GEOLOGY OF BANJARAN, WEST JAVA AND THE GEOCHEMICAL EVOLUTION OF ITS VOLCANIC PRODUCT

by

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APPROVAL

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

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DECLARATION

I declare that this thesis entitled “Geology of Banjaran and Geochemical Evolution of Its Volcanic Product” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....
Name :
Date :

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GEOLOGY OF BANJARAN, WEST JAVA AND THE GEOCHEMICAL EVOLUTION OF ITS VOLCANIC PRODUCT

ABSTRACT

Banjaran area located at West Java, was not comprehensively studied in past five years, therefore the lack of geological information about that area give effects to people, especially who work in geological background. The target area would be a suitable place to study more detail of the geology in Banjaran. Therefore, the relationship between various types of volcanic product in this area should be expounded by geochemical analysis. Indication towards systematic changes in mineral composition, isotopic, major and trace elements are quite difficult due to inadequate data in term of petrological and geochemical analysis of the study area. Besides that, the distribution of volcanic product that present on the previous map shows no differentiation on their origin centre of eruption. The main objectives are to produce geological map of the study area in the scale of 1:25000 and identifying the geochemical relationship between various types of volcanic products that present in Banjaran. The research be carried by geological mapping, petrography analysis (thin section) , and using geochemical analysis approach (XRF) . The result of geochemical analysis is plotted in petrology diagram and interpretation has been done to identify magma source, their series and petrogenesis of the volcanic rock in Banjaran. Through geochemical analysis , the relationship between different type of volcanic product can be explain in term of their origin parent magma and their evolution to become their current state of rock in the study area

GEOLOGI BANJARAN, JAWA BARAT DAN EVOLUSI GEOKIMIA YANG MEMPENGARUHI BATUAN GUNUNG BERAPI

ABSTRAK

Banjaran adalah nama kawasan kajian yang terletak di Jawa Barat, Indonesia. Dalam tempoh lima tahun yang lalu, kajian berkenaan geologi agak kurang dilakukan di kawasan ini dan telah memberi kesan kepada mereka yang bekerja dalam latar belakang geologi. Kawasan in amat sesuai dipilih untuk kajian yang lebih mendalam terutama dalam konteks geologi. Oleh yang demikian, hubungan antara pelbagai jenis batu gunung berapi sewajarnya dihuraikan melalui analisis geokimia. Perubahan sistematik yang menunjukkan komposisi mineral, isotop, unsur utama, dan unsur surih agak sukar ditentukan kerana kekurangan data petrologi dan geokimia dikawasan kajian. Selain itu, sebaran batu gunung berapi tidak dibezakan berdasarkan pusat letusan dalam peta terdahulu. Objektif utama adalah menghasilkan peta geologi kawasan kajian dalam skala 1 :25000 dan mengenal pasti hubungan geokimia antara pelbagai jenis batuan yang dijumpai di Banjaran. Kajian ini dilaksanakan melalui kaedah pemetaan geologi, analisis petrografi (vastis tipis) dan pendekatan analisis geokimia(XRF). Hasil analisis geokimia diplot dalam rajah petrologi dan ditafsir untuk mengenal vastis umber magma, sirinya dan petrogenesis batuan gunung berapi di kawasan Banjaran. Melalui analisis geokimia , hubungan antara batu gunung berapi yang berbeza dapat diperjelaskan dalam bentuk asal usul magma yang berevolusi untuk menjadi batu yang sedia ada di kawasan kajian.

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LIST OF ABBREVIATIONS

Al	Aluvium unit by (Bronto, Koswara, & Lumbanbatu, 2006)
BV	Baleendah Volcanics
MiV	Miocene volcanic products
m.y.a	Million years ago
SV	Soreang Volcanics
Tpv	Volcanic Breccia 1 Unit
Qpv	Volcanic Breccia 2 Unit
Qpl	Lahar Unit
LOI	Loss of ignition
MV	Malabar Volcanics
Qa	Alluvium (This report, 2018)
Ppm	Parts-per million

LIST OF SYMBOLS

°	Degree
’	Minutes
”	Seconds
<	Less than
>	Greater than
=	Equal
+	Addition
x	Multiplication
%	percentage

CHAPTER 1

INTRODUCTION

1.1 Background of Study

One of the planet earth activities that show its dynamic is magmatism. Magmatism occurs in few types of tectonic setting such as convergent plate margin (island arcs and active continental margins), convergent plate margins (island arcs and active continental margins) , and within plate settings (oceanic within plates and continental within plates). As a comparison to other tectonic settings, subduction zone or arc magmatism have the most complex history due to their multisource and multi process phenomena. Generation of arc magmatism occurs in three potential sources that are the subducted slab which consists of an oceanic basaltic crust and possibly sediments , including material derived either through melting or release of fluids, the mantle wedge (lithospheric and asthenosphere mantle), and the arc crust. The composition of a rock that form may vary from primary magma due to differentiation (equilibrium and fractional crystallization), magma mixings, and crustal contamination.

The main process that responsible for geochemical variation in all arc magma is fractional crystallization, including crustal component involvement by contamination mechanism. Trace element that being distributed in several arc magma can be an indicator of whether the magma being derived from mantle wedge melting and assimilated by the crust or not. In Java, Indonesia, crustal contamination more occur at the west along the arc. This is because the crust is thicker and older in the west region.

The petrology of West Java often related to volcanic rock, In general, this study will focus on petrogenesis and geochemical analysis of volcanic rock that form near the subduction zone between Eurasia plate and Indo-Australia plate. Geochemical evolution of volcanic product in West Java, or to be more precise location, Banjaran region have the significant type of rock that maybe can bring some clue and information about their origin magma. Geochemical analysis of rock is important by detecting the major element and trace element content.

1.2 Study Area

West Java is a province of Indonesia. It is situated in the western part of Java island and its capital and largest urban centre are Bandung. The Province of West Java is subdivided into 9 cities and 17 regencies. All 17 regencies are Bogor Regency, Sukabumi Regency , Cianjur Regency , Bandung Regency, West Bandung Regency, Garut Regency, Tasikmalaya Regency, Ciamis Regency, Kuningan Regency, Cirebon Regency, Majalengka Regency, Sumedang Regency, Indramayu Regency, Subang Regency, Purwakarta Regency, Karawang Regency and Bekasi

Regency. These 26 cities and regencies are divided into 620 districts which comprise 1,576 urban villages and 4,301 rural villages.

The study area is focused on Banjaran in Bandung Regency. Figure 1.1 shows Bandung Regency and research study area with the coordinate of (07^{o}2’25.50” S, 107^{o}33’25.43” E) ,(07^{o}2’25.50” S, 107^{o}36’08.96” E) , (07^{o}5’08.11” S, 107^{o}36’08.96” E), and (07^{o}5’08.11”S, 107^{o}33’25.43” E). Meanwhile, Figure 1.2 shows that base map of Banjaran.

Focus study area; Banjaran

Figure 1.1 : Bandung Regency and focus study area (Source : Google Maps)

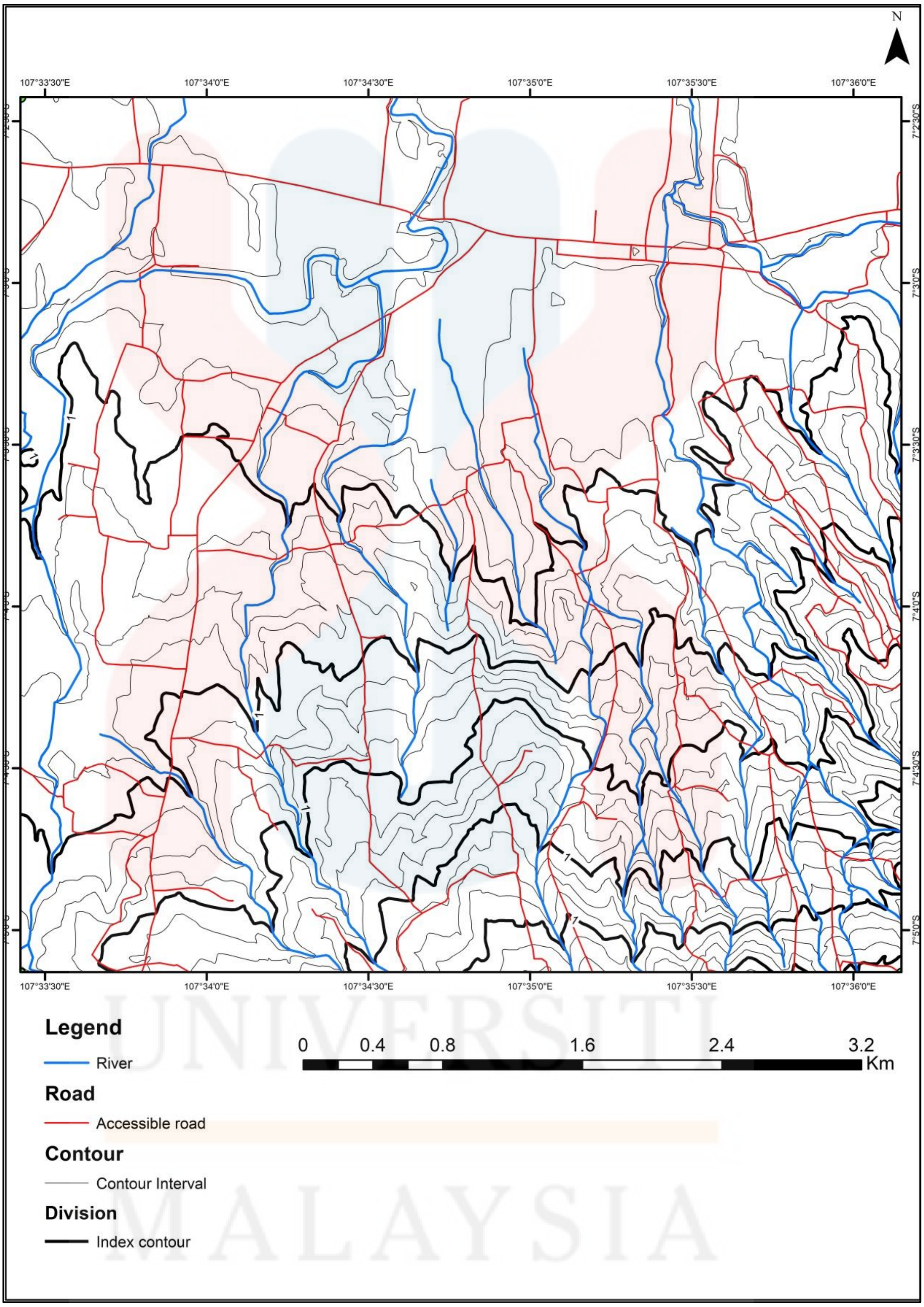


Figure 1.2 : Base map of Banjaran with scale 1: 25000m

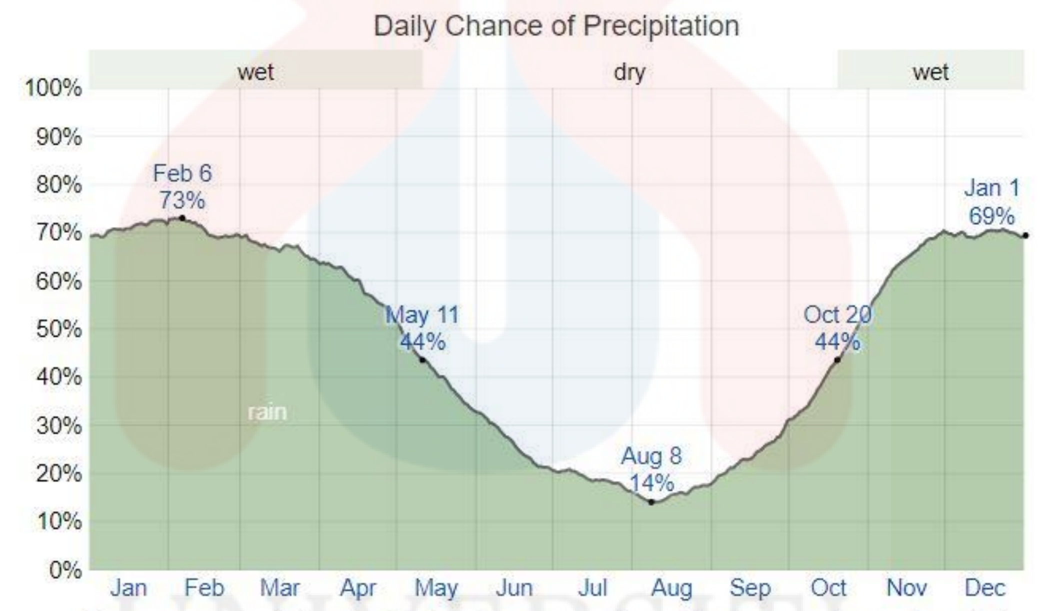
1.2.1 Demography

In mid-2010, the population of West Java was put at 43,054,000 making it the most populous province of Indonesia, home to 18% of the national total on 1.8% of the national land. While in Bandung Regency that covers an area of 1,767.96 km^2 with population of 3,418,246 in January 2014 . This makes Bandung population is about 7.9 % of West Java Population.

1.2.2 Rain distribution and precipitation

Bandung Regency has a chance of wet days varies very significantly throughout the year . Figure 1.3 shows annually precipitation data of Bandung Regency in 2017. From October 20 to May 11, is wetter season that lasts for 6.7 months, with a greater than 44% chance of a given day being a wet day. The chance of wet day peaks at 73% on February 6. From May 9 to October 21, Bandung Regency experienced drier season that lasts for 5.3 months . August 8 have a 14% chance of the wet day, which is the smallest throughout the year .Among wet days, weather being distinguishes between those that experience rain alone, snow alone, or a mixture of the two. Based on this categorization, the most common form of precipitation throughout the year is rain alone, with a peak probability of 73% on February 6.

Figure 1.4 shows Bandung Regency rainfall variation in 2017. Within the months and not just the monthly totals the rainfall accumulated over a sliding 31-day period centered around each day of the year. Bandung experiences extreme seasonal variation in monthly rainfall and throughout the year, rain falls in Bandung. 31 days centered around January 29, is the most rain falls with an average total accumulation of 10.7 inches. The least rain falls that have been recorded is around August 12, with an average total accumulation of 1.4 inches.



The percentage of days in which various types of precipitation are observed, excluding trace quantities: rain alone, snow alone, and mixed (both rain and snow fell in the same day).

Figure 1.3: precipitation of Bandung Regency in 2017
(Source : https://weatherspark.com/y/118108/Average-Weather-in-Bandung-Indonesia-Year-Round)

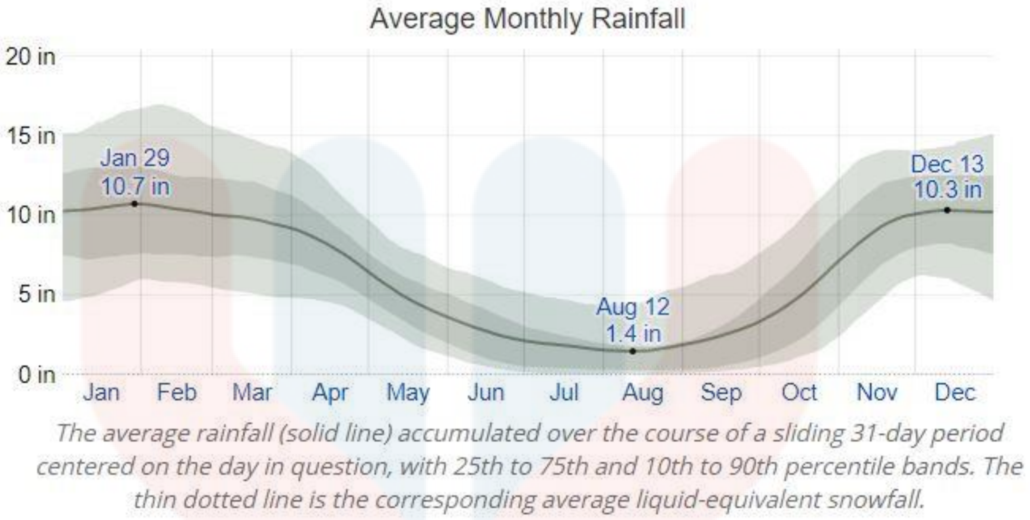


Figure 1.4 : rainfall distribution of Bandung Regency

(Source : https://weatherspark.com/y/118108/Average-Weather-in-Bandung-Indonesia-Year-Round)

1.2.3 Landuse

Bandung Regency residents often utilize the land for farming and agriculture. Increasing the standard of quality and quantity of life necessity causes competition in the use of agricultural land and non-agricultural land that is increasing. Bandung is the capital of West Java Province and the development of the region is very dynamic. Territory Bandung is divided into Bandung City, West Bandung and Bandung Regency. District Bandung with an area of 176,238.67 ha most of its territory is mountainous or hilly areas have undergone many changes in land use. Bandung Regency Government has determined the allocation of space in the regional spatial plan (RTRW) Bandung Regency, but existing conditions land use often does not follow the allocation has been determined, so that a deviation occurs inconsistency in space utilization. Deviation from spatial plans can be identified from the occurrence inconsistency of land use in existing conditions towards the policies that have been established in the Spatial Plan.

1.2.4 Social economic

Majority residents of Bandung regency work in the agricultural sector. They become a farmer and work at paddy fields. In 2015, a number of people in Bandung that works in agriculture sector including forest resources, and fisheries reached 121.138 peoples. Followed by industry sectors, 96.064 peoples . Third most people involving sector of Sumedang regency is restaurants and accommodation, having 99.959 peoples. Social services, and individuals sectors become number four most Sumedang residents work for, which is 62.792 peoples. Economic sector contribution in Bandung Regency can be divided into three group which is primary, secondary, and tertiary..

1.2.5 Road Connection and Accessibility

The study area is located about 19.9 km form biggest capital of West Java, Bandung. The shortest time taken to travel to the box is 48 minutes according to Google Map estimation time arrival. The route from Bandung city to study area is being displayed in figure 1.5. About accessibility, there is some place that traverse only can be done by walking, while in the north part of the study area, research is much easier due to more road.

Figure 1.5 : Route map of study area(Source : Google Maps)

1.3 Problem Statement

The research area was not comprehensively studied in the past five years, therefore the lack of geological information about that area gives effects to people, especially who work in the geological background. The target area would be a suitable place to study more detail of the geology in Banjaran. Therefore, the relationship between various types of volcanic product in this area should be expounded by geochemical analysis. Indication towards systematic changes in mineral composition , isotopic, major and trace elements are quite difficult due to inadequate data in term of petrological and geochemical analysis of the study area. Besides that, the distribution of volcanic product that present on the previous map, shows no differentiation on their origin centre of eruption.

1.4 Objective of Study

The research objectives are:

1. To produce a geological map of the study area in the scale of 1:25000
2. To investigate the geochemical relationship between various type of volcanic products that present in the study area.

1.5 Scope of Study

This study is to focus on producing a geological map of Banjaran that will be covered for the 5km x5km box. In 25km^2 of the study area, lithologic boundaries of volcanic product/rock will be determined by traversing through the box and collecting samples to analyse. The boundaries can be produced on the geological map by using ArcGIS, famous software for producing a geological map. Cross section of lithology and relative age of rock will be included in the geological map through the strike and dip reading that found in study area.

For petrography section of studies, preparing thin section is necessary for identification of mineral composition, the texture of rock, fabric, and also minerals under polarized microscope observation. The geochemical analysis in this study involve x-ray instrument named X- Ray Fluorescence (XRF). XRF can be used to detect the major element and trace element in volcanic product/rock sample that found in study area. By detection the abundance of major elements and traces element, general assumption of their origin magma can be made. They also are significant indicator to various geological processes such as magma formation, differentiation, interaction of hydrothermal fluids and rocks including ore deposits formation.

The functional principle of an X-Ray Fluorescence Spectroscopy (XRF) instrument is the X-ray tube generates the primary X-radiation. The cathode emits electrons when electrically heated. The electrons being applied at high voltage, accelerated at very high speeds bombard the anode material. This generates the primary X-radiation. The shutter serves as a safety device and closes the access of the primary X-radiation to the measurement chamber, if needed. A light source illuminates the sample.

1.6 Significance of Study

To specify the previous study on the different type of volcanic products/rocks units in a wider scale of the geological map which is 1:25000 of the research area. This research also improve the previous research conducted which are not completely update and basic knowledge towards the geology of Banjaran can be shared, bringing a lot of benefits to the society . Through geochemical analysis , the relationship between the different types of volcanic products be explained in term of their origin parent magma and their evolution to become their current state of rock in the study area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, a previous related study being a review in details. The review usually related to objective, problems, and method that have been applying by previous research. This research aimed to study geology and geochemical evolution of volcanic products in Banjaran , West Java, Indonesia . The literature review is related to tectonic setting and regional geology of Indonesia followed by regional geology of West Java. This is important as a research needs to be conducted by firstly, analysing surrounding geologic setting and give a clue to the rock distribution in the study area. The previous study also can be a reference to construct the geological map of the study area. Besides that, history of volcanism in West Java be a review to increase understanding towards volcanic product that presents in the study area. Previous analysis of petrology and geochemical characteristic also need to be a review in details in order to expand knowledge and help in achieving research objective.

2.2 Regional Geology and Tectonic Setting

2.2.1 Tectonic Setting and regional geology of Indonesia

Hall (2009) explained that Indonesia is located at the southeastern edge of the Eurasian continent and have complex geology region. Indonesia is characterized by seismically intense and high volcanism as it is bordered by tectonically active zones resulting from subduction. A micro-continental fragment from Gondwana was detached at the end of Cretaceous to Early Eocene, and drifted in direction of northeastward approaching the subduction zone (Sribudiyani et al.,2003 ; Clements&Hall, 2007 ; Smyth et al., 2007). Hamilton (1979) claimed that Indonesia is located between various plate boundaries such as Eurasia, India-Australia and Pacific- Philippine .There is more arc and ophiolitic crust in eastern Indonesia with several young ocean basins while in western Indonesia is largely underlain by continental crust . According to Hall (2009), the Indian-Australian Plate with convergent rate of about 7cm per year moves northward and is being subducted underneath the Eurasian Plate. The subduction zone has form volcanic arc stretching about 5000 km from Sumatra to Molluca Sea and have extendeds up to 600 km depth.

2.2.2 Regional geology of West Java

According to Fauzi et al. (2015) Java is situated at the southern path of Sunda Land of Eurasian Plate, where Indian-Australian plate being subducted beneath the Eurasian plate. Since the early Oligocene, active plate convergence along Sunda Arc has produced arc volcanism and intrusion. In 2012, Hall found that the plate convergence along the subduction zone can be divided into the western part(oblique subduction) and eastern part(frontal subduction). The western part of convergence is on Sumatra and adjacent area while the eastern part of convergence subduction that produces Java, Bali and Sumbawa islands. It can be considered that West Java is situated at the transitional zone between frontal subduction at the eastern part of West Java and oblique subduction in Sumatra (Fauzi et al. ,2015).

Darman and Sidi (2000) state that West Java has five tectonic provinces which is 1) Northern basinal area, 2) Bogor through 3) Modern Volcanic Arc 4) Southern slope regional uplift and 5) Banten block. The northern basinal area contains sedimentary deposit from Eocene – Miocene .Bogor through compost of Tertiary deep water sediment. The modern volcanic arc is composed by andesitic product that comes from volcanic activity due to the subduction process. Southern slope regional uplift or Southern Mountain (Van Bemmelen, 1949) comprises of Old andesite formation (OAF), Eocene- Miocene sedimentary rock, and complex structure. Banten Block locating in western West Java can be divided into three parts ; the Seribu carbonate plat form, Rangkas-bitung Sub-basin and Bayah High(Darman & Sidi, 2000)

2.3 Stratigraphy of West Java

In 1984, Martodjojo divided West Java into three regional areas based on sedimentary characteristics of Tertiary rocks. The Continental Platform is in the northern part of West Java with the characteristic of shallow marine sedimentary rocks up to 5000m thickness (Bronto, 1989). Bogor Basin includes Bogor, Bandung and Southern Mountains Zones with 7000 m thickness are comprises of mostly igneous and sedimentary rocks such as andesite , basalt tuff and limestone. Meanwhile Banten Area that consist of Rangkasbitung Basin is located in the western part of West Java . The separation of Rangkasbitung Basin and Bogor Basin is maybe caused by major fault (Bronto, 1989).

Clements and Hall (2007) found that "Almost all the rocks exposed on Java are Cenozoic, and they include igneous intrusions, volcanic products, siliciclastic sedimentary rocks and shallow marine carbonates". Formed in quite different settings, Middle Eocene formations in the Ciletuh Bay area are the oldest Cenozoic rocks in West Java. Volcanogenic sediments deposited in fluvial to deeper water marine environments, terrestrial quartz-rich sandstones, reefal and foraminiferal limestones can be found in the Oligocene epoch of West Java.

2.4 Structural geology of West Java

There is four group of structural patterns that can be found in Java which is N-S trending of Sunda pattern, N-E trending of Meratus pattern, E-W trending of Java pattern , N-W trending of Sumatra pattern (Pulunggono and Martojojo 1994, Untung and Sato (1978) and Satyana (2007). Satyana (2007) claimed that the age for every structures is different from Late Cretaceous(Meratus Pattern) , Late Cretaceous to Paleocene(Sumatra Pattern), Eocene to Late Oligocene(Sunda Pattern) and Early Miocene(Java trend). Besides, all Sumatra, Meratus and Sunda pattern is consist of strike slip and normal fault.

N-W strike slip fault of Sumatra pattern highly dominate West Java area (Untung & Sato (1978) and Satyana (2007). High density lineament can be found in the vicinity of Bogor and southwest Cirebon, with a concentration of shallow and intermediate earthquake foci around the Bogor lineament (Bronto, 1989).

2.5 Volcanism history of West Java

The volcano-magmatic arc in West Java is a subduction-related product that was developed since early Tertiary (Fauzi et al., 2015). Soeria-Atmadja et al. (1994) explained that on 40 ma to 19-18 Ma, the first volcanic activity occurs while second volcanic activity took place 12 Ma or 11 Ma to 2 Ma and these volcanic product were covered by Sunda Arc Quaternary volcanoes. In 1949, Bemmelen found that the Quaternary volcanism is divided by into young volcanic and old volcanic, where young volcanic occur in Late Pleistocene while old volcanic occur in early to middle Pleistocene (Sunardi & Kimura, 1998). Sendjaja and Kimura (2010) discovered there are two volcanic range in West Java , which is volcanic front and rear arc. Geochemical characteristics from Tertiary and Quaternary volcanoes show that for past 10 Ma, magmatic product e.g. lava of Sunda Magmatic arc in West Java has been in steady state (Sendjaja & Kimura ,2010).

2.6 Geochemical and Petrology Study of Arc Magma Volcanic Product

Hartono and Sulistyawan (2011) explained that arc magma could be classified into two main groups, primary magma that originate from either melting lithospheric mantle or crust, and secondary magma which felsic magmas are derivative products from more primitive magma. This primitive magma also undergoes differentiation process . Arc magma source come from the upper mantle with either OIB-like or MORB-like, the subducted slab consisting an oceanic basaltic crust and possibly sediments, including material derived either through melting or release of fluid and the arc crust.

Most arc magmas with trace element and isotopic evidences, are derived from melting of upper mantle induced by released fluids and incompatible elements from subducted oceanic crust. When the depth of Benioff-Wadato zone increase, the amount of of K_2O content in many arcs would also increase. The strontium (Sr) and neodymium (Nd) isotopic characteristics that are present in the arc rocks within the mantle array could generate arc magma from either depleted asthenospheric mantle sources (MORB characters) or enriched mantle source unmodified by subduction zone components (OIB characters). Arc magma contamination by crustal components can be identified using Sr and Nd isotopic data.

