half of Peninsular Malaysia, is separated from the Main Range granite province by the Bentong-Raub suture zone, which marks the closure of the Paleo-Tethys Ocean (Metcalf, 2000, 2013).

The Eastern Granite Province plutons were deposited in the Indochina-East Malaya Block after the suturing event, while the Main Range Granite Province is situated on the Sibumasu Terrane (Metcalf, 2013). The Sibumasu and Indochina-East Malaya collision, which joined the two plates, ended the subduction process at 230–

220 Ma (Ng et al., 2015b). The Main Range batholith and the Bintang batholith are two significant intrusive phases in the Main Range granite province. The two batholiths were part of a region of Lower Paleozoic rocks that included felsic to intermediate Ordovician meta-sedimentary rocks and meta-volcanic rocks. (Jones, 1970, 1973)

CHAPTER 5

SPECIFICATION PETROGRAPHY OF METAMORPHIC ROCKS MINERAL ASSEMBLAGES

5.1 INTRODUCTION

In order to determine mineral assemblages and the nature of the rocks, this chapter will place an emphasis on petrography studies that analyse the petrography of metamorphic rocks in the research region of Banding Island, Perak. Based on the texture, mineral composition, and mineralogy of the rocks, SEM and XRD examination is the approach employed. The study area are dominated by phyllite on the west side and mica schist from the east side. The goal of this study was to learn more about the metamorphic rock mineral assemblages found on Banding Island in Gerik, Perak. As a result, seven samples total from four locations are taken for petrographic examination and SEM and five samples from the study region are obtained for XRD analysis.

5.2 PETROGRAPHIC ANALYSIS


1) Phyllite

The sample was taken at the very first location ; on the Banding island with the elevation of 410m. The sample appears in highly weathered condition as the rock are in white and brownish colour. The foliation are visible but was covered with weathering features. Chemical weathering occurred altering the colour of the original phyllite.

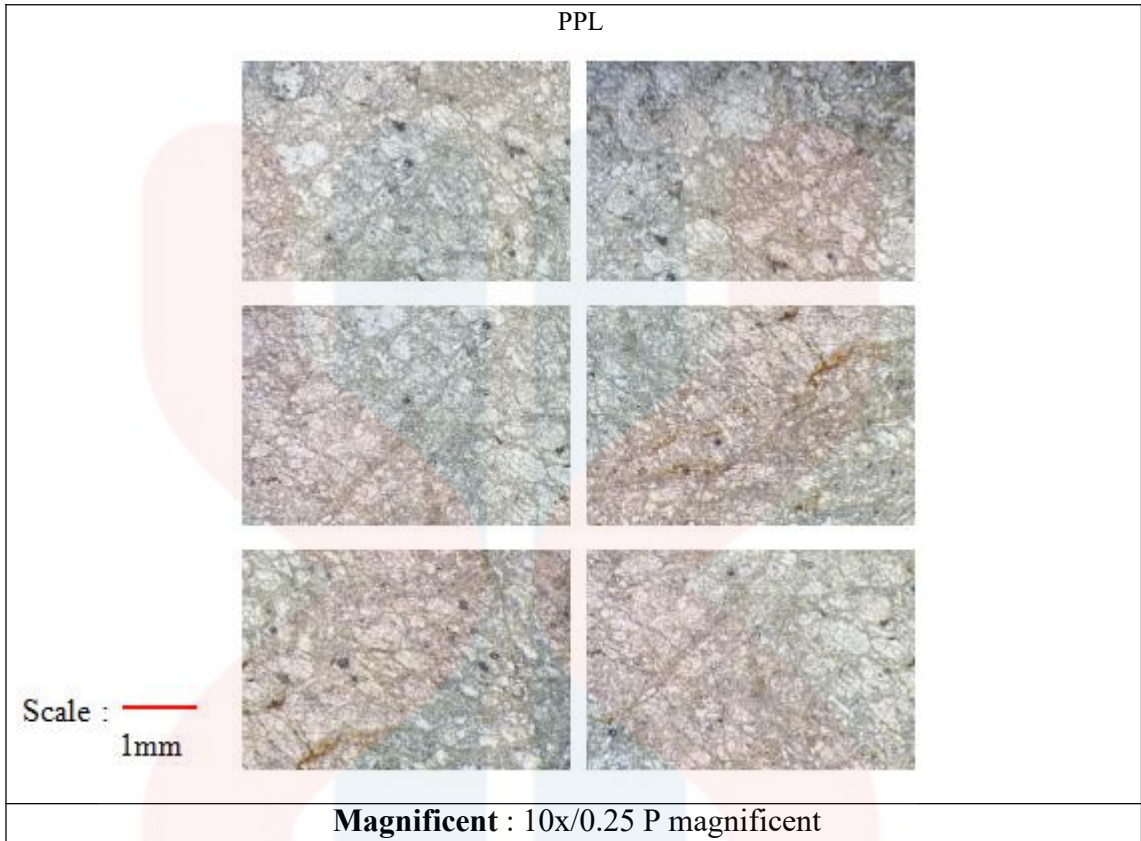


Figure 5.1 The hand specimen of location 1.

Sample code	E001U	Location	1
Coordinate	N 05° 33' 33", E 101° 20' 21"		
Rock Name	Phyllite		
Rock Type	Metamorphic rock		
Colour	Greyish white		
Grain Size	Fine grained		
Texture	Aphanitic		
Structure	Foliation		
Domination	Mica, Quartz		
Level weathering	Highly weathered		

Thin section Analysis	
Minerals	Description
Mica	Mica is white in xpl and appears colourless in ppl.
Quartz	The quartz appears black and white in xpl while colourless in ppl. It has subhedral or subangular shape.
Opaque	The opaque appears solid black in colour through xpl and ppl.
Description	
<p>The sample E001U has small grains, slightly metamorphosed quartz particles, with biotite filling the spaces between the grains. Quartz still displays sedimentary rock characteristics, but mica minerals are beginning to form and fill the matrix in the rocks. When viewed in cross-polarized light and wavy extinction, the quartz is greyish to milky white. In this sample, quartz is more abundant. In cross-polarized light, the mica exhibits 2nd order colour and seems to be second dominating in the thin portion. Examples of minerals found in the mica group mineral include biotite, chlorite, and muscovite.</p>	
XPL	
Scale :  1mm	
Magnificent : 10x/0.25 P magnificent	

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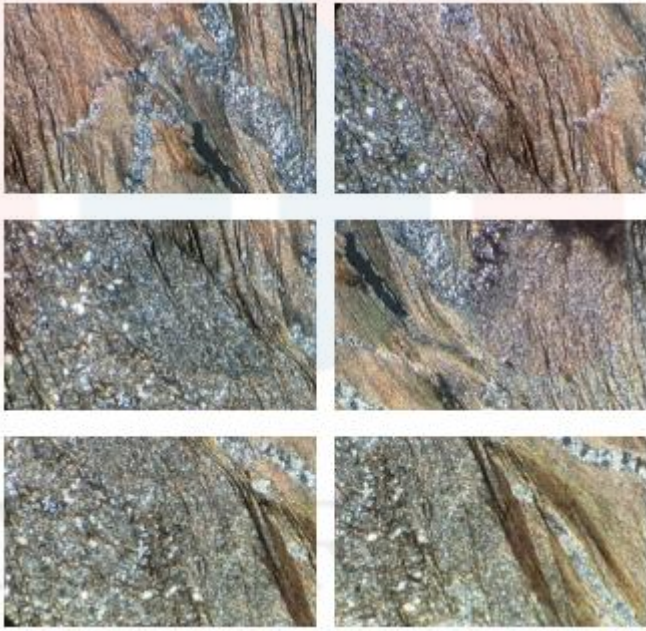

2) Phyllite

This sample was taken at second location along with other 3 samples labeled E102U, E103Q1 and E103U2 at the elevation of 440m. The colour of sample are dark grey and shining due to mica presence. It has flaky and brittle texture with visible schistosity. The joint cracks found in the outcrop and few of the samples appears brownish in colour due to slightly weathered



Figure 5.2 The hand specimen of location 2.

