GEOLOGY OF THE BAYAT AREA, KLATEN AND VOLCANIC HAZARD OF MOUNT MERAPI, CENTRAL JAWA, YOGYAKARTA, INDONESIA

by

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

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UNIVERSITI MALAYSIA KELANTAN

2019

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Geology of Bayat Area, Klaten and Volcanic Hazard of Mount Merapi, Central Java, Special Province of Yogyakarta, Indonesia

ABSTRACT

Geological research includes geological structure, geomorphology, lithology and petrography in Bayat Area, Klaten with coordinate 110^{0} 37’ 39.78” E - 110^{0} 39’ 46.9” E and latitudes 7^{0} 44’ 17.58” S - 7^{0} 46’ 24.78” S. The previous map of Bayat have a scale or 1:100,000 so the area of Bayat does not clearly cover and accurated. The area of the location is approximately 25 km^2. The study area for this research is 5 km × 5 km wide. The objective of this research are to update the current geological map of the area and to analyzed the volcanic hazard in Mount Merapi. As the previous eruption of Merapi was on 2010, and considered as one of the most tragic eruption, the hazard till can be seen till today and still remembered by most villagers nearby of the destruction. The method used in this study is by geological mapping and analysis of rock sample. Mount Merapi located at the Central Java of Indonesia and is one of the most active volcanoes in the world. Krasak River is one of the main river of the lahar flow and was chosen to study of lahar deposition. The lahar still can be observed there as the site now becomes the mining site. The impact from the eruption was very destructive and the impact can be observed on the nearest village which totally lost from the eruption now becomes a museum and shows the actual destruction from the previous eruption. The volcanic hazard in Mount Merapi is identified. Both geological map and hazard map can be used by the government of Yogyakarta in the future and the hazard map can prevent more lost of life.

Geologi Am Bayat Area, Klaten dan Bahaya Gunung Api Merapi, Central Jawa, Daerah Istimewa Yogyakarta, Indonesia

ABSTRAK

Kajian geologi ini termasuk struktur geologi, geomorfologi, lithology dan petrografi di Bayat Area, Klaten dengan koordinat 110^{0} 37’ 39.78” E - 110^{0} 39’ 46.9” E dan latitud 7^{0} 44’ 17.58” S - 7^{0} 46’ 24.78” S. Peta geologi Bayat yang terdahulu mempunyai skala 1:100,000 jadi pemetaan di Bayat tidak terlalu jelas dan tepat. Kawasan kajian ini berkeluasan 25 km^2, iaitu 5 km × 5 km luas. Objektif kajian ini ialah untuk mengemaskini geologi map terkini dan juga untuk menganalisis bahaya bencana gunung api di Gunung Merapi. Letupan terbaru ialah pada tahun 2010 and diklasifikasikan sebagai salah satu letupan yang paling dasyat dan bahaya letupan itu masih boleh dilihat sehingga ke hari ini dan diingati oleh penduduk kampong yang terlibat. Cara analisa yang digunapakai dalam kajian ini ialah pemetaan geologi and analisa sample batuan. Gunung Merapi terletak di Jawa Tengah Indonesia dan salah satu gunung api paling aktif di dunia. Sungai Krasak adalah salah satu sungai utama untuk aliran lahar dan telah dipilih untuk kajian pemendapan lahar. Lahar masih boleh dilihat di sungai ini walaupun kawasan ini telah dijadikan kawasan perlombongan. Kesan daripada letupan lepas telah banyak melakukan kemusnahan dan kesan tersebut masih dapat dilihat di sekitar kawasan perkampungan yang terlibat yang telah rosak sepenuhnya dan kini telah dijadikan muzium and dipamerkan kemusnahan sebenar yang berlaku. Bahaya bencana di Gunung Merapi telah dikenalpasti. Kedua-dua peta geologi dan peta bencana boleh digunakan oleh kerajaan Yogyakarta di masa hadapan dan kegunaan peta kebencaan dapat mengurangkan risiko kehilangan nyawa.

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LIST OF SYMBOLS

% - percentage

°C – degree celcius

Ha – hectar

Ft – feet

µm – nano meter

º - degree

’ - minute

” – second

σ -Sigma

LIST OF ABBREVIATIONS

1. SME’s – Small and Medium Enterprise
2. VSI – Volcanological Survey of Indonesia
3. GPS – Global Positioning System
4. 3D – 3-dimension
5. I – 1
6. II – 2
7. III – 3
8. IV – 4
9. V – 5
10. VI – 6
11. S – South
12. E – East
13. NW – North-West
14. NE – North-East
15. KRB – Kawasan Rawan Bencana

CHAPTER 1

INTRODUCTION

1.1 General Background

Geology is a course that related to our Earth, atmosphere and the entire aspects in this Earth. As a future geologist, each of geology student need to have a knowledge even a basic one about the Earth. One of the expertise that each student need to learn and practice is mapping. Mapping is a basic study or knowledge that every geology student need to expert. Geology student will learn about geological features which will be used in mapping. This geological features will give information about a place that we study. With this information, geologist can produce a special purpose geological map of the study area.

Yogyakarta urban area is located on the highly populated with fluvio-volcanic plain near Mount Merapi Volcano with elevation of 2961m in Central Java. The northern limit extension of the city between Magelang street and Gadjahwong river while western and southern extension is allowed only along five main roads leading to Wates, Godean, Bantul, Parangtritis, and Imogiri. Based on Mulyaningsih, et al. (2011) the geology of western part of the Yogyakarta had influence by the volcanic activities of Central Java, Indonesia.

This study also includes volcanic hazard of the Mount Merapi which it last eruption as on May 11, 2018. According to Volcano Discovery, on May 11, 2018 at 07:32 local time there is a sudden, large explosive eruption which producing the ash plumes approximately 10 km altitude from the summit. According to the preliminary information, the eruption does not erupt any magma but the result overpressure accumulated over time where water and magmatic gases trapped inside the plugged suddenly free burst.

Mount Merapi is located in South East Asia in the country of Indonesia. It is in North of Yogyakarta and West of Solo on the island of Java. The causes of the past eruption were caused by the Indo-Australian Plate being subducted beneath the Eurasian Plate. Mount Merapi is a stratovolcano which are a tall, conical volcano composed of layer of hardened lava, tephra and volcanic ash. These volcanoes are characterized by a steep profile and periodic explosive eruptions. Merapi is an almost persistently active basalt to basaltic andesite volcanic complex in Central Java and often referred to as the type volcano for small volume pyroclastic flows generated by gravitational lava dome failures (Merapi –type nuée ardentes).

1.2 Study Area

Yogyakarta is located at Southern coast of the central part of Java Island. The end of the north province is Mount Merapi, Progo River and Opak River which all this lie in the western and eastern part of the slope of the mountain. Yogyakarta consists of Yogyakarta city and four residency (kabupatens). Kab. Bantul is located at the fluvial plain at the south-central part pf this province. Kab. Sleman located at south slope of Mount Merapi at the north central part of this province. This kabupatens are most densely populated in this province. Kab. Kulonprogo and Kab. Gunung Kidul are hill area to the east of Opak River and the west of Progo River respectively. The study area of Bayat, Klaten is located in Kab. Gunung Kidul.

The research will be focused on the geology of Bayat Area, Klaten, Yogyakarta as shown in Figure 1.1 and Western foot of Mount Merapi for specification. This area contains interesting geological features, tectonic activities, geomorphology and other sedimentation process that formed Bayat Area. By studying the geology of Ngalang Area, the ancient events and processes that formed can be identified.

Geographically, the Bayat Area, Klaten is located between the coordinates of longitudes 110^0 37’ 17.89” E - 110^0 39’ 58.9” E and latitudes 7^0 45’ 30.00” S - 7^0 48’ 07.88” S. The area of the location is approximately 25 km^2. The study area for this research is 5 km × 5 km wide. Figure 1.2 shows the base map for the study area. Figure 1.3 shows the imagery image for the study area while LANDSAT image volcanic hazard map of Mount Merapi is shown in Figure 1.4.

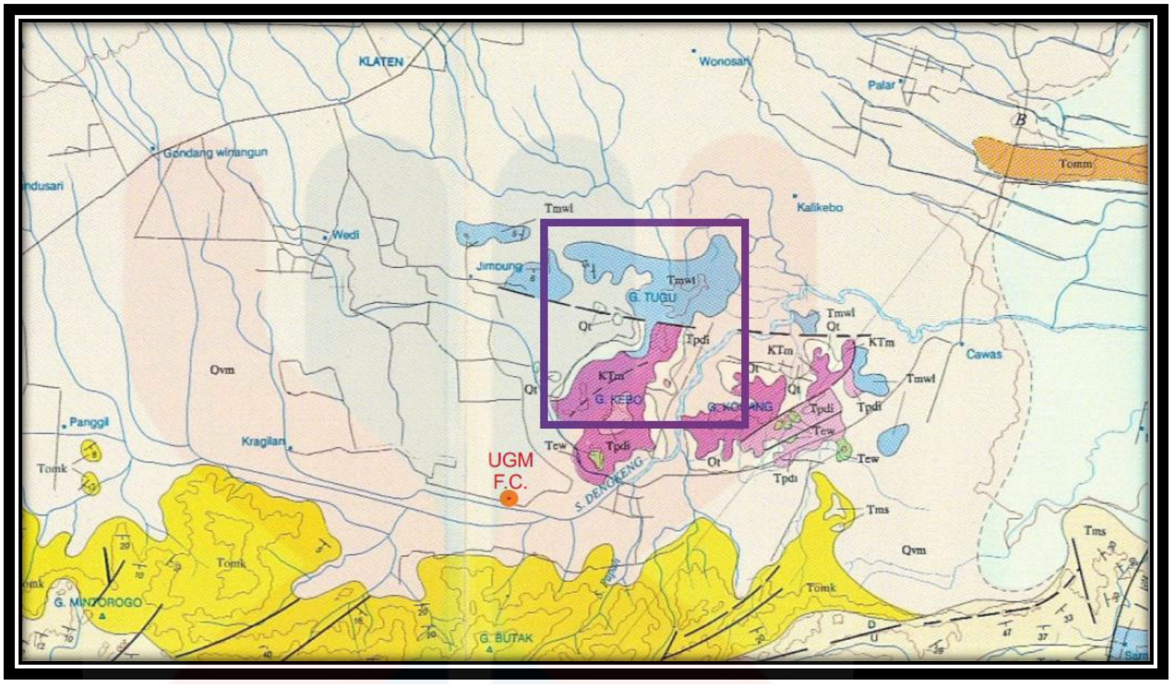


Figure 1.1: The location of the study area

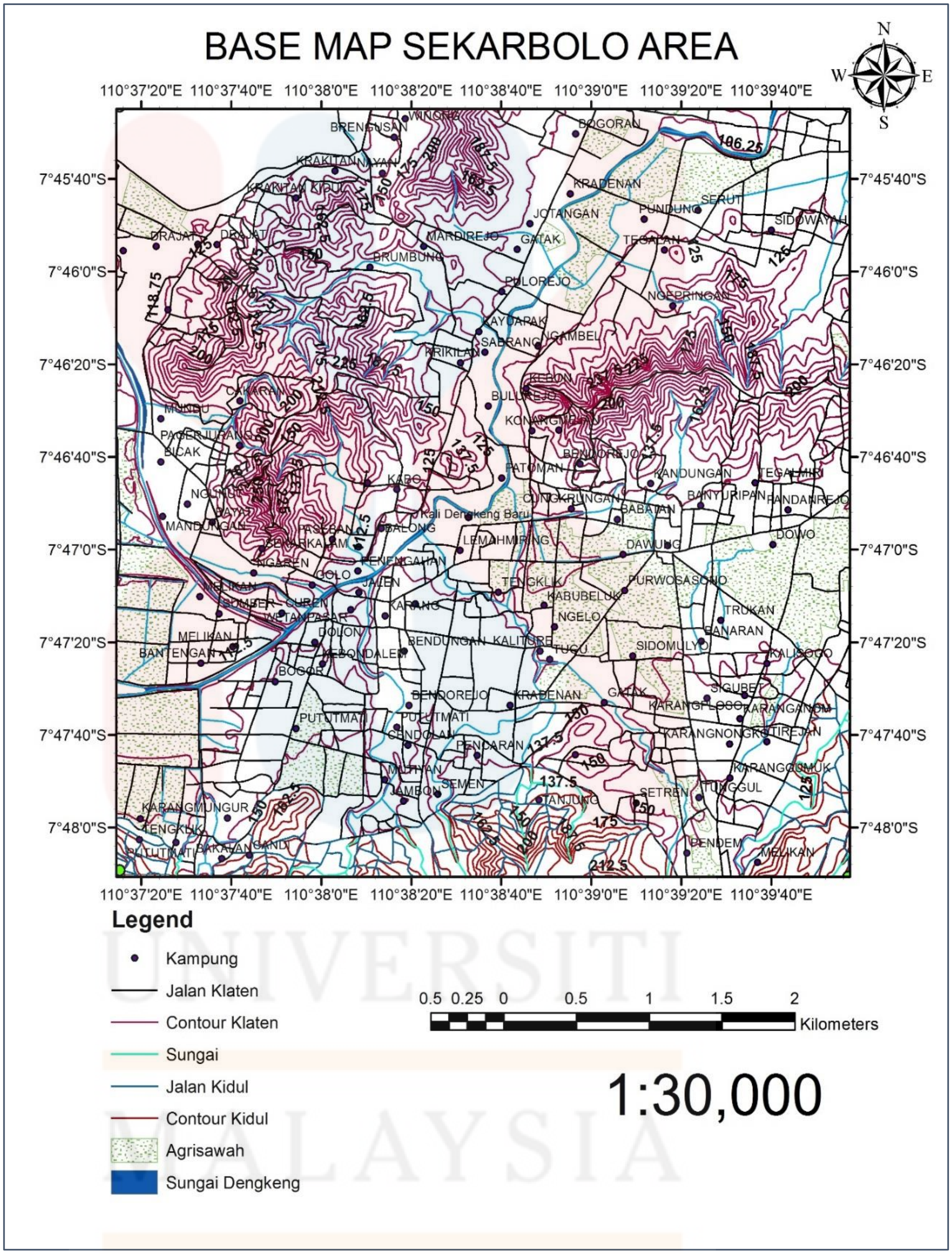


Figure 1.2: Base map of study area

Figure 1.3: Imagery image of study area

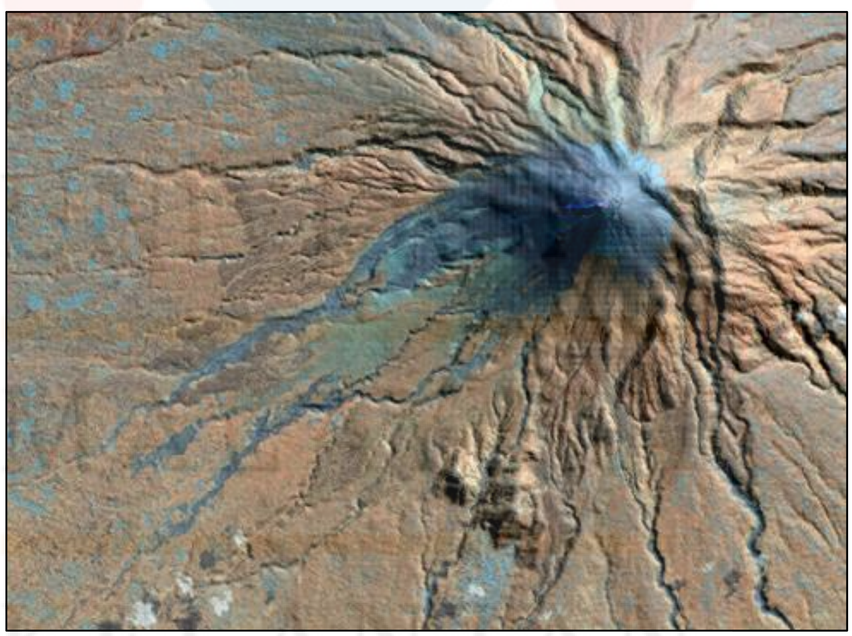


Figure 1.4: LANDSAT image for Mount Merapi

1.2.1 Accessibility

The study area is located around 34 km away from the town area of Yogyakarta, Indonesia. It is around 53 minutes driving from the town to Bayat Area, Klaten. The area can be easily through driving along Jalan Raya Solo-Yogyakarta in Maguwoharjo which takes normally 1 hour 16 minutes if the traffic is normal. Besides, there is another route to Klaten through Jalan Raya Solo - Yogyakarta and Jalan Ngaran - Sajen which take 1 hour 22 minutes for normal traffic. Figure 1.5 shows the route from Yogyakarta city to study area via driving.

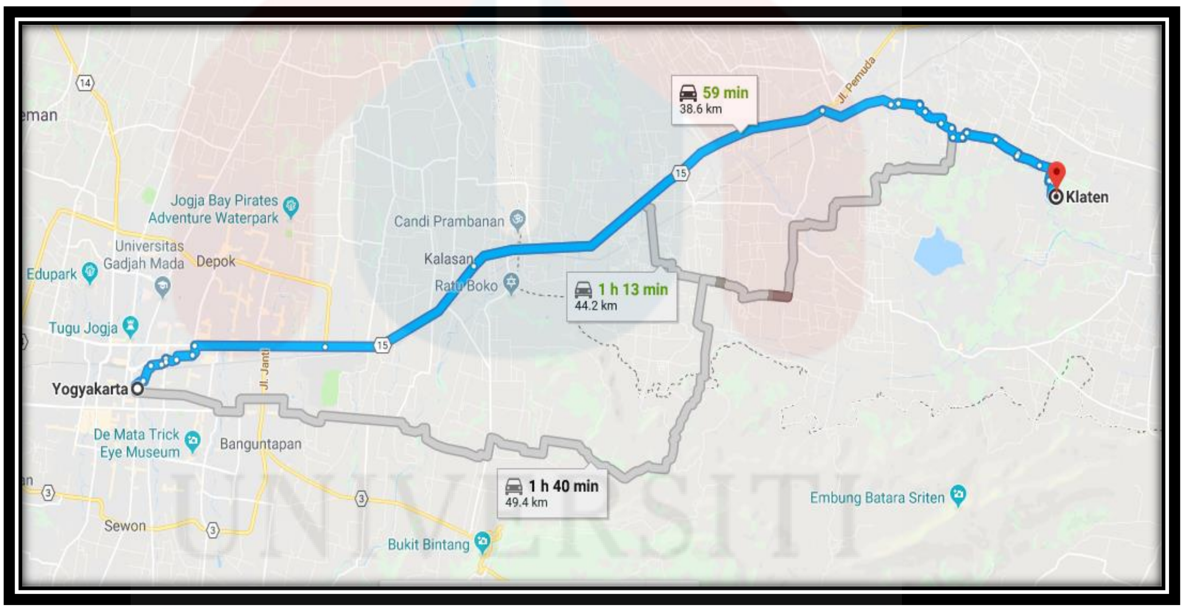


Figure 1.5: Route from Yogyakarta to study area via driving (sources: Google Map)

The study area also can be access by transit. There is a transit to Klaten every 20 minutes. The transit express available are Pasundan, Prambanan Express, Lodaya and Argo Dwipangga which all of it from Lembuyangan Station. The station from Yogyakarta city is about 19 minutes for 1.5 km and takes about 43 minutes to Klaten. Normally, the train schedule starts at 3:00 PM for Lodaya Express, 3:25 PM for Argo Dwipangga Express and for Prambanan Express the schedule at 3:57 PM and 4:56 PM. Figure 1.6 shows the transit schedule from Yogyakarta city to Klaten.

Figure 1.6: Transit schedule from Yogyakarta to Klaten (Sources: Google Maps)

1.2.2 Demography

The city's population was 388,627 inhabitants at the 2010 census. Its built-up area was home to 4,010,436 inhabitants, which includes Magelang and 65 districts across Sleman, Klaten, Bantul, Kulon Progo and Magelang regencies. Yogyakarta-Magelang and Surakarta are being agglomerated in several years. The last known population of Klaten Area is 124,500 in the year of 2010. This was 0.052% of total Indonesia population. If population growth rate would be same as in period 1990-2010 (+0.94%/year), Klaten population in 2018 would be 134 118. Table 1.1 shows the historical population in Yogyakarta in the year of 2010.

Table 1.1: Historical Population of Yogyakarta, Indonesia

Year	Population	± %
1971	2,489,360	-
1980	2,750,813	+ 10.5%
1990	2,913,054	+ 5.9 %
1995	2,916,779	+ 0.1%
2000	3,122,268	+ 7.0 %
2010	2,452,390	+10.6 %
2014	3,594,290	+ 4.1%

Sources: Badan Pusat Statistik 2010

The population at the 2010 Census was 3,452,390 people, but according to the latest official estimate on January 2014, it has risen to 3,594,290. It has an area of 3,133.15 km² making it the second-smallest area of the provinces in Indonesia, after the Jakarta Capital Region. Along with the surrounding areas in Central Java, it has some of the highest population densities in Java.

Mount Merapi is located to the immediate north of the city of Yogyakarta and Sleman Regency. It is the most active volcano in Indonesia and has erupted regularly since 1548. The distribution population at Yogyakarta was shown in Table 1.2.

Table 1.2: Population on subdivided regencies and city

Name	Capital	Area (km²)	Population 2000 Census	Population 2005 estimate	Population 2010 Census	Population 2014 estimate	HDI 2014 Estimates
Yogyakarta City	Yogyakarta City	32.50	396,700	433,539	388,627	404,003	0.837 (Very high)
Bantul Regency	Bantul	508.13	781,000	859,968	911,503	947,568	0.771 (High)
Gunung Kidul Regency	Wonosari	1,431.42	670,400	681,554	675,382	702,104	0.670 (Medium)
Kulon Progo Regency	Wates	586.28	371,000	373,757	388,869	404,155	0.706 (High)
Sleman Regency	Sleman	574.82	901,400	988,277	1,093,110	1,136,360	0.807 (High)
TOTALS		3,133.15	3,121,045	3,337,095	3,457,491	3,594,201	0.768 (High)

Sources: WikiPedia

Yogyakarta has a tropical climate. The temperature is pretty constant throughout the year. There is also hardly any difference between seasons. Officially there is a rainy and a dry season. However, the rain is fairly constant throughout the year. Average temperature varies little from month to month. September and October are warmest with an average temperature of 31.3 °C at noon. July till August is coldest with an average temperature of 20.2 °C at night. The wet season has a rainfall peak around January till March. The dry season centers around the month of September till October which has the most sunshine. Figure 1.7 shows the line graph that indicate the maximum, minimum, and average temperature in Yogyakarta.

