GEOLOGY AND GEOCHEMISTRY EVOLUTION OF IGNEOUS ROCK IN CARITA, INDONESIA

By

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

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2020

DECLARATION

I declare that this thesis entitled "Geology and Geochemistry Evolution of Igneous Rock in Carita, Indonesia" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and its not concurrently submitted in candidature of any other degree.

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

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Date : …….

ACKNOWLEDGMENT

First and above all, I praise to Allah almighty for His never ending gifts in my life. The one who gives me all the time and opportunity for me to proceed successfully in completing my Final Year Project.

A respectful gratitude to my supervisor, Dr Roniza Bt Ismail for her guidance, patient, and hard work for giving a lot of constructive advice that very helpful in completing this project. I also want to give my respectful gratitude to my Universitas Padjadjaran mobility program supervisor, Prof. Ir. Mega Fatimah Rosana, M.Sc., Ph,D. for guiding me and open my vision more through out the Final Year Project time in Indonesia. Also, I wanted to give my respectful gratitude for my former lecturer in Universiti Malaysia Kelantan, Prof. Dr. Ir. Udi Hartono and his family for taking care of me in my mobility journey and giving me a lot of useful tips through my completion of Final Year Project. This project gives me a chance to learn more and developed my self more.

Besides that, I would like to express my sincere appreciation to my parents, Franz Joseph Gustav Pesch and Weny Syaftarini that gave me an amazing support either in moral, physical or financial support.

Last but not least, I would like to thank all my fellow geoscience comrades especially Akila Bt Amirrudin, Astriana Emaonang Bt Sipranus, Nurul Shaadah Bt Mohamad and Wan Nur'Afifa Bt Wan Mustapa who helped me through out my geological mapping on field. To Siti Jihan Fahira, thank you for all your moral support.

To everyone who helped, thank you.

ABSTRACT

Volcanism has occuring in Indonesia from the birth of its land and up until now. Through out the process, it forms an igneous rock that scattered inside the Banten Province. Through out the formation process of the igneous rock, it evolves from the more mafic magma down to the more basic in characteristic and changing its chemical composition through out the partial melting and fractional crystallization process. The purpose of this paper are 1) to produce a geological map of the study area in scale 1 : 30 000, 2) to identify the mineral and chemical content of the rock in the study area, 3) to identify the evolution of igneous rock inside the study area. In this research, the methods that have been used were geological mapping, petrographic analysis, X-Ray Fluorescence major element detecting and SiO_2 vs K_2O, TiO_2-10MnO-P_2O_5 and AFM triangular geochemistry diagram plotting.

Geologi dan Evolusi Geokimia Batuan Igneus di Carita, Indonesia

ABSTRAK

Vulkanisme telah berlaku di Indonesia dari semasa pembentukannya dan sehingga sekarang. Melalui proses, ia membentuk batu igneus yang bertaburan di dalam wilayah Banten. Melalui proses pembentukan batu igneous, ia berkembang dari komposisi magma yang lebih basa ke magma lebih asam dan menukar komposisi kimia melalui proses lebur dan pecahan separa. Tujuan kajian ini adalah 1) untuk menghasilkan Peta geologi kawasan kajian dalam skala 1:30 000, 2) untuk mengenal pasti kandungan mineral dan kimia batu di kawasan kajian, 3) untuk mengenal pasti evolusi batu igneus di dalam kawasan kajian. Dalam kajian ini, kaedah yang telah digunakan adalah pemetaan geologi, analisis petrografik, analisa x-ray Fluorescence unsur utama batuan igneus dan pembuatan plot geokimia SiO2 vs K2O, TiO2-10MnO-P2O5 dan segitiga AFM.

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INTRODUCTION

1.1 General Background

Indonesia is situated between two continental plate, the Eurasian plate and the Australian plate and also the Indian plate and Pacific plate. Sunda trench formed by the northward subduction of Indian plate and Pacific plate. This subduction resulting an island arc to formed in the Cenozoic times and has been active since Eocene times (Hamilton, 1979).

This subduction also forms a magmatic arc that stretches from Sumatra to Java Island. This magmatic arc called the Sunda Banda magmatic arc. The Sunda Banda Magmatic arc making a volcanic activity that forms mountain ranges in Sumatra and Java Island. The subduction zone forms the study area which is Labuhan, Banten. It is rich with minerals and pyroclastic material because of the volcanically active mountain. Because of the pyroclastic materials that come out from the eruption of volcanic mountain, the most abundance rock that are study to be exist in the study area is tuff and other volcanic rocks. This research is determining to find out the evolution in chemical composition from the igneous rock in the study area and also to identify the tectonic setting that forms the rock.

Geochemical evolution in rocks is a change in chemical composition of a major segment of the earth during geologic time, as the oceans. This chemical composition in rocks can change in a long period of time. However, it takes a lot of times since the cooling of lava in the earth subsurface are very slow due to the

high temperature in the subsurface. In the cooling of a certain temperature can resulting a different type of minerals.

This research is conduct to determine the chemical composition of igneous rock in the study area using the XRF and analysis method. XRF is the emission of characteristic "secondary" (or fluorescent) X-rays from a material that has been excited by bombarding with high-energy X-rays or gamma rays. This method is widely used for geochemical analysis and also elemental analysis.

The main chemical components that will be analyse is SiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, SO_3. Also, in this research, we would like to know the trend of the magma evolution by plotting the major elements data from the igneous rock with the SiO_2 vs K_20 diagram. These two elements always have the opposite pattern. The increasing of SiO_2 means decreasing in K_2O and vice versa (Peccerillo, 1976)

1.2 Problem statement

Volcanism have already occurring since the earths previous years. This research is conducted to find the evidence of the evolving magma in the study area by identifying the chemical composition of the igneous rock.

1.3 Objective

1. To produce a geological map of the study area by 1:30.000 scale
2. To identify the mineral and chemical content of the rock in the study area
3. To identify the evolution of igneous rock inside the study area

1.4 Scope of Study

The scope of study of this research will be focused on the study from the aspect of geology that including the lithology, geomorphology, geological structure, mineralogy and petrology, sedimentology, stratigraphy, palaeontology, and depositional environment of the study area. The other main focuses on this study which is the research specification is the studies on evolution of magma that forms the igneous rock. In this research specification, X-ray Fluorescence (XRF) is the main instrument that will be used in this research in order to identifying the chemical and minerals that forming the rock of the study area.

1.5 Significant study

The significant study of this research is to improve our knowledge in understanding the sources of magma that forms the earths rock and also predict the trend of the changing of composition of the rock in the study area. This research also could recognize the environment and the evolution of parent rocks, therefore it may useful in the exploration activities of mineral and energy resources in the future.

1.6 Study area

The study area in this research is situated in east side of the Labuhan city center. Which is in the province of Banten, Indonesia. The study area is already populated by humans so there is a lot of human settlement and farms that can be find in the study area. The access to the study area is relatively easy because of the existence of the main road and also little settlement access road. Figure 1.1 shows the map of study area and figure 1.2 shows the base map of the study area.

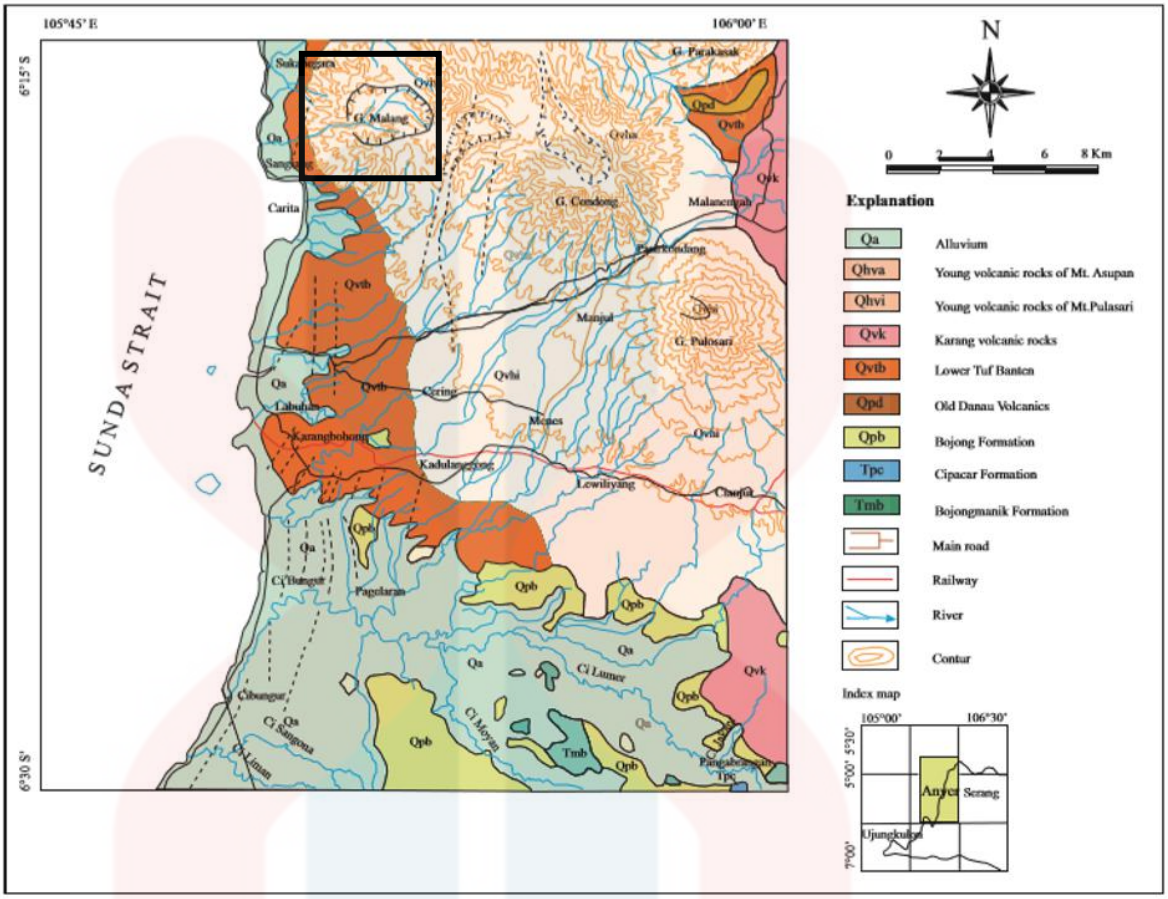

Figure 1.1.: The map of study area in Labuhan, Indonesia

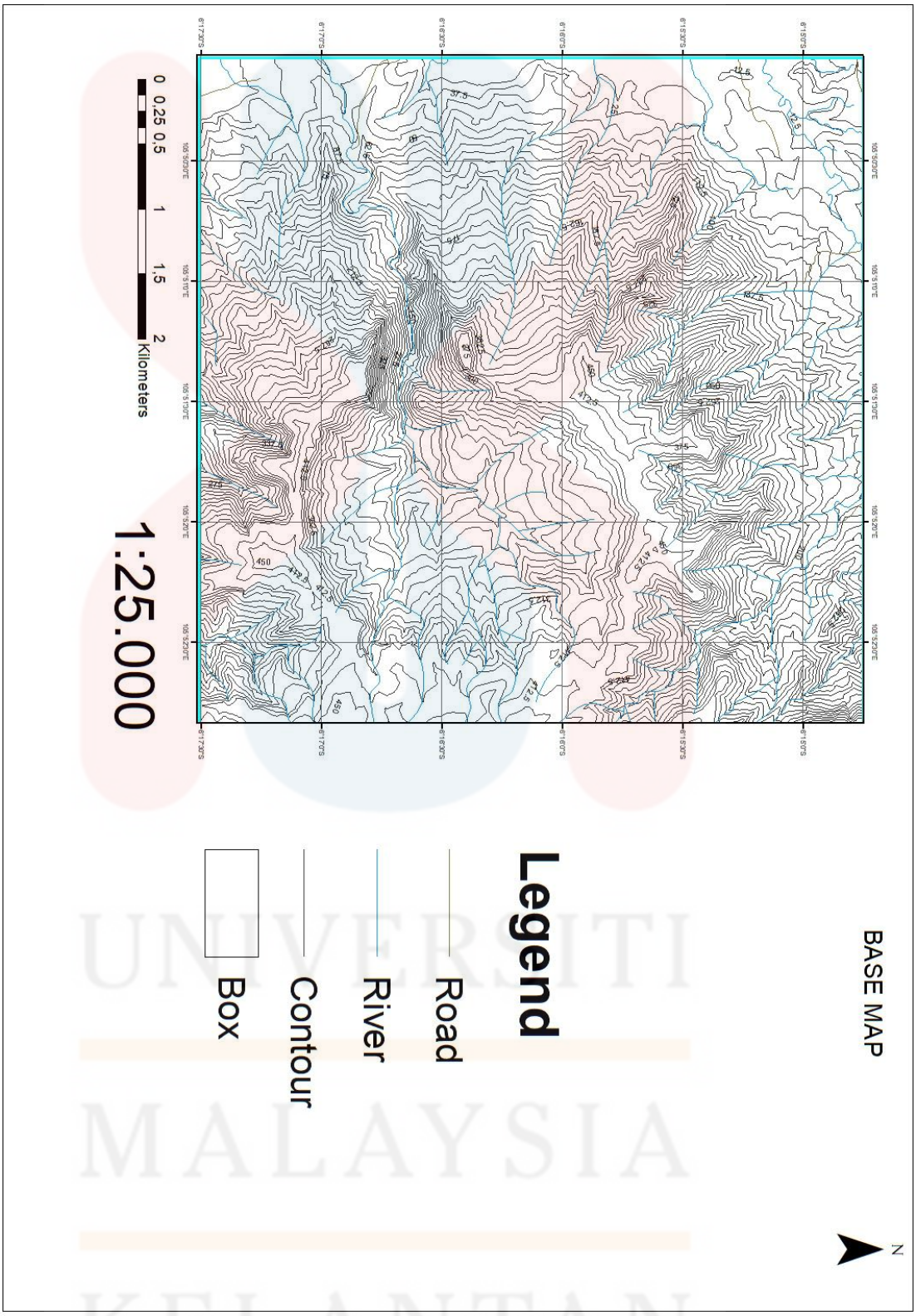

Figure 1.2: Base map of the study area

1.6.1 Topography

Topography map give an explanation of features that exist on earth. There are two categories of features which is natural features and human – made. Topography map informs the detail of an area such as mountains, hills, creeks, rivers, lakes, building, road and etc. It also shows the land elevation in the area.

A total of 9 villages registered inside Labuhan. Which is, Cigondang, Sukamaju, Rancateureup, Kalanganyar, Labuan, Teluk, Banyumekar, Banyubiru and Caringin. The lowest elevation is recorded at Teluk Village which is 21 metre from sea level and the highest elevation that recorded in Labuan are at Banyumekar Village which is 57 metre from the sea level. The topographic unit based in mean elevation (Raj, 2009) are rolling and undulating. The study area itself have the lowest elevation of 12 meter and the highest which is 412 meter.

1.6.2 People Distribution

The people that live in Labuan are generally the Sundanese. Although the study area is in Java Island, the majority ethnic group of people in Labuan are the Sundanese. Other than that maybe Javanese and other small group of different ethnic that cannot be identify.

From 56.947 people that registered in Labuan, 29.358 people are the males and 27.409 are females. The amount of male and female is nearly the same, so it can be said that the distribution of male and female are nearly 50-50.

The majority age group are in 0 – 4 years old people as this group is registered to be 6.363 people. And the people that range from more than 75 years old

are 575 people. Labuan are the most populated village which have the total population of 11.123 people.

The people in the area works as a trader, fisherman and also some owns a private villa for them to rent it, considering Labuan and the upper part of the region which is Carita are a tourism place. Figure 1.3 shows the people distribution inside Labuhan in 9 villages and figure 1.4 shows the ages distribution in the area.