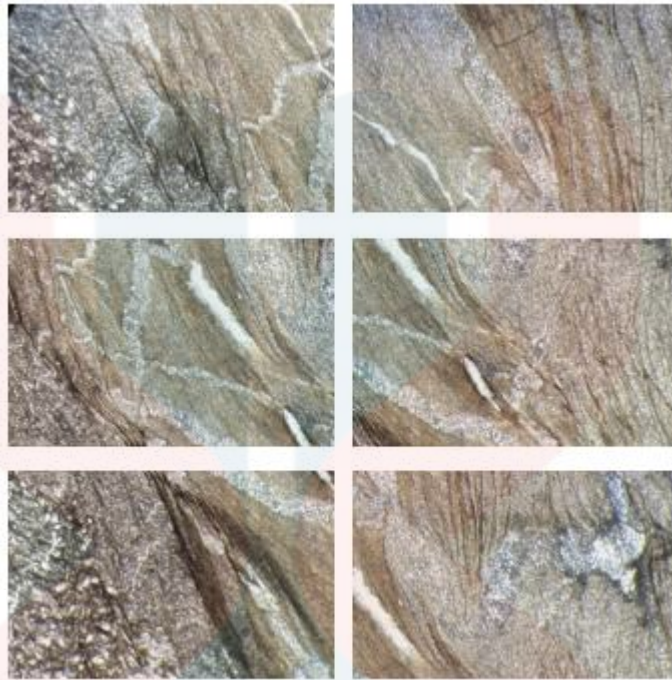
Sample code	E101P	Location	2
Coordinate	N 05° 33' 07", E 101° 18' 27"		
Rock Name	Phyllite		
Rock Type	Metamorphic rock		
Colour	Dark grey		
Grain Size	Fine grained		
Texture	Aphanitic, flaky, brittle		
Structure	Schistosity		
Domination	Biotite, Quartz		
Level weathering	Slightly weathered		


Thin section Analysis	
Minerals	Description
Biotite	Appears brownish with foliation and fracture in xpl and ppl.
Quartz	Quartz appears white in xpl and colourless in ppl.
Description	
<p>The rock sample E101P is fine-grained with a distinct foliation structure. In comparison to quartz, mica minerals like chlorite and biotite are more abundant. The biotite mineral has clear visible fractures because the mineral may have undergone rock deformation.</p>	
XPL	
	
Scale :	 1mm
Magnificent : 10x/0.25 P magnificent	

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Scale : 
1mm

Magnificent : 10x/0.25 P magnificent

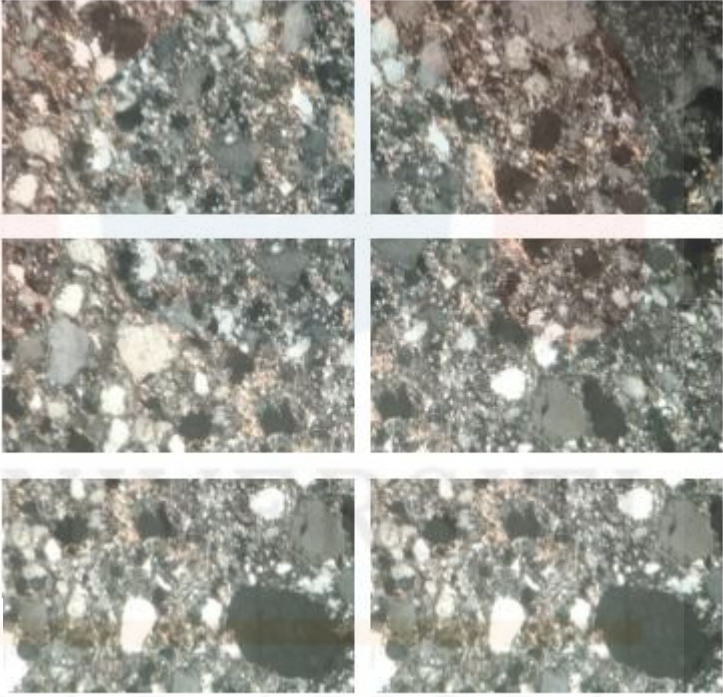

3) Metasandstone

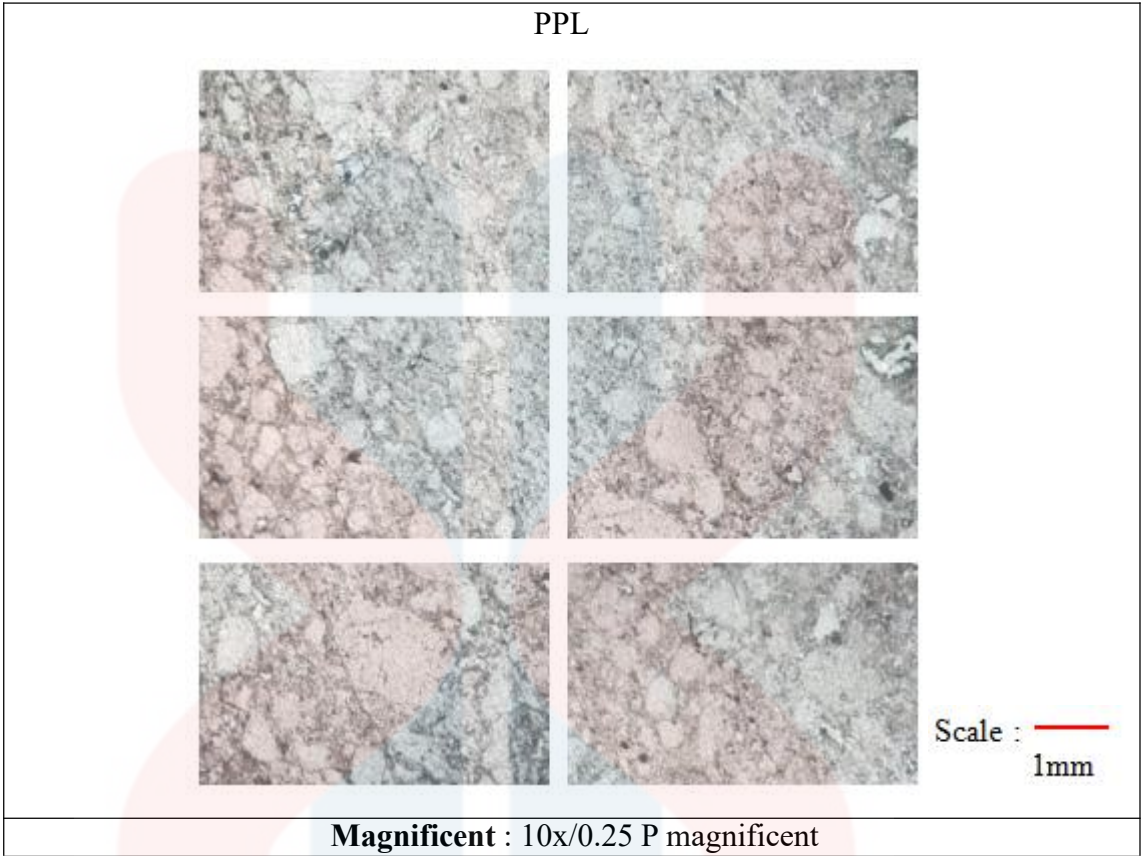
This sample was taken at the second location along with other 3 samples labeled E101P, E103Q1 and E103U2 at the elevation of 440m. The sample appears in greyish colour with a small amount of quartz vein sticks to the sample as this sample are interbedded with quartz vein. Due to mica presence it has shining appearances and are slightly weathered.



Figure 5.3 The hand specimen of location 2.

Sample code	E102U	Location	2
Coordinate	N 05° 33' 07", E 101° 18' 27"		
Rock Name	Metasandstone		
Rock Type	Metamorphic rock		
Colour	Dark grey		
Grain Size	Fine grained		
Texture	Porphyritic		
Structure	Interbedded		
Domination	Quartz, Mica, Chlorite		
Level weathering	Slightly weathered		

Thin section Analysis	
Minerals	Description
Quartz	Appears white and black in xpl while colourless in ppl due to extinction.
Chlorite	Chlorite filled up the spaces between mica and chlorite.
Mica	Appears white in xpl and colourless in ppl.
Description	
<p>Chlorite and biotite are visible quartz minerals that are present in the matrix of Sample E102U. It is clear that quartz dominates in the sample. The spaces between quartz and mica were filled by chlorite.</p>	
XPL	
	
Scale :	 1mm
Magnificent : 10x/0.25 P magnificent	



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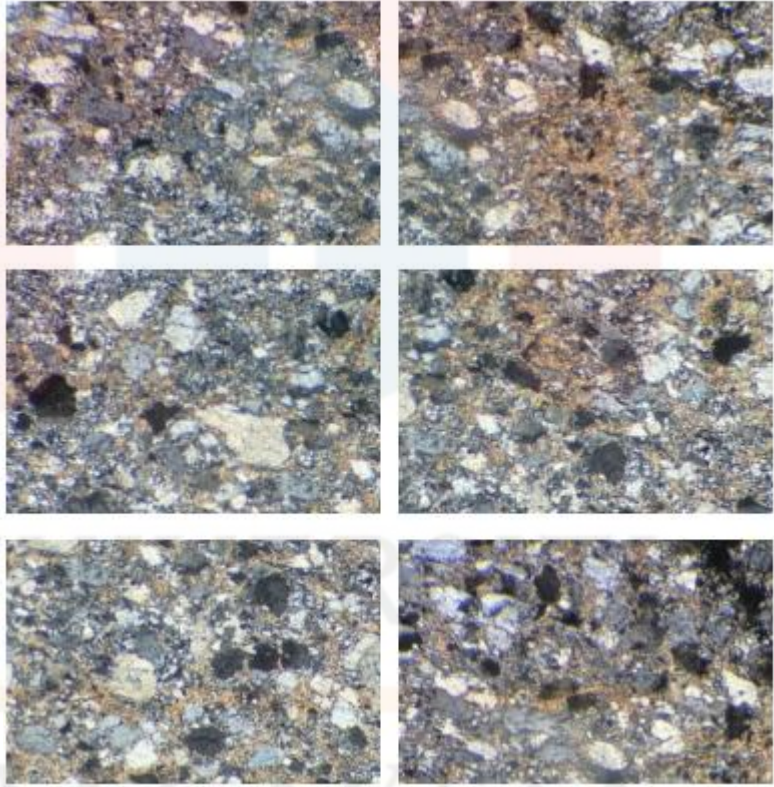

4) Metasandstone

This sample was taken at the second location along with other 3 samples labeled E101P, E102U and E103Q1 at the elevation of 440m. Greyish in colour but has some part appears in brownish colour due to weathering in joint crack. The sample is hard with medium to fine grain size. Interbedded with quartz vein with thickness varies from 0.5cm to 6cm.

