GEOLOGY AND DEPOSITIONAL ENVIRONMENT OF GUA MUSANG FORMATION IN THE PERASU AREA, GUA MUSANG, KELANTAN

by

NOR INTAN SHAZLIN BINTI MOHAMAD ROJALI

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

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APPROVAL

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

Signature : …………………………….........

Name of Supervisor I : Dr. Mohammad Muqtada Ali Khan

Date : January 2019

DECLARATION

I declare that this thesis entitled "Geology and Depositional Environment of Gua Musang Formation in the Perasu Area, Gua Musang, Kelantan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : Nor Intan Shazlin Binti Mohamad Rojali

Date : January 2019

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ABSTRACT

Abstract: The large scale of geological map (1: 750 000) does not give sufficient information about each outcrop in the study area. In addition, there is no previous study explain about depositional environment of Gua Musang Formation in the study area. Thus geology and depositional environment of Gua Musang Formation in the Felda Perasu area was determined. To achieve the objective, different materials and equipment such as hammer, compass and gps was used to collect and record sample. From geological mapping and analysis, the study area show few structures such as fold, quartz vein and joint. From field and petrography analysis, the lithologies that consist in the study area is limestone, siliclastic, volcaniclastic, extrusive volcanic and metasediments. Besides that, also prepare lithology to study depositional environment of study area. Three parameters were used to determined depositional environment which is lithology, sedimentary structure and fossils. Based on all the evidence elaborates, the depositional environment of the Gua Musang Formation in the study area at the shallow marine carbonate setting. This study produces geological map which is useful for detail observation and give significantly to industrial, construction and economic activity.

Keywords: Gua Musang, Perasu, Depositional environment, shallow marine, Geology map.

ABSTRAK

Abstak: Peta geologi berskala besar (1:750 000) tidak memberi informasi yang secukupnya mengenai setiap batuan di dalam kawasan kajian. Tambahan lagi, tiada kajian terdahulu yang menentukan sejarah pengendapan Formasi Gua Musang di dalam kawasan kajian. Oleh sebab itu, geologi dan sejarah pengendapan Formasi Gua Musang dikaji. Untuk mencapai objektif, pelbagai bahan dan barang seperti tukul, kompas dan gps digunakan untuk mengumpul dan merekod sampel. Berdasarkan pemetaan geologi dan analisi, kawasan kajian mempunyai beberapa struktur seperti lipatan, urat kuarza, dan kekar. Berdasarkan kajian lapangan dan petrografi, kawasan kajian mengandungi batuan jenis batu kapur, siliklastik, volkaniklastik, batuan beku ekstrusif, dan metasedimen. Selain itu, log stratigrafi disediakan untuk menentukan sejarah pengendapan kawasan kajian. Tiga parameter telah digunakan untuk menentukan sejarah pengendapan iaitu jenis batuan, struktur sedimen, dan fosil. Berdasarkan kesemua bukti diperjelaskan, sejarah pengendapan Formasi Gua Musang di dalam kawasan kajian adalah di kawasan lautan cetek landasan batu kapur. Kajian ini menghasilkan peta geologi yang berhuna untuk kajian yang lebih mendalam and memberi kepentingan kepada pihak industry, pembinaan dan ekonomi.

Kata Kunci: Gua Musang, Perasu, Persekitaran endapan, Lautan cetek terbuka, Peta geologi.

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CHAPTER 1

INTRODUCTION

1.1 General Background

This research consist 6 chapters which is introduction, literature review, material and methodology, geology, depositional environment, and conclusion.

Geology is defined as the study of the Earth. Historical geology examines the origin and evolution of Earth, its continents, oceans, atmosphere, and the evolution of organisms over a period of time. Geology has also played an important role in the history and culture of humankind (James et al., 2007). The most interesting in geology is it can discover the Earth history and identify the potential of the natural resources.

A depositional environment is a place where there is deposition process happened. It is characterized by specific physical, chemical and biological processes that act on the sediment deposited. The sedimentary processes and conditions that collectively constitute the depositional environment play the primary role in determining the textures, structures, bedding features, and stratigraphic characteristics of sedimentary rocks (Sam, 2012).

The combined knowledge of sedimentology and stratigraphy are required in order to identify depositional environment. Both of them are the disciplines of geology. Sedimentology is the study of the processes of formation, transport, and deposition of material that accumulated as sediment in continental and marine environments and eventually forms sedimentary rocks, whereas stratigraphy is the study of rocks to determine the order and timing of events in Earth history (Nichols, 2009a). By stratigraphy information, sedimentary rock can be interpreted in terms of dynamic evolving environment because it provides the time frame information. The fundamental database for understanding the plate tectonics through time, the evolution of life and global climate change can be identified from the stratigraphy record of sedimentary rocks. The environmental analysis thus involves identifying response elements or properties that have environmental significance. Sam (2012) stated that these properties include sedimentary structures and textures (which reflect depositional processes such as current flow and suspension settling of grains), sedimentary facies associations (such as fining-upward and coarsening-upward successions of facies, which indicate shifts in environmental conditions), and fossils (which are useful indicators of salinity, temperature, water depths and water energy, and turbidity of ancient oceans.

The study area is situated at Perasu area. It is a rural area, located in the Southern part of the Gua Musang District. Oil palm is widely cultivated in the Perasu area. Currently, the geological map of Perasu is in the scale of 1: 250, 000. This large-scale map provides limited geological information on the lithology, stratigraphy, and geomorphology. Besides that, there is insufficient information regarding the depositional environment of the Perasu.

Thus, this research is proposed to produce a more detailed geological map for the Perasu area with the scale of 1: 25, 000 and identify the depositional environment of the area. The geology and depositional environment of the Perasu area can be interpreted by geological mapping, laboratory investigation, and constructing sedimentary log. The results of the research are believed to be useful for further geological research.

1.2 Study Area

In this chapter, location, road accessibility, demographic, land use, social economic, and rate of precipitation and temperature were discussed.

1.2.1 Location

The study area (Figure 1.1) is located at Felda Perasu which is sub-district of Gua Musang Kelantan. It has the dimension of 5 km×5 km. The coordinate of the study area is 102° 4’ 20.15” E to 102° 7’ 2.58” E and 4° 56’ 31.30” N to 4° 53’ 49.61” N. It is located beside Felda Chiku and Felda Aring. Felda Perasu located 55km from Gua Musang town. The study area is located at 12Km from Kuala Krai-Gua Musang main road. Felda Perasu also has a river which is Sungai Chiku. The river in Felda Perasu is described as a meandering river. This river is believed as the place for siliciclastic rock deposited. Felda Perasu is covered by plantations such as rubber tree and palm oil tree. This is because the economy of a population in that location is the farmer. Felda Perasu also is surrounded by hill limestone. The ranges of elevation in the study area were from 120 m to580 m in elevation. The study area is considered as the mountainous area because of the elevation in ranges >301m.

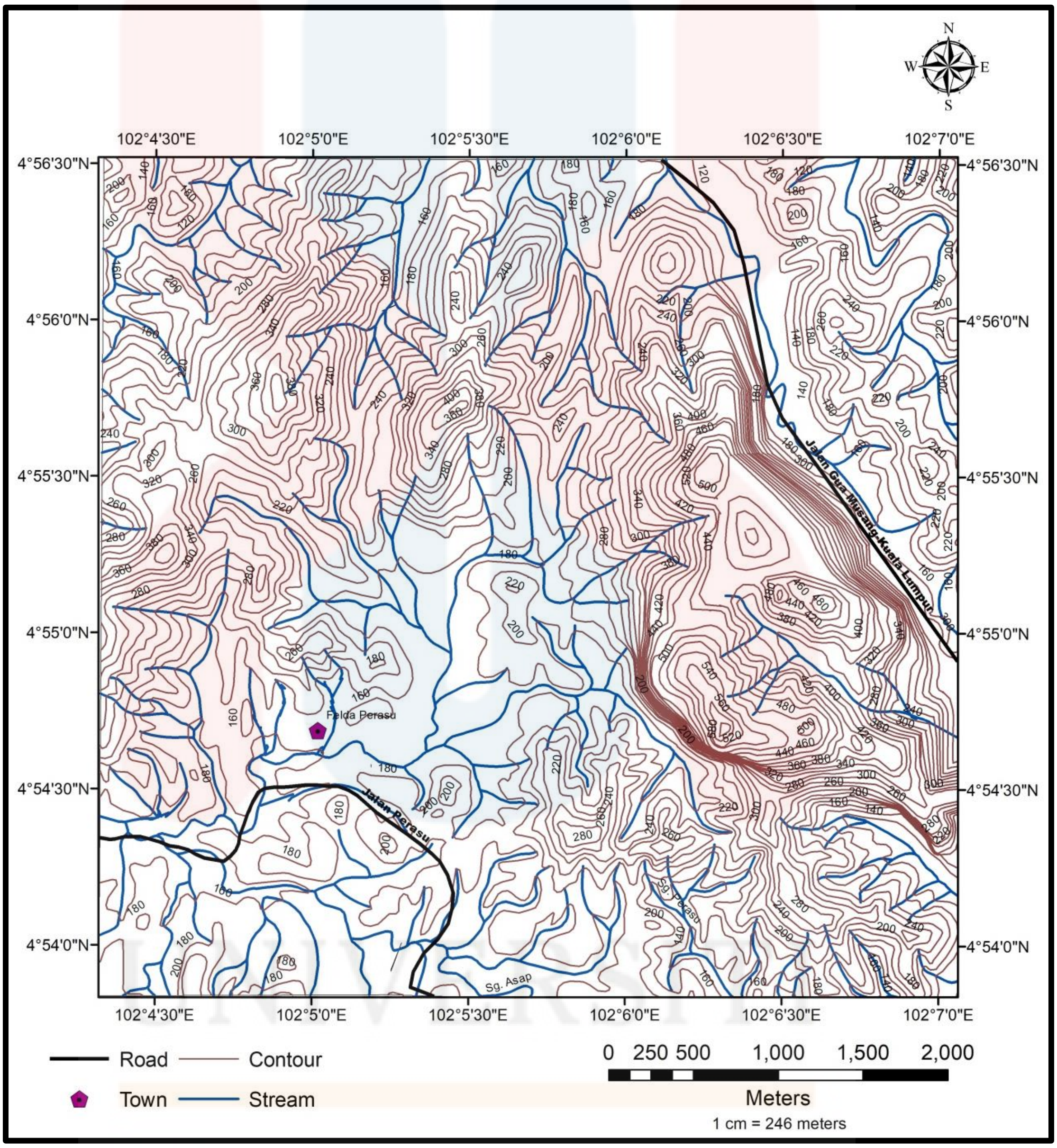


Figure 1.1: Base map of the study area

1.2.2 Road Accessibility

The main road in Felda Perasu is 12km Kuala Krai – Gua Musang. When passing through this road. The road in Felda Perasu area is connected between Perasu village and main road Kuala Krai-Gua Musang. There are three main roads of accessibility to the study area, Felda Perasu. The first road is from Kuala Krai, Dabong and Gua Musang as shown in Figure 1.2.

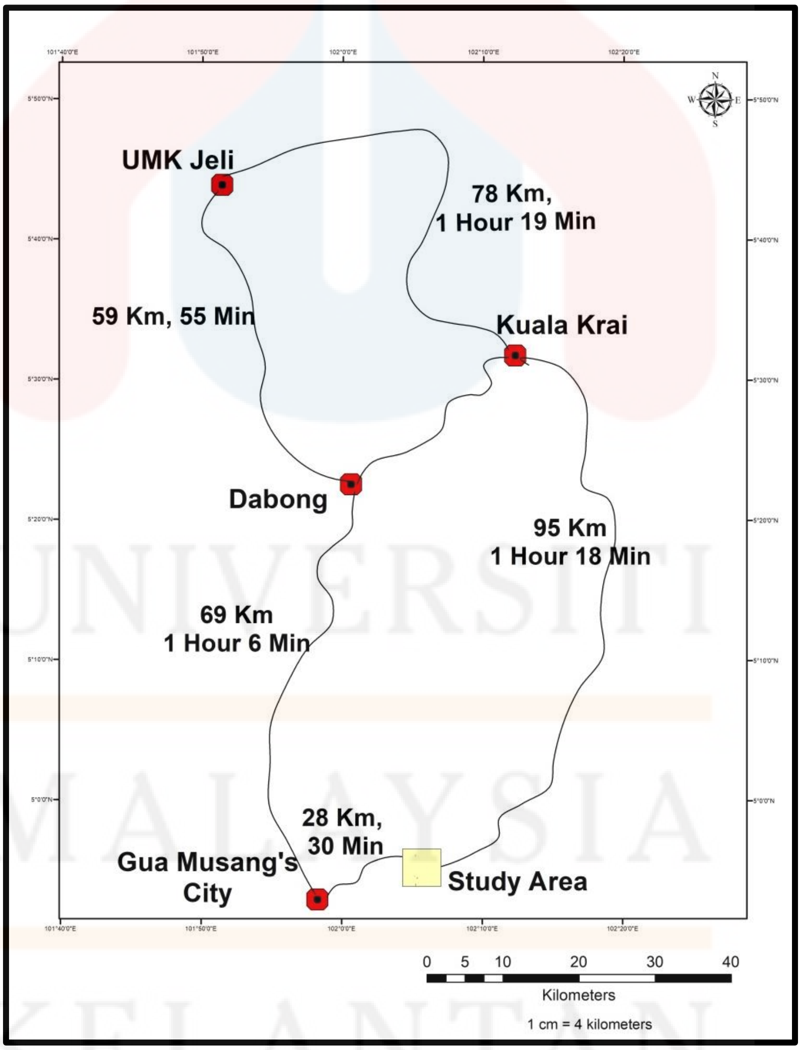


Figure 1.2: Accessibility Map to Study Area

1.2.3 Demography

Table 1.1 shows the number of persons and average annual population growth rate (percent) by state and administrative district, in the year 1991, 2000, and 2010. The number of population in Gua Musang is increasing over decades. From 63,816 number of populations in the year 1991 to 74,988 populations in the year 2000. While in the year 2010, the number of population is increasing to 85,677 populations. In the study area, however, there is a small town that locates a community of Felda Perasu. However, 100m from the study area, People distribution at Felda Perasu, Gua Musang, Kelantan is 2110 people from 240 families. They have their own assets such as lands and orchards.

Table 1.1: Number of persons and average annual population growth rate (percent) by state and administrative district, 1991, 2000, 2010.

State and administrative district	Population			Percentage average annual population growth rate (%)	
	1991	2000	2010	1991-2000	2000-2010
Gua Musang	63,816	74,988	85,677	1.79	1.33

Source: (Department of Statistic Malaysia, 2010)

1.2.4 Landuse

Kelantan has varieties type of land use but the restricted forest still cover big area of Kelantan. As shown in figure 1.3, study area consists of oil palm, rubber and forest but forest is domain vegetation in the study area (M Hashim et.,al 2017). In 2008, FELDA own 10,552.50 hectare of oil palm plantation (Fauzi, 2012).

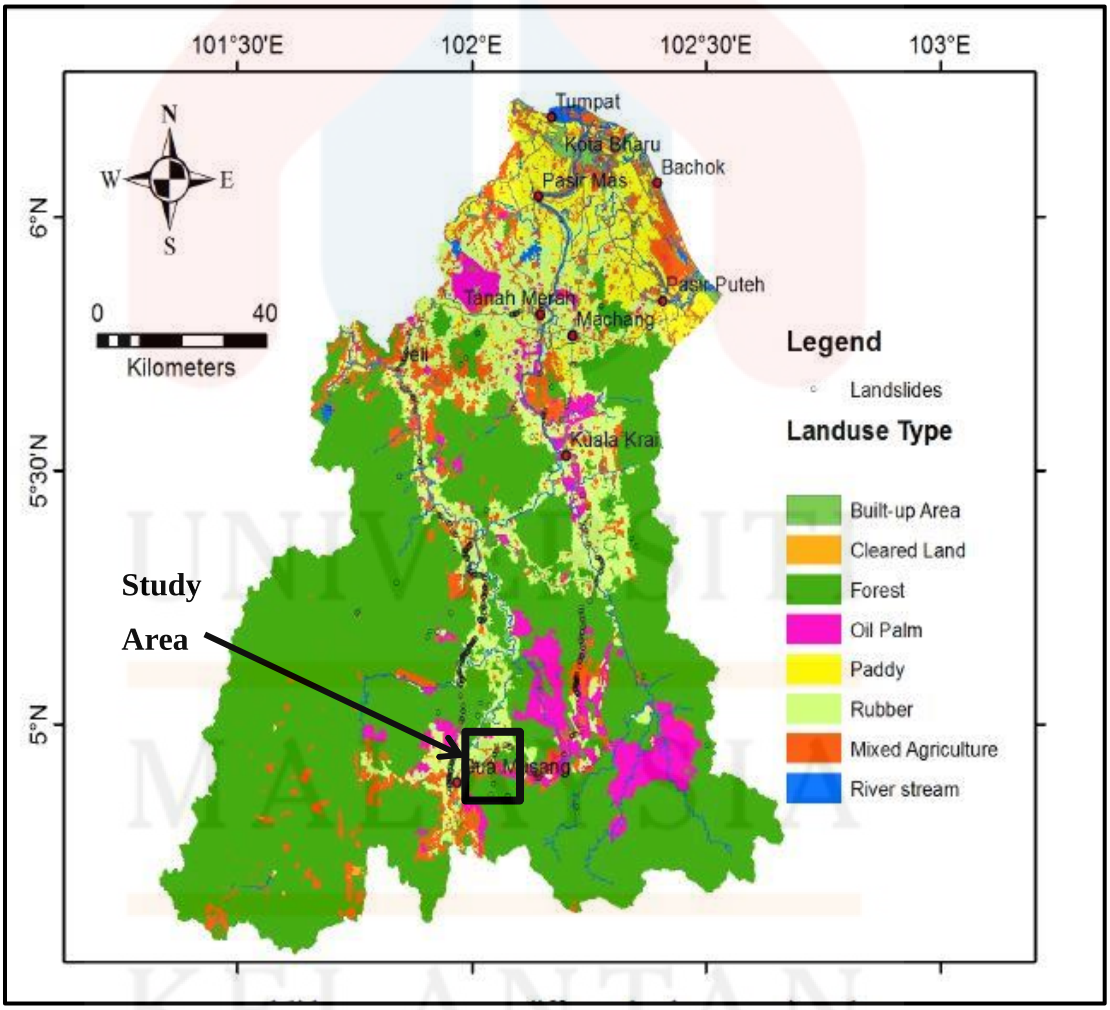


Figure 1.3: Map of land use type in Kelantan state.

1.2.5 Social Economic

The social economy of people at Felda Perasu are mostly depend on farming. There are 244 people who are being farmers. People who are working and live in Felda Perasu get benefits such as get own assets land.

1.2.6 Climate

Gua Musang has a hot, humid tropical climate. Temperature and rainfall are generally high throughout the year. Figure 1.4 and Figure 1.5 show average days with precipitation per month and average temperature per month for Gua Musang (Jensen, 2018).

Figure 1.4: Bar graph of average days with precipitation per month for Gua Musang district.

Figure 1.5: Line graph of average temperature per month for Gua Musang district.

1.3 Problem Statement

The study area is a part of Gua Musang district in developing area. The latest geological map of Peninsular Malaysia is produced by the Jabatan Mineral dan Geosains (JMG) Malaysia in the year 2014 with the scale of 1: 750, 000 which not contain enough geological data such as detailed lithology. Besides that, that map does not focus on the small scale of the study area of Perasu area and does not show specific distribution lithology of this area.

There is no previous study explain about depositional environment information that shows environment history of Gua Musang Formation in the study area. However, a depositional environment is important as it will give the important sedimentology data to the next researcher and value of study area.

1.4 Objectives

i. To produce a geological map of Perasu area in the scale of 1: 25, 000.

ii. To determine the depositional environment of Gua Musang Formation in the Perasu area, Gua Musang

1.5 Scope of Study

The area of study covered 25 km^2 (5 km × 5 km) of the Perasu area, Gua Musang, Kelantan, Malaysia. The geology such as geomorphology, stratigraphy, structural geology and historical geology was studied to produce the geological map of Perasu. Besides that, sedimentary logs based on lithology, fossils, and sedimentary structures are constructed to identify the depositional environment of a clastic sedimentary unit which has good exposure in this area.

1.6 Significant of Study

This study can be useful for updating a regional geological map.

Another important of the research is identifies the depositional environment of Perasu area. Based on the depositional environment of the area, the geologists can analyze the area and locate the potential resources such as mineral and water aquifers. These resources can improve human life quality. When the age and foraminifera fossils identified, the communities will appreciate the history value of the study area and they will preserved it for futures.

Besides that, geological map and depositional environment provide the sedimentation information to people that can be used to avoid the natural hazards such as landslide and flood. This turn gives rise of awareness to the engineering sector to construct the building in a safe condition. The geological map also gives significant to industrial, construction, and economic activity that can generate entrepreneur activity.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapters review the previous research that is related to the research. A literature review is important as the gaps that existed in the literature review can be identified and fulfilled the need for additional research. The review is based on the title, objectives, problem statements and methodology of the research. These include the regional geology and tectonic setting, stratigraphy, and sedimentology, structural geology, fossil, historical geology, depositional environment and clastic sedimentary rock.

2.2 Regional Geology and Tectonic Setting

Peninsular Malaysia is divided into three main geological domains which are Western, Central and Eastern belts as shown in Figure 2.1. These domains are characterized based on several aspects including lithology, age, tectonics, structures, and paleogeography. Gua Musang was located on Central Belt of Peninsular Malaysia. The prominent N–S Palaeo-Tethys Bentong-Raub suture divides Peninsular Malaysia into a Sibumasu block on the west and an Indochina block on the east, known locally as East Malaya as shown in Figure 2.2. Hutchison (2014) state that Sibumasu collided with East Malaya and Indochina in the Late Triassic (the Indosinian Orogeny), causing crustal thickening resulting in important tin-bearing S-type granites, characterize by the Main Range of the Peninsular, the 'tin islands' of Indonesia and parts of central Thailand. Southeast Asia region has a new mechanism on tectonic evolution that is known as an escape or extrusive tectonics.

Central Belt has a very significant of the volcanism activity. Marine sediments that on the age of Permian and Triassic with acidic to andesitic composition was believed from volcanic rock. Khoo & Tan (1983) stated that Central Belt has abundant intrusive of mafic and ultramafic than in Western Belt.

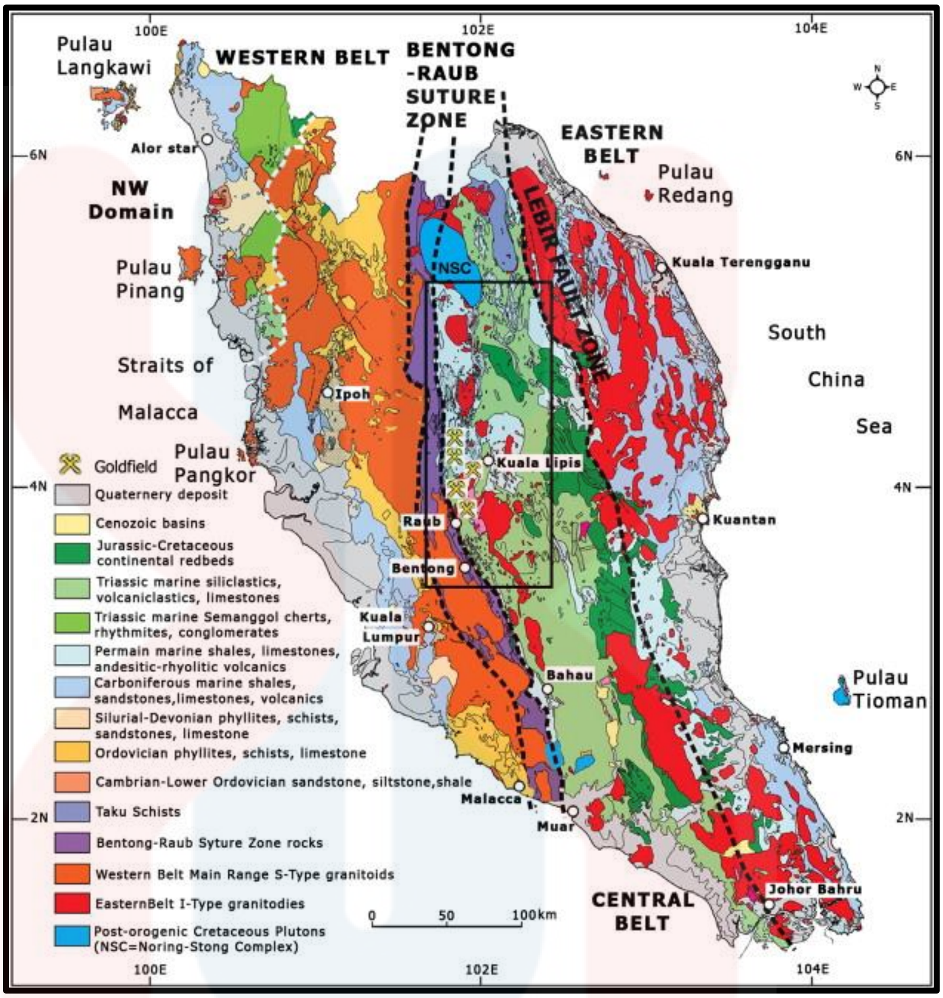


Figure 2.1: Geological map of Peninsular Malaysia (Amin Beiranvand Pour, 2015)

Heng et al., (2006) stated that Kelantan consists of sedimentary and metasedimentary rocks in the central zone that bordered by granites at west and east by Main Range (Titiwangsa Range) and Boundary Range respectively. There are granite intrusive within the Central zone, such as the Senting batholith, the Kemahang pluton, and the Stong Igneous Complex. The granites belts in central and west of Kelantan are contributed northward to south Thailand, whereas the granite in Boundary Range (east of Kelantan) is overlain by the coastal alluvial flat of Sungai Kelantan.