Desa	Rumahtangga	Laki-laki	Perempuan	Jumlah
(1)	(2)	(3)	(4)	(5)
1. Cigondang	1.899	4.723	4.153	8.876
2. Sukamaju	697	1.907	1.935	3.842
3 . Rancateureup	649	1.370	1.273	2.643
4 . Kalanganyar	1.545	4.161	3.772	7.933
5 . Labuan	2.612	5.632	5.491	11.123
6 . Teluk	2.453	6.270	5.710	11.980
7 . Banyumekar	431	905	813	1.718
8 . Banyubiru	557	1.011	980	1.991
9 .Caringin	1.447	3.559	3.282	6.841
Total	**12.290**	**29.538**	**27.409**	**56.947**

Figure 1.3: Total people distribution in Labuan based on the gender group

Kelompok Umur (Tahun)	Laki-laki	Perempuan	Total
(1)	(2)	(3)	(4)
0 – 4	3.270	3.093	6.363
5 – 9	3.212	2.974	6.186
10 – 14	2.939	2.677	5.616
15 – 19	2.767	2.393	5.160
20 – 24	2.366	2.056	4.422
25 – 29	2.388	2.158	4.546
30 – 34	2.227	2.001	4.228
35 – 39	2.182	2.071	4.253
40 – 44	1.976	1.955	3.931
45 – 49	1.909	1.726	3.635
50 – 54	1.461	1.350	2.811
55 – 59	1.010	981	1.991
60 – 64	800	758	1.558
65 – 69	473	485	958
70 – 74	333	381	714
75+	225	350	575
Total	**29.538**	**27.409**	**56.947**

Figure 1.4: Total people distribution in Labuan based on the age group (Source: BPS Kabupaten Pandeglang)

1.6.3 Rain Distribution

Table shows total rain distribution of year 2013 until 2015. The data shows the declining of rain from January until April. April until September, the rain is tending to be fluctuate and shown no exact pattern. October until January, is where it seen the rain has increasing trend, and the pattern start over again.

The changes of the rainfall pattern in a year are generally the same every year, but from the total of rainfall that produce every year, the data shows that there is a declining of total rainfall that produce every year. Table 1.1 shows the rain distribution in the study area.

Month	2013 (in mm)	2014 (in mm)	2015 (in mm)
January	662	493	324
February	232	354	313
March	208	229	193
April	181	195	311
May	293	341	184
June	157	97	229
July	359	169	35
August	132	163	47
September	201	58	38
October	108	247	154
November	164	261	240
December	409	165	521
total	3106	2772	2589

Table 1.1: Total rain distribution in Pandeglang (Source: Badan Pusat Statistik Kabupaten Pandeglang)

1.6.4 Land Use

Land use data can be obtained from Google Earth software and data from the authority in the area. From the data that have been obtained. The land use at the study area can be divided into human settlement, paddy field, palm oil tree field, unused forest and other features such as rivers and water bodies. The human settlement is consisting with man-made infrastructure such as schools, houses, mosque, storage, hospitals, trading places and etc.

The paddy field have the most land use in the area and followed by unused forest. The palm oil field is situated on north east of the area and the human settlement can be found scattered in the map. Human have occupied this place for a long time so the distribution of town and settlements are generally packed.

1.6.5 Road connection

Road is a main infrastructure in connecting places to places. There are two main road types that exist in the study area. Which is the tar road and also the dirt road that the local use for entering their farm. The connectivity of these road is good considering the study area are not well developed by the government.

The tar roads are accessible with vehicle such as motorcycle and car but the condition is poorly maintained by the local and the government. As for the dirt road, it also accessible with motorcycle and car, but the risk is high for vehicle to go inside as the dirt road can damage the vehicle more easily.

However, although the road is poor maintain, the accessibility to the nearest town which is the Labuhan City is very straight away because the main road to the Labuhan city lies inside the study area. Figure 1.5 shows the road connection of the study area.

Figure 1.5 : overall road connection of study area and Labuhan City

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discuss the study of the previous paper and journals that have been reviewed for this research. This chapter focusing on regional geology, tectonic setting structural geology, stratigraphy, historical geology, igneous rock evolution, petrographic analysis and geochemical analysis.

2.2 Regional Geology and Tectonic Setting

Banten Province has the landscape area that lying between Tangerang and Serang, undulating hills (between Serang – Pandeglang – Cibaliung) and mountains are scattered in the South with the peaks of Mt. Sanggabuana (1,919 m. above sea level), Mt. Halimun (1929 m. above sea level), Mt. Endut (1,297 m above sea level) and g. Nyungcung.

The State form of the landscape is very closely related to the regional geological conditions' region of Banten which are part of the line/arc magmatic age of Tertiary-Quaternary which stretches from the northern tip of Sumatra island to as Nusa Tenggara known as The Sunda-Banda Magmatic arc (Hamilton, 1978). In the area of Banten bow Dome, dykes and cones of active volcanic activity report.

2.3 Structural Geology

The research areas as Banten Block which consists of Neogene deposits would highly folded and intruded by the local igneous rock. This region is relatively stable since the Tertiary. There is a difference between the direction of dip and strike

within the geological structures in Banten Block dominated by North-South with the Java structures dominated by East-West direction (Van Bemmelen, 1949).

2.4 Stratigraphy

The study area is form by two major formations which is the Cipacar Formation and also the Bojongmanik Formation. Cipacar Formation Lithology unit consists of pisolitic pumice tuff, marl, sandstone, and claystone. In general, this unit is well bedded and it have a thickness ranging from 200 - 600 m. This unit is unconformably overlain by Bojongmanik Formation and coral limestone.

Bojongmanik Formations lithology consists of claystone interbedded with marl and sandstones, limestone, conglomerate, Tuff, and lignite. foraminifera fossils are found on this unit shows the age of the late Miocene-Pliocene or on zoning Blow N16 – N19. In addition to the fossil foraminifera are found also fraction of molluscs, ostracoda, echinoid, and scallops with the depositional environment of shallow sea to land. Thickness of formation is estimated at 400 m (Sudana and Santosa, 1992).

The study area also shows that there is an existence of a young volcanic rocks from the eruption of Pulasari and Asupan Mountain. In general, they are composed of volcanic breccias, lavas, tuffs, and lava flows. The young volcanic rocks were deposited on the continental environment of Holocene age, and unconformably overlies the older rock units (Usman, 2014).

2.5 Historical Geology

The study area consists of three major formations which is the Cipacar Formation, Bojongmanik Formation and the young volcanic rock from the Pulasari and Asupan Formation. Cipacar Formation form in the Pliocene and the deposition environment of the formation is in shallow water. The formation undergoes a weathering process after the process of forming it, then the Bojongmanik Formation overlain the Cipacar Formation uncomformabbly (Sundana, 1992).

The Bojongmanik Formation deposited in miocene to the late Pliocene, the formation deposited in a deep to shallow marine. The formation itself deposited in a shallow marine environment. At the Holocene, the Asupan and Pulasari Mountain erupts and form the igneous and pyroclastic rock in the study area. It overlies the older formation beneath it (Usman, 2014).

2.6 Research Specification Review

2.6.1 Igneous Rock Evolution

Some of the most important in geology are theories about the evolution of igneous rocks. Without these theories, the modern ideas of plate tectonics and earth history would be impossible, just as our ability to interpret tectonic processes from igneous rocks would be impossible**.**

The idea of evolving igneous rock was presented first in the early 20th century by Norman Levi Bowen. Bowen conducted comprehensive experiments with igneous minerals and rocks and created many of the current phase diagrams principles. Bowen's Reaction Series is an overview of Bowen's findings. Not only does it describe the interactions between minerals that forming the rock, it also helps to identify the relation of the minerals under a different conditions the minerals forms.

Bowen makes a hypothesis in his work for determining the origin and evolution of the igneous rock. The hypothesis is that the silica rich minerals and ultramafic rock is the parent rock of all other types of igneous rock. This process is happened when the parent rock begins to fractionated. The fractionation resulting a two different type of fractions with a different mineral composition from its parent rock. The fractionation can happen when the magma crystallizes inside the magma chamber or melted from the previous rock that already exist.

When the fractionation of mafic rock occurs, it selectively melts and produce a two different types of fractions. The first one melts into a composition that closer to the bottom of the Bowen Reaction Series than the parent rocks composition. The melt is intermediate in nature of the composition. The second one is residue of unmelted crystal with a more mafic mineral composition in nature than the parent

rock. In the Bowen Reaction Series, the composition is sitting higher than the parent rock.

Under a certain amount of time and conditions, the fractionation process can continue and the intermediate rock that have been produced in the first fractionation can fractionate and transform into a more felsic magma in nature. It leaves a crystal residue that more mafic in nature than the intermediate rocks.

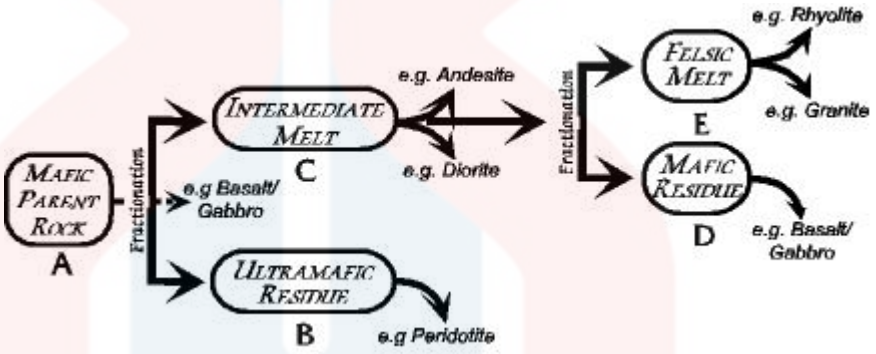

Figure 2.1: The Bowen Reaction Series

The process occurs when magma beneath the earths surfaces slowly cooling down its temperature. When the magma starts to cool down, a crystallization process begins to happen and it starts with minerals that sits highest in the Bowen Reaction Series. It occurs because these minerals have the highest specific gravity than other minerals. The minerals then continue to settled in the bottom of magma chamber by gravity settling.

These first formed minerals have a high concentration of Ca, Mg, and Fe. As they settled at the bottom of the magma chamber, these elements are carried out by the first formed mineral group in the process. The amount of Ca, Mg and Fe quantities that brought to the bottom with them are far bigger than their average

composition in the original melt. Because of this process, the remaining melt will be less in Ca, Mg and Fe and has a mineral composition that sits lower in the Bowen Reaction Series diagram.

Thus, the original magma that used to be one in terms of mineral composition is divided into two fractions. The first fraction accumulates at the bottom of the chamber and form a much more density in Ca, Mg and Fe elements. While the second fraction have a lower density of Ca, Mg and Fe, the second fraction is denser with Na, K and Si elements than the first fraction. The second fraction tends to produce minerals that sits down at the bottom of the Bowen Reaction Series.

The mechanism of fractional melting can happen both in the convergent boundaries nor the divergent boundaries. At the divergent boundaries, a convection cells carry out a hot, plastic, silica rich ultramafic rock into the earth surface. The magmas fractionation and solidification process form a four layered rocks that form the oceanic lithosphere, it is called the Ophiolite Suite. At depth, the magma natural form will turn into more plastic like. It moves slowly under a great pressure and it also have a high melting point. As it moves closer into the surfaces, the pressure that the hot rock experiencing slowly fading and then, the fractional melt will begin. A basalt sweats off and rises to the ocean floor and form a pillow basalt. The process produces an unmelted residue such as olivine (dunite) and pyroxene rich (peridotite) ultramafic which stay at the mantle.

Fractional melting that occurs in the convergent plate boundaries occurs at a subducting oceanic plate. Cold basalt that previously form in the ocean floor descends into the mantle following the plate subducting motion. Gradually, the basalt igneous rock undergoes a temperature rising as the plate slowly subducted. The

temperature rises because of the geothermal gradient and also the friction of the subducting motion. The descending slab also carries a big amount of sea water with it and about 120 km on the depth of earth, water and heat leads to fractional melting. The molten rock than rises to the surface due to the high pressure in the depth and crystallize to from an intermediate rock in nature in mineral composition such as diorite and granodiorite. The residue of the recrystallization mineral in intermediate rock are the unmelted mafic and ultramafic residue that left behind.

2.6.2 Petrographic Analysis

Petrographic analysis is conducted to identify the mineralogy of the associated igneous rock. The primary mineralogy of volcanic rocks reflects crystallization during magmatic cooling over a temperature interval from approximately 1,300 to 900 °C (W. Ian Ridley, 2010).

This crystallisation process can occur in different variety of tectonic settings. By identify the minerals that composed the igneous rock, it can determine the process that the rock undergo beneath the surface of the earth. Structures of minerals is crucial in determining the geological tectonic and also the process the molten rock undergoes in the depth of the earth.

2.6.3 Geochemical Analysis

2.6.3.1 X-ray Fluorescence Method

The application of XRF method is widely used by scientist all around the world. It is a method to analyse major element that composed a certain sample. The sample could be in a form of liquid, powder or gas. The XRF analysis method is not destructive toward the sample. In any case, analysing sample with this method does not destroyed or changed by exposure to X-rays. Thus, the sample could be saved for

the future reference or used for other types of analysis (Bertin, 1978). The preparation is also relatively easy and does not used a lot amount of sample in the process.

The XRF method also fast. It can determine the chemical composition of the sample within seconds and easy to handle because the instruments are handled under a computer with effective software to handle the measurement of the sample. The cost of the method also is relatively cheap because there is a minimum effort in preparing the sample.

The XRF method will trace the major element that needed in the research such as SiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, and SO_3.

CHAPTER 3

MATERIAL AND METHOD

3.1 Introduction

This chapter describe about the materials for geological mapping and the specification research. To complete this research, the methodologies that carried in order to complete this research such as preliminary study, field study, traversing, sampling, laboratory analysis and report writing.

3.2 Material

Material is appliances and tools that need to be use in order to fulfil and complete geological research and activity during whole mapping and lab session. There are some material and also apparatus need to use altogether. With the help of material and apparatus, the data collection and sample investigation will become much easier and data calculation become more accurate. The apparatus and material are list below.

3.2.1 Tools:

1) Topographic map

Topographic map or in other word base map is one of the most important material when conducting geological mapping. The heart of mapping is very useful to record all the geological data in field. Topographic map can be created by using many geological software like ArcGis 10.2

2) Global Position System (GPS)

A Global Position System is also a crucial tool. The function, to navigate direction and locate all the waypoints also tracks in the GPS system. From the GPS data, all the information can be projected outwards into Arc Map. GPS Garmin 62 s is used to record coordinate the current location.

3) Geological Hammer

There many types of geological hammer. The type of hammer must follow the correct type of rock and the sample. Normally, tip point, chisel and jumbo hammer have been used to take and collect the rock sample.

4) Compass

The geological compass also important material and be used for collecting geological data like dip direction, dip angle, strike angle, slope, bearing and many other uses more. In addition, there also two type of hammer which are suntoo and Brunton compass.

5) Hand lens

Hand lenses is used for analyse identification of mineral on the rock sample. The small mineral that cannot be seen by naked eye supposed to be clear when using hand lens.

6) Sample bag

Sample bag also important in the field. The rock sample will be put in the sample bag so that it will not harm our stuff in the bag. All sort of information about the outcrop will be noted on the bag sample.

7) Digital camera

Digital camera helps with taking the pictures of the geological structures in field and other data, this will provide a clear visual data rather than just a raw data of numbers and words. The picture will also take with a scale in it so we can have an idea on the size of the object.

8) Field book

Field book is used to collect data in field work, using the field book we can write down the collected data that are very precious in our research. The data that can be written is the traverse data, dip and strike, sedimentology and lithology and also the types of rock that we encounter in field

9) HCl

Hydrochloric acid always being used to determine sedimentary rock type of limestone or calcite. Also, metamorphic rock, marble. Bubble of gas is release indicate presence of calcite.

3.2.2 Software

1) ArcGIS 10.2

   This software is a standard software for producing a geological map in a geological mapping activity. By using the data base online, this research can produce a geological map of the study area

2) Georose

   A software to calculate one of the geology structures which is joint. The software can calculate how much the joint are in the study area and then plot

it in the diagram, which in the end of the research will identify the certain degree of the tectonic force coming in the area.

3) PetroGraph

This software is used for processing geochemical analysis. The software can process the three main plot diagram to determine the chemistry characteristic of the rock. This software requires XRF analysis data to work.

3.3 Methodology

Method is the way of how certain study must be conducted. While methodology is a body of method, rules and postulates which is employed by a discipline and a particular procedure and also set of procedures. There three type of methods need to be used to complete the geological scientific research. In general, method can be classified into three which are preliminary study, geological mapping include uses of software Arc GIS 10.2 and lab work session. Without a proper method, the research will never reach the objective.

3.3.1 Preliminary Research

Before conducting the research, data from the existing paper from other institution is gathered to understand the research field even further. The data that studied can be the types of rocks in the area, geological structures and also the geomorphology of the study area. This is very important to get the first idea of the area and to filled the research gap of the previous study.