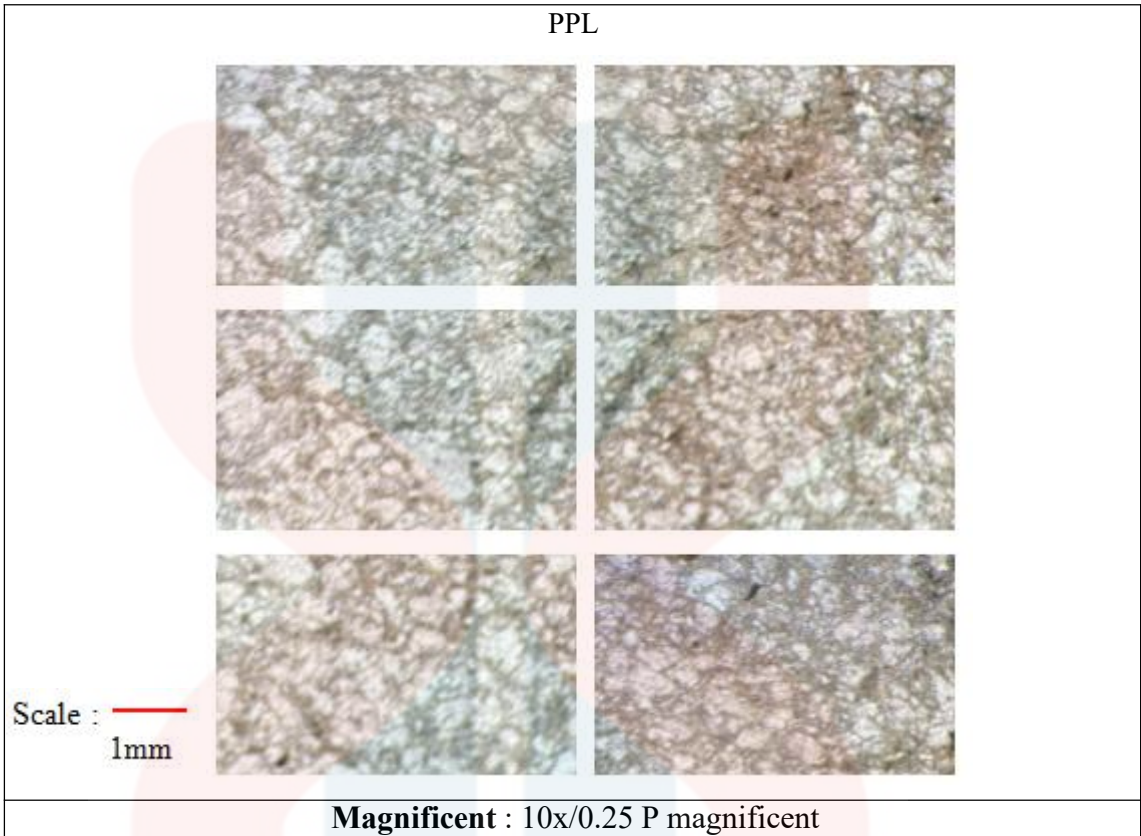


Figure 5.4 The hand specimen of location 2.

Sample code	E103U2	Location	2
Coordinate	N 05° 33' 07", E 101° 18' 27"		
Rock Name	Metasandstone		
Rock Type	Metamorphic rock		
Colour	Greyish white		
Grain Size	Fine grained		
Texture	Porphyritic		
Structure	Interbedded		
Domination	Chlorite, Quartz		
Level weathering	Slightly weathered		

Thin section Analysis	
Minerals	Description
Chlorite	Filled up spaced between quartz and mica.
Quartz	Quartz appears black and white in xpl while colourless in ppl.
Description	
<p>Similar to sample E001U, sample E103U2 exhibits the same traits and rock textures with the addition of chlorite minerals. However, compared to samples E001U, the mica is more prevalent in the thin section, while the composition of the quartz is deteriorating.</p>	
XPL	
	
Scale :	 1mm
Magnificent : 10x/0.25 P magnificent	

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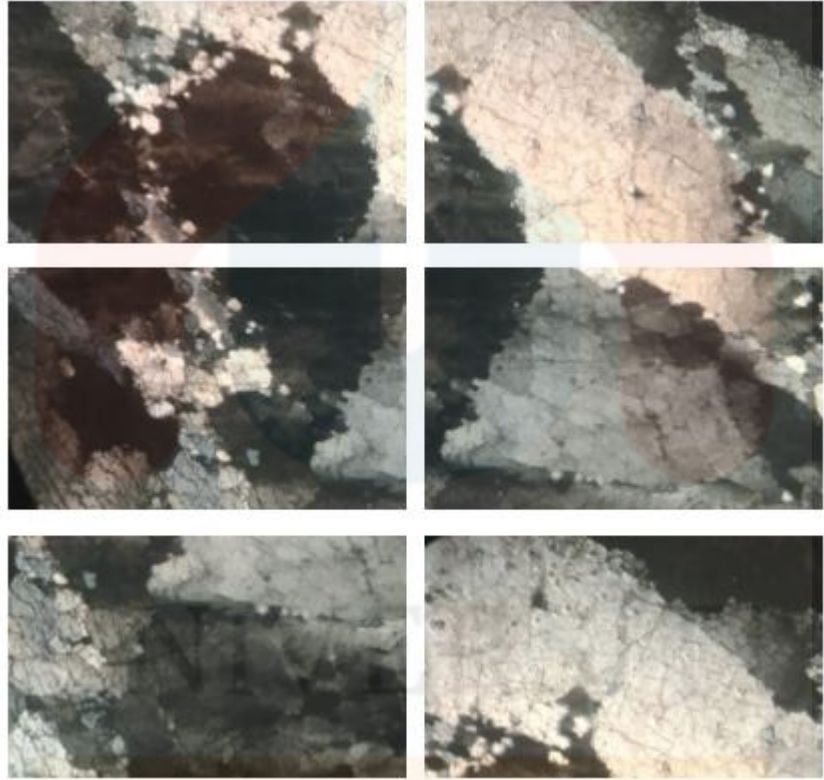

5) Quartz

This sample was taken at the second location along with other 3 samples labeled E101P, E102U and E103U2 at the elevation of 440m. This sample is a part of quartz vein that interbedded with metasandstone. The thickness of vein recorded from 0.5cm to 6cm. Appears white in colour but has brownish part due to slight weathering.



Figure 5.5 The hand specimen of location 2.

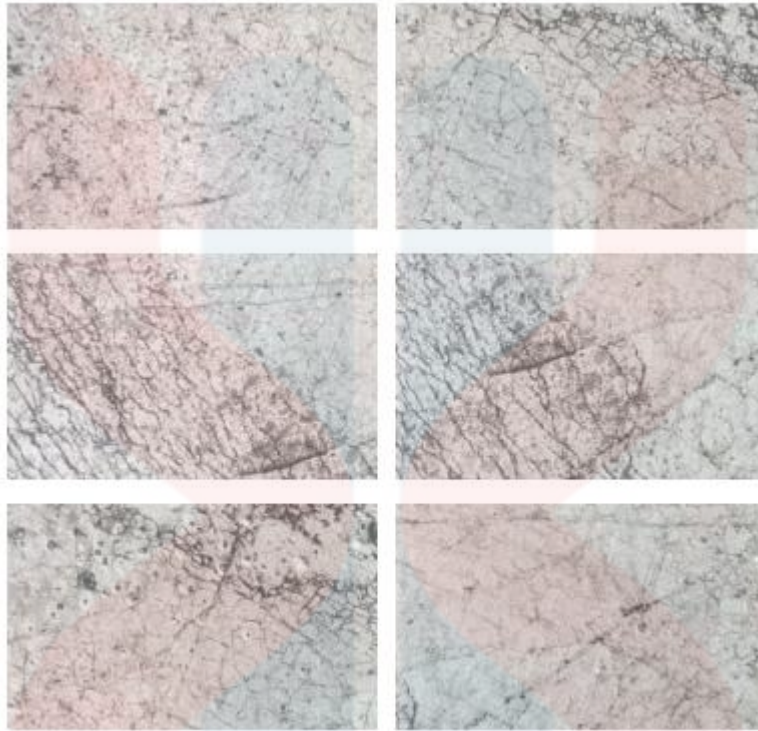
Sample code	E103Q1	Location	2
Coordinate	N 05° 33' 07", E 101° 18' 27"		
Rock Name	Quartz		
Rock Type	Igneous rock		
Colour	White		
Grain Size	Fine grained		
Texture	Aphanitic		
Structure	Fracture , Quartz vein		
Domination	Quartz		
Level weathering	Slightly weathered		


Thin section Analysis	
Minerals	Description
Quartz	Appears white and black in xpl and colourless in ppl.
Description	
<p>Quartz with heavily fractured characteristics is seen in Sample E103Q1, possibly as a result of the rock's deformation.</p>	
XPL	
<div style="display: flex; justify-content: space-around;">  </div> <div style="text-align: right; margin-top: 10px;"> <p>Scale :  1mm</p> </div>	
Magnificent : 10x/0.25 P magnificent	

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Scale : 
1mm

Magnificent : 10x/0.25 P magnificent

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6) Metasandstone

The sample was taken at the third location with elevation of 340m. It is a weathered metasandstone and due to its alteration in colour, it appears white with some part brownish in colour. The sample was found interbedded with slate that has thickness of 0.5cm.