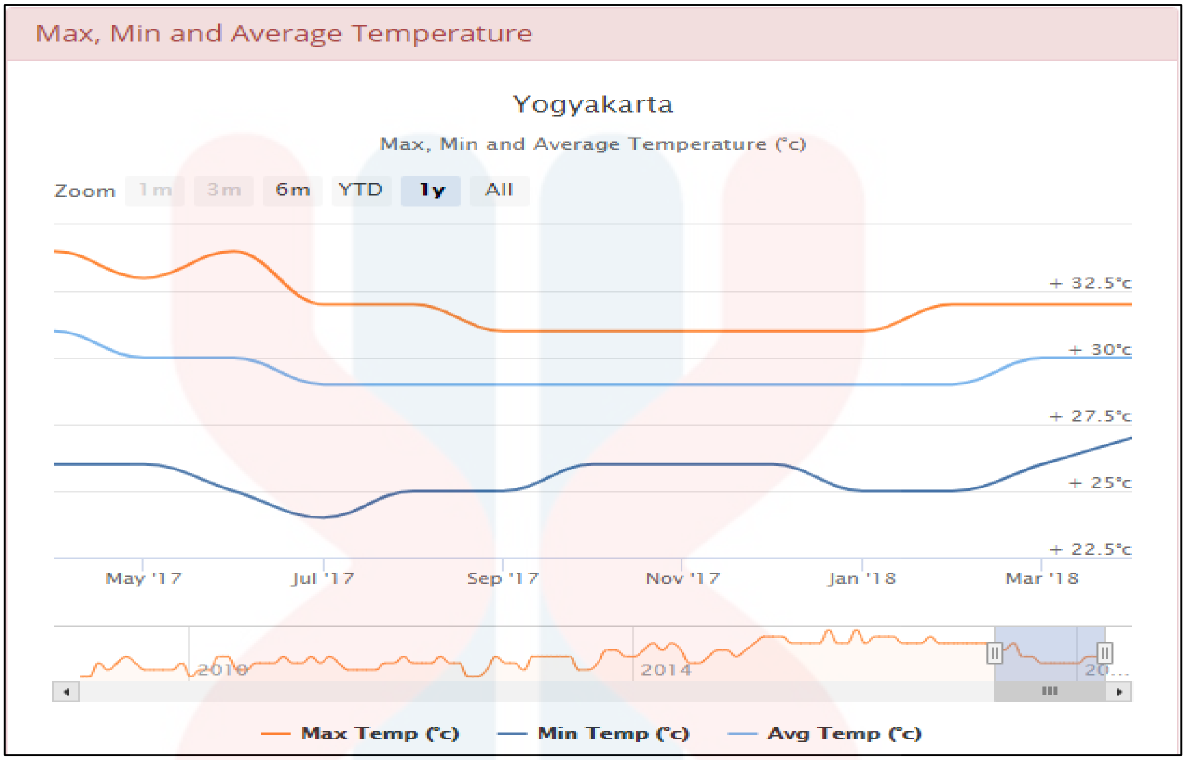


Figure 1.7: Average temperature in Yogyakarta (Sources: WorldWeatherOnline.com)

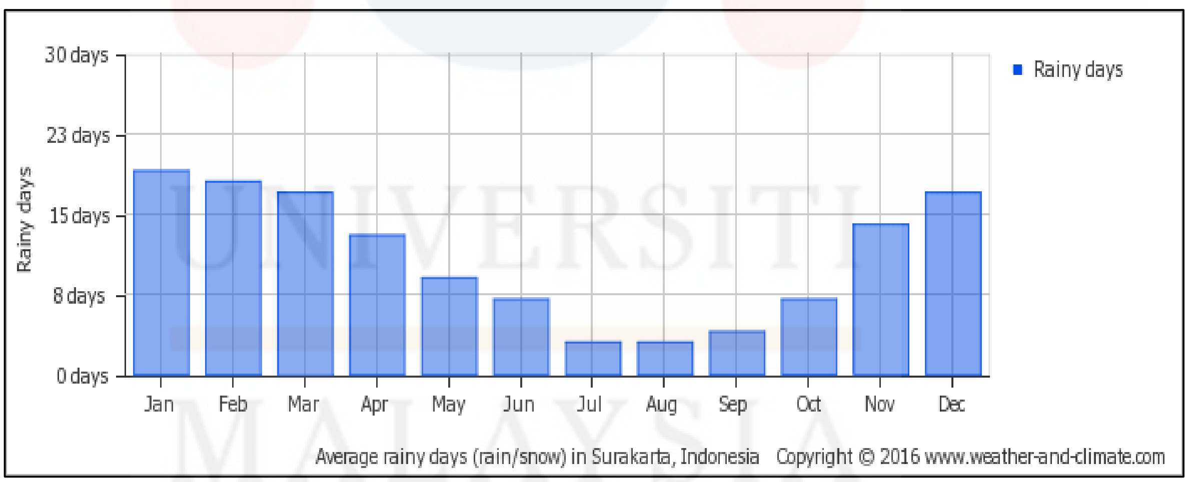


Figure 1.8: Average rainy days in Surakarta, Indonesia (Sources: weather-and-climate.com)

As shown in Figure 1.8, the rainiest days are in January, February, March, and December, which means the humidity during this month is high. Those whose does not like humid weather, this month was not the best time to travel to Yogyakarta. On average, the rainiest is on January and the least is on August. The average annual amount of rainy days is 131.0. The month of July till September was the warmest month overall and the best time for travel.

1.2.3 Land Use and Social Economics

The land use in the Bayat Area, Klaten is mainly on the agriculture and farming purpose. There are around more than 100,000 people live in this area and it is considered as a rural area in Yogyakarta. The non-urbanized area normally will focus on the farming sector, forestry sector and husbandry sector which is the main source of the economic aspect. According to Susilo (2017), in his dissertation title Spatial Modelling of the Dynamics of Land Use in Urban Yogyakarta Area, he said that the total of land use on Yogyakarta in 1993-2000 was 704.9 hectares. This changes occurred in seven forms with different sizes ranging between 0.2 ha and 359.8 ha.

The most common change that can be seen is paddy fields which becoming the residential settlement which comprising 359.8 ha. The total change size was 755.7 ha in between the years of 2000-2007 with fifteen forms of changes ranging between 0.5 ha and 365.5 ha.

Agriculture production of this province accounts for a small percentage of the total production of Java because of the small area which is 3,133 km^2, which accounts on 2% of Java. Even though it has small area but various food crops such as wetland and upland paddy, palawija, vegetables, fruits were produced in diverse land states. Some crops such as wetlands and upland paddy and Shallot (red onion) were cultivate more intensively than others. Table 1.3 shows the average yield per hectare of main food crops in Java Island and Total Indonesia in the year 2003 (Ton/Ha).

Table 1.3: Average Yield per Hectare of Main Food Crops in Java Island and Total Indonesia in 2003 (Ton/Ha)

	Padi Sawah	Padi Ladang	Kc Tanah	Kc Kedelai	Bawang Merah
DKI Jakarta	4.3	0	1.0	0	0
Jawa Barat	5.5	2.7	1.3	1.3	9.0
Jawa Tengah	5.4	3.1	1.2	1.5	8.4
DI Yogyakarta	5.6	3.5	0,8	1.0	10.4
Jawa Timur	5.4	3.6	1.2	1.3	9.1
Benten	5.1	2.9	1.3	1.3	5.4
Java Island	5.4	3.1	1.2	1.3	8.9
Indonesia	4.8	2.5	1.1	1.3	8.7

Sources: BPS Statistik Indonesia 2004

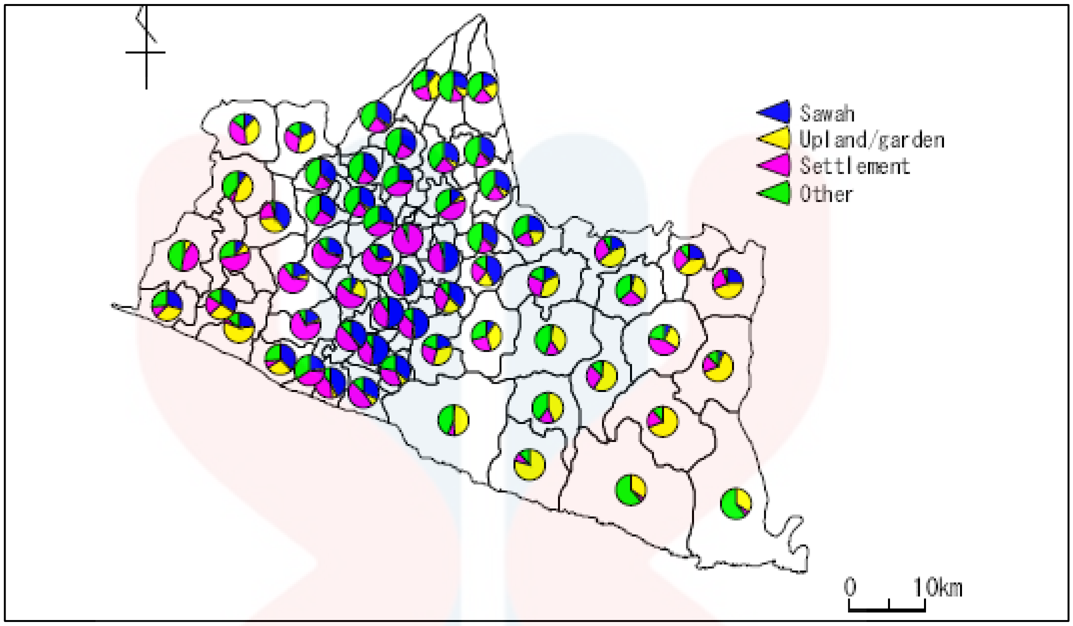


Figure 1.9: Land Use in D.I Yogyakarta by Kecamatan in 2003 (%)

Indonesia's export-oriented small and medium enterprises (SMEs) such as the ones forming the three clusters in Yogyakarta-based tourism and handicraft industries. This industry encountered major deficit in capacity to integrate fully in international trade activities. The deficit dues to predominantly to lingering structural constraints that prevent them to capture significant portion in export share, hence hinders them in connecting to the commodify and related services value chains.

1.3 Problems Statements

Previous geological map in scale 1:100,000 were carto graphed by Surono and Sudarno (1992) and were compile by Geological Research and Development Centre. The scale for the map is too small which the information from the map might not be accurate enough. Through our mapping and observation, the scale was increase to 1:25 000 and this mapping add on more detail of geological information data to the area. This also indicates that the map with bigger scale will provide more detail geological information for the study area.

Previous hazard map of Merapi by Pardyanto et al., (1978) identifies three hazard zones, which include a lahar zone which termed as 'second danger zone'. This hazard map of scale 1:100,00 is not large enough to delimit accurately lahar inundation in specific channel. The large scale of hazard map might focus on big area for the hazard. For this mapping and production of an update hazard map, the scale was 1:2000 which focus on western foot area of Mount Merapi only. This large scale also will provide more precise hazard zone for level of danger in each zone.

1.4 Objectives

1. To produce a geological map of the study area with 1:25 000 scale.
2. To produce a hazard map at 1:2000 for Mount Merapi area.
3. To analyzed the volcanic hazard of Mount Merapi.

1.5 Scope of Study

This research proposal was basically set the study area at the Bayat Area, Klaten and Western foot of Mount Merapi, Central Jawa, Yogyakarta, Indonesia. The basic geological mapping needed to be done in order to produce an informative geological map with the scale of 1:25,000. Meanwhile, basic mapping also needed to produce a hazard map with scale of 1:100 000. The basic tools that will be use are the geological hammer, compass, Global Position System (GPS) and hand lens. During the mapping process, all the data were recorded and the rock sample was taken. As the type of rocks and lithology of the area have been studies and identified, the rock had been confirmed at the field during mapping process. The type of rock and structure at Indonesia was young, so it does not difficult to interpret the data at the field as we can saw the structure clearly with our naked eyes or with hand lens.

Besides, this study also focus on volcanic hazard of Mount Merapi as the last eruption was on May 11, 2018. Volcanic hazard can be categorized into two, (1) primary hazard and (2) secondary hazard. The primary hazards include pyroclastic flow, air-fall tephra, lava flow, and emittance of volcanic gases. For the secondary hazards which mostly occur after the eruption include deformation, lahar (mudflow), landslide, and possibilities of tsunami as the volcanic activity might have triggered the tectonic plate setting. This study was focus on both primary and secondary hazard. As the last eruption is on 2018, the sample and the hazard were still in fresh condition and can be saw originally. The latest eruption of the Mount Merapi occurred twice on May 11, 2018 and May 12, 2018. During the eruption, the pyroclastic flow covered the entire atmosphere of the Mount Merapi area. According to the news, the pyroclastic flow or Nuée ardente have spread until the city of Yogyakarta till the government need to close the nearby airport.

1.6 Significance of Study

This study significantly provides a more detail geological information for the Bayat Area, Klaten. This can give more informative geological data and brings convenient for future research. An update geological map will give a benefit to the government related for urbanization. Geological mapping provides basic data for us to understand the past and present-day process related to our Earth. All this information is important for four main reasons. First and foremost, geological information can reduce the death and damage caused by geologic hazard such as earthquakes and landslides. Different type of geologic information can amplify shaking or even liquefy during earthquakes. A geological map can show the location of fault as well as joint and fracture that may lead to the landslides and earthquakes. Second, with this geological map can help to better find and protect or safely extract geologic resources. A geological map can show the distribution of the resources such as concrete, metal and even petroleum in sedimentary basin. The third importance of geological mapping was to improve our stewardship of the Earth through informed agriculture, construction, and environmental practices. This map can give information about the distribution of geologic material that not suitable for agriculture and this geologic material also can give information about the suitable foundation of base for construction which might at last end up collapse and lead to serious injury or death. Last but not least, through this mapping also will help geologists unravel the geologic history of the region. There is a relation between the geologic material such as the type of rock with the structure at the outcrop. Through the details that can be recorded such as the lithology data, the sequence of the past events can be revealed on the area and the age of the rock in the area can be known.

Hazards are forever a threat but can be managed if we learn the lessons from past disasters. For the specification, an update hazard map can give information to the people there about the level of the danger of each zone. Hazard map is a map that highlights area that have been affected by or vulnerable to a particular hazard. In this study, a hazard map of volcanic hazard was update whenever there is an eruption. Each hazard poses different key in different area. Each area also will have different level zone of dangerous. With this map, the level zone of dangerous was updated and the percentage of death due to volcanic hazard can be reduced from time to time in the future eruption. On the other hand, this study also focusses on volcanic hazard present at Mount Merapi. This can contribute scientific knowledge and informative data in many different fields especially volcanologist for further research. To be effective, the risk from each volcanic hazard need to identified first. Volcanic hazard can be analyzed based on the past eruption. By studying the geological report, observing and survey the past eruption, monitoring the level of activity, more like the future hazard can be gained.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Indonesian archipelago is one of the enigmatic areas in South-East Asia in terms of its geological and tectonic evaluation. It shows all the evidence of the complex collision processes between tectonic elements. In tectonically terms, Indonesia is highly unstable and it lies on the Ring of Fire Pacific which the Pacific plate and Indo-Australia continent plate pushed below the Eurasian continent plate.

2.2 Regional Geology and Tectonic Setting

Java Island, Indonesia is located at the southern part of the Sunda land that connected with the Sunda Shelf-sea. Geologically, Java belongs entirely to the tertiary mountain system around the pre-Paleogene Sunda land. It was formed by the rock assemblages and associated with a tectonic setting of active margin of plate convergence. According to Robert Hall (2009), Indonesian is an immense archipelago of more than 18,000 island which extending over 5000 km from east to west between 95^{o} and 141^{o}E, and crossing the equator from 6°N to 11°S which indicated this present-day tectonic setting. Figure 2.1 shows the regional geology of Indonesia.

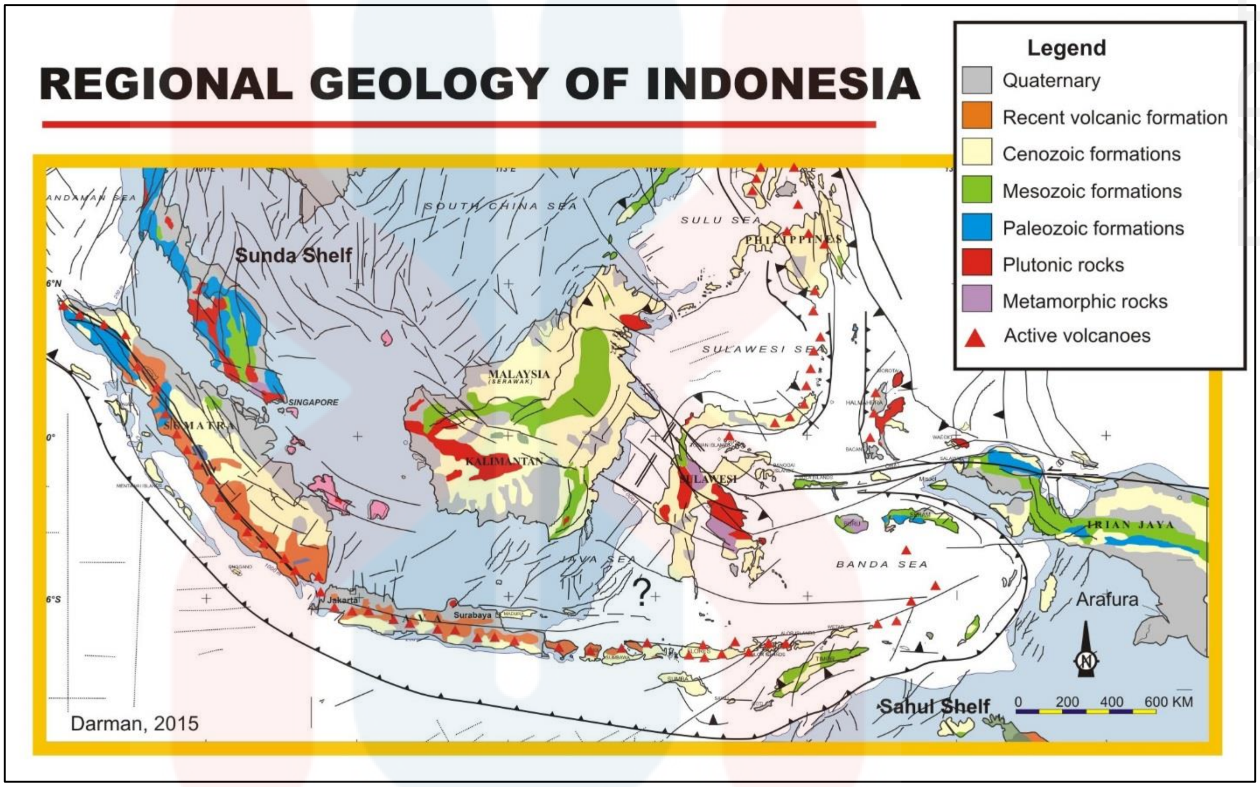


Figure 2.1: Regional geology of Indonesia

Indonesia have a lot of volcanoes age of Quaternary or less than 200,000 years ago. Java is considered as the southernmost leading edge of the Sunda continental that overriding the oceanic Australia-Indian plate as it is a backbone of a subduction-induced volcano plutonic-arc**.** The alternating highs and traverse depressions of the structural complex related to the more complex pattern. This indicated that discrete crustal blocks can be interpreted as pieces from the original monolithic craton that already separated long time ago. There are two dynamic processes that interact. Fist is the collision of blocks in Pre-Tertiary times by closing the oceanic gaps was marked by roughly east-west ophiolitic belts which located in two locations in Ciletuh in West Java and Lok Ulo in Central Java. But thou the colliding pieces are not clearly identified. Second processes that involved are the displacement that occurred laterally between blocks in Tertiary that was made by trans-current faulting. This process formed a component of large-scale strike-slip movement which results to the response of the plate-convergence process itself. Both process mentioned was a part of the extensional and convergent global tectonic event that related to the formation of fore-and back-arc basin, and plus lead to the occurrence of volcanism. The dividers of the Java sea called as meridian-line which divides this to sea into West and East Java. This dividers act as a connecter of the Karimun-jawa Islands to Semaring which continuing until southwards on land.

The West Java region currently marks the transition between frontal subduction beneath Sumatra, to the west. However, this region has been continuously active tectonically since rifting in the Eocene. The Eocene rifting occurred throughout the SE Asia and probably related to the collision between India and Asia. After modified Martodjojo, 1975; Lemigas, 1975, and Keetley et al, 1997, West Java may be subdivided into several tectonic provinces.

1) Northern basinal area; a basin which have a stable platform area which considered as a part of Sundaland Continent. The basin orientation is N-S trending rift offshore and adjacent offshore. This basin filled with non-marine clastic from Eocene-Oligocene that overlain by Miocene and younger shallow shelf deposits.
2) Bogor Trough foreland basins; composed of Miocene and younger sediments mostly deeper water sediment gravity flow facies. Young E-W trending anticlines formed during a recent episode of north directed compressive structuring.

3) Modern Volcanic Arc; active andesitic volcanism related to subduction of Indian Ocean Plate below Sundaland Continent.
4) Southern slope regional uplift; mainly Eocene-Miocene sediments, including volcanic rocks belonging to the Old Andesite Formation. In between the area of volcanic arc and submerged accretionary with the northward subduction of the Indian Ocean Plate, it contains a sedimentary basin that formed within the axial ridge in the South-West Java.
5) Banten Block; most western part of the Java Island which may be subdivided into Seribu Carbonate Platform in the north, Rangkas Bitung sedimentary sub-basin, and Bayah High in the south.

2.3 Stratigraphy

The Southern Mountains of Central Java, Indonesia is a mountainous region which located in the south-eastern part of Central Java, Indonesia. It is bounded to the west, east and north by depressions, which are the Solo Zones depressions, Yogya-Bantul depressions and Wonogiri-Baturetno depressions respectively.

The naming of the lithostratigraphy of the rocks at Southern Mountain has been done due to a few observations. From the previous observations (Bemmelen, 1949; Sumosusatro, 1956; Surono, et al., 1992) the stratigraphy of Yogyakarta from oldest to youngest are metamorphic rocks, Wungkal-Gamping Formation, Kebo-Butak Formation, Semilir Formation, Nglanggran Formation, Sambipitu Formation, Oyo Formation, Wonosari Formation and Kepek Formation. Figure 2.2 shows the stratigraphy of Yogyakarta.