3.3.2 Field Studies

Field study is conduct to update the geological map of the area. This require the research to make a traverse in the area and examine the geological structures and also its rock. The data includes taking the dip and strikes, joint measurements and sampling. Sampling includes of sampling the rock that is present in the study area, especially igneous rock. Later, the igneous rock sample will be converted into a thin section sample then it will be analyse using polarizing petrographic electron microscope to see the existence of minerals.

3.3.3 Traverse Mapping

Traverse mapping is a geological mapping methods that used by geologist in the study area. Traverse mapping aims to identifying all of the geological aspect in the study area. This is done by travelling the study area by walking or in a vehicle such as car or motorcycle. The best way on gaining data while traversing is by walking because examining the area will be more easy in a slow movement rather than with a vehicle.

GPS and base map that contains the information such as elevation, road connection, human settlement and also forest have to be brought for navigating the way inside the study area. The GPS in the other hand, will record the track that have been through inside the area. Later, the track will be plotted inside the base map for marking the places that have been through.

When traversing is conduct, the information that have to be gathered are coordinates of the outcrops, lithology of the outcrops, morphology of the area, strike and dip measurements and also samples form the outcrop. This

data and sample would be gathered and labelled according to their outcrop origin.

3.3.4 Sampling

Sampling is a crucial part of the mapping. Rocks that are sampled in the area contains information for the specification in the research and also the geological history of the area. It is also act as a prove for our presents in the certain part of the study area.

Selecting the right sample for the research are very important because later on, the sample would be identify by xpl and ppl microscope for their petrography and also the XRF instruments for determining the major element that contains inside the rock. The sample should be fresh and not weathered. Weathered means the rock have undergone a weathering process which damaging the mineral and chemical composition of the rock.

Taking the sample requires a geological hammer with a pointing edge called chisel. The outcrop that found in the study area is hammered so its fractured to a size that is appropriate for sampling. The size should be no less than the size of a hand. Sample than must be put inside a plastic bag for each own. Sample cannot put together unless it is the same rock type in one outcrop. After that, coordinates and rock physical characteristic is written on the plastic bag.

3.3.5 Lab work analysis

Thin section of the sample is crucial so that, identification of mineral can be easily recognized and drawn. The thin sample of rock slice must be taken properly by using diamond saw and on flat shape. Then, the sample will

be mounted on a glass slide and ground smooth with fine abrasive grit until the sample 30 micrometre. By using polarizing petrographic electron microscope, the thin section sample will be examined through two methods which is cross polarized, xpl and plane polarized, ppl with the correct orientation. The mineral that can be seen below the xpl or ppl must be adjust to correct lens so that it can show actual mineral properties. All this lab work will lesser work on petrographic mineral analysis. Rock mineral petrographic analysis may be classified by three type of rock which are igneous, sedimentary and metamorphic. All the data is important in determination of rock type, depositional environment and rock grade type.

For research specification, igneous rocks that found in the study area will be examine using XRF method to trace major element inside the rock. The rock sample of the igneous rock will be turn into a powder for preparation of the XRF method. The instruments scan the powder and in a few minutes, then a graph will be produce to show the major element that contains inside the rock. The major element that examine are SiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5 and SO_3.

The next step is to make calculations for each geological model, such as the triangular TiO_2-10MnO-FeO total, P_2O_5, and AFM triangles. Triangle TiO_2-10MnO- P_2O_5 (Mullen,1983) aim to identify the tectonic environment and evolution of the rocks chemically. The content of FeO total calculated based on the amount between the natural occurring FeO and 0.8998 Fe_2O_3, i.e. FeOtotal = natural occurring FeO + 0.8998 Fe_2O_3 (Rollinson, 1992). AFM triangles aims to find out the origin and evolution of magma on igneous rock (Rollinson, 1992) the AFM triangle is (A = Na2O+K2O, F = FeO total, M =

MgO). The AFM triangle can identify the evolution progression of each igneous rock by comparing the $SiO_{2\ vs}\ K_2O$.

After all the diagram has been done, an interpretation is made to identify the tectonic setting and the evolution of the magma that forms the igneous rock from the study area.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

In this chapter, the general geology of the area provides the geological information that necessary for the analysis for this thesis. The information in this chapter are based on the observation and traversing in the study area. The general geology covers the geomorphology parts, structural geology, petrography, stratigraphy, historical geology and also other information that needed to elaborate in this chapter.

Geomorphology is the knowledge of understanding the landform of the earth. This knowledge helps to understand the geological process that occurs in the area. Structural geology is the knowledge of understanding structure of the rocks so it can give the understanding of the tectonic process that occurs in the area. Orientation of the structure is the key of structural geology to find the major forces direction in the area that forms the landform. Petrography is the knowledge of understanding the mineral content and the textural of the rock. This knowledge is important in this research because it give the information of the relationship between the igneous rock that scattered inside the study area. Stratigraphy is the knowledge about the rock strata and can be used to correlate the environment that occurs in the past. last but not least, the historical geology discussed the chronology of the geological process that forms the study area. This include on when the landform forms and the lithological unit forms in the area.Figure 4.1 shows the traverse and mapping station in the study area.

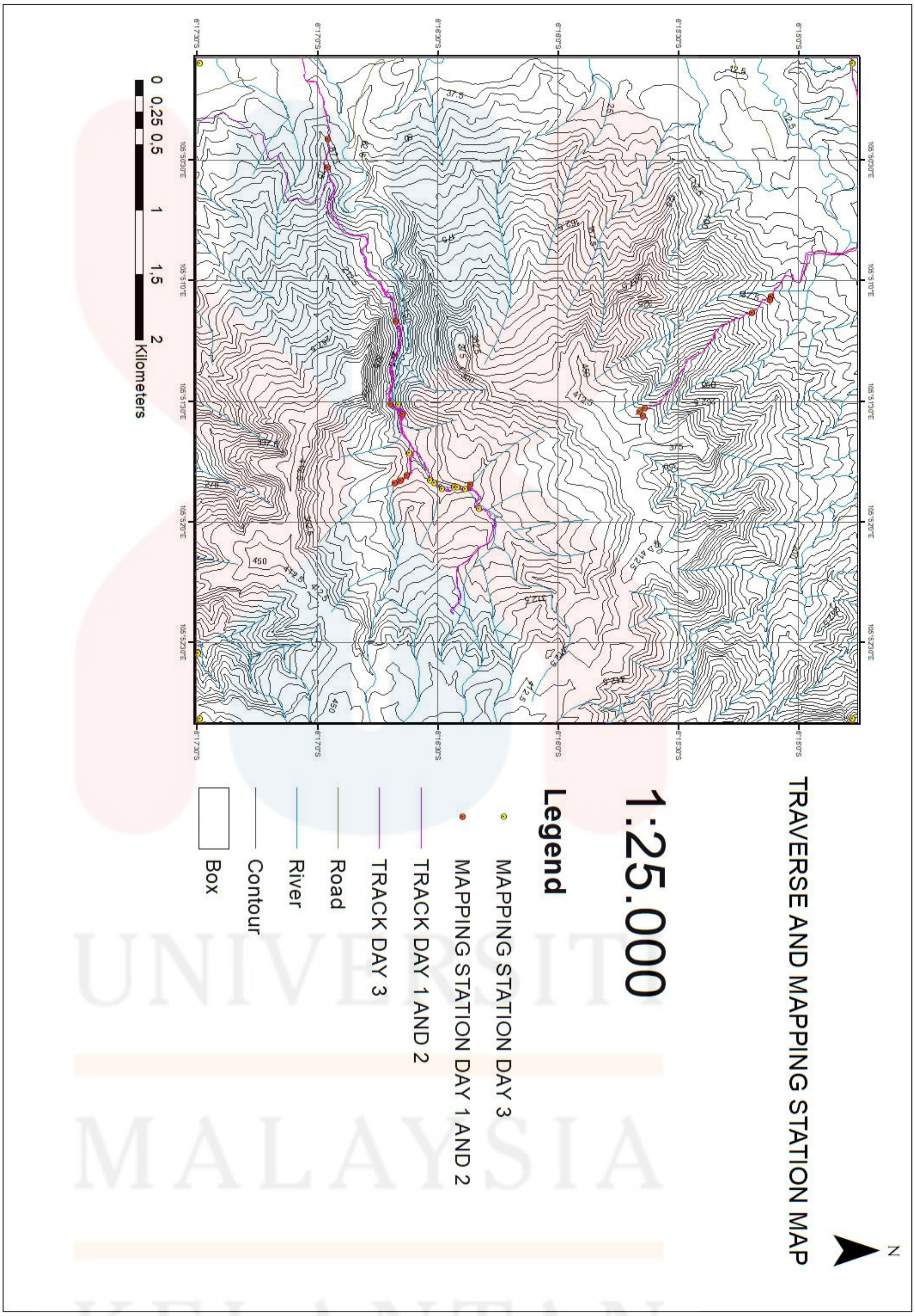

Figure 4.1: Traverse and mapping station map

4.2 Geomorphology

The geomorphology knowledge refers to information about the landform of South Pandeglang area. There are many factors to determine the geomorphological map. The topography map gave the information about the geomorphological features in the area. Drainage pattern in geomorphology identify the shape of water body and the hydrology information in the area. Drainage pattern is identified by study the river system and the pattern of the stream.

4.2.1 Topography

The elevation of the study area is discussed in this part. Topography is used to identify the landform and elevation of the area. Topography is the major part of the geomorphology study and it discussed mainly the physical criteria. The topography map is used to distinguish the landform types that exist in the study area and is used to discuss the history of the geological process that happened in the area.

The topographic unit is divided into five topographic unit according to Raj (2009). This topographic unit is divided based on the elevation of the landform or contour relative to the sea water level. The topographic units are low lying, rolling, undulating hilly and mountainous.

class	Topographic unit	Mean elevetion
1	Low lying	<15 m
2	Rolling	16-30 m
3	Undulating	31-75 m
4	Hilly	76-300 m
5	mountainous	301> m

Table 4.1: Topographic unit according to Raj (2009)

The study area consist of all the topographic unit based on Raj classification. The west side of the area have the lowest elevation by 12.5 metre and the highest point of the area is at the centre of the study area which is 450 metre. The highest point of the area is a the ancient volcano crater ridge that forms in the Holocene. The highest point based on the classification is mountainous and the lowest is low lying. And not least, the north and south part of the area are Hilly and gradually changing into mountainous topographic criteria.

The crater from the holocene is a good depositional environment for the young tuff unit to deposited and forms layers of tuff. It acts like a cup to deposit the volcanic ash from Asupan and Pulasari Mountain that erupts in the holocene.

The terrain in the area also can be distinguish by the type of geomorphological landscape and landform that exist in the area. Valley is located at the west side of the crater. The valley acts as the passage of surface water to flow into the ocean from inside the crater. Floodplain covers most of the study area since the study area is located near the shore of ocean.

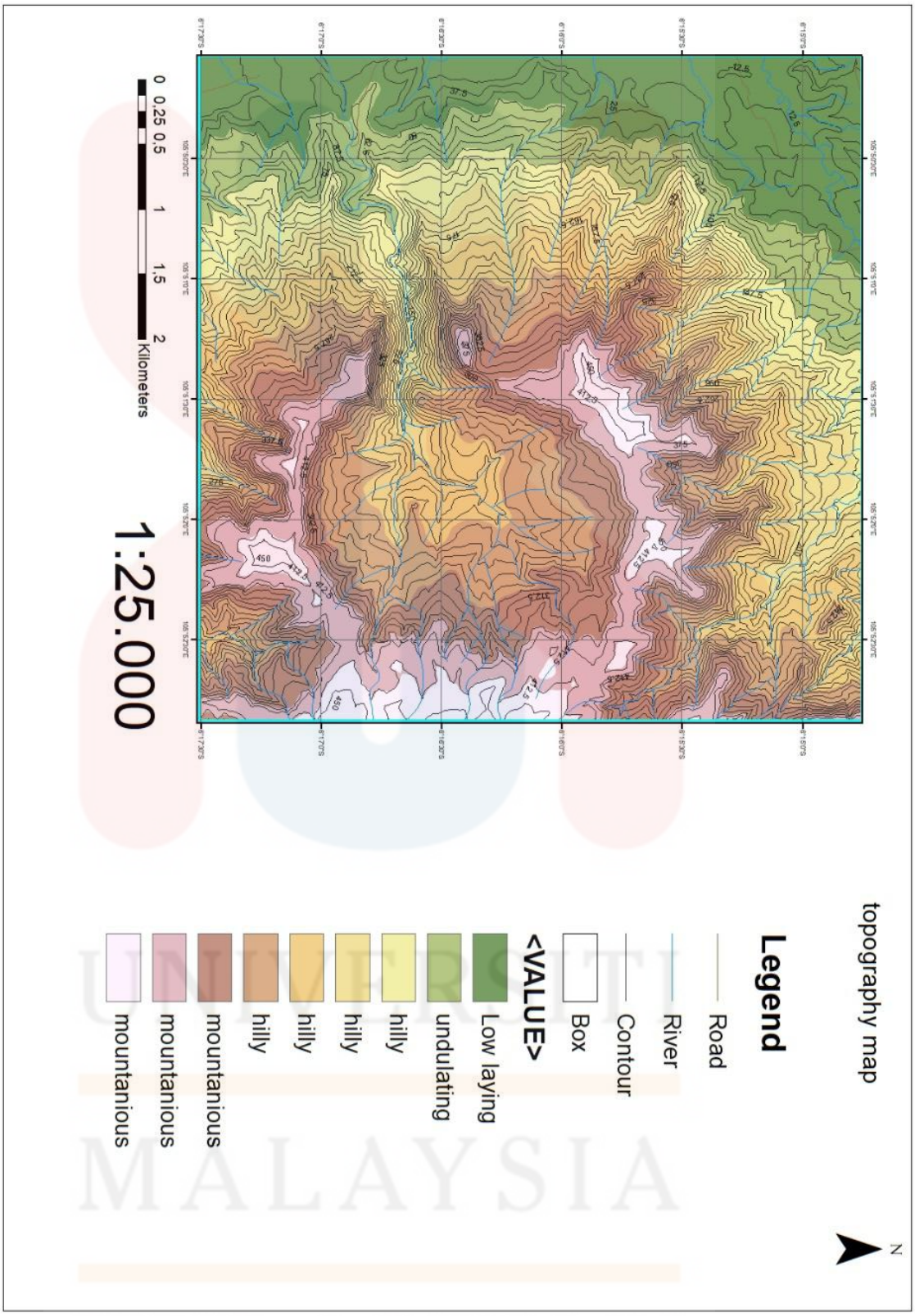

Figure 4.2: Topography map that classified the geomorphology of the area based on the mean elevation

4.2.2 Drainage Pattern

Drainage pattern created by the stream erosion overtimes that reveals characteristics of a specific types of rock and geological structures in an area drained by streams. Drainage pattern is forms by streams, rivers, and lake by particular drainage basin. It is controlled by topography of the land, whether the area is mostly dominated by hard or soft rocks. Another variable that controlled the drainage pattern is the gradient of the land.

According to Horton (1932), recognizing drainage pattern can help define the lithology unit, recharge areas and potential and also general hydrology condition of the study area. By classified the drainage pattern, it will provide an accurate interpretation of the rock types and the general structures of the area. It also can interpret the type of aquifers and the direction of groundwater flow.

Water body in the study area are all in the form of river with no massive waterbody such as lake or oceans even the study area is near the shore line. The drainage pattern of this river can be classified as two types which is trellis and radial. Trellis pattern indicates that the region is consist of sedimentary rock that have been eroded. This type of drainage pattern occurs inside the ancient volcanic crater.

The radial type drainage pattern covers mostly of the study area. This type of drainage pattern is a unique and distinctive drainage pattern that occurs in mountains. The streams radiate outwards from a central high point. Other landform that connected with thiss drainage pattern is domes and laccoliths.Figure 4.3 shows the drainage pattern in the study area.