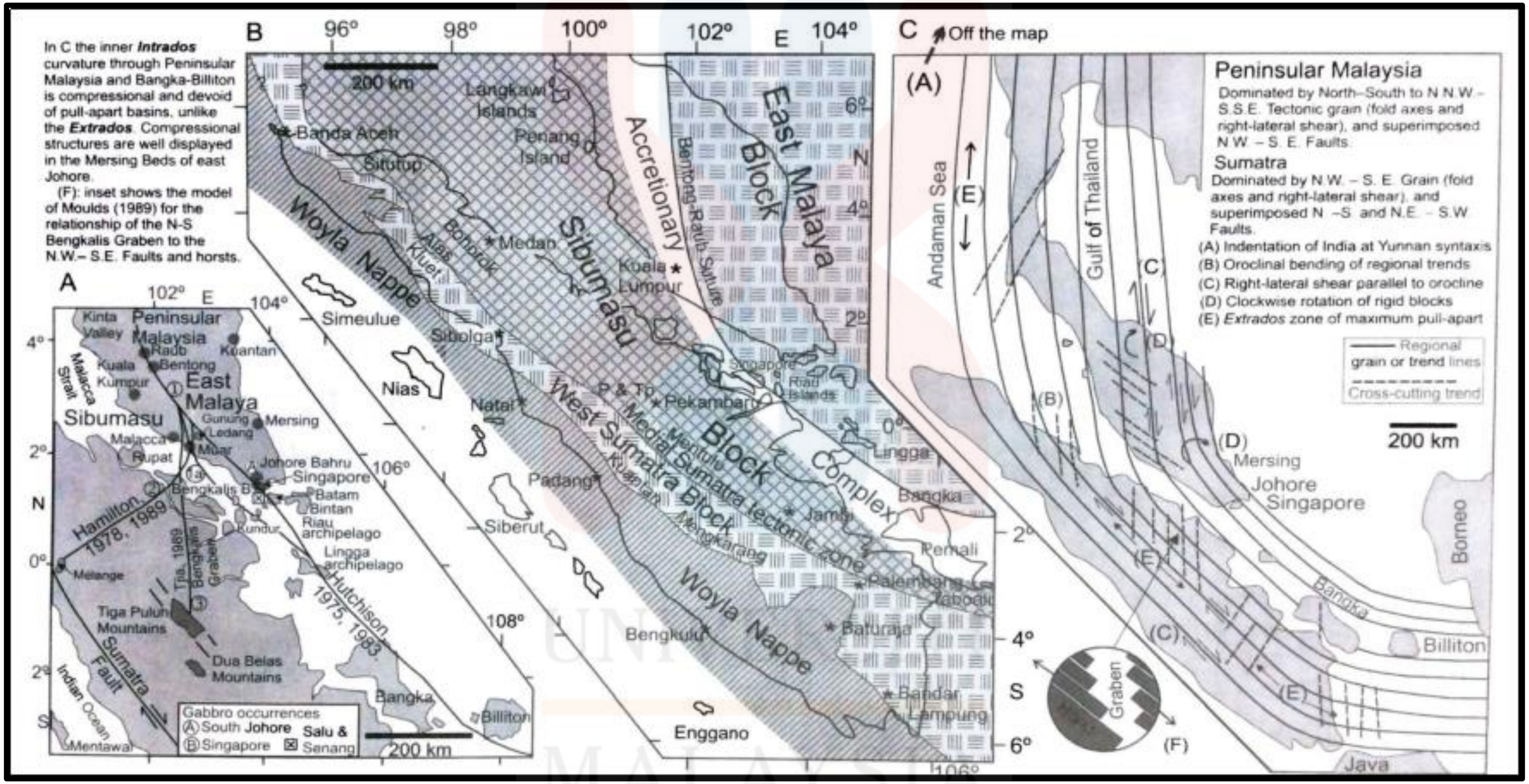


Figure 2.2: A: Positions of the Bentong-Raub Suture as proposed by various workers (Hutchison, 2014). B: Pre-Tertiary tectonic block according to (Barber *et.al.* 2015). C: Schematic plan for oroclinal bending resulting from the strong Indian indentation into Yunnan syntaxis (Hutchison, 2014)

The sedimentation in the Central zone of Peninsular Malaysia is associated with the plate tectonics. During Permo-Triassic period, there is convergence occurred between the western part of the Peninsula and the Eastern part by subduction of oceanic crust and a latest Triassic collision of the two tectonic blocks (Harbury et al., 1990). Hutchison (1973), Ridd (1980) and Sengor (1986) proposed that it was westward subduction whereas Mitchell (1977) and Hutchison (1973) proposed it as eastwards inclined subduction. However, there is no evidence that the peninsula collided with Asian mainland in late Triassic (Harbury et al., 1990).

During Jurassic period, the crustal extension occurred in the Central Basin. Audley-Charles (1983) stated that it was the arc and back-arc extensional processes which associated with the subduction at the active continental margin of eastern Gondwana. However, the Central Basin of the Peninsula is known as back-arc basin by Hutchison (1973) and Ridd (1980), as fore-arc basin by Mitchell (1977), Sengor (1986) and Hutchison (1973) and as rift graben by Tan (1981).

According to Workman (1975), there is Triassic-Jurassic major orogenic compression happened in central Thailand, NW Laos, west and southern Cambodia, and North Central Vietnam. Since there is absent of deformational event from Peninsular Malaysia, it indicates that Peninsular Malaysia, western Thailand and Burma were not possible to attach to central and east Thailand, and Indochina until after the Middle Jurassic.

2.3 Stratigraphy & Sedimentology

In Central Belt of Peninsular Malaysia, there is 2 to 3 km of marine Triassic and subsequently, 1.5 to 2 km of Jurassic to Early Cretaceous continental sediments accumulated. Along the margin of the graben, the Early Triassic sediments include shallow marine limestone, siliciclastic, olistostrome and conglomeratic calcareous sediments (Metcalfe, 1989).

In Kelantan, Permian sediments are widely distributed along the rivers such as Sungai Lebir, Sungai Aring, Sungai Relai, Sungai Paloh and Sungai Badong (Fontaine, 2002). The Jurassic to Cretaceous continental rocks are the youngest rocks in Kelantan. They overlay the Boundary Range Granite and Triassic sediments in the Gunung area and to the west in the Gunung Perlis and Gunung Pemumpu areas. The sequences consist of conglomerate which overlain by sandstone with sporadic volcanic intercalations.

The geological formation of Kelantan ranges from Lower Paleozoic to Quartenary and can be divided into three main chronology; Paleozoic, Mesozoic and Cenozoic. The Upper Paleozoic rock consists of Gua Musang Formation and Aring Formation in the south of Kelantan while it is the Taku Schist in eastern of Kelantan. The Upper Paleozoic formation is dominated by argillaceous and volcanic facies while the rest belong to calcareous and arenaceous. The Mesozoic formations are dominant in the central belt that forms continuous North-South trending belt. The Mesozoic formations are dominated by shallow marine clastic and carbonated with volcanic interbeds (Peng, 1983). The Cenozoic formation is mainly represented by Quarternary sedimentary deposits. The Quartenary sediment covering part of North

Kelantan consist extensively of unconsolidated to semi-consolidated boulders, gravel, sand, silt and clay that underlie the coastal and inland plain.

Kamal et al., (2016) concluded that Gua Musang, Kelantan is made up of the following facies : (i) Argillaceous ; (ii) Carbonate; and (iii) Volcanic or pyroclastic. The Argillaceous facies which consists of shale, siltstone, mudstone, slate, and phyllite, is the dominant facies in Gua Musang and Telong formations and occurs as interbeds or lenses in the Aring Formation and Nilam marble. Yee (1983) said that carbonate is the dominant facies in Nilam marble and as extensive facies in the Gua Musang formation, and form beds or lenses within the Telong and Aring formations. The volcanic facies is dominant in the Aring Formation and is interlayered with carbonate and argillite in other formations studied.

Gua Musang Formation is located at the northern part of the Gua Musang-Semantan depocentre that lies east of the Bentong-Raub Suture within the Central Belt. The Gua Musang Formation is composed of crystalline limestone, interbedded with thin beds of shale, tuff, chert nodules and subordinate sandstone and volcanic. The structure such as bedding, cross-lamination, and oolites can be observed in the formation (Hutchison & Tan, 2009). According to Yin (1965), the Gua Musang Formation is composed predominantly of calcareous and argillaceous rocks with arenite, pyroclastic and lava flows. They are shallow-water platform facies. The most extensive facies in the Gua Musang Formation is Calcerous rocks. Limestone constitutes around 80% of the total rocks exposed in the Gua Musang – Merapoh area which assume by (Burton, 1973). The majority of Triassic limestone occurs as block or lenses in shale and olistoliths.

Aring Formation can correlate with Gua Musang Formation, Pahang Volcanic series and metasediments in southeast Pahang. Aring Formation is predominantly volcanic rock which dominated by pyroclastic with minor lava, dolomitic marble and argillite. Aw (1990) discovered a thick basal section of dolomitic marble which overlain by tuff and calcerous argillite. Paloh member located at the top of the formation consists of 1000 m thick argillo-tuffaceous limestone unit. The remainder of the formation composed of fine to coarse pyritiferous tuff with subordinate interbedded rhyolitic tuff, andesite lava, argillite and limestone (Hutchison & Tan, 2009).

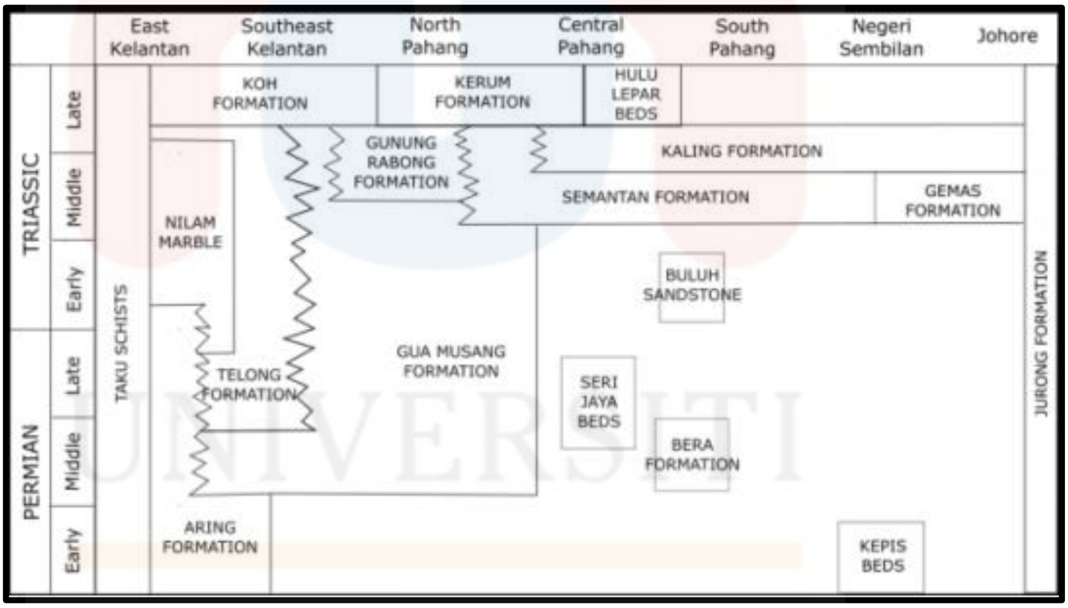


Figure 2.3: Permo-Triassic stratigraphic correlation chart of Central Belt Peninsular Malaysia. (Sources: Kamal et al., 2016)

2.4 Structural Geology

As indicated by Dony et al., (2015), tectonic activities in Peninsular Malaysia during the Paleozoic and Mesozoic era affect the land mass principally on the formation of faulting and folding. Faulting and folding were observed as a localized structure that includes folding, jointing, and faulting in the sedimentary and igneous rock.

Strike-Slip fault can forms compression or extension locally at continental margins, island arc and within continents. It will develop sedimentary basin when the fault kinematics are divergent with respect to the plate vector along strike-slip faults (Noda, 2013).

Based on the report by Noda (2013), Malay Basin is considered as fault-termination basins. It is formed under transtentional stress at the end of a strike-slip fault. The sediment supply into the basin along the strike-slip fault is dominated by rivers. Both tectonic depression and high surface heat flow have contributed the subsidence of basin.

Tjia (1994) stated that initially fault had slipped left-laterally which develop en enchelon east-west trending grabens and half-grabens within the Malay Basin. This transtentional stress regime affects the deposition of Oligocene beds in the basin.

During the deposition of middle to upper Miocene, the stress conditions changed into a transpressional regime. The Malay faults thus changed slip direction and wrench right-laterally and caused tectonic inversion of a basin (Tjia, 1994). The initial transpressive period is related to the collision of Indian Plate and Eurasia Plate

(Tapponnier et al., 1982). In post-Miocene, basin experienced younger tension in which there is normal faulting developed across the anticlinal crest and causing subsidence of Malay Basin (Tjia, 1994).

The Central Basin of Peninsular Malaysia is an extensional graben boarded by major faults along the Bentong-Raub Line at the west and by the Lebir fault zone at the east. It happens during the Triassic when a major normal faulting which possibly began in the Permian occurred along the Bentong-Raub Line and Lebir Zone and eventually producing a graben (Metcalfe, 1989). According to Metcalfe (1989), the Triassic rocks in Central Basin has generally upright or gently plunging folds (both symmetrical and asymmetrical) that represent a single folding phase.

2.5 Fossils

Fossils are one of the valuable geological resources which serve as an important key to learning about the ancient environment, study the past history of Earth and determine the age of strata. It can be divided into body fossil, trace fossil and chemical fossil.

As eloquently stated by Kamal et al., (2016) that the Middle Permian to Late Triassic age of the Gua Musang formation and its lateral equivalents were determined based on fossil findings. Based on diagnostics fossils that research by Kamal et al., (2016) fossils that found at Gua Musang are macrofossils which consist of bivalves, ammonia and brachiopod and microfossils that consist of conodant and foraminifera. According to Dony & Rosli (2014), there are a lot of small-sized marine invertebrate fossils discovered in Aring area. This includes mollusk and brachiopods. Example of the mollusk is ammonoids, bivalves and gastropod. The ammonoids include *Balatonites* cf. *B. balatonicus, Kellnerites samneuensis, Danubites kansa, Hollandites* sp. and *Axcrocordiceras* sp. (A. Rosli & Shafeea, 2010). These fossils found in the area are important to determine the age of the Triassic rock formations in Peninsular Malaysia. Aw (1990) stated that both Lower Carbon brachiopods and Fusulinids are estimated as the oldest fossils in the Central Belt of Peninsular Malaysia.

2.6 Historical Geology

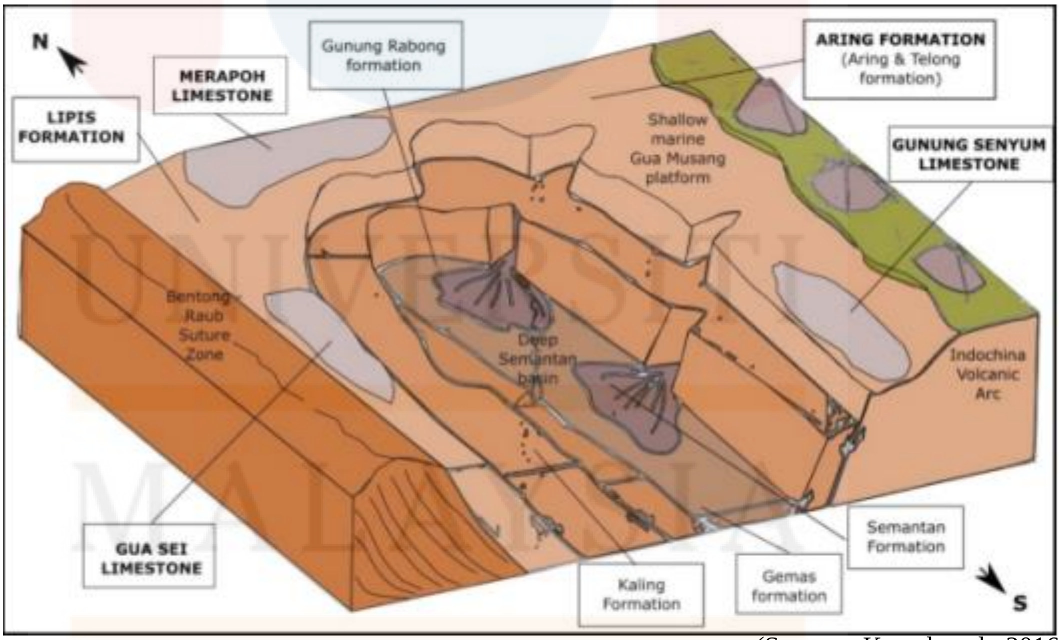
Kelantan is situated in the Central basin that makes Kelantan has the youngest rocks. The bulk of the Upper Paleozoic sediments consist of marine Permian strata that occur as linear belts flanking Mesozoic sediments in the Central Belt (Farhafiezah, 2017). Basin was started to accumulate the sediments from the Triassic period. In an early stage of the deposition, only the fine grain marine sediment are deposited, then followed by coarser continental sediments at Jurassic to Cretaceous period (Metcalfe, 1989).

During the Permian period, sinistral strike-slip fault movement happened in the Malay Basin which causes the extension of the crustal (Tjia, 1994). This results in the formation of graben, the pul- apart basins, which is known as Central Basin. The basin was started to accumulate the sediments from the Triassic period. In an early stage of the deposition, only the fine grain marine sediments are deposited, then followed by coarser continental sediments at Jurassic to Cretaceous period (Metcalfe I., 1989). Furthermore. Hutchison & Tan (2009) stated that Paloh consists of

Triassic argillo-tuffaceous limestone unit which strongly indicates that Paloh is a part of the Central Basin.

2.7 Depositional Environment

A depositional environment is a place which affected by the specific sedimentary process condition to deposit the sediments. There is three major type of depositional environment, which are continental, transitional and marine. Based on the sedimentological and paleontological evidence, Kamal (2016) conclude that the formations within the Gua Musang area were deposited in a warm, shallow marine environment within the Paleo-Tethys Seaway of the Central Belt during Permo-Triassic time as Figure 2.4.



(Sources: Kamal et al., 2016)

Figure 2.4: Middle Triassic depositional setting of Central Belt Peninsular Malaysia. Proposed formations are Aring formation, Lipis formation, Merapoh limestone, Gua Sei limestone, and Gunung Senyum limestone (in bold). The shallow marine platform extends further north until Malaysia-Thai border, while deep Semantan-Gemas basin extends south until Johore.

According to Hashmie et al., (2016), the depositional environment can be interpreted based on the facies characteristics. These include its texture, grain size, grain composition, fossil content and energy index classification. This statement is supported by Abouessa et al., (2015) as they indicate the depositional environment of Sirt Basin, Libya as Fluvial floodplain as they found the evidence of cylindrical burrow trace fossil and interbedding of sand and mud. Kepferle (2016) interpreted Kenwood Siltstone Member in United State as the deltaic environment from the evidence of stratigraphy, petrology and bedding structures.

The facies characteristics of the formation are represented by the sedimentary log. Based on Trujillo & John (2015), stratigraphy column is important as it can improve the understanding and communication between the geoscientist of given rock layers. A stratigraphic column includes bed number, base depth, rock type, primary lithology, grain size, and color. For example, Klein (1971) described the depositional environment of paleotidal range by plotting bed thickness, lithology, grain size and sedimentary structure of the facies in a graphics unit. The sedimentary log also used by Back et al., (2001) to represent the facies characteristics for determining the depositional environment along the Jerudong Anticline in Brunei Darussalam and correlated the detail section with another detail section.

The data of the facies characteristics from a detailed section can be computed into the digital style sedimentary log by using the Corel Draw software. This method was used by Dolezal (2004) to construct graphic logs for interpreting depositional environment Rockwell-Price Formation in Western Maryland. Another software for constructing the graphic sedimentary log is Sedlog which suggested by Zervas et al., (2009).

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

This part will explain what materials are used and how the research is conducted before, during and after the field. The materials needed for the field are topographic map, Global Position System (GPS), compass, geological hammer, hydrochloric acid solution (HCl), stationery, digital camera, field notebook, measuring tape, hand lens, and sample bags.

There are six stages of the research, which are preliminary research, desk study, field studies, laboratory work, data analysis and interpretation, and report writing (Figure 3.1).

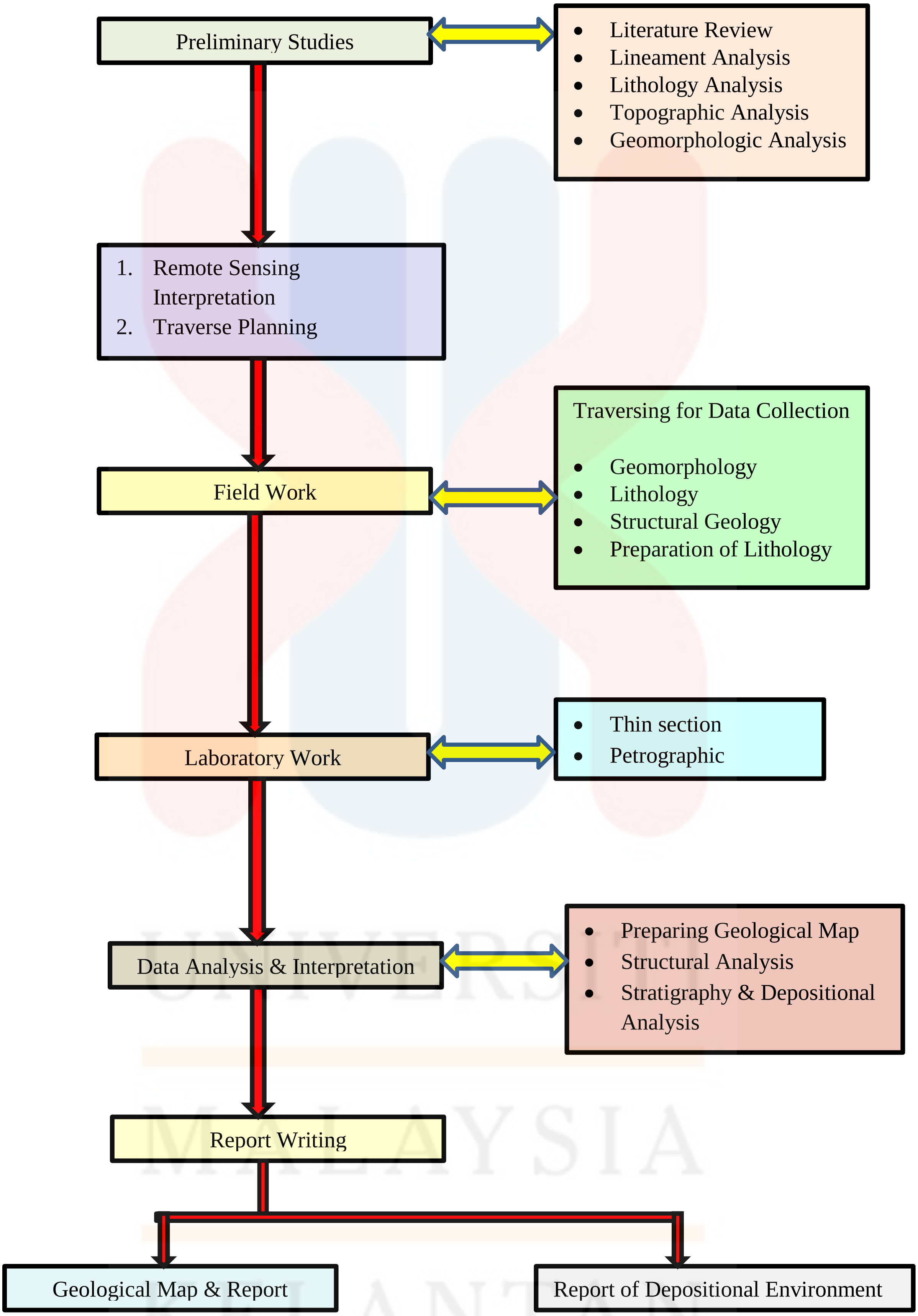


Figure 3.1: Research Flow Chart.

3.2 Materials

There are twelve materials that used to conduct research. All of the material was explained at below.

3.2.1 Topographic Map

A map is important as a reference for geological fieldwork. The topographic map represents a portion of the three-dimensional of Earth's surface in a two-dimensional way. It acts as a base map of geological mapping as the position of contour, river and paved road in the North direction, coordinates, scale bar and magnetic declination date are known.

3.2.2 Global Position System (GPS)

GPS is a space-based satellite navigation system which can provide the location and time information on the Earth's surface. Length of a track can be directly measured from the GPS. GPS is useful to create accurate plots on the map. With GPS, the planned traverse can be reached.

3.2.3 Compass

A compass is a tool used to measure the accurate bearing based on the landmarks precise directional measurements. It is also needed for measuring the orientation of the structures present on the outcrop and the attitude of the sedimentary beds to construct the sedimentary log.

3.2.4 Geological Hammer

Hammer is a basic tool for geologist as it used to collect outcrop samples. The flat end of the hammer is used to break the rocks and light chisel work. The pointed end is used for prying the rocks and prospecting in soil and loose rock debris. Hammer also can be used as a scale. Chisel hammer is more preferred in this research as a way to avoid to destroy the contained fossil.