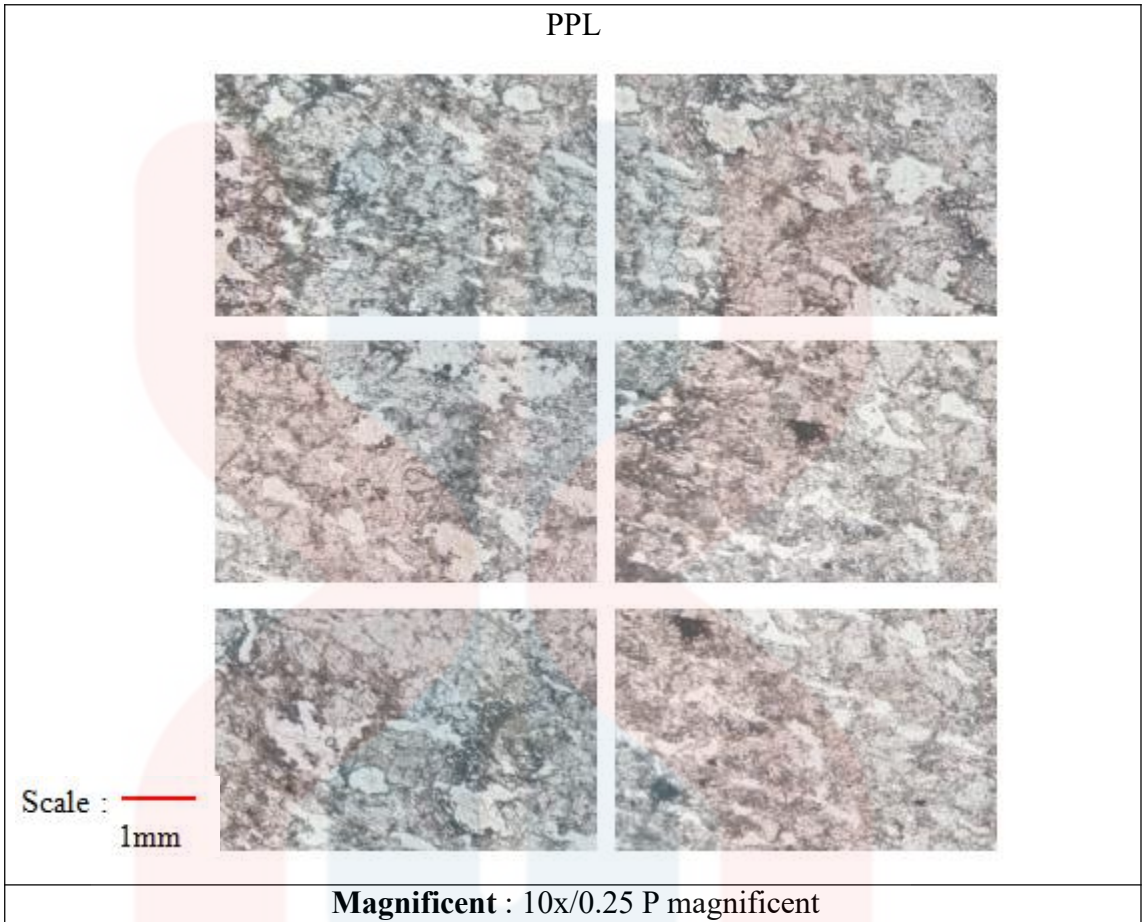


Figure 5.6 The hand specimen of location 3.

Sample code	E201U	Location	3
Coordinate	N 5° 32' 54", E 101° 19' 14"		
Rock Name	Metasandstone		
Rock Type	Metamorphic rock		
Colour	Greyish white		
Grain Size	Fine grained		
Texture	Porphyritic		
Structure	Foliation, Interbedded		
Domination	Mica, Quartz		
Level weathering	Slightly weathered		

Thin section Analysis	
Minerals	Description
Mica	Appears filled up spaces between quartz.
Quartz	Appears white and black in xpl and colourless in ppl.
Description	
<p>Despite sharing a similar rock type with samples E001U and E102U, sample E201U has more obvious foliation. The mineral appears in ppl to be elongated, maybe as a result of the metamorphism process, which is evidence of foliation.</p>	
XPL	
Scale :	 1mm
Magnificent : 10x/0.25 P magnificent	

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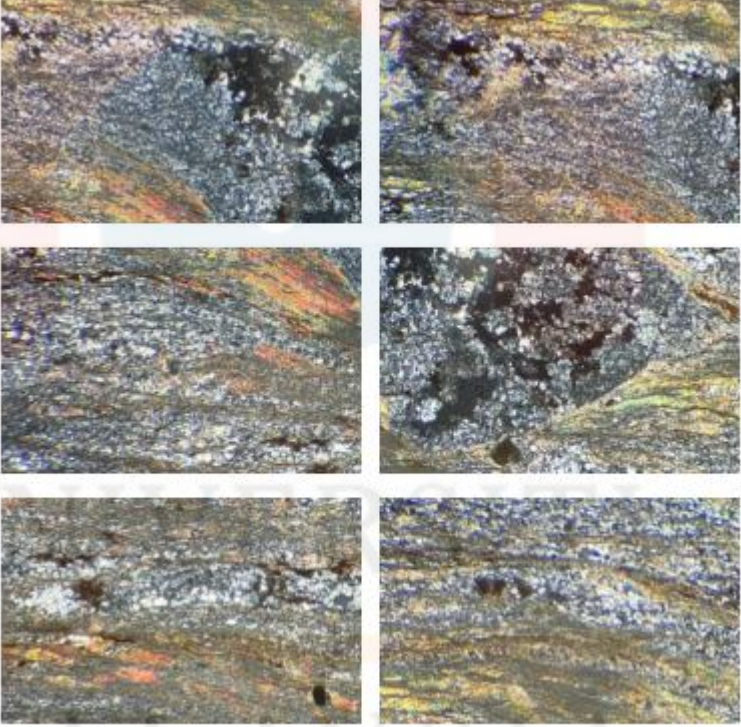

7) Mica schist

The sample was taken at the last location at the elevation of 410m. The sample appears brownish and blackish due to weathering which supposed to be grey and green. It has visible schistosity that are obvious to determine minerals. The minerals are quartz interlayered with mica.



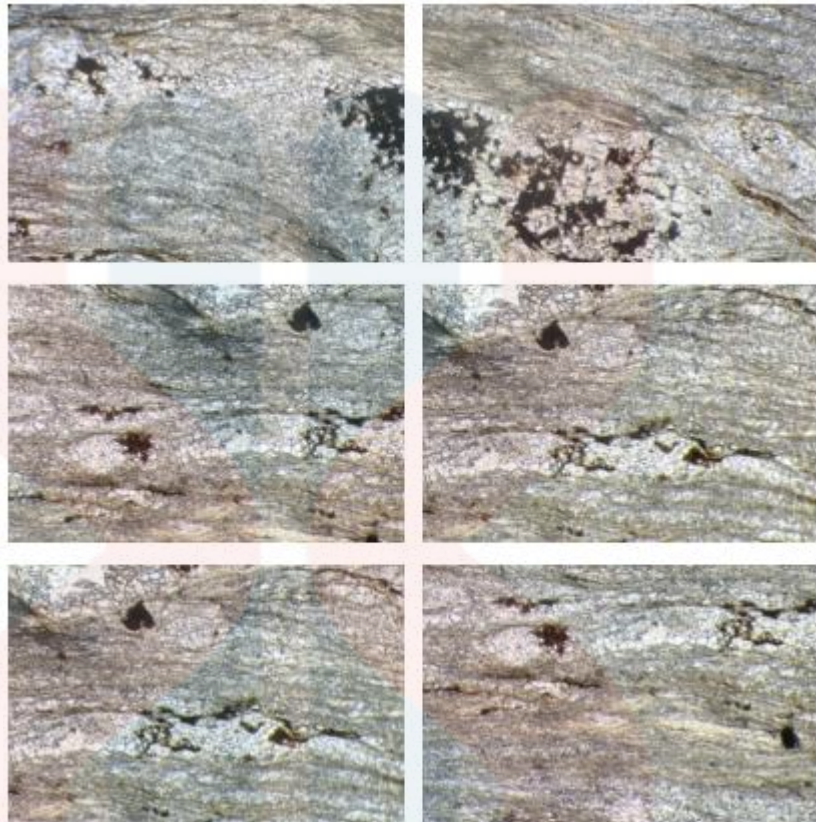
Figure 5.7 The hand specimen of location 4.