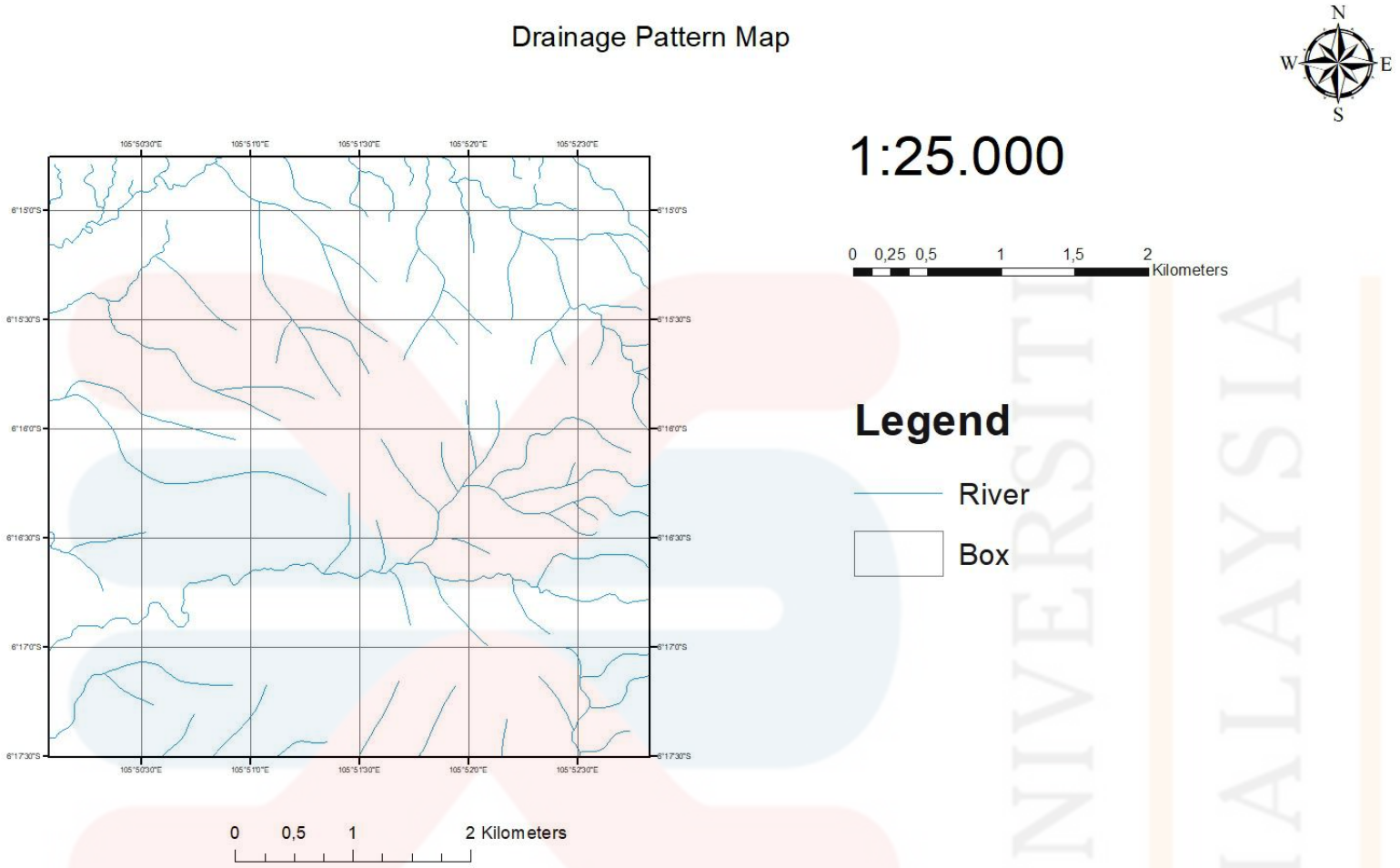

Figure 4.3 : Drainage pattern map

4.2.3 Weathering and erosion

Weathering is the breakdown of rock, chemically altered rock, yielding rock fragments and ions that were removed in a solution. The weathering process is depending on erosion, moisture and temperature, transportation and deposition of rock debris by many types of geomorphic systems, controlled by gravity, flowing water such as waves and currents, wind and glacial ice. Weathering makes the rock weaker and more permeable, thus it makes them significantly more vulnerable to removal by the agents of erosion and the removal of weathered products exposes more rock to weathering process.

Physical weathering process is triggered by the changing of temperature on rocks. This cause the rocks to break without changing its chemical properties. In the study area, the changing of temperature of day and night caused the rock to triggered the fatigue effect. Fatigue effect is an effect that triggered by the cause of changing temperature and making the rock easily to breakdown. The effect makes the rock to expand and shrink repeatedly. The outer layer than starts to peel off since it is the first surface that exposed. This resulting a sheet joint in the study area on the igneous rock. Another physical weathering triggers are the precipitation of water that enters the pores of the rock. The water crystallizes inside the pores and expanding the rock and thus triggered the fatigue effect. This type of expansion does often because Indonesia have a tropical weather.

The colour of the rock also has a role in the weathering process inside the study area. Since the rock in study area have a relatively dark colour, the rock is exposed more to the sunlight heats. The blacker the objects get the higher rate of

sunlight's heat that received by the rock. All of this action triggered the fatigue effect and makes the rock breakdown more rapidly.

Biological weathering is the weakening and disintegration of rock by animals, plants and microorganism. Plants such as trees grows its roots inside joints or cracks in rocks to find moisture. As the tree grows larger, the roots also become bigger and breaks the rock apart gradually.

Chemical weathering is the breaking down of rock by a mechanical mechanism. This process changes the chemical composition of the rock. The process includes hydration, hydrolysis, carbonation and oxidation depends on the characteristic of the rock itself.

The main process of chemical weathering process in the study area are oxidation since the study area rocks are mostly composed of igneous rock that contains iron that easily oxidise by the exposure of water contact since rain is common in a tropical area.

Erosion is the act of earth that is worn away by forces of water, wind, ices and gravity. In the study area, this erosion occurred because of the act of seepage and runoff to the exposed and unprotected soil material, and also because of the high velocity of flowing water, forces of rain drop and overland flow. The study area most common erosion agent is water by the rivers in the riverbanks. This process makes the stream to be wider. Figure 4.4 shows the physical weathering in the study area and figure 4.5 shows the biological weathering in the study area.

Figure 4.4: Physical weathering of a tuff outcrop

Figure 4.5: Biological weathering of a tuff outcrop

4.3 Stratigraphy

Stratigraphy is the branch of geology to study the relationship between different rock layers or strata and its layering (stratification). This branch also studies the general history of the rock layers that represented on the study area. It described the rock layer or strata from the youngest to the oldest that present in the study area. Table 4.2 shows the stratigraphic column in the study area.

Era	Period	Epoch	Lithology	Lithology	Description
Cenozoic	Quaternary	Holocene	Alluvium Unit		Unconsolidated mud, sand and gravel along the river
			Tuff Unit		Very fine grain and dark grey in colour
			Andesite Unit		Fine grain and grey to blueish colour

Table 4.2: Stratigraphic Column of Carita, South Pandeglang.

According to Usman (2014). The young volcanic rocks from the eruption of Pulasari and Asupan Mountain. In general, they are composed of volcanic breccias, lavas, tuffs, and lava flows. The young volcanic rocks were deposited on the continental environment of Holocene age, and unconformably overlies the older rock units (Usman, 2014). The older rock unit or formation in this case are Bojongmanik Formation and Cipacar Formation but it is nowhere found in the study area since the eruption of the Pulasari and Asupan Mountain covers the whole South Pandeglang region. The types of lithology unit that found in the study area are

Alluvium, Tuff and Andesite with the age sequences starts from the oldest which is Andesite, Tuff and Alluvium.

4.3.1 Lithostratigraphy

Although the andesite is seated at the highest elevation in the stratigraphy, it is older than the other lithology. This information is obtained by inspecting the deformation on the rock unit. The deformation is founded mostly and massively at the andesite unit than the other lithology unit. The tuff which are bedded appears to have less deformation, thus this can conclude that the tuff unit comes after the andesite forms from the eruption of Asupan and Pulasari Mountain. However, all of the unit have the same age which is forms in Holocene.

4.3.2 Lithology

Lithology is the study and description of the physical characteristics of rocks, especially in terms on hand specimens and outcrops. Its studies focussing on the physical characteristics such as the rock type, colour, grain size, mineral composition, grain size and even the texture of the rock.

The study area is consisted with two types of rock which is igneous rock and sedimentary rock. The igneous rock type of lithology that can be found inside the study area are the andesite unit and the sedimentary rock type of lithology that have been found in the study area are the tuff unit. Figure 4.14 shows the geological map and the lithological distribution of the study area.

4.3.2.1 Andesite

Andesite is an extrusive igneous rock, which is an igneous rock that forms from lava that cools down on the earth surface. The lava cools down quickly hence the mineral grain size is small (does not appear in naked eyes) and the texture is very smooth or fine grain.

The colour of the rock is ranging from dark grey to pale blue depending on the chemical content of the rock. The most common colour for this rock inside the study area are dark grey similar to basalt. However, from the geochemical analysis that have been conducted, it is confirmed that the rock is andesite based on the silica content that the rock has which is more than 50%.

The outcrop of the rock can be found almost entirely inside the study area ranging from a weathered boulder in the foot slope to the fresh one that can be found in the river. It is the most abundant rock that can be found in South Pandeglang. Unfortunately, because of the high weathering rate and the less resistance nature

from weathering process of the rock, andesite is very hard to find in a fresh condition in the study area.Figure 4.6 shows the andesite outcrop of study area.

The hand specimen gives a more detail information of the rock. The texture is holocrystalline or in other word, composed entirely with crystals. The granukarity of the rock is apahanitic or simply from a naked eye, the crystal does not very visible through naked eyes and the fabric or texture are equigranular which mean the crystals inside the rock have the same size among each other. Figure 4.7 shows the hand sample that have been sampled from the outcrop.

However, based on the thin section observation. The rock has another different information from the observation of hand specimen. The rock does have a unique texture that can only be seen by thin section analysis. Based on the observation, the rock has a differs texture. The rock tends to have more resemblance to porphyritic which is a term in geology for a rock that have a distinct difference in the size of crystals with at least one of the minerals are much bigger than the other. In this particular rock, plagioclase and hornblende minerals are bigger than the other minerals. These two forms a big chunk of fragments inside the rock. As for the groundmass, it is form by a microlite plagioclase. For the accessory minerals, they are consisted of pyroxene, a few quartz fragments and opaque minerals. Figure 4.8 and table 4.3 shows the mineral composition by petrographic analysis..

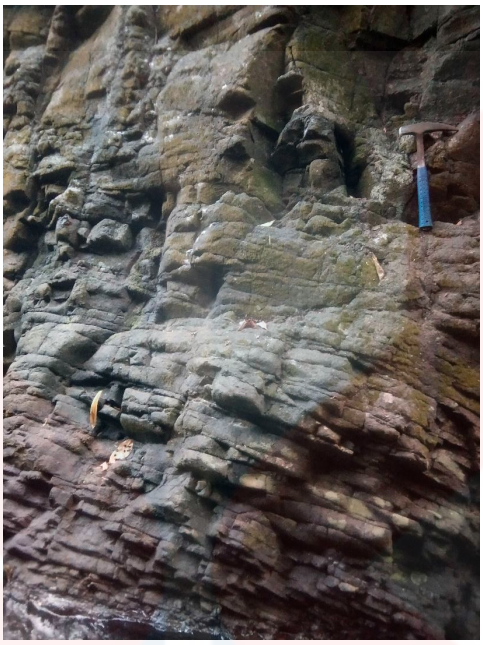

Figure 4.6: Andesite outcrop near a river with a systematic shear joint

Figure 4.7: Andesite Hand Specimen

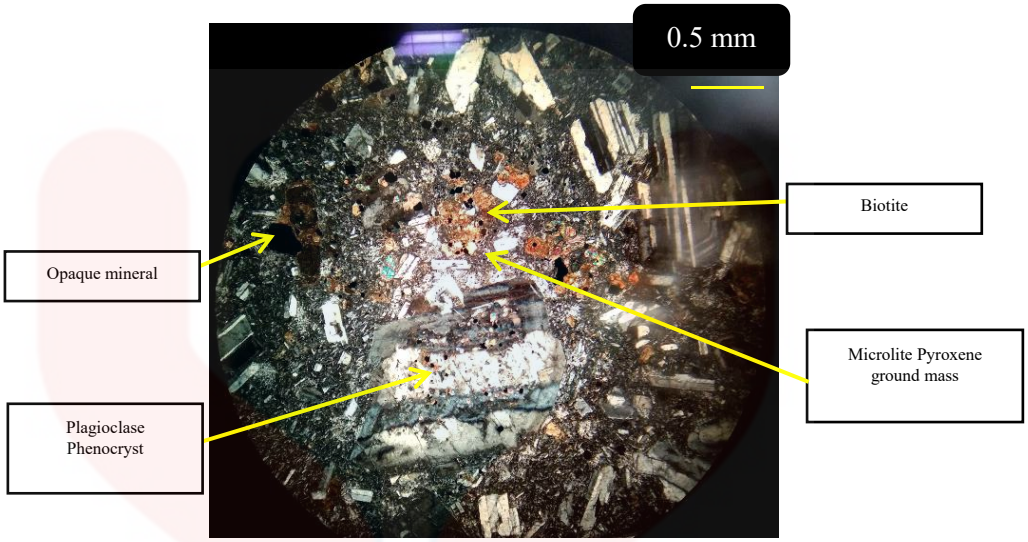

Figure 4.8: Andesite under XPL

Mineral composition	Total(%)	Description of mineral
Plagioclase	40%	Mineral is colourless. Anhedral shape. Twinning tends to occurred. Low relief. Phenocryst.
Biotite	10%	Brown in colour. Anhedral shape. Pleochroism colour are black and brown. Medium relief.
Pyroxene	30%	Dark brown to black in colour. Pleochroism colour is dark brown to greenish. Microlites shape forming the groundmass.
Quartz	5%	Mineral is colourless. Anhedral shape. Low relief.
Hornblende	15%	The colour is brown. Euhedral shape. Twinning tends to occurred. Pleochroism is brown to black.

Table 4.3: Andesite mineral compositions

4.3.2.2 Layered Tuff

Tuff is a sedimentary rock that forms from the product of an explosive volcanic eruption. The eruption produces ash, rock, magma and other materials. The materials travels through air and falls back on the earth. Later, this materials compacted an cemented into a sedimentary rock. Tuff is special because it is form by igneous rock related materials but deposited and form similar to sedimentary. However, this rock are considered as a sedimentary rock rather than an igneous rock because of the forming process.

The outcrop is found along the river inside the ancient crater. The river is the only known place for the outcrop to form. The thickness is estimated to be 4 to 10 meter. The outcrop also shows that the eruption occurred numerous times since the tuff unit forms layering at each others. It also found that the tuff unit is intercalated by mudstone or sillstone. Each layers have a thickness not more than 2 centimeter. This indicated that the gap between the eruption is relatively short.

Figure 4.9: Tuff outcrop inside the study area

Tuff appears to have a brown colour in outcrops. But after looking at the hand specimen, the colour is various from brown, white, grey and dark grey depending on the layers. Tuff is a clastic sedimentary rock and through hand specimen observation, it have a sill or mud grain size. The feel of the rock also very soft or fine grain. This indicated that through out the transportation process, the sediments are sorted very well without any inclusion of pebble or cobble materials. Figure 4.9 shows the tuff outcrop in study area and Figure 4.10 shows the hand specimen from the ourcrop.

From the thin section observation, minerals that can be observe are a few quartz an an opaque mineral. It also appears to be fine grain with all of the grain size equally the same. Quartz appears to be white in colour under ppl or colourless and has a low relief. Figure 4.11 and table 4.4 shows the mineral composition of the tuff unit in petrographic analysis.

Figure 4.10: Tuff hand specimen

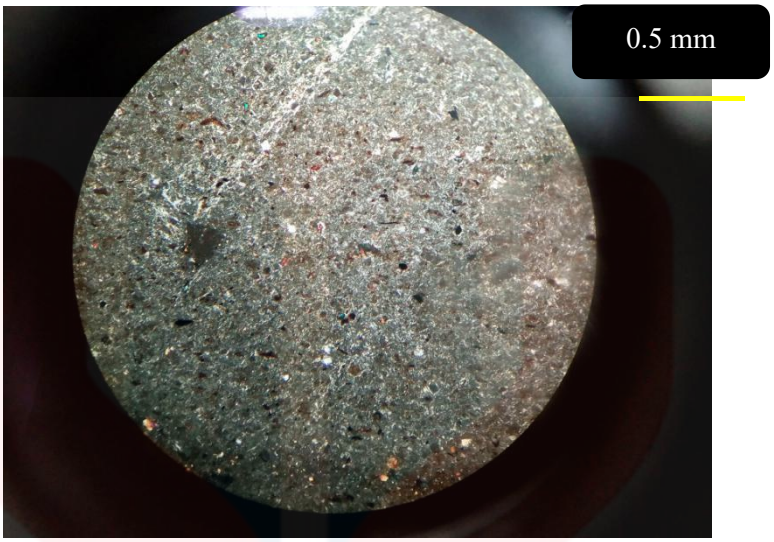

Figure 4.11: Tuff under XPL

Mineral composition	Total(%)	Description
quartz	5%	Mineral is colourless. Anhedral shape. Low relief.
Opaque mineral	5%	Appears black without light passing through. Metallic mineral
Fine grain volcanic fragment	90%	Fine grain of volcanic product that becomes the ground mass.

