GEOLOGY AND DEPOSITION OF VOLCANICLASTIC IN NGLANGGERAN FORMATION AT PATUK AREA, GUNUNG KIDUL, YOGYAKARTA, INDONESIA

by

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

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DECLARATION

I declare that this thesis entitled Geology and Deposition of Volcaniclastic in Nglanggeran Formation at Patuk Area, Gunung Kidul, Yogyakarta, Indonesia is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

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

Signature : ________________________________

Name : ________________________________

Date : ________________________________

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Geology and Deposition of Volcaniclastic in Nglanggeran Formation at Patuk Area, Gunung Kidul, Yogyakarta, Indonesia

ABSTRACT

The research study was located at Patuk area, Gunung Kidul Indonesia, Yogyakarta, with coordinate of 7°49'17.67"S to 7°52'0.16"S for the latitude and 110°28'15.17"E to 110°30'58.2"E for the longitude. The geological information of Patuk area must be updated for current usage as the latest geological map was in scale 1: 100 000, where the accuracy of the map is decrease because of the large scale. The first objective for the research is to produced geological map with scale of 1: 25 000. The geomorphology, the structural geology and the lithology unit of Patuk area was observed, measured and analyzed in order to produce geological map. The historical geology for Patuk area can be determined and explained based on the geological study. The research specification was made in study area, where the formation that was focused on is Nglanggeran Formation. The deposition and lithology unit of Nglanggeran Formation consist of volcaniclastic sediments. Therefore, the method is different from the method used in sedimentary rock. Lithology log of volcaniclastic sediments was made and analyzed, based on the rock fragment size and mineral composition. The petrographic analysis play important roles in both geological mapping and research specification as the dominant lithology for Nglanggeran Formation is volcanic rocks. The second and third objectives were achieved based on the analysis of the research specification. The facies analysis was made based on the lithology log where there were four type of different facies in Nglanggeran Formation in study area. The deposition environment was determined based on the facies analysis and lithology log. The depositional environment for Nglanggeran Formation in study area is submarine environment.

Keywords: Depositional Environment, Nglanggeran Formation, Patuk area, Submarine environment, Volcaniclastic analysis.

Geologi dan Pengendapan Volkaniklastik di Formasi Nglanggeran, kawasan Patuk, Gunung Kidul, Yogyakarta, Indonesia

ABSTRAK

Kajian penyelidikan ini terletak di kawasan Patuk, Gunung Kidul, Indonesia, Yogyakarta dengan koordinat 7°49'17.67"S hingga 7°52'0.16"S untuk latitude dan 110°28'15.17"T hingga 110°30'58.2"T untuk longitude. Maklumat berkaitan geologi untuk kawasan Patuk seharusnya dikemaskini untuk pengunaan semasa kerana peta geologi terkini berada pada skala 1: 100 000, dimana ketepatan peta berkurang kerana mempunyai skala yang besar. Tujuan pertama untuk penyelidikan ini adalah untuk menghasilkan peta geologi dengan skala 1: 25 000. Geomorfologi, geologi struktur dan unit litologi kawasan Patuk diperhatikan, diukur dan dianalisis untuk menghasilkan peta geologi. Sejarah geologi untuk kawasan Patuk boleh ditentukan dan dijelaskan berdasarkan kajian geologi tersebut. Spesifikasi penyelidikan dibuat di kawasan kajian, di mana difokuskan pada Formasi Nglanggeran. Unit pemendapan dan litologi pembentukan Formasi Nglanggeran terdiri daripada sedimen gunung berapi. Oleh itu, kaedah ini berbeza daripada kaedah yang digunakan dalam batuan sedimen. Lithologi Log untuk sedimen gunung berapi dibuat dan dianalisis, berdasarkan saiz serpihan batu dan komposisi mineral. Analisis petrografi memainkan peranan penting dalam pemetaan geologi dan spesifikasi penyelidikan kerana litologi dominan untuk Formasi Nglanggeran adalah batu gunung berapi. Objektif kedua dan ketiga telah tercapai berdasarkan analisis spesifikasi penyelidikan. Analisis fasies dibuat berdasarkan log lithology dimana terdapa empat jenis fasa yang berlainan di Formasi Nglanggeran di kawasan kajian. Persekitaran pemendapan ditentukan berdasarkan analisis fasies dan log litologi. Persekitaran endapan untuk Formasi Nglanggeran di kawasan kajian adalah persekitaran dasar laut.

Kata Kunci: Analisis Volkaniklastik, Formasi Nglanggeran, Kawasan Patuk, Pengendapan Persekitaran, Persekitaran dasar laut.

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LIST OF SYMBOLS

°	Degree
”	Inch
'	Minute
×	Multiply
%	Percentage
"	Second
Σ	Sigma
°C	Temperature (Degree Celsius)

LIST OF ABBREVIATIONS

cm	Centimeter
E	East
Fs	Feldspar
GPS	Global Positioning System
HCI	Hydrochloric Acid
km	Kilometer
m	Meter
Opq	Opaque Mineral
Qtz	Quartz
S	South
km^2	Square Kilometer

CHAPTER 1

GENERAL INTRODUCTION

1.1 General Background

The phrase of the present is the key to the past is a very common phrase in geoscience study. This is because the history and evolution of earth can be explored by the study of geoscience. In simple words, geoscience is the study of the Earth. This includes the study of the process and formation of the earth, the oceans, and the rivers. From those four systems related to each other, the past of any location could be investigated. In geoscience, people can know the history of the location by the depositional environment.

The depositional environment is a location where the deposition process of sediments occurs. It is characterized by specific physical, chemical and biological processes that act on the sediments deposited. Therefore, to recognize the depositional environment of an area, the geologist will first analyze the sedimentary facies as it shows the depositional pattern of sediments at certain locations. The same concept was applied for volcaniclastic sediments. The volcaniclastic facies will be analyzed. Based on that, the deposition environment can be identified. Sedimentology is the study of sedimentary rocks and the processes of their formation while Stratigraphy concerned with the order and relative position of strata and their relationship to the geological timescale.

The study area is located at Gunung Kidul Regency, Yogyakarta, Indonesia with a minor part of the Bantul Regency in the west part of the study area and Sleman Regency in the north part of the study area. Yogyakarta city is the capital city of Yogyakarta Province that situated at the southern part of volcanic arc island of Java. It located in a flat land area at the slope of Merapi Volcano. There are several formations founded in the study area, which are Sambipitu Formation, Semilir Formation and Nglanggeran Formation. The location of depositional environment analysis was focused on Patuk area in the Northern part of the study area as the main formation, Nglanggeran Formation located there.

The research was concerned with the basic geological mapping and geology history study of Gunung Kidul, Yogyakarta area. The geology such as geomorphology, stratigraphy, structural geology and historical geology was studied in order to produce the geological map of the study area. Besides that, sedimentary logs based on lithologies, fossils, and sedimentary structures were constructed to identify the depositional environment of a sedimentary unit for this area.

The Nglanggeran Formation dominantly consists of volcaniclastic sedimentary rocks followed by carbonate rocks at the upper of this formation (Priady, 2014). Therefore, instead of depending on the usual depositional environmental parameters such as sedimentary analysis and fossil analysis, a new method was included in this research. Volcaniclastic facies analysis, where the volcaniclastic sediments were focused on along with other sedimentary rocks at Nglanggeran Formation in order to identify the depositional environment of the study area.

Volcaniclastic sediment is a clastic deposit derived from the transport, deposition of products from volcanic activity. The volcaniclastic facies analysis involves the identification of volcanic sediments by observing the fragmentation, transportation and depositional processes of the volcaniclastic sediments (Manville, Németh, & Kano, 2009). In this research, the precision of volcaniclastic facies analysis along with sedimentary facies analysis was used to determining the depositional environment of Nglanggeran Formation.

In addition, the current geological map that shows the study area is on a scale of 1: 100 000. This large scale map provides limited geological information on the lithology, stratigraphy and geomorphology. Besides that, there is insufficient information regarding the depositional environment for the study area. Therefore, this research is purposed to produce a detailed geological map with a scale of 1: 25 000 and to identify the depositional environment of the area.

1.2 Study Area

1.2.1 Location

The study area is a specific given location where the data or geological features of that place will be observed and analyzed. Based on Figure 1.1 and Figure 1.2, the research was conducted in Yogyakarta Special Province, Indonesia with three main districts present in the study area, which are Gunung Kidul Regency, Bantul Regency, and Sleman Regency. While the specification, depositional environment analysis was conducted at Patuk area, Gunung Kidul Regency with a minor part of Piyungan area, Bantul Regency.

Figure 1.1: Map of Indonesia, with the province of Yogyakarta, Indonesia (Prihutami, 2016).

Figure 1.2: Map of the study area at Java Island, Indonesia (Source: Google Map).

The study area is located majority at the west of Gunung Kidul Regency and part of the study area is at the east of Bantul Regency, Yogyakarta. Based on Figure 1.3, the highest elevation of the study area is 387.5 m, while the lowest elevation is at 75 m.

The specific study area with a range of 25 km^2 with longitude and latitude of the study area mark at four different locations, starting from 7°49'17.67"S to 7°52'0.16"S for the latitude and 110°28'15.17"E to 110°30'58.2"E for longitude.

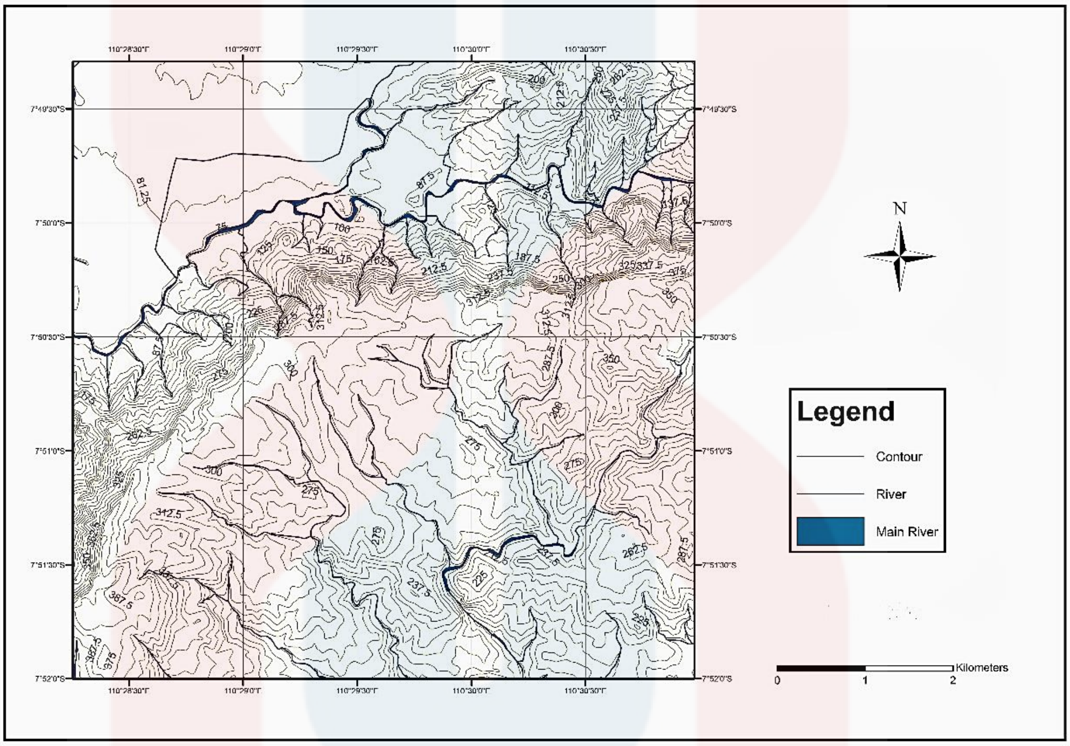


Figure 1.3: Base Map of the study area that shows the contour, river and main river.

1.2.2 Road Connection/ Accessibility

Most of the sites in the study area are accessible through the connected road, mostly a paved road. There are mosques, villages, and residency through the three districts, Gunung Kidul, Bantul and Sleman Regency, therefore it easy to reach any location with public transportation. Based on Figure 1.4, Patuk is a town located about 20 km from Yogyakarta city, which takes about 25 to 30 minutes to get there by cars.

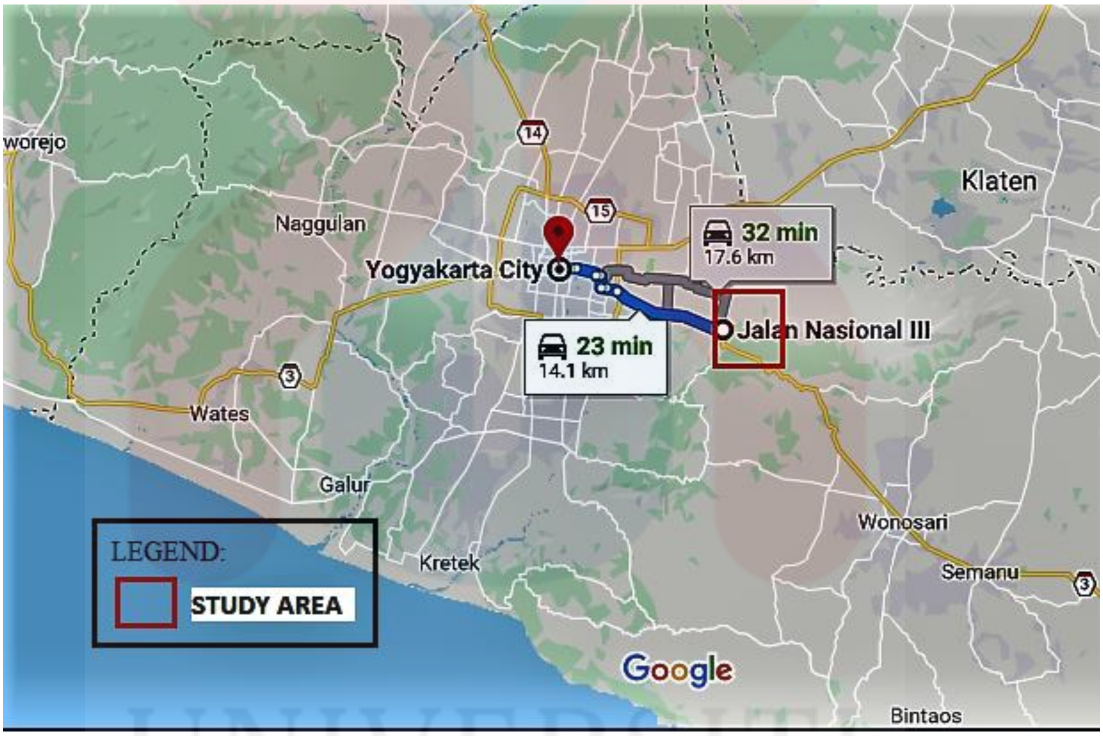


Figure 1.4: Direction from the study area to Yogyakarta city (Source: Google Map).

The Yogyakarta city has a good and wide transportation system of public transportation throughout the Yogyakarta Province. Based on online research, motorbikes are the most common transportation among citizens there, as public transport and personal transportation. Figure 1.5 shows the accessibility of the study area, with various types of roads that made traverse for geological mapping become easier and accessible.

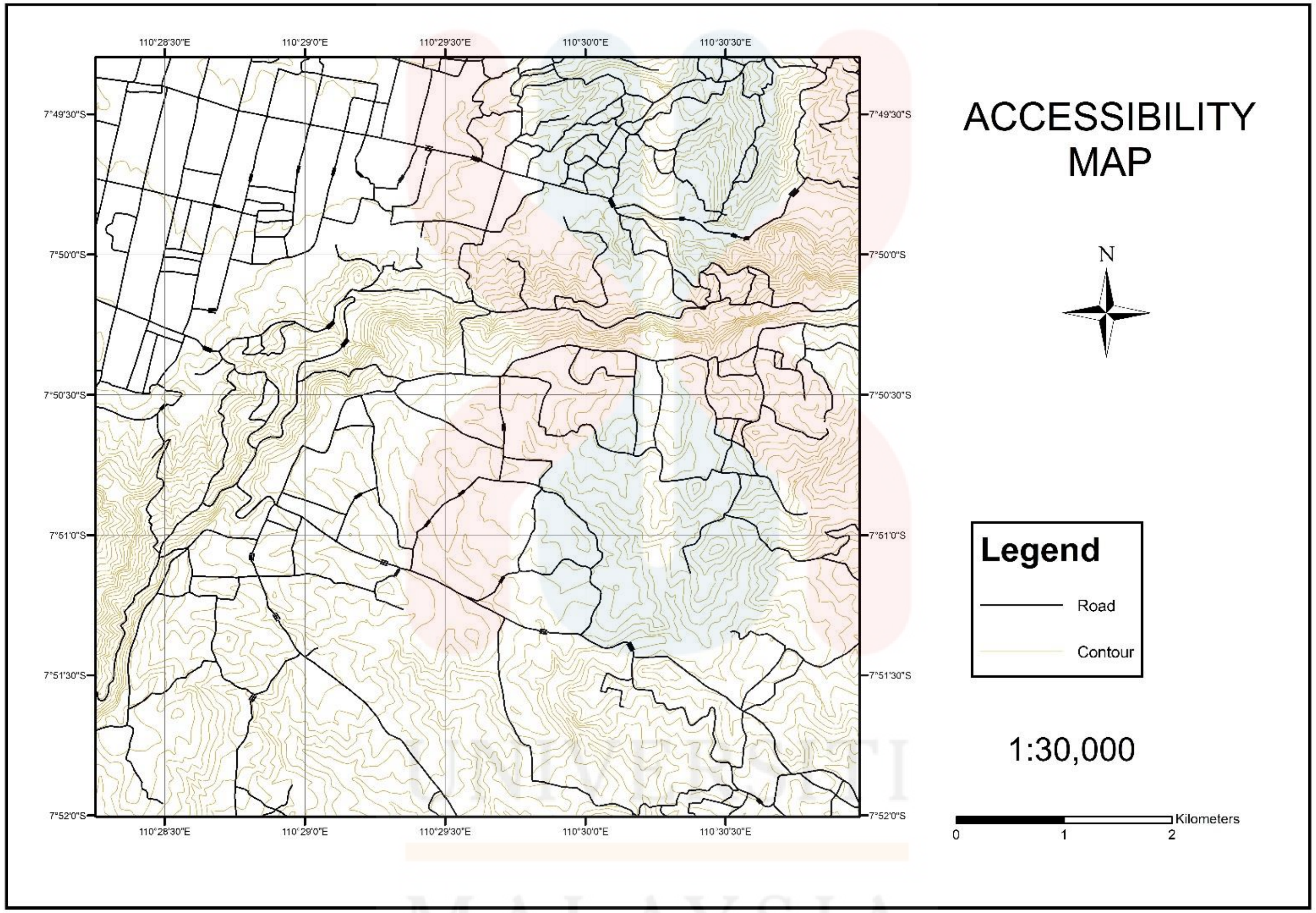


Figure 1.5: Base Map of the study area with road accessibility.

1.2.3 Demography

The Special Province of Yogyakarta, Indonesia located bordered with the Central Java and the Indonesian Ocean where Central Java located in the northern part of Yogyakarta. There are four main districts in Yogyakarta namely Gunung Kidul, Bantul, Sleman and Kulon Progo with one main city, known as Yogyakarta City. For the study area, Gunung Kidul is the major district, bordered with Bantul Regency in the west part of the study area and Sleman Regency in the north part of the study area. Gunung Kidul Regency covered about 50% of the study area, followed by Bantul Regency about 45% and Sleman Regency included 5% in the study area.

Based on the online article, the population of Yogyakarta covered about 9 200/ km^2 during 2017, with 422 732 inhabitants at Yogyakarta city. While specifically for the three main districts, Gunung Kidul Regency covered 1 485.36 km^2 in area with a total population of 714 656 during May 2015. Sleman Regency covered about 574.82 km^2 area with a total population of 1 079 210 during 2016. Lastly, Bantul Regency covered 508.13 km^2 with a total population of 947 568 during 2014. Table 1.1 shows the area and total population for each district.

Table 1.1 Area and total population for each district.

District / Details	Gunung Kidul Regency (2015)	Bantul Regency (2016)	Sleman Regency (2014)
Area, km^2	1 485.36	574.82	508.13
Total Population	714 656	1 079 210	947 568

(Source: Wikipedia)

Indonesia is a multiracial country where the citizens speak Indonesian as their native language and the religion in Indonesia is wide and varies. Focusing on

Yogyakarta, the majority of the population is Javanese. While the main religion is Islam and Christianity followed by Buddhism, Hinduism, Confucianism and others. Based on Badan Pusat Statik Indonesia, the percentage of Islam adherent is the highest followed by Christianity religion. Table 1.2 shows the type of religion in Yogyakarta along with the percentage. Table 1.3 shows the distribution of the population based on religion for the three main districts.

Yogyakarta is a state with large numbers of schools and universities were not many government workers or office workers. Based on online sources, locals there focused on agriculture and business such as in the hospitality sector and restaurants. Therefore, living in Yogyakarta is relatively low cost compared to other Indonesian cities. As a result, Yogyakarta attracted significant numbers of students from all over Indonesia. There are some foreigner communities in the city, which mainly foreign students or tourists.

Table 1.2 Type of religion and the percentage in Yogyakarta.

Religion	Islam	Christianity	Buddhism	Hinduism	Confucianism	Others
Percentage	83.22%	15.65%	0.29%	0.20%	0.02%	0.01%

(Source: Badan Pusat Statik Indonesia)

Table 1.3 Type of religion based on population at three main districts.

District	Religion					
	Islam	Christianity	Buddhism	Hinduism	Catholic	Others
Bantul	147 835	888	6	16	1 277	9
Gunung Kidul	592 812	9 286	475	1 138	8 591	323
Sleman	87 317	551	2	37	6 942	3

(Source: Badan Pusat Statik Indonesia)

1.2.4 Landuse

Generally, Yogyakarta is a site for tourist attractions with Mount Merapi located nearby the city of Yogyakarta. Jalan Malioboro is the main shopping street for the tourist that visit the city. While Patuk is a well-develop sub-district with many facilities. Paddy fields and Nurseries are abundances in the study area, with paddy fields becoming residential settlements. Based on an online source, the percentage of agricultural land at Yogyakarta that was converted to non-agricultural land range from 17.5% to 27%. The dominant changes happen when the paddy fields become a residential settlement.

1.2.5 Social Economic

Generally, Yogyakarta played an important role in the economy in Indonesia where it covered wholesale and retail trade, information and communication, government administration, educational services, health services and social activities. In 2017, the economic growth of Yogyakarta City reached 5.24 percent faster compared to 2016 (Mahrizal, 2017).

The capital region of Gunung Kidul, Wonosari undergoes rapid development while other districts are lagged behind because of the underdeveloped and having low economic contribution (Adinugroho, 2017). The main source of economic development in Gunung Kidul is the tourism sector. Tourism seems to be one of the alternatives as the number of tourists is increasing throughout the years. While in general, Gunung Kidul Regency consists of various economic potentials ranging from agriculture, livestock, industry, mining and tourism. Gunung Kidul Regency has extensive beach length located at the south, bordered with the Indian Ocean stretching for about 65 km. The potential of marine and tourism production is very wide and can be explored more.

In Sleman Regency, the economy more focused on agriculture. This is because the ash falls from Mount Merapi, the Sleman land becomes very fertile where the soil is thick with suitable moisture. However, under the influenced of rapid expansion of Yogyakarta, there is some area in Sleman district undergoes urbanization. Tourism also being developed in order to take advantage of many tourist sites such as Mount Merapi and temples.

1.3 Problem Statements

The latest geological map of the study area is from 1992, printed by Geological Research and Development Centre. Almost 30 years passed, it can show huge differences in geological structures, lithology and geomorphology of the study area. The scale for the map is 1: 100 000, which consider a large scale of the regional map. The current map contains not enough detailed geological data.

Based on previous geological research, the references focusing on the study area, Nglanggeran Formation is hard to be found. Most of the research papers are focusing on social economic and cultural studies. Besides, the depositional environment research about the study area is still insufficient. Next, Nglanggeran Formation rocks are known as volcaniclastic sediments, where the sediments and volcanic materials are deposited together. However, there is lack of research papers about the volcaniclastic sediments in the study area. The sedimentary facies of volcaniclastic sediments is different from non-volcanic sedimentary rocks, which helped in determining the volcaniclastic deposition in more precise.

Previous research mainly using facies analysis or fossil analysis in determining the depositional environment. In this research, volcaniclastic sediment facies of Nglanggeran Formation was analyzed to determine the depositional environment. Therefore, volcaniclastic sediment facies analysis method was conducted in order to identify the volcaniclastic deposition and deposition environment of Nglanggeran Formation.

1.4 Objectives

The objectives of the research are:

a) To produce the geological map of the study area with the scale of 1: 25 000.

b) To analyze volcaniclastic sediment facies in Nglanggeran Formation.

c) To determine the deposition environment of the Nglanggeran Formation in Patuk area, Gunung Kidul, Yogyakarta.

1.5 Scope of the Study

The area of study covered 25 km^2 (5 km × 5 km) of the Patuk area, Special Region of Yogyakarta Indonesia. The geology of the Patuk area and its surroundings such as geomorphology, stratigraphy, structural geology and historical geology was analyzed in order to produce a good geological map of the study area. Geological mapping was conducted along with a thin section of rock samples in the different locality for identification of rocks unit to produce a geological map with rocks unit boundary and describing the structural geology of the study area.

Besides, to identify the volcaniclastic deposition of the study area, volcaniclastic logs will be constructed. These logs will be based on the lithologies' physical properties of the study area. The volcaniclastic sediment deposition will be analyzed where the depositional process and sources of volcanic material will be interpreted to assist in identifying the depositional environment of the study area.

1.6 Significant of Study

Based on the research, a detail geological map with a smaller scale of 1: 25 000 will be useful for other researchers in the future. It was constructed in more detail compared to the previous map with current geological features of the study area. The depositional environment of the area was identified. Based on the data gained from this research, another geologist or other researcher can analyze the area and locate the potential resources such as oil, coal and water aquifers. These resources found can improve the social life quality in the Patuk area of Yogyakarta.

Volcaniclastic sediments involved the study of sedimentology combined with volcanology study. Therefore, the information would be useful to describe another aspect of geology study. For example, in identifying natural hazards such as landslide and ancient flood. Thus, people can avoid a natural hazard or take precaution steps from the data gained. In addition, this research, in turn, gives awareness to the engineering sector to construct the building in safety conditions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is focused more on the geological aspect of the Special Province of Yogyakarta, Indonesia, and the study area. It will cover the regional geology and tectonic settings including structural geology and historical geology, stratigraphy and sedimentology of study area, focusing on Nglanggeran Formation. The research specification will be explained in detail, which is a depositional environment, including sedimentary facies and volcaniclastic facies.

In sedimentology study, the depositional environment can be considered as the end result because it combined all the analysis from sediments to sedimentary rocks including facies analysis, sedimentary structure analysis and fossils analysis. The aim of the depositional environment study is to describe the history of the places and the geological setting of the study area back in time about a hundred thousand years ago. Depositional environment act as a geomorphic unit where the deposition will take place. This is because the geomorphic unit is recognized by the features that preserved in sediments or preferably known as ancient sediments (Kalasaiah & Balasubramanian, 2013).

In Indonesia, the sediments are abundance with volcaniclastic accumulation because of the volcanism activity from thousands of years ago (Selles, Deffontaines, Hendrayana, & Violette, 2012). Therefore, the sedimentation for certain areas in Indonesia involved volcanic clastic sediments that act as a parameter for identifying the depositional environment for certain places (Nichols, 2009).

2.2 Regional Geology and Tectonic Settings

Yogyakarta City located about 30 km from the Merapi Volcano makes it a city that prone to geohazard that resulted from geological phenomena. Merapi Volcano is the most active volcano Indonesia where it exists along with the Indian Ocean control the geodynamical processes at Yogyakarta city and province (Karnawati, Pramumijoyo, & Hendrayana, 2006).

Based on the research paper of Geology of Yogyakarta, Java, the city of Yogyakarta is controlled by active plate tectonic phenomena such as Merapi Volcano and active subduction of Indo-Australia oceanic plate below the Euro-Asian continental plate. The rate of the subduction is some centimeter per year where 6.0 cm per year in the West Most of Indonesia's volcanoes are part of the Sunda arc, a 3000 km long line of volcanoes extending from Northern Sumatra to the Banda Sea. The active Merapi Volcano results from the continuous subduction of those plates, which also brought the formation of volcanic morphology and carbonate rocks (Aydan, 2015).

The tectonics of Indonesia are very complex, as it becomes a meeting point of several tectonic plates. Based on Figure 2.1, Indonesia is located between two continental plates, Eurasian Plate or known as Sunda Shelf and Australian Plate. It also located between two oceanic plates, Philippine Sea Plate and Pacific Plate. Figure 2.2

shows the Pacific and Australian plate movements controlled the tectonics of the eastern part of Indonesia. Therefore, the tectonic movement in Indonesia gives a large impact on the geology structure where it formed major structures in Indonesia.

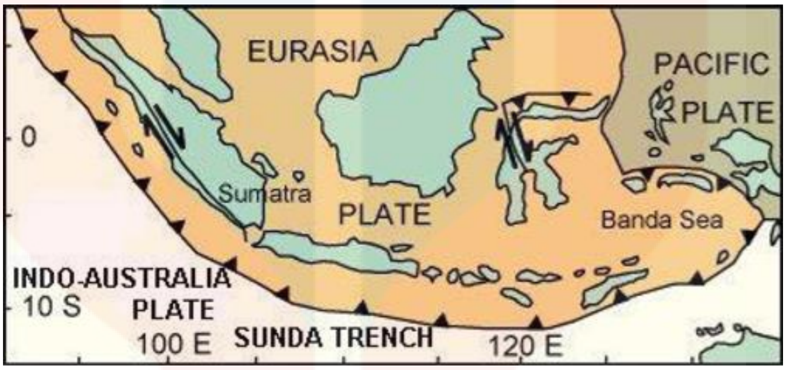


Figure 2.1: The tectonic model of Indonesia (Aydan, 2015).

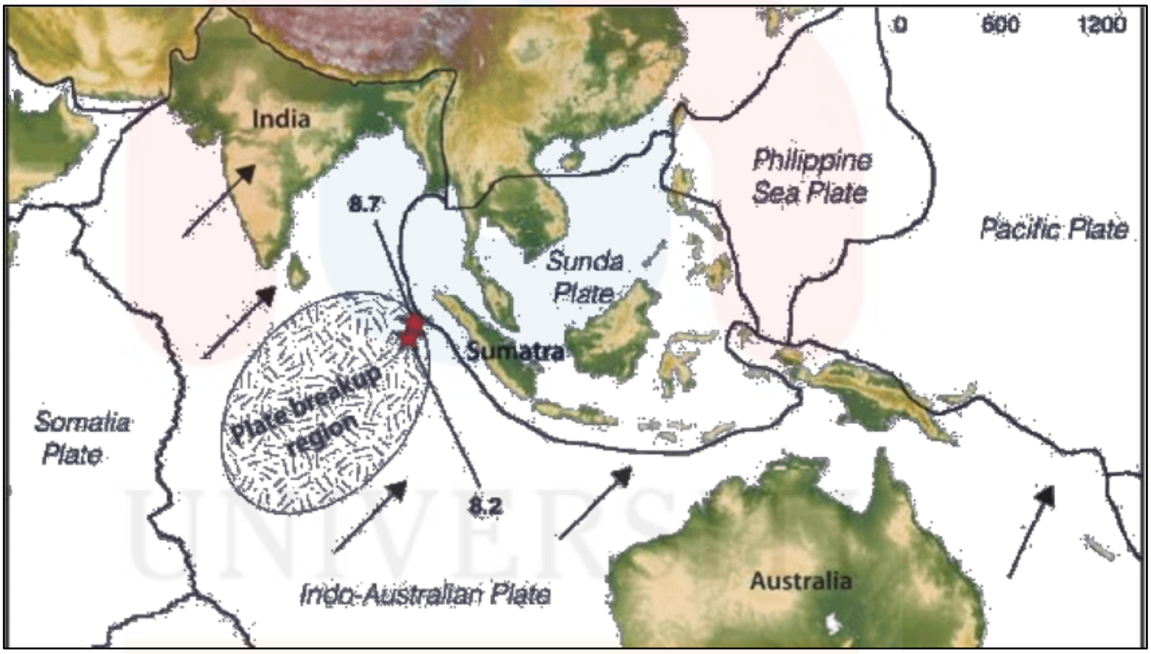


Figure 2.2: Major Plate Tectonics in Indonesia (Damayanti, 2013).

The chain of active volcanoes forms in Sumatra, Java, Bali and Nusa Tenggara Islands, but dominantly occurs at Java and Bali. The chain of volcanoes shows in figure 2.3, where the yellow dot represents the volcano. The subduction of the Indian Oceanic Plate beneath the Eurasian Continental Plate formed a volcanic arc in the western part of Indonesia. The chains of volcanoes form from this process where the distance is around 300 km from the trench. When the Indo-Australian plate reaches a depth greater than 100 km during subduction, the water contains will lower the fusion point of surrounding tocks, which creates magma. The characteristics of the magma triggered it to migrate towards the surface where it eventually generates volcanism typical of subduction. The chain of volcanoes forms from the trench, which Indo-Australian and Eurasian plates. Therefore, volcanoes form at Java Island are all under the influence of the Indo-Australian Plate and Eurasian Plate.

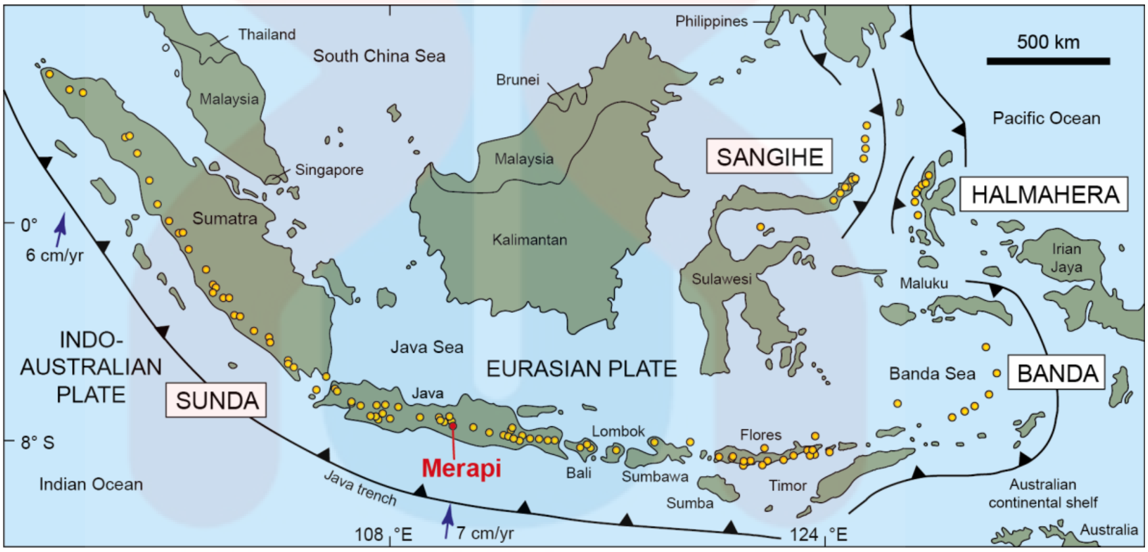


Figure 2.3: The chain of volcanoes in Indonesia. (Preece, 2003)

2.3 Stratigraphy

Stratigraphy is considered as the relationship between rocks strata and time, where it allows geologists to determine the sequence of events based on the sedimentary information (Nichols, 2009). The simplest principle of stratigraphy states that the youngest sediments or strata deposited at the top of older sediments. The study of stratigraphy involved with the correlation, interpretation and description of stratified sediments and rocks. From the study of stratigraphy, the rocks unit, the beginning, and the ending of the formation can be determined.