3.2.5 Hydrochloric acid (HCl) solution

HCl solution is used to test the presence of carbonate minerals in the rock. Small bottle of HCl solution is enough to bring to the field. If rocks contain carbonate minerals, effervescence will occur when the HCl solution is added to the rock.

3.2.6 Stationary

Stationary especially ballpoint pencil, eraser, ruler and permanent marker are prepared to bring to mapping. The pencil is used to jot down the note, sketch outcrop, and mark coordinate on the map, whereas marker is used to mark the sample bags.

3.2.7 Digital Camera

Every geological data needs references and evidence after going back from the field. A camera is the best tool to capture the useful geological data or activities in the field. The outcrop, structure, landform and other geological information can be recorded by high-resolution camera with appropriate scale as a backup memory.

3.2.8 Field Notebook

Field notebook will be used to jot down all the data and information that are obtained from the field mapping. It should be fully protected especially during the rainy day. Without these recorded data, the analysis and interpretation data cannot proceed.

3.2.9 Measuring Tape

The precise measurement of lithology and structures is required to collect field data. The measuring tape can be used to measure the size of the outcrops, structures and also the thickness of the sedimentary beds.

3.2.10 Hand Lens

The hand lens can be used to quickly observe the tiny particles in the rock that cannot be seen by naked eye, especially the microfossils and minerals. It can be used for the early identification of the mineral contained in the rock sample before the further petrographic analysis is a laboratory.

3.2.11 Sample Bags

Sample bags are needed to keep the sample that will be collected from the field. The sample bags must be labeled with the sample number and coordinates. The sample bags have to suitable for hard, soft or wet rock.

3.2.12 Remote Sensing Image

Remote sensing image is the representation of Earth's surface that captured by the satellite. The information can be obtained from Google Earth. It is very useful to gain the geomorphology information and road accessibility data.

3.2.13 Microscope

The microscope is used to determine the nature of rocks and minerals in the laboratory. The detailed thin section of rock specimen is observed by the polarizing light of the microscope. The results will give the important data for identification of rock.

3.2.14 ArcGIS 10.3 Software

A software that used to create, edit, analyze and share information to construct a map. A base map is created by adding the topographic data from Jabatan Mineral and Geosains (JMG) Malaysia into the software for field studies. The software is also used to produce a geological map of Perasu area.

3.2.15 Georose Software

A software that is used to analyze the joint orientation and fault. The data of the orientation of the structures are added to the software. It may generate the rose diagram of a strike, dip direction and dip angle of the structures, as well as their stereonet diagram.

3.2.16 Corel Draw Software

A software that is used for drawing stratigraphic column and three-dimensional block diagram. At first, the necessary data that collected from the field are computed into the software to draw the sedimentary log. Then, the output of the software is used for depositional environment interpretation of Perasu area.

3.3 Methodology

3.3.1 Preliminary Studies

The first step for conducting the research is preliminary research. The regional geology of the study area is studied before going to field through preliminary research. In this stage, it involves the study of topography map and literature review. Topographic map provides the geomorphology information of the study area. The topographic map is the base that produces by the Arcgis 10.5 software. The analysis of topographic map is done before going to field. The position of the lineament in the study area can be identified through the analysis of topographic map. Lineament can be indicators of faults that have good evidence of the historical geology of an area. Besides that, the boundary of different lithology can be determined from the topographic analysis by recognizing different contour pattern. For example, the small contour interval is igneous rock or hard rock, whereas the large contour interval is sedimentary rock or soft rock. From Google Earth, the geomorphology of the study area can be analysed. The location with the highest and lowest elevation are identified. Through Google Earth, the ways to access the highest elevation can be identified. After analysis of the maps, traversing is planned to carry out the field studies. A well prepared traversing will get sufficient and useful data of the area.

The literature review also must be done before going to the field. It needs to obtain the knowledge and geological information from the previous researchers that may help in this research. Sources of preliminary research may involve the references books journal, journal article, Internet and map of Malaysia.

Library of University Malaysia Kelantan Kampus Jeli is a good place to get the source of the literature review as it provides useful references such as scientific books and journals. It also provides the service of Internet and My Athens link which is very useful for searching the scientific journal articles. The availability of the senior thesis report can act a guideline for conducting a research.

The books that contain the guideline on the methods to collect the data of geology and deposition environment are available in the library. The procedures and the precaution of the field works are studied to make sure all the adequate information are not missed.

3.3.2 Field Studies

In field studies, it needs quite couples of weeks to complete it. The accommodation, transport, and food should be well prepared during the fieldwork days.

Geological mapping will be done to record and collect the data in the field that will be carried out by traverse method. At first, it is a good way to get some geological impression in the study area. This includes observing the landform and road access for mapping to get the potential data. The position of landmarks such as river, paved road, shops and mosque are recognized and recorded.

Secondly, traversing will be done to conduct a detailed mapping. Observing, measuring, and sampling is three aspects that should be considered when conducting geological mapping. These aspects are very important for collecting the data for both geological map and depositional environment.

By conduct geological mapping, all the information regarding geomorphology, lithology, structural geology and stratigraphy of the study area can be obtained to produce a geological map. In geomorphological mapping, the location with the highest elevation in the study area is accessed to observed the geomorphology of the study area by ground truth. Observation is done to determine the landscape of the study area. The compass is placed on the map to identify the direction in N-S. The panorama of the view is taken by the camera and the important data is recorded.

In structural geology, the bedding structure and secondary structures like joints, a fracture will be observed and their orientation will be measured. The direction of strike and dip angle of the beds are determined by using right-hand rule. When a hand is placing the bedding surface, the dip direction is where the fingers pointing down, whereas the strike is where the thumb pointing. After knowing the direction, the attitude of the bed is measured using the compass. For joint and fractures, their orientation is measured to do the joint and fault analysis.

In lithostratigraphy, the observation of the texture of the rock unit in term of color, structure and grain size will be done. The boundary and the thickness of the rock within the rock unit will be measured and recorded. For further identification of the rock name by petrographic analysis, sampling is needed to collect the rock. The rock samples collected should be fresh and at least the size of the fist by using a hammer. Sketching the lithostratigraphy unit to shows the relationship of the rocks within it. The appropriate photographs are taken by the camera.

For collecting depositional environmental data, observation is important to do the detailed section. As through observation, the properties of depositional environment can be identified. These properties include sedimentary structure and textures, sedimentary facies associations, and fossils. In general, the depositional basin is filled with sediments that eventually form the sedimentary rocks. Thus, in term of lithology, the texture of the sedimentary rock is observed in terms of grain size, grain shape, grain sorting and grain orientation. The thickness of the beds is measured using the measuring tape. Next, a sedimentary structure that formed during the deposition is observed as they are good evidence for the research. The fossil content in the sedimentary rocks is observed as it useful to identify the relative age of the rocks and depositional environment. Stratigraphic column is sketch to show the relationship of the facies. Both the rock and fossil are sampled to do the laboratory analysis.

During the field studies, every outcrop and important geological information are sketched and taken photograph with appropriate scale. The traversing and the location of observation, measuring and sampling are marked on the base map. All the samples are labeled and put in the sample bags.

3.3.3 Laboratory Work

In laboratory work, the rock samples that collected from the field will be cut into a thin section. The rock will first cut by non-deformational diamond saw into small pieces (Figure 3.2). The small sawn piece of rock will be ground by hand or grinding machine until the rock is completely flat (Wase, 2000). Besides grinding machine, the surface of the cutting rock was polished using Silicon Carbide Powder 1000 (P2000) Grit (Figure 3.3). Then, with using mixture of 10 ml Epoxy Hardener and 10 ml Epoxy Resin, the dry flat surface will be attached to the slide (Figure 3.4). After the glue dried, the sample will be cut down using thinning machine to the thickness approximately 2 mm (Figure 3.5). Another side of the thin section sample will be covered and mounted with the glass cover. The completed thin section can do the petrography investigation under a microscope. The minerals, fragments and their coverage percentage in the rock can be identified from the petrographic analysis. Thus, the appropriate rock name is then identified by rock identification chart. If there is microfossil is found in the outcrop, a microscope is useful to observe microfossil and identify the fossil name.

Figure 3.2: Cutting the rock sample into smaller pieces.

Figure 3.3: Polish the surface of cutting rock.

Figure 3.4: (a) mixture of epoxy, (b) polished rock attached to slide.

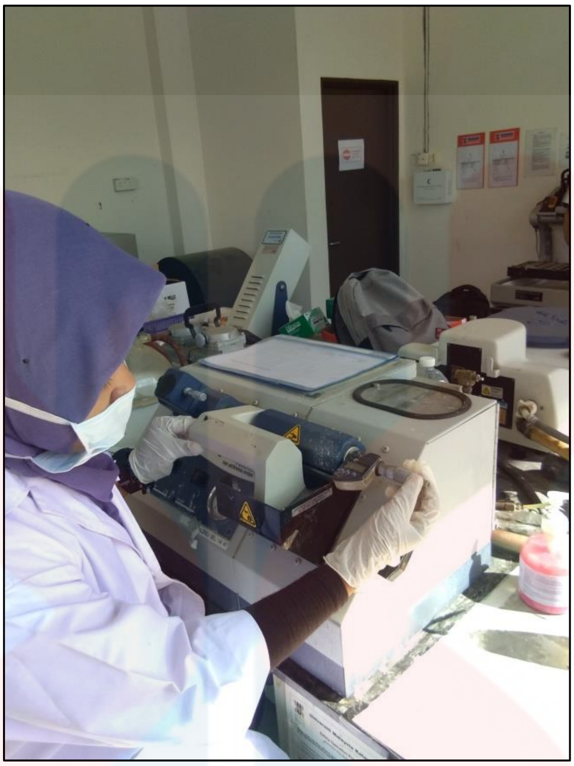


Figure 3.5: Thinning machine.

3.3.4 Data Processing

All the data that gather and record from preliminary studies, field studies and laboratory work need to process before analyze and interpret it. For the geological map, the geomorphology data will be obtained from the remote sensing in preliminary studies. During the fieldwork, the geological data regarding the geomorphology, lithology, structural geology and stratigraphy will be obtained and recorded. The results of petrography of the rock will be acquired using a microscope in the laboratory. All of these data will be gathered, combined and integrated to produce a detailed geological map.

For the identification of the depositional environment, the data such as lithology, sedimentary structures, and fossils are obtained from the fieldwork. In the laboratory, the petrography of the facies can be obtained. Same as a geological map, both fieldwork and laboratory data will be combined.

The data from different stages are gathered and compared. Those data that have the high variation compared to others are removed as they will affect the accuracy of the results.

3.3.5 Data Analysis and Interpretation

The GPS data and field data that obtained from fieldwork and laboratory work will be transferred into ArcGIS 10.5 to produce the geological map with scale 1: 25, 000 the orientations of the secondary structure measure will be integrated into GeoRose for interpretation of force.

The data of detailed section that obtained from the field and laboratory are used to plot the sedimentary log. The sedimentary log will be constructed using Corel Draw software. From the characteristics of the sedimentary log plotted, the division of the sedimentary facies will be done to interpret the depositional environment of the Perasu area. All the research findings are written clearly and understandable in a report for future references.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

The geography and geology of the study area will be discussed in Chapter 4. Geography is the study of the earth landscape and the relationship between the people distributed and the environment. The geography of the study area will be described at the beginning of the chapter. It includes the accessibility, settlement, forestry, and vegetation of the study area.

The study area is covered by plantation and forest reserve. The majority of vegetation covered is oil palm plantation and rubber plantation which is managed by the FELDA agency. Most of the people living there are working as the FELDA workers or officers. Since the area is cultivated with the vegetation or forest, the accessibility of the area is quite challenging, especially on a rainy day. It required 4x4 vehicles for the ease of the work. The rocks and the soils that distributed at the study area show that it very suitable for the plantation due to the presence of the much vegetation.

For the geology, five important aspects such as geomorphology, petrography, stratigraphy, structural geology and historical geology of the study area. Geomorphology of the study area is mainly covered by hilly, plain and karst. The contour elevation is increasing to the North and East. The petrography is involving a description of the thin section to prove the type, name, and composition of the rocks. Age and lithology unit of the study area were described and explained in the stratigraphy section. Structural geology is the study of the geological structures and the tectonic forces that formed upon it. A fault, fold, joint, and vein are secondary geological structures that found in the study area. The provenances of the study area were described in historical geology to illustrate the geology process that acts on the study area.

4.1.1 Accessibility

There are two paved roads that available in the study area that located at south and east of the study area. The paved road that located at the south of the study area is known as Gua Musang-Kuala Lumpur highways. That highway connects Felda Chiku 1, Felda Perasu , Kesedar Sungai Asap and Kesedar Rantau Manis. This highway acts as the important main road to access parts of the study area especially at the upper and eastern part of the study area. The southern and western part of the study area can be accessed through the Jalan Perasu that connect highway of Gua Musang-Kuala Lumpur, Felda Perasu and Kesedar Renok. Jalan Perasu acts as an important road to access parts of the study area especially at a bottom part of the study area. At northern part, has former logging road that connects two hills in a study area. It is impossible to access to the center of the study area as there is an unavailable road with thick forestry and which limited the track for the motorcycle and walking. The center of the study area is fully covered with thick and reserved forest that consists many of wild animals such as tiger, leopard, elephant, bear, and rhinoceros that does not assure safety and life. The existences of a wild animal were identified by found the paw, scratches and their voice.

In the plantation area, it has an unpaved road which is used by the FELDA and KESEDAR workers for working. Hilux are very useful to access these plantation areas compared to other vehicles as the unpaved roads have an uneven surface. However, in the deeper plantation area, the available unpaved roads are getting lesser and smaller. Walking is needed to traverse the places that are impossible to get in with Hilux.

Figure 4.1 shows the map of accessibility in the study area that consist of Highway of Gua Musang-Kuala Lumpur, the main road of Felda Perasu, and former logging road.

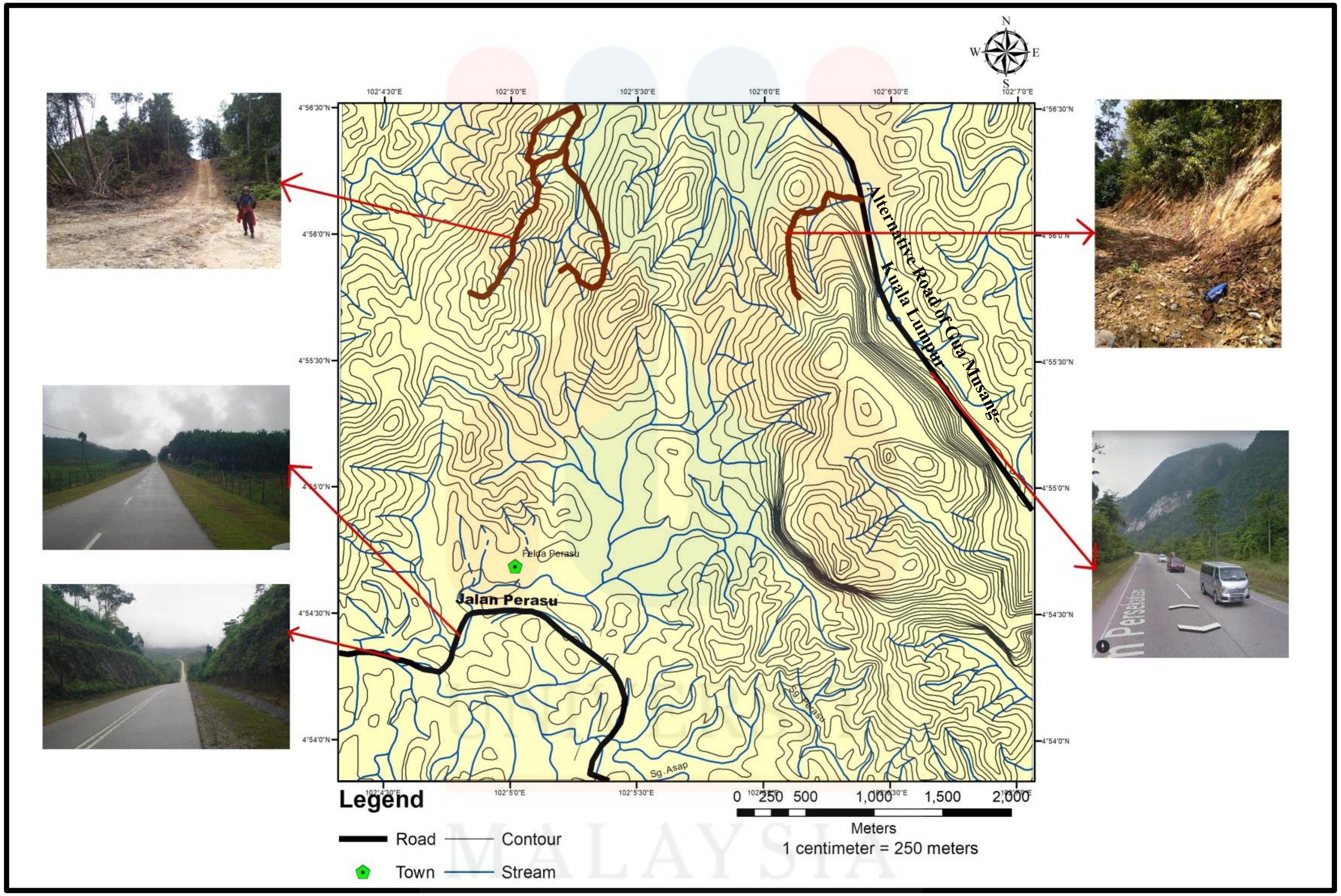


Figure 4.1: Accessibility Map of the Study Area.

4.1.3 Settlement

The settlement includes the places and area that are settled by humans (Figure 4.2). There is a small village, known as Felda Perasu located at the southwest of the study area. The majority of the villages are made up of Malays, with less than 5% of them are Indonesian, Chinese and Indians. Most of them worked for FELDA agency as its officers, staffs, workers, and drivers. Others are involved in small businesses like grocery shop and food stall. Besides that, others are work at a rural clinic and school. They live peaceful in the Kampung style house and government quarters. The place has a lot of young and adult people. For most of the families, the males are working for a living, while 60% of females are doing their house chores and taking cares their children. But, about 40% young female in age 18-40 years old work in school, clinic, Felda office, and food stall. They are very friendly and helpful. The place is convenient as the need for living of the people have been fulfilled such as the electricity, continual supply of clean water, available of telecommunication network (Figure 4.3), mosque for Muslim people (Figure 4.4), primary school for education (Figure 4.5), and also the food stalls and grocery shops.

Figure 4.2: Photo with one of the villagers while he is working in palm plantation.

Figure 4.3: Substation on Felda Perasu that give good telecommunication.

Figure 4.4: Masjid Felda Perasu.

Figure 4.5: Sekolah Kebangsaan Perasu.

4.1.4 Land-Use

The study area is covered by oil palm plantation (Figure 4.6), rubber tree plantation (Figure 4.7), and forest reserved (Figure 4.8). Both the rubber tree and oil palm plantation are managed by FELDA. The plants are matured and already produced fresh oil palms and rubbers. In the rubber plantation area, the size of the unpaved road is much smaller than in the oil palm plantation area. This is because the workers used a motorcycle to collect the rubber whereas Hilux was used to collect the oil pam every working day. In rubber tree plantation area, the soil brown in color whereas the soil is darker brown in the oil palm plantation area. Most of the outcrops in the plantation area are highly weathered and turn into the soil. The oil palm plantation is dominated at the south of the study area, while rubber plantation area was distributed at southern-eastern and southern western of the study area. The majority all rubber plantation were placed on high hill area while oil palm plantation was placed on the plain area. The forest reserved in the study area is an unidentified name but also known as Hutan Bukit Sejuk. It is dominated at the center until the upper part of the study area. The forest in the study area is matured that covered by thick forest. The color of the leaves is darker than the plantation. In addition, there is also a hamlet cultivated by Felda Perasu residents that can add to their source of livelihood at their houses area.

Figure 4.9 shows the map of land use distribution. The most dominant of land use of the study area is forest reserved, followed by oil palm plantation, rubber tree plantation and the least vegetation is a hamlet.

Figure 4.6: The oil palm plantation area. The picture was taken at station 35

Figure 4.7: The rubber plantation area. The picture was taken at station 40.

Figure 4.8: Thick forest with matured tree. The picture was taken at station 2.

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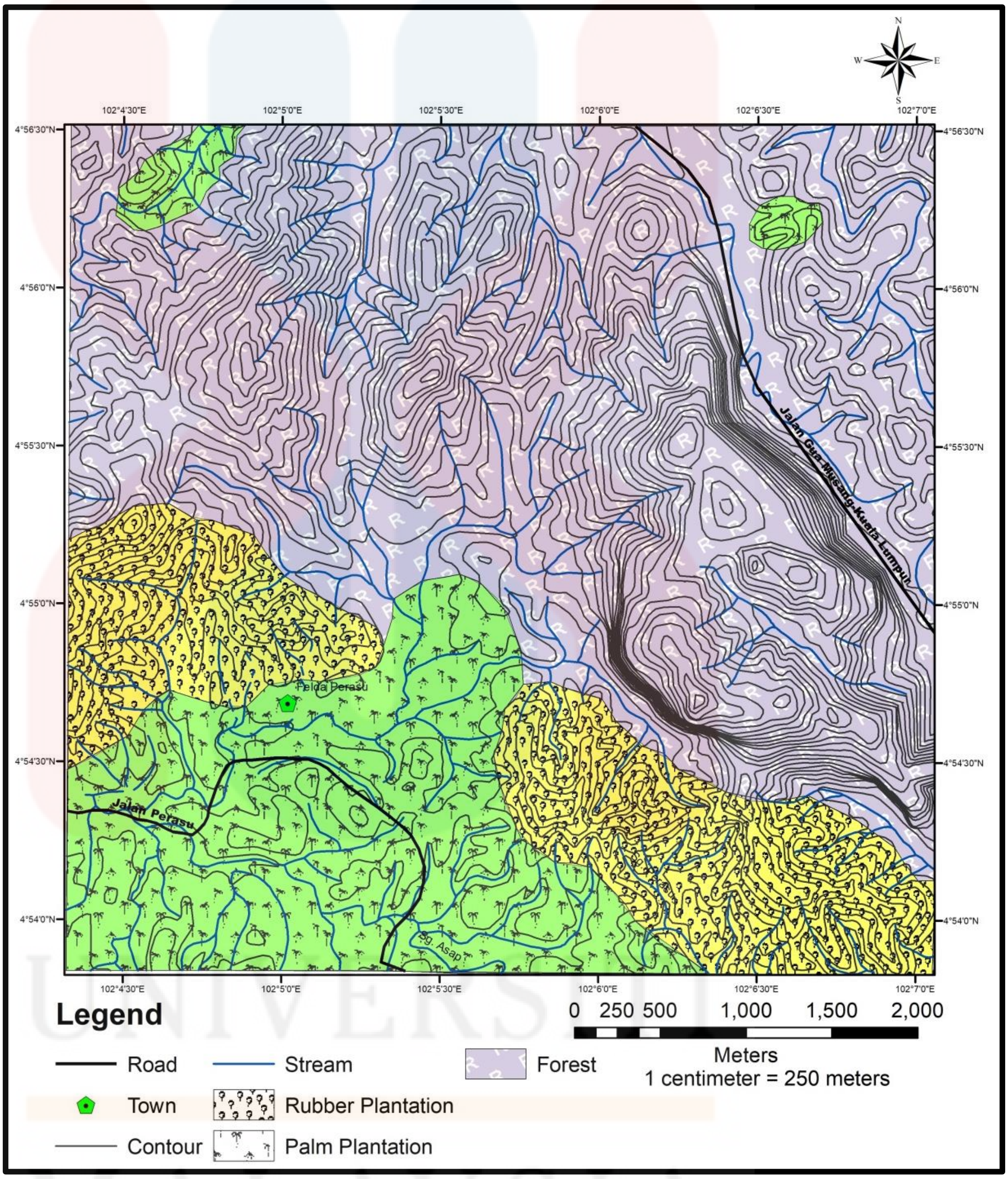

Figure 4.9: Land-use map of the study area.

4.1.5 Traverses and Observation

Before going to the field, traverse planning is done by the observation and interpretation of remote sensing image. In order to collect geological data, rock sampling and measuring, traversing and observation method were used to do geological mapping on the study area. Traversing is one of the alternatives mapping strategy to follow the different pattern of contour and lithology. The traverse route and target were planned and set before going to the field. The whole geological fieldwork process for the study area takes approximately 10 days to complete and collect geological data.

Topographic map acts as the base map. The contour pattern of base map is used for first interpretation to differentiate the rock units. Different characteristics of the rock composition showed with difference contour elevation and contour interval. Those contours with low elevation are composed of soft rocks, whereas hard rocks show high contour elevation. On the other hand, short contour interval may indicate that the rock composed may more compact than the others or vice versa.

Figure 4.10 depicts the map of transverse. Based on the figure, red dotted shows the location of outcrop observation in the field. Total of 43 coordinated is observed and sampling in the field of the study area. Overall, the traversing of the study area is covered around 70% with the most at the south of the study area, followed by at the north, west and the least at the east of study area. The center of the study area is failed to access due to very high elevation and thick reserved forest. The plantation roads are almost unavailable and the transverse is stopped when faced the strong vegetation and steep slope. .

