GEOLOGY AND DEPOSITIONAL ENVIRONMENT OF SEMILIR FORMATION OF HARGOMULYO AREA, GEDANGSARI, YOGYAKARTA, INDONESIA

By

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DECLARATION

I declare that this thesis entitle Geology and Depositional Environment of Semilir of Hargomulyo Area, Gedangsari, Yogyakarta, Indonesia is the result of my own research except as cited in the reference. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ______________________________

Name : ______________________________

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APPROVAL

This is to certify that, the thesis entitled “Geology and Depositional Environment of Semilir Formation of Hargomulyo Area, Gedangsari, Yogyakarta, Indonesia” is prepared by Sharon Rose a/p Anthony Dass, with matric number E15A0260, a student under my supervision and guidance. I have gone through the thesis in every aspect of the research topic. It is to be noticed that the thesis fulfils the partial requirement of degree. It has not been submitted to other universities or institutes for the same degree.

The report is approved and accepted in quality form.

____

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GEOLOGY AND DEPOSITIONAL ENVIRONMENT SEMILIR FORMATION OF HARGOMULYO AREA, GEDANGSARI, YOGYAKARTA, INDONESIA

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Abstract: Geological map of the Surakarta-Giritontro Quadrangles, Java scaled of 1:100,000 produced in 1997 and not updated since then. The pervious data are might change in term of geomorphology and new outcrop which might expose in the study. Thus this research is to update the geological map of study area scaled 1:25 000, to determine the facies characteristics and to interpret the depositional environment of Semilir Formation in Yogyakarta, Indonesia. The research was conducted by field studies and lab analysis involving traversing and thin section. Data was interpreted by using lithological section for Semilir Formation. The research area over all consists of six lithology unit namely tuff, tuffaceous sandstone, green tuff, tuff breccia, lapilli and andesite breccia All these rock aged from Late Oligicene-Early Miocene. Semilir Formation was form during volcanism period, mostly dominated by tuff breccia, lapilli, tuff and volcanic sandstone aged Early Miocene. Semilir Formation are separated into five facies and it has deep marine depositional environment. It form at underwater submarine fan at inner fan.

Keywords: Geological map; Facies; Depositional Environment; Yogyakarta, Indonesia; Deep Marine; Inner fan

GEOLOGI DAN LINGKUNGAN PENGENDAPAN FORMASI SEMILIR DI SEKITAR HARGOMULYO, GEDANGSARI, YOGYAKARTA, INDONESIA

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Abstrak: Peta geologi Surakarta-Giritontro Quadrangles, Java dengan skala 1:100 000 diwujudkan pada tahun 1997 dan tidak di kemas kini sehingga sekarang. Data sebelum mungkin ada perubahan dari segi geomorphologi dan struktur baru mungkin terwujud di tempat kajian. Kajian ini dijalankan untuk mengemaskini peta geology kawasan kajian pada skala 1:25 000, menentukan fasies and lingkungan pengendapan formasi Semilir di Yogyakarta, Indonesia. Kajian ini dijalankan melalui kajian lapangan and kajian di makmal. Data ditafsirkan melalui bahagian lithological untuk formasi Semilir. Kawasan Kajian terdiri daripada enam jenis lithologi iaitu tuff, batu pasir tufaceous, tuff hijau, breski tuff, lapilli and breski andesita. Semua batuam ini berumur Akhir Ologosen- Awal Miosen. Formasi Semilir semasa letusan gunung berapi dan dominanis oleh breski tuff, lapilli, tuff and batu pasir vulkanik berumur Awal Miosen. Formasi Semilir dibahagikan kepada lima fasies dan ia mempunyai lingkungan pengendapan lautan dalam. Ia terbentuk kipas bawah laut di kipas inner

Keywords: Peta Geologi; Fasies; Lingkungan Pengendapan; Yogyakarta, Indonesia; Lautan Bawah; Kipas Inner

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LIST OF ABBREVIATIONS

cm	Centimeter
DIY	‘Daerah Istimewa Yogyakarta’
E-W	East West
f	Frequency
GIS	Geographic Information System
GPS	Global Positioning System
km	Kilometer
m	Meter
mm	Millimeter
N-E	North-East
N-S	North-South
NE-SW	North East- South West
NW-SE	North West- South South West
NNE-SSW	North North East- South South West
NNW-S	North North West- South
opq	Opaque
plg	Plagioclase
PPL	Plane Polarization
Pm	Pumice
Pyx	Pyroxene
Qtz	Quartz
XPL	Cross polarization

LIST OF SYMBOLS

°	Degree
’	Minute
”	Second
σ	Sigma
°C	Degree Celcius

CHAPTER 1

INTRODUCTION

1.1 General Background

Gedangsari is located at Yogyakarta Special Region on Southern Java, Indonesia with latitude 7° 58’ 0.05” S and longitude 101° 36’ 9.22”E. Gedangsari are borders by Nglipar district at the north, Karangmojo Semanu district at east. Tanjungsari district at south and Paliyan and Playen district to the west of Yogyakarta. Yogyakarta Special Region covers about 3,185.80km total area.

The research study is focusing on depositional environment of volcanic rock in Hargamulyo area, Gedangdari, Yogyakarta. Based on the geological map of the previous study by (Surono, 2008) that this area is mostly cover in Semilir Formation and comprise a small part of Nglanggran Formation above and Kebo-Butak Formation below the study area.

A geological map study represent the different type of rocks, their deposits and geological structure such as fault and folds. The information that obtained from the geological map are used to interpret the geological history of an area and give a better understanding by giving a clear picture on the rock distribution and rock structure.

Deposition Environment is also called as sedimentary environment. It is a combination process of physical, chemical and biological process where the sediment transport and lithified into sedimentary rock. The depositional environment eventually give the geological history of rock and certain place can be identified.

1.2 Problem Statement

The problem that might occur in the study area are mainly on geological map of the Surakarta-Giritontro Quadrangles, Java which is produce in 1997 and not updated since that (Surono,2008). The previous map that the Geological survey Centre produced geological map with scaled of 1:100,000. The pervious data are might change in term of geomorphology and new outcrop which might expose in the study area thus change the geological information of the present time.

In the previous study, there were not many research on facies analysis and depositional environment in smalls scale map of 1: 25 000. The sedimentary facies are usually able to differentiate the various sedimentary deposits with different facies which indicate the mode of sediment deposits or its depositional environments.

1.3 Research Objective

There are three main objective:

1. To update the geological map of the study area scale 1:25000
2. To determine the facies characteristics of Semilir Formation
3. To interpret the depositional environment of the Semilir Formation in the study area

1.4 Study Area

Figure 1.1 shows the study area at Hargomulyo area, Gedangsari, Yogyakarta, Indonesia which over approximately 25 km^2 which comprises between with latitude 7° 49’ 7” S to 7° 51’ 21” S and longitude 110° 36’ 8”E to 110° 36’ 18”E. Morphologically, the study area mainly at mountainous area namely “Mount Batuarung and Mount Jatiseketi”. Mount Butak also near to the study area. The study area has three different type of formation which are Semilir Formation and follows by Nglanggran Formation above and Kebo-Butak Formation below the study area.

Figure 1.1: Location Yogyakarta, Indonesia (Surono, 2009)

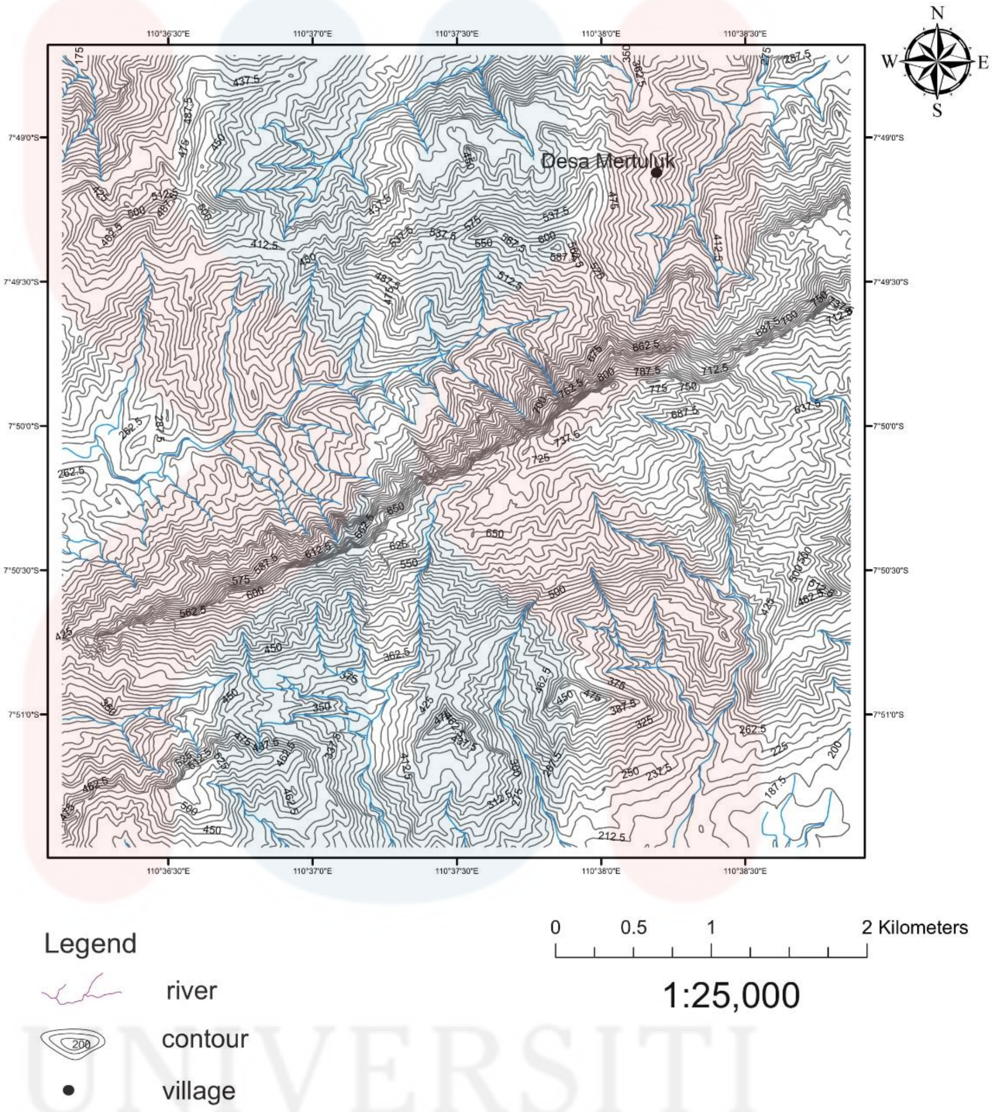


Figure 1.2: Map of Hargomulyo Area, Yogyakarta, Indonesia.

1.4.1 Demography

Yogyakarta is a special district in Java, Indonesia. It lies about 29 km from the southern Java and near Mount Merapi. Based on table 1.3 all the cities in Yogyakarta undergoes constant increase in population from 2011 until 2016. Majority of the population are Javanese. The city has large numbers of school and universities. The living cost in Yogyakarta has low cost of living compare to other Indonesian cities.

Source: Statistics of D.I. Yogyakarta, 2018

Table 1.1: Population by Regency/ City in D.I Yogyakarta (Soul)

Regency/ City	**Population by Regency/ City in D.I. Yogyakarta (Soul)**					
	2011	2012	2013	2014	2015	2016
D.I. Yogyakarta	3 509 997	3 552 462	3 594 854	3 637 116	3 679 176	3 702 912
Kulonprogo	394 200	398 672	403 179	407 709	412 198	416 683
Bantul	922 104	934 674	947 072	959 445	972 511	983 527
Gunung Kidul	685 003	692 579	700 191	707 794	715 282	722 479
Sleman	1 116 184	1 128 943	1 141 733	1 154 501	1 167 481	1 180 479
Yogyakarta	392 506	397 594	402 679	407 667	412 704	417 744

1.4.2 Climate and rain distribution

The precipitation between dries and wettest month are about 376 mm. The variation in temperature throughout the year is about 1.7 °C. The climate is influence by monsoon. The average temperature for a year is roughly about 26 -27 °C. The hottest month is April with average temperature 27.1 °C.

Source: CLIMATED DATA.ORG, 2018

Table 1.2: Climate and rain distribution

	Avg. Temperature (°C)	**Min. Temperature (°C)**	**Max. Temperature (°C)**	**Precipitation/ Rainfall (mm)**
January	26.3	22.9	29.8	392
February	26.5	22.8	30.2	299
March	26.6	22.9	30.4	363
April	27.1	23	31.3	149
May	26.9	22.7	31.1	141
June	26.2	21.5	31	68
July	25.4	20.6	30.3	29
August	25.6	20.6	30.7	16
September	26.4	21.7	31.1	49
October	27	22.7	31.4	136
November	26.8	23	30.7	237
December	26.4	22.8	30.1	278

1.4.2 Land use

Yogyakarta has about 32.5 km^2 of city. The city is spread in all direction from the craton or known to be Sultan's place. The Yogyakarta is the core of modern city to the north, centre around building and the commercial district. Yogyakarta is has main production of crops such as rice paddy, corn, yam, ground nuts, peanuts and sweet potatoes. The Yogyakarta land are one of mainly tourist spot as it's because there were many temples such as Prambanan and Borobudur temple. Mount Merapi also one of the tourist spot in Yogyakarta.

1.4.3 Social Economy

The centre of Javanese which is Yogyakarta is art culture, a city with many cultures and customs as rich as they follow the traditional Sultanate system which is different from the rest of Indonesia cities. The Yogyakarta gives importance mainly for education, economy and tourism. Gadjah Mada University is one of the Indonesia most prominent universities and other different local university. Yogyakarta economy is mostly on whole, transportation and warehousing, real-estate and other corporate service.

1.4.4 Road Connection/ Accessibility

The Yogyakarta is mainly use public transport such as city bus, trains and taxis, andongs and becaks. The major departure is for inter-city buses to other cities in Java and Bali. Motorbikes are most commonly used for own transportation. Ring road and overpasses Janti Overpass and Lempunyangan Overpass are the highway in Yogyakarta.

1.5 Scope of Study

The scope of study for this research area is conducted at Hargomulyo Area, Gendangsari, Yogyakarta. A basic geological mapping will be conducted at this area about 5 x 5 km^2 with 1:25 000 scale of map. The scope of this study is focusing more on the Semilir Formation by studying the lithostratigraphy of the layer of visible outcrop that laterally will reflect the changes of depositional environment of rock layer and analysis the characteristic of the formation.

1.6 Significant of Study

The research significantly provides more information on the study area. This enable future researchers to utilize the map of 1:25 000 scale. The facies analysis gives a complete sedimentology information regarding lithology, texture especially grain size, structure and fossil contain which essential to interpret the depositional environment of the study area which eventually enable the researcher to reconstruct the past climate and the ancient geography's of the study area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter are discussing about the overall tectonic process including regional geology and tectonic setting. Structural geology, geology history and several related event that occur at Special Province Yogyakarta and the study area. Indonesia is a Southern Asia country. There are many province in Indonesia, however, there are five provinces which have special status namely Aceh, Special Region of Yogyakarta, West Papua and Special Capital Region of Jakarta. The Yogyakarta in in Java unit and the preliminary study focus in the Special Region of Yogyakarta.

2.2 Regional Geology and Tectonic Setting

Indonesia has many general geological features. The basement formation of Indonesia is where metamorphic and it is intruded with plutonic formation. It is then overlain with Mesozoic, Cenozoic, recent volcanic formation and quaternary deposits. The oldest rock in Sumatra Island are gneiss, schist and often contain gold. These rock undergoes fold and denude before the Carboniferous bed were deposits. Granitic rock at several location is from Pre-Carboniferous.

The next rock unit is slate that occur below the limestone. This is probably unconformity upon the older rock. The limestone belong to the Upper Carboniferous.

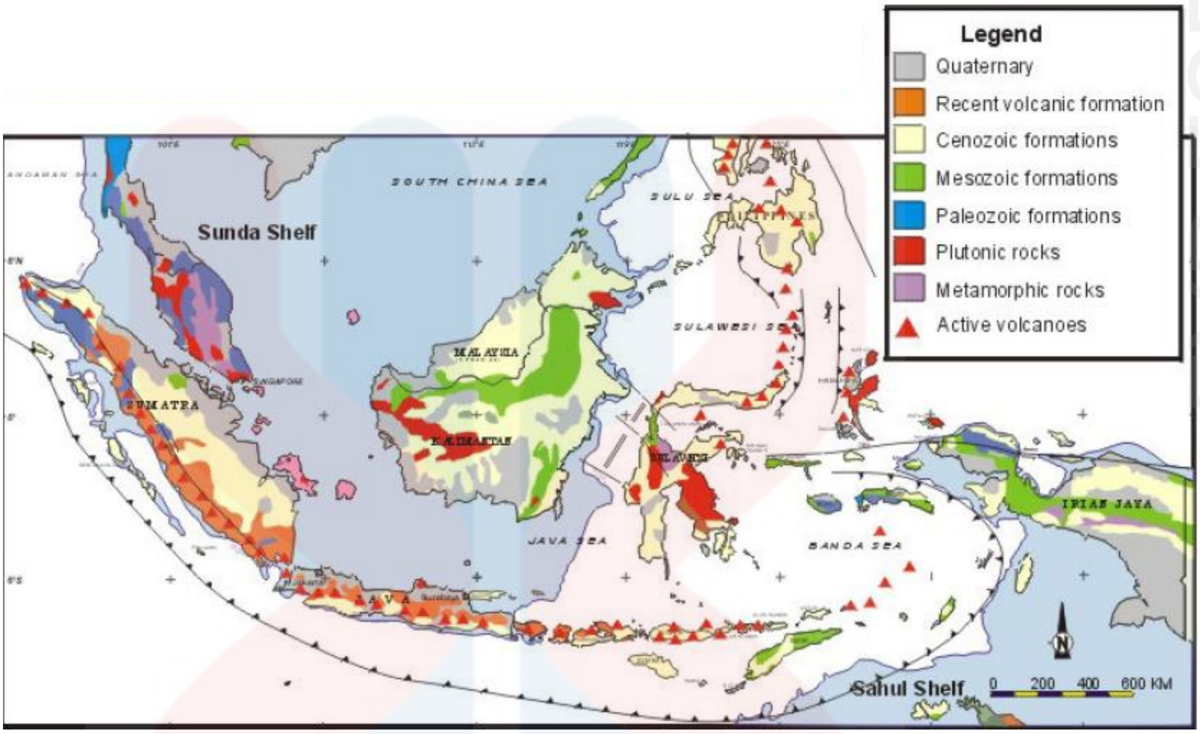


Figure 2.1 Regional Geology of Indonesia (Darman H, 2015)

The bed of slate underlie the limestone is probably occur only at northern Sumatra. It is believed that these rock also intruded by diabase and gabbro. However, no Permian beds trace are found yet Mesozoic deposits are found. The Mesozoic deposits such as Triassic clay and sandstone at East Sumatra.

The Central and East Java can be physio graphically grouped into five zone (Van Bemmelen, 1949) from the south to north namely

1. Southern Mountain Zone
2. Solo Zone
3. Kendeng Zone
4. Randublatung Zone
5. Rembang Zone.

This physiographic zone reflect the structural element of gravity anomaly. Keledeng and Rembang Zone has positive structural anomalies, while Semarang-Pati depression, Randublatung depression and Kanye Solo depression have negative anomalies. The main structure of Central Java in E-W direction and also NE-SW trending structure around boundary zone Rembang and volcanic Muria.

Figure 2.2 Plate Tectonic of Indonesia. (Tectonic of Indonesia, 2002)

Indonesia are has three major plate that boundaries each other namely Eurasia, India-Australia and Pacific-Philippine Sea (Holloway, 1883) (Figure 2.2). The subduction of plate boundary between Eurasian and Indian plate is called Sunda Trench which form at western Indonesia while the subduction between Australia plate under Eurasian plate form volcanoes activities. Volcanoes in the Banda Sea is occur subduction of the Pacific plate under Eurasian plate. Java is form between Asia and Australia at the centre of Indonesia archipelago where the subduction of Indo-Australia plate below the Eurasian plate. The subduction at Java Trench since early Cenozioc, while in Eocene to early Miocene volcanic arc activities in East Java, the Southern Mountain Arc.

Most of Indonesia's volcanoes are part of Sunda Arc, where the volcanoes extending about 3 000 km long line from northern Sumatra to the Banda Sea. Most of the volcanoes is result from the subduction of Australia plate beneath the Eurasia plate. While the volcanoes in Banda Sea is result from subduction of Pacific plate below the Eurasia plate at the centre part of Indonesia. There also a major transform fault (Lee and Lawver. 1995).

About one-fourth of Indonesia's volcanoes are located in north of Sunda arc with complex tectonic setting area. Many small plates are form in the subduction zone mostly in the direction of north-south. The volcanoes of Sulawesi, Halmahera and Sangihe are result of these subduction zone in centre Indonesia (Hamilton, 1979). The volcanoes of Sulawesi, Sangihe, and Halmahera generate magma in asthenosphere mantle which modify by fluids derived from the subducted Molucca Sea Plate. However, all of the Molucca Sea Plate will be subducted and the Sangihe and Halmahera plates will collide, shutting off volcanism (Hamilton, 1979).

The earthquake region usually due to Indo-Australia plate moves toward the north-east relative to the Euro-Asian plate. This is due to oblique convergence at the Sunda Trench. The oblique motion separated into two namely thrust-faulting and strike-slip faulting. The thrust fault occur as the plate move slip direction perpendicular to the trench. While the strike-slip fault move in slip direction parallel to the trench.

This fault known to be Sumatran fault. The fault divided into three segment north, south and centre. The fault has dextral movement. It has age of Middle Miocene and the opening of Andaman Sea.

2.3 Historical Geology

(Husein & Srijono, 2016) stated that Southern Mountain on Yogyakarta Special Region (DIY) is referred as Southern Java Mountain East part of West. These southern mountain of east Java can be divided into three zones north, middle and south. The northern part is mountainous line with a strong relief, the middle part is topographic depression and the southern part is characteristics by karst topography by a series of conical hills as well as some beachfront pattern (Hussein and Srijono, 2016).

The Southern Mountain area from Yogyakarta to east comprising Wonosari, Wonogiri, Pacitan continue to the south of Malang and Blambangan area. The Southern Mounatain consist mainly mountains which extend relatively east-west direction. This place comprise mainly volcanic clastic material. The Southern Mountain zone is limited by Surakarta plains in the west and north, while to the east by Gajah Mungkur Reservoir, Wonogiri and to the south by Indian Ocean. At the west between Southern Mountain and Yogyakarta it is limited by a fault system. The fracture is known to be Opak Fault where western block moves downward to the eastern block.

The Southern mountain can be divided into three subzone namely Baturagung, Wonosari and Gunung Sewu subzone. The Wonosari subzone is located in the middle of Yogyakarta and it is surrounded by Baturagung in the west and south and the south east by Gunung Sewu subzone. There is a main river, Oyo River, which flow to the west and intercept with Opak Fault. Thus this area consists of black clay and lake primordial sediment and base by limestone.

The Yogyakarta city is located at Central Java, Indonesia. The city is located only about 30 km from the Mount Merapi and it is comprise under continue subduction of Indo-Australia Oceanic plate from the south direction below the Eurasia continental plate (Karnawati, Pramumijoyo, & Hendrayana, 2006). Yogyakarta is a depression in the north by Mount Merapi and in the east boundary by Mount Kulon Progo. Both composed by tertiary rock. The depression or basin known to be Yogyakarta basin.

The Southern mountain and Kulon Progo Mountain consists of rock which from ancient volcanic product along with carbonate superficial sediment deposition product. The volcanic product under several formation namely Nanggulan, Kebobutak, Semilir, Ngalanggran, Wuni and Sambipitu formation and the carbonate product under Wonosari, Jonggrangan, Kepek and Sentolo formation.

2.4 Stratigraphy

Surono, (2009) state that the lithostratigraphy of the Southern Mountain generally formed by clastic sediments and carbonates mixed rock with aged tertiary rock. Surono, (2009). The sedimentary rock in Southern Mountain Arc in East Java were deposited on the basement which is overlain by poorly dated poorly dated regional unconformity (Hall R, Nicholas G & Smyth H, 2008). The unconformity separated the Upper Cretaceous basement rock and the Cenozoic succession rock during the uplift and erosion occurred.

The basement rock can be found in Karangsambung and Jiwo Hills. This place have the basement rock are aged Cretaceous including basaltic pillow lava, radiolarian cherts, various metasedimentary rock such as quartz-mica schist and high-graded metamorphic rock. The basement rock has ophilitic material accreted to the margin of Sundaland during Late Cretaceous (Hall R, Nicholas G & Smyth H, 2008).

The stratigraphy can be divide into three unconformity-boundary. The first unconformity recorded during the initial of arc volcanism and early stage of development which happen middle Eocene to early Oligocene. It is believed that the oldest sedimentary rock overlain on the basement in angular conformity. The lithologies stands from conglomerate and interbedded sandstone. This are the only exposure rock onshore that does not contain any volcanic material.

They are dominated by quartz grain and metamorphic and igneous clasts including vein and metamorphic quartz, chert, phyllite, schist, metasedimentary rock and basalt. The rock are nearly similar to basement rock in Cretaceous basement. During the age of middle Eocene to early Oligocene, the southern mountain presenting transgressive succession where it has coal, conglomerate, sandstone, siltstone and mudstone form the top to the bottom.

The second conformity recorded the growth until the termination of volcanism in the Southern Mountain which happen at late Oligocene to the early Miocene. At this time the unconformity deposited primary by volcanic rock and epiclastic rock. These rock spread widely in Southern mountain and also within thrust-fold belt of the Kendeng Basin. The oldest rock of this event are bioclastic tuffaceous mudstone. There are many explosive and acidic composition in Southern mountain and has the deposit range from andesite to rhyolite according to the composition of SiO_2 (Smyth H, 2005).

The lithologies of on this period is thick mantling of tuffs, crystal-rich tuff, block and ash flows, pumice-lithic breccia, andesite breccia, silicic lava domes and lava flows. Thus this is under Semilir formation and there were major eruption at the end period and have the accumulation of pyroclastic surge, flow breccia. The deposits show the end of volcanism.

The third unconformity where the abundance of carbonate rock growth and there were erosion and redeposition of rock from the earlier unconformity in middle Miocene until no volcanic activities. In this period bioturbation and there are several tuff can be found at the top of turbidite. The limestone are thick bed and the carbonate source within volcanogenic turbidites.