There are two types of contamination, crustal contamination and source contamination. Crustal contamination can be defined as contamination of mantle derived magmas through direct assimilation when the magma move ascend through it. Meanwhile source contaminations are involving crustal components enrichment, via either bulk mixing or subducted slab-derived melt, into the mantle. The Sr and Nd isotopic characteristics and Zr/Nb values of Wilis Basalts may be an indication of this mantle has a MORB-like isotopic composition

2.7 Methodological approaches for volcanic product study

The method that have been used for previous study of volcanic products is X-ray Fluorescence (XRF) , the inductively coupled plasma (ICP) ion source mass spectrometers (MS) and thin section. According to (Abdurrachman & Yamamoto, 2012) 35 samples of Papadayan and Cikuray Volcanoes were selected for chemical analysis of major and trace elements by using Rigaku 3270 X-ray Fluorescence (XRF).

CHAPTER 3

MATERIAL AND METHODOLOGY

3.1 Introduction

This chapter is focusing on work flow that covers preliminary research, materials and equipment, field studies, sampling laboratory work and data analysis. A method for general geology study is geological mapping. For geochemical evolution analysis, laboratory work X-ray fluorescence (XRF) is the best approaches. Meanwhile for further petrology studies of the volcanic product/rock sample, thin section preparation is also important.

3.2 Preliminary research

This studies done by review the literature review on previous work such as books, journal article and conference bulletin to understand more about the research topic. Preliminary research is important to bring the idea and problem statements that could be found in the literature and being utilized as a source of writing new information about the research topic. Therefore, there are also sources on the internet. Internet resource that can help complete the studies includes free e-journals, electronic books and online published thesis. The base map is prepared to assist understanding about geomorphology and lineament analysis of study area such as road, town, contour elevation and also rivers.

3.3 Materials and equipment

Materials that are used for geological mapping in the study area included Brunton Compass, GPS, geological hammer, 1 mol of HCL, digital camera, hand lens, measuring tape ,sample bag, field notebook , and clipboard. For the geochemical study, the equipment will be used is x-ray fluorescence (XRF) . Meanwhile for petrology, the prepared thin section will be observed by polarized microscope.

3.4 Field studies

Geological mapping be conducted by observing the study area environment. Field book is significant for rock classification especially to name the rocks in the field.. These included strike and dip reading as well as dip angle by using Brunton compass. During traversing, rock samples are collected and data about structural geology of the study area were recorded for further analysis. Apart from that, a picture of structures and outcrop was taken by placing an object such as a compass for the scale to give estimation size of the outcrop.

Besides that, several maps were prepared using GIS software such as base map, station map, elevation map, geomorphological unit map, drainage map and geological map. Due to age rock in study area, there is no structural geology being found or less significant to be included in this research. The samples that were collected bought to the laboratory for further petrography investigation.

3.5 Sampling

Samples were collected during undergoing geological mapping by breaking the outcrop using a geological hammer. The size of the sample needs to be as big as knuckle to get precise observation and have wider fresh surface area. The sample needs to be label to avoid any confusion of their locality in the study area. This is to make sure that rock samples are in good condition for further lab analysis.

3.6 Laboratory Work

Laboratory work can be divided into two categories, geochemical analysis and petrology analysis. For geochemical analysis, this research applies a technique that well known in rock composition study, that is X-ray fluorescence (XRF). For petrology analysis, method from petrography , preparing thin section by observing the mineral present in the volcanic products/rocks.

3.6.1 Thin section

The thin section is important for optical mineralogy and petrography study. The thin section were used with a polarizing petrographic microscope . A diamond saw was use to cut rock sample into thin sliver and ground optically flat. It is then mounted on a glass slide and then ground smooth using progressively finer abrasive grit until the sample is only 30 µm thick. Michel-Lévy interference colour chart is involved. Commonly, quartz which is one of the most abundant minerals is used as the gauge for thickness determination. two polarizing filters set at right angles to each other. As different minerals have different optical properties, most rock forming minerals can be easily identified.

A thin section is a 30 µm (= 0.03 mm) thick slice of rock attached to a glass slide with epoxy. Although larger ones can be produced, typical thin section slides are 26 mm x 46 mm. Generally they are covered by another glass slide, a cover slip also attached to the rock with epoxy. The epoxy ideally has an index of refraction of 1.54.Five main tools is used to complete a thin section, that is the slab saw, the trim saw, the grinder, the cut-off saw, and the lap wheels. Preparation of glass slide is important. The glass slide must be flat for the rock section to end up with a constant thickness. Frost the slide to remove the thick spots on the slide and adjusting the slide face to be parallel to the grinding wheel's face.

Step 1 is, cutting a slab. A suitable size slab for mounting on a slide is cut from a piece of rock or drill core with a diamond saw. The slab then need to be cleaned to remove any oil and grit from the slab saw process. Step 2 is initial lapping of the slab. Label one side on the slab and the other side is lapped flat and smooth first on a cast iron lap with 400grit carborendum, then finished on a glass plate with 600 grit carborondum. Move to step 3, the glass slide is added. The glass slide needs to be drying on a hot plate before being glued to the lapped face of the slab with epoxy. Epoxy is an adhesive, plastic, or other material made from a class of synthetic thermosetting polymers containing epoxide groups.

Step 4, the slab is sectioned. By using a thin section saw, the slab is cut-off close to the slide. A thin section grinder is used to further reduced the thickness of the slab. Powders are mixed with epoxy, then spread on a slide and allowed to cure. The surface is ground flat on the thin section grinder, then finished similarly to thin sections. Next is step 5, final lapping. To achieved a finished thickness of 30 microns, lapping the section by hand on a glass plate with 600 grit carborundum need to be done. A fine grinding with 1000 grit prior to polishing is optional.

Polishing is the sixth step. To achieved a suitable polish for a microscope or SEM studies, the section is placed in a holder and spun on a polishing machine using nylon cloth and diamond paste. And last but not least, step 7, final inspection.

3.6.2 X-ray fluorescence (XRF)

The energy dispersive X-ray fluorescence spectroscopy (XRF) is a method for measuring the thickness of coatings and for analysing materials. It can be used for the qualitative and quantitative determination of the elemental composition of a material sample as well as for measuring coatings and coating systems. In both laboratory and industrial environments, the fluorescence spectroscopy (XRF) is now well established and can be readily utilised with modern equipment

Volcanic products or volcanic rocks that have been collected during field study were brought to a laboratory for further preparation. Weathered surface rock needs to be removed before the rock sample being crush into coarse grain in the jaw crusher. 50-80 gram of grain being select and will be ground into a tungsten-carbide swing mill (Hartono and Sulistyawan,2010). A major element was measured from glass discs, by preparing 0.7 gram sample powder, 3.75 gram lithium borate flux , and 0.05 gram lithium nitrate, using an automated Phillips PW 1480 X-Ray fluorescence spectrometer.

The sample for the XRF method is prepared in fused disks. The dissolution of a portion of the sample by flux and fusion into a homogeneous glass entirely eliminates particle size and mineralogical effects. The fusion technique also has additional advantages, high specimen dilution to decrease matrix effects and easy to prepare standards of desired composition. The fusion is done by heating the mixture of 4 grams of sample and 9 grams of lithium tetraborate flux at high temperatures

(800 to 1200°C). This is to make sure the flux melts and the sample dissolves. The end product after cooling is a one-phase glass and the overall composition. Heating of the sample-flux mixture is done in platinum alloy crucibles, and then poured into a Pt mold.

After the sample well prepared, startup and performance check of the XRF instrument being done. When XRF is confirmed in good condition, software is set up favoring to the type of sample being analysed. Turn on the helium if running a liquid sample and clandestine laboratory samples. Pressure is set at approximately 20 psi. The software is ready to start data collection if everything is set systematically. Choose the Analyse from the main menu. The instrument can remain on after analysis is complete. The x-ray is not on while the instrument is idle. Due to some limitations ,this instrument is unable to identify the following elements, hydrogen, helium, lithium,beryllium, boron, carbon, nitrogen, oxygen, fluorine, and neon. Therefore this limit can be overcome by using ICPMS.

3.7 Data Analysis

After all method have been conduct, data that be collected from field and laboratory work were analysed. Distribution of major elements and trace elements that shows in result of XRF would be most significant data that can give further interpretation of volcanic rocks formation. For the trace elements abundance was plotted in spider diagram with Chondrite-normalize. The abundance of certain elements would give some recognition of their parents magma and thus determination of their relationship to the magma can be determine. By comparison to previous study, interpretation of their evolution while moving to the surface can be made, whether it undergoes fractional differentiation or crustal contamination. Thin section of the volcanic products would give further understanding about mineral contents and their abundances in the sample collected and naming the rock.

CHAPTER 4

GEOLOGY

4.1 Introduction

Geological mapping is one of the ways to learn about Earth and rocks with historical events that build through the endogenic or endogenic process. In general, there is few approaches that were use to complete this geological mapping such as traversing, geomorphology, stratigraphy and structural geology. 5km x 5 km map of Banjaran area were produced after completing geological mapping that will represent traverse data, geomorphological data, lithology data, stratigraphy data and structural geology data. This map is very useful for natural resources exploration, site investigation and construction in future.

Geological mapping is done at Banjaran, Bandung Regency, West Java Province, Indonesia. The coordinate is (07^{o}2’25.50” S, 107^{o}33’25.43” E) ,(07^{o}2’25.50” S, 107^{o}36’08.96” E) , (07^{o}5’08.11” S, 107^{o}36’08.96” E), and (07^{o}5’08.11”S, 107^{o}33’25.43” E).

The location can be accessed by using various types of vehicles from Bandung which takes about one hour to arrive. During mapping, most of the place in the study area especially in the southern area can only be travel by using a small vehicle such as a motorcycle, and there is some place that traverse only can be done by walking. Meanwhile at north east of study area, the population is quite dense because the town of Banjaran is located here.

Based on observation and interview session with few villagers, most of the community in mapping area is Sundanese and they can speak Sundanese language fluently. Their source of income is various depend on the place in the mapping area. They involve in farming and trading business, while some of them work with government agency such as schools, district office and police station. The level of exposure or residents towards education is quite good, they mostly at least entered high school and not illiterate.

Regional map indicate that the area is dominant of volcanic product and lahar that come from young and old volcanic eruption. While conducting research, the base camp is at Padjajaran University Hostel. The activity of geological mapping not so difficult, about 80% of study area can be covered. This is due to many small roads that made by villagers for their agricultural activity. Another 20% cannot be covered because it is a military area that has very high security.

Weather during the study was quite good because at the time, drought was occurring and the water in the river dried up, allowing a lot of outcrops to be easily reached. Most of the outcrop station marked in study area is in the dried river. Samples of the rocks are collected for megascopic analysis and some been thin section. The traverse map is shown in Figure 4.1, while Figure 4.2 shows the station map for each outcrop that has been marked in GPS.

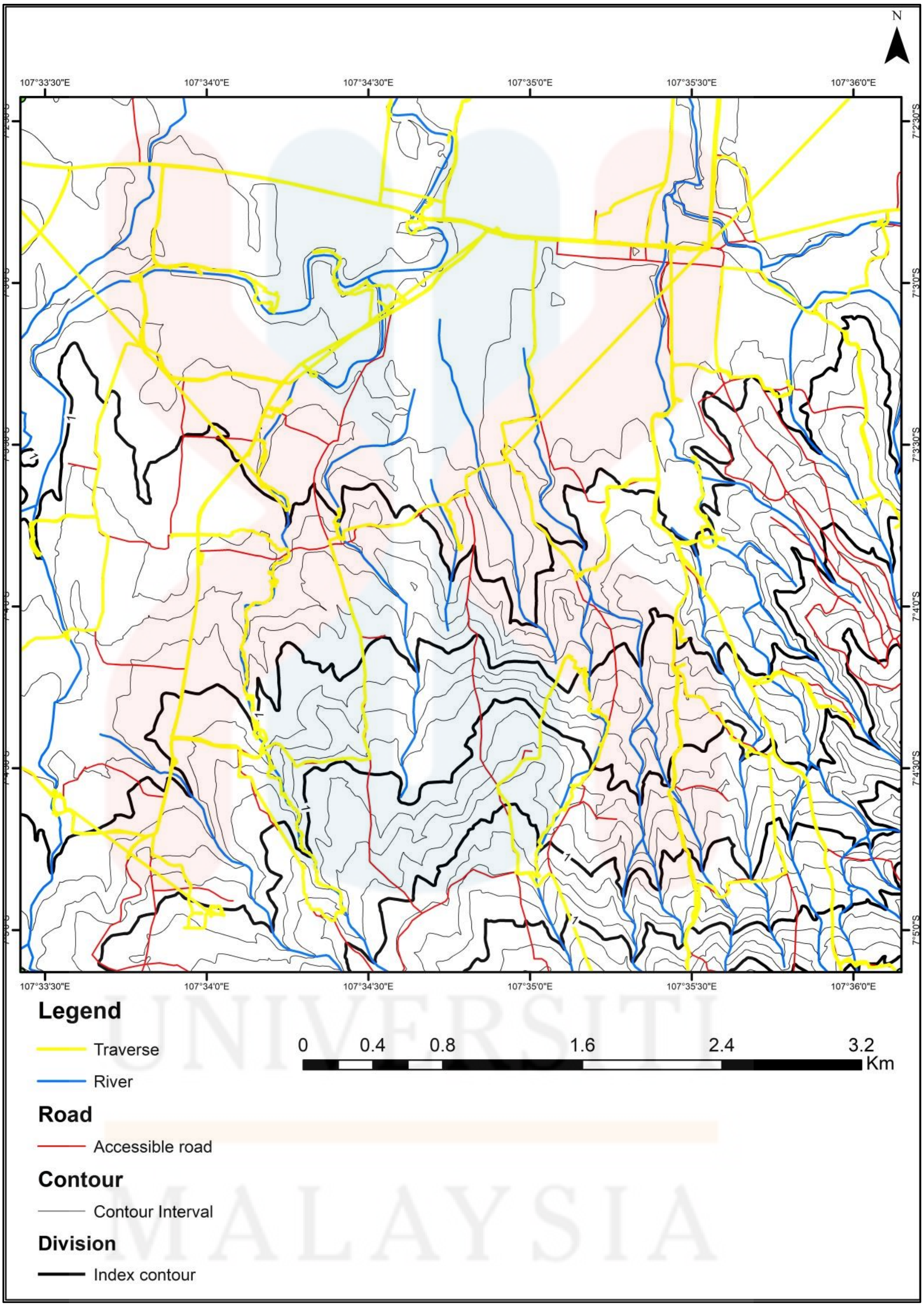


Figure 4.1: Traverse map

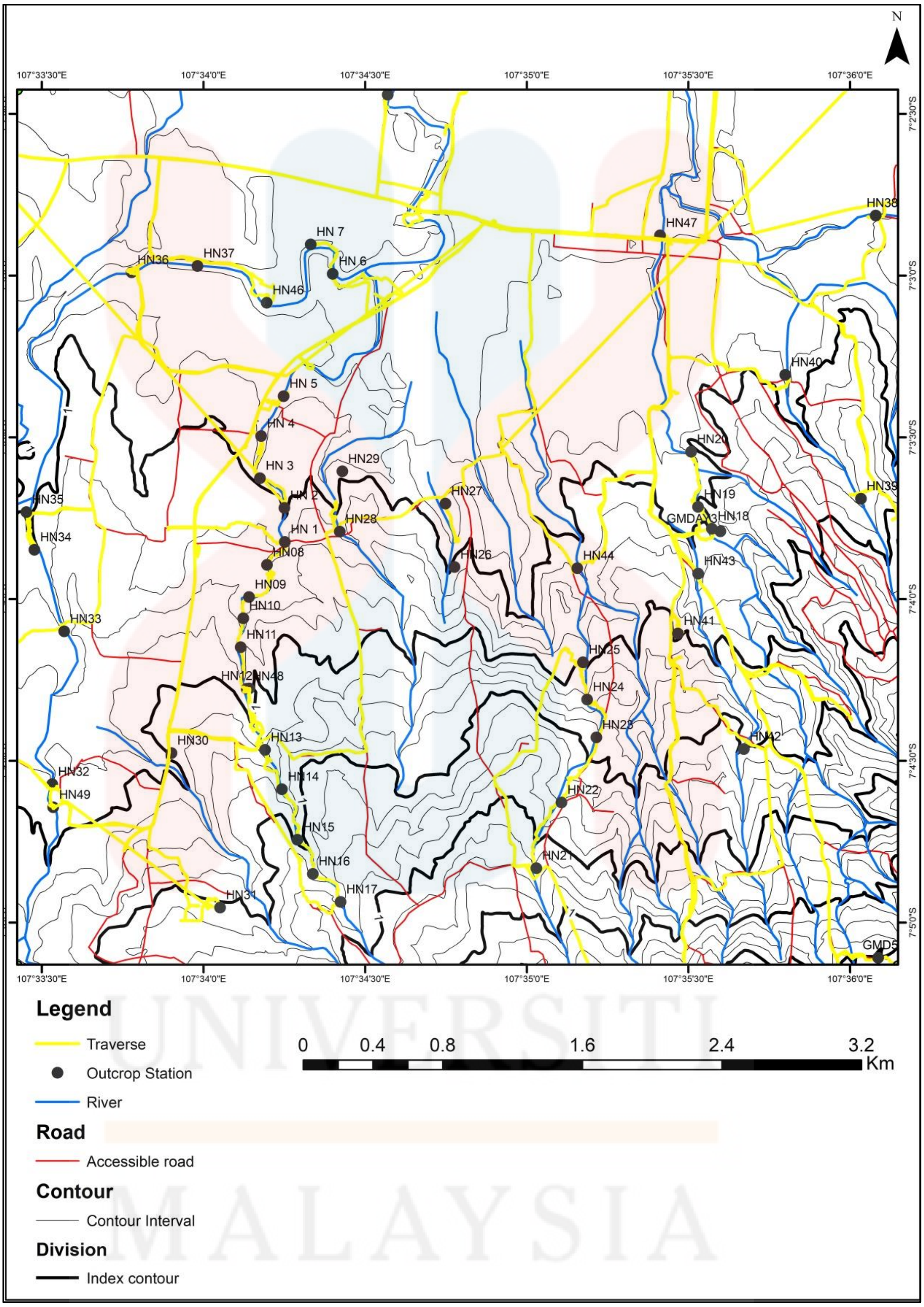


Figure 4.2: Station Map

4.2 Geomorphology

Geomorphology explains the landform features on the Earth surface. Earth surface morphology is strongly associated by structures, processes and erosion stages which these events is the cause of landforms in study area to occur. Geomorphology is the sub study of geology that studies the forms of Earth surface and all the changes that occurred during evolution as result of geological activities. Landform that occur by the Earth dynamic includes mountains, hills, low plain , plateau , highland and valleys. There are several factors that affect the formation of landform such as composition of rock in the area and intensity of geological structures work. Simple example is hard rock will have high resistant towards weathering compare to soft rock that are highly susceptible to weathering process. In addition, tectonic movement produce regional landform that shown by lineaments and straighten river due to faults and folds.

Based on the elevation map in Figure 4.3, the lowest elevation in this study area is located at north which is about 625 meter to 700 meter meanwhile the highest point is about 900 meter at southeast of Banjaran. The elevation of study area is increasing towards the southeast due to it close to the foot of ancient volcano Mount Guntur that have about 2000 meter high. Region dark blue, light blue and light green are mostly composed of volcanic product such as volcanic breccia and tuff.. Light brown region are part of Bandung Basin meanwhile dark blue, light blue and light green region are part of Bandung highland. This is supported by Bronto and Hartono (2006) that claim geologically, Bandung Basin and the surrounding area are comprise of volcanic rocks

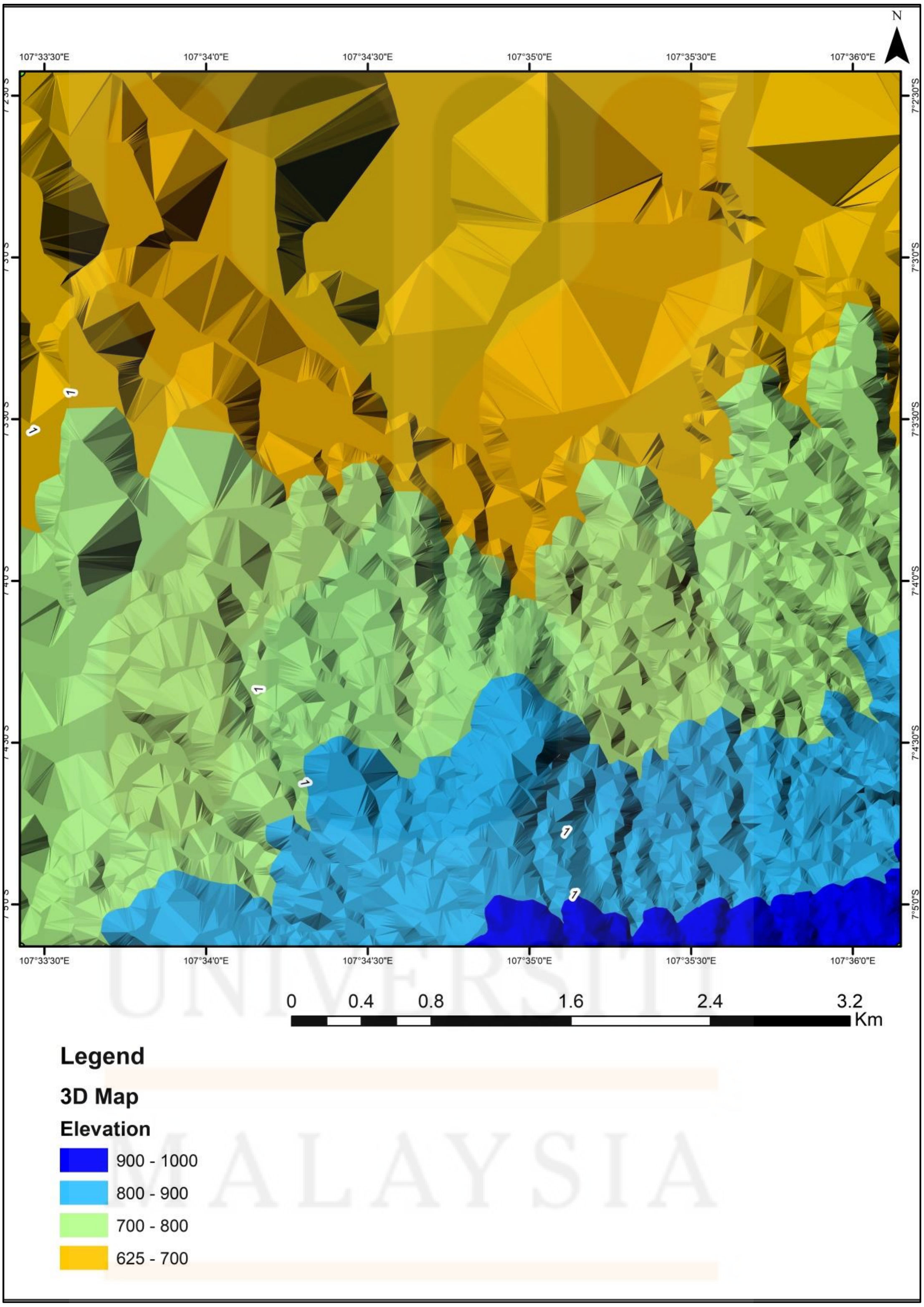


Figure 4.3 : Elevation map of Banjaran area

4.2.1 Geomorphological Unit

The unit of morphology can be divided base on morphogenesis and morphography. There are two morphological unit that can be identified in Banjaran which is, low elevation with surficial deposits unit and high moderate elevation compose of volcanic product unit.

Low elevation surficial deposits are unit in peach colour that can be refer in Figure 4.4. This unit is part of Bandung Basin. Regionally Bandung Basin can be describe as is an oval-shaped basin (ellipse) extending south-southeast to the northwest. This Bandung basin starts from Nagreg area in the east to Padalarang in the west to the bar with a horizontal distance of about 60 km. The Bandung basin is almost surrounded by Quaternary volcanoes. The volcanic products that come from these volcano experienced erosion from weathering process and being transport to the lowest elevation part in this area.

Although this unit have elevation about 650-700 meters, the plain is quite horizontal. Due to horizontal, it have sedimentary characteristic as flow of river such as Ci Sangkuy river and Ci Sangkung transport unconsolidated material and start to deposits. The geomorphology is highly related to fluvial. Fluvial refers to the process associates with running water such as degradation, widening and aggradation. Low elevation surficial deposits comprise about 40% of the study area. This unit is composing of unconsolidated rocks such alluvium and being used as agricultural area. This can be refer in Figure 4.5 and Figure 4.6.

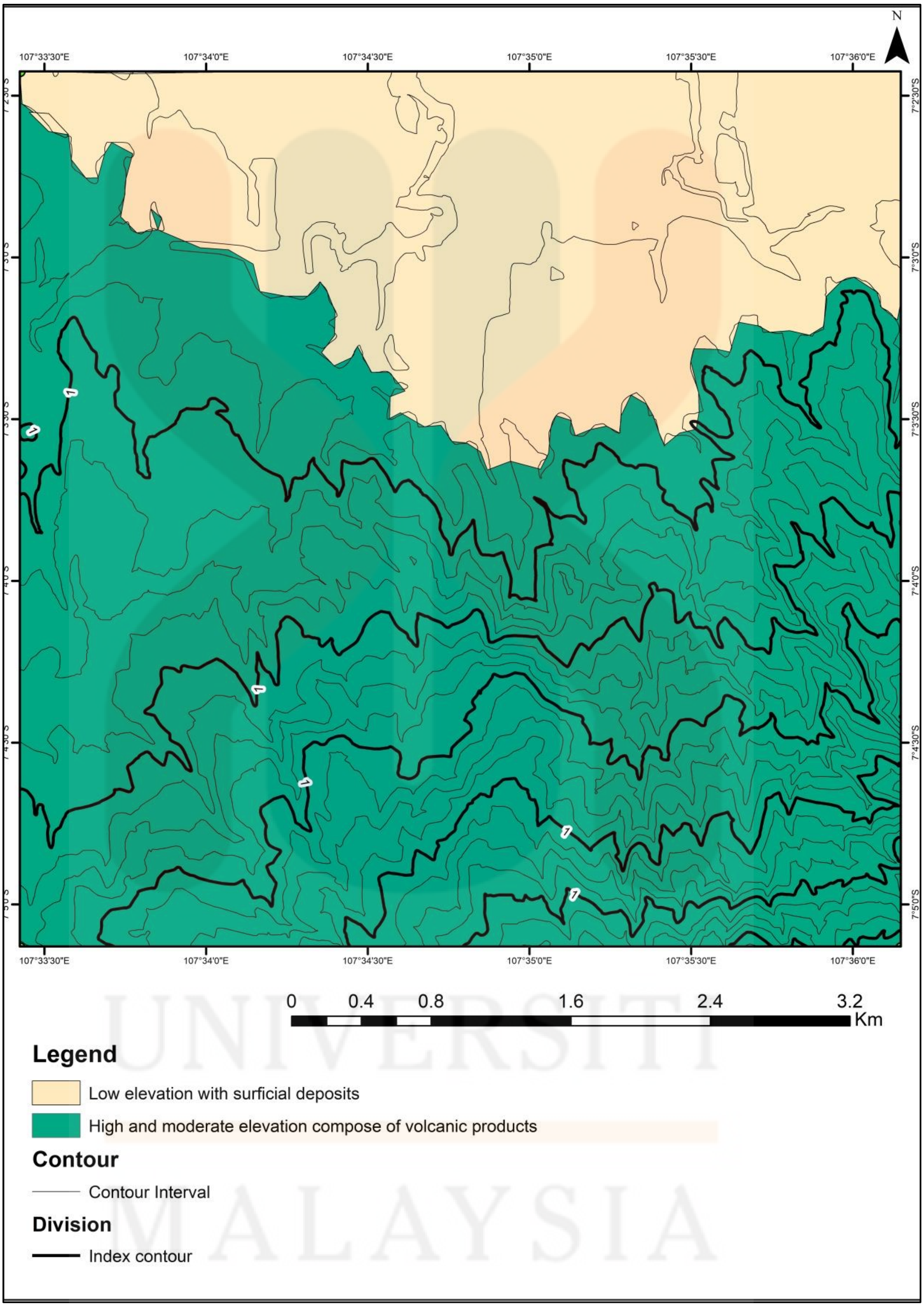


Figure 4.4: Geomorphological Unit map of Banjaran area

Figure 4.5 : Ci Sangkuy river , one of the river that act as contributor of fluvial process, azimuth 135^{o}

Figure 4.6: Most of this unit being used as agricultural area due to its type of unconsolidated rock very fertile.