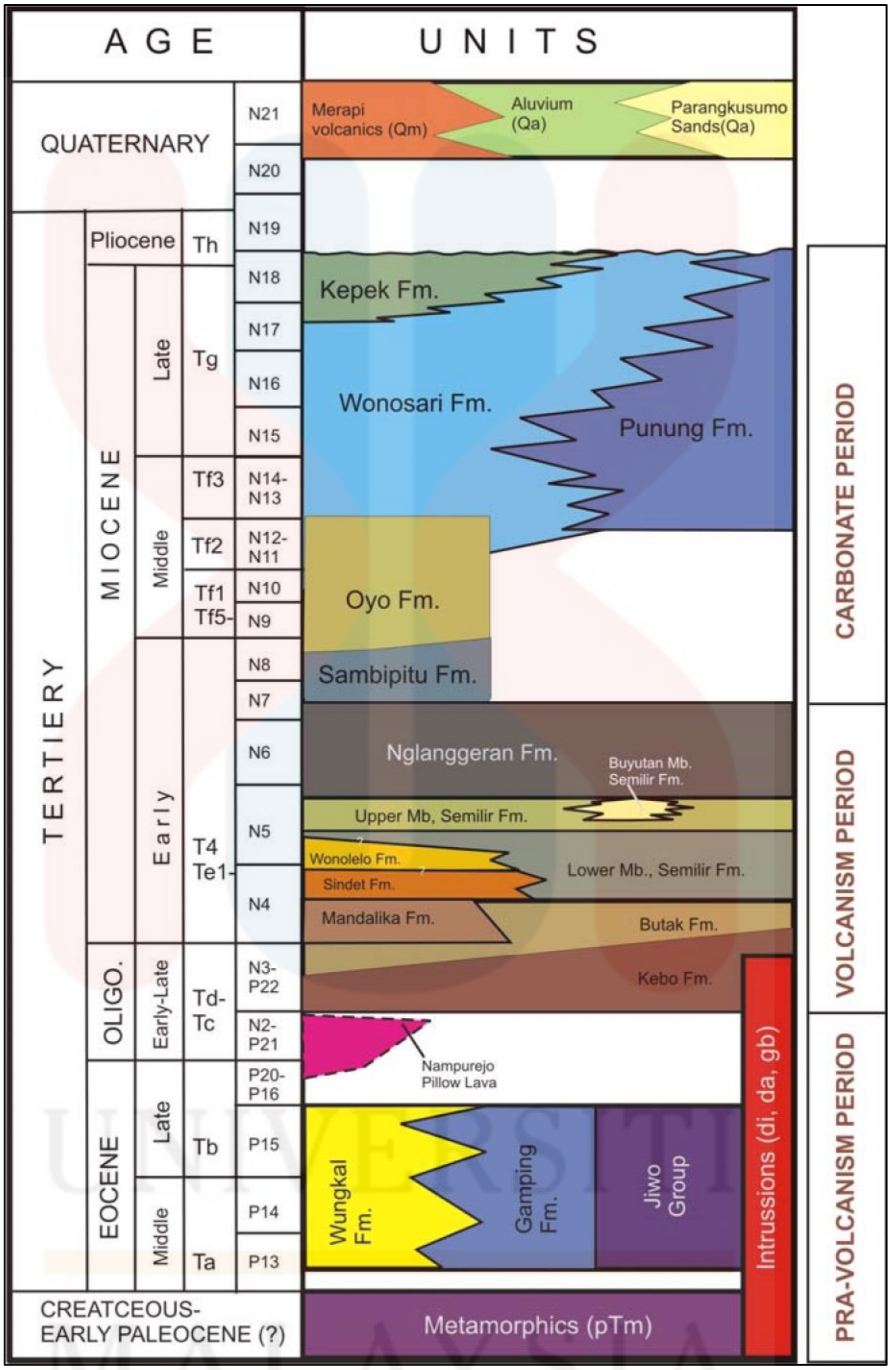


Figure 2.2: Stratigraphy of Yogyakarta (Surono, 2009)

2.3.1 Gamping Wungkal Formation

The location of this type of formation is located in G. Wungkal and G. Gamping, both in the Jiwo Hills. The oldest Tertiary rock units in this Southern Highlands area at the bottom consist of an intermingling between sandstone and limestone and a lenses limestone. At the top, this rock unit is in the form of a sandstone and a lenses limestone. This formation spread in Jiwo Hills, among others in G. Wungkal, Sekarbolo Village, West Jiwo. The thickness of it about 120 meters (Bronto and Hartono, 2001).

2.3.2 Kebo-Butak Formation

Bothe (1929) named Kebo Beds and Butaks Bed as one geological map of Jiwo Hills and Southern Mountains. Sumarso and Ismoyowati (1975) and Surono (1992) finalize the formation as Kebo-Butak Formations. The lower part is known as Kebo Beds, which consists of the interbedded breccia., conglomerate, tuff sandstones, mudstones and some deposition of sediment fragments.

The upper part of Kebo-Butak Formation consists of conglomeratic that interbedded stack with sandstones. The vertical grade was from siltstones or mudstone size. The upper part beds were known as the Butak Beds. The Kebo-Butak Formation total bed thickness is more than 800 meters. The age of this Formation is Late Oligocene (Sumarso & Ismoyowati, 1975).

Kebo Formation is an intertwining between sandstones and gravel sandstones, with present of claystone, tuff, and flakes. Some of the sandstone and claystone are limestone and locally found conglomerates and various materials (polymic) breccia. The center of this formation is dominated by gravel sandstone. The sediment structure found are normal arranged layers, parallel dance, wavy aerials, erosion surfaces, flute spikes and slumps. Bioturbation, foraminifera, coral strips, and charcoal are found in several locations.

Butak Formation, which overlaps the Kebo Formation consists of a polymic bridge with sandstones, claystone and shales. Polymic breccias have fragments of gravel to lump, in the form of andesite, basalt, carbon sedimentary rock and quartz. Some fragments have altered into green chlorite. The appearance of petrographic sandstone in Butak Formation shows that the fragments are dominated by volcanic materials (basal, plagioclase, andesite, tuff, and quartz).

2.3.3 Semilir Formation

The Semilir Formation is overlying on the Kebo-Butak Formation. It is the rocks that formed due to the results of the volcanic eruption during the Early Miocene. The lithology of the formations is the lapilli tuff and tuff volcanic rocks. At the lower part of the Semilir Formation, the tuff volcanic rocks and lapilli tuff were mixed with the clastic sediments. At the upper part of the Semilir Formation, it is dominated with the tuff with lapilli tuff fragments, tuff sandstones. Surono (2008) reported that the geological age of the formation at Early Miocene based on the fossils track.

This formation is a formation that composed from a volcanic origin material. The rock type can be identified at the field with characteristic of massive and thick. According to Bothe (1929), this formation composed of gray-white colored on the top layer and dominance of tuff breccia pumice. The study by Sumosusastro (1956) said that this formation is in the repeating form of tuff breccia pumice, tuff sandstone with good and little coating fossil content.

2.3.4 Wonosari Punung Formation

The Wonosari-Putung Formation is generally composed of limestone. As mentioned by Surono, et al., (1992), compilers Wonosari-Punung Formation form limestone, tuff lace, conglomerate limestone, sandstones tuff and rocks. Toha, et al., (1994) mentions the main constituent of Wonosari-Putung Formation is in the form of layered limestone and reefal-limestone. Surono (2009) separates Wonosari Formation and Putung Formation by mentioning it that the Wonosari Formation is mainly composed of layered limestone while the Punung Formation is composed by reef limestone.

The limestone constituent of Wonosari-Punung Formation generally has white color on the rocks are fresh and white brownish on the rocks that undergo weathering. While the soil results to show the color redness called terra rossa. However, in the Sawahan Region and surroundings such as Ponjong District, Gunungkidul Regency, Special Region Yogyakarta found a red limestone with a locally spreading. Hidayaturrahman (2008) mentions the existence of limestone was uniquely identified on the structural contact.

2.3.5 Oyo Formation

This formation consists primarily of limestone and napal. Its spread extends almost half of the Southern Range extending eastward, veering northward next to the Stage Hills until it reaches the western part of the Wonogiri - Baturetno depression region.

The lower part of the Oyo-Wonosari Formation is mainly composed of layered limestone that show symptoms of turbidities carbonates deposited on deeper ocean conditions, as seen in the outcrops in the area near the mouth of the Widoro River into the Oyo River. In the field this limestone is seen as a layered limestone, showing grain sorting and on the smooth part found many fossils of burial type traces found in the surface of the coating or cutting the parallel layer. The group's limestone is referred to as an Oyo member of Wonosari Formation.

In the younger direction, the members of Oyo graduated into two different facies. In the Wonosari area, the more southward limestone is transformed into rudstone, frame stone, float stone, harder coral reefs and named as Wonosari members of the Oyo-Wonosari Formation (Bothe, 1929). While in the southwest of Wonosari City, this limestone turned into a layered stone that graded into a napal called Kepek member of the Wonosari Formation. The Kepek member is also exposed in the eastern part of Wonogiri - Baturetno depression, under a quarterly deposit like the one in Eromoko area. Overall, this formation was formed during the Late Miocene (N9 - N18).

2.3.6 Kepek Formation

The Kepek Formation is the youngest age at Southerrn Mountains Zone which distribution is too broad, only growing western part of the Southern Mountains area with relatively gentle slope (less than 10°) and a thickness of less than 200 meters (Samodra, 1984).

The Kepek Formation is composed by carbonaceous claystone with a fresh color of white and grayish dark brown weather, sandstone clay colored grayish brown and limestone with yellow fresh color brownish and dark brown weather, layered structure to massive, clastic texture, the size of fine grains of sand to very coarse sand with the composition of shell pieces' foraminifera.

Carbonaceous limestone forming slayer structure with a thickness of 3-45 cm to form conchoidal fractions, while carbonate claystone clarity is dominated by clay grain size to fine sand. According to Pandita, the limestone at Kepek Formation are in brownish-yellow colored, clastic texture, fined-graind to sand size and massive structure. This limestone can be found in some layered spots where there are three layers of limestone from the bottom to the top with each thickness being 5 m, 3.5 m and 1.2 m.

2.4 Structural Geology

According to Van Bemmelen (1949) the Southern Mountains area has undergone uplift process. Four pattern of geological structures that exist in the South Mountains are:

(1) The NE-SW direction, generally a sinisterly shear fault occurring due to subduction of the Indo-Australian plate during the Eocene to Middle Miocene. This direction is indicated by alignment along the Opak River and Bengawan Solo River.

(2) The N-S direction is largely a sinisterly shear fault, except for the western boundary of the Southern Mountains which is a falling fault.

(3) The NW-SE direction, generally a fault of the dextral shear. This second and third set of directions appears as a fracture pair formed by the NNW-SSE directional compression force developed in the Late Pliocene.

(4) The direction of E-W, largely a downward fault occurring due to the N-S trending force and developed in the Early Pleistocene.

2.5 Historical Geology

The structural history of the East Java cannot be separated from the structural history of the western part of the island and the tectonics of the SE Asia region. This area is located on the southeastern edge of the Sundaland craton where basement is Cretaceous to basal Tertiary mélange. The old continental margin has a northeast to southwest structural trend that is clearly seen on offshore north Java seismic data.

Mount Merapi was the youngest volcano in the series that leads to south of Mount Ungaran. This mount formed from the subduction zones of activity in the Indo-Australia Plate under the Eurasian Plate that causes the movement along the central part of the island of Java. From the result of stratigraphy, past studies indicate the formation history of Mount Merapi was very complex. According to Wirakumusah (1989), geology of Mount Merapi was divided into two major groups, namely Merapi Young and Merapi Old. Subsequent research (Berthomier, 1990; Newhall & Bronto, 1995; Newhall *et.al*, 2000), they found the stratigraphic unit in an increasingly detailed Merapi.

2.6 Volcanic hazard of Mount Merapi

The research specification was conducted at the western foot of Mount Merapi, Yogyakarta. Lahar generation is complex, resulting from a combination of volcanic and climatic processes. The hazard map of Merapi identifies three hazard zones, including a lahar zone (Pardyanto *et al*., 1978)

2.6.1 Volcanic hazard

The continuing eruptive activity at Merapi poses a permanent threat to the over 1 million inhabitants in the surrounding area for the foreseeable future. According to Gertisser *et.al,* (2011), devastating pyroclastic flows generated by gravitational or explosive lava dome failures and subsequent lahars remain the most likely hazards near the volcano. However, given Merapi's more powerful eruptions in the past and short-term alternations between effusive and explosive phases as observed in 2010, the possibility of violent eruptions that affects areas farther away from the volcano in the future cannot be discounted**.** The amalgamation of the past record of the Merapi's eruption history need to be update into the existing volcanic hazard map. An update hazard map is crucial for the usage of the government as it can be used to longer-term hazard assessment and can be used as a safety risk to reduce the volcanic risk.

Mount Merapi is located on the border between Central Java and Yogyakarta. Indonesia which on the densely populated area is one of the active stratovolcano in Indonesia. It is the most active volcano in Indonesia and in the world that has erupted regularly since 1548. It is located approximately 28 kilometers (17 mi) north of Yogyakarta city which has a population of 2.4 million, and thousands of people live on the flanks of the volcano, with villages as high as 1,700 meters (5,600 ft.) above sea level.

Smoke can often be seen emerging from the mountain top, and several eruptions have caused fatalities. On 22 November 1994, a large explosion occurred and a devastated pyroclastic flow blew out from the. The explosion killed 27 people which mostly lived in the town of Muntilan, which is on the west part of the volcano. On 2006, another large eruption occurred in for Mount Merapi right before the huge earthquake occurred at the city of Yogyakarta. In light of the hazards that Merapi poses to populated areas, it has been designated as one of the Decade Volcanoes. Mount Merapi last eruption was on March 10, 2014 have killed about 360 villagers.

2.6.2 Lahar deposits

The term lahar, of Javanese origin, is a rapidly flowing mixture of rock debris and water from a volcano (Smith and Fritz, 1989). The flow behavior exhibited by lahars may be complex and includes a debris flow phase, where sediment concentration is in excess of 60% by volume. The lahar deposit mainly along the river between Krasak River. At Mount Merapi, there are two processes that triggered the lahar; (1) eruption-induced lahar or primary lahar from the admixing of pyroclastic flow; (2) rain-triggered lahars or secondary lahar from heavy rainfall. The lahar that triggered from the mixing with pyroclastic flow depend on the material of fresh pyroclastic flow deposit in the source areas. According to Volcanological Survey of Indonesia (VSI), lahars are generated from rainfall exceeding 40 mm in 2 hours. Lahar at Mount Merapi predominantly last one or two hours briefly when related to rainfalls. Lahar velocity and discharge can be high. The maximum velocity recorded is 15 m/s was measured in the year 1995 in Boyong river which 7 km from the summit. The dilution of the lahar usually very fast. Within kilometers, lahar can transform from debris flow to hyper-concentrated streamflow and back to normal streamflow. Rain-generated lahars can cause a serious hazard at any time during monsoon seasons. Past history which occurred on 22 October 1974, 9 people were killed at Krasak River due to rain lahar and 25 more on 25 November 1976. This incident because of the large volume of lahar flow and the high level of rainfall during that year.

CHAPTER 3

METHODOLOGY

3.1 Introduction

To complete this research there are many materials and methods that must be use. Materials are the items and equipment that used to obtain data and information of the research while methods are the steps and procedure that must been taken to get the data and information of the research. For the research to work, the components research of methodology which is preliminary research, materials, field study, sampling, laboratory investigation, and data analysis must be include. Then some of these components research methodologies are include in flow chart for better understanding of the research in Figure 3.1.

3.2 Materials and Equipments

Materials are the substances used to identify the certain information about the rock when at field, while equipment are the tools used in order to take a data or sample. Detailed mapping and measuring stratigraphic sections were undertaken in order to acquire stratigraphic relations between the widely spaced outcrop sections in the studied area. This it to established a stratigraphic framework of key stratigraphic levels, which can be used for defining detailed stratigraphic positions of paleontological samples. In order to do the data collection, field mapping is a compulsory to find the data sample and to observe the type of rock, rock composition, grain size, grain shape, rock color, and sedimentary structures in the study area. There are several instruments needed for the data collection during field mapping. The materials needed for data collection are:

a) Geological Hammer

Hammer head on one end and a slightly curved chisel-shaped blade on the other. Used to obtain fresh sample of rocks in order to determine the information about the rocks and minerals.

b) Compass

For determine the directions and to find strike and dip of the outcrops and geological structure.

c) Hand lenses

For observe properties of rocks with small size in the fields.

d) HCL solutions

To identify the carbonate rocks in field by observe the reactions of the HCL with the rocks.

e) Global Positioning System (GPS)

Satellite-based navigation system made up of a network of 24 satellites placed into orbit. Used for determine the locations, marking the geological feature, tracking the feature, and others that involve geological mapping.

f) Measuring tapes

To measure the size or length of lithology and structure. It also being used to measure the thickness of sedimentary beds.

g) Field notebook

To write down the information and data that obtains in the fields.

h) Sample bags

To store the sample before the samples are transfer to the laboratory for the research purpose

3.3 Methodologies

Methodology explained the procedure and methods that have been conducted throughout the whole process, First, preliminary studies of Bayat Area, Klaten have been done, followed by the field studies. After all the raw data collected, laboratory work, data processing, data analysis and interpretation have been done until the whole thesis writing complete.

3.3.1 Preliminary Studies

Preliminary study was needed in order to get the information about the study area and the specification. This study need to be done earlier and continuously until we went to the field to confirmed the result based on what we read with the one available in the study area. The information about the study area can be gathered by using software CorelDraw X5 to survey the locations, geomorphology and access to the study area. For both information of study area and related topic can be gathered by using journals, maps, article and photo of the previous study. The best journals that can be reviewed must be within five years back if available. All this journals, books and article that have been reviewed, it will give some information and even previous data about the study area and topic for the specification. By using remote sensing data, some information regarding the contour, stratigraphy of the study area can be known. The remote sensing imageries for the Yogyakarta had been observed and there is much useful information about the location that had been recorded and plotted in the software.

For the specification, which related to the Mount Merapi and volcanic hazard available, there was many article or journal related as this volcano is one of the most active volcanoes. This volcano also under observation of the government as it might have sudden eruption and as a precaution, everyone need to be ready for any circumstances. The data of the previous eruption also have been studied and taken from website available. The previous hazard map also

3.3.2 Field Studies

At this stage, Bayat Area, Klaten topographic base map used was the study area for references and data plotting. Fields study is compulsory for the research in order to find the sample and to observe the type of rock, rock composition, grain size, grain shape, rock color, and sedimentary structures in the study area. All data needed was gather in order to produce the final geological map. Basically, all the information on the rock was observed in the field and the sample taken was the fresh one in order to see the minerals, lamination or other structure on the rock.

The geological tools played important role throughout the whole fieldwork process especially the GPS, compass and hammer. This is because the data and information in journal and other resources sometimes are changes due to time and climate. Besides, by doings fields study we can scale by own the size of lithology and geological structure in fields to do the research. During this field work, traverse was important thing to create a route to complete the study. Everything that was seen during the field was marked on the GPS and data was recorded. While traversing, sampling and observation also will be completed. This features that will be observed are geomorphology, stratigraphy, lithology and structure available. The strike and dip available was observed and the data needed was recorded by using compass. During geomorphology observation, a sketching was done and every element related to geomorphology was recorded and observed and if a picture is needed, a photograph was taken.

For the specification which is volcanic hazard mapping, sampling and observation will be done. As the Mount Merapi was one of the active volcano, the sample taken was not from the top of the mount. The sample from the last eruption of the Mount Merapi will be taken at the specific area such as near the river for the lahar deposition and was observed at the field. The sample of lahar was taken to be further observed during thin section. A survey also will be done from the institute or villagers available to get more data about the hazard. The villagers have experience many eruptions from the Mount Merapi, so the survey will help to get more information regarding the hazard that they have experienced.

3.3.3 Laboratory Work

After the geological mapping have been done, lab work was done to identify the name of the rock found. The thin section at the lab gave the information about the mineral contains in the rock. Thin section is a laboratory preparation for rock sample by using polarizing petrographic microscope, electron microscope and electron microprobe. This work was part of petrology as it can help to reveal the origin and evolution of the rock.

From the mineral contain in the sample, the name of the rock can be confirmed. The most common mineral that found in a rock were olivine, amphibole, pyroxene, quartz, feldspar and mica especially in igneous rock. Mica, feldspar and quartz are very common while others may be found in one or two location worldwide. Rock may contain many mineral and specific mineral that vary widely. From the thin section also, a thin silver of rock was cut from the sample taken using a diamond saw and ground optically flat. Normally, the sample was sent to the specific workshop to be cut down into the size required. The student received the one that have been mounted on a glass slice that have been ground smoothly until the sample only 30 μm thick. The sample was placed between two polarizing filters et 90° in angle to each other. The optical properties of the mineral in the thin section altered the color and intensity by the viewer. Different mineral has different optical properties. Most rock forming mineral can be identified easily.

3.3.4 Data Processing

There are several processes that have been done in order to process and analyzed the data that obtained from the field. All the data were plotted, recorded and digitized on the Bayat Area, Klaten base map by using software like ArcGIS 10.2, ER Mapper 7.0 and Corel Draw X5. The geological map of Bayat Area, Klaten with scale 1:25 000 was produced. The petrology and sampling were analyzed and interpreted. The geological map and hazard map will be done at the studio by using the suitable software. An interpretation on the map will be done once the map complete. The interpretation includes the geology history and structure analysis from the complete map that contain the lithology unit with stratigraphy.

3.3.5 Data Analysis and Interpretation

All the data gathered from both field studies and laboratory work was analyzed carefully to obtain precise interpretations. The data collected before can be manage systematically by grouping them according to the necessary task. This will make the process easier. The accuracy of the data is really important as it will be used in the discussion and conclusion part. This interpretation should be related to the petrography analysis of the research area.

Petrographic analysis and interpretation will determine the detail information on the mineral content and the textural relationship within the rock. A complete analysis and investigation was done on all rock sample. A further detailed analysis was done during petrographic preparation which was during the thin section.

Report writing was the last step for the whole processes. The report writing was done in the thesis writing format and total in six different chapters, together with the geological map of Bayat Area, Klaten and volcanic hazard map has been attached. In this report writing, the data information and geological map attached was collected and drawn based on all essential method as mentioned before. For specification of the research was explained and discussed more detailed according to the mapping data and others finding during the whole project.