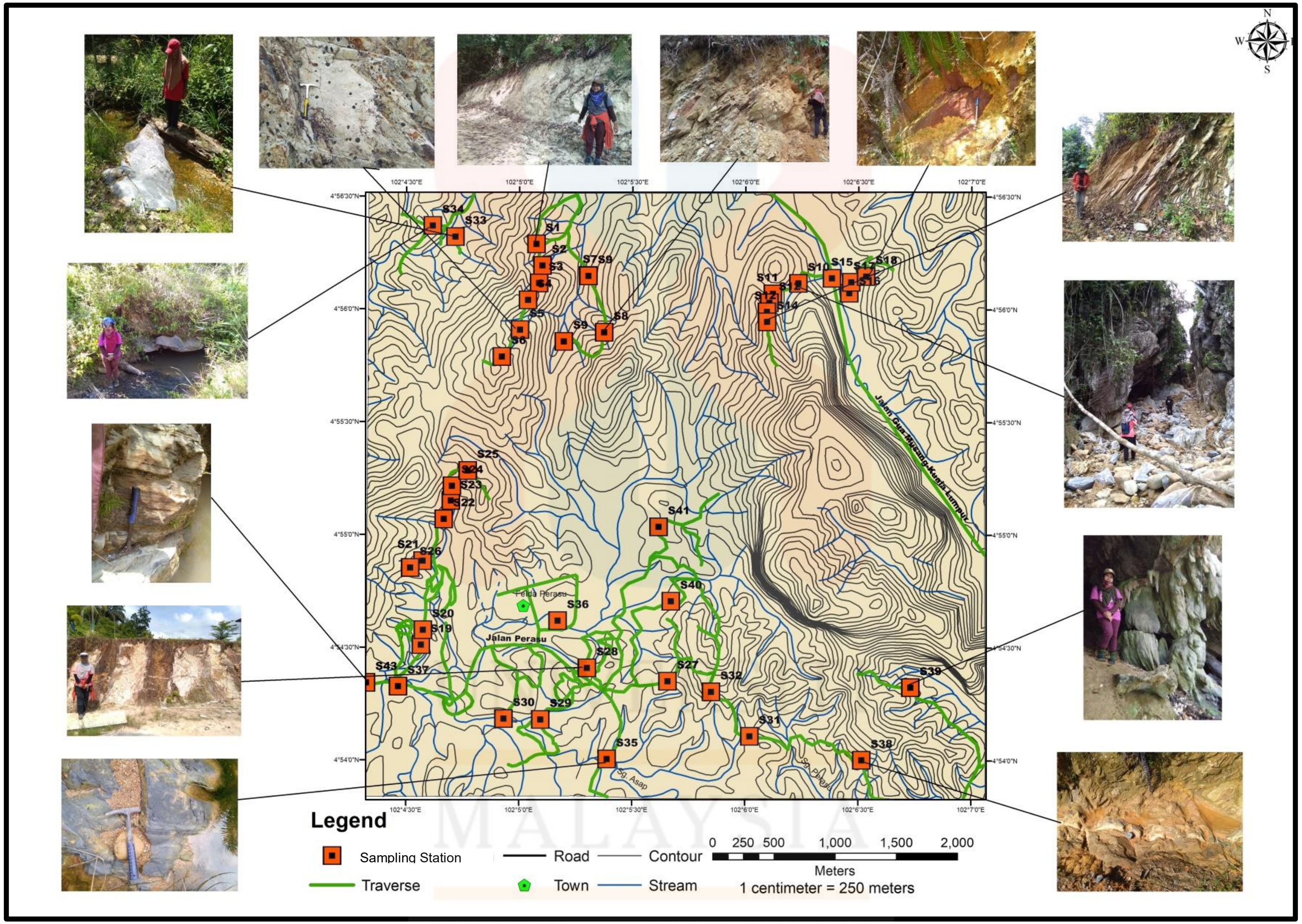

Figure 4.10: Traverse and Sampling Map.

4.2 Geomorphology

Geomorphology is the study of the Earth's geological processes that formed the Earth's landform. The earth landform is caused by the endogenic and exogenic process. Geomorphology discussed the landscape classification, weathering processes, and drainage patterns of the study area. Most of the geomorphological process are considered to be interconnected and are easily observed. In addition, the individual processes are considered to be either depositional, erosional or both. The process that involved the wearing down of the earth's surface either by water, wind, or ice is known as an erosional process. Meanwhile, the process of settle-down of particle and material that resulted from erosion is known as a depositional process. The observation and consideration of geomorphology location are important and useful for environmental and sustainable management. Another benefit of geomorphology study is it an effective tool in the management of natural resources and helps various types of planning and developmental activities.

4.2.1 Geomorphologic Classification

Table 4.1: Classification of topographic unit based on mean elevations.

Topographic Unit	Mean Elevation (m above sea level)
Low lying	Less than 15 m
Rolling	16 to 30 m
Undulating	31 to 75 m
Hilly	76 to 300 m
Mountainous	More than 301 m

(Source: Hutchison, 2009)

Based on C. S. Hutchison (2009), landform can be categorized into five different topographic units according to their differences in mean elevation (Table 4.1). Figure 4.12 shows the topography map in three dimensional (3D) views. The highest elevation of the contour in the study area is 580 m whereas the lowest elevation of the contour in the study area is 105 m from the sea level. As the range of elevation of the contour in the study area is 105 m and 580 m, the topographic units are then classified into hilly and mountainous. As a result, there is only two type of topographic unit in the study area. The mountainous area is dominated from the western to eastern part of the study area with a steep slope and sharp peak while other parts of the study area are dominated by hill, just as shown in Figure 4.11. A mountainous area at the eastern part is dominated by carbonate rock that also can call as karst. Karst is a result of the dissolution of soluble rock by downward percolating meteoric water that caused many cavity and pores (Figure 4.12). The karst features in the study area are steep-sided limestone hill area surrounding by low elevation that resulting from tropic humid (Figure 4.13).

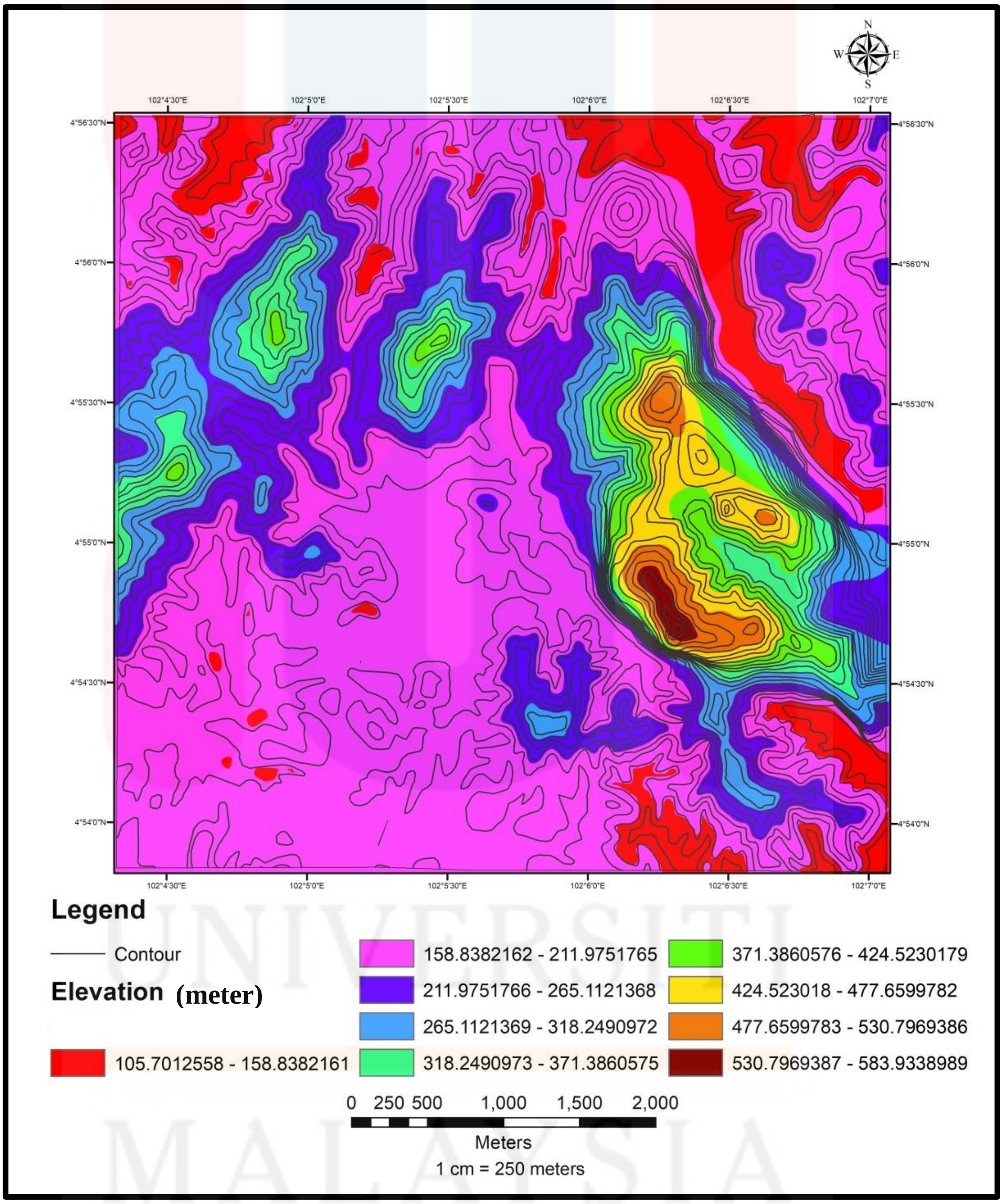

Figure 4.11: Geomorphological map of the study area.

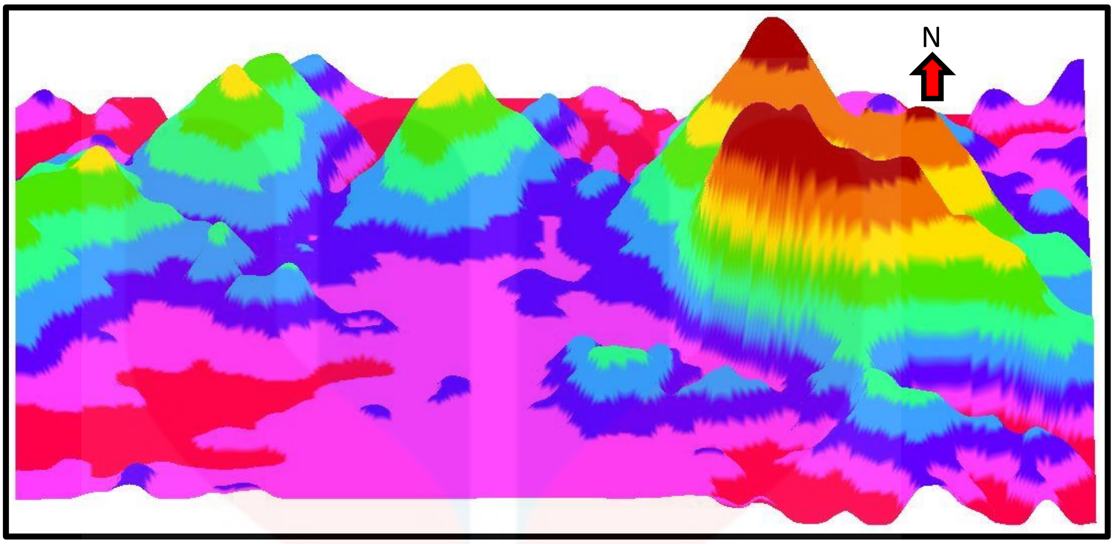

Figure 4.12: Topographic map of study area in 3D.

Figure 4.13: Dissolution of cavities on carbonates rock that resulting on cave.

Figure 4.14: The steep-hill karst limestone that surrounded will low land area. Picture taken with azimuth S 15^0 W at coordinate N 04^0 45' 39.62, E 102^0 6' 39.58".

Figure 4.15: From the North-East to Northern part of study area. Picture are taken with azimuth S 35^0 W at coordinate N 04^0 45' 39.62, E 102^0 6' 39.58".

Figure 4.16: From the southern part, center part to eastern of the study area which is taken with azimuth N 40^0 E at station 35 .

Figure 4.14 and Figure 4.15 show the view of the topography in the study area. From these figures, they show an increase of elevation from the south to the north of the study area. The mountainous area that observed in Figure 4.16 has different morphology with the hills in front of it. The mountainous feature has a sharper peak and very steep slope than the hill surrounding it.

Mountainous topography unit composed of the topography units with more than 301 m of elevation from the sea level. The contour interval is more closes than hills, showing that it has a steeper slope. Mountainous area has high contour elevations which give characteristic of rock distributed. The rock that distributed on the mountainous area is a hard rock with high resistance to the weathering. The rock may contain a high composition of quartz minerals which it has high resistance on weathering. The example of hard rock is limestone rock.

On the other hand, hilly topography unit composed of the topography unit between 105 m to 300 m. Hilly topography has lower elevation and gentle slope than mountain topography. Part of the hilly area in the study area has two categorized which is flat area and slope area. The rock on slope area has high hardness than a flat area. The example of rock on slope area is metasedimentary rock such as phyllite and slate. The flat topography area on the southern part of the study area was dominated by soft rock such as volcanic rock and fine clastic sedimentary rock. The rocks distributed around the hilly area are less resistant to the weathering process.

On south-south-east of a study area, there are has caved in limestone rock. Cave form when there have cavities in limestone rock due to the dissolution of calcite rock when reacting with water. There is a stream on the cave that can be called an underground stream. The cave passage for entrances which located at the eastern side and exist is located at the west side of a cave. One of the geologic structures that can commonly observe is stalactites and stalagmites (Figure 4.17. From stalactites, a pillar can be formed after a precipitation drip for hundreds to thousands of years (Figure 4.18. Conduit is linear passages that connect between one aquifer with another aquifer (Figure 4.19).). A pothole such as in Figure 4.20 that is formed when abrasion occurs from the process of erosion can be observed in the cave.

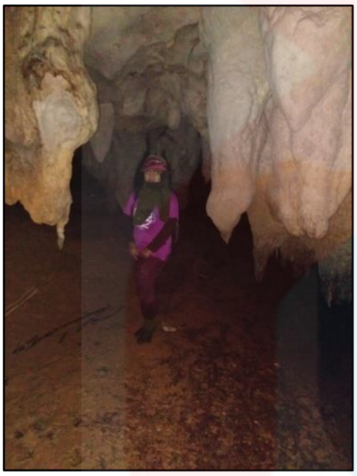

Figure 4.17: Stalactite structure in cave.

Figure 4.18: Continues grow of stalagmite and stalactite create pillar structure.

Figure 4.19: Pathole on cave wall.

Figure 4.20: Conduit passage on cave.

4.2.2 Weathering

Table 4.2: Scale of Rock Mass Weathering

Term	Grade	Description
Unweathered (fresh rock)	I	Rock mass shows no loss of strength, discolouration or other effects due to weathering. There may be slight discolouration on major rock mass defect surfaces or on clasts.
Slightly Weathered	II	The rock mass is not significantly weaker than when fresh. Rock may be discoloured along defects, some of which may have been opened slightly.
Moderately Weathered	III	The rock mass is significantly weaker than the fresh rock and part of the rock mass may have been changed to a soil. Rock material may be discoloured and defect and clast surfaces will have a greater discolouration, which also penetrated slightly into the rock material. Increase in density of defects due to physical disintegration.
Highly Weathered	IV	Most of the original rock mass strength is lost. Material is discoloured and more than half the mass is changed to a soil by chemical decomposition or disintegration (increase in density of defects/fractures). Decomposition adjacent to defects and at the surface of clast penetrates deeply into the rock material. Lithorelicts or corestones of unweathered or slightly weathered rock may be present.
Completely Weathered	V	Original rock strength is lost and the rock mass changed to a soil either by decomposition (with some rock fabric preserved) or by physical disintegration.
Residual Soil	VI	Rock is completely changed to a soil with the original fabric destroyed (pedological soil)

Weathering process can be categorized into three ways which are physical, chemically, and biologically. All of this type weathering found in the study area. Majority all outcrop in the study area are undergoes physical weathering (Figure 4.21). The effects of physical weathering are changes of color, hardness, and size of rocks. While chemical weathering is found at northeast and northwest of the study area. Carbonate rock is soluble with rainwater that can cause alteration of rock which changes the texture, shape, and composition (Figure 4.22). Andrei (2015) said that spheroidal weathering is a quite common result of chemical weathering which it involves corestones of various composition and size which are surrounded by concentric shells arranged in zones (Figure 4.23). Dendrites usually black with fine and complex branches that result from mineral growths (Figure 4.24). Dendrites form when the minute mineral crystals grow end to end and forming a delicate branched pattern along the crack or joint surface in the rock. Common minerals that form dendrites are manganese oxide and iron (Alex Cook, 2011). Dendritic also was known as pseudofossil because it looks like plants fossil. Dendritic are usually found indifferently angles fracture plane in the rock with more complex and less regular in a pattern than plant fossils. The north area are dominantly undergoes biological weathering. Roots of a plant can seep and grow in cracks of rock Figure 4.25. As they grow bigger, the roots push open and expand the crack that made them wider and deeper over a time.

Table 4.2 shown scales of rock mass weathering. The study area have grade II until VI. Grade II dominantly on west of the study area which is composed with limestone lithology. Besides that, all outcrops in the study area has grade between III to VI.

Figure 4.21: Jointing on rhyolite rock that cause physical weathering. Picture were taken with azimuth S 15^0 W at station 6 .

Figure 4.22: Dissolution of carbonates rock resulting of chemical weathering. Picture was taken with azimuth S 34^0 W at station 11.

Figure 4.23: Spheroidal weathering that has circular shape with look like peel onion. Picture were taken with azimuth N 40^0 W at station 14 .

Figure 4.24: Dendrites (pseudofossil) that result of chemical weathering. Picture were taken at station 3.

Figure 4.25: Biological weathering resulting of growth roots in crack of the rock. Picture was taken with azimuth S 26^0 W at station 2.

4.2.3 Mass Movement

Table 4.3: Type of Movement Involved

	Type of mass Involved	
Types of Movement Involved	Bedrock	Soils
Falls	Rockfall	Soilfall
Slides	Slums, slides and glides	Slums, slides and glides
Flows	Fragment flow	Earthflow, debris flow, mud flow
Complex	Complex type of movement	

(Sources: Balasubramanian, 2016)

Table 4.3 show types of movement that can be categorized into falls, slides, flows and, complex. A downward movement that induced by gravity pulls on soil and rock without changing any chemical composition was call as a mass movement. Type of mass movement that found in the study area is only slides that occur on soils area. The factors that causes the mass movement is weathering, climate, slope and, vegetation.

A slump can be observed in the study area (Figure 4.26). A slump is slipping of coherent rock materials along the curved surface of a decline (Balasubramanian, 2016). Slump usually happen due to human activities where slopes are cut over steeping. The high rate of rainfall and weathering can trigger the occurrence of a slump.

Besides that, a slide can also be observed in the study area (Figure 4.27). Masses of soils that experience the sudden downhill with straight movement are defined as slides. Slide in the study area occur about 10 m height due to vegetation and high rate weathering and rainfalls.

Figure 4.26: Slump type of mass wasting. Picture were taken with azimuth N 54^0 E at station 17.

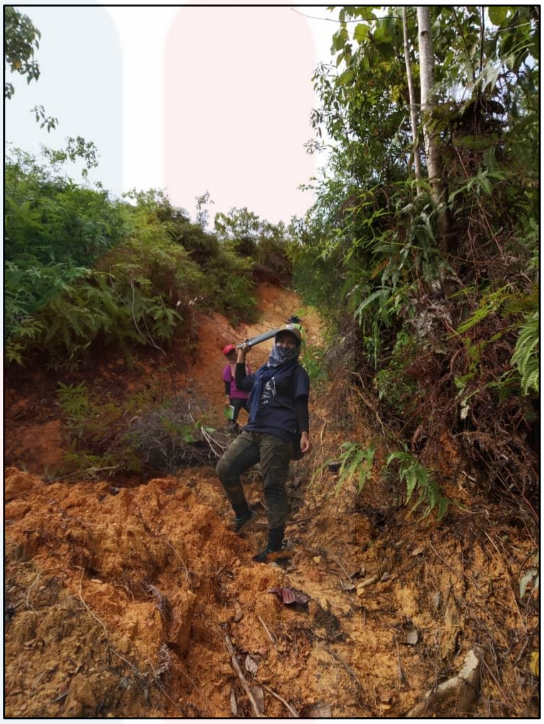

Figure 4.27: Slide type of mass wasting. Picture was taken with azimuth S 42^0 E at station 15.

4.2.4 Drainage Pattern

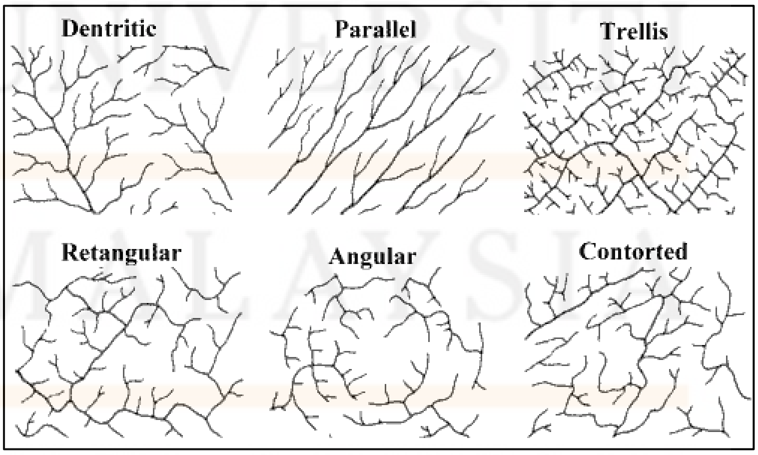

Figure 4.28: Type of drainage pattern (Sources: Hanson, 2007)

A drainage pattern is the pianimetric arrangement of streams etched into the land surface by a drainage system (K. Guru Rajesh, 2007). The geologic information such as topographic, slope, structure, history and underlying rock can be identified and observed through drainage pattern. Drainage pattern all over the world has more than six type and all the type has their own characteristic (Figure 4.28). The drainage map in Figure 4.29 shows the study area only has a dendritic style of drainage pattern.

Dendritic pattern of drainage pattern is characterized by irregular branching look like a tree branch in all directions. Dendritic patterns particularly characteristic of rock which is homogenous with respect erosion with running water. Flat-lying beds, soft rock, and massive crystalline rock are the characteristic of a dendritic pattern. A dendritic pattern has lack of geology structural control (Fig 4.30 & Fig 4.31).

There are two stages that take places in the development of a dendritic pattern. At the first stages, erosion of rock in stream goes downwards and tributaries increased. At the final stages, a small valley was capture by a large valley. Rainfall, relief, and lithological was responsible for the development of dendritic patterns.

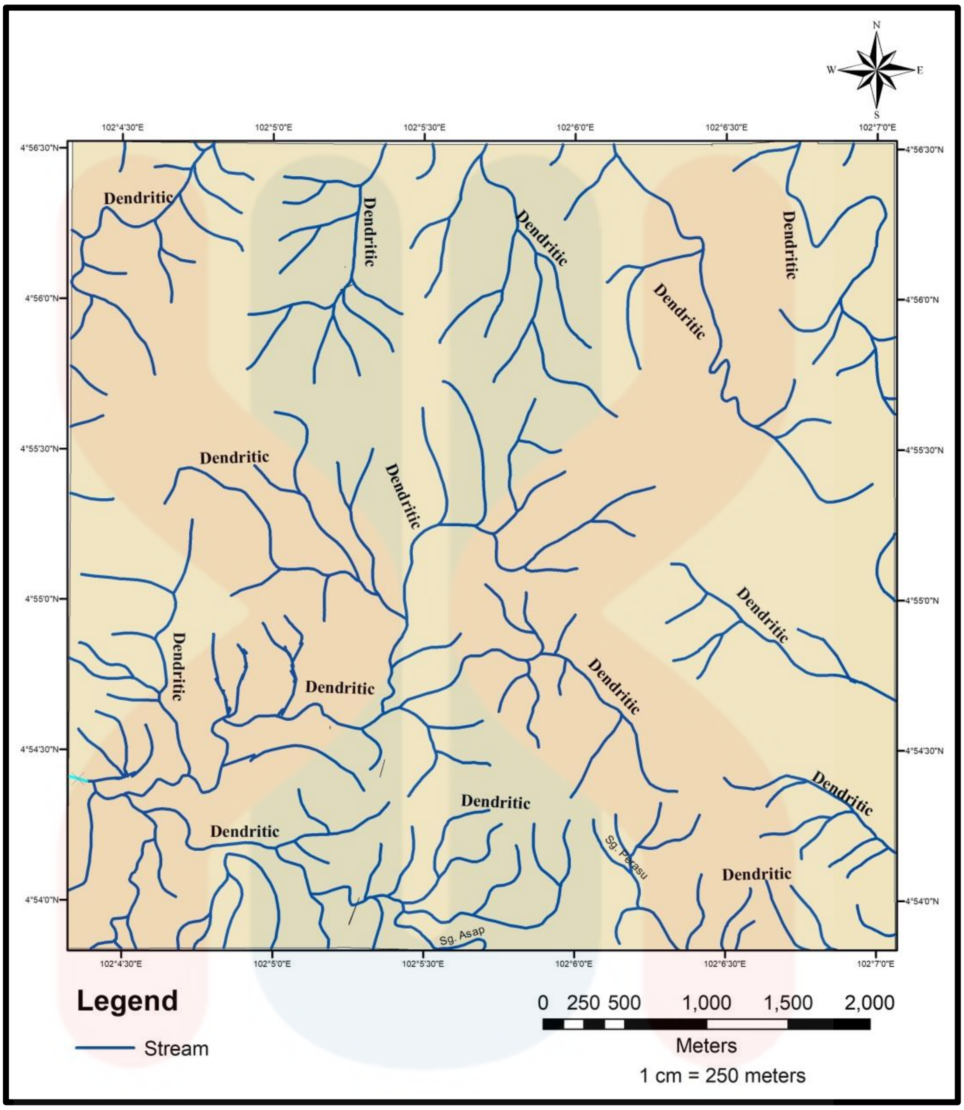

Figure 4.29: Drainage map of the study area.

