GEOLOGY OF KP.CIPEUTEUY, BANDUNG WEST JAVA AND PETROLOGY OF ITS VOLCANIC PRODUCTS.

by

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APPROVAL

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

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DECLARATION

I declare that this thesis entitled " **GEOLOGY OF KP.CIPEUTEUY, BANDUNG WEST JAVA AND PETROLOGY OF ITS VOLCANIC PRODUCTS**" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date :

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In the name of Allah, The Most Gracious and The Most Merciful, on whom we depend on ultimately in all aspects, for words are insufficient to describe grateful and appreciation for the long process that I had taken for this thesis from early stage to the end. Along the journey of this thesis, I would like to express my deep gratitude to those who constantly gives guidance, assistance, motivation and support directly and indirectly, named;

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Geology of Kp.Cipeuteuy, Bandung West Java and Petrology of Its Volcanic Products.

ABSTRACT

A geological study is conducted in Kp.Cipeuteuy, Bandung West Java with an area of 25km^2 and contour interval of 12.5 meters. The area is located in Kabupaten Bandung, geographically in 107 °35′45.03″ - 107 °38’30.06” East-longitude, and 7°1′53.00 - 7°4'37.38” on South-latitude. This study aims to produce a geological map of 1:25,000 scale and specify in petrogenesis and evolution of magma based on the volcanic products in the study area. The evolution and genesis of volcanic products is studied and supported with thin section and detection of major and trace elements using X-Ray Fluorescent (XRF). The result is analysed through few plotting made based on Streckeisen, (1973), Mullen (1983), Peccerillo and Taylor, (1976), Le Bas et.al, (1986), and Harker’s diagram for major and trace elements. Stratigraphically, the study area has occurred few series of eruptions happened continuously in the period of Late Miocene and Pleistocene. The oldest rock is *Tan*, andesite with composition of plagioclase and pyroxene. *Tan* is pillowing *Qan* and *Ql*, series of andesite with composition of plagioclase, pyroxene and hornblende that interfingering with each other due to the age gap happened in volcanic eruptions. The youngest lies on top of *Qan* and *Ql* are *Qvb* which is volcanic breccia, a monomict type of breccia, with component of andesite and tuff as matrix. *Qvb* is interfingered with *Qt*, which is crystal-dominated tuff. The genesis of magma is in the island arc with calc-alkaline series. The geological map and geochemical analysis will provide additional and updated data for the use of future scientific research.

Geologi di Kp.Cipeuteuy, Bandung Jawa Barat dan Petrologi Batuan Volkaniknya.

ABSTRAK

Kajian geologi dijalankan di Kp.Cipeuteuy, Bandung Jawa Barat dengan kawasan seluas 25km^2 dan selang kontur sebanyak 12.5 meter. Kawasan ini terletak di Kabupaten Bandung, di 107 °35′45.03″ - 107 °38’30.06” longitude-timur , dan 7°1′53.00 - 7°4'37.38” di latitude-selatan. Kajian ini bertujuan untuk menghasilkan peta geologi berskala 1:25,000 dan menentukan petrogenesis dan evolusi magma berdasarkan produk gunung api di sekitar kawasan kajian. Evolusi dan asal usul produk gunung api ini diketahui melalui pemerhatian sayatan tipis dan pengesanan unsur-unsur utama dan unsur-unsur surih menggunakan X-Ray Fluorescent (XRF). Hasil yang didapati dianalisis melalui beberapa komplot berdasarkan Streckeisen, (1973), Mullen (1983), Peccerillo and Taylor, (1976), Le Bas et.al, (1986), and Harker untuk unsur-unsur utama dan unsur-unsur surih. Secara stratigrafi, kawasan kajian telah melalui beberapa siri letusan gunung api yang berlaku secara berterusan dalam tempoh akhir Miosin dan Plistosin. Batuan tertua adalah *Tan*, merupakan andesit dengan komposisi plagioklas dan piroksen. *Tan* membantal *Qan* dan *Ql*, siri andesit dengan susunan plagioklas, piroksen dan hornblende yang berselang Antara satu sama lain disebabkan oleh jurang umur yang berlaku di dalam letusan gunung berapi. Satuan termuda di atas *Qan* dan *Ql* adalah satuan *Qvb*, iaitu batuan monomik breksi berkomponen andesit dan tufan sebagai matriks batuan. *Qvb* berselingan bersama *Qt*, iaitu tufan yang berdominasi dengan kristal. Asal usul magma berada di arka pulau dengan siri alkali-kalsium. Peta geologi dan analisis geokimia akan membantu menyediakan data tambahan yang dikemaskini untuk kegunaan penyelidikan saintifik di masa hadapan.

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LIST OF SYMBOL

mm	Millimeters
km	Kilometer
%	Percentage
°	Degree
µ	Micro
±	Plus-Minus

LIST OF ABBREVIATION

XRF	X Ray Fluorescent
LILE	Large Ion Lithophile Elements
HSFE	High Field Strength Elements
REE	Rare Earth Elements
LOI	Loss on Ignition
NMORB	Normal Mid Oceanic Basalt
S_iO_2	Silicon Dioxide
T_iO_2	Titanium Oxide
Al_2O_3	Aluminium Oxide
FeO	Iron Oxide
MnO	Manganese Oxide
MgO	Magnesium Oxide
CaO	Calcium Oxide
Na_2O	Sodium Oxide
K_2O	Potassium Oxide
P_2O_5	Phosphorus Pentoxide

Th	Thorium
K	Potassium
La	Lanthanum
Ti	Titanium
Tan	Tertiary Andesite Unit
Ql	Quaternary Lava Unit
Qan	Quaternary Andesite Unit
Qvb	Quaternary Volcanic Breccia Unit
Qt	Quaternary Tuff Unit

CHAPTER 1

INTRODUCTION

1.1 General background

The title of this research is given as the Geology of Kp.Cipeuteuy, Bandung West Java and Petrology of Its Volcanic Products. This research is focused on the geological study and petrologic study of the tertiary and quaternary volcanic formation in the study area. The nearest volcano is located at the southern part of the study area that is Gunung Malabar, existed as quaternary volcano approximately 23 thousand years ago. The aim of the study is to obtain a better understanding on the geology of the area, and study the petrology of the volcanic products presents in the stud area, in order to determine its magma source and magma evolution.

The study begins with geological study of the area with a map scale of 1:25000 that covers 5km×5km (25km^2) for specific data for geological map. Geological mapping is carried out to obtain more accurate results and obtain rock samples for further analysis. The best geological mapping is being carried out through three phases which are planning, data collection and data analysis with report writing. According to (Barnes,2004), a precise and accurate geological map is the most important element in geological field as it is a basis for most geological works. Based on the samples collected from geological mapping, few methodologies are neede1d to analyse the chemical and the elements of the rock composition. The methods chosen are thin section, and X-Ray Fluorescence (XRF). Thin section enable the samples to be analysed under polarising microscope, while XRF is needed to characterise the rocks based on its major and trace elements.

In Java, it is supported by the backbone that lies a series of young active volcanoes that become part of ‘The Ring of Fire”. According to Gorsel, (2016) most of the volcanoes are about 3000 meters high and the distance between each of them approximately 80 kilometres apart. Java Island is divided into 3 parts, which are East Java, Central Java and West Java. Based on Bayah area that is located in the western part of Java, which is about 215 kilometres from Banjaran, the area is located in the subduction zone of Indian-Australian Plate under the Eurasian Plate. This process occurred from Early Cretaceous to Late Cretaceous period. Is it stated by (Suparks et al, 1982) that there are volcanic rocks that exposed in the Bayah area age Early Tertiary period.

While in Bandung district, it is considered to be part in Bandung Basin, that has elips shape elongate towards to SE-NW. Bandung Basin starts from the area of Nagreg on the eastern part towards Padalarang on the western part with horizontal distance approximately 60 kilometres while 40 kilometres vertically. Bandung Basin is surrounded with series of quaternary volcanoes, such as Gunung Burangrang-Sunda-Tangkubanparahu, Gunung Bukit Tunggul, Cupunagara volcanic rocks, Gunung Manglayang, and Gunung Tampomas on the northern part of Bandung. On the eastern border, are series of volcanoes such as Bukitjarian Volcano, Gunung Karengseng-Gunung Kareumbi and complex of volcanic rocks of Nagreg until Gunung Mandalawangi, The Southern border, lies series of Kamojang volcano, Gunung Malabar, Gunung Patuha, and Gunung Kendeng. Looking on the western part of Bandung Basin, there is a border by Tertiary volcanic rocks that included in Rajamandala Formation (Bronto.S and Hartono.U, 2006).

The study continue towards the research specification. This research specify on the petrologic studies of the volcanic rocks believed to be in tertiary volcanoes and quaternary volcanoes in Kp.Cipeuteuy area in Bandung District, West Java, Indonesia.

1.2 Study Area

a) Location.

The study area is located in Kp.Cipeuteuy area, West Java, Indonesia. The study area located under Bandung district, where the main volcanic products are coming from Gunung Malabar-Tilu. The study area covers 5km × 5km ($25km^2$) with contour interval of 12.5 metres. The research area located in between of 107 °35′45.03” - 107 °38’30.06” East-longitude, and 7°1′53.00 - 7°4'37.38” on South-latitude. The map is prepared by using ArcGIS 10.2 software. The area are covered with quaternary volcanic products which are believed to be Old Malabar-Tilu Volcanics, Waringin-Bedil Andesite and Malabar-Tilu Volcanics. These 3 formations are dominated by volcanic breccia and tuff, and andesite with hornblende and pyroxene composition. The research area has moderate to high steep slope, based on the contour shown. The area has a very fertile soil, where almost 60% of the study area is covered by paddy fields and plantations, where another 40% is roughly covered by housing area. The distribution of the villagers are spreading equally in the area, with good road connections as the accessibility of one place to another is easy.

b) Road connection

Road connection is referred as the accessibility of road for transportation. The research area has a good road connections from main road, to other small villages in the area. At the centre of the study area, Kp.Cipeuteuy is one of the village' name that can be considered as sub-urban area, where the area is developed as an agricultural area that has variety of plantation and paddy that become major income source for the villagers. The study area can be access from all sides, and accessible towards the centre of the study area as shown in Figure 1.1 below.

Figure 1.1: Accessibility map of study area, Cipeuteuy. (source: Google Maps)

c) Demography

Demography is the study of the population growth where population is counted on the people that dominated a terrestrial area for 6 months and above, or dominated an area less than 6 months but have the intention to stay longer. In population growth, the rate of certain population over a particular time, and the data collected will be analysed for its population density in a particular area. The data includes the statistical result, for example on sex ratios, number of household members, working age, labour force, and the total of working hour, employment status and industrial field.

Demography of the study area covers in Bandung District, specifically named after Kp.Cipeuteuy town. Based on the data obtained from Badan Pusat Statistik, Indonesia, the population projection for 2015 in Bandung Province shows a value of 1253.30 for male and 1228.20 for female. In Bandung province they have total of 2481.50 population.

d) Landuse

Agricultural sector has become an important strategies in structure of national economic development. During the time when other sector in the industry unable to absorb additional labor force, agricultural sector is often a choice for non-agricultural sectors. According to Nuraeni, Risma, Sitorus et al, (2017), the land use in Bandung province was classified into six division, which are forest, plantation and estate, dry land farming crops, wetland farming crops, developed landmasses, and water bodies. Every year there is a significant change on the land use in Bandung province. Each land use area in Bandung province is shown in comparison between 2002 to 2012 in Table 1.1.

Table 1.1: Area of land use and its changes in 2002 and 2012.

Type of land use	Year 2002 (ha)	Year 2012 (ha)	Changes (ha)
Forest	31.722,86	31.716,30	-6,56
Plantation and outcrops	29.225,08	29.179,62	-45,46
Dry land farming crops	61.782,22	60.662,55	-1.119,67
Wetland farming crops	31.215,87	29.244,84	-1.971,03
Developed landmasses	21.504,24	24.646,96	3.142,72
Water bodies	449,89	449,89	0,00

(Source: Badan Pusat Statistik, Indonesia)

Based on Table 1.1, the largest land use was in 2002 in Bandung province that is on the dryland farming crops that takes up to 61.782,22 ha. The dryland farming crops spread throughout the Bandung province. In 2012, the type of landuse area that has decreased is the wetland farming crops which was 1.971,03 ha wide, followed by dryland farming crops which was 1.119,67 ha. As for plantation and estate the value is 45, 56 ha wide and for forest is 6.56 ha wide.

e) Social economics

In West Java, Bandung city has become the highest economic growth. Commerce and industry are the major contributor in Bandung's total GDP per year. According to Tarigan, Sagala, Samsura et al, (2016) the most outstanding activities in commercial sector are the clothing factory outlets and boutique business that able to attract not only local people but also from other parts of Indonesia, Malaysia and Singapore. The driver of Bandung's economy has long been known as industrial sector. In Bandung there are several centres of medium to large scale industries such as electronics, furniture, and textiles. All this sectors help in increasing Bandung's GDP, absorb local labour and drive local economic activities. There are various industrial sector in different districts, for example Binongjati Knitting Industry, Cihampelas Jeans Industry and Cibuntu Tofu and Tempeh Industry. Bandung province also major in their agriculture sector, where they produced paddy and soy refer to Table 1.2 and Table 1.3.

Bandung also has a significant role in expanding its industrial sector. The educational sector in Bandung plays a significant role in Bandung's economics. Bandung, known as city of education has 78 colleges and universities that actively operate.

Table 1.2: Paddy production in Bandung, Sumedang and West Java Province (Ton), from 2010-2015.

Wilayah Provinsi	2010	2011	2012	2013	2014	2015
1. Bandung	459.077	464.425	479.425	584.335	462.977	48.316
2. Sumedang	453.303	460.212	447.546	503.912	475.190	433.576
3. Provinsi Jawa Barat	11.737.071	11.633.891	11.271.861	12.083.162	11.644.899	11.373.143

(Source: Badan Pusat Statistik Indonesia)

Table 1.3: Soy Production in Bandung, Sumedang and West Java Province (Tons) from 2010-2015.

Wilayah Provinsi	2010	2011	2012	2013	2014	2015
1. Bandung	59	74	81	139	202	760
2. Sumedang	7,365	5,435	3,802	2,099	2,555	1,732
3. Provinsi Jawa Barat	55,823	56,166	47,426	51,172	115,261	98,938

(Source: Badan Pusat Statistik Indonesia)

1.3 Problem statement.

Regionally, there are number of researchers that had studied the area such as Alzwar, Akbar and Bachri, (1992). However, a particular understanding is needed to study the petrology of volcanic products in Kp.Cipeuteuy area in a scale of 5km×5km ($25km^2$). This research decides to focus on the volcanic products that is believe to be from tertiary to quaternary age. With the help from previous research, this research is run by geological mapping to obtain, observe and record the geological data and all the related information. Then, the samples are analysed based on the geochemistry of its related information. Then, the samples are analyse based on its geochemistry using X-Ray Fluorescence (XRF).

1.4 Research Objectives

The research objectives for this research are:

a) To produce geological map of the study area in the scale of 1:25000;

b) To identify the magma source in Kp.Cipeuteuy area.

c) To determine the evolution of magma in Kp.Cipeuteuy from its volcanic product.

1.5 Scope of study.

This research focussed on the petrographic studies of volcanic rocks. Volcanic rocks are differentiated from other types of igneous rocks such as plutonic and hypabyssal rocks based on its grain size. According to (Frost.R.B, 2014), volcanic rocks usually crystallise at the surface. The cooling rate of magma is important in determining the grain size of the rocks, and there is a relationship between both the temperature of the magma and the ambient temperature of the rocks. Generally, the grain size increases with depth but there is no specific value for the transition phase. To obtain the samples of the rock, geological mapping is conducted focussing on the geography, geomorphology, lithology and structural analysis of the study area. The samples collected and obtained are used in petrographic analysis, and thin section to determine the characteristics and mineral composition of the rock unit. All details and data obtained are important to be used to update the geological map within the research area using ArcGIS 10.2 software.

1.6 Significance of study.

This research had provided understanding on the geology of the research area with the scale of 1:25,000 that contains proper documentation of recorded data. Specific geological features were presented in a geological map in details. Moreover, petrology of the volcanic products which were specification of this research were able to provide scientific evidence in scientific report on the characteristics of the rocks presence, and magma source and its evolution with the occurrence of the minerals in specific temperature and pressure.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This research covers an area of 5km X 5km = 25km^2 located in between of two provinces, which are Sumedang province and Bandung province. The formation goes under Rajamandala Formation, which made up of limestone, mudstone, and quartz sandstone. Rajamandala Formation pillowing the quaternary volcanic products from the volcano. In the study area, there is one inactive volcano, named Gunung Kareumbi, which reaached 1400 m of elevation as shown as in the base map. The lowest elevation is within the range of 600 m.

2.2 Regional Geology and Tectonic Setting.

Based on the plate tectonic theory, the convective currents pushed the Earth lithosphere surface, and pulled due to their weight of the diving slabs. Due to this, there are three types of plate boundaries which are divergent boundaries, convergent and transform.

West Java is divided into few physiographic regions with different characteristics such as, The Plain of Jakarta, The Bogor Zone, The Banten Area and

The Bandung Zone. The Continental Platform located in the northern part of the area, which is West Java, is characterised as the geological features showed the Plain of Jakarta is a low plain. Generally, geological features shown in Figure 2.1, the basement formation is metamorphic and it is intruded with plutonic formations. They are overlain with Mesozoic, Cenozoic and recent volcanic formations and quaternary deposits.

Indonesia forms the southeastern extremity of the Euro-Asian lithospheric plate. The causes of this extremity is due to the two moving plates bounded together. The two moving plates are the northward-moving Indo-Australian plate and the westward-moving Pacific (Philippine) plates. When these two bounded with each other, it results in becoming the most complex active tectonic zone on earth. Australia Plate was subducted beneath the Eurasia Plate. The activity of subduction occurs few centimeters per year, that is 6 cm per year in the West Java Trench at 0°S 97°E (azimuth 23°); 4.9 cm per year in the East Java Trench at 12°S 120°E (azimuth 19°); and 10.7 cm per year in New Guinea at 3°S 142°E (azimuth 75°) according to Tarigan, Sagala, Samsura et al, (2016). The subduction zone that occur around the Euro-Asian plate is called the Sunda Trench. Most of the part where the volcanoes extends are in part of Sunda arc. The volcanoes extended approximately 3000 km long from northern Sumatra to the Banda Sea. Tarigan, Sagala, Samsura et al, (2016) mentioned in their journal that the presence of volcanoes in the Banda Sea is resulted from the subduction of Pacific Plate under Eurasia Plate.

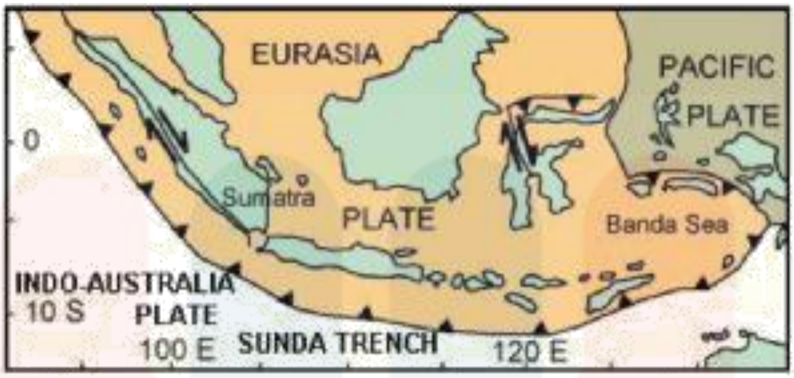


Figure 2.1: Plate tectonic model of Indonesia, source from A.Tarigan, S. Sagala, D. Samsura et al, (2016).

West Java is divided into few physiographic regions with different characteristics such as, The Plain of Jakarta, The Bogor Zone, The Banten Area, and The Bandung Zone. The Continental Platform located in the northern part of the area, which is West Java, is characterised as the geological features showed the Plain of Jakarta is a low plain extending from the Serang to Cirebon. The lower plain composed with mainly alluvial and lahar deposits from volcanoes with older sediments.

In addition to that, the Bogor Zone is located in an area of hills and to the south of the Plain of Jakarta. The mountains and hills are the result of the intrusions that resulted in the mountainous geomorphology. While in Bandung Zone, located in the central part of West Java, there are depressions that are filled with young volcanic products and alluvial from surrounding area. This depressions are originated from Sukabumi,Cianjur, Bandung, Garut and Tasikmalaya.

Looking into the southern part of West Java, the presence of a gentle slope southward to the Indian Ocean with an average width of 50 km. Central part of the zone, are said to be a high mountainland that peaks over 2000 m, where the lowest are reaching 1000 m at the western (The Jampangs) and eastern (Karanunggal) section.

According to Bronto, (1989), Quaternary volcanoes occurred actively at the central part of West Java. Tampomas Volcano is a famous volcano that existed during the Quaternary period of time until recent. The hydrothermal fluids conduits induced by the regional structure that shows a (WNW-ESE) fault trend.

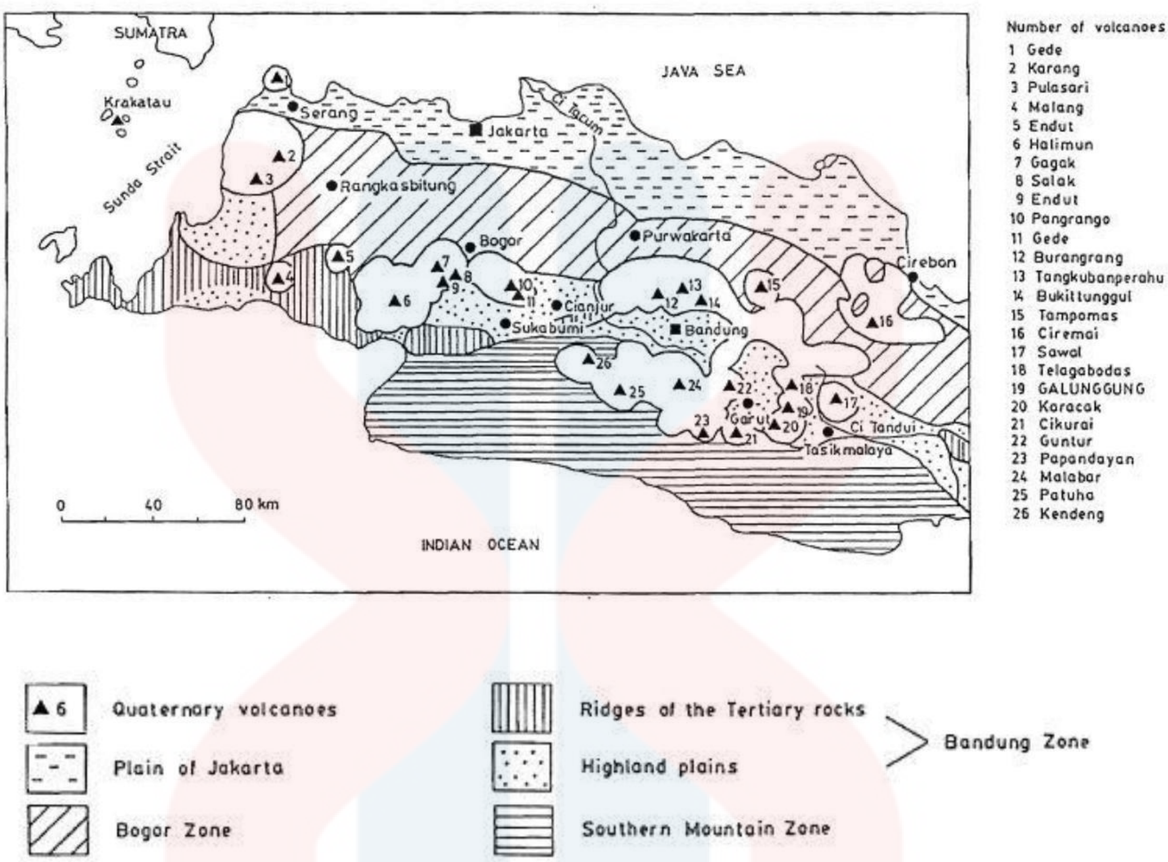


Figure 2.2: Physiographic sketch map of West Java simplified after Van Bemmelen (1949). Souce from S.Bronto, (1989).