For second unit, being represent in dark green colour on the map, this is classify as high and moderate elevation compose of volcanic rock. The elevation starts with 700 meter until 1000 meter from sea level. This unit are mostly form from Quaternary and Tertiary volcanism and being part of Bandung Highland. Regionally, Bandung Highland area is composed of Quaternary volcanoes such as Kamojang volcano complex, Mount Malabar, Mount Patuha and Mount Kendeng. Bronto, Koswara and Lumbanbatu (2006) mention that the highlands of Bandung (700 m) are located in the north, ranging from the western region of Banjaran and Majalaya to the east extends north to Cimahi and Bandung

High and moderate elevation compose of volcanic rock occupies about 60% of the study area. Volcano morphology characteristic of this unit are progressively mountainous towards southeast. This is consistent direction approaching Mount Malabar volcano complex. Mostly river and drainage pattern such as dendritic and parallel are related to this morphology as it has wide range homogenous type of rock which has yet to undergo any structural changes due to tectonic movement.

Lithology of this geomorphology unit composed of pyroclastic rocks such as tuff and volcanic breccia. This highland also accumulated with dense population as there are many settlements build and plantations are also pioneered by hill paddy. The surrounding condition of this unit can be refer in Figure 4.7 shows the mountain range meanwhile Figure 4.8 that shows the settlement of local people.

Figure 4.7 : Mountain range in study area

Figure 4.8 : Local people settlement

4.2.2 Drainage pattern

Drainage pattern can be analyse based on topographic map which is stream are associated with the main river. Drainage pattern generally is controlled by structural geology condition and resistance of rocks towards act upon it. Therefore, the drainage patterns that occur in the study area are dendritic pattern and parallel pattern. Landform and topography including the slope gradient and lithology give big influenced towards drainage pattern that later form a system by the streams, rivers and lakes in drainage basins. Drainage basin can be defined as topographic region which have streams receive runoff, through flow and groundwater flow. The larger the topographic map, the more information on the drainage basin is available and various number, shape and size of the drainage basins can be found. The surface runoff of the rain water formed the streams in the study area. Due to gravity, the flowing of rain water will move downward from higher elevation to lower elevation.

Dendritic pattern or tree-shaped drainage pattern is the most widespread pattern that can be found all around the earth's surface. It characteristic, such as tributaries of various orders and magnitudes of the trunk or master stream that looks like roots branches of a tree making it get such a name. Dendritic pattern often related to the areas that comprise of homogenous lithology, horizontal or very gently dipping strata and extensively flat topographic surface with low reliefs. Eventhough dendritic pattern not really influenced by structural and lithological controls but most lithology with uniform type provide ideal state for the development of dendritic drainage pattern. Factors that contribute to the evolution of drainage patterns are lithological characteristics mainly the permeability of underlying rocks, resultant surface runoff, the amount or regime of rainfall and the time factor. Different with dendritic drainage pattern, numerous rivers follow the regional slope and parallel to each other are the main characteristics of parallel drainage pattern. The development of this pattern is commonly on uniform sloping and dipping rock beds such as newly emerged coastal plains or cuestas. Due to the steep slopes, the streams are straight and all have same flow direction. They are very few tributaries can be found in parallel drainage pattern compare to dendritic pattern. Both of drainages pattern can be found occur in Banjaran study area which have similar characteristics that were mention before. This can be refer in drainage pattern map in Figure 4.9.

a) Dendritic drainage pattern

The dendritic drainage pattern covered about 50% from the total area of the study area. It can be found at the southeast of the study area where small streams come from many directions resembles tree roots structure, then it merge to the main rivers that flow from high elevation to low elevation. The direction of flow is towards the north of the study area. There are also small tributaries that are merged with the stream but have not yet been merged with main River. This shows the drainage pattern that is still in the early stages of formation. This flow is the same direction that goes downhill. This drainage pattern composed of homogenous lithology that is volcanic breccia.

b) Parallel drainage pattern

Parallel drainage pattern is a system unit which is predominantly characterized by steep –shaped valleys and coarse to medium rounded topographic structure. Regional and uniform sloping at certain area in Banjaran is one of the occurrence factors of parallel drainage pattern. Ci Guereuh is the river that flow parallel with Pasirlanjung River and merge at Ci Sangkuy River. Both Ci Guereuh River and Pasirlanjung River flow from southwest to the north of study area. The total extend of parallel drainage pattern is about 50% of study area. The lithologies found in this drainage pattern are composed by laharic and volcanic breccia, move to alluvium unit at north of the study area.

c) Watershed

There are three main rivers that flow from south to the north of Banjaran. Generally the geomorphology of this box is compose of high elevation hilly area and lowland that compose of alluvium deposits. The flow from high altitude brings together the eroded product from the process of weathering to the lower area where deposition of sediment begins to form alluvium.

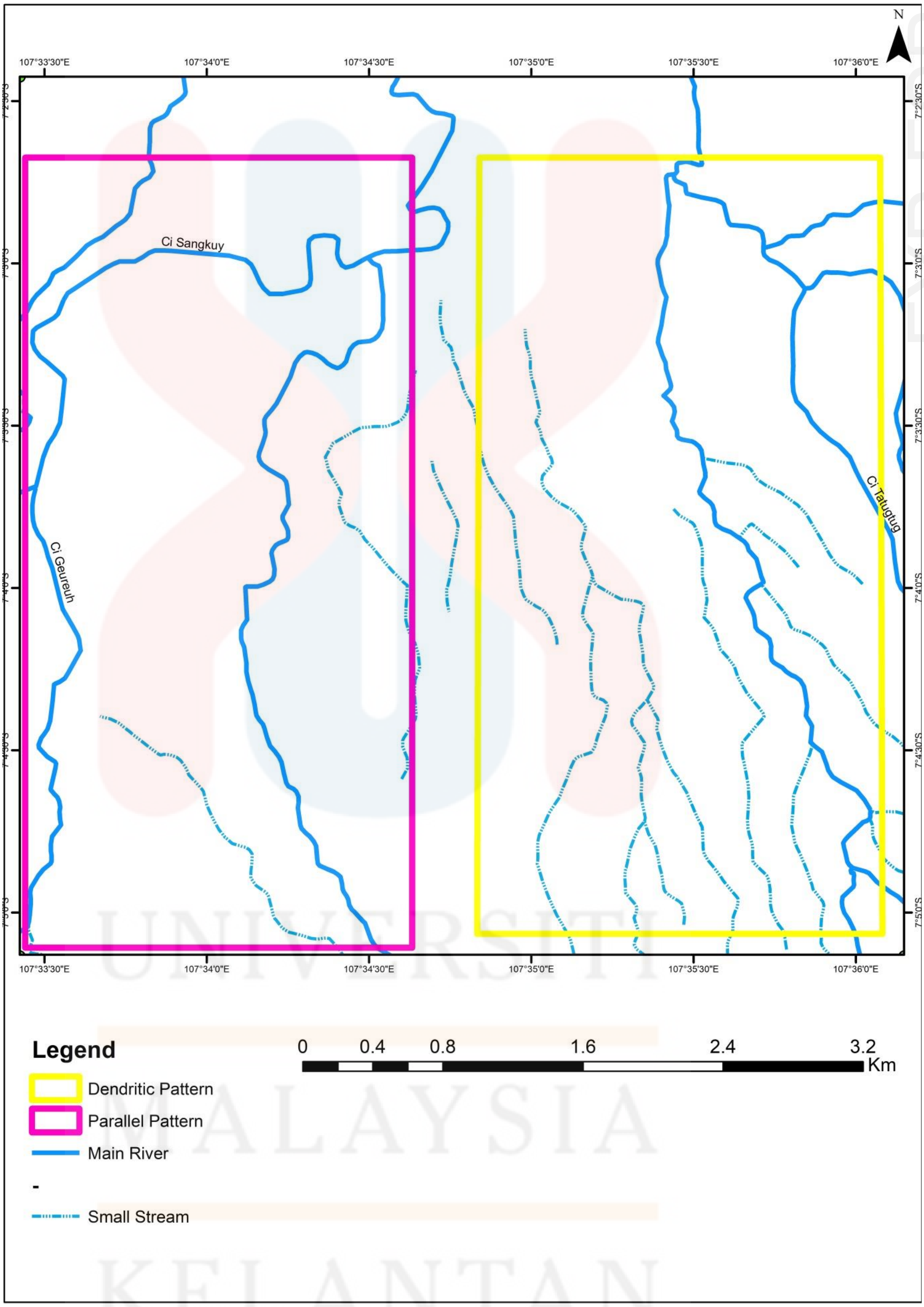


Figure 4.9: Drainage pattern map

4.2.3 Weathering

The weathering processes is the disintegration of rock or mineral and undergo decay process. There are several weathering agents that involve in rock weathering process such as water, atmosphere air, biological (animal and plant) and physical forces(earth movement). The weathered rocks then being eroded, transfer to another place and will be carried by agents such as wind or water to be deposited in as the soil. The weathering process can be seen as the features present in the study area are the main indicator of past geologic activity.

Physical weathering is caused by mechanical disruption by temperature, wind and water. Figure 4.10 shows very clear physical weathering, found at station HN26, with coordinate of 07^o 02’ 59.4” S and 107^o 33’ 46.7” E. This outcrop is located in the middle of the river. Mechanical weathering can be seen with this outcrop form which every day is hit by heavy river water. This is called abrasion process. Abrasion can be define as wearing down of rock particles by friction by weathering agent such as water, wind or ice. The continued vulnerability to these elements gradually breaks down the exposed surfaces of the rocks.

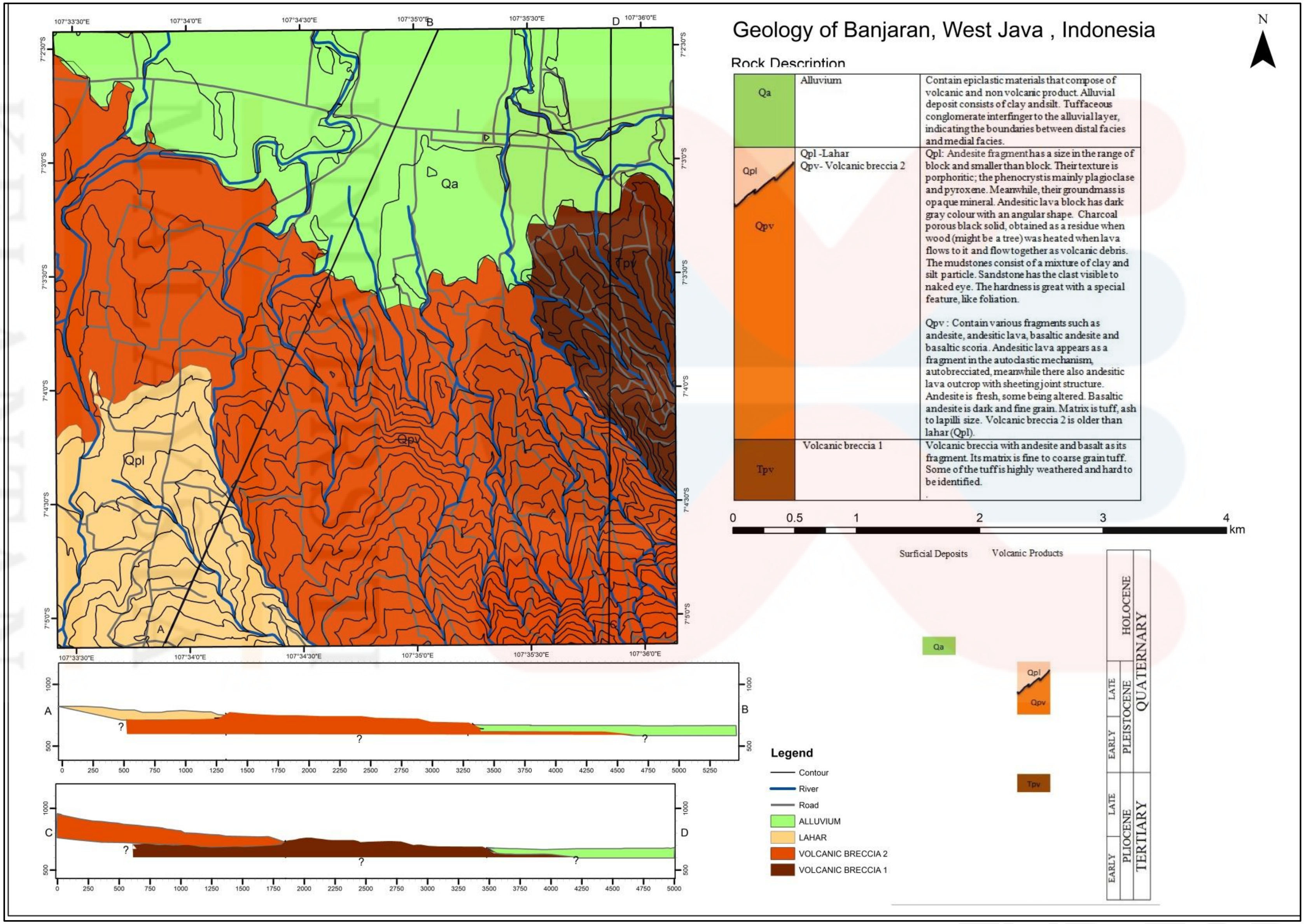
Figure 4.10: Outcrop at station HN26, that shows mechanical weathering by abrasion process of water.

Next is chemical weathering as the rock is decay by chemical reaction. Most of the study area is covered by volcanic rocks. This volcanic rock contains mineral that can be oxidized. Oxidation involves the addition of oxygen and destruction of old compound. Last is biological weathering as the agent is plant or animal. The rate of the weathering is moderate which is caused by the vegetation

4.3 Lithostratigraphy

Informal lithostratigraphy, or rock unit is used for discussion of stratigraphy in the study area. Rock unit that has been categorized during geological mapping will be arranged according to their estimated age. This can be determine by analysis the findings and outcrop during geological mapping. Generally, rock unit classification is based on a common physical characteristic that is observed at the field, including rock type, uniformity of the rock and the stratigraphy position between the rock. Basically the stratigraphy position obeys the laws of stratigraphy such as oldest deposition is located below the younger when there is no unconformity occurred (superposition principle) and the intrusion of rocks is classified as youngest.

The southern part of Bandung including Banjaran, is composed of volcanic rocks. The region experienced Tertiary volcanism at least twice, at Miocene and Pliocene and followed by Quaternary volcanism. Thus, the Tertiary volcanic rocks are stratigraphically overlapped by quaternary volcanic rocks (Bronto et al., 2006). Most of the rock forming is from volcanic eruption that is either in pyroclastic, lava or lahar flow and epiclastic volcanic sediments. Volcanic rock formation and distribution is also influenced by volcanic facies. Important aspects of volcanic facies include distance from eruption source, type of transporting agent and deposition environment. The geological map can be refer in Figure 4.11 meanwhile Table 4.1 shows the stratigraphy sequence and rock description of Banjaran volcanic rock. Figure 4.12 shows the correlation age of lithology unit in study area.



Geology of Banjaran, West Java , Indonesia

Rock Description

Qa	Alluvium	Contain epiclastic materials that compose of volcanic and non volcanic product. Alluvial deposit consists of clay and silt. Tuffaceous conglomerate interfinger to the alluvial layer, indicating the boundaries between distal facies and medial facies.
Qpl Qpv	Qpl -Lahar Qpv- Volcanic breccia 2	Qpl: Andesite fragment has a size in the range of block and smaller than block. Their texture is porphoritic; the phenocryst is mainly plagioclase and pyroxene. Meanwhile, their groundmass is opaque mineral. Andesitic lava block has dark gray colour with an angular shape. Charcoal porous black solid, obtained as a residue when wood (might be a tree) was heated when lava flows to it and flow together as volcanic debris. The mudstones consist of a mixture of clay and silt particle. Sandstone has the clast visible to naked eye. The hardness is great with a special feature, like foliation. Qpv : Contain various fragments such as andesite, andesitic lava, basaltic andesite and basaltic scoria. Andesitic lava appears as a fragment in the autoclastic mechanism, autobrecciated, meanwhile there also andesitic lava outcrop with sheeting joint structure. Andesite is fresh, some being altered. Basaltic andesite is dark and fine grain. Matrix is tuff, ash to lapilli size. Volcanic breccia 2 is older than lahar (Qpl).
Tpv	Volcanic breccia 1	Volcanic breccia with andesite and basalt as its fragment. Its matrix is fine to coarse grain tuff. Some of the tuff is highly weathered and hard to be identified.

Figure 4.11 : Geological map of Banjaran

Table 4.1 : Stratigraphy secquence and rock description of lithology unit of Banjaran box

Qa	Alluvium	Contain epiclastic materials that compose of volcanic and non volcanic product. Alluvial deposit consists of clay and silt. Tuffaceous conglomerate interfinger to the alluvial layer, indicating the boundary between distal facies and medial facies.
Qpl Qpv	Qpl -Lahar Qpv- Volcanic breccia 2	Qpl: Andesite fragment has a size in the range of block and smaller than block. Their texture is porphoritic; the phenocryst is mainly plagioclase and pyroxene. Meanwhile, their groundmass is opaque mineral. Andesitic lava block has dark gray colour with an angular shape. Charcoal porous black solid, obtained as a residue when wood (might be a tree) was heated due lava flows and flow together as volcanic debris. The mudstones consist of a mixture of clay and silt particle. Sandstone has the clast visible to naked eye. The hardness is great with a special feature, like foliation. Qpv: Contain various fragments such as andesite, andesitic lava, basaltic andesite and basaltic scoria. Andesitic lava appears as a fragment in the autoclastic mechanism, autobrecciated, meanwhile there also andesitic lava outcrop with sheeting joint structure. Andesite is fresh, some being altered. Basaltic andesite is dark and fine grain. Matrix is tuff, ash to lapilli size. Volcanic breccia 2 is older than lahar (Qpl).
Tpv	Volcanic breccia 1	Volcanic breccia with andesite and basalt as its fragment. Its matrix is fine to coarse grain tuff. Some of the tuff is highly weathered and hard to be identified.

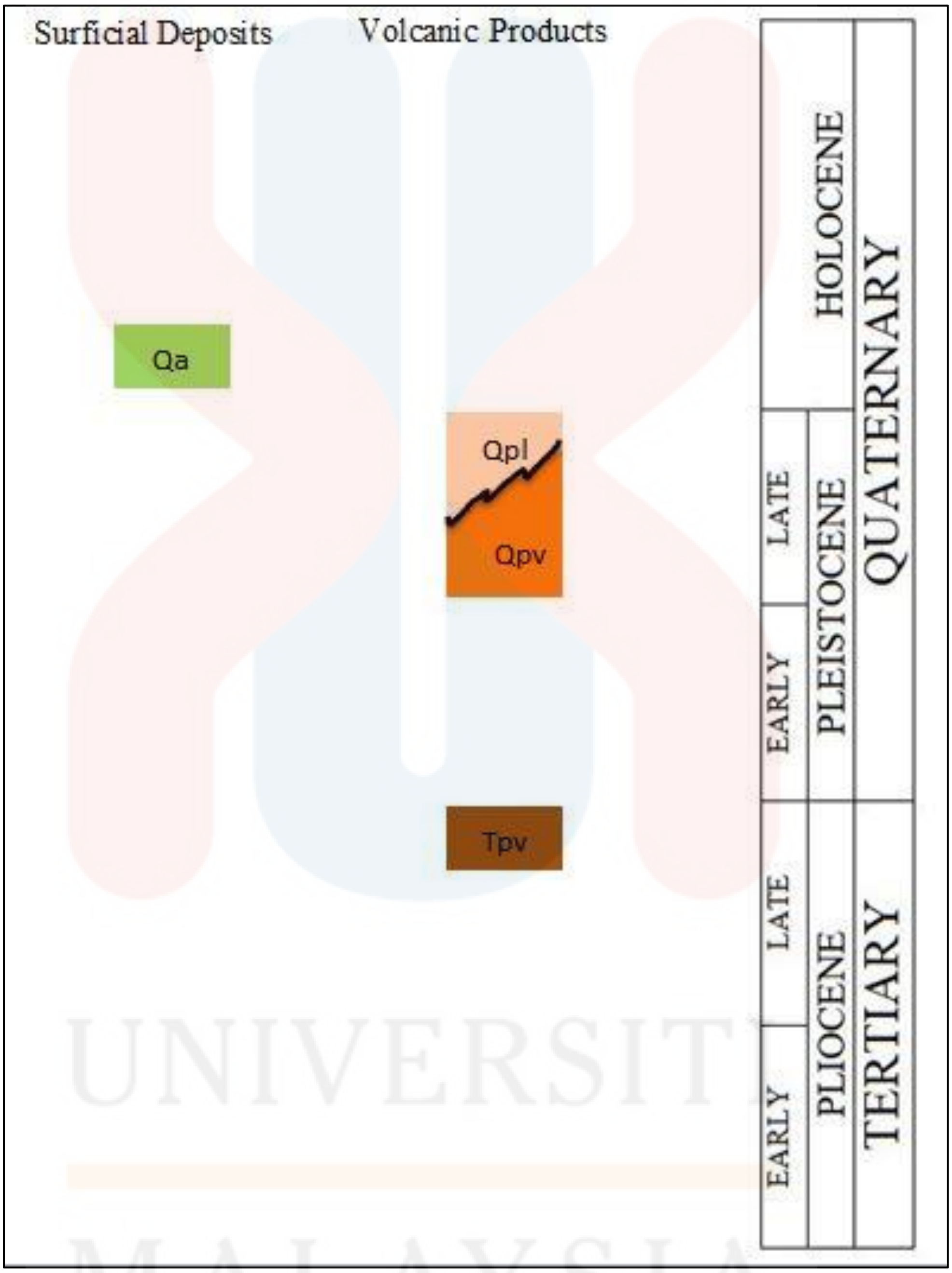


Figure 4.12 : Correlation age of lithology unit in study area

There are four type of facies which is central facies, proximal facies, medial facies and distal facies (Bogie & Mackenzie, 1998). For further understanding, Figure 4.13 shows the sketch of facies arrangement and its rock composition. Central facies contain volcanic rocks that settle nearest to the volcanic vents, and can be distinguished by a characteristic combination of consanguineous dykes ; coarse agglomerates ; thick, steeply banded siliceous lavas; consanguineous sills that are concordant with breccia pipes. This facies has steep initial dips and can be found in 0.5 to 2 km from central vents.

Proximal facies dominated by broad and thick partially autobrecciated lavas and intercalated coarse grained pyroclastics. Their initial dip can be moderate or steep, extends up to 5 to 10 km from central vents. In medial facies, the rocks are laid down on the volcano outer flanks, highly autobrecciated. The lahars may have angular or subangular blocks up to 10 m. Clastic debris is deposited by water, have low initial dips and located 10 to 15km from central vents. Distal facies is when volcanic rocks laid well beyond the base of massive volcano, have great lateral continuity and they conform more similar to conventional stratigraphic law, as predominate epiclastics product.

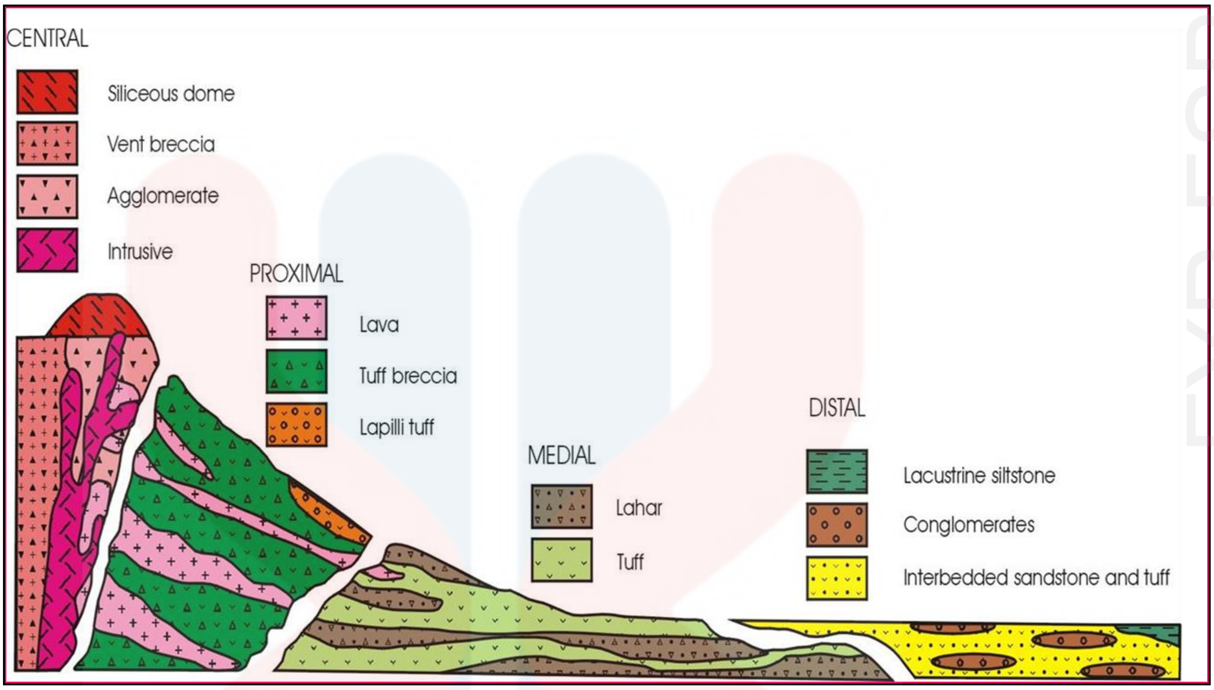


Figure 4.13: The division of volcanic facies into the central facies, proximal facies , medial facies and distal facies and its rock compositions (Bogie & Mackenzie, 1998)

The age of rocks in the study area can be determined by understanding volcanic facies together with contour pattern interpretation. Therefore, geological mapping area can be differentiated to several units starting from the oldest to youngest.

a) Volcanic breccia 1(Tpv)

b) Volcanic breccia 2(Qpv)

c) Lahar(Qpl)

d) Alluvium(Qa)

4.3.1 Volcanic Breccia 1 Unit (Tpv)

a) Lithology Characteristic

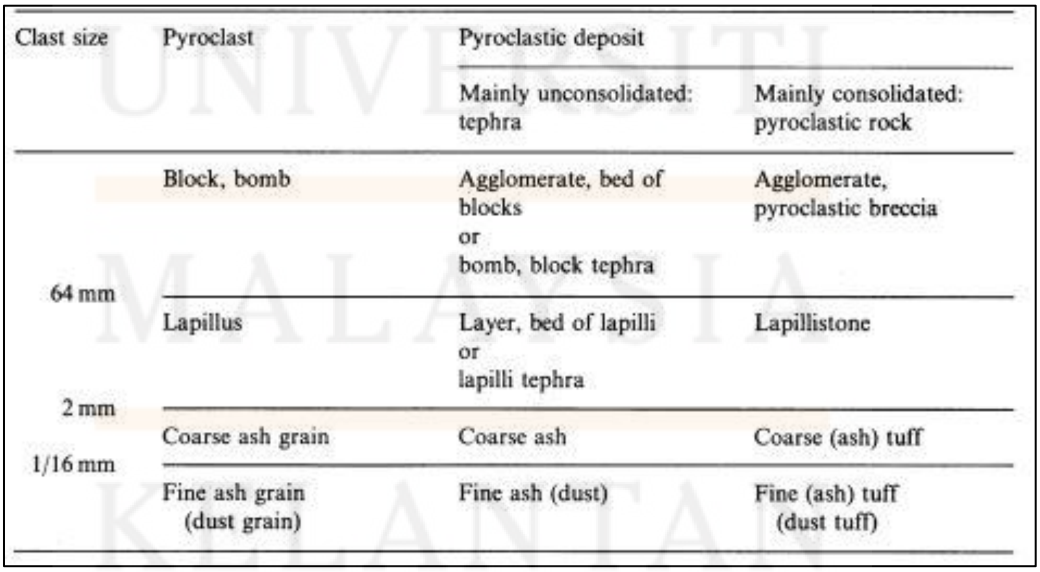
In this lithology unit, observation has been undertaken in five outcrop station which is has code HN18, HN19, HN20, HN39 and HN40 . List of the outcrop is shown in Table 4.2. This unit consists of volcanic breccia. Volcanic breccia is the term that applies for all coarse grain rocks containing abundant angular volcanic fragments (greater than 2 mm in size) and matrix. Fisher (1960) explained that there are three major type of volcanic breccia that have been distinguished according to their fragmentation mechanism ; autoclastic, pyroclastic and epiclastic. Autoclastic volcanic breccias composed of the broken fragment that solidifies first, and then assemble together with liquid, solid or semisolid lava during their movement. Pyroclastic breccia composes of explosions and ejection of liquid and/or solid fragments from volcanic sources. Epiclastic volcanic breccia consists of fragments that undergo any rock fragmentation process which are transported by any epigene geomorphic agent such as running water.