Figure 4.30: The only main stream in study area with low lying contour. Picture were taken with azimuth N 78 E at station 43 .

Figure 4.31: Stream with mudstone lithology. Picture were taken with azimuth N 16 E at station 35

4.3 Lithostratigraphy

The lithology of the study area is interesting as it composed of a various type of rock such as sedimentary, pyroclastic, meta-sediment and igneous rock. All of these type of rock in the study area are then classified into five main lithology unit which is a limestone unit, mudrock unit, phyllite unit, tuff unit, and rhyolite unit. All the units were named based on their dominant in lithology. The most common rock in the study area is a meta-sedimentary rock as it distributed widely. All the main lithology unit were recorded and divided in the geological map.

4.3.1 Stratigraphic Position

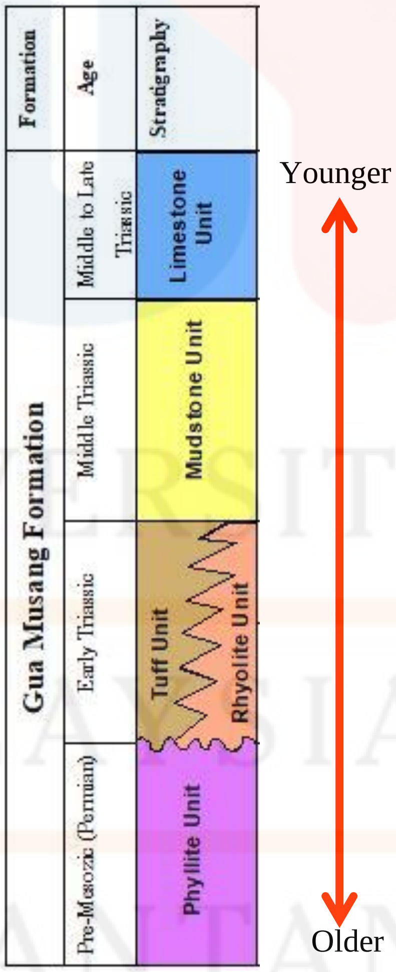

Figure 4.32.: Stratigraphic column of the study area.

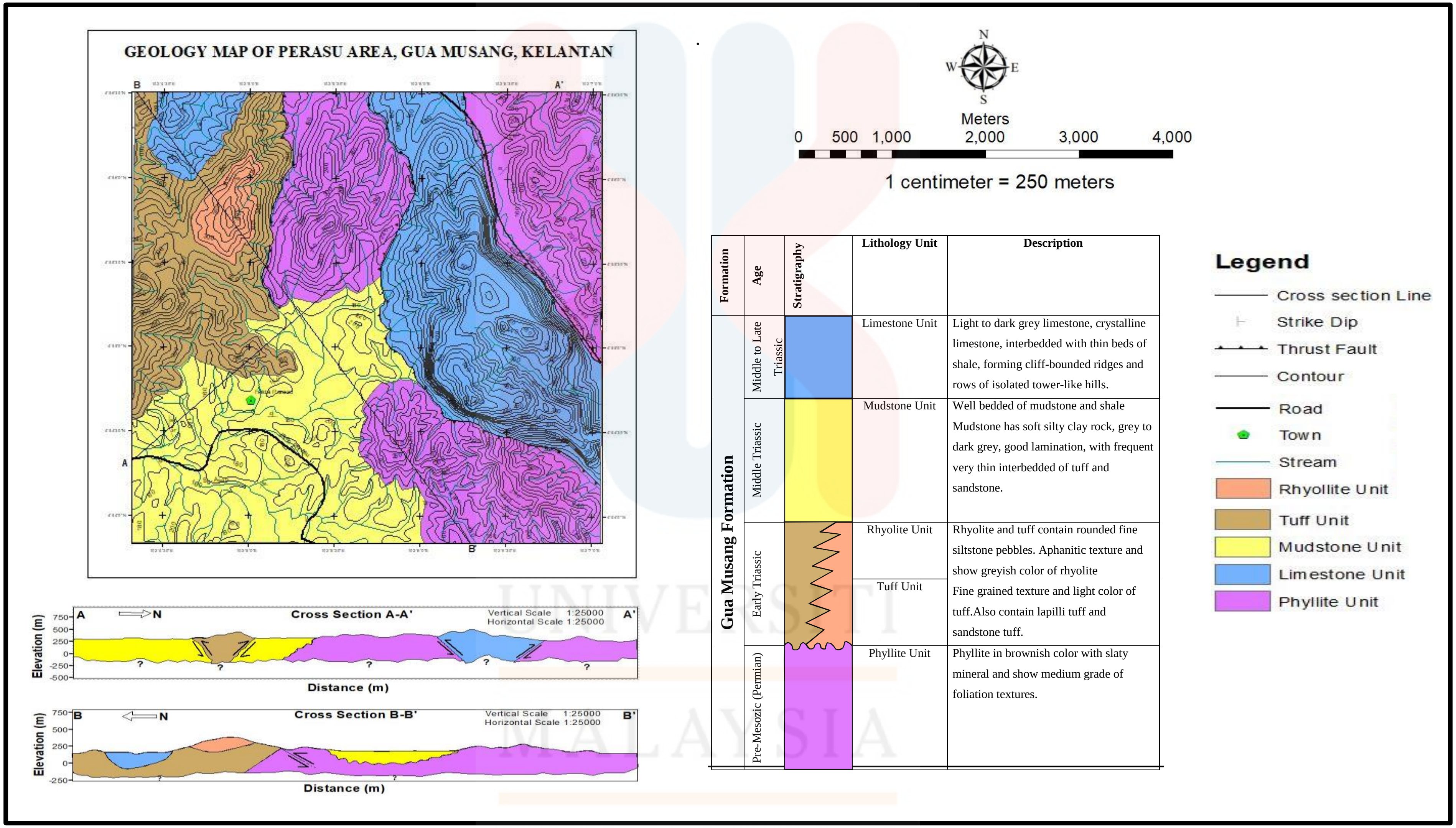

Figure 4.33: Geological map of the study area

Figure 4.33 shows the geological map of the study area. The geological map of 1:25, 000 in scale is shown in Appendix A. The study area is consists of five unit, which are a limestone unit, phyllite unit, tuff unit, mudstone unit, and rhyolite unit. Mudstone unit is located at the south-west of the study area, a location of the tuff unit and rhyolite unit is at north-west of study area, limestone unit is distributed massively at east of study area and small-scale were distributed at northeast of study area, whereas phyllite unit is located from north to east of study area. Metasediment unit has a big distribution in the study area while rhyolite unit has very small distribution in the study area. The oldest unit is metasediment which is phyllite unit. It is overlain unconformity by a volcanic rock which is tuff unit and rhyolite unit. The tuff unit and rhyolite unit is then underlain conformity by mudstone unit. The youngest unit is andesite unit. In correlation with Gua Musang Formation, the age of these units is between Permian to Late Triassic (Kamal Roslan, 2016). The stratigraphy column was shown in Figure 4.32.

4.3.2 Unit Explanation

a) Limestone

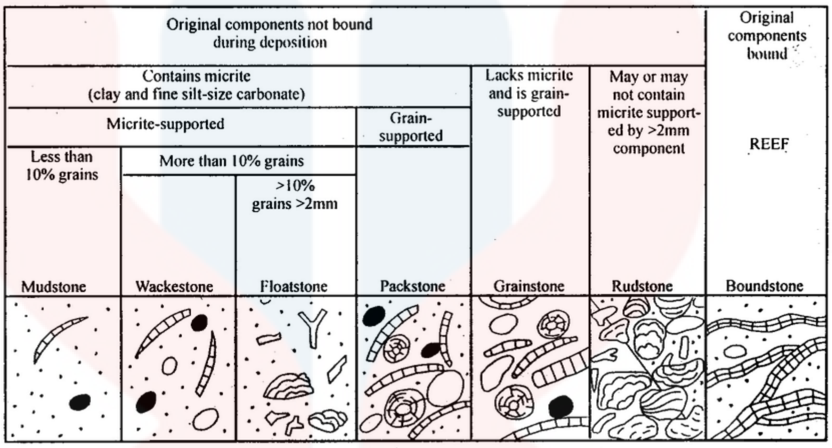

Figure 4.34: R.J. Dunham Classification of Carbonate Rock.

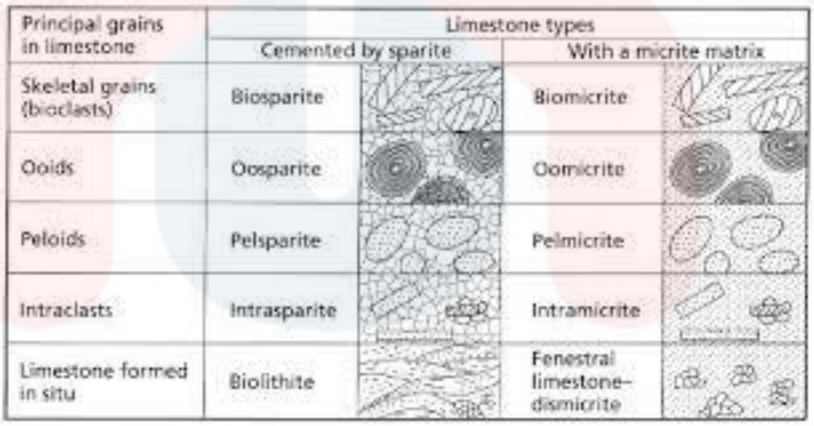

Figure 4.35: R.L. Folk Classification of Limestone Rock.

The youngest rock in the study area is limestone rock. Limestone is the result of the biological and biochemical process although inorganic precipitation of $CaCO_3$ from seawater also takes places (Sam Boggs, 2009a). The carbonate sediment is modified by the chemical and chemical process of diagnosis once they deposited. Two common minerals in carbonate sediment are aragonite and calcite that has their own significance of magnesium content. The classification of limestone can be decided with R.L. Folk and R.J. Dunham classification. Figure 4.34 show classification of R.J. Dunham divides limestone on the basis of texture such as grains without matrix, grains in contact with a matrix, coarse grain floating in a matrix and a micrite with few grains. R.L. Folk classification in Figure 4.35 was divided limestone by distinguishes the grain, matrix chiefly micrite and cement.

Limestone in the study area has blackish white in color (Figure 4.36). The grain size is fine grain because the grain cannot see in naked eyes. Based on R.J. Dunham classification, limestone in study area is classified as mudstone because it has the mud-supported characteristic. The original component of mud-limestone not bound together during deposition. When touching the surface of limestone, it has smooth to a rough surface. Limestone has more carbonates mineral and gives vigorously bubble reaction to Hydrochloric Acid (HCl). Bedding of limestone is failed to found due to massive bedding.

Limestone is easily dissolved with water. In a stream of the study area, an outcrop of limestone is underlain in a stream and dissolved slowly with water (Figure 4.37).

Figure 4.38 shows the plane and cross-polarized view of a thin section through a light microscope. Through thin section analysis, limestone in the study area is classified as mudstone because it is mud supported with less than 10% grain. The original components of limestone are not bound together during deposition. The fabric of limestone is grain supported fabric. The grain of the limestone sample is sub-angular with high sphericity. The sortation of limestone is well sorted

Figure 4.36: Massive limestone outcrop. The picture was taken at station 10.

Figure 4.37: Limestone outcrop underlies in streams. The picture was taken at station 34.

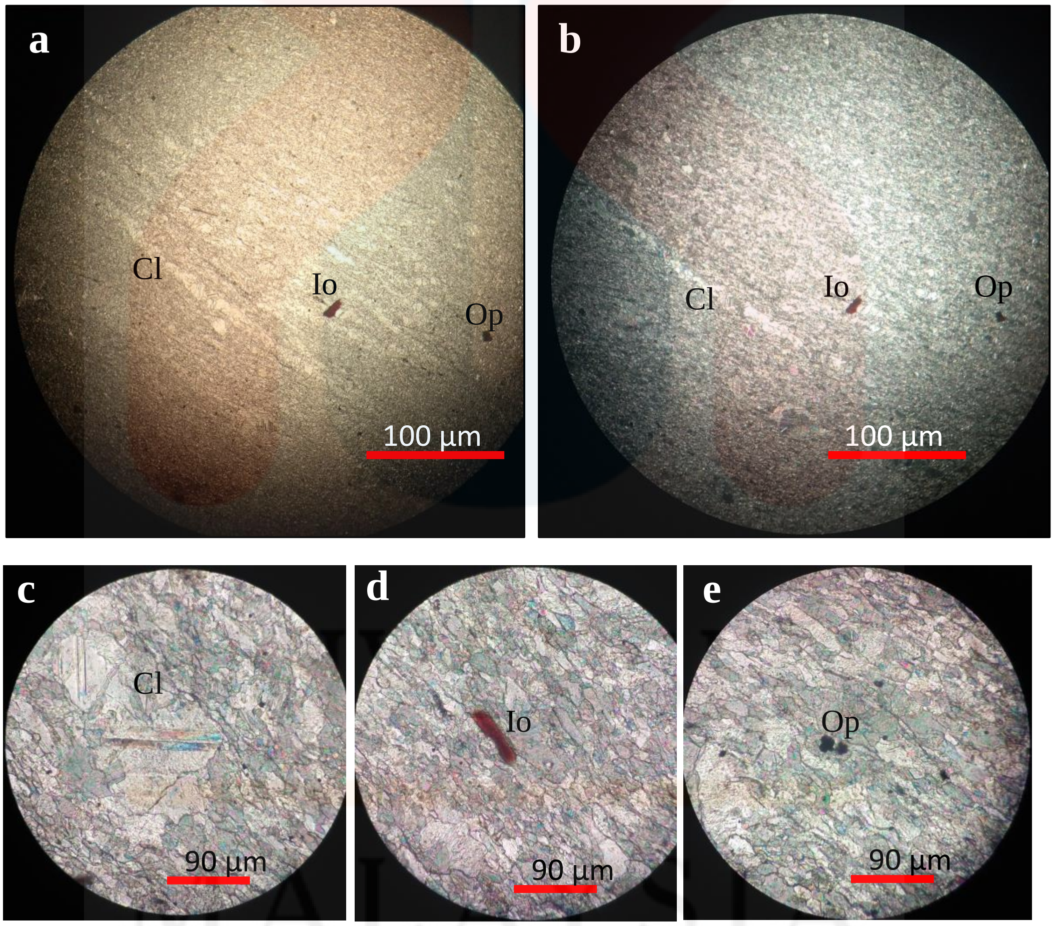

Figure 4.38: The thin section photo-micro of limestone sample on (a) PPL (b) XPL. Calcite= Cl ,Hydrate Iron (III) Oxide= Io , Opaque= Op (a , b) ; Magnification of 40×0.65P; (c,d,e) Magnification of 60×0.80P

Minerals found in limestone thin section is calcite, iron oxide mineral and opaque minerals. Calcite has rhombohedral cleavage. Calcite colorless in a plane view and color. Birefringe is third order because to extreme and change of relief with rotation. The alteration of hydrated iron (III) oxide can be seen distributed widely as figure above. The color of the alteration is dark brown. Limestone often associated with these. Opaque mineral of iron oxide in plane and cross polarized, the color is black with the shape of the mineral is subangular and which has less than 1mm in sizes.

b) Phyllite

Phyllite outcrop is found at the hill with high weathering rate that with the brown-orange surface (Figure 4.39). Bedding structure can be observed and recorded from the outcrop. The hand specimen is quite hard with a medium smooth surface. Its grain size is medium to fine and shows phyllitic foliation (Figure 4.40). Phyllite has wavy and silky surface when split it into two. This shows that the outcrop had undergone a low degree of regional metamorphism.

The rock undergoes continued metamorphism that caused grain size increased while the orientation of platy minerals is maintained. At this stage of metamorphism, small porphyroblast starts to develop and are observed as small bumps on otherwise smooth cleavage surfaces (Harvey et al., 2006).

Figure 4.41 shows the thin section of phyllite under a microscope in 40x magnification. It shows clearly the foliation with a preferred orientation of the platy minerals from the thin section. The size of a mineral is fine and has good sortation. The black color of porphyroblast that more than one mineral occurs as subhedral to anhedral crystals distinctly larger than the matrix start to develop.

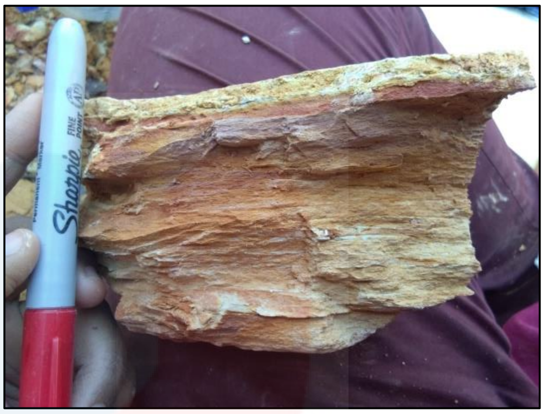

Figure 4.39: Outcrop of phyllite. The picture was taken at station 9.

Figure 4.40: Hand sample of phyllite rock.

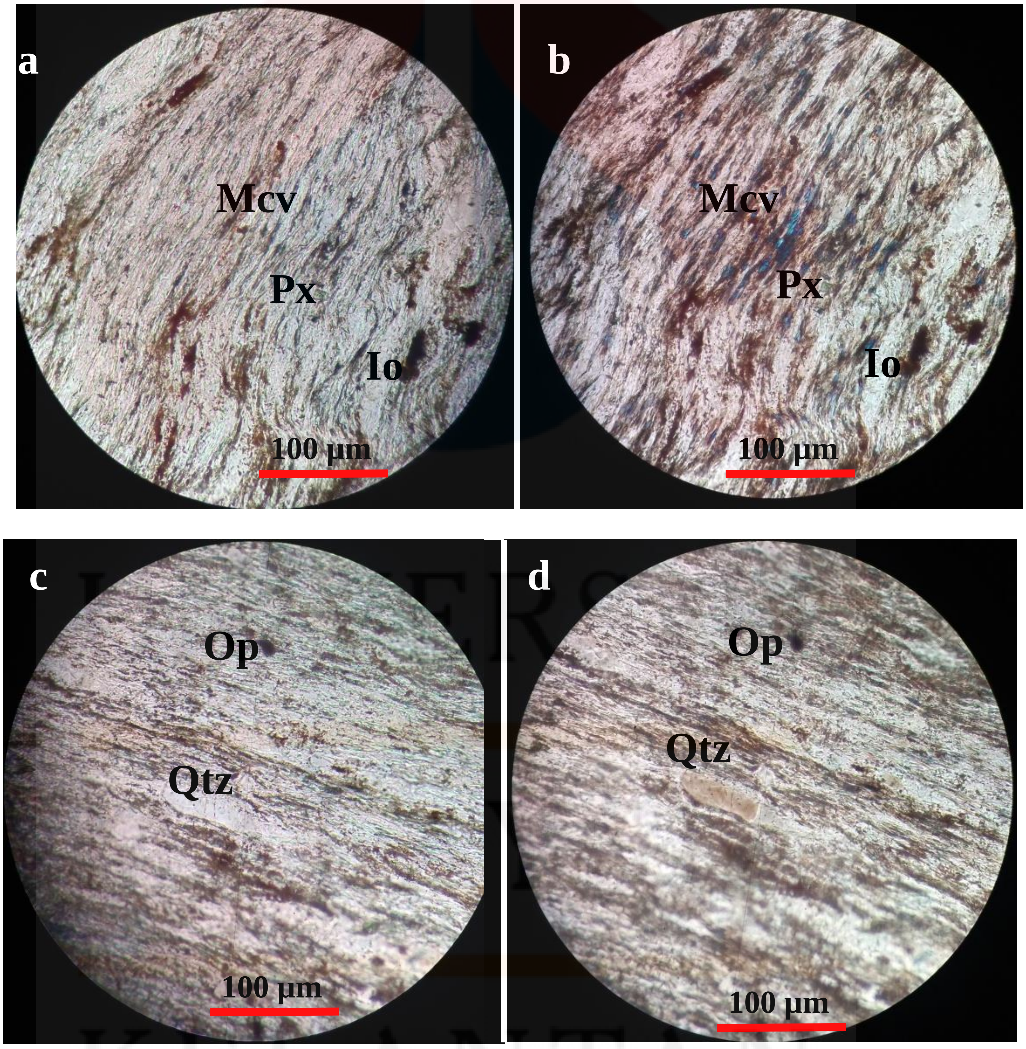

Figure 4.41: Thin section of phyllite on (a) PPL (b) XPL. Muscovite (Mcv), Hydrate Iron (III) Oxide (Io), Opaque Mineral (Op), Quartz (Qtz), Pyroxene (Px) ; Magnification is 40×0.65P .

Minerals in a thin section of phyllite are quartz, muscovite, hornblende, opaque mineral of iron oxide and hydrate iron (III) oxide. Muscovite is colourless in plane polarized with low relief and perfect cleavage. Muscovite has high birefringe and low relief. Quartz in plane polarized, the color is colorless. Quartz has subangular shape, low relief, exhibit no pleochroism. In cross polarized, the color of quartz turns to light brown. Hydrate iron (III) oxide show brownish color in both plane polarized and cross polarized. Opaque mineral of iron oxide in plane and cross polarized, the color is black with the shape of the mineral is subangular and which has less than 1mm in sizes. Proxene show green-yellow in plane and cross polarized. It has high relief with second order birefringes.

c) Mudstone

Mudstone rock is distributed in low elevation covered with vegetation and poorly exposed in the study area. Mudstone rocks were found in the stream of the south study area (Figure 4.42). The mudstone outcrop is dark grey and medium weathered. It is soft and powdering. When mudstone reacts with water, the mud particles easily eroded, and the color and particles of mud easily stick to hand. It is non-fissile and blocky rock. The grey color of mudstone is an indicator whether mudstone is origin from marine or the deltaic environment.

The hand specimen is a light grey color, has a lamination structure and smooth surface (Figure 4.43). The grain size of mudstone is small than 4μm in diameter. The existence of many 0.1cm laminations on fine mudrock is characteristic of lacustrine mudrock that transported by a suspension of water and deposited in low-energy and quiet environment.

The main constituents of mudrock are clay minerals and silt-grade quartz that derived from grain collision in aeolian and aqueous media (Sam Boggs, 2009b). The concentration of feldspar and biotite in mudrock generally low but muscovite is common. Figure 4.44 shows a thin section of mudrock in a plane and cross-polarized microscope. First sight in a microscope is direct sees the lamination of mudstone in which black carbonate sediment aligned with lamination. It has very well sortation and characteristic with grain-supported fabric. The grains of mudstone are angular roundness and have high sphericity. The porosity in mudstone is less because the fine grain sediment was packing compacted with each other.

Figure 4.42: Outcrop of mudstone that distributed in stream. The picture was taken at station 35.

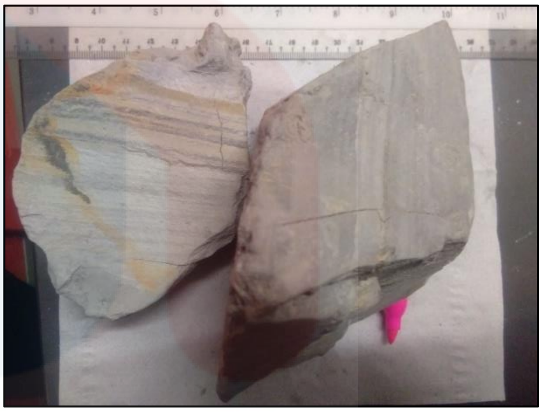

Figure 4.43: Hand specimen of mudstone.

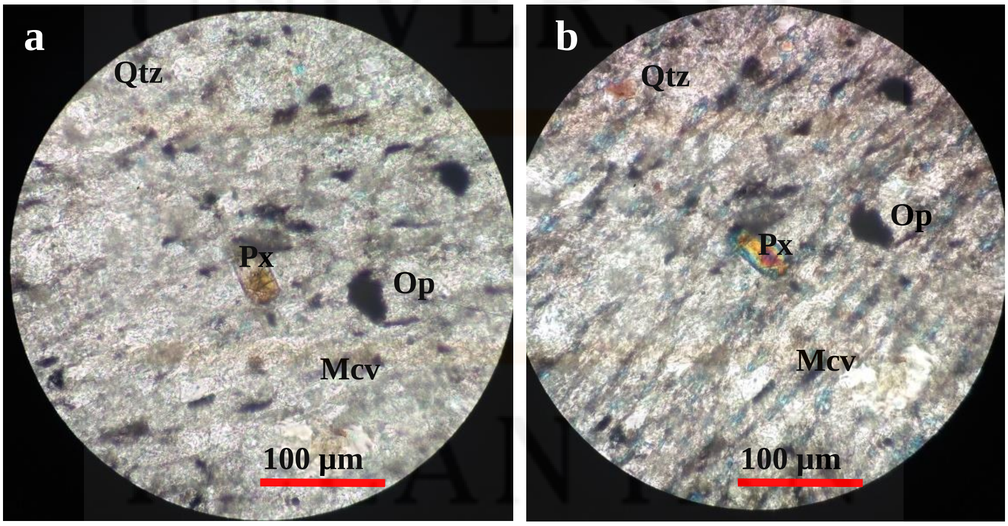

Figure 4.44: Thin section of mudstone sample on (a) PPL (b) XPL. Quartz (Qtz), Muscovite (Mcv), Opaque mineral (Op), Pyroxene (Px). Magnification is 40×0.65P.