Table 4.4: Tuff mineral compositions

4.4 Structural Geology

Structural geology is the study of deformed rocks that occurred in the upper crust. The rock change it physical features when it is applied by a stress that exceed more than the rock strength. Structural geology can also defined as a branch of geology that studies the shape, arrangement and the relationship between the rock unit and the forces that cause them to deformed.

4.4.1 Lineament

Lineament is a linear features in a landscape on the earth surface that reflected as presences of geological structure. This structure mostly presence as the shape of fault or folding. The linear structure shaping and controlling the landscape shape of the study area such as ridges, waterfall, slopes and river system. The lineament analysis is conducted by observing the contour and topography map. The main force comes from N 45º E or S 45º W and N 30º W or S 30º E. the minimum force comes scattered in three direction from the north east side. Figure 4.12 shows the main forces in the lineament analysis and figure 4.13 shows lineament map.

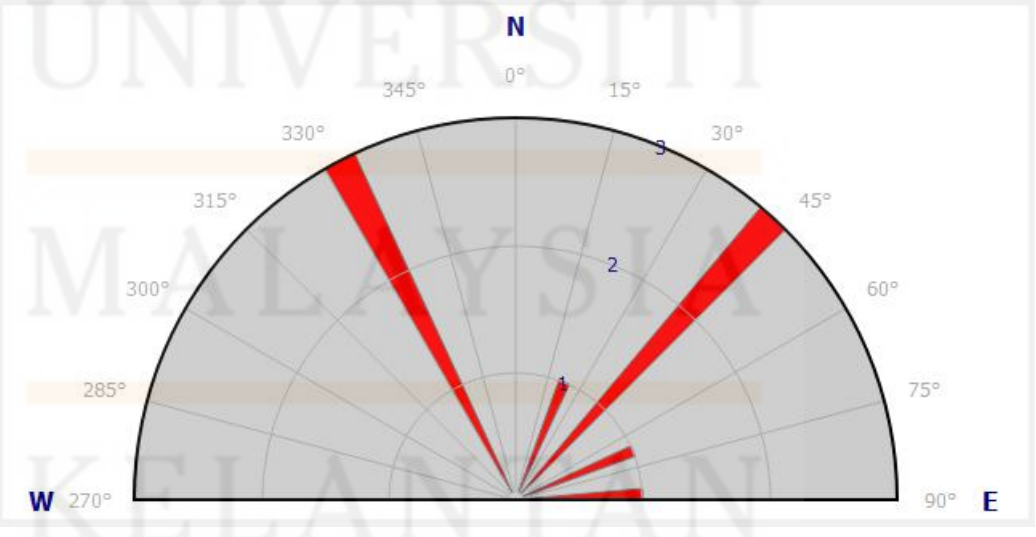

Figure 4.12: Lineament analysis result shows the direction of the force

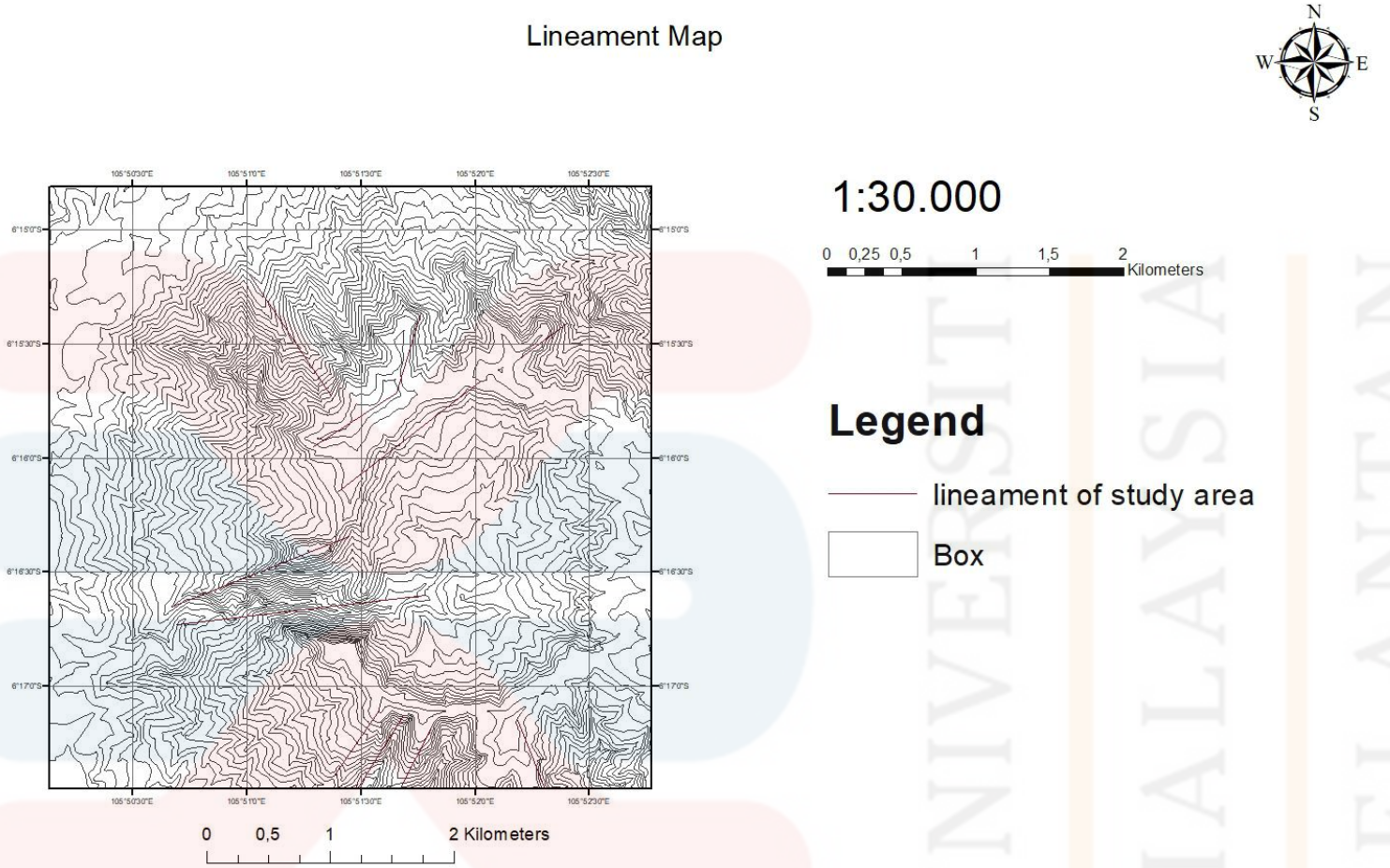

Figure 4.13: Lineament map

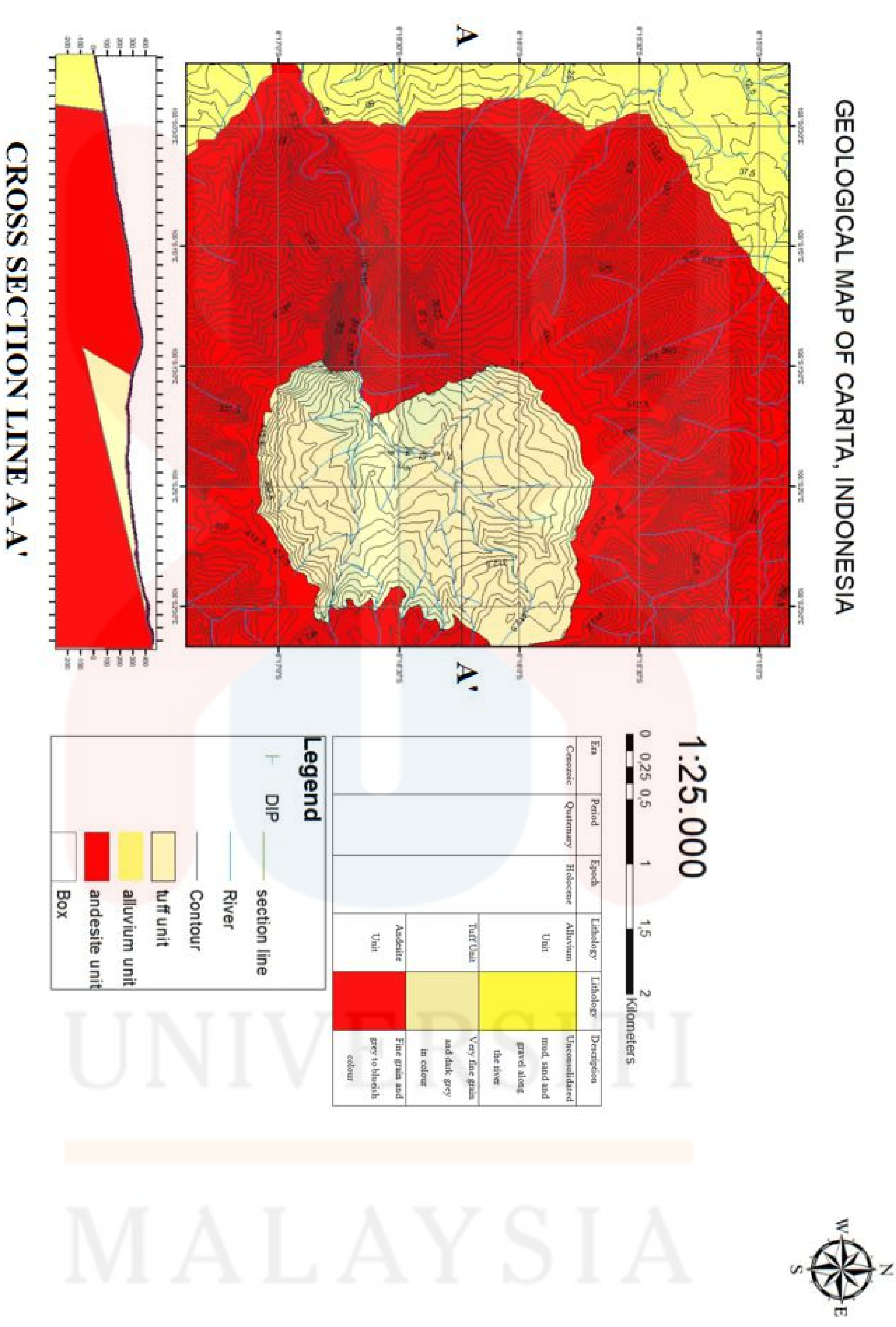

Figure 4.14: Geological map of Carita, South Pandeglang

4.4.2 Joint

Joint is a fracture within a rock that has no appreciable displacement parallel to the fracture and there is only slight movement to the fracture plane. Joints happens most in the zone where the plane have the weakest bond where further more will result a faulting could happen.

Joint that has been found in the study are most commonly found on the andesite outcrop near the waterfall, river and national forest area. Joints that found in the study are is a type of systematic join due to the regular occurrence and evenly spaced distances. The joints also shows to have a distinctive sets. The total of sets that can be observed are two sets of joint with the spacing of joint approximately 2 - 10 centimeter which is very close to each other. This type of joint can be classified as tectonic joints due to the identical and curve orientation. The joints developed in the surface of the earth since andesite form from a lava flow that cooled down at the volcanoes slope. The tectonic joints are often reflected as the local tectonic stresses that associated with the forming of faulting and folding in the area. The tectonic joints are also resulting a conjugate joint to form.

Another type of joint that encountered in the study area are the sheet joint or exfoliation joint. This type of joint forms as a sets of flat lying large joints that usually follows the topography of the area. This joints occurred when an exposed rock joints eroded by the weathering agent such as water or air. Thus, make the rock to have a sheet like features almost similar to columnar joint. Figure 4.16 shows the systematical shear joint and figure 4.17 shows the sheeting joint in the study area.

Joint analysis can be done by recording its strike. The result then calculated in a rose diagram. The rose diagram will determine the direction of the principle

stress that applied in the study area. The rose diagram is plotted from the GeoRose software. Figure 4.15 shows the shear joint force analysis by the rose diagram.

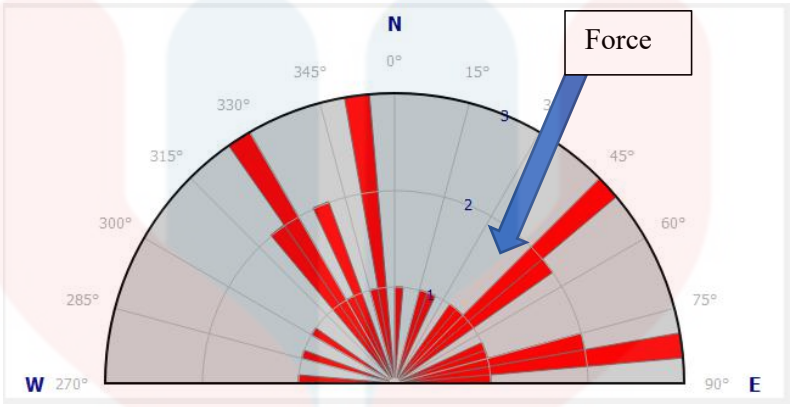

Figure 4.15: Force analysis based on the shear joint measurement

Since the type of joint that measured in the study area is a shear joint, the main force of the stress have to be measured 45º from the joints strike. The main force comes from N 20º E while the minimum force comes from N 30º W.

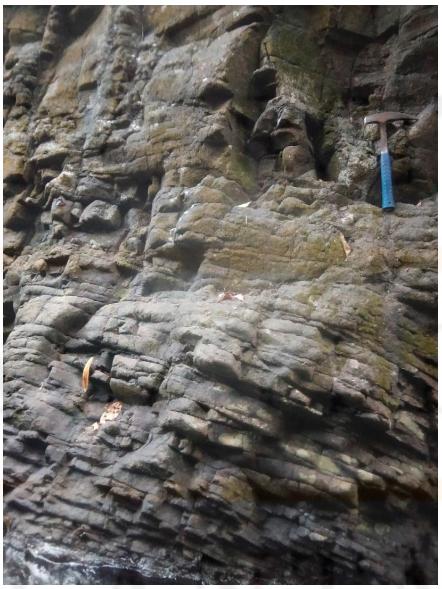

Figure 4.16: Systematical shear joint near the river system

Figure 4.17: Sheeting joint

4.4.3 Fold

Fold structure produce when a flat planar surface of rock applied with stress that cause deformation on the rock. This deformation will shaped a bent or curves on the rock that permanent. The process occurred when the rocks are ductile or elastic enough to bent. This is usually happens in the sub surface since the rock below still applied with a higher temperature to make the rock ductile enough. Also, the flowing ground water inside makes a contribution to prevent the rock rigid.

Folding types that occurs in the study area can be divided into two categories which symmetrical fold and asymmetrical fold. Symmetrical fold means the folds limbs has a relatively equal length. As for the asymmetrical fold, it defined as a folding that does not have an equal length of limbs. Figure 4.18 shows the anticline folding, figure 4.19 shows the chevron fold and figure 4.20 shows the recumbent fold.

Figure 4.18: Anticline folding on tuff outcrop

Figure 4.19: Chevron fold on tuff outcrop

Figure 4.20: Small recumbent folding

4.4.4 Fault

Fault is a planar fracture or discontinuity in a volume of rock across which there has been significant displacement as a result of rock mass movement. Faults are caused by the activity of tectonic plate that produces a force to displace the rock. Faults occurred in the earths crust.

The type of faults that can be observed in the study area are the normal fault. This type of fault occurred when the rocks body fractured and half of the body sliding or collapse and forming the hanging wall. This process effect the topography and morphology of an area. An indication of fault that occurring in an area are the lost of strata in a rock and also a waterfall which these two conditions can be found in the study area. Figure 4.21 and 4.22 shows the normal fault in the study area.

Figure 4.21: Waterfall, indication of a normal fault

Figure 4.22: Normal fault on tuff bedding

4.4.5 Historical Geology

Historical geology is a study that used principles and techniques of geology to reconstruct and understand the geological history of the earth. Its mainly focus on the geologic process that change the surface and the subsurface of the earth.