Table 4.2 : Rock description of Volcanic Breccia 1 (Tpv) unit and sample photograph at field (Continued)

STATION	LOCALITY AND ELEVATION (M)	SAMPLE PHOTO AT FIELD	DESCRIPTION
HN18	S 07 03 47.0 E 107 35 34.3 ELE : 719		Volcanic breccia, the fragment is weathered andesite with matrix tuff white to light brown in colour.
HN19	S 07 03 42.9 E 107 35 31.8 ELE : 721		Volcanic breccia, the fragment is weathered andesite with matrix tuff white to light brown in colour.
HN20	S 07 03 32.7 E 107 35 30.5 ELE : 717		Volcanic breccia with andesite fragments that have slightly weathered condition. The size of the andesite fragment range from pebble to coble.

HN39	S 07 03 41.4 E 107 36 02.0 ELE : 745		Volcanic breccia with matrix tuff. Andesite fragment slightly weathered
HN40	S 07 03 18.4 E 107 35 48 ELE : 710		Volcanic breccia with fragment andesite, mudstone,and basalt. Andesite fragment is divided by two, fresh and weathered.

Table 4.3 : Granulometric classification of pyroclasts and of unimodal, well-sorted pyroclastic deposits (Schmid, 1981)



Clast size	Pyroclast	Pyroclastic deposit	
		Mainly unconsolidated: tephra	Mainly consolidated: pyroclastic rock
64 mm	Block, bomb	Agglomerate, bed of blocks or bomb, block tephra	Agglomerate, pyroclastic breccia
2 mm	Lapillus	Layer, bed of lapilli or lapilli tephra	Lapillistone
1/16 mm	Coarse ash grain	Coarse ash	Coarse (ash) tuff
	Fine ash grain (dust grain)	Fine ash (dust)	Fine (ash) tuff (dust tuff)

Outcrop at all five station has shown the characteristic of pyroclastic breccia, the fragment is majorly composed of andesite, but at outcrop station HN40, basalt also present. This fragments are angular in shape, with the size of the block (diameter more than 64mm). The classification of volcaniclastic grain size can be referred to Table 4.3. The andesite fragment that found in this unit is slightly weathered that have the greyish colour and rate of crystallization is subhedral in the texture of aphanitic with the matrix tuff in coloured of whitish ash and the weathered coloured is light brownish ash. Matrix tuff is coarse (ash) tuff, less than 2mm in size. Andesite fragment that found in HN40 have their mineral altered to pyrite. Basalt fragment in HN40 is block in size, have fine grain and dark in colour. Figure 4.14 show the outcrop at HN39 which contain volcanic breccia with andesite as the fragment, and tuff as the matrix, while figure 4.15 shows the outcrop at HN40, which contain andesite and basalt as fragment with matrix tuff. Thin section are describe in Table 4.4

Figure 4.14: Outcrop at HN39, shows the volcanic breccia with andesite in bomb size fragment

Figure 4.15: Outcrop at HN40, shows the volcanic breccia with andesite and basalt fragment

b) Distribution of Rock Unit

The rock unit is spread through east to the northeast which covered about 10 % of the study area. The outcrop can be found at Citamiang and Ciapus Girang.

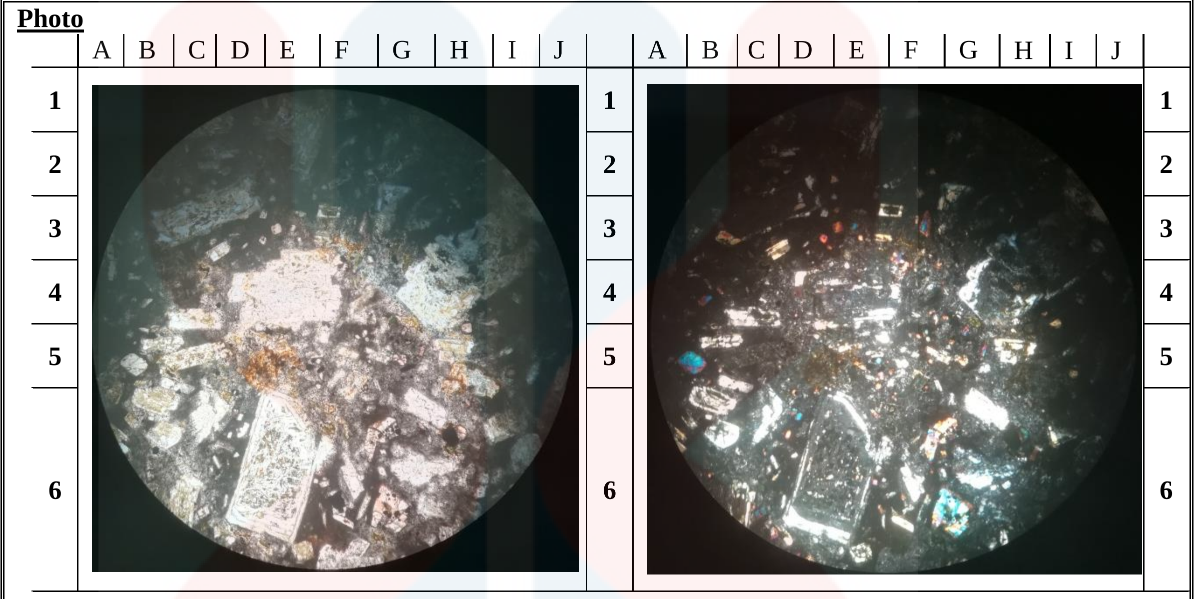
c) Relative age and facies

Volcanic breccia that found in this lithology unit shows the characteristic of medial facies. The gradation of volcanic product occur as outcrop HN18, HN19, HN20 has abundant tuff matrix compare to andesite fragment. Andesite fragment also have medium size from 30 mm to 50 mm. Pyroclastic product like fine ash tuff tend to be dispersed away from eruption source based on its smooth and light size. At HN39 and HN40, the andesite fragment is bigger in size as it nearer to source of eruption.

Table 4.4 : Thin section description of basalt

Station No: HN 40
Rock Name : Basalt

Photo



Plane polarize

Cross polarize

Magnifying Lense Objective 4x, Ocular Lense 10 x. Total Magnifying 40 x

Rock Type : Pyroclastic rock
Stucture Of Rock : Porphoritic
Microscopic Description : Overall is hypocrystalline .Porphoritic with phenocryst of plagioclase, opaque mineral and pyroxene. The groundmass is opaque mineral

Mineralogy Of Description

Composition of Material	**Amount (%)**	**Description of Optical Mineralogy**
Plagioclase(6E)	**50**	Euhedral shape, high relief ,occur zoning. Extinction angle is 31^{o}.
Pyroxene (5B)	**30**	Subhedral , high relief, also have high pleochroism. The extinction angle is 34^{o}.
Hornblende(3E)	**10**	Euhedral, low relief, low pleochroism. The extinction angle is 12^{o}
Opaque mineral (3G)	**10**	Occur inclusion in hornblende, it also the major constituent of groundmass

This consistently follow volcano facies concept as volcanic products coarsening towards eruption source. The initial dipping is relatively flat lying and it is bordered by Alluvium Unit that has distal facies characteristic. In the previous study, Bronto et al. (2006) explained that the Baleendah Volcanic units (BV) spread to Banjaran area. The Baleendah Volcanics unit was originated from eruption of Baleendah Mountain Complex that have three ancient volcano phase which occur about 2.8 m.y.a to 3.2 m.y.a years ago. Baleendah Mountain Complex located at east Banjaran, out of the study area. Figure 4.16 is a map; show the location of Baleendah Mountain Complex.

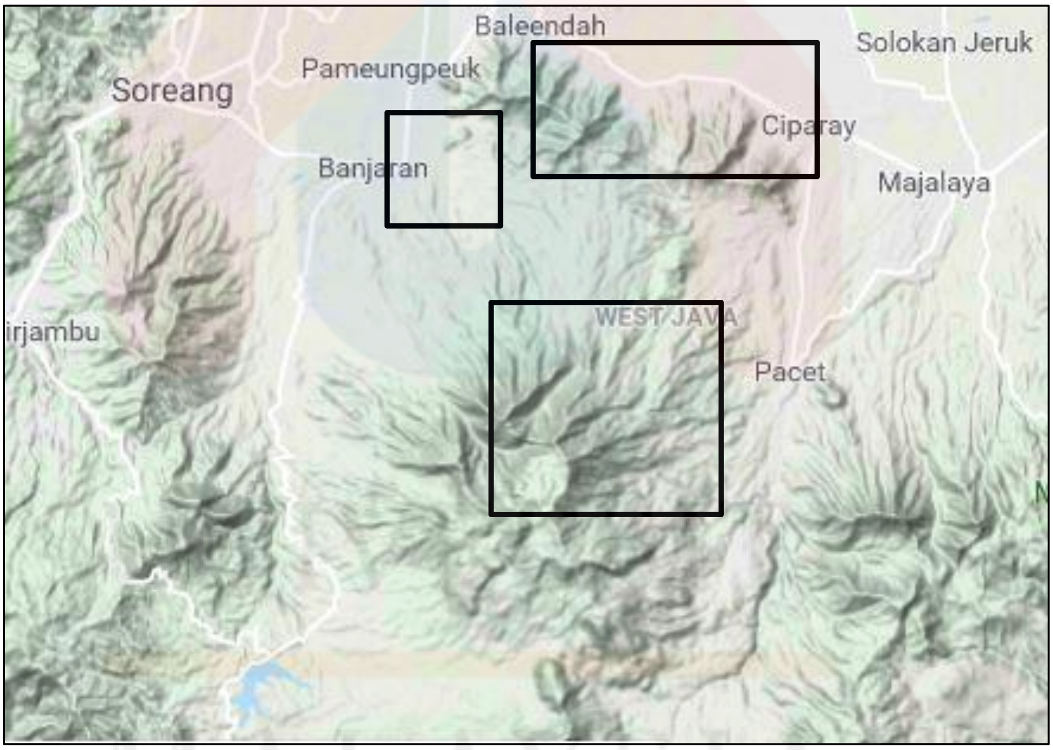


Figure 4.16 : The satellite image shows the location of Gunung Baleendah Complex , east of Banjaran. Baleendah Mountain is the eruption source of Volcanic Breccia 1 Unit meanwhile Malabar Mountain Complex, southeast Banjaran is the eruption source of Volcanic Breccia 2 Unit (Source : Google Map)

Therefore, the relative age of this unit is in Pliocene. Determining the source of eruption is important to estimates the relative age of the rock. This is due to lithological composition is not strong enough to be a separator of rock units, as in volcanic activity a source of volcanic eruption can produce different compositions. Conversely, at many eruption sources and different ages can produce the same rock composition.. Correlation of Volcanic Breccia 1 with Baleendah Volcanic is shown in Table 4.5.

Table 4.5. : Correlation between Volcanic Breccia 1 unit and Baleendah Volcanic

Parameter	Volcanic Breccia 1 unit (Tpv) (This Report,2018)	Baleendah Volcanic (BV) (Bronto et al., 2006)
Lithology	Volcanic breccia with andesite and basalt as its fragment. Its matrix is fine to coarse grain tuff. Some of the tuff is highly weathered and hard to be identified.	Mainly composed of layers of andesitic lava flow with insertion of pyroclastic breccia. The andesitic lava is grey in color, porphoryaphanitic textured, with a massive structure to a smooth - medium hole. The phenocryst mineral composition is plagioclase, pyroxene, and hornblende which are embedded in the aphanitic base mass. White decayed pyroclastic breccia, containing bread crust bombs embedded in the tuff-lapilli matrix
Stratigraphy Position	Below Volcanic Breccia 2	Below Malabar Volcanics
Age	Pliocene	Late Pliocene (2.8 million to 3.2 million years ago)

4.3.2 Volcanic Breccia 2 Unit (Qpv)

a) Lithology Characteristic

Volcanic Breccia 2 Unit have 31 outcrop stations overall. It also is the biggest rock unit in Banjaran. All outcrop station have the code starting with HN1, HN2, HN3, HN4, HN5, HN10, HN11, HN12, HN13, HN14, HN15, HN16, HN17, HN21, HN22, HN23,HN24, HN25, HN26, HN27, HN28, HN29, HN33, HN34, HN35, HN36, HN37, HN41, HN42, HN43, HN44. Table 4.6 shows the outcrop station with sample photo and rock description. This unit contain various fragments such as andesite, andesitic lava, basaltic andesite and basaltic scoria. These entire fragments are embedded together in various matrices such as lapilli-ash tuff , ash-lapilli tuff, and tuff dominated forming volcanic breccia in this lithology unit. According to Schmid (1981), lapilli-ash tuff is term that used for polymodal or poorly sorted pyroclastic rock that contain more than one dominant size which is ash tuff > lapilli tuff. For ash-lapilli tuff, lapilli > ash tuff, meanwhile tuff dominated, the matrix tuff is more than fragment, fragment rarely found being segregated.

Volcanic breccia rock in Volcanic Breccia 2 Unit has a fragmentation mechanism of pyroclastic, autoclastic and epiclastic volcanic rock. Pyroclastic breccia is a common rock in this lithology unit as their characteristic such as block andesite fragment can be found spread across the unit. Outcrop HN28, pyroclastic breccia is shown in Figure 4.17. Autoclastic breccia is found in few outcrops, the fragment is andesitic lava with sheeting joint on their surface. There is also an andesitic lava outcrop at several stations such as HN10, HN17 and HN21. Figure 4.18 shows the autoclastic breccia outcrop HN12, while Figure 4.19 shows andesitic lava outcrop at HN21. Tuffites at HN35, HN36, HN37 is the evidence this rock unit also composed of epiclastic volcanic rocks. Tuffites are rock consist of not more than 75% pyroclasts and more than 25% epiclasts by volume.

Figure 4.17 : Pyroclastic breccia at HN28, the fragment is block andesite

Table 4.6: Station Description of Volcanic Breccia 2 Unit (Qpv) (Continued)

STATION (HN)	LOCALITY/ ELEVATION (M)	SAMPLE PHOTO AT FIELD	DESCRIPTION
1	S 07 03 49.4 E 107 34 15.1 ELE : 728		Volcanic breccia. Fragment is andesite. Some of the mineral in andesite fragment already being altered to chlorite. The matrix is polymodal (poorly sorted) lapilli-ash tuff , white to light brown(weathered) in colour.
2	S 07 03 43.1 E 107 34 15.0 ELE : 722		Volcanic breccia. Fragment is andesite.. The matrix is polymodal (poorly sorted) lapilli-ash tuff, white to lightbrown (weathered) in colour.
3	S 07 03 37.6 E 107 34 10.5 ELE : 712		Volcanic breccia. Fragment is andesitic lava and andesite. Andesitic lava have sheeting joint. The matrix is lapilli-ash tuff, white in colour.

4	S 07 03 29.8 E 107 34 10.7 ELE : 704		Volcanic breccia. Fragment is basaltic andesite with matrix lapilli-ash tuff, white in colour.
5	S 07 03 22.4 E 107 34 14.9 ELE : 699		Volcanic breccia. Fragment andesite with matrix of polymodal lapilli-ash tuff. Tuff white in colour and also light brown colour(weathered) .
10	S 07 04 03.6 E 107 34 07.4 ELE : 745		Andesitic lava block with sheeting joint, andesite also being altered. Matrix ash tuff, white in colour.

11	S 07 04 08.9 E 107 34 06.9 ELE : 754		Volcanic breccia. Andesite fragment have altered mineral. The matrix is ash tuff white in colour.
12	S 07 04 16.6 E 107 34 08.5 ELE : 751		Volcanic breccia. Andesitic lava and andesite fragment. The matrix is lapilli-ash tuff, with colour white and light brownish ash.
13	S 07 04 28.0 E 107 34 11.4 ELE : 785		Volcanic breccia. Fragment is andesite.. The matrix is polymodal (poorly sorted) lapilli-ash tuff, white to lightbrown (weathered) in colour.

14	S 07 04 35.3 E 107 34 14.6 ELE : 806		Volcanic breccia, highly weathered matrix ash tuff, with fresh andesite fragment, ash tuff is dark brown because weathered.
15	S 07 04 44.7 E 107 34 17.4 ELE : 819		Volcanic breccia. Fragment is andesite.. The matrix is polymodal (poorly sorted) lapilli-ash tuff, white to lightbrown (weathered) in colour.
16	S 07 04 51.0 E 107 34 20.3 ELE : 835		Volcanic breccia. Fragment is andesite.. The matrix is polymodal (poorly sorted) lapilli-ash tuff, white to lightbrown (weathered) in colour.

17	S 07 04 56.2 E 107 34 25.5 ELE : 846		Andesitic lava with also sheeting joint found. Andesite fragment is altered to base metal pyrite, matrix ash tuff with dark brown colour(weathered)
21	S 07 04 49.9 E 107 35 01.8 ELE : 881		Lava with sheeting joint. This lava contain oxide. At lower of the outcrop, found volcanic breccia with fresh andesite fragment, the matrix is ash tuff with brown in colour.
22	S 07 04 37.7 E 107 35 06.5 ELE :858		Volcanic breccia with andesite fragment moderately weathered. Some of andesite fragment already altered while some in fresh state. With matrix ash tuff white in colour.

23	S 07 04 25.7 E 107 35 12.9 ELE : 813		Volcanic breccia with andesite fragment moderately weathered. Some of the andesite fragment already altered while some in a fresh state. With matrix ash tuff white in colour.
24	S 07 04 18.6 E 107 35 11.5 ELE : 793		Ash tuff dominated, white and light brown in colour. Only few weathered fragment andesite can be found.
25	S 07 04 11.7 E 107 35 10.4 ELE : 775		Fine ash tuff (< 1/16 mm) dominated. Colour is white and light brown.

26	S 07 04 48.9 E 107 34 47.0 ELE : 699		Fine ash tuff dominated with slightly weathering.
27	S 07 03 42.3 E 107 34 44.9 ELE : 701		Volcanic breccia with andesite fragment. Matrix ash tuff with white in colour.
28	S 07 03 47.5 E 107 34 25.3 ELE : 728		Volcanic breccia with fresh andesite fragment with matrix lapilli-ash tuff that brown (weathered) in colour.

29	S 07 03 36.8 E 107 34 25.8 ELE : 724		Volcanic breccia with fresh andesite fragment. The matrix is ash tuff that brown (weathered) in colour.
33	S 07 04 06.0 E 107 33 34.2 ELE : 736		Volcanic breccia with various fragment size. The fragment is andesite while the matrix is fine ash tuff.
34	S 07 03 50.4 E 107 33 28.5 ELE : 725		Volcanic breccia with andesite fragment. The matrix is ash-lapilli tuff , white and light brown in colour. Andesite fragment has sub rounded shape.

35	S 07 03 43.9 E 107 33 27.2 ELE : 727		Tuffites. The rock is tuffaceous breccia. Mixed of pyroclastics and epiclastics. Andesite fragment have sub rounded shape. The matrix is fine ash tuff white in colour.
36	S 07 02 59.4 E 107 33 46.7 ELE : 702		Outcrop has contact between tuff dominated and volcanic breccia at below. The fragment andesite have been altered and contain mineral pyroxene and few chlorite. Matrix is tuff that also mix with few sediments.
37	S 07 02 58.2 E 107 33 58.9 ELE : 693		Volcanic breccia with andesitic fragment with matrix tuff. Matrix lapilli-ash tuff ,white in colour with fine grain.

41	S 07 04 06.4 E 107 35 28.1 ELE : 765		Volcanic breccia with matrix ash tuff. Matrix ash tuff weathered and white in color. Andesite fragment slightly weathered.
42	S 07 04 27.8 E 107 35 40.3 ELE : 822		Volcanic breccia with matrix ash tuff. Matrix tuff weathered and white in color. Andesite fragment slightly being altered.
43	S 07 03 55.5 E 107 35 31.8 ELE : 745		Fine ash tuff dominated , white in colour.

44	S 07 03 54.3 E 107 35 09.4 ELE : 732		Volcanic breccia but tuff is dominant with slightly andesite fragment. Scoria also found as fragment in block size. Matrix is ash-lapilli tuff, white to light brown in colour.

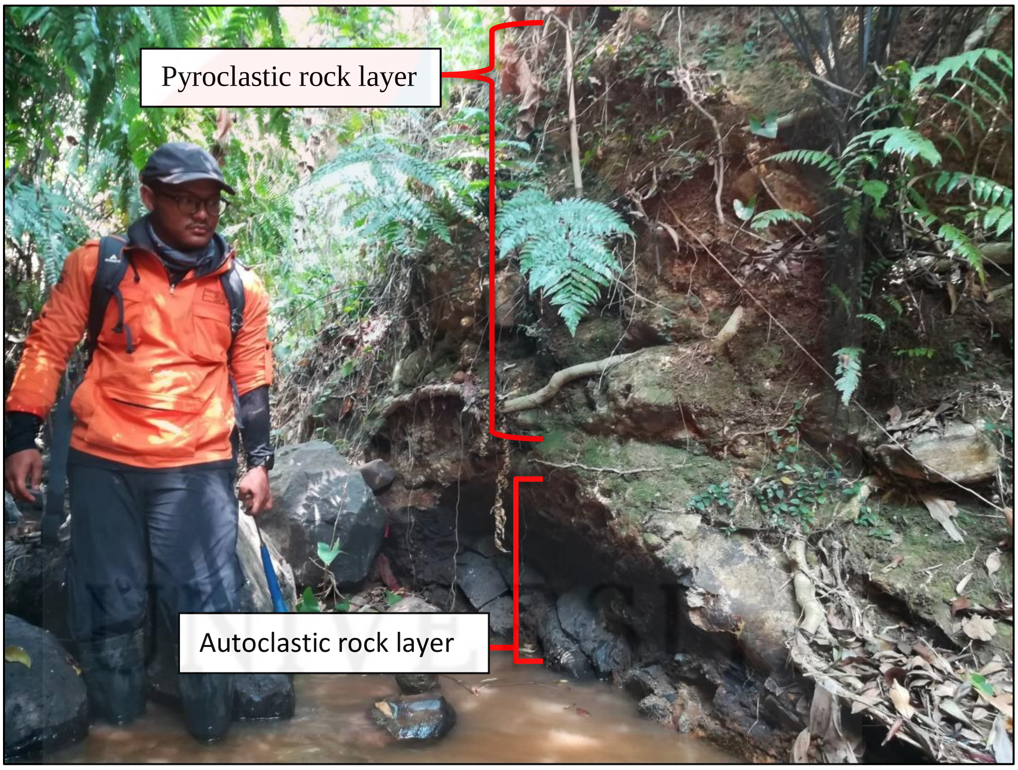


Figure 4.18 : Outcrop HN12 shows the autoclastic rock layer is below the pyroclastic rock layer, this is because the autoclastic rock such as andesitic lava flow and broken down into fragment, and the ashes and other block fragment that erupted in the air, settle on top it, making pyroclastic rock situated on top, and autoclastic rock at below.

Figure 4.19 : HN21 shows the andesitic lava outcrop that has the characteristic of sheeting joint.

Rock description in this lithological unit can be divide into a description of their fragment , and description of their matrix. The andesite fragment is block in size, have angular and subangular shape, some of them can be found as fresh specimen while some are highly weathered. Andesite fragment chemically altered and their mineral composition change to chlorite. This can be seen clearly in hand specimen, but there is also unaltered andesite. Their texture is porphoritic, the phenocryst is mainly plagioclase and pyroxene, meanwhile their groundmass might is opaque mineral. The degree of crystallization is subhedral. Basaltic andesite can be distinguished by its colour. Their colour is darker than common andesite as they contain more mafic mineral. Basaltic andesite is the transition of andesite to basalt. They also porphoritic with phenocryst of plagioclase.

Andesitic lava is not much different from andesite in term of mineral content. The reason this rock being named as andesitic lava is the mechanism of their formation that is lava flow from eruption source. The sheeting joint on the lava surface is because of lava cooling process, making them in sheet like shape. Scoria was found in HN44 as fragment in volcanic breccia and the only outcrop that has it. This rock is dark in colour with physical composition of basaltic like. It has abundant round bubble- like cavities known as vesicles. Figure 4.20 shows the hand specimen of scoria. Thin sections of rocks in Volcanic Breccia 2 Unit are being shown in Table 4.7 for andesite lava, Table 4.8 for basaltic andesite. Table 4.9 for scoria and table 4.10 for tuff matrix

b) Distribution of Rock Unit

The rock unit is spread through south to southeast, and west to northwest. This covered about 45 % of the study area. The outcrop can be found at Dangdeur , Kebonkalapa, Bugel Girang, Pasirgede, Cigeuntur, and Citanjung.

c) Relative age and facies

This lithological unit covers about 45% of study area parameter. With a wider area distribution, is also the most extensive unit within the study area making the volcanic facies is easier to determine. Bronto et al. (2006) explain that the source of this volcanic product is from ancient Malabar Volcano. Ancient Malabar Volcano is massive volcano, diameter in the range of 20 km. Bogie and Mackenzie (1998) claimed this volcanic rocks have age about 0.23 m years ago by doing K-Ar dating. Now, the remains of this ancient volcano form such high peaks of Puntang Mountain and Puncak Besar Mountain. In Figure 4.16, ancient Malabar Volcano is located far beyond the southeast of Banjaran box.

Based on observation at field, the southern side of Banjaran box, at station HN17 and HN2 have end of proximal facies boundary indication. The indication is andesitic lava outcrop that form when lava flow to this area from previous ancient eruption of Malabar Volcano. This is supported by occurrence of autobrecciation mechanism at outcrop HN12, which is overlaid by pyroclastic rocks product, can refer Figure 4.18.