The minerals that observed under microscope in thin section are quartz, muscovite, pyroxene and opaque minerals. In plane polarized, the color of quartz is colorless, while in cross polarized, the color turns to brown. Quartz has subangular shape, a low relief, and exhibits no pleochroism. Opaque mineral of iron oxide was black color in both plane and cross polarized. The shape of the opaque mineral is subangular, which has less than 1mm in sizes. Muscovite is colourless in plane polarized with low relief and perfect cleavage. Muscovite has high birefringe and low relief. Proxene show green-yellow in plane. It has high relief with second order birefringes.

d) Tuff

Tuff rocks in the study area are located at hill area and low land area. Figure 4.45 show tuff outcrop that exposed along cutting slope with light white color. Tuff at the low land area is highly weathered than at hill area. Tuff is made stick reaction with tongue because it has high porosity. Tuff is a product of pyroclastic that comes from volcanic fragments ejected from a fissure as a result of a magmatic explosive thousand years ago (Sam 2009b). Volcaniclastic sediments are divided into five types which is agglomerate, volcanic breccias, lapilli stone, volcanic sandstone, and volcanic mudstone.

Tuff is easily broken because is only in dust form that does not compact and lithified hardly. Very hard to get a fresh and good sample because it very easily broke (Figure 4.46). The grain size of tuff rock in the study area are can classify into three tephra. The grain size of tuff rocks in study area are fine ash, coarse ash, and lapilli that show a type of tuff in the study area are volcanic mudstone, volcanic sandstone, and lapilli stone respectively.

Figure 4.47 show plane and cross-polarized view of a tuff thin section. Because the samples in form of partial dust, the thin section does not show good grain and minerals. Too many bubbles in thin section caused very hard to found minerals in thin section. A porosity of tuff is quite high because it has very low compaction. Tuff grain has angular roundness and high sphericity. The fabric type of tuff rock is cubic packing and has poorly sorted.

Figure 4.45: Outcrop of tuff at hill area white light white color. The picture was taken at station 1.

Figure 4.46: Hand sample of tuff rock

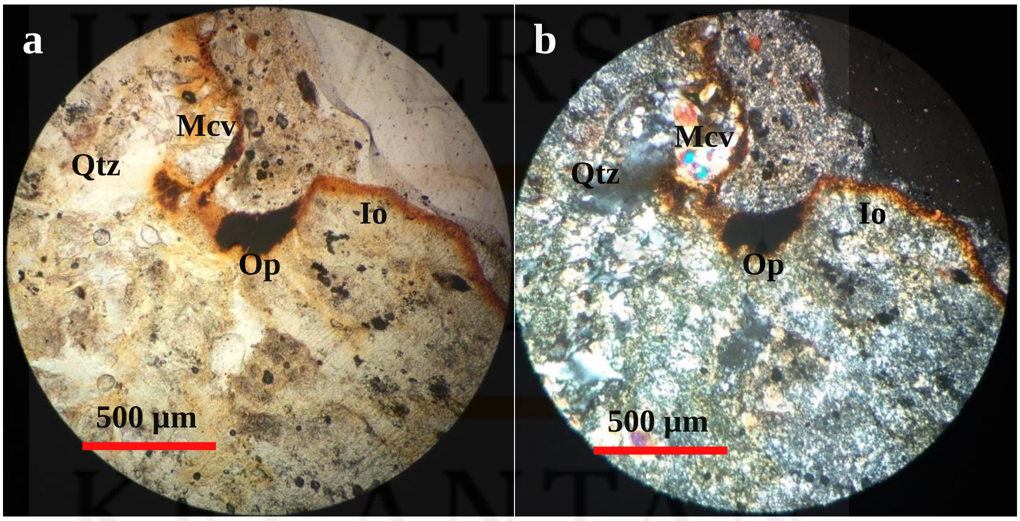

Figure 4.47: Thin section of tuff sample on (a) PPL (b) XPL. Quartz (Qtz), Muscovite (Mcv), Opaque mineral (Op), Hydrate Iron (III) Oxide (Io). Magnification is 10×0.25P.

The minerals that observed under microscope in thin section are quartz, muscovite, pyroxene, hydrate iron (III) oxide and opaque minerals. In plane polarized, the color of quartz is colorless, while in cross polarized, the color turns to brown. Quartz has subangular shape, a low relief, and exhibit no pleochroism. Opaque mineral was black color in both plane and cross polarized. The shape of the opaque mineral of iron oxide is subangular, which has less than 1mm in sizes. Muscovite is colourless in plane polarized with low relief and perfect cleavage. Muscovite has high birefringe and low relief. Iron oxides show brownish color in both plane polarized and cross polarized.

e) Rhyolite

Rhyolite in the North of the study area has light white and light green color with fine grain size (Figure 4.48). Rhyolite in the study area has a unique feature because it has round and black fine siltstone in rock body. Rhyolite is a felsic extrusive igneous rock with aphanitic texture. Due to fast cooling, the rhyolite body creates scoria features due to a high content of gas during an eruption. From naked eyes, it can see quartz mineral-dominated the rock and little amount of biotite (Figure 4.49). The existences of joint on rock body cause the outcrop break into a small block.

Figure 4.50 shown plane polarized and cross-polarized of a thin section. Quartz is distributed fully in rhyolite thin section. A degree of crystallinity of rhyolite is holocrystalline because it consists entirely of crystals. A form of individual grain in rhyolite is anhedral where crystal face entirely absent. Because most the grain in rhyolite is anhedral, the relationship between crystal is allotriomorphic.

Figure 4.48: Outcrop of rhyollite. The picture was taken at station 5.

Figure 4.49: Hand-sample of rhyolite

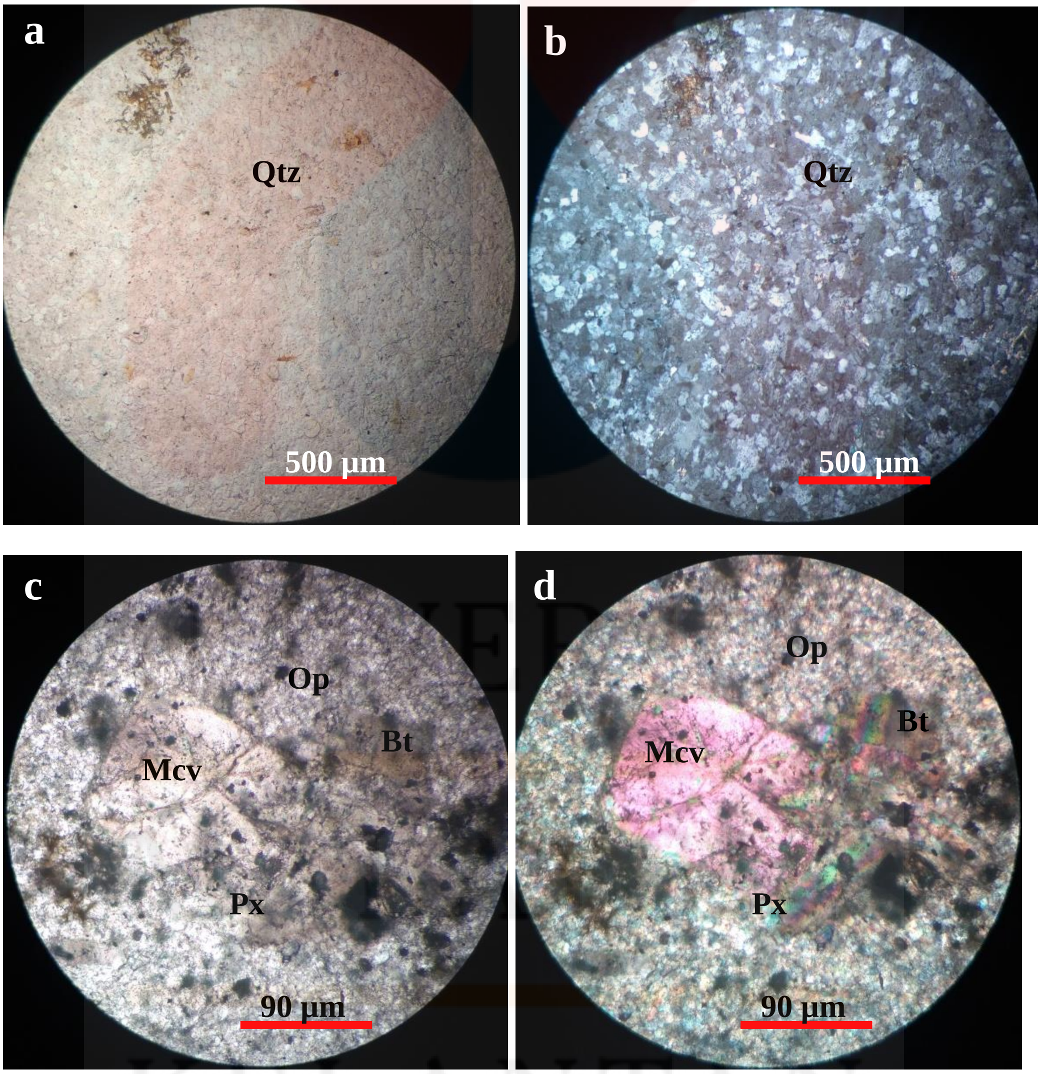

Figure 4.50: Thin section of rhyolite sample on (a) PPL (b) XPL. Quartz (Qtz), Muscovite (Mcv), Opaque mineral (Op), Biotite (Bt), Pyroxene (Px). (a ,b) Magnification is 10×0.25P. (c, d) 60×0.50P

Minerals in rhyolite thin section that can observe under a microscope are quartz, biotite, muscovite, pyroxene and opaque minerals. In plane polarized, the color of quartz is colorless, while in cross polarized, the color turns to brown. Quartz has subangular shape, a low relief, and exhibit no pleochroism. Opaque mineral of iron oxide was black color in both plane and cross polarized. The shape of the opaque mineral is subangular. Muscovite is colourless in plane polarized with low relief and perfect cleavage. Muscovite has high birefringe and low relief. The color of biotite in plane polarized is green to brown, low to moderate rellief and high birefringe.

f) Fine Siltstone

The fine siltstone in study area was founded in a body of rhyolite (Figure 4.51). It does not have actual outcrop because it only deposited in rhyolite in round condition. Fine siltstone has fine grain and dark color (Figure 4.52). The biggest size is 40 mm in diameter and the smallest is 25mm in diameter. From my observation and research, the fine siltstone fragments are deposited in rhyolite body. The fine siltstone fills in the scoria of rhyolite body during the sedimentation process. Grain of siltstone is coarse than clay but fine than sand. Deposition of silt can be from water or wind and then continued with the process of compaction and cementation.

Figure 4.53 is a thin section of fine siltstone in plane and cross-polarized. It shows good sortation and compaction. The porosity is less. The grain size of fine siltstone is angular roundness with high sphericity. Fine siltstone has grain-supported fabric.

Figure 4.51: Fine silt stone that deposit in scoria of rhyolite. The picture was taken at station 5.

Figure 4.52: Fine silt stone with weathered rhyolite. The picture was taken at station 6.

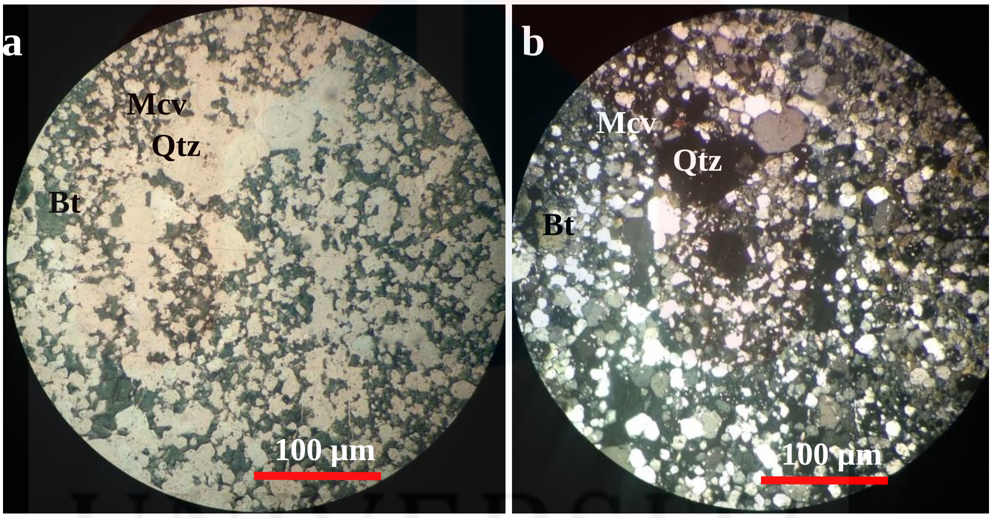

Figure 4.53: Thin section of fine silt stone sample on (a) PPL (b) XPL. Quartz (Qtz), Muscovite (Mcv). Magnification is 40×0.65P.

Mineral that can observe in thin section of fine siltstone is quartz, biotite, and muscovite. In plane polarized, the color of quartz is colorless, while in cross polarized, the color turns to brown. Quartz has sub-angular shape, a low relief, and exhibit no pleochroism. Muscovite is colorless in plane polarized with low relief and perfect cleavage. Muscovite has high birefringe and low relief. The color of biotite in plane polarized is green, low to moderate relief and high birefringe.

g) Sandstone

Sandstone outcrop was found at two locations in the study area but it is not mappable. The same stream has two type of rock at a long distance. Sandstone outcrop only distributed at a downstream part. The color of sandstone is light brown (Figure 4.54). Sandstone in the study area has many laminations. The parallel lamination in sandstone is formed through deposition from suspension, slow-moving sediment or low-density current. The size or particle is sub-angular in shape and high sphericity. The sorting of the sandstone is good. Hand sample of sandstone shows the grain is fine to medium (Figure 4.55). The grain of sandstone has gritty features when touch by hand. The clastic grains are released through chemical and physical weathering processes and then transported to the depositional site by a variety of mechanism such as water and wind (Sam, 2009b).

Thin section of sandstone rocks was shown in Figure 4.56. Under the thin section, it can see that have cross-lamination in sandstone rock. Cross-lamination is an indicator of rapid deposition due to lamination 'climbs' up the stoss side of the one downstream. Minerals in sandstone thin section that can observe under a microscope are muscovite, olivine, quartz, iron oxide and opaque minerals. In plane polarized, the color of quartz is colorless, while in cross polarized, the color turns to brown. Quartz has subangular shape, a low relief, and exhibits no pleochroism. Opaque mineral was black color in both plane and cross polarized. The shape of the opaque mineral is subangular. Muscovite is colourless in plane polarized with low relief and perfect cleavage. Muscovite has high birefringe and low relief. Iron oxides show brownish color in both plane polarized and cross polarized. Olivine was colorless in plane polarized with moderate relief. Olivine has strong birefriges and has fracture.

Figure 4.54: Outcrop of sandstone in stream. The picture were taken at station 43.

Figure 4.55: Hand specimen of sandstone sample.

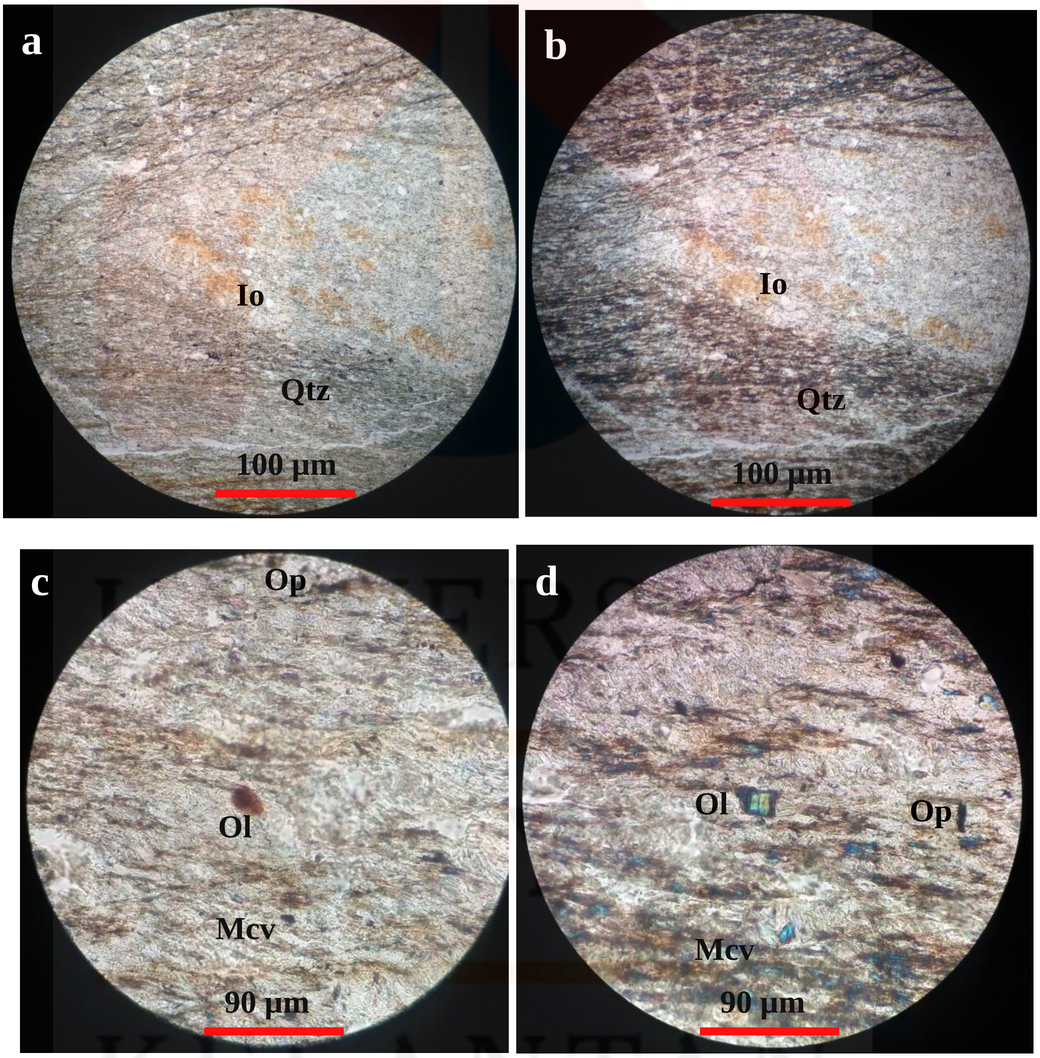

Figure 4.56: Thin section of sandstone sample on (a) PPL (b) XPL. Quartz (Qtz), Muscovite (Mcv), Hydrated Iron (III) Oxide (Io), Olivine (Ol), Opaque (Op). Quartz (Qtz)); (a , b) Magnification 40×0.65P ; (b,c) Magnification 60×0.80P.

4.4 Structural Geology

Structural geology studies the secondary structures and the forces that act the rocks. The secondary structure that found in the study area are veins, joints, fault scrap and fold.

4.4.1 Lineament

A lineament is a straight line that commonly identified through the drainage and hill analysis during desk study. There is two type of lineament which is positive and negative. Positive lineament is based on drainage analysis while negative lineament based on a backbone of hills. Drainage is a weak zone where the best indicative for a structure such as a fault, fold, and joint. Straight hills not necessarily indicative of fault because it not weak zone, the straight pattern of hills can be because of fault or morphology effect. There are 29 lineaments are identified in the study area (Figure 4.59).

4.4.2 Vein

A vein is a structure which the crack within the rock body is deposited by minerals intruded. Before mineral filled the fracture, the crack was undergone extension fracture with the mode I that does not involve displacement but only involve opening mode that tensile stress normal to the plane (Figure 4.57). The vein is white dull in color and can measure its width (Figure 4.58). Vein usually dominated by two types of mineralized mineral which is quartz and calcite indicate high fluid pressure. As the vein does not react with dilute HCl, the mineral in a vein is quartz instead of calcite. The vein is intruded phyllite rock which is mean vein is more youngers than phyllite. The existence of vein is related to a fault. When fault developed, the displacing vertical vein becomes a pull-apart and then overlap as displacement increases enough for the phyllite beds to be faulted past each other that resulting in mineralized fault plane (Peacock, 2004).

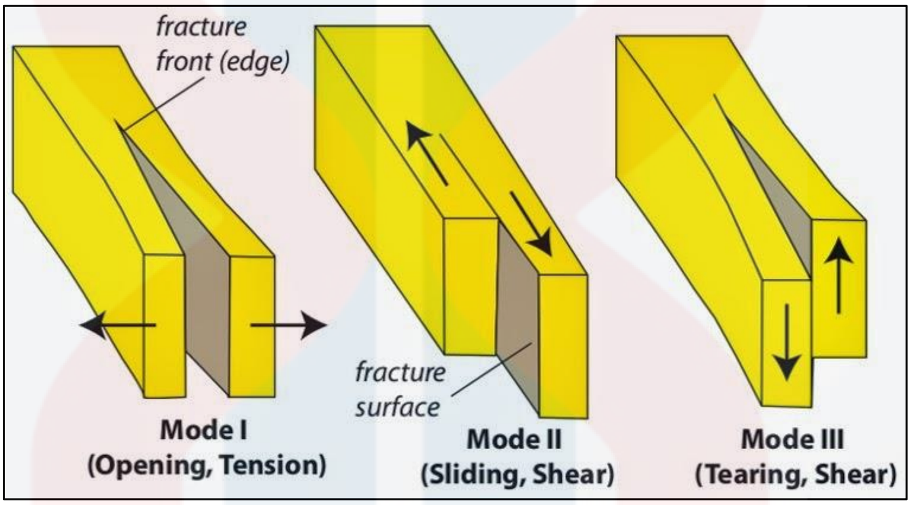

Figure 4.57: Mode of fracture (Sources: Lauren, 2015)

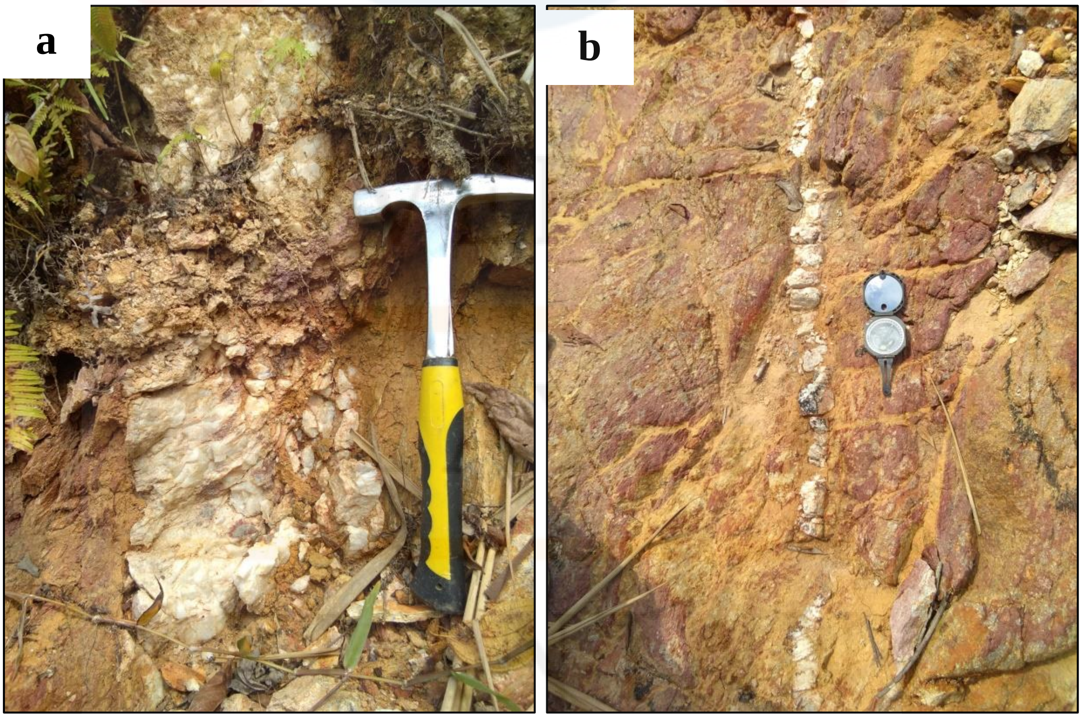

Figure 4.58: (a) About 20cm width of vein intrude phyllite rock, (b) about 4cm vein along the road on vegetation area. . The picture were taken at station 18.