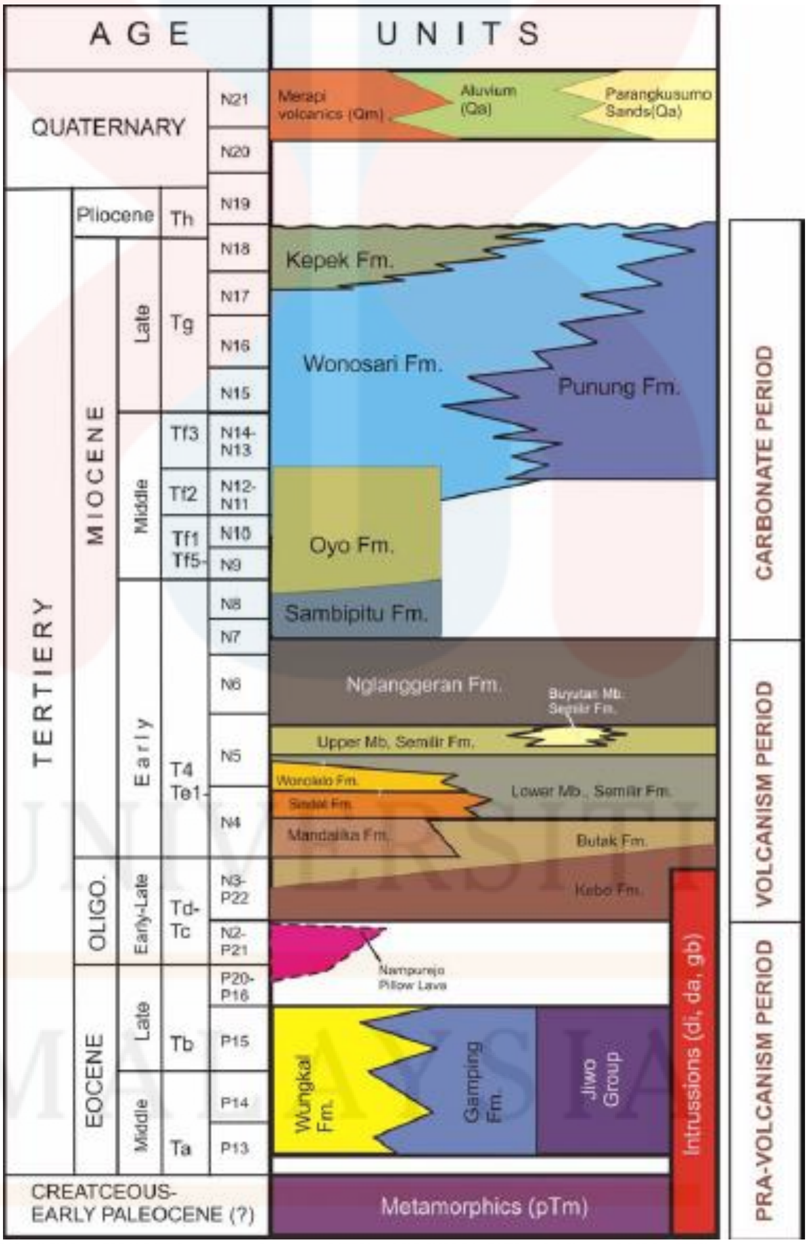


Figure 2.3: Stratigraphy of Southern Mountain Indonesia (Surono, 2008)

The rock unit formed during this period are igneous rock that are totally opposite with Jiwo group. Period of volcanism, take place during volcanic eruption. The rock unit form are Kebo-Butak group which sequentially overlap by the Semilir Formation and Nglanggran Formation. At post-volcanic period which takes place after the volcanic eruption end, the carbonate organism grow in fertile. This period known to be carbonate period. At this period the rock unit are form such as Oyo Formation, Wonosari Formation, Punung Formation and Kepek Formation

From the regional geological map sheet Surakarta-Giritontro, Java, the research area comprise Semilir Formation, Nglanggaran Formation and Kebo-Butak Formation. All the formation in the research area under volcanism period (Figure 2.3). However the research focus only Semilir Formation.

Kebo-Butak Formation

Surono (2009) says that the bottom stratigraphy of Southern Mountain is formed during the period of volcanism are Kebo-Butak formation. This formation overlap uncertain with Wungkal and Gamping in the pre-volcanic period stratigraphy Bothe (1929, in Surono, Toha B and Sudrano 1992). Kebo Beds is bottom and its top are Butak Beds. Both beds can be seen at foot of Baturagung mountain south of Klaten thus it known to be Kebo-Butak Formation.

The Kebo Butak Formation consists of sandstone, claystone, shale, tuff and agglomerate. The sandstone has tuff characteristics. Andesite and basalt are found in the middle of the formation and overlain by andesite breccia. Fossil such as foraminifera are found in late Oligocene to early Miocene. The deposition environment of this formation is generally open sea influenced by turbidity current.

Semilir Formation

Surono, Toha B and Sudarno (1992) state that Semilir Formation mainly consists of tuff, breccia pumice, tuffaceous sandstone and shale. Lapilli tuff and clay interbedded tuff, breccia are found at the bottom of this formation. It come from marine sediment and has under sea landslide structure.

Semilir formation has very little fossil. The range of age for the fossil are from early Miocene to middle Miocene. It has shallow to deep sea depositional environment. This is because at bottom and middle of formation it has shallow marine and deep marine due to turbidity current which at the top of formation.

Nglanggaran Formation

Surono, Toha B and Sudarno (1992) state most of Nglanggaran Formation composed of volcanic breccia, agglomerate, and tuff and andesite basalt lava. Volcanic breccia and agglomerated dominate this formation. Volcanic breccia is found coral limestone which form lens in the middle of formation. The surrounding area has sandstone epiclastic sandstone. This formation aged from early Miocene until middle Miocene. The Nglanggaran Formation were experienced underwater landslide and it reflect marine depositional environment.

2.5 Structural Geology

According Pulunggono and Martodjojo (1994) and Satyana in Prasetyadi (2007) that there are only four main structure direction of Java namely:

1. Northeast-southwest is called Meratus Pattern
2. North-South is called the Sundanese Pattern
3. East-west is called Java Pattern
4. Northwest-southeast is called Sumatra Pattern

The Southern mountain area only have two that are Meratus Pattern in the direction NE-SW and Java Pattern in E-W. Meratus Pattern structure is parallel to subsurface structure southern mountain. The direction usually is used to interpret gravity. The tectonic period is a period of time strongest experienced by the southern mountain.

There were three studies on structure of southern mountain. The studies state that there were Miocene Central rapture and there were also a large rapture occurs at earlier Pleistocene. Surono, Toha B and Sudarno (1992) state that there were deformation to form a shear fault at the same aged. Besides that, there were another deformation occur in the middle of Pleistocene which cause changes in Bengawan river. While Van Bemmelem (1949) state that the southern mountain uplift southward.

At the end of Eocene and central Miocene there were compressional stress in the direction N-S. However, in early Pleistocene there were still compressional stress but it change into tension stress in direction to NNW-S in middle Pleistocene in the direction NNE-SSW and NW-SE. Therefore, most of fault trending N-E and N-S direction and it move downward. Some occur as shear as dextral fault.

Opak fault occurred and found as parallel fault on the eastern margin but on the western side there no fault of the Yogyakarta. Due to this reason, there were no any research and almost no tectonic research has been carried out. The Opak Fault also known as Opak-Muria Fault is a major structure in the direction NE-SW. This fault is known to oldest structure and aged Cretaceous to Paleocene in Meratus Suture. The fault can be divide into five part from the oldest to youngest arrangement. Collision between micro continents in Eastern Jawa at early Tertiary result this Opak fault in Meratus Suture.

There are compressional tectonic in Middle Eocene in Meratus Suture thus Nanggulan and Gamping-Wungkal formation deposited. The subduction with Indo-Australia oceanic crust moving to north in early Oligocene to Early Miocene deposited Kebo-Butak, Semilir and Nglanggran formation. In middle Miocene there were volcanism activities due to compression of tectonic associated with Indo Australia oceanic crust. The inactive and erode middle Miocene deposits volcanic of Sambipitu. After that, Opak fault reactive back and recorded with carbonates facies in Jonggrangan, Oyo, Wonosari, Sentolo and Kepek formation in range of age middle Miocene to Pleistocene.

2.6 Research Specification

The research focused in depositional environment of Semilir Formation. The depositional environment of formation can be determine through field relationship and distribution of grain and morphologies studies (Adeigbe, 2009). Semilir Formation has shallow to deep marine depositional environment. Thus, the methods that can be refer to determine the depositional environment by interpreting the lithology and sediment properties of the formation.

CHAPTER 3

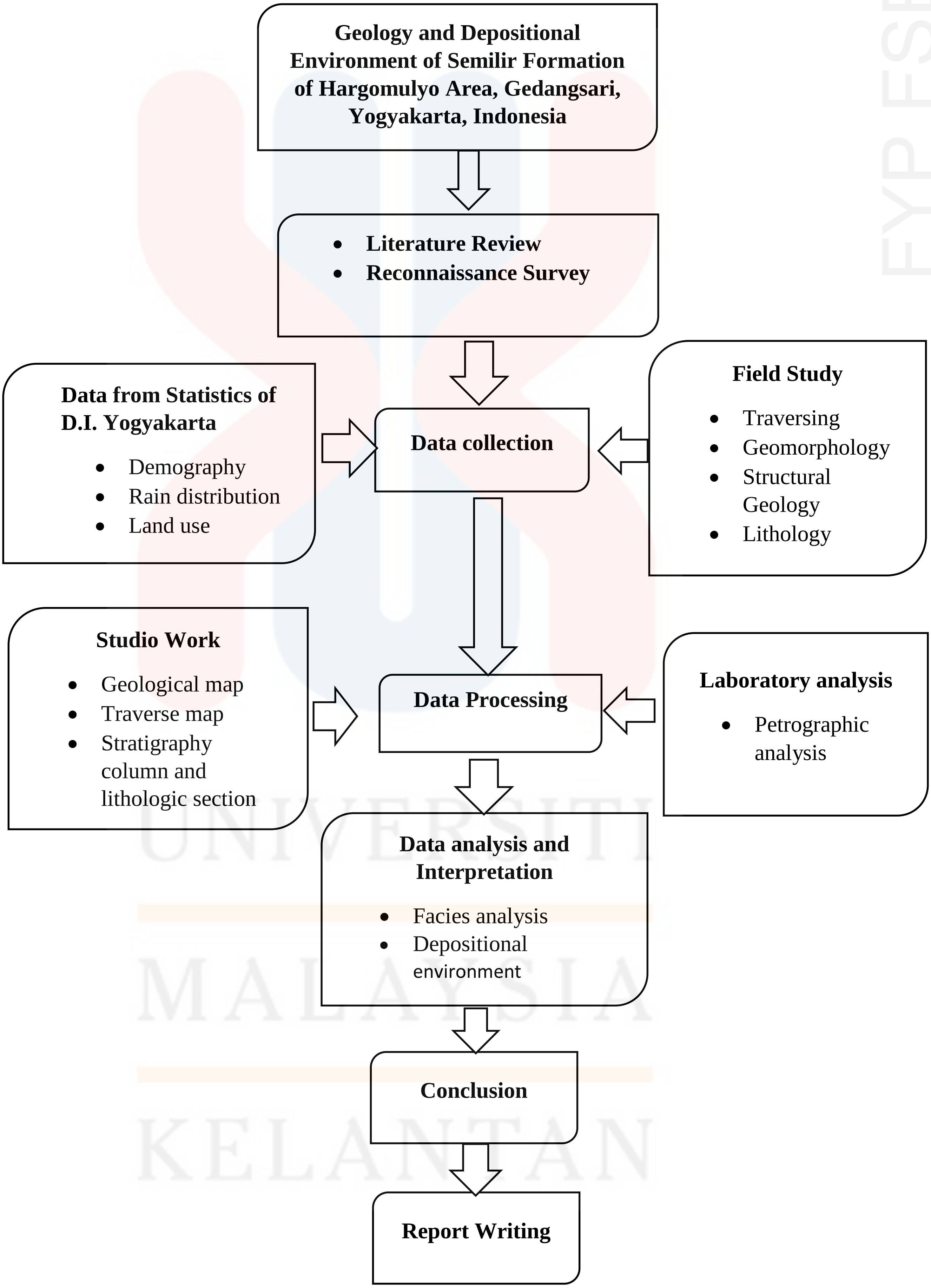
MATERIALS AND METHODOLOGY

3.1 Introduction

Material and methodology are important to show the research will be conducted. There are many methods that will be used in this research in order to fulfil geological mapping and specification study. Preliminary analysis, laboratory investigation are few method that conducted in the study. Based on exposed and petrographic analysis are done for facies determination. Figure 3.1 illustrates the research flow chart that present the phase of the research that will be conducted.

Figure 3.2: Field equipment for mapping

Research Flow Chart



3.2 Material

3.2.1 Field equipment

The material needed to do field work are topographic map that use for taking the sample, hand lens, compass, Global Positioning System (GPS), Hydrochloric acid (HCL, measuring tape, lithology sheet shown in Figure 3.2.

3.2.2 Lab equipment

The main tool needed are to make thin section and observe it are slab saw, trim saw, grinder, and polarizing microscope.

3.2.3 Software

Few software are used for this research namely ArcGIS and CorelDraw to produce a map, Georose and Stereonet to make joint analysis and Sedlog and CorelDraw to produce a lithog.

3.3 Preliminary study

Preliminary studies will be done to get access and understanding of the study area before fieldwork session. The preliminary study is done by reading journal, book, article, thesis, and other publication which to understand and gather information about the study area to understand about the research and the previous thesis and make clear on the method to use in in research that going to be done. The internet also very helpful to gain the information needed the research by providing e-journal that contained a lots of research.

3.4 Methodologies

3.4.1 Field studies

Field studies important method in conducting geological research in order to describe and interpret the geological map and identify the geology features of the study area. The field studies are important to get data from the exposed outcrop, the geomorphology, structural and lithostratigraphy of study area.

a. Traversing

In field study traversing is essential for geologist where used to produce and interpret geological map. However, how one will produce a geological map? Traversing is usually done by walking from one place to another traversing point. Traversing enable to access to small area or reach outcrop at inaccessible by car or other vehicles. The geological map is produce from the outcrop that obtain from traverse then digitize in the ArcGIS software in the map scale 1:25 000.

b. Structural Geology

The field studies also to determine the structural geology of the study area. Structural geology is a study of three dimensional distribution of large body of rock that deform the surface of the rock. The structural geology enable to interpret the past geological environment and the tectonic setting which causes the rock to deform. The structural geology feature mainly measure bedding planes, joints and fractures and faults. Therefore the strike and dip reading is taken to determine the orientation of force that cause the deformation occur. The strike is a line of intersection between planar surface and the horizontal plane and the dip is the inclination of bed vertical to the strike. For joint, 100 bearing reading, 1meter=1frequeny (1m=1f), is taken to plot in Rose diagram for studying the stress acting on the body of rock

c. Geomorphology

Geomorphology is also involve in field study. The geomorphology study of earth landform such as mountain, hill, karst and river morphology. The geomorphology study is done by traversing in the study area. In the field study the morphology is sketch in a paper and is determine in the base map. Other way is by observe the imagery by using GIS software to produce the geomorphological map includes the lineament map, drainage pattern map and contour pattern map. The erosion and deposition of sediments were the factors that affect the shape of the landform. This is because the sediment will transported by several media such as wind, water, gravity and ice and deposited at a new place and creating new landscape.

d. Sedimentological analysis

According to Tucker (2011), there are six aspect of sedimentary rock which should be recorded in detail as possible. These are the lithology, that is the composition of the sediment, the texture, in term or features and arrangement of the grains in the sediment, the sedimentary structure, present on bedding surface or within the beds, the colour and the distribution of fossil contained within the sedimentary rock.

Sediments and sedimentary rock will be identify together with the process of transport and deposition that take place within study area. The sedimentary rock eventually define the facies, which is the product of a particular depositional environment. All the aspect of sedimentary attributes of a succession were examined in detail because there are relatively small number of different type to look closely for similar attributes under the same facies.

e. Lithologic and stratigraphy analysis

Lithologic analysis distinguished by the lithology, grain size, sedimentary structure, colour and the last is the fossil that found. The length, width and colour of outcrop is measured and recorded. The fossil is the indicator to determine the time scale and the geological event occurred in the study area. The data were made digital by using SedLog software to get the lithologic log that will make the changes of grain size and the width of every rock found appeared clearly. All the lithology information regarding the type of rock, grain size, colour, fossil content need to be written in the lithology sheet (Figure 3.3).

Basic principle of stratigraphy are contact between two beds which indicate the depositional environment of the study area. The contact can be differentiate sharp, abrupt, gradational, plunging and lenses. All of this very useful to study ancient depositional environment.

The correlation is used to determine the sequence of deposition with equivalency in time which means that two or more events happened at the same time. In order to do that, find the certain indications in rock sequence in the study area that allow to link and match in the time rock occur or deposited. The correlation also can correlate the lithologies or rock unit, besides, it also use for large and small scale distance.

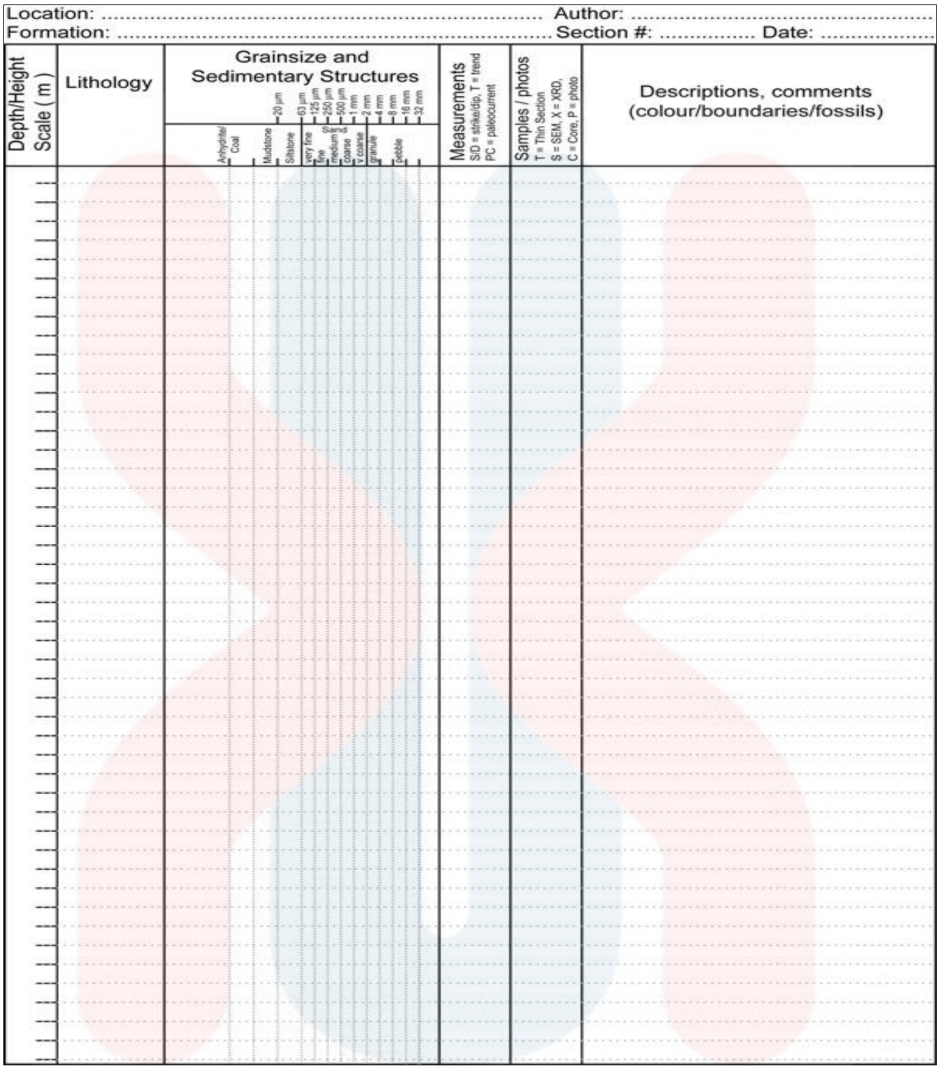


Figure 3.3: Lithology sheet (Endeeper, 2017)

3.4.2 Laboratory analysis

<u>Thin section preparation</u>

Thin section slice of mineral of a rock. The thickness is about 25 micrometer and the mineral can only be seen under the polarizing microscope. The mineral of the rock sample will be identify under this process. The petrographic microscope eventually enable to identify the mineral present in the rock, thus it helps to name the lithology of the rock by determine the percentage of particular mineral. For microscopic study, it mainly focus to determine the fossil in the rock.

There are few step preparing thin section which are included:

i. Rock sample will be segmented by using diamond saw with dimension of 1cm x 3cm.

ii. One side of the rock sample will be polished for desired thickness.

iii. Next, the polished rock will be attached onto a glass slide with a dimension of 1cm x 4cm and it left dried.

iv. The sample will be washed and them left dries.

v. With aid of Canada balsam, a thin glass, the sample will be covered by thin glass and air bubble is avoided from being trapped.

vi. Lastly, excess cement will be removed by using methyl sprit.

3.5 Data Analysis and Interpretations

The data that obtain from the field such as geological data and photographs are consider as resource material. Analysis and interpretation of the data was based on information obtained from library search, field studies and laboratory analysis. All the data collected are update in the lithology by using CorelDraw software. Then the rock and name according to the main mineral composition in facies analysis and the depositional environment are get to know the sedimentary features.

3.6 Report writing

All the data complete with interpretation from the earlier studies, field studies, map, figures, photographs and appropriate schedule and result from the laboratory studies. The writing of the report include in six chapter namely:

a) Chapter 1: Introduction
b) Chapter 2: Literature review
c) Chapter 3: Material and Methods
d) Chapter 4: General Geology
e) Chapter 5: Depositional Environment of Hargomulyo area, Wonosari, Yogyakarta Indonesia
f) Chapter 6: Conclusion and Recommendations

CHAPTER 4

GEOLOGY

4.1 Introduction

In this chapter, geology, will be discussed about the details of geological information of Hargomulyo area in terms of geomorphology, lithostratigraphy, structural geology and historical geology based on the field analysis which done by traversing observing, measuring and sampling the data which obtain from the study area which is important for analysis the physical, chemical and biological process of the Earth. Few maps namely topography, drainage pattern, lithology map is created in order to understand the characteristics of study area. Furthermore, the data which collected in the field used for to create a geological map of the study area with scale of 1:25 000.

4.1.1 Accessibility

In Hargomulyo area, the major road to access the study area is from Jl Nglanggeran which is located in near Desa Nglang, Desa Hargomulyo and Desa Patuk of Gedangsari. This area has well developed road system. The study area is about 10.5km from the base camp. However, the study area comprise of paved Figure 4.1 and unpaved village road. Therefore, only vehicle such as truck, four wheel, car and motorcycle can access the study area. The study area has hills to mountainous topography with some rocky road. The unpaved road is the major road to connect all houses in the village area. Figure 4.2 shows the road connection map of the study area. Moreover, tourist spot such as Green Village was approximately 6.05km which located at North West direction of the research area can easily access due to newly build tar road. While Empung Sriten also one of the tourist spot was difficult to access due to unpaved rocky road which only can access by motorcycle, truck and four wheel vehicle. Therefore, the study area easy to access.

Figure 4.1: Paved village road access study area from Desa Nglang

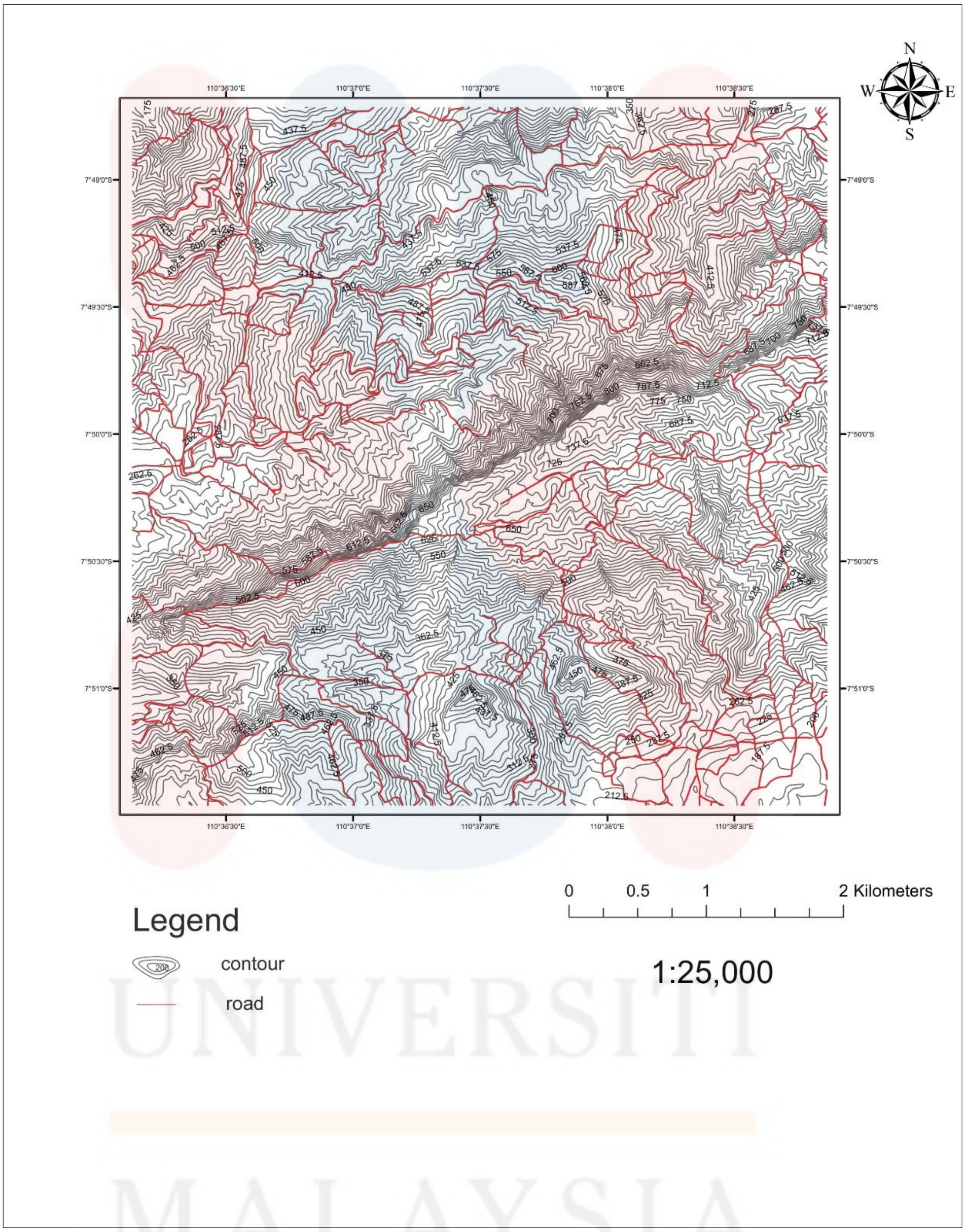


Figure 4.2: Road accessibility of study area

4.1.2 Settlement

Settlement refers to the place and area has human activities. The study area can be divided into three village area namely Desa Nglang, Desa Hargomulyo and Desa Mertuluk. The study area mostly cover under Desa Mertuluk and Desa Hargomulyo which is located at the north ad middle respectively of study area. The study area managed under administrative of Gedangsari. The native people of the study area were Javanese. Their daily activities were farming and build cliffs along the road to prevent from flood during raining seasons. The settlement of villagers in Desa Hargomulyo shown in Figure4.3.