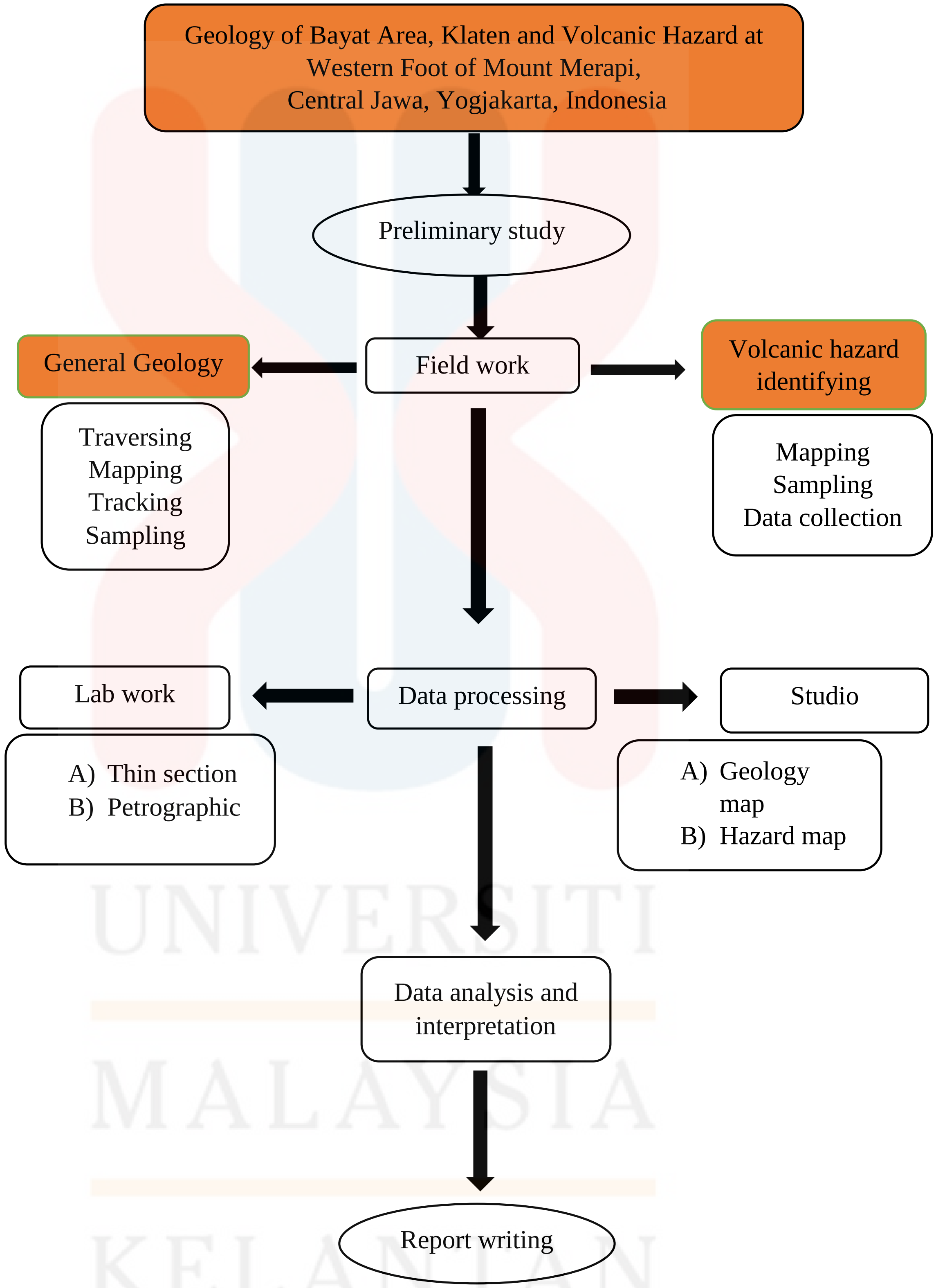


Figure 3.1: Flow chart of the research methodology

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

The general mapping for this project had been done in area of Bayat, Yogyakarta, Indonesia. The duration of 60 days given have been fully utilized with mapping project which will be presented as a geological map. Bayat located in a district called Klaten and the study area coordinate of longitudes 110^0 37’ 39.78” E - 110^0 39’ 46.9” E and latitudes 7^0 44’ 17.58” S - 7^0 46’ 24.78” S. The area of the location is approximately 25 km^2. This chapter will discuss mainly about the general geology of the study area of Bayat.

(A) Traverse map

Figure 4.1.1 shows the traverse map during a month of my mapping schedule. This traverse had been transferred from GPS to computer via DNR GPS. During this mapping, the observation of geomorphology, the lithology had been done. The sample found at the site can determined the lithology boundary that exist.

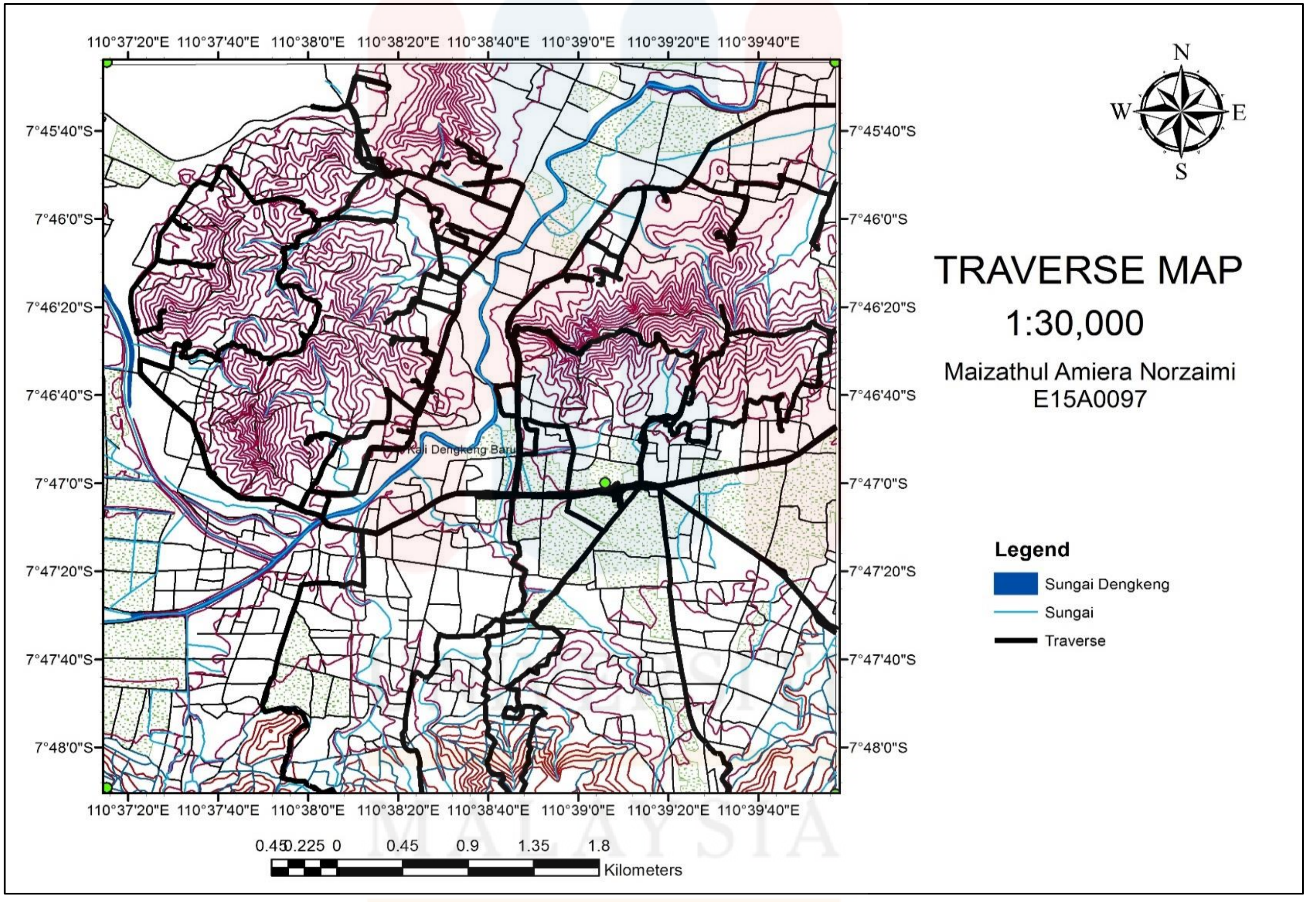


Figure 4.1.1: Traverse map

4.2 Geomorphology

Geomorphology is the scientific study of landforms and the processes that shape them such as by erosion of the wind, water, ice or depositional process of the laying down material that have been eroded. The understanding of the geomorphology and its processes is essential to the understanding of physical geology. The geomorphology will be discussed in this research are related to the topography, drainage system and weathering processes.

Figure 4.2.1: Geomorphology for the Southern part of the study area

From the geomorphology in Figure 4.2.1, the picture shows the southern area of the study area. The Gunung Kidul which known as Southern Mountain by the Javanese can be seen clearly in the picture above. On latitude and longitude 7^{o} 46' 30.33" S and 110^{o} 39' 00.0" E respectively, with the elevation of 251 meter, which is one of the highest point of the study area the picture recorded shows that most of the area covered with a forestry. From the observation, the slope of Gunung Kidul can be in the range of 20^{0} - 30^{0} and from the observation, no exogenic process can be seen. This point of the picture was taken was one of the tourist spot which known as Bukit Pertapan.

Figure 4.2.2: Geomorphology for the Northern part of the study area

The geomorphology in Figure 4.2.2 above shows the Northern part of the study area. As can be interpret from the above picture, the northern part mostly covered by paddy field plantation, forestry and alluvium. The hills that can be seen from the picture above. The range of slope for this part can be interpret from 5^0 - 10^0 which can be said as gentle slope. From this point of the picture was taken, no erosion or weathering can be observed due to the distance from the point of this picture was taken and the hills in the Northern part. Figure 4.2.3 show the geomorphologic unit map on the study area with a denudation hill of elevation

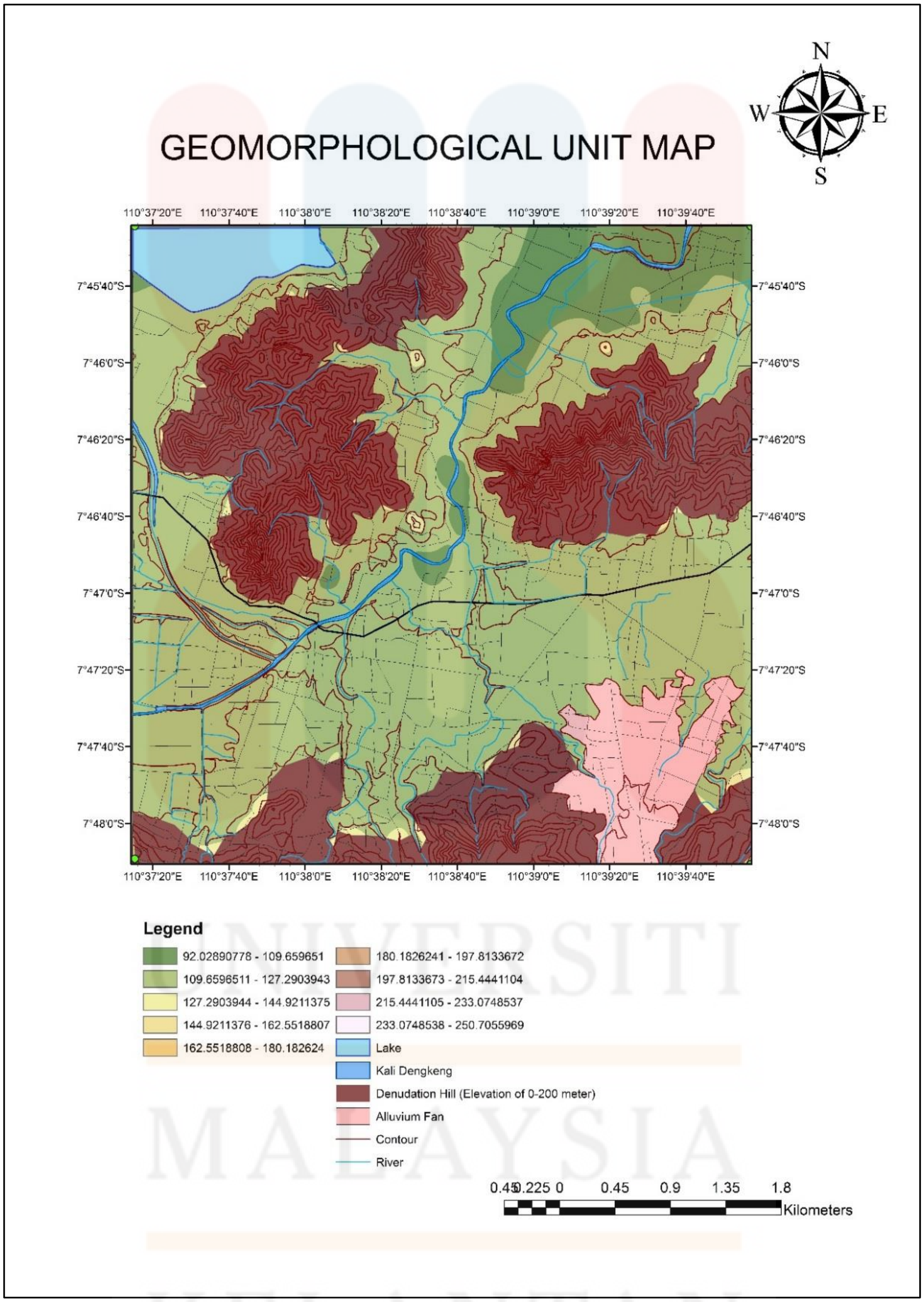


Figure 4.2.3: Geomorphological Unit Map

4.2.1 Topography

Topography is the physical features of a surface area including relative elevations and the position of natural/man-made features. It is the field of earth science comprising the study of surface and features of the Earth and other observable astronomical objects including the planets, moon and asteroids. It involves recording of relief of terrain, three-dimensional (3D) quality of the surface and the identification of specific landforms.

The physical features of the study area include small hills named as Bukit Pertapan that located on eastern part of the map on Jiwo Hills. The highest elevation is 280 meters. Gunung Sari which located on the northern part of the map has the elevation of 200 meters. The is a long river from north-east to west-south called Dengkeng River (Kali Dengkeng).

Most of the residential areas are concentrated to the south-east, northern and the south of the study area. The houses mostly are built along the roads for an easier connection. The main roads extend from the west to east that connecting the two district that is Bayat and Cawas. Topography map of the study area are provided in Figure 4.2.4.

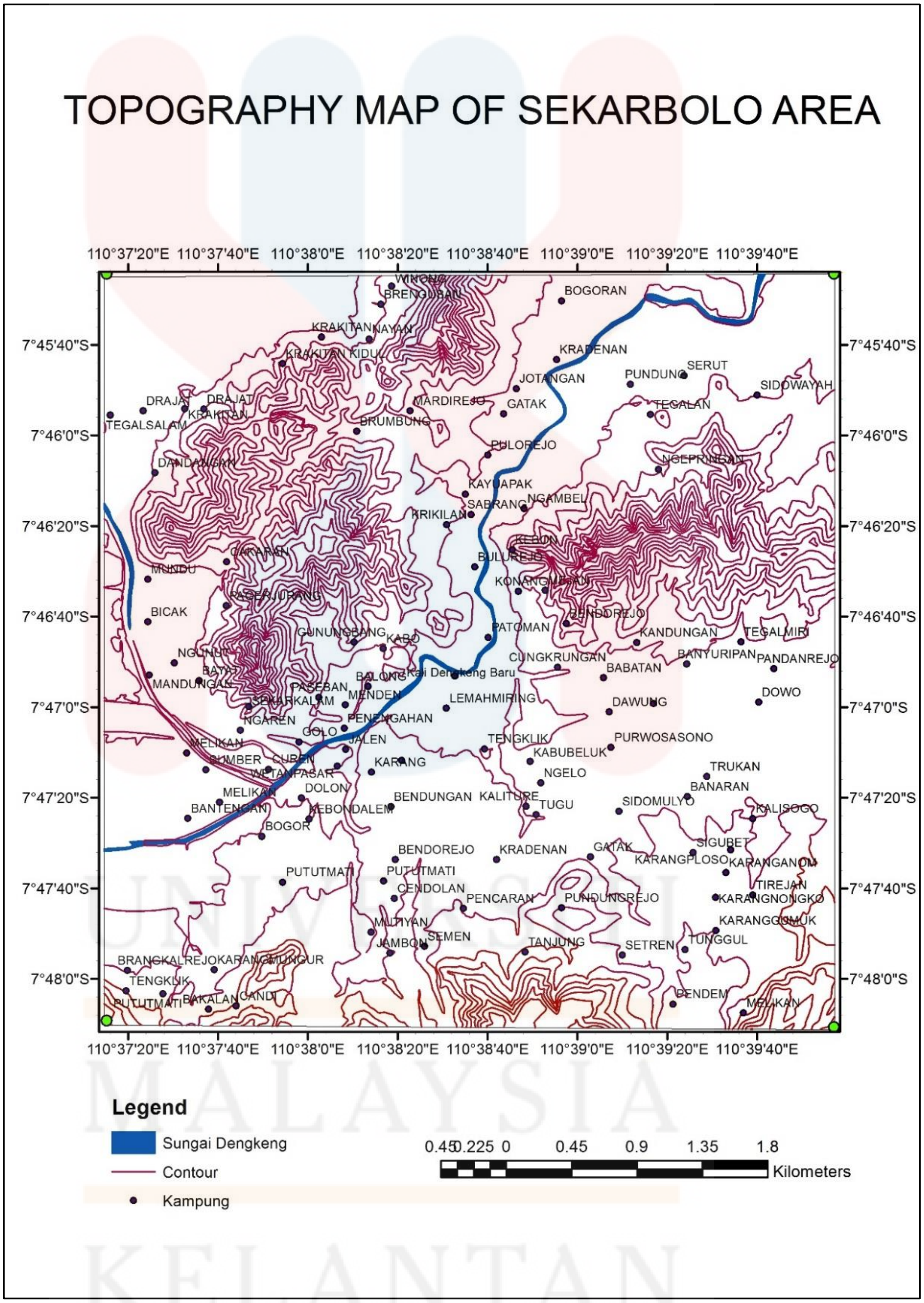


Figure 4.2.4: Topography map of study area

4.4.2 Drainage Pattern

In the study area, based on Figure 4.2.5 it consists one main rivers that is Dengkeng River (Kali Dengkeng). It also shows the flow of water movement that move towards to south of the study area. Rivers can flow down mountains, through valleys (depressions) or along plain. A current, in a river or stream, is the flow of water influenced by gravity as the water moves downhill to reduce its potential energy. The current varies spatially as well as temporally within the stream, dependent upon the flow volume of water, stream gradient, and channel geometry. Usually river water will flow to weak water current flow that called a weak zone. The water in a river is usually confined to a channel, made up of a stream bed between banks. In the study area, from the observation, it may be a dendritic drainage pattern where many contributing streams which are then joined together into the tributaries of the main river.

Other patterns can be observed in the study area is a parallel drainage system. It can see by the pattern of rivers caused by steep slope with some relief. The streams are swift and straight with very few tributaries and all in the same direction because of the steep slopes. The rectangular drainage system also can be found in the study area. It was developed on rocks that are of approximately uniform resistance to erosion but it must have two directions of joint at approximately right angles.

The dominant pattern of drainage this study area is dendritic pattern. The water flow of river in study area is laminar and turbulent flow both. Laminar flow occurred when a fluid flows in parallel layers, with no disruption between the layers. It has a low velocity of fluids tend without mixing the particle in the river. Turbulent flow was occurred when a fluid flow in random direction. It has a rapid velocity of fluids tend with mixing all particles in the river.

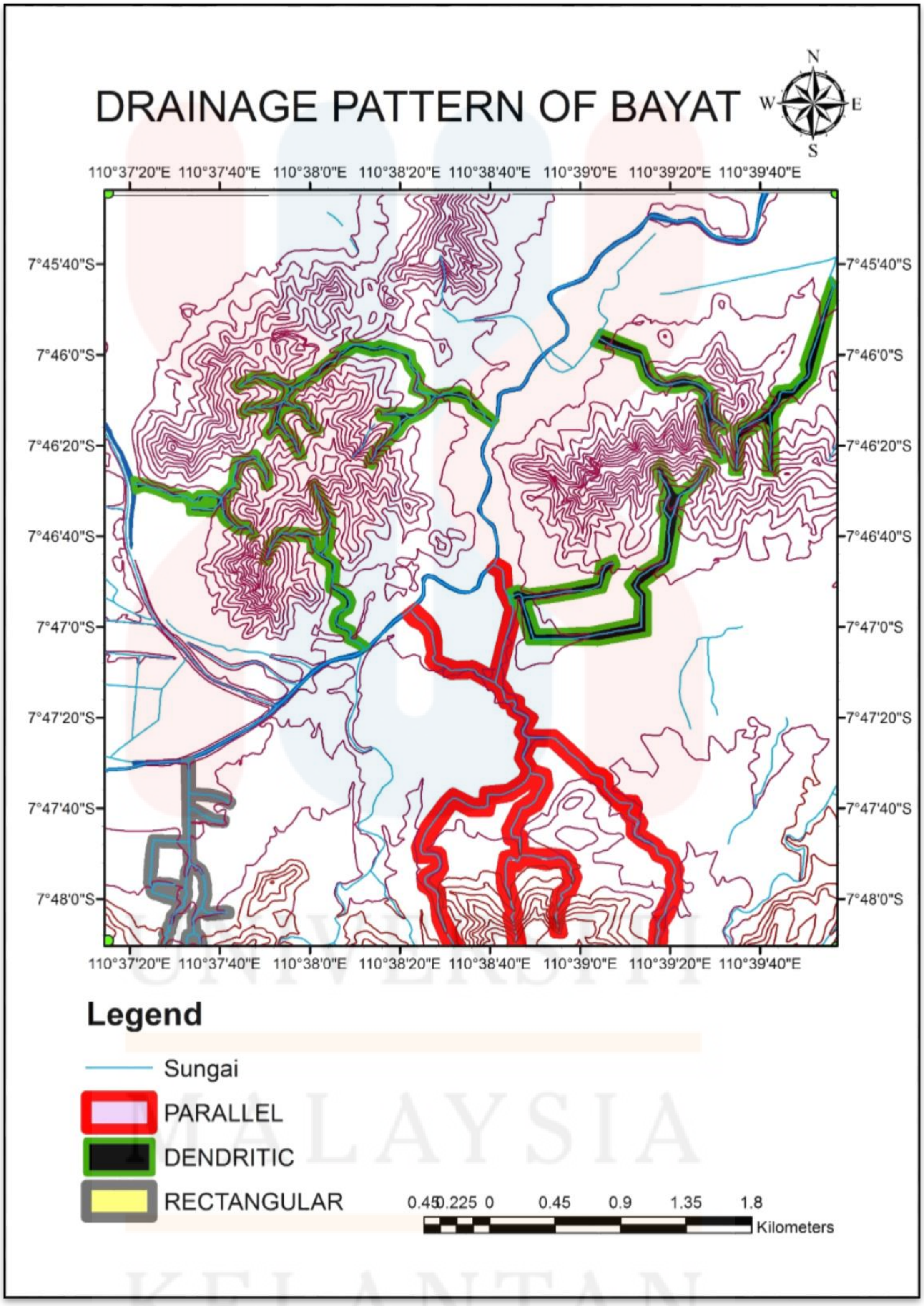


Figure 4.2.5: Drainage pattern in the study area

4.4.3 Weathering Process and Erosion

In this study area, the weathering process was divided into three parts that is biological weathering, chemical weathering and physical weathering. Chemical weathering is the decay of rock forming minerals caused by water, temperature, oxygen, hydrogen and mild acids. Physical weathering processes that break a rock or mineral into smaller pieces without altering its composition. Biological weathering is processes that are caused by/or assisted by, the presence of vegetation, or to a lesser extent animal, including root wedging and the production of organics acids. where the final product will produce a new mineral or change the characteristics of rock from the origin. There are six grade of weathering that are describe by the percentage of the rock that was composes from rock material. Based on observation on the field and refer to Table 4.2.1 the grades of weathering of study area are from grade I until grade VI.

Table 4.2.1: Weathering grades of different rock (Paul M. Santi, 2006)

Weathering Grade	General Description
VI-Residual soil	The rock is completely changed to soil in which the original rock texture has been completely destroyed.
V-Completely decomposed	The rock is changed to soil in which the original rock texture is (mainly) preserved.
IV-Highly decomposed	50-100 percent soil from decomposition of the rock mass.