2.3 Stratigraphy

Based on the basis of sedimentary characteristics of Tertiary rocks, Martodjojo (1984) has divided West Java into three regional areas. The Continental Platform is in the northern part of West Java, and corresponds closely to the physiographic region of the Plain of Jakarta. The area is characterised as shallow marine sedimentary rocks that is up to 5000 m thick with a simple geological structures.

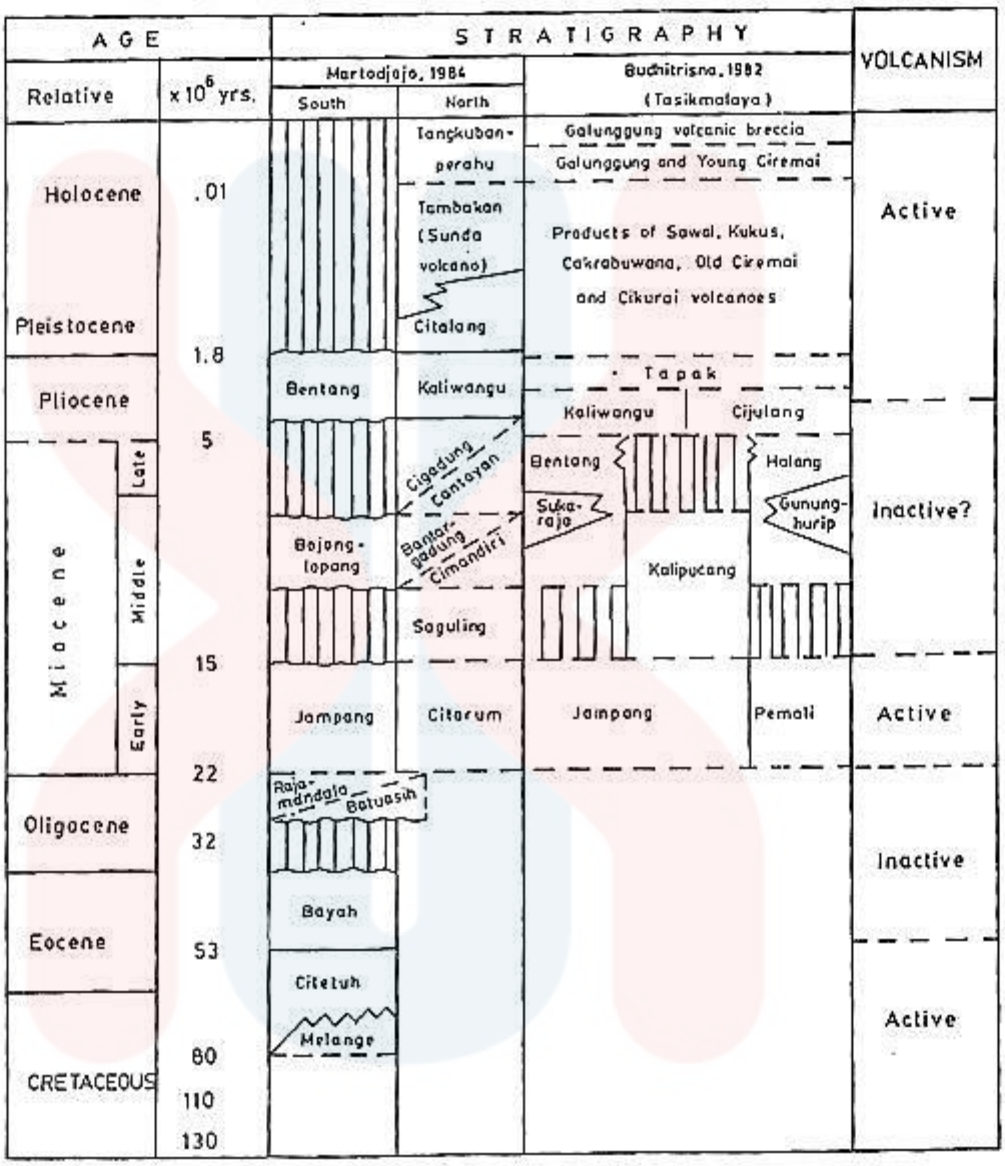


Figure 2.3: A stratigraphic column that shows the history of Bogor Basin simplified after Budhitrisna (1982) and Martodjojo (1984) source from S.Bronto, (1989).

- **Cretaceous – Eocene**

The oldest rock, and a melange complex in West Java. Melange Complex comprising metamorphosed basic and ultrabasic rocks such as peridotites, gabbros and pillow lavas, including sedimentary rocks such as serpentinite, chloritic schists, phyllites and quartzite together with chert, black shale, greywacke and limestone. The outcrops are exposed in southwestern part of West Java. According to Bronto, (1989), the melange complex is only found in Luk Ulo and Jiwo Hills, Central Java. As for the basic and ultrabasic rocks they are absent. In his journal, it is stated that the basic and ultrabasic rocks of the melange complex in Ciletuh area have a similar age to the granite intrusion in the Java Sea. Intrusive and volcanic rocks might represent the old subduction zone, whereas eruptive centres in Java Sea and area between Cikotok and Jibarang may represent a magmatic arc.

Ciletuh Formation comprising of sedimentary rocks, such as claystones and shales, alternating with sandstone in the lower part while the upper part is composed of quartz sandstone and breccias. As seen based on the stratigraphic column, Bayah Formation comformably overlies the Ciletuh Formation. The lower part of this unit is dominated by quartz sandstone, gradual changing upwards with interbedded sandstones, claystones and coals. The thickness is from 200 m to 1500 m.

- **Oligocene**

It is a sedimentary rocks, that was divided into Batuasih and Rajamandala Formations. The Batuasih Formation consists of calcareous claystone with intercalations of thin sandy siltstone. Pyrite is common in this formation, and the thickness of this formation is up to 110 m to 570 m. In Rajamandala Formation, it is mainly limestone, with 100 m thick. The two formations are likely to represents a facies change from anaerobic marginal marine (Batuasih Formation) to shallow marine (Rajamandala Formation) environments.

- **Miocene**

At this stage, the rocks are volcanic and sedimentary. The volcanic rocks was named as the Old Andesite Formation that now grouped into the Jampang Formation located in the south and Citarum Formation in the north. Jampang Formation in its lower part composed of dacitic to andesitic composition, and comprises mostly fine-grained volcaniclastics with lapilli size. The upper part is composed of basaltic breccias and lavas with clasts of limestone. It is 2000 m thick.

In the Middle Miocene, they are grouped into four formations which are Saguling Formation in the northern part of Bogor Basin, Bantargadung Formation, Cimandiri Formation and Bojonglopand Formation in the southern part of Bogor Basin. In the Late Miocene the sedimentary rocks also were divided into four formations. The Cigadung Formation in the west, the Cantayan Formation in the north, the Halang Formation in the east and the Bentang Formation in the south. The thickness is up to 700 m and it is considered as the youngest marine sediments in the Bogor Basin.

- **Pliocene**

During Pliocene the volcanic and sedimentary rocks comprises of andesitic breccias, lavas, dikes and tuffs which are local distributed in the eastern part of West Java. Volcanic rocks are located from the Cijulang Formation in Tasikmalaya quadrangle and the Kumbang Formation to the east.The maximum thickness of Cijulang Formation and Kumbang Formation are approximately 1000 m and 2000 m respectively.

Pliocene sedimentary rocks occur in the north named as the Kaliwangu Formation, while in the south and east they occur in the Tapak and Bentang Formation. In these formations, they are composed by tuffaceous sandstones and claystones with intercalated lignites and conglomerates with abundance of mollusca. The thickness is up to 1000 m.

- **Pleistocene – Recent**

From Pleistocene to Holocene, West Java was dominated by volcanisms. West Java is classified into the Citalang and Tambakan Formations with extinct volcano such as Sunda and active volcanoes such as Tangkubanperahu.

Citalang Formation consists of interbedded conglomerates and tuffaceous sandstones with intercalated breccias, siltstones and claystones that is 1000 m thick with vertebrate fossils. The depositional environment is an alluvial plain or braided stream. For Tambakan Formation, it is composed of laharic breccias with intercalated sandy tuffs, claystones and lignites with 470 m thick.

2.4 Structural geology

Based on the research by Bronto (1989), from a Landsat image of West Java, it is detected that there were four major lineaments and a high density of lineaments are found in the vicinity of Bogor and southwest Cirebon. Around the Bogor lineaments there are a concentration of shallow to intermediate earthquake.

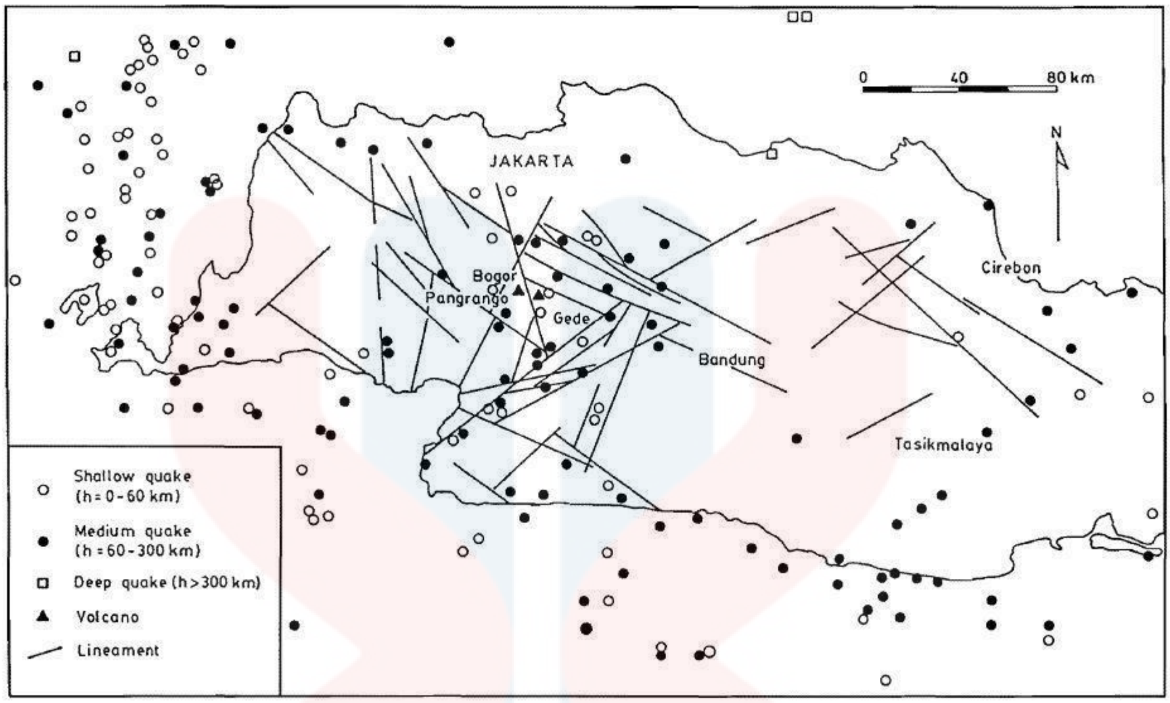


Figure 2.4: Lineament patterns from Landsat images and distribution of earthquake epicentres by (Suwijanto, 1978). Source from S.Bronto (1989).

Based on the lineament studies, there are three fault orientations that are also dominant in wider region of Kalimantan, Java and Sumatra. Sumatra Fault System predominated in the west, with northwest direction. In the western and eastern part of Java Sea, the direction of faults come from the north and northeast striking (Meratus Trend). Sumatra Fault is an active dextral strike-slip fault with a lateral displacement of 20-25 km and a horizontal slip-rate of 6 cm/year. The basin and intervening highs are assumed to be produced by the differential vertical movements that taken place. The northeast striking faults are mostly found from geophysical and oil drilling exploration programs.

2.5 Historical Geology

Indonesia is a well-known for its very complex tectonic evolution that lies at the junction between three lithospheric plates named Indian – Australian, the Pacific and the Eurasian plate. In Early Cretaceous that is 130-80 million years ago, the opening of Indian oceans causes India to be drifted away moving to the north-west from Antarctica-Australia along a transform fault known as Wallaby Fracture Zone. The transform fault is said to be parallel to the Sumatra Fault which possibly from this period.

While during Cretaceous – Early Paleogene that is 80 – 50 million years ago, the Indian Ocean plate moved rapidly with 15 – 17.5 cm/year moving to the north towards Antarctica. The plate was obliquely subducted along a transform fault in the wet to Sumatra but nearly perpendicular to Java.

This is how the volcanism was induced in the Western Indonesia. The Jatibarang Formation and volcanic rocks at Cikotok were formed in the intra-arc basin and these might happened during 50-30 million years ago probably due to the slow rate of movement which was 3-7 cm/year of the Indian Ocean plate.

Indian and Australian plates united around 32 million years ago that caused a Miocene volcanism in western Indonesia. The subduction zone is maintained aligned with the trench that is in the direction of E-W, parallel to and south of Small Sunda Islands. This activity result in the Miocene volcanic arc that extended to Small Sunda Islands. The deposition of Miocene volcanics were in the Bogor Basin forming Jampang and the CItarum Formations. The volcanism were terminated at the end of Early Miocene and the sedimentation process occurred until Pliocene.

According to Bronto (1989), he said that many authors considered that the major uplift of Java began during Late Pliocene. The theory was accompanied by the new period of volcanism, produced the Cijulag Formation and continued until present time as Quarternary volcanism.

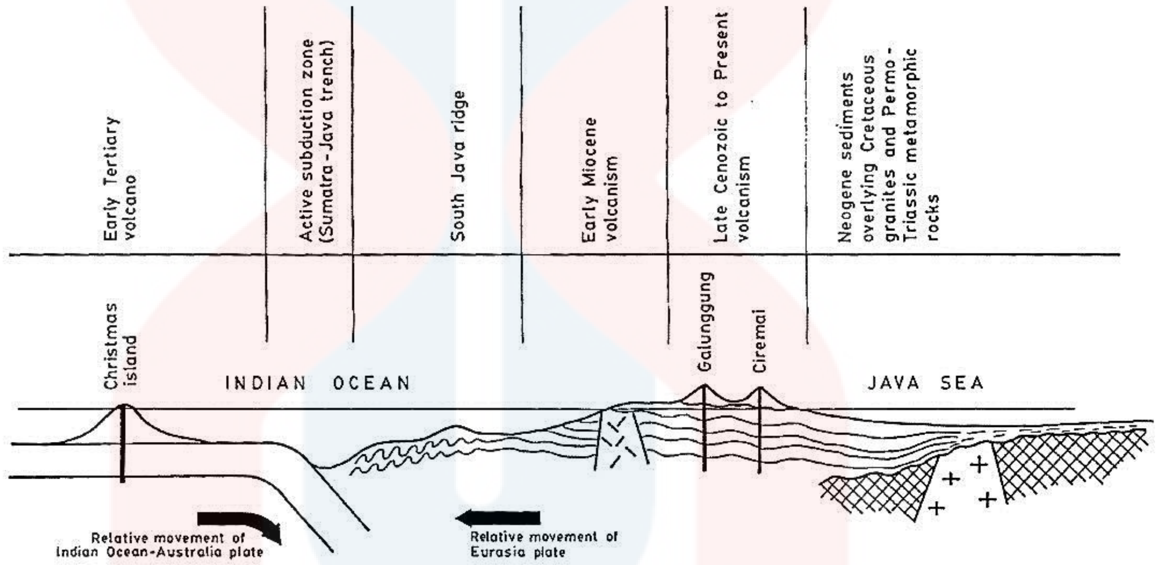


Figure 2.5: The plate tectonic schematic section (SSW-NNE) across West Java. Source from S.Bronto,(1989).

2.6 The Petrology of volcanic rocks.

- **Magmatism**

Magma is the ultimate sources of rock which cools and solidifies to form igneous rocks. The Earth interior is very hot and works like a thermal engine, where the heat seeps through the atmosphere through few processes, such as conduction, or by convection. These processes support the plate tectonic theory, where the source of heat is from the convection cells. Conduction process, acts throughout the Earth's surface, where convection is restricted to only along belts or isolated spots where volcanic activities, or volcanoes occur. Earth’s interior is very dynamic. The melting point of the mantle increases as the pressure increases approximately about 100km depth with 1350 °C. Using the sources of the heat from the mantle, the tectonic plate is able to move with the speed of few cm per year.

In partial melting, mantle peridotite can occur in three ways, which are pressure release without heat loss, also known as adiabatic decompression melting. Secondly, is by increasing heat supply, and the third one is addition of water that lowers the solidus system. Partial melting will lead the mantle into melt segregation, and the production of basaltic magma Leyrit, (2000).

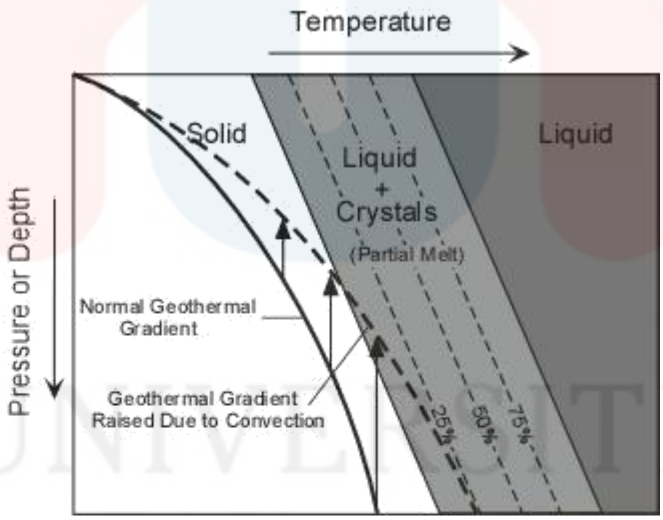


Figure 2.6: How adiabatic decompression of the mantle (arrow) can lead to melting even if the mantle is dry.

The mechanism for partial melting of the mantle; firstly, the normal temperatures encountered at increasing depth in the mantle (refer dashed line in figure) are always below the solidus for fluid absent lherzolite. Under ordinary circumstances, therefore, the mantle is solid. However, the number of phenomena can generate mantle melting. The normal geothermal gradient must be locally hot, usually occur beneath ocean island called “hotspot” for example, in Hawaii.

Second, the temperature at which melting begins could be lowered by addition of a component to dry lherzolite. The addition of CO2 and/or H2O to peridotite lowers the solidus significantly. Meaning the addition of CO2 and even small amount of H2O can lower the solidus, and that melt can be produced from lherzolite at the temperature and pressure. Since subduction carry water-rich fluids along with oceanic crust into the mantle, this process becomes an important mechanism for fluid addition that depress the mantle solidus and trigger partial melting.

A third mechanism that may produce melting is decompression of ascending mantle. A mantle material may go up either as part of convection cells or as diapirs. As we know the temperature of the centre of convection cell is adiabatic; means there is no heat is transferred in or out of the mass under consideration. For mantle material, the adiabatic gradient is around 0.3□C/km. Meaning that the mantle rising adiabatically does not cool appreciably as it ascends. It will melt when it crosses the fluid-absent solidus at around fifty kilometres depth. Because mid-oceanic ridges are located above up-going limbs of convection cells, decompression melting is particularly important at mid-ocean spreading centres.

- **Tholeiitic and Calc-alkaline magma series**

It is important to understand the petrogenesis of the magma to know the tectonic setting and magma evolution. It links with the idea of where lithosphere is thought to be reabsorbed and the theories of orogenesis. The volcanic rocks in island arc or orogenic zones range from basalt (alkaline), basaltic andesite (intermediate), andesite and dacite (acidic). This association is commonly called as calc-alkaline series. But to differentiate with those two series, is by examine the general petrographic characteristics. In calc-alkaline series, petrographically it is dominated by plagioclase phenocryst with complex oscillatory zoning, moth-eaten appearance, and calcic-cores with pyroxene groundmass that is more likely to be hypersthene than pigeonite, P.Jakes, J.G, (1970). Calc-alkaline series often characterised by high-alumina content approximately ~17% Al_2O_3 in basalt towards andesitic members. While for tholeiitic series, roughly is has a greater silica series SiO_2 > 52%. At any silica content they have less FeO, MgO, Ni and Cr but more K, Rb, Ba, Cs, Pb, and Sr. in island arc tholeiitic series, the composition is enrich with alkali elements.

- **Volcanic products.**

In southern Bandung, the volcanic eruptions occurred several times within a period and the parameter for the rock unit boundaries is hard to make since in a volcanic activity, one magma source can produced variation of product. According to Bronto.S, Koswara.A, and Lumbanbatu.K, (2006), based on the source of eruptions, there are nine lithologies that able to be produced with additional of rock units known as Piroklastika Pangalengan (PP). Based on the research, all sedimentary rocks placed on top of the Miocene volcanic rocks. All nine lithologies are;

a) Satuan Batuan Gunung Api Soreang(SV)

b) Satuan Batuan Gunung Api Baleendah (BV)

c) Satuan Batuan Gunung Api Pangalengan (PV)

d) Satuan Batuan Gunung Api Tanjaknangsi (TV)

e) Satuan Batuan Gunung Api Kuda (KV)

f) Satuan Batuan Gunung Api Kendang (KdV)

g) Satuan Batuan Gunung Api Dogdog(DV)

h) Satuan Batuan Gunung Api Wayang-Windu (WW)

i) Satuan Batuan Gunung Api Malabar (MV)

- **Chemistry and Petrography.**

Based on petrographic analysis in Bukit Cangkring according to Soviati, A. E., Syafri, I., & Patonah, A. (2017), the naming is used with classification of Travis, (1955). Then, the paragenesis of the compilation of lava is analysed from Bowen reaction series. It is stated in the journal that plagioclase and pyroxene crystallise together. All the samples have plagioclase, with inclusion of opaque minerals and pyroxene. This occur vice versa in pyroxene where there is also inclusion of plagioclase and opaque minerals. The mineral that inclusion other mineral is the one which occurred first that the included minerals. For opaque mineral, it shows that the opaque minerals has a texture of replacement from previous minerals. Opaque minerals are secondary minerals that formed due to alteration process in the rock. Chlorite and clay minerals in samples were secondary minerals, showing the occurrence of primary minerals before secondary minerals existed. Both of these minerals replaced plagioclase and pyroxene in rocks.