Moving to the northwest of the study area (this unit only), the facies is medial facies as abundance of pyroclastic product forming volcanic breccia is clearly visible. The pyroclastic product such as tuff, andesitic lava block, andesite, basaltic andesite, basalt and scoria has their own size gradation. The composition of fragment depleted, and tuff progressively start to dominated as move further from eruption source. Tuffites, shown at Figure 4.21 indicate the boundary of distal facies. HN26, HN27, HN43 and HN44 is volcanic breccia with few fragment and highly compose of tuff matrix, shows that it located at the end of medial facies. Correlation of Volcanic Breccia 2 with Malabar Volcanic is shown in Table 4.11.

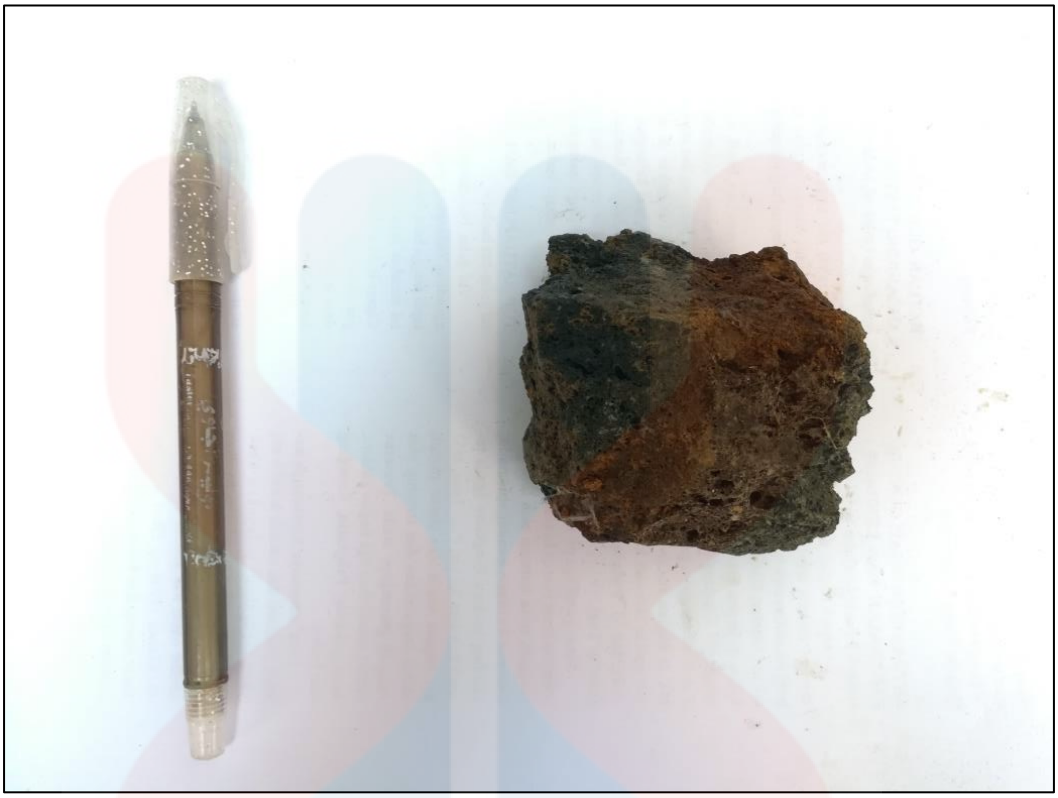


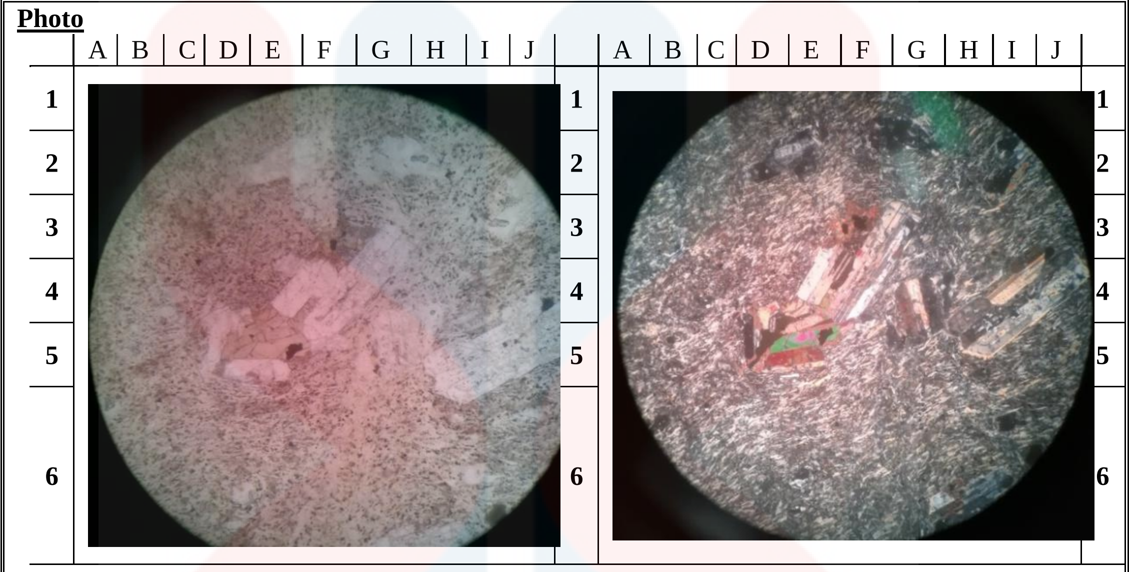
Figure 4.20 : Hand specimen of scoria.

Figure 4.21 : Tuffites that can be found at station HN35

Table 4.7 : Thin section description of andesitic lava

Station No: HN 12
Rock Name : Andesitic lava

Photo



Plane polarize

Cross polarize

Magnifying Lense Objective 4x, Ocular Lense 10 x. Total Magnifying 40 x

Rock Type : Autoclastic rock
Stucture Of Rock : Porphoritic

Microscopic Description : Overall is hypocrystalline. Porhoritic with phenocryst of plagioclase, opaque mineral , hornblende and pyroxene. The groundmass is microcristalline plagioclase, opaque mineral and hornblende. The orientation of lava flow are obvious in groundmass as it have flow pattern. The phenocryst also tend to accumulate in direction of lava flow

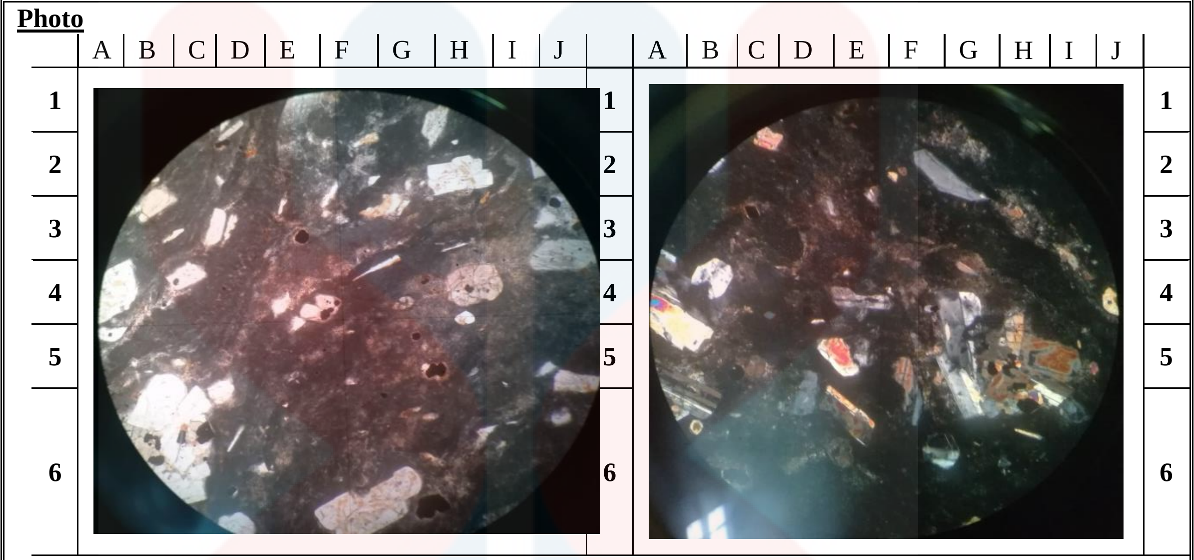
Mineralogy Of Description

Composition of Material	**Amount (%)**	**Description of Optical Mineralogy**
Plagioclase (4E)	**50**	Euhedral texture with low relief, the extinction angle is 26^{o}.
Pyroxene (5G)	**10**	Extinction angle is 19^{o} , relatively euhedral and some of them subhedral. High pleochroism. Pyroxene and plagioclase are interlocking.
Hornblende (5C)	**20**	Euhedral , have cleavage angle of 40^{o} with extinction angle of 10^{o}, some of them also have shape anhedral with low relief.
Opaque mineral (6I)	**20**	Inclusion in plagioclase and hornblende, show flow orientation in groundmass.

Table 4.8 : Thin section description of basaltic andesite

Station No: HN 15
Rock Name : Basaltic Andesite

Photo



Plane polarize

Cross polarize

Magnifying Lense Objective 4x, Ocular Lense 10 x. Total Magnifying 40 x

Rock Type : Pyroclastic rock
Stucture Of Rock : Porphoritic

Microscopic Description : Overall is hypocrystalline .Porphoritic with phenocryst of plagioclase, opaque mineral and pyroxene. The groundmass is glassyy mineral such as opaque mineral, microcrystaline plagioclase

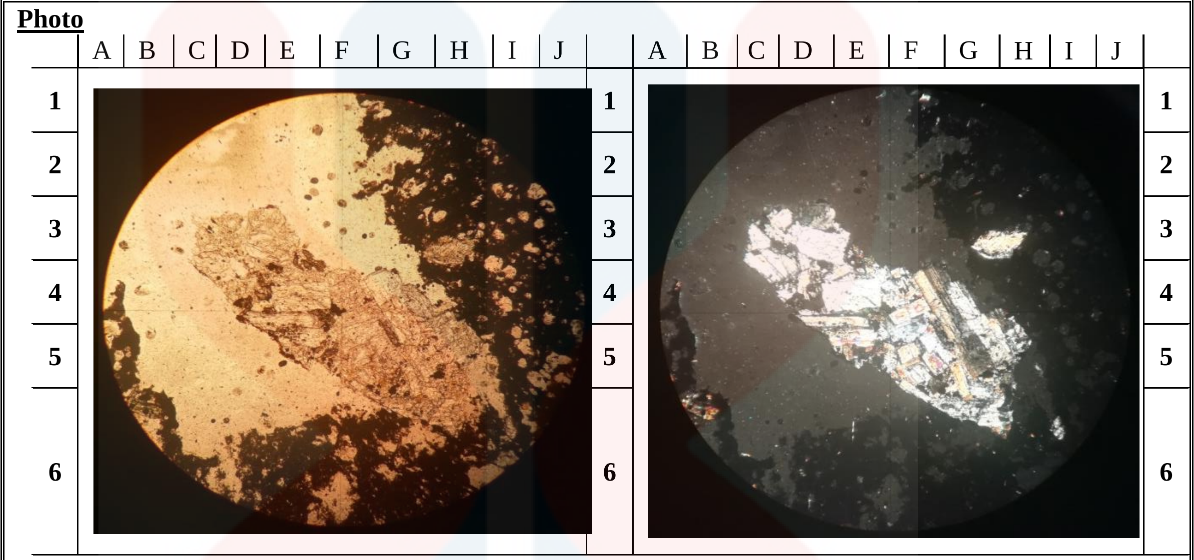
Mineralogy Of Description

Composition of Material	Amount (%)	Description of Optical Mineralogy
Plagioclase (5G,5H ; cross polarize)	**40**	Extinction angle is 30.5^o. By using albite method, the plagioclase is classify as labradiorite which is tend to appear in basalt. It have low relief with euhedral shape and low pleochroism.
Pyroxene (4B)	**20**	Subhedral shape, extintion angle is 32^o as found in anhedral pyroxene, it have clevage that almost perpedicular that is general characteristics of pyroxene.
Opaque mineral (3E)	**40**	Inclusion in pyroxene. No relief and pleochroism and it acts as major groundmass

Table 4.9 : Thin section description of scoria

Station No: HN 44
Rock Name : Scoria

Photo



Plane polarize

Cross polarize

Magnifying Lense Objective 4x, Ocular Lense 10 x. Total Magnifying 40 x

Rock Type : Pyroclastic rock

Stucture Of Rock : Vesicular

Microscopic Description : Porhoritic with phenocryst of plagioclase, opaque mineral and pyroxene. The groundmass is opaque mineral and pyroxene. It have vesicular space that air bubble tend to trap during early solidification

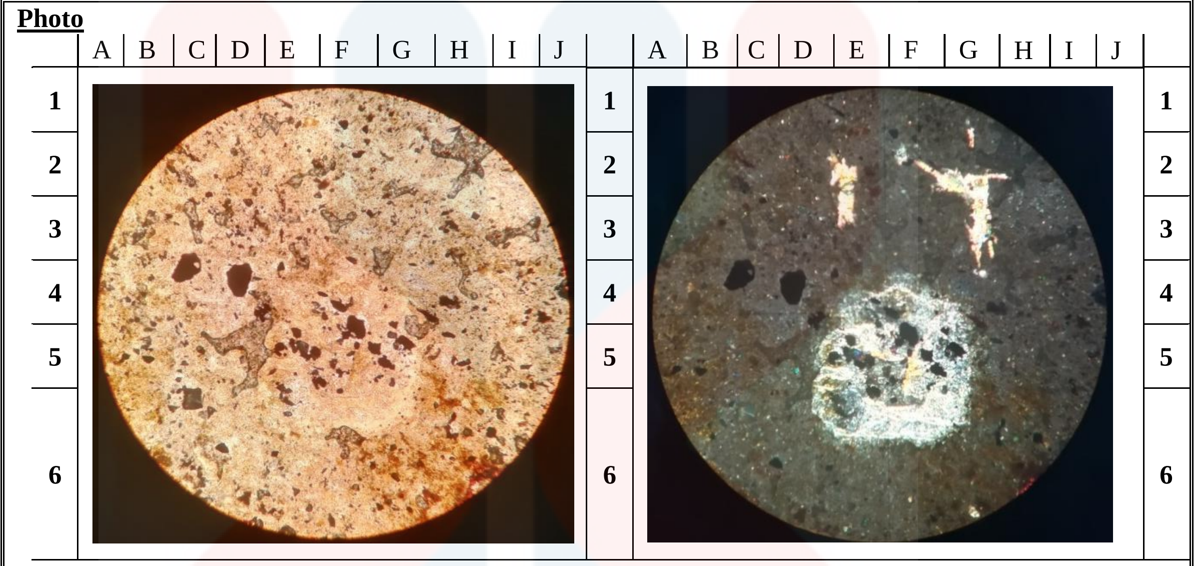
Mineralogy Of Description

Composition of Material	**Amount (%)**	**Description of Optical Mineralogy**
Plagioclase (4E)	**30**	Euhedral texture with low relief, interlocking with pyroxene
Pyroxene (3G)	**10**	relatively euhedral and some of them subhedral. High pleochroism. Pyroxene and plagioclase are interlocking.
Opaque mineral(4A)	**60**	Act as groundmass. No relief and pleochroism

Table 4.10: Thin section description of tuff matrix

Station No: HN 43
Rock Name : Tuff matrix

Photo



Plane polarize Cross polarize

Magnifying Lense Objective 4x, Ocular Lense 10 x. Total Magnifying 40 x

Rock Type : Pyroclastic rock
Stucture Of Rock : Porphoritic

Microscopic Description : Porhoritic with phenocryst of plagioclase, opaque mineral , hornblende pyroxene and clay mineral. The groundmass is clay mineral derive from feldspar, volcanic ashes and crystal tuff.

Mineralogy Of Description

Composition of Material	Amount (%)	Description of Optical Mineralogy
Plagioclase (5E,5F,5G)	**40**	Anhedral texture with low relief, low pleochroism
Pyroxene(2F)	**10**	Hardly to indentify due to weathering
Opaque mineral(4D)	**10**	Act as groundmass
Clay mineral, volcanic ashes and crstal tuff (6G)	**30**	Compose majority mineral of matrix. The clay mineral come from weathering of feldspar. Crystall tuff and volcanic asher in microscopic size are distribute during pyroclastic eruption.

Table 4.11: Correlation between Volcanic Breccia 2 Unit and Malabar Volcanic

Parameter	Volcanic Breccia 2 Unit (Qpv) (This Report,2018)	Malabar Volcanic (MV) (Bronto et al., 2006)
Lithology	Contain various fragments such as andesite, andesitic lava, basaltic andesite and basaltic scoria. Andesitic lava appear as fragment in in autoclastic mechanism, autobrecciated, meanwhile there also andesitic lava outcrop with sheeting joint structure. Andesite is fresh , some being altered. Basaltic andesite is dark and fine grain. Matrix is tuff , ash to lapilli size.	The rock composition vary from basalt to basaltic andesite, the basal lava flows in Ci Sangkuy are dark gray, textured glass, aphanitic to a very fine porphyritic, massive sheet structure. Phenocryst consists of very fine-grained plagioclasts and pyroxene (<1mm). Basal andesite on the slopes of Mount Puntang is a dark gray lava block, smooth porphyriaphanitic textured, massive structure - smooth perforated, phenocryst consisting of plagioclase and medium-fine (1-2 mm) grained pyroxene embedded in the aphanitic base mass.
Stratigraphy Position	Above Volcanic Breccia 1 unit	Above Baleendah Volcanics
Age	Pleistocene	Late Pleistocene (K-Ar dating ; 0.23 m.y.a)

4.3.3 Lahar Unit (Qpl)

a) Lithology Characteristic

Lahar Unit have five outcrop stations, HN30, HN31, HN32, HN48, and HN49 that show the characteristic of lahar. These outcrop further describe in Table 4.12 Lahar is the volcanic breccia that transported by water or volcanic debris flow, a mass of flowing volcanic debris intimately mixed with water (Fisher & Schmincke, 1984). Because lahar involves water as a transport agent, or being called mudflow, it can be categorized most closely with epiclastic volcano rock. However, the lahar also has its own distinctive characteristic in which it should be distinguished from other rock units in this study area. Lahar Unit composed of laharic breccia rocks. The laharic breccia has andesite as common fragment, while there is also andesitic lava block, charcoal, mudstone, and sandstone. The origin of these fragment are further to be explain in c) relative age and facies.

Table 4.12: Station Description of Lahar Unit (Qpl) (Continued)

STATION (HN)	LOCALITY AND ELEVATION (M)	SAMPLE PHOTO AT FIELD	DESCRIPTION
30	S 07 04 28.6 E 107 33 54.1 ELE : 768		Volcanic breccia. The matrix ash tuff already weathered and turn to soil. The andesite fragment is altered.
31	S 07 04 57.2 E 107 34 03.1 ELE : 826		Volcanic breccia with highly altered andesite. The andesite fragment is relatively cobble in size. The matrix is ash tuff, white colour and moderately weathered.
32	S 07 04 34.3 E 107 33 32.0 ELE : 752		laharic breccia with polymic fragment, the fragment found is mudstone, andesite and also charcoal. The charcoal is lahar indicator

48	S 07 04 16.7 E 107 34 08 ELE : 770		This outcrop shows two different type of lahar occurrence with a different medium. On the top layer , that shows bedding like structure is lahar that flow with water medium, meanwhile lower layer is lahar flow by itself. The lahar has very high viscosity which can carry big fragment from other places. Strike : 244° Initial Dip : 27°
49	S 07 04 38.6 E 107 33 32.1 ELE : 761		Polynomic breccia, it contains several type of rock fragment such as andesite, lava, and sandstone. The sandstone has foliations.

Andesite fragment are most likely have same physical characteristics with Volcanic Breccia 2 Unit. The size is range of block to smaller than blocks with shapes of angular and sub angular. They can be found as fresh specimen while some is highly weathered and chemically altered. Their texture is porphoritic, the phenocryst is mainly plagioclase and pyroxene, meanwhile their groundmass is opaque mineral. The degree of crystallization is subhedral. Andesitic lava block have dark gray colour with angular shape.

The texture is very fine grain. Charcoal porous black solid, obtained as residue when wood (might be tree) was heated or burnt by lava flow, and flow together as volcanic debris. The hand specimen is shown in Figure 4.22. The mudstones, shown in Figure 4.23, consist of a mixture of clay and silt particles. The grain size is <0.06mm, white in colour. Sandstone have grain size 0.06-2mm, the clast are visible to naked eye. The hardness is great with special feature, like foliation. Thin section can be refer in Table 4.13 for andesite rock and Table 4.14 for sandstone

b) Distribution of Rock Unit

The rock unit covered about 15 % of the study area and spread through southwest. The outcrop can be found at river in Cimenteng, Pasirpanjang and Pasirlanjung.

Figure 4.22: Charcoal fragment

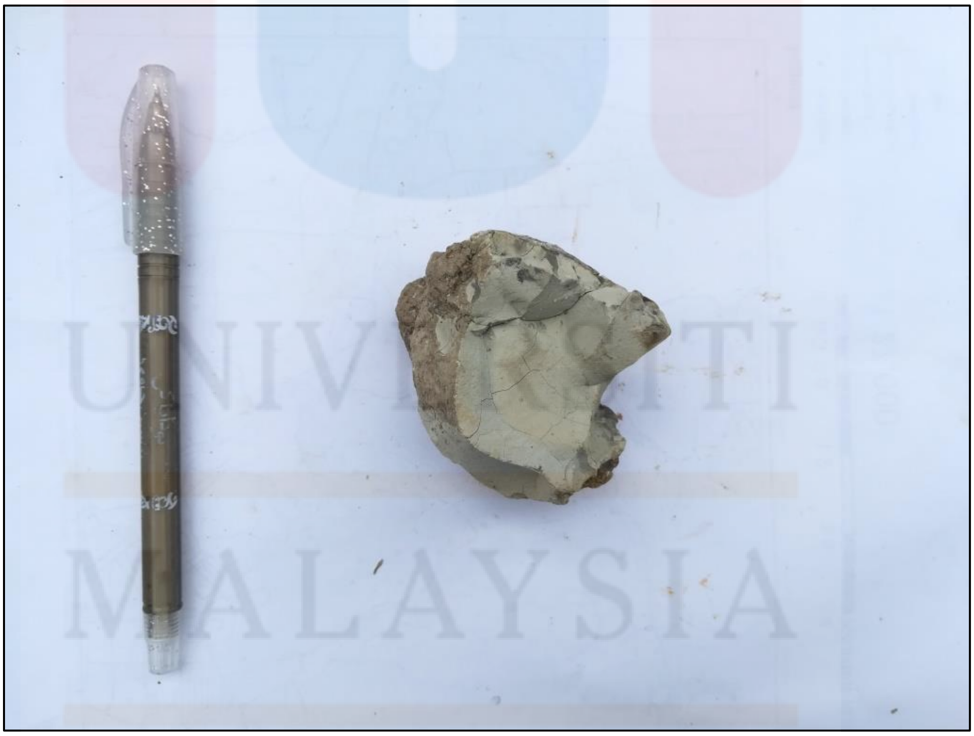
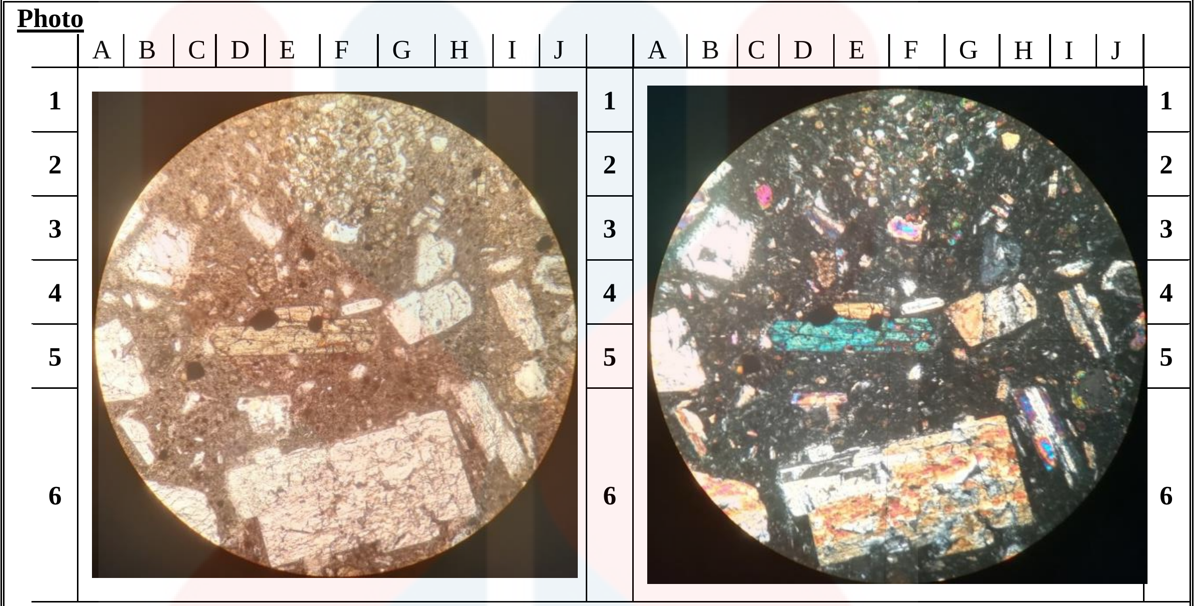


Figure 4.23 : Mudstone fragment

Table 4.13: Thin section description of andesite

Station No: HN 32
Rock Name : Andesite

Photo



Plane polarize

Cross polarize

Magnifying Lense Objective 4x, Ocular Lense 10 x. Total Magnifying 40 x

Rock Type : Pyroclastic rock
Stucture Of Rock : Porphoritic

Microscopic Description : Overall is hypocrystalline. Porphoritic with phenocryst of plagioclase, hornblende and pyroxene. The groundmass is microcristalline plagioclase, and opaque mineral.