III-Moderately decomposed	Up to 50 percent soil from decomposition of the rock mass.
II-Slightly decomposed	100 percent rock, discontinuity surfaces or rock material may be discolored.
I-Fresh	100 percent rock, no discoloration, decomposition, or other change.

(A)Biological weathering

Figure 4.2.6: Biological weathering by a tree

In study area, vegetation of biological weathering happens when the roots can exert stress or pressure on rock. Plants can grow within the cracks in a rock formation and the root grow bigger they push open cracks in the rocks making them wider and deeper. Following time, the growing tree eventually prizes the rock apart. Figure 4.2.6 shows that example of biological weathering in the study area.

(A) Chemical weathering

Figure 4.2.7: Chemical weathering due to mineral alteration

Chemical weathering process is the internal structure of a mineral is altered by the addition or removal of elements. Change in phase and composition are due to the action of chemical agents. Chemical weathering is dependent on available surface for reaction temperature and presence of chemically active fluids. Smaller particle sizes weather by chemical means more rapidly than large particles due to an increase of surface area. The factors that influence chemical weathering are climate, living organisms, time and mineral composition. Where living organisms is divide to two that is bioturbation and acid production or mineral decomposition. The product that can produce from chemical weathering is clays, metal ores and rounding of boulders. Figure 4.2.7 show the chemical weathering by oxidation at the study area.

(C) Physical weathering

Figure 4.2.8: Physical weathering due to thermal expansion

Physical processes in this area are happens due the temperature change as called as thermal expansion where it describes the effect of heating and cooling on a rock. Consider o rock outcrop in a moderate climate. During the day, this rock is exposed to sunlight, gradually heating the rock and causing it to expand. As the temperature drops overnight, the rock begins to cool and contract. Moreover, the rock may not be uniformly heated or cooled depending on its orientation and variety of other factors. The repeated heating and cooling places stress on the rock which can cause it to fracture and break. It cracks form eventually causing pieces of the rock to fall away. Figure 4.2.8 shows the crack appeared on the outcrop.

4.3 Lithostratigraphy

The stratigraphy unit description in order of increasing age, where the oldest formation is Schist-Phyllite Unit followed by Nummulitic Limestone Unit, Volcanic Clastic Unit, Tuffaceous Sandstone Unit, Intrusion Andesite Unit and Alluvium Unit.

Field work for geological mapping conducted throughout the study area. This update map shows the development of urbanization in the study area. The percentage of built-up land also increases from the top-up placement and increasing infrastructure that gets expanded. For connection road, the main road is developing in Bayat and it still in construction.

The majority of rock exposed in the study area is a metamorphic rock with different grain size and mineral composition. The dominant accessory mineral in the metamorphic rock is feldspar. Metamorphic rock was covered from the west till east part. Because of road construction, the metamorphic rock is exposed to the earth's surface by the cut slope of the hill. Igneous rock was covered on certain part within the same area with metamorphic rock as there is an intrusion occurred in the study area. The dominant accessory mineral composition in the igneous rock is silica, feldspar.

Table 4.3.1: Stratigraphy of Bayat

Age		Formation	Lithology
Quaternary			**Collovium**: gravelly sand of young Merapi deposits. Mainly argillaceous sand, conglomeratic sand and conglomerate with components of metamorphic, igneous and sediment. **Alluvium**: consists of gravels, sands and clay from Dengkeng River. **Alluvium Fan Deposit**: Gravels-sands-clay
Miocene	Middle		**Diorite Unit**: Intrusion of igneous rocks which consists of Diorite, Andesite and Rhyolite. This igneous formed in Diabase Formation. This Diorite can be found in Pendul Hill (Eastern Jiwo Hill) and Kebo Hill (Western Jiwo Hill).
Miocene	Early		**Volcanic Clastic Unit**: consist of alteration of volcanic breccia, sandstone and siltstone. This rock is from Butak Formation. Some fragment have altered into green chloride.
Oligocene	Early-Late		**Tuffaceous Sandstone**: consist of tuff, tuffaceous sandstone, volcanic sandstone but dominated by gravel sandstone. This rocks formed in Kebo Formation. This unit was deposited in deep-marine environment.
Eocene	Late		**Nummilitic Limestone Unit**: consist on limestone from Gamping Formation which attached on with nummulite fossil which is very abundance. Upwards, the unit is dominated by fine-grained calcareous sediment.
Eocene	Middle		
Cretaceous	Late		**Schist-Phyllite Unit**: consist of two type of metamorphic rock from Metamorphic Formation which is schist and phyllite. The unit has no fossils.

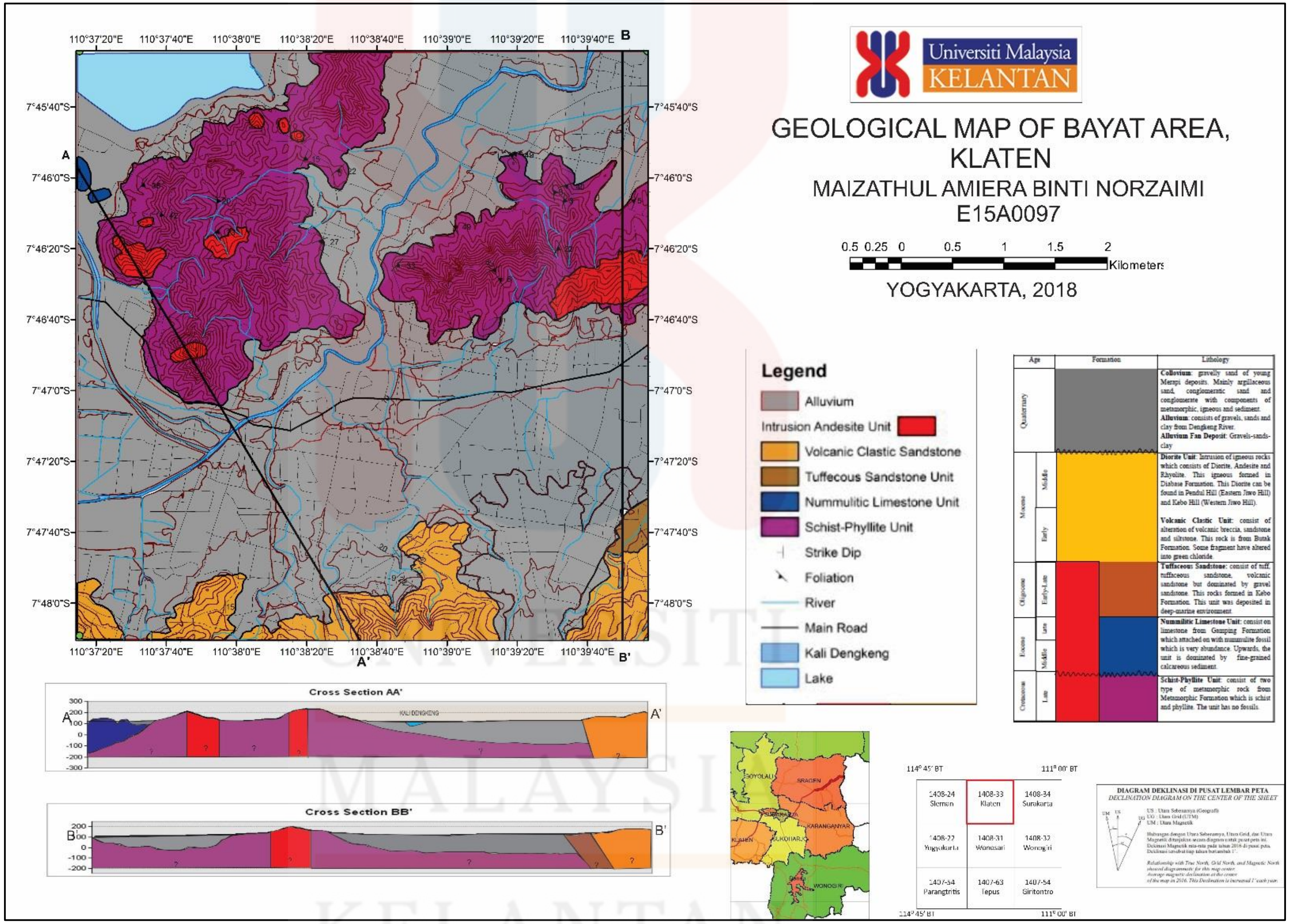


Figure 4.2.9: Geological map

A. Schist-Phyllite Unit

In this unit, schist-phyllite was the most abundant of rock unit that can be found. Other than schist-phyllite, some area consists of marbles. Most of the schist-phyllite outcrop were highly weathered due to physical weathering of sunlight, raining and also biological weathering from tree as shown in Figure 4.3.1. As the structure of the rock very fragile, a fresh sample cannot be obtained and most of the sample highly weathered and the foliation cannot be seen. In this unit also contains a few type of schist such as Mica Schist, Graphite Schist and Chloride Schist which all of them in a group of Green Schist facies. Due to highly weathering process, the size of the grain and the texture was fine to very fine. The color of the grain is brownish like a soil. The length of this outcrop approximately around 2 meters.

Figure 4.3.1: Schist-phyllite outcrop

Figure 4.3.2 shows an outcrop found in an area located at the eastern part Jiwo Hills, Gunung Pendul in coordinate of 7° 46’ 53.6” S, 110° 39’ 19.5” E. The outcrop found at this area is different. The foliation can be seen with naked eyes at this area. The grain color more likely from greenish-blue to blackish-blue. The condition of the outcrop was moderately weathered. The mica mineral was very fined and cannot be seen with naked eyes. The first conclusion that can be interpret the outcrop may be a phyllite. Figure 4.3.3 shows the sample taken from the outcrop and it shows a mineral accumulation which is quartz accumulation.

Figure 4.3.2: Schist-phyllite outcrop on Eastern Jiwo Hills

Figure 4.3.3: Mineral accumulation (in the circle)

Figure 4.3.4 shows hand specimen for Schist-Phyllite sample that was sent for thin section. Figure 4.3.5 and Figure 4.3.6 shows the mineral content that have been observed under microscope respectively for cross polarized and plane polarized.

Figure 4.3.4: Rock sample of Schist

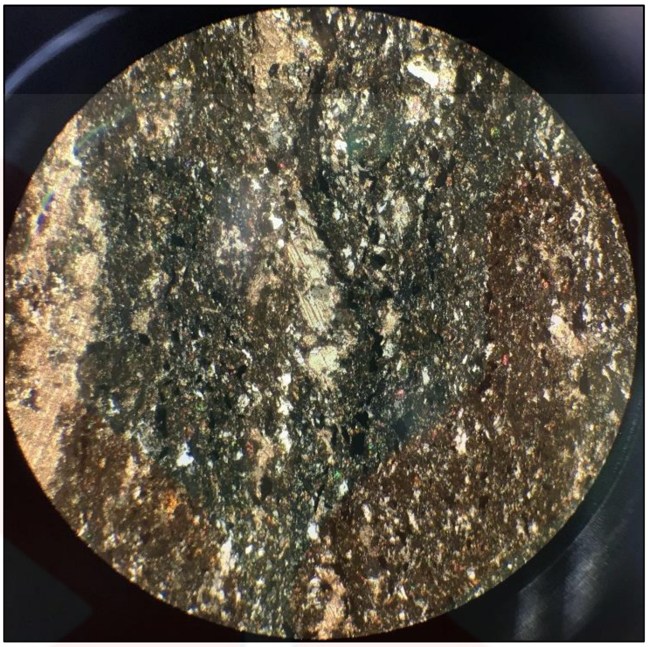


Figure 4.3.5: Cross Polarized of Schist

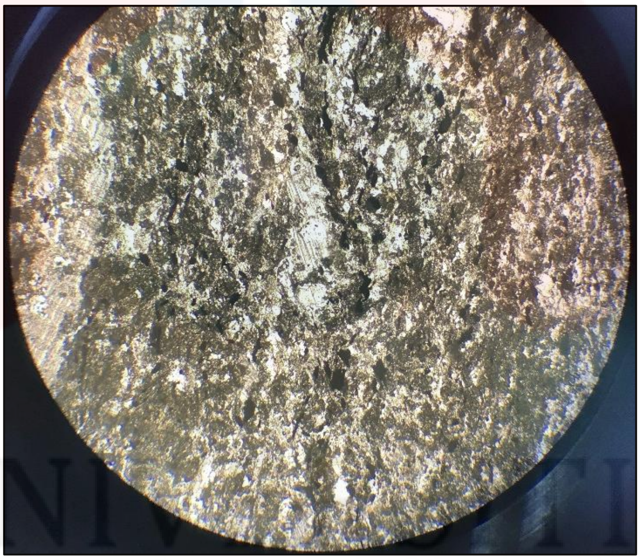


Figure 4.3.6: Plane Polarized of Schist

B. Nummulitic Limestone Unit

The type of the limestone that can be found in this area is nummulitic limestone. Nummulite is a large lenticular fossil which characterized by its numerous coil. Figure 4.3.7 shows the nummulite fossil which attached on the limestone millions years ago. The nummulitic limestone can be found in an area called Sekarbolo area in coordinate of 110° 37' 19.6" E, 7° 46' 02.8" S. The grain size of this limestone is medium grain and the color from the surface that can be seen mostly dark color, which is dark-grey color with quartz mineral that can be seen with naked eyes. This nummulitic limestone can be found in a village called Sekarbolo Village. This area is very famous with nummulitic limestone and can be easily found. There only a few outcrop found in the study area but most of the outcrop can be easily identified as nummulitic limestone such as shown in Figure 4.3.8

Figure 4.3.7: Nummulite fossil

Figure 4.3.8: Outcrop of nummulitic limestone in Sekarbolo

Figure 4.3.9: Rock sample of Nummulitic Limestone

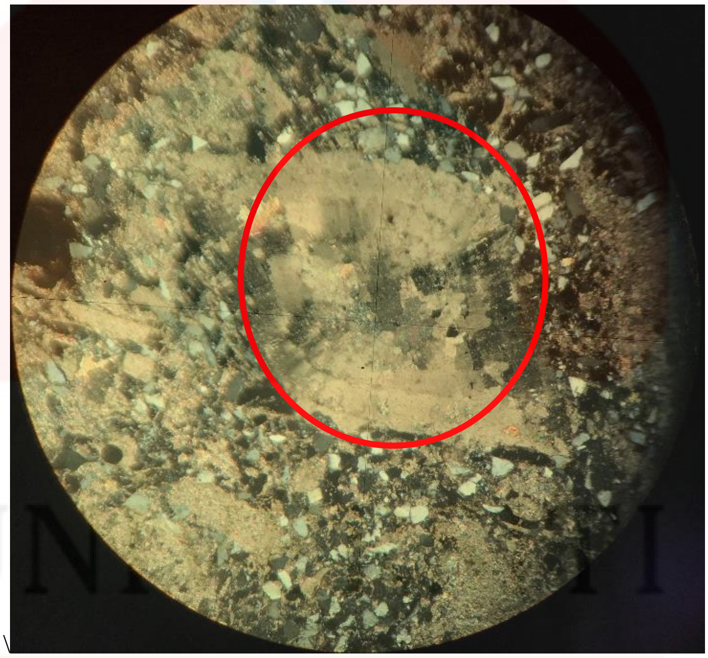


Figure 4.3.10: *Nummulite sp.*

In the Lower Tertiary, nummulites is the largest and the best-known foraminifera. It has the thick wall with radial fibrous structure. The matric is mainly micritic sediment with a little-blue stained ferroan calcite cement. Figure 4.3.10 shows the *Nummulite sp.* found in the thin section of the nummulitic limestone.

Figure 4.3.11 below shows a Foramnifera fossil found in Nummulitic Limestone. The foraminifera was known as *Fusulinids sp.* which one of the Order that have extinct in Permian-Triassic Extinction Event. This fossil is a single-cell organisms that related to modern Amoeba which are composed tightly packed, secreted microgranular calcite.

Table 4.3.2: Scientific Classification of *Fusulinids sp.*

Domain	Eukaryota
Phylum	Retaria
Subphylum	Foraminifera
Order	Fusulinida

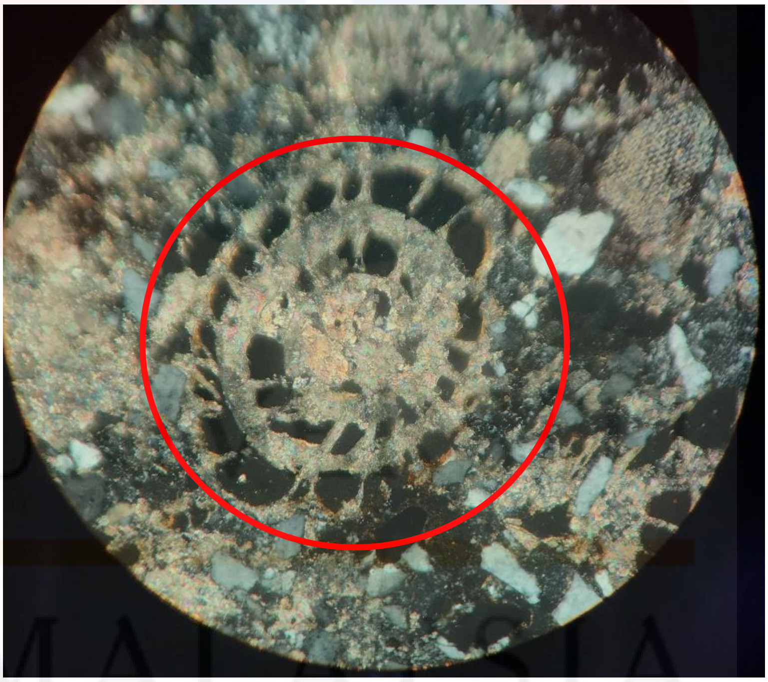


Figure 4.3.11: *Fusulinids sp.*

C. Tuffaceous Sandstone Unit

Tuffaceous Sandstone Unit or known as Kebo-Butak Formation where the Butak Formation overlapping with Kebo Formation located in a lower part of Southern Mountain. This area mostly covered with sandstone and most of the outcrop, the bedding can be seen clearly as shown in Figure 4.3.12. The grain size of sandstone is fine grained. The color of the of the grain mostly are light brown colored with quartz mineral can be seen directly. Figure 4.3.13 shows an outcrop of sandstone found in the southern part of the study area. Figure 4.3.14 shows a hand specimen of the tuffaceous sandstone. From the picture, we can see that there is a green colour of texture on the sandstone. The green colour is a chloride that have been altered from some fragments.

Figure 4.3.12: Alternation of sandstone and siltstone

Figure 4.3.13: Outcrop of sandstone

Figure 4.3.14: Rock Sample of Tuffaceous Sandstone

Location: Along a dry river

Coordinate: 7° 48’ 17.7” S, 110° 39’ 51.7” E.

Table 4.3.3: Percentage of Mineral Composition in Tuff Sandstone

Mineral	Percentage (%)	Description	Extension Angle (^{0})
Pyroxene	5	Mainly greenish-orange in colour and have two distinctive plane of cleavage.	
Chloride	10	Some fragment that have been altered.	
Volcanic Ash	30	Might come from the Mount Merapi due to the past eruption. Size <2mm	
Microcrystalline feldspar	50	Abundant of colourless and very micro feldspar	
Opaque Mineral	5	Black opaque colour and do not change colour under PPL as light cannot transmit through it.	

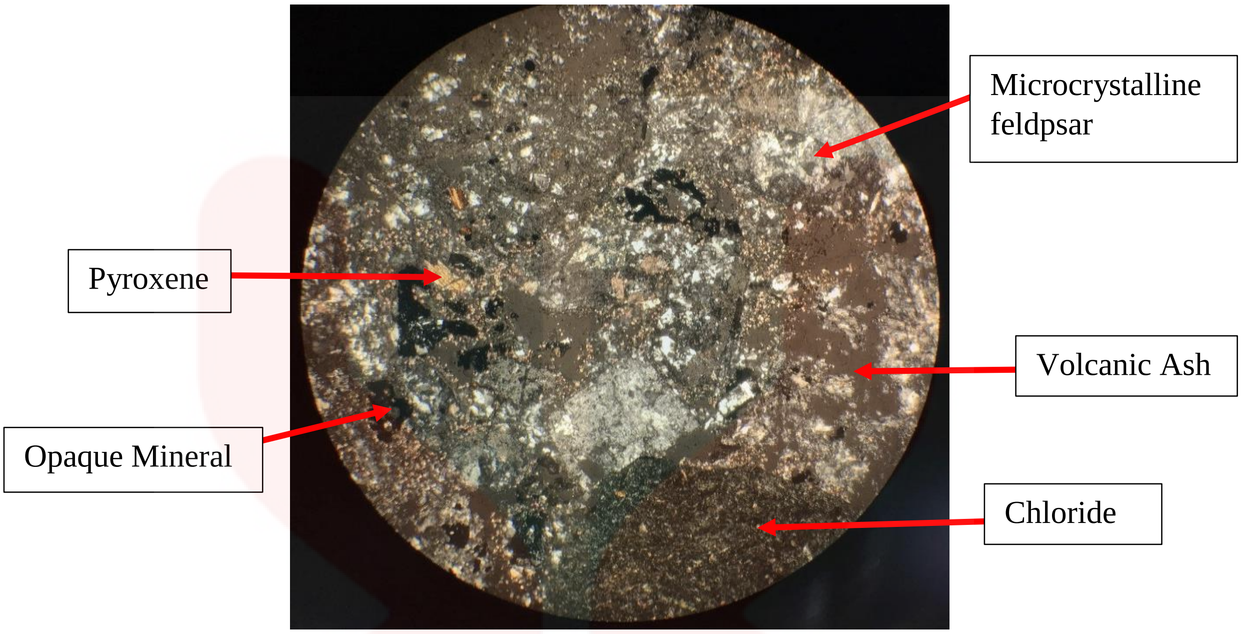
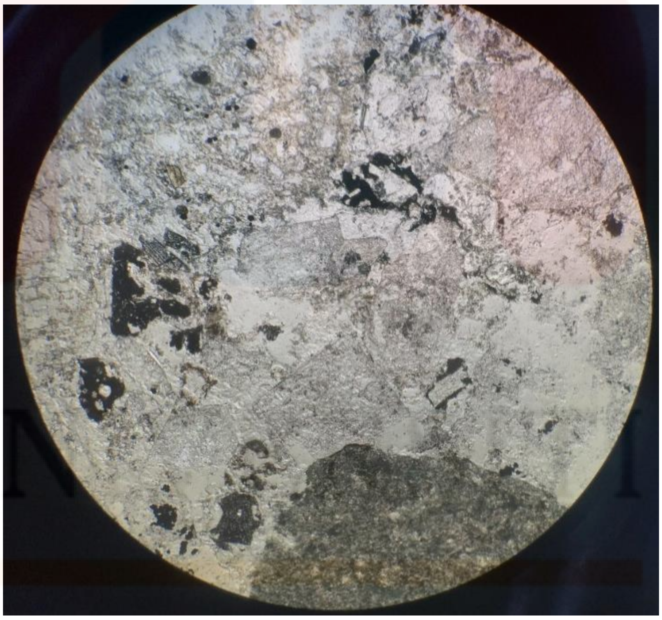


Figure 4.3.15: Cross Polarized of Tuff Sandstone



4.3.16: Plane Polarized of Tuff Sandstone

D. Volcanic Clastic Sediment Unit

In this unit, it was called Volcanic Clastic Sediment as it consists volcanic fragment that deposited on this area. The volcanic might deposited form the previous year of eruption. This unit also known as Butak Formation which covered the Southern Part or Gunung Kidul. The appearance of petrographic sandstone in Butak Formation as shown in Figure 4.3.19 shows that the fragments are dominated by volcanic materials (basal, plagioclase, andesite, tuff, and quartz).