Figure 4.3: (a) Villagers in Desa Hargomulyo, Indonesia and (b) villagers build cliff

4.1.3 Vegetation

Plantation were the major source of income for the villagers in the study area. The vegetation were planted terrace and it is one of the major socioeconomic activity in Gedangsari. The villagers planted variety of vegetable such as sweet potatoes, banana, paddy, cabbage, green bean, chilli, corn and lalang. Lalang is for cow food and they also dried sweet potatoes at hilly area to make “tiul” Figure 4.4. All the crops were sold in market in order to make money.

The vegetation were plant in hilly and flat area shown in Figure 4.5. The plant were planted terrace with variety of plantation. Paddy and lalang mostly planted at hills while beans planted at flat area. The study area does not have forest area, this is because forest are removed and used for plantation activities. The plantation continue throughout the year and variety of vegetable planted according to the changes of seasons ad soil nutrient.

Figure 4.4: Sweet potatoes are dried to make “tiul”

Figure 4.5: (a) Bean plantation planted in flat area and (b) Lalang planted at hilly area in terrace form.

4.1.4 Traverses and Observation

The research area of Hargomulyo is done by traversing and observing geological features in study area. The traversing is mainly in river and road area. Traversing in the river pathway gives the dramatically change of outcrop according to the formation which present in the study area and at the same time the outcrop is clearly visible due to drought season in Yogyakarta. The outcrop in river is mostly fresh compare to the road which undergoes weathering process.

The traversing took about 8 days to complete and collect the geological data which included in sampling and recording the geological field work. Each day, new route is planned before mapping start. The geological data is recorded every 200m from previous point to a new point. All the tracks and checkpoint of observed location were plotted in traversing and observation location map in Figure 4.6.

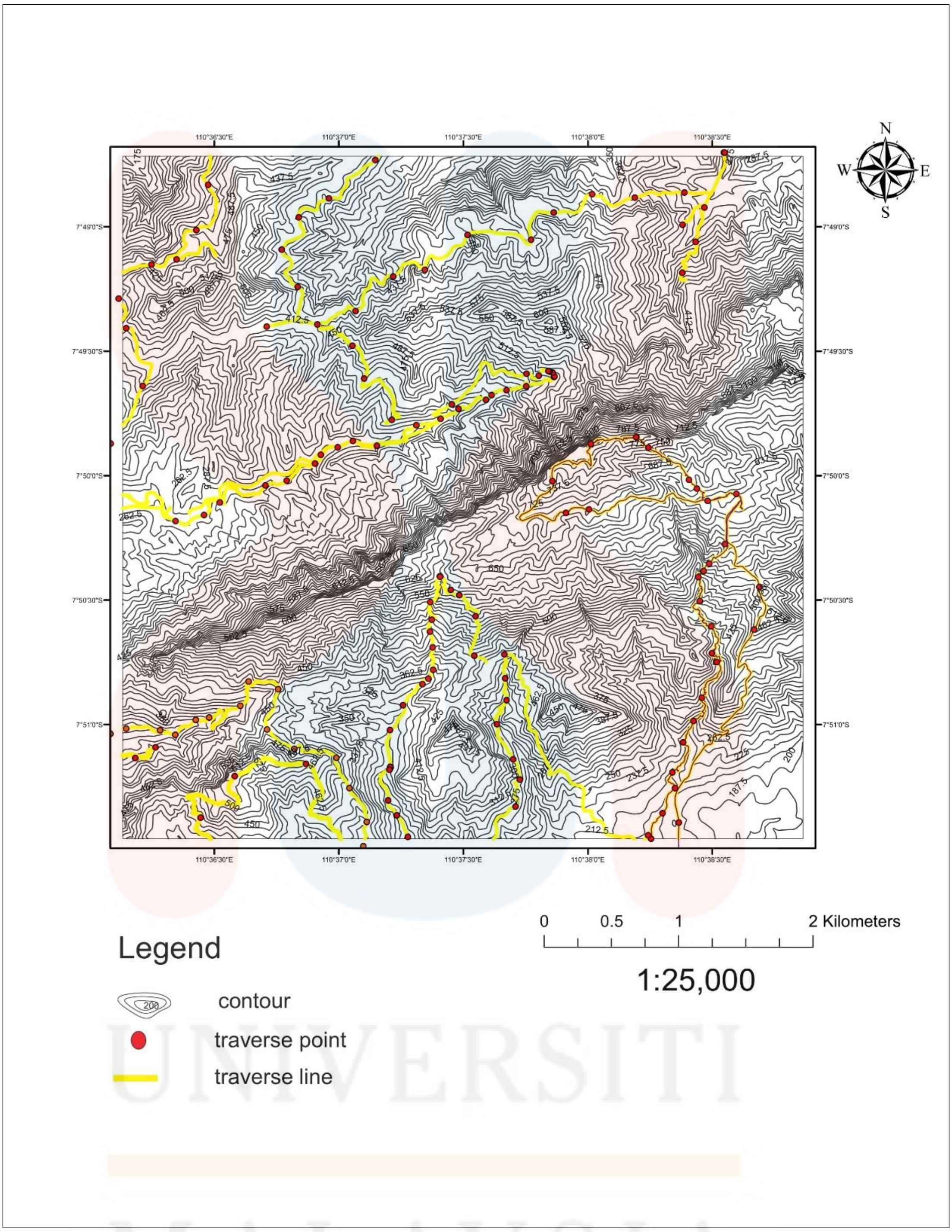


Figure 4.6: Traverse track with checkpoint on observation

4.2 Geomorphology

Geomorphology is a study of landform and its process related to the origin and evolution of topographic features due to physical, chemical and biological processes operating which occur near the Earth surface. Geomorphology further can be explained in term of geomorphological unit, weathering and drainage pattern. The geomorphological map which is important to development activities.

4.2.1 Geomorphological Classification

Geomorphological classification refers to identification and grouping of landform according to their morphography, shape and surface geometry which consideration on underlying geology, relief forming process and their forms. This can explained in topography unit description with mean elevation in Table 4.1.

Source: Peninsular Malaysia,

Table 4.1: Topography unit with mean elevation

No	**Topography unit**	**Mean Elevation, m (sea level)**
1	Low Lying	Less than 15
2	Rolling	16 to 30
3	Undulating	31 to 75
4	Hilly	76 to 300
5	Mountainous	More than 301

The study area consists of volcanic sediments, thus the morphology present in the study area is due to volcanic activities. The highest elevation in study area is about 905 meter above the sea level which at Embung Sriten while the lowest elevation is about 150 metre. The highest elevation of study area can observe about 360° view of Gunung Kidul Regency. The north view of Embung Sriten still consists of hill to mountainous topography compare to the south view the topography become flat topogrphy (Figure 4.7). The hill to mountainous topography compose of volcanic rock that form from the eruption process while in south flat landscape which compose of carbonate clastic sediment.

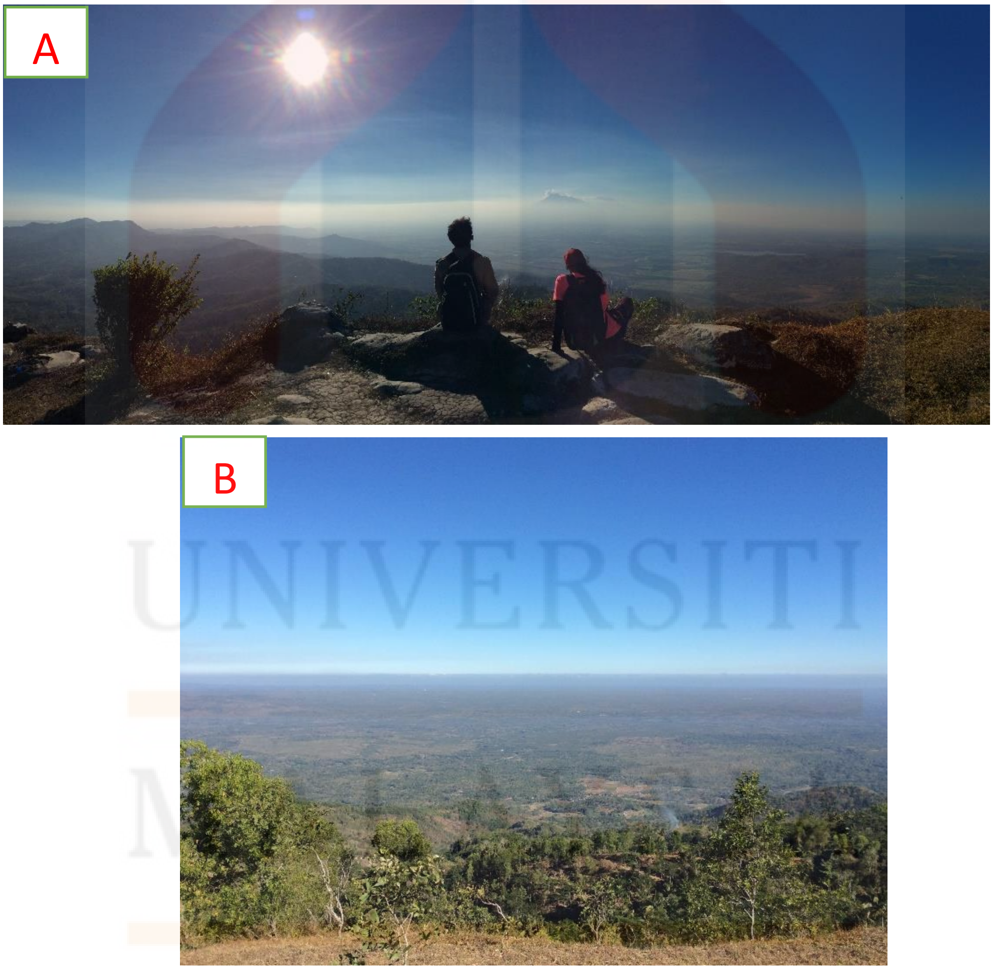


Figure 4.7: Gemorphology view of 360° view of Embung Sriten 7° 49’ 50.8” S 101° 38’ 11.6”E (a) north view still mountainous landscape while (b) south view flat landscape

The research area was formed by homocline hills morphology. It is because the hills shows straightness pattern in middle and northern about part of study area and the dipping is nearly same. Other morphology present in study area is valley is in “U” shape due to denudation. Both morphology of homocline hill and valley shown in Figure 4.8. The steep of hill is moderate to steep and the valley is rolling to steep.

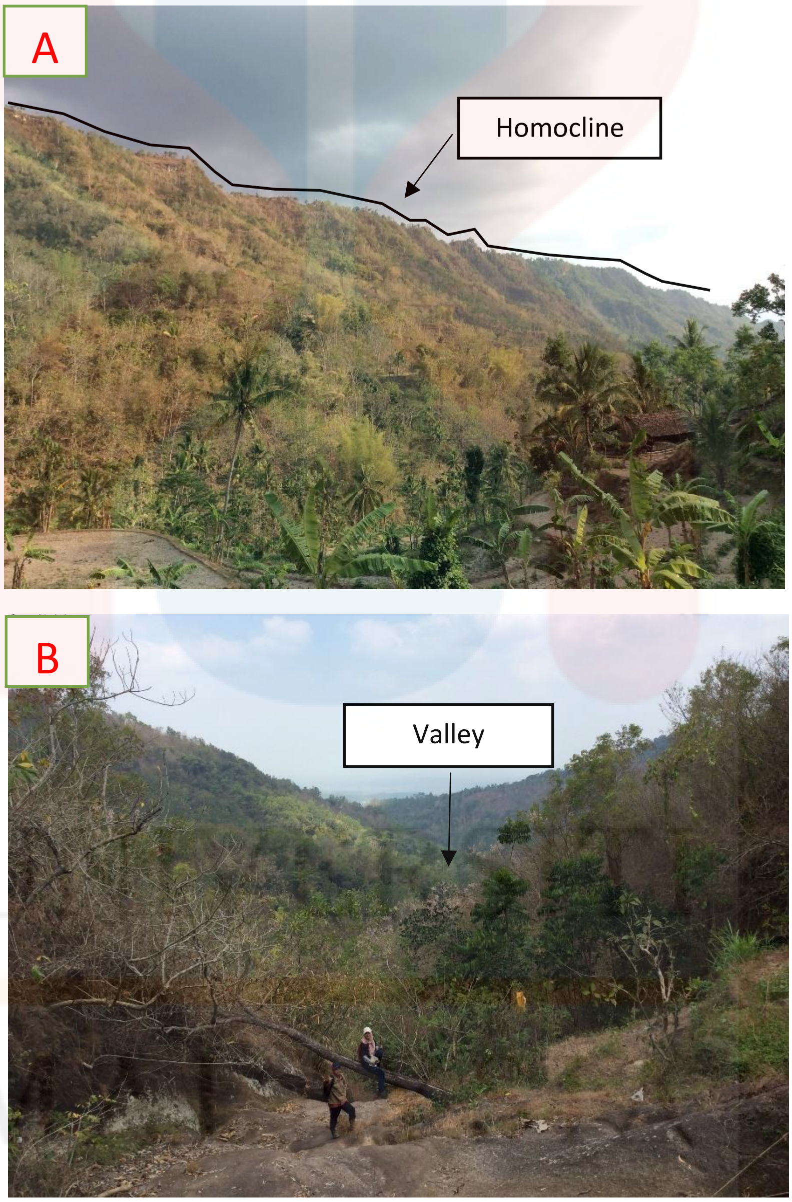


Figure 4.8: Morphology of (a) homocline hill 7° 49’ 36.1” S 101° 37’ 52”E and (b) valley with coordinate 7° 50’ 41.1” S 101° 37’ 22.6”E

Slope map which shown in Figure 4.9 showing dark and light green area has gently slope. While the yellow has moderate sloping and it showed the contour getting closer to each other. The orange region which located in the middle of the research area range 555m to 690m elevation above the sea level and it has steep slope while the red region is the steepest slope and it can observe on the contour line where the contour line is very closely arrange in the middle of research area.

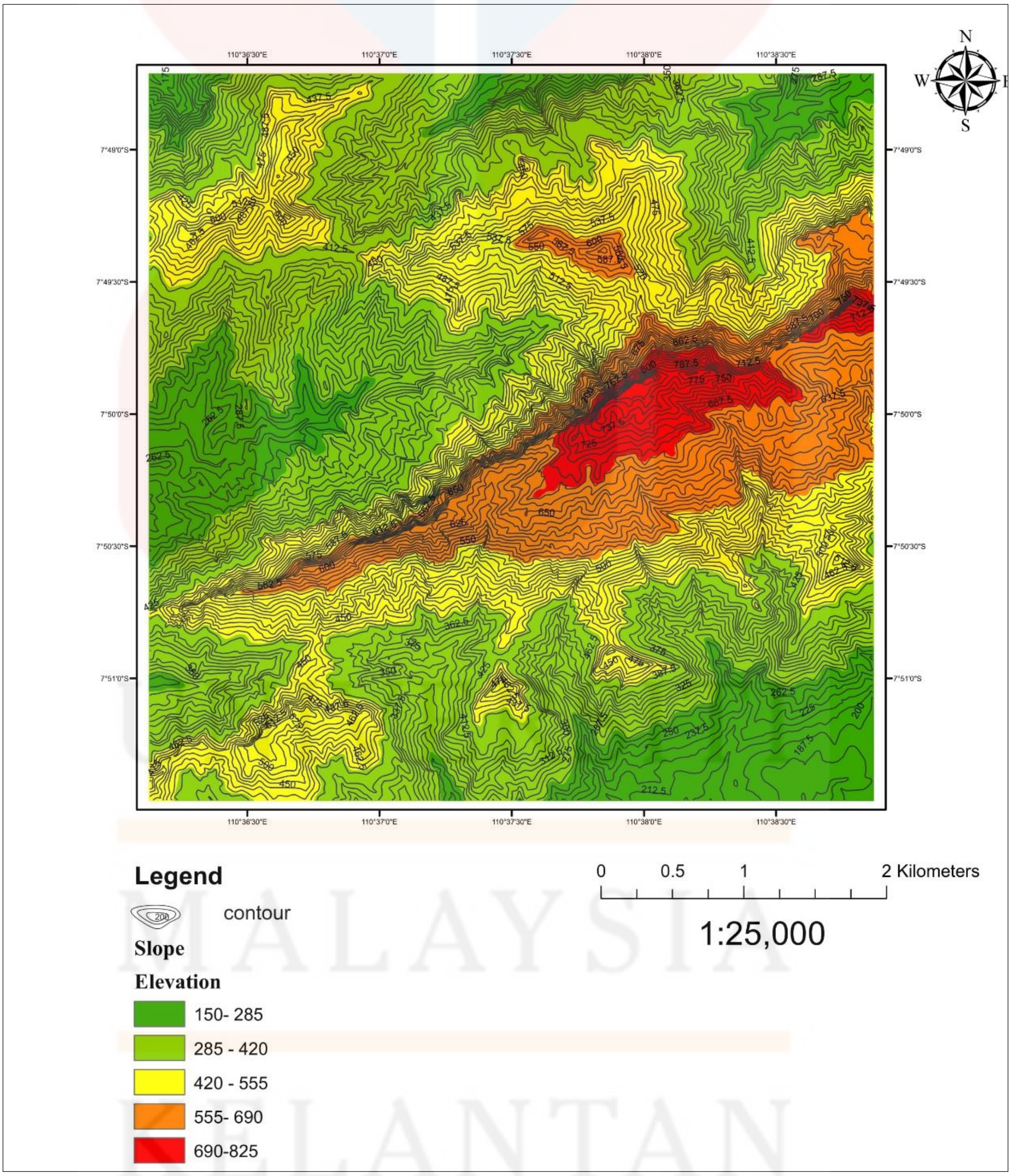


Figure 4.9: Slope map of Hargomulyo, Indonesia

Furthermore the topography of Hargomulyo area was observed in 3D map of geomorphology (Figure 4.10) which enable us to see clearly on the type of landform in the study area.

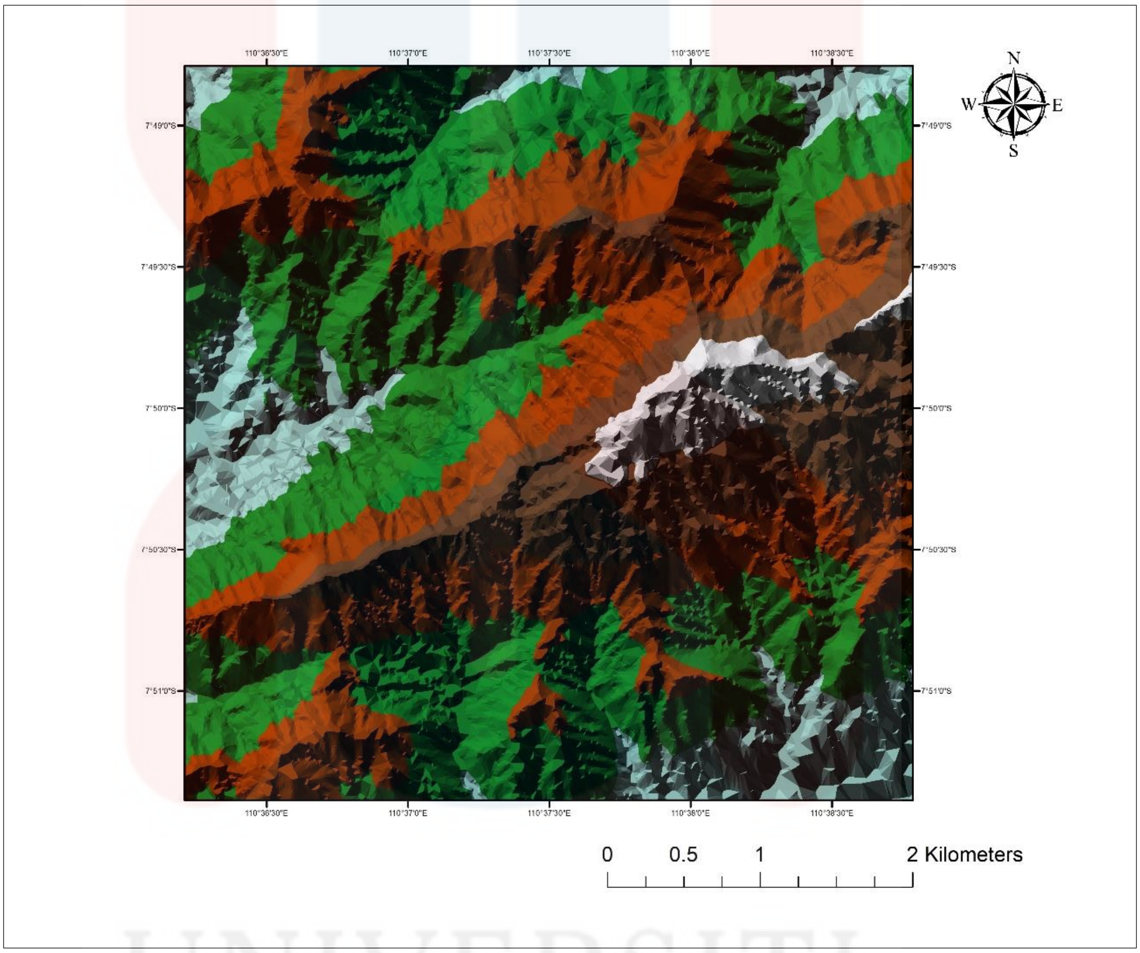


Figure 4.10: 3D view of geomorphology

4.2.2 Weathering

Weathering is process where rocks are broken down to form soil. It is also call disintegration process. The rock is broken into sediments, clays, soils and substance that are dissolve with water. The weathering process occur when the body of rock is exposed on the surface of Earth. The weathering can be divided into three type namely physical weathering, chemical weathering and biological weathering. The rate of weathering depend on some factors such as climate, rock composition and surface area. However weathering can process is essential because the rock broke and provide nutrient for different kind of plant.

Physical weathering is mechanical broke down of rock without changes the rock chemical composition. The study area has exfoliation weathering and spheroidal weathering. Exfoliation weathering (Figure 4.11) occur on less parallel to the surface or curved surface. It is caused by instability of reduce in pressure at the earth's surface area, thus allowing the rock to expand and deform.

Spheroidal weathering (Figure 4.12) is another form of exfoliation weathering. These weathering were the boulder rounded by concentric shell broken up similar to onion pealing structure. The outer pealled-off structure is due to chemical weathering where water seeped inside the joint and crack on the rock and form these structure.

Figure 4.11: Physical weathering (exfoliation weathering)

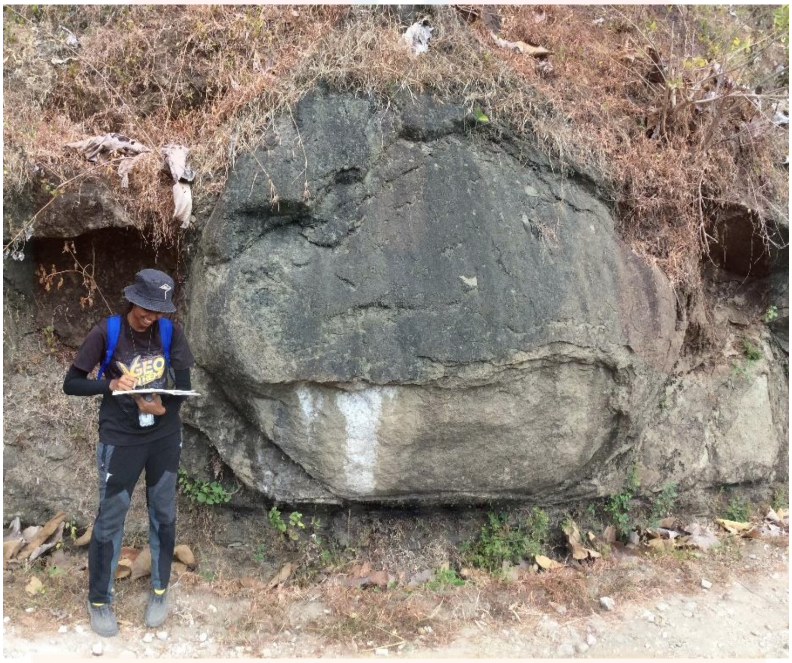


Figure 4.12: Physical weathering (Spheroidal weathering)

Chemical weathering is chemical alteration on the rock which causes chemical composition of rock changed. The study area has alteration on rock which cause the rock to rust and river erosion. The rock rust (Figure 4.13) when oxygen, water and moist in air, thus cause the rock to rust. Water is an important agent it is because the water seep into crack and dissolve the mineral as it make the rock softer and break into small pieces. It can be seen in Figure 4.14 erosion river cause by water.

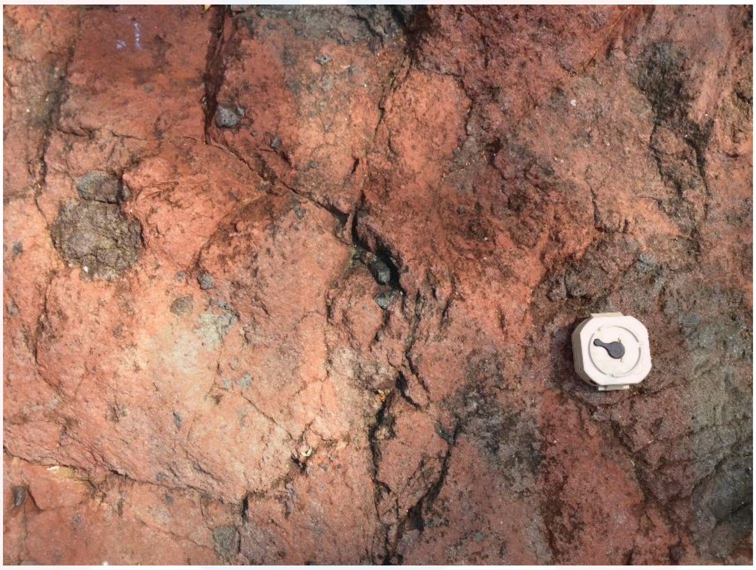


Figure 4.13: Chemical weathering (alteration on rock)

Figure 4.14: Chemical weathering (erosion in river due to water)

Biological weathering is where the root of plant enhance to disintegration of rock. It is because the root of plant penetrate the crack of the rock. As the process continued for a long time cause the rock to deform (Figure 4.15).