South Pandeglang in Banten is situated near the Sunda-Banda Magmatic Arc that active with tectonic activity. The oceanic and continental plate collided in here and forming the land of Banten Provinces. This process happens in Tertiary through the Quaternary. From this process produces an active volcano at that time which is the Pulasari and Asupan Mountain which is the main producer of the andesite and tuff unit in the study area. The andesite and tuff unit form as a young volcanic rock formation which overlies the older formation which is the Bojongmanik Formation.

The eruption of Asupan and Pulasari Volcano occurred at the Holocene. the lava flowing through the ancient crater and forms the andesite unit and as the andesite cools down, ashes of the volcanic material deposited above the lava flow. This theory is strongly supported by the findings of andesite unit that have been wrap by volcanic ashes and form a tuff rock. After these two unit forms, weathering process occurred resulting the weathering product to transported into the foot hill and forming the alluvial unit.

CHAPTER 5

GEOCHEMISTRY EVOLUTION OF IGNEOUS ROCK

5.1 Introduction

This chapter discussed on the results of thin section analysis on the five sample to determined the mineral content and also the chemical content based on the X-Ray Fluorescence geochemistry analysis that have been conducted at Pusat Survei Geologi (PSG) in Bandung.

The geochemistry analysis and petrographic analysis is conducted to the five sample of andesite unit that taken inside the study area. The five sample that have been taken are code named as OCK1D1, OCK2D1, OCK2D2, OCK3D2 and BC. This sample name are based on the outcrops name that found in the study area. Figure 5.1 shows the sampling location for the five sample.

The X-Ray Fluorescence analyzed the total of major elements inside the five rock samples. The major elements are SiO_2, $Al2O_3$, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5 and SO_3.

These elements provides the information needed to identifying the tectonic environment of the magma, type of the magma and also the evolution of the magma inside the study area that closely related to the differentiation of magma. This information is obtain by plotting the main three geochemistry diagram which is the AFM triangle, TiO_2-10MnO-P_2O_5 triangle and SiO_2 vs K_2O diagram.

AFM triangle diagram is obtained by plotting the FeO total, Na_20 + K_2O and MgO to determine the each samples magma characteristic. The TiO_2-10MnO-P_2O_5

triangle diagram is used for determined the tectonic setting that forms the rock and lastly the SiO_2 vs K_2O diagram is used for determining the type of rock and also the evolution progress of the igneous rock inside the study area.

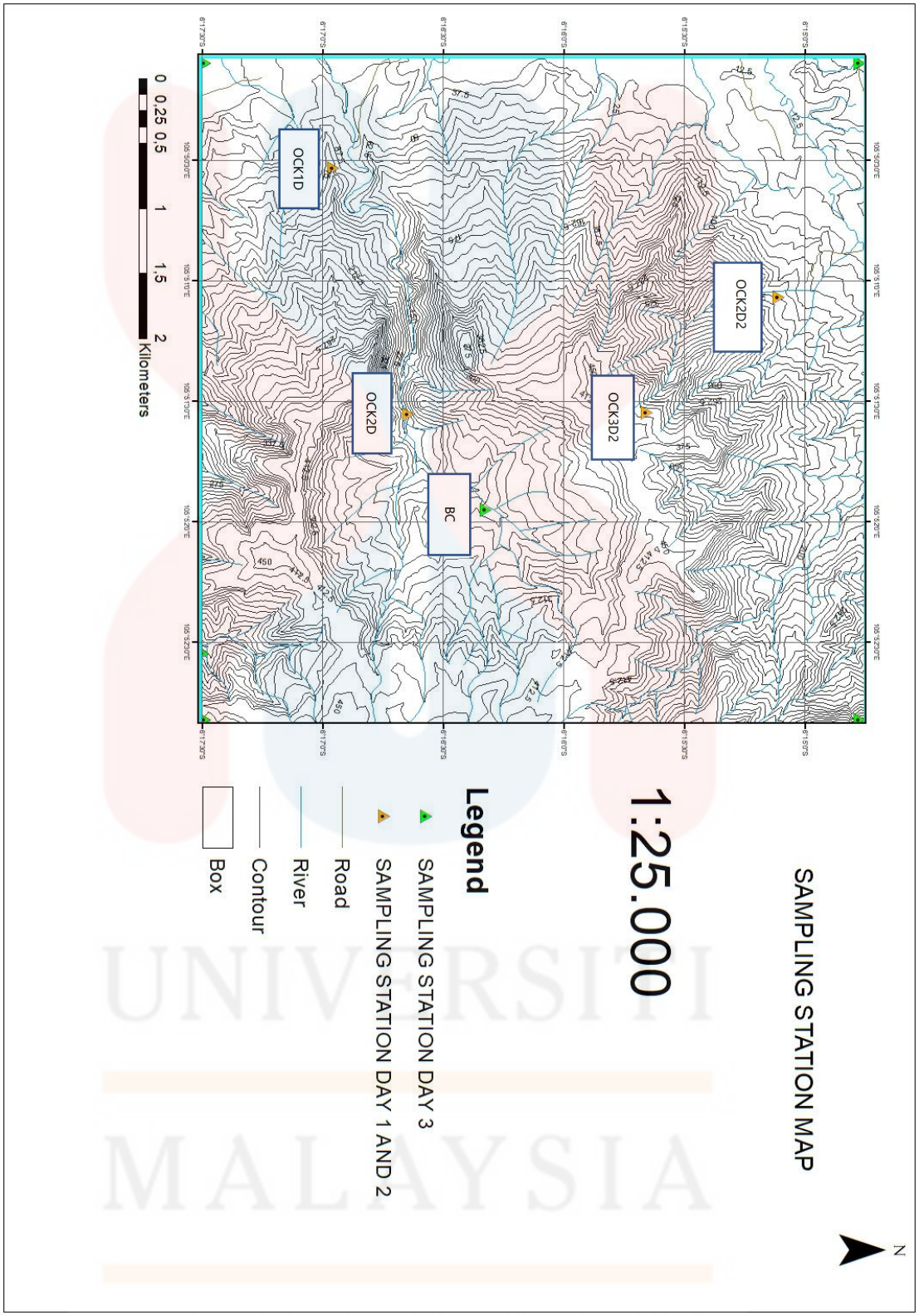

Figure 5.1: Sampling station map and location of the sample

5.2 Andesite Physical Characteristic

The five hand specimen of andesite unit are examined by naked eyes to determine it physical characteristic. The characteristic are the colour of the rock. Feel, which is the early hardness judgement by hand. Fracture, which is the presence of crack in the outcrop or hand specimen. Structure, which is the presences of geological structure in the sample's outcrop. Texture, which is the the mineral form that forms the rock. Granularity, the mineral size and Fabric which is the size difference of the mineral.

- OCK1D1

Colour	Black
Feel	Hard
Fracture	Non
Structure	Massive
Texture	Holocrystaline
Granularity	Aphanitic
Fabric	Equigranular

Table 5.1: OCK1D1 physical characteristic

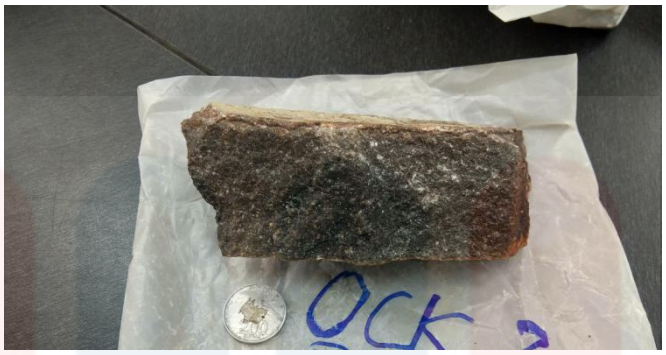

Figure 5.2: Sample of OCK1D1

- OCK2D1

Colour	Black, a little blueish
Feel	Hard
Fracture	Non
Structure	Massive
Texture	Holocrystaline
Granularity	Aphanitic
Fabric	Equigranular

Table 5.2: Physical characteristic of OCK1D2

Figure 5.3: Sample of OCK2D1

- OCK2D2

Colour	Grayish light black and blue
Feel	Hard
Fracture	Non
Structure	Massive
Texture	Holocrystaline
Granularity	Phaneritic
Fabric	Equigranular

Table 5.3: Physical characteristic of OCK2D2

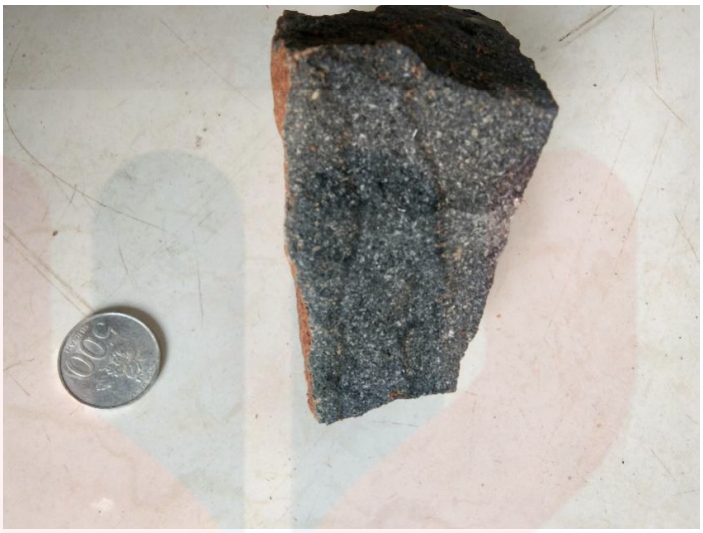

Figure 5.4: Sample of OCK2D2

- OCK3 D2

Colour	Grayish black
Feel	Hard
Fracture	Non
Structure	Massive
Texture	Holocrystaline
Granularity	Aphanitic
Fabric	Equigranular

Table 5.4: Physical characteristic of OCK3D2

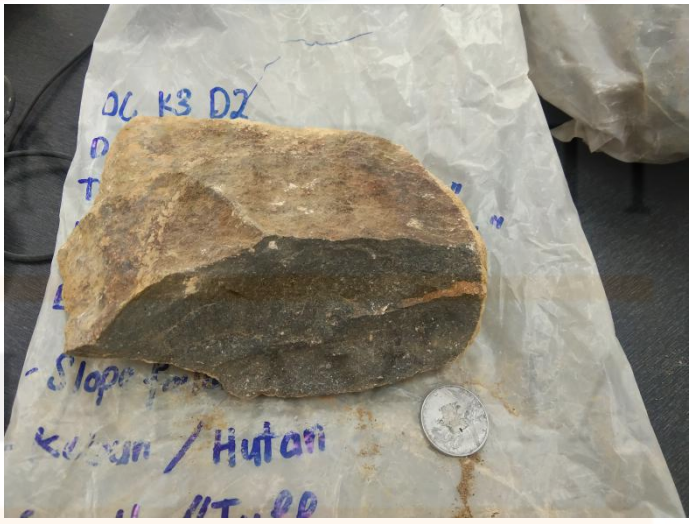

Figure 5.5: Sample of OCK3D2

- BC

Colour	Grayish black
Feel	Hard
Fracture	Non
Structure	Massive
Texture	Holocrystaline
Granularity	Aphanitic
Fabric	Equigranular

Table 5.5: Physical characteristic of BC

Figure 5.6: Sample of BC

5.3 Andesite Sample Petrographic Analysis

- OCK1D1

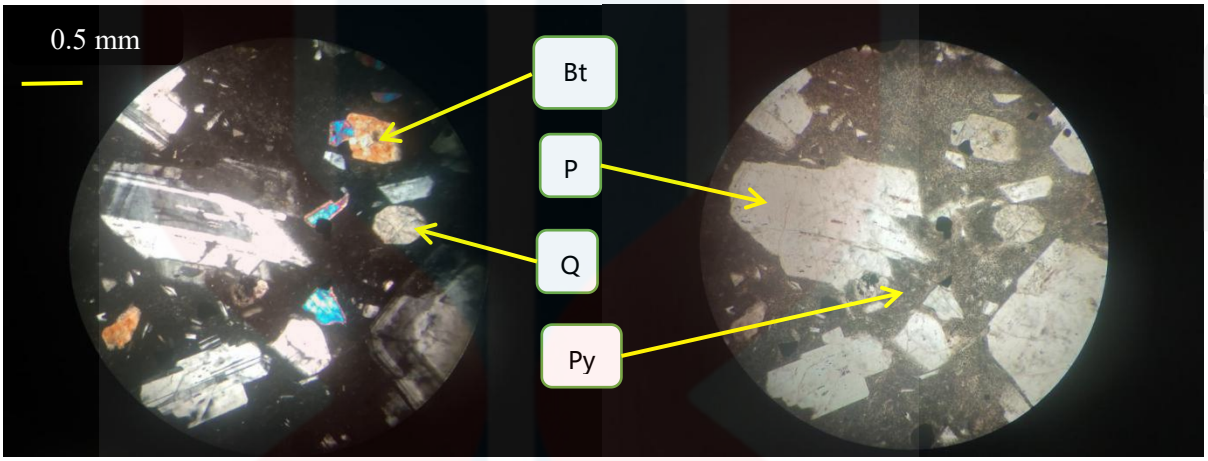

Figure 5.7: Mineral compositions under XPL (Left) and under PPL (right)

Mineral composition	Total(%)	Description of mineral
Plagioclase (P)	40%	Mineral is colourless. Anhedral shape. Twinning tends to occurred. Low relief. Phenocryst.
Biotite (Bt)	10%	Brown in colour. Anhedral shape. Pleochroism colour are black and brown. Medium relief.
Pyroxene (Py)	40%	Dark brown to black in colour. Pleochroism colour is dark brown to greenish. Microlites shape forming the groundmass.
Quartz (Q)	10%	Mineral is colourless. Anhedral shape. Low relief.

Table 5.6: OCK1D1 mineral composition

- OCK2D1

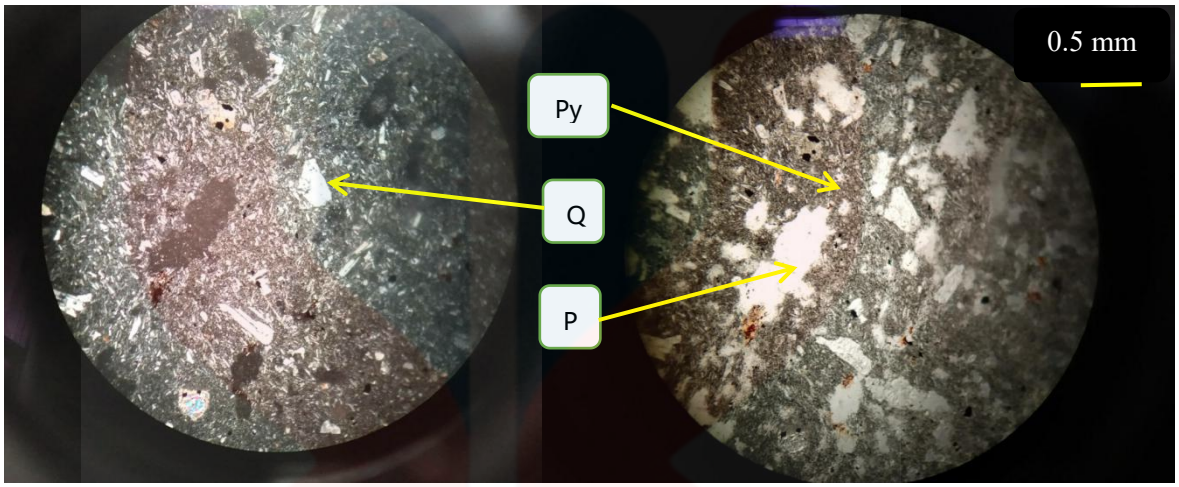

Figure 5.8: Mineral composition under XPL (left) and under PPL (right)

Mineral composition	Total (%)	Description of mineral
Quartz (Q)	5%	Mineral is colourless. Anhedral shape. Low relief
Pyroxene (Py)	40%	Dark brown to black in colour. Pleochroism colour is dark brown to greenish. Microlites shape forming the groundmass.
Plagioclase (P)	55%	Mineral is colourless. Anhedral shape. Twinning tends to occurred. Low relief. Phenocryst.