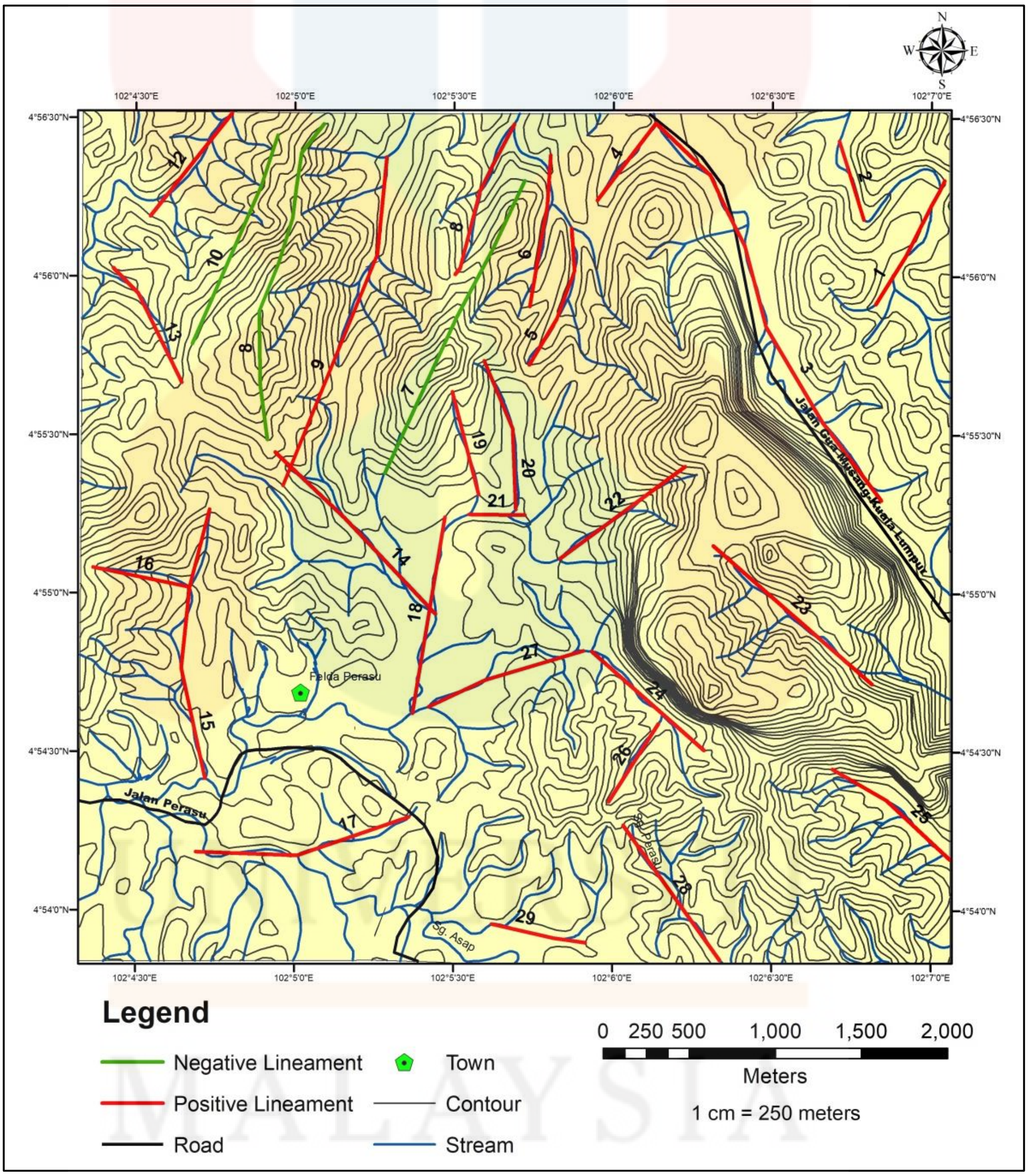

Figure 4.59: Lineament map of study area.

4.4.3 Joint

Joint is a crack that does not have any displacement within rock body because of tensional stress pulled apart the brittle rock. Normally, joint present in brittle rock with low-temperature and low pressure condition. Joint and vein have the same mode of fracture but the characteristic that differentiates between joint and vein is joint does not have measurable shear displacement and does not have mineralized minerals. Joint typically form with a complex network of fractures. There are two joint measured in the field. Joint was formed after closing of a vein and does not form under high fluid pressure.

Based on joint analysis, the result shown states that the major force which is sigma 1(δ1) approximately come from N 20 W (340^0) and S 20 E (160^0) while the minor force (δ3) approximately come from S 70 W (250^0) and N 70 E (Figure 4.61). The cross joints in rhyolite outcrop unit (Figure 4.60). The joint in rhyolite body exist in many directions not only parallel to each other. The cross joint refers to the joint that formed perpendicular to fold axis. Rhyolite outcrop mostly fractures in systematic direction due to the existence of joint that influence by physical weathering. The second joint in the study area is on phyllite outcrop in a gully (Figure 4.62). The joint is systematic. Based on the joint analysis, the result has shown states that the major force which is δ1 is approximately come from S 68 E (112^0) and N 68 W (292^0) while δ3 approximately come from N 22 E (022^0) and S 20 W (202^0) (Figure 4.63).

Figure 4.60: The cross joint structure on rhyolite rock. The picture was taken at station 5.

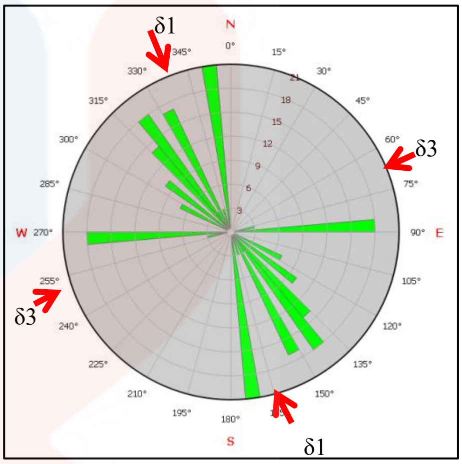

Figure 4.61: Rose diagram for cross joint analysis at Station 5.

Figure 4.62: Parallel joint on phyllite outcrop in palm vegetation area. The picture was taken at station 19.

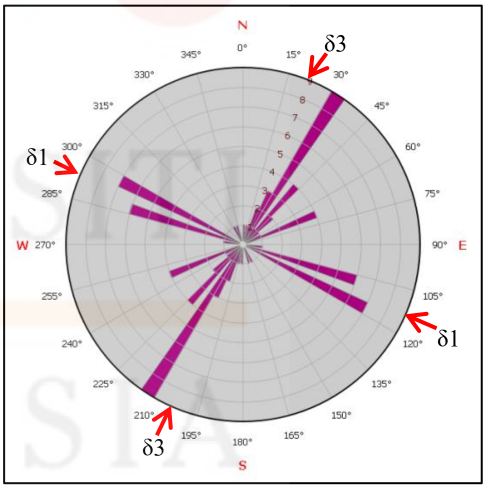

Figure 4.63: Joint analysis in rose diagram at station 19.

4.4.4 Fault and Scarp

Thrust fault may present in the study area. It is identified through the geomorphology of the study area. From the topography map, there is an indicator of the trust fault located from the North to North-East of the study area and fewer indicators of fault at the Southern and Western of the study area. Lineament 3, 7, and 9 are the most possible indicator of thrust fault in the study area. The sudden difference lithology contact between sedimentary rocks with metamorphic rock is one of the indicators of a thrust fault. A gradient of topography along suspected thrust fault area were increased sharply.

Scarp is the feature on the surface of the rock that looks like a step caused by slip on the fault. It is topographic that expression of faulting attributed to the displacement of the land surface by movement along faults and an indicator of a thrust fault. On the limestone outcrop, it can see that the surface wall of limestone has steep vertical erosion (Figure 4.64). Compare to other parts of limestone, only at fault scarp no vegetation and look like erosion or landslide but it has nearly smooth surface.

Figure 4.64: Scarp that has irregular shape on limestone wall.

4.4.4 Fold

A fold is the wave-shaped features that present in the layered rock. The fold structure indicated that the rock and its mineral content are ductile. A fold has occurred when high pressure force the body of rock is in many directions which is right and left or up and down or can both of it. Figure 4.65 shows recumbent fold that observed at location 11 of the map. Along the same rock cutting, three recumbent fold found. Because all three folds appear in the same rock, it considers long recumbent fold along a body of rock. Recumbent fold in the study area at found on phyllite outcrop. Due to fold forces, some part of phyllite outcrop has turned to mica schist. A mechanism that involve in the recumbent fold is a flexural slip. Flexural slip usually acts in low pressure and low temperature at shallow depth within the earth's crust (K.Manikandabarath, 2014). Flexural slip mechanism of fold commonly generated constant layer thickness. A recumbent fold is when two limbs are parallel with each other and parallel to an axial plane, the fold is isoclinal that caused overturned strata in one limb of fold.

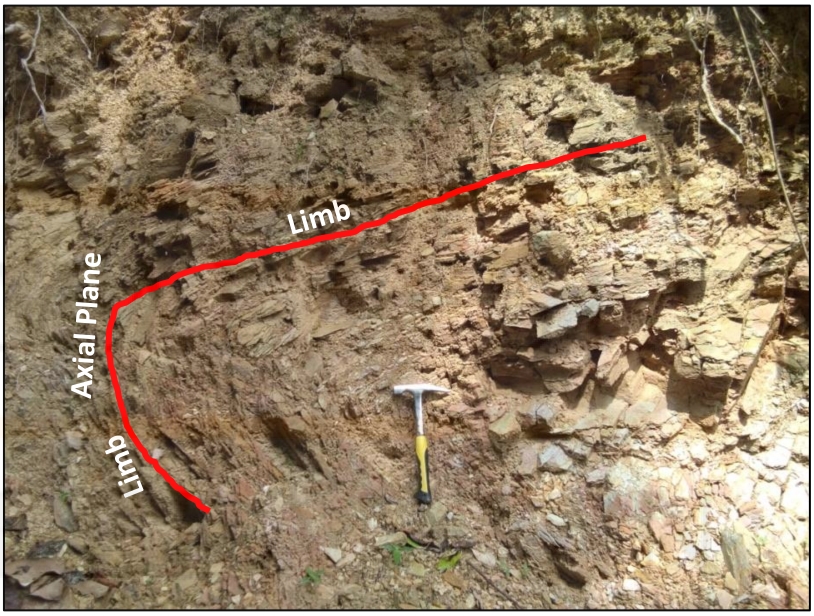

Figure 4.65: Recumbent fold. The picture was taken at station 11.

4.4.5 Mechanism of Structure

The lineament analysis is done based on lineament in figure 4.61. The forces come from both direction but NNW-SSE of the study area has greater forces than an NNE-SSW direction of the study area. From the shape of drainage pattern, the age of lineament can be estimated through looking the level of straight of drainage pattern. The lineaments from NNW-SSE are younger than NNE-SSW because most of the stream that formed in NNW-SSE is obviously straight. From the lineament analysis (Figure 4.66), the major force δ1 that encountered the study area come from N 26 W (334^0) and S 26 E (154^0) while minor force δ3were on N 64 E (064^0) and S 64 W (244^0).

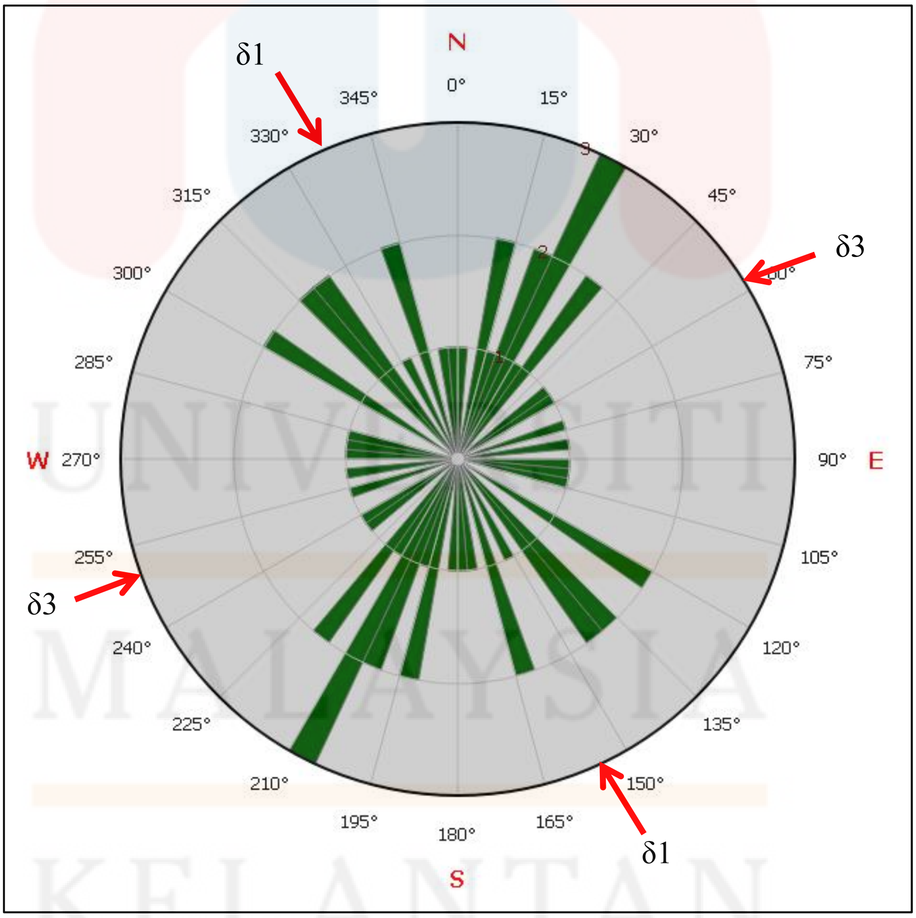

Figure 4.66: Rose diagram of lineament of the Perasu area.

The greater force is nearly perpendicular to the direction of the thrust fault of the study area (Figure 4.67). δ1 is the greater primary compression force and maximum pressure force in the study area. The analysis of the forces that causes the formation of folds in the study area refers to the theory of the ellipsoid strain according to Riedel Theory by Mc Clay, which stated that the general force that forms a fold is perpendicular to the fold (form an angle of 90^0 to δ1), or in the direction of the dipping of the rock with the main stress in the form of compression force. Based on Riedel Theory, the general direction of the force acting on the fold is Northeast-Southwest. δ1 acting on NNW and SSE direction create compressional while δ3 on NE and WS create extensional process. The δ3 forces acting on rock cause rocks in the study area to reach elastic deformation phases. In this phases, the elastic limit of a rock has been reached or exceeded so that part of the dimensions of the rock will be permanently altered to form a fold such as a Figure 4.65. Due to continues compression force on the rock, hence causing rocks in the study area to go beyond the elastic deformation phase where if the elastic boundary of a rock has exceeded it will causes cracks, in the form of joint in the lithology of rhyolite and phyllite. Furthermore, if the force continues to act and causes the pressure in the rock to continue to increase, the rock will reach the deformation phase where the rock fracture formed will experience a shift or fault, so that a thrust fault which in NNW and SSE direction of the study area. Thrust fault occurs on limestone and phyllite lithology.

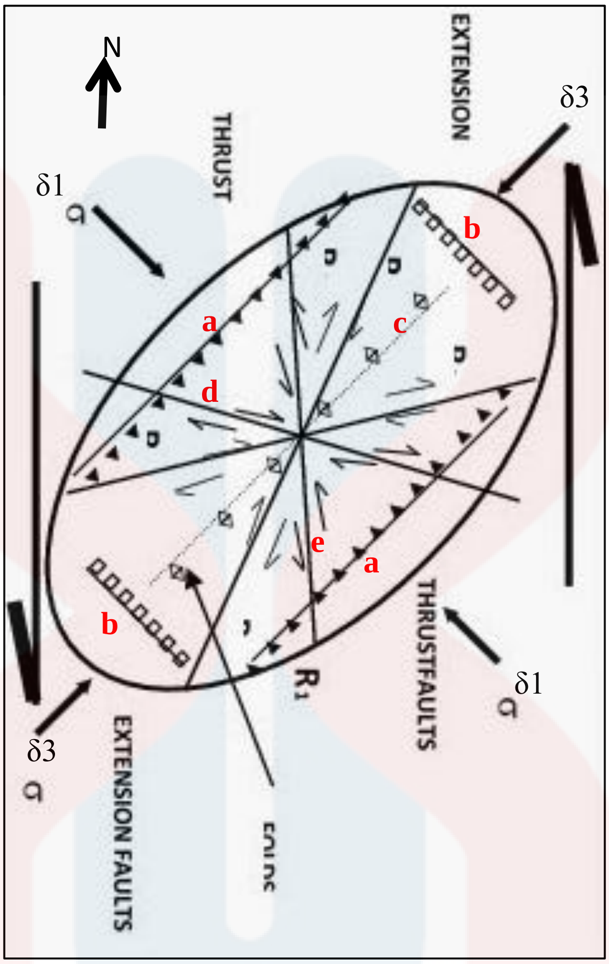

Figure 4.67: RIEDEL Theory (After Mcclay, 1987) (source: Fridolin, 2014)

Where:

a = Thrust fault

b = Normal Fault

c = Fold

d = Synthetic strike-slip fault

e = Antithetic strike-slip fault

4.5 Historical Geology

Study area located on a central belt of Malay Peninsula. In late Early Permian, the Sibumasu block that located to the west of the Bentong-Raub suture start derived from Gondwana as the Meso-Tethys opened (Metcalfe, 2013). Sibumasu block start collides with Indochina block on middle Triassic and then Sibumasu block was subducted beneath Indochina block. The colliding between two blocks cause the Palaeo-Tethys closed.

During Middle-Late Permian, oblique subduction of Sibumasu aided process of basin segmentation on the subsiding Gua Musang platform. Besides that, thick argillites and volcanoes created shallow marine Gua Musang platform. The fine grains of argillaceous have undergone transportation and settle down in the Gua Musang basin when the energy is decreased and cannot carry them longer. Parallel lamination signifying the deposition of the suspension is has low energy, warm and quiet environment. At the same time, the precipitation of the carbonates minerals such as calcite starts deposited on this shallow marines environment.

Felsic volcano rocks were produced by volcanoes of I-Type granite magmas in East belt. According to Metcalfe (2013), a thick felsic volcano that origin from middle to early upper Triassic accumulated in the central belt and documenting a change from andesitic volcanism in the Permian to felsic rhyolite volcanism in the Triassic. The change in geochemistry from intermediate (andesitic) to felsic (rhyolite) indicates a major change in Sukhothai Arc product resulting from the collision of Sibumasu and Indochina in the Early Triassic and cessation of subduction in Middle Triassic. The eruption activity of the volcanoes produces pyroclastic rock and deposited with carbonaceous mudstone. After the sedimentation, pyroclastic was converted into volcanic sandstone. Carbonaceous mudstone was accumulated with tuff, lapilli and volcanic sandstone.

Thick piles of volcanic clastic reworked tuffs of Permian and Triassic age occur in the Central Belt of Malay Peninsular (Metcalfe et al. 1989), together with intermediate to felsic volcanoes. Carbonates deposition was suppressed due to murky water during volcanic activities. Once volcanic debris was deposited, the water becomes clear again and carbonate deposition resume back (Kamal, 2016).

The continues sedimentation during the Triassic period has added the weight and vertical stress which cause the oldest Permian argillaceous and limestone to deep burial. Deep burial increases both the pressure and lithostatic pressure of the rocks which then caused them to undergo low-grade metamorphism. The thrust fault during the Late Triassic period causes the degree of the metamorphism increased. This regional metamorphism causes the Permian rock to altered and recrystallizes to meta-sediments such as phyllite and slate.

CHAPTER 5

DEPOSITIONAL ENVIRONMENT OF GUA MUSANG FORMATION

5.1 Introduction

Depositional environment is a reveal a history of some place where the sediments are deposited and undergo sedimentation process such as compaction and lithification when the energy is no longer to carry sediments. Depositional environment is studied by interpreting facies such as lithology, sedimentary structure, fossil content, texture, color, geometry, paleocurrent and so on.

The depositional environment of Gua Musang Formation in Perasu area as discussed. It is interpreted based on three parameters which are bedding thickness, lithology, sedimentary structure, and fossils. Two lithologs were prepared to describe the depositional environment of Gua Musang Formation in the study area. The first location is dominated by a tuff unit with interbedded with clay and sandstone at coordinate 4^0 54’ 33.02” N and 102^0 4’ 55.83” E. Second location is limestone interbedded with phyllite sandstone at coordinate 4^0 55’ 57.40” N and 102^0 6’ 05.5” E

5.2 Location of Detail Litholog

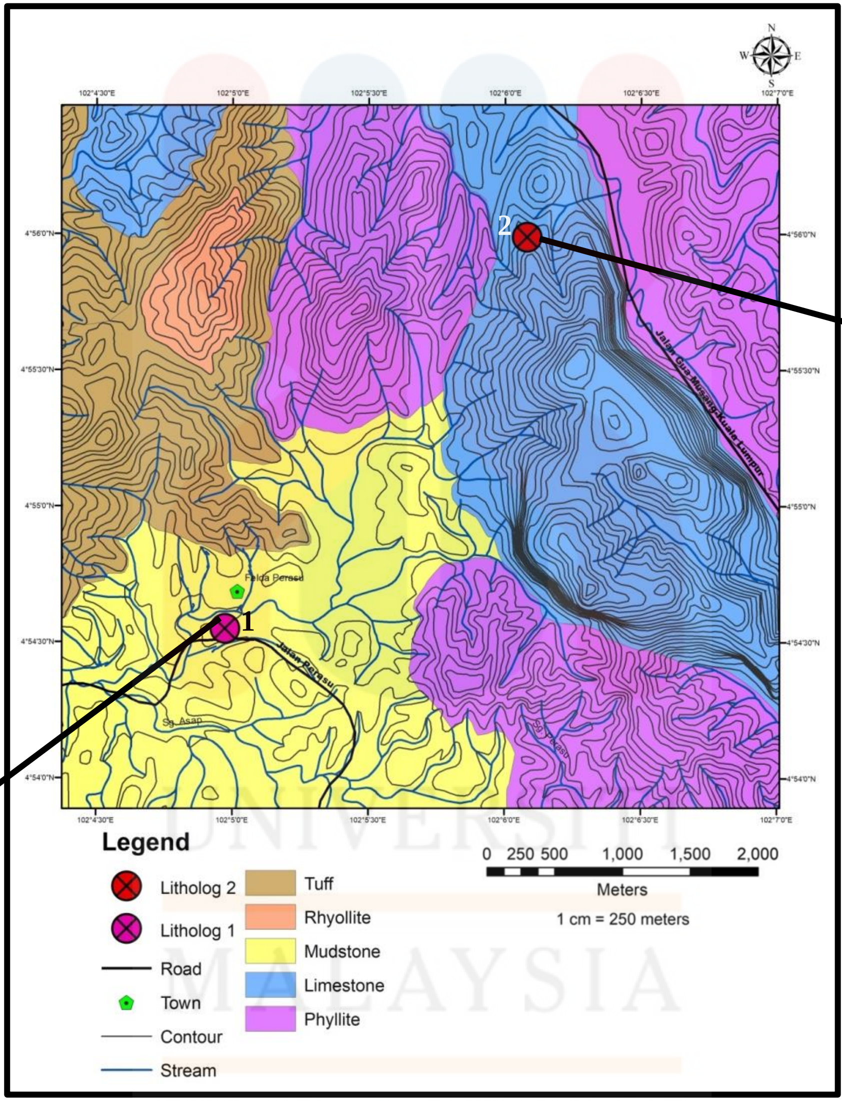

Figure 5.1: Location of lithologs for depositional environment interpretation

Figure 5.2: Outcrop of first litholog

Figure 5.3: Outcrop of second litholog

The criteria for specification is based on the best outcrop in the study area. The study area lack with good and perfect expose outcrop for do litholog. The rate of weathering in the study area is quite high. The first outcrop is highly weathered but fortunately, the bedding still can be observed in short distance (Figure 5.2). The contact between rocks on first outcrop is gradually contacts. The second outcrop in the study area is slightly weathered. The second outcrop can see every contact of each bedding with sharp contact between rocks (Figure 5.3). The constituent lithofacies are recurring and grouped into four lithofacies sub-unit which is sub-unit A, B, C, and D. Sub-unit A, B, and C are from the first lithology while the second lithology only has one sub-unit.

5.3 Facies Analysis

The facies is the rock body of rock characterized by a particular combination of physical, lithology, and biological structures that give an aspect that differs from the bodies of rock above, below and laterally adjacent (Hamdani, 2014). The facies concept refers to the sum of a characteristic of a sedimentary unit that commonly at a small (mm-cm) scale that including lithology, grain size, sedimentary structure, color, composition, and fossils content. Only lithofacies and biofacies were observed for interpretation of every sub-unit. The facies may connect to each other and give significance of an environment. The four different facies association are named as Sub-unit 1, Sub-Unit 2, Sub-unit 3, and Sub-unit 4. All of this Sub-unit have their own different characteristics and is explained in Figure 5.4.