Figure 4.15: Biological weathering (root penetration)

4.2.3 Drainage Pattern

Drainage pattern formed by streams, lakes and rivers in a particular drainage basin. The drainage pattern depended on the topography and geology of the particular region whether the region dominated by hard or soft rock. The gradient of the land also able to determine. The tributaries that flow to some location along the stream within basin describe the characteristics of the parent rock and the structure within that rock such as fold, fracture and fault.

The study area consists of three type of drainage pattern namely dendritic, parallel and rectangular shown in Figure 4.16. Dendritic pattern is most common pattern which occur in many area. This pattern develop where unconsolidated material located at beneath the stream and has no particular structure. This pattern eroded equally easily in all directions. The pattern like tree branching shape and characteristics by flat or homogenous rock.

Parallel pattern where the river caused by steep slopes with some relief. This is because the stream is steep slope, the stream straight and has few tributaries and flow in the same direction. The tributaries usually join the major stream and have approximately the same angle. Parallel stream indicate of gentle dipping beds or uniformly sloping topography.

Rectangular pattern have very few topography and it form due by fracture or fault associated by massive volcanic, igneous or sedimentary rock. The dipping of this pattern usually close to 90° angle.

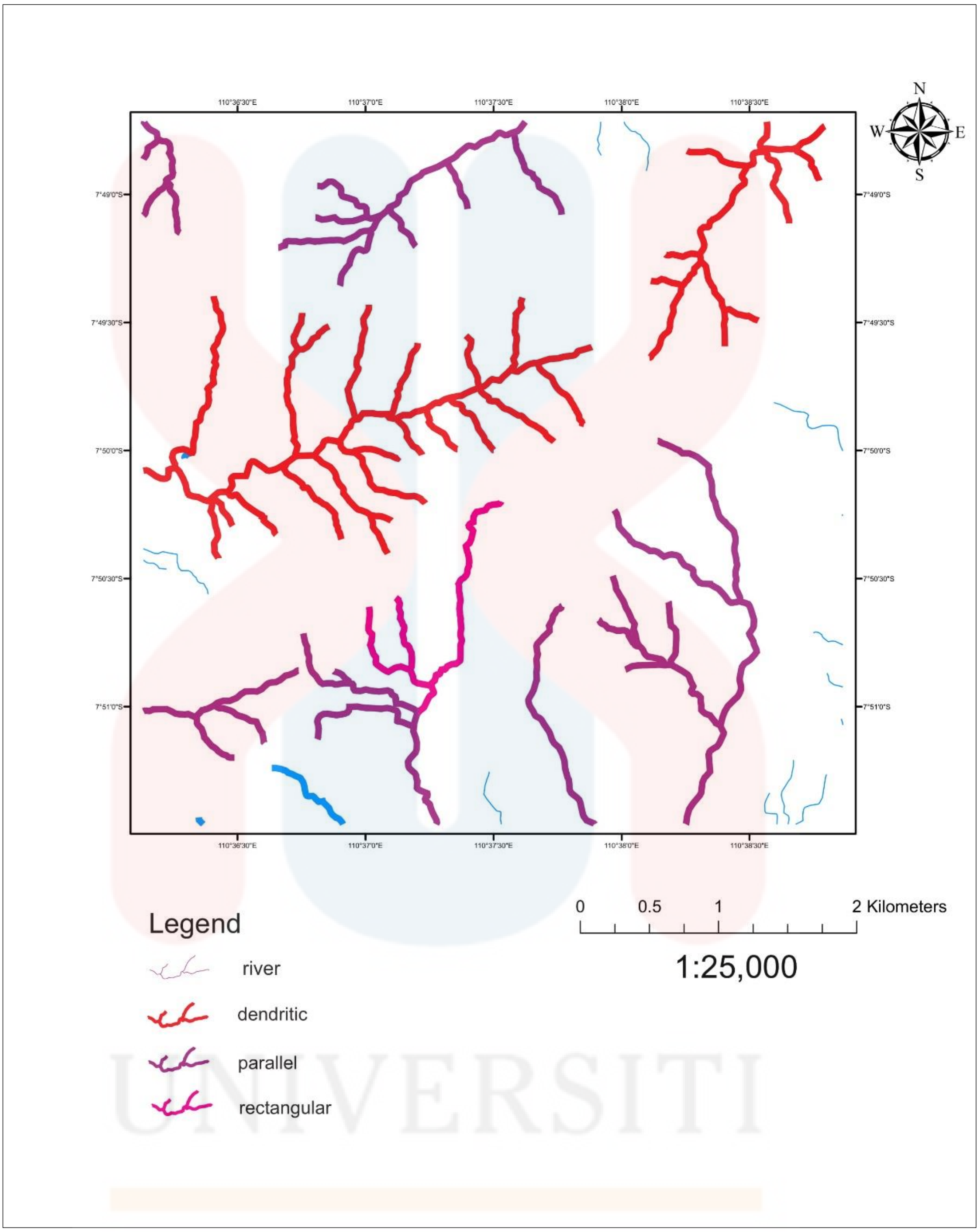


Figure 4.16: Drainage pattern map of Hargomulyo, Indonesia

4.3 Lithostratigraphy

Lithostratigraphy in is the study of sequence of rock in layers and the relative stratigraphic position in geological time scale. The relative stratigraphic position of rock unit can be determine by considering geometric and physical characteristics of rock that indicate the older and the younger rock. There are 6 lithological unit in study area. Each unit are named according on the dominant lithology formation which shown in Figure 4.17 name tuff, tuffaceous sandstone, green tuff, tuff breccia, lapilli tuff and volcanic unit.

4.3.1 Stratigraphy Position

The oldest unit in study area is Kebo-Butak formation it is located at the northest part of study area. Where it has tuff unit is the oldest, followed by tuffaceous sandstone and green tuff unit from oldest to youngest. The rock unit in Kebo-Butak formation is age late Oligocene.

Semilir formation is younger than Kebo-Butak formation which age early Miocene. Semilir has two unit of rock tuff pumice at upper and lower lapilli unit. These two rock unit believed interfinger each other. Semilir formation is comprising middles of the study area. The youngest rock unit in study area is volcanic unit which has pyroclastic, epiclastic andesite breccia and it is under Nglanggaran formation which age early Miocene. Figure 4.18 illustrate stratigraphic position of rock unit.

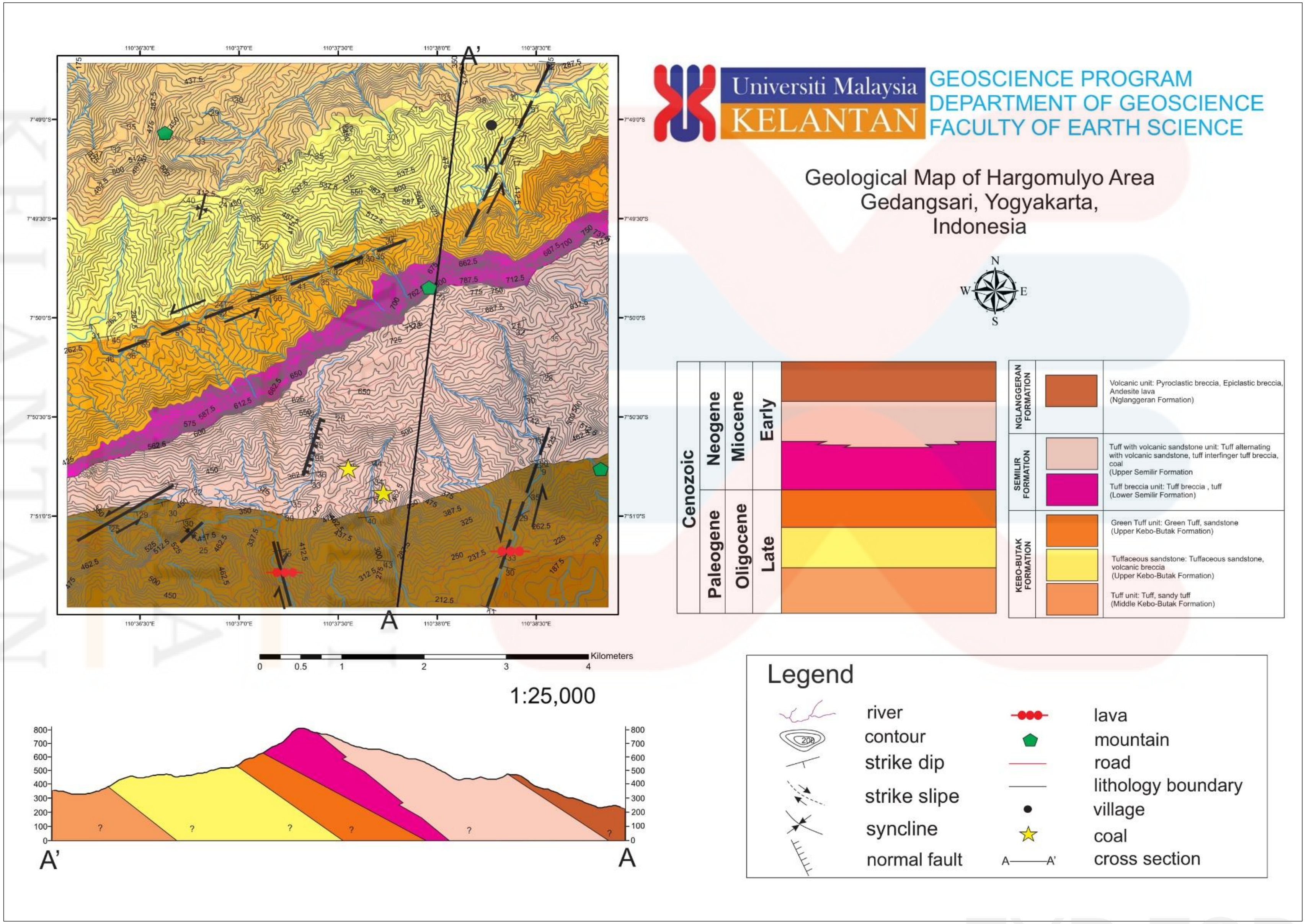


Figure 4.17: Geological Map of Hargomulyo with lithology unit description

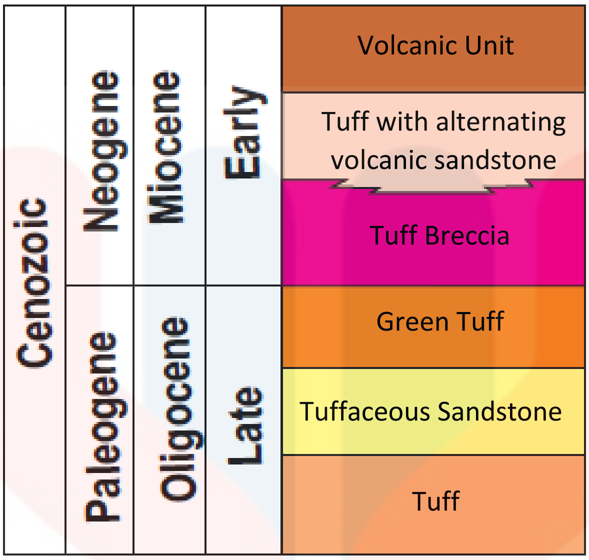


Figure 4.18: Stratigraphy column of rock unit

4.3.2 Unit description

In this subtopic, each unit were explained in term of horizontal and vertical distribution, thickness, rock composition and petrography analaysis of the unit were explained in detailed. The unit explanation will be from the oldest tock unit to the youngest rock unit. Based on the field observation, there are six different rock unit that can be identified which are tuff, tuffaceous sandstone, green tuff, tuff breccia, volcanic sandstone alternating tuff and volcanic unit which is breccia andesite. All these unit are volcanic product that have been deposited at Late Oligocene to Early Miocene.

Pyroclastic rock can be described as clastic rock made up of volcanic materials by ashes, lapilli and bombs or block ejected out from the volcano and mixed with parent rock. The classification of the pyroclastic rock has been done with the help of two ternary plot diagram which is proposed by Schmist (1981) and Fisher (1984) in Figure 4.19.

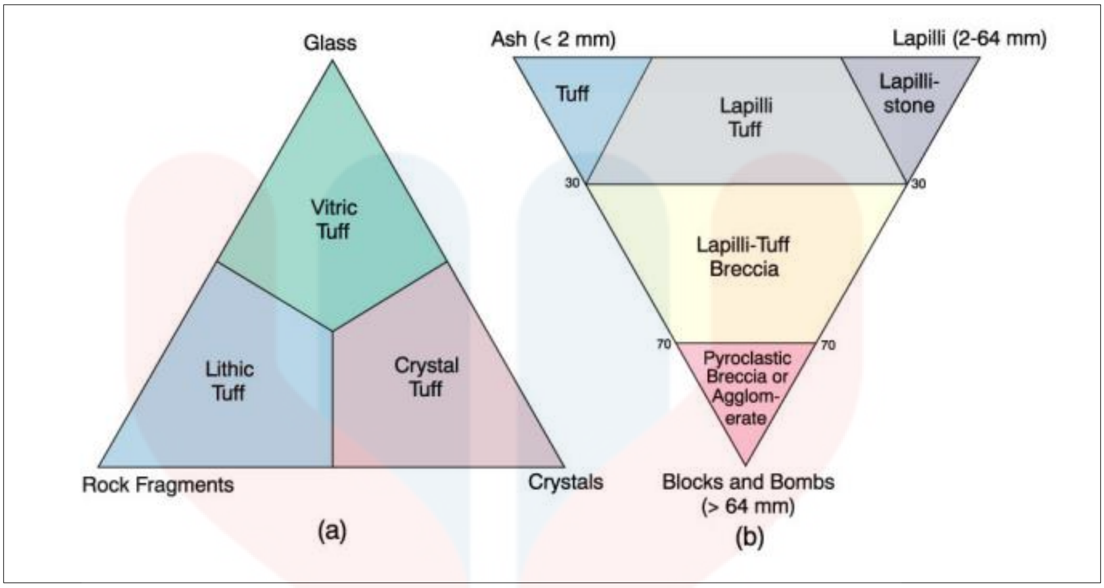


Figure 4.19: Pyroclastic classification

A QAFT diagram proposed by Streckeisen (1967) was used to classified the aphanitic rock of igneous rock and volcanic rock where the mineralogy composition where able to determine. The QAFT diagram stands for Quartz, Alkali Feldspar, Plagioclase and Feldspar. Feldspathoid are the mineral used to classify the rock nomenclature by calculating the percentage so that their sum will be 100%. The name of the can be determine by using these charts. Figure 4.20 shows the classification and nomenclature of volcanic rock according to their mode of mineral content by using QAFT diagram.

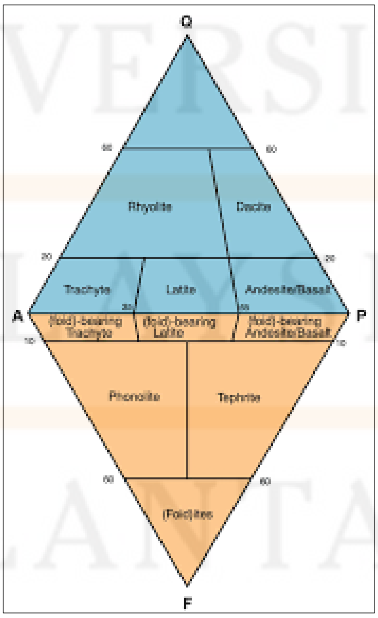


Figure 4.20: QAFT diagram for mineral percentage

(a) Tuff unit

Tuff unit is a one of dominated unit in the study area. The tuff unit are found from Semilir to Kebo-Butak Formation which mostly in Gendangsari area. It seem that the tuff unit occurs at the mountainous area therefore the tuff unit occur at the middle and at the north of study area. Tuff appear in white and fine texture. The tuff unit has presented in bedded and parallel lamination structure. The tuff rock is made of volcanic ash, it is very light and the rock is compact. It form from the ejection of ash during volcanic eruption and consolidate over time. Figure 4.21 shows the tuff rock in outcrop and hand specimen and Table 4.2 shows the description of tuff unit rock

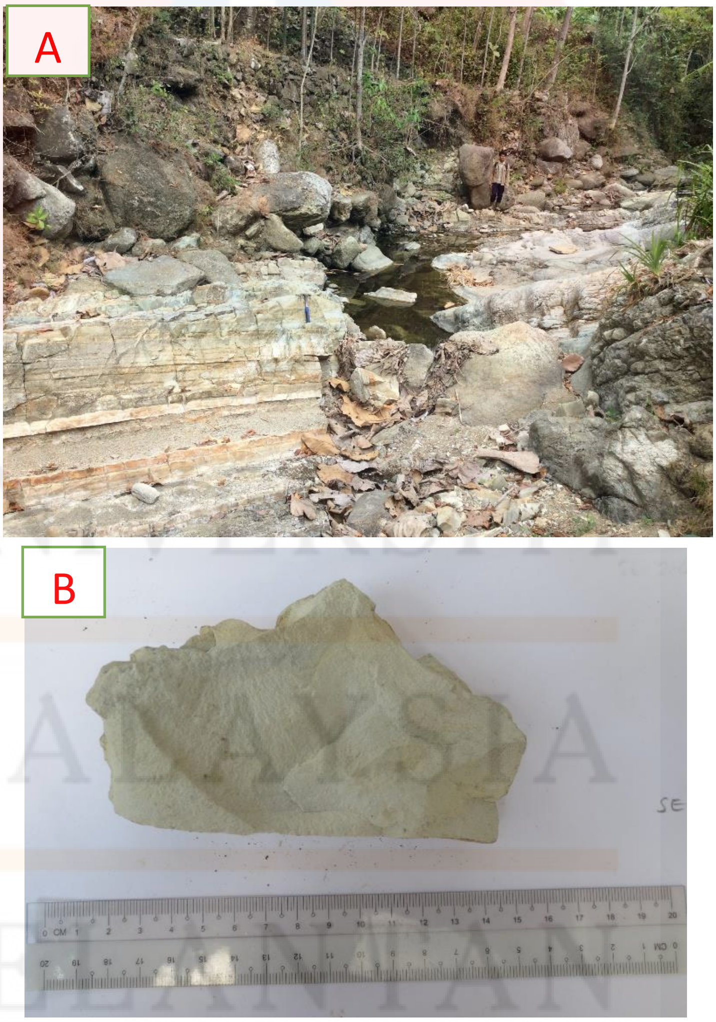


Figure 4.21: (a) Tuff rock in outcrop at coordinate 7° 48’ 51.8” S 110° 38’ 23.8”E and (b) the tuff rock in hand specimen.

Table 4.2: Description for tuff rock unit

Sample Code	:	Z11
Coordinate	:	7° 48’ 51.8” S 110° 38’ 23.8”E
Location	:	Hargomulyo, Yogyakarta, Indonesia
Rock Name	:	Tuff
Colour	:	White
Structure		Massive
Texture	:	Fine grain
Mineral	**%**	**Description**
Quartz	30	In PPL it is irregular shape, low relief and colourless to cloudy. In XPL it has no twining.
Opaque	20	Black colour in PPL and XPL, no pleochroism, anhedral shape and high relief
Matrix	**%**	**Description**
Clay and Tuff	50	In PPL it appear frosted green, no pleochroism, anhedral and present evenly in incisions as matrix. The matrix anhedral and have triangulate shape.

Description

From the petrographic analysis, the thin section has white colour. It has hypocrystalline for degree of crystalline because it consist of both crystal and glass and more matrix. Aphanitic grain size because most minerals are too fine-grained to see with necked eye. It composed mostly anhedral and some mineral occur as subhedral. The relationship between crystals are most of the grain are anhedral, called allotriomorphic. It consists of quartz (qtz), opaque mineral (opq) and glass and clay and tuff as matrix. According to Schmidt, 1981 it is Vithic tuff

Photo

PPL **XPL**

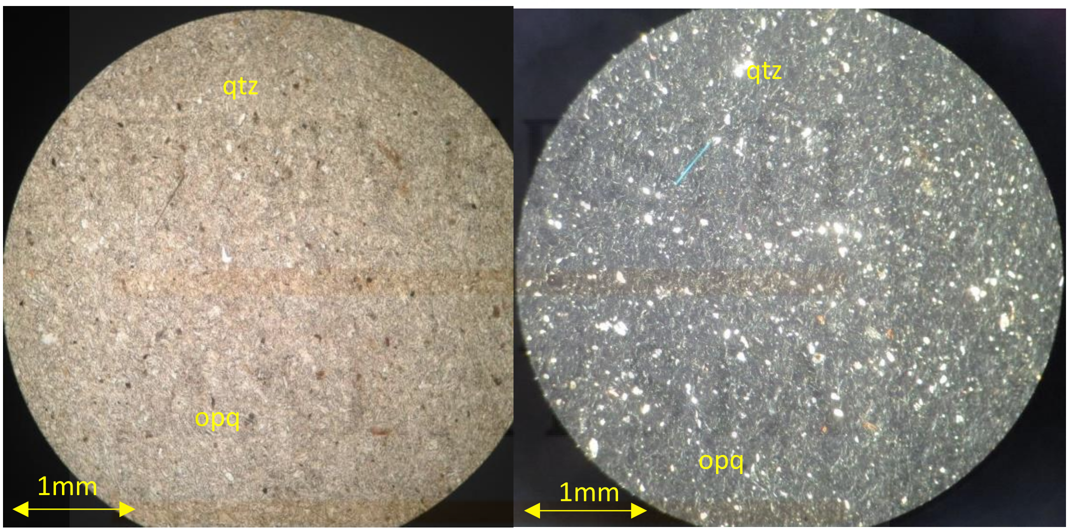


Figure 4.22: Plane polarised (PPL) and Cross polarised (XPL) Tuff unit with magnification 10x10

(b) Tuffaceous Sandstone unit

Tuffaceous sandstone is located at the north of study area in Kebo-Butak formation. The rock tuffaceous rock unit seem to have channel present in outcrop which compose of mudstone and claystone. Besides that some there are some volcanic breccia with sandstone matrix present at area of these unit present. The mudstone and claystone is deposited at low velocity. The tuffaceous sandstone has light brown colour with medium grain. The structure present in study area are bedded and have channel. The tuffaceous sandstone is a semiconsolidate to well-consolidated rock. Figure 4.23 shows the tuffaceous sandstone outcrop and with channel and the hand specimen. Table 4.3 shows the description of tuffaceous sandstone unit.

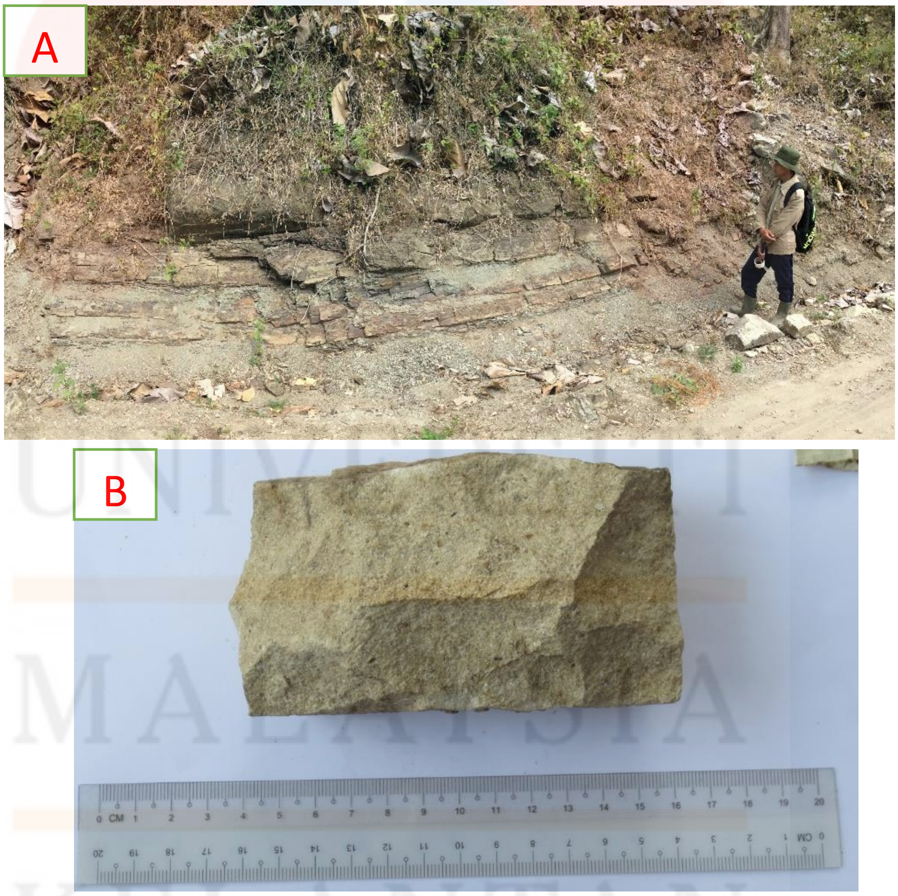


Figure 4.23: (a) Tuffaceous sandstone in outcrop at coordinate 7° 49’ 52.8” S 110° 37’ 9.2”E and (b) hand specimen of tuffacoeus rock unit

Table 4.3: Description of tuffaceous sandstone

Sample Code	:	Z3
Coordinate	:	7° 49’ 52.8” S 101° 37’ 9.2”E
Location	:	Mertuluk, Yogyakarta, Indonesia
Rock Name	:	Tuffaceou Sandstone
Colour	:	Brown
Structure	:	Bedded
Texture	:	Medium grain
Mineral	**%**	**Description**
Plagioclase	60	It is colourless and low relief. It has euhedral shape under PPL. In XPL has albite twinning and Carlsbad twining with extension angel 21°.
Quartz	10	In PPL it is irregular shape, low relief and colourless to cloudy. In XPL it has no twining.
Opaque	20	Black colour in PPL and XPL, no pleochroism, anhedral shape and high relief
Matrix	**%**	**Description**
Lithic fragment	10	In PPL it has irregular shape, high relief, no twining and anisotropic and consist of tuff

Description

From the petrographic analysis, the thin section has greyish to white and some brown colour incision. It has hypocrystalline for degree of crystalline because it consist of both crystal and glass. It compose of euhedral to anhedral minerals crystal. It as hypidiomorphic where predominantly subhedral grain. It consists of plagioclase (plg), quartz (qtz), opaque mineral (opq) and lithic fragment. According to Schmidt, 1981 it is Lithic tuff

Photo

PPL **XPL**

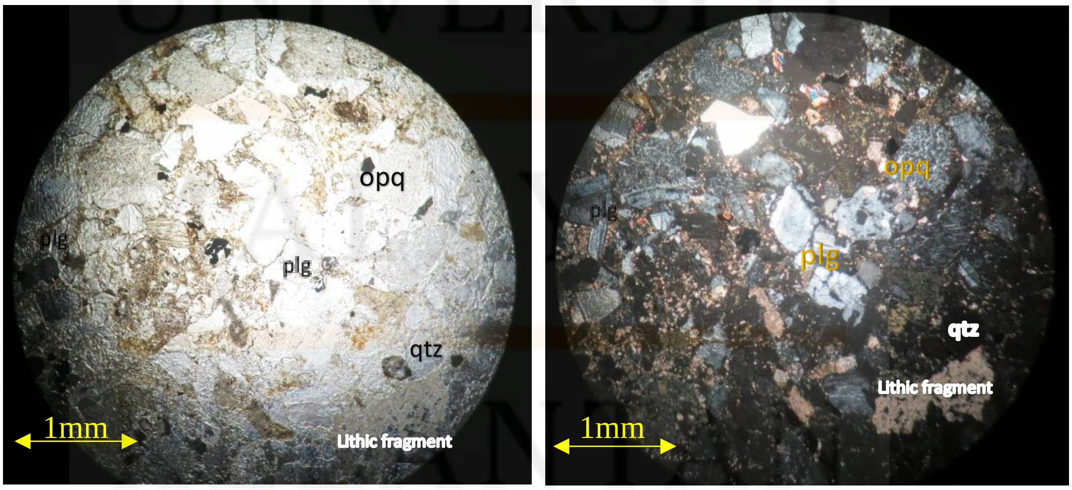


Figure 4.24: Plane polarised (PPL) and Cross polarised (XPL) of tuffaceous sandstone unit with magnification 10x10

(c) Green Tuff unit

Green Tuff is specially found in Kebo-Butak formation and it distribute throughout the formation. The green tuff unit mostly found in the late Oligocene. The precious research the green tuff called as Tuff Zeolith. The green tuff is originate from tuff which later undergoes pressure, heat and alteration from farming it become tuff zeolith (Kiflan Muzwar, Wahju Krisna Hidajat and Tri Winarno, 2005). The green tuff is named by it colour which appear green, It has very fine grain and very compact. It present clay mineral in that tuff. This green tuff only able to find Kebo Butak formation. Figure 4.25 shows the green tuff in filed outcrop and hand specimen. Table 4.4 shows the description of green tuff unit.