Table 5.7: OCK2D1 Mineral Composition

- OCK2D2

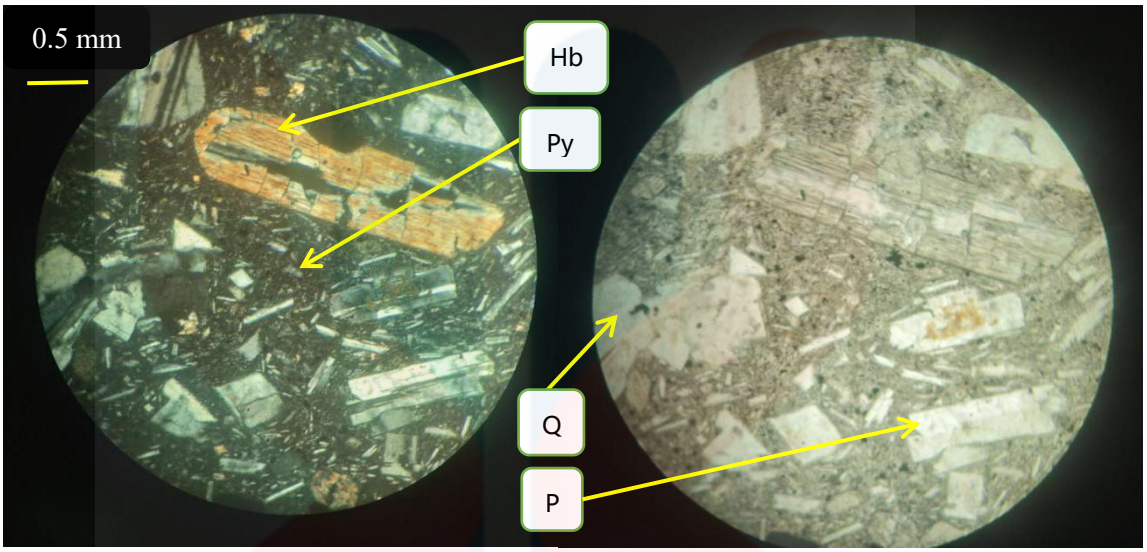

Figure 5.9: mineral composition under XPL (left) and PPL(PPL)

Mineral composition	Total (%)	Description of mineral
Quartz (Q)	5%	Mineral is colourless. Anhedral shape. Low relief
Pyroxene (Py)	30%	Dark brown to black in colour. Pleochroism colour is dark brown to greenish. Microlites shape forming the groundmass.
Plagioclase (P)	50%	Mineral is colourless. Anhedral shape. Twinning tends to occurred. Low relief. Phenocryst.
Hornblende (Hb)	15%	The colour is brown. Euhedral shape. Twinning tends to occurred. Pleochroism is brown to black.

Table 5.8: OCK2D1 Mineral composition.

- OCK3D2

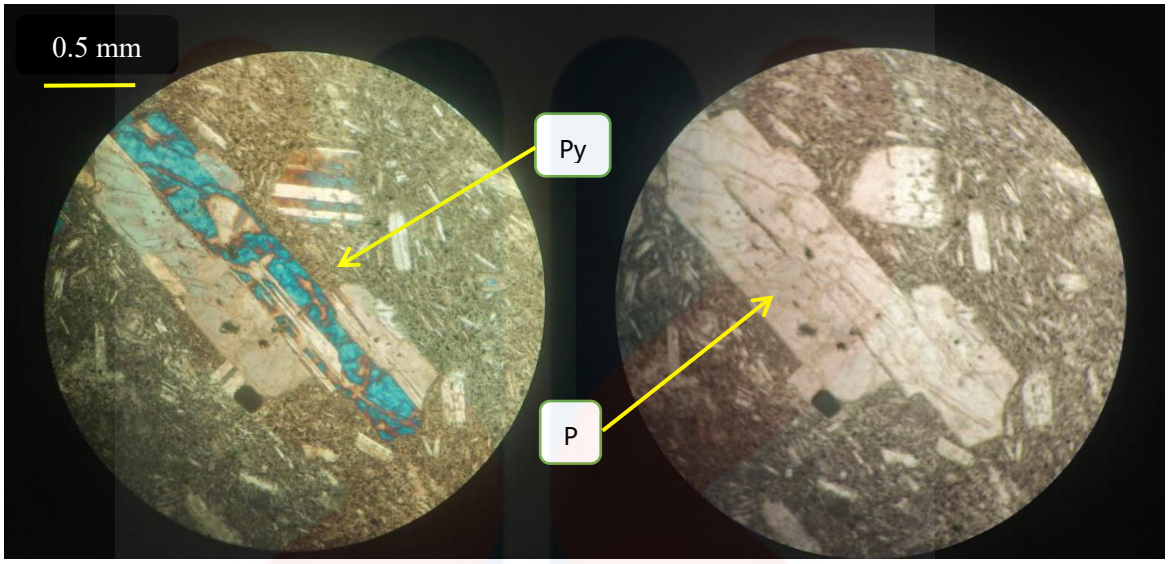

Figure 5.10: Mineral composition under XPL (left) and under PPL (right)

Mineral composition	Total (%)	Description of mineral
Pyroxene (Py)	55%	Dark brown to black in colour. Pleochroism colour is dark brown to greenish. Microlites shape forming the groundmass.
Plagioclase (P)	45%	Mineral is colourless. Anhedral shape. Twinning tends to occurred. Low relief. Phenocryst.

Table 5.9: OCK3D2 mineral composition.

- BC

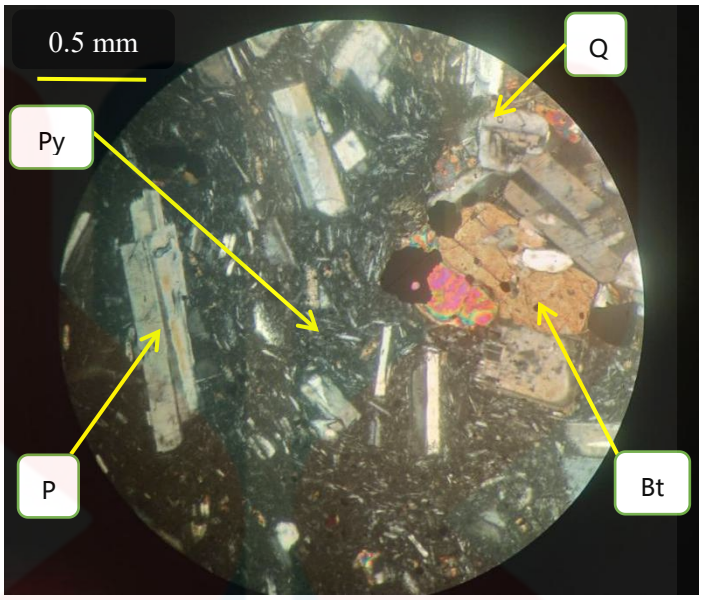

Figure 5.11: BC under XPL.

Mineral composition	Total (%)	Description of mineral
Quartz (Q)	5%	Mineral is colourless. Anhedral shape. Low relief
Pyroxene (Py)	35%	Dark brown to black in colour. Pleochroism colour is dark brown to greenish. Microlites shape forming the groundmass.
Plagioclase (P)	50%	Mineral is colourless. Anhedral shape. Twinning tends to occurred. Low relief. Phenocryst.
Biotite (Bt)	10%	Brown in colour. Anhedral shape. Pleochroism colour are black and brown. Medium relief.

Table 5.10: BC mineral composition.

5.3.1 Andesite Petrographic Discussion

Based on the petrographic analysis of the five sample, the five sample have a high plagioclase which becomes the phenocryst inside the rock and ground mass of microlite plagioclase and microlite pyroxene. Some other mineral variation are quartz, biotite, hornblende and also muscovite. The texture of the rock also have a characteristic more to porphyry. The porphyritic texture indicates two separate stages of solidification. The first stages is when the magma column is rising and cooled down slowly in the earth's crust. This stages creates a larger crystal size that becomes the phenocryst of the rock. The second and final stage is when the magma at a shallow depth, it cooled down rapidly because of the cooler temperature and thus creating the smaller mineral grain called the ground mass.

This porphyritic texture and the presences of big fragment of plagioclase mineral are an early support for an evolution of igneous rock can happen in the study area since the environment of the rock to form have a similar environment for a changing in magma series.

Another evidences that support the evolution of the magma are the presences of opaque mineral which is a small grain of metallic mineral. This is an indication that partial melting and magma differentiation occurring in the magma. This metallic mineral comes from the product of residual melt of mafic magma.

5.4 Result and Discussion

Sample Code	Major Element Composition Percentage (%)										
	SiO_2	Al_2O_3	$Fe2O_3$	CaO	Na_2O	K_2O	MgO	TiO_2	P_2O_5	MnO	SO_3
OCK1 D1	58.84	18.46	6.26	8.15	3.63	1.29	1.50	0.75	0.18	0.13	0.012
OCK1 D2	60.2	17.64	7.82	5.5	3.65	1.88	0.96	0.65	0.28	0.14	0.013
OCK2 D2	59.87	17.68	8	5.53	3.79	1.79	1.05	0.67	0.28	0.13	0.017
OCK3 D2	60.54	17.74	7.9	4.97	3.99	1.50	0.84	0.66	0.30	0.12	0.010
BC	57.4	18.08	9.15	6.41	3.61	1.39	1.28	0.98	0.22	0.15	0.021

Table 5.11: XRF analysis result of the five sample

Based on the X-Ray Fluorescence analysis (Table 5.11), the analysis of X-Ray Fluorescence of the five sample of rock shows a relatively similar percentage of the major elements. With the SiO_2 ranging from 57-60% and K_2O ranging from 1.3-1.8%. Although it seems similar in major element percentage, the increasing trend of SiO_2 shown more in the higher altitude or at the ridge of the crater and decreasing as its descending into the lower altitude or at the foot slope.

However, there is a lost of pattern in the BC station sample. The analysis data of SiO_2 in BC sampling station have a lowest concentration among all of the sample and breaks the pattern which is the more the area goes to the east, the higher the SiO_2 percentage. This could be caused by the topography of the area that effect the rate of crystallization quicker. The bowl shape volcanic crater and the presence of river system that flows the area makes the lava to cooled down quicker thus resulting a shorter time for the fractional melting to happened. As a result, K_2O depleting fewer and the SiO_2 increase is stop more sooner.

Another pattern that can be observe on BC sample based on the analysis data is the higher concentration of metallic element than other sample. The metallic elements are Al_2O_3, MnO and Fe_2O_3. This is could be caused by contact with tuff unit at the time of rock forming process. Since the volcanic materials that have been burst out from the volcano is high in metallic mineral, it is deposited at the same time as the lava was flowing around the crater thus slightly increases the metallic element inside the BC sample. This theory is suggested based on the presence of a crystal tuff that found at the boundary of andesite and tuff unit. Crystal tuff form as the heavier volcanic material falls and deposited quicker and lithified. The contact between these two rock also makes the crystal tuff more compact and hard than other tuff rock that found in the study area. The rock also only found in one particular outcrop at a river. Figure 5.12 shows the crystal tuff outcrop and figure 5.13 shows the hand sample.

Figure 5.12: Crystal tuff outcrop on the river

Figure 5.13: Crystall tuff hand specimen

The higher concentration of SiO_2 at the higher altitude could be caused also by the time amount of time the lava have to crystallize and conduct the fractional melting. Since the rock is at a closer range from the Asupan and Pulasari Mountain, the lava have more time to undergo the fractional melting process than the lava that settled more far than its source of magma since it have more flowing time and fewer settling time than the lava that settled at the ridges of the crater.

5.4.1 Tectonic Environment

Tectonic environment is defined as location relative to the boundary of a tectonic plate, particularly a boundary along which plate tectonic activity is occurring or has occurred. Certain tectonic environment will produce a certain type of magma and thus formed a specific type of igneous rock. The tectonic environment of the rock that formed at the study area is determined by plotting three major element of the rock. This diagram is called the TiO_2-10MnO-P_2O_5 diagram. The diagram worked by plotting the total content of TiO_2, 10MnO and P_2O_5 of the rock. The plotting of these

major elements were conducted using a PetroGraph software. Figure 5.14 shows the plotting result of the TiO_2-10MnO-P_2O_5 diagra.

The diagram can determine five types of tectonic environment which are mid-ocean ridges basalt, island arc tholeiite, oceanic island tholeiite, oceanic island andesite and continental arc.

MnO is depleted relative to TiO_2 in mid-ocean ridge analyses and may be controlled by early fractionation of olivine and clinopyroxene under conditions of low-Fo_2. In island arc rocks, MnO is enriched relative to TiO_2 due to early crystallization of titanomagnetite in a high-Fo_2 environment. Primitive mid-ocean ridge and arc tholeiites have similar MnO/TiO_2/P2O_5 ratios which indicate a grossly similar parent magma. Increasingly differentiated basaltic rocks are more easily classified by the diagram. High relative abundances of TiO_2 and P_2O_5 in ocean island rocks are consistent with their derivation from a separate source (Mullen, 1983).

From the plotting in PetroGraph software, the tectonic environment that formed the lava that becomes the igneous rock in the study area are from Oceanic Island Tholeiites. Oceanic Island Tholeiites or more commonly named as Oceanic Island Basalt mainly formed at the ocean sea floor, more specifically in a intraplate settings. Thus, OIB (Oceanic Island Basalt) are different from other principle types of volcanism that occurs in the ocean basins along the plate boundaries such as Mid-Ocean Ridge Basalt. OIB occured at a volcanic hot spots, which correspond to the surface location of upwelling mantle plumes. Mantle plumes are a mantle region that uplifted by the buoyant force and are thought to have a high temperature. This mantle plumes that becomes the lava at a volcanism hotspot are thought to originated as

deep as the core mantle and mantle boundaries. It is estimated as 2900 kilometer deep.

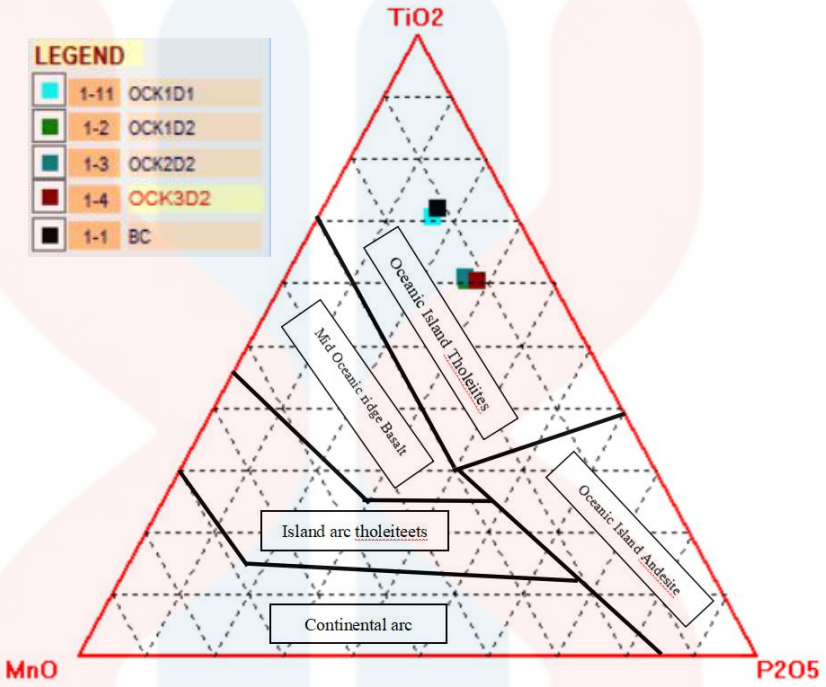

Figure 5.14: TiO_2-MnO-P_2O_5 diagram shows the oceanic island tholeiites tectonic environment

5.4.2 Lava Characteristic

Lava characteristic of an igneous rock is classified by a magma series. It is based on the ratio and also the total of certain major elements that contained inside the igneous rock. The magma series is divided into four different types which is Shosnonitic Series, High-K Calc-Alkaline Series, Calc Alkaline series and Tholeiitic Series. This magma series is distinguish from each other by using the SiO_2 vs K_2O diagram and also the AFM triangular diagram. Figure 5.15 shows the SiO_2 vs K_2O diagram plotting result.

The classification of the magma series that conducted with the SiO_2 vs K_2O diagram is based on the ration and total of the SiO_2 and K_2O contained in the rock.

Shosnonitic series magma are distinguish if the SiO_2 content is more than 50-70% and the K_2O is between 1.5-6%. High-K Calc-Alkaline Series is distinguish by 1.3-1.6% K2O content, Calc-Alkaline Series with a K_2O content of 0.2 - 1.2% and Tholeiitic Series K_2O content ranging between 0-0.2%. The plotting of these diagram was done with PetroGraph Software.