In geochemical analysis using X Ray Fluorescent (XRF), the characteristics of the rocks, magma source and depth of the magma can be identified. Magma series of tholeiitic and calc-alkaline series is important to determine to know the source of magma using AFM diagram by Irvine, T.N. and Baragar, W.R.A. (1971). In Bukit Cangkring area, Kecamatan Baleendah the area consist of both tholeiitic and calc-alkaline magma series. The magma series can also be classified by Peccerillo and Taylor (1976) using potassium (K2O), and silica (SiO2). To determine the magma source, Pearce, J.A., and Gale, G.H., (1977) is used to plot the content of K2O, TiO2, and P2O5 in ternary diagram. Based on the data obtained in the research, the magma source is from the continental crust. Through this magma source, tectonic setting where the magma form the rocks are divided into 5 parts based on Mullen (1983), which are Mid Oceanic Ridge Basalt, Island Arc Tholeiite, Island Arc Calc-Alkaline Basalt, Oceanic Island Tholeiite, and Oceanic Island Alkaline Basalt. These magma tectonic setting can be determine based on the percentage of TiO2, 10x MnO, and 10xP2O5 which are later plotted in ternary diagram. The data ni Bukit Cangkring showed that the magma that form the volcanic rocks is Island Arc Calc-Alkaline Basalt based on the ternary diagram of Mullen (1983).

CHAPTER 3

MATERIALS AND METHODOLOGIES

3.1 Introduction.

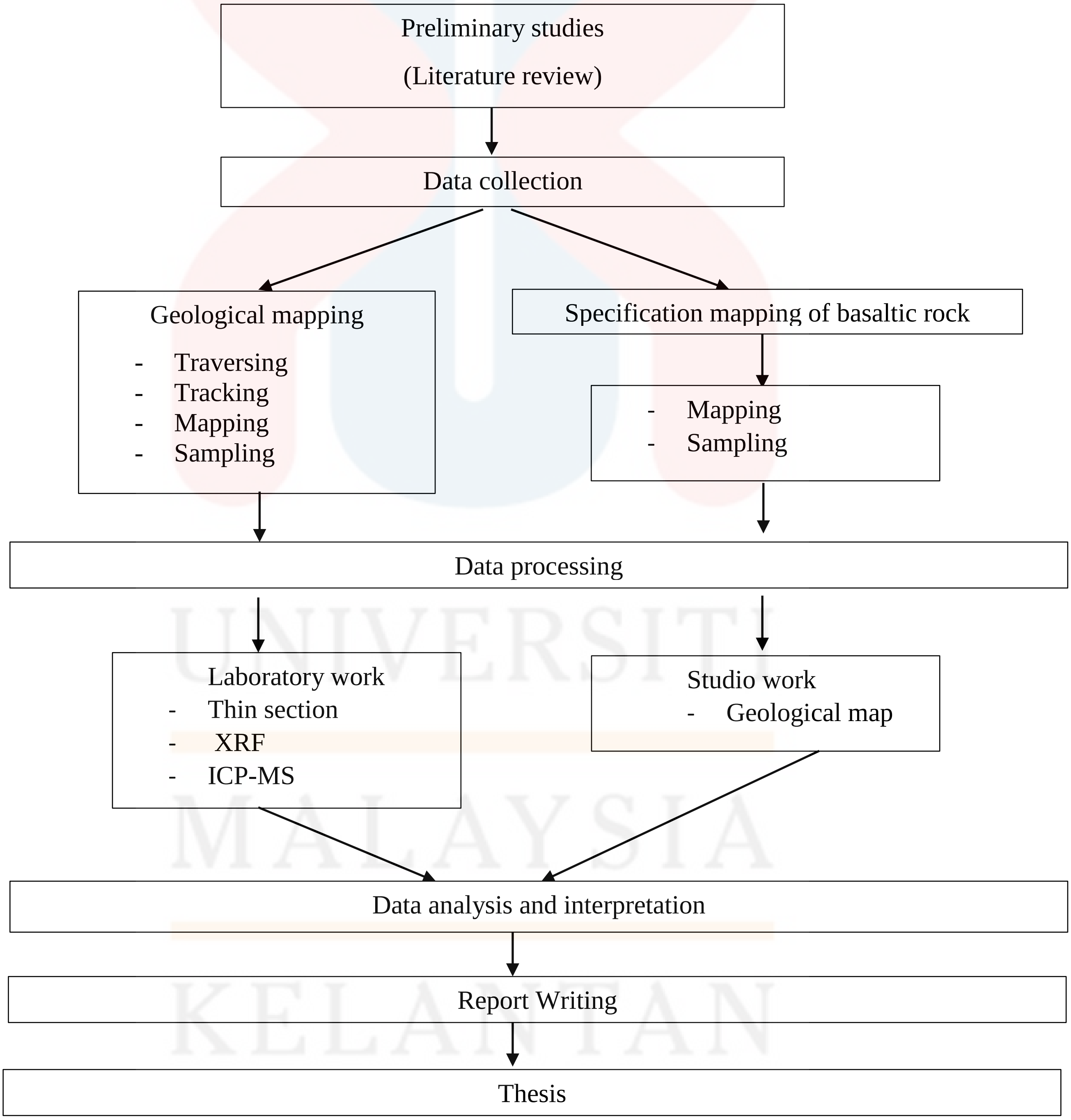
Specific materials and methodology is used in order to conduct geological mapping systematically. A systematic planning helps student to achieve the objective of the research within the timeline. Based on previous research, few methodologies had been chosen to be conducted in this research.

3.2 Materials.

Several equipment is used in conducting geological mapping. The required equipment are the common tools used in geological mapping, such as geological hammer, Global Positioning System (GPS), Brunton compass, sample bags, digital camera, stationery, measuring tape, clipboard, notebook, and polarizing microscope for laboratory work. Another important tools for geological mapping is the software used to digitised required study area. The software used is ArcGis v10.2 ESRI Company.

3.3 Methodology.

Methodology is a body that consists of methods, or rules that employed by a specific procedure or a set of procedure in the research that is very important in obtaining best results.



3.3.1 Preliminary studies.

Preliminary studies is an initial step taken to gather information that is related to the research field. The process is done by revising and reading previous research articles and scientific journals, and professional publications. The source of the information and input is very important since it needs to be used as a citation. Preliminary studies is done on the geomorphology of the study area, structural geology, stratigraphy and local population for the area . Preliminary studies is very important in data preparation and collection for the use of future project and site visiting.

3.3.2 Base Map and Equipment.

Preparing a base map is important as it will be used to plan the route and traverse for geological mapping. With the help of the base map, plotting and analysing geological structures is easier before going to the field. The study area is enlarged with the scale of 1:25000 that equals to 1cm on the map is 250m on earth. Software that will be used to produce geological map is the ArcGIS v10.2 ESRI Company. There are few equipment needs to be prepared before going to fieldwork. This includes geological hammer, Brunton compass, Global Positioning System (GPS), sample bags, digital camera, stationery, clipboard and notebook.

3.3.3 Fieldwork or Geological Mapping.

Fieldwork is a process of gaining, collecting and observing all the geological structures and information by traversing the research area. Faults, folds, lineament, lithologic sequence, weathering process and landforms that will be observed is the key to the history. Any geological features is recorded such as the outcrop features, and samples are taken to observed and analyse in the laboratory. Strike and dip reading has to be plotted on the map for further analysis and reference.

3.3.4 Sampling.

Rock samples that are collected from the site are needed for petrographic analysis. The samples are needed to study the accuracy of the rock name and rock type for lithology of the research area. It is important to collect fresh samples for thin section process, as weathered rocks tend to have altered chemical compositions. Thus, the accuracy of the results will be low. Samples taken are best to be labelled on the spot with the chronological numbers and coordinates of the location to avoid confusion and mistakes in the laboratory.

3.3.5 Laboratory work.

After geological mapping or fieldwork, all the rock samples are taken to the laboratory for petrographic analysis. Thin section is done to analyse the sample under polarized microscope. The minerals and texture can be determined accurately, and the name of the rock is more precise and can be proved scientifically. This stage act as a scientific arguments and evidence for the lithology of the research area.

- Thin section.

A 1cm thick is cut from hand specimen. The chip is mounted on a grinder for a smooth surface on one side of the chip. The grounded surface is lapped on a piece of glass using Silicon Carbide Powder. Once the surface had been polished, the chip then mounted onto another glass slide using Canada Balsam that set on a hot plate for 120C. Next, the chip is trimmed to obtain thinner rock slide using a trimmer machine. The grinding process is repeated to get a very thin slide. The sample is lapped until it is 50 µm thick, and will left 20-30 µm thick with a final polish Lastly, the cover glass is cemented on top with a material used before. There should be no air bubbles trapped in between the cover glass and the glass slide.

- XRF.

Most of the time, XRF is used for minor and trace element analysis, this method is also can be used to determine major elements. A proper preparation needs to be done carefully together with the use of proper devices to prevent contamination in the sample. The basic materials used are for example mills, mortars and pulverisers that are made of agate, silicon carbide or tungsten carbide. Grain size often affect the XRF analysis, grinding is needed to reduce the particle size (International, A., & Agency, E. (1997).

Before starting any analytical procedure, the mineral samples are cleaned and prepared. Then, selection of mineral grain through handpicking under a binocular is done, usually very slow and tedious. Thus, it is recommended to select only important and desired samples. Next, in powdered samples, it is usually prepared by using binders, although in some journals they suggested to use small sample pellets that weight 1.5 g, but sample amount is usually reach lower value. Next after grinding, the sample is needed to be sieved to obtain particles smaller than <60 µm. then, the sample is mixed with the binder and pressed. Then the sample is obtained on the pellets.

3.3.6 Data analysis.

From all the stages above, all the data gained based on the preliminary studies, geological mapping, laboratory work and data processing can be used and combine to interpret the characteristics of the study area. Field data can be used for further analysis and interpretation such as interpreting the forces on certain geological structure and its relationship with the geomorphology and lithostratigraphy of the study area.

a) Igneous rock classification (Streckeisen, 1973).

To classify igneous rocks in this thesis is by using parameters of Q, A, P and F comprise of felsic minerals, including M which is mafic minerals. Sum of Q+A+P+F+M must be normalise to 100%. Then, the data and information is plotted onto the QAD diagram by Streckeisen, (1973; 1976).

b) Diagram of geochemical analysis.

From XRF analysis, the data obtained are major elements and trace elements. The major elements are needed to normalise before plotting in diagram of analysis. The first diagram of analysis is AFM diagram of Irvind and Baragar (1971), to check the magma series either the rock samples in Kp.Cipeuteuy is from tholeiitic series or calc-alkaline series. Next, is by plotting a diagram of Peccerillo and Taylor (1976) with K_2O vs SiO_2 to represent alkalinity of magma.

The type of rocks in the study area is important to be classified, once the magma source is known. Through Le bass (1986), igneous rocks are divided based on the percentage of Total Alkali Silica (TAS). These classification is specific for volcanic rocks which the geochemical data of Na_2O+K_2O (Alkali Total) and SiO_2 (Silica) is used.

Next step, is to know the geochemical evolution and the paragenesis of the magma in the study area. Based on the XRF data, Harker diagram is used. This diagram shows variation diagrams by plotting element or oxides are plotted against SiO_2. SiO_2 is always used in plotting since silica is able to show a wide range of values which is from ultramafic to acid. For minor and trace elements, the percentage can be plotted against major element oxides. Trace element diagram can identify magmatic differentiation and fractionation process that can be observed through chemical trend. Magma differentiation is able to study. A straight line produced indicates the magma mixing and assimilation.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter specified in Kp.Cipeuteuy located in Kabupaten Bandung, West Java. Geological mapping was done for 2 weeks period to collect lithological data, structural data, hand specimen data, morphological data produced complete geological map of Kp.Cipeuteuy at the end of this chapter.

a. Brief content

This chapter discussed the geomorphology, petrology, stratigraphy, structural geology, and historical geology of the Kp.Cipeuteuy. Geomorphology includes precise observation and description on the division of morphology, description of river pattern, which includes type of river, genetic type used to further discuss about the processes occurred within Kp.Cipeuteuy.

b. Accessibility

The area can be classified as sub-urban area, where it has an easy access from one place to another. The area is easily traversed during the mapping process, as shown in the traverse map. Almost 80% of the area is reachable. The area is connected with bituminous road, and also non-bituminous road in certain part of the area, especially in vegetation and terraced plantation area. The main entrance to the box from the basecamp is through Jalan Raya Banjaran as shown in the map below.

Figure 4.1: A is the location of the basecamp, SPLPP-Faperta UNPAD, B is the Jalan Raya Banjaran, and C is the centre of study area known as Kp. Cipeuteuy.

c. Settlement

A settlement pattern is referred as shape of a settlement that mainly influenced by the landscape of an area. A settlement can be divided into two types which are rural and urban. Both is differentiate by their function. For rural areas, it is dominated by primary activities. But for urban area, it is dominated by secondary and tertiary activities. Another obvious different is the population, where in rural areas it is composed of lower density of population in comparison with the urban. The area is under the category of rural settlement, since the population is small. With a small range of population, the gap between each houses with one another is small. Based on the Banjaran's population in Bandung, it is populated by 164,952 populations (source: https://www.maps-streetview.com/Indonesia/Banjaran) as compared with Jakarta city population, which is estimated to be over 10 million (source: http://worldpopulationreview.com/world-cities/jakarta-population/).

Settlement pattern.

Based on the Human Resources development of India, module 9 the types of rural settlements consist of four categories, which are:

- Compact/clustered/nucleated settlement
- Semi-compact/semi-clustered/fragmented settlement
- Helmeted settlement
- Dispersed settlement

Based on the study area, the area mainly consist on compact/clustered/nucleated settlement type. From the name itself, it represents the characteristics of this settlements. The settlement is closely build up in the area. Settlements are concentrated in central site, and there is presence of small gap separating the housing areas from farms and vegetation. Living in compact settlements bring few advantages to the population. One of the advantages is it can ensure security and defence, and maximise the usage of natural resources such as underground water and cultivation land in an area. The development of cluster settlement must be influenced by external factors too, where the most important factor is the intervening street patterns. Based on these few external factors, there are 5 major patterns. These patterns are: a) Linear pattern b) rectangular pattern c) Circular pattern d) Square pattern e) Radial pattern.

In the study area, specifically there are few pattern developed following the channels of road pattern. Based on the observation, there are two patterns saw in the study area that are going to be discussed, which are linear pattern and radial pattern.

a) **Linear pattern:** The housing pattern follows along the main road, railways, streams and many more. The houses are constructed in a single row along the main road or arteries.

b) **Radial pattern:** The housing pattern follows the road pattern, where the streets is converge from one centre. The centre could be the source of water, hills, and a centre of commercial activities or just an open space.

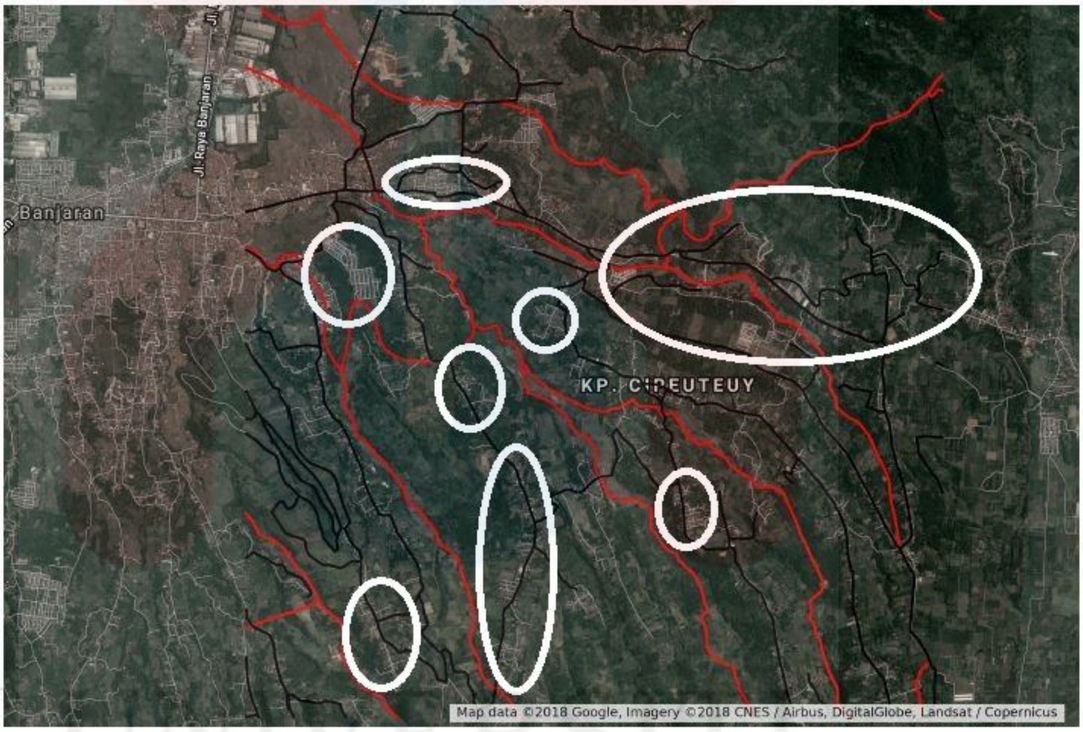


Figure 4.2: The photo shows both linear and radial pattern in the study area. Red line; main road, Black line; streets, and white circle; settlement.

d. Forestry and vegetation

In Kp.Cipeuteuy, the name is pronounced as (Ci-pe-tai) by the locals that brings out the meaning of “Ci” as ‘a-lot’, and ‘Peuteuy’ as ‘Petai’ that is also known as “Stinky beans/bitter beans” in English. Thus the study area is name after the presence of a lot of stinky beans in that area by the locals. From the name itself, it shows that the area is a flourishing land, with a lot of agricultural activities on the land. Most of the area is covered with vegetation that become the source of economy to the villagers. Based on observation, the area is mostly covered by paddy field, and other vegetation field such as sweet potatoes and sugar cane.

The study area comprises 25km^2 land, covered 50% by forestry area, and another 50% is developed into housing and economic area. The topography of the area comprises various landforms, from flat area to hilly-mountainous area in Gunung Geulis. The elevation ranges from 668m to 1100m. The presence of volcanic soils come from the product of weathering from quaternary volcanic activities. The soils comes from the parent rock of tuff and andesite that produces high fertility rate towards vegetation due to its permeability and porosity. During the period of July-September 2018, the study area is influenced under the dry season where the rainfall rate is null.

Figure 4.3 : Dried outcrop land due to seasonal dry season. The land is used to be covered by paddy.

Figure 4.4: Study area mostly covered by outcrop land, but dried out due to dry season. This land is used to be planted with sweet potatoes.

Based on the figure above, it shows that the land is high fertility. The soil is the product of tuff, which undergone high rate of weathering.

e) Traverse and observation.

In the study area that comprises 25 km^2 in total, almost 80% of the area is successfully traversed. The basecamp is located in SPLPP-Faperta UNPAD in Jalan Raya Laswi, Jelekong, Baleendah, Bandung, Jawa Barat 40375, Indonesia. From the basecamp, the box is access through Jalan Raya Banjaran that is located southern-west of the study area.

4.2 Geomorphology.

4.2.1 Geomorphologic classification.

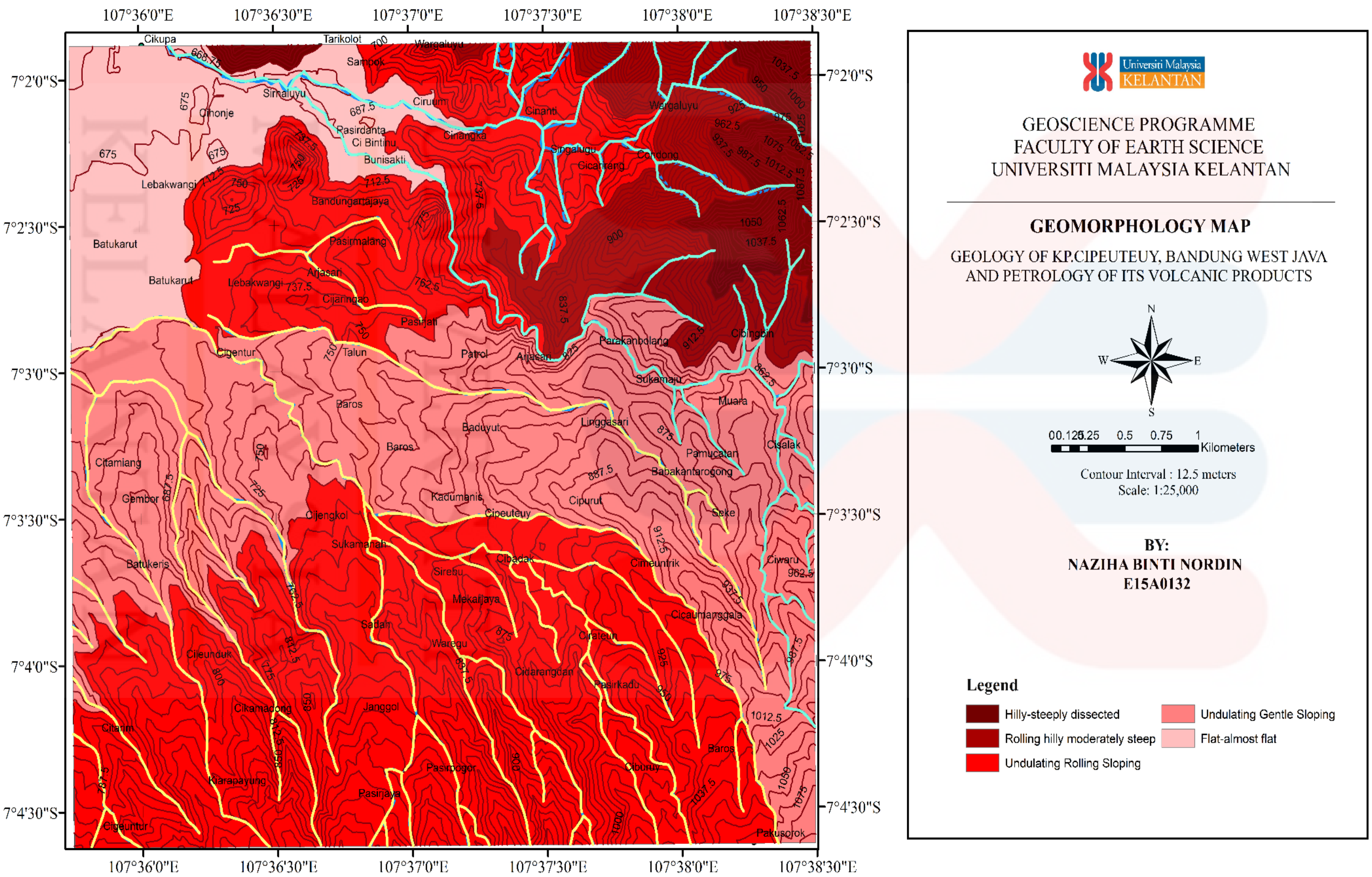
The most common method use to define geomorphology as the study of descriptive geomorphological landforms and processes and its relationship between landforms and its processes. The Earth is very dynamic thus the processes varies the landscape on the earth as shown in Table 4.1.