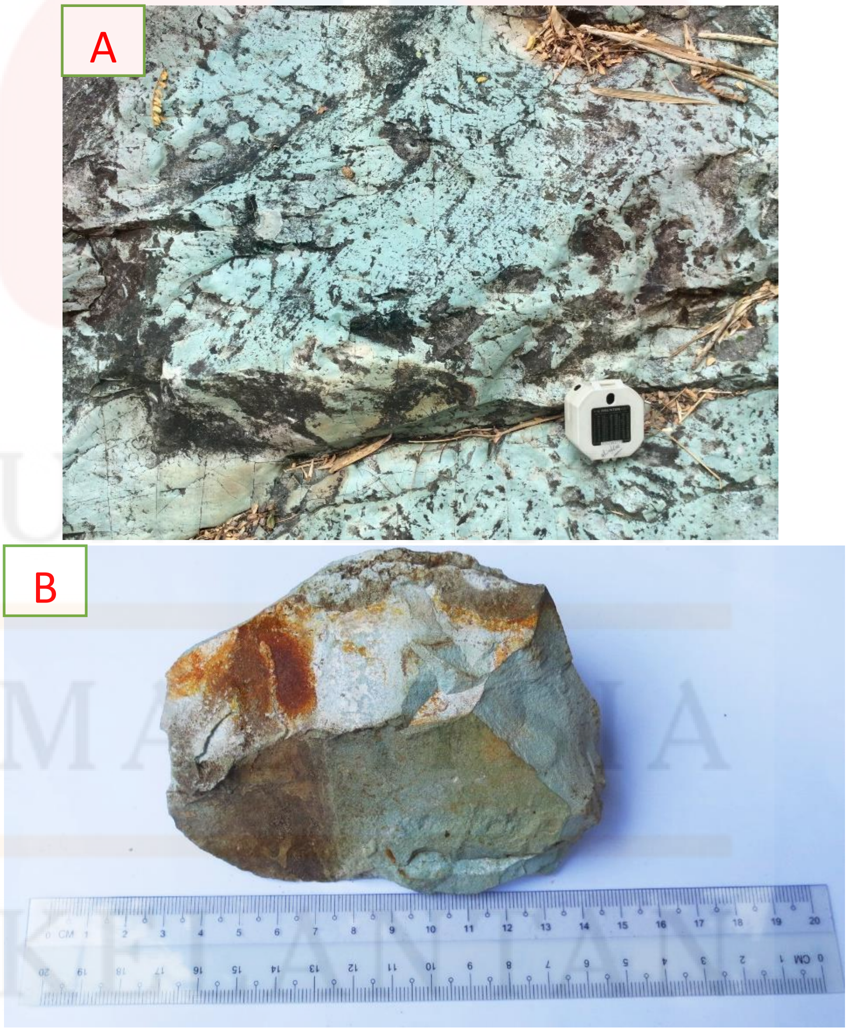


Figure 4.25: (a) Green tuff rock at Kebo-Butak Formation at 7° 49’ 47.9” S 110° 37’ 18.7”E and (b) hand specimen of green tuff

Table 4.4: Description of Green Tuff

Sample Code	:	A10
Coordinate	:	7° 49' 47.9" S 110° 37' 18.7"E
Location	:	Hargomulyo, Yogyakarta, Indonesia
Rock Name	:	Green Tuff
Colour	:	Greenwish
Structure	:	Massive
Texture	:	Very Fine grain
Mineral	**%**	**Description**
Quartz	10	In PPL it is irregular shape, low relief and colourless to cloudy. In XPL it has no twining. The quartz appear as incision as a fragment
Glass	10	Microlite is rectangular in shape in all over the thin section. It is pearly and white to glassy appearance in PPL and XPL.
Opaque	10	Black colour in PPL and XPL, no pleochroism, subhedral shape and high relief
Matrix	**%**	**Description**
Clay and Tuff	70	In PPL it appear frosted green, no pleochroism, anhedral and present evenly in incisions as matrix. The matrix anhedral and have triangulate shape.

Description

From the petrographic analysis, the thin section has greenwish white colour. It has hypocrystalline for degree of crystalline because it consist of both crystal and glass and more matrix. Aphanitic grain size because most minerals are too fine-grained to see with necked eye. It composed mostly anhedral and some mineral occur as subhedral. The relationship between crystals are most of the grain are anhedral, called allotriomorphic. It consists of quartz (qtz), opaque mineral (opq) and glass and clay and tuff as matrix. According to Schmidt, 1981 it is Vithic tuff

Photo

PPL **XPL**

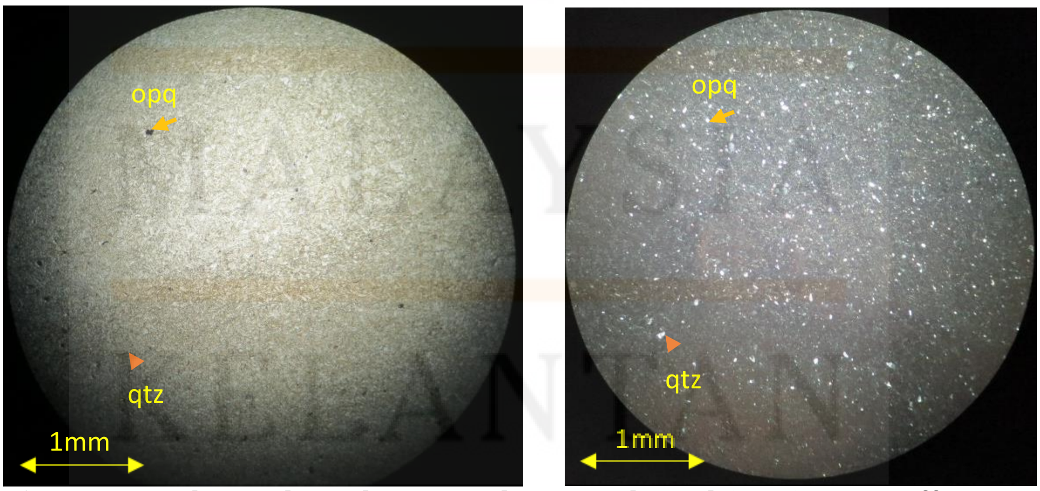


Figure 4.26: Plane polarised (PPL) and Cross polarised (XPL) green tuff unit with magnification 10x10

(d) Tuff Breccia unit

The Tuff breccia unit another dominated lithology in the study area. The Tuff breccia is very special rock which only found in Semilir Formation. It is distribute all over the Semilir Formation and it dominated at lower Semilir. The tuff breccia is a type of coarse grained pyroclastic rock. The colour is from white to grey. The breccia fragment dominated by pumice with variable shape and size which the fragment range from 0.2m to 64mm. The main characteristics of this type of rock are light weighted. Tuff breccia formed during volcanism period. In additional, the Semilir formation is typically originated from the product of a very tremendous explosive volcanic activities. Figure 4.27 shows the tuff breccia in outcrop and hand specimen. Table 4.5 shows the rock description of tuff breccia.

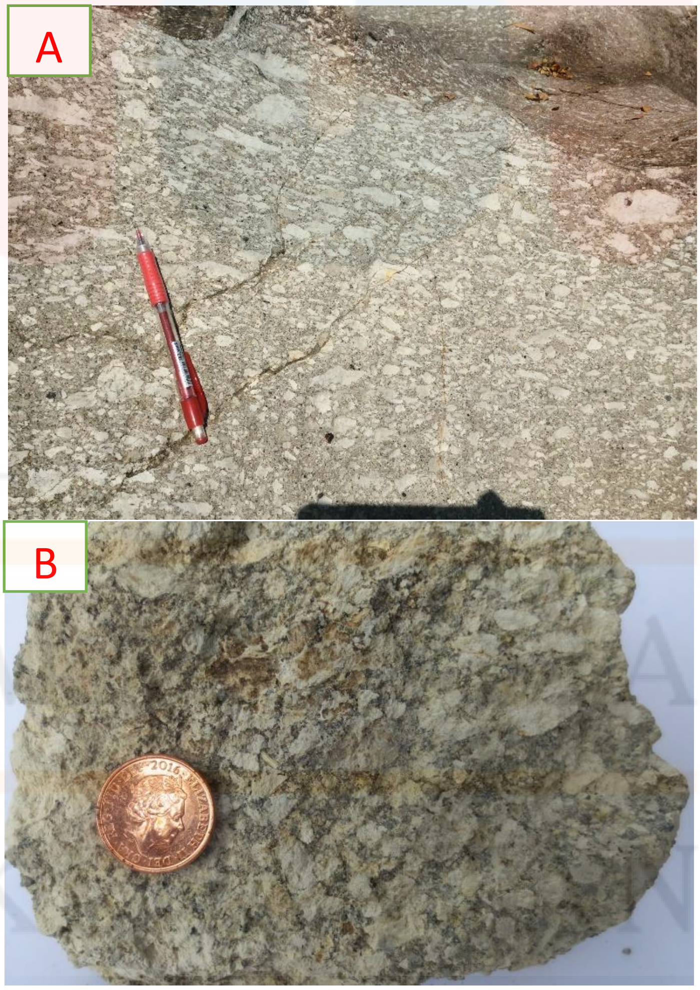


Figure 4.27: (a) Tuff Breccia at Semilir formation at coordinate 7° 50’ 4.5” S 110° 38’ 35.8”E outcrop and (b) hand specimen of tuff breccia

Table 4.5: Description of tuff breccia

Sample Code	:	B05
Coordinate	:	7° 50’ 4.5” S 110° 38’ 35.8”E
Location	:	Hargomulyo, Yogyakarta, Indonesia
Rock Name	:	Tuff Breccia
Colour	:	White
Structure		Massive
Texture	:	Fragmental and coarse grain
Mineral	**%**	**Description**
Plagioclase	10	It is colourless and low relief. It has euhedral shape under PPL. In XPL has twinning with extension angel 25°.
Vesicle/Pumice	50	It occur light cream to yellowish colour under PPL and dark black colour XPL. The size ranging from 0.25mm to 5mm. Pumice is the dominant mineral.
Pyroxene	5	Colourless and moderate relief. It has subhedral shape and it presence of cleavage In PPL. In XPL it occur in pale green colour with extension angel 30°
Opaque	5	Black colour in PPL and XPL, no pleochroism, subhedral shape and high relief
Matrix	**%**	**Description**
Volcanic ash	30	It is known as shards and “Y” shaped. It is low relief in PPL and dark bluewish with glass shatter

Description

From the petrographic analysis, the thin section has white and brownish colour. It consists both crystal and glass for degree of crystalline called hypocrystalline. It composed from euhedral to anhedral shape mineral. The relationship between crystals are hypidiomorphic where it consists mostly subhedral grains It consists of plagioclase (plg), opaque mineral (opq), pyroxene (pyx) and vesicle/pumice (Pm). According to Schmidt, 1981 it is Vitric Tuff

Photo

PPL **XPL**

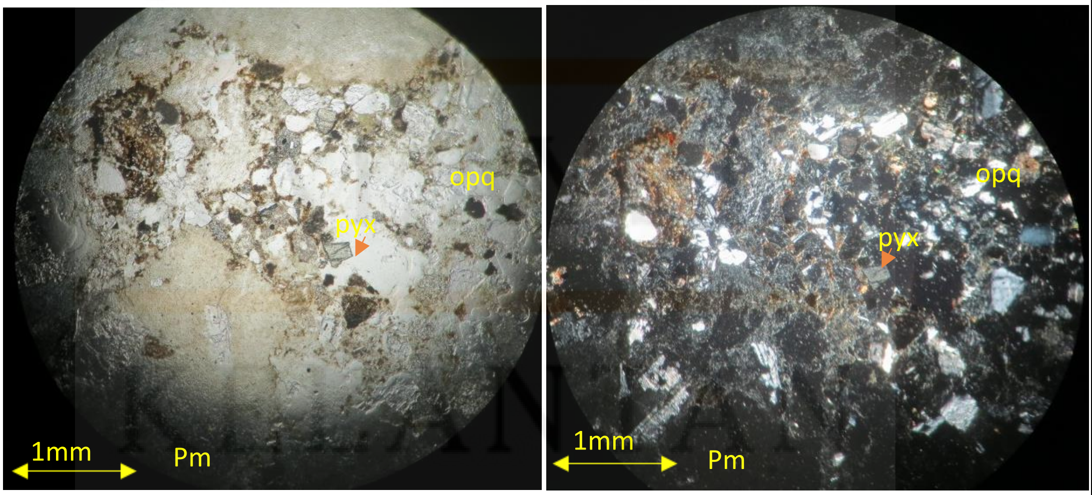


Figure 4.28: Plane polarised (PPL) and Cross polarised (XPL) Tuff breccia unit with magnification 10x10

(e) Lapilli unit

Lapilli founded in Semilir formation. This unit has alternating lapilli and tuff throughout the Semilir formation. Besides that, this unit inter finger tuff breccia because same type of rock founded equal distributed around Semilir formation. Tephra, where the ash particle falls out from the air during volcanic eruption while they are still at partly molten and in appear as tuff fragment as graded bedding in lapilli. The lapilli is in grey to light blue colour with medium grain. They are massive. Figure 4.29 shows the volcanic sandstone outcrop and with hand specimen. Table 4.6 shows the description of lapilli tuff unit.

Figure 4.29: (a) Lapilli at Semilir formation at coordinate 7° 51’ 0.0” S 110° 37’ 38.1”E outcrop and (b) hand specimen of Lapilli

Table 4.6: Description for lapilli unit

Sample Code	:	Z5
Coordinate	:	7° 51’ 0.0” S 110° 37’ 38.1”E
Location	:	Hargomulyo, Yogyakarta, Indonesia
Rock Name	:	Lapilli
Colour	:	Greywish blue
Structure	:	Massive
Texture	:	Medium grain
Mineral	**%**	**Description**
Plagioclase	20	It is colourless and low relief. It has euhedral shape under PPL. In XPL has twinning with extension angel 21°.
Opaque	10	Black colour in PPL and XPL, no pleochroism, subhedral shape and high relief
Pyroxene	10	Colourless and moderate relief. It has subhedral shape and it presence of cleavage In PPL. In XPL it occur in pale green colour with extension angel 32°
Quartz	30	In PPL it is irregular shape, low relief and colourless to cloudy. In XPL it has no twining
Vesicle	20	It occur light cream to yellowish colour under PPL and dark black colour XPL. The size ranging from 0.2mm to 4mm. Pumice is the dominant mineral.
Matrix	**%**	**Description**
Tuff	10	Low pleochroism, scatter through the slide

Description

From the petrographic analysis, the thin section has greyish blue and some brown colour incision. It has hypocrystalline for degree of crystalline because it consist of both crystal and glass. It compose of euhedral to anhedral minerals crystal. It as hypidiomorphic where predominantly subhedral grain. It consists of plagioclase (plg), quartz (qtz), opaque mineral (opq), pyroxene (pyx) and vesicle/pumice (Pm). According to Schmidt, 1981 it is Crystal tuff

Photo

PPL **XPL**

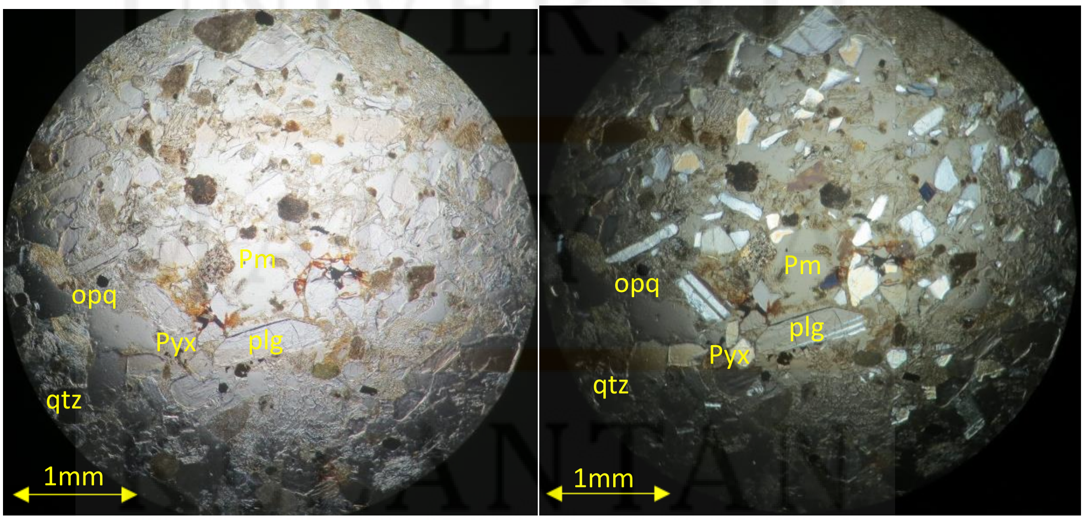


Figure 4.30: Plane polarised (PPL) and Cross polarised (XPL) lapilli unit with magnification 10x10

(f) Volcanic sandstone unit

Volcanic sandstone found in Semilir formation almost everywhere. This unit can be found along with lapilli unit. The volcanic sandstone comprise of sandy grain of matrix which was cemented together and yet there where empty space between them. It form as the volcanoes erupt, as it consist of material such as lava, gases and pyroclastic rock with different grain particle. So over time it deposited and become lithified thus forming volcanic sandstone. The volcanic sandstone in this unit where same with location of measuring section. The volcanic sandstone in this has dark grey with tuff particles. Figure 31 shows the volcanic sandstone outcrop and with hand specimen. Table 4.7 shows the description of volcanic sandstone unit.

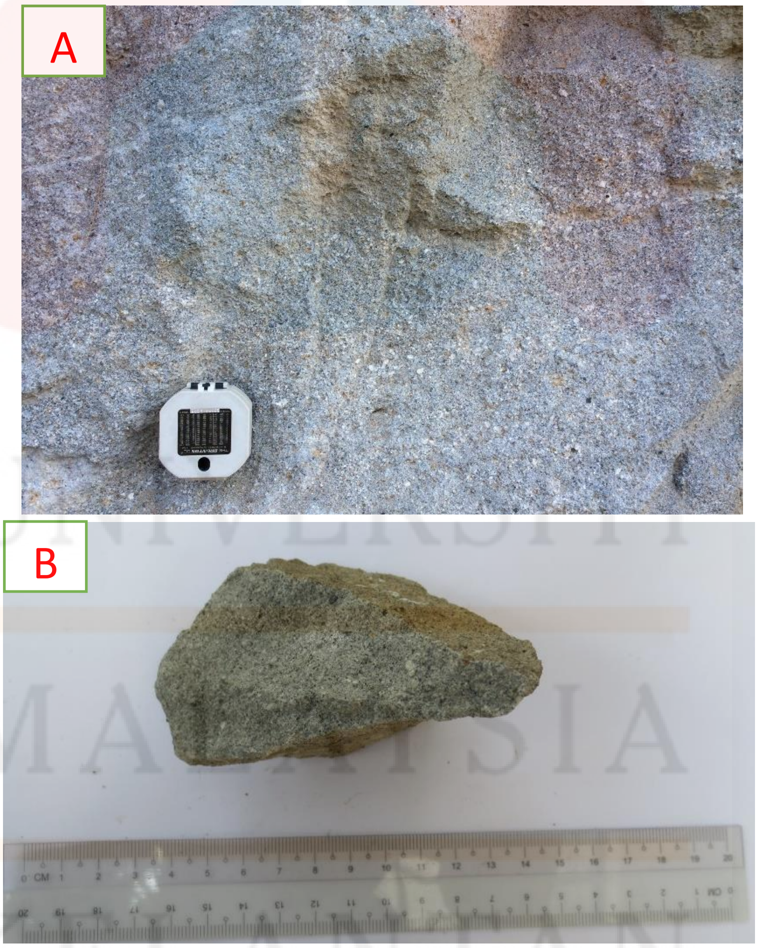


Figure 4.31: (a) Volcanic sandstone at Semilir formation at coordinate 7° 49’ 48.7” S 110° 32’ 4.5”E outcrop and (b) hand specimen of volcanic sandstone

Table 4.7: Description for volcanic sandstone

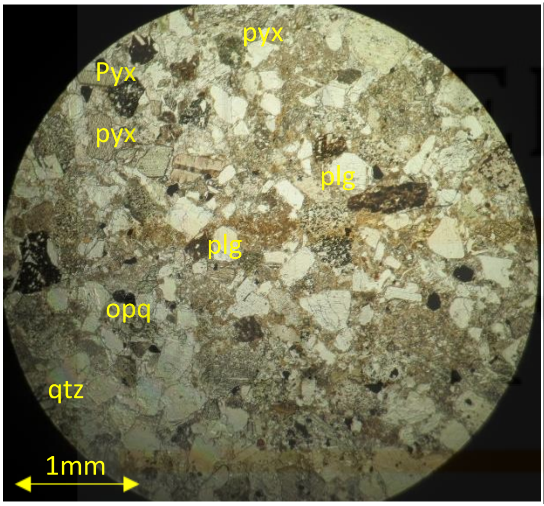
Sample Code	:	Z8
Coordinate	:	7° 49’ 48.7” S 110° 32’ 4.5”E
Location	:	Hargomulyo, Yogyakarta, Indonesia
Rock Name	:	Volcanic sandstone
Colour	:	Dark grey
Structure	:	Massive
Texture	:	Coarse grain
Mineral	**%**	**Description**
Plagioclase	15	It is colourless and low relief. It has euhedral shape under PPL. In XPL has twinning with extension angel 24°.
Opaque	10	Black colour in PPL and XPL, no pleochroism, subhedral shape and high relief
Pyroxene	10	Colourless and moderate relief. It has subhedral shape and it presence of cleavage In PPL. In XPL it occur in pale green colour with extension angel 30°
Quartz	35	In PPL it is irregular shape, low relief and colourless to cloudy. In XPL it has no twining
Matrix	**%**	**Description**
Lithic fragment	30	In PPL it has irregular shape, high relief, no twining and anisotropic and consist of tuff

Description

From the petrographic analysis, the thin section has dark grey and some brown colour incision. It has hypocrystalline for degree of crystalline because it consist of both crystal and glass. It compose of euhedral to anhedral minerals crystal. It as hypidiomorphic where predominantly subhedral grain. It consists of plagioclase (plg), quartz (qtz), opaque mineral (opq) pyroxene (pyx) and lithic fragment.

Photo

PPL **XPL**



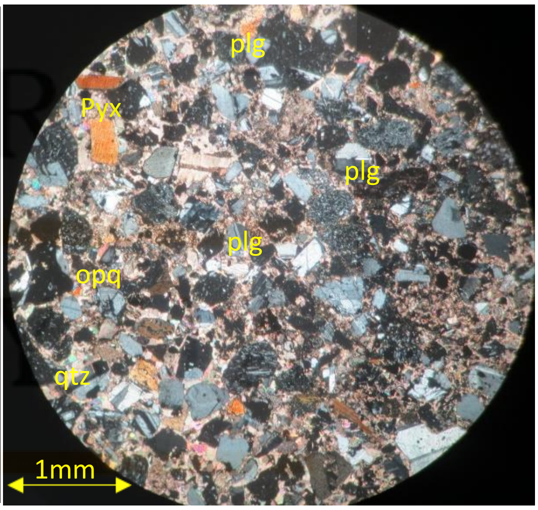


Figure 4.32: Plane polarised (PPL) and Cross polarised (XPL) volcanic sandstone unit with magnification 10x10

(f) Andesite unit

Andesite unit is dominated unit at south of study area. This unit comprised below Nglanggeran Formation. , the Nglanggran breccia unit which was deposited from the volcanic eruption of the ancient Nglanggran mountain. The Nglanggran mountain only have one type of breccia which were andesite breccia which originate from andesite lava and it composes such as pyroclastic and epiclastic breccia. There are also several sandstone founded during this period. Thus, this unit was deposited in marine environment. After the formation of volcanic unit of breccia, there were no active sedimentary material deposited in the study area. Figure 4.33 shows the andesite breccia outcrop and with hand specimen. Table 4.8 shows the description of andesite unit.