Sample code	E301MS	Location	4
Coordinate	N 5° 32' 57", E 101° 21' 80"		
Rock Name	Mica Schist		
Rock Type	Metamorphic rock		
Colour	Brownish and blackish		
Grain Size	Fine grained		
Texture	Aphanitic		
Structure	Schistosity		
Domination	Mica layered with quartz		
Level weathering	Slightly weathered		

Thin section Analysis	
Minerals	Description
Mica	Filled up spaces between quartz and muscovite.
Quartz	Appears white In xpl and colourless in ppl.
Muscovite	Exhibit speckled extinction in xpl and colourless in ppl.
Description	
<p>Sample shows foliation and the presence of biotite and muscovite. In cross-polarized light, the mica exhibits 2nd order colour and seems to be second dominating in the thin section.</p>	
XPL	
	
Scale :	 1mm
Magnificent : 10x/0.25 P magnificent	

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PPL



Scale : 
1mm

Magnificent : 10x/0.25 P magnificent

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XRD Analysis

In this study, a unique approach for mineral quantification utilising XRD methodology was proposed. A substantial amount of the material from each sample was powdered and combined in about 100 g in order to prevent issues during sampling. For experimental purposes, measuring peak intensity only required a modest amount of material—roughly 15 g. For the duration of the entire XRD study, all test settings were held constant. The mineral mixing ratios were selected based on what the petrographic analysis revealed. The peaks in the XRD patterns that correspond to each mineral were selected using a database of pattern data. Each distinct mineral found in the rock sample was represented by the interatomic distance

(d) value ranges. Table 5 provides information on the mineral reference values of d, based on the database that is currently accessible. The values of (d) were calculated for the highest peak intensities of the various minerals found in XRD samples of the same type of material. The most intense peaks in every diffraction pattern have relative intensity values that are significantly higher than those of the other peaks. The third and second peaks' results are exceedingly challenging to see. The regression calibration curve was used to correct all intensity values, and the mixing ratio was used to calculate the weight percentage of each intensity ratio based on the mineral composition of each sample.

Table 5.1 Test parameters used in all XRD analyse

Parameter	Value
Sample amount	5 gram
Powder grain size	Maximum 70 μm
2 Theta (θ) range	0° - 90°
Scanning rate (2 θ)	3.002° / 10.002°
Slew	5.0001°/min
Anode	Cu (30 kV, 20 mA)
Wavelength	1.5406 Cu

Table 5.2 Range of interatomic distances the most intense peak of the each sample.

Sample	Range of d [\AA]
E001U	3.38-4.31
E102U	3.34-4.26
E103U2	3.34-4.25
E103Q1	3.34-4.25
E201U	3.34-4.25

Table 5.3 Mineral Content (Wt %), Crystal System For Each Type of Sample using The XRD Methodology

Sample	Mineral	Percentage (%)	Crystal system	Axis system
(1) Phyllite	Quartz	87	Hexagonal	a=4.9143 c=5.4058
	Berlinite	70	Hexagonal	a=4.8955 c=10.841
(2) Metasandstone	Quartz	72	Hexagonal	a=4.921 c=5.4163
	Feldspar	53	Triclinic	a=4.916 b=4.917 c=5.407
	Berlinite	22	Hexagonal	a=4.8955 c=10.841
	Graphite	95	Hexagonal	a=2.461 c=6.708
(3) Quartz	Quartz	97	Hexagonal	a=4.9158 c=5.4091
(4) Metasandstone	Quartz	91	Hexagonal	a=4.921 c=5.4153
	Berlinite	59	Hexagonal	a=4.927 c=10.918
(5) Metasandstone	Quartz	98	Hexagonal	a=4.9134 c=5.4051
	Berlinite	79	Hexagonal	a=4.8955 c=10.841

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Result of XRD analysis for 5 samples.

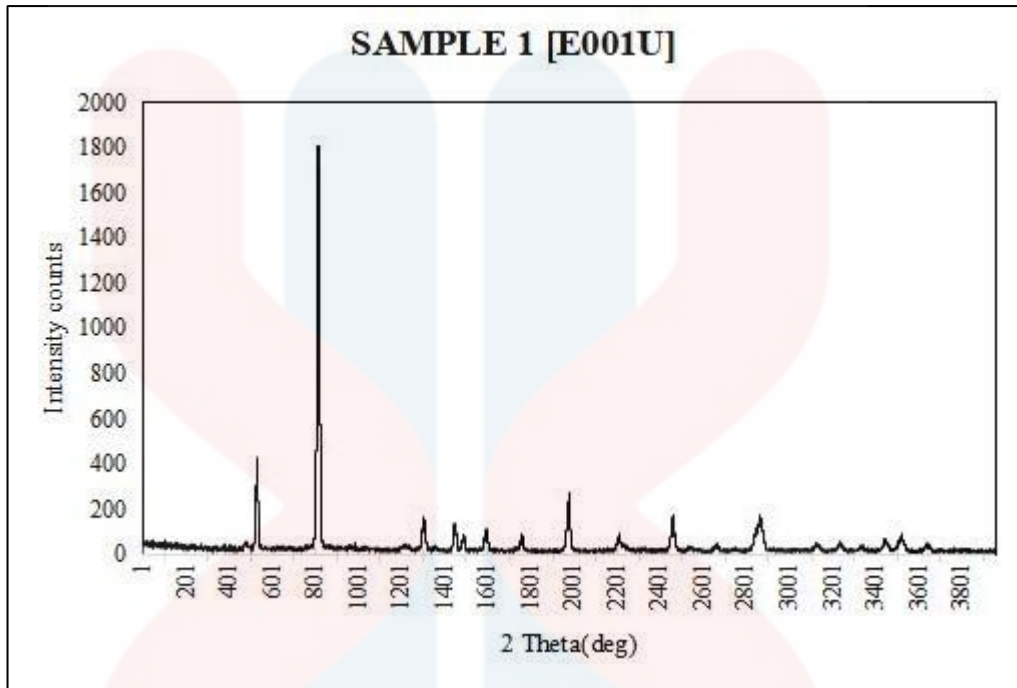


Figure 5.8 Graph for sample 1.

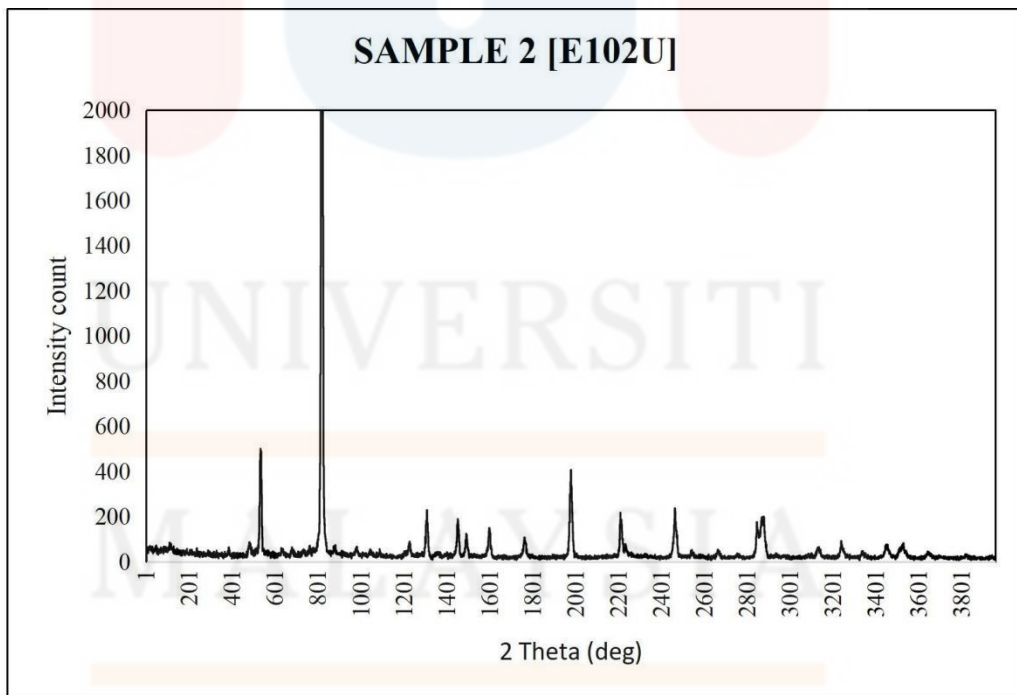


Figure 5.9 Graph for sample 2.