Table 4.1 Van Zuidam's elevation classification.

Absolute Elevation	Morphology element
< 50	Lowland
50-100	Low –lying plain
100-200	Low Hill
200- 500	Hill
500- 1500	High Hill
1500- 3000	Mountain
>3000	High Mountain

Table 4.2 Slope edge classification by Van Zuidam, (1985).

Slope	Explanation	Classification USSM	Classification USLE
0-2	Flat-almost flat (dark green)	0-2	1-2
3-7	Undulating/gentle sloping (light green)	2-6	2-7
8-13	Undulating rolling/sloping (light yellow)	6-13	7-12
14-20	Rolling – hilly/moderately steep (dark yellow)	13-25	12-18
21-55	Hilly-steeply dissected (pink)	25-55	18-24
56-140	Steeply dissected-mountainous /very steep (red)	>55	>24


Universiti Malaysia KELANTAN
GEOSCIENCE PROGRAMME
FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN
GEOMORPHOLOGY MAP
GEOLOGY OF KP.CIPEUTEUY, BANDUNG WEST JAVA
AND PETROLOGY OF ITS VOLCANIC PRODUCTS
N
W
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NAZIHA BINTI NORDIN
E15A0132
Legend
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107°38'0"E
107°38'30"E
7°2'0"S
7°2'30"S
7°3'0"S
7°3'30"S
7°4'0"S
7°4'30"S

Based on geomorphological classes that has been describe by Van Zuidam, (1985), the highest elevation in the map is noted to be 1100 m, while the lowest elevation is 668 meters. The average is 216 meters, where it lies under *hill* category where the range is from 200-500 meters. The morphology is then categorised according to the slope angle, calculated with a formula based on Van Zuidam (1985) which is $S_{xy} = (\frac{(n-1)I_c}{D_x.S_p} \times 100\%)$;

S_{xy} = Slope percentage

n = number of contour lines

I_c= contour interval

$D_{x.S_p}$= (length on map).(scale of map)

With the formula above, the study area is classified with five classes of slope angle which are *hilly-steeply dissected, rolling hilly moderately steep, undulating rolling sloping, undulating gentle sloping and flat-almost-flat* sloping from steep to flat respectively. Geologically the morphology of the slope is always influenced by the lithology of the area. Thus different slope classes might represent different lithologies as explained below.

i. Hilly-steeply dissected

In this morphology class, the study area composed of steep hills that has elevation range from ± 1100 m to 930 m. The closest landmark point is the foothill of Gunung Geulis, located in the northern east of the map. In this class, the lithology is composed of andesite, with presence of sheeting joint and volcanic breccia.

ii. Rolling-hilly moderately steep

For this class, rolling-hilly moderately steep comes with an elevation range from ± 930 m to 825 m. The land that covers this morphology class started from the foothill of Gunung Geulis, located in the northern east of the study area to downwards. The elevation started to decrease, as the steepness of the slope is decreasing. The lithology in this class is composed of the same type of andesite, but the presence of breccia is not found during the traverse.

iii. Undulating rolling sloping

Undulating rolling sloping class has an elevation range of ±800 m to 700 m. The land is covered by settlement area, with medium rate economic activities that focussing mainly in agricultural activities such as paddy and sweet potatoes planting. The lithology is composed of volcanic breccia, and andesite.

iv. Undulating gentle sloping

In this class, the elevation range from ± 900 m to 680 m and covered by terraced plantation. For this class, the land started to become gentle and less floating. The lithology in this class is tuff.

v. Flat-almost flat

This area is mainly covered by almost-flat land. The range of the elevation is approximately 700 m to 600 m. In this area, the land is mainly covered by housing and settlement area, that composed by andesite.

Figure 4.5 : Undulating rolling sloping.

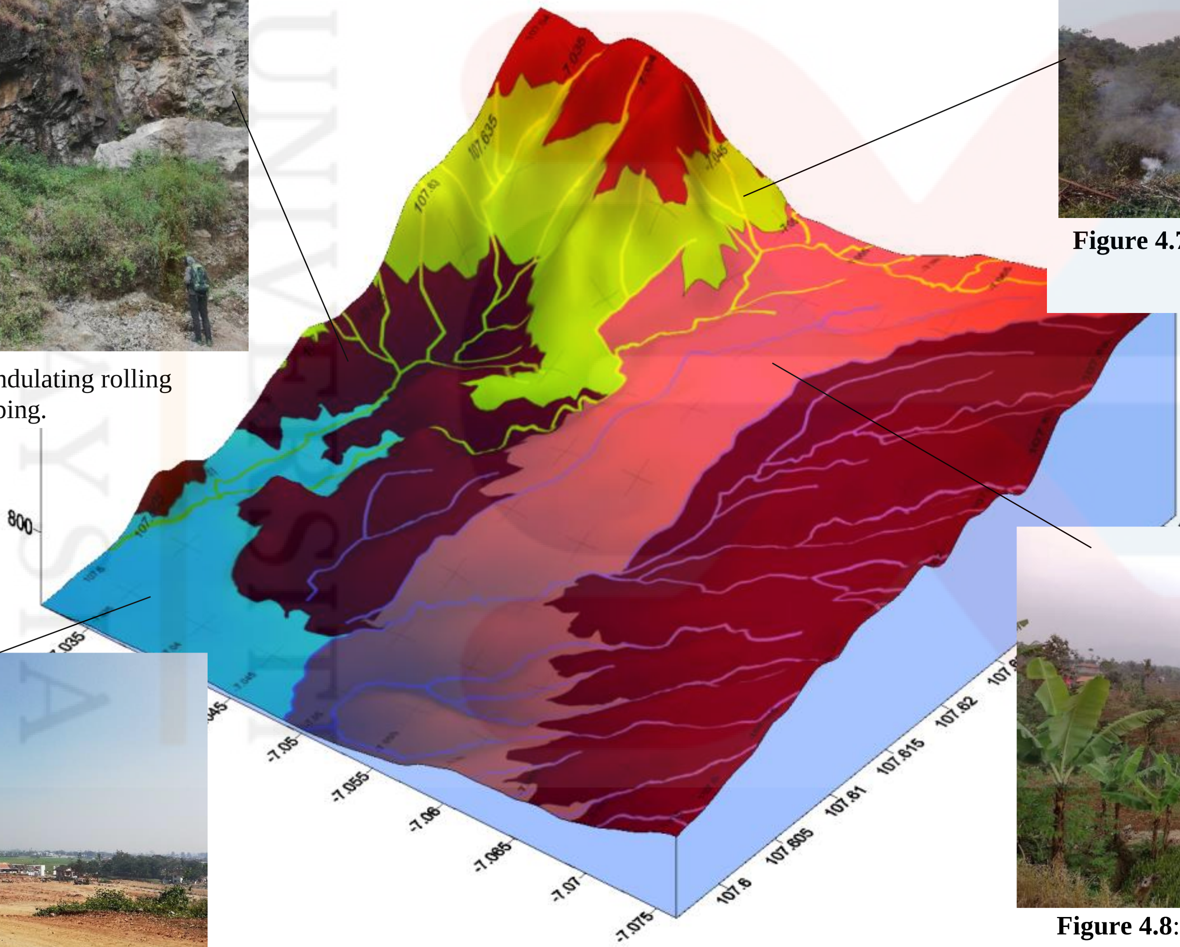


Figure 4.7: Rolling hilly moderately steep.

Figure 4.6: Flat-almost flat class.

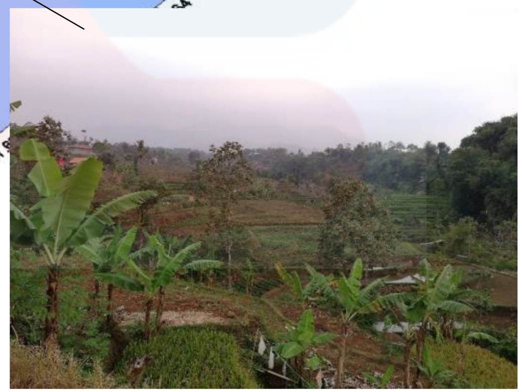


Figure 4.8: Undulating Rolling sloping.

Table 4.3: Geomorphology classification in the study area.

Geomorphology classification (Van Zuidam, 1985) **[$S_{xy} = \frac{\{n-1\}Ic}{Dx.Sp} \times 100\%$]**	**Explanation**	**Mitigation and potential land planning**	**Drainage pattern**
1) Hilly-steeply dissected	- The elevation in this class range from ±1100 m to 930 m. -Located in the foothill of Gunung Geulis. -Composed of andesite.	**Andesite** - Intermediate rock, with 50%-60% silica, high resistant to weathering. - Widely used in construction and road-making industries. - Can be used for making monuments and statues. - High resistance = making it suitable for making tiles for home decoration **Potentia**l : This area is high potential as a mining area to extract silica and other important elements for uses as mention above.	Dendritic Dendritic or tree shaped drainage pattern, composed of andesite, high resistance, steeply to gentle sloping.
2) Rolling-hilly moderately steep	- The elevation in this class range from ± 930 m to 825 m. -From Gunung Geulis to downwards. - Composed of andesite.	**Andesite** - Lava of andesitic along road cutting, no plantation, road moving upwards towards peak of Gunung Geulis. - Gunung Geulis, become one of the local attraction for its beauty in scenery and view. **Potential** Potential for tourism spot, favour interest in outdoor activities such as hiking, cycling and offroad biking.	

3) Undulating rolling sloping	- The elevation in this class range from ± 800 m to 700 m. - Settlement area - Composed of volcanic breccia, and andesite.	**Volcanic Breccia and Andesite** - Volcanic breccia with matrix of tuff , and presence of andesite. - Matrix of tuff is weathered, very high fertility, suitable for terraced cultivation. Terraced plantation give negative impact, where it changes the terrain morphology and landscape. - Andesite extracted for mining industries and change the landscape of a place.	Parallel - Tributaries are parallel to each other, follow sloping, area has uniform sloping and dipping, - Composed of tuff and volcanic breccia
4) Undulating gentle sloping	- This elevation class range from ± 900m to 680 m. - Covered by terraced plantation. - Composed of tuff.	**Tuff** - Tuff weathered, very fertile. Terraced plantation, but gentle sloping. Settlement area for villagers, agricultural activity become major income for villagers. *Bad effects* of terraced plantation is rainwater saturation, where terracing retains too much water.	
5) Flat-almost flat	- This elevation class range from ± 700 m to 600 m. - Housing and settlement area. - Composed of andesite.	**Andesite** - Area already blasted and mined. - Transform into housing and settlement area. Can see ex-mining area.	

4.2.1 Weathering

Weathering is a process where rocks are broken down and decomposed by the action of external agencies such as wind, rain, temperature changes, plants and bacteria. Weathering is the initial stage in the process of denudation. An essential features of the process is that it affects rocks in situ; which means no transportation is involved. This is the factor which distinguishes it from erosion process, Whitten, D.G.A., Brooks, J.R.V (1972).

There are two types of weathering;

a. Mechanical weathering

Mechanical weathering, which also known as physical weathering is brought about chiefly by variety processes in temperature changes and water. This refer as the expansion of water on freezing, in pores or cracks of the rocks. The differential expansion occurred in the rocks, or the rock minerals when it is strongly heated by the sun (insolution). With time, this process tend to cause thin sheets of rock to split off and creates a broken fragment or also known as detritus that categorise based on its sizes from coarse grained (boulders, cobbles and pebbles), medium grained (sand), and fine grained (silt and clay). Besides that, due to water, when the water percolates either through pore spaces or fractures, it might carried together ions which later undergone precipitation and form crystal, that can cause the rock to break as the crystal growth is exert outward. This process is called crystal growth process.

Plants also can be part of the weathering processes that is known as root wedging. Presence of plants sometimes become a factor of physical weathering when the plant root extended grew through the fractures and spaces. This cause the fractures to be expanded and when it reached the rock elastic limit, it will break into fragments.

The concept is the same applied into frost wedging, but in frost wedging, temperature changes takes place. It is known that inside of every rocks, there are pore spaces present.

Due to extreme low temperature, upon freezing, an increase in the volume of water in the pore spaces occurred. The increase in volume exerts a force outwards to the surrounding that cause the rock to break. In addition to that, in some cases, animals also can be the factor of weathering process take place. When the animals moved in a way such as burrowing, the animals' activity is able to break the rock.

Apart from those processes, another common process that occurred and mainly seen in igneous rocks is due to the development of joint. Joints, are cracks or spaced fractures with no offset showed across the fracture. Presence of offset in the fractures is known as faults. Presence of joints, is shown as the result of expansion due to relief of pressure or even cooling as the overlying rocks are removed by erosion, Nelson.S.A, (2015). The spaced between the joint enable other agents either chemical or physical weathering to enter and pass through.

Several examples were found in the study area which are;

1. Crystal growth (quartz vein).

Quartz vein fills an existing cracks in rocks. Veins are formed when external forces are acted on the tectonic plates during various process such as mountain building process (orogenesis), folding, faulting and even due to shattering during the release of pressure and also temperature. Through convection cell beneath the earth's surface, the minerals percolate and transported over time in the cracks at lower temperature and pressure. The process is repeated until the cracks are completely filled by minerals.

Figure 4.9: Quartz vein in andesite in station NN36.

2. Development of joints (Cracking and fissuring)

Presence of sheeting joints, especially in the study area that is dominated with igneous rocks, cracking and fissuring is normal. It indicates the massive zones of weakness where the rocks tend to crack along the natural zoning that induces by physical weathering factors.

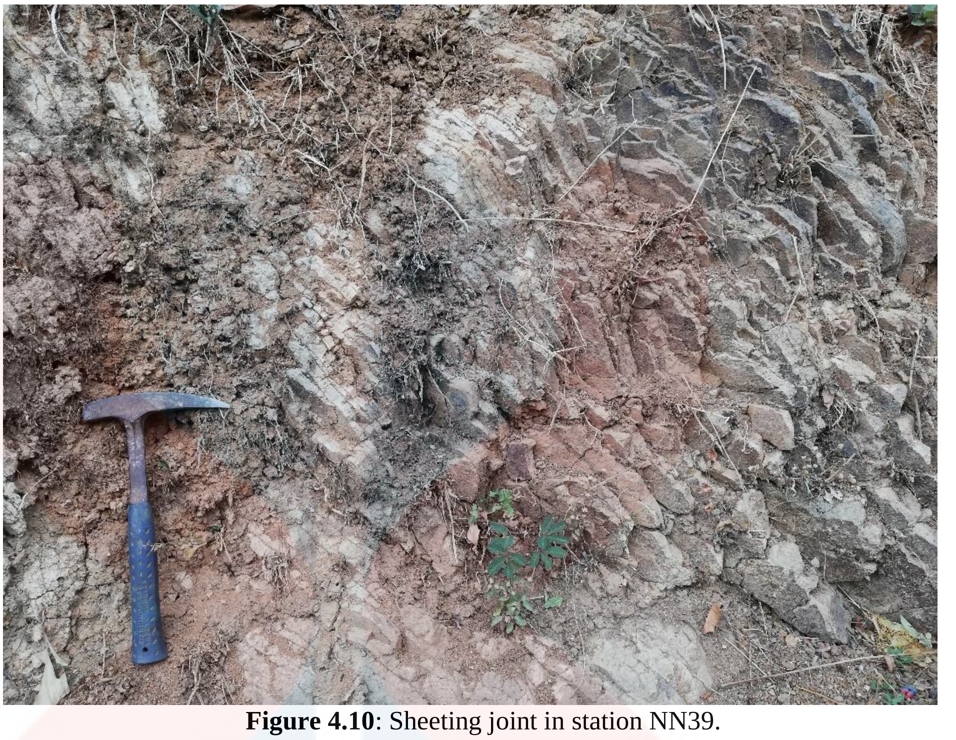


Figure 4.10: Sheeting joint in station NN39.

b. Chemical weathering

Chemical weathering is a weathering process that causes by the reaction of chemicals in any agents, mainly by water. The action is mainly brought about by the action of substances dissolved in rain water. Since different minerals that formed under different conditions deep within the earth's crust, the minerals in rocks have different stability when reacted with their new environment when expose on the earth surface. Minerals that are stable are minerals that crystallised under low temperature, from the liquid magma, for example quartz. Weaker minerals crystallise in higher temperature from the magma, for example mafic minerals such as olivine, pyroxene, biotite and amphibole.

The main agent for chemical weathering process is water and weak acids that formed in water, with condition of;

- Acid that consist of abundant free H^+ ions.

- Carbonic acid which is the most common weak acid that formed in surface water.
- The reaction of rainwater and carbon dioxide gas (CO_2) in the atmosphere will produce carbonic acid.

$$H2O + CO2 \rightarrow HCO \ \rightarrow H + HCO$$

H+ is a small ion. It can enter crystal structure easily and release the ion in the water. Based on these mechanism, it creates a few different types of chemical weathering according to the conditions that applied. Few types of reactions in chemical weathering are;

- Hydrolysis = process occurred when H^+ or OH^- replace the ion presence in the mineral water.
- Oxidation = on the earth's surface, it is more common for the free oxygen (o_2) that might react with minerals exposed, and later change the oxidation state of an ion. An example is in Fe(iron) bearing minerals that have several oxidation states which is in Fe, Fe^{+2}, Fe^{+3}. The condition for Fe^{+2} is more likely

  common in deeper earth. The example of an oxidation process is shown below;

$$3Fe^{+2}SiO_3 + \ 1/2O_2 \ \rightarrow \ Fe_3O_4 + \ 3SiO_2$$

Pyroxene Oxygen Magnetite Quartz

- Dehydration = 'de' brings a meaning of 'remove', while 'hydration' refers to the process in something to absorb water. Thus dehydration carry a meaning of removing water particles which is H_2O or OH^- ions from minerals.

- Complete dissolution = dissolution means "the action of formally ending, or dismissing", (source: https://www.google.com/search?q=dissolution+meaning&oq=dissolution+meaning&aqs=chrome..69i57.5050j0j9&sourceid=chrome&ie=UTF-8). In this context, the term refer to a condition when all minerals is completely dissolved by the water. Based on Nelson.S.A, (2015), an example is given as below;

$$CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2(HCO_3)^-$$

Calcite   Carbonic Acid   Calcium ion   Bicarbonate ion

- Leaching = according to Google Dictionary (retrieved from: https://www.google.com/search?q=dissolution+meaning&oq=dissolution+meaning&aqs=chrome..69i57.5050j0j9&sourceid=chrome&ie=UTF-8#dobs=leaching), the word leaching refers to a soluble chemical or mineral that drain away from soil, ash, or similar material by the action of percolating liquid mainly by rainwater.

- Other living organism = this includes plants, fungus, bacteria and many more that can secrete acids on the surface of the minerals that can cause dissolution according to Nelson.S.A, (2015).

There are few example that were found in the study area as listed and describe below;

1) Spheroidal weathering.

According to Ollier, C.D, (1971) spheroidal weathering is referred when concentric shells is completely surround a corestone, and is distinguish from other types of exfoliation. In weathered boulders, there is frequently presence of corestone surrounded by number of concentric sheets or rock layers. In few cases in exposed weathered rocks, it is found rocks that contain cracks, concentric shells, and banded iron oxides in spheroidal. This type weathering often found in igneous type of rocks such as basalt, dolerite and granite, and occasionally found in gabbro and alluvial.

Figure 4.11: Spheroidal weathering.

Figure 4.12: Spheroidal weathering up-close.

Based on the figure above, the causes of spheroidal weathering was influenced by many factors. This include the influence of exfoliation process, assumed to be caused by expansion of rock when weathering process take place. Expansion process can be caused by many factors such as temperature, presence of foreign substance for example frost, salts and another factor is by the expansion due to chemical changes. Since it is igneous type of rocks, the presence of colour banding is absent, but the concentric cracks and concentric coloured zones are presence. The cracking is resulted from the shrinkage, followed by segregation and dehydration of the hydroxides. The outcrop might retain its original volume, but due to the local shrinkage it caused the rock to cracks.

Another possible assumption is due to the unloading process, based on unloading hypotheses by Ollier, C.D (1971), which explains when deep rock in the earth is slightly compressed by the overlying materials. When the overlying material has eroded off, there is still presence of residual stress acting, thus it became the factor of the outer layer is expanding to balance the force back into normal. Based on the outcrop weathering rate, it can be said that the outcrop has undergone a high rate of weathering based on the characteristics of the rock, which is volcanic breccia, where the matrix composed of tuff, as turned into red coloured soil. The component is composed of andesite that already weathered too where debris is present.

2) Oxidation and macro crack.

As explain above, oxidation is a reaction that took up free oxygen (O_2) on the earth's surface that commonly present and change the oxidation state of certain ions. Oxidation is commonly related to the presence of iron (Fe) bearing minerals. Due to oxidation process, minerals in rock tend to become less resistant towards weathering.

Figure 4.13: Rust in macro crack of outcrop.

In iron bearing minerals such as olivine and pyroxene, tend to become red in colour when it is oxidised. Thus the red stain on figure above showed the effect of oxidation process that resulted in rusting on the rocks. Observed there is a presence of cracks, and the rusting occurs along the cracks, it is assumed that the cracking started forming from a structural micro-crack. The terminology of structural micro crack is referred as cracking that formed not through weathering process but by structure for example, joints and cleavage. It can be distinguish with the term micro-crack only to refer as features that caused by weathering process. Based on the figure and field data, the crack on the picture shown is cleavages that formed on the igneous rock andesite. Along the line, there is presence of sheeting joint, and both of these features are referred as structural micro-crack.

These structural micro crack act as an initial stage of weathering. Through the cracks, original water in pores, or water from external sources such as rainwater, flow through the openings and through time causing segregation of iron hydroxides.

3) Oxidation.

This type of chemical weathering is found in different location, which is in NN41, (refer station map). The igneous rock andesite undergone oxidation process, causes rusting in the outcrop.

Figure 4.14: Station photo in NN41.

Figure 4.15: Rusted outcrop on the inside due to oxidation of iron (Fe) bearing minerals.

These rocks has turned to rust with the process of oxidation. As the rust expanded through the outcrop, it weakens the rock and enable it to easily break apart. Above is andesite that can be easily break

c) Soils (Interaction of both physical and chemical weathering).