4.3.17: Outcrop of Volcanic Sandstone

4.3.18: Rock sample of Volcanic Sandstone

Location: Lower part of Gunung Kidul (Southern Mountain)

Coordinate: 7° 47’ 51.8” S, 110° 38’ 52.0” E.

Table 4.3.4: Percentage of Mineral Composition in Volcanic Sandstone

Mineral	Percentage (%)	Description	Extension Angle $(^{0})$
Opaque Mineral	20	Black opaque colour and do not change colour under PPL as light cannot transmit through it.	
Plagioclase	20	Colourless or may appear cloudy-black in twinning.	
Volcanic Ash	45	Might come from the Mount Merapi due to the past eruption.	
Feldspar	15	Colourless crystals	

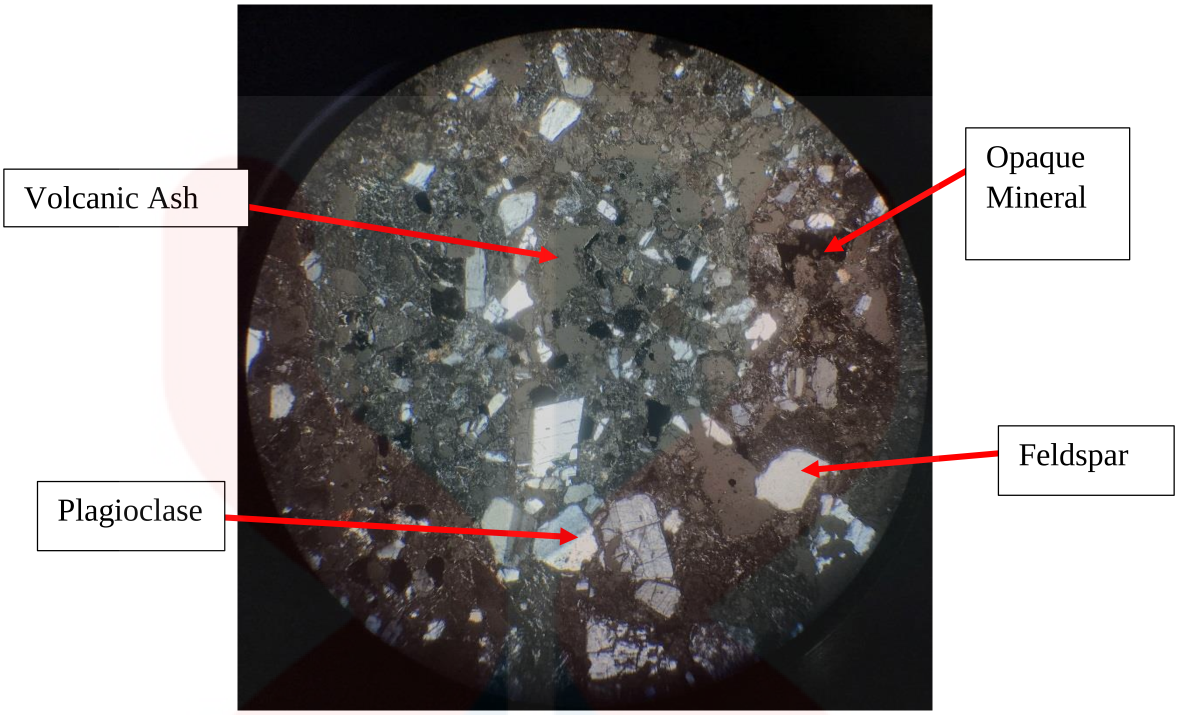


Figure 4.3.19: Cross Polarized of Volcanic Sandstone

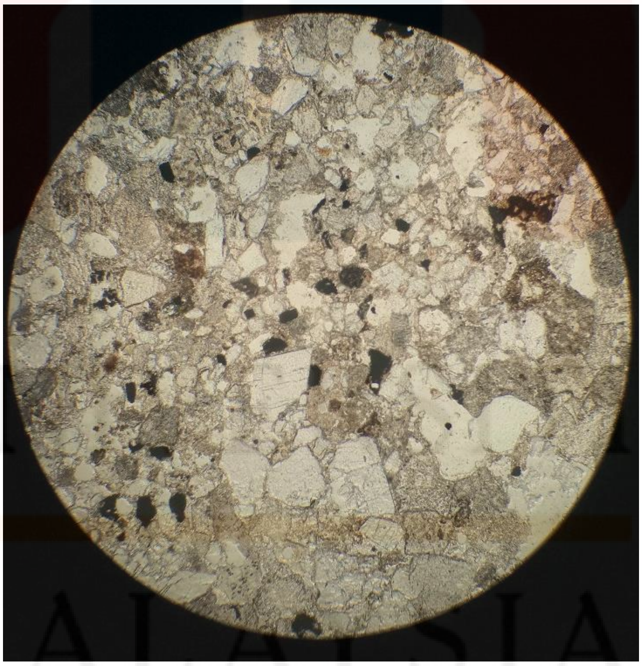


Figure 4.3.20: Plane Polarized of Volcanic Sandstone

E. Intrusion Andesite Unit

The type of igneous rock that can be found during this mapping was volcanic rock, which may be deposited from the previous eruption of the Mount Merapi. This igneous rock was an intrusion into the metamorphic rock. From the earlier interpretation, the type of igneous rock that can be found may be andesite or diorite. Figure 4.3.21 below shown an outcrop of igneous rock found in a river. The size of the grain is medium and the color of the sample is grey which is felsic because it contains more than 25% quartz and silica. This unit was named by intrusion because the andesite intruded most of the schist phyllite unit as a dyke. After a further study using microscope by thin section, the rock can be identified as Andesite based on the percentage of its mineral as shown in Table 4.3.5.

Figure 4.3.21: Andesite outcrop found in a river

Location: In a river

Coordinate: 7^0 46’ 29.0” S, 110^0 37’ 57.30” E.

Table 4.3.5: Percentage of Mineral Composition in Andesite

Mineral	Percentage (%)	Description	Extension Angle (^{0})
Hornblende	10	Pleochroic in various shade of green to brown. Crystal often hexagonal.	0
Plagioclase	65	Colourless or may appear cloudy-black in twinning.	39
Quartz	10	Colourless and no cleavage	
Opaque Mineral	15	Black opaque colour and do not change colour under PPL as light cannot transmit through it.	

Figure 4.3.22: Rock sample of Andesite

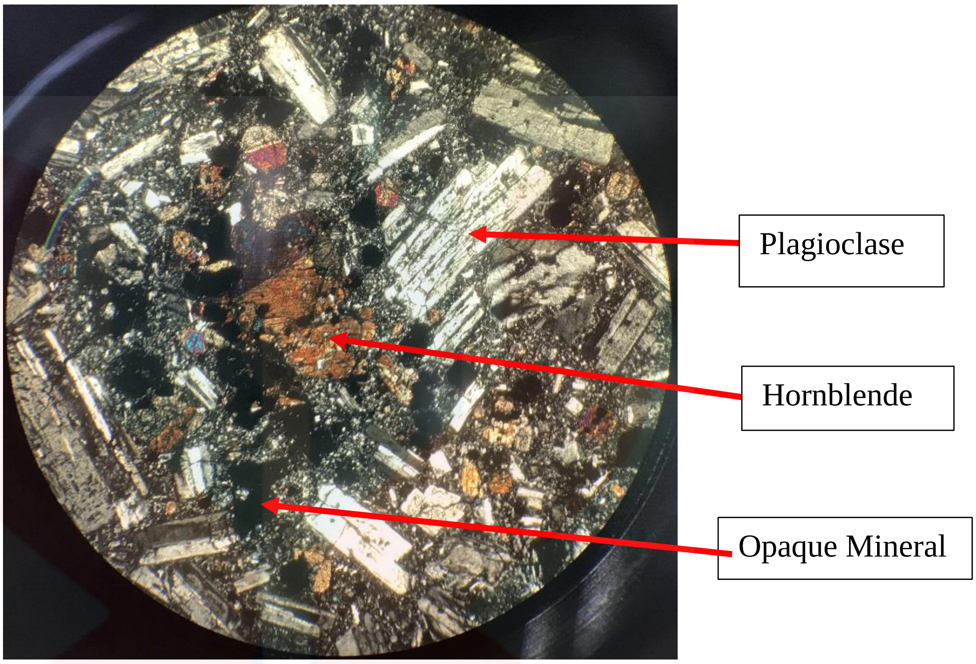


Figure 4.3.23: Cross Polarized of Andesite

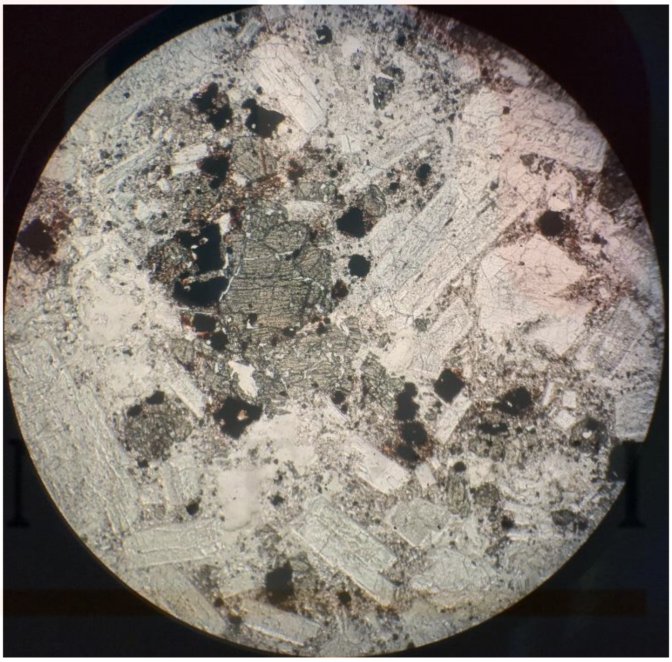


Figure 4.3.24: Plane Polarized of Andesite

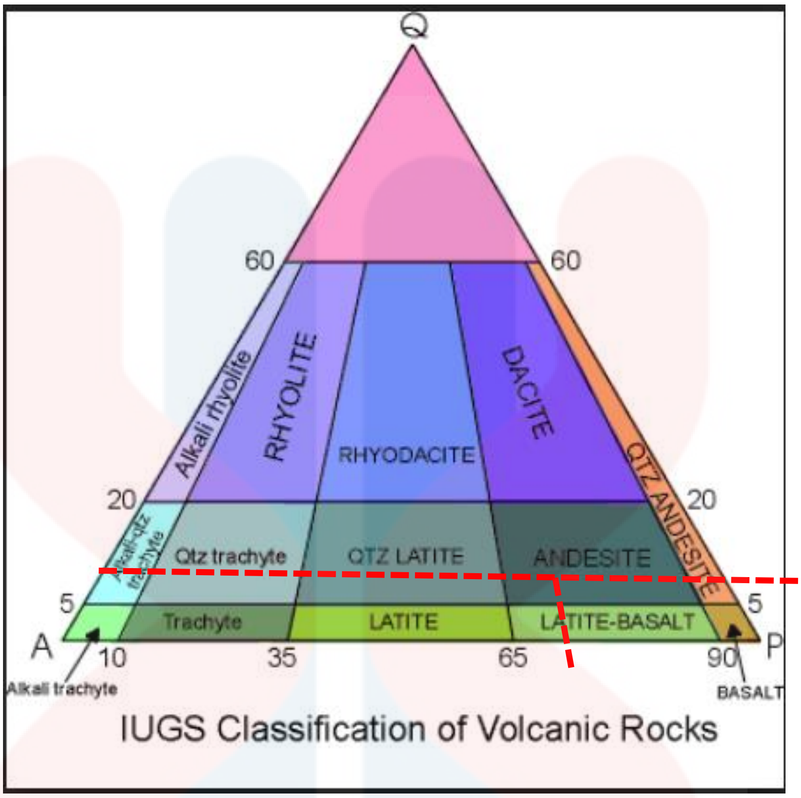


Figure 4.3.25: Volcanic Rock classification diagram

Name of Rock: Andesite

4.4 Structural Geology

Structural geology is the study of the three dimensional distribution of rocks units with the respect to their deformational histories. The purpose of structural geology is that to uncover information about the history of deformation or strain in the rocks and to understand the stress field that resulted in the observed strain and geometries. This understanding can be linked with the important events in the regional geologic past. With the respect to the regionally widespread patterns of rock deformation due to plate tectonics, understanding the structural evolution of a particular area is the common goal.

Structure geology rarely can be found in this study area. Most of the structure that can be found were joints, fracture and fault breccia. Table 4.4.1 and Table 4.4.2 shows the data for the GeoRose Diagram for Figure 4.4.1 and Figure 4.4.2 respectively.

The data for the Table 4.4.1 was taken at an outcrop in a river which consist a huge outcrop of igneous rock. The result shown in Figure 4.4.1 that the major force that is σ_1 comes from the direction of North (N) while the tension or minor force, σ_3 being taken from the North East (NE), directly proportional to the major force.

Table 4.4.1: Joint data on igneous outcrop

STRIKE (RANGE)	FREQUENCY
181-190	56
191-200	15
201-210	2
211-220	5
251-260	4
261-270	7
271-280	4
281-290	1
291-300	2
301-310	5

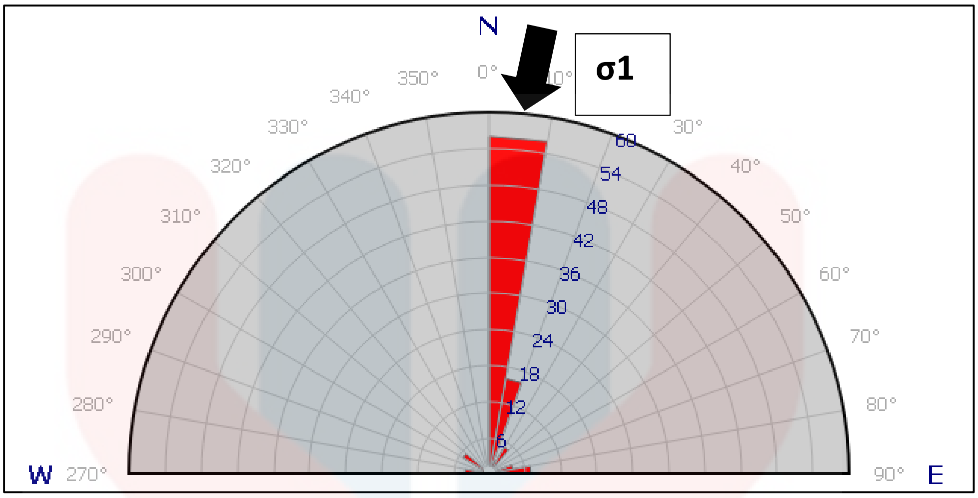


Figure 4.4.1: GeoRose Diagram

The joint data for the table 4.4.2 was taken at the southern part of the study area, which the basement of Gunung Kidul (Southern Mountain). The lithology available at this site consists of chloride which make most of the rock sample have slightly green colour.

Using the Rosenet application, a Rose diagram can be plotted in order to obtain the direction of forces, tension and shear (Figure 4.4.2). The result shown that the major force that is σ_1 comes from the direction of North West (NW) while the tension or minor force, σ_3 being taken from the North East (NE), directly proportional to the major force.

Table 4.4.2: Joint data on Southern Mountain

STRIKE (RANGE)	FREQUENCY
21-30	4
31-40	4
41-50	7
51-60	1
71-80	2
91-100	1
141-150	3
151-160	5
161-170	11
171-180	11
201-210	1

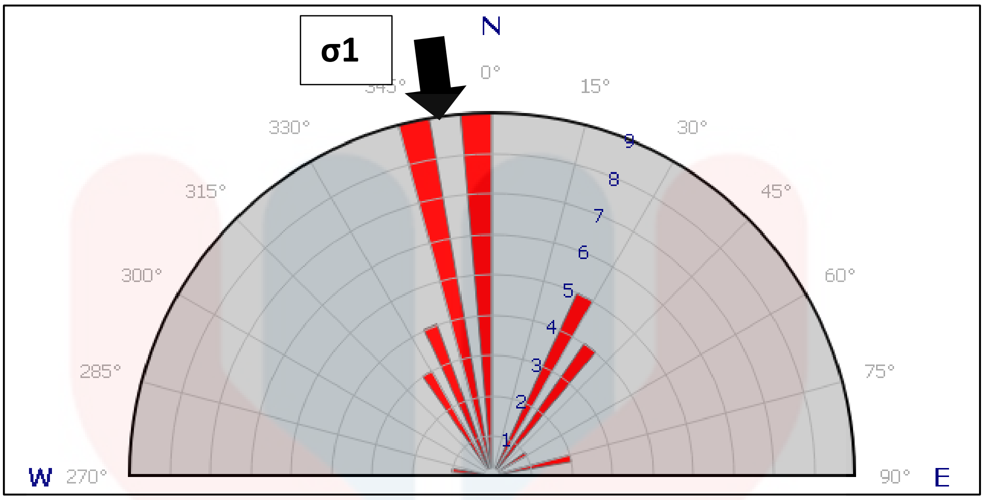


Figure 4.4.2: GeoRose Diagram

CHAPTER 5

VOLCANIC HAZARD

5.1 Introduction

Previous eruption of Mount Merapi back in 2010 have caused lahar flow along the Gendol River and Opak River which changes the morphology of both river and caused huge destruction to the surrounding of the river. The eruption not only destroyed the morphology of the river, but it also gave a huge impact to the surrounding of Mount Merapi. Figure 5.1.1 below adapted from CITRA Satellite shows the huge differences of the morphology before and after eruption in 2010.

Figure 5.1.1: Merapi before and after eruption 2010 (sources: CITRA Satellite)

The lahar formed was triggered from a few aspects:

(1.) Volcanic eruption; the lahar formed the snow and ice around the mountain melt and flow from the crater of the volcanoes.

(2.) Heavy flow of rain during and after the eruption; The rain can flow in between the volcanic rock and the valley of the volcanoes to the stream. This formation is the most dominant in formation of lahar.

(3.) Starting from the movement of soil and undergo hydrothermal alteration at valley of the volcanoes. Movement of soil triggered by volcanic eruption, earthquakes, rain or increasing in the gravity at the volcanoes.

(4.) Cold lahar was formed by pyroclastic material from volcanic ash, sand, gravel and rock from the eruption that transported by rain and flow in between the valley or stream available. Lahar flow will flow to the nearest stream to the downstream with high velocity to transported the rock, gravel, sand and even the volcanic ash which act as a lubricant in between the rock and gravels. In Japan, this process known as 'Sabo' which the sediment from the eruption is a lahar flood which origin from volcanic eruption, landslides or even erosion of the stream which caused a river become shallow.

5.2 Lahar deposition in Krasak River

Krasak River is one of the main river that contribute to the lahar flow after the eruption. Figure 5.2 (i), (ii) and (iii) shows the lahar deposit in the river. The Krasak River now have become the mining site. So it is easier for us to see the deposition of lahar. The river also become shallow as the lahar deposition have disturb the morphology of the river.

Figure 5.2.1 (i)

Figure 5.2.1 (ii)

Figure 5.2.1 (iii)

Figure 5.2.1: (i). (ii). (iii) shows the lahar deposition in Krasak River

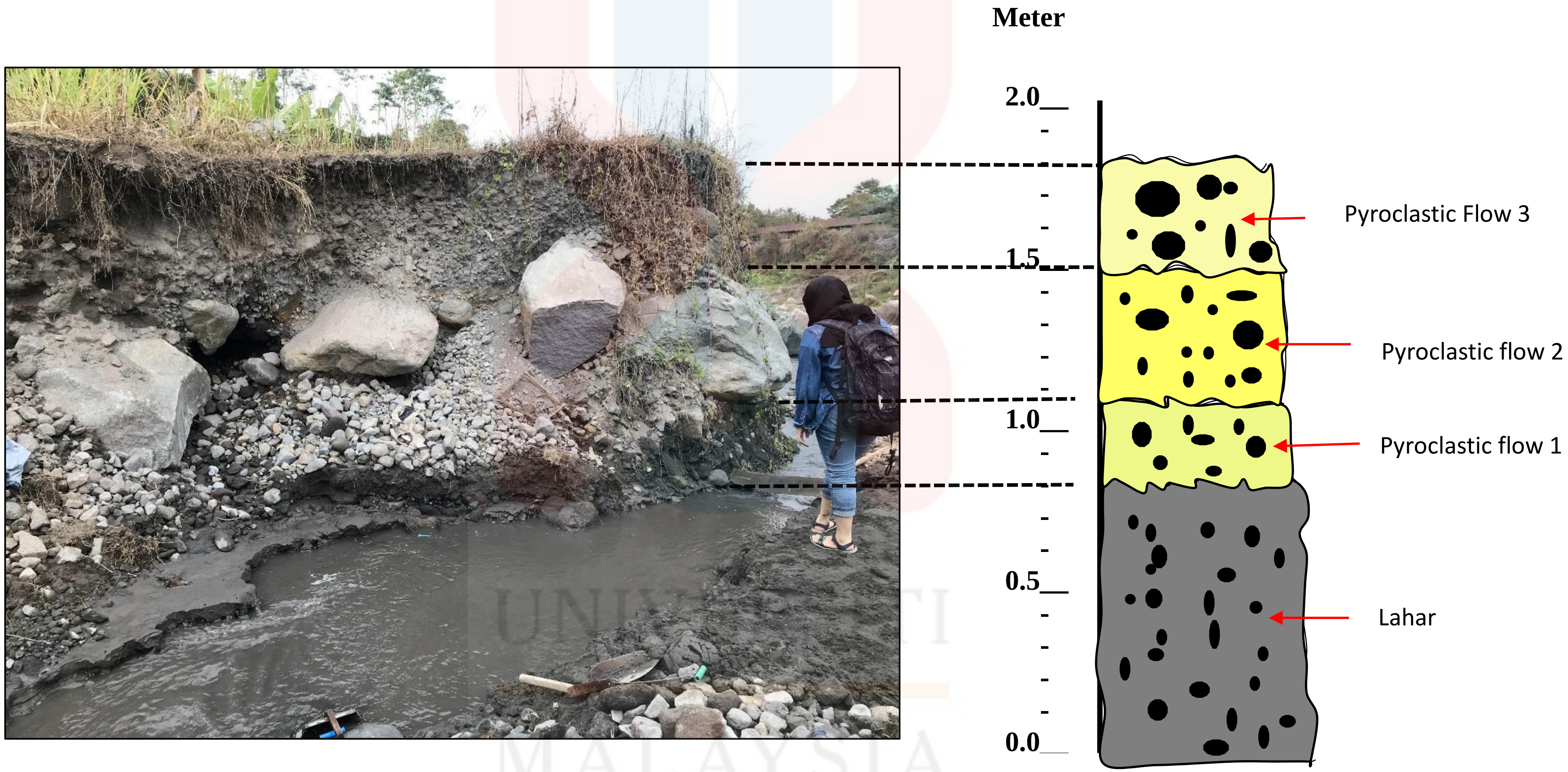


Figure 5.2.2: Lahar stratigraphy of Krasak River

Pyroclastic flow 3

The colour of the deposition is light brown which might have been mixed with sand that have a medium grain size. The fragment have a large size with 60 cm. The sortation is poor with shape of sub-rounded to very angular. The thickness is around 0.3 meter.