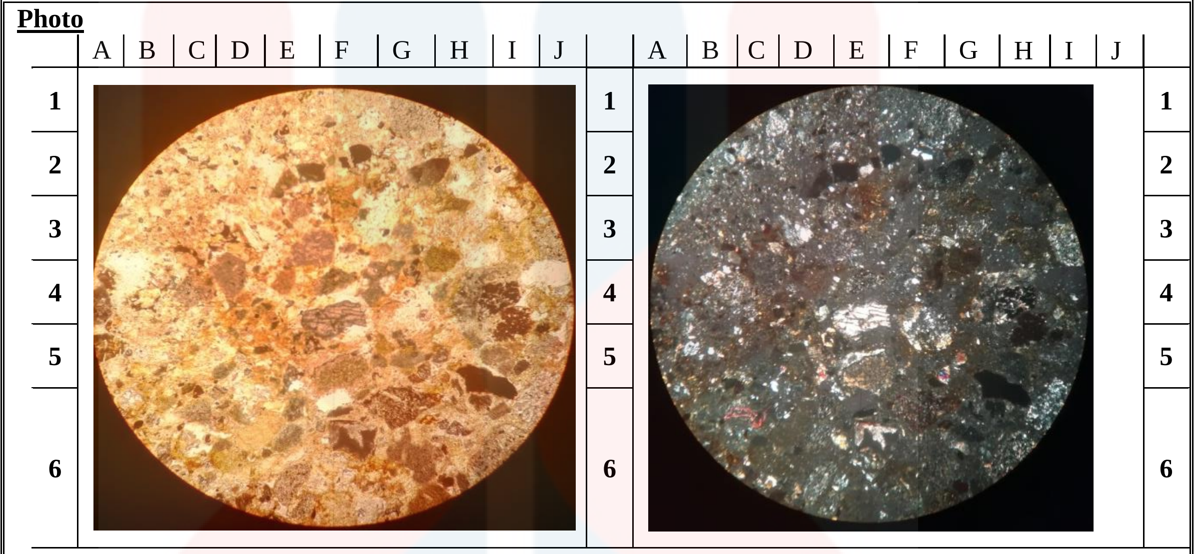
Mineralogy Of Description

Composition of Material	**Amount (%)**	**Description of Optical Mineralogy**
Plagioclase(6F)	**40**	Euhedral texture with low relief, the extinction angle is 30^{o}.
Pyroxene(3F)	**30**	Extinction angle is 20^{o} , relatively subhedral. High pleochroism. Have cleavage about 90^{o}
Hornblende(5E)	**20**	Euhedral , have cleavage with low relief. Extinction angle of 12^{o}, some of them are subhedral.
Opaque mineral(4D,4F)	**10**	Inclusion in hornblende

Table 4.14: Thin section description of sandstone

Station No: HN 49
Rock Name : Sandstone

Photo



Plane polarize

Cross polarize

Magnifying Lense Objective 4x, Ocular Lense 10 x. Total Magnifying 40 x

Rock Type : Sedimentary rock
Stucture Of Rock : microbedding/ foliation
Microscopic Description :

Mineralogy Of Description

Composition of Material	**Amount (%)**	**Description of Optical Mineralogy**
Quartz grain(2E)	**20**	Euhedral, high relief, no pleochroism occur due to weathering, as the extinction angle cannot be taken
Lithic grain(5H)	**60**	The lithic grain might come from ancient pieces of volcanic rock such as andesite and basalt
Accessory mineral (pyroxene) (5F)	**10**	Pyroxene act as accessory mineral, low relief and low pleochroism. The extinction angle is 20^o
Plagioclase feldspar (4F)	**10**	Low relief, subhedral shape, low pleochroism. The extinction angle is 35^o.

c) Relative age and facies

Most of lahar occurrences are initiated directly from volcanic eruption. To discuss about volcanic facies involving lahar deposition, understanding of the lahar flow mechanism is extremely important. Lahar flow in form of fluid. Fisher and Schmincke (1984) distinguished this flowing fluid into two, based on their weight of solids percentage. Hyperconcentrated stream are those with 40 to 80 % by weight of solids, while mudflows (debris flow) are 80 % and above. Observation at field reveals that lahar flow as debris flow. Debris flows form an intimate mixture of water and solids that flow in laminar motion. As debris flow from steep slope to less steep, the velocity gradually decrease. The entire flow stops abruptly after water separates from granular material by evaporation and percolation.

When the flow is thinning, the shear stresses increase until the flow congeals to its very base. Thus the deposition is complete. Charcoal, mudstone and sandstone is non volcanic product. Non volcanic products that become fragments within this laharic breccia are likely to be brought together as debris flows move down the slope then mixed with running water in the stream and moves along in the direction of the stream. The flowing volcanic debris then deposited and forming laharic breccia. Supporting evidence by the discovery of outcrops station HN32 (Figure 4.24) and HN49 (Figure 4.25), both are located at the riverbank.

Figure 4.24 : Various size of fragment, that brought by high viscosity lahar

Figure 4.25 : Lava block embedded in lapilli ash tuff matrix and also sedimentary clastics, flow together as debris flow

Many lahars are associated with stratovolcanoes of which they may comprise significant volumes of the volcanoes' bulk. Most stratovolcanoes are or andesitic to dacitic composition, and hence most lahars have been reported from Indonesia. It is hard to determine the source of eruption as there is no solid evidence from previous study. M.Alzwar, N.Akbar and S.Bachri (1992) stated that rocks in this study area are composed of Malabar-Tilu Volcanic. Malabar-Tilu Volcanic consist of laharic breccia , tuff and lava. Laharic breccia in Malabar-Tilu Volcanic is undifferentiated and not mapped its boundaries. The strike reading taken at outcrop HN48 is 244^{o} which is trending to northwest of Banjaran Box. This follows the contour pattern, and might flow from southeast direction from where Ancient Malabar Volcano located. Assumptions have been made to say that its source of eruption comes from the Ancient Malabar Volcano. HN48 outcrop are shown in Figure 4.26.

This Lahar Unit have medial facies. The occurrence of lahar is common in medial facies. When the steepness of slope gradually decrease, velocity of flow decrease, and at particular place that mostly horizontal, the flow stop. Therefore deposition of laharic breccia occurs. Initial dip is 27°, moderately steep. Correlation of Lahar Unit and Malabar-Tilu Volcanic can be seen in Table 4.15.

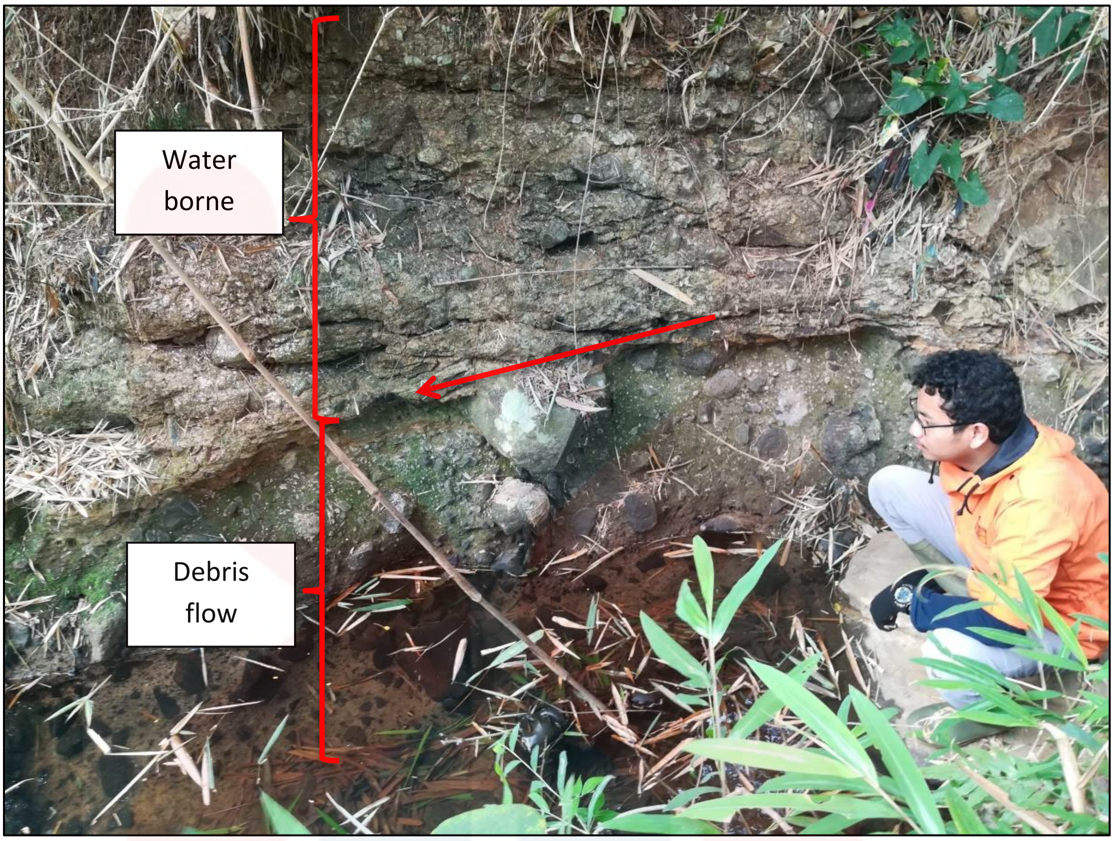


Figure 4.26 : Outcrop HN48 shows the bedding like structure, the strike(red arrow) is 244^{o} with initial dip 27^{o}. In the inlets, there are two flows that apply, the upper layer, with a finer fragment, is waterborne, cooling first, after the water evaporates. The lower layer, with larger fragment size up to the size of the block, is debris flow that has a higher viscosity, has high energy to transport big fragments further.

Table 4.15: Correlation of Lahar Unit and Malabar Tilu Volcanic

Parameter	Lahar Unit (Qpl) (This Report,2018)	Malabar Tilu Volcanic (Qmt) (Alzwar, Akbar, & Bachri, 1992)
Lithology	Andesite fragment have size in range of block and smaller with. Their texture is porphoritic Andesitic lava block have dark gray colour with angular shape. Charcoal porous black solid, obtained as residue when wood (might be tree) was heated when lava flow to it, and flow together as volcanic debris. The mudstones consist of a mixture of clay and silt particle. Sandstone have the clast visible to naked eye. The hardness is great with special feature, like foliation.	Tuff, which is composed of andesite, contains a small amount of pumice. This tuff is spread north and northwest of Mt. Tilu, the local area is rather solid and forms breccia. Laharic breccia contains a small amount of pumice in the area of Mt. Tilu . lava is generally composed of pyroxene andesite, hornblende andesite, a basal locale, in the form of parasitic flow and cone.
Stratigraphy Position	Above Volcanic Breccia 2 Unit	Above Beser Formation
Age	Pleistocene	Late Pleistocene

4.3.4 Alluvium Unit (Qa)

a) Lithology Characteristic

There are six outcrop stations in Alluvium Unit that is HN6, HN7, HN38, HN45, HN46, and HN47. Table 4.16 shows the rock description for each outcrop station. Generally, Alluvium Unit composed of epiclastic volcanic breccia resulting from transportation of loose volcanic material by epigene geomorphic agents such as mudflow, glaciers, running water and gravity (mass wasting). In this case, running water is the prime agent transporting those materials from higher gradient. Three main type of rock that can be found in this unit is tuff, tuffaceous conglomerate and alluvium (unconsolidated rock). Tuff that is found in HN6, HN45 and HN47 can be classified as lapilli ash tuff, as ash grain size highly dominated compare to lapilli grain size. Tuffaceous conglomerate can be defined as epiclastic rock because it is mainly consolidated epiclastic deposits. The fragment is sub rounded to rounded andesite, below than 64mm in size while the matrix are mixture of sediment material from sand to silt size and also tuff with size of lapilli to ash. Alluvium consists of unconsolidated aggregate epiclasts with the size of silt to clay.

At outcrop station HN7, shown in Figure 4.27, the layer of unconsolidated rock and consolidated rock can be clearly observe. In this outcrop there is an alluvial layer deposit above the tuffaceous conglomerate. Refer to figure 4.28, station HN46, the situation is vice versa. Therefore, the layer position between the alluvium and the tuffaceous conglomerate is inconsistent, so the acceptable assumption is the inter fingering occurrence of the tuffaceous conglomerate into alluvium layer. Thin section of andesite fragment can be refer in Table 4.17

Figure 4.27 : alluvial deposits above tuffaceous conglomerate, the thickness si about 0.3 meter

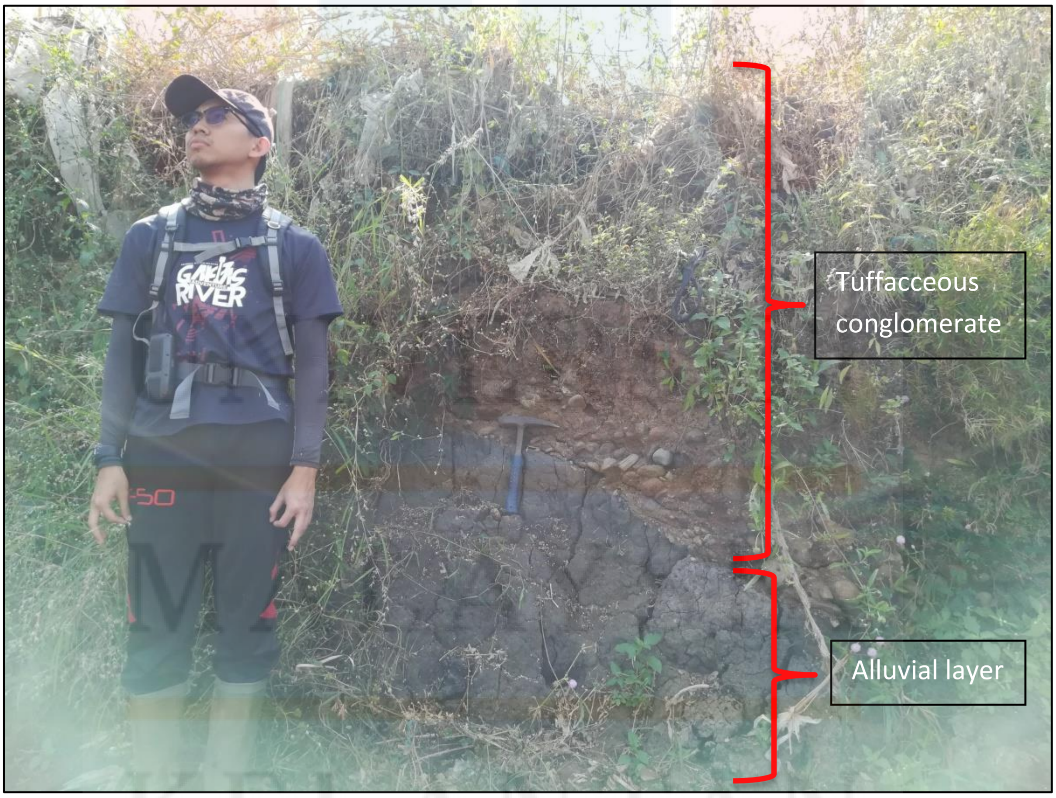


Figure 4.28: The position of alluvial layer below the tuffaceous conglomerate.

Table 4.16 : Station Description of Alluvium Unit (Qa) (Continued)

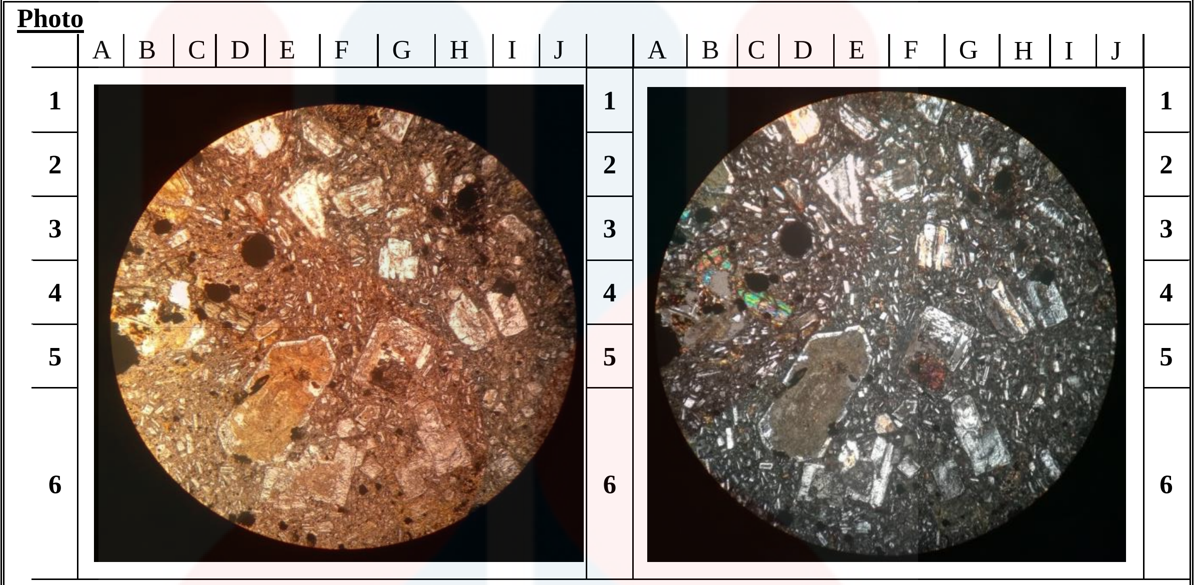
STATION (HN)	LOCALITY AND ELEVATION (M)	SAMPLE PHOTO AT FIELD	DESCRIPTION
6	S 07 02 59.7 E 107 34 24.0 ELE : 684		Lapilli-ash tuff white in colour and also light brown colour (weathered).
7	S 07 02 54.2 E 107 34 19.9 ELE : 683		Tuffaceous conglomerate is overlaid by unconsolidated rock which have silt to clay grain size . Andesite fragment have sub angular shape with size of lapilli to block . The matrix is composed of tuff and other loose material
38	S 07 02 48.9 E 107 36 04.9 ELE : 706		Volcanic breccia with the weathered matrix. The matrix turns to light brown soil. Andesite fragment with angular and sub angular shape, might be transported from far area. The fragment size of andesite from coarse grain to cobble.

45	S 07 02 26.5 E 107 34 34.2 ELE : 693		Weathered tuff
46	S 07 03 05.1 E 107 34 11.8 ELE : 694		Alluvium deposited overlaid by tuffaceous conglomerate. Structure like inter fingering between two layer. Tuffaceous conglomerate have rounded shape andesite fragment with relatively in size of lapilli. The matrix is composed of tuff and loose material (silt and clay size)
47	S 07 02 52.6 E 107 35 24.8 ELE : 699		Ash tuff

Table 4.17 : Thin section description of andesite

Station No: HN 07
Rock Name : Andesite

Photo



Plane polarize

Cross polarize

Magnifying Lense Objective 4x, Ocular Lense 10 x. Total Magnifying 40 x

Rock Type : Pyroclastic rock

Stucture Of Rock : Porphoritic

Microscopic Description : Overall is hypocrystalline. Porhoritic with phenocryst of plagioclase, opaque mineral , and pyroxene. The groundmass is microcristalline plagioclase, opaque mineral and hornblende.

Mineralogy Of Description

Composition of Material	Amount (%)	Description of Optical Mineralogy
Plagioclase(5E)	**60**	Certain with zoning, also occur inclusion of opaque mineral, have low relief. The extinction angle is 32^o.
Pyroxene(3G)	**20**	Extinction angle at 51^o with subhedral shape. Also have cracking which make it hard to observe the cleavage. High relief
Hornblende (4C)	**10**	Have the shape of subhedral, high relief with the extinction angle of 10^o.
Opaque mineral(3D)	**10**	Inclusion in plagioclase and plagioclase, anhedral texture.

b) Distribution of Rock Unit

Spread on the north of Banjaran box. It composes of 30% of the study area and here is where Banjaran town located. Most of the land here is used to grow paddy and vegetables because it is fertile. Sometimes outcrops are difficult to access as it is located in a fenced private area.

c) Relative age and facies

In general, alluvium, of course, has a younger age due to the sedimentation process which is still insufficient to form consolidate rocks. These sediment materials are volcanic or non-volcanic materials that were eroded and transported by river water flow mainly from Ci Tarum river. Bronto et al.(2006) mention that Alluvium Unit is part of Bandung Basin. In the upstream of Ci Tarum and Ci Hejo, alluvium deposits form a large fan up to the Majalaya Plain in between Mount Malabar in the west and Mount Dogdog in the east. Also occur at Ci Sangkuy downstream flow, which was limited by the height of Mount Tanjaknangsi in the west and Mount Malabar in the east.

The facies are distal. This is because lack of rock gradation that comes from eruption or mud flow. Tuff mixed with clastic sediment and become matrix to tuffaceous conglomerate. The fragment found in the tuffaceous conglomerate is not agglomerate bomb but the fragment that has been transported due to its sub rounded shape. Correlation of rock unit can be refer in Table 4.18

Table 4.18 : Correlation of Alluvium Unit

Parameter	Alluvium Unit (Qa) (This Report,2018)	Alluvium Unit(Al) (Bronto et al., 2006)
Lithology	Contain epiclastic materials that compose of volcanic and non volcanic product. Alluvial deposits consist of clay and silt. Tuffaceous conglomerate interfinger to the alluvial layer, indicating the boundaries between distal facies and medial facies	Alluvium deposits consist of loose grained material from clay to clay which is spread across the plain and valley of the river. The plains in the area of alluvium are now deposited into fertile residential and rice fields, but in the rainy season are often flooded
Stratigraphy Position	Above Lahar unit	Above Malabar Volcanic
Age	Holocene	Holocene

4.4 Historical Geology

Regionally, volcanism in Southern Bandung started from Miocene (12 m.y.a) that produces calc-alkaline andesite pyroxene (MiV) lava flow that currently be overlayed by Wayang Windu Quaternary volcanic rock (WV) (Bronto et al., 2006). Next volcanism occurs in Pliocene (4-2.6 m.y.a) formed Mount Soreang (SV) and Mount Baleendah (BV) composed of dacites and andesites. Mount Baleendah (BV) volcanic rock is corelate with Volcanic Breccia 1 (Tpv) unit which is the oldest unit in Banjaran area. The ancient Early Pleistocene Pangalengan Mountain built itself to form a composite cone with basalt (PV) composition.

This Pangalengan Mountain then erupts and forms the Pangalengan Caldera. On the northern edge of Pangalengan Caldera, Mount Malabar start to form and based on Bogie and Mackenzie (1998), the age of the rock is 0.23 m.y.a (Late Pleistocene) with the composition of basalt to basaltic andesite (MV). MV unit being corelate with Volcanic Breccia 2 (Qpv) unit in study area. Lahar also is the product from MV unit which is flow on MV pyroclastic product that already deposit earlier. This makes Lahar (Qpl) unit is slightly younger than Volcano Breccia 2(Qpv) unit but both of unit still form in Late Pleistocene.

Alluvium unit (Qa) is the youngest lithologic unit in Banjaran that be correlate with Alluvium unit (Al) by Bronto et al. (2006).The eroded and weathering product of volcanic and non volcanic rocks are transported by flow of Ci tarum and Ci hejo river which boundary in between Mount Malabar to the west and Mount Dogdog to the east . The eroded volcanic and non-volcanic products are also transported by Ci Sangkuy River fenced by the height of Mount Tanjaknangsi in the west and Mount Malabar in the east

CHAPTER 5

GEOCHEMICAL EVOLUTION OF VOLCANIC ROCKS

5.1 Introduction

Geochemical analysis of major elements and trace element will be further described in this chapter. Interpretation is made by plotting data and observing the pattern of major and trace element in various petrology diagrams. The objective to interpret the source origin and the process occur that cause variation of geochemical composition of volcanic rocks in Banjaran area. The volcanic rocks are mostly products from Baleendah Volcano and Malabar Volcano which have the age of Tertiary to Quaternary. The volcanic rocks in Banjaran were analysed using the geochemistry method, x-ray fluorescence (XRF) and this can be associated with the type of magma involved in the geochemical variation process.

5.2 Major Elements

Rock geochemistry is the parameter and data that highly important in paragenesis. Geochemical analyses including major element and trace element of Banjaran volcanic rocks are presented in several tables and diagram. For this section, major elements are the main focus. 5 samples were taken from the vicinity of Banjaran and were analyzed geochemically using XRF that can be referred on Table 5.1. All 10 major elements are SiO2, TiO2 ,Al_2O_3,Fe_2O_3, MnO, CaO, MgO, Na_2O, K_2O and P_2O_5. The major elements are normalized to 100% volatile free with Fe as

FeO. The result from the analysis of major elements on rock genesis is used for classification, grouping and naming the rock based on geochemical data.

All data from 5 samples in Banjaran have considerable amount loss of ignition (LOI) which is the highest reading reached 7.41% for sample HN40. The LOI percentages is associated with water content in the rocks and slightly effect the total volatile content due to FeO conversion to Fe_2O_3. In other words, high LOI will disrupt the oxide compound composition. Volcanic rocks in Banjaran have a relatively narrow range of major element composition which is 53.86 – 63.95 weight per cent SiO_2 that have average 61. Composition of K is low to medium (Figure 5.1). Major elements content in rock samples from Banjaran area consist of % weight: SiO2 = 53.86- 63.95, TiO2 = 0.514 – 0.946, Al_2O_3= 14.22- 20.41, Fe2O3= 6.39-10.71, MnO= 0.115- 0.204, CaO= 3.12- 5.50, MgO= 0.541- 1.05, Na_2O= 1.75 – 3.71, K_2O= 0.961-2.395 and P_2O_5= 0.164- 0.251

Table 5.1 : Geochemical Analysis Result of Major Elements in Banjaran area

Major Elements (% weight)	SIO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	P_2O_5	LOI
HN 40	53.86	0.514	20.41	10.71	0.140	3.12	0.635	1.75	0.983	0.165	7.41
HN 12	63.35	0.916	16.17	6.39	0.123	4.77	0.541	3.16	1.983	0.237	2.09
HN 04	63.95	0.946	14.22	7.81	0.204	4.03	0.759	3.43	2.395	0.251	1.68
HN 15	63.60	0.903	14.99	7.62	0.115	4.83	0.593	3.46	2.15	0.220	1.22
NN 1	62.45	0.521	16.52	6.93	0.142	5.50	1.05	3.71	0.961	0.164	2.67

For interpretation, additional data from previous researcher will be combined together with this geochemical analysis of major elements in the study area. Table 5.2 shows the major elements data from samples of Cangkring Hill, Jelekong Area, Baleendah District, Bandung Regency, West Java (Soviati, Syafri, & Patonah, 2017). This samples are selected due to their adjacent locality and type of rock that have major similarities.

Table 5.2: Geochemical Analysis Result of Major Elements in Cangkring Hill area (Soviati et al., 2017)

Major Elements (% weight)	SIO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	Na_2O	K_2O	P_2O_5
Jec_21	62.47	0.780	16.06	1.98	0.140	5.77	2.88	3.27	1.000	0.230
Jec_13	55.58	0.690	16.73	3.06	0.123	5.37	2.21	3.04	0.920	0.220
Jec_15	60.46	0.650	15.73	2.02	0.204	6.28	2.66	3.27	1.040	0.250
Jec_17	61.66	0.730	15.88	1.89	0.115	4.70	2.32	3.14	1.110	0.250

Le Bas, Maitre, Streckeisen and Zanettin (1986) classify the type of volcanic rocks by using Total Alkali-Silica diagram (TAS). The diagram is divided into 17 root names: basalt, basaltic andesite, andesite, dacite , rhylolite, trachybasalt, basaltic trachyandesite , trachyandesite, trachyte , trachydacite, picrobasalt , basanite, tephrite, phonotephrite , tephicriphonolite, phonolite and foidite. Geochemical data that being used is Na2O + K2O (Total Alkali) dan SiO2 (Silica). The plotting can be seen in Figure 5.1 which shown volcanic products from

Banjaran area are from type Andesite to Dacite. This type of rock is from intermediate to acid.

Using classification diagram of Peccerillo and Taylor (1976) in Figure 5.2 , the magma series that form the type of rock can be determine. A magma series is to distinguish magma chemical compositions that explain the evolution of a mafic magma into a more evolved, silica rich end member. Data by HN(This report, 2018) and Jec (Soviati et al., 2017) being plotted and its pattern being observed for interpretation. It shows that volcanic rocks in the study area is spread in the affinity calc-alkaline series (medium-K) except for rock sample NN1 that located in low- K tholeiitic series. Rock sample HN15 nearly formed at high-K series as it located at the boundary of medium-K. Calc-Alkaline magma series is one of two main subdivisions of the subalkaline magma series, another is tholeiitic. Calc-alkaline series magma can form various volcanic rock types such as basalt, andesite, dacite and rhyolite. The variation of volcanic rocks is related to fractional crystallization that will be discussed later. Rocks that originate from calc-alkaline magma series indicate that the tectonic setting of study area is in subduction zone. Based on the K_2O vs SiO, the volcanic rocks of Banjaran area can be said forming from convergent plates.