Soils are considered as weathering product that consist of rock and sediment that has been modified by physical and chemical process and interaction, with the help of few agents such as organic material or rainwater which over a period of time, produces a product that able to support the growth of plants. In the study area, the area can be said 60% is covered by soils that are very fertile that able to support the villagers with the economic activities from it. Soils are very important natural resources, since it is a medium that provide nutrient to the plants. The organic material in the soil is received from the decomposition of decaying plants and animals in the form of carbon.

When the soil is developed on a rock layer, a soil profile is formed. Though it form layers, these layers are different from sediment bedding, instead each layer is formed and grows in place through weathering process and addition of organic material from decayed plants and roots, or animals.

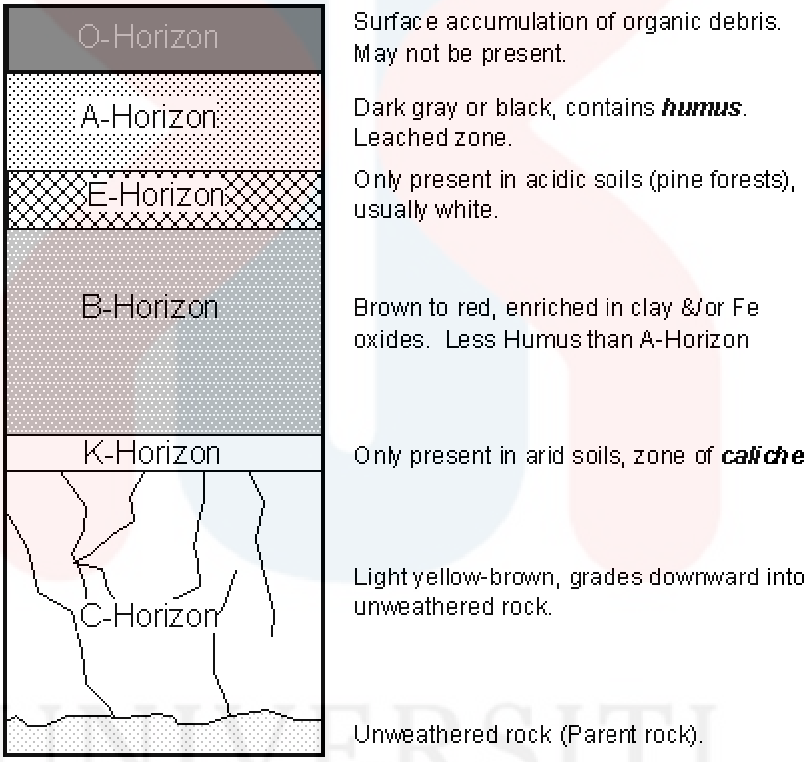


Figure 4.16: Soil profile and description of each layer, Nelson,S.A, (2015).

In this terminology, caliche is when calcium carbonate (calcite) is formed in arid soils in K-horizon through precipitation of calcite. The Ca and Carbonate is dissolved from upper layers and then later precipitated in K-horizon. In arid climate, water is limited and the present amount of water is not enough to completely dissolve this caliche, and resulted in thickening layer of caliche through time.

While laterites, occurs in humid tropical climates that has intense rate of weathering involving leaching process, that leaves behind a soil rich in iron (Fe) and aluminium oxides (Al), which resulted the soil to have deep red in colour. This extremely leached soil is called laterite.

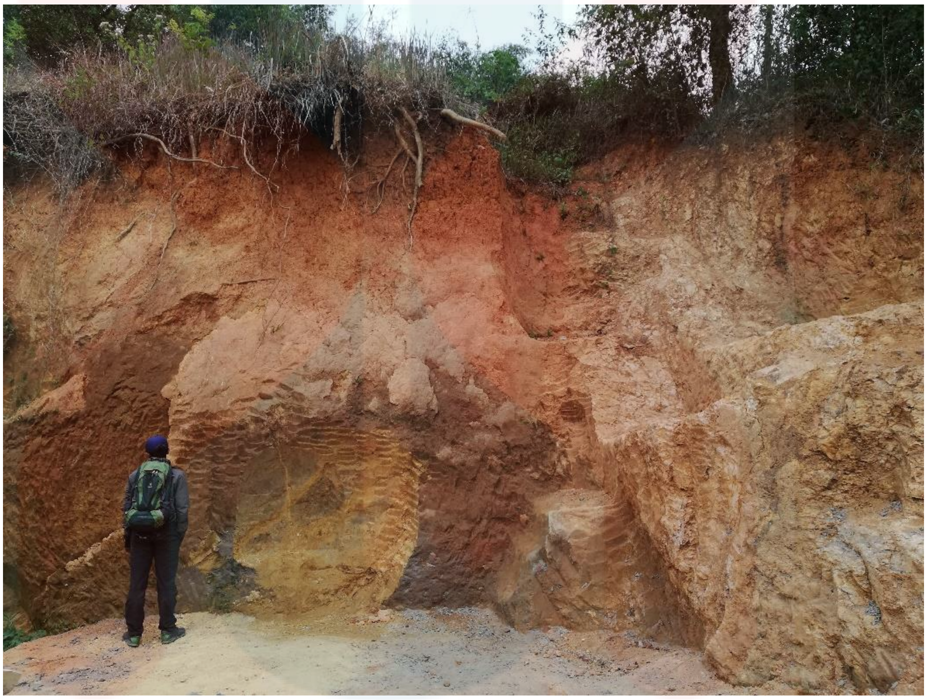


Figure 4.18: Laterite in soils.

Based on the figure above, the red coloured soil is massive. This is called laterite as it contain high amount of iron oxide.

Figure 4.19: Laterite layer in soil.

The upper layer shown on figure has darker brown compared to bottom layer. From above, it can be classified as A-horizon and B-horizon. A-horizon contain humus, and carbon from the accumulation of organic material which is from the plants in the upper layer, and B-horizon is rich in iron oxides but contain less humus compared to A-horizon. Thus it is noticeable the gradation of colour.

4.2.2 Drainage Pattern

In a drainage system of an area, it formed by series of streams, rivers and lakes is a drainage basin. Drainage pattern is important as it is related to other geological factors such as topography, soil type, bedrock type, climate, vegetation, transport of sediment and water. It can reflect geographical characteristics of a river network to a certain extent. In this study area, there are two type of drainage pattern which are dendritic pattern and parallel pattern. These drainage pattern is classified based on few indicator as explain as below;

1) Dendritic pattern

Dendritic pattern is known as the most common form of river system. It shows tributaries of a main system join together in a shape analogous to the twigs of a tree Zhang, L., & Guilbert, E. (2012).

i) Contour pattern

Based on the drainage pattern map, it is observable the contour pattern in dendritic drainage has steeper sloping. The contour sloping difference causes differences in the flow of water from tributaries to the main channel. The flow of the tributaries is freely, since the rock is highly resistance towards weathering and erosion. With time, it produces dendritic pattern drainage system.

ii) Lithology

After the recognition of contour patter, the lithology data is matched. The lithology of the area is mainly composed of andesite. Dendritic pattern is most likely to develop in massive crystalline rocks that implies a lack of structural control.

Moving down the contour, the number of tributaries are increasing and captured by larger valley.

As a supportive data, to recognise the dendritic pattern drainage using Google Earth is easy according to few geometric quantitative indicators according to Zhang.L,(2012), as explained as below;

- Angle: Usually in dendritic pattern, the tributaries are joined together at an acute angle which is < 90°
- Sinuosity: This feature is used to distinguish between dendritic and rectangular pattern. The shape of the tributary is observed, if it is rectangular pattern, the tributary streams are bended almost to right angle. According to Schumm (1977), the sinuosity of a stream is set as a ratio between the channel lengths to the valley length. If the value of the sinuosity ratio is equal or greater than 1.5, the channel is considered to be meandering. Based on the drainage pattern map, the dendritic drainage is almost reaching 90°
- Length ratio: The ratio of tributaries to main stream. In dendritic, the length is not included as an indicator since it is difficult to be calculated due to the length of tributaries is vary towards the main stream.
- Catchment elongation: This terminology brings a meaning of characterisation by the ratio of the depth to the breadth of the Minimum Bounding Rectangle (MBR) of the catchment. If the catchment is elongated, the ratio will be large. But for dendritic, the pattern formed in small and shorter tributaries, thus it has an elongation of less or equal to 1.

2) Parallel pattern

Parallel patterns are usually found in pronounced slope or structural controls leading to almost parallel to parallel streams. As described in dendritic pattern drainage, the parallel pattern is classified based on;

i) Contour

In the area covered by parallel pattern streams, the contour has gentle to rolling sloping. There are certain area that has steep slope, but with some relief. The parallel pattern is develop due to the parallel region, which is the outcrop that elongated followed the slope on the surface. The slope contour interval has larger gap compared with dendritic pattern drainage system.

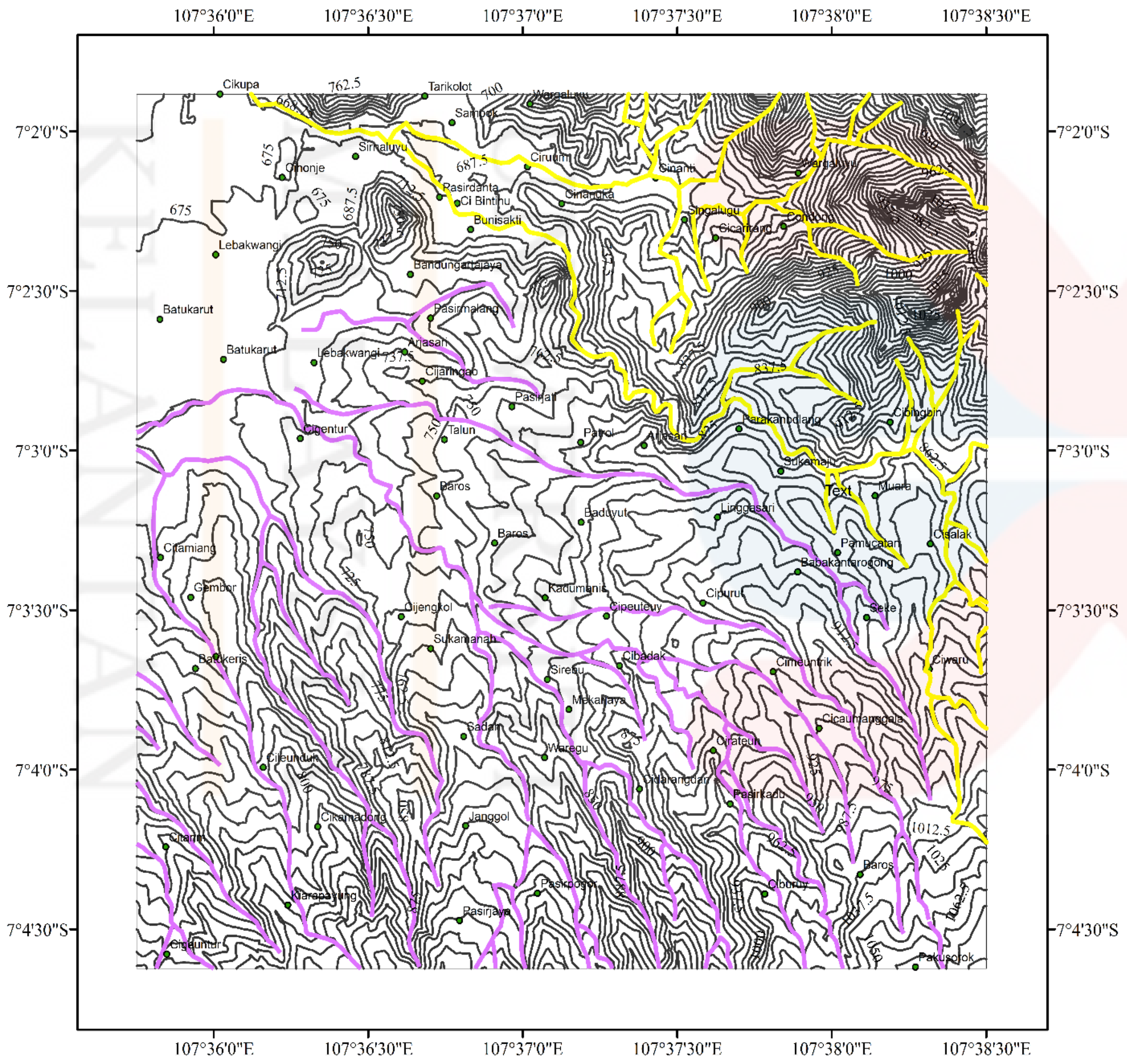
ii) Lithology

The land that covered with parallel pattern in the study area is mainly composed of volcanic breccia and tuff. Volcanic breccia and tuff has lower resistance towards weathering.

To support the data of the parallel pattern drainage is easy according to few geometric quantitative indicators according to Zhang.L, (2012), as explained as below;

- Angle: Usually in dendritic pattern, the tributaries are joined together at an acute angle which is smaller <<90°.
- Sinuosity: The sinuosity in parallel drainage system is smaller that 90°.
- Length ratio: The length ratio can be used to differentiate between trellis and parallel drainage patter. As for parallel, the length ratio should be equal or smaller than 90°.

- Catchment elongation: In parallel pattern, the form of elongated catchment is characterised to have high elongation, which is more than one.



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DRAINAGE PATTERN MAP

GEOLOGY OF KP.CIPEUTEUY,BANDUNG WEST JAVA AND PETROLOGY OF ITS VOLCANIC PRODUCTS.

N E S W

0 0.15 0.3 0.6 0.9 1.2 Kilometers

Contour Interval : 12.5 meters
Scale : 1:25,000

By:
NAZIHA BINTI NORDIN
E15A0132

Parallel Pattern

Dendritic Pattern

4.3 Lithostratigraphy.

In this terminology, stratigraphy is the study of layered sequences of sedimentary or volcanic rock that conform with the principle of superposition. Lithostratigraphy is a geologic rock unit that conform to the principles of superposition. Regionally, the study area is covered by three different formations according to Alzwar.M, Akbar.N and Bachri.S (1992) which are Beser formation, Waringin-Bedil,Old-Malabar and Malabar-Tilu formations with the relative age oldest to youngest respectively.

There are few procedures that neede to be followed in establishing lithostratigraphic units which are;

1) Stratotype and type of localities.

For each lithostratigraphic unit, it should have a clear and precise description and characterisation. In the study area is mostly covered by non-layered unit, thus type of localities is important to support the definition of the unit.

2) Boundaries

Boundaries are placed when there is an occurrence of lithologic change in the study area. It is important to traverse almost all the area to note down the lithologic change. But, it is hard to notice an obvious changes in the field. Thus with precise data collection and observation, any zones of vertical or lateral lithologic gradation or interfingering is marked. The most dominant rock is mark as boundaries in an area.

3) Uncomformities and hiatuses.

When there is a separation of regional uncomformities, or major hiatuses it is considered and mapped as different lithologies. But, if it is minority, either hiatuses, diconformity, or unconformities it is not considered as different lithostratigraphic unit.

Since the area is covered by quaternary volcanic product, any structure is very hard to identify. Any contact of rock layer is not found, thus the differences in lithologies is mapped and marked as unconformities.

Once these physical appearance is mapped, the data is correlate with other geological evidence such as vegetation, structure (if present) and contour pattern. Once the study area is divided according to its lithologic unit, the naming of lithologic unit is made based on few criteria;

1) General

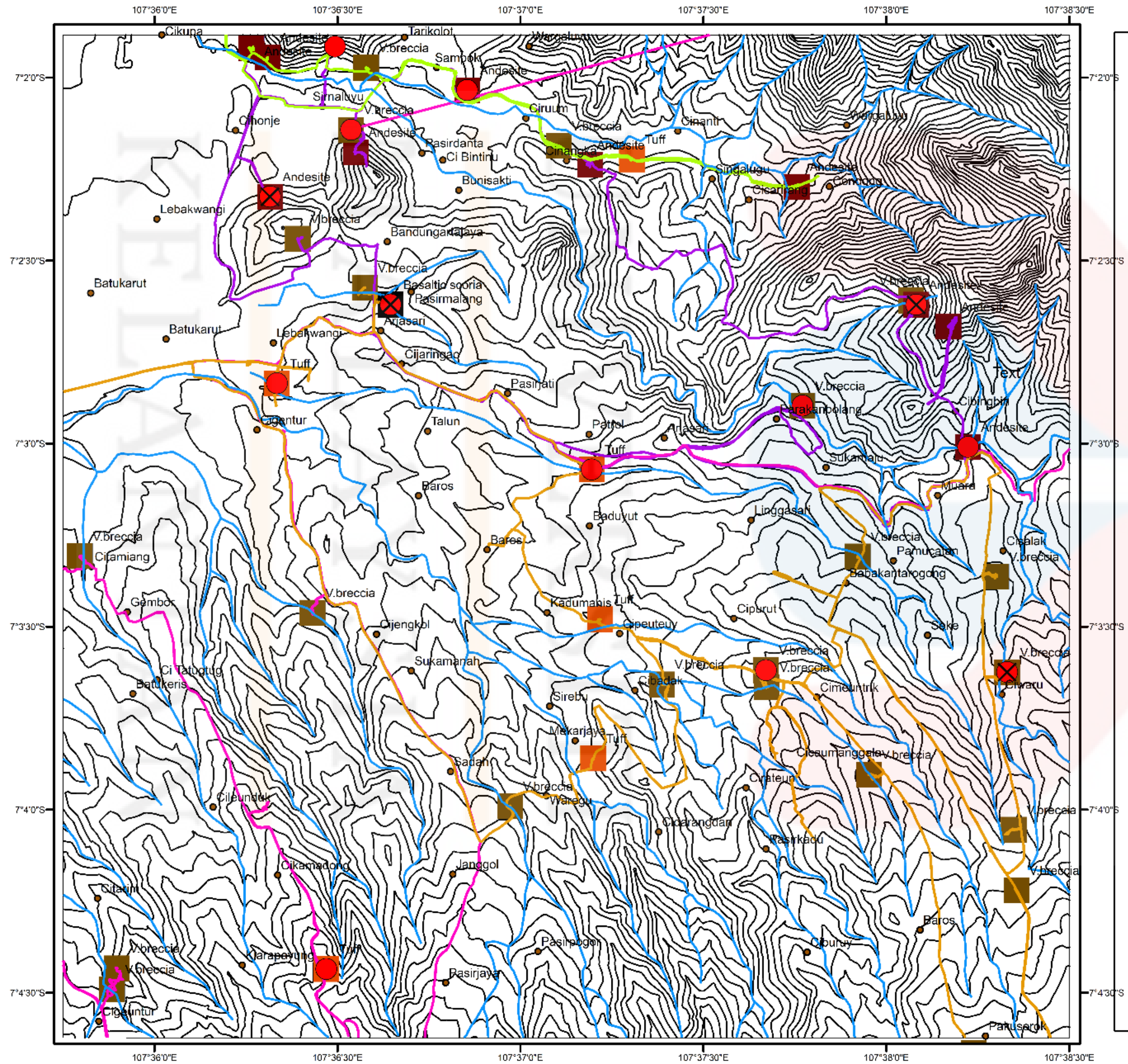
The name of lithostratigraphic units mainly follow the general rule that is based on the dominant rock type of an area. This general naming of lithostratigraphic unit is used during an initial stage of naming the unit in this research. This is to differentiate each unit based on the samples collected. For example, in the northern part of the study area, it is named as andesite, although in the station map there is presence of volcanic breccia since andesite is dominant in the area.

2) Geographic component of name.

This refer when there is changes laterally in lithological composition, causes by regional changes that occurred majorly in an area. For this stage, minor changes is considered as undesirable.

3) Lithological composition

This can help in naming the lithological unit precisely based on the mineral composition. The study of mineral help to correlate with the rock occurrence and age. There might be same type of rock in the field, but the characteristics might be different. Different characteristics is caused by specific process for example in the study area “pyroxene andesite” and “pyroxene hornblende andesite”. Based on the fieldwork data, it is noticeable that the study area has 5 different rock units with detail differentiation with its mineral composition. The rock unit is explain in detail in table below;



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TRAVERSE AND STATION MAP

GEOLOGY OF KP.CIPEUTEUY, BANDUNG WEST JAVA AND PETROLOGY OF ITS VOLCANIC PRODUCTS

N / W / E / S

0 0.1250.25 0.5 0.75 1 Kilometers

Contour Interval: 12.5 meters
Scale : 1:25,000

By:
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Legend

Station
- Geochem analysis
- Thin section
- Track Day 4
- Track Day 3
- Track Day 2
- Track Day 1

Lithology
- V.breccia
- Andesite
- Basaltic scoria
- Tuff
- River

Table 4.4: Stratigraphic column of Kp.Cipeuteuy, Bandung

Age		Legend	Rock Unit	Explanation
Quaternary	Pleistocene	Qvb, Qt	*Qt* = Tuff *Qvb* = Volcanic breccia	**Tuff** - Light colour, weathered, in reddish coloured soil. - Area dominantly covered by terraced cultivation/plantation. **Volcanic breccia** - Monomict, component of andesite, dark grey colour, slightly porphyritic with plagioclase feldspar, pyroxene and hornblende, matrix of tuff, crystal dominated, with presence of FeO2, weathered into reddish soil.
Quaternary	Pleistocene	Ql, Qan	*Ql* = Pyroxene hornblende andesite *Qan* = Pyroxene Hornblende Andesite	**Lava of andesite** - Presence of sheeting joint, light grey colour, porphyritic with plagioclase feldspar, pyroxene and hornblende. **Pyroxene Hornblende Andesite** - Pyroxene andesite and hornblende andesite. - Lava of andesitic with sheeting joint.
Tertiary	Late Miocene	Tan	*Tan* = Pyroxene Andesite	**Pyroxene Andesite** - Andesite alternated with volcanic breccia, andesite slightly porphyritic to porphyritic, composition of plagioclase feldspar, and pyroxene.

According to Bronto et.al, (2006) the oldest rock in southern Bandung through K-Ar analysis of lava andesite shows a result that the rock was from Miocene age. This rocks are pillowing the quaternary Gunung Wayang. The oldest formation in this area is Beser formation and intrusive rock. Based on historical volcanic eruptions, the volcanic product in southern Bandung can be divided into nine units with additional of Pangalengan Pyroclastics (PP) and Aluvium lake deposits (Al). All of these product lies on top of the Miocene volcanic rocks which existed approximately 12,0 ± 0,1 million years ago. All nine rock units are listed as;

1. Soreang Volcanics Rock Unit (SV)
2. Baleendah Volcanics Rock Unit (BV)
3. Pangalengan Volcanics Rock Unit (PV)
4. Tanjaknagsi Volcanics Rock Unit (TV)
5. Kuda Volcanics Rock Unit (KV)
6. Kendang Volcanics Rock Unit (KdV)
7. Dogdog Volcanics Rock Unit (DV)
8. Wayang-Windu Volcanics Rock Unit (WV)
9. Malabar Volcanics Rock Unit (MV)

Based on the stratigraphy of these volcanic product, the study area only covers three roc unit, which are Baleendah Volcanics Rock Unit, Wayang-Windu Volcanics Rock Unit and Malabar Volcanics Rock Unit. According to the list the order from oldest to youngest in stratigraphy of these volcanic product are;

Based on these discussion, thus the lithostratigraphic is arranged according to their age referred on literature review describe in Table. The study area is smaller, thus the description is more detailed and precise.