Generally, western Indonesia or the Island of Sumatra contains most of the oldest rocks in Indonesia. There were Paleozoic sediments with a range of age from Carboniferous to Triassic, with Permian volcanic rocks. While Cenozoic rocks cover most Indonesia, specifically Neogene age at Java-Sumatra (Hall, 2009). East Java can be subdivided into three parts, which are the Cenozoic Southern Mountains Arc, deep basin north of the arc and marine shelf north of the basin (Smyth et al., 2008). Based on Figure 2.4, the study area located in the Southern Mountains Arc, Yogyakarta.

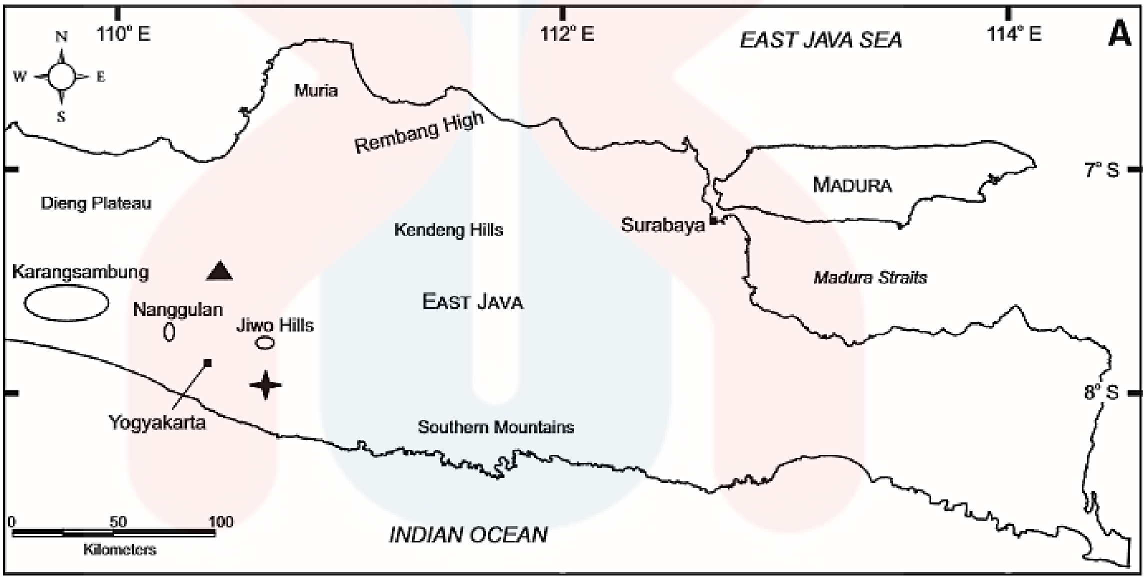


Figure 2.4: East Java location map (Smyth et al., 2008).

Figure 2.5 shows the Southern Mountains of East Java where the landscape consisting of mountain range extending from west to east, which the volcanic arc was formed from the middle Eocene to the Miocene in Southern Java (Smyth et al., 2008). The lithology of the area is dominated by volcaniclastic sediment materials. The area extended from the area of Central Java Mountainous zone including Gunung Kidul Regency with more than 55 km to East Java (Bronto, Pambudi, & Hartono, 2002).

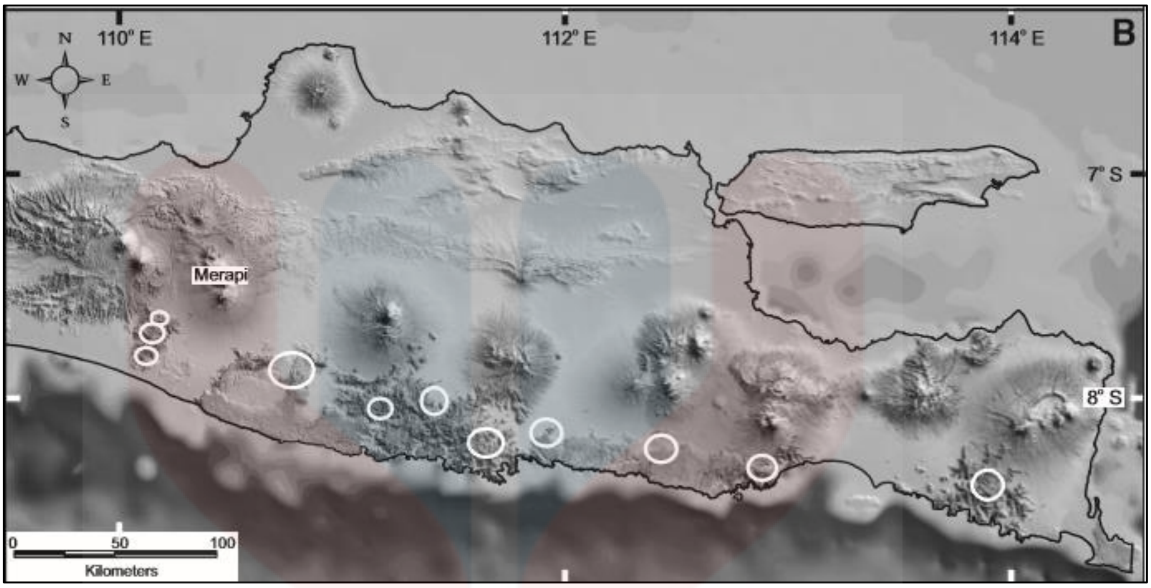


Figure 2.5: The Southern Mountains of Indonesia (Smyth et al., 2008).

The stratigraphy thickness of the Southern Mountains is more than 2500 m and within this sequence, andesite is well known. The Southern Mountains Arc is now uplifted and partially eroded with the strata typically dip uniformly toward the south between 20° to 30° (Smyth et al., 2008). The modern stratigraphy of the Southern Mountains is at Cenozoic era with Late Cretaceous period as the basement.

The formation involved for the research is Semilir Formation, Nglanggeran Formation and Sambipitu Formation. All of the formations are in the Tertiary period, Miocene age. Refer to Figure 2.6, Tertiary period rocks in the Southern Mountains consist series of ancient volcanic clastic rock products from several formations such as Kebo-Butak, Semilir, Nglanggeran and Sambipitu formation with an age range about 18 to 57 million years ago (Husein & Srijono, 2016). It is an Eocene to Middle Miocene volcanic sedimentary basin that conformably overly by Middle Miocene to Pliocene limestone, which later was uplifted and block-faulted so the formation is gently dipped to the south (Husein, 2015).

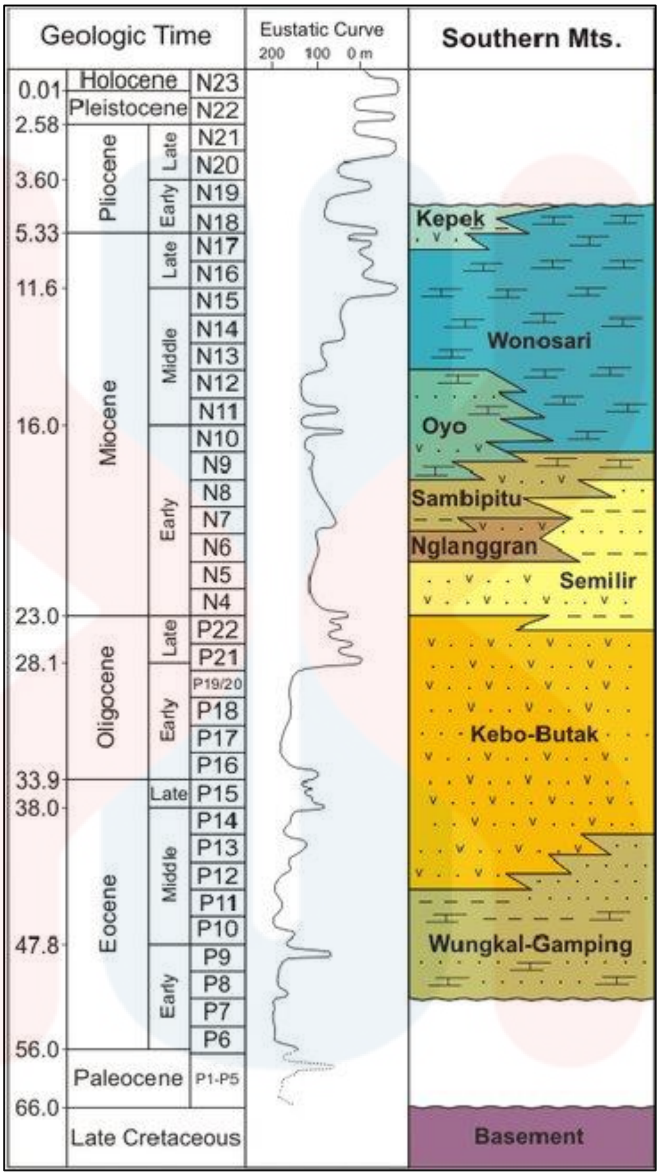


Figure 2.6: The stratigraphy of the Southern Mountains (Husein, 2015).

The stratigraphy of Southern Mountains is composed of old to young formation starting from Wungkal-Gamping Formation, Kebo-Butak formation, Semilir formation, Nglanggeran formation, Sambipitu formation, Oyo formation and Wonosari formation. Based on Figure 2.6, Wungkal-Gamping composed of carbonaceous rock and deposited during Early Miocene. Kebo-Butak formation deposited during Middle Eocene to Early Miocene, which composed of pebbly sandstones, siltstones and claystone. While Semilir formation interfingered deposited over Kebo-Butak formation during late Oligocene to Early Miocene that composed with tuffaceous sandstones in the upper part. Andesite lava occurred in the lower part, while carbonaceous siltstones were found in the middle part (Husein, 2015).

Followed by Nglanggeran formation, this formation interfingered with Semilir formation in early Miocene mainly composed of volcanic clastic sediments such as andesitic breccia tuff and basaltic lavas. Sambipitu formation conformably overlying Nglanggeran formation in the late early Miocene where it interbedded of calcareous sandstone with tuffaceous siltstones where carbonate component is increasing upwards (Husein, 2015).

2.4 Structural Geology

The main aspect of the understanding structural geology of places is to learn about the tectonic movement history, past geological events and environments that deformed them. This can be achieved by understanding the stress field that resulted in the observed strain and geometries from geological mapping and understands the structural evolution of those places due to plate tectonics.

Generally, the formation of the major structure is under the influenced of the tectonic process. Based on Susilohadi (1995), the structural deformation in eastern Java and surroundings are from the stress of northward motion of Indian Plate and Australian Plate. Faults are the most well-known structure formed at the Sunda Shelf, where these faults known as dextral strike-slip faults and some differential vertical movement (Susilohadi, 1995).

The major fault found in Yogyakarta is Opak Fault. Opak Fault is commonly used to describe the subsurface rupture beneath the Opak River. Opak River located in Bantul District, Yogyakarta of Java Island generally trending from Southwest to

Northeast, which covered by young Merapi Volcano sediment at the west of Gunung Kidul. Based on Sutiono et al. (2018), Opak Fault was believed to become the main cause of earthquakes occurs in Yogyakarta. Dr. S.W. Visser stated that during the Yogyakarta earthquake in 1867, the epicenter located near the Opak River, followed by the earthquake on 27 May 2006 (Sutiono et al., 2018). Opak Fault system striking from the Southwest to the Northwest as shown in Figure 2.7.

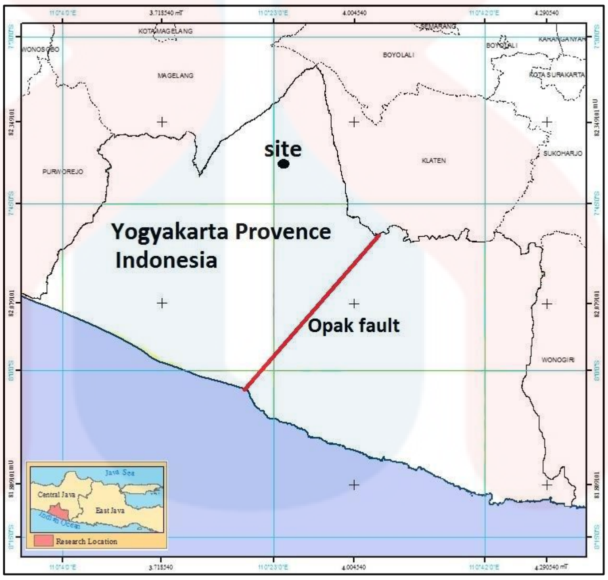


Figure 2.7: The Opak Fault in Yogyakarta, Indonesia (Makrup, 2017).

2.5 Historical Geology

Generally, the geological history of Yogyakarta is known as the pull-apart basin. Based on Hall (2009), in the Java-Sulawesi sector of Sunda arc history, volcanism activity reduced greatly during the Early and Middle Miocene, even though the northward subduction still occurs. The declined in magmatism activity is because of the collision of Australian in eastern Indonesia, causing the rotation of Borneo and Java. This prevents the replenishment of the upper mantle sources until the rotation started to decrease during the late Middle Miocene. Then, approximately 10 million years ago, the volcanism started to active back, along the Sunda Arch from Java eastward. Since the late Miocene, thrusting and deformational occurs at Java Island, including the Opak Fault. The island elevated above the sea level in the last few million years ago (Hall, 2009).

2.6 Volcaniclastic Deposition

Every layer of volcaniclastic sediments that accumulate in each type of depositional environment has distinctive characteristics that recorded important information about geological history for that area. Each volcaniclastic facies has its unique combination of physical and chemical features where these features help researchers to identify the depositional environment (Kalasaiah & Balasubramanian, 2013).

Based on Manville et al. (2009), there are four main facies for volcaniclastic sediments study. First, the volcanic core facies where the dominant component is lava and intrusion body. Next is proximal volcaniclastic facies. In these facies, the dominant component is breccia unit with minor part of lava. The third is medial volcaniclastic facies, where it only composed of breccia rock only. The distal volcaniclastic facies consist of tuff and ashes as it is far away from the sources of volcanic products. The depositional environment that was focused on in volcaniclastic deposition is the type of volcano present along with the depositional environment. For example the subaerial environment or submarine environment.

In Southern mountain formation, focusing on Nglanggeran formation, several research papers regarding the depositional environment at the formation area was discovered. Based on previous research, the parameters used for identifying the depositional environment are sedimentary analysis, where the facies of sediments had been analysis along with the sedimentary structure and fossil identification. Lithology and sedimentary aspects are the main aspects to differentiate the nature of the depositional environment (Razi, 2018). Based on Razi (2018), the overall succession of Nglanggeran Formation shows the depositional environment was in a shallow marine environment. The depositional environment for this research paper is different from other previous research stated by Priyady (2014). The different result maybe happens because differs from the study area.

However, Razi (2018) suggested that another method should be used in identifying Nglanggeran Formation as the rocks units in this formation contain volcanic materials and volcaniclastic sediments. Therefore, the research should be conducted using more detailed methods involving volcaniclastic sediments. The purpose is to find a better result in studying the origin of the volcano deposition history, which related to sedimentary analysis.

Volcanic activity can create depositional environments and it can contribute material to all other settings, both land and oceans. Volcaniclastic material will be deposited and can be identified through volcaniclastic facies (Nichols, 2009). Volcaniclastic sediments consist of some unique characteristics resulting from their volcanic-related origin. There are many structures in volcaniclastic sediments that indicate their origin. For example, pyroclastic fall deposits show normal grading, while pumice clasts show reverse grading particularly in water-lying beds (Stow, 2005).

Therefore, in identifying the depositional environment for Nglanggeran formation, volcaniclastic facies and sedimentary facies analysis should be carried out together for the depositional environment to be more precise.

2.6.1 Nglanggeran Formation

Based on the previous studies and research articles, Nglanggeran Formation is different from other formation at southern mountain formations. This formation is mostly characterized by the main deposition in the form of breccia with volcanic clastic materials, which does not show enough thickness of layers. The layers are mostly composed of andesite lava blocks that have undergone brecciation (Priady, 2014). The deposition of this formation can be interpreted from a submarine volcano in the marine environment where the deposition process is rapid, which occurs during the Early Miocene.

The location for Nglanggeran formation is at the Nglanggeran Village, where the rocks found in the area are volcanic breccias, agglomerates, tuffs and andesite basaltic lava. The dominant rocks units are volcanic breccia and agglomerates where the rock is not found in bedding form but deposited in block form. In addition, Nglanggeran formation consists of volcanic sandstones and tuff where these rocks were deposited in bedding. The fossils in Nglanggeran formation are not abundant. There were only several fossils found at this formation, which useful in determining the ages of the formation. Based on the sedimentary rocks and the fossils found in this formation, the researcher assumed that the depositional environment is from shallow to deep marine (Priady, 2014).

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction

In order to carry out the research, several materials and methods were listed to make sure the main objectives of the research are achieved. The materials were divided into two-part, which materials used for geological mapping and materials used for data processing and analysis such as software.

There are several stages in the methods, which are preliminary studies, field studies, sampling, laboratory work, data processing and data analysis and interpretation. The research flow chart for the research was shown in Figure 3.1 at the end of Chapter 3.

3.2 Materials/ Equipment

In order to carry out geological mapping or field study, several materials and equipment were used in order for all the field data to be recorded successfully. The data observed are geological structures, geomorphology, sedimentary analysis and fossils analysis. The materials used during the geological mapping;

Topographic Map

The map is an important item in geological mapping because it acts as a reference in the field. All the data observed at the field was recorded directly on the map. From the data recorded, all the geological features such as the rocks boundaries, geological structures, strike and dip data can be correlated to form a more detailed geological map.

Global Position System (GPS)

GPS is a space-based satellite navigation system that provides the location and time information on the earth's surface. With GPS, the length of track can be directly measured and planned traverse can be reached. From GPS, the observation point and the measured point at the field can be identified along with the traverse. The data processing was easier because the data can be transfer directly into the computer and laptop.

Compass

Commonly used compasses are Brunton or Suunto compass. It used to locate and give the right positions and directions to be compared with a map. In this research, the compass is needed for measuring the orientation of the structures present on the outcrop for a geological map and the attitude of the sedimentary beds in order to construct a sedimentary log and cross-section.

Geological Hammer

Geological hammer used for geologists specifically in collecting outcrop samples. The flat end of the hammer is used to break the rocks and the pointed end used to prying the rocks. Chisel hammer is more preferable in this research to prevent the destroying of sedimentary rocks containing fossils. Besides that, hammer also used to be a scale for the sample of rocks.

Field Book

The field book is a necessary item in geological mapping as all the data and information about the location or observation point was jotted down in the books. Without these recorded data, the analysis and interpretation data cannot proceed. The book must be fully protected especially during the rainy day later. The lithology log was roughly sketched at the field book first before transfer it to softcopy for data processing.

Measuring Tape

In this research, the precision in recording the measurement of lithology is very important as well as the structures. This is because the data processing and interpretation were decided based on the measurement of lithology. The measuring tape used to measure the size of the outcrops, structures and also the thickness of sedimentary beds.

Hand Lens

In this research, sedimentary facies are an important aspect that needs to be observed. Therefore, grains size for sedimentary rocks must be precisely observed. A hand lens used to observe the grain size of sedimentary rocks in order to identify the name of the rocks. It also used to identify the mineral contained in the rock sample before further petrographic analysis in the laboratory.

Hydrochloric Acid (HCI) solution

HCI solution used to test the presence of carbonate minerals in the rocks such as limestone. This will help in differentiate between calcite minerals and carbonate minerals. If the rock contains carbonate minerals, the reaction will occur when the HCI solution poured at the rocks.

While for data processing, there are several equipment and materials needed, including software applications. The data processing becomes easier with the presence of the equipment and software. The software and equipment used for the data analysis:

<u>ArcMap Software</u>

ArcMap software is a software that used to produce a base map before going to fieldwork and produce geological maps after fieldwork. Before going to fieldwork, the base map was constructed with the help of ArcMap, where the layers of contour were added along with the river and main rivers. ArcMap help to interpret the slope information about the study area, by given the detail about the degree of the slope. This shortens the time for data analysis and the data gained are more precise. Next, the geological map was produced by using ArcMap after the geological mapping was done. All the data was collected and the geological map was produced. From the geological map, the cross-section was constructed with this software.

<u>SedLog Software</u>

SedLog is a software that was used to construct the volcaniclastic log and stratigraphy column. This software is one of the important software for depositional environment research, wherefrom the construction of the volcaniclastic log, the depositional environment was determined. Therefore, the volcaniclastic log and stratigraphy column must be detailed and in the correct form. Therefore, by using this software, the data can be shown in more neat and precise ways compare with handwriting.

CorelDraw Software

CorelDraw is a software that used vector-based graphics tool, where people can illustrate pictures or maps, create original images or edit them. In this research, CorelDraw was used to construct the lithology log and stratigraphy column too. After constructed in SedLog software, the picture was edited in CorelDraw to add color to the stratigraphy column and lithology log based on the rock unit color to make it more presentable and visual.

Petrographic Microscope

In order to identify the type of rock especially the volcanic-sedimentary rock, the polarizing microscope is importance. A thin section was made and analyze using this microscope in order to identify and ensure the type of rock found. While for volcanic sedimentary rock, the fabric of the rock was identified in order to analyze the origin of the rock. Therefore, the rock units of the study area and the facies identification was made in ways that are more precise.

Georose Software

Georose is a software used to produce stereonet and joint data. This involved the structural geology analysis, where the data gained from the fieldwork was analyzed. The stress of the force in the study area was identified by using the joint data. The movement of fault was identified from the stereonet produced by Georose Software.

3.3 Methodology

3.3.1 Preliminary Studies

A preliminary study is the first step in conducting research. Through preliminary studies, the research gap of the research topic was found and the regional geology of the study area was obtained. This is because the purpose of preliminary studies is to obtain sufficient information about the research that will be carried out. Literature review and topographic also included in preliminary studies. Through the early analysis of the topographic map, the basic structure in the study area was identified. In this research, the different lithology was determined by topography analysis.

While for the literature review, previous research paper can be obtained in order to gain more understanding of the research topic. The literature review was done before going to the field because the knowledge and geological information from the previous researcher might be helpful in conducting the research.

3.3.2 Field Studies

Field studies for this research need a couple of weeks to complete it. Geological mapping was conducted in order to obtained geological information about the study area. Geological mapping was carried out by several methods. By conducting geological mapping, information regarding geomorphology, lithology, structural geology and stratigraphy of the study area was covered to produce a geological map. Lithology information is important in order to determine the volcaniclastic facies of the study area. For further analysis, the rock was named by petrographic analysis, thin section. The methods applied for geological mapping:

Traverse Method

The traverse method is a method that shows the recorded mapping progress throughout the study area. It is important to ensure the study area is completely covered without losing any important data specifically sedimentary and fossils data. The traverse track was recorded both manually and automatically. The track was manually plotted in the base map while automatically save and recorded from GPS.

Geomorphology Analysis

Geomorphology analysis is important in this research in order to determine the type of landforms in the study area. These landforms used to predict the origin, process and history of the study area. In this research, the highest point of the study area was chosen in order to conduct a geomorphology analysis. While observation was made, pictures and sketches of the surrounding landforms were made for data processing. The geomorphology analysis includes topography, drainage system and weathering processes of the study area.

Geological Structure Analysis

Geological structures form from the deformation of primary structures, usually on sedimentary rock involved the movement of the tectonic process. Examples of geological structures are folds, joint and faulting. All these structures show different characteristics and can be correlated with each other. From these structures, the orientation of the force of the study area was determined where it shows the direction forces that occurred in the study area. For fault structures, the attitude of the fault was measured along with the measurement of the fault displacement. For joint analysis, the direction of the joint was measured using a compass and recorded. Next, for folding, the attitude for each limb was recorded to observe the changes of the folding and to identify types of folding there. The structural analysis included lineament analysis, bedding analysis where the data can be gained from the structures mentioned above.

Facies Analysis

Specifically, to determine the depositional environment for volcaniclastic deposition in the study area, facies analysis is the crucial method. This included collecting the data, observation and measuring section as the indicators for depositional environments were determined from these aspects. The most important aspect in order to recognize volcaniclastic sediments is the composition of the materials (Nichols, 2009). Every material in volcaniclastic sediments shows different characteristics of deposition. The structures of the volcaniclastic sediments were observed. The lithology of the study area that must be focused on is the grain size, grain shape, grain sorting and grain orientation in order to determine the facies of sedimentary. The boundary and the thickness of the rock within the rock unit were recorded and measured.

Rock Sampling

The purpose of sampling in this research is to identify and to compare each rock found in a different area for lithology analysis. The rocks were collected in a different location and different lithology. Each of the samples was kept in different sample bags with labeled of the coordinate and description of the rocks. The thin section was made from the sample collected during the geological mapping.

3.3.3 Laboratory Work

The rocks sample collected from the fieldwork was cut into a suitable size for the thin section process. The thin section is one of the petrographic analyses where the minerals were observed in order to identify the types of rocks in more precise. The petrographic analysis was done in the laboratory using a petrographic microscope. The mineralogy, matrix and textures of the rocks were identified under the microscope.

While preparing a thin section, several methods were conducted in order to gain a clear and thin layer of rocks for detailed observation of the mineralogy and petrographic characteristics of the rocks. A thin section was prepared in several steps:

1. Each rock sample was cut and the face of the rock was grinded using a diamond grinder until the rock samples were smoothed.

2. Then, the rock was placed on the hot plate at 400°C in temperature for approximately 15 minutes in order to let it dry.

3. After that, epoxy hardener and the resin were applied on the surfaces of the rocks in the ratio of 1: 2 in order to fill any pores or cracks and heated until it bubbled to fill into the pores. This step is needed in order to avoid carborundum powder to fill into the pores during the polishing step. Especially with sedimentary rock, because of the soft surface of the rock.

4. The epoxy on the surfaces of the rock was removed by using a diamond bit grinder.

5. Then, the rock sample was polished again using a carborundum 120 grit powder until the surfaces get clean and smooth.

6. The polishing step was continued on a piece of glass by using a carborundum 600 grit powder. The size of the glass is approximately 12” × 10”, where the rock sample was stick to the glass slide.

7. The glass slide was polished using carborundum 180 grit powder. While for the gluing purpose, epoxy was used. Epoxy was applied on the smoothen rock surface then was covered by the polished side of the glass slide.

8. Each of the sample prepared was clipped and let dry at room temperature for 24 hours.

9. After 24 hours, the sample was thinned using a diamond bit grinder.

10. The sample was thinned until approximately 0.03 mm.

3.3.4 Data Processing

All the geological data gained was processed according to the related software. Georose software was used to plot the joint data, strike and dip measurement and other structure reading that was gained from the geological mapping. Next, the thin section was observed using the microscope to identify the name of the rocks.

For the identification of the depositional environment, the data such as lithology, rock composition and mineral were obtained from the fieldwork. The data from difference locality was compared and interpret. From the measuring section measurement, the volcaniclastic log was constructed in order to correlate the entire lithology log in the study area. The stratigraphic column was constructed based on the rocks, boundaries and thickness. The characteristics of volcaniclastic sediments were observed and interpreted.

3.3.5 Data Analysis and Interpretation

All the data that had been processing was analyzed and interpreted by using several methods. The structural analysis was made and the main force was determined along with the direction of the force. Thus, the structural deformation of the study area was identified along with the morphology of the study area.

Microscopic analysis of thin-section was used to recognize the minerals found in the volcaniclastic rock. This is because some of the rocks might go alteration process, the materials can be determined only from the relict fabrics of the mineral. Therefore, from identifying the volcaniclastic sediment facies, the deposition of volcanic succession was determined. By the combination of the analysis of the stratigraphy column and the analysis of volcaniclastic sediment, the depositional environment was identified. The GPS data and the field data based on lithology, geomorphology and others will be transferred into software making a map, ArcGIS 10.2 to produce a geological map with a scale of 1: 25 000.

RESEARCH FLOW CHART

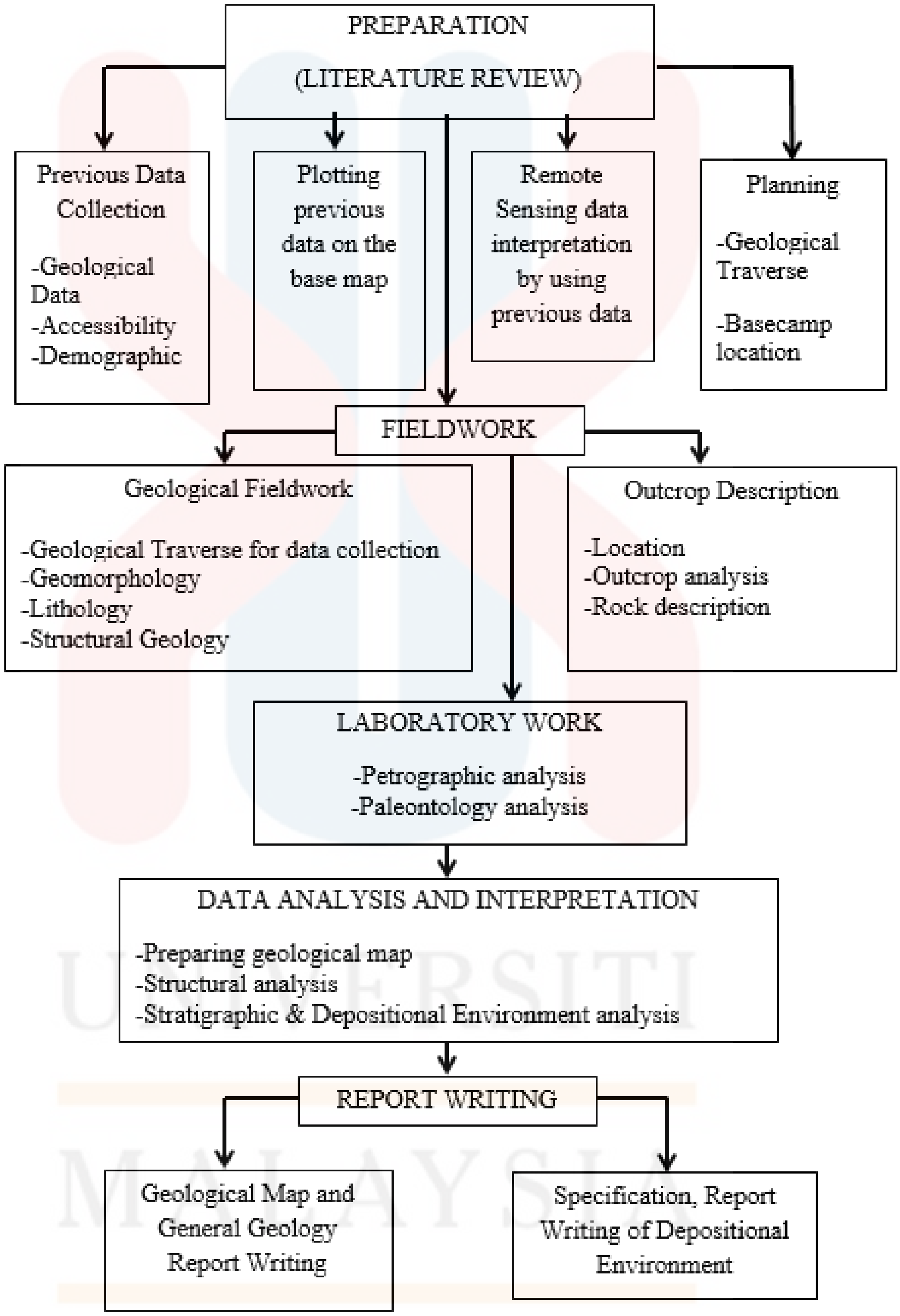


Figure 3.1: Research flow chart for the research.

CHAPTER 4

GEOLOGY

4.1 Introduction

4.1.1. Brief Content

In this chapter, the geology and information about the study area were discussed in more detailed. All the geological information was provided along with the data and results to understand the overall geology of the study area. Geology information such as geomorphology, lithostratigraphy, petrology, and the geological structure that was observed along with the sampling and analyzing of the data in the study area. Then, the information gained was used to interpret the historical geology of the Patuk area. In geomorphology aspect, the geomorphological map and the drainage map were provided in order to assist more understanding about the characteristics of the study area. All the geological information about Patuk area is important in order to achieve the objective of the research. The geological data was used to produce geological maps in more detailed, with scale of 1: 25 000. Furthermore, the geological information gained was used and explained more detail in next chapter according to the research specification.

4.1.2. Accessibility

Accessibility in the study area describes the ability of the study area to be reached or obtained easily that ease the communities in the study area. In the Patuk area, the main accessibility is road networks. This is because road network becomes an outcome for the transportation activities for socioeconomics of study area. The socioeconomic for the Patuk area can be determined based on the accessibility details.

Based on Figure 4.1, the study area consists of several road networks and every road has its own purposed, which is the main road, local or other road and footpath road. The main road becomes the road that connects two cities that known as Wonosari City and Yogyakarta City. Wonosari City is in the East of the study area, while Yogyakarta City is toward the Northern of the study area. Figure 4.2 shows a part of the main road in the study area. The local road or other road has the same purpose, which used for local villagers to access residential areas. The footpath road is accessible for motorcycles and streetwalkers. It can be seen that there was a direct geographic relationship between the land use system and road network. Therefore, the road network in the study area is considered accessible as it was used in daily economic activities of the local villagers.