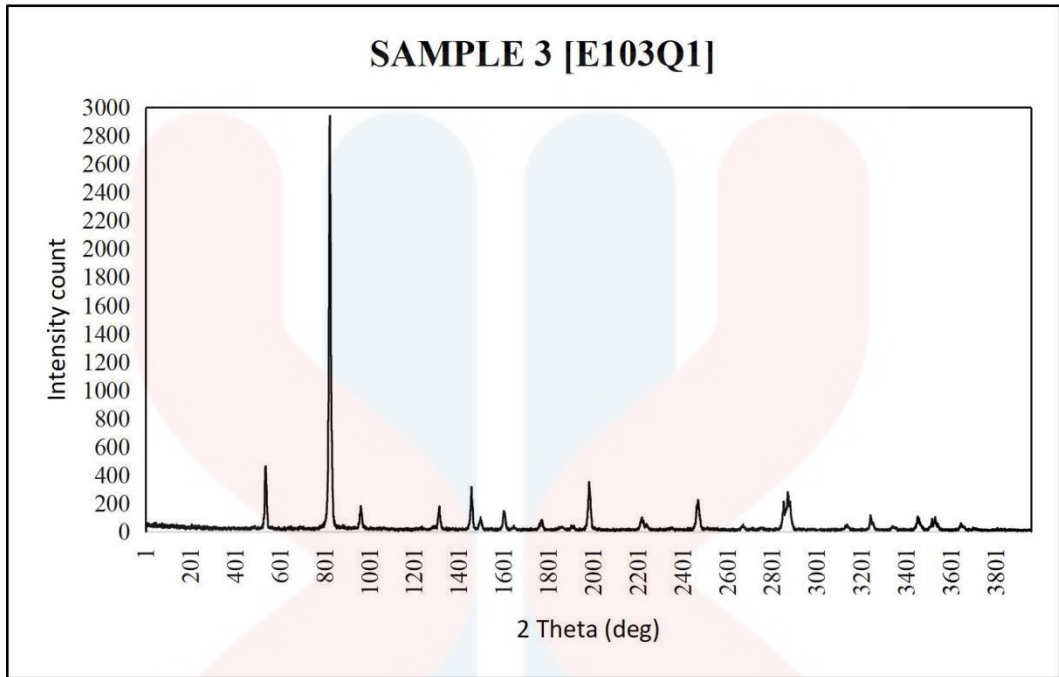


Figure 5.10 Graph for sample 3.

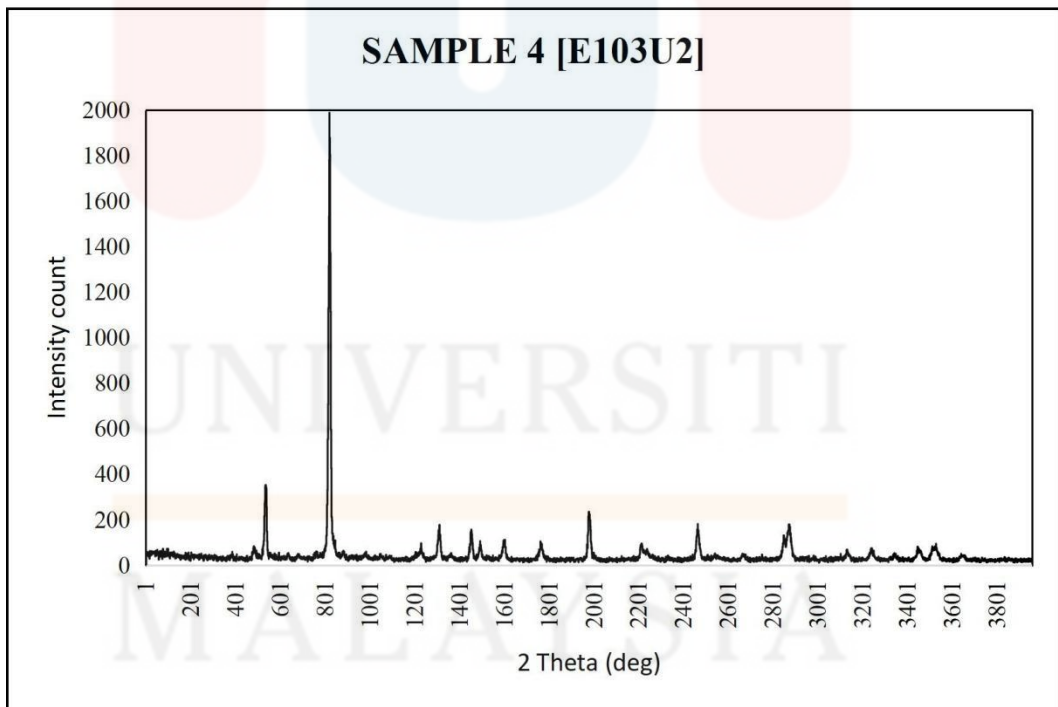


Figure 5.11. Graph for sample 4.

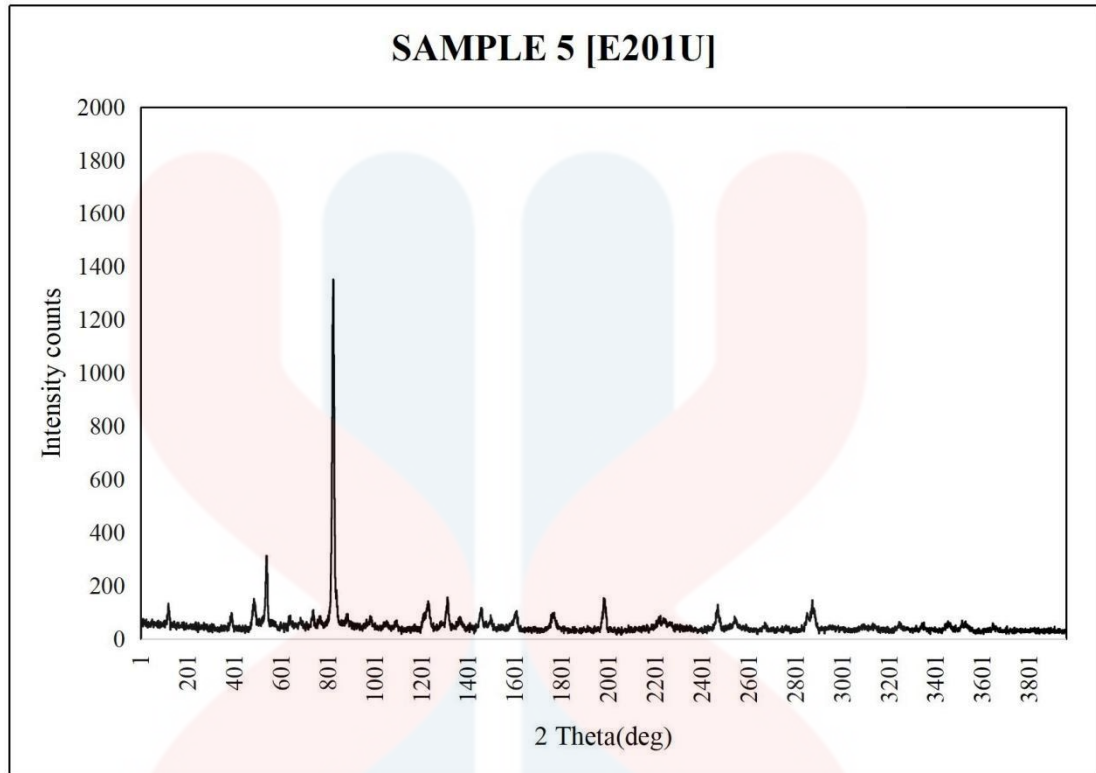


Figure 5.12 Graph for sample 5.

Based on the results of XRD analysis and petrographic determination using both methodologies, it was discovered that there are not much differences in the aspect of the mineral compositions. The minerals present in each sample are listed on the 5.3 table and the minerals are determined based on the XRD analysis's highest peak.

The first graph of sample 1 exhibit the highest peak of percentage is quartz with 87% followed by berlinite at 70%. Second graph that represent sample 2 exhibit 72% of quartz as it highest peak. Graph of sample 3 and sample 4 exhibit quartz as its highest peak with percentage of 97% and 91% respectively. 98% of quartz as the highest peak followed by 79% of berlinite exhibits in the sample 5 graph.

SEM Analysis

SEM was performed for solid surface imaging and investigation of its finest details. SEM is a method that scans the sample surface and projects the image of a focused electron beam across it. SEM were used in order to support the finding of certain minerals using XRD, This method makes it simple to deduce the mineralogy, particle texture, and pore structure of polished rock samples, as well as to analyse the outcomes of XRD examination in greater detail. Samples for SEM has been cut up into pieces ranging from 0.5 cm x 0.5 cm or 2 cm x 2 cm in size.