1) Facies analysis in determining lithostratigraphy of study area.

The terminology of facies is any rock that is characterised by the combination of lithology, texture, structures, fossils, colour, paleocurrent pattern, and depositional environment. The study area is purely composed of igneous rocks, and each rock unit is described based on its lithology, relative age, and rock distribution.

4.3.1 Tan (Tertiary Andesite) Unit.

Figure 4.20: Hand specimen of pyroxene andesite in station NN1.

i) Rock description = this rock unit is mainly composed of andesite, volcanic breccia, basaltic to andesitic composition, where pyroxene andesite alternating with volcanic breccia along the northern part of the study area. Volcanic breccia is monomict breccia. Physically, the rock is black in colour (basaltic scoria) found in NN19, vesicular. For andesite, example in NN1 is dark grey to greyish colour. It has porphyritic texture, with phenocryst composed of plagioclase, and pyroxene, groundmass made up has texture that is microcrystalline of plagioclase, mafic minerals and opaque minerals. The outcrop is presence of sheeting joint, and quartz vein. The description is supported with thin section analysis.

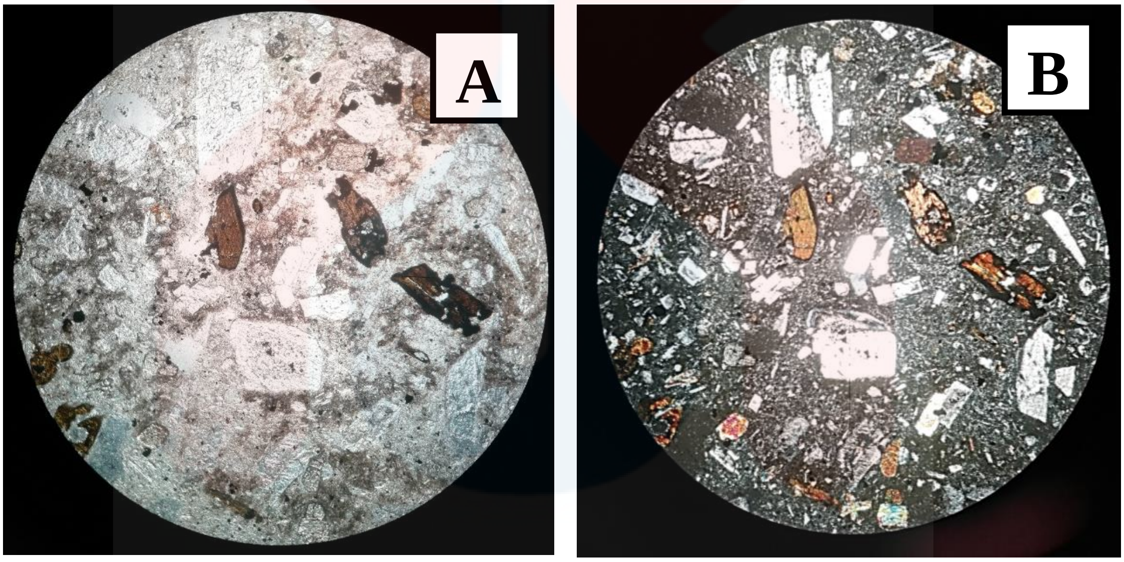


Figure 4.21*:* A is thin section under PPL with 4x10 magnification, showing low relief of plagioclase, and high relief of pyroxene; B is XPL with 4x10 magnification, pyroxene has inclusion of iron due to crystallisation process.

In this thin section it can be observed that rock has a porphyritic texture, with presence of phenocryst composed of plagioclase and pyroxene, groundmass composed of microcrystalline of glass minerals and plagioclase. Degree of crystallinity is hypocrystalline with shape of crystal range from euhedral-subhedral, has inequigranular order of crystal, and the crystal relationship is hyphydiomorphic.

Plagioclase: colourless, anhedral-subhedral, low relief (colourless), no pleochroism, presence as phenocryst and groundmass, extension angle is 39.5, in between labradorite and bytownite of plagioclase series, interference colour is greyish in 1st order.

Pyroxene: high relief (brown colour), subhedral, extension angle is 20°, parallel cleavage is seen, pleochroism is from brown to black.

Opaque mineral: black, anhedral, isotrophic, high relief(black), no pleochroism, .

Groundmass: greyish colour, presence of plagioclase and glass minerals, microcrystalline made up the groundmass.

ii) Relative age and rock distribution = Based on Bronto.S, Koswara.A, and Lumbanbatu.K, (2006) this rock unit is distributed in Kecamatan Baleendah and Kecamatan Arjasari. It is spread towards Kecamatan Banjaran and Kecamatan Ciparay. This product build up Gunung Geulis in the northern east of the study area. The characteristics of its volcanic product is lava andesite with greyish colour, has porphyritic texture and composed of plagioclase, pyroxene and hornblende. With K-Ar analysis by Sunardi and Koesoemadinata, the results shows its age of 4,08 and 4,07 million years ago. But based on the research on energy resources exploration in Malabar-Papandayan block, the result in K-Ar is in between of 4,32 ± 0,004 until 2,62 ± 0,03 million years ago. It indicates that there is twice volcanism activities that occurred which is during Miocene and Pliocene.

4.3.2 *Qan* (Quaternary Andesite) Unit.

Figure 4.22: Hand specimen of station NN4.

i) Rock description = this rock unit is composed of andesite, that has greyish coloured. The texture is porphyritic, phenocryst made up of plagioclase, pyroxene and hornblende, groundmass is made with microcrystalline of plagioclase and mafic minerals. The presence of hornblende marks the different volcanism and environment of the volcanic rocks, there are also presence of sheeting joint in station NN4. The thin section of this rock is described as below;

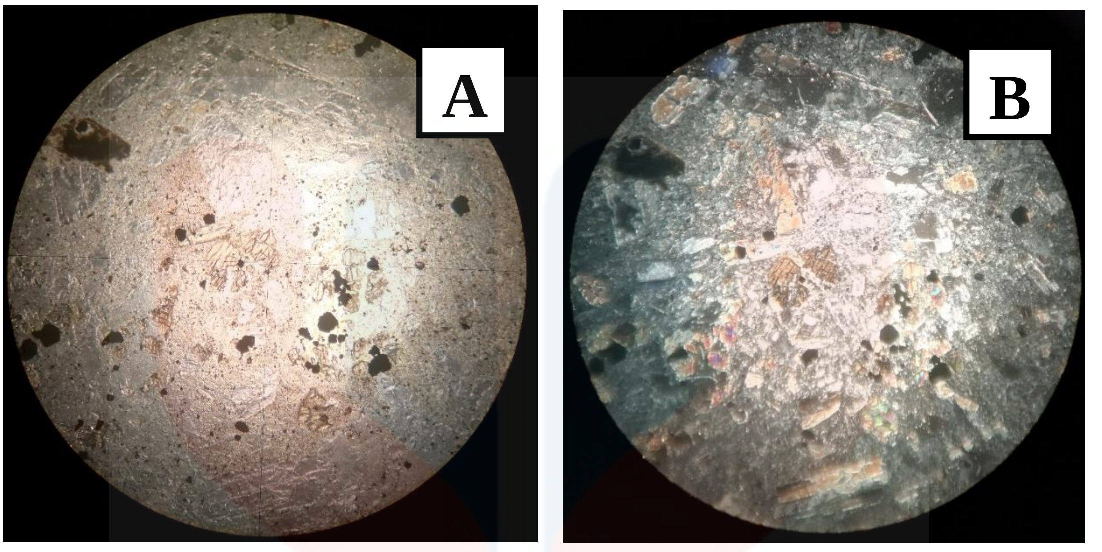


Figure 4.23: A shows low relief of groundmass and phenocryst; B is the XPL with 4x10 magnification.

In this thin section it can be observed that rock has a porphyritic texture, with presence of phenocryst composed of plagioclase and pyroxene, groundmass composed of microcrystalline of glass minerals and plagioclase. Degree of crystallinity is hypocrystalline with shape of crystal range from subhedral-anhedral, has inequigranular order of crystal, and the crystal relationship is hyphydiomorphic.

Plagioclase: colourless, subhedral-anhedral, low relief(colourless), no pleochroism, presence as phenocryst and groundmass, extension angle is 36°, in labradorite of plagioclase series, interference colour is greyish in 1st order.

Pyroxene: medium relief(pale brown colour), subhedral, extension angle is 32°, 2 direction cleavage is seen, pleochroism is from green to brown.

Opaque mineral: black, anhedral, isotrophic, high relief(black), no pleochroism, .

Groundmass: greyish colour, presence of plagioclase and glass minerals, microcrystalline made up the groundmass.

ii) Relative age and rock distribution = this volcanic product build up the cone shape in the middle of Dataran Pangalengan at the southern part of Gunung Malabar. There are three volcano peak from north to south, which are Gunung Bedil, Gunung Wayang and Gunung Windu. From secondary data, it is stated that Gunung Wayang existed 0.49 million years ago while Gunung Bedil is 0.19 million years ago and Gunung Windu is 0.10 million years ago. The characteristic of rock found is hornblende andesite, greyish colour, phenocryst mainly consist of plagioclase, hornblende and quartz in aphanitic groundmass. In the distribution area of Gunung Wayang and Gunung Windu there are few sources of hot springs due to hydrothermal activity in southern Bandung

4.3.3 *Ql* (Quaternary Lava) Unit. Zuhairah.MF, (2019).

i) Rock description = The lava of andesite has light grey colour, presence of sheeting joint, porphyritic texture where phenocryst is made up from plagioclase feldspar, pyroxene and hornblende, groundmass of aphanitic with microcrystalline of pyroxene and plagioclase. There is also presence of sheeting joint. The rock unit is seems to be interfingering with *Qan*, as the volcanic activity is in the same period, might occurred age gap that is unplottable in geologic time scale.

ii) Relative age and rock distribution = the rock unit is interfingering with *Qan*, thus the relative age is assumed to be the same as *Qan*. Regionally the rock is distributed in the sloping to the foothill of the volcano, and Gunung Windu acted as its central facies. Some is already altered from hydrothermal process.

4.3.4 *Qvb* (Quaternary Volcanic Breccia) Unit.

Figure 4.24: An example of monomict breccia found in station NN24. These picture shows both of the component and matrix of the rock.

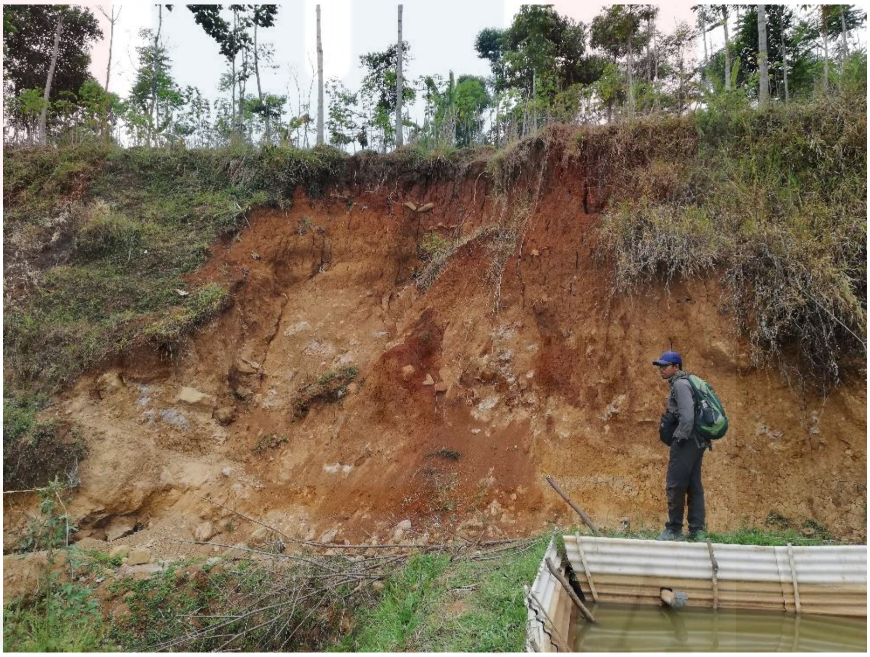


Figure 4.25: Outcrop photo of station NN24.

Figure 4.26: Hand specimen of volcanic breccia in station NN24.

Figure 4.27: Hand specimen of volcanic breccia's matrix in NN24. The matrix is made up of tuff, highly weathered.

i) Rock description = Composed of monomict breccia, with component of andesite and matrix is tuff, texture of component is slightly porphyritic, black in colour, phenocryst of plagioclase, and presence of hornblende and pyroxene while tuff is crystal-dominated with presence of FeO_2 indicates high weathering. The thin section of volcanic breccia unit describe as below;

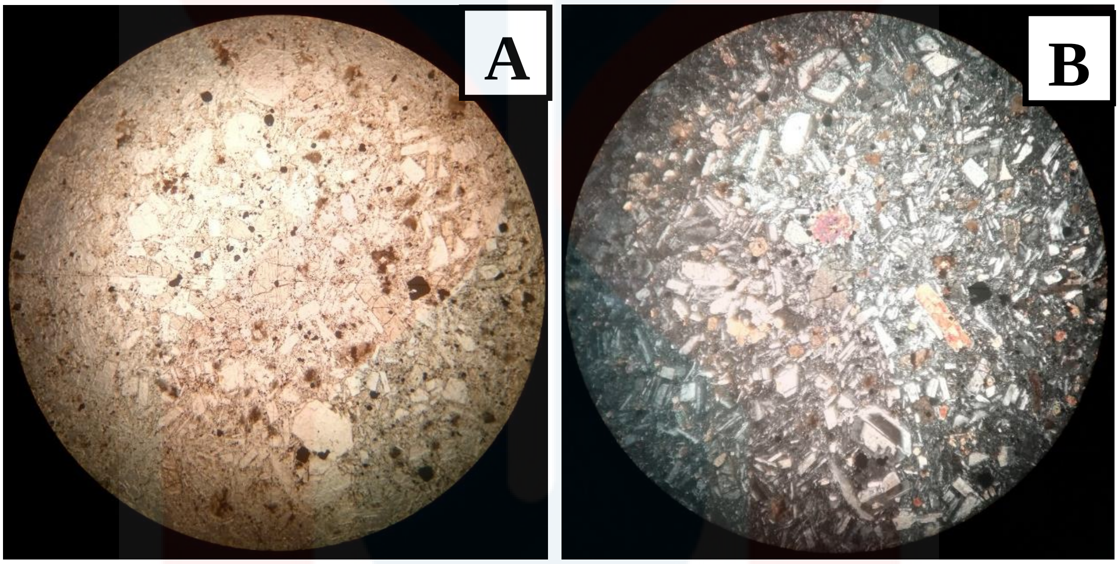


Figure 4.28: A shows the view under PPL showing low relief of plag, with opaque minerals; B is the view under XPL, composition of microcrystalline of plag and opaque minerals as groundmass.

In this thin section it can be observed that rock has a porphyritic texture, with presence of phenocryst composed of plagioclase and pyroxene, groundmass composed of microcrystalline of glass minerals and plagioclase. Degree of crystallinity is hypocrystalline with shape of crystal range from subhedral-anhedral, has inequigranular order of crystal, and the crystal relationship is hyphydiomorphic.

Plagioclase: colourless, euhedral-subhedral, low relief(colourless), no pleochroism, presence as phenocryst and groundmass, extension angle is 26.5°, in andesite of plagioclase series, interference colour is greyish in 1^{st} order.

Pyroxene: medium relief(pale brown colour), subhedral, extension angle is 0°, parallel direction cleavage is seen, pleochroism is from green to brown.

Hornblende: low relief, pale green colour, subhedral, extension angle 10°.

Opaque mineral: black, anhedral, isotrophic, high relief(black), no pleochroism, .

Groundmass: greyish colour, presence of plagioclase and glass minerals, microcrystalline made up the groundmass.

ii) Relative age and rock distribution = in the study area, the rock is distributed in the southern part of it. Regionally, Gunung Malabar is located in the southern part of the study area. Approximately, the age of Gunung Malabar product is 0,23 million years ago. Although the distance is quite big, but the product of this volcano is massive. It has a diameter of approximately 20km. This volcano become the main border between highland of Bandung (700m) to the north, and highland of Pangalengan (1400m) to the south. The volcanism activity that ongoing later producing another new volcano known as Gunung Malabar Muda. The type of rock present is various from basalt to basaltic andesite with darker grey in colour glassy, aphanitic to porphyritic. It composed of phenocryst that made up by plagioclase and pyroxene in aphanitic groundmass.

4.3.5 *Qt* (Quaternary Tuff) Unit.

Figure 4.29: Hand specimen of tuff in station NN17.

i) Rock description = Tuff, light brown colour, weathered and mostly has turned into reddish soil. The thin section of tuff is showed below;

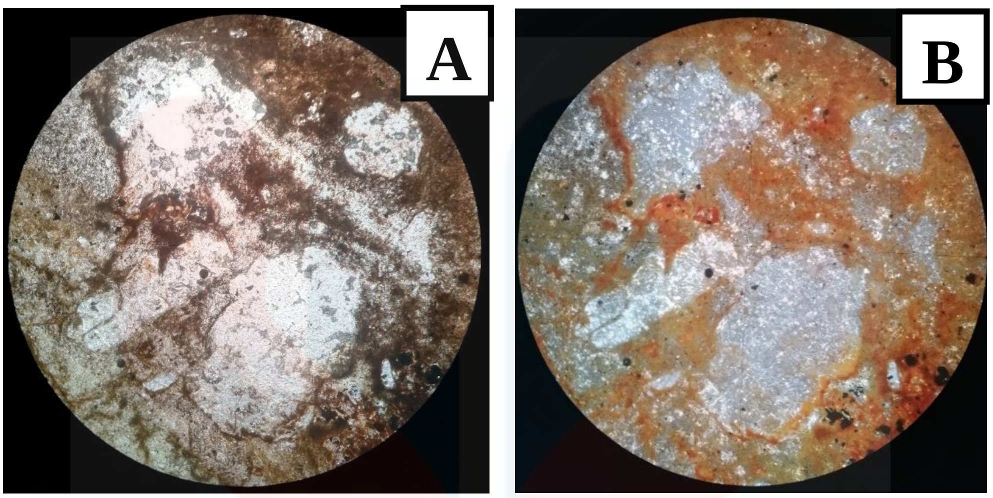


Figure 4.30: A is tuff under PPL, seen is the pyroclastic material with presence of FeO_2;
B is under XPL showed the crystal-dominated tuff.

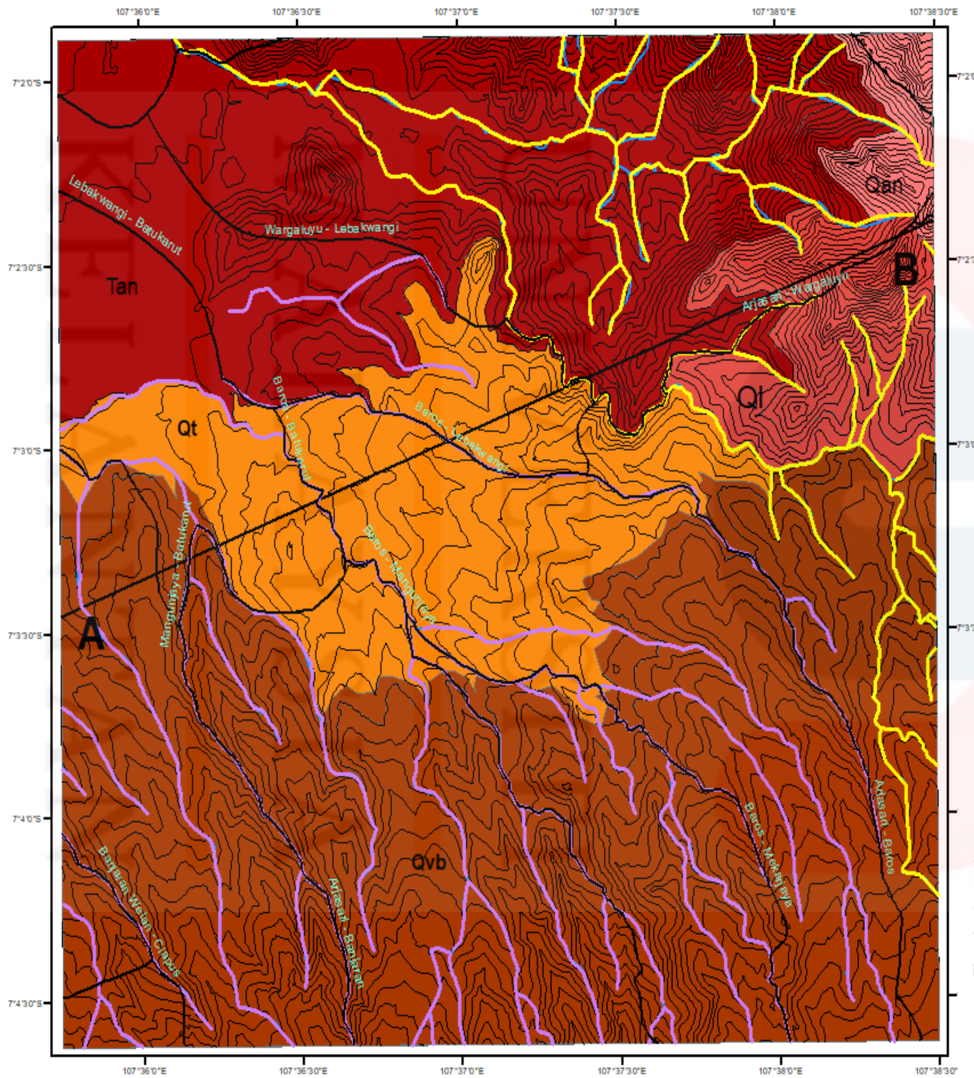
In this thin section it can be observed that rock has a porphyritic texture, with presence of phenocryst composed of crystals, groundmass composed of volcanic ash and . Degree of crystallinity is hypocrystalline with shape of crystal range from subhedral-anhedral, has inequigranular order of crystal, and the crystal relationship is hyphydiomorphic.

Crystal domination: fragment of crystal dominated the rock.

Opaque mineral: black, anhedral, isotrophic, high relief(black), no pleochroism, .

Groundmass: volcanic ash, pyroclastic material and oxidation of $Fe0_2$ (brown colour).

ii) Relative age and rock distribution = Tuff is relatively younger than *Qvb,* based on the contour distribution. Regionally, the Gunung Malabar had another volcanic activity, producing Gunung Malabar Muda that existed in the northern part of Gunung Malabar. Tuff is covered in the central part of the study area, where Qvb and Qt is interfingering with each other due to the occurrence of the age gap in volcanic activity in Bandung.