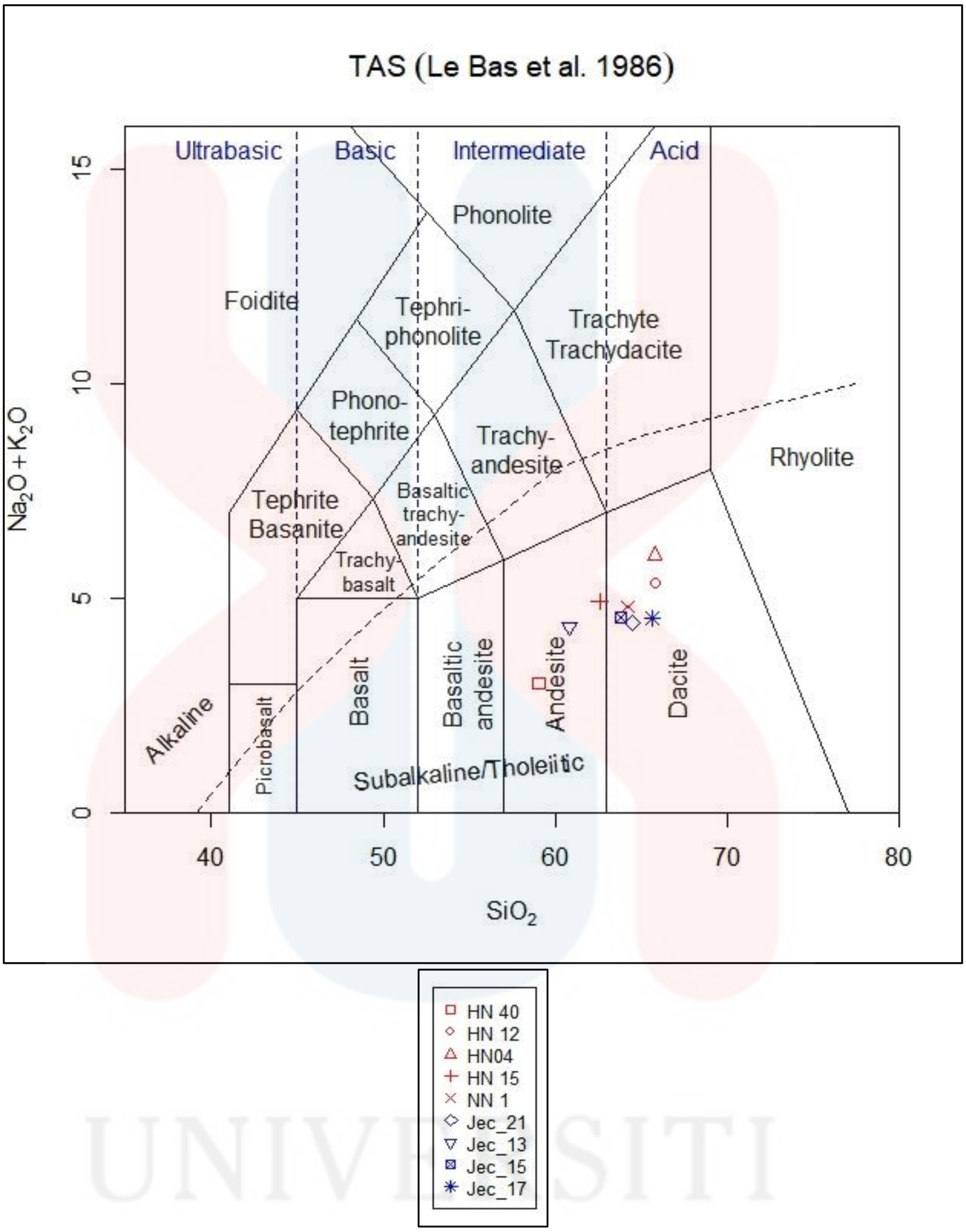


Figure 5.1: TAS diagram, both sample HN and Tec are located in intermediate to acid type rock, andesite and dacite.

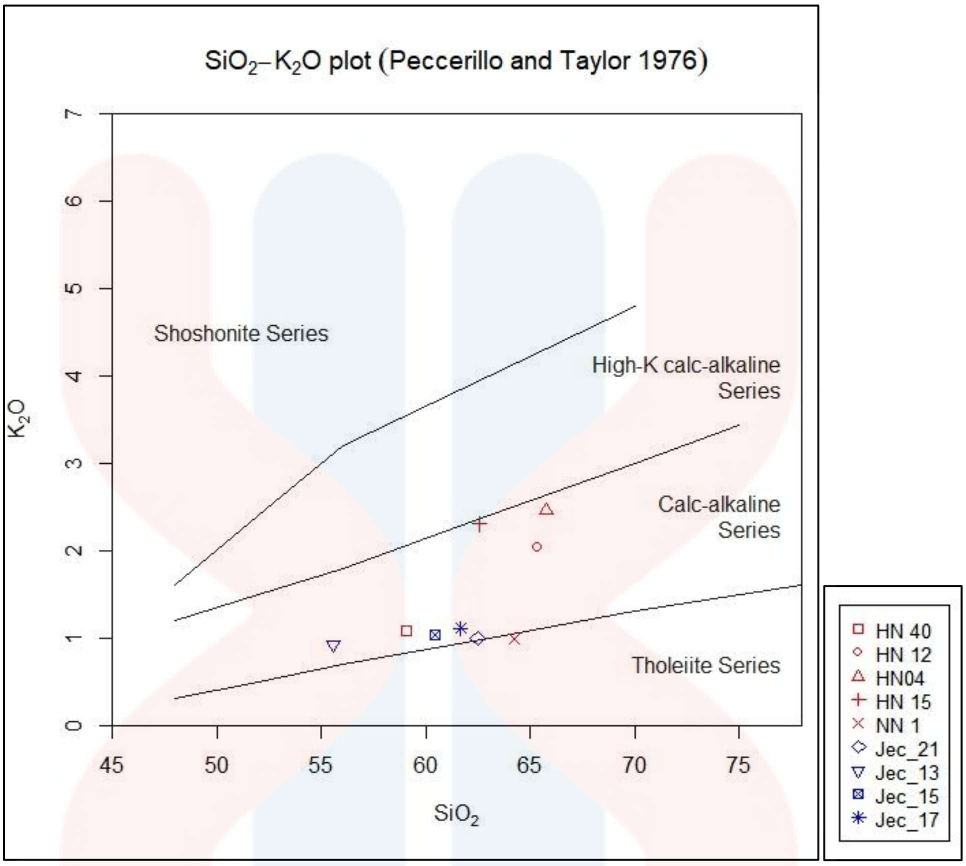


Figure 5.2 : K_2O vs SiO_2 for magmatic series classification (Peccerillo & R. Taylor, 1976)

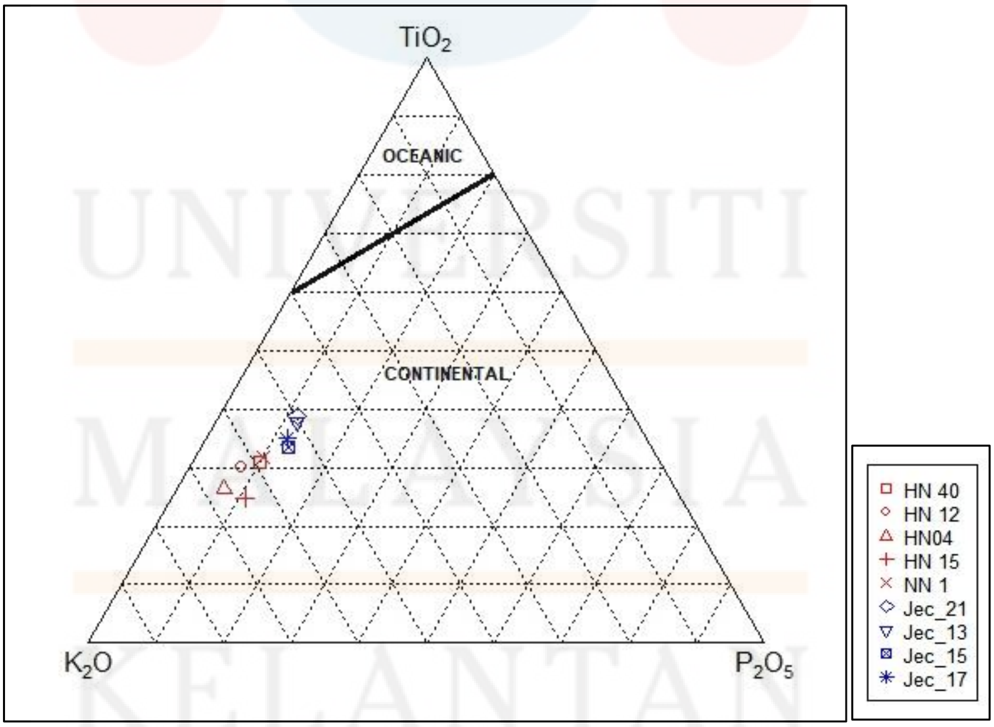


Figure 5.3: Pearce's Diagram Magma Origin of Volcanic Rocks in Banjaran area

The characteristic of magma describes the origin of the magma. Based on the interaction between the rock origin and the magma, characteristic of magma can be distinguished into two which are continental or oceanic crusts. Data plotting on Pearce’s diagram in Figure 5.3 represent the interaction with continental crust. Volcanoes of West Java including Malabar Volcano and Baleendah Volcano are Sunda Arc Volcanoes. According to Dempsey (2013), magmatism study of Sunda Arc states that the continental crust is located in western regions and progressively oceanic towards the East. The subduction of Sunda Arc has been continuous at Java trench since the Mid Eocene (~ 45 m.y.a). The direction is propagating northward of the Indo-Australian beneath the Eurasian plate at rate of ~6/7 cm per year.Therefore the tectonic setting is oceanic-continental subduction zone

Based on the tectonic setting where the magma formed rocks, Mullen (1983) divided the source of magma into five sources. The five sources is from Mid Oceanic Ridge Basalt, Island Arc Tholeiite, Island Arc Calc-Alkaline Basalt, Oceanic Island Tholeiite, and Oceanic Island Alkaline Basalt. The determination of the magma origin based on the percentages of TiO_2, 10 x MnO, and 10 x P_2O_5 being plot in Mullen's triangular diagram (Figure 5.4). Thus, it appears that the origin of the magma that forms volcanic products of Banjaran area is island arc calc-alkaline basalt. Soviati et al. (2017) also claim that the magma origin of Cakring Hill volcanic product is from is island arc calc-alkaline basalt.

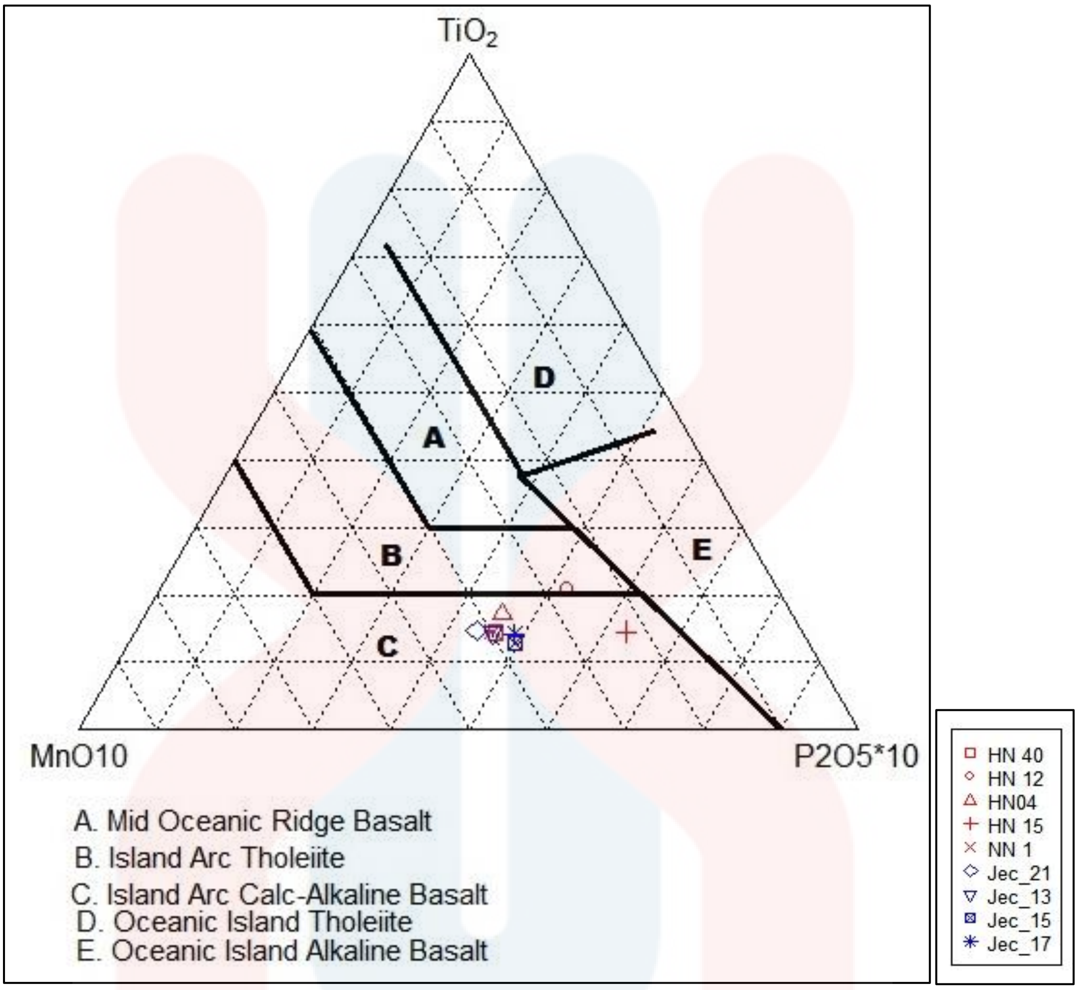


Figure 5.4 : Rock sample plotting on Mullen's Triangle(Mullen, 1983)

Next is plotting data on the diagram of Harker variation (Figure 5.5) which are major elements against SiO_2. Due to lack of sample, certain plotting are somewhat dispersed and there is little gap. However, the trend is still visible. The pattern TiO_2, Na_2O and K_2O have positive trend when plotted against SiO_2. The diagram shows quite steady decline trends of Al_2O_3, FeO* and CaO against SiO_2 meanwhile MnO, MgO and P_2O_5 show negative linear trends with increasing of silica content.

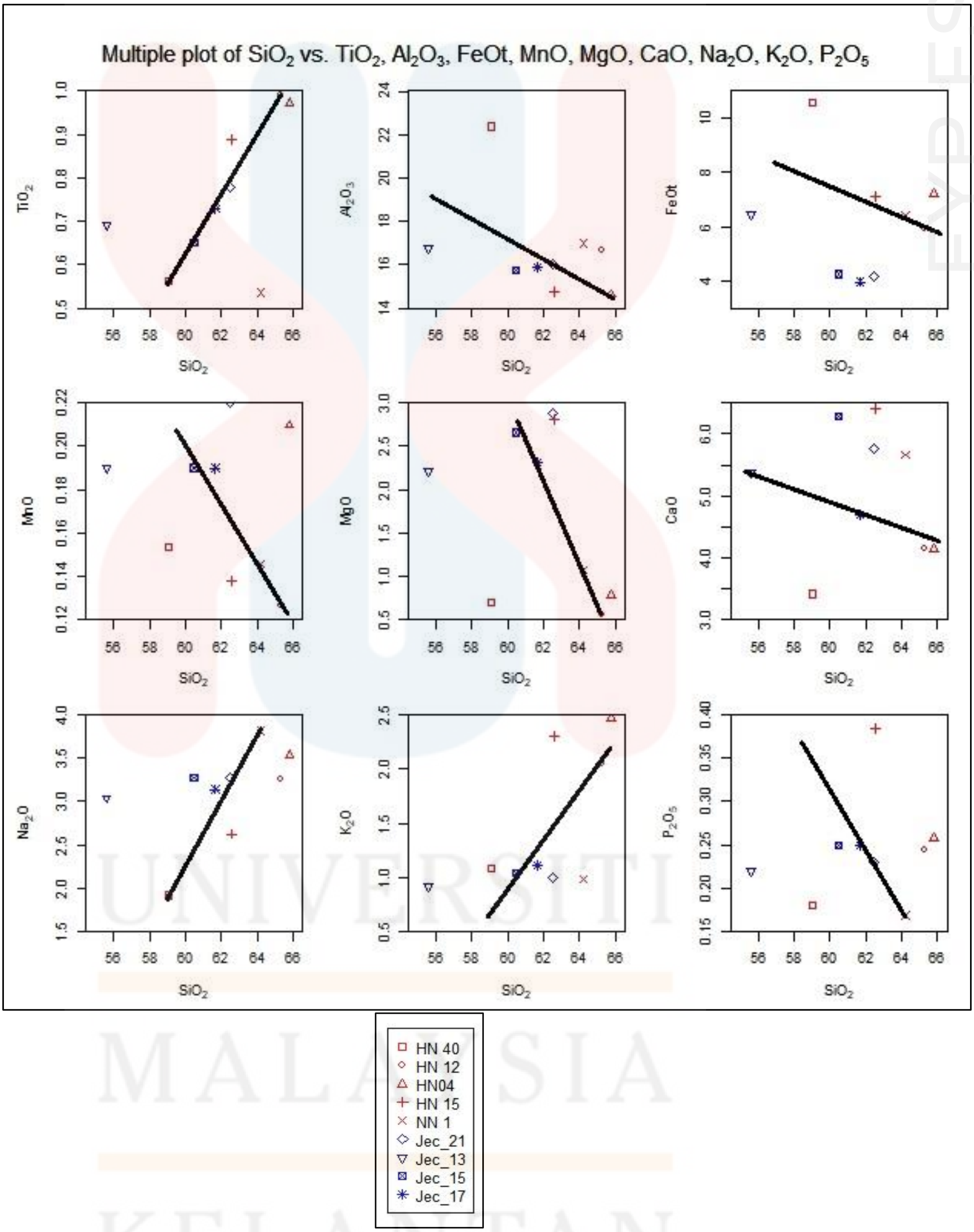


Figure 5.5: Harker's Diagrams of Major Elements against SiO_2 in Banjaran area

5.3 Trace Elements

Same goes with major element analyse, all 5 samples from Banjaran area also be analyse their trace elements. The analysis data are presented in Table 5.3. Note that the plotting only for sample HN as Soviati et al. (2017) does not provide analysis data for trace elements. This can be considered because of trace elements, only spider diagrams are plotted and not to look at linear trends of binary plot. Spider diagram of trace elements can be refer in Figure 5.6 for normalized to chondrites (Thompson, 1982) while normalize to Normal Mid Oceanic Ridge Basalt (N-MORB) (Sun & McDonough, 1989) is in Figure 5.7.

Table 5.3 : Geochemical Analysis Result of Trace Elements in Banjaran area

Trace element (%ppm)	Ba	Rb	K	La	Sr	P	Zr	Ti	Y
HN40	-	61	8160	45	93	719	-	3083	28
HN12	-	73	16460	-	148	1036	-	5493	94
HN04	285	99	19890	21	129	1096	99	5673	62
HN15	294	85	17840	-	132	959	58	5414	49
NN 1	209	20	7970	-	190	717	-	3130	17

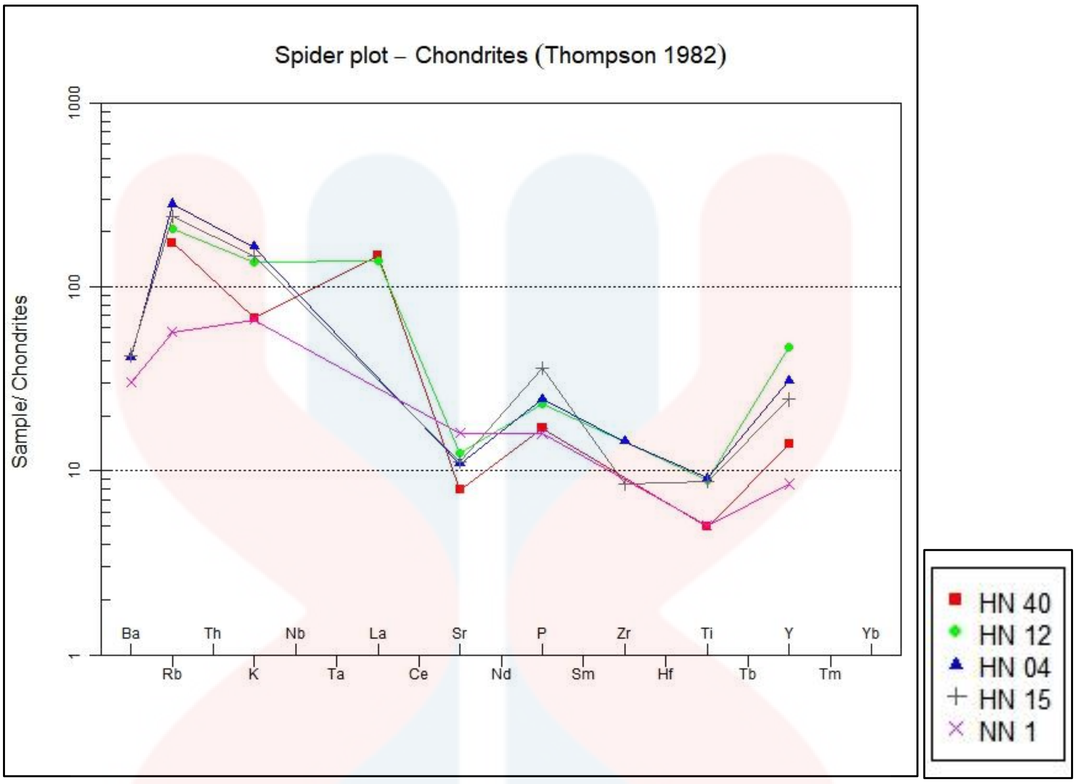


Figure 5.6: Trace element that normalized to chondrites (Thompson, 1982)

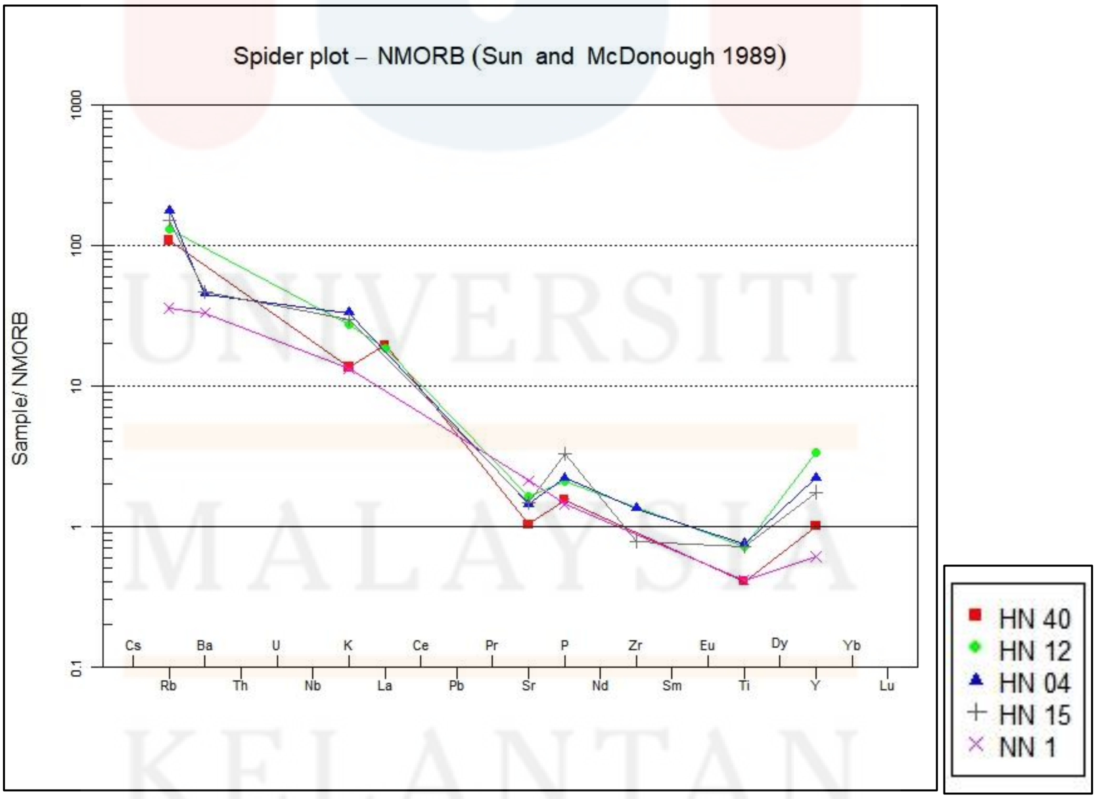


Figure 5.7: Trace element that normalized to normalize to Normal Mid Oceanic Ridge Basalt (N-MORB) (Sun & McDonough, 1989).

5.4 Discussion

5.4.1 Geochemical evolution of rocks by major element concentration

Volcanic rocks in Banjaran area have geochemical characteristic that consistent with the rock that originated from magma in a subduction zone environment. Based on TAS diagram in Figure 5.1, rock samples from Banjaran area are from andesite and dacite type. Therefore the evolution of these rocks from intermediate to acid rock can be explained by observing the trend of major element plotting in Harker variation. All major elements of the samples being plot against SiO_2 and correlation between those elements with SiO_2 will show either positive or negative trend. Linear lines of all major elements against silica indicate that there is parent daughter relationship between andesite and dacite. Referring to major elements data distribution, fractional crystallization is the main differentiation process responsible for evolution of magma that form Banjaran volcanic rocks.

Generally, the major element data is consistently matched with phenocryst phases present in the rocks. Declining pattern of MgO, FeO with increasing silica is the indicator of ferromagnesian mineral fractionation. Ferromagnesian mineral includes olivine and pyroxene. Grove and Baker (1984) state that olivine and pyroxene will dominate the precipitation as it occurs in early stage of basaltic fractionation. This would cause a calc-alkaline differentiation trend and consistent with calc-alkaline characteristic in Figure 5.2. Pyroxene separation also can be characterized by decreasing of CaO from intermediate to acid rocks. Decreasing of CaO can also be linked to plagioclase separation together with decreasing of Al_2O_3 against silica. Hornblende is calcium- rich amphibole mineral. Most hornblende is product of reaction between basaltic liquid with less than 6% weight of H_2O and pre-existing olivine that crystalize earlier (Anderson Jr., 1980).

However, TiO_2 positive trend is contradict with general geochemical fractionation in arc magma. According to Osborn (1969), TiO_2 distribution increase with increasing silica suggesting no magnetite precipitation occurred. It might be consistent to rocks tholeiitic affinity, as precipitation of magnetite in basaltic magma would make silica enrichment and maintaining the calc-alkaline differentiation trend. Na_2O and K_2O increase with increase SiO_2 content shows that no K-feldspar fractionation. This if prove by absence of K-feldspar mineral found in any thin section of the rock samples. P_2O_5 shows negative trend towards silica. P_2O_5 is element compatible to apatite and decreasing of this element might indicate small amount of apatite fractionation to become accessory mineral

5.4.2 Trace Element Concentration

Trace element is classified into their behaviour in basaltic magmas. Elements which behave compatibly can be categorized by those which are readily mobilized in aqueous fluids but incompatible, and those which are incompatible but relatively immobile (Kogiso, Tatsumi, & Nakano, 1997). Large-Ion Lithophile Elements (LILE) such as Cs, Rb, Ba, K, Sr Pb and U are trace elements that have high ionic radius, low ionic charge and have high solubility in aqueous fluid. They usually the ones to be most readily mobilize to mantle wedge by fluids during dehydration process of the subducting slab. Commonly in most arc magmas, the LILE will elevated related to Mid-Ocean Basalt (MORB) compositions which are the result from subduction component. Besides that, Nb, Ti and Zr are High Field-Strength

Elements (HFSE) with high ionic charge and low ionic potential which makes them less soluble in aqueous fluids and more likely to reflect a source prior to subduction component addition. Another trace element are Light Rare Earth Elements (LREE) such as La and Ce.