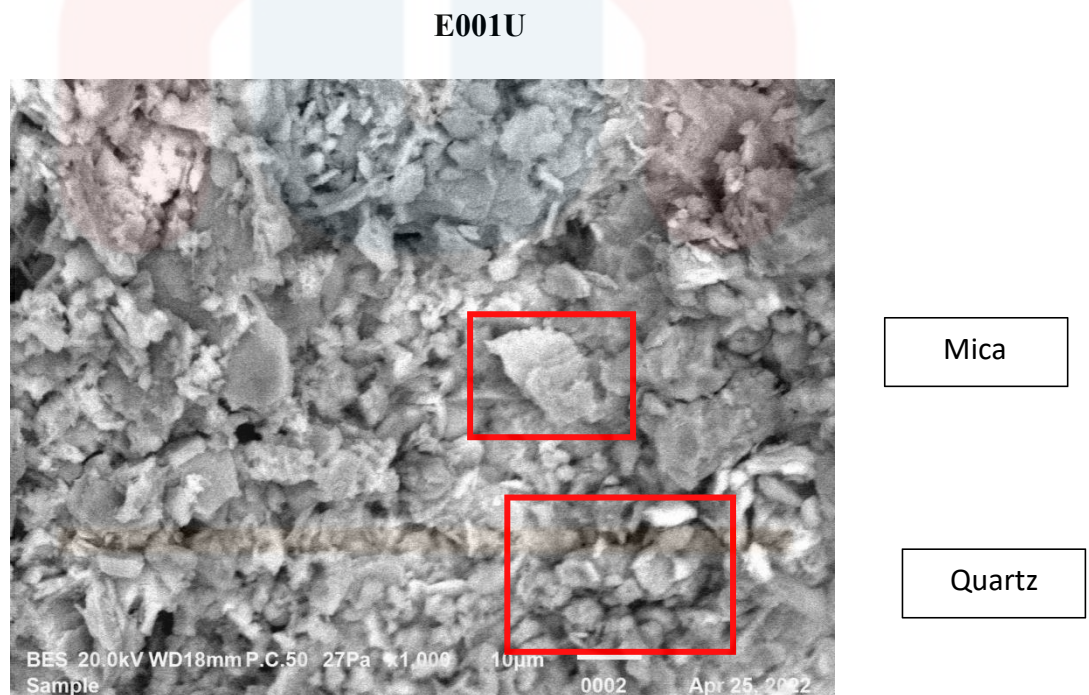


Figure 5.13 The surface of sample 1.

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E102U

Quartz

Mica

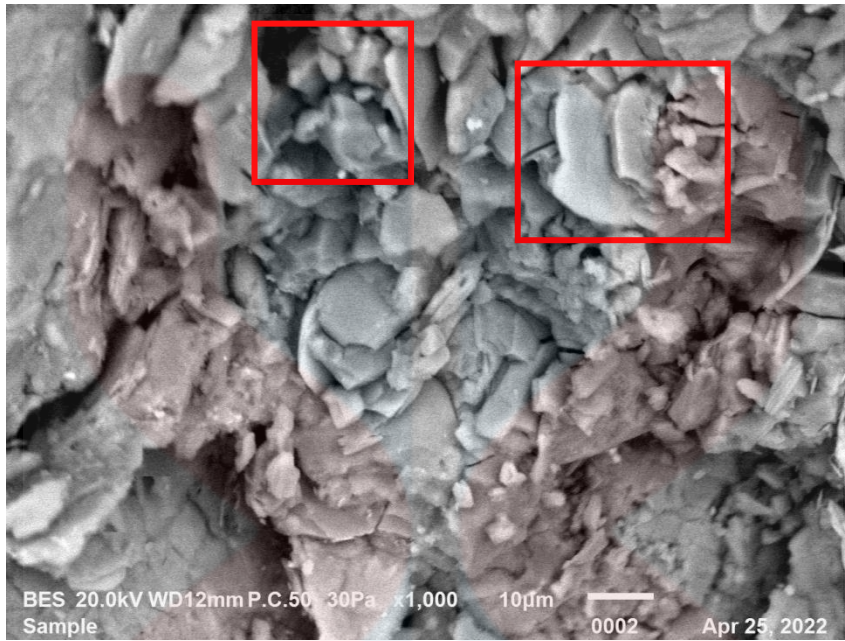


Figure 5.14 The surface of sample 2.

E103Q1

Quartz

Quartz

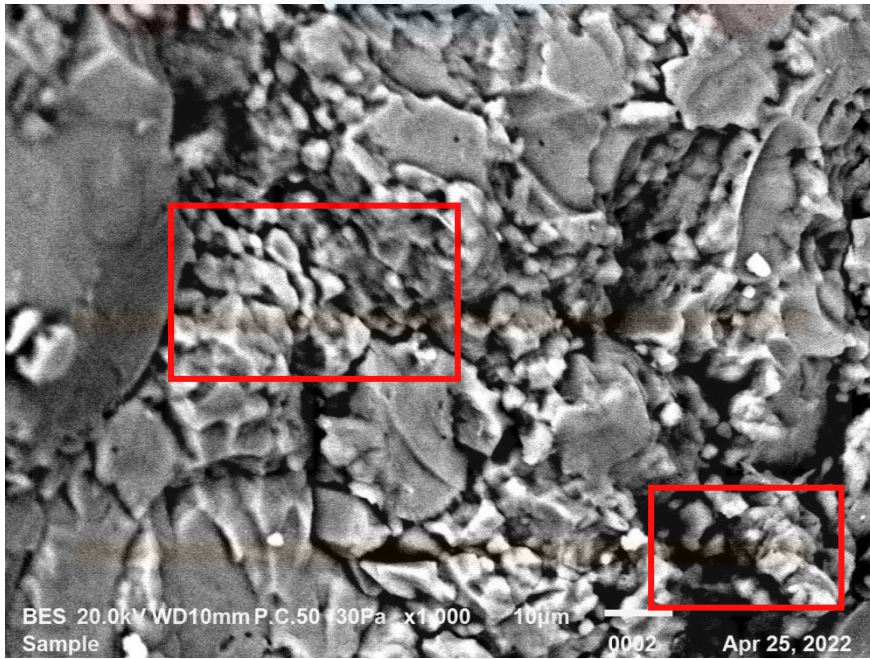
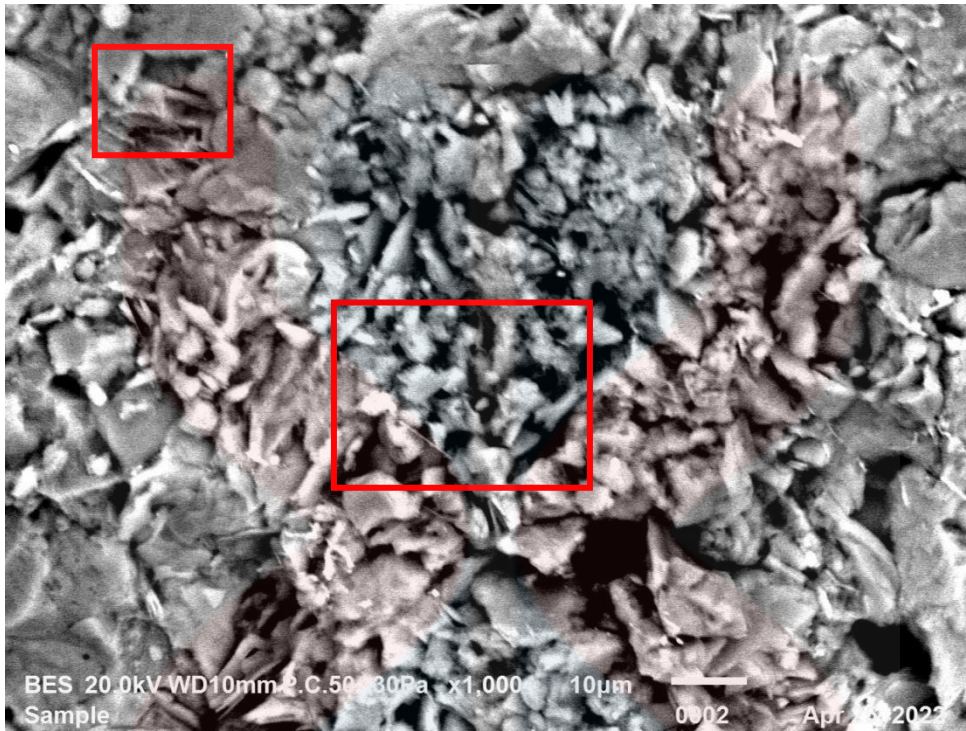


Figure 5.15 The surface of sample 3.

E103U2

Mica

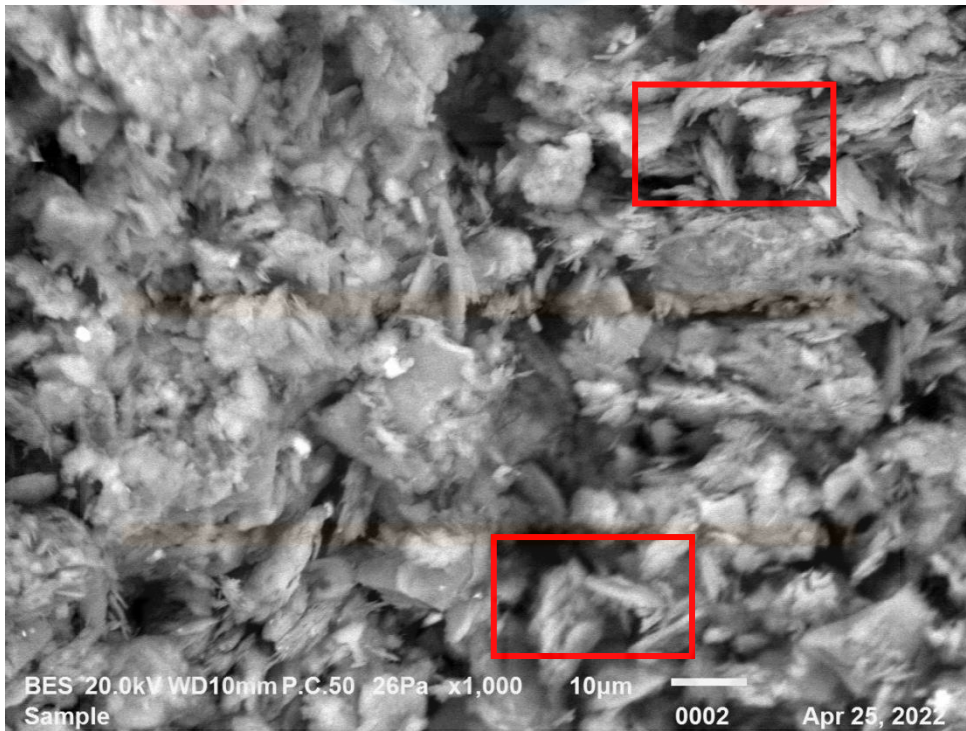


Quartz

Figure 5.16 The surface of sample 4.