Pyroclastic flow 2

The deposition has a slightly colour of reddish to brownish. The size of sand grain is medium with fragment size 30 cm. It has poor sortation with angular to very angular shape of the fragment. The thickness of the deposition is 0.4 meter.

Pyroclastic flow 1

The colour of the deposition is light brown to grey. The size of sand grain is medium till fragment with 25 cm. The deposition deposited from the latest eruption of Mt. Merapi on May 2018. The fragment has a poor sortation but the shape in between angular to very angular. The thickness of the deposition ranges in 0.3 meter to 0.5 meter. Charcoal or coal can be found in this deposition but due to the sortation and colour of the deposition same to the coal, the coal cannot be found.

Lahar

The colour of the deposition is grey-brownish like an ash. It has a medium size of sand till fragment with size of 15 cm. The fragment has a poor sortation, shape classification of sub-rounded to very angular. The deposition of lahar has a thickness of 0.8 meter which have been mixed with water that make it texture like a mud.

5.3 Volcanic Hazard Analysis

The evidence of the volcanic hazard for the previous eruption on 2010 were shown in the picture above. This picture was taken in one of the village distance 7 km from the Mount Merapi. This village totally lost from the previous eruption and now this village turns into a museum. People all over the world come here to see the hazard causes by the eruption.

The hazard that cause such a huge destruction were from pyroclastic flow and volcanic ash. As told by the villagers, after the eruption this village was covered with ash with thickness more than 20 km. Till today the ash can still be seen but not as thick as previous.

The hazard of the volcanic have been identified and classified into three part according to the level of danger in an area. Most of the figure shown starting from Figure 5.3.1 till Figure 5.3.4 located in a classification as KRB III (Kawasan Rawan Bencana III) which have been identified as the most danger area which will give a huge destruction and more loss of life.

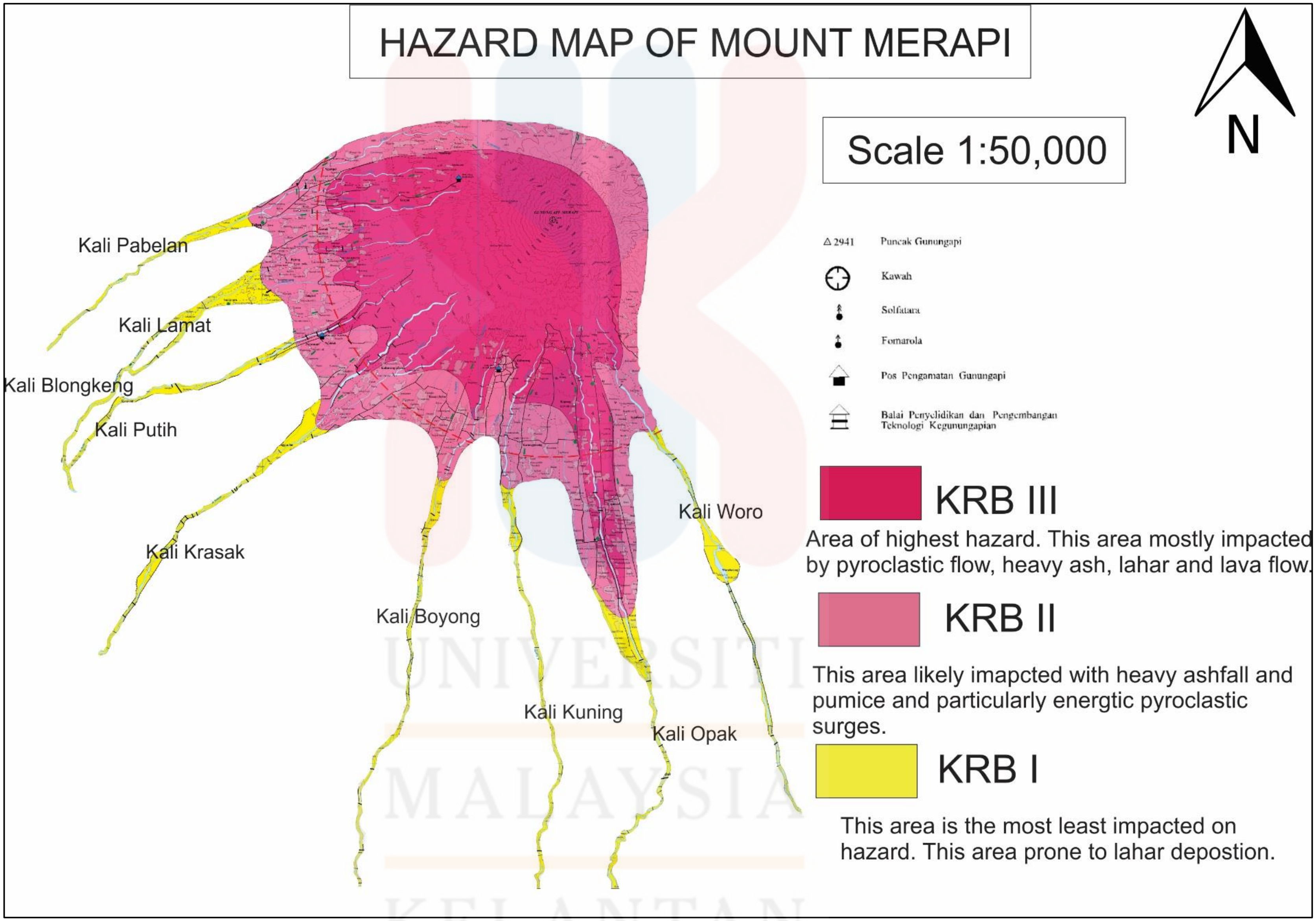


Figure 5.3.1: Hazard Map of Mount Merapi

5.3.1 Hazard Classification

I. Disaster-Prone Areas III (Kawasan Rawan Bencana,KRB III)

This area mostly will be hit by pyroclastic flow, lava flow, hazardous gas and affected hit by the rock from the eruption. KRB III mostly have a range of 2 km from the volcanoes. KRB III located near to the sources of eruption. As can be seen on Figure 5.3.1, the dark pink colour represent the area related to KRB III. Due to its high prone of risk, the villagers at this area are not advice to stay permanently.

Since the year of 1930 till 1992, pyroclastic flow of Mount Merapi affected the area of North, West till South-West. But the eruption that occurred on November 22, 1994 crater of the lava grown at the edge of the south area, till some of the dome collapsed and formed pyroclastic flow till it entered the Bodong River and Bedog River (Abdurachman, 1998 and Abdurrachman et al., 2000).

The eruption on 1998 and 2001, the direction of the pyroclastic flow was towards West and South-West. The eruption on 2006 have create a route for the pyroclastic flow to the South area and its dominant to Gendol River. Figure 5.3.2 below shows a model for the lava dome in 2006. As can be seen in the figure above, after the eruption the peak of the Mount Merapi have been destroyed by a pyroclastic flow. The eruption on 2010 was an explosive eruption that have caused the pyroclastic flow direction dominant to South till Gendol River as shown in Figure 5.3.3 belows. The route for the flow bigger than in 2006.

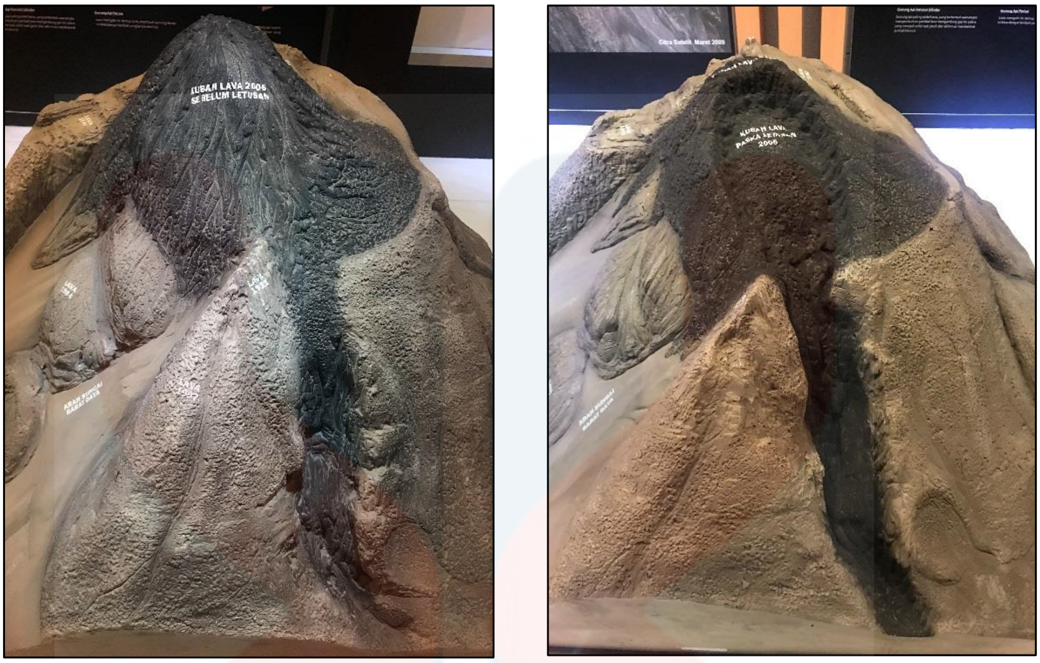


Figure 5.3.2: Lava dome model of Mount Merapi before and after eruption on 2006

Figure 5.3.3: Lava dome model of Mount Merapi after eruption on 2010

II. Disaster-Prone Areas II (Kawasan Rawan Bencana,KRB II)

Disaster-Prone area or KRB II can be divided into two categories:

1. Mass flow form: Pyroclastic flow, lahar and lava flow
2. Mass hit form: Material and rock

In the area of KRB II, the villagers can stay here but if the authorities give a warning regarding the eruption, they need to take a precaution to temporary relief center until the warning sign due to eruption stable. In the Figure 5.3.1, the hazard map to the KBR II represent by the colour of light pink.

When there is huge eruption, the area in KRB II in the valley at North, West, South-West, South and South-East will be affected with pyroclastic flow. The boundary for the pyroclastic flow in KRB II area is 17 km or further. Based on Figure 5.3.3 above, the enlargement of the lava dome has caused the pyroclastic flow increase till it reached the village area.

Lahar formed when the deposition of the pyroclastic flow mixing with water due to high intensity of rain. Lahar can formed in bigger scale when the volume of rain reached 20 mm in 2 hours. Potential zone for lahar affected in range of 600 – 450 m in height. River in Merapi area mostly much more longer in West Valley. There is 13 rivers in surrounding of Merapi that have been affected by lahar.

III. Disaster-Prone Areas I (Kawasan Rawan Bencana,KRB I)

KRB I is an area that prone to be affected by lahar flow, but this area also does not excepted to be hit by pyroclastic flow and lava flow. Lahar is mass flow that have been mixed with water and material from the past eruption. The eruption on 2010, 30-40 % of the eruption product was pyroclastic flow that has deposited in Gendol River. The remaining percentage of the product of eruption being transport and deposited in other river such as Krasak River, Bebeng River, Bedog River, Boyong River, Kuning River and other river surrounding of Mount Merapi. Deposition of pyroclastic flow on those river have a potential to formed lahar when there is high intensity of rain occurred. The area for KRB I in the map on figure 5.3.1 as represented by yellow colour.

Figure 5.3.4: Destruction from the previous eruption

Figure 5.3.5: Destroyed of household utensil

Figure 5.3.6: Destruction of a tree

Figure 5.3.7: Destruction of a furniture

5.4 Volcanic Rock Analysis

Date: 7th August 2018

Location: Gunung Merapi, Yogyakarta, Indonesia

Table 5.4.1: Percentage of Mineral Composition in Rhyodacite

Mineral	Percentage (%)	Description	Extension Angle (^{0})
Pyroxene	10	Mainly greenish-orange in colour and have two distinctive plane of cleavage.	43
Plagioclase	40	Colourless or may appear cloudy-black in twinning.	44
Quartz	35	Colourless and no cleavage	
Opaque Mineral	15	Black opaque colour and do not change colour under PPL as light cannot transmit through it.	

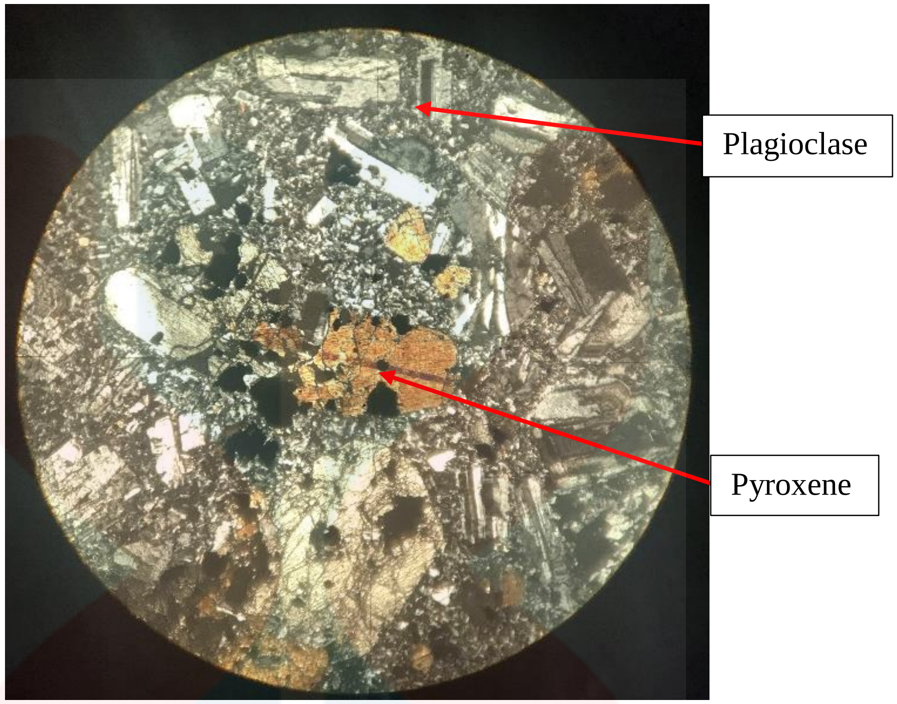


Figure 5.4.1: Cross Polarized of Rhyodacite

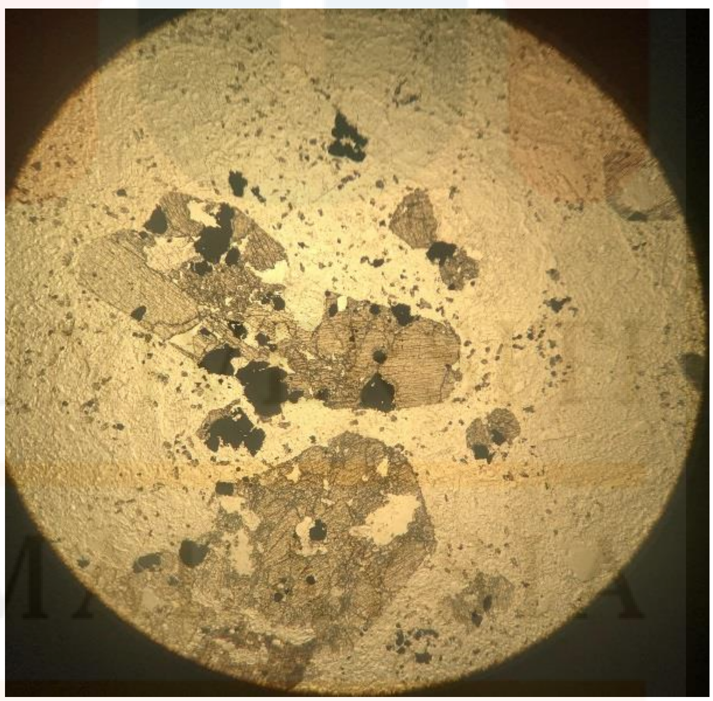


Figure 5.4.2: Plane Polarized of Rhyodacite

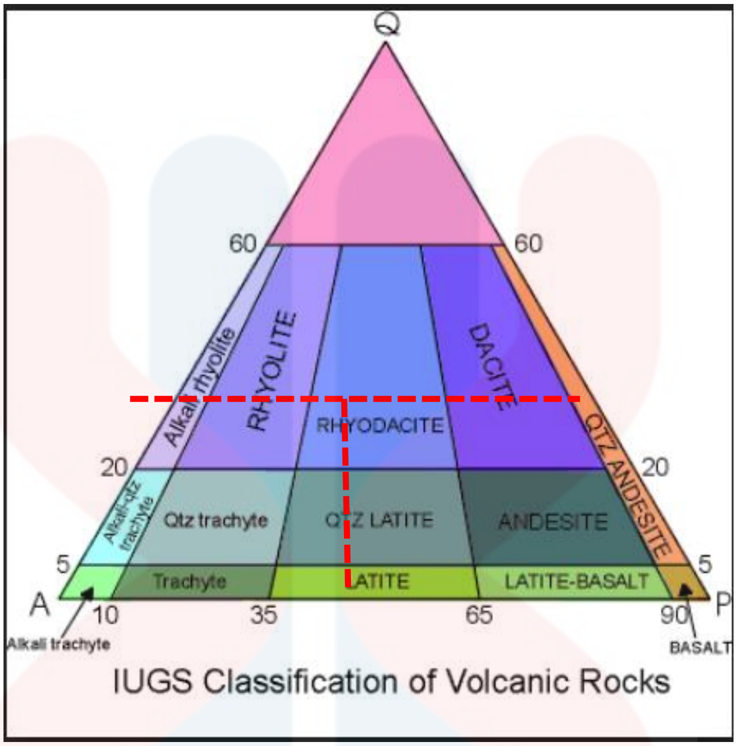


Figure 5.4.3: Volcanic Rock Classification diagram

Name of rock: Rhyodacite

Date: 7th August 2018

Location: Krasak River, Yogyakarta, Indonesia

Table 5.4.2: Percentage of Mineral Composition i4 Andesite

Mineral	Percentage (%)	Description	Extension Angle (^{0})
Pyroxene	5	Mainly greenish-orange in colour and have two distinctive plane of cleavage.	33
Plagioclase	65	Colourless or may appear cloudy-black in twinning.	42.5
Quartz	20	Colourless and no cleavage	

Figure 5.4.4: Rock sample of Andesite

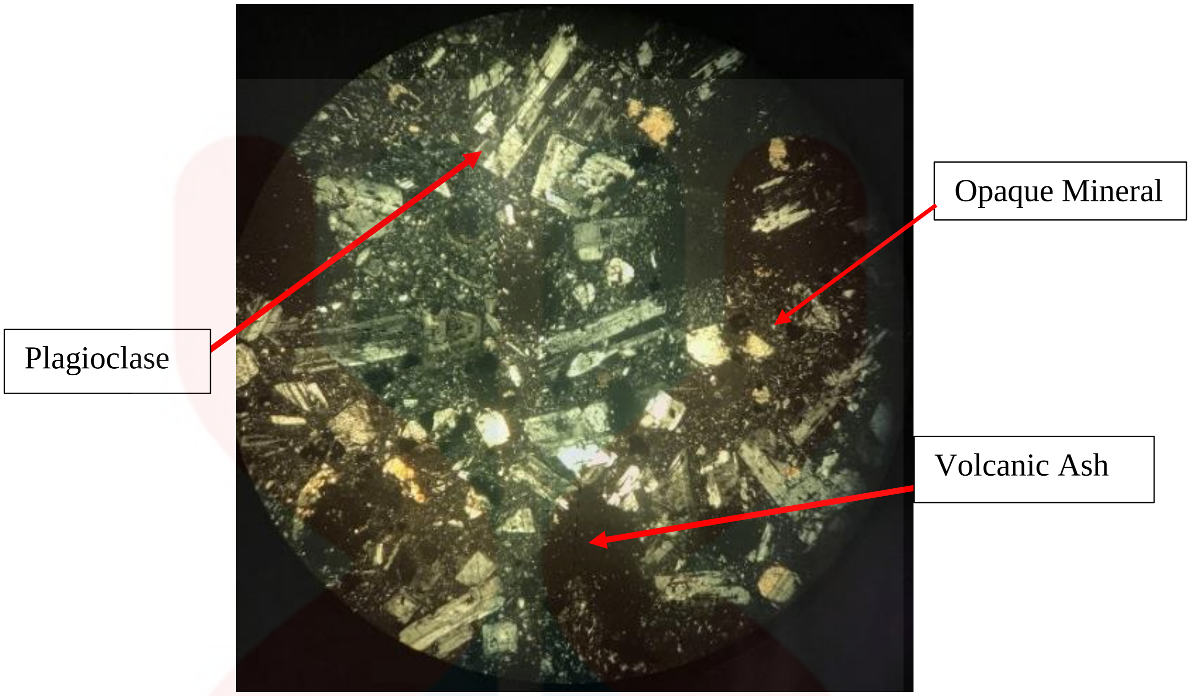


Figure 5.4.5: Cross Polarized of Andesite

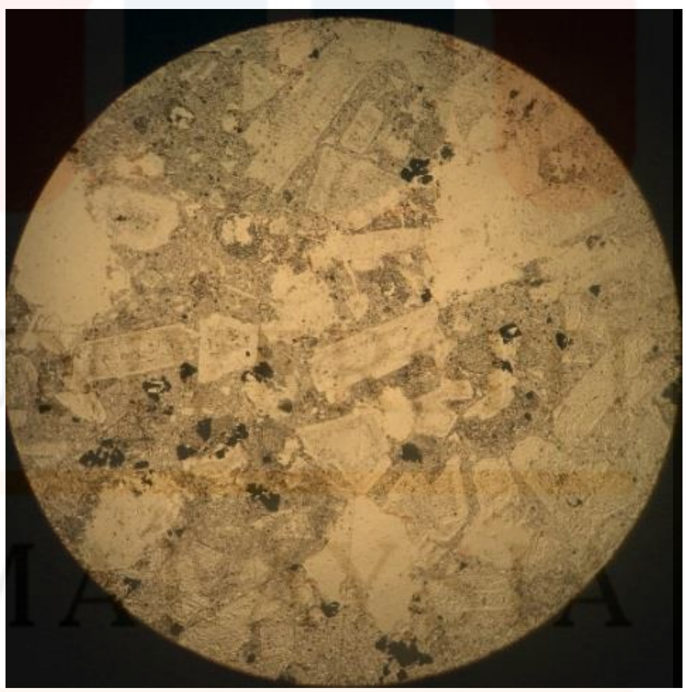


Figure 5.4.6: Plane Polarized of Andesite

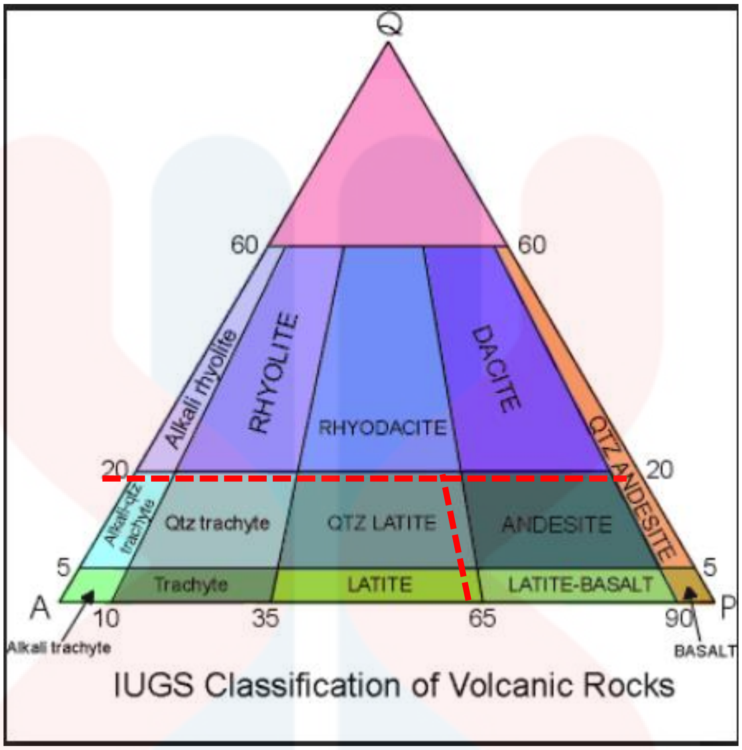


Figure 5.4.7: Volcanic Rock Classification Diagram

Name of rock: Andesite

Date: 7th August 2018

Location: Gunung Merapi, Yogyakarta, Indonesia

Table 5.4.3: Percentage of Mineral Composition Rhyodacite

Mineral	Percentage (%)	Description	Extension Angle (^{0})
Pyroxene	15	Mainly greenish-orange in colour and have two distinctive plane of cleavage.	18
Plagioclase	40	Colourless or may appear cloudy-black in twinning.	39.5
Quartz	30	Colourless and no cleavage	
Opaque Mineral	15	Black opaque colour and do not change colour under PPL as light cannot transmit through it.	