To evaluate the concentrations of selected incompatible trace elements, normalised variation diagrams correlate with a reference are used. Typically, Normal Mid-Ocean Ridge Basalt (N-MORB) is choosen as reference. NMORB act as index against subduction-related magma to observe the enrichment of LILE and LREE as they are fluid mobile elements and depletion of less mobile element groups such as HSFE and HREE(Handley, Macpherson, Davidson, Berlo, & Lowry, 2007). Normalize to chondrites in Figure 5.6, the pattern from trace element data plotting shows a common subduction-zone pattern of high LILE and LREE compare to low HFSE. This is supported by the enrichment pattern shown when plotted normalize to N-MORB. The magma source that produce Banjaran volcanic rocks may be depleted peridotice upper mantle and experiencing enrichment of LILE(Ba, Rb, K) and LREE (La) from a subducted slab.

Mantle wedge above the slab melt then release water and other volatiles. This process lowers the mantle solidus and LILE from a downgoing lithosphere elevated above to enrich the elements in the mantle wedge. As mention before, LILE is incompatible elements that highly mobilize in aqueous fluid. Therefore the enrichment occurs by the transfer elements from downgoing slab by fluid phase. In contrast, the HFSE element such as Ti and Zr shows depleted pattern. This depletion is because of mass flux processes from the subduction plate to the mantle wedge (Münker, Wörner, Yogodzinski, & Churikova, 2004). Depletion is associated to their immobility in aqueous fluid phase during dehydration process, and this make the HFSE element do not elevated into mantle wedge.

5.5 Conclusion

In conclusion, the evolutions of volcanic rocks found in the Banjaran area are from magma originating from the island arc basalt. The magma belongs to calc-alkaline affinity series. Magma series produces rocks from intermediate to acid which is andesite rocks to dacite rocks. This evolution is through the differentiation process, which is fractionation crystalization. Crustal contamination cannot be ascertained due to lack of isotope data. Through the concentration of trace elements plotted in the spidergram, there is an enrichment of LILE element compare to HFSE that have depletion. This is consistent with the general pattern of arc magma subduction.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

By using data in chapter 4 and geological mapping of study area, Banjaran, the geological map were produce in the scale of 1:25000. The study area have coordinated is (07°2’25.50” S, 107°33’25.43” E) ,(07°2’25.50” S, 107°36’08.96” E) , (07°5’08.11” S, 107°36’08.96” E), and (07°5’08.11”S, 107°33’25.43” E). Geomorphology of study area was divided into low elevation with surficial deposits unit and high moderate elevation compose of volcanic product unit. The drainage patterns that can be found in this study area are dendritic and parallel pattern. Based on mapping study and observation, the study area consist four lithology unit from older to younger unit that be arrange in stratigraphy column. The lithology unit are Volcanic Breccia 1(Tpv) , Volcanic breccia 2 (Qpv), Lahar (Qpl) and Alluvium (Qa). There is no structural data that can be found in this study area.

The historical geology started with Tertiary volcanism that form Volcanic Breccia 1 unit followed by Quaternary volcanism. Quaternary volcanism such Mount Malabar eruption form Volcanic Breccia 2 and Lahar unit. After million years this volcanic product experience weathering and erosion, this process form unconsolidated layer at less elevated plain area and form Bandung Basin. Alluvium unit is part of it and located at south of Bandung Basin.

Based on geochemical analysis, the relationship between different type of rocks can be determine by their petrogenesis from magma source. The magma source is from island arc basalt that have calc-alkaline affinity series. The type of rock classified by geochemical data is from andesite to dacite. The fractionation crystallization is the main process of magma differentiation that produces rock from intermediate to acid. The crystallization of mineral is main factor that produce different type of rocks in Banjaran area. The magma also being enrich of LILE and depleted HFSE element due to subduction zone tectonic setting.

6.2 Recommendation

The geochemical analysis need to use more accurate method such as Induced Couple Plasma – Mass Spectromenter (ICP-MS) in order to obtain more trace element and rare earth element (REE) . XRF method only is not enough detect trace element and REE due to detection limit. More petrology diagram and plotting can be done if more variation of trace element and REE data. Researcher in future is recommended to use isotopes data as this data can be plot to interpret the crustal contamination of magma and the original depth of the magma. Next study need to be conduct by further understanding of the volcano internal process such as the effects and impacts of past volcanic eruptions by using various field such as geological mapping ,petrology, mineralogy , geochemical analysis and petrography. This is also for improving the preparation and mitigation for next active volcanic eruptions. In term of hazard analysis, it is important for understanding the physical processes of magma movement and volcanic eruption.

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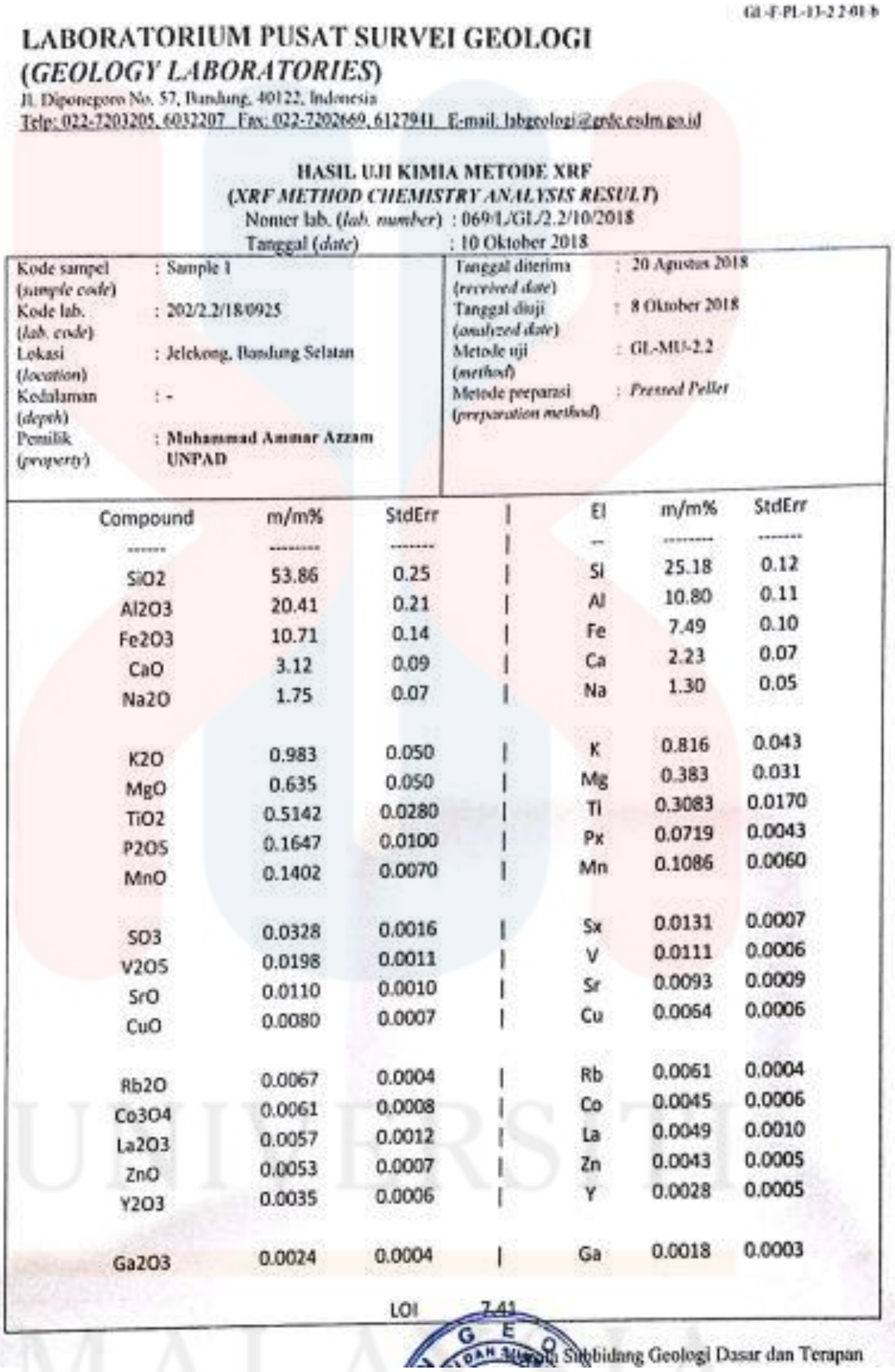
APPENDIX A



GI-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*) : 069/L/GL/2.2/10/2018
Tanggal (*date*) : 10 Oktober 2018

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Kode lab. (*lab. code*)	: 202/2.2/18/0925	Tanggal diuji (*analyzed date*)	: 8 Oktober 2018
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Kedalaman (*depth*)	: -	Metode preparasi (*preparation method*)	: *Pressed Pellet*
Pemilik (*property*)	: **Muhammad Ammar Azzam** **UNPAD**		

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   Compound      m/m%      StdErr     |    El     m/m%      StdErr
   ------        --------  -------    |    --     --------  -------
   SiO2          53.86     0.25       |    Si     25.18     0.12
   Al2O3         20.41     0.21       |    Al     10.80     0.11
   Fe2O3         10.71     0.14       |    Fe     7.49      0.10
   CaO           3.12      0.09       |    Ca     2.23      0.07
   Na2O          1.75      0.07       |    Na     1.30      0.05

   K2O           0.983     0.050      |    K      0.816     0.043
   MgO           0.635     0.050      |    Mg     0.383     0.031
   TiO2          0.5142    0.0280     |    Ti     0.3083    0.0170
   P2O5          0.1647    0.0100     |    Px     0.0719    0.0043
   MnO           0.1402    0.0070     |    Mn     0.1086    0.0060

   SO3           0.0328    0.0016     |    Sx     0.0131    0.0007
   V2O5          0.0198    0.0011     |    V      0.0111    0.0006
   SrO           0.0110    0.0010     |    Sr     0.0093    0.0009
   CuO           0.0080    0.0007     |    Cu     0.0064    0.0006

   Rb2O          0.0067    0.0004     |    Rb     0.0061    0.0004
   Co3O4         0.0061    0.0008     |    Co     0.0045    0.0006
   La2O3         0.0057    0.0012     |    La     0.0049    0.0010
   ZnO           0.0053    0.0007     |    Zn     0.0043    0.0005
   Y2O3          0.0035    0.0006     |    Y      0.0028    0.0005

   Ga2O3         0.0024    0.0004     |    Ga     0.0018    0.0003

                           LOI        7.41
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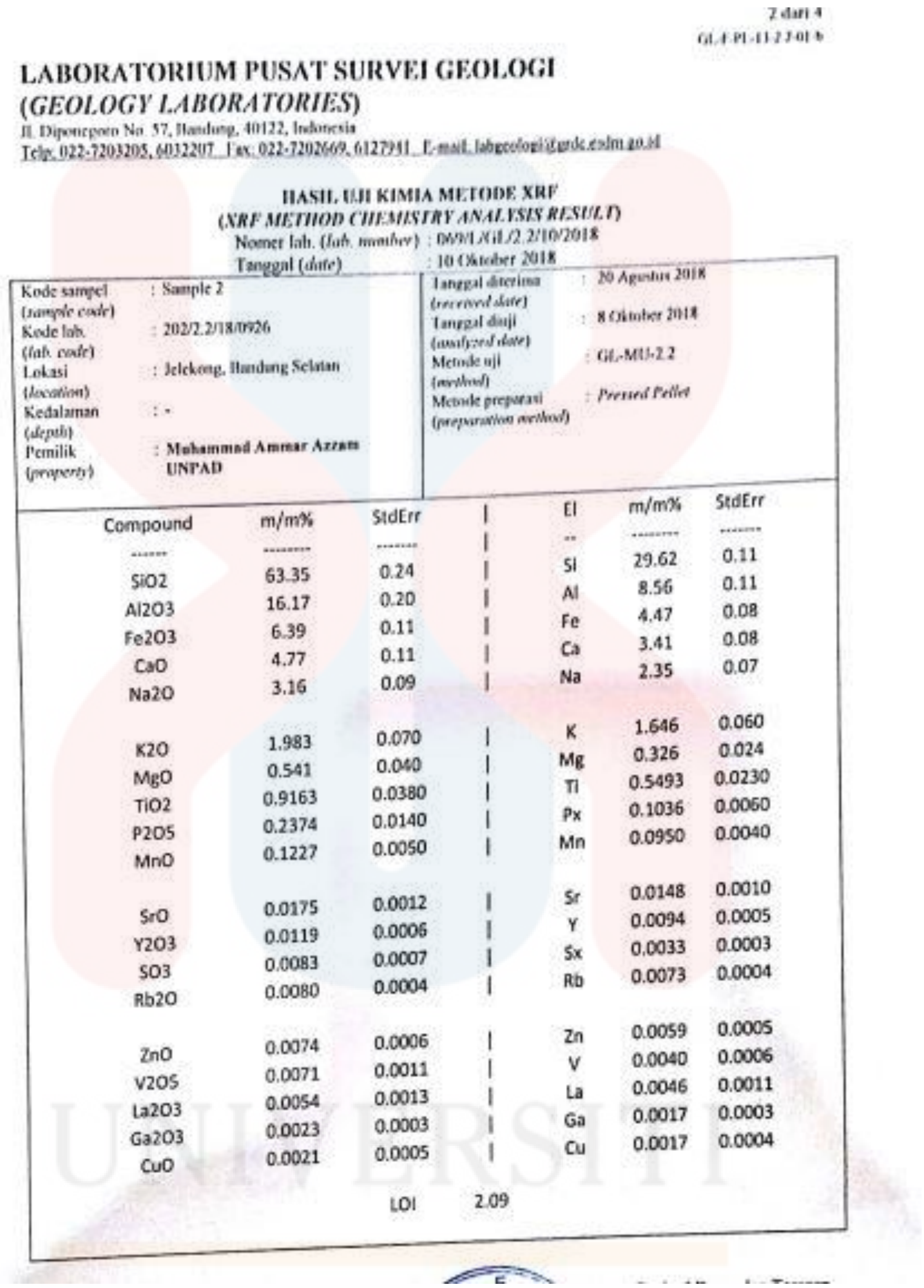

2 dari 4
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HASIL UJI KIMIA METODE XRF
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Tanggal (*date*) : 10 Oktober 2018

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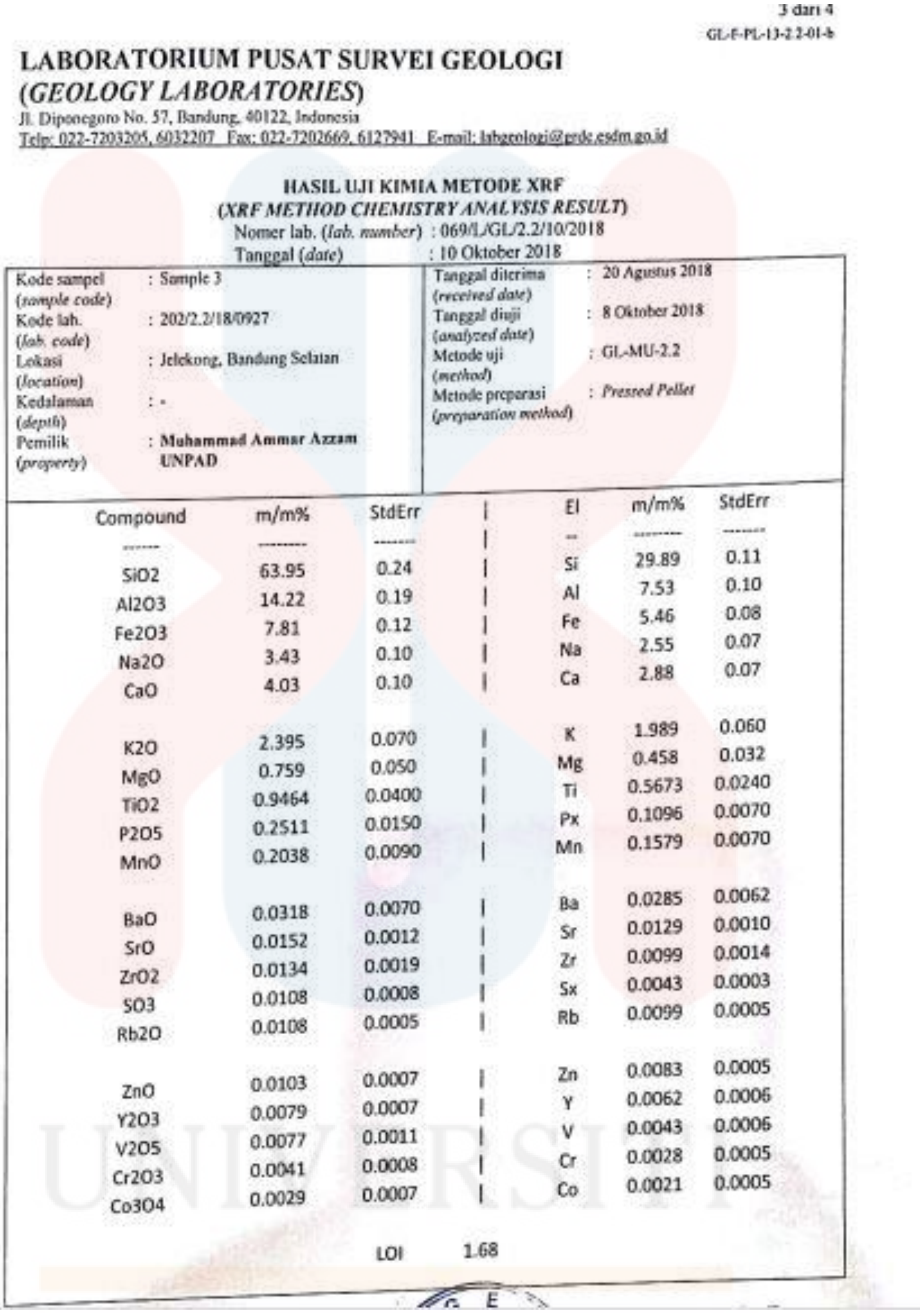
Kedalaman (*depth*) : -
Pemilik (*property*) : **Muhammad Ammar Azzam UNPAD**

Tanggal diterima (*received date*) : 20 Agustus 2018
Tanggal diuji (*analyzed date*) : 8 Oktober 2018
Metode uji (*method*) : GL-MU-2.2
Metode preparasi (*preparation method*) : *Pressed Pellet*

Compound	m/m%	StdErr	El	m/m%	StdErr
------	--------	-------	--	--------	-------
SiO2	63.35	0.24	Si	29.62	0.11
Al2O3	16.17	0.20	Al	8.56	0.11
Fe2O3	6.39	0.11	Fe	4.47	0.08
CaO	4.77	0.11	Ca	3.41	0.08
Na2O	3.16	0.09	Na	2.35	0.07
K2O	1.983	0.070	K	1.646	0.060
MgO	0.541	0.040	Mg	0.326	0.024
TiO2	0.9163	0.0380	Ti	0.5493	0.0230
P2O5	0.2374	0.0140	Px	0.1036	0.0060
MnO	0.1227	0.0050	Mn	0.0950	0.0040
SrO	0.0175	0.0012	Sr	0.0148	0.0010
Y2O3	0.0119	0.0006	Y	0.0094	0.0005
SO3	0.0083	0.0007	Sx	0.0033	0.0003
Rb2O	0.0080	0.0004	Rb	0.0073	0.0004
ZnO	0.0074	0.0006	Zn	0.0059	0.0005
V2O5	0.0071	0.0011	V	0.0040	0.0006
La2O3	0.0054	0.0013	La	0.0046	0.0011
Ga2O3	0.0023	0.0003	Ga	0.0017	0.0003
CuO	0.0021	0.0005	Cu	0.0017	0.0004

LOI 2.09



3 dari 4
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*) : 069/L/GL/2.2/10/2018
Tanggal (*date*) : 10 Oktober 2018

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Kedalaman (*depth*)	: -	Metode preparasi (*preparation method*)	: *Pressed Pellet*
Pemilik (*property*)	: **Muhammad Ammar Azzam** **UNPAD**		

Compound	m/m%	StdErr	El	m/m%	StdErr
------	--------	-------	--	--------	-------
SiO2	63.95	0.24	Si	29.89	0.11
Al2O3	14.22	0.19	Al	7.53	0.10
Fe2O3	7.81	0.12	Fe	5.46	0.08
Na2O	3.43	0.10	Na	2.55	0.07
CaO	4.03	0.10	Ca	2.88	0.07
K2O	2.395	0.070	K	1.989	0.060
MgO	0.759	0.050	Mg	0.458	0.032
TiO2	0.9464	0.0400	Ti	0.5673	0.0240
P2O5	0.2511	0.0150	Px	0.1096	0.0070
MnO	0.2038	0.0090	Mn	0.1579	0.0070
BaO	0.0318	0.0070	Ba	0.0285	0.0062
SrO	0.0152	0.0012	Sr	0.0129	0.0010
ZrO2	0.0134	0.0019	Zr	0.0099	0.0014
SO3	0.0108	0.0008	Sx	0.0043	0.0003
Rb2O	0.0108	0.0005	Rb	0.0099	0.0005
ZnO	0.0103	0.0007	Zn	0.0083	0.0005
Y2O3	0.0079	0.0007	Y	0.0062	0.0006
V2O5	0.0077	0.0011	V	0.0043	0.0006
Cr2O3	0.0041	0.0008	Cr	0.0028	0.0005
Co3O4	0.0029	0.0007	Co	0.0021	0.0005

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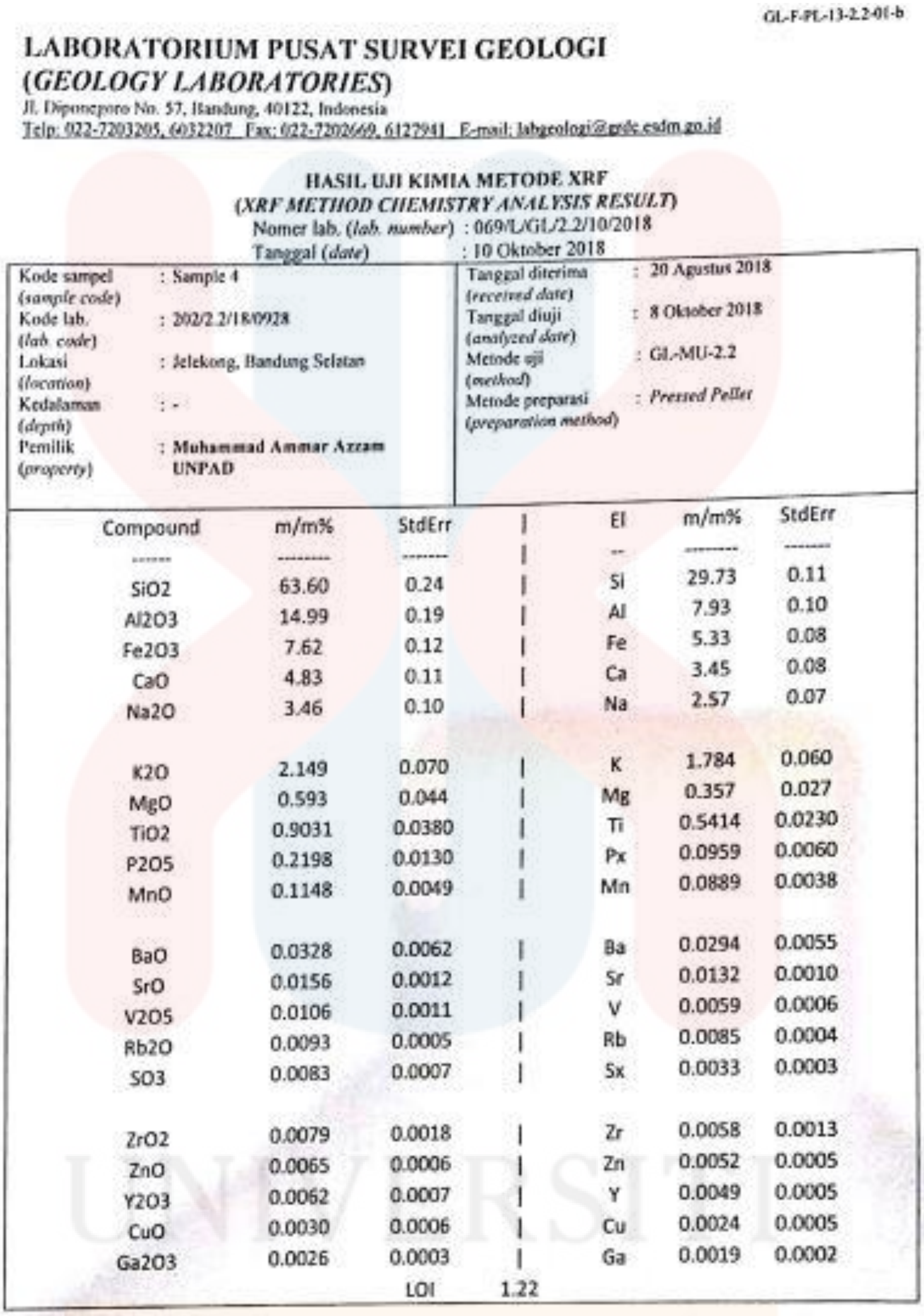

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HASIL UJI KIMIA METODE XRF
(*XRF METHOD CHEMISTRY ANALYSIS RESULT*)
Nomer lab. (*lab. number*) : 069/L/GL/2.2/10/2018
Tanggal (*date*) : 10 Oktober 2018

Kode sampel (*sample code*) : Sample 4
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Kedalaman (*depth*) : -
Pemilik (*property*) : **Muhammad Ammar Azzam UNPAD**

Tanggal diterima (*received date*) : 20 Agustus 2018
Tanggal diuji (*analyzed date*) : 8 Oktober 2018
Metode uji (*method*) : GL-MU-2.2
Metode preparasi (*preparation method*) : *Pressed Pellet*

Compound	m/m%	StdErr	El	m/m%	StdErr
SiO2	63.60	0.24	Si	29.73	0.11
Al2O3	14.99	0.19	Al	7.93	0.10
Fe2O3	7.62	0.12	Fe	5.33	0.08
CaO	4.83	0.11	Ca	3.45	0.08
Na2O	3.46	0.10	Na	2.57	0.07
K2O	2.149	0.070	K	1.784	0.060
MgO	0.593	0.044	Mg	0.357	0.027
TiO2	0.9031	0.0380	Ti	0.5414	0.0230
P2O5	0.2198	0.0130	Px	0.0959	0.0060
MnO	0.1148	0.0049	Mn	0.0889	0.0038
BaO	0.0328	0.0062	Ba	0.0294	0.0055
SrO	0.0156	0.0012	Sr	0.0132	0.0010
V2O5	0.0106	0.0011	V	0.0059	0.0006
Rb2O	0.0093	0.0005	Rb	0.0085	0.0004
SO3	0.0083	0.0007	Sx	0.0033	0.0003
ZrO2	0.0079	0.0018	Zr	0.0058	0.0013
ZnO	0.0065	0.0006	Zn	0.0052	0.0005
Y2O3	0.0062	0.0007	Y	0.0049	0.0005
CuO	0.0030	0.0006	Cu	0.0024	0.0005
Ga2O3	0.0026	0.0003	Ga	0.0019	0.0002
		LOI	1.22		