E201U

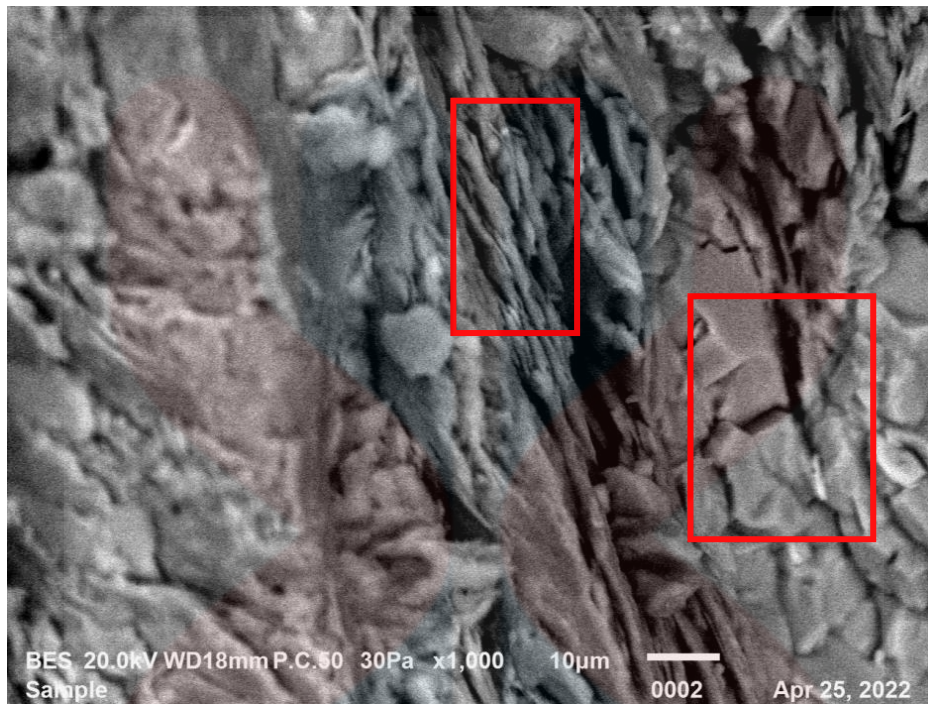
Mica



Mica

Figure 5.17 The surface of sample 5.

E101P

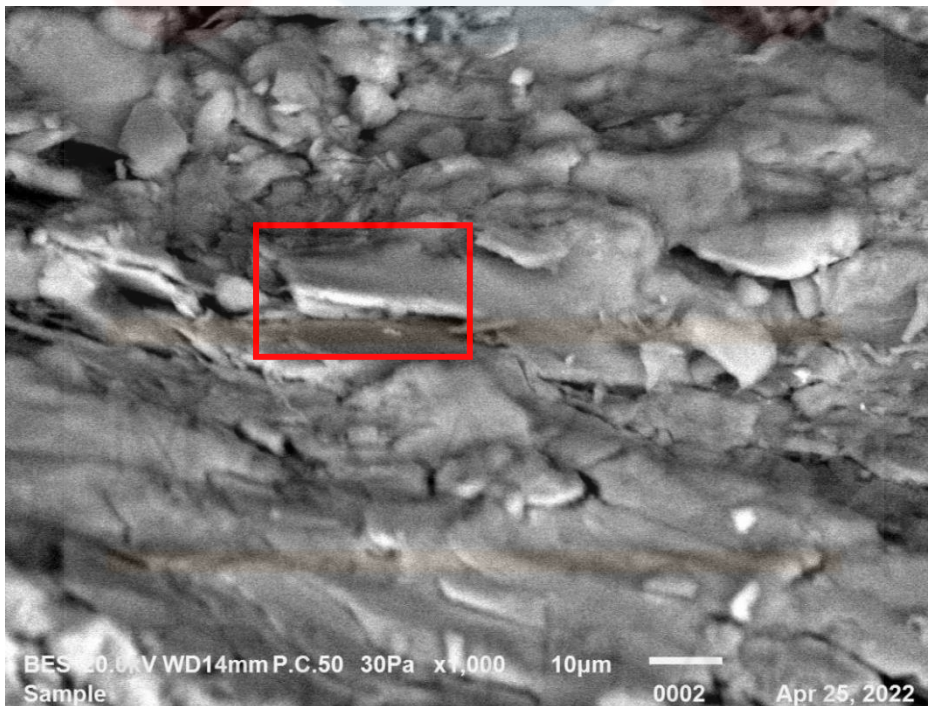


Mica

Quartz

Figure 5.18 The surface of sample 6.

E301MS



Mica

Figure 5.19 The surface of sample 7.

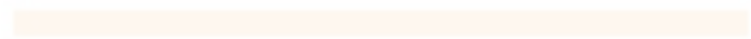
Based on the Scanning Electron Microscope (SEM) images, in the mica schist showing biotite minerals are visible and showing schistose texture. On the other hand, the phyllite are showing the biotite minerals are visible and platy as shown in figure 5.14 and figure 5.18 while quartz are more blocky as shown in figure 5.15 and 5.18. As for the metasandstone showing the quartz minerals are dominant. Some rock samples have a fracture texture due to the breakdown of their flat, crystal-fixed surface. As the most changed rock among the samples, mica schist exhibits a visible schistose texture, and all of the samples are fine-grained. The presence of mica in the samples fills the spaces between the quartz grains, and because of earlier volcanic activity's high temperatures, which caused the melting of each grain's border, the grains' shapes range from subrounded to subangular. Biotite, chlorite, and muscovite are a few minerals that belong to the mica group. The petrographic investigation of the study area's metamorphic facies, which changed from phyllite to schist, supports the direction of the regional metamorphism, which is lowest from the west of Banding Island to slightly moderate metamorphism toward the east.

The groundmass is where foliation is most frequently observed due to regional metamorphism. The findings of the petrography examination that the rocks contained minerals like quartz and mica were verified by the SEM results. Mica can withstand temperatures of up to 1000 °C. Due to its low thermal conductivity, high thermal stability, and nonflammability, it is a good heat insulating material. The mica group is represented by the index minerals chlorite, muscovite, and biotite, which each indicate various rock grades (Faidz, 2022). Up to roughly 650–700° C, muscovite is stable before decomposing into potassium feldspar and quartz changes.

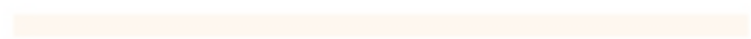
On the other side, quartz reveals how mature the outcrops are. With more quartz present, the rock becomes more mature.



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CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

As conclusion, this chapter concludes the results that obtain from the research of Geology and Sequences of Metamorphic Rocks Mineral Assemblages in Pulau Banding. A 1:25,000 scale geological map of Banding Island was created. The structural geology, lithology, geomorphology, and stratigraphy data for the research area were gathered from field observations, literature reviews, and secondary data that are from satellite imagery. For the specification part, petrographic analysis, XRD analysis, and SEM analysis were used to examine metamorphic products from the research area. According to the geological map that was created, the lithology of the banding island area was dominated by the phyllite unit and the mica schist unit. Slate, metasandstone, and quartz vein are three other types of rock that are discussed throughout the paper but are found in much smaller quantities and appear to be interbedded between outcrops.

According to Chabala (2013), the geomorphology of the study region was classified into one unit which are the lowland unit, as it was considered to be below that elevation of 1420m. The study region is between 270 and 440 metres above sea

level. Dendritic drainage pattern is the only form of drainage pattern in the studied region. This is due to the homogenous lithology of the research area, which is represented by the phyllite rock unit on the west side of the map and mica schist on the east. Other than joints and foliations, no other structures related to structural geology has been discovered. For laboratory study such as petrographic analysis, the behavior of minerals under thin section was determined using index mineral . XRD was conducted to determine the samples' mineral component and SEM analysis was conducted to support the discovery of minerals through XRD analysis.

6.2 RECOMMENDATION

For the first recommendation, it is difficult to determine the relationship between each facies due to the numerous faults and varies of elevation as well as the fact that it shift both vertically and horizontally, therefore further investigation is required by the next researcher. Specifically, Banding Island which is a part of the Belum rainforest and is situated in the centre of the Temenggor Dam, are exposed to harmful animal conditions, making it unsuitable for a girl to survey the region alone without proper supervision and the appropriate safety measures. There are few factors need to improve or add more safety conditions for next researchers to implement their research here.

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