GEOLOGICAL MAP

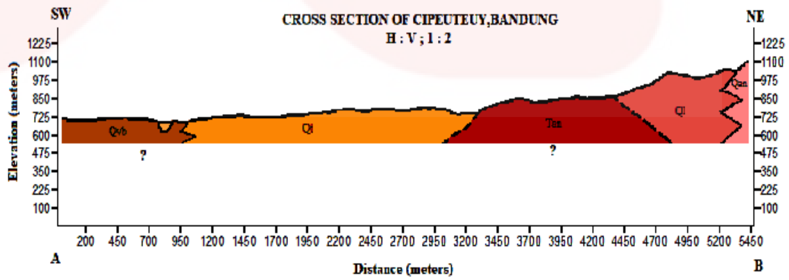
GEOLOGY OF KP.CIPEUTEUY, BANDUNG WEST JAVA AND PETROLOGY OF ITS VOLCANIC PRODUCTS

0 0.125 0.25 0.5 0.75 1 Kilometers

Contour Interval :12.5 meters
Scale : 1:25,000

By:
NAZIHA BINTI NORDIN
E15A0132

Age		Legend	Rock Unit	Explanation
Quaternary	Pleistocene	Qvb, Qt	*Qt* = Tuff *Qvb* = Volcanic breccia	**Tuff** - Light colour, weathered, in reddish coloured soil. - Area dominantly covered by terraced cultivation/plantation. **Volcanic breccia** - Monomict, component of andesite, dark grey colour, slightly porphyritic with plagioclase feldspar, pyroxene and hornblende, matrix of tuff, crystal dominated, with presence of FeO2, weathered into reddish soil.
		Ql, Qan	*Ql* = Lava of andesite *Qan* = Andesite	**Lava of andesite** - Presence of sheeting joint, light grey colour, porphyritic with plagioclase feldspar, pyroxene and hornblende. **Andesite** - Pyroxene andesite and hornblende andesite. - Lava of andesite with sheeting joint.
Tertiary	Late Miocene	Tan	*Tan* = Andesite	**Andesite** - Andesite alternated with volcanic breccia, andesite slightly porphyritic to porphyritic, composition of plagioclase feldspar, and pyroxene.



By: Naziha binti Nordin
E15A0132

4.4 Historical Geology.

Historically, Southern Bandung has undergone few series of eruptions that happened continuously throughout the period of Miocene to Quaternary. Volcanism activities that initiated during the Miocene age (± 12 mya) produces lava of pyroxene andesite that pillowing the Quaternary volcanic product of Wayang-Windu, where this lava of pyroxene andesite is spreaded in the northern part of the study area, known as *Tan.*

Then, the area undergone second eruption during Pliocene age (±4 – 2,6 mya) that build up Gunung Soreang and Gunung Baleendah that composed of dacite and andesite. At the same age, old Gunung Pangalengan build up itself becoming a composite cone composed of basalt. Parasitic volcano that appeared on the side of the slope is Gunung Tanjaknangsi. Gunung Pangalengan had a big explosion which formed Pangalengan Caldera that produces pyroclastics volcanic product. In the middle of the caldera, Gunung Windu, with three volcano peak from north to south, which are Gunung Bedil, Gunung Wayang and Gunung Windu. From secondary data, it is stated that Gunung Wayang existed 0.49 million years ago while Gunung Bedil is 0.19 million years ago and Gunung Windu is 0.10 million years ago. With composition of andesite appeared with Gunung Malabar on the northern part of it. Gunung Malabar composed of basalt, and basaltic andesite. In the study area, the product in the northern east is believed to be from Gunung Bedil based on the regional geologic information, where the formation is from Waring-Bedil, Old Malabar. The rock unit is *Ql* and *Qan.*

Then, Gunung Malabar that formed undergone volcanic activity, which produced another volcano known as Gunung Malabar Muda. Thus with the small age gap of both eruptions, *Qvb* and *Qt* interfingered with each other, but relatively *Qvb* is spreaded first followed by *Qt.*

CHAPTER 5

PETROLOGY OF VOLCANIC ROCKS

5.1 Introduction.

This chapter focusses on geochemical analysis of major elements and trace elements obtained from X-Ray Fluorescence (XRF). The data obtained is able to interpret the source origin of the magma and the process occurred that caused the variation in composition of geochemical of volcanic rocks in Kp.Cipeuteuy area. In the study area of Kp.Cipeuteuy, there is Late Tertiary volcanic rock, and domination of Quaternary volcanic rocks mainly from the source of Gunung Malabar. This chapter also describes the relationship between the magma and its sources that is related to the variation and dynamics of Earth's processes.

5.2 Major Elements.

Geochemistry of rock is the data which taken as the parameter that is needed in determining the paragenesis of the rock. Through the geochemistry data, the result is more accurate. In this analysis, 10 major elements and LOI (Loss on Ignition) is examine from the rocks which are SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, Cao, MgO, Na_2O, K_2O, and P_2O_5. This data obtained from XRF analysis is used for classification, grouping and naming the rock, Hazizad.A, (2018). There are 6 rock samples were sent for XRF specifically taken from volcanic rocks in the area of Kp.Cipeuteuy. All 6 samples is chosen and the geochemical data is tabulate in Table 5.1. Based on the geochemical data, volcanic rocks in Kp.Cipeuteuy area has range of 57.612-64.212 weight per cent SiO_2 with an average of 61.1814% with relatively low-medium K (Figure 5.1). Before plotting the data, the oxides elements from the rock samples are normalised.

The LOI percentage in all samples can be considered as acceptable, although it is best to be used in the value of ≥2.00. The percentages in all samples range in 2.31, where the highest value is 4.47 in rock sample NN4. In this analysis, all the geochemical data from all samples are used. The causes of the value for LOI to be high is due to several factors, either between the interaction with the volatile substance during the formation of the rock or because of the weathering.

The volcanic rocks which have less than 57% mainly composed pyroxene and in range of basalt to intermediate, more than 60% SiO_2 content are rich in pyroxene and hornblende and basically range in andesitic to dacite.

Table 5.1: Geochemical Analysis Result of Major Elements in Kp.Cipeuteuy and its surrounding.

Major Elements (% weight)	SiO2	TiO2	Al2O3	FeO*	MnO	MgO	CaO	Na2O	K2O	P2O5	LOI
NN1	64.2122	0.5357	16.986	6.4136	0.146	1.0796	5.6552	3.8147	0.9881	0.1686	2.67
NN4	63.853	0.5565	17.704	6.5215	0.1187	1.3231	5.1767	3.3812	1.1971	0.168	4.47
NN19	57.612	1.1815	17.026	11.017	0.2191	1.5451	6.5338	3.3426	1.3633	0.1596	0.64
NN24	59.803	0.7158	20.53	7.349	0.1366	0.7035	6.2545	3.0194	1.3351	0.153	2.27
STZ4	60.427	0.6743	18.513	7.4307	0.1588	1.4365	6.3764	3.6965	1.073	0.2133	1.52
HN40	59.046	0.5637	22.375	10.568	0.1537	0.6961	3.4204	1.9185	1.0776	0.1806	7.41

In this analysis, the result is combined with previous research for additional data for interpretation analysis. Additional data is taken from Soviati, et.al (2017). The major elements are normalised to 100% anhydrous weight. FeO was changed to total FeO* to be used in plotting and modelling. From Table 5.1, the range of the data of major elements can be seen one the data are normalised. Next, the data is plotted using major elements Soviati, et.al (2017) using classification diagram of Peccerillo and Taylor (1976) as shown in Figure 5.1.

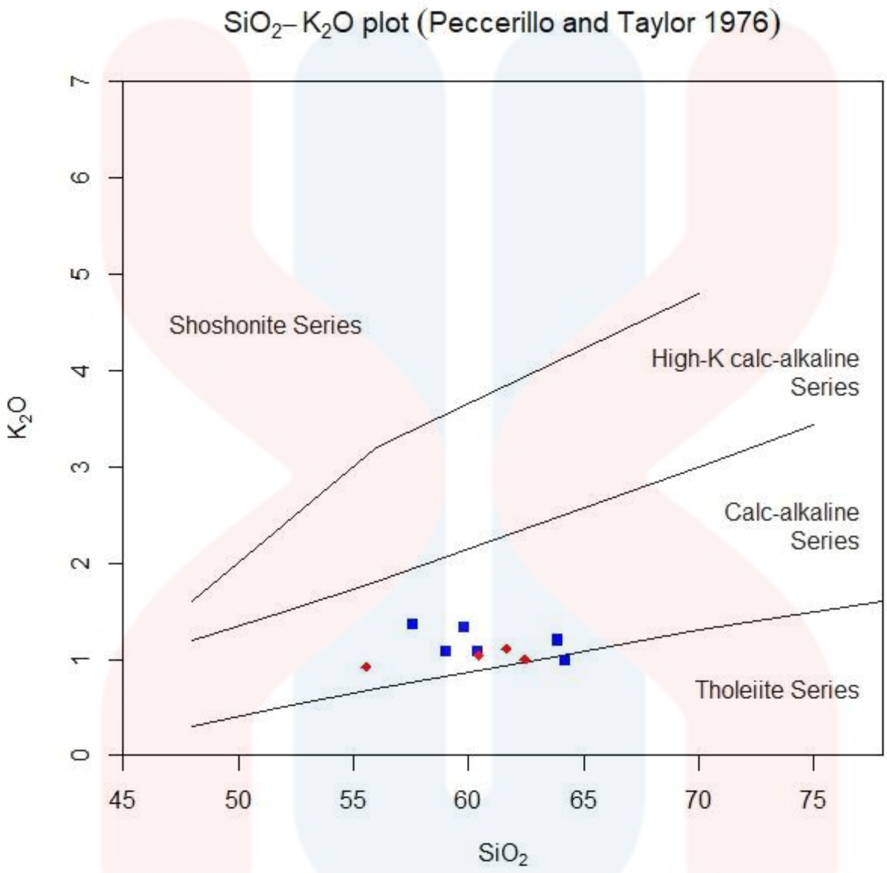


Figure 5.1: K_2O against SiO_2 based on the classification diagram of Peccerillo and Taylor (1976) in Kp.Cipeuteuy.

Based on the graph, the classification shows that the samples obtained in Kp.Cipeuteuy (blue colour) showed that the most of the volcanic rocks spread in the calc-alkaline series magma. The nearby data that were taken as parameters from Kecamatan Baleendah to compare the results. Both results are in the same range of magma series, which in calc-alkaline magma series. Only one sample which is in NN1, has the content of SiO_2 of 64.21% and K_2O value of 0.9881% fall under tholeiitic series. Based on the diagram, it is believed that the volcanic products are formed in convergent plate.

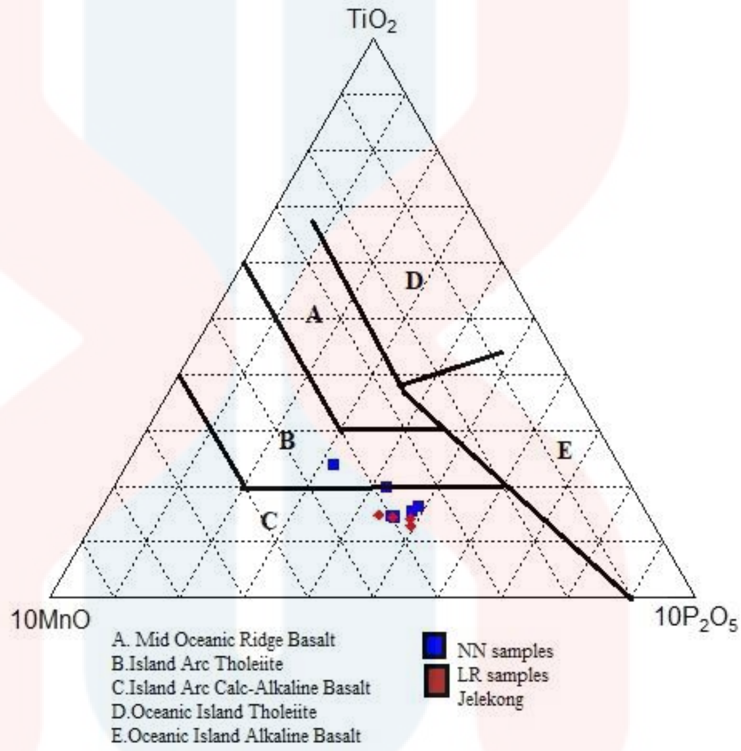


Figure 5.2: TiO_2-MnO-P_2O_5 tectonomagmatic discrimination diagram (Mullen, 1983) showing the volcanic rocks are from the Island Arc Calc-Alkaline Basalt.

Data of MnO and P_2O_5 were multiply by 10 with values of TiO_2 and plotted in the ternary diagram. Mullen (1983) classification diagram of tectonomagmatic discrimination, the volcanic rocks in Kp.Cipeuteuy showed that the series are in Island Arc Calc-Alkaline Basalt. The red colour showing the parameter used to compare with the samples of NN obtained from Soviati, et.al (2017) in Jelekong Kecamatan Baleendah.

According to Hazizad.A (2017) based on Whitford 1976) the type of rocks can be classified with the content of SiO_2 which are;

a) SiO_2 <52% = Basalt

b) SiO_2 52% - 56% = Andesitic basalt

c) SiO_2 56% - 63% = Andesite

d) SiO_2 63% - 70% = Dacite

e) SiO_2 >70% = Rhyolite

Table 5.2: SiO_2 content and classification.

Samples	SiO2	Classification
NN1	64.2122	Dacite
NN4	63.853	Dacite
NN19	57.612	Andesite
NN24	59.803	Andesite
STZ1	60.427	Andesite
HN40	59.046	Andesite

The alkalinity known as K_2O composition of volcanic rocks will increase in the island arc moving away from the trench. For subalkaline magma series, it is basically represented in oceanic island arc setting, while high-K and alkaline magma series are common active continental margin of tectonic setting. Most arc magmas will occurred calc-alkaline magma differentiation which causes the increase of K_2O and Na_2O that result in the evolution of volcanic rocks in the study area from andesitic to dacite.

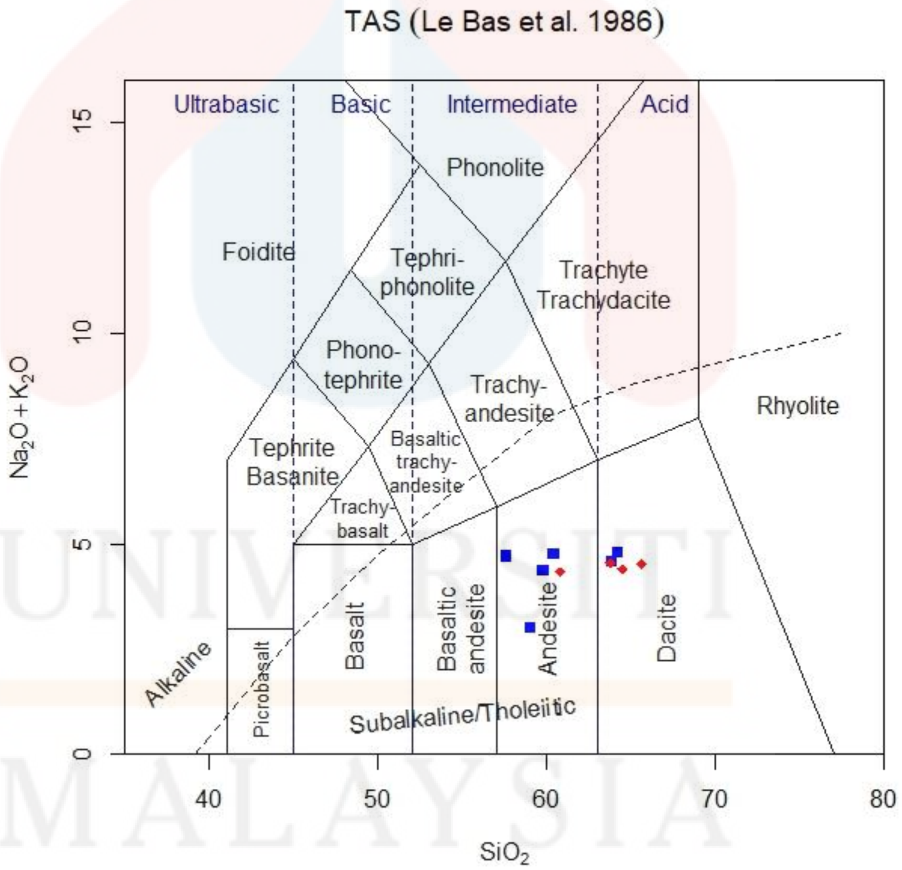


Figure 5.3: NN, (This report, 2018) samples in blue colour. The samples showing the evolution of volcanic rocks of andesite to dacite with different value of Na_2O+K_2O against SiO_2.

Once the tectonomagmatic discrimination is confirm, the magma process is important to know the evolution and fractionation occurs in the magma source. The next step taken is plotting the major elements against SiO_2 using Harker variation diagram as shown below.

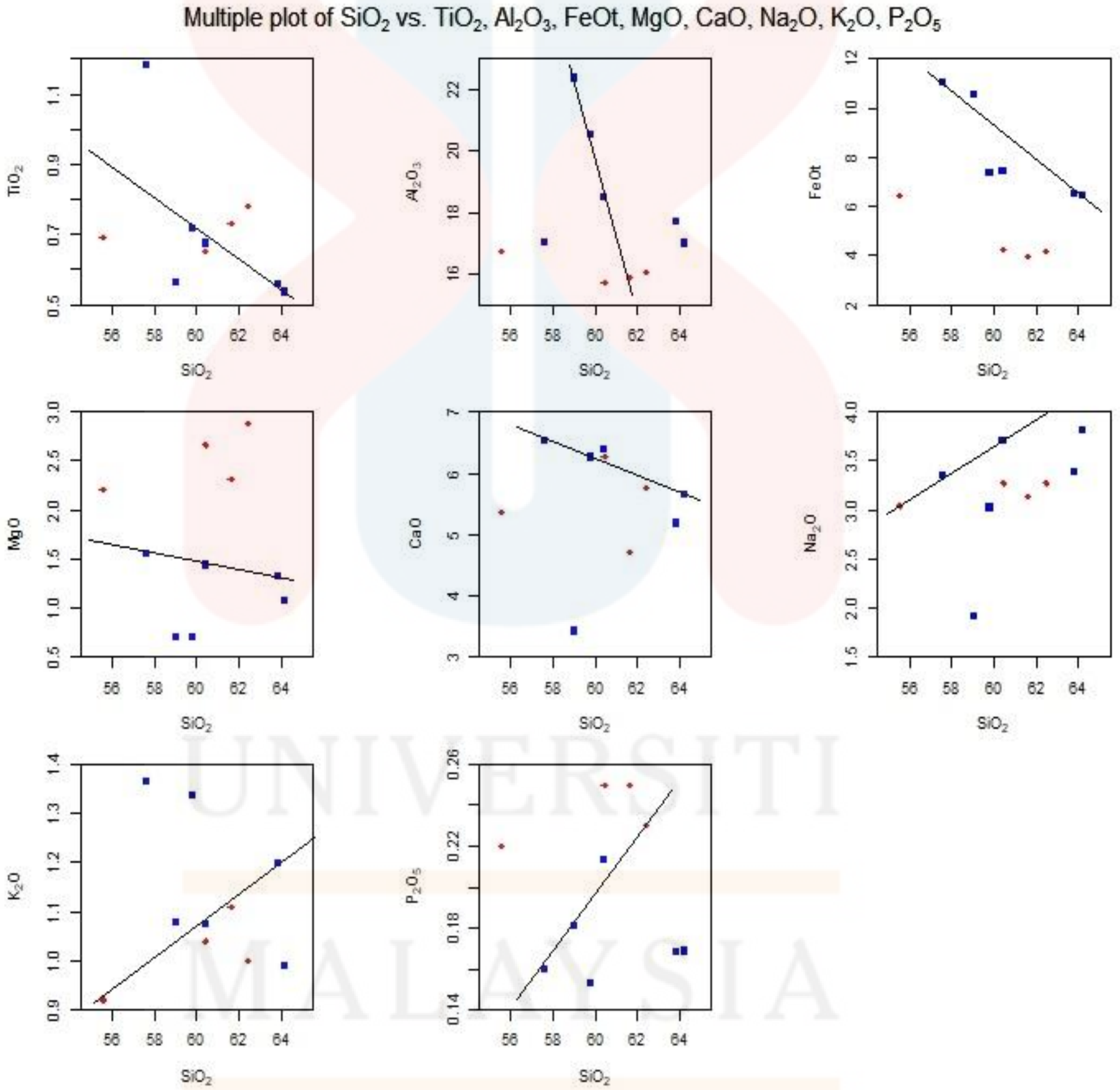


Figure 5.4: Harker's Diagram of major elements in Kp.Cipeuteuy.

5.3 Trace elements.

Trace elements are elements that occur in low concentration of rocks reported to be less than 0.1% of parts per million (ppm). Trace elements are divided into two groups, which are incompatible elements and compatible elements. Incompatible elements are element that do not easily fit into the crystal structure of minerals in the mantle. While compatible elements are elements that fit easily into the crystal structure of minerals in mantle. Incompatible elements are K,Rb,Cs,Ta,Nb,U,Th,Y,Hf,Zr and Rare Earth Elements (REE) of La,Ce,Pr,Nd,Pm,Sm,Eu,Gd,Tb,Dy,Ho,Er,Tm,Yb, and Lu. Compatible elements are like Ni,Cr,CO,V,and Sc that fits easily into crystallographic sites that normally accommodate Mg, and Fe since they have smaller ionic radii. The trace elements in Kp.Cipeuteuy is plotted in Harker's diagram, and the variation is examined that brings indication of its genetic between them. The list of trace elements from the samples is as shown in the table below. The study area mainly Alkaline earths; Rb,Sr,Ba. Transition elements of the first; Sc, V, Cr, Co, Cu, Zn.

Table 5.3: 6 samples obtained from Kp.Cipeuteuy and their trace elements.