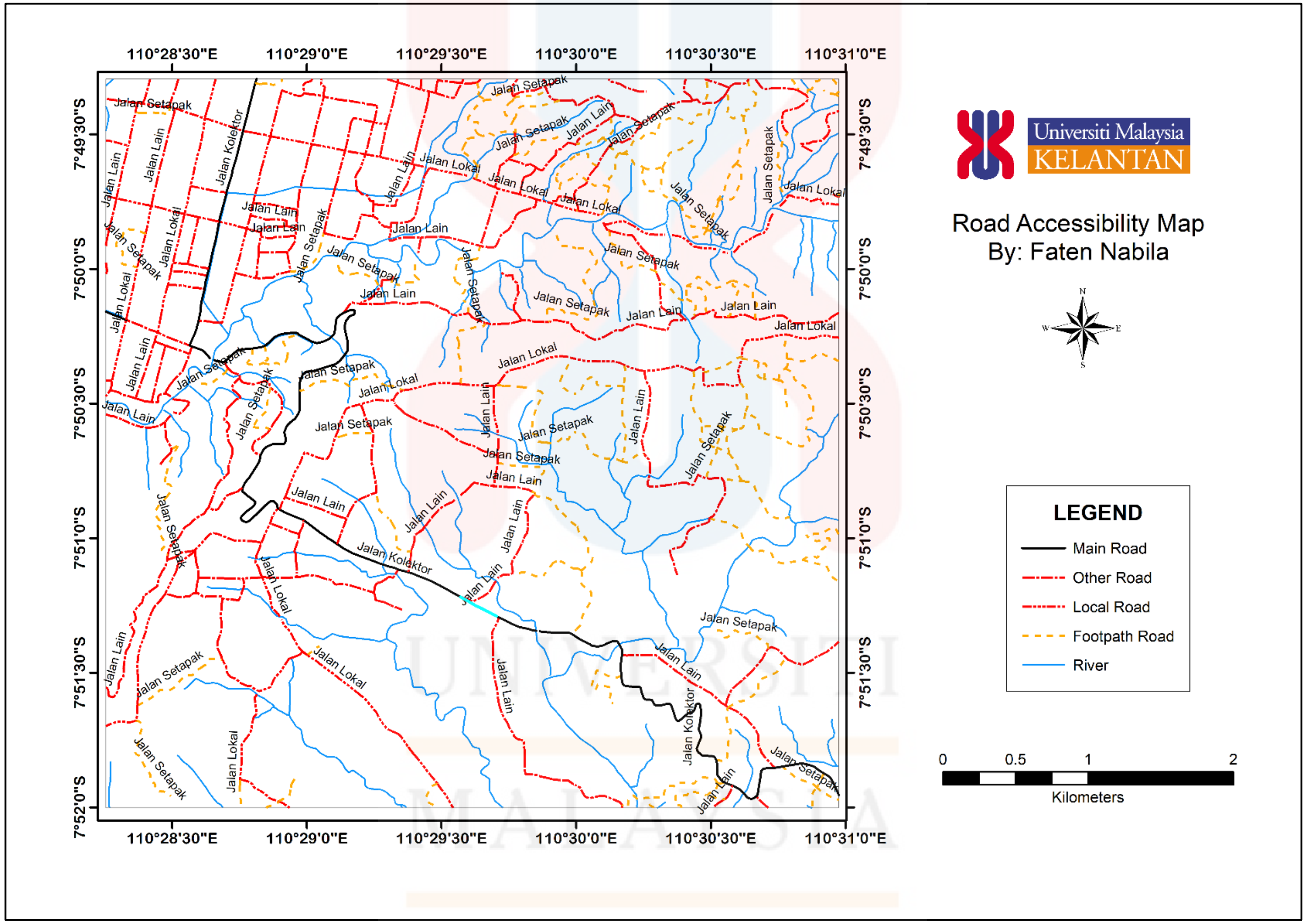


Figure 4.1: The Accessibility Map of Patuk Area.

Based on Figure 4.3, the footpath road is dominant by villagers by walking, as it is the main route in villages and some access to motorcycles. Therefore, it is easy to access the study area in conducting geological mapping. This helps in reducing the cost of transportation and time in geological mapping. In order to carry out geological mapping, the dominant road network used is footpath road and main road. In the study area, river is the main focused for data collection. Therefore, by using footpath road, rivers can be easily accessed in shorten time.

Next, the telecommunication system in the study area is accessible, easy to reach especially in high elevation locations. In the Northern part of the study area, there was the main substation for telecommunication for Yogyakarta City. Therefore, the systems are good and easy to access. However, the accessibility depends on the locations in the study area where some location does not have the coverage of telecommunication system. The location for low coverage usually at low elevation or low land location. Overall, the accessibility for the study area is efficient, which help in reducing the transportation cost and time for geological mapping.

Figure 4.2: The main road of the study area.

Figure 4.3: A part of footpath in the study area.

4.1.3. Settlement

The settlement is placed where people establish a community, usually the one that has previously been uninhabited. For the study area, the settlement is usually in villages or residential areas. Based on Figure 4.4, there are three districts in the study area, Bantul district, Sleman district and Gunung Kidul district.

In Sleman district, there are two villages found in the study area, which are Jogotirto, Berbah village and Wukirharjo, Prambanan village. While for Bantul district, three main villages are included, which are Piyungan, Srimartani and Srimulyo. Lastly, the main district in study area, Gunung Kidul district consists of sub-district known as Patuk. Patuk consists of four villages, which are Salam, Ngoro-oro, Nglanggeran and Semoyo. Patuk sub-district covered almost 50% of the study area and Patuk area is the largest location in study area.

The residential house or neighborhood arrangement was in a scattered pattern, where the houses were built based on the geographic surface of the area. There some houses built isolated with other houses because it is located at higher elevation. Overall, Patuk area settlement is influence based on its geographic surface and socioeconomic of the area.

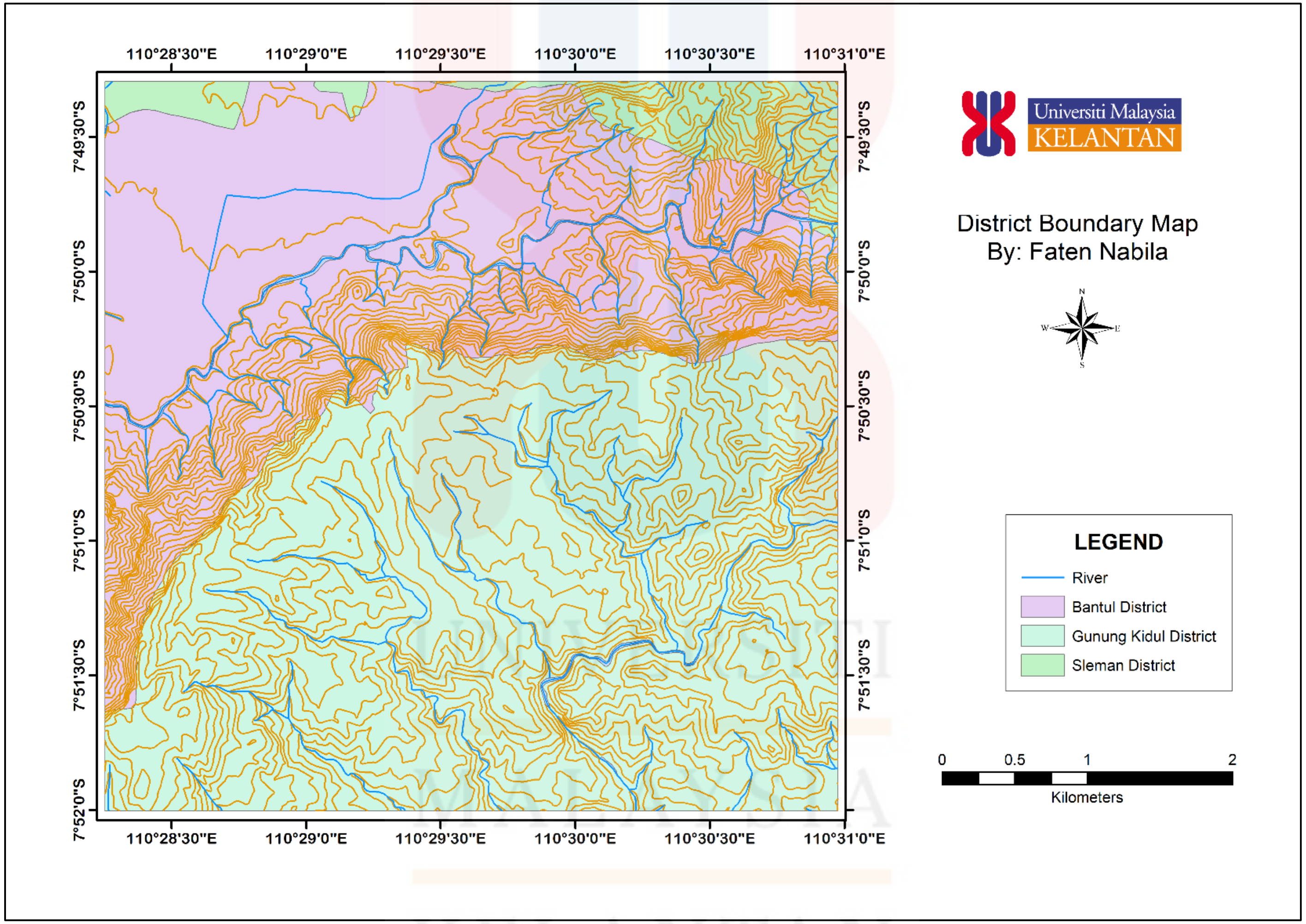


Figure 4.4: The district boundary map of the study area.

4.1.4. Vegetation

The vegetation in the study area is varied depends on the location and type of soils. However, the location in the study area is dominant with vegetation and a minor in forestry. This is because the villagers utilized the area of the space for vegetation, as the vegetation is the main socioeconomic activity for the villagers in Patuk area. It also becomes the main source of income.

The major vegetation found in the study area is paddy fields and teak trees, planted in different localities based on the types of soils. Commonly, paddy fields were found in volcanic areas, where the volcanic product is very suitable in paddy growth. Teak trees found mainly towards the southern part of study area. The teak trees leave was used to wrap the foods or rice to be sold on market. The trunk of the trees was used domestically where it will be sold to outsiders for business purposes. Other than that, minor vegetation such as coconut trees, chilies and potatoes. All the vegetation was fully used efficiently by the villagers including the thatch where it was used to feed the livestock of the villagers.

Figure 4.5 shows one of the paddy fields in the study area. The paddy field was planted in a terrace arrangement because of the geographic surface. It was planted at hilly area. While based on Figure 4.6, the paddy fields were planted in compartment arrangement because of the flat area of the location. Therefore, the usage of the land and the natural resources of the study area was maximized. It can be seen that vegetation is their main socioeconomic activities and sources of income.

Figure 4.5: Paddy field with terrace plantation.

Figure 4.6: Paddy field with compartment plantation.

4.1.5. Traverses and Observation

The main method for completing geological mapping is by traversing and observation in order to get the geological information in the study area. All the information gained from geological mapping will help in creating a geological map of 1: 25000 scale.

In order to produce the geological map and analysis of specifications, 12 days of mapping was conducted in the study area. 8 days for geological mapping and the other 4 days were used for specification of research. 1 day in geological mapping was completed by using motorcycles. Traversing was done mainly along the rivers in the study area. This is because of the outcrop in the rivers usually less weathered and less vegetation. Therefore, the outcrops were fresh and well exposed along with the geological structure. Figure 4.7 shows the traverse route where almost 90% of the study area was covered with observation points. From the collected data, a detailed geological map was created.

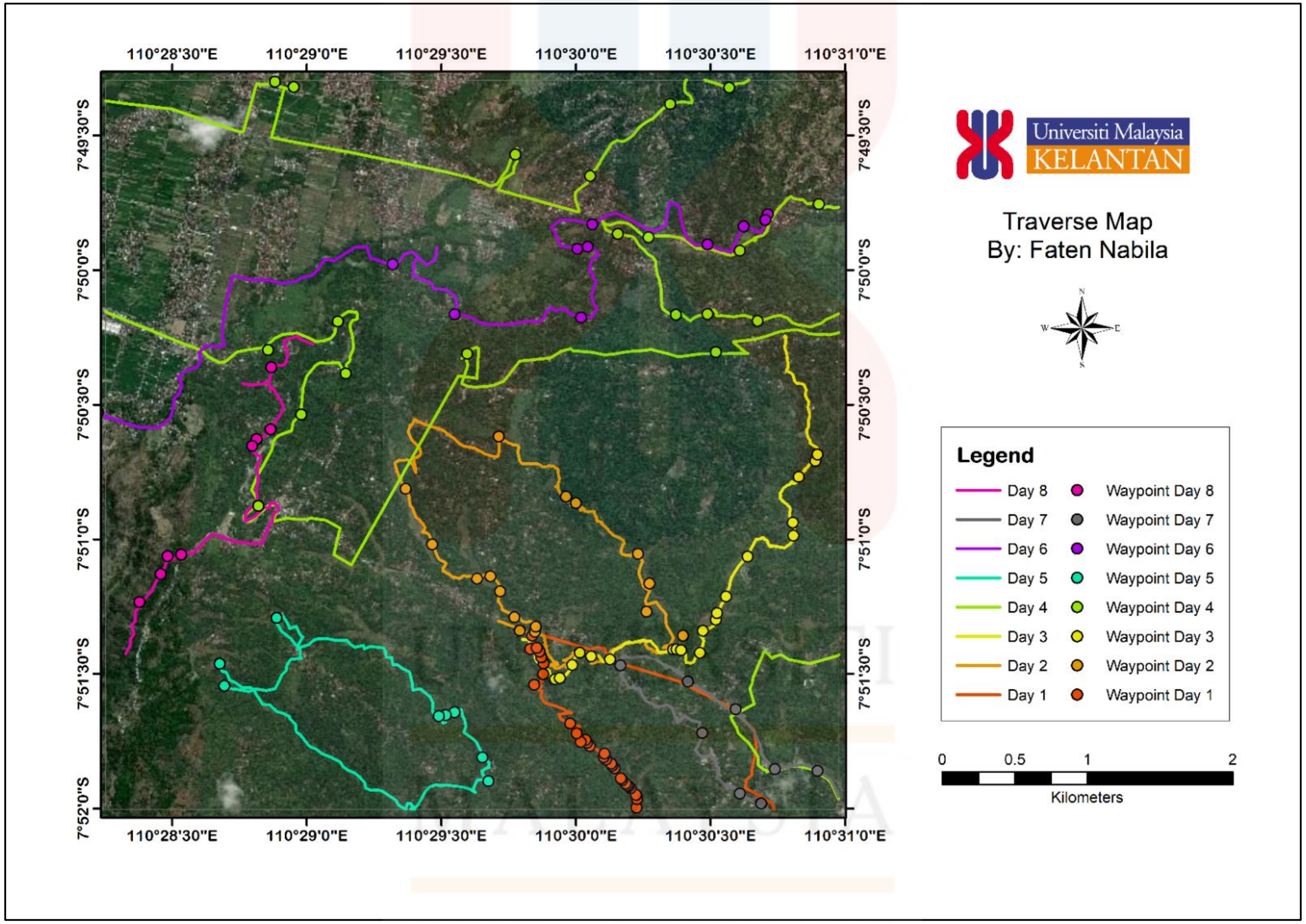


Figure 4.7: The Traverse Map and Observation Point.

4.2 Geomorphology

Geomorphology study covered and described the earth surfaces physical features and its landform including the evolution of the landforms through time from the origin. In this research, the main aspect of geomorphology that will be explained is the geomorphological classification, the weathering process and the drainage pattern of the study area. Figure 4.9 is the geomorphological map that shows the distribution of the landform based on the elevation. By knowing the morphology of the study area, the evolution and the properties of the study area can be determined, It is also an effective tool that helps in various type of planning and development activities.

4.2.1. Geomorphologic Classification

The geomorphological classification in the study area is explained topographically. Based on Raj (2009), topographic unit can be divided into five mean elevations, low lying, rolling, undulating, hilly and mountainous. The topographic unit with their mean elevations was shown in Table 4.1.

The highest elevation at the study area is 387.5 located in the eastern and southern part of the study area where it is more than 300 m above sea level. Therefore, it can be categorized as a mountainous location in the study area. The topographic unit found in the study area is undulating, hilly and mountainous where hilly becomes the main topographic unit in the study area. Figure 4.8 shows the part of study area with undulating and hilly topographic. The yellow line indicates the hilly area, while red line covered the undulating area of the study area.

Table 4.1: Topographic Unit

No.	Topographic Unit	Mean Elevation, m (sea level)
1.	Low Lying	Less than 15 m
2.	Rolling	16 m to 30 m
3.	Undulating	31 m to 75 m
4.	Hilly	76 m to 300 m
5.	Mountainous	More than 300 m

(Raj, 2009)

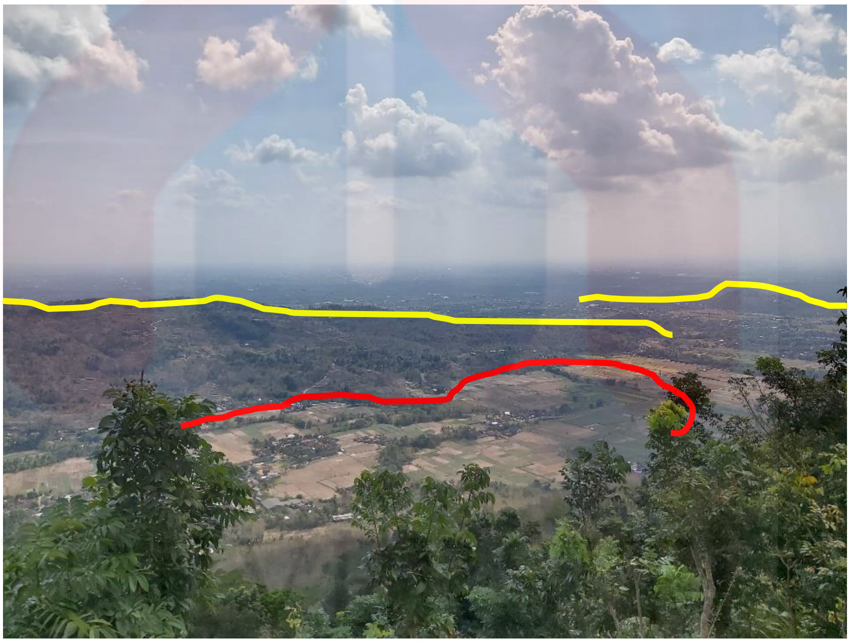


Figure 4.8: The undulating and hilly topographic.

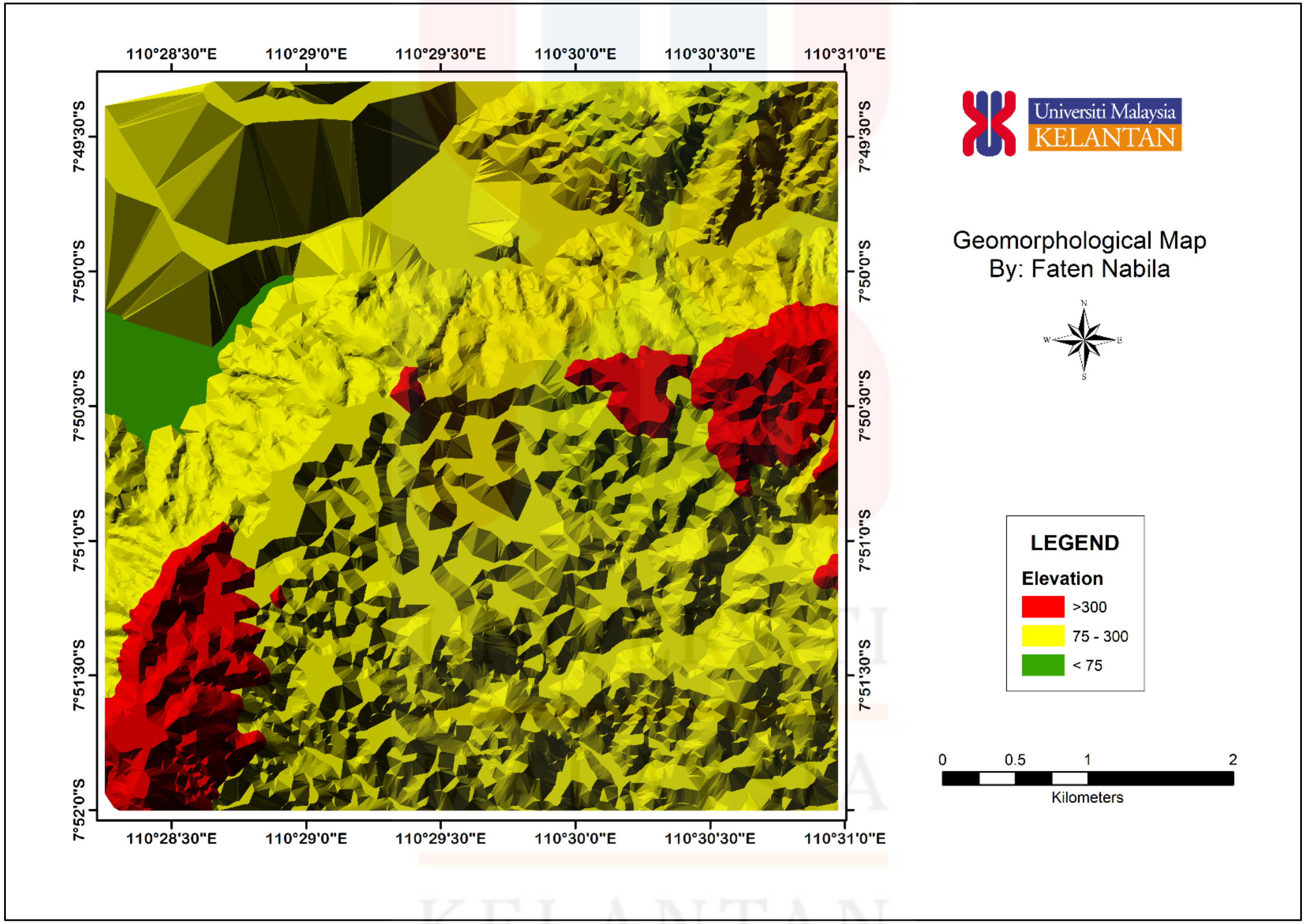


Figure 4.9: The Geomorphological Map of Study Area.

Based on the topographic unit classification, the geomorphologic classification can be identified where it consists of three types. The undulating hills landscape, escarpment valley and flat landscape. The undulating hills landscape is majority located in the southern part of the study area. The lithologies were dominantly volcanic rocks, which are pyroclastic breccia, epiclastic breccia and lava. The different contour patterns are because of the influences of resistance in the rock. If the contour was close with each other, it shows that the rock is highly resistance while for the loose pattern of contour; the rock is low in resistance.

Next, escarpment valley located in the middle of the study area from east to the west. Based on Figure 4.10, the escarpment valley can be found along the hills, resulted from faulting occurs in the study area. The lithologies are dominant with volcanic products such as tuff and pumice. The last geomorphological class is the flat landscape in the north-west of the study area was deposited by recent volcanic products. Figure 4.11 shows the 3-D Map of Patuk area where the undulating hills landscape labeled as (1), the escarpment valley labeled as (2) and flat landscape labeled as (3).

Figure 4.10: Part of the escarpment in the study area.

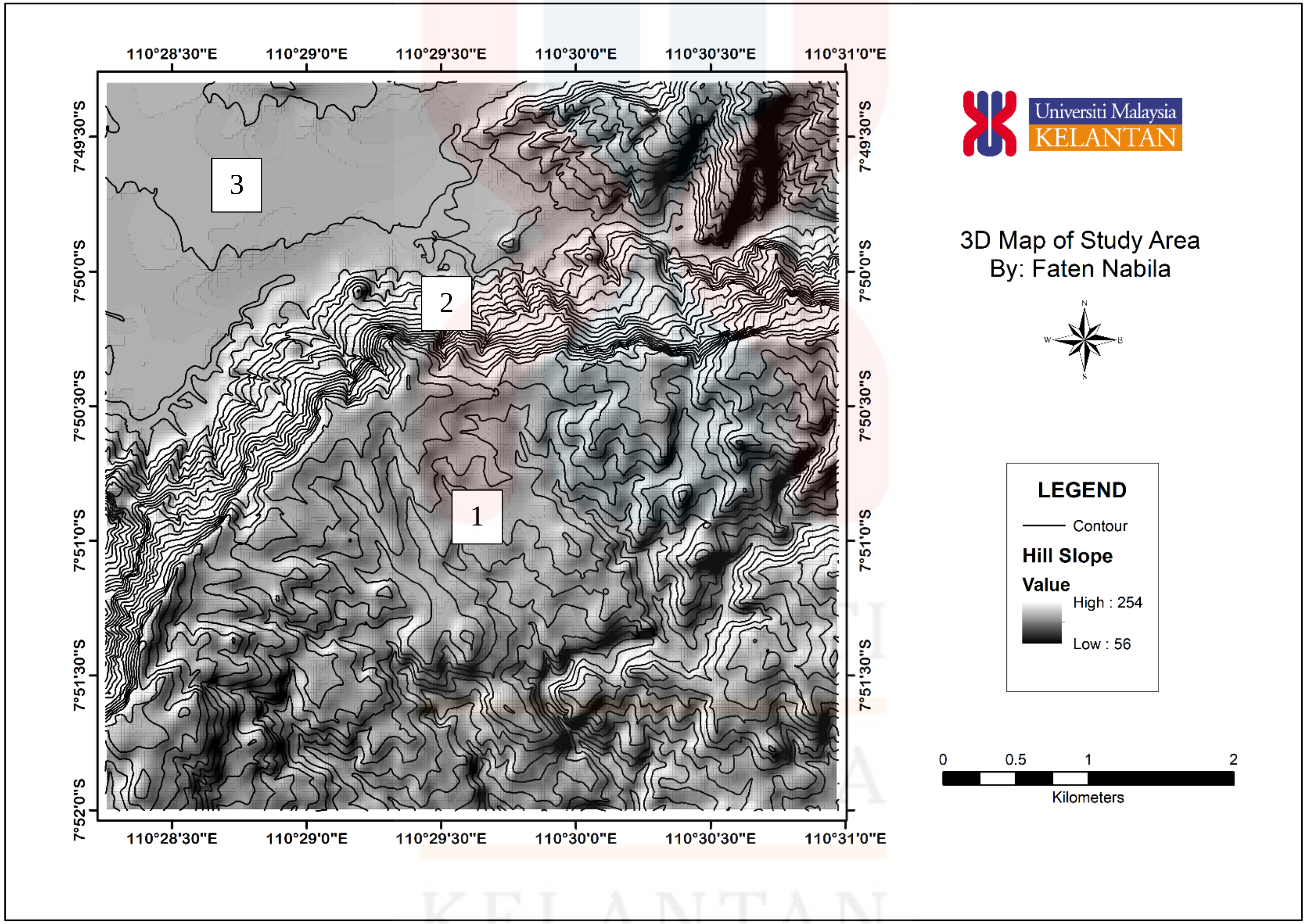


Figure 4.11: 3-D Map of the Study Area.

4.2.2. Weathering

Weathering is one of the endogenic process agents that change the landforms of earth's surface where the breakdown of rocks occurs by the chemical, biological or physical process. In Patuk area, there was three weathering process found, which is physical weathering, chemical weathering and biological weathering.

First, physical weathering. Physical weathering is known as mechanical weathering. It usually occurs because of changes in temperatures on rocks with the assist of water. The physical weathering found in the study area majorly occurs under the influence of water. Figure 4.12 shows the physical weathering where the rapidly moving water breaks the rocks at the outcrop resulting in holes below the outcrop. The large fragment of rock was breakdown from the parent rocks, pyroclastic breccia.

Figure 4.12: Example of Physical Weathering.

Next, the common chemical weathering in the study area is spheroidal weathering. Spheroidal weathering occurs at volcanic sandstone where chemical alteration occurs between the jointed rocks. Then, it will form spherical layers of highly decayed rock within the weathered parent rock. This is because of the abundant of secondary mineral in the altered rock. First, physical weathering takes place where joints were formed on the rock. Then, chemical alteration triggered the rock to weathered in spherical layers. Figure 4.13 shows the spheroidal weathering of rock at Patuk area.

Figure 4.13: Spheroidal Weathering, chemical weathering.

The last weathering type is biological weathering. Usually, biological weathering found in the study area is from the growth of tree roots. The small plant growth the root through the joint or open crack of rocks. Figure 4.14 shows the example of biological weathering in the study area.

Figure 4.14: The plant's root, biological weathering.

4.2.3. Drainage Pattern

Refer to Figure 4.15, shows the drainage map for the Patuk area. There were three main drainage basins known as Kali Gawe, Kali Petir and Kali Pentung. Kali Pentung river flows from North to South while Kali Petir flows from East to West of the study area. Kali Gawe flows towards the northern part of the study area. The river streams flow in the same direction for each main river and all the tributaries were connected together at the main river, known as a drainage basin. All of the small streams were collected there.

There was two drainage pattern found in the study area, which is a rectangular drainage pattern and dendritic drainage pattern. Based on Figure 4.15, rectangular drainage pattern is the dominant pattern in the study area. The rectangular pattern was identified based on the right angles caused by the fault structure in the study area. The study area is dominant with structure, where it can be seen from the drainage pattern especially at Kali Petir. Dendritic pattern found at the study area was determined by the characteristics of lithology, where it usually non-porous, impervious and highly resistance to the erosional process, usually volcanic rock, such pyroclastic breccia.

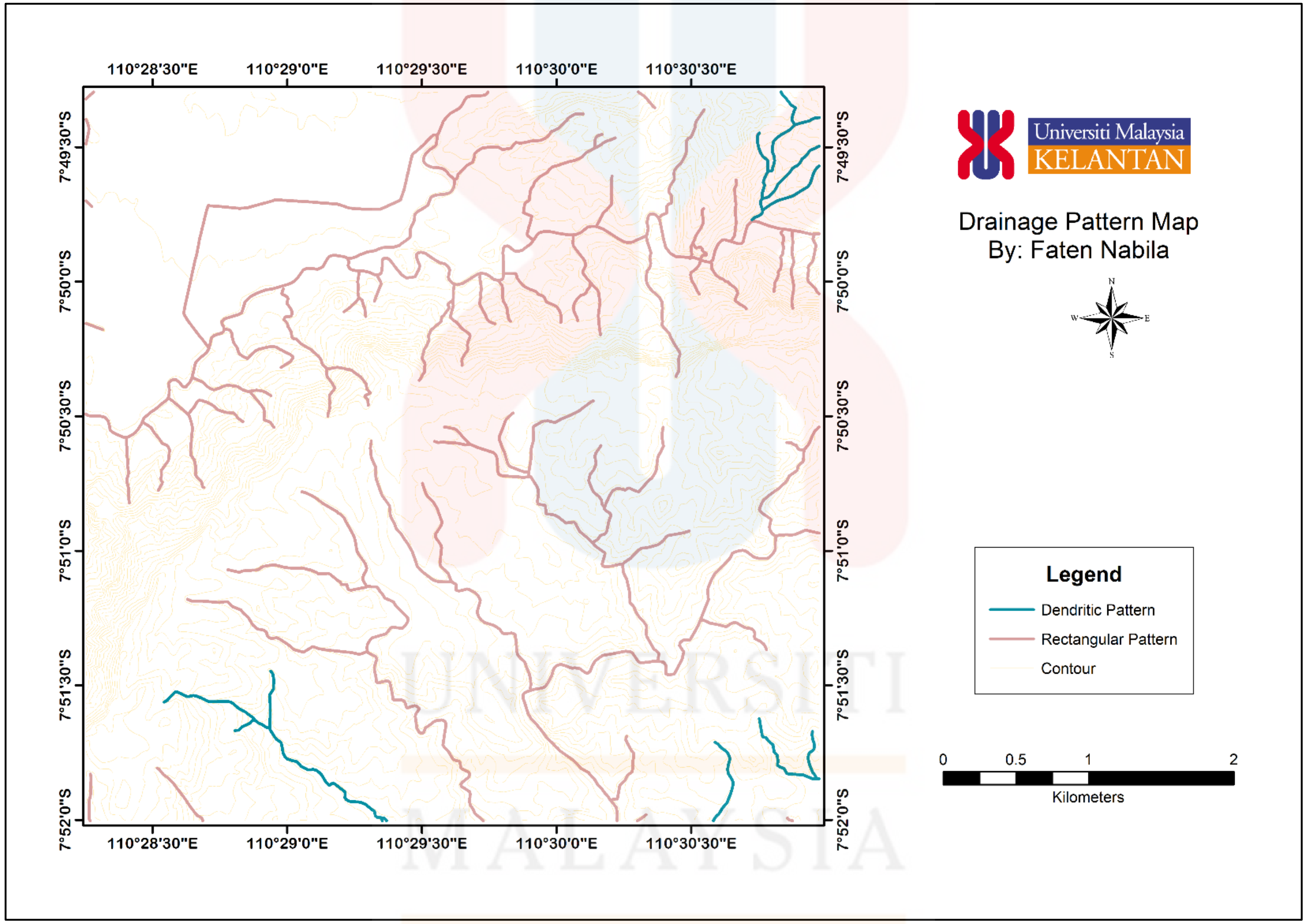


Figure 4.15: The Drainage Pattern Map of the Study Area.

4.3 Lithostratigraphy

Lithostratigraphy focus on the lithology unit of the study area that included the bodies of rocks, bedded and unbedded. The main lithology that covered the study area is volcanic rocks and consists of minor sedimentary rocks.

In order to determine the lithology unit of the study area, the differences between rocks were observed and marked during the traversing process. The result was shown in the lithology-traverse map in Figure 4.16. The map will help in identifying the major distribution of the rocks in the study area. Therefore, the lithology unit can be determined as well as the boundaries of different lithology units in the study area.

Specifically, the lithologies units for the study area were divided into five units, which are the Tuff Unit of Semilir Formation, Pyroclastic Breccia Unit of Nglanggeran Formation, Epiclastic Breccia Unit of Nglanggeran Formation, Lava Unit of Nglanggeran Formation and Merapi Alluvium Unit. All the units were named based on their dominant lithology. The lithology unit was divided accordingly in the geological map.

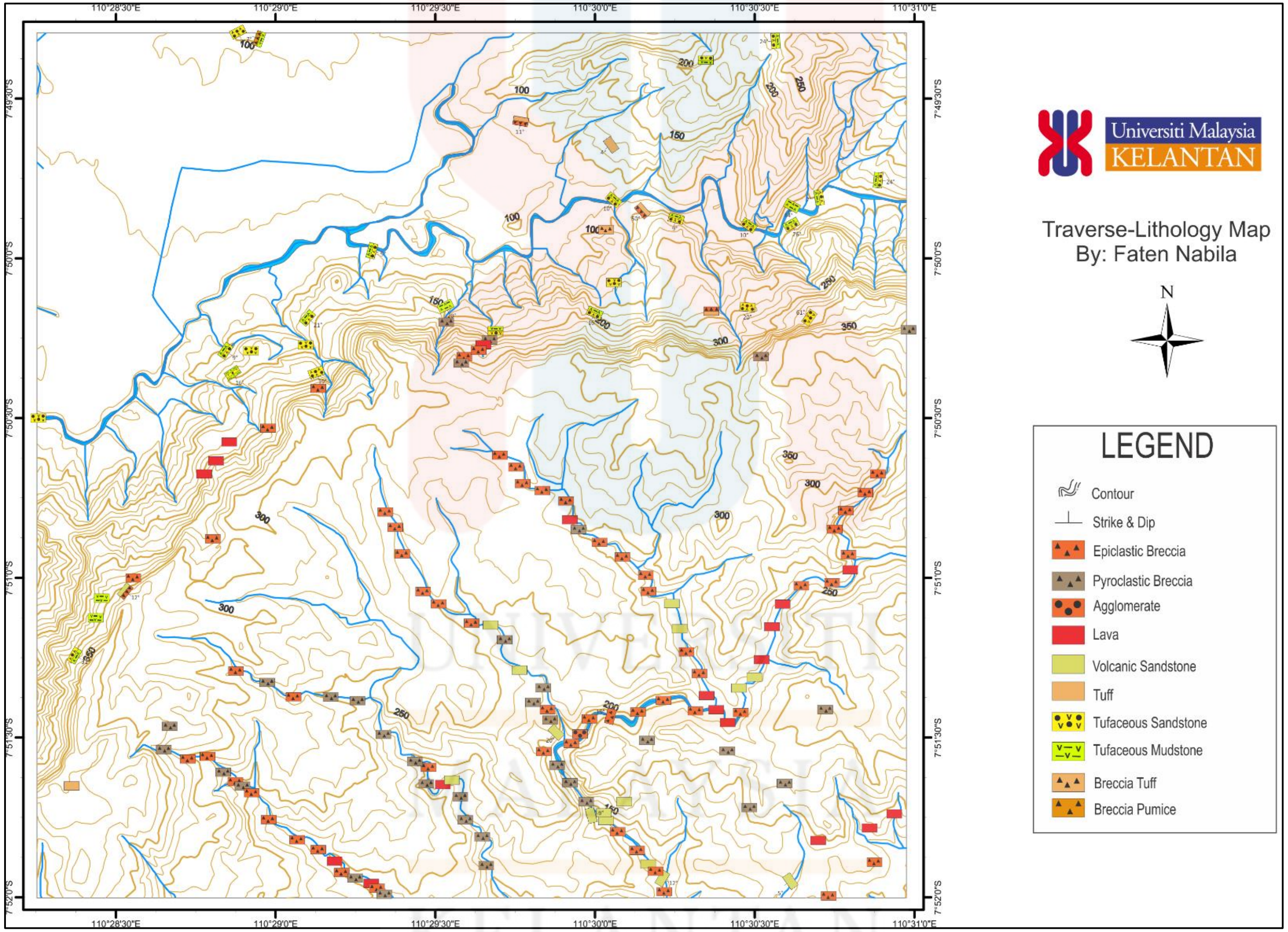


Figure 4.16: The Traverse-Lithology Map of Study Area.