Figure 4.33: (a) Andesite breccia at Nglanggaran formation at coordinate 7° 50’ 1.4” S 110° 37’ 12.3”E outcrop and (b) hand specimen of andesite unit

Table 4.8: Description for andesite unit

Sample Code	:	Z06
Coordinate	:	7° 50’ 1.4” S 110° 37’ 12.3”E
Location	:	Nglang, Yogyakarta, Indonesia
Rock Name	:	Andesite Breccia
Colour	:	Black
Structure		Massive
Texture	:	Medium grain
Mineral	**%**	**Description**
Plagioclase	50	It is colourless and low relief. It has euhedral shape under PPL. In XPL has albite twinning and Carlsbad twining with extension angel 24°.
Pyroxene	10	Colourless and moderate relief. It has subhedral shape and it presence of cleavage In PPL. In XPL it occur in pale green colour with extension angel 33°
Hornblende	10	Colourless and moderate relief. It has elongated shape and it presence of cleavage In PPL. In XPL it occur in pale green colour.
Opaque	10	Black colour in PPL and XPL, no pleochroism, subhedral shape and high relief
Matrix	**%**	**Description**
Groundmass	20	Anhedral with glass scatter

Description

From the petrographic analysis, the thin section has grey to brown colour. It has hypocrystalline for degree of crystalline because it consist of both crystal and glass. It compose of euhedral to anhedral minerals crystal. It as hypidiomorphic where predominantly subhedral grain. It consists of plagioclase (plg), hornblende (hbd), opaque mineral (opq), and pyroxene (pyx).

Photo

PPL **XPL**

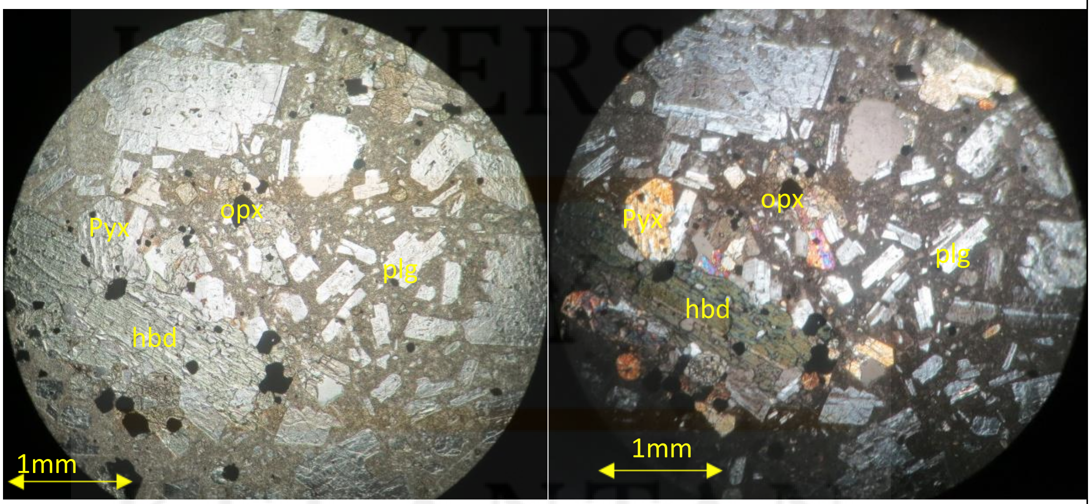


Figure 4.34: Plane polarised (PPL) and Cross polarised (XPL) andesite unit with magnification 10x10

4.4 Structural Geology

Structural geology is a study of rock deformation, it can occur either in small or regional scale. The structural geology are used to determine the past deformation history from the geometries of present rock. Structural geology in these subunit explain all the structure present in study area such as fault, joint, fold and other structure which occur due to tectonic force and regional force. From these structure, the mechanism of rock deformation can be interpret and it can be linked to the current geology of the study area. The lineament which has plotted in order to identify the type of structure that occurred at the location.

4.4.1 Joint

A joint is deformation of rock which has lack of movement. A joint is form due to brittle deformation which result from tensile stress. The stress can be from internal or external. The joint that found in study area are systematic joint and non-systematic joint.

Systematics joint in Figure 4.35 found in study area which can be seen in tuff outcrop. The systematics joint have parallel or subparallel orientation and evenly regular spacing. Non-systematics joint in Figure 4.36 does not parallel and don't share the same orientation. It can be curved and irregular fracture surface. These joint is found at volcanic lava and other some tuff in study area which has irregular form, spacing and orientation.

Figure 4.35: Systematic joint at coordinate 7°48'51.8"S 110°23.3"E

Figure 4.36: Non-systematics joint 7°51'11.6"S 110°38'20.4"E

Joint analysis was taken about 100 reading of joint to plot in rose diagram in order to determine the direction of stress which cause the rock to deform (Figure 4.37). The degree of angle in shown in Appendix 2. The maximum force acted at $\sigma 1$, thus it can be interpret that at $\sigma 3$ causes the rock to deform at angel 85°

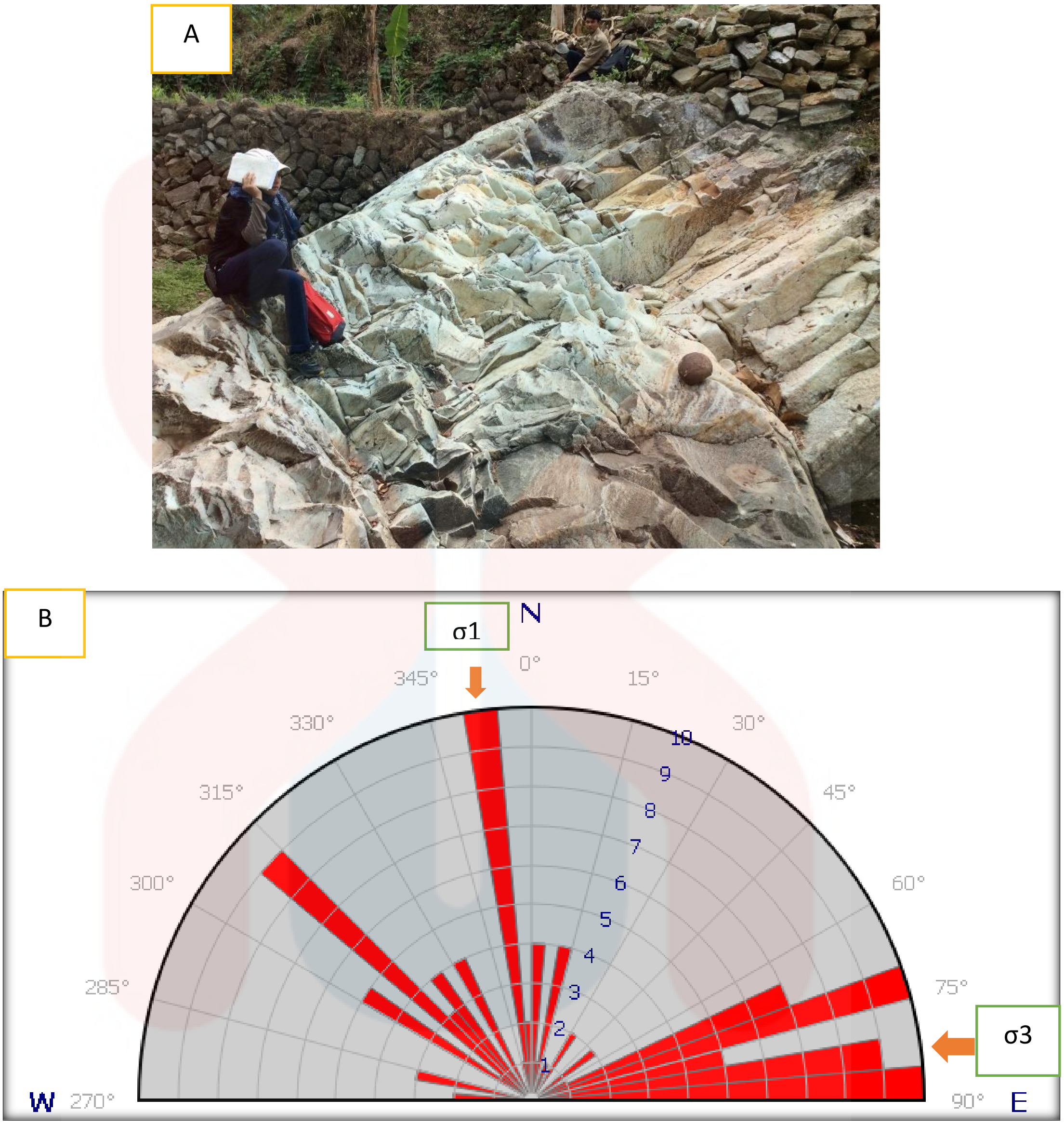


Figure 4.37: (a) The outcrop of joint analysis at 7°49’55”S 110°36’55.7”E, Kebo-Butak formation (b) Rose diagram analysis for the outcrop

4.4.2 Fault

There are plenty of fault were found in study area. The fault that was able observed are strike-slip fault and normal. Some fault was observed based on regional map and which cause the rock to deform due to tectonic and regional forces based on Riedel Theory (Figure 4.38). The structure were plotted in geological map in Appendix 1.

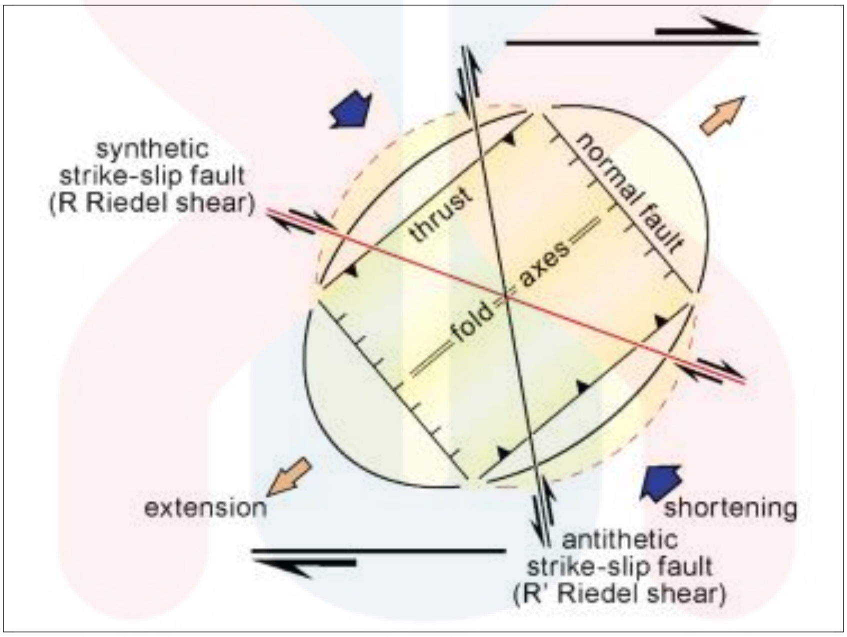


Figure 4.38: Fault movement based on Riedel Theory

One of the indication of fault such as slicken side, fault gauge, gas and pinnate fracture and others. The study area has slicken sides as one of the indication of fault (Figure 4.39). Slicken side has smooth surface of fault surface which form due to the movement of strata due to fault. Slicken side generally are useful to knowing the direction of the last movement on a fault surface.

Normal fault were observed as footwall move upward, while the hanging wall slide downward (Figure 4.40). The normal fault in shown large view of movement of the outcrop. The maximum force, $\sigma 1$, exerted on the top of vertical direction while the minimum force, $\sigma 3$, is acting at the horizontal direction.

Figure 4.39: Slicken side at coordinate 7°50’6.5”S 110°36’31.31”E

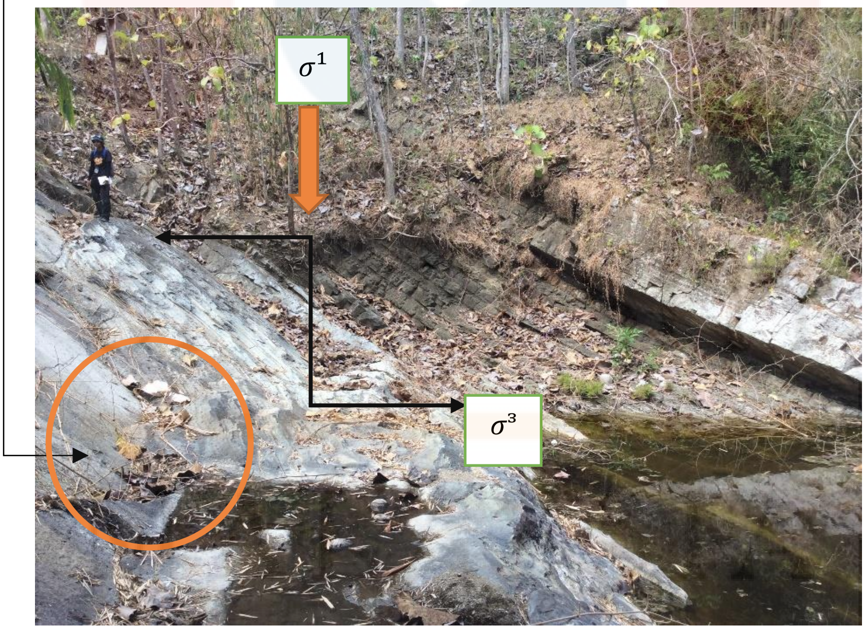


Figure 4.40: Normal fault at coordinate 7°50’6.5”S 110°36’31.31”E

Strike slip fault were abundant in the study area. Commonly there were two type of strike slip fault namely dextral and sinistral strike slip fault in the study area that were observed (Figure 4.41). The dextral strike slip fault has right lateral movement, while sinistral strike-slip fault has left lateral movement. The stress principal is based on Riedel Theory.

Sinistral strike slip fault with bearing 200° and bedding 77°/36° strike/dip. While dextral strike slip fault with bearing 175° and bedding 85°/30° strike/dip. The strike slip fault occur horizontal direction.

Figure 4.41: (a) Sinistral strike slip fault at coordinate 7°50’46.9”S 110°37’22.7”E and (b) Dextral strike slip fault at coordinate 7°51’1.4”S 110°37’12.3”E

4.4.3 Fold

Fold are most common geological structure found in rock. Fold is form the rocks were subjected to compressive force. This force act horizontal and cause then to bend, where it can be folded upward or downward. The study area has two type of fold plunging fold and slumping fold (Figure 4.42). Plunging fold is a fold that have inclined axis of a fold or horizontal. Slumping fold occur due movement of unconsolidated sediment.

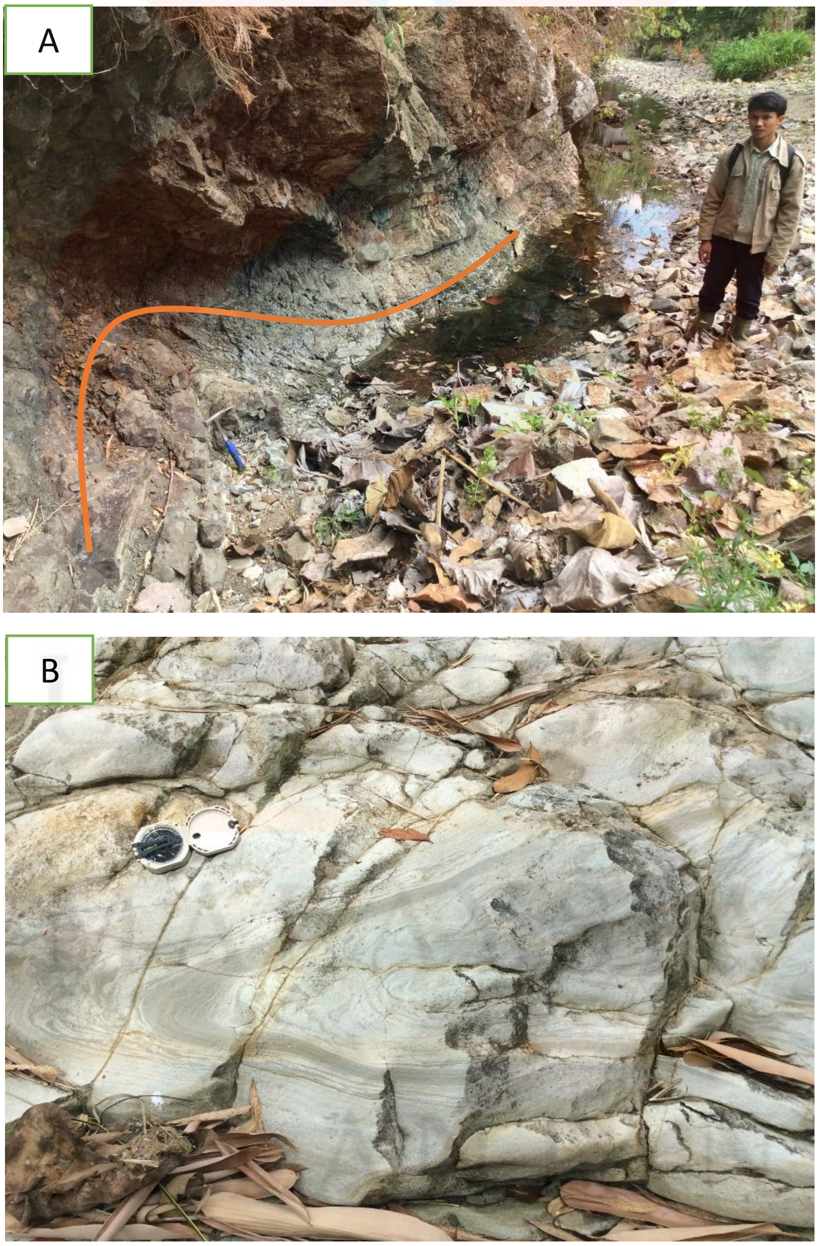


Figure 4.42: (a) Plunging fold at coordinate 7°50’6.5”S 110°36’31.31”E and (b) Slumping fold 7°50’2.7”S 110°36’33.8”E

4.4.4 Lineament Analysis

Lineament is a landscape which illustrate the geological structure such as fault, valley and fold-aligned hills from the outline of contour. The aerial photograph or satellite image showed a clear phase of lineament. Besides that fracture, shear zone and igneous instruction also can be expressed as geomorphic lineament.

The research location mostly covered with rivers, valley and ridge due to extension and compression force. The red line present valley lineament while yellow represent fault lineament shown in Figure 4.43.

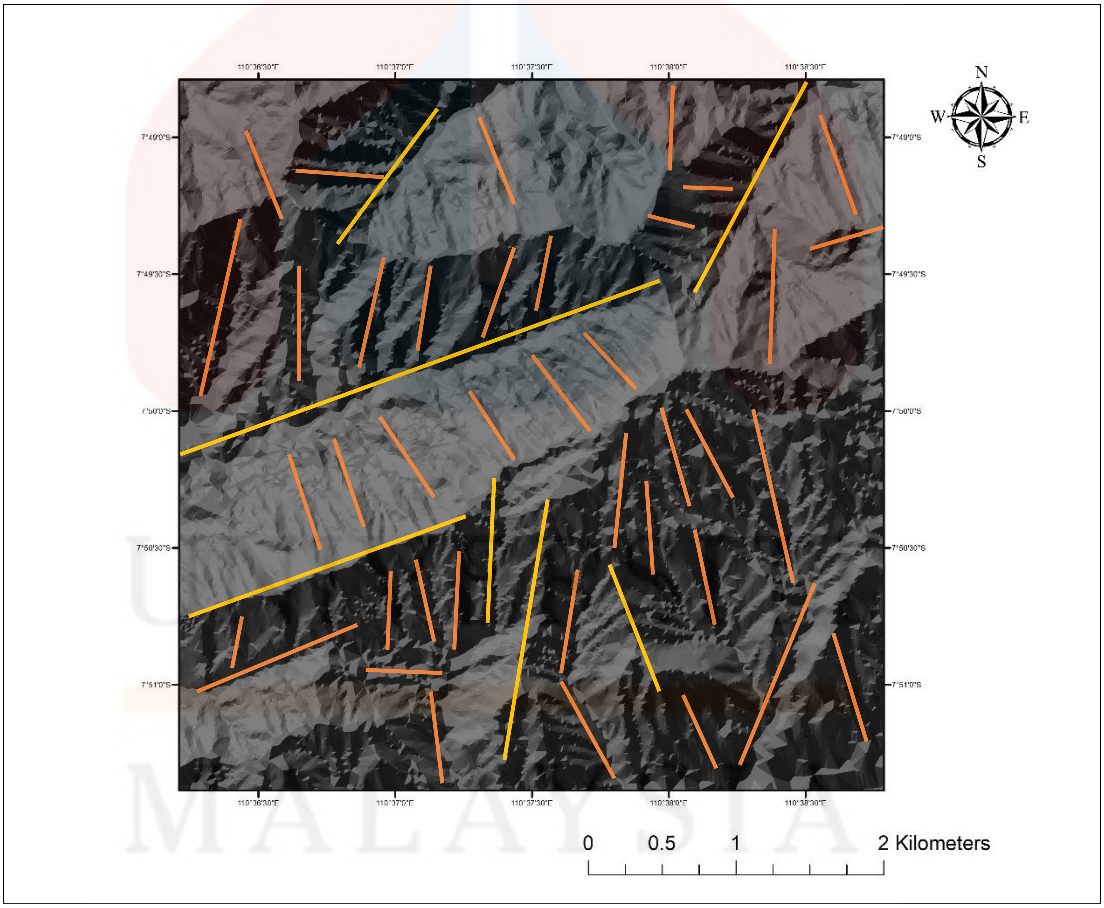


Figure 4.43: Lineament map of Hargomuyo, Indonesia

4.4.5 Bedding Analysis

The mechanism of structure is to analysis the force occur regionally at the study area. It is done by plotting all the strike and dip on the stereonet in order to determine the force direction towards the study area which cause the rock to deform. The previous study show that the study area tilted towards the south and the data which obtain in field also were dipping though south. The bedding analysis is done by plotting pole for the bedding which present in the all over the study area. Therefore, bedding data have been plotted to determine the bedding in field were same as in the analysis of stereonet. Thus the result turn to be same as previous and the field analysis. The rock titled in south direction. The orientation of plane 84/29 strike and dip and with line 345/61 shown in Figure 4.44.

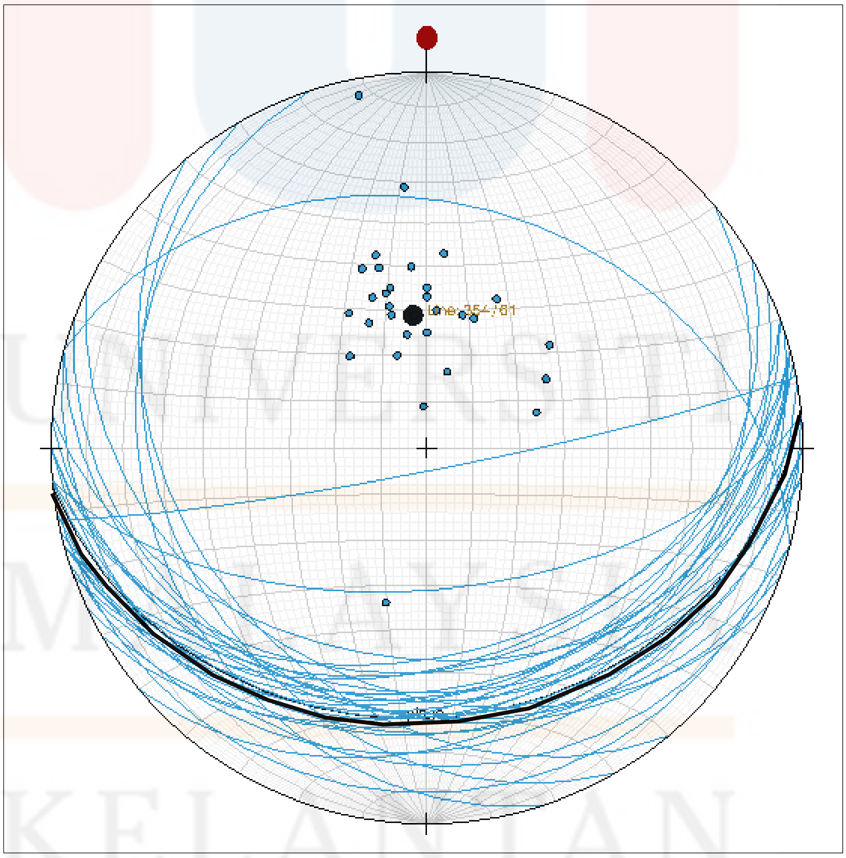


Figure 4.44: The bedding analysis

4.4.6 Mechanism of structure

The mechanism of structure is the procedure which were used for structure analysis. Stereonet and Rose diagram software were used to determine the stress acted on the rock. Both software were easy to handle and enable to determine the force which acted in the study area more precise.

4.5 Historical Geology

Based on geological data and field data which consists of lithological characteristic, age, and depositional environment enable to determine the historical geology of the study area. The historical geology also refers to the regional geology of previous researcher. Therefore from the data collected the historical geology of study area can be divided into three phase.

Phase I, the tuffaceous sandstone, sandy tuff, tuff and green tuff unit of Kebo-Butak Formation is believed in the deep sea environment which took placed in Late Oligocene. These unit deposited in lithic lithology. Thus this cause sedimentation process occur in fast rate. Claystone layer found in Kebo-Butak formation illustrate that the unit deposited in low velocity current. Phase I occur pre-volcanism period. At the same time right after of these unit completely deposited, The Semilir volcanic unit of tuff breccia and lapilli unit result from volcanic process of Semilir mountains in Early Miocene.

Phase II, Early Miocene had undergoes many volcanic activities. The tuff breccia resulted for higher rate of explosion which occur during that period. This period also known as period of destruction. The Semilir formation unit deposited with sediment supply from volcanic activities. The type of volcano was predicted sub-aqueous where the volcanic material directed contact with water, thus form a turbidity process finally deposited into the underwater fan. In this phase sedimentary structure namely bedding, lamination, graded bedding and massive rock are founded. Primarily, the units were fine to coarse and also had some claystone containing tuff in several place. Phase II occur during volcanism.