Samples	Si	Al	Ca	Fe	Na	Mg	K	Ti	Px	Mn	Ba	Sr	V	Sx	Cr	Zn	Cl	Y	Rb	Ga	La	Co	Sc	Cu
NN1	292000	87400	39300	48400	27500	6360	7970	3130	717	1090	209	190	63	38	41	47	56	17	20	16	0	0	0	0
NN4	284300	89200	35200	48200	23800	7630	9460	3180	699	874	0	168	94	43	0	48	0	37	25	19	61	0	0	0
NN19	266700	89200	46300	84600	24500	9240	11300	7010	688	1680	0	221	184	121	63	99	698	47	61	21	0	32	28	26
NN24	272300	105800	43600	55500	21800	4140	10700	4180	649	1030	0	156	90	69	0	59	0	41	68	24	0	0	0	44
STZ4	275100	95400	44400	56200	26700	8430	8670	3937	906	1198	0	207	119	38	34	60	0	25	37	19	0	27	0	25
HN40	251800	108000	22300	74900	13000	3830	8160	3083	719	1086	0	93	111	131	0	43	0	28	61	18	49	45	0	64

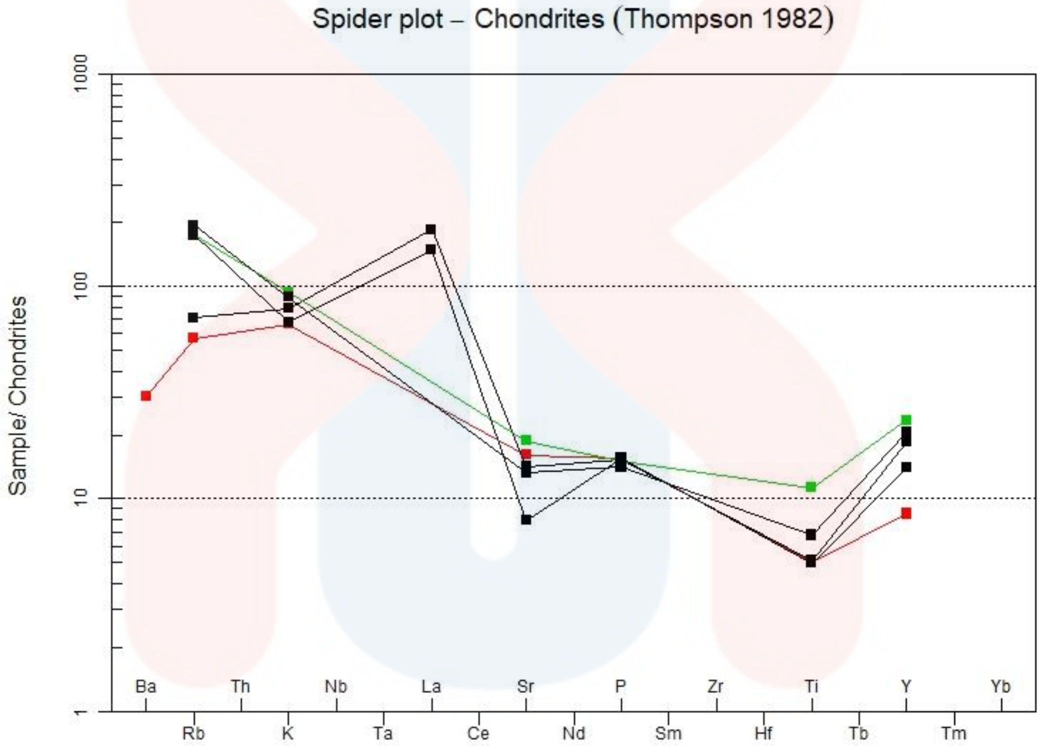


Figure 5.5: Trace element in spider plot of Thompson (1982), to detect the variation that indicates the magma source in subduction zone.

Based on the spider plot of Thompson (1982), from the trace elements plotted vs chondrite, it prove the magma originated from magma in a subduction zone environment. The characteristics of trace elements are observed where enriched in LILE of Th, K and La, and depleted in Ti.

5.4 Discussion.

5.4.1 Crystallisation of magma.

The diagram of major elements shows negative linear when correlated between silica and TiO_2, Al_2O_3, FeO, MgO, and CaO. These data indicates the fractionation of calcic plagioclase and primary mafic minerals such as olivine, pyroxene and hornblende. Based on Harker's diagram, decrease in MgO and FeO characterised the olivine fractionation. The decreasing of Mg, Fe, and Ca also reflect the fractionation of clinopyroxene (Hazizad.A, 2017). The decrease in CaO and AlO and increase in the Na_2O shows the fractionation of plagioclase from Ca-rich to Na-rich.

Based on Harker's diagram in Figure 5.4, the trend of depletion shows in the plotting of TiO_2, Al_2O_3, FeOt, MgO, and CaO against SiO_2. The trend of increases showed in the plotting Na_2O, K_2O and P_2O_5.

The study area was dominated with volcanic rocks, mainly igneous rocks that showing trends of evolution of andesite to dacite. This is related with the crystallization of magma that happened during the cooling process, range with different temperature and mixing of liquid. From the major elements data, crystallisation of magma can be related with the petrology of the rocks, using the concept of Bowen's reaction series.

Original magma of one composition is divided into two fraction. The first fraction is a cumulate (early formed crystals which accumulate) at the bottom of the magma chamber contains high density of Ca, Mg and Fe rich minerals. The second fraction is lower density, more Na, K and Si rich remaining melt. In Bowen's reaction series, olivine is the first mineral to form in the discontinuous series. When the temperature drops, SiO_2 started to react with MgO in the remaining liquid magma and converted into pyroxene. Rock samples from the study area were absent in olivine, showing that the rocks solidifies in lower temperature compared to very high temperature if olivine is presence.

Samples from the study area are rich in pyroxene, and hornblende and plagioclase. The fractionation showed in the depletion of CaO graph from andesite to dacite. There is a gap in CaO graph due to sampling which is not representative. In the study area, the volcanic rocks are rich in CaO, and Na_2O. Presence of zoning in plagioclase indicates that the cooling process occurs rapidly, from Ca-rich early forming plagioclase crystals coated with progressively more Na-rich plagioclase. The depletion in TiO_2 against SiO_2 showed that the rock samples in the study area has occurred separation of magnetite in the early phase of crystallisation.

Based on the thin section description, almost all rock samples are porphyritic in texture. The texture of large crystal embedded in a matrix of finer crystal, or microcrystalline as stated in Chapter 4, is an indicative of two-stage cooling process. Partially cooled liquid magma has move towards the surface, either through magma pipe or volcanic eruptions and cooling process occurred faster than in magma chamber.

Through the study of major elements distribution it shows a reflection of the mineralogy of studied samples. The pyroxene, hornblende and plagioclase almost presence in all samples. The structure of pyroxene, hornblende and plagioclase can be seen obviously. All three main minerals crystallise as phenocryst in microcrystalline composed of plagioclase and glass minerals. Microcrystalline plagioclase as groundmass as well as glass minerals in the degree of hypocrystalline crystallinity. The fractional crystallisation also formed plagioclase zoning.

5.4.2 Tectonic setting

In this research, the trace elements are limited to observe the evolution, thus the graph from the spider plot is used to show the tectonic setting. Based on the graph, volcanic rocks commonly shows the enrichment in Large Ion Lithophile Element (LILE) and depletion in High-Field-Strength Elements (HFSE). Mantle wedge hypothesis link HFSE anomalies to the presence of Ti-rich minerals that retain these elements during melt generation and transport. The slab hypothesis proposed that the content of HFSE depletions due to few processes related to the generation of fluids and melt distilled from the subducting plate. The spider plot shows the enrichment in LILE of Th, K, and La and the depletion of HFSE of Ti element. HFSE depletions are produced due to LILE are already partitioned into H_2O rich fluids/melts released by devolatilization or partial melting of slab rocks.

Through this discussion, thus the tectonic setting is confirm to be in the subduction zone. The magma series exhibit in the island arc is calc-alkaline series through Peccerillo and Taylor diagram.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The geological map of Kp.Cipeuteuy, Bandung West Java, Indonesia is made using data obtained from geological mapping process that is recorded and shown in Chapter 4. Morphologically, the study area has five classification based on slope angle of Van Zuidam, (1985) which are hilly-steeply dissected, rolling-hilly moderately steep, undulating rolling sloping, undulating gentle sloping and flat-almost flat. The drainage patterns in the study area mainly composed of two types, which are dendritic and parallel pattern. The weathering rate can be considered as high through two main processes which are physical weathering and chemical weathering. These resulted in the appearance of land covered in laterite in several part of the study area due to high content of FeO_2.

Based on geological mapping data, the study area has five rock units that were separated according to hand sampling and the age of the volcanic activity. The five rock units from oldest to youngest are Andesite unit (Tan), Quaternary Andesite unit (Ql and Qan), Volcanic breccia unit (Qvb) and Tuff unit (Qt). The volcanic product in the area range in the Late Miocene and Pleistocene, which can be considered as young volcanic product, thus there is no geological structures in the study area.

Historically, based on the volcanic products in the study area the oldest rock unit (Tan) is the product of few series of eruptions happened in southern Bandung. In the age of Quaternary, sub volcanoes that appeared after massive eruptions from main volcano resulted in the distribution of Qan and Ql, as products from Gunung Bedil. Then, Qvb and Qt overlies on top of the present volcanic product when Gunung Malabar produces a new volcano after it exploded known as Gunung Malabar Tua. Age gap in the series of eruptions causes Qan and Ql, Qvb and Qt interfingered with each other.

6.2 RECOMMENDATION

The analysis for the geochemistry is need to improve in terms of data analysis where more methods could be used to obtained more accurate data such as by Induced Couple Plasma-Mass Spectrometry (ICP-MS). Diagrams of rare earth element plotting should be used to support and prove the result. The next researcher is needed to study further in the depth of origin magma, type of magma, and the age gap between each volcanic eruptions using isotopes for dating. A detail discussion is needed in understanding of internal process of volcanoes, using petrology and geochemistry field to know the past eruptions, and the mitigation for future eruptions in the area. This helps to improve the geological hazard in the area through the understanding of physical process of magma movement and stability of volcanic eruptions.

APPENDICES

Analysed data	:	01-10-2018	Classification	:	Streckeisen (1974)
Sample code	:	NN 1	Petrographer	:	Naziha Nordin

Rock name	:	Pyroxene andesite
Colour	:	Transparent to brownish colour.
Structure	:	-
Texture	:	Porphyritic, Hypocrystalline, Hyphydiomorphic, and Inequigranular

Phenocryst	Cnt (%)	Assesories Minerals	Cnt (%)
Plagioclase Pyroxene	35 15	Opaque Minerals	10

Groundmass	Cnt (%)	
Microcrystalline - Plagioclase - Glass minerals	50 25 25	

Description :

In this thin section it can be observed that rock has a porphyritic texture, with presence of phenocryst composed of plagioclase and pyroxene, groundmass composed of microcrystalline of glass minerals and plagioclase. Degree of crystallinity is hypocrystalline with shape of crystal range from euhedral-subhedral, has inequigranular order of crystal, and the crystal relationship is hyphydiomorphic.

Plagioclase: colourless, anhedral-subhedral, low relief(colourless), no pleochroism, presence as phenocryst and groundmass, extension angle is 39.5, in between labradorite and bytownite of plagioclase series, interference colour is greyish in 1st order.

Pyroxene: high relief(brown colour), subhedral, extension angle is 20°, parallel cleavage is seen, pleochroism is from brown to black.

Opaque mineral: black, anhedral, isotrophic, high relief(black), no pleochroism, .

Groundmass: greyish colour, presence of plagioclase and glass minerals, microcrystalline made up the groundmass.

Analysed data	:	01-10-2018	Classification	:	Streckeisen (1974)
Sample code	:	NN 4	Petrographer	:	Naziha Nordin

Rock name	:	Andesite
Colour	:	Brownish to greyish colour.
Structure	:	-
Texture	:	Porphyritic, Hypocrystalline, Hyphydiomorphic, and Inequigranular

Phenocryst	Cnt (%)	Assesories Minerals	Cnt (%)
Plagioclase Pyroxene	35 10	Opaque Minerals	5

Groundmass	Cnt (%)
Microcrystalline - Plagioclase - Glass minerals	50 40 10

Description :

In this thin section it can be observed that rock has a porphyritic texture, with presence of phenocryst composed of plagioclase and pyroxene, groundmass composed of microcrystalline of glass minerals and plagioclase. Degree of crystallinity is hypocrystalline with shape of crystal range from subhedral-anhedral, has inequigranular order of crystal, and the crystal relationship is hyphydiomorphic.

Plagioclase: colourless, subhedral-anhedral, low relief(colourless), no pleochroism, presence as phenocryst and groundmass, extension angle is 36°, in labradorite of plagioclase series, interference colour is greyish in 1st order.

Pyroxene: medium relief (pale brown colour), subhedral, extension angle is 32°, 2 direction cleavage is seen, pleochroism is from green to brown.

Opaque mineral: black, anhedral, isotrophic, high relief(black), no pleochroism, .

Groundmass: greyish colour, presence of plagioclase and glass minerals, microcrystalline made up the groundmass.

Analysed data	:	01-10-2018	Classification	:	Streckeisen (1974)
Sample code	:	NN 24 (component)	Petrographer	:	Naziha Nordin

Rock name	:	Volcanic breccia (andesite,component)
Colour	:	Brownish to greyish colour.
Structure	:	-
Texture	:	Porphyritic, Hypocrystalline, Hyphydiomorphic, and Inequigranular

Phenocryst	Cnt (%)	Assesories Minerals	Cnt (%)
Plagioclase	50	Opaque Minerals	5
Pyroxene	20		
Hornblende	10		

Groundmass	Cnt (%)	
Microcrystalline	15	
- Plagioclase	10	
- Glass minerals	5	

Description :

In this thin section it can be observed that rock has a porphyritic texture, with presence of phenocryst composed of plagioclase and pyroxene, groundmass composed of microcrystalline of glass minerals and plagioclase. Degree of crystallinity is hypocrystalline with shape of crystal range from subhedral-anhedral, has inequigranular order of crystal, and the crystal relationship is hyphydiomorphic.

Plagioclase: colourless, euhedral-subhedral, low relief(colourless), no pleochroism, presence as phenocryst and groundmass, extension angle is 26.5°, in andesite of plagioclase series, interference colour is greyish in 1st order.

Pyroxene: medium relief (pale brown colour), subhedral, extension angle is 0°, parallel direction cleavage is seen, pleochroism is from green to brown.

Hornblende: low relief, pale green colour, subhedral, extension angle 10°.

Opaque mineral: black, anhedral, isotrophic, high relief(black), no pleochroism, .

Groundmass: greyish colour, presence of plagioclase and glass minerals, microcrystalline made up the groundmass.

Analysed data	:	01-10-2018	Classification	:	Streckeisen (1974)
Sample code	:	NN 17	Petrographer	:	Naziha Nordin

Rock name	:	Tuff
Colour	:	Brownish to greyish colour.
Structure	:	-
Texture	:	Porphyritic, Hypocrystalline, Hyphydiomorphic, and Inequigranular

Phenocryst	Cnt (%)	Assesories Minerals	Cnt (%)
	50	Opaque Minerals	5
Groundmass	Cnt (%)		
Microcrystalline - Plagioclase	15 10		

Description :

In this thin section it can be observed that rock has a porphyritic texture, with presence of phenocryst composed of crystals, groundmass composed of volcanic ash and . Degree of crystallinity is hypocrystalline with shape of crystal range from subhedral-anhedral, has inequigranular order of crystal, and the crystal relationship is hyphydiomorphic.

Crystal domination: fragment of crystal dominated the rock.

Opaque mineral: black, anhedral, isotrophic, high relief (black), no pleochroism, .

Groundmass: volcanic ash, pyroclastic material and oxidation of $Fe0_2$ (brown colour).

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*) : 065/L/GL/2.2/10/2018
Tanggal (*date*) : 10 Oktober 2018

Kode sampel (*sample code*)	: NN 1	Tanggal diterima (*received date*)	: 20 Agustus 2018
Kode lab. (*lab. code*)	: 201/2.2/18/0921	Tanggal diuji (*analyzed date*)	: 8 Oktober 2018
Lokasi (*location*)	: Jelekong, Bandung Selatan	Metode uji (*method*)	: GL-MU-2.2
Kedalaman (*depth*)	: -	Metode preparasi (*preparation method*)	: *Pressed Pellet*
Pemilik (*property*)	: **Rijal Ghani Hafiyyan UNPAD**		

Compound	m/m%	StdErr	El	m/m%	StdErr
SiO2	62.45	0.25	Si	29.20	0.11
Al2O3	16.52	0.20	Al	8.74	0.10
CaO	5.50	0.12	Ca	3.93	0.08
Fe2O3	6.93	0.11	Fe	4.84	0.08
Na2O	3.71	0.10	Na	2.75	0.07
MgO	1.05	0.06	Mg	0.636	0.04
K2O	0.961	0.049	K	0.797	0.041
TiO2	0.521	0.026	Ti	0.313	0.015
P2O5	0.164	0.010	Px	0.0717	0.0043
MnO	0.142	0.007	Mn	0.109	0.005
BaO	0.0233	0.0058	Ba	0.0209	0.0052
SrO	0.0225	0.0011	Sr	0.0190	0.0010
V2O5	0.0112	0.0011	V	0.0063	0.0006
SO3	0.0096	0.0007	Sx	0.0038	0.0003
Cr2O3	0.0060	0.0008	Cr	0.0041	0.0005
ZnO	0.0059	0.0006	Zn	0.0047	0.0005
Cl	0.0056	0.0012	Cl	0.0056	0.0012
Y2O3	0.0022	0.0005	Y	0.0017	0.0004
Rb2O	0.0022	0.0004	Rb	0.0020	0.0003
Ga2O3	0.0022	0.0003	Ga	0.0016	0.0002

REST= 2.67 LOI

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Aries Kusworo, 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*).

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

Nomer lab. (*lab. number*) : 065/L/GL/2.2/10/2018
Tanggal (*date*) : 10 Oktober 2018

Kode sampel (*sample code*)	: NN 4	Tanggal diterima (*received date*)	: 20 Agustus 2018
Kode lab. (*lab. code*)	: 201/2.2/18/0922	Tanggal diuji (*analyzed date*)	: 8 Oktober 2018
Lokasi (*location*)	: Jelekong, Bandung Selatan	Metode uji (*method*)	: GL-MU-2.2
Kedalaman (*depth*)	: -	Metode preparasi (*preparation method*)	: *Pressed Pellet*
Pemilik (*property*)	: **Rijal Ghani Hafiyyan UNPAD**		

Compound	m/m%	StdErr	El	m/m%	StdErr
SiO2	60.81	0.25	Si	28.43	0.12
Al2O3	16.86	0.20	Al	8.92	0.10
Fe2O3	6.90	0.11	Fe	4.82	0.08
CaO	4.93	0.11	Ca	3.52	0.08
Na2O	3.22	0.09	Na	2.38	0.07
MgO	1.26	0.07	Mg	0.763	0.04
K2O	1.14	0.05	K	0.946	0.045
TiO2	0.530	0.026	Ti	0.318	0.016
P2O5	0.160	0.010	Px	0.0699	0.0042
MnO	0.113	0.006	Mn	0.0874	0.0043
SrO	0.0199	0.0011	Sr	0.0168	0.0009
V2O5	0.0167	0.0012	V	0.0094	0.0007
SO3	0.0108	0.0007	Sx	0.0043	0.0003
La2O3	0.0072	0.0013	La	0.0061	0.0011
ZnO	0.0060	0.0006	Zn	0.0048	0.0005
Y2O3	0.0047	0.0006	Y	0.0037	0.0004
CuO	0.0034	0.0006	Cu	0.0027	0.0005
Rb2O	0.0027	0.0004	Rb	0.0025	0.0004
Ga2O3	0.0026	0.0004	Ga	0.0019	0.0003

REST= 4.47 LOI

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HASIL UJI KIMIA METODE XRF
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Nomer lab. (*lab. number*) : 065/L/GL/2.2/10/2018
Tanggal (*date*) : 10 Oktober 2018

Kode sampel (*sample code*)	: NN 19	Tanggal diterima (*received date*)	: 20 Agustus 2018
Kode lab. (*lab. code*)	: 201/2.2/18/0923	Tanggal diuji (*analyzed date*)	: 8 Oktober 2018
Lokasi (*location*)	: Jelekong, Bandung Selatan	Metode uji (*method*)	: GL-MU-2.2
Kedalaman (*depth*)	: -	Metode preparasi (*preparation method*)	: *Pressed Pellet*
Pemilik (*property*)	: **Rijal Ghani Hafiyyan UNPAD**		

Compound	m/m%	StdErr	El	m/m%	StdErr
SiO2	57.05	0.25	Si	26.67	0.12
Al2O3	16.86	0.20	Al	8.92	0.10
Fe2O3	12.12	0.15	Fe	8.46	0.10
CaO	6.47	0.13	Ca	4.63	0.09
Na2O	3.31	0.09	Na	2.45	0.07
MgO	1.53	0.08	Mg	0.924	0.05
K2O	1.35	0.06	K	1.13	0.05
TiO2	1.17	0.05	Ti	0.701	0.032
MnO	0.217	0.011	Mn	0.168	0.008
P2O5	0.158	0.010	Px	0.0688	0.0042
Cl	0.0698	0.0035	Cl	0.0698	0.0035
V2O5	0.0329	0.0016	V	0.0184	0.0009
SO3	0.0303	0.0015	Sx	0.0121	0.0006
SrO	0.0261	0.0013	Sr	0.0221	0.0011
ZnO	0.0123	0.0008	Zn	0.0099	0.0007
Cr2O3	0.0092	0.0009	Cr	0.0063	0.0006
Rb2O	0.0067	0.0005	Rb	0.0061	0.0004
Y2O3	0.0060	0.0007	Y	0.0047	0.0006
Co3O4	0.0043	0.0009	Co	0.0032	0.0006
Sc2O3	0.0043	0.0008	Sc	0.0028	0.0005
CuO	0.0033	0.0007	Cu	0.0026	0.0006
Ga2O3	0.0028	0.0004	Ga	0.0021	0.0003

REST= 0.64 LOI

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(*XRF METHOD CHEMISTRY ANALYSIS RESULT*)
Nomer lab. (*lab. number*) : 065/L/GL/2.2/10/2018
Tanggal (*date*) : 10 Oktober 2018

Kode sampel (*sample code*)	: NN 24	Tanggal diterima (*received date*)	: 20 Agustus 2018
Kode lab. (*lab. code*)	: 201/2.2/18/0924	Tanggal diuji (*analyzed date*)	: 8 Oktober 2018
Lokasi (*location*)	: Jelekong, Bandung Selatan	Metode uji (*method*)	: GL-MU-2.2
Kedalaman (*depth*)	: -	Metode preparasi (*preparation method*)	: *Pressed Pellet*
Pemilik (*property*)	: **Rijal Ghani Hafiyyan UNPAD**		

Compound	m/m%	StdErr	El	m/m%	StdErr
SiO2	58.23	0.25	Si	27.23	0.12
Al2O3	19.99	0.21	Al	10.58	0.11
CaO	6.09	0.12	Ca	4.36	0.09
Fe2O3	7.95	0.12	Fe	5.55	0.08
Na2O	2.94	0.09	Na	2.18	0.06
K2O	1.30	0.06	K	1.07	0.05
MgO	0.685	0.05	Mg	0.414	0.031
TiO2	0.697	0.034	Ti	0.418	0.021
P2O5	0.149	0.009	Px	0.0649	0.0039
MnO	0.133	0.007	Mn	0.103	0.005
SrO	0.0184	0.0011	Sr	0.0156	0.0009
SO3	0.0173	0.0009	Sx	0.0069	0.0004
V2O5	0.0161	0.0012	V	0.0090	0.0007
Rb2O	0.0074	0.0004	Rb	0.0068	0.0004
ZnO	0.0073	0.0007	Zn	0.0059	0.0005
CuO	0.0055	0.0006	Cu	0.0044	0.0005
Y2O3	0.0052	0.0007	Y	0.0041	0.0005
Ga2O3	0.0032	0.0004	Ga	0.0024	0.0003

REST= 2.27 LOI

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