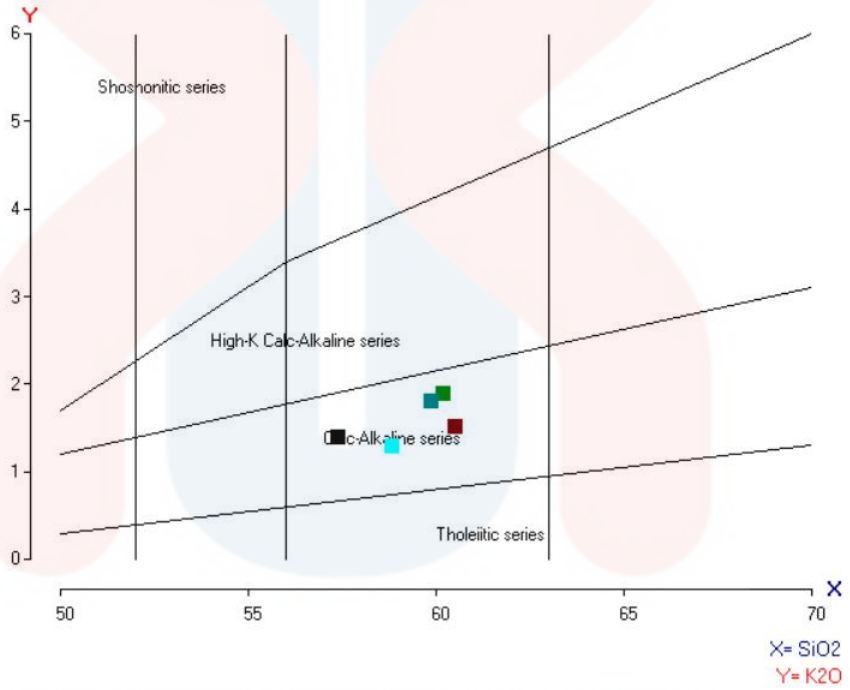

Figure 5.15: SiO_2 vs K_2O diagram plotting shows the magma series are Calc-Alkaline

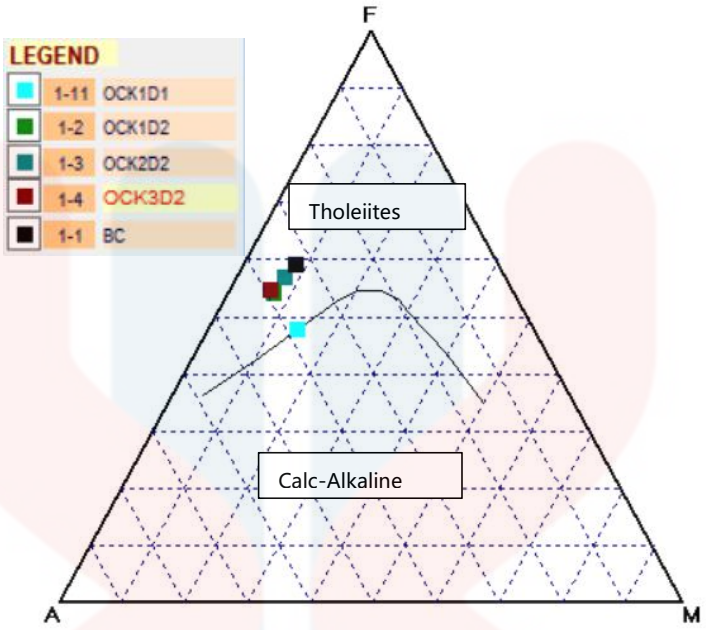

Figure 5.16: AFM triangular diagram shows the magma series are Tholeiites Series.

Based on the SiO_2 vs K_2O plotting. The magma series that form the rock in the study area comes from an Calc-Alkaline Series. This series of magma comes from the evolution of a more mafic magma which in composition is high on magnesium and iron content. After the magma fractionally crystallize, the content of magnesium and iron are depleted. This is because of when mafic magma crystallize, they preferred to crystallize the more magnesium rich and iron poor forms of the silicate minerals olivine and pyroxene. Hence, the iron content of tholeiitic magma increase as the melt was depleted iron poor crystals.

As for the AFM triangle diagram, the data shows that the magma series belongs to the tholeiitic series. However, there are a differences in the OCK1D1 sample. The diagram showed that the OCK1D1 sample data plotted at the border of Tholeiitic Magma Series and Calc-Alkaline Magma Series. Figure 5.16 shows the AFM triangular diagram plotting result.

5.4.3 Igneous Rock Evolution

Based on the diagrams and locality of the igneous rock, the evolution of the igneous rock can be seen in the changing of magma series from Tholeiitic Series into Calc Alkaline Series. This is caused by the partial melting and fractional crystallization of the magma at the forming process. The fractional melting changes the basaltic composition into a more andesitic composition. The basaltic magma crystallize a certain minerals that in the process it removed from the melt. The removal process can be done by variety of ways, but the most likely to occur are the crystal settling. The first minerals that crystallize and removed from the parent rock are the olivine and amphiboles. These mafic minerals settled out of the magma and make a mafic cumulates. After the mafic minerals already removed, the magma has no longer or have only a few basaltic composition . Silica content inside starts to form thus makes the rock more andesitic. From the location of each sample, the evolution starts from east side of the box into the west side of the box. This indicated that the flow of the lava comes from the east side of the region and flowing through the west side and finally cooled down to formed an igneous rock.

CHAPTER 6

CONCLUSION AND RECOMENDDATION

6.1 Conclusion

Based on the SiO_2 percentage of the igneous rock, the type of igneous rock in the study area are basaltic andesite and andesite. From the TiO_2-10MnO-P_2O_5 diagram information, the andesite unit comes from an Oceanic Island Tholeiites tectonic environment from intraplate settings in an oceanic floor. The evolution of the igneous rock tends to change from Tholeiites Magma Series into the Calc-Alkaline Magma series from the east side to the west side of the study area.

6.2 Recommendation

When conducting a research in a volcanically active area. It is recommended to always stay focus and aware of an earthquake and tsunami potential in the area. As this could be a life threatening situation. An earthquake does happened at the time of the research and based on the local institution, it have potential of tsunami occurring. Luckily, it does not happen and from this incident, we must aware of our safety from the danger of geohazard and always listen to the local government.

It is recommended for a geological mapping to conduct at least a week for one box to maximize the investigation of the site. And lastly, always spare more budget on geochemical analysis as it could exceed the budget that all ready planned or the amount of sample could be more than expected.

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APPENDICES

GL-F-PL-13-2.2-01-b

LABORATORIUM PUSAT SURVEI GEOLOGI
(GEOLOGY LABORATORIES)
Jl. Diponegoro No. 57, Bandung, 40122, Indonesia
Telp: 022-7203205, 6032207 Fax: 022-7202669, 6127941 E-mail: labgeologi@grdc.esdm.go.id

HASIL UJI KIMIA METODE XRF
(XRF METHOD CHEMISTRY ANALYSIS RESULT)
Nomer lab. (*lab. number*) : 118/GL/2.2/10/2019
Tanggal (*date*) : 4 Oktober 2019

Kode sampel (*sample code*)	: OCK 1 D1	Tanggal diterima (*received date*)	: 3 September 2019
Kode lab. (*lab. code*)	: 118/2.2/19/0663	Tanggal diuji (*analyzed date*)	: 3 Oktober 2019
Lokasi (*location*)	: -	Metode uji (*method*)	: GL-MU-2.2
Kedalaman (*depth*)	: -	Metode preparasi (*preparation method*)	: *Pressed Pellet*
Pemilik (*property*)	: **Kevin Heinrich Pesch UNPAD**		

Compound	m/m%	StdErr	El	m/m%	StdErr
SiO2	58.84	0.25	Si	27.50	0.12
Al2O3	18.46	0.20	Al	9.77	0.11
CaO	6.26	0.13	Ca	4.47	0.09
Fe2O3	8.15	0.13	Fe	5.70	0.09
Na2O	3.63	0.10	Na	2.69	0.07
MgO	1.501	0.080	Mg	0.905	0.050
K2O	1.290	0.060	K	1.071	0.050
TiO2	0.7578	0.0400	Ti	0.4543	0.0240
P2O5	0.1798	0.0110	Px	0.0785	0.0046
MnO	0.1357	0.0070	Mn	0.1051	0.0050
SO3	0.0127	0.0008	Sx	0.0051	0.0003
		LOI	0.44		

Kepala Subbidang Geologi Dasar dan Terapan
selaku Manajer Teknis,

Ir. Sri Kuncoro, S.T., M.T.
NIP. 197203112006041001.

Catatan (*notes*):
Hasil pengujian ini hanya berlaku untuk sampel yang diuji (*this analysis result is only valid for the tested sample*).

Figure 6.1: OCK1D1 XRF analysis data from Pusat Survey Geologi

LABORATORIUM PUSAT SURVEI GEOLOGI
(GEOLOGY LABORATORIES)
Jl. Diponegoro No. 57, Bandung, 40122, Indonesia
Telp: 022-7203205, 6032207 Fax: 022-7202669, 6127941 E-mail: labgeologi@grdc.esdm.go.id

HASIL UJI KIMIA METODE XRF
(XRF METHOD CHEMISTRY ANALYSIS RESULT)
Nomer lab. (*lab. number*) : 118/GL/2.2/10/2019
Tanggal (*date*) : 4 Oktober 2019

Kode sampel (*sample code*)	: OCK 1 D2	Tanggal diterima (*received date*)	: 3 September 2019
Kode lab. (*lab. code*)	: 118/2.2/19/0664	Tanggal diuji (*analyzed date*)	: 3 Oktober 2019
Lokasi (*location*)	: -	Metode uji (*method*)	: GL-MU-2.2
Kedalaman (*depth*)	: -	Metode preparasi (*preparation method*)	: *Pressed Pellet*
Pemilik (*property*)	: **Kevin Heinrich Pesch UNPAD**		

Compound	m/m%	StdErr	El	m/m%	StdErr
SiO2	60.20	0.25	Si	28.14	0.12
Al2O3	17.64	0.20	Al	9.33	0.11
Fe2O3	7.82	0.12	Fe	5.47	0.09
CaO	5.50	0.12	Ca	3.93	0.09
Na2O	3.65	0.10	Na	2.70	0.07
K2O	1.885	0.070	K	1.565	0.060
MgO	0.962	0.060	Mg	0.580	0.038
TiO2	0.6533	0.0350	Ti	0.3916	0.0210
P2O5	0.2892	0.0170	Px	0.1262	0.0070
MnO	0.1407	0.0070	Mn	0.1090	0.0060
SO3	0.0135	0.0008	Sx	0.0054	0.0003
		LOI	0.86		

Kepala Subbidang Geologi Dasar dan Terapan
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Catatan (*notes*):
Hasil pengujian ini hanya berlaku untuk sampel yang diuji (*this analysis result is only valid for the tested sample*).

Figure 6.2: OCK2D1 XRF analysis data from Pusat Survey Geologi

GL-F-PL-13-2.2-01-b

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HASIL UJI KIMIA METODE XRF
(XRF METHOD CHEMISTRY ANALYSIS RESULT)

Nomer lab. (*lab. number*) : 118/GL/2.2/10/2019
Tanggal (*date*) : 4 Oktober 2019

Kode sampel (*sample code*)	: OCK 2 D2	Tanggal diterima (*received date*)	: 3 September 2019
Kode lab. (*lab. code*)	: 118/2.2/19/0665	Tanggal diuji (*analyzed date*)	: 3 Oktober 2019
Lokasi (*location*)	: -	Metode uji (*method*)	: GL-MU-2.2
Kedalaman (*depth*)	: -	Metode preparasi (*preparation method*)	: *Pressed Pellet*
Pemilik (*property*)	: **Kevin Heinrich Pesch UNPAD**		

Compound	m/m%	StdErr	El	m/m%	StdErr
SiO2	59.87	0.25	Si	27.99	0.12
Al2O3	17.68	0.20	Al	9.36	0.11
Fe2O3	8.00	0.13	Fe	5.59	0.09
CaO	5.53	0.12	Ca	3.95	0.09
Na2O	3.79	0.10	Na	2.81	0.07
K2O	1.796	0.070	K	1.491	0.060
MgO	1.057	0.070	Mg	0.638	0.040
TiO2	0.6714	0.0360	Ti	0.4025	0.0210
P2O5	0.2893	0.0170	Px	0.1263	0.0070
MnO	0.1389	0.0070	Mn	0.1076	0.0060
SO3	0.0179	0.0009	Sx	0.0072	0.0004
		LOI 0.76			

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Catatan (*notes*):
Hasil pengujian ini hanya berlaku untuk sampel yang diuji (*this analysis result is only valid for the tested sample*).

Figure 6.3: OCK2D2 XRF analysis data from Pusat Survey Geologi

GL-F-PL-13-2.2-01-b

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HASIL UJI KIMIA METODE XRF
(XRF METHOD CHEMISTRY ANALYSIS RESULT)
Nomer lab. (*lab. number*) : 118/GL/2.2/10/2019
Tanggal (*date*) : 4 Oktober 2019

Kode sampel (*sample code*)	: OCK 3 D2	Tanggal diterima (*received date*)	: 3 September 2019
Kode lab. (*lab. code*)	: 118/2.2/19/0666	Tanggal diuji (*analyzed date*)	: 3 Oktober 2019
Lokasi (*location*)	: -	Metode uji (*method*)	: GL-MU-2.2
Kedalaman (*depth*)	: -	Metode preparasi (*preparation method*)	: *Pressed Pellet*
Pemilik (*property*)	: **Kevin Heiarich Pesch UNPAD**		

Compound	m/m%	StdErr	El	m/m%	StdErr
SiO2	60.54	0.25	Si	28.30	0.12
Al2O3	17.74	0.20	Al	9.39	0.11
Fe2O3	7.90	0.12	Fe	5.52	0.09
CaO	4.97	0.11	Ca	3.55	0.08
Na2O	3.99	0.10	Na	2.96	0.07
K2O	1.505	0.060	K	1.249	0.050
MgO	0.849	0.060	Mg	0.512	0.036
TiO2	0.6623	0.0350	Ti	0.3970	0.0210
P2O5	0.3098	0.0180	Px	0.1352	0.0080
MnO	0.1233	0.0060	Mn	0.0955	0.0050
SO3	0.0107	0.0007	Sx	0.0043	0.0003
		LOI 1.06			

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Catatan (*notes*):
Hasil pengujian ini hanya berlaku untuk sampel yang diuji (*this analysis result is only valid for the tested sample*).

Figure 6.4: OCK3D2 XRF analysis data from Pusat Survey Geologi

GL-F-PL-13-2.2-01-b

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HASIL UJI KIMIA METODE XRF
(XRF METHOD CHEMISTRY ANALYSIS RESULT)
Nomer lab. (*lab. number*) : 118/GL/2.2/10/2019
Tanggal (*date*) : 4 Oktober 2019

Kode sampel (*sample code*)	: BC	Tanggal diterima (*received date*)	: 3 September 2019
Kode lab. (*lab. code*)	: 118/2.2/19/0667	Tanggal diuji (*analyzed date*)	: 3 Oktober 2019
Lokasi (*location*)	: -	Metode uji (*method*)	: GL-MU-2.2
Kedalaman (*depth*)	: -	Metode preparasi (*preparation method*)	: *Pressed Pellet*
Pemilik (*property*)	: **Kevin Heinrich Pesch UNPAD**		

Compound	m/m%	StdErr	El	m/m%	StdErr
SiO2	57.40	0.25	Si	26.83	0.12
Al2O3	18.08	0.20	Al	9.57	0.11
Fe2O3	9.15	0.13	Fe	6.40	0.09
CaO	6.41	0.13	Ca	4.58	0.09
Na2O	3.61	0.10	Na	2.68	0.07
MgO	1.285	0.070	Mg	0.775	0.040
K2O	1.395	0.060	K	1.158	0.050
TiO2	0.9812	0.0500	Ti	0.5882	0.0310
P2O5	0.2270	0.0130	Px	0.0991	0.0060
MnO	0.1545	0.0080	Mn	0.1197	0.0060
SO3	0.0211	0.0011	Sx	0.0084	0.0004
		LOI 0.92			

Kepala Subbidang Geologi Dasar dan Terapan
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Catatan (*notes*):
Hasil pengujian ini hanya berlaku untuk sampel yang diuji (*this analysis result is only valid for the tested sample*).

Figure 6.5: BC XRF analysis data from Pusat Survey Geologi