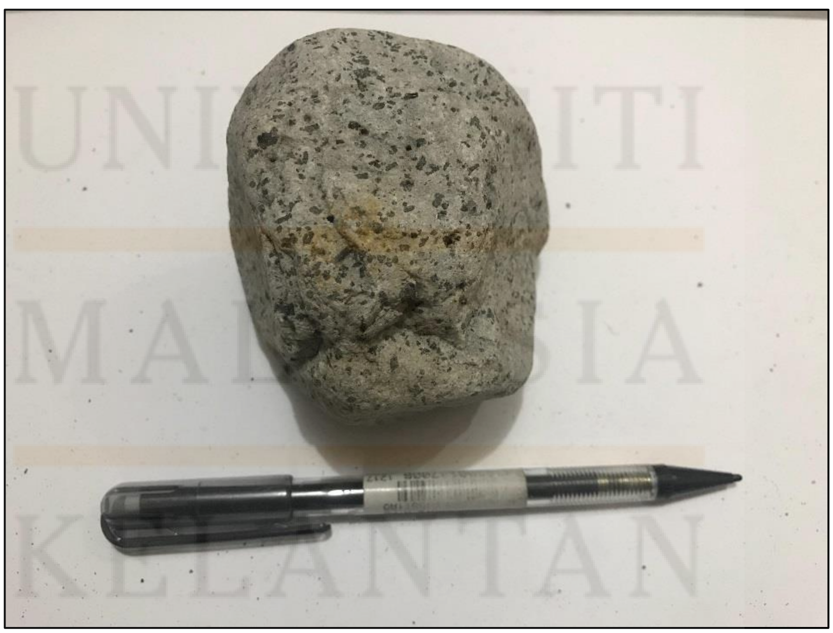


Figure 5.4.8: Rock sample of Rhyodacite

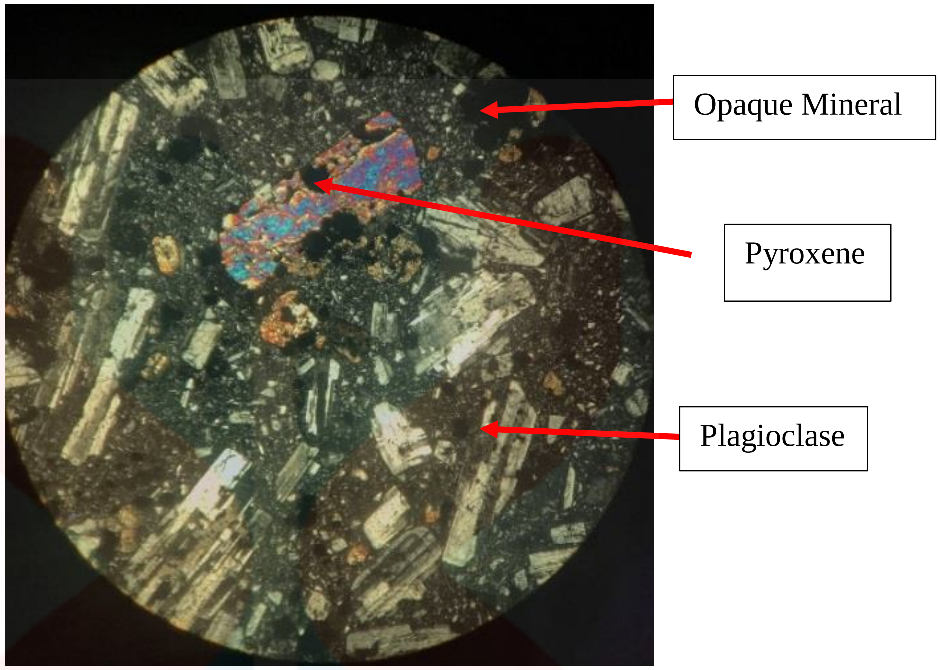


Figure 5.4.9: Cross Polarized of Rhyodacite

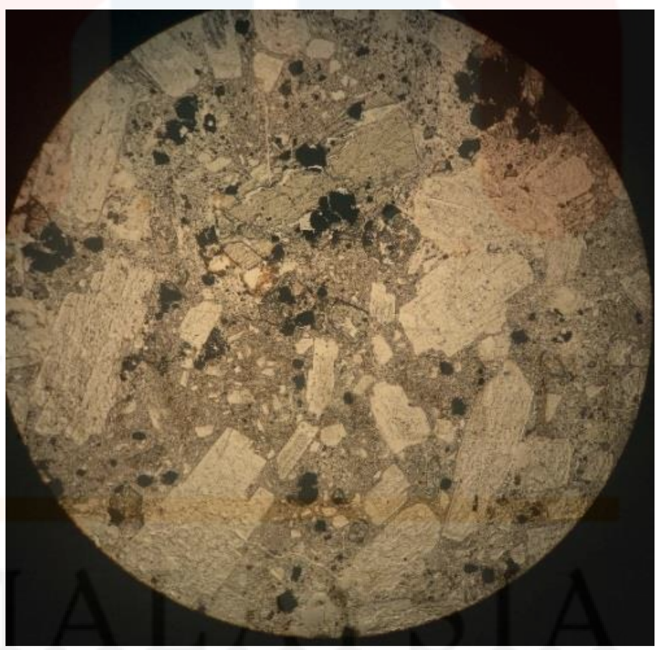


Figure 5.4.10: Plane Polarized of Rhyodacite

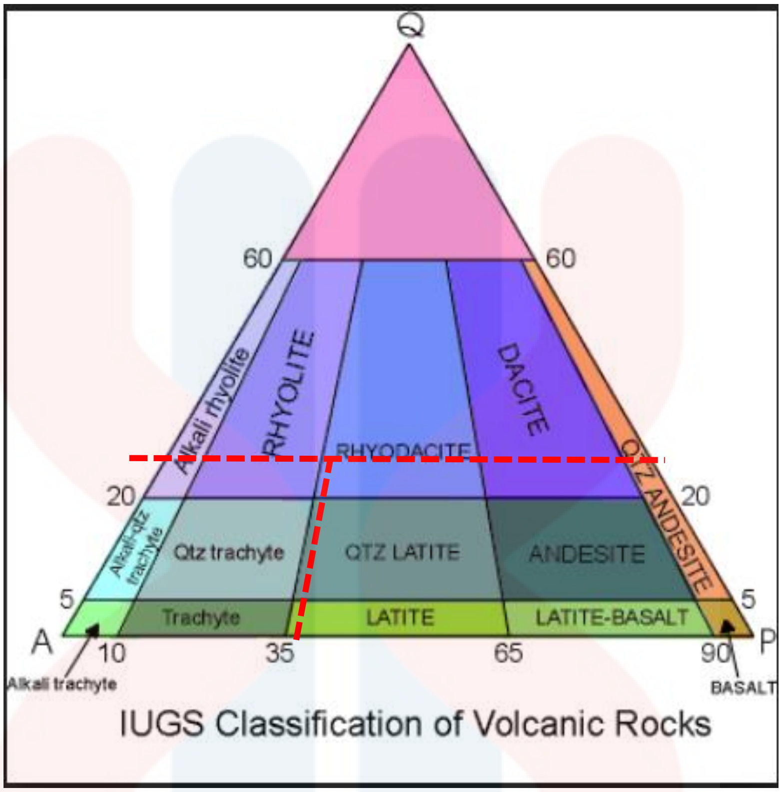


Figure 5.4.11: Volcanic Rock classification diagram

Name of Rock: Rhyodacite

Date: 7th August 2018

Location: Krasak River, Yogyakarta, Indonesia

Table 5.4.4: Percentage of Mineral Composition Pumice

Mineral	Percentage (%)	Description	Extension Angle $(^0)$
Pyroxene	20	Mainly greenish-orange in colour and have two distinctive plane of cleavage.	50
Plagioclase	30	Colourless or may appear cloudy-black in twinning.	44
Volcanic Ash	40	With residue and vesicle can be seen under microscope with XPL and PPL with diameter <2 mm	
Opaque Mineral	10	Black opaque colour and do not change colour under PPL as light cannot transmit through it.	

Figure 5.4.12: Rock sample of Pumice

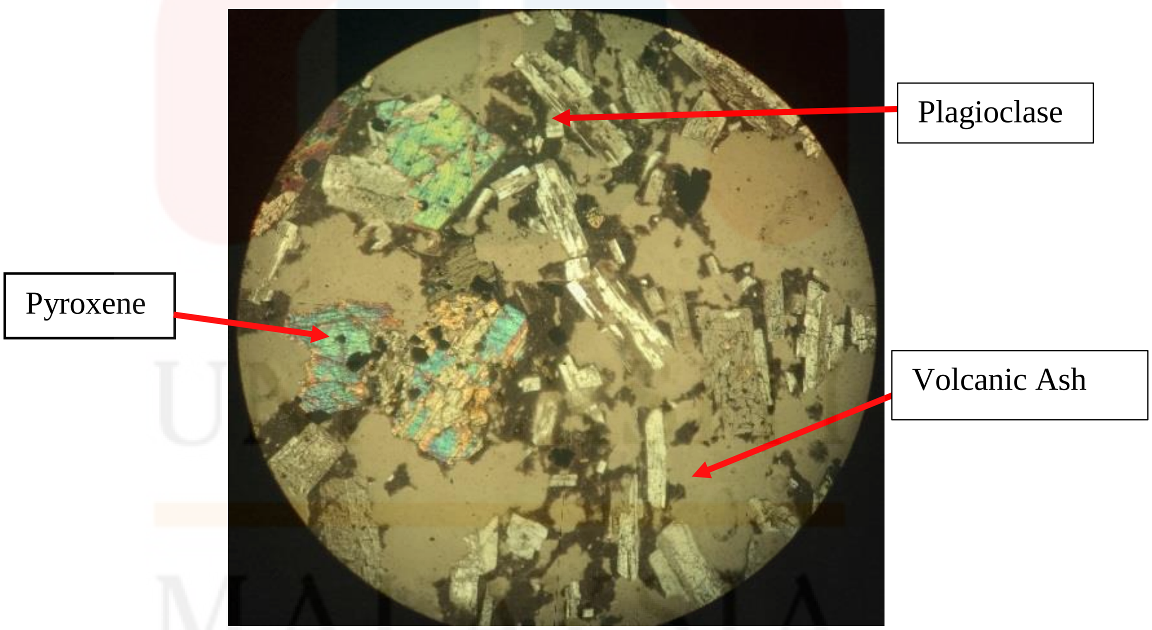


Figure 5.4.13: Cross Polarized of Pumice

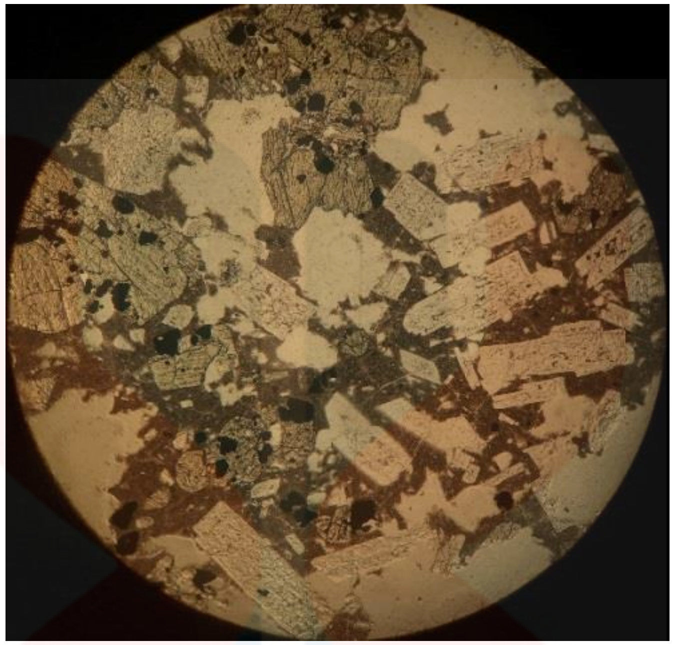


Figure 5.4.14: Plane Polarized of Pumice

Name of Rock: Pumice

Date: 7th August 2018

Location: Gunung Merapi, Yogyakarta, Indonesia

Table 5.4.5: Percentage of Mineral Composition in Rhyolite

Mineral	Percentage (%)	Description	Extension Angle $(^0)$
Pyroxene	40	Mainly greenish-orange in colour and have two distinctive plane of cleavage.	58
Plagioclase	30	Colourless or may appear cloudy-black in twinning.	42
Volcanic Ash	10	With residue and vesicle can be seen under microscope with XPL and PPL with diameter <2 mm	
Opaque Mineral	20	Black opaque colour and do not change colour under PPL	

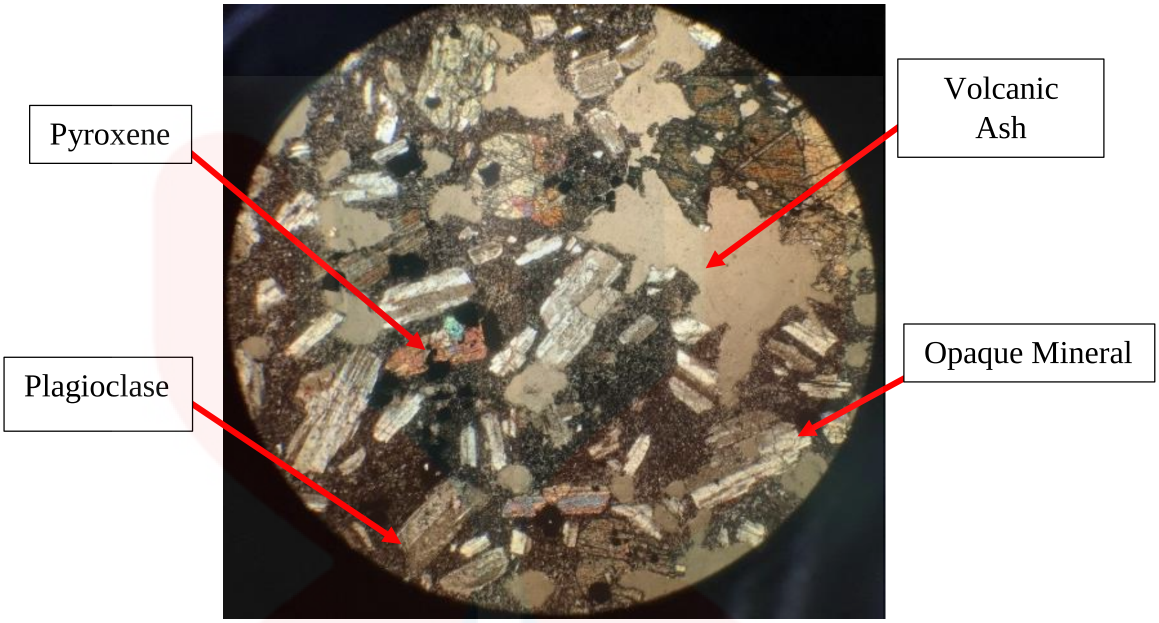
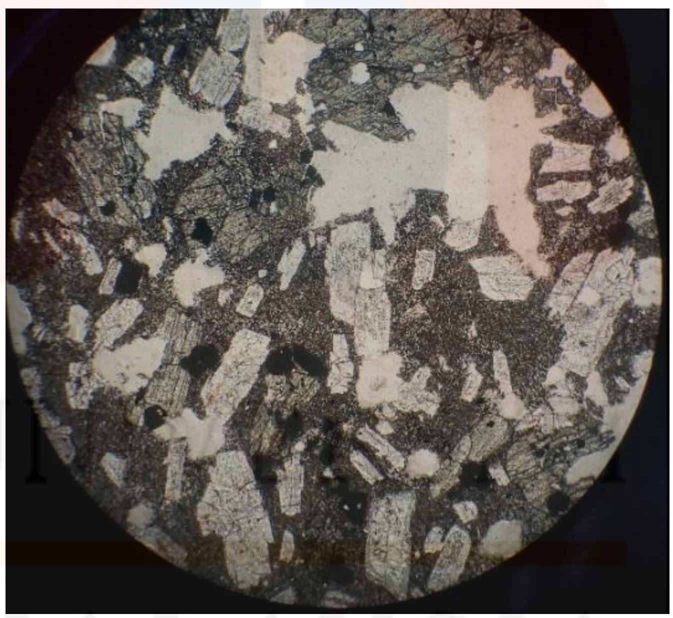


Figure 5.4.15: Cross Polarized of Rhyolite



5.4.16: Plane Polarized of Rhyolite

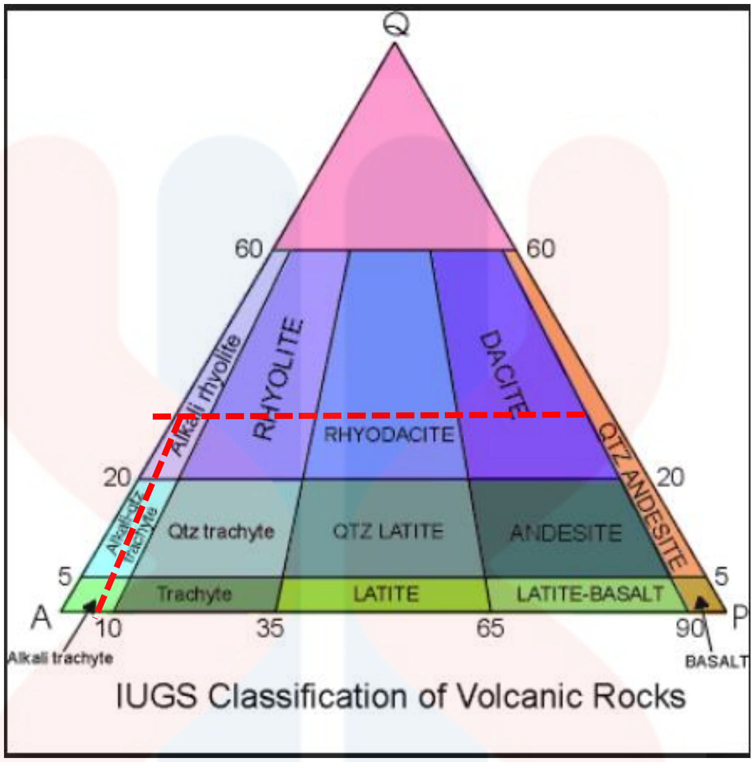


Figure 5.4.17: Volcanic Rock classification diagram

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The study area for mapping to produce the geological map was performed in the area called Bayat which located at Klaten, Yogyakarta. This area is one of the famous site for geologist to do a mapping. Bayat have a complex distribution of rock. In one formation, it consists more than one lithology unit. Dengkeng River, is a new river that formed. But the formation of the river still become a question as the river was formed in between of Eastern Jiwo Hills and Western Jiwo Hills. Both hills have a complex structure of rock. The question is, how a new river can form in between of a hill? Geologist from other university also have not come out with any conclusion. If the river formed from a fault, the evidence of the fault still not been found till today.

Gunung Kidul or Southern Mountain is a long mountain range that consist of more than one formation. From the literature review, the conclusion that can be make is the formation is younger to the south of the Southern Mountain. So the lithology that available in the study area is tuffaceous sandstone but then still have an intrusion of pillow lava.

6.2 Recommendation

The following is a brief list of recommendations for government authorities and citizens of Central Java, Indonesia based on the results of this study.

(1.) Should the responsible authorities update the volcanic and seismic emergency plans as soon as possible. All the evacuation wither by air, sea or land should be considered during the crisis. Refuge points should be identified and made aware to the public.

(2.) Before a crisis occurred, public awareness campaign should be undertaken for both volcanic eruptions and earthquakes immediately

(3.) Volcanic and seismic hazards should be taught as part of the regular school curriculum to assure ongoing awareness. A volcanic and seismic awareness week would also be effective for the larger population and could involve simulation exercises for both hazards.

(4.) When the volcanic hazard map of Mount Merapi have been update completely, it should be used in land-use planning. This will avoid further building development in an area that will give a huge impact and risk during the eruption or earthquake.

(5.) An update volcanic hazard map of Mount Merapi should be available to the general so as public, school and others so that the citizens can judge for themselves whether they want to risk living or working in areas of highest potential for the hazard.

In order to minimalize the death and lost due to eruption, the mitigation before and during eruption should be taken:

(1.) Monitoring the activity of the volcanoes via observation post with seismography should be done 24 hours in seven days. By monitoring the activities of the volcanoes, we can observe the changes in its behavior visually. The changes that we can observed such as the crater smoke in term of height, velocity and even changes in color

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