4.3.1. Stratigraphic Position

Refer to Figure 4.17, the oldest lithology unit for the study area is Tuff Unit, which belongs to Semilir Formation. Tuff Unit formed during Early Miocene at the North of study area consists of Tuffaceous Sandstone and Tuffaceous Mudstone as the dominant rock. The second oldest rock belongs to Pyroclastic Breccia Unit, followed by Epiclastic Breccia Unit and Lava Unit, which all three of the lithology unit belong to the Nglanggeran Formation. These rocks unit located in the middle of the study area and have the same age Semilir Formation. It can be seen that Nglanggeran Formation overlay Semilir Formation, where the relationship between these two formations is conformity. It was shown on the geological map and in the field based on the observation. Next, there was a sharp contact between those two formations, where tuffaceous mudstone from Semilir Formation was overlain by pyroclastic breccia from Nglanggeran Formation. There was no interfingered sign between Semilir Formation and Nglanggeran Formation.

While the rocks unit in Nglanggeran Formation, the relationship between Pyroclastic Breccia Unit, Epiclastic Breccia Unit and Lava Unit is these lithology units are interfingered with each other as the deposition of the lithology unit is repeating and alternating with each other. The youngest lithology unit located at north of study area known as Merapi Alluvium forms during the Quaternary Period in Quaternary Volcanic Formation. The relationship between Merapi Alluvium Unit with other rocks units is unconformity because the different periods of deposition.

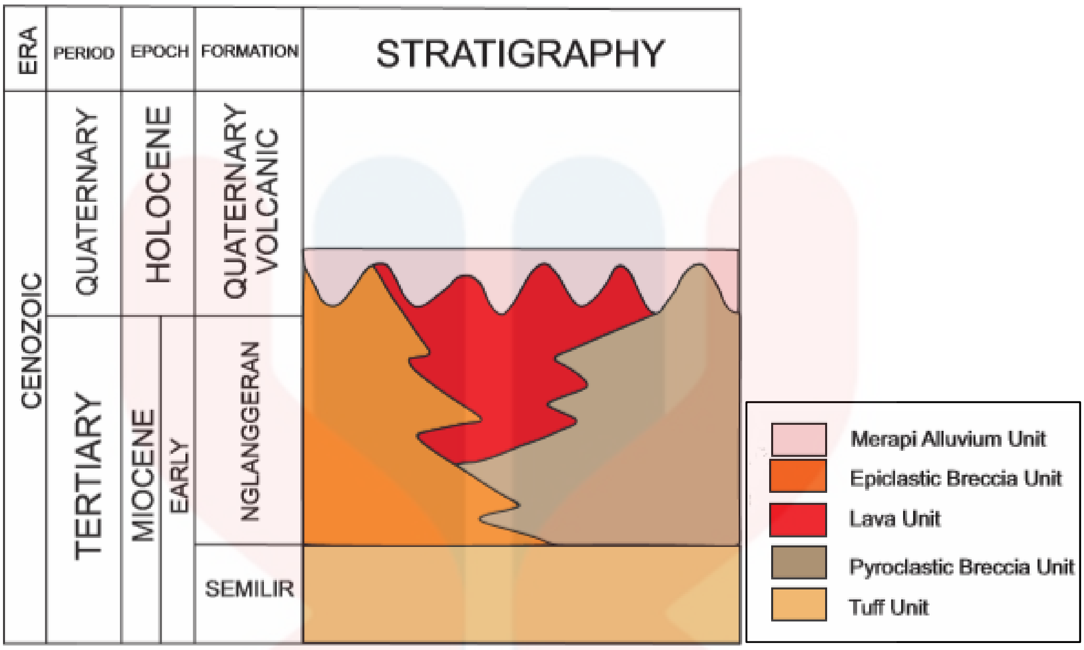


Figure 4.17: The Stratigraphic Position of Lithology unit for Patuk Area.

The stratigraphic position for the lithology unit in study area was determined based on the cross section produced from the geological map. The relationship for each lithology unit can be determined and stratigraphy column can be created. The cross section and stratigraphy column were shown in the geological map in Figure 4.18.

Based on the geological map and stratigraphy column, the lithology unit is decreasing in ages from North to South of the study area. Generally, the oldest lithology unit is in the Northern part of the study area, while younger towards the Southern part of the study area but the youngest lithology unit is in the Northern part of the study area. It consists of different periods between other lithology units in the Patuk area. The A1 size of geological map was shown at the last page of this thesis.

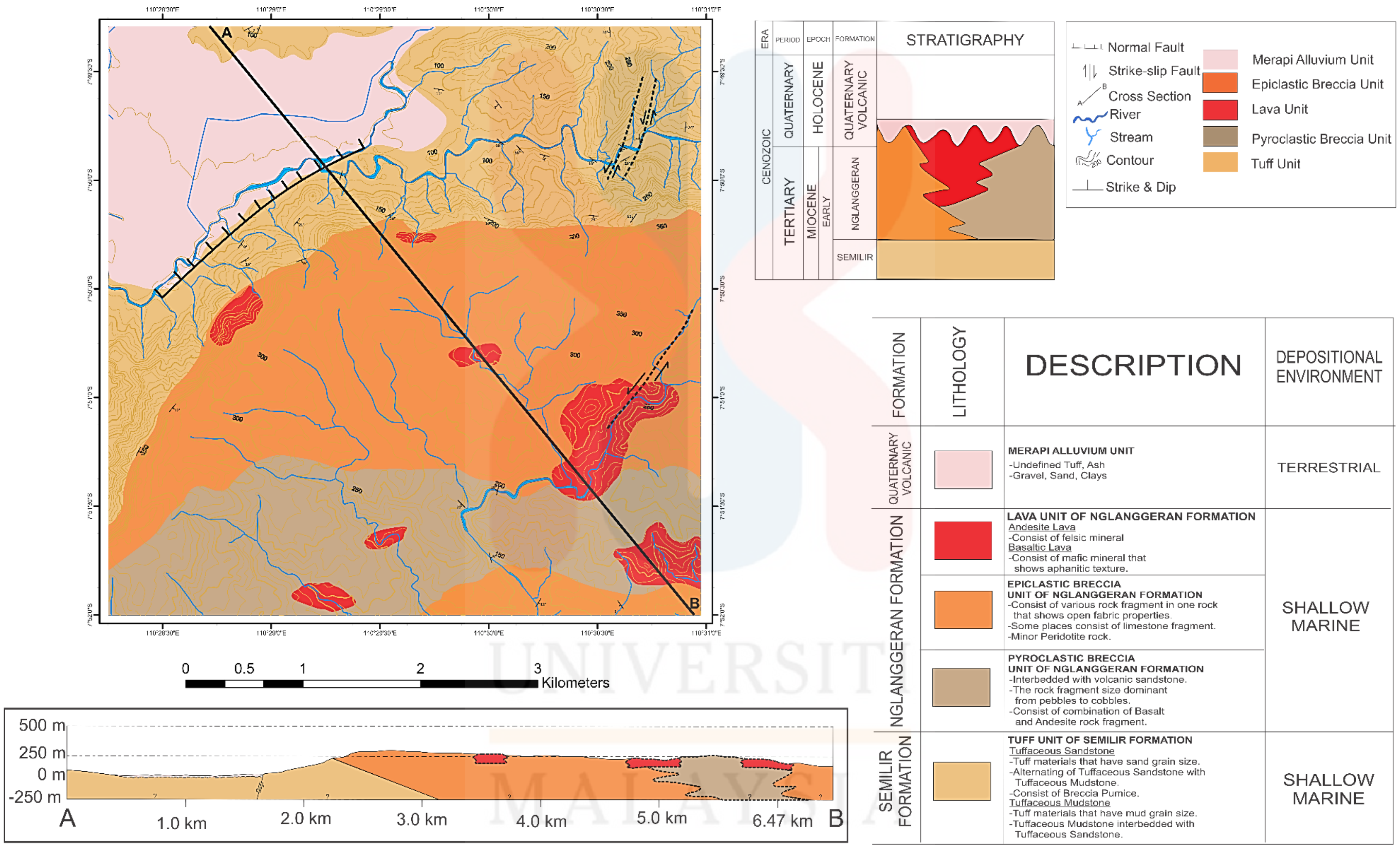


Figure 4.18: The Geological Map of Patuk Area.

4.3.2. Unit Explanation

In this sub-topic, all the lithology units are explained in more detail started from the oldest lithology unit to the youngest lithology unit. Each rock has different properties depending on the rock compositions based on the petrographic analysis in mineral identification. The properties of each rock unit were explained together with the primary structures found on the rocks such as turbidite features, lamination and others. These features can be an indicator of the depositional environment and help in determining the historical geology of each lithology unit. The rocks unit will be explained accordingly based on Figure 4.19.

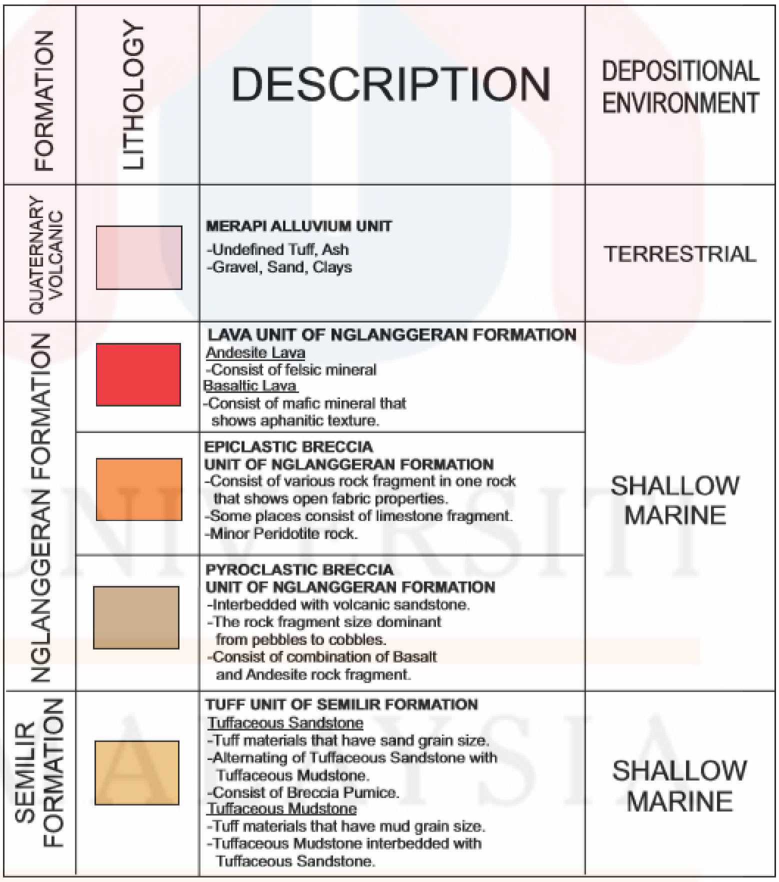


Figure 4.19: The Lithology Column for Patuk Area.

4.3.2.1. Tuff Unit of Semilir Formation

Tuff Unit is the oldest unit in a study area located in the northern part of the study area and was overlain by Merapi Alluvium and Nglanggeran Formation. This unit is unconformity with Merapi Alluvium and conformity with Nglanggeran Formation. There are two parts of Tuff Unit in the study area, which the minor part is in the upper part of study area known as Semilir Hill. While the major part of Tuff Unit is in the eastern part of the study area.

This unit is named as Tuff Unit because of the dominant composition of tuff mostly in every rock found in this formation. The majority of the rocks type found in the study area is sedimentary rock that consists of volcanic products as their main composition. The only difference is the grain size of the tuff products. The dominant rocks found at Tuff Unit are Tuffaceous Mudstone and Tuffaceous Sandstone followed by Tuff, Epiclastic Breccia Tuff and Breccia Pumice.

Based on Figure 4.20, the minor part that known as Semilir Hill is dominant with alternation of Tuffaceous Mudstone and Tuffaceous Sandstone and overlain by Breccia Pumice. This whole Semilir Hill represents the major lithologies for Semilir Formation. Semilir Hill outcrop was found at 7°49'23.97" S, 110°28'54.90" E in Bantul District.

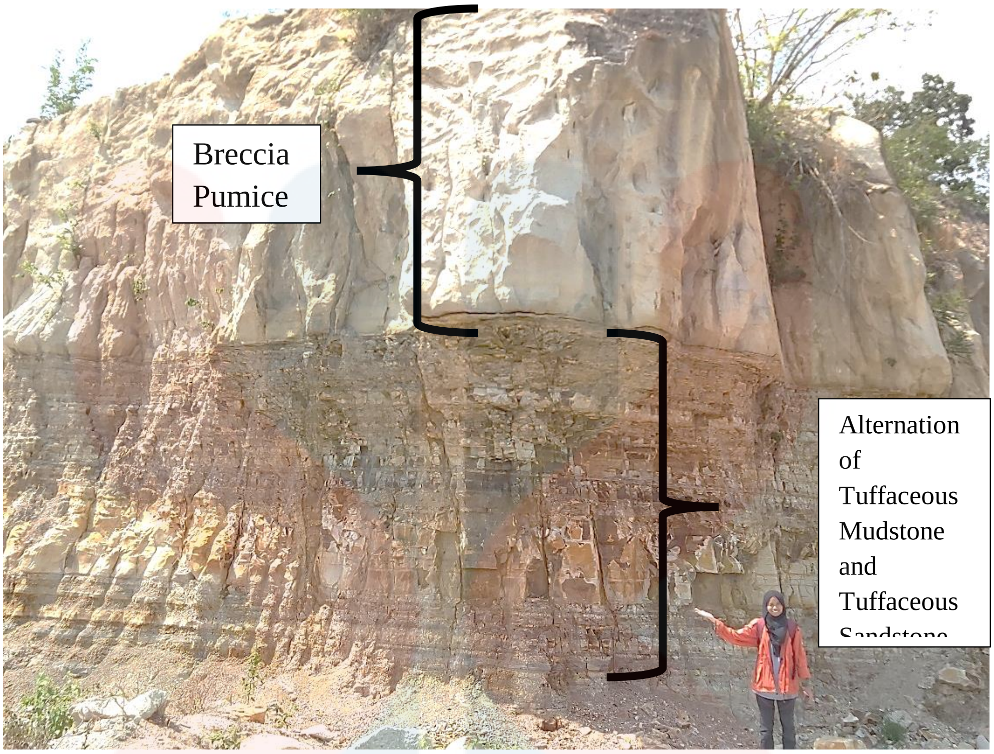


Figure 4.20: Semilir Hill.

Tuffaceous Sandstone

The tuffaceous sandstone composed of volcanic product dominant of tuff that has sands grain sizes. It was named based on the composition and the grain size of the rocks. Tuffaceous sandstone is one of the abundance rock in Semilir Formation where it usually alternating with tuffaceous mudstone and fragment of breccia pumice. Tuffaceous Sandstone can be found scattered in Tuff Unit of Semilir Formation. Figure 4.21 shows the outcrop of massive Tuffaceous Sandstone at Semilir Formation. The sample was taken and petrographic analysis was made. The sample for Tuffaceous Sandstone was collected at the coordinate of 07°50'11.35″S 110°30'40.46″E in the middle part of Semilir Formation.

Figure 4.21: The outcrop of Tuffaceous Sandstone.

The tuffaceous sandstone is white to light grey in colour because of the dominant tuff product composition. Most of the outcrop is less vegetation and can be observed clearly. The grains of this rock cannot be seen with naked eyes but can be felt by hand. Usually, tuffaceous sandstone can be found alternating with tuffaceous mudstone or interbedded in tuffaceous mudstone. The average thickness for the outcrop is around 45 cm to 100 cm. Figure 4.22 shows the hand specimen of tuffaceous sandstone labeled as FOC1.

Figure 4.22: Tuffaceous Sandstone (FOC1).

The picture for the thin section of tuffaceous sandstone was shown in Figure 4.23 in both Plain Polarize Light (PPL) and Cross Polarize Light (XPL). The observation was made in magnification of 10× where it can be seen that the tuffaceous sandstone was massive with grain size less than 1/256 mm to 1/16 mm. The grains are well sorted with the fragment and are close to each other.

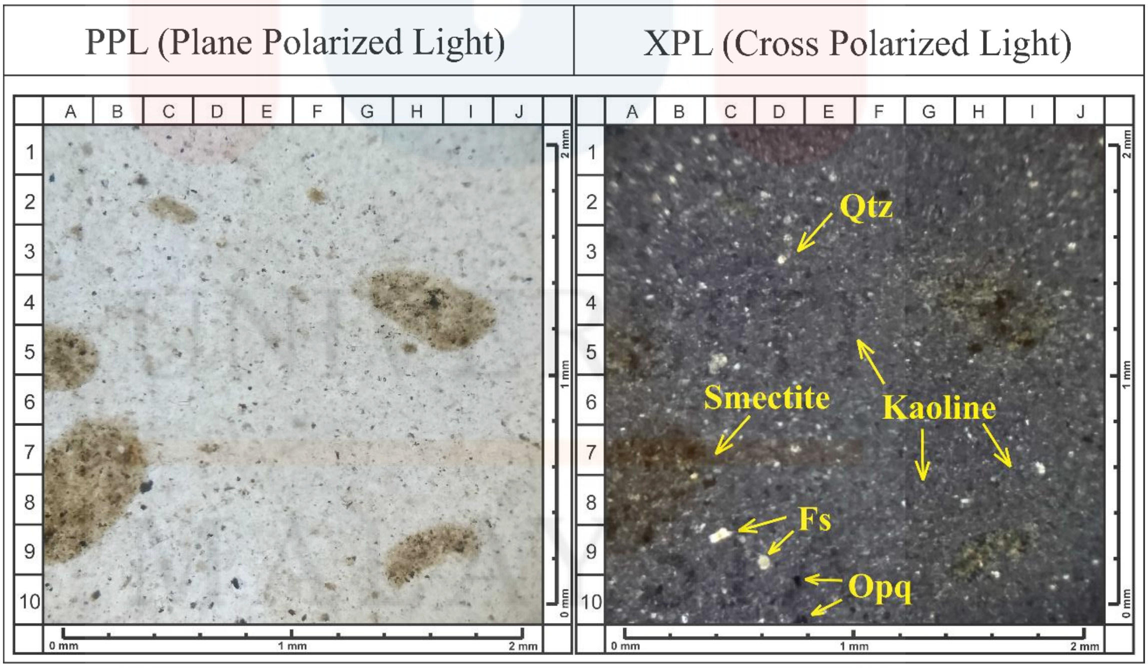


Figure 4.23: The photomicrograph of tuffaceous sandstone (FOC1). Quartz=Qtz, Fs=Feldspar, Opaque minerals=Opq.

There are five minerals found in the rock sample, which are Quartz (Qtz), Feldspar (Fs), Clay mineral is known as Kaoline and Smectite and Opaque mineral.

The description for each mineral was shown in Table 4.2. The descriptive properties of the rock sample show the characteristic of tuffaceous sandstone. While for the petrographic analysis, the rock sample can be classified as Vitric Tuffaceous Sandstone because of the dominant of vitric tuff product.

Table 4.2: The description of mineral under the thin section for Tuffaceous Sandstone rock sample (FOC1).

Mineral	**Description of Optical Mineralogy**
Quartz (Qtz)	White colour under the PPL and light grey colour under XPL. It shows low relief without cleavage. The pleochrosim is low and the crystal habit is an anhedral where it spread as microlit matrix. The percentage Quartz mineral in thin section is 2%.
Feldspar (Fs)	Light colour under PPL and red greyish under XPL. The crystal system is subhedral to euhedral where the crystal is bounded by its characteristic faces. It shows albite twinning with moderate of pleochrosim and cleavage breaks in one direction. The percentage of Feldspar is 1%.
Clay Mineral, Kaoline	Under PPL, the colour of the mineral is white, while under XPL, the colour is greyish black. There is no relief, pleochrosim, crystal system and crystal habit found. It spread in the thin section as a matrix with percentage of 88% mineral abundance.
Clay Mineral, Smectite	White colour under PPL and greyish black under XPL. There is no distinct crystal system and crystal habit,

	pleochrosim and relief found in the mineral. The abundance of the mineral is 8%.
Opaque Mineral (Opq)	Black colour under both PPL and XPL. The mineral can be found spread in the rocks where the abundance of the mineral is 1%.

Tuffaceous Mudstone

Tuffaceous Mudstone consists of dominantly of tuff product, but the grain size of tuff is finer than Tuffaceous Sandstone. The colour of the rock is more to greyish colour and dark grey. The major different between Tuffaceous Sandstone and Tuffaceous Mudstone is the cleavage on the rocks. Tuffaceous Mudstone is finer than Tuffaceous Sandstone. Therefore, the cleavage is more clear and distinctive on the rock.

Tuffaceous Mudstone usually found interbedded or alternating with Tuffaceous Sandstone. There is no massive Tuffaceous Mudstone outcrop found in the Tuff Unit of Semilir Formation. The outcrop for Tuffaceous Mudstone is moderately weathered where it easily breaks because of the cleavage of the outcrop. Figure 4.24 shows the outcrop of the Tuffaceous Mudstone. There is no petrographic analysis as the sample is really weathered and it only breaks in small fragments. The location of the Tuffaceous Mudstone in Figure 4.24 is at 7° 49' 19.3512" S 110° 30' 34.1388" E labeled as FOC8.

Figure 4.24: The Tuffaceous Mudstone.

Breccia Tuff and Tuffaceous Sandstone

Breccia Tuff consists of Tuff fragment that overlay by Tuffaceous Sandstone. The location of the outcrop can be found at 7° 49' 55.7076" S 110° 30' 36.5292" E labeled as FOC6 and 7° 49' 19.2144" S 110° 28' 57.0972" E labeled as FOC11. Figure 4.25 shows the Breccia Tuff at location FOC6. Figure 4.26 shows that Pumice structure was present in the Breccia Tuff. The colour of the breccia tuff is white where the fragment size is majority is granule fragment size. The sample of Breccia Tuff was collected at FOC11 and used for petrographic analysis.

Figure 4.25: The Breccia Tuff overlay with Tuffaceous Sandstone at FOC6.

Figure 4.26: Pumice structure found in Breccia Tuff.

The minerals found in the Breccia Tuff are Quartz (Qtz), Feldspar (Fs), Volcanic Glass and Opaque Mineral (Opq). The sample rock for Breccia Tuff was shown in Figure 4.27 and the description of the mineral was shown in Figure 4.28 and was explained in Table 4.3. The observation was made in 10× magnification of microscope. The structure of the rock is massive with texture of grain size in range of 1/256 mm to 1/2 mm with poorly sorted arrangement and subangular to subrounded shape of fragment.

Figure 4.27: The Breccia Tuff sample (FOC11).

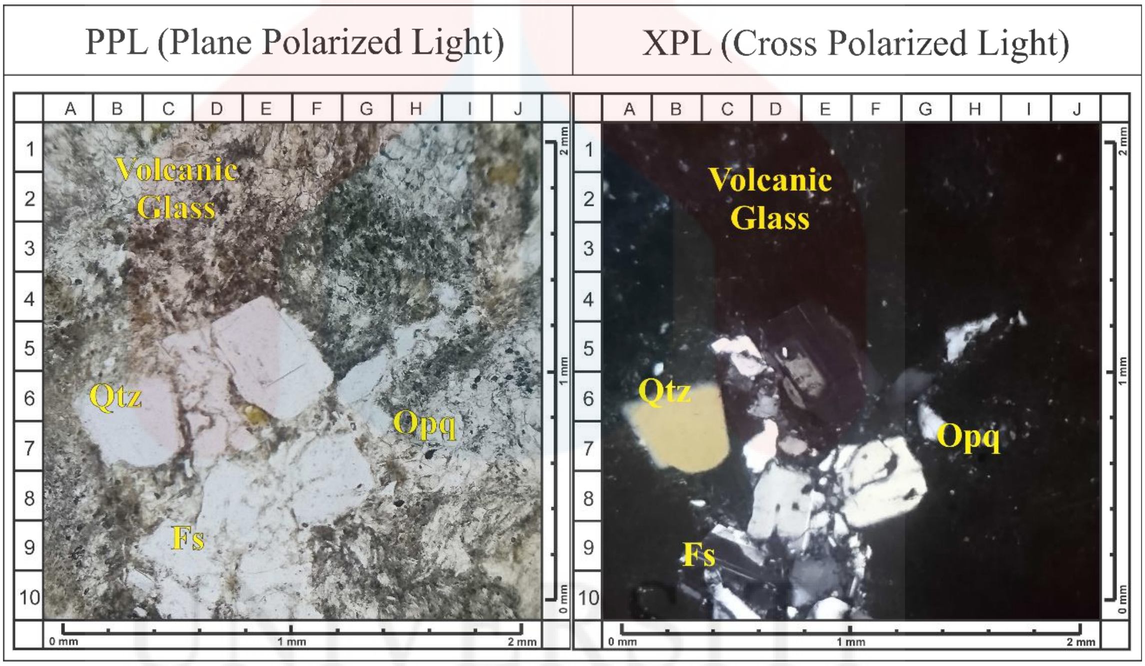


Figure 4.28: The photomicrograph of Breccia Tuff (FOC11). Quartz=Qtz, Fs=Feldspar, Opaque minerals=Opq.

Table 4.3: The description of mineral under the thin section for Breccia Tuff rock sample (FOC11).

Mineral	**Description of Optical Mineralogy**
Quartz (Qtz)	More like secondary quartz is known as cement. Under PPL shows white colour and greyish black under XPL. Low relief without cleavage. The pleochrosim is low and the crystal habit is anhedral. Spread in the rock with mineral abundance of 10%.
Feldspar (Fs)	Light colour under PPL and red greyish under XPL. The crystal system is subhedral to euhedral where the crystal is bounded by its characteristic faces. It shows albite twinning with moderate of pleochrosim and cleavage breaks in one direction. The percentage of Feldspar is 10%.
Volcanic Glass	White brownish under PPL and black greyish colour under XPL. The relief, pleochrosim, crystal habit and cleavage cannot be seen. It acts as matrix with abundancy of 79% in rock.
Opaque Mineral (Opq)	Appear black under both PPL and XPL. The mineral can be seen scattered in the rock with abundancy of 1%.

It can be called Vitric Tuff because of the presence of pumice and volcanic glass in the rock. Therefore, in genesis aspect, the Breccia Tuff is known as Vitric Tuff.

<u>Massive Tuffaceous Sandstone</u>

A massive outcrop of Tuffaceous Sandstone was found at the study area labeled as FOE8, located at 7° 50' 10.5828" S 110° 30' 1.1124" E. The properties of the outcrop and the description of the rock is similar with other Tuffaceous Sandstone but the grain size is different. The thickness of the Tuffaceous Sandstone found is more than 1.6 m. Figure 4.29 shows the outcrop of the massive Tuffaceous Sandstone. The grain size of the Tuffaceous Sandstone is from very fine at the upper of the outcrop to coarse grain size downwards. The sample taken was shown in Figure 4.30.

Figure 4.29: The massive Tuffaceous Sandstone (FOE8).

Figure 4.30: The sample for Tuffaceous Sandstone (FOE8).

The minerals found in the Tuffaceous Sandstone are Lithic Fragment, Quartz (Qtz), Feldspar (Fs), Clinopyroxene (Cpx) Volcanic Glass and Opaque Mineral (Opq). The petrographic image was shown in Figure 4.31. The characteristics of each mineral were explained in Table 4.4. The observation was made in 10× magnification of microscope. The structure of the rock is massive with texture of grain size in range of 1/256 mm to 1 mm with poorly sorted arrangement and subangular to subrounded shape of fragment.

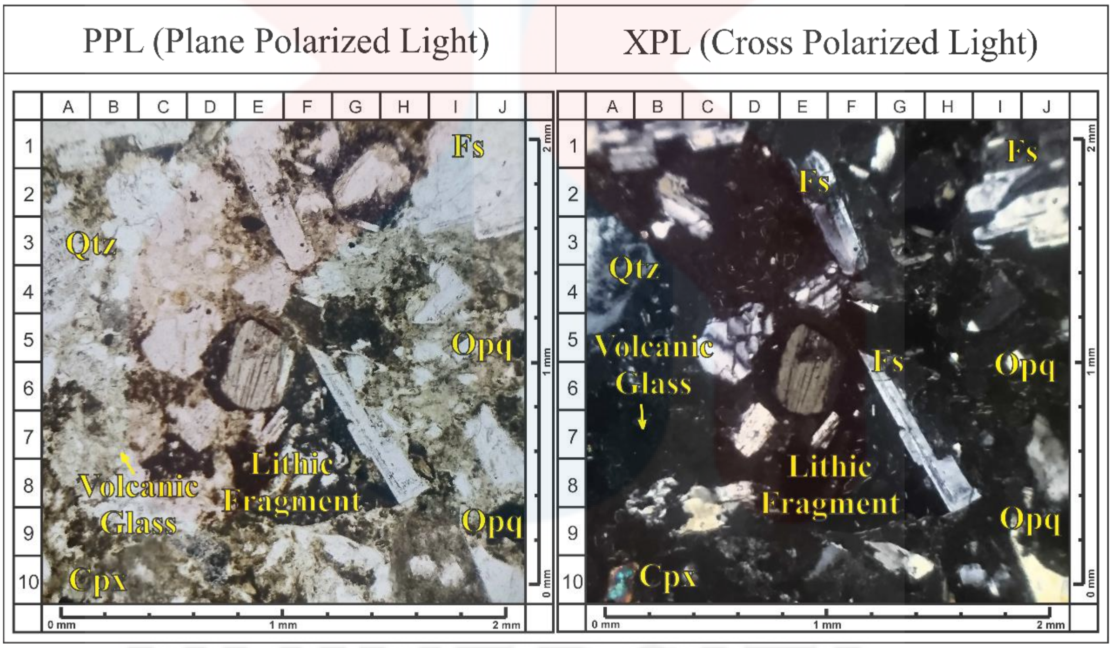


Figure 4.31: The photomicrograph of Tuffaceous Sandstone (FOE8). Quartz=Qtz, Fs=Feldspar, Opaque minerals=Opq, Clinopyroxene=Cpx.

Table 4.4: The description of mineral under the thin section for Tuffaceous Sandstone rock sample (FOE8).

Mineral	**Description of Optical Mineralogy**
Lithic Fragment	Brown colour under PPL and dark brown under XPL. Consist of quartz, feldspar, pyroxene, volcanic glass and opaque mineral in the fragment. The fragment abundancy is 20%.
Quartz (Qtz)	More like secondary quartz is known as cement. Under PPL shows white colour and greyish black under XPL. Low relief without cleavage. The pleochrosim is low and the crystal habit is anhedral. Spread in the rock with mineral abundance of 5%.
Feldspar (Fs)	Light colour under PPL and red greyish under XPL. The crystal system is subhedral to euhedral where the crystal is bounded by its characteristic faces. It shows albite twinning with moderate of pleochrosim and cleavage breaks in one direction. The percentage of Feldspar mineral is 30%.
Clinopyroxene (Cpx)	Light brown under PPL and various colour under XPL, which is blue, purple, pink and orange in colour. Low relief with two directions of cleavage. Consist of low pleochrosim and the mineral is in spotted pattern in the rock. The abundance of the mineral is 2%.
Volcanic Glass	White brownish under PPL and black greyish colour under XPL. The relief, pleochrosim, crystal habit and cleavage cannot be seen. It acts as matrix with abundancy of 38% in rock.

Opaque Mineral (Opq)	Appear black under both PPL and XPL. The mineral can be seen scattered in the rock with abundancy of 5%.

The genesis of Tuffaceous Sandstone is dominant with volcanic glass. Therefore, it can be classified as vitric tuff. The genesis name for this rock is Vitric Tuffaceous Sandstone.

4.3.2.2. Pyroclastic Breccia Unit of Nglanggeran Formation

Pyroclastic Breccia Unit is overlain the Tuff Unit of Semilir Formation. The unit can be found interfingered with Lava Unit and Epiclastic Breccia Unit in Nglanggeran Formation. This unit can be found dominantly in the southern part of the study area. The minimum thickness of the unit based on geological map is 625 m and the maximum thickness is 1.3 km. The Pyroclastic Breccia unit was classified as one unit because of the dominant of pyroclastic breccia in this area. Pyroclastic Breccia can be found scattered in Nglanggeran Formation, but it was abundance in southern part of study area.

The dominant rock found in the study area is pyroclastic breccia. Figure 4.32 shows the outcrop of massive pyroclastic breccia found in the study area. It usually in a high elevation where the rock is high resistance towards weathering or erosion. The fragment found are basalt fragment or andesite fragment. The fragment size can vary depends on the location where it can be from granule to cobbles size of fragment. Pyroclastic breccia can be found as a large boulder more than 200 m diameter size as shown in Figure 4.33.

Figure 4.32: The massive outcrop of Pyroclastic Breccia.

Figure 4.33: Large boulder of Pyroclastic Breccia.

The deposition of the pyroclastic breccia triggered by the explosion at the volcanic vents where it resulted from the expansion of the magmatic gas eruption. Therefore, pyroclastic breccia can be found deposited in many locations in study area where every pyroclastic found represent differences periods of eruptions. Every location consists of different sizes of fragments. This will be explained more detailed in Chapter 5, for specification of the research.

Figure 4.34 shows the close-up image for the pyroclastic breccia where the arrangement of the rock fragment can be seen. The fragment composition is more dominant than its matrix. The size of the fragment can be vary, from 0.3 cm to more than 25 cm that composed of andesite and basaltic type of rocks. The angular fragment sizes in the pyroclastic breccia reveal that the rocks have transport nearby, which acts as indicator for its deposition process where it might near the sources of the volcanic product.

Figure 4.34: Pyroclastic Breccia outcrop (Close Up).

Pyroclastic Breccia usually black or dark greyish in colour depends on the dominant rock fragment in the rock. The hardness of the rock is high where the fabric of the rock is silica with a closed arrangement between rock fragments. The texture of the rock based on field observation is classified as lithic texture. It is classified as a low porosity of rock and bad sorting of rock fragments and minerals. The sample was taken at 7° 51' 27.72" S 110° 28' 40.5624" E labeled as FOD10. Figure 4.35 shows the hand specimen for pyroclastic breccia rock.