Phase III, at same period early Miocene, the Nglanggran breccia unit which was deposited from the volcanic eruption of the ancient Nglanggran mountain. The Nglanggran mountain only have one type of breccia which were andesite breccia which originate from andesite lava. There are also several sandstone founded during this period. Thus, this unit was deposited in marine environment. After the formation of volcanic unit of breccia, there were no active sedimentary material deposited in the study area. However, due to tectonic process the rock unit lifted and exposed in the land. Then the erosional process develop high elevation area. It is proven that the formation of the river larger with a valley shaped "U". Later the material undergoes erosional and transportation. It occur post volcanism period. Then these unit Sandstone of Sambipitu formation overlies the breccia unit by disconformity.

4.6 Summary

In this chapter, as an introduction, the accessibility to the study area, settlement, vegetation or forestry and traverse to the study area have been discussed. It is also discussed the road system in the study area, throughout the study area. After that few aspects in geomorphology have been discussed namely geomorphology classification, weathering and drainage pattern discussed which enhanced the mapping process. There are seven lithology unit in study area namely tuff, tuffaceous sandstone, green tuff, tuff breccia, lapilli tuff alternating tuff and volcanic unit. The unit then arranged in stratigraphy column in order to determine the age. The structural geology, mechanism of structure and history geology also have been written.

CHAPTER 5

DEPOSITIONAL ENVIRONMENT OF SEMILIR FORMATION

5.1 Introduction

Depositional environment is a process which the sediment transported from one place to a new place and soon deposited when the energy is no longer to carry them. It has wide range of setting, from land to deep marine (Boggs, 2014). The processes involve in forming the different environment such as physical, chemical and biological processes.

The physical parameter are such as temperature, current velocity, water depth, sunlight, water depth and wind speed. The factor that give effect on the depositional environment are salinity of water and the mineral composition of the sediment on chemical aspects. Depositional environment also bring important on fossil for biological aspect which interpret the ancient environment and life present.

Every depositional environment has its own special characteristics by its unique combination of sedimentary process. Depositional environment is identified by interpreting facies. Facies refers to the particular characteristics of sedimentary unit (Nichols, 2009). It involve in interpreting lithology, sedimentary structure, fossil content, texture, colour, geometry, paleo-current and others.

Depositional environment can be classified into few environment namely continental, shallow and marginal marine and deep marine depositional environment. The continental can further classified into glacial, fluvial and desert environment. The shallow and marginal marine environment can be divided into deltaic, linear shorelines and estuaries environment. Deep marine environment is different from other. It occur underwater sea where it can be divided into offshore which occur at continental slope and deep marine at basin floor.

The facies association in the study area are divided into five subunit namely. The detailed explanation of facies association is describe in 5.3 Facies Analysis subtopic in this chapter.

Sedimentary structure present in the study area are such as cross bedding, lamination, slump structure, Bouma interval sequence, current ripple and graded bedding. The detailed study of sedimentary structure present at the study area can help by given information of the energy involve and the time of deposition occur. The detailed explanation are describe in subtopic 5.4 Structure of lithostratigraphy.

In this chapter, stratigraphy section of Semilir formation is measured and interpreted the environment which the formation undergoes and formed. It is interpreted based in four parameter which is bedding, thickness, lithology and sedimentary structure.

5.2 Location of Depositional Environment

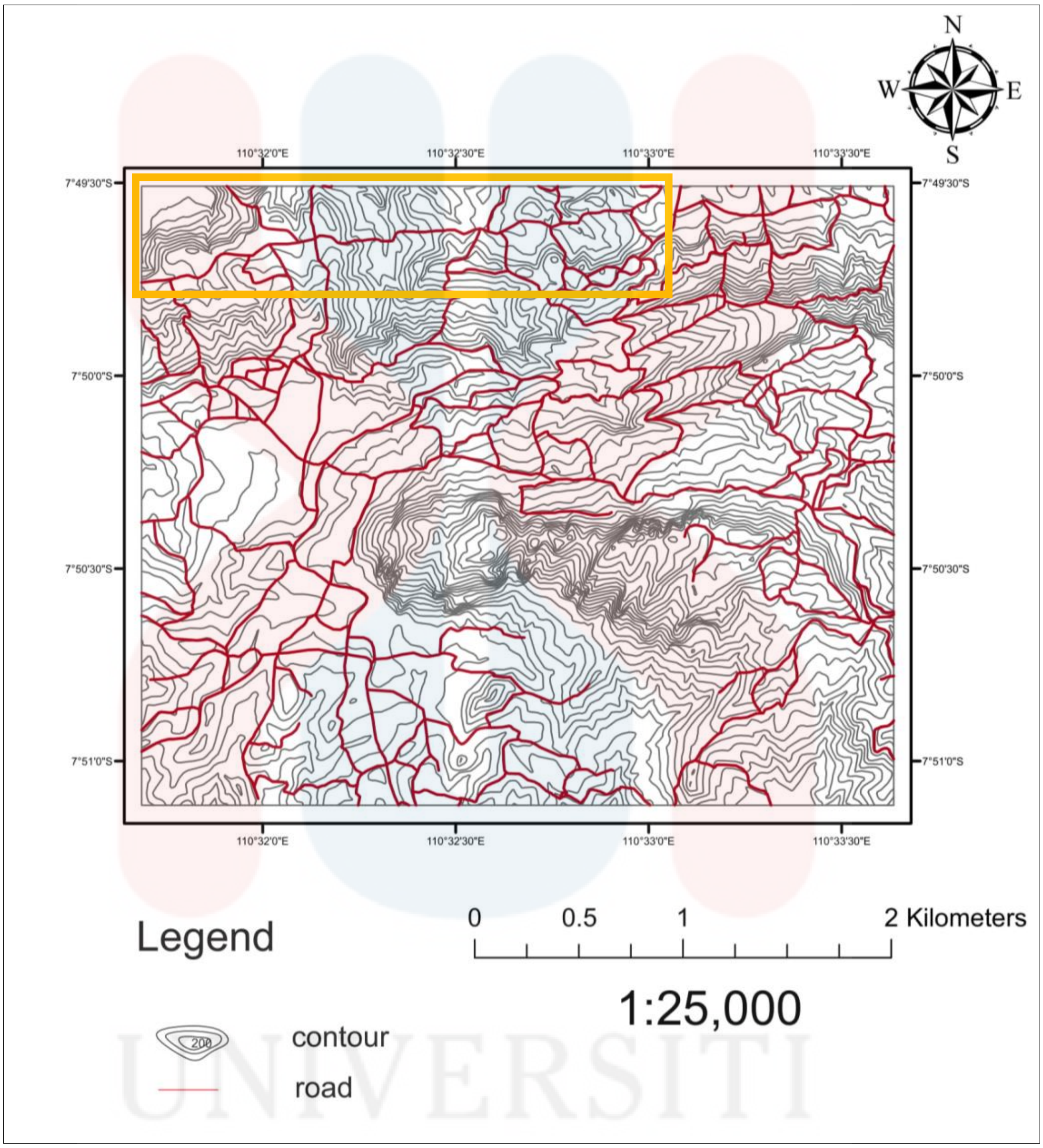


Figure 5.1: Location of stratigraphy for depositional environment interpretation. On the yellow lined box at the north west of study area.

Due to high to mountainous study area of chapter 4, the indicator of depositional environment from a stratigraphic log difficult to obtain from outcrop. Therefore, the depositional environment study for chapter 5 is taken outside the study area location. The study are is then conducted at roadside Desa Patuk nearby ancient volcano Nglanggaran. This is because the study area in chapter 4 has the same contour unit of tuff and consists of similar lithologies. As revised to chapter 4, tuff unit consists of tuff, lapilli, volcanic sandstone and intercalated by carbonaceous siltstone.

The Litholog outcrop of Semilir Formation (Figure 5.2) is about 98 meter long. The outcrop mainly consists of volcanic sandstone, lapilli, tuff, tuff breccia, calcerous clay stone, mudstone, siltstone and claystone.

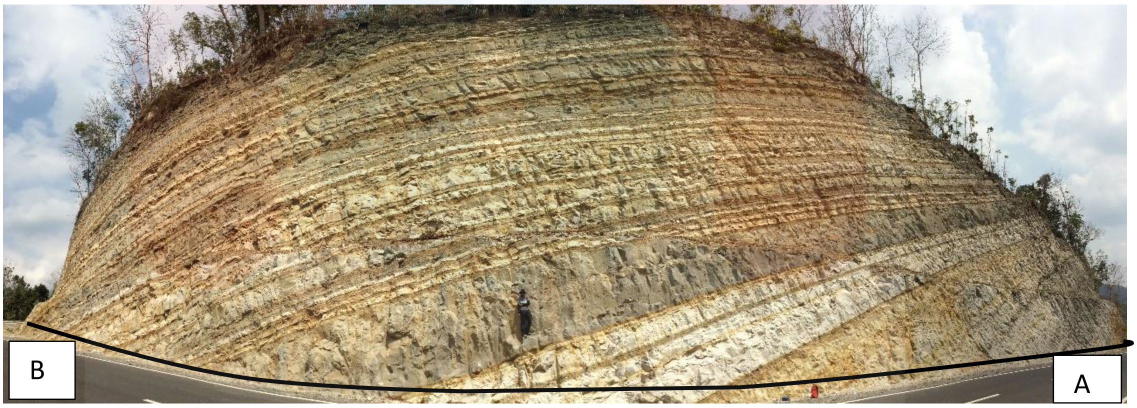


Figure 5.2: Litholog of Semilir Formation at coordinate 7°49’48.7”S 110°32’0.45”E

5.3 Facies Analysis

A facies is defined by a particular set of sediment characteristics on lithology, texture, suite of sedimentary structure, fossil content, colour, geometry, palaeo-current and others. A facies is produced by one or several processes operating in a depositional environment although the appearance of the facies can be consideration modified by post-depositional, diagenetic process (Tucker, 2011). Within a sedimentary succession there may have many different facies present. Some facies may be repeated several or many times in succession.

The indicator of depositional environment include bed thickness, lithology, sedimentary structure and fossil content of a facies. The facies characteristics of Semilir Formation can be divided into six facies name Facies A, Facies B, Facies C, Facies D, Facies E and Facies F. These characteristics are expressed in the form lithology Figure 5.3. The more detail lithology are shown in Appendix 3.

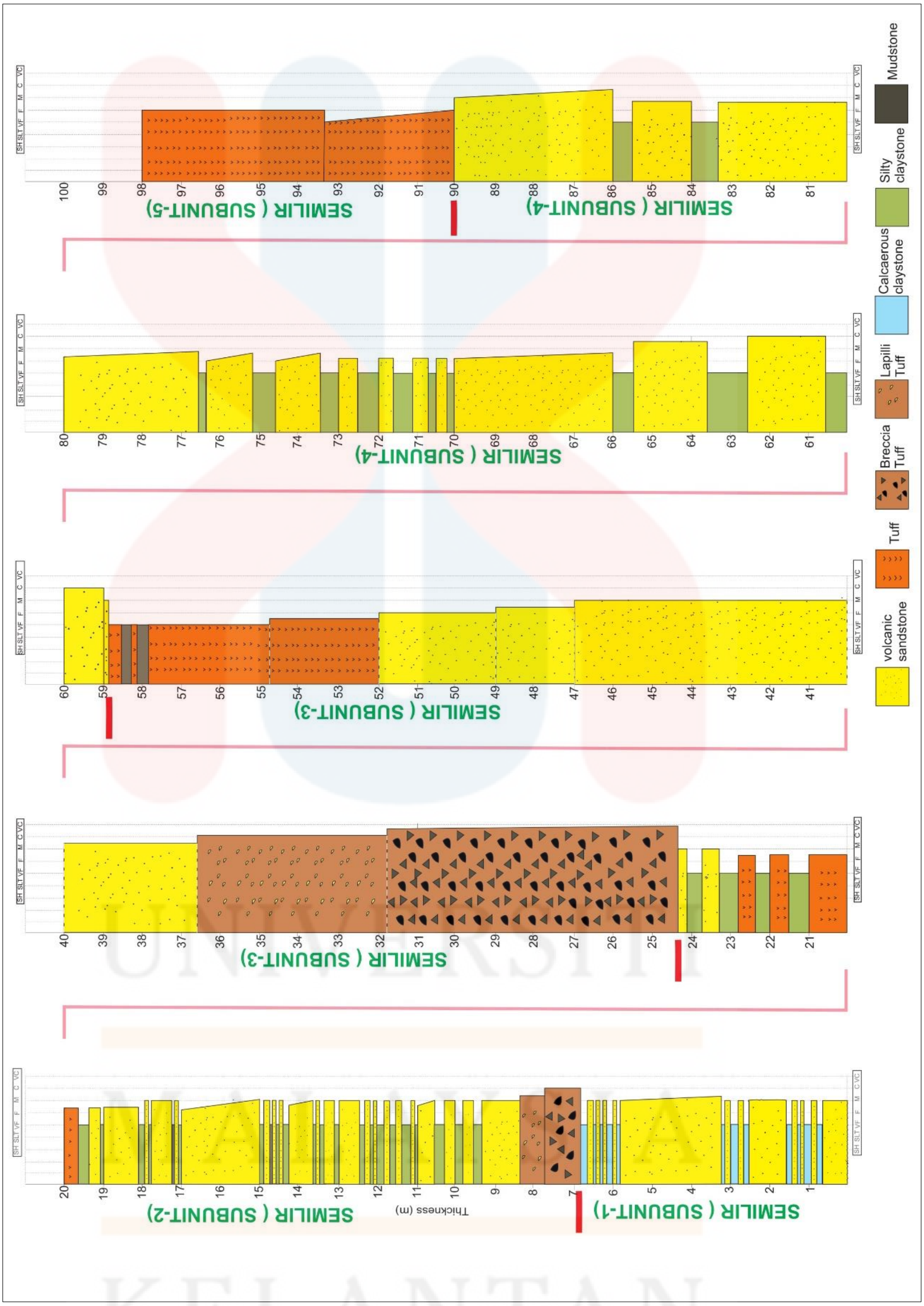


Figure 5.3: Litholog of Semilir Formation

5.3.1 Subunit-1 of Semilir Formation

Subunit-1 is the first facies about 7 meter thickness and composed only volcanic sandstone. It has one massive with 3 medium bed and few small beds. The small bed thickness to medium bed has light grey colour with fine to medium grain is nearly same thickness about 0.1 to 0.2 meter followed by medium bed of sandstone about 0.5m to 1 meter. In the section the sandstone has parallel lamination of carbonaceous siltstone in the small bedding of sandstone (Figure 5.3.1 a).

The sandstone appear in white to light grey colour with medium to coarse grain in massive volcanic sandstone (Figure 5.3.1 b) which is about 2.6 meter. It has small fine grain of tuff in the sandstone composition and it appear in greyish blue colour. The calcareous claystone founded interbedded in the carbonaceous siltstone (Figure 5.3.1 a). It was white in colour and in some bed it has lamination. The calcareous claystone has equal amount of thickness. The calcareous claystone only found in this facies, other facies only has normal claystone and siltstone. The sandstone has sharp contact with bedding alternating the calcareous claystone.

The structure present in the facies was parallel lamination on the massive sandstone bed. This structure deposited due to pyroclastic surge deposits which turbulent flow was dominant. This facies deposited during weaker eruption phases and it indicate low energy of wave action and occur during the fallout of soft sediment. It probably form at middle submarine fan channel in deep sea environment. The rock undergoes weathering, erosion, and sedimentation process.

Figure 5.3.1 a: Siltstone laminated mudstone with carbonaceous claystone

Figure 5.3.1 b: Massive volcanic sandstone with medium to coarse grain with parallel lamination

5.3.2 Subunit-2 of Semilir Formation

Subunit-2 is about 15 meter in thickness and composed tuff breccia, lapilli tuff, volcanic sandstone and tuff and at the same time there were high amount of sandstone interbedded with claystone. In this facies the rock can be seen fining upward sequence. This facies presence in many bed with different thickness and structure. It generally appear in graded bedding.

At this subunit the tuff breccia is at the lower part. It is also known as medium pebbly volcanic sandstone about 1 meter thick (Figure 5.3.2a). The tuff breccia has coarse texture and appear in whitish grey in colour in massive bed with tuff fragment about 0.2mm to 0.5mm with poor sortation. Followed by lapilli tuff greyish blue (Figure 5.3.2b) about 0.7 meter thick with medium grain size and lamination of tuff fragment range 0.1 mm to 0.2 mm in the rock. The thickness of rock decreases as it goes upward.

The energy level in this subunit decrease as it goes upward. It can be seen in the massive pebble volcanic sandstone or tuff breccia. It occur pebbly because it was carries in high velocity during the failure of submarine slope thus creating turbidity slow and form underwater submarine fan. It has high density turbidity current in upper flow regime. As the spread the form gradation the lapilli form in the gradation bedding with lamination of the tuff fragment. The energy at this level was still high thus it creating parallel lamination in the upper regime. The lapilli occur as diffuse stratification which still consists of tuff fragment. Therefore it can be said at this point the rock deposited in strong eruption.

There were five volcanic sandstone bed with medium thickness range from 0.7 meter to 2 meter in thickness, while the small volcanic sandstone beds has same thickness about 0.2 to 0.3 meter. The medium thickness volcanic sandstone occur in white colour with fining upward sequence in the bed itself. This indicate that there were changes of energy level as during the facies deposited. The energy decreases thus forming few structure such as current ripples (Figure 5.3.2c) which form by weak current which has alternating volcanic sandstone and carbonaceous mud due to wave effect. The volcanic sandstone are deposited during times of rapid flow while the mud deposited at low level energy level. The current ripple has thickness about 1 meter.

White very fine tuff appear after the volcanic sandstone fining. The claystone which interbedded in the sandstone does not has calcareous composition but it has composition of silt. Thus it was silty claystone. The claystone laminated of siltstone. It form in the form of mixture. The energy form at level was primary low.

To conclude this facies has some of the Bouma sequence series such as parallel lamination, current ripple and graded bedding. This facies has believed occur in the underwater submarine fan in middle fan. Erosional and sedimentation form in this level.

Figure 5.3.2a: Tuff breccia also known as pebbly volcanic sandstone

Figure 5.3.2b: Parallel lamination in lapilli tuff

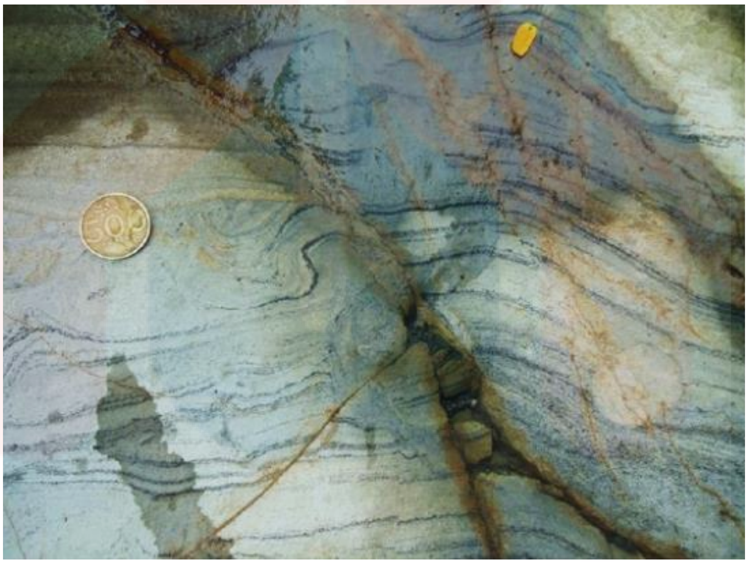


Figure 5.3.2c: Current ripple deposited by wave action on volcanic sandstone

Figure 5.3.2d: Coarsening upward between at the top of Subunit-2 joining with Subunit-3

5.3.3 Subunit-3 Semilir Formation

Subunit-3 about 36 meter thickness composed of massive beds of tuff breccia, lapilli, volcanic sandstone and tuff. The mudstone only occur at the upper part of this facies range 0.4 to 0.5 meter thick. Each beds are gradation contact and the facies seems to fining upward in massive structure. The lithologies in this subunit are similar to subunit-2, however, the sequence energy, structure and the thickness of the lithologies were different.

The tuff breccia or pebbly volcanic sandstone in this subunit was greyish blue in colour with very coarse grain texture. It was massive bed about 7 meter thickness and it has moderate sorted grain with angular shape. The range of the tuff fragment were large about more than 2cm as it goes upward of the bed the tuff fragment were about less than 1cm. Followed by lapilli about 4.5m thickness. It has well sorted grain with angular shape tuff fragment and it was spread randomly. As the lapilli fining upward the pyroclastic grain became well sorted with poor tuff fragment where it has stratified tuff. The volcanic sandstone in this subunit was white in colour about 14.5 meter. The Bouma sequence can clearly identified in this massive structure. At the upper the subunit-3 there were parallel lamination of tuff with carbonaceous siltstone and few beds were mudstone interbedded in few massive tuff bed.

The Bouma sequence structure are such as graded bedding, convolute lamination, current ripple, parallel lamination, cross bedding in one bed layer (Figure 5.3). Some structure are same with subunit-2. The graded bedding in this subunit was appear in normal graded bedding usually result through deposition from waning flow. As the flow decelerate so the coarsest or heaviest particle are deposited first and then the finer particle. Such graded bedding typical of turbidity current at point where decrease in slope wide area with low energy. Thus the turbid sediment arrange with appropriate size and shape of sediment.

Parallel lamination in this subunit was more intense that subunit-2. Yet the parallel lamination was form due to strong current flow at upper flow regime with low and high density current. Current lineation are present at this level which appear as fabric or streakiness. The parting lineation is formed from parallel to the flow direction and indicate the trend of the paleo-current which was in unimodal.

Convolute lamination and were present fine grain tuff which usually in one rock layer. It present with small anticline, sharp syncline. Such convolution are commonly asymmetric and overturn in paleo-current direction (Tucker, 2011). It look like irregular complex and crumpling folding without any preferred orientation or arrangement and occur as dewatering effect in the deposit area. As the bed continue to deposit the energy also decrease thus it form this convolute structure and also deposited in cross bedding. The silt sand were deposited in the cross bedding in this subunit. These both structure is form in low density turbidity current at lower regime which occur at strong eruption.

To conclude, this subunit-3 occur deep sea submarine fan at upper fan. The energy level decrease as the massive beds fining upward. Some major structures present in this subunit were important to differentiate the middle fan with upper fan.

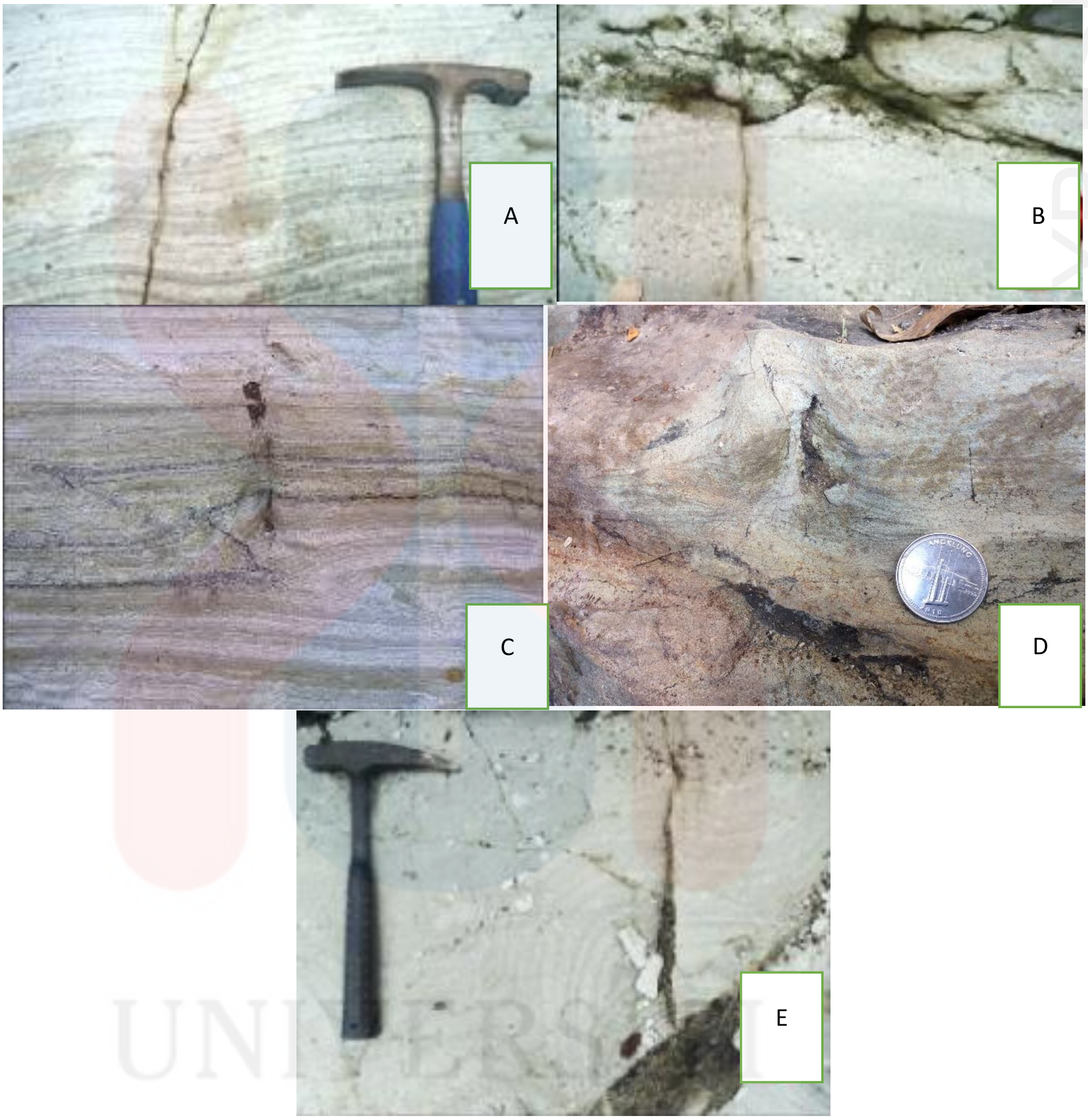


Figure 5.3.3: The picture of Bouma sequence structure in volcanic sandstone. (a) parallel lamination (b) normal graded bedding (c) current ripple (d) cross bedding (e) convolute structure

5.3.4 Subunit-4 of Semilir Formation

Subunit-4 is about 31 meter thickness and composed of volcanic sandstone. The volcanic sandstone occur in medium to thick bed with fining upward sequence in some beds and coarsening upward the upper part of the subunit-4. The volcanic sandstone consists form fine grain to coarse grain texture. Some volcanic sandstone bed in this subunit is slightly different from the previous subunit.