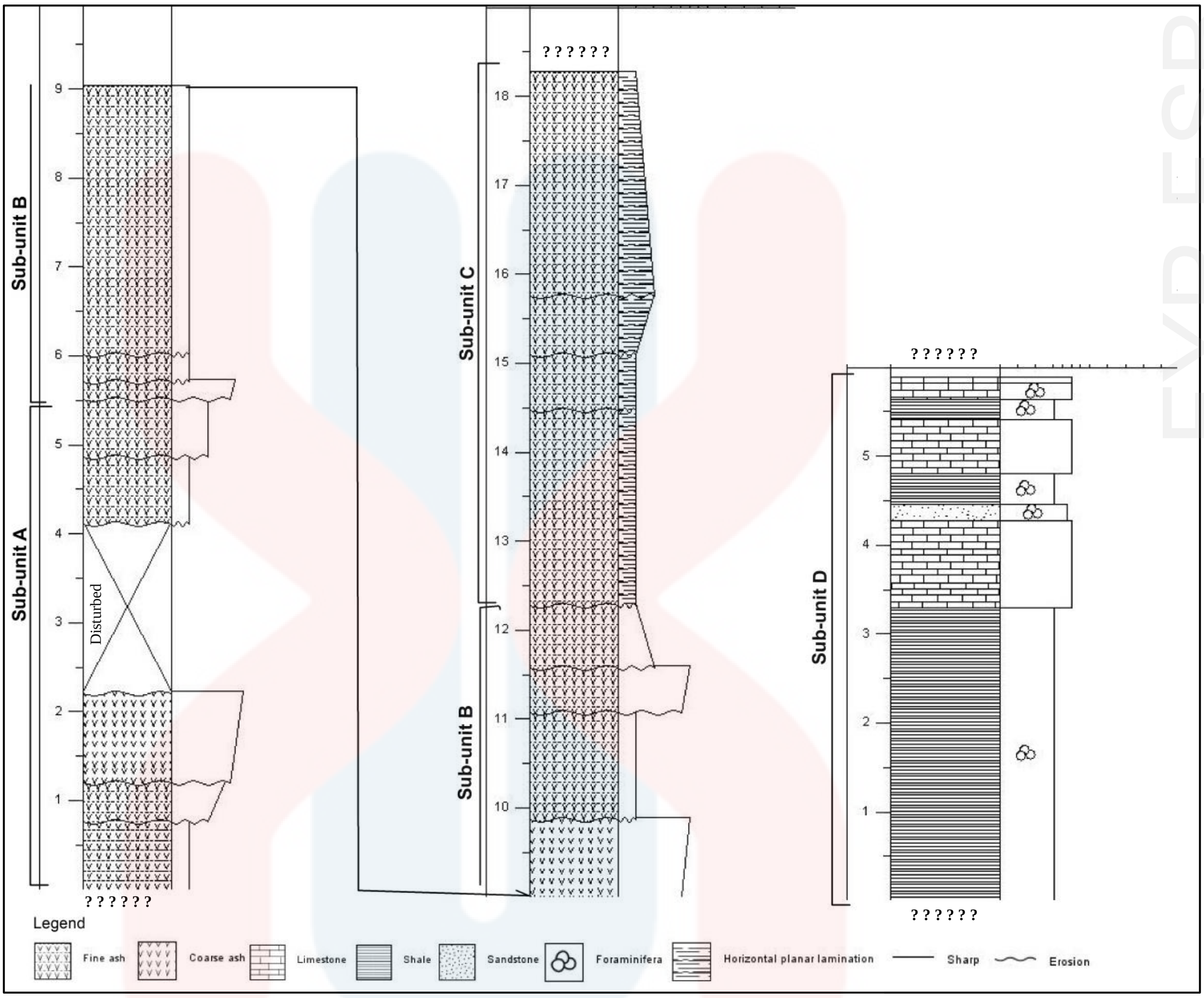

Figure 5.4: Litholog of the locations. Location 1 (Sub-unit A,B and C) ; Location 2 (Sub-unit D)

5.3.1 Sub-Unit A of the Gua Musang Formation

The thickness of this Sub-unit is 5.54 meter. The lithologies that can be found in Sub-unit 1 are volcanic mudstone with interbedded of lapilli tuff. The volcanic mudstone found is from Gua Musang Formation, has a color of light grey to little reddish, the mean grain size is clay size and often found to be intercalated with tuff. The volcanic mudstone is very well sorted. The thickness of the volcanic mudstone ranges from 0.8 meters to 3.0 meter thick. Meanwhile, the lapilli tuff found in Sub-unit A has a light brown to medium browns, the mean grain size is in a medium range, and well sorted. The range thickness of lapilli tuff is around 1.0 meter. About 1.9 meters, there are disturbed bedding with the unknown rock. Quartz vein with 0.3 meter width intruded between tuffaceous clay and lapilli tuff and has a minor folding. There are no any sedimentary structure and fossils.

5.3.2 Sub-Unit B of the Gua Musang Formation

The thickness of Sub-unit 2 is 6.0 meter. The lithologies that can be found in Sub-unit 2 are tuff interbedded with volcanic mudstone, lapilli tuff, and volcanic sandstone. The characteristic of volcanic mudstone and lapilli tuff are same as Sub-unit 1. The tuff found is from Gua Musang Formation, has a color of light to reddish brown, fine grain size and well sorted. The thickness of the tuff ranges from 0.3 to 0.7 meter. Volcanic sandstone is medium grain size and brownish color. The sorting of volcanic sandstone is moderately sorted. As can see in petrology image in Figure 4.3.2, polycrystalline quartz mineral is sub-angular in shape with suture contact with other minerals. There are no any sedimentary structure and fossil found in Sub-unit B.

5.3.3 Sub-Unit C of the Gua Musang Formation

Sub-unit C is dominated by tuff lithologies interbedded with volcanic mudstone. Tuff and volcanic mudstone in sub-unit C same as Sub-unit A and Sub-unit B. Only sub-unit C has a sedimentary structure which is parallel lamination along 6.0 meter outcrop. Each lamination has a thickness of around 0.2 centimeters to 0.3 centimeters (Figure 5.6). Lamination is commonly an internal structure of bedding on an outcrop. Lamination arises from changes in size-grading within lamination, grain size between lamination, or changes in composition between lamination (Sam, 2009c). Each lamination can have their single depositional event and all laminations also can have same depositional events. Parallel laminations also refer to horizontal, flat, or planar lamination that can be resulted in several ways. According to Sam, (2009c), in clay and tuff it commonly formed through deposition from suspension, slow-moving sediment clouds, very shallow water depth, or low-density turbidity currents. In laminar flows, all molecules within the fluid move parallel to each other in the direction of water flow (Figure 5.5). Heterogenous fluid almost no mixing occurs between molecules during laminar flow (Nichols, 2009c).

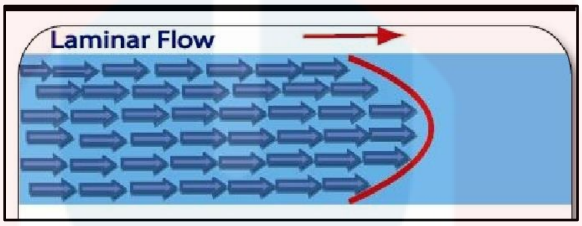

Figure 5.5: Lamination mechanism.

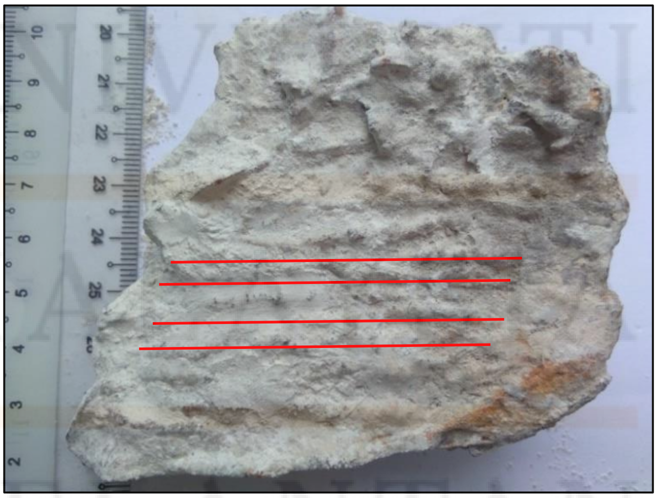

Figure 5.6: Lamination on tuff lithologies.

5.3.4 Sub-Unit D of the Gua Musang Formation

The thickness Sub-unit D is 5.92 meter. The lithology that can find in Sub-unit D is phyllite interbedded with limestone. The range thickness of limestone 0.98 meters to 0.7 meters. Based R.J. Dunham classification, limestone is contained lime mud and grain supported was simplify as packstone. In packstone rock, it can see that grains in contact and with a matrix. Packstone could be a biomicrite. Based on petrology observation, limestone in Sub-unit D was cemented by micrite (Figure 5.7 b, d, f). Micrite is the equivalent of very fine grain sediments of clastic such as clay and shale. Micrite is probably a mixture of biochemical and chemical origin. For the biochemical origin of micrite, the sediment coming from the breakdown of calcareous algae skeletons which live abundantly in modern carbonate environment (Ficthels, 2000). Micrite usually origin from clay is deposited in generally quiet water. Usually, quiet water environment is associated with deep water, where currents and wave do not touch them. But that rules are not good for carbonates rock. Micrites form readily in the upper regions of tidal flats. In an area of tidal flat, there have two depositional places which are intertidal and supertidal. Micrite origin at an area of upper intertidal and supertidal where periodic exposure to air is common.

Limestone and phyllite lithology has sharp contact between bedding. The range thickness of phyllite is 3.30 meter to 2.3 meters. Originally, the origin rock that interbedded with limestone is shale but due to pressure and tectonic setting, shale was undergone low grade of metamorphism that resulting of phyllite. Internally, this facies, through shale-dominated, also contains thin interbedded of sandstone on a middle of Sub-unit D. The color of shale is dark grey with a fine grain size that have platy mineral (Figure 5.7 a, e). Based on figure 5.7c, sandstone rock has showed lamination structure. The beds of sandstone that occur with limestone deposit when there is a low supply of terrigenous clastic detritus (Nichols, 2009b). The lithofacies develops in a calm and tranquil environment. Based on Ali Adnan et al., (2014), this shale that interbedded with limestone beds may also indicate their formation below the wave base and also may develop on the mud flats in an intertidal domain.

Sub-unit D composed of microfossil existence although have some of the fossils were undergone metamorphism and being a stretch. All of the two type fossils in shale and limestone are foraminifera phylum (Figure 5.8). Fossils are abundant in shale lithology compare in limestone lithology. Fossils in Sub-unit D are composed of *Hemigordiellina* sp., and *Retroseptellina* sp that both from Fusulinata class. Based on foraminifers, type-locality of Sub-unit D has been assigned as middle to late Permian (Nazif et al., 2014). *Hemigordiellina* sp. and *Retroseptellina* sp. are usually existed in lime-mudstone to wackestone and packstone. *Hemigordiellina* sp. presents some additional particulate of coiling and shape of a test (Jeremie & Daniel, 2007). Based on Enzo et al., (2014), *Hemigordiellina* sp. habitats is on open shallow marine that low current and wave. Jeremie & Daniel, (2007) state that *Retroseptellina* sp is typically glabivalvulinids entirely coiled and with a relatively constant shape of a chamber with a simple wall. *Hemigordiellina* sp., and *Retroseptellina* sp. are commonly in Permian to Triassic age (Bastian et al., 2012).

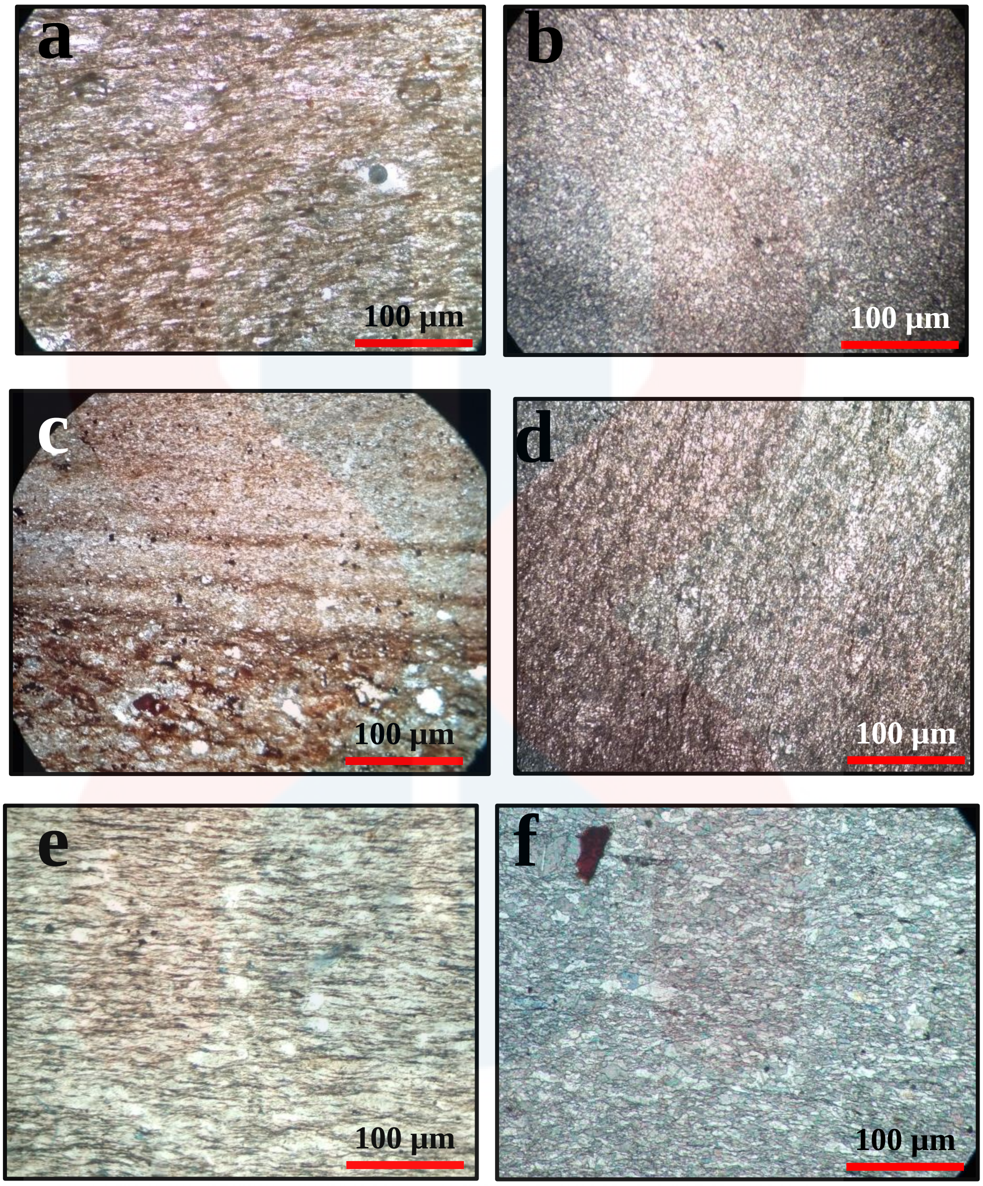

Figure 5.7: Petrology of every bedding in sub-unit D. (a, e) phyllite (b, d, f) limestone (c) phyllite interbedded sandstone. Magnification of microscope is 40 × 0.65 p. a, b, c, d, e, and f is increase sequence bedding of sub-unit D.

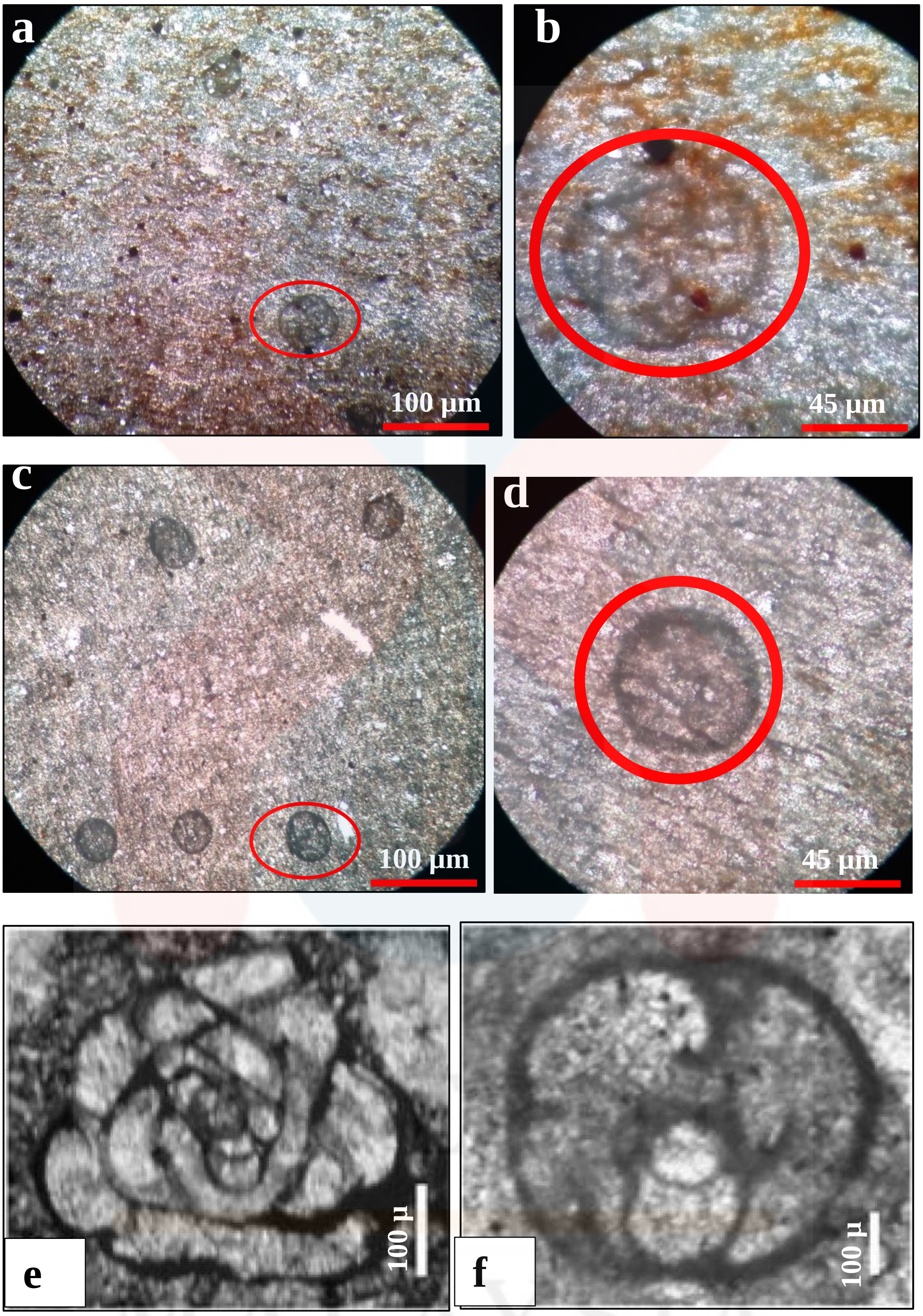

Figure 5.8: Foraminifera fossils. (a,b.e) *Hemigordiellina* sp., (c.d.f) *Retroseptellina* sp. ;(a,c) magnification of 40 × 0.65 p, (b,d) magnification of 60 × 0.50 p

5.4 Interpretation of Depositional Environment

Based on the parameters of facies associations, microfacies association, sedimentary structures, and the existence of fossils present in the study area, the interpretation of the depositional environment of the Gua Musang formation can be made.

In Sub-unit A and Sub-unit B, the dominant lithologies are volcaniclastic which fallout of volcanic fragments ejected from a vent of fissures as a result of a magmatic explosion. Because the volcaniclastic rock in form of ash, it can be interpreted that volcaniclastic in the study area are ejected explosively from a vent, producing a plume of tephra and gas, and ash-cloud derived fall deposits, resulting in part from ash clouds rising off a moving pyroclastic flow (Sam, 2009d). The ash may be carried many tens of kilometers and dust thousands of kilometers away from the vent before being transport and deposited. Parallel lamination on Sub-unit C indicates that it forms through deposition from suspension, slow-moving sediment clouds, and shallow water depth. In Sub-unit D, limestone interbedded with low-grade phyllite. Micrite limestone that evolutions from clays material were deposited between upper intertidal with supertidal. While the shale lithologies that interbedded with limestone is resulted from formation below the wave base and also may develop on the mudflat in intertidal. Habitats of *Hemigordiellina* sp. was on a shallow platform as shown in Figure 5.9. The range age of *Hemigordiellina* sp., and *Retroseptellina* sp. is from middle Permian to Triassic. So, all of the Sub-unit is interpreted to have a shallow depositional environment as in Figure 5.10 (Fichter, 2000).

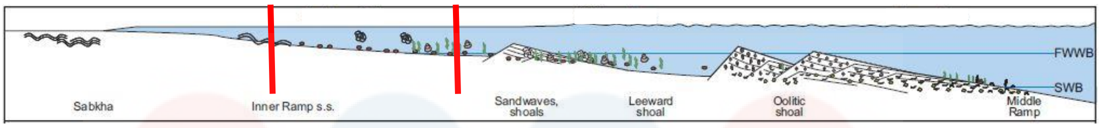

Figure 5.9: Habitat environment of *Hemigordiellina* sp. (Modified: Enzo et al., 2014)

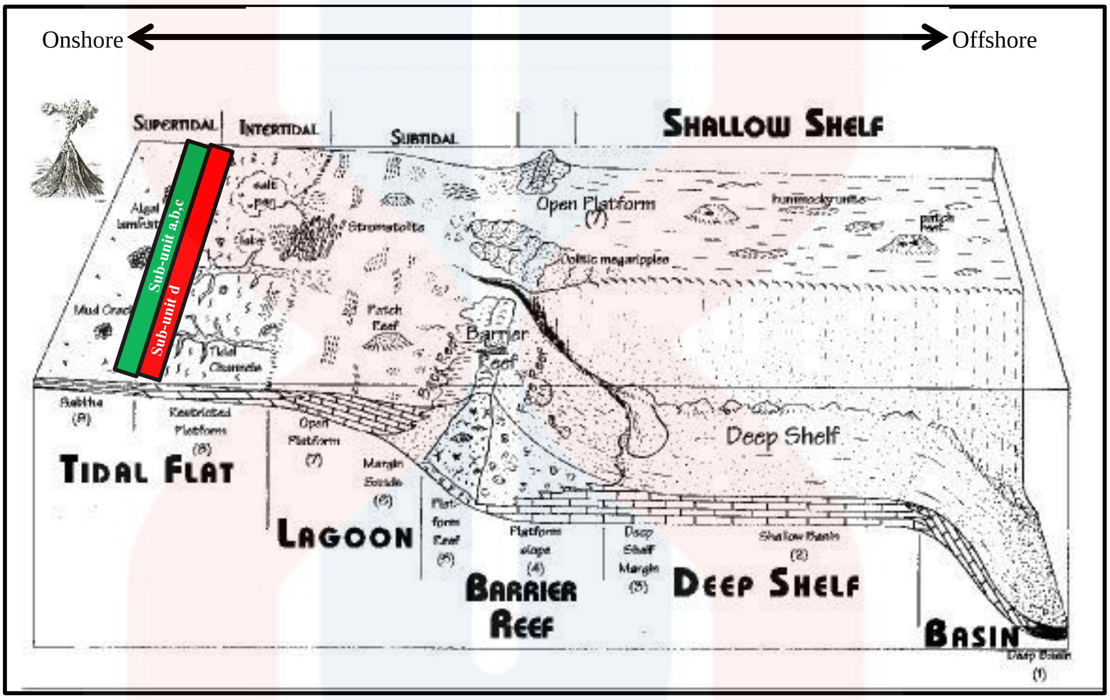

Figure 5.10: Depositional environment of carbonate and clastic facies of Gua Musang Formation. (Modified: Fitcher, 2000)

5.5 Summary

Based on all the evidence elaborated, the depositional environment of the Gua Musang Formation in the study area is said to be at the shallow marine setting when all of the criteria for recognition of shallow marines and all the parameters justify this results. The depositional environment ranges between upper intertidal to supertidal on a tidal flat. The existence of foraminifera fossils indicated that age of depositional environment in between middle Permian to Triassic. From the criteria mentioned and the interpretation that has been made, it can be proved that the depositional environment of Gua Musang Formation is in the shallow marine.

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

All of the objectives mentioned are able to be accomplished by producing the detailed geological map of the study area in scale 1: 25 000 scales and by identifying the depositional environment of the Gua Musang Formation in the study area.

Throughout the end of the field works, the geology of the study area was interpreted based on the geomorphology, lithostratigraphy, structural geology and historical geology of the study area. In the aspect of geomorphology, the mountainous topographic is found from the western to the eastern part of the study area while other part s of the study area is dominated by hills. Elongated karst with a steep slope and a sharp peak was found at the eastern part of the study area. The only one drainage pattern of the study area is a dendritic pattern, which is composed with flat-lying bed, soft rock, and massive crystalline rock.

Stratigraphically, the study area consists of the Gua Musang Formation. In the Gua Musang Formation, the lithologies consist of limestone, siliclastic, volcaniclastic, metasediments, and extrusive igneous rock. The youngest rock was limestone while the oldest is metasediments rocks. The structural geology that can be found in the study area is fold, fault scarp, vein, and joints.

The depositional environment of the Gua Musang Formation is focused based on the research specification. There are a few parameters used in order to interpret the depositional environment of the Gua Musang Formation. The parameters that are used are the facies associations, the sedimentary structures present and the microfossils found within the study area. All of this parameter help in giving the information such as the energy level of the formation and the environment on where and when the sediments are deposited. The Gua Musang formation is divided into four sub-unit based on facies associations. Sub-unit A refer to volcanic mudstone interbedded with lapilli tuff, Sub-unit B includes volcanic sandstone interbedded with tuff, lapilli tuff, and volcanic mudstone, Sub-unit C is dominated by volcanic mudstone interbedded with tuff with parallel lamination structure and Sub-unit D consist of limestone interbedded with sandstone and shale. All the facies associations and sedimentary structure found are associated with open shallow marine with low current and energy. Based on the fIndings, depositional environment of the Gua Musang Formation is interpreted to lies in the tidal flat region. The interpretation is supported by the presence of foraminifera microfossils, such as *Hemigordiellina* sp., and *Retroseptellina* sp. The foraminifera mentioned are found in the shallow marine on Middle Permian to Triassic age.

6.2 Suggestion

Some of the parts of the Perasu area, Gua Musang is inaccessible due to heavy vegetation. It is recommended to use some modern technology such as drones or unmanned aerial vehicles (UAV) to conduct the geological mapping for those inaccessible parts. The modern UAV has upgraded its function and able to a geological assessment of facies and examine the geological features of the rocks.

Besides that, it will be good if UMK can provide thinning machine to do thin section. By that, we can get thin section with 2mm thickness. As my problem, thin section that I done is quite thick and have difficulties to seen in microscope.

Although the depositional environment of Gua Musang Formation is identified through this research, there are still lacks more of other sedimentary structure and sedimentology data such as paleocurrent direction. It is recommended to do the research on this related topic to understand the composition and the source of the mother rock. Besides that, there is only two type of microfossil found in the Perasu area, Gua Musang. It is encouraging to do more research especially on paleontology including trace fossil and body fossils to examine the unidentified fossils.

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