The minerals found in the pyroclastic breccia rock sample are lithic fragment, Quartz (Qtz), Feldspar (Fs), Orthopyroxene (Opx), Volcanic glass and opaque minerals (Opq). The mineral distribution was shown in Figure 4.36. While for the petrographic analysis, the analysis was made in 10× magnification. The structure of the rock is massive with average fragment texture of less than 1/256 mm to 1.5 mm. The rock was arranged in closed fabrics with poor sortation. The mineral description was explained in Table 4.5.

Figure 4.35: The hand specimen for pyroclastic breccia (FOD10).

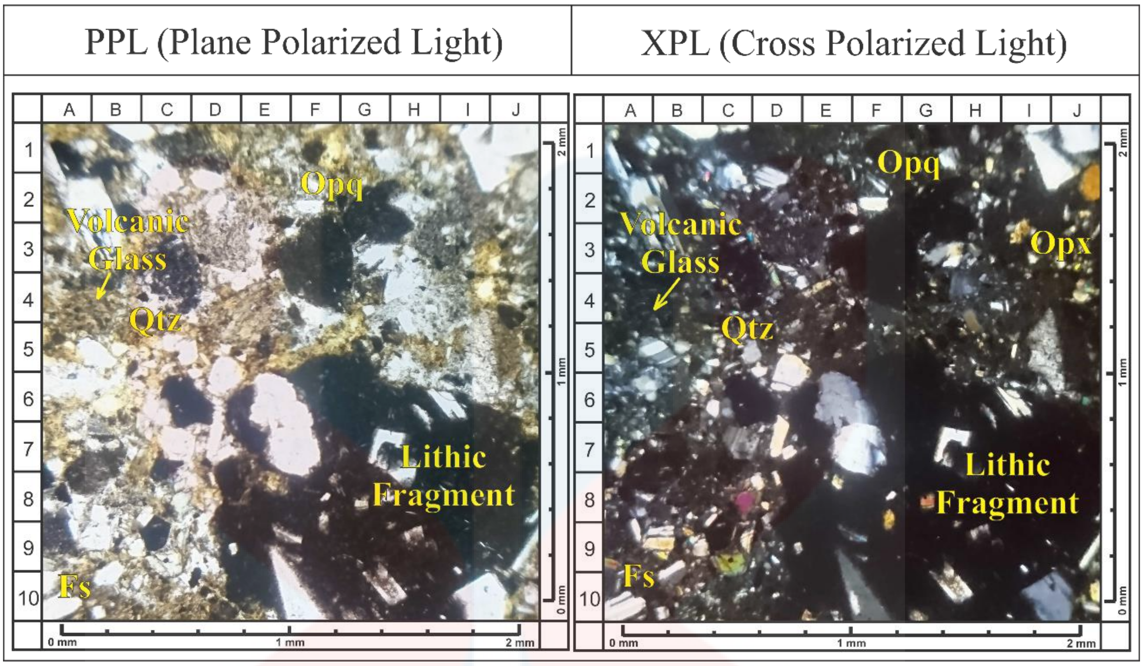


Figure 4.36: The photomicrograph of Pyroclastic Breccia (FOD10). Quartz=Qtz, Fs=Feldspar, Opaque minerals=Opq, Orthopyroxene=Opx.

Table 4.5: The description of mineral under the thin section for the Pyroclastic Breccia rock sample (FOD10).

Mineral	**Description of Optical Mineralogy**
Lithic Fragment	Appear brown colour under PPL and dark brown under XPL. The fragment consists of quartz, feldspar, pyroxene mineral, opaque mineral and volcanic glass. Its presence as spotted in thin section. The abundancy of lithic fragment is 35%.
Quartz (Qtz)	White colour under PPL and white greyish colour under XPL. The relief is low without any cleavage with low pleochrosim. The crystal system is anhedral. The mineral can be found scattered in the rock with an abundancy of 8%.
Feldspar (Fs)	Light colour under PPL and reddish grey under XPL. The crystal system varies from subhedral to euhedral. Albite

	twinning present with moderate pleochrosim. Consist of one direction of cleavage with abundancy of mineral is 15%.
Orthopyroxene (Opx)	Appear light brown under PPL and greyish-yellow with brownish-orange under XPL view. The relief is low with two directions of cleavage. It has low pleochrosim and appears as spotted in the thin section. The abundancy is 4%.
Volcanic Glass	White brownish under PPL and black greyish colour under XPL. The relief, pleochrosim, crystal habit and cleavage cannot be seen. The abundancy is 33%.
Opaque Mineral (Opq)	Appear black under both PPL and XPL. The mineral can be seen scattered in the rock with abundancy of 5%.

4.3.2.3. Epiclastic Breccia Unit of Nglanggeran Formation

Epiclastic Breccia Unit is the major unit found in the study area for Nglanggeran Formation. It consists of two part, which is in the middle part of the study area, from west to east and the small part at the south of Patuk area. The thickness for the unit is approximately 2 km, larger than Pyroclastic Breccia Unit. This unit is interfingered with Pyroclastic Breccia and Lava Breccia because of the same age of deposition. The unit named as Epiclastic Breccia Unit because the rocks found at these parts are dominant by epiclastic breccia rock. There are several different rocks found at this unit, such as limestone fragment and volcanic sandstone. Epiclastic breccia rock outcrop can be found scattered in Nglanggeran Formation but usually interbedded along with lava and pyroclastic breccia rock depends on the volcanism activity.

The properties of rock for the Epiclastic Breccia Unit in the middle and in the south of study area are slightly different. The middle part of the study area consists of a limestone fragment that becomes larger towards the Semilir Formation. This part also consists of Basalt porphyry outcrop. While in the Southern part of study area, volcanic sandstone can be found abundance towards the formation Sambipitu. The grain sizes are coarser and mineral is hard to be observed. The rock's properties are very similar to Sambipitu Formation rock. Refer to Figure 4.37, epiclastic breccia outcrop deposited at low elevation compared to pyroclastic breccia outcrop. The resistance of the rocks also slightly low compared with the pyroclastic breccia. This is because the arrangement of the rock fragment and properties of the rock itself.

Figure 4.37: The epiclastic breccia outcrop.

Epiclastic breccia is different from pyroclastic breccia because of the deposition system. Epiclastic breccia or known as epiclasts or lahar flow formed from the deposition and sedimentation process of the pyroclastic fragment. The explosive volcanic product or pyroclastic fragments from the volcanoes eruption transported by the water and deposited under the influenced of water and sedimentation. The main agent for epiclastic breccia deposition is water. Therefore, because of the abundance of epiclastic breccia rock in study area, it was deposited in marine environment.

Figure 4.38 shows the close up image for epiclastic breccia rock where the fragments for the rock can be seen clearly. The fragment composition is more dominant than the matrix. The size of the fragment are varied and smaller than pyroclastic breccia, which is 2 mm to 15 cm composed of various types of rock depending on the location, it can be limestone fragment, sandstone, basaltic and andesite fragment rock. The angular to subrounded fragment sizes shows that the rocks transport far away from the sources.

Figure 4.38: The close up of epiclastic breccia.

Epiclastic Breccia usually dark greyish in colour depends on the dominant rock fragments in the rock. The hardness of the rock is classified as brittle compared to pyroclastic breccia rock. The rock fabrics composed of silica with opened arrangement between rocks fragment. The matrix for the rocks is composed of tuff with moderately quality of porosity. However, the arrangement of the rock fragment is low and bad sortation. The sample was taken at 7° 51' 33.6" S 110° 28' 43.2" E labeled as FOD1. Figure 4.39 shows the hand specimen for epiclastic breccia rock.

The minerals found in epiclastic breccia rock are lithic fragment, Quartz (Qtz), Feldspar (Fs), Orthopyroxene (Opx), Volcanic glass and opaque minerals (Opq). The mineral distribution was shown in Figure 4.40. While for the petrographic analysis, the analysis was made in 10× magnification. The structure of the rock is massive with an average fragment texture of less than 1/256 mm to 1.5 mm. The rock was arranged in open fabrics with poor sortation. The mineral description was explained in Table 4.6.

Figure 4.39: The hand specimen for epiclastic breccia (FOD1).

PPL (Plane Polarized Light)	XPL (Cross Polarized Light)

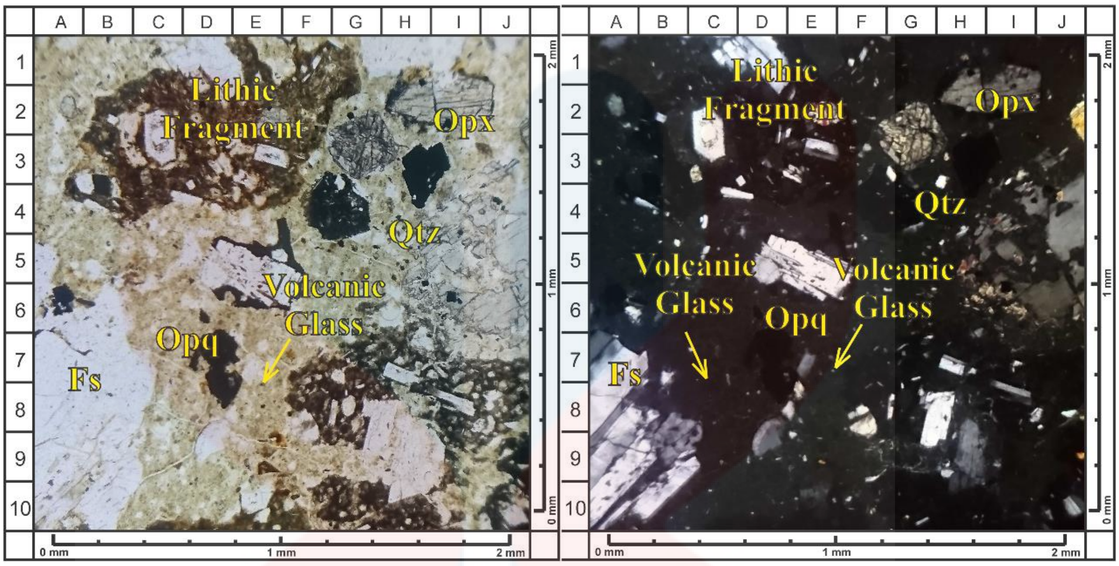


Figure 4.40: The photomicrograph of Epiclastic Breccia (FOD1). Quartz=Qtz, Fs=Feldspar, Opaque minerals=Opq, Orthopyroxene=Opx.

Table 4.6: The description of mineral under the thin section for Epiclastic Breccia rock sample (FOD1).

Mineral	**Description of Optical Mineralogy**
Lithic Fragment	Appear brown colour under PPL and dark brown under XPL. The fragment consists of quartz, feldspar, pyroxene mineral, opaque mineral and volcanic glass. Its presence as spotted in thin section. The abundancy of lithic fragment is 40%.
Quartz (Qtz)	White colour under PPL and white greyish colour under XPL. The relief is low without any cleavage with low pleochrosim. The crystal system is anhedral. The mineral can be found scattered in the rock with an abundancy of 2%.
Feldspar (Fs)	Light colour under PPL and reddish grey under XPL. The crystal system varies from subhedral to euhedral. Albite

	twinning present with moderate pleochrosim. Consist of one direction of cleavage with abundancy of mineral is 15%.
Orthopyroxene (Opx)	Appear light brown under PPL and greyish-yellow with brownish-orange under XPL view. The relief is low with two directions of cleavage. It has low pleochrosim and appears as spotted in thin section. The abundancy is 15%.
Volcanic Glass	White brownish under PPL and black greyish colour under XPL. The relief, pleochrosim, crystal habit and cleavage cannot be seen. The abundancy is 30%.
Opaque Mineral (Opq)	Appear black under both PPL and XPL. The mineral can be seen scattered in the rock with abundancy of 5%.

<u>Volcanic Sandstone and Breccia Tuff</u>

The south part of the study area in Epiclastic Breccia Unit consists a few locations of volcanic sandstone. Figure 4.41 shows the outcrop of volcanic sandstone with bedding with strike and dip reading of N 31°E/ 12°. The rock name as volcanic sandstone because of the composition where it consists of dominant sandstone grain size with volcanic product and tuff fragment. Volcanic Sandstone usually came with the alteration of epiclastic breccia and pyroclastic breccia rock. The fragment size is usually 1/256 mm to 2 mm. The location for volcanic sandstone shows in Figure 4.41 was labeled as FOP2 with coordinate of 7° 51' 56.9844" S 110° 30' 13.392" E.

Figure 4.41: The outcrop of Volcanic Sandstone (FOP2).

There is some volcanic sandstone with dominant of tuff product known as breccia tuff. Figure 4.42 shows the volcanic sandstone with breccia tuff. The location of this outcrop is labeled as FOF1 at 7° 51' 57.1" S 110° 30' 37.0" E, near with Sambipitu Formation. Therefore, this rock has similar properties with Sambipitu Formation rock, which mainly composed of Sandstone. However, because the major composition is volcanic rock, it still is considered as Nglanggeran Formation rock unit.

Figure 4.42: Volcanic Sandstone with a tuff fragment (FOF1).

Figure 4.43: The hand specimen for Volcanic Sandstone and breccia (FOF1).

Refer to Figure 4.43, the hand specimen for volcanic sandstone shows dark greyish brown colour with a medium grain size of sandstone. This rock has good porosity with moderately good fragment sortation. While Figure 4.44 shows the photomicrograph of volcanic sandstone labeled FOF1. The observation of petrographic analysis was made with 10× magnification. The structure of mineral is massive with grain size from less than 1/256 mm to 1 mm. Volcanic sandstone consists of open fabric arrangement of rock with subrounded to angular shape of fragment. In petrographic view, volcanic sandstone fragment shows poor sortation in arrangement of rock. The minerals for the rock were listed and explained in Table 4.7.

PPL (Plane Polarized Light)	XPL (Cross Polarized Light)

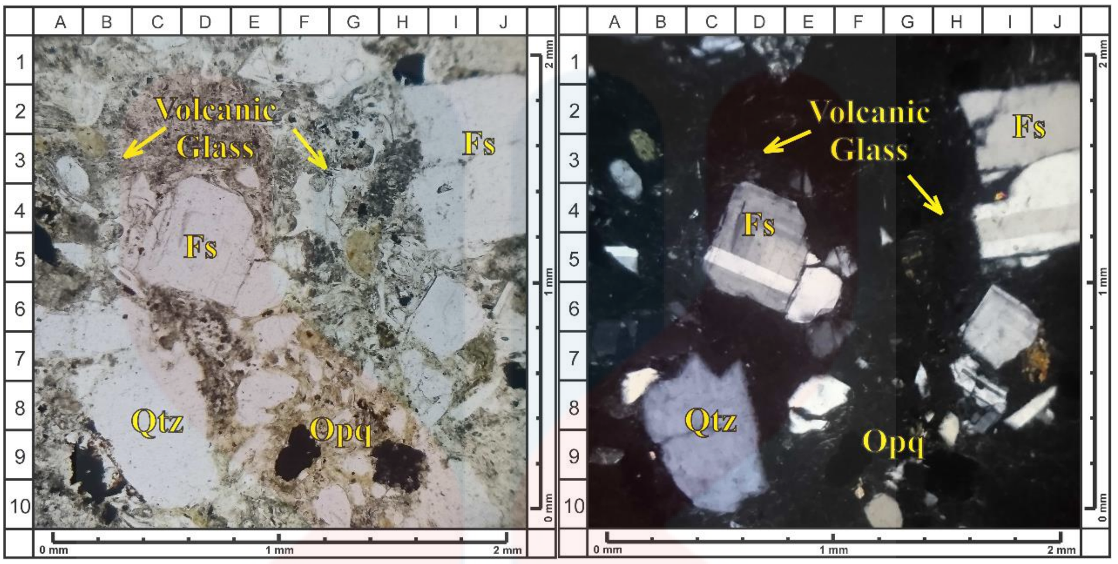


Figure 4.44: The photomicrograph of Volcanic Sandstone (FOF1). Quartz=Qtz, Fs=Feldspar, Opaque minerals=Opq.

Table 4.7: The description of mineral under the thin section for Volcanic Sandstone rock sample (FOF1).

Mineral	**Description of Optical Mineralogy**
Quartz (Qtz)	More like secondary quartz is known as cement. Under PPL shows white colour and greyish black under XPL. Low relief without cleavage. The pleochrosim is low and the crystal system is anhedral. Spread in the rock with mineral abundance of 10%.
Feldspar (Fs)	Light colour under PPL and red greyish under XPL. The crystal system is subhedral to euhedral where the crystal is bounded by its characteristic faces. It shows albite twinning with moderate of pleochrosim and cleavage breaks in one direction. The percentage of Feldspar is 20%.

Volcanic Glass	White brownish under PPL and black greyish colour under XPL. The relief, pleochrosim, crystal habit and cleavage cannot be seen. It acts as matrix with abundancy of 65% in rock.
Opaque Mineral (Opq)	Appear black under both PPL and XPL. The mineral can be seen scattered in the rock with abundancy of 5%.

Limestone Fragment

There are several limestone fragments found scattered along the Pentung River in the northeast of the study area. The limestone fragment size increase towards the north of the Kali Pentung River. Figure 4.45 shows one of the limestone fragments found in the study area. The fragment size varies from 2 cm to more than 25 cm.

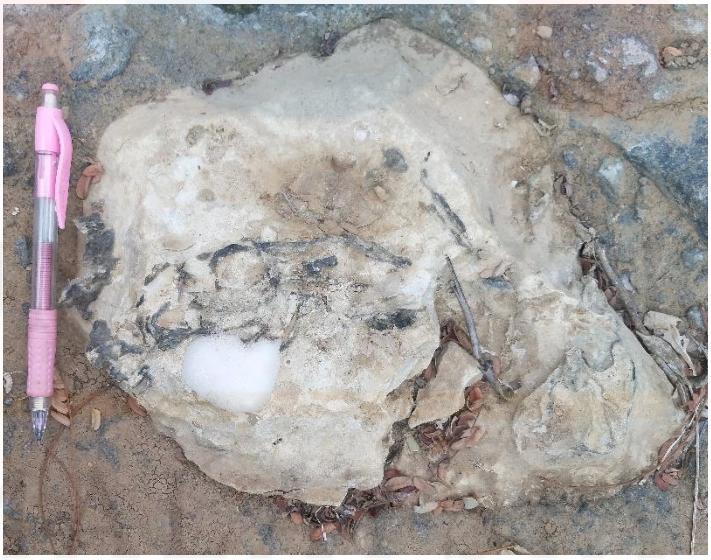


Figure 4.45: The limestone fragment in the study area.

It has an angular size of the fragment, where this can be an indicator where the limestone fragment deposited not far from the parent rocks. The large fragment of limestone was transported because of strong water velocity during the deposition of Epiclastic Breccia Unit in Nglanggeran Formation. Based on Figure 4.45, the colour of the limestone is yellowish white. The colour of limestone also can be an indicator of the sources of reefs. Usually, limestone with white colour or light colour is from the front back reefs, which is in shallow marine environment.

Figure 4.46 shows the hand specimen of limestone fragment at the study area that has been cut horizontally for thin section analysis usage. The limestone fragment was labeled as 92 was collected at 7° 51' 12.762" S 110° 30' 33.4368" E. The surface of the limestone fragment shows characteristic of a clastic type of limestone, which made up from weathered and eroded reefs.

Figure 4.46: The hand specimen of limestone fragment (92).

Under the petrographic analysis in Figure 4.47, it can be observed that there are many fossils presence in the limestone fragment. The limestone fragment can be categorized as Wackestone. This is because it was mud supported with more than 10% of grains. Therefore, it is classified as an allochthonous limestone where the original components are not bound during the deposition.

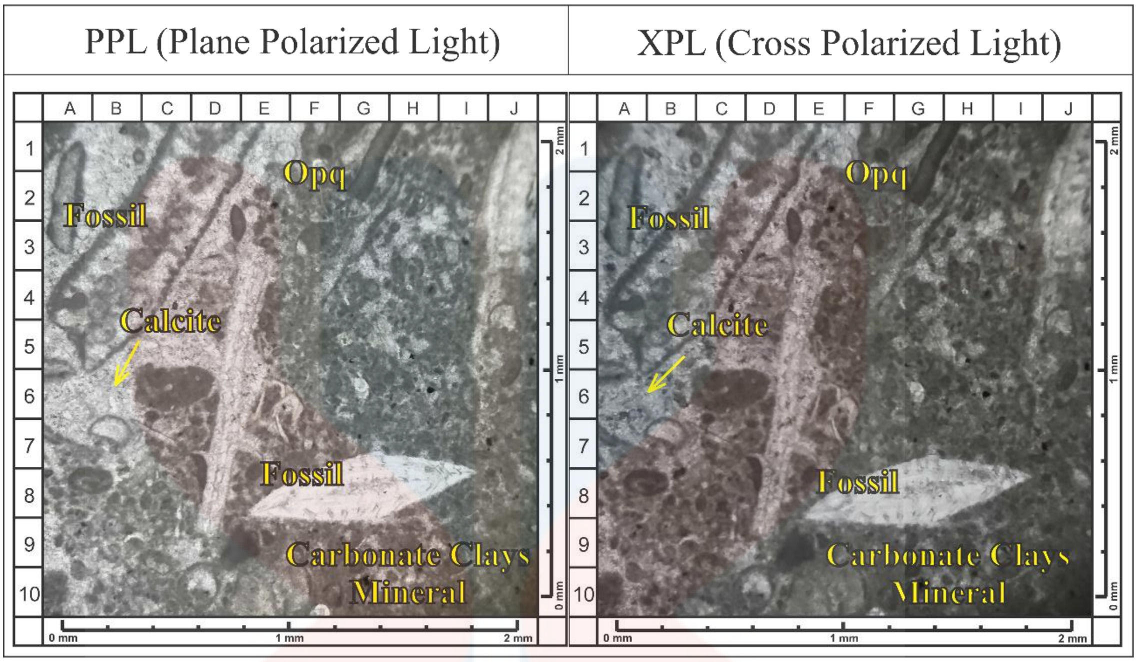


Figure 4.47: The photomicrograph of Limestone Fragment (92). Opaque minerals=Opq.

Table 4.8: The description of mineral under the thin section for Limestone hand specimen sample (92).

Mineral	**Description of Optical Mineralogy**
Fossil	Appear brown under PPL and reddish brown under XPL. Low relief and moderately pleochrosim. Good sortation of calcite mineral and carbonates. Have good shapes of fragment suitable with the organism. The abundancy is 30%.
Calcite	The alteration from plagioclase mineral where it appears as white under PPL and multicolor under XPL. There is no cleavage. Consist of birefringence characteristic with high pleochrosim. Exist as microlit matrix with abundancy of 18% in thin section.
Carbonate Clays Mineral	Appear as white brown under PPL and light red to brownish under XPL. The relief, pleochrosim and crystal system

	cannot be seen. Scattered in thin section with an abundancy of 51%.
Opaque Mineral (Opq)	Appear black under both PPL and XPL. The mineral can be seen scattered in the rock with abundancy of 1%.

4.3.2.4. Lava Unit of Nglanggeran Formation

Lava Unit existed at random location in the study area of Nglanggeran Formation depending on the volcanism activity. It consists of two types of lava, which are basaltic lava and andesitic lava. Lava Unit is interfingered with Pyroclastic Breccia Unit and Epiclastic Breccia Unit as these units have the same period, which is Tertiary Period. There are differences characteristics between basaltic lava and andesite lava. This lava mostly found in autobreccia structure undergoes brecciation, weathered or in sheeting joints formed.

Andesitic Lava

Andesitic Lava usually composed of an andesite rock mineral, which made the colour appears dark grey or grey. Figure 4.48 shows the outcrop of andesite lava, where there is no rock fragment found. Andesite lava usually dominant with plagioclase mineral. It is the dominant type of lava in Nglanggeran Formation and most andesite lava is weathered especially that lava near with Semilir Formation. The petrographic analysis was made to identify the mineral found in the andesite lava, where the hand specimen labeled as 70 was shown in Figure 4.49. The location for the hand specimen is at 7° 51' 18.14" S 110° 30' 30.77" E. The lava texture is aphanitic with the level of hardness is brittle. The colour of the lava is grey with moderately weathered and low vegetation covered.

Figure 4.48: The lava andesite outcrop.

Figure 4.49: The hand specimen of lava andesite (70).

The minerals found in andesite lava are Plagioclase (Pl), Chlorite and opaque minerals (Opq). The mineral distribution was shown in Figure 4.50. While for the petrographic analysis, the analysis was made in 10× magnification. The structure of the rock is massive with phenocryst aphanitic texture. The minerals size varies from fine to moderately. The rock is in closed arrangement of fabrics. The mineral description was explained in Table 4.9.

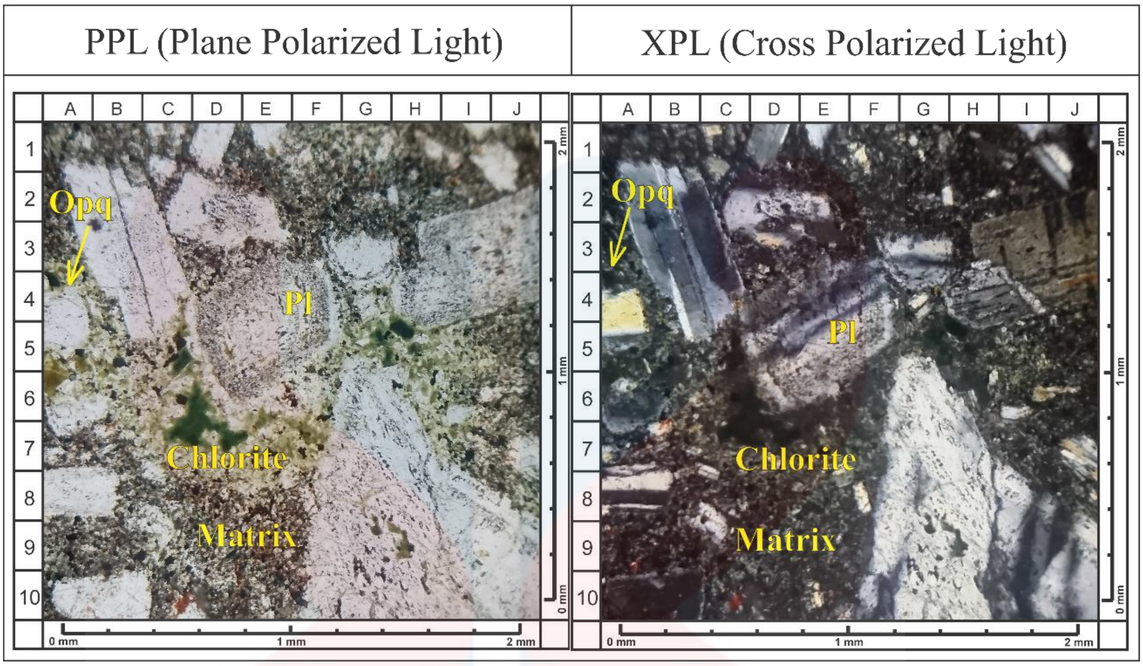


Figure 4.50: The photomicrograph of Andesitic Lava (70). Plagioclase=Pl, Opaque minerals=Opq.

Table 4.9: The description of mineral under the thin section for Andesitic Lava (70).

Mineral	**Description of Optical Mineralogy**
Plagioclase (Pl)	Light colour under PPL and greyish red under XPL. Crystal system from subhedral to euhedral. The type of twinning found is Albite and Carlsbad twinning. Moderate level of Pleochrosim with one direction of cleavage. Present as phenocryst and matrix in the thin section. The abundancy of 5%.
Chlorite	Greenish brown under PPL view and dark green under XPL. Relief and pleochrosim are moderate with zero direction of cleavage. The abundancy in thin section is 7%.
Matrix	Appear white brownish under PPL and dark greyish under the XPL view. It is in good sortation because the influences

	of volcanic glass, silica and quartz mineral. Has 42% abundancy in thin section.
Opaque Mineral (Opq)	Appear black under both PPL and XPL. The mineral can be seen scattered in the rock with abundancy of 1%.

Basaltic Lava

Basaltic Lava usually composed of basalt rock mineral, which made the colour of the rock appear dark grey to black. Figure 4.51 shows the outcrop of basaltic lava, which also consists of aphanitic texture, no mineral or grain can be seen with naked eyes. Basaltic lava usually dominant with pyroxene mineral and plagioclase. Several outcrops of basaltic lava were found at study area, which usually consists of brecciation or sheeting joint structure. Sheeting joint on basaltic lava can be seen in Figure 4.51.

The petrographic analysis was made to identify the mineral found in the basaltic lava. The hand specimen was labeled as FOB14 and was shown in Figure 4.52. The location for the hand specimen is at 7° 51' 16.43" S 110° 30' 31.43" E. Based on the hand specimen, the basaltic lava appeared as a reddish dark grey colour with aphanitic mineral texture. The porosity of the hand specimen is moderately good with vesicle structure. The weathering is low with high hardness level rock.

Figure 4.51: Outcrop for basaltic lava.

Figure 4.52: Hand specimen for basaltic lava (FOB14).

In the petrographic analysis, the minerals found are plagioclase (Pl), Orthopyroxene (Opx) and Opaque Mineral (Opq). The mineral distribution was shown in Figure 4.53. While for the petrographic analysis, the analysis was made in 10× magnification. The structure of the rock is massive with porphyry aphanitic texture. The minerals size is categorized as phenocryst mineral with coarse textures. Therefore, lava basalt for FOB14 is classified as basalt porphyry. The mineral description was explained in Table 4.10.

Vesicles presence in basaltic lava because of the solidified process. When the magma finally reaches the surface and cool, the rock will solidify around the gas bubbles and traps the bubbles inside. Thus, the bubbles filled with gas known as vesicles. This happens because of the rapid cooling of magma when reaching the surface and contact with the atmosphere.

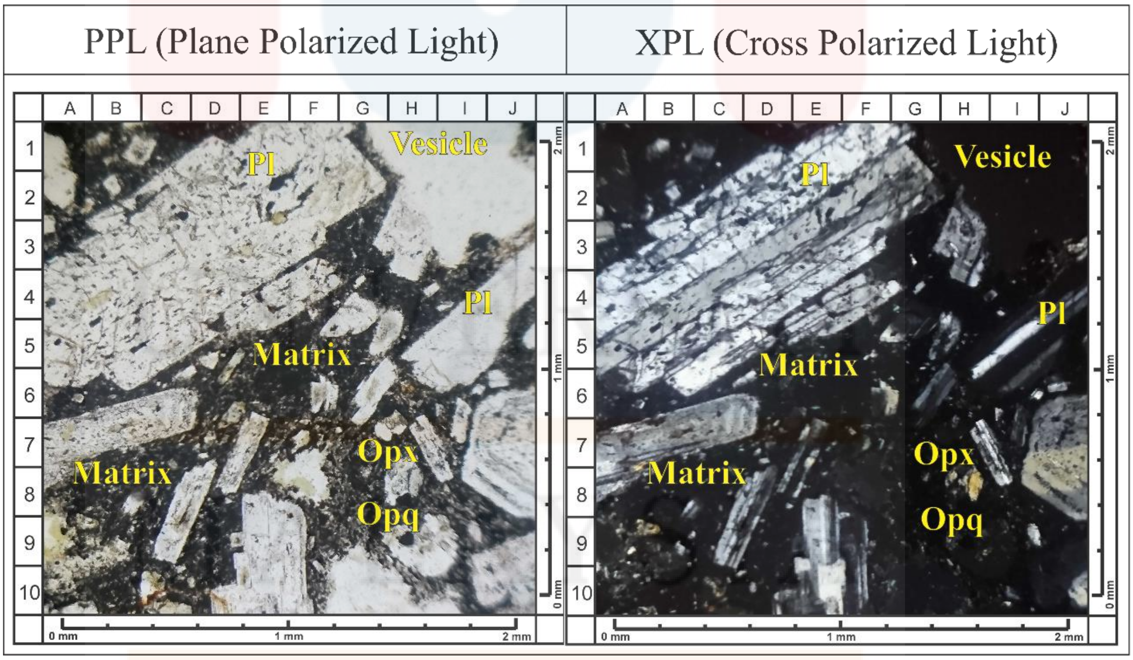


Figure 4.53: The photomicrograph of Basaltic Lava (FOB14). Plagioclase=Pl, Orthopyroxene= Opx and Opaque minerals=Opq.

Table 4.10: The description of mineral under the thin section for Basaltic Lava (FOB14).

Mineral	**Description of Optical Mineralogy**
Plagioclase (Pl)	Light colour under PPL and greyish red under XPL. Crystal system from subhedral to euhedral. The type of twinning found is Albite and Carlsbad twinning. Moderate level of Pleochrosim with one direction of cleavage. Present as phenocryst and matrix in the thin section. The abundancy of 45%.
Orthopyroxene (Opx)	Appear light brown under PPL and greyish yellow with brownish orange under XPL view. The relief is low with two directions of cleavage. It has low pleochrosim and appears as spotted in the thin section. Abundancy is 1%.
Matrix	Appear in light colour under PPL and dark colour under XPL. A matrix composed of microlit quartz, microlit feldspar and volcanic glass. Has abundancy of 38% in thin section.
Opaque Mineral (Opq)	Appear black under both PPL and XPL. The mineral can be seen scattered in the rock with abundancy of 1%.
Vesicle	Light colour under PPL and dark colour under XPL. Vesicle structure presents 15% in thin section.

4.3.2.5. Merapi Alluvium Unit

Merapi Alluvium Unit is composed of volcanic products from Mount Merapi volcano, an active volcano in Yogyakarta, Indonesia. It consists of alluvium products such as gravel, sand and clays along with the volcanic product, tuff and ashes. It covered the northwest of the study area, which is the flat area in the study area.

The distance of the study area from Mount Merapi only 53 km. That area was included as foothills of Mount Merapi, which is why it can be found in the northwest of the study area. The deposition of Merapi alluvium occurs during the Quaternary age, which is in recent period. It covered the underlying bedrock of Semilir Formation. Merapi Alluvium Unit is unconformity with Semilir Formation unit and Nglanggeran Formation unit because deposited in different periods. Figure 4.54 shows the deposition of Merapi alluvium in the study area. The grain size of the sediments varies from silt, clay, sands, granular and pebbles.

Figure 4.54: The deposition of alluvium at the Merapi Alluvium Unit.

4.4 Structural Geology

Structural geology is known as secondary structures where the deformation process occurs after the formation of bodies of rocks. From the study of structural geology, the deformation process of earth surface and subsurface can be reconstructed by analyzing the local and regional stress of the study area. Thus, geological structures were observed during the geological mapping of Patuk area. There are structures found through the analysis of structure in the study area such as joint, fault and cleavage.

The regional structures usually give a bigger impact to surrounding, which leads to the local structures. Local structures are the minor structures that were found during geological mapping. By mapping the local structures, the regional structure can be mapped and shown on the map.

4.4.1. Lineament Analysis

Lineaments are forms that represent as linear of earth surface because of the process of tectonic faults or fractures in bedrocks. It usually forms on the earth's surface and can be determined from the drainage, topographic and vegetation. These observations can be made from the interpretation of remotely sensed data. Figure 4.55 shows the lineament map of the study area, which has been analyzed during the preliminary study stage. From lineament interpretation, faults and linear zones can be determined. The lineament identification from the imageries image is approximately 300 m to 1.5 km long and can be found at rivers, ridge and valleys based on the topography of the study area.

The direction orientation of the lineament in Figure 4.55 was measured based on the geological mapping observation. The data gained was plotted in Georose software in order to determine the main stress direction that influenced the structures in the study area. Figure 4.56 shows the result plotted in the Georose diagram and the strike data were organized in to 15° intervals. The lineament orientations are dominantly found from North to South with north-west and southeast consistence frequency. Therefore, the regional maximum tectonic stress of the study area can be determined from the trend of the lineament. The maximum stress exerted from the 335°, which is similar to the regional stresses of the Java Islands. Java Island forces are dominantly exerted in North to South direction. The minimum stress was exerted from the 80°, resulting in extension process.

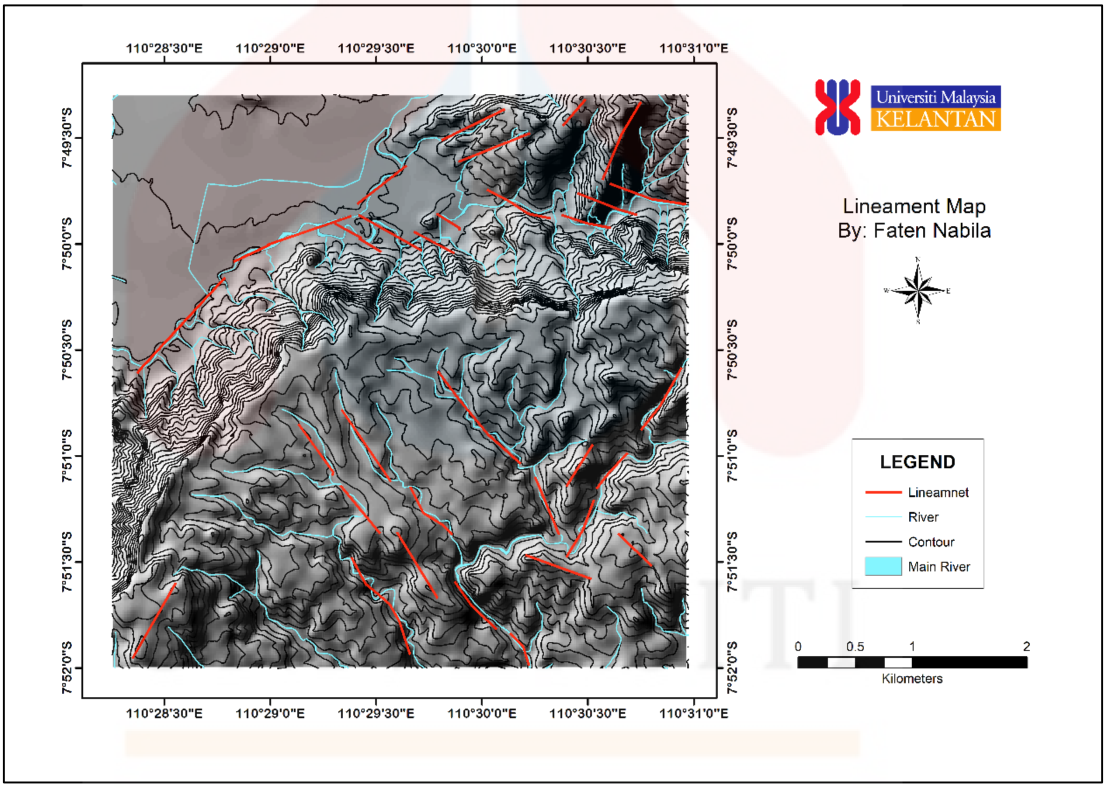


Figure 4.55: The lineament map of the study area under the satellite imagery of Patuk area.

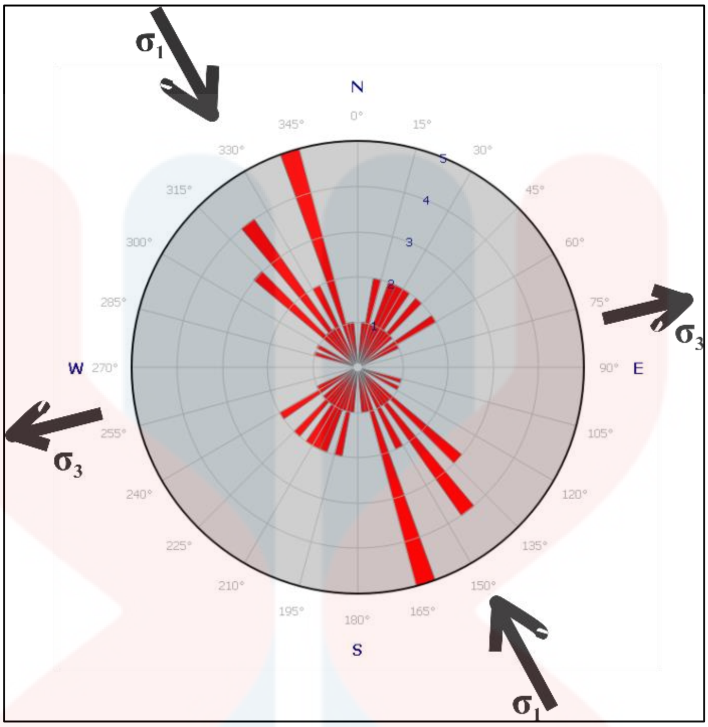


Figure 4.56: The rose diagram of the lineament analysis that shows a major force of 335°, σ1 and minimum force of 80°, σ3.

4.4.2. Bedding Orientation

Bedding orientation analysis was made in order to compare it with the regional bedding orientation and to determine the stress direction. Therefore, the geological structure in the study area can be easily determined. Based on the regional study, the bedding at Yogyakarta dominantly tilted towards the south direction.

Based on the 31 strike and dip data for bedding in the Patuk area, stereonet projection was produced and shown in Figure 4.57. The main density concentration of the bedding is forming a contour pattern towards the red colour. This is an indication of the mean bedding orientation, which is located at the red line. The mean bedding orientation for Patuk area is N 85° E/ 10°, which the bed is tilted in average direction of 85° with dipping of 10°. The bedding orientation of the study area is similar to the regional bedding orientation.

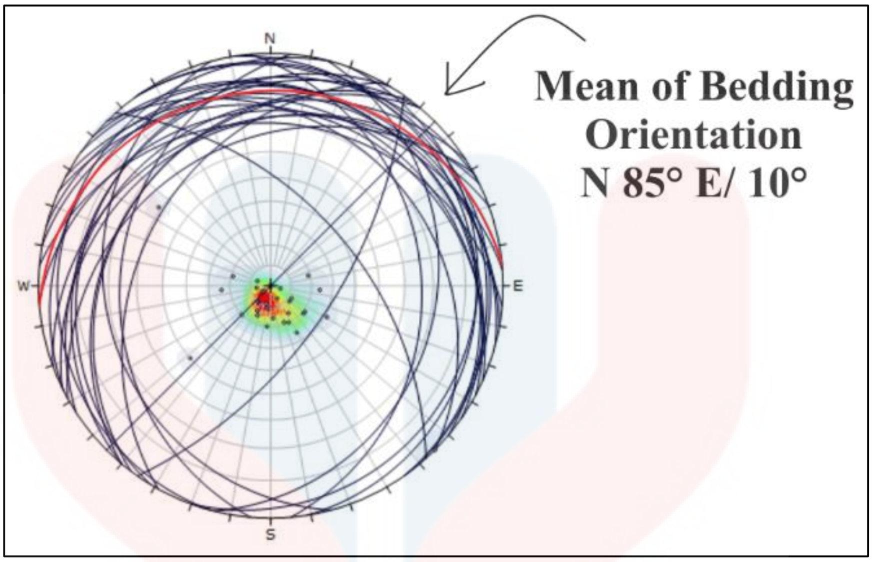


Figure 4.57: The bedding analysis of the study area based on stereonet.

4.4.3. Cleavage

Cleavage developed because of the deformation or metamorphism process. There are two types of cleavage, which are primary and secondary cleavage. In the study area, the type of cleavage present is the primary cleavage, which related to sedimentary rocks. Cleavage appeared on the very fine-grained rock such as mudstone and claystone, where it is usually perpendicular with the bedding planes. Refer to Figure 4.58; the yellow lines are the cleavages where it is perpendicular to the red lines, the bedding planes.

In the structural geological study, cleavages usually related to folding structure. Cleavage shows the same direction with axial planes of folds that developed during the deformation process. By mean, if the cleavage is in perpendicular direction with the bedding planes, the bedding is in normal bedding form. However, if the cleavage is parallel with the bedding planes, the bedding already undergoes overturned deformation. Most of the cleavages found in Patuk area are in a perpendicular direction with the bedding planes.

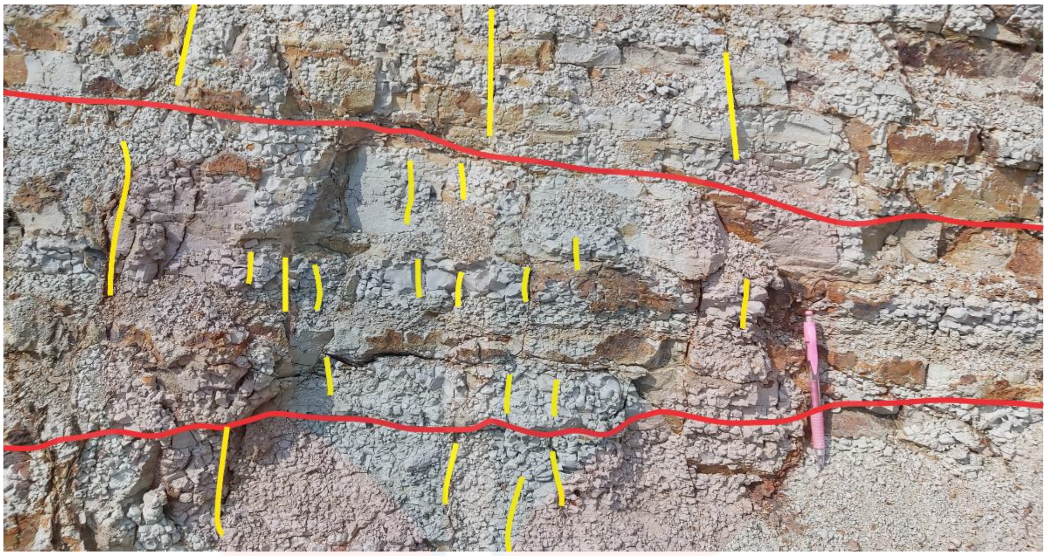


Figure 4.58: The cleavages (yellow lines) of tuffaceous mudstone at the Patuk area.

4.4.4. Joint

Joint is known as rock fractures that do not involved with displacement of the rocks. There two types of joints, which are the primary joint and secondary joint. For structural geology, the secondary joint will be focused on. The joint formed because of the tectonic forces such as shear joint. The joint orientation was measured in order to determine the force direction that formed the joints on the body of rocks.

The main type of joints formed in the study area is the shear joint and conjugate joint. Figure 4.59 (a) shows the shear joint in the study area. Next, conjugate joint is known as two shear joint was crossed together and formed an acute angle. It was shown in Figure 4.59 (b) where conjugate joint acts as an indicator for strike slip structure. The location for the joint orientation measurement is at 7° 51' 24.2" S 110° 30' 23.2" E on lava lithology.

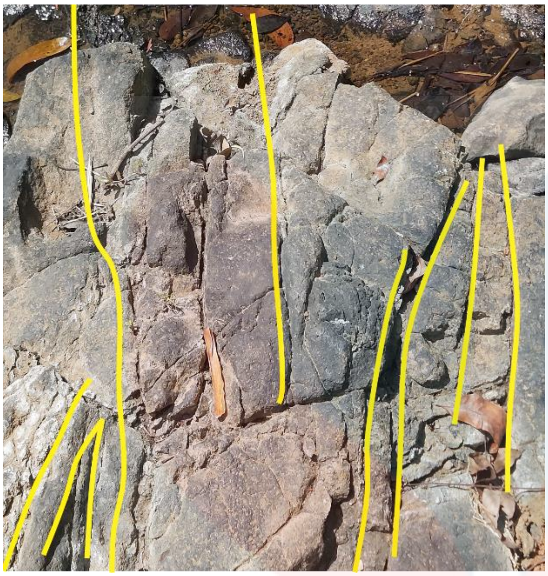


Figure 4.59 (a): Shear Joint.

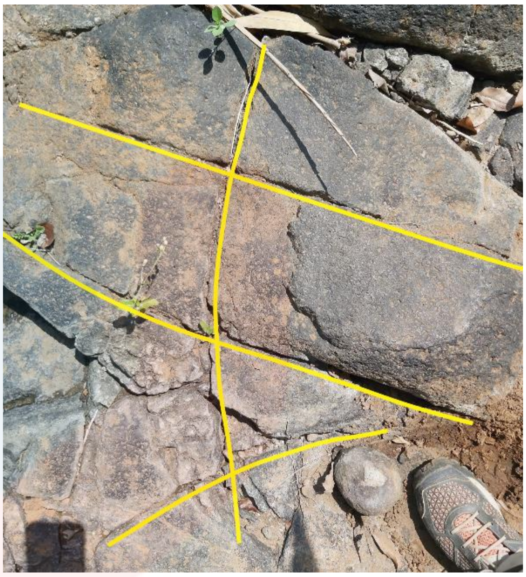


Figure 4.59 (b): Conjugate Joint.

The joint orientation was measured on the conjugate joint, where its joint shows two different directions. The analysis of joint is important to determine the paleo-stress for Patuk area. The orientation of the joint was measured and plotted in the Georose software. Based on Figure 4.60, the main force that influenced the deformation of the rocks was labeled as σ1 at 47° direction. The direction is at North to South with consistency frequency at northeast and west south direction. Therefore, the main stress is from the direction of 47° where the direction is compatible with the lineament and structure found at the location.

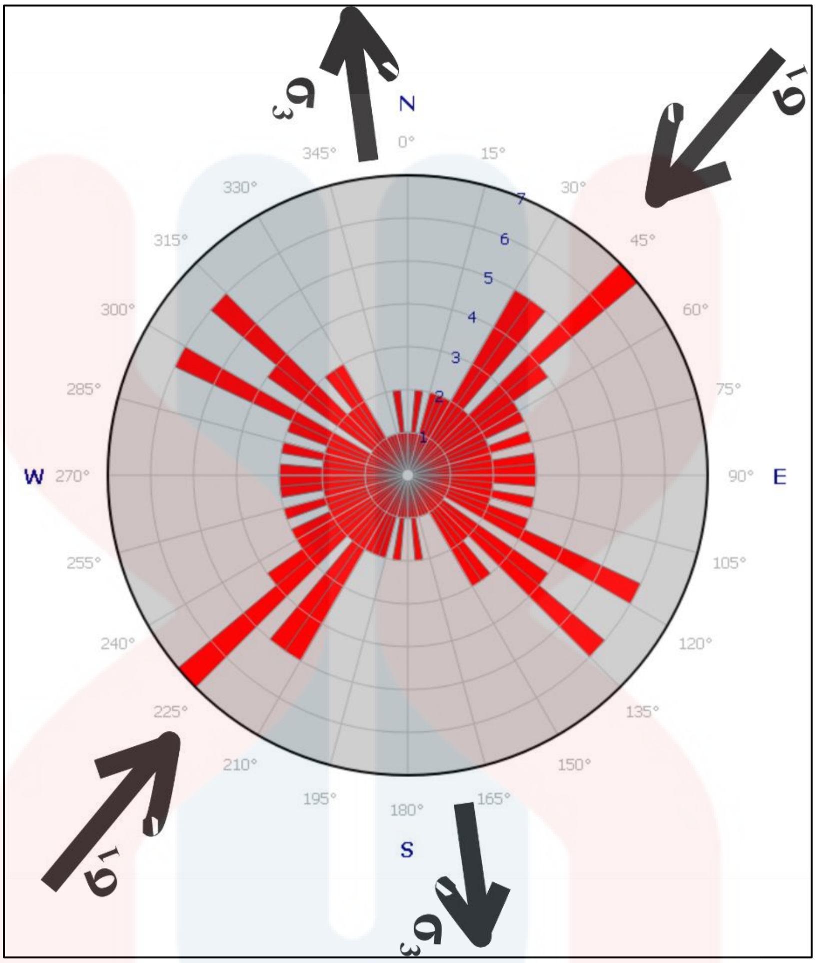


Figure 4.60: The rose diagram for the joint analysis.

4.4.5. Fault

There are two types of faulting found in the Patuk area, which are Sinistral Strike Slip Fault and Normal Fault. Faults structure was observed and recorded during the geological mapping was plotted in geological map. The faults structure was shown and labeled as 1, 2 and 3 in Figure 4.61. The direction for the maximum and minimum principal stress is important in fault analysis. Types of fault can be determined by the stress direction and the lineament orientation direction. In addition, evidence of faults also can be observed in field, whether it is from the geological structure or morphology evidence. For example, brecciation and escarpment.

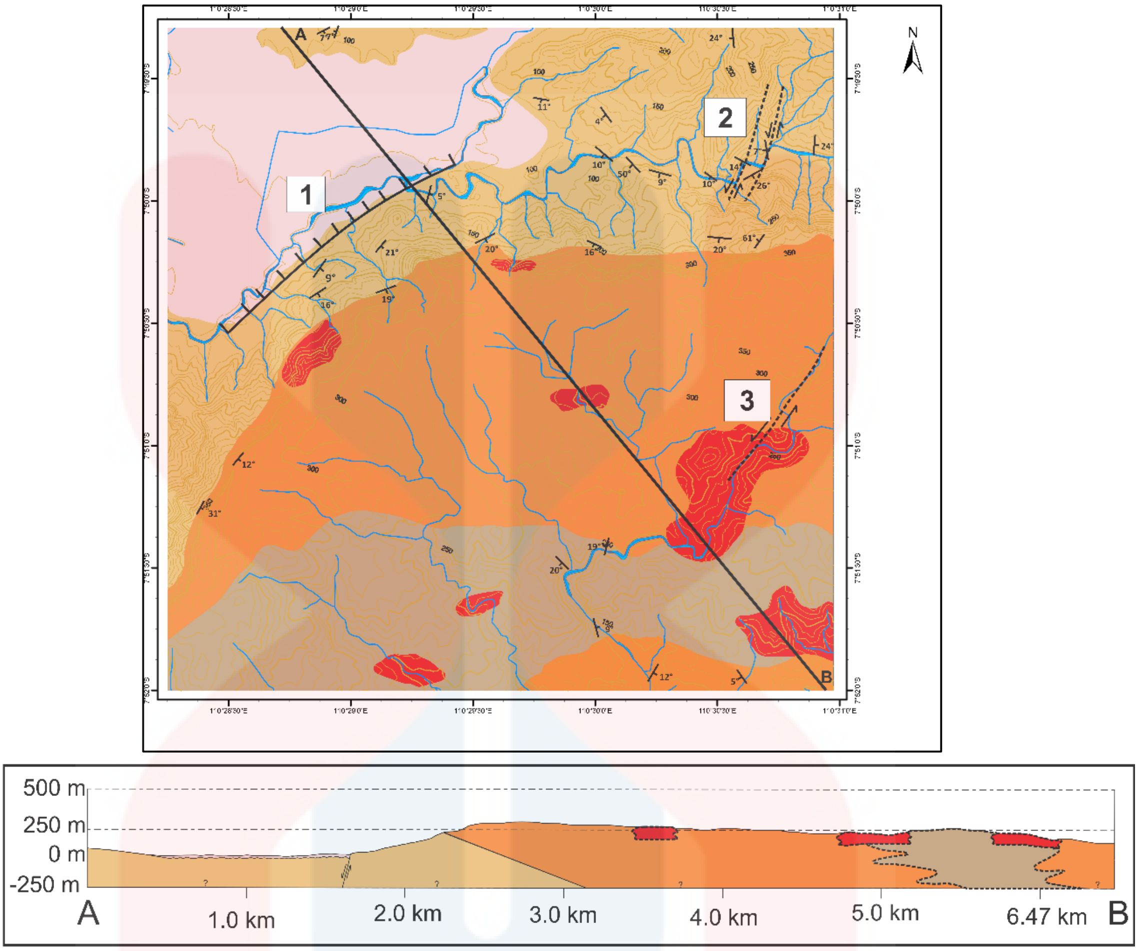


Figure 4.61: The fault structure labeled as 1 (Petir Normal Fault), 2 (Petir Sinistral Strike Slip Fault), 3 (Petung Sinistral Strike Slip Fault).

4.4.5.1. Petir Normal Fault

The movement of footwall where it moves upwards and hanging wall moving downward determined the normal fault. The movement of the wall can be seen in Figure 4.61 at the cross section of the normal fault. The Merapi Alluvium Unit is in lowered elevation compare to Tuff Unit of Semilir Formation.

The normal fault cannot be seen clearly during geological mapping as the location already filled with infrastructure and residential areas. However, there is morphology evidence in the study area where the location of the normal fault occurs. Based on Figure 4.62, there was an escarpment hill found in the study area. Scarp was known as fault evidence. It formed a very steep hillside, which because of faulting process. Next, the lineament of the river in the surrounding area shows an offset characteristic where the drainage pattern is in rectangular pattern. In addition, the normal fault location was the location where Opak Fault occurred. Therefore, the normal fault was happened because of Opak Fault that exerted as major fault in Yogyakarta.

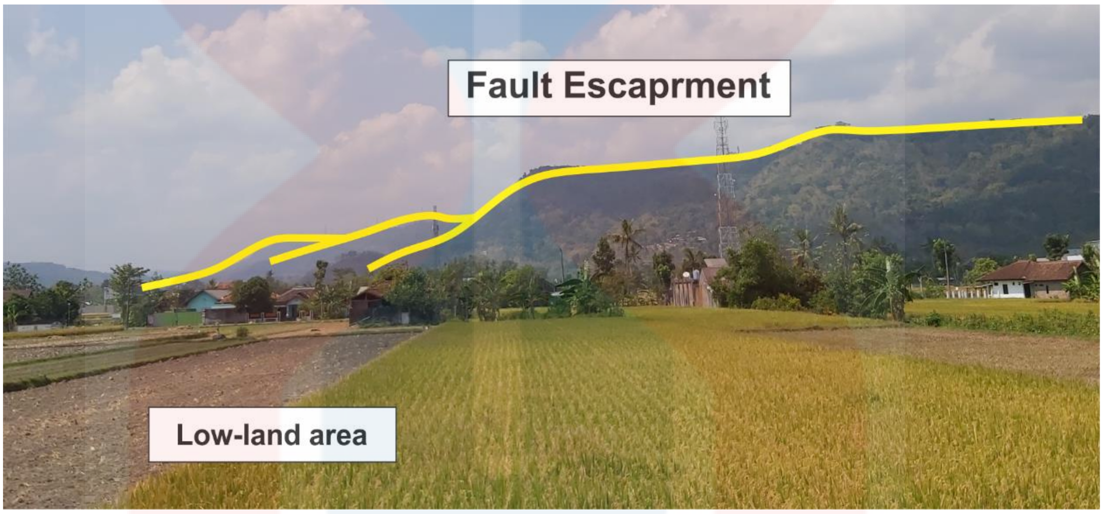


Figure 4.62: The location of the normal fault where the scarp was shown in yellow line.

4.4.5.2. Strike-Slip Fault

There is two main strike slip faults found in the study area. However, based on the lineament analysis, there was abundances of strike slip found. The strike slip found in study area is known as sinistral strike slip, where the left part of the fault block moves forwards. The direction of strike slip found in the study area is the same as the regional strike slip of Yogyakarta, which is Sinistral Fault. There is two sinistral strike slip faults found in the study area, labeled as 2 and 3 in Figure 4.61. The strike slip that labeled as 2 was shown in Figure 4.63 known as Petir Sinistral Strike Slip Fault. There was brecciation observed at the location of the strike slip, which acts an as indicator for faulting process.

The strike slip labeled 3 named as Petung Sinistral Strike Slip Fault. It cannot be found in the field because the area is a residential area. However, it can be determined as sinistral strike slip because of the strike and dip data that are not in the same orientation direction. The lineaments of the river and the drainage pattern shows signs of faulting process occurred at the location. The main force, which exerted from the South to north determined that faulting process occurred at the location is sinistral strike slip fault, which is compatible with the regional strike slip of Patuk area.

Figure 4.63: The Sinistral strike slip (2) found in the study area.

4.5 Historical Geology

The study area was divided into 5 different units, starting from Early Miocene and Quaternary Period. The sequences of each unit were explained in the sub-topic of lithostratigraphy. The depositional process for each unit will be explained in more detailed in this subtopic in order to determine the depositional environment of each formation.

During Early Miocene, the volcanoes activity was very active. This can be seen from the lithology of the Tuff Unit of Semilir Formation. The dominant volcanic product is tuff, breccia pumice and tuffaceous sandstone. All the lithology in this unit is fine grained with light weighted fragment of rock. The presence of pumice shows that the volcanic eruption was very explosive during that time. Pumice is included in the pyroclastic rocks fall where it travelled and deposited across the bedrock slope. The volcanic activity occurred at subaerial deposition where the explosive product was deposited in the oceanic environment. The turbidite sequence of breccia pumice and tuff product is the indicator it was formed because of the submarine slope.

Tuff Unit deposited in bedding form, where the sedimentation process involved. The increasing of the sedimentation process along the Semilir Formation also indicates the frequent of volcanism activity in the study area. The sedimentation process involves transportation grains and fragment rock, which under the influence of transportation agents such as water and air. The grain sizes change from fine to coarser in tuff unit, where the energy of the environment can be determined based on the grain size (Triana, 2013). Fine grain sediments tend to deposited in calm environment, which is deep marine. Therefore, it can be seen that there was transition from the deep marine to shallow marine depositional environment. In Patuk area, the

Semilir Formation lithology can be classified as Lower Semilir Formation. Therefore based on the data and analysis, the depositional environment at study area is shallow marine compatible with the regional deposition environment of Semilir Formation.

Then, the deposition of Nglanggeran Formation takes place, where the three units in Nglanggeran Formation were interfingered with each other. The contact between Nglanggeran Formation with Semilir Formation formed sharp contact with poor bedding of rock. Both of these formations occurred in the same period, which is Tertiary Period during the Early Miocene. The repeated lithology between the three units shows that several eruption periods occurred during this period. The lava unit deposited between the eruption processes after the pyroclastic breccia product deposited.

The epiclastic breccia found in the study area consists of large fragments. Thus, this can be as indicator that very strong energy flow was involved during the deposition process. There was limestone fragment found along with the epiclastic breccia deposition. This is an indicator of shallow marine environment for Nglanggeran Formation, where the limestone fragment was transported through water flows. The presence of the epiclastic breccia and limestone fragment shows the marine deposited environment. Therefore, the depositional environment for Nglanggeran Formation is at submarine volcanoes environment where the volcanic activity and deposition of epiclastic breccia, pyroclastic breccia and lava occurred in the same period.

After the Nglanggeran Formation, the Sambipitu Formation takes place, which is not included in the study area. Sambipitu Formation is known as sedimentary deposition where there is no sign of volcanism activity during that period of deposition. Therefore, Nglanggeran Formation volcanic activity might have ended at the end of the deposition of the formation. The volcanoes in Nglanggeran Formation become inactive, collapsed, and deposited in submarine environment. The epiclastic breccia near the Sambipitu Formation is the product from the destructive volcanoes where it interfingered with Sandstone Unit of Sambipitu Formation.

In the Quaternary Period, there is active volcano, known as Mount Merapi. The volcanic product from the Mount Merapi deposited at the basin of Semilir Formation and overlain half of Semilir Formation in study area. The volcanic product is dominantly ashes and tuff with other alluvium deposits such as gravel, sand and clays. This indicates that volcanic products are far away from the source. The Quaternary Volcanic is unconformity with Nglanggeran Formation and Semilir Formation because of the different periods of deposition. Overall, the depositional environment in study area is under the influence of volcanic activity.

CHAPTER 5

DEPOSITION OF VOLCANICLASTIC IN NGLANGGERAN FORMATION

5.1 Introduction

From the analysis of volcaniclastic sediments, the depositional environment and volcanic activity during the deposition of the Nglanggeran Formation can be determined. Every different character of deposited rock shows different background process of deposition. The volcanism periods in Nglanggeran Formation can be determined through the facies analysis where the changes of the lithology were observed. Overall deposition of volcaniclastic can be determined through the facies analysis and geological mapping as well as the depositional environment of Nglanggeran Formation.

5.2 Field Exposure

In order to get the best result for the analysis of volcaniclastic in the Nglanggeran Formation, the measuring section was made started from the Sambipitu Formation until the Semilir Formation. The measuring section was made along the river because of the good exposure of outcrop, where four rivers were chosen. Figure 5.1 shows the measuring section route in study area. The study area for research specification was expanded for 500 m at the south side in order to include the Sambipitu Formation.

The measuring section was made from the south to the north, where it started from the youngest rock to the oldest rock. The measuring for Section 1 started at Kali Pentung River, 07° 52' 17.55" S 110° 29' 55.21" E with an elevation of 111 m. The strike and dip for finding the true thickness for volcaniclastic log were based on the measurement from Sambipitu Formation sandstone bedding. This is because there was no obvious bedding in Nglanggeran Formation. From this, the changes in the lithology can be measured and the thickness of Nglanggeran Formation can be determined.

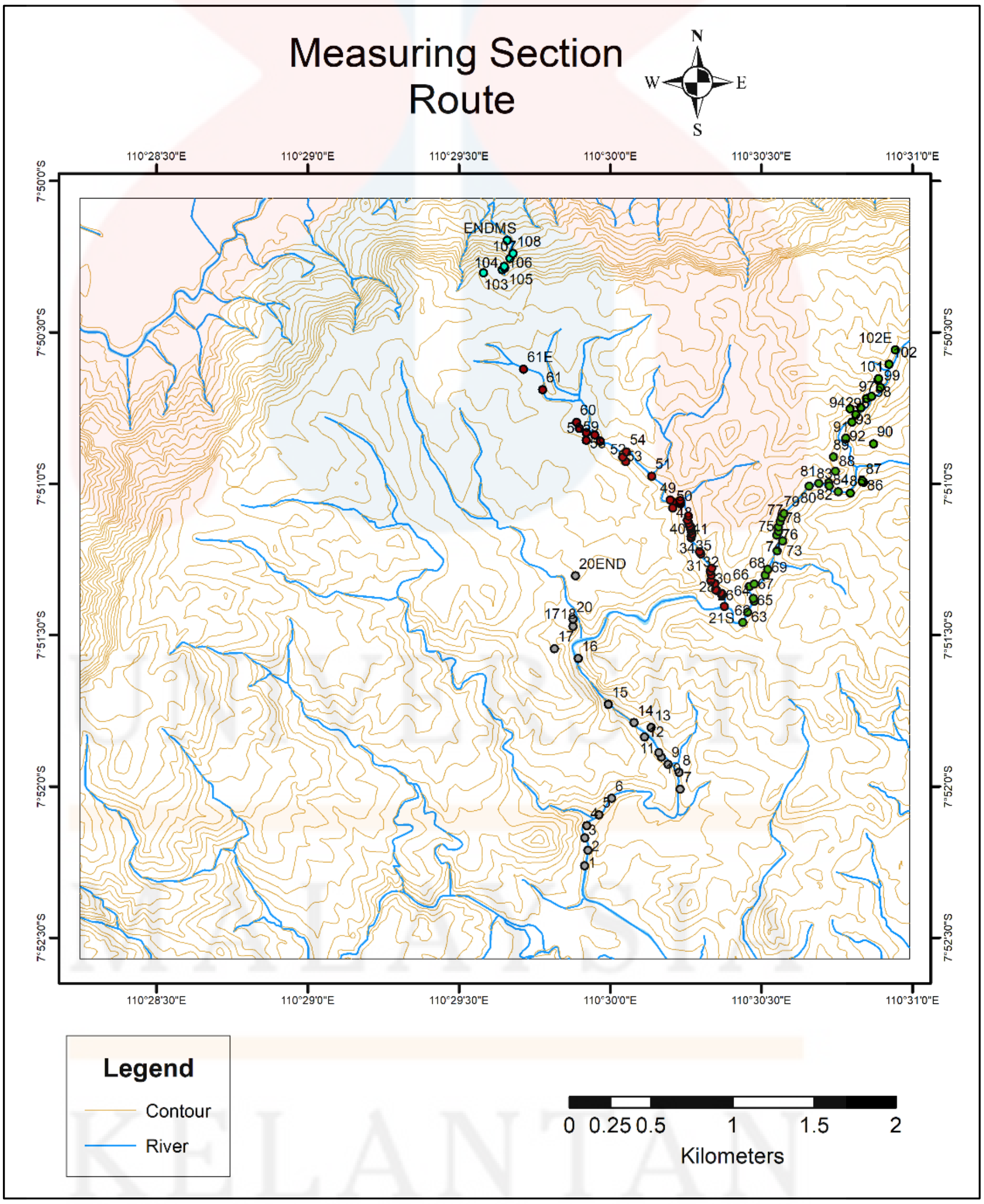


Figure 5.1: The four measuring section for research specification.

5.3 Petrography of Volcaniclastic Deposition

The main volcaniclastic sediments found in the study area are epiclastic breccia, pyroclastic breccia, lava, volcanic sandstone, basalt porphyrys and limestone fragment found in epiclastic deposit. Some of the petrographic samples for the Nglanggeran Formation were explained in Chapter 4 and will be discussed more detailed in this chapter. The mineral composition within the volcanic rock helped in explained the facies analysis.

There are two types of lava found in the study area, which are Lava Andesite and Lava Basalt. The types of alteration will be determined from the petrography analysis to describe the background of deposition and alteration occurs on some part of lava in Nglanggeran Formation. In describing the period activity of volcano, the first product will be pyroclastic breccia, followed by expulsive of lava. Then, the eruption stopped where erosion and weathering take place on pyroclastic breccia. This is when epiclastic breccia formed. This type of deposit can be considered as one period of volcanism. After that, followed by the second eruption of volcano and the cycles of eruption and erosion goes on.

5.3.1 Lava Andesite Alteration

The petrographic analysis for Andesite Lava was shown in Chapter 4. Most of the Andesite Lava in Kali Pentung River was in an alteration zone and some undergo weathering. Therefore, the sample taken for this analysis represents all the lithology for Andesite Lava in study area. Based on Figure 5.2, the alteration mineral is known as Chlorite, dark greenish color mineral located as C6.

Andesite consists of hornblende and biotite mineral as mineral composition. The alteration for these minerals will lead epidote-chlorite-albite alteration. This is known as Propylitic alteration. Propylitic alteration involved the chemical alteration of a rock, where it caused by iron and magnesium bearing in hydrothermal fluids (Norman, Parry, & Bowman, 1991). The alteration occurs due to hot fluids with high sodium ion composition, which altered the minerals of hornblende and biotite to mineral chlorite. Therefore, it can be concluded that the alteration occurred in Andesite Lava of Nglanggeran Formation is because of the hydrothermal fluids. There were hydrothermal fluids present in Nglanggeran Formation. The main sources of hydrothermal fluids are from the seawater. That is why the main composition for Propylitic alteration is sodium ion. Therefore, during the alteration occurred, the seawater in Nglanggeran Formation are modified because of the interactions with heat and earth crust. From the volcanic activity, these fluids dissolved in oceanic water and made contact with the andesite lava.

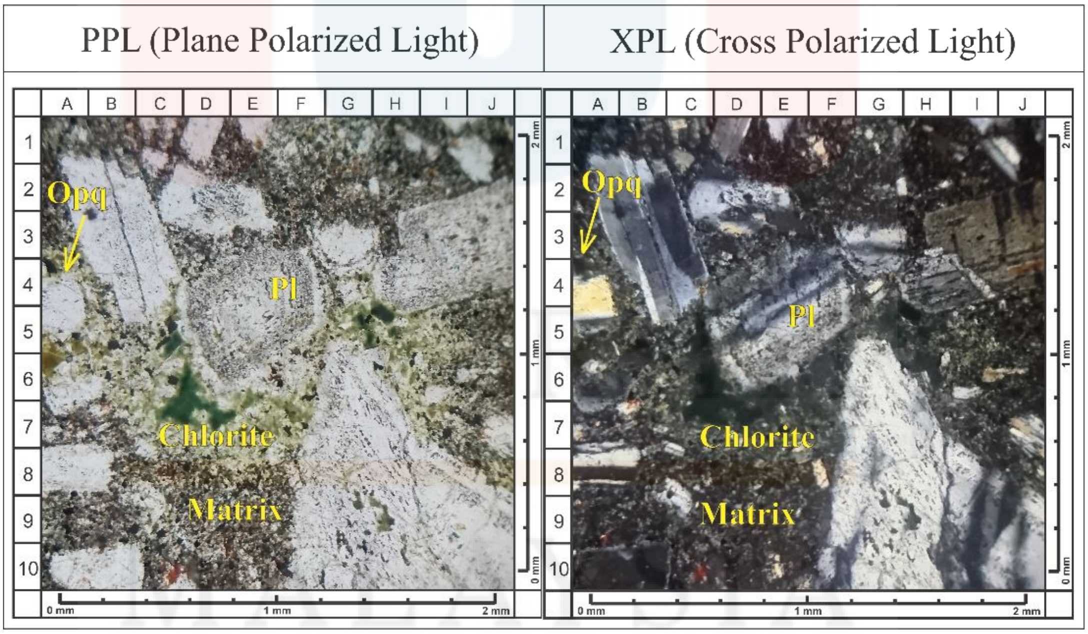


Figure 5.2: The alteration of andesite lava under a thin section with Chlorite mineral present.

5.3.2 Basalt Porphyry

Basalt Porphyry is an igneous rock consisting of large grained crystals such as quartz and feldspar dispersed in a fine-grained silicate rich, commonly aphanitic matrix. The mineral composition is dominant with olivine and pyroxene. Figure 5.3 shows the mineral content in basalt porphyry rock in petrographic view of PPL and XPL. The rock found classified as basalt porphyry because of the composition of olivine is more than 50%. In the study area, only one locality shows the presence of basalt porphyry outcrop, which is at the eastern side with coordinate of 7° 50' 58.9" S 110° 30' 48.4" E. The thickness of the basalt porphyry outcrop is less than 100 m.

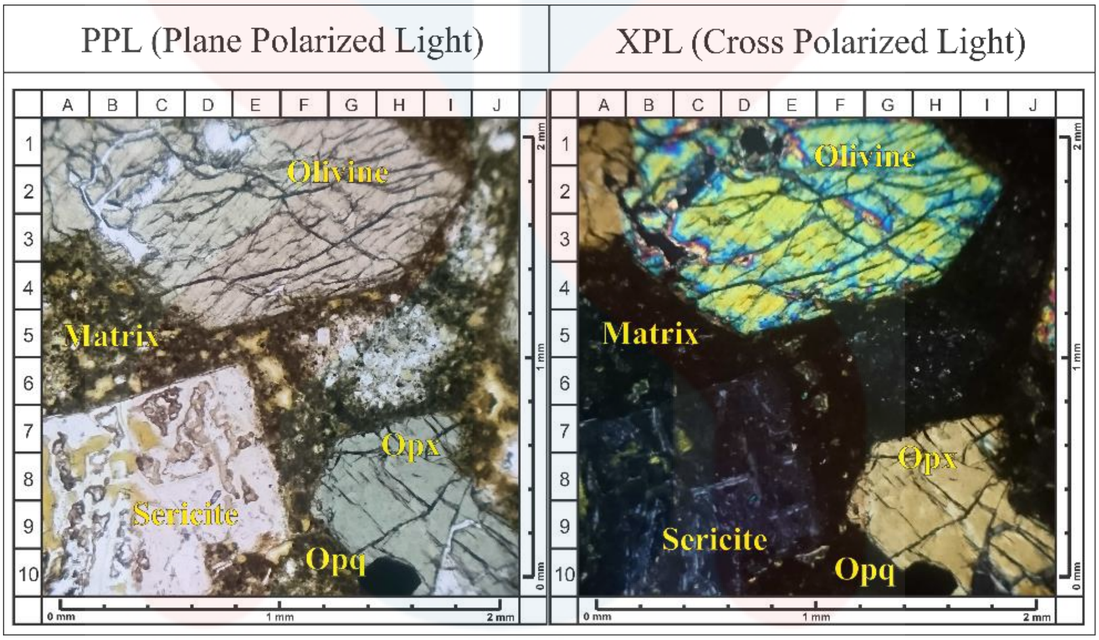


Figure 5.3: The mineral composition of Basalt Porphyry under the thin section.

The porphyritic texture indicates two separate stage of solidification. The magma began to crystallize while still underground producing large phenocrysts. However, before the crystallization was complete, the magma erupted onto the surface and crystallized quickly to produce the fine grained groundmass. Therefore, the present of basalt porphyry in study area shows that the rock formed under the influenced of rapid cooling magma during the eruption of volcano. The rock composition might represent the peridotite component mineral but the texture of the rocks shows the characteristic of porphyry mineral. Figure 5.4 shows the outcrop of basalt porphyry labeled as checkpoint FOB17 and Figure 5.5 shows the hand specimen of the rock. The rock texture is more to fine-grained with dominant of porphyry mineral. The dark and elongated mineral shows in the hand specimen is known as pyroxene mineral.

Figure 5.4: Basalt porphyry outcrop (FOB17)

Figure 5.5: The hand specimen of basalt porphyry (FOB17).

5.4 Volcaniclastic Lithology Log

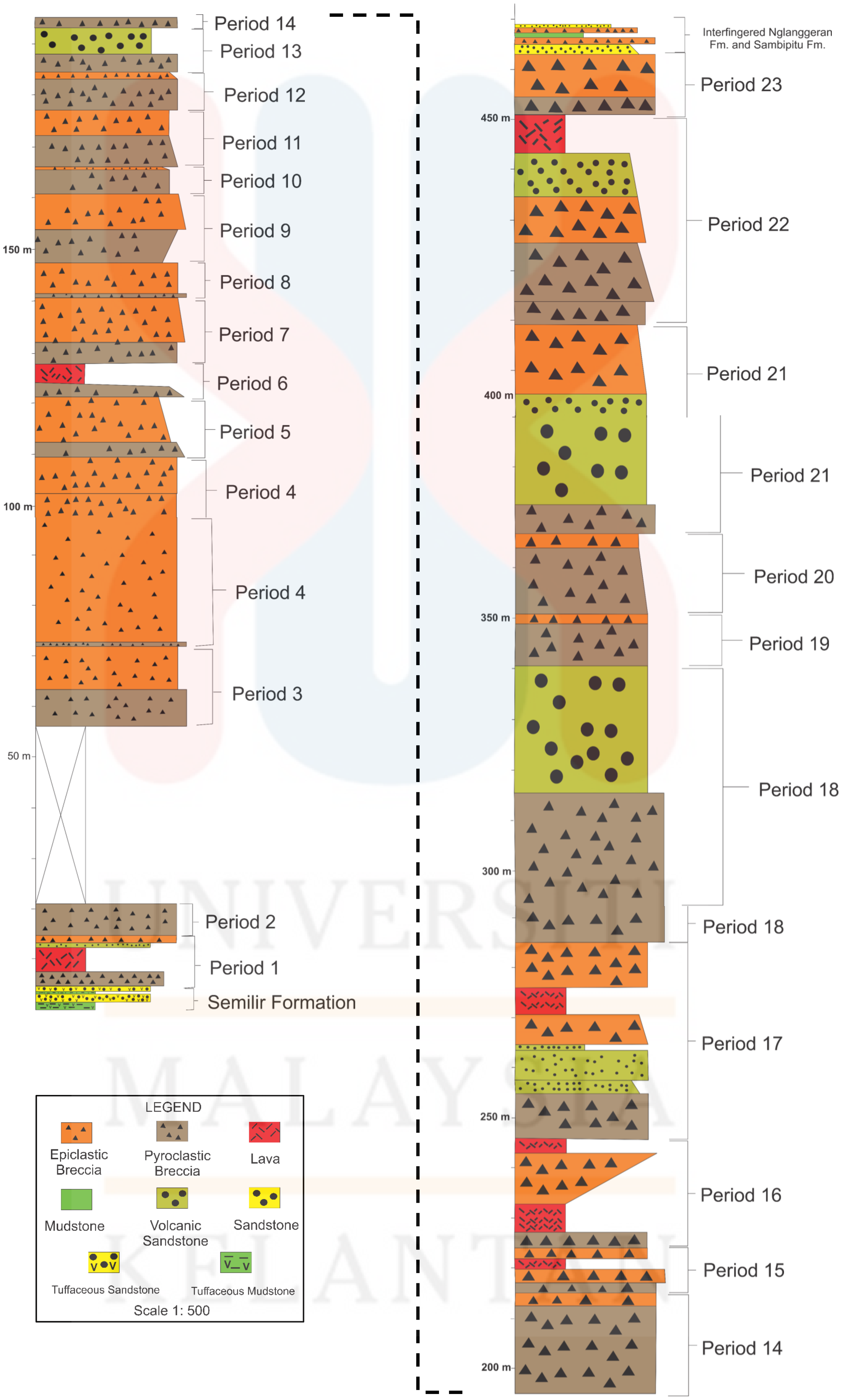


Figure 5.6: The volcaniclastic lithology log for four sections in the study area.

5.5 Volcanism Period

The volcanism activity and period were explained based on Figure 5.6. There was sharp contact between Semilir Formation and Nglanggeran Formation. After the deposition of pyroclastic Breccia, the deposition of Semilir Formation stops immediately because of the end of the volcanism activity in Semilir Formation. The volcanism period for Patuk area was divided into 23 periods and was determined from the data interpretation from the measuring section. The scale for the lithology log is 1: 500 cm for the bedding thickness.

In the first period, the deposition of pyroclastic breccia followed by the expulsive of lava, which andesitic lava. The size of the pyroclastic breccia fragment varies from pebbles to cobbles, where indicates the energy transported the fragment is intermediate at that moment. The deposition of volcanic sandstone overlain the pyroclastic breccia, where the sandstone also consists of pebbly size of fragment. Then, the erosion of the deposited volcanic product occurred and epiclastic breccia formed with cobble size of fragment. The rock fragment form in cobble size due to the high energy of transportation during that time. The thickness of period one is approximately 16.5 m.

Next, in the second period of volcanism, a thick succession of pyroclastic breccia deposited with cobble size of fragment. This indicates that the energy of transported medium is increasing. The third period of pyroclastic breccia consists of dominant boulder fragment. This shows that during the third period, the energy keep increasing compare with in the second period. Then, erosion occurred produce epiclastic breccia where the epiclastic breccia layer overlain the pyroclastic breccia layer. The thick succession of epiclastic breccia indicates that the presence of water in transported the rock fragment is higher than the first period.

For fourth period, the thickness of pyroclastic breccia was very smaller compared to other pyroclastic breccia deposits. Then followed by the thick succession of epiclastic breccia. This is an indicator, during that time, the influence of water is very high and triggered for more weathering, erosion and transportation forming epiclastic breccia. The thickness value for epiclastic breccia is 37 m. There was several limestone fragment found during this period, where the limestone fragment increasing in size when moving forward to southern part of study area. From the petrographic analysis in Chapter 4, the limestone fragment consists of allochthonous properties where it was transported by the influence of water far away from the parent rocks. The fifth period shows the same deposition pattern with the fourth period with the rock fragment is varies from gravels to cobbles. The energy of transportation during the fifth period is quite low because of the small volcanic fragment present in this period compare to other period.

During the sixth period, small succession of pyroclastic breccia deposited and followed by lava deposit. Then, another pyroclastic breccia was found deposited overlain the lava layer. This pattern of deposition shows that there was no erosional agent present during the sixth period. Period seven to period twelve shows the same pattern of alternating of pyroclastic breccia and epiclastic breccia with different thicknesses and sizes of fragment. Different thickness represents the activity of the volcano at that time and the size of fragment represents the energy transported at the time. The limestone fragment was present in every epiclastic deposits from period seven to period twelve.

Next, during the period thirteen there is no epiclastic breccia deposition. Instead, volcanic sandstone deposition occurred, the erosion of volcanic products takes place and formed very coarse sandstone. In petrographic analysis of volcanic sandstone in Chapter 4, the volcanic sandstone known as vitric tuff. This shows that the volcanic product composed in the rock are vitric ash or vitric tuff. The ashes or tuff product was from the eruption activity of volcanic during that period.

For the period fourteen, the pyroclastic breccia succession is 17.4 m thickness. The thickness of pyroclastic breccia shows that the volcanic activity during this period is very active. Then, the deposition of epiclastic breccia takes place with slow erosional and depositional activity. While for period fifteen, the thickness of pyroclastic breccia decreases compared to the pyroclastic found in period fourteen.

After the deposition of pyroclastic breccia, epiclastic breccia formed from the slow erosional process and was overlain by expulsive lava. The lava in this period might be deposited under the influence of tectonic process, where major structure formed at the location. This is because there was brecciation structure found at the lava layer. Then the erosional activity occurred back and epiclastic breccia was deposited on the lava. The epiclastic breccia deposited in this period mark the end of limestone fragment deposit in Patuk area. The size of limestone fragment found in period fifteen is dominant in cobble size. The size of limestone fragment decreasing gradually from the fourth period until the period fifteen.

Then during period sixteen, the pyroclastic breccia formed in small thickness and was overlain by a body of lava. Then, a body of basalt porphyry was found interbedded between the lava lithology. The lava at this period show brecciation structure along with the alteration of lava. It was intruded from the earth surface because of tectonic process and basalt porphyry formed between the lava.

The volcanism activity in the seventeen period shows thick pyroclastic breccia deposited and overlain by volcanic sandstone. The pyroclastic breccia during this period shows dominant of basalt fragment in the deposition. The volcanic sandstone can be formed because of the weathering of lava and pyroclastic breccia from other period. The tuff and ashes in this rock might come from the explosive of volcano activity in the period. The erosional and transportation activity for period seventeen is high, where there were two layers' deposition of epiclastic breccia, interbedded with lava. The rock fragment found at the late deposition of this period shows dominant of andesite fragment.

During the period eighteen of volcanism activity, the pyroclastic breccia shows massive deposition characters. The eruption of volcanoes become active from the period eighteen to period twenty. This can be seen from the thick layers of pyroclastic breccia. There was thick succession of volcanic sandstone during this period. It was sand matrix supported with volcanic product. The deposition formed from the high erosional process where the dominant rock fragment was pebbles. The pebbly size of fragment shows active transportation and erosional process occurred, with the influenced of water. While the erosional process decreasing in period nineteen and twenty.

The deposition of pyroclastic breccia during period twenty-one decreasing because of the decreasing of volcanic activity during that period. However, the erosional process increasing distinctively during period twenty-one until the last period of volcanism activity in Nglanggeran Formation, which is at period twenty-three. The erosional and transportation of volcanic products at that moment is under the influence of water with a lot of volcanic products resulted from active volcanic activity.

The pyroclastic breccia increase in thickness during the period of twenty-two along with the erosional of the volcanic product forming epiclastic breccia and volcanic sandstone. The last lava expulsive deposited in period twenty-two with dominantly basaltic composition. After that, the pyroclastic breccia undergoes erosion and deposited as epiclastic breccia. Then the volcanism activity stopped. The remaining volcanic product was deposited and eroded forming epiclastic breccia and interfingered with the sandstone and mudstone of Sambipitu Formation.

During the period of twenty-three, water play big influenced in the deposition of epiclastic and sandstone of Sambipitu Formation. The gradually changes in fragment size of epiclastic breccia, sandstone and mudstone shows the changes in energy of water during that period. The volcanism activity of Nglanggeran Formation occurred during Early Miocene and ended during the deposition of Sambipitu Formation. The full description for each period and lithology was shown in Appendix A .

5.6 Facies Analysis

Volcaniclastic Facies consist of four type of facies and was explained in Chapter 2. The facies was determined based on the location and landform of volcano, the distance of the lithology from the source of volcano and the lithology of volcaniclastic at the study area itself. Therefore, based on the criteria mention, the volcaniclastic facies for Patuk area was determined.

There were two main type of volcaniclastic facies in study area, which are medial volcaniclastic facies and distal volcaniclastic facies. Based on the lithology log for the volcaniclastic sediment, the pattern of the volcaniclastic deposition shows different sequence of layers of the rock. Figure 5.7 shows the facies model and location of medial and distal volcaniclastic facies.

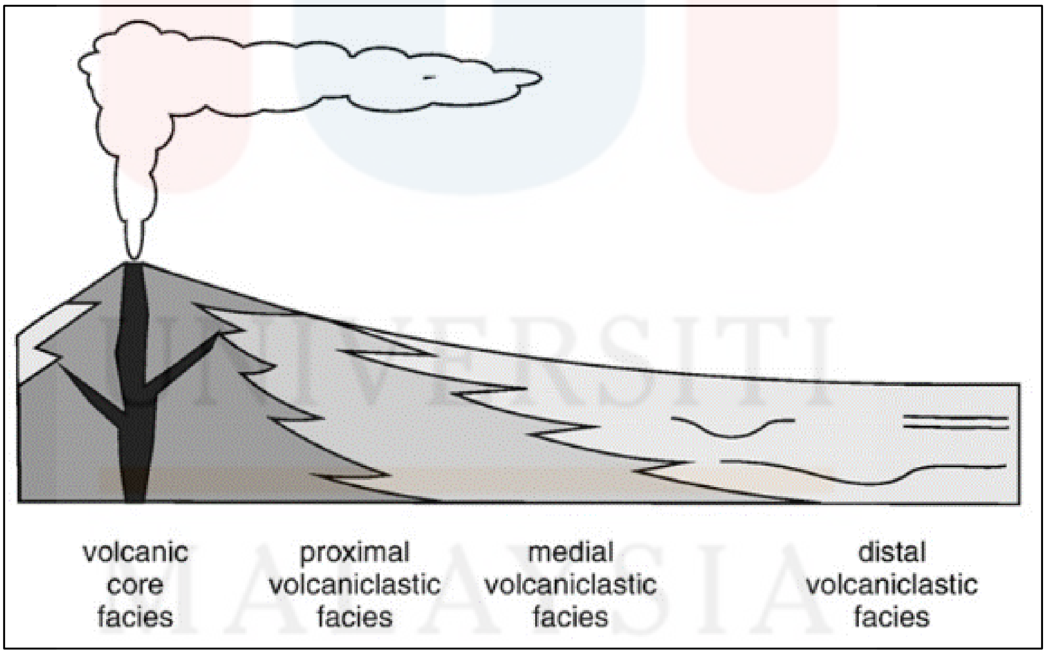


Figure 5.7: Volcaniclastic Facies Model (Selles et. al, 2012).

First, the medial volcaniclastic facies. In this facies, the main lithology of volcaniclastic sediment is dominantly pyroclastic breccia and deposition of epiclastic breccia. This pattern can be seen from the period of seven until the period of twelve. The alternating deposition of pyroclastic breccia and epiclastic breccia shows the characteristic of medial volcaniclastic facies. The distance of the medial facies is approximately 10 to 15 km from the crater or the sources of volcano activity (Selles et al., 2012) with high elevation. The characteristics of medial facies match with the characteristic in study area where the deposition from period seven until period twelve found. The medial volcaniclastic facies was shown in Figure 5.8. The medial volcaniclastic facies deposited at the low slope of volcano, located at the middle of the Patuk area.

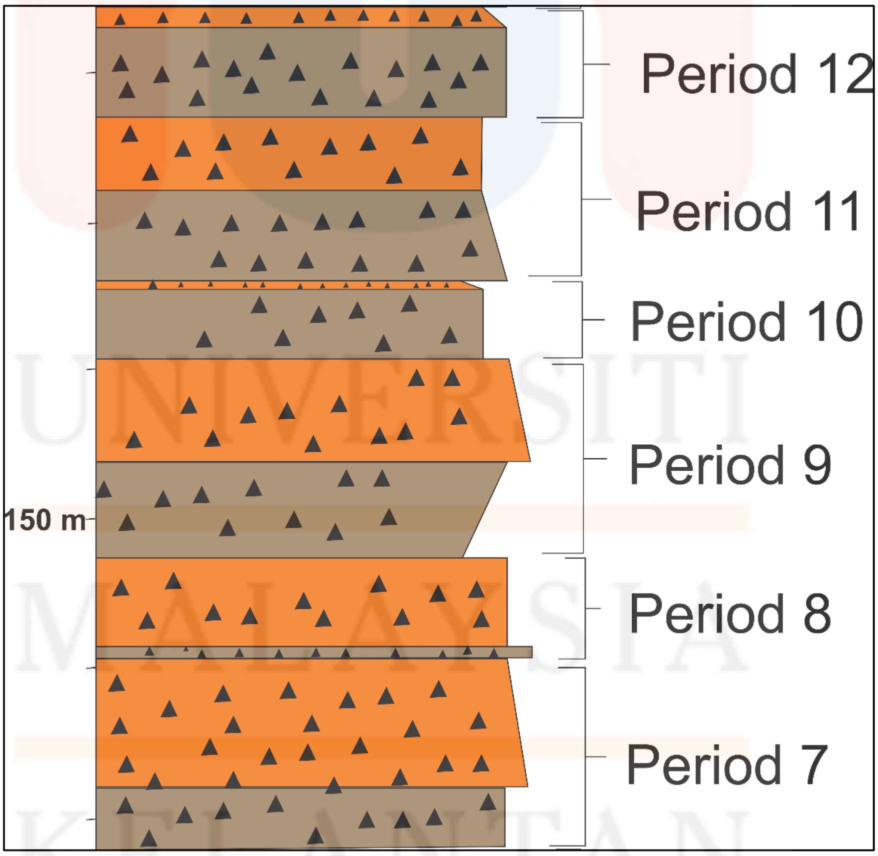


Figure 5.8: The medial volcaniclastic facies of Patuk area.

Next, the distal volcaniclastic facies. The main lithology found in this facies are the polymitic volcaniclastic sediment. The types of rock were majorly deposited under the influenced of water and undergoes erosion process. The rock found is volcaniclastic sandstone and epiclastic breccia. It was dominant with breccia, gravel and sand unit. Most of the deposits are weathered and show high proportion of sand as the matrix.

The distal zone distance from the sources of volcanic product or crater is about 15 to 25 km. Figure 5.9 shows the distal volcaniclastic facies at Patuk area. The facies of distal was found during the period of twenty-one until the end period activity of Nglanggeran Formation. The volcaniclastic facies found at the southern part of study area. At the end of the volcaniclastic deposition, the interfingered between sandstone of Sambipitu Formation and epiclastic breccia occurred.

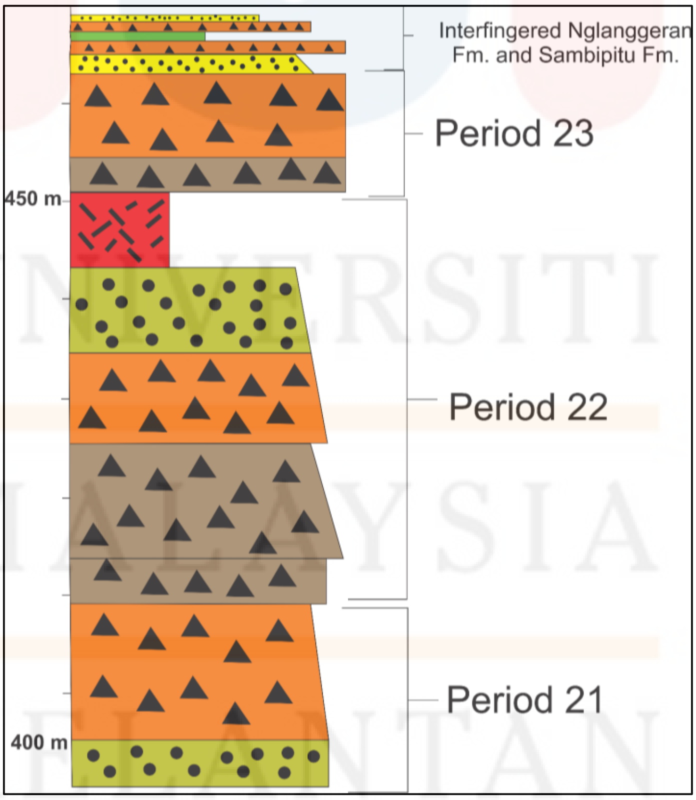


Figure 5.9: The distal volcaniclastic facies of Patuk area.

The rough model of volcaniclastic facies in Patuk area was shown in Figure 5.10 where the medial and distal volcaniclastic facies was shown. The Patuk area landform is higher and the elevation decreasing from north to south. The lithology and the landform of the study area is suitable with the characteristics shown in the volcaniclastic facies model.

The medial volcaniclastic facies shows an alluvial fan characteristic based on the lithology and the landform of Patuk area. The deposition occurred under the high energy of transportation to low energy of transportation based on the changes in fragment size. It deposited at the slope of volcano and deposited as detrital fan or known as alluvium fan in depositional environment. While the distal volcaniclastic facies was formed under high influenced of water where erosional and depositional process take place. The deposition of distal facies in Patuk area occurred at the lowest slope of the volcano in the shallow marine environment, with turbidite properties of lithology.

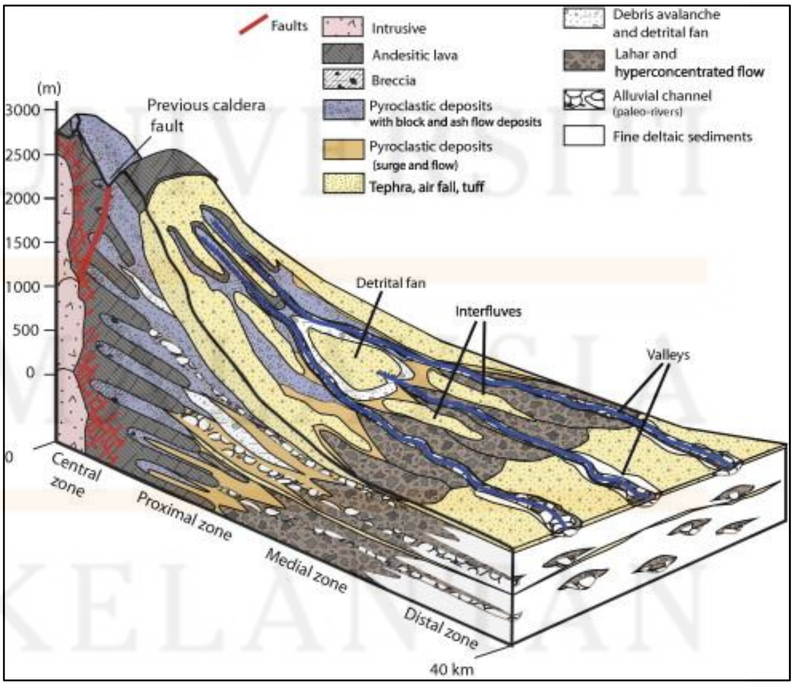


Figure 5.10: The volcaniclastic facies model with lithology (Selles et al., 2012).

5.7 Suggestion of Depositional Environment in Nglanggeran Formation

Based on the volcaniclastic lithology log, the type of volcano in the study area is Stratovolcano. The volcaniclastic lithology shows that deposition is from the short viscous lava flows and the deposition shows inter-layering of pyroclastic breccia, lava and epiclastic breccia. There was twenty-three periodic of volcanism activity, which consist of alternating of eruptive phase and post-eruptive sedimentation for pyroclastic breccia and epiclastic breccia. Based on Selles, et.al (2012) the stratovolcanoes form over periods of tens or hundreds of thousands of years by repeated volcanism activity with small scales of eruption pattern. Figure 5.11 shows the duration of volcanic eruptions for stratovolcano.

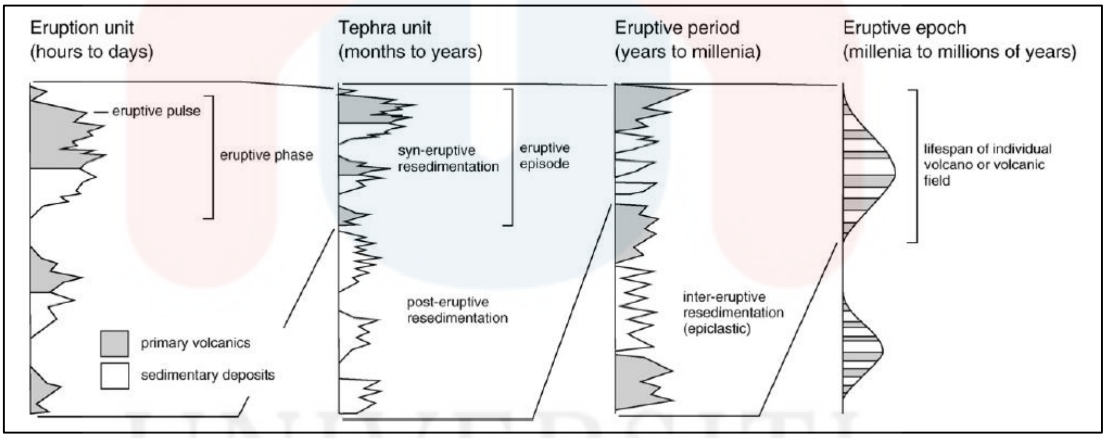


Figure 5.11: The hierarchies of scale in duration of volcanic eruptions and intervening quiescent intervals (Manville et al., 2009).

However, the pyroclastic breccia and epiclastic breccia almost have the same abundancy of lithology in the study area. The explosive materials deposited becoming the pyroclastic breccia. The alternating of pyroclastic breccia and epiclastic breccia units over short distances and along with the sedimentation process shows the roles of water in the volcanic activity. The limestone fragment present in the epiclastic breccia can be proved that the Nglanggeran Formation is from the shallow marine environment or specifically as submarine environment.

Based on Figure 5.12, the volcanic products, pyroclastic breccia deposited in a submarine deposition. The volcanic product undergoes fallout and flows deposition process and deposited at the slope of the volcano and at the Semilir Formation. As mention in Chapter 4, Semilir Formation depositional environment is subaerial deposition. When the volcanic activity ended in Semilir Formation, new volcanic form in Nglanggeran Formation deposition. The volcanic formed and actively erupted as submarine eruption. These can be proved from the lithology log of volcaniclastic sediments where there is a repetition between the volcanic deposition and the erosion deposition. Pyroclastic breccia and lava as the submarine deposition of volcaniclastic, while epiclastic breccia formed from the erosion of pyroclastic breccia and deposited as volcaniclastic sediments.

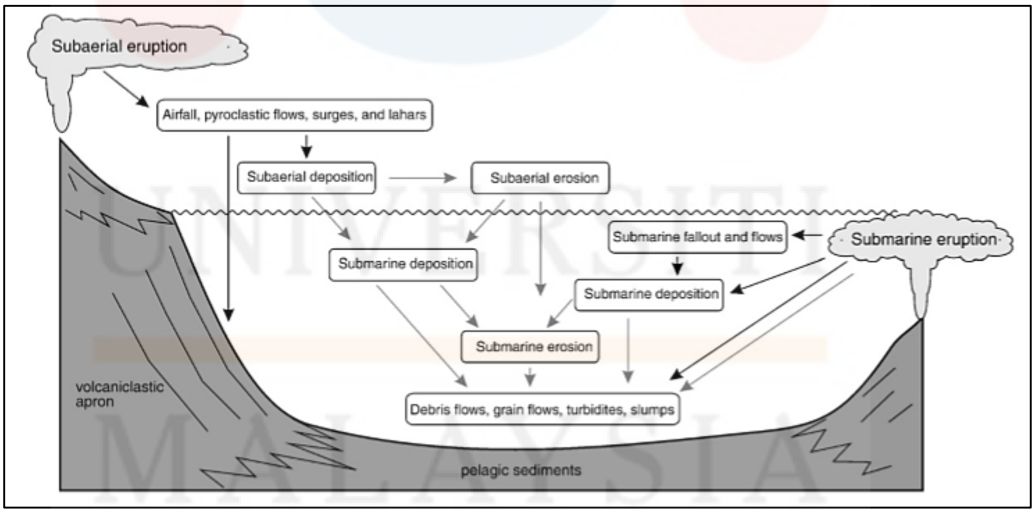


Figure 5.12: The sources and transport processes of volcaniclastic sediments (Selles et al., 2012).

5.8 History of Volcanic Activity in Nglanggeran Formation

The overall thickness for volcaniclastic sediments in the Nglanggeran Formation is 436.4 m with 23 Period of volcanism activity. Every period composed of different sizes of fragments and deposition of lithology, which represent volcanism activity during the period. The pyroclastic breccia and epiclastic breccia are alternating with each other shows the pattern of volcanism process in submarine environment along with the interbedded of lava, which acts as indicator for the chemical composition of magma during the expulsive of volcanic occurs.

Based on the lithology log of the volcaniclastic construct, facies analysis for the study area was made. There were two types of facies for volcaniclastic sediments found in the study area. All the facies shows different properties of lithology and represents the volcanic model and location in study area.

The main type volcano at Nglanggeran Formation is Stratovolcano, where the alternating layers of epiclastic breccia and pyroclastic breccia formed layers on the slope of the stratovolcano. The dominancy of epiclastic breccia in the study area is because major erosion from the volcano itself. The explosive eruptive activity covers the slopes of volcano and the dome growth on top of the volcano. The frequent volcanic activity in Nglanggeran formation resulted in the collapsing of the dome. Therefore, at the end of the Nglanggeran Formation, the thickness of pyroclastic breccia increase and drastically decrease and ended. The volcanic activity ended because of the dome collapse, which ended the deposition of Nglanggeran Formation and the volcanic deposition in Patuk area.

There was an alteration process occurred during the volcanic activity, which mainly can be seen at Andesite Lava. The type of alteration involved in Nglanggeran

Formation is propylitic alteration. The shallow marine in Nglanggeran Formation is one of the factors for the alteration to occur, where the seawaters contact with the magma during volcanic activity formed hydrothermal fluids. Next, based on the lithology log of volcaniclastic sediments, the pattern for the deposition can be determined. From the pattern of deposition, there was erosion and deposition process occurred repeatedly. This shows the environment of submarine environment, along with the limestone fragment found in the study area. Therefore, the main depositional environment for Nglanggeran Formation is shallow marine and the study area is the submarine environment. The overall deposition of volcaniclastic Nglanggeran Formation at Patuk area was shown in Figure 5.13. For the distal part, focused on the marine deposition. This is because the deposition of volcaniclastic sediment in Nglanggeran area is in marine environment.

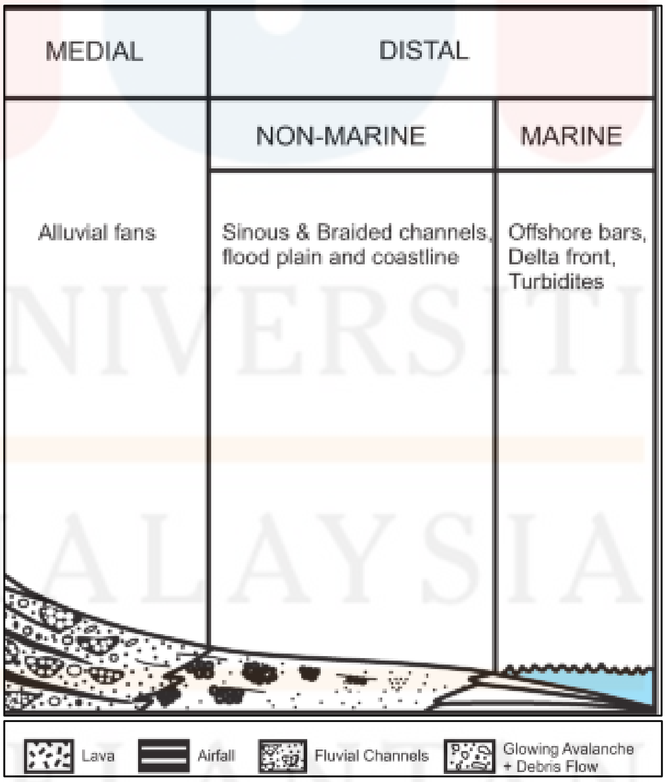


Figure 5.13: The overall deposition of volcaniclastic sediment in study area (Modified from Olavsdottir, 2009).

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The research focused on the geology of the Patuk area, Gunung Kidul, Yogyakarta, Indonesia and the specification of research, which is the volcaniclastic deposition for Nglanggeran Formation. All the objective listed in Chapter 1 was achieved. The geological map of Patuk area was produced on a scale of 1: 25 000 based on the geological structure, the lithology unit, the stratigraphy and the geomorphological study of the study area. The historical geology was explained based on the data gained from the geological mapping.

The accessibility, the settlement and the vegetation of the study area depends on the geographical surface. All the socioeconomics of the villagers is depending on vegetation and settlement, where it became their main source of income. The traverse for geological mapping in producing geological map is 8 days, where 4 days was focused on the research specification. The traverse was conducted mainly along the rivers because of the less vegetation and clear outcrop.

Next, there were three geomorphology units based on the geomorphological classification of topographic in study area. The geomorphological unit is undulating hills landscape, escarpment valley and flat landscape. All the landscape represents different types of lithology. The types of weathering found in Patuk area are physical weathering, chemical weathering and biological weathering. All the weathering has different process of formation. The main drainage pattern in study area is rectangular pattern and dendritic pattern. The main river, Kali Pentung and Kali Petir become the main drainage basin in the study area. The rectangular pattern and dendritic pattern represent different types of geomorphology and act as indicator for structures.

The lithology unit that was found in Patuk area was divided into five units. First, Tuff Unit of Semilir Formation, Pyroclastic Breccia Unit of Nglanggeran Formation, Epiclastic Breccia Unit of Nglanggeran Formation, Lava Unit of Nglanggeran Formation and Merapi Alluvium Unit. There were three main formations, which are Semilir Formation, Nglanggeran Formation and Quaternary Merapi. The stratigraphic column was produced based on the lithology unit. Every formation consists of different types of depositional environments. Both Nglanggeran Formation and Semilir Formation are based on shallow marine environment. However, in the study area, it can be determined that the Semilir Formation is known as aerial marine environment, while Nglanggeran Formation is submarine environment.

The mechanism structure was determined from the bedding orientation and the lineament analysis. The main forces exerted at the study area are 335° with average bedding orientation of N 85° E/ 10°. The main type of faulting found in the study area is strike-slip fault and normal fault. The normal fault was determined based on the geomorphology evidence while the strike-slip from the measurement of bedding and lineament. The dominant strike-slip in study area is sinistral strike-slip. Another structure found is cleavage and joint.

Based on the lithology log of volcaniclastic sediments, there was 23 Period for volcanism activity of Nglanggeran Formation. The overall thickness for Nglanggeran Formation was determined, which is 436.4 m. There were two facies of volcaniclastic found in the study area. Each facies found represent different types of lithology unit. The main type of volcano in the study area is Stratovolcano with repeatedly volcanism activity. The volcanism activity occurred in shallow marine where the Nglanggeran Formation depositional environment is submarine environment. The second and third objective was achieved successfully. The types of facies and depositional environment of Nglanggeran Formation in Patuk area, Gunung Kidul, Yogyakarta, Indonesia.

6.2 Recommendations

Nglanggeran Formation consists of mainly volcaniclastic sediments, where it is from the deposition of ancient volcanic. There are many aspects to be explored in Nglanggeran Formation. The lithology unit, the interesting geomorphology and the history of the volcanoes activity in Nglanggeran Formation can be the values for Geoheritage study.

In order to determine the depositional environment for Nglanggeran Formation, the measuring section must be made along with the grid mapping. Grid mapping shows the distribution of lava in the study area. Therefore, the facies analysis for Nglanggeran Formation can be analyzed in more detail with two supported results. The fragments and chemical composition of the Nglanggeran Formation is the most important aspect in order to determine the volcanism activity. From the volcanism activity and lithology log of volcaniclastic sediments, the detailed information about Nglanggeran Formation can be produced. This will help other researchers to analyses the Nglanggeran Formation later.

Next, focused on the limestone fragment found in the study area. Research can be made from the limestone fragment to determine the age of the limestone fragments.

The sources of the limestone fragments are still unknown, but for now the conclusion was made only based on literature review. While for Basalt porphyry rock, this new finding in the study area. Chemical analysis should be made in order to determine the sources of the parents' rock and chemical elements in the rocks.

REFERENCES

Adinugroho, G. (2017). Hubungan Perkembangan Wisata terhadap Ekonomi Wilayah di Gunungkidul Selatan The Impact of Tourism Development towards Regional Economy at Southern Gunungkidul. *Journal of Regional and Rural Development Planning Februari*, *1*(1), 16–27.

Aydan, Ö. (2015). Chapter 3 Geology & Tectonics. *Tectonics*, *Volume 7*(Issue May), Pages 12-17.

Bronto, S., Pambudi, S., & Hartono, G. (2002). The Genesis of Volcanic sandstones associated with basaltic pillow lava, Bayat areas: A case study at the Jiwo Jills, Bayat area (Klaten, Central JAva). *Geologi Dan Sumber Daya Mineral*, *3*, 2–16.

Damayanti, E. (2013). *Transitions to Sustainable Forest Management and Rehabilitation in the Asia Pacific Region-Indonesia Country Report*.

Hall, R. (2009). *INDONESIA , GEOLOGY*. 454–460.

Husein, S. (2015). *" Petroleum and Regional Geology Northeast Java Basin , Indonesia ."* (December).

Husein, S., & Srijono. (2016). Peta Geomorfologi Daerah Istimewa Yogyakarta. *Simposium Geologi Yogyakarta*, (March 2010). https://doi.org/10.13140/RG.2.2.10627.50726

Kalasaiah, M., & Balasubramanian, A. (2013). Depositional Environments. *Lithostratigraphic Analysis of Sedimentary Basins*, (November), 197–293. https://doi.org/10.1016/b978-0-12-186050-9.50008-x

Karnawati, D., Pramumijoyo, S., & Hendrayana, H. (2006). Geology of Yogyakarta , Java : *IAEG2006 Proceeding*, (363), 1–7.

Mahrizal, V. (2017, November 7). Pertumbuhan Ekonomi DIY Triwulan III-2017 Capai 541 Persen. *Tribun Jogja*. Retrieved from http://jogja.tribunnews.com/2017/11/07/pertumbuhan-ekonomi-diy-triwulan-iii-2017-capai-541-persen

Makrup, L. (2017). *Change the Frequency Characteristics of the Earthquake Acceleration Wave By Fourier Analysis*. *8*(12), 12.

Manville, V., Németh, K., & Kano, K. (2009). Source to sink: A review of three decades of progress in the understanding of volcaniclastic processes, deposits, and hazards. *Sedimentary Geology*, *220*(3–4), 136–161. https://doi.org/10.1016/j.sedgeo.2009.04.022

Nichols, G. (2009). *Sedimentology and Stratigraphy, Second Edition* (2nd ed.). United Kingdom: A John Wiley & sons, Ltd. Publication.

Norman, D. K., Parry, W. T., & Bowman, J. R. (1991). Petrology and geochemistry of propylitic alteration at Southwest Tintic, Utah. *Economic Geology*, *86*(1), 13–28. Retrieved from https://doi.org/10.2113/gsecongeo.86.1.13

Olavsdottir, J. (2009). *Reservoir quality assessment of the volcaniclastic post-basalt sediments in the Faroese area of the Faroe-Shetland Basin*.

Preece, K. (2003). Indonesian Subduction Zone System. *Journal of Petrology*, *44*, 457–489.

Priady, F. (2014). *Formasi_nglanggran*. Java, Indonesia.

Prihutami, D. (2016). *Social Housing Development in Indonesia - Challenges and Opportunities in the Practice of Community-Based Housing for the Low-Income Residents*. Kyoto, Japan.

Raj, J. . (2009). Geomorphology of Peninsular Malaysia, Kuala Lumpur. *Geological Society of Malaysia*, p.5-29.

Razi, H. (2018). *Geology and Depositional Environment of Nglanggeran Formation in Gunung Kidul Regency, Yogyakarta, Indonesia*. Universiti Malaysia Kelantan.

Selles, A., Deffontaines, B., Hendrayana, H., & Violette, S. (2012). Characterisation of the volcano-sedimentary deposits of an active strato-volcano: the Merapi case example (Central Java, Indonesia). *Proceeding of 5th AUN/SEED-Net Regional Conference on Geo-Disaster Mitigation in ASEAN*, (SEPTEMBER), 1–14.

Smyth, H. R., Hall, R., & Nichols, G. J. (2008). Cenozoic volcanic arc history of East Java, Indonesia: The stratigraphic record of eruptions on an active continental margin. *Special Paper 436: Formation and Applications of the Sedimentary Record in Arc Collision Zones*, *2436*(10), 199–222. https://doi.org/10.1130/2008.2436(10)

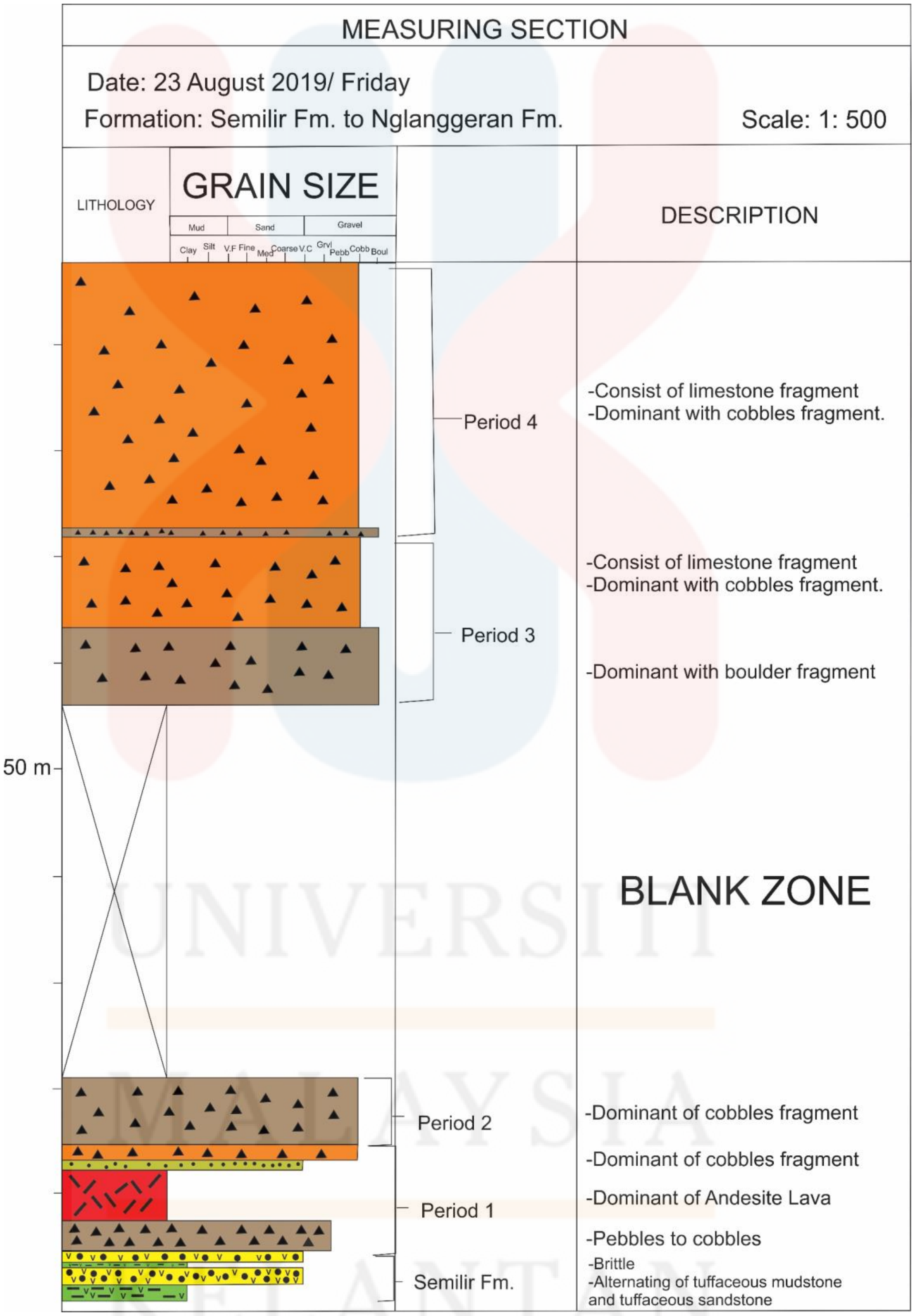
Stow, D. A. . (2005). *Sedimentary Rocks in the Field, A Colour Guide*. Australia: Manson Publishing Ltd.

Susilohadi. (1995). *Late tertiary and quaternary geology of the East Java Basin, Indonesia*. 169.

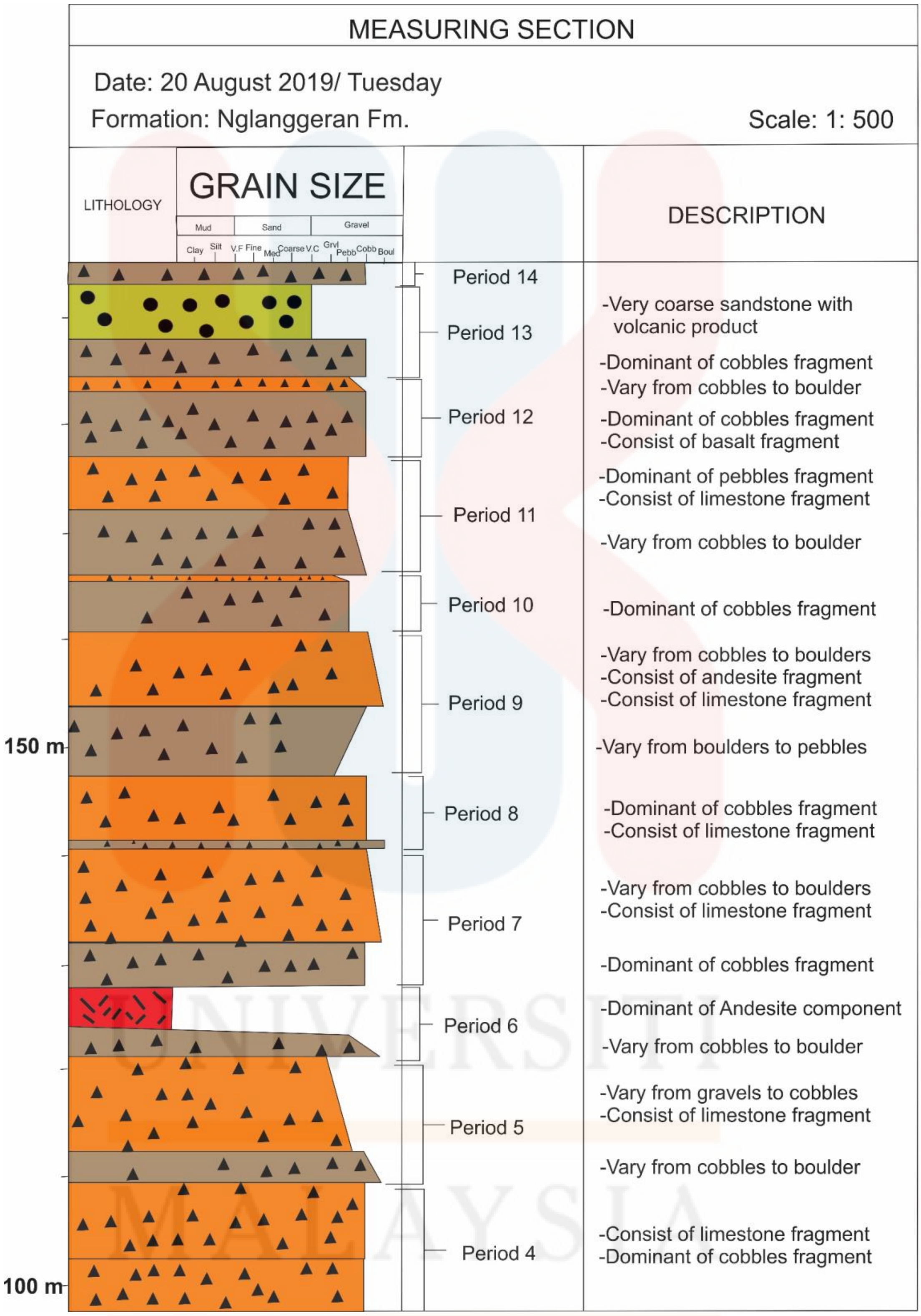
Sutiono, A., Prastistho, B., Prasetyadi, C., & Supartoyo. (2018). Opak fault: A comparative review. *IOP Conference Series: Earth and Environmental Science*, *212*(1). https://doi.org/10.1088/1755-1315/212/1/012049

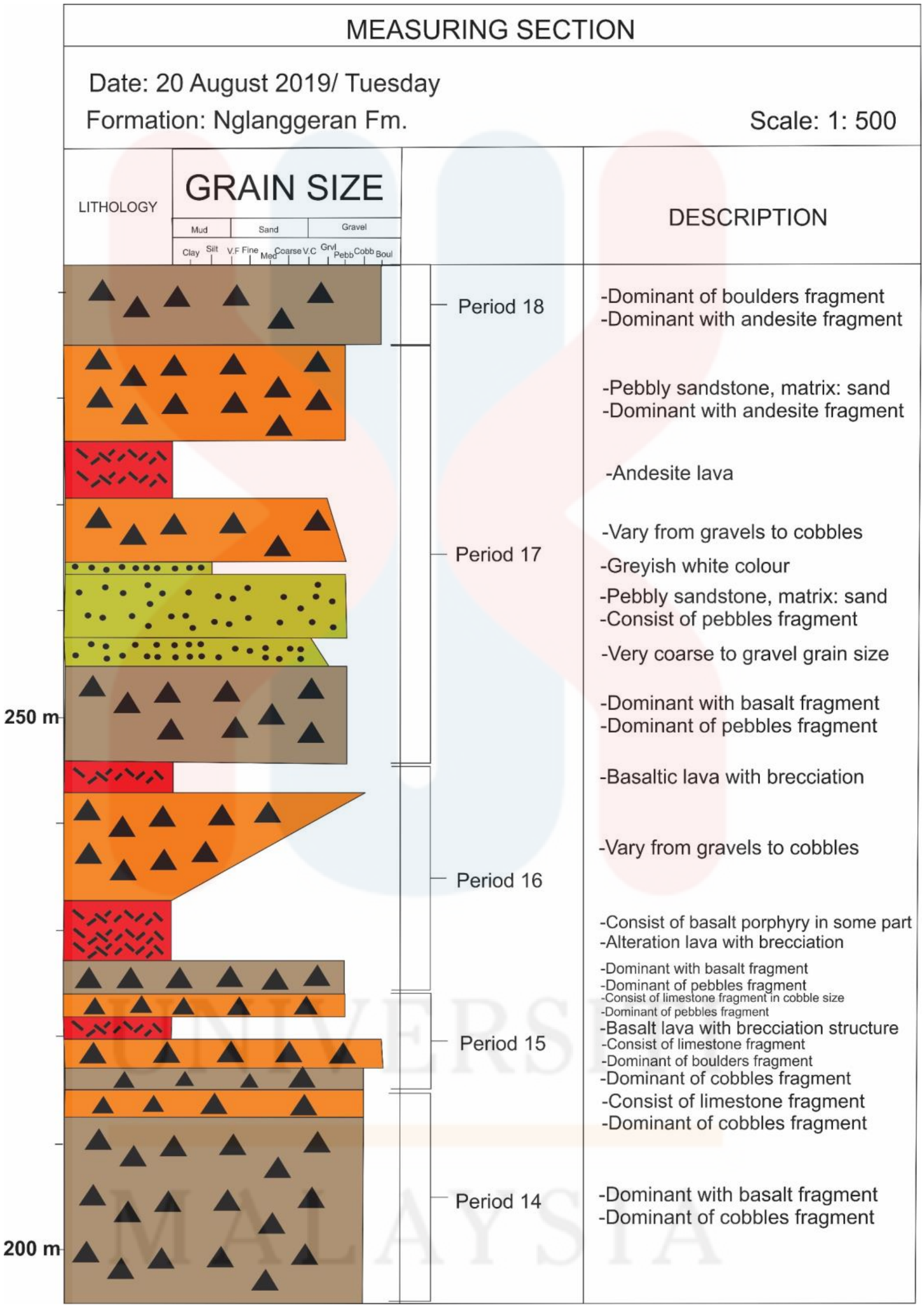
Triana, K. (2013). *Geologi Regional Pengunungan Selatan , Jawa Tengah*. 27.

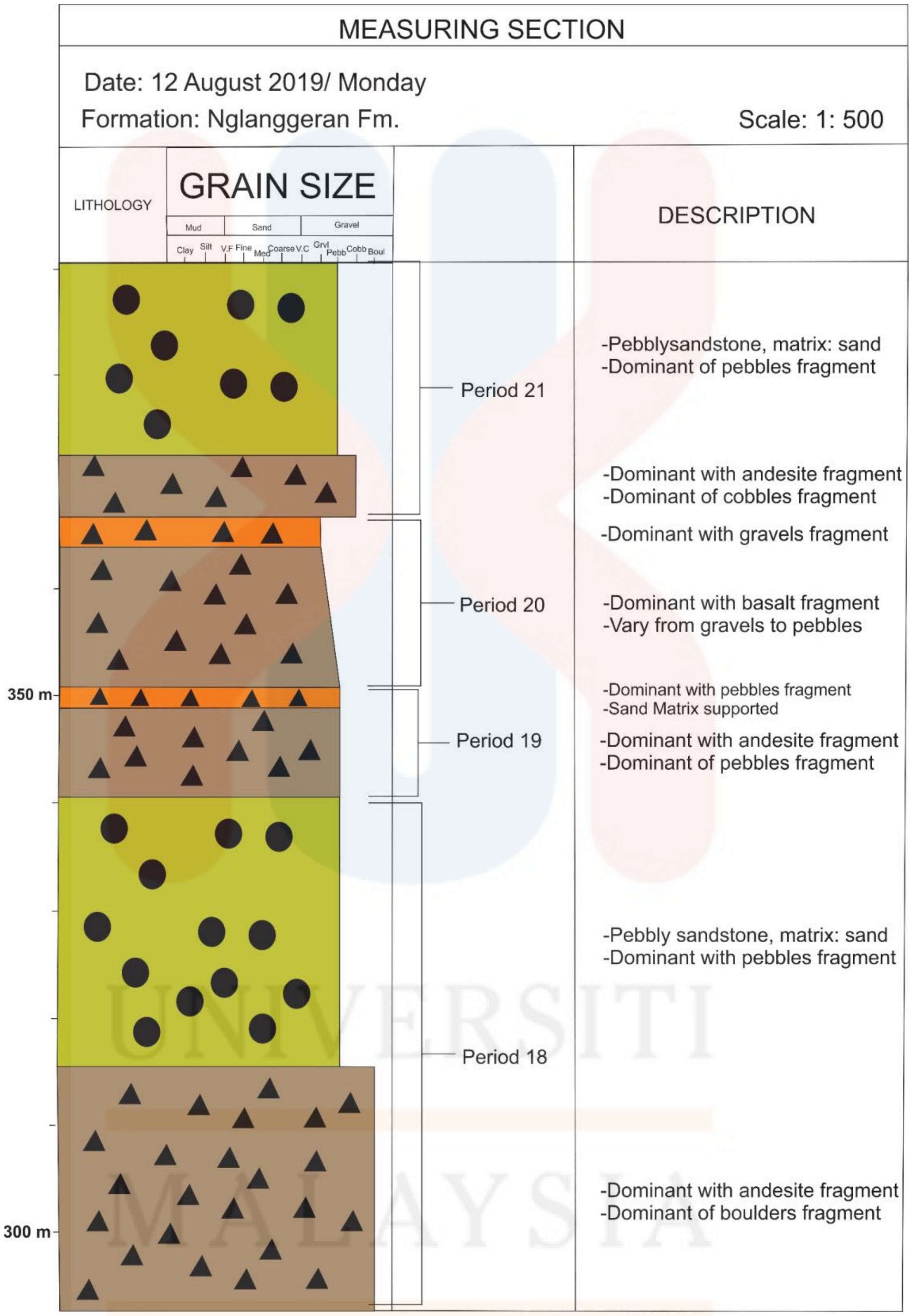
APPENDIX A

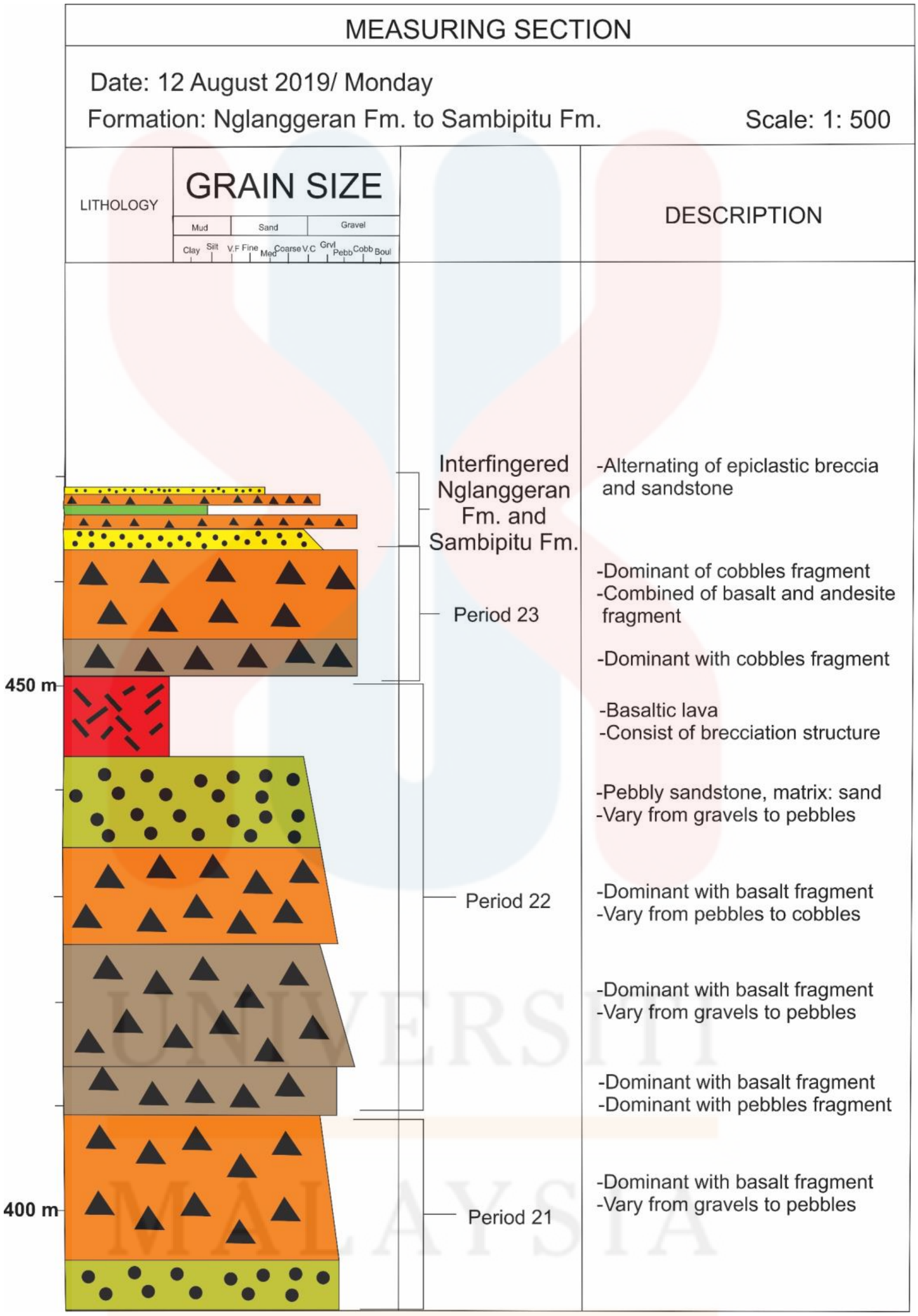


MEASURING SECTION
Date: 23 August 2019/ Friday
Formation: Semilir Fm. to Nglanggeran Fm.
Scale: 1: 500
LITHOLOGY
GRAIN SIZE
Mud
Sand
Gravel
Clay
Silt
V.F
Fine
Med
Coarse
V.C
Grvl
Pebb
Cobb
Boul
DESCRIPTION
Period 4
-Consist of limestone fragment
-Dominant with cobbles fragment.
Period 3
-Consist of limestone fragment
-Dominant with cobbles fragment.
-Dominant with boulder fragment
50 m
BLANK ZONE
Period 2
-Dominant of cobbles fragment
-Dominant of cobbles fragment
Period 1
-Dominant of Andesite Lava
-Pebbles to cobbles
Semilir Fm.
-Brittle
-Alternating of tuffaceous mudstone
and tuffaceous sandstone


MEASURING SECTION
Date: 20 August 2019/ Tuesday
Formation: Nglanggeran Fm.
Scale: 1: 500
LITHOLOGY
GRAIN SIZE
Mud
Sand
Gravel
Clay
Silt
V.F
Fine
Med
Coarse
V.C
Grvl
Pebb
Cobb
Boul
DESCRIPTION
Period 14
Period 13
-Very coarse sandstone with volcanic product
-Dominant of cobbles fragment
-Vary from cobbles to boulder
Period 12
-Dominant of cobbles fragment
-Consist of basalt fragment
-Dominant of pebbles fragment
-Consist of limestone fragment
Period 11
-Vary from cobbles to boulder
Period 10
-Dominant of cobbles fragment
-Vary from cobbles to boulders
-Consist of andesite fragment
-Consist of limestone fragment
Period 9
150 m
-Vary from boulders to pebbles
Period 8
-Dominant of cobbles fragment
-Consist of limestone fragment
-Vary from cobbles to boulders
-Consist of limestone fragment
Period 7
-Dominant of cobbles fragment
-Dominant of Andesite component
Period 6
-Vary from cobbles to boulder
-Vary from gravels to cobbles
-Consist of limestone fragment
Period 5
-Vary from cobbles to boulder
-Consist of limestone fragment
-Dominant of cobbles fragment
Period 4
100 m


MEASURING SECTION
Date: 20 August 2019/ Tuesday
Formation: Nglanggeran Fm.
Scale: 1: 500
LITHOLOGY
GRAIN SIZE
Mud
Sand
Gravel
Clay
Silt
V.F
Fine
Med
Coarse
V.C
Grvl
Pebb
Cobb
Boul
DESCRIPTION
Period 18
-Dominant of boulders fragment
-Dominant with andesite fragment
-Pebbly sandstone, matrix: sand
-Dominant with andesite fragment
-Andesite lava
Period 17
-Vary from gravels to cobbles
-Greyish white colour
-Pebbly sandstone, matrix: sand
-Consist of pebbles fragment
-Very coarse to gravel grain size
-Dominant with basalt fragment
-Dominant of pebbles fragment
250 m
-Basaltic lava with brecciation
-Vary from gravels to cobbles
Period 16
-Consist of basalt porphyry in some part
-Alteration lava with brecciation
-Dominant with basalt fragment
-Dominant of pebbles fragment
-Consist of limestone fragment in cobble size
-Dominant of pebbles fragment
Period 15
-Basalt lava with brecciation structure
-Consist of limestone fragment
-Dominant of boulders fragment
-Dominant of cobbles fragment
-Consist of limestone fragment
-Dominant of cobbles fragment
Period 14
-Dominant with basalt fragment
-Dominant of cobbles fragment
200 m


MEASURING SECTION
Date: 12 August 2019/ Monday
Formation: Nglanggeran Fm.
Scale: 1: 500
LITHOLOGY
GRAIN SIZE
Mud
Sand
Gravel
Clay
Silt
V.F
Fine
Med
Coarse
V.C
Grvl
Pebb
Cobb
Boul
DESCRIPTION
Period 21
-Pebblysandstone, matrix: sand
-Dominant of pebbles fragment
-Dominant with andesite fragment
-Dominant of cobbles fragment
-Dominant with gravels fragment
Period 20
-Dominant with basalt fragment
-Vary from gravels to pebbles
350 m
-Dominant with pebbles fragment
-Sand Matrix supported
Period 19
-Dominant with andesite fragment
-Dominant of pebbles fragment
-Pebbly sandstone, matrix: sand
-Dominant with pebbles fragment
Period 18
-Dominant with andesite fragment
-Dominant of boulders fragment
300 m


MEASURING SECTION
Date: 12 August 2019/ Monday
Formation: Nglanggeran Fm. to Sambipitu Fm.
Scale: 1: 500
LITHOLOGY
GRAIN SIZE
Mud
Sand
Gravel
Clay
Silt
V.F
Fine
Med
Coarse
V.C
Grvl
Pebb
Cobb
Boul
DESCRIPTION
450 m
400 m
Interfingered Nglanggeran Fm. and Sambipitu Fm.
Period 23
Period 22
Period 21
-Alternating of epiclastic breccia and sandstone
-Dominant of cobbles fragment
-Combined of basalt and andesite fragment
-Dominant with cobbles fragment
-Basaltic lava
-Consist of brecciation structure
-Pebbly sandstone, matrix: sand
-Vary from gravels to pebbles
-Dominant with basalt fragment
-Vary from pebbles to cobbles
-Dominant with basalt fragment
-Vary from gravels to pebbles
-Dominant with basalt fragment
-Dominant with pebbles fragment
-Dominant with basalt fragment
-Vary from gravels to pebbles