The volcanic sandstone in these subunit can be divided into three categories according to the grain size which are coarse, medium and fine grain volcanic sandstone (Figure 5.3.4 a). The coarse grain volcanic sandstone occur at lower and upper bed of this subunit. It appear in thick bed dark grey in colour. Volcanic sandstone at this level has very tiny tuff fragment throughout the thick bed. Other bed with fining upward sequence were volcanic sandstone similar lithology with white colour and has some similar Bouma sequence structure such as parallel lamination, cross bedding and convolute structure in a single bed layer (Figure 5.3.4 b).

The convolute structure in this subunit are slightly different from the previous subunit. It is because, the convolute structure present in flame structure (Figure 5.3.4 c). The flame structure is soft sediment which undergoes deformation in an unconsolidated sediment. The weight of the upper bed supply forces and cause it to compress. It generally occur during the sedimentation process where both saturated with water, thus it resemble flames structure and turbidity facies.

Other structure present were scour structure at the base of bed coarse volcanic sandstone and it presented at the lower bed and upper bed of this subunit-3 in erosional contact with previous subunit beds (Figure 5.3.4 d). The term of scour would be used for a small-scale erosional structure. According to Tucker (2011), it was typical features of scoured surface that cutting out of underlying sediment. The truncation of underlying laminae and the presence of coarser sediment overlying the scoured surface. The scour structure does not have any lithologies unit nor environment but the current sufficient to erode the underlying sediment and able to form during single erosional event.

In conclusion abundant of the volcanic sandstone shows the high supply of sand sized volcanic sediment and it was deposited in high energy level and at some bed the energy decrease thus creating fining upward sequence. This subunit probably occur at upper submarine fan at inner channel.

Figure 5.3.4 a: Coarse volcanic sandstone at upper facies

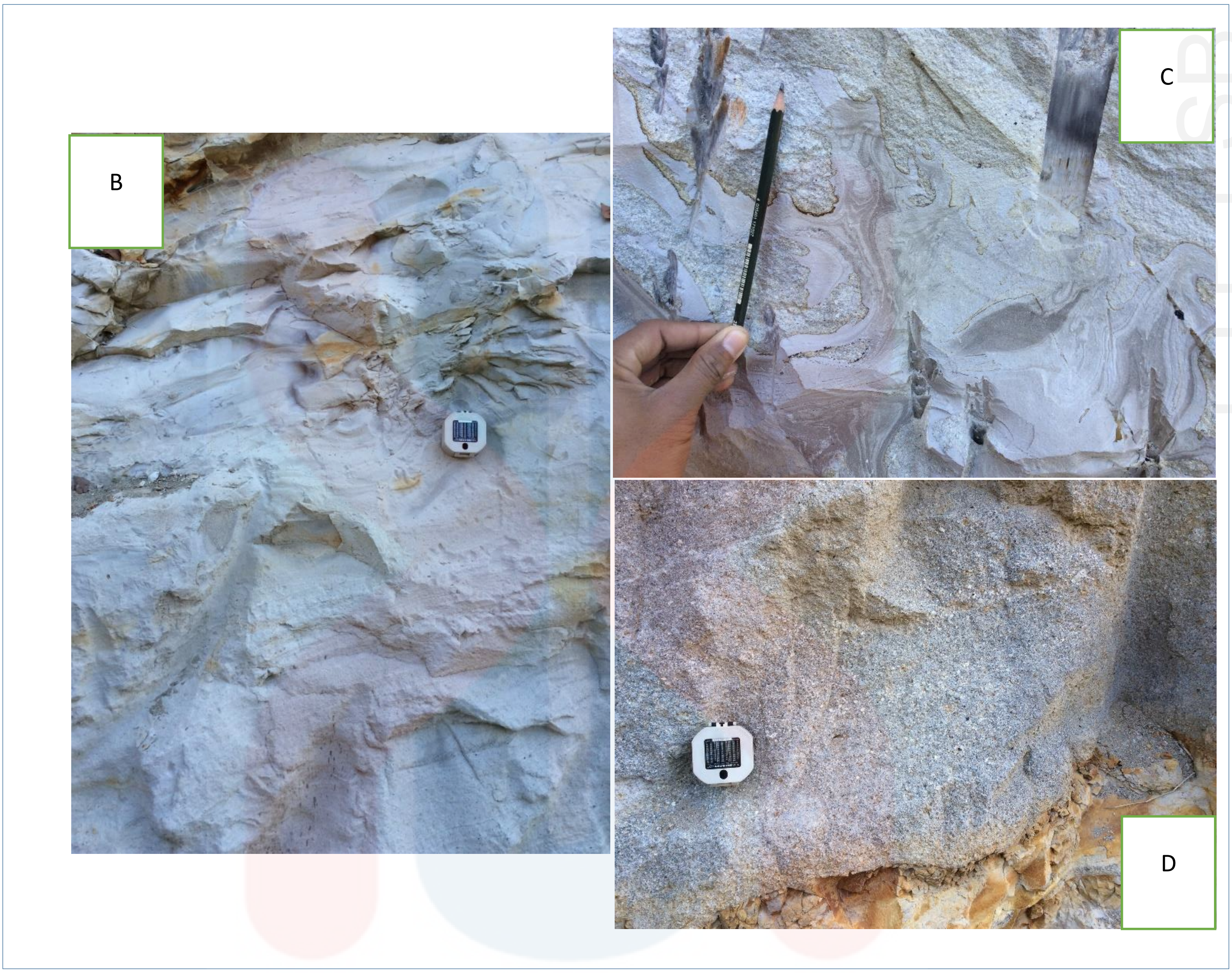


Figure 5.3.4 b,c,d: The picture in volcanic sandstone (b) Bouma sequence in a single bed outcrop (c) flame structure (d) Scour structure

5.3.5 Subunit-5 of Semilir Formation

Subunit-5 is about 8 meter and composed of tuff and it has fining upward sequence. It occur as massive bed with white colour tuff and grey. The grain size is form fine grain tuff to very fine grain tuff. Besides that the tuff seem to compact and hard.

The Bouma sequence are still present in this subunit and similar to previous subunit (Figure 5.3.5 a). The energy that deposited this subunit was very low. The tuff which was original from tephra deposited in compact and hard in this subunit and previous unit (Figure5.3.5 b and c). In conclusion this subunit believe occur at deep sea marine in submarine fan at inner fan channel fill.

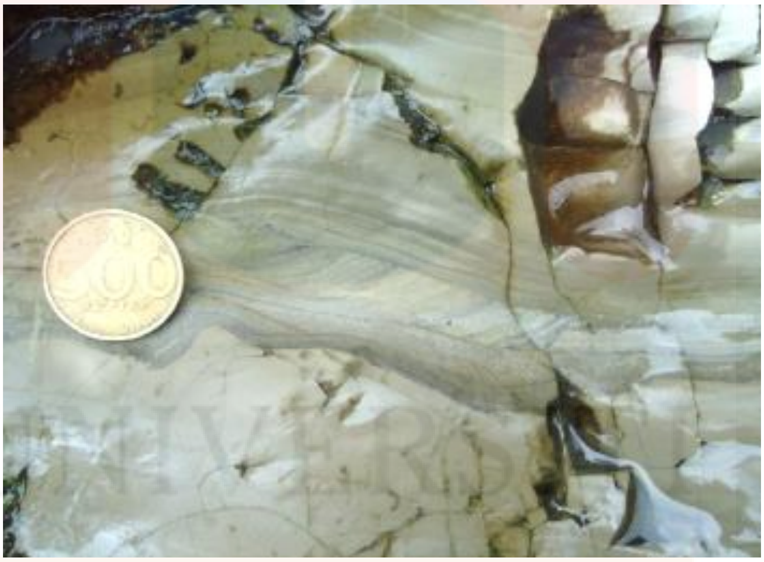


Figure 5.3.5 a: cross bedding and parallel lamination on fine tuff

Figure 5.3.5 b: Fine tuff

Figure 5.3.5 c: Very fine tuff present in compact and hard and some parallel lamination near compass

5.4 Interpretation of Semilir Formation

Based on the parameter of facies associations, lithologies and sedimentary structure in study area, the depositional environment of Semilir Formation has deep marine which form at underwater submarine fan. It has turbidite deposition environment because a turbidity current are founded in the area which has density currents operate or turbidity. It can occur at few environment such as lakes, delta, reservoir, continental shelves and deeper ocean basin.

In order to identify the turbidity facies few features must occur in the bed of current such as sharp base with scour, graded bedding and Bouma sequence. The classical turbidites facies can be divided into three attribute, firstly the beds has to be laterally covers about hundreds of meters, secondly, the they has to parallel sided and has small thickness bed but it is about hundreds of meter and third it logically to use Bouma model for this description and interpretation. These facies can be classified such as massive sandstones, pebbly sandstone, clast supported conglomerates and chaotic matrix-supported pebbly sandstone and conglomerate (Walker, R.G., 1970).

The Bouma's Turbidite Facies by Walker (1984) has few sedimentary features which under classical turbidity and it present in the lithology of the study area. The feature are shown in Figure 5.4.

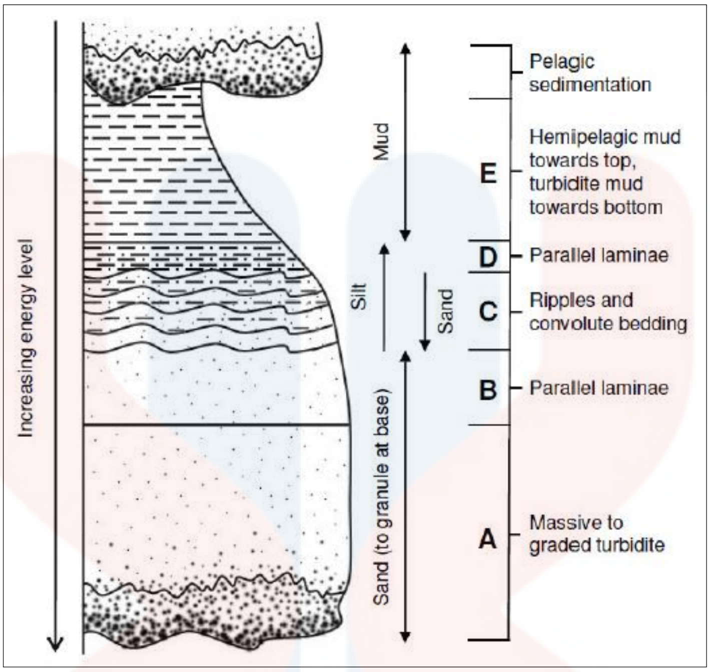


Figure 5.4: Bouma sequence division (*Source: Earth Science*,*2014*)

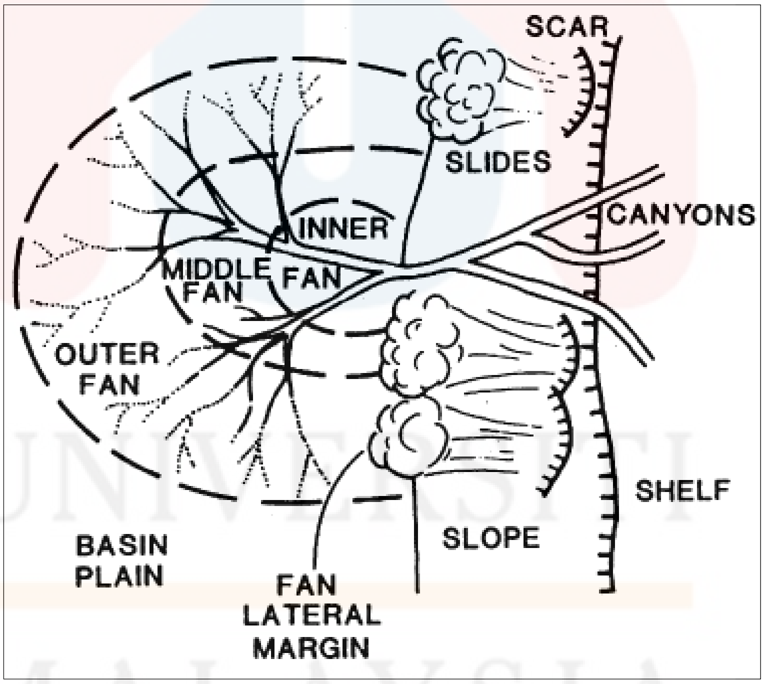


Figure 5.5: Submarine fan at deep marine environment (*Source: Sedimentology, 2003*)

Subunit-1 of Semilir formation probably occur at middle submarine fan channel. This unit dominant with volcanic sandstone and at lower part there were some calcareous claystone. At this part the sedimentary structure that characterize it channel because the volcanic medium to coarse grain volcanic sandstone and there where erosional contact on the bedding. It has low turbidity current which dominated by medium sand-sized deposits to fine volcanic sandstone. Only parallel lamination are found in this subunit. This facies deposited during weaker eruption phases and it indicate low energy of wave action and occur during the fallout of soft sediment. There it deposited at channel supra lobes of middle fan.

Subunit-2 of Semilir formation the energy level form under strong explosion and has high density turbidity current. This subunit also present of channel which where erosional contact on the beddingThe Bouma sequence present in this subunit were graded bedding, current ripple and parallel lamination on volcanic sandstone. This indicate upward sedimentation smoothing pattern. According to Mutti concept the fine grain facies is upper layer turbidity staining structure founded graded bedding however coarse grain facies is not very thick however this subunit form high and low density current. Thus it believed form at deep marine depositional environment at channel portion of supra channel lobe at submarine middle fan.

Subunit-3 of Semilir formation the energy level decrease as the bedding sequence increase. These subunit has gradation contact from one bedding to another bedding and it appear massive. It believe the rock at lower part undergoes high debris flow because it deposited massive coarse grain pebbly volcanic sandstone then the sequence fining upward from coarse grain facies to fine grain facies. All Bouma sequence structure present in this subunit such as current ripple, parallel lamination, graded bedding, cross bedding and current ripple. Thus it believed form at deep marine depositional environment in inner fan or upper submarine fan deposit.

Subunit-4 of Semilir formation has high to medium energy level. It has fining upward sequence besides that the Bouma sequence structure present in a single bed. There were also scour structure present at volcanic sandstone. It has sharp and some erosional contact between the bedding and there were channel between the bedding. The volcanic sandstone at the upper part is compact and hard. Thus it believed form at deep marine environment at inner channel at upper submarine fan.

Subunit-5 of Semilir formation has fine to very fine tuff. It deposited at low energy level. The tuff at this subunit is compact and very hard. There were cross bedding and parallel lamination at this part. Thus, it has deep marine depositional environment at inner fan at upper submarine fan.

5.5 Model of Depositional Environment

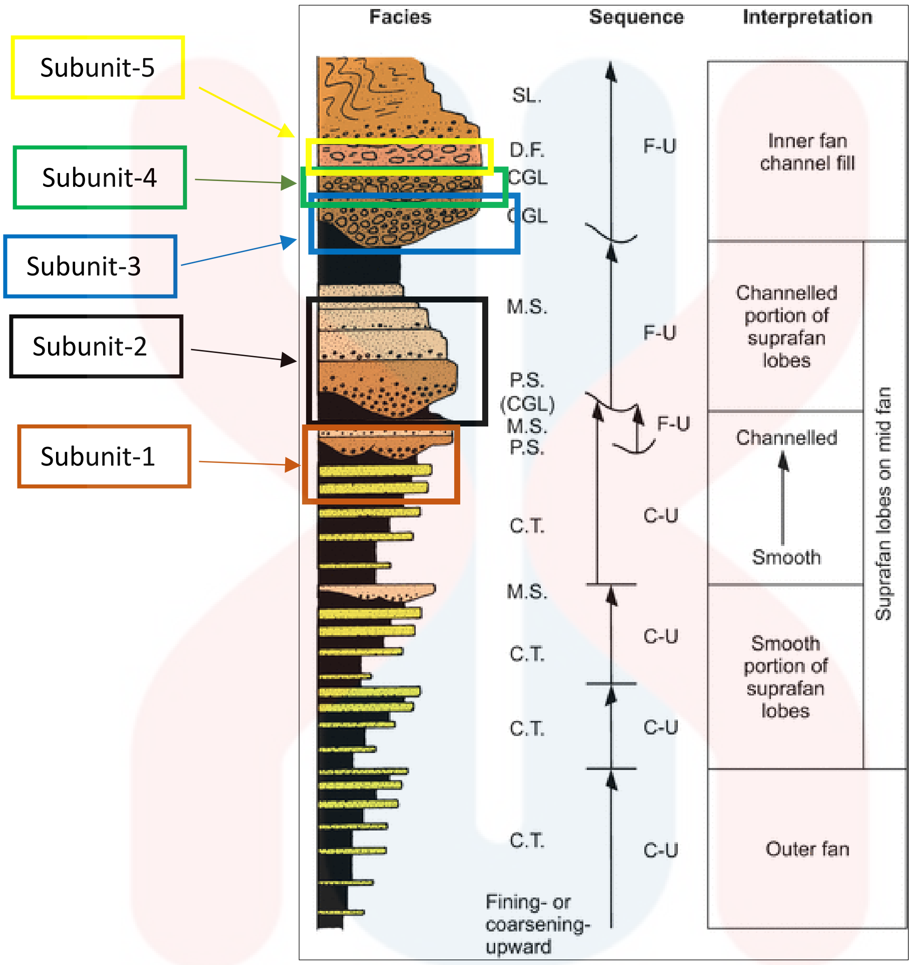


Figure 5.6: Hypothetical submarine fan stratigraphic sequence by fan progradation (Depositional Model)

5.6 Summary

The depositional environment of volcanic rock of Semilir Formation in Hargomulyo was interpreted based on bed thickness, lithology and sedimentary structure. Few turbidity facies feature namely Bouma, Walker and Mutti Turbidity facies was used to interpret the subunit and depositional environment. The Semilir Formation at this area under middle to upper inner channel fill submarine fan in deep marine environment.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In conclusion, the objective for this research conducted in Hargomulyo, Yogyakarta, Indonesia has been achieved. First a geological map of Hargomulyo area able to update scaled 1:25 000.

Geological map of Hargomulyo area consists of six lithological unit and these unit were explained from the oldest rock unit to the youngest rock unit. The oldest rock form under Kebo-Butak Formation aged late Oligocene at pre volcanism period the lithological unit where it has tuff, sandy tuff, tuffaceous sandstone, green tuff and sandstone. In Early Miocene during volcanism period under Semilir Formation the unit comprise of volcanic sandstone, lapilli, tuff breccia and tuff interfinger. At post volcanism period under Nglanggeran formation it consists only one type of breccia which was andesite breccia. The geology of study area were comprised hilly to mountainous topography.

The depositional environment of study area were classified deep marine depositional environment at Submarine fan. It can be divided into two fan namely submarine middle fan and submarine upper fan. The facies were classified by bed thickness, lithology and sedimentary structure. Few turbidity facies feature namely Bouma, Walker and Mutti Turbidity facies was used to interpret the subunit and depositional environment. Subunit-1 and 2 under submarine middle fan while Subunir-4, 5 and 6 under submarine upper fan.

6.2 Recommendation

Further research and analysis should be conducted using petrography and geochemistry method to further describe about provenance study of a formation. This is because a petrographic analysis give a deeper investigation of chemical and physical features of a particular rock sample. The petrographic analysis can be done through macroscopic to microscopic investigations of the rock sample. Geochemistry method provide a clear picture of melting of volcanic system, thus it can use for dating to determine the age of the rock to get better data interpretation. Lastly, other way to determine the depositional environment by determining paleo-current. It is the indicator of flow at the time the sediment were deposited. The flow direction of sedimentary could give an interpretation of depositional process.

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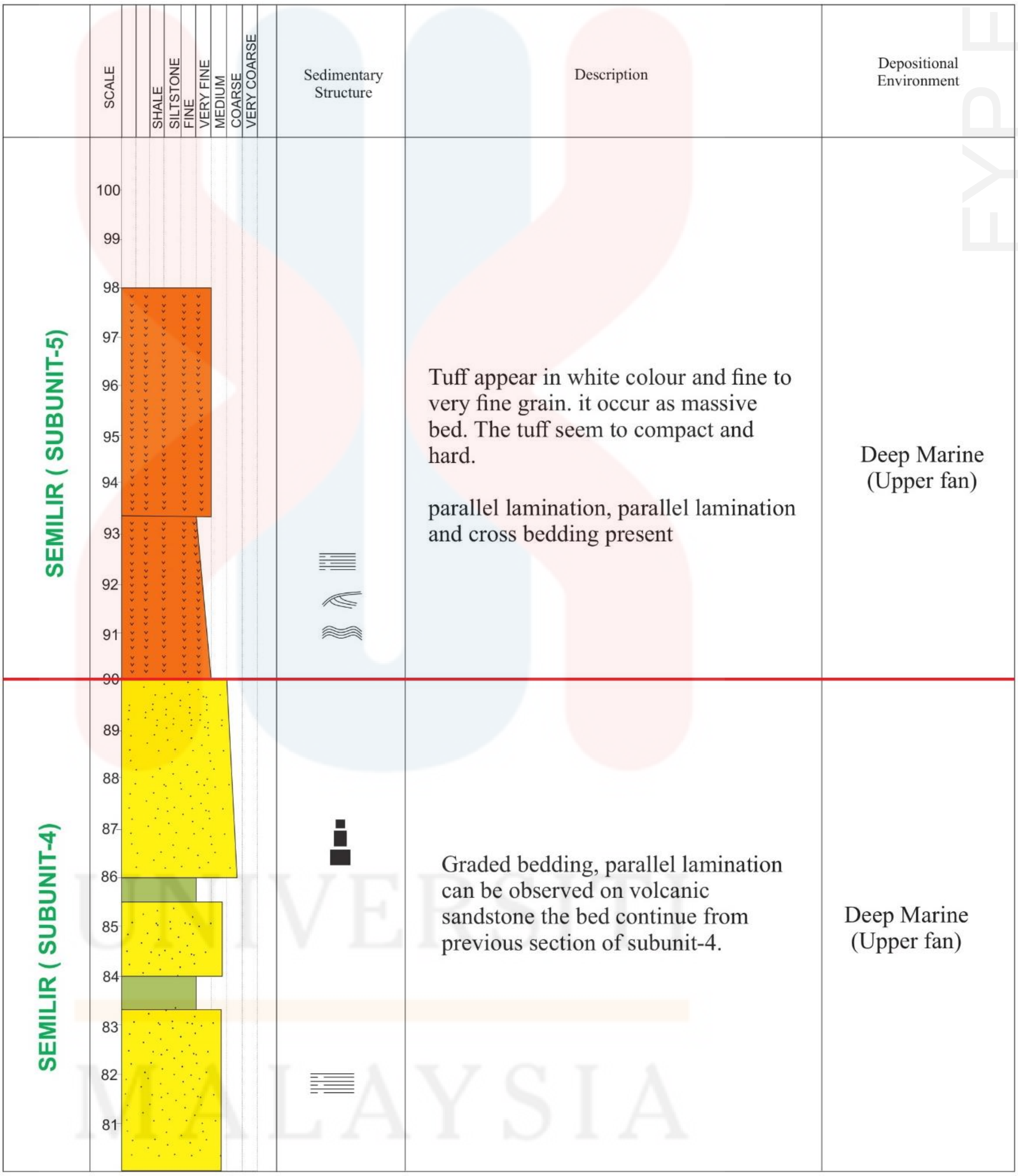
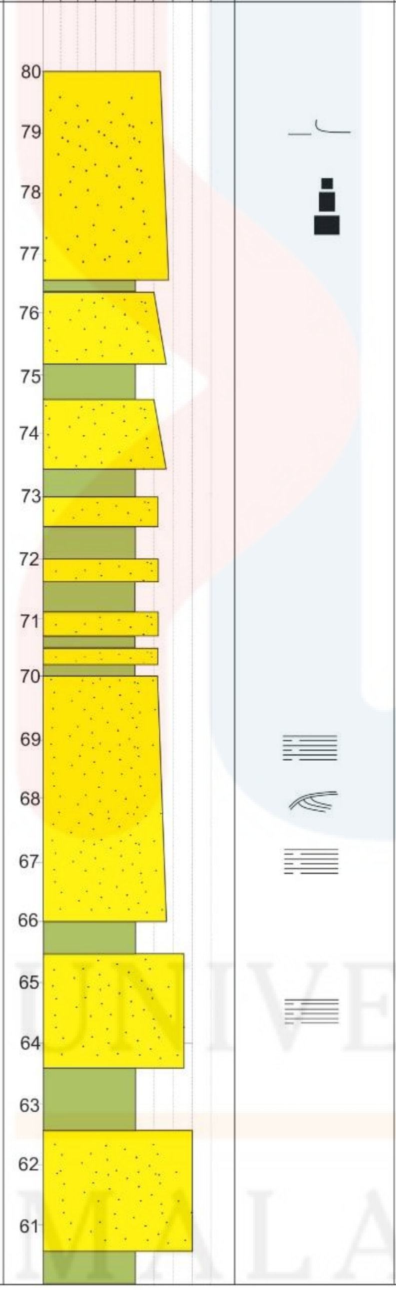
APPENDIX 2

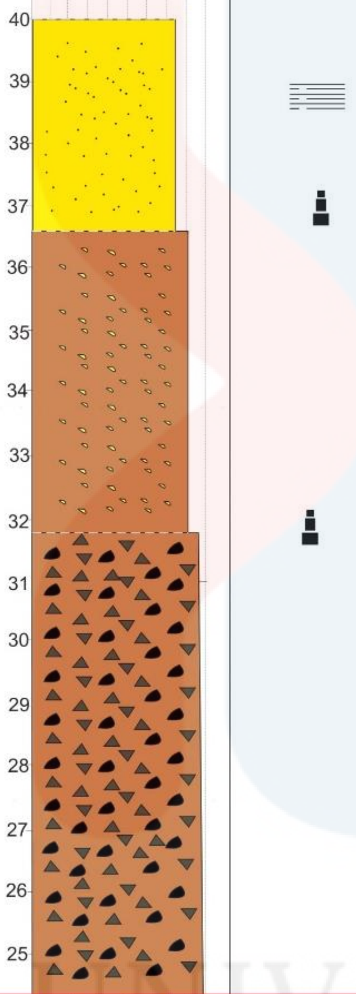
350	355	280	270	30	168	170	340	180	220
350	355	260	270	30	40	30	260	180	320
350	155	260	96	30	40	30	245	175	340
350	155	260	345	170	40	338	256	175	40
350	155	50	345	80	84	338	80	175	240
174	240	50	345	10	43	344	340	268	335
355	240	50	229	10	43	344	340	280	335
355	240	50	229	10	43	350	340	124	340
355	280	260	270	161	170	220	340	140	332
355	280	38	290	92	84	45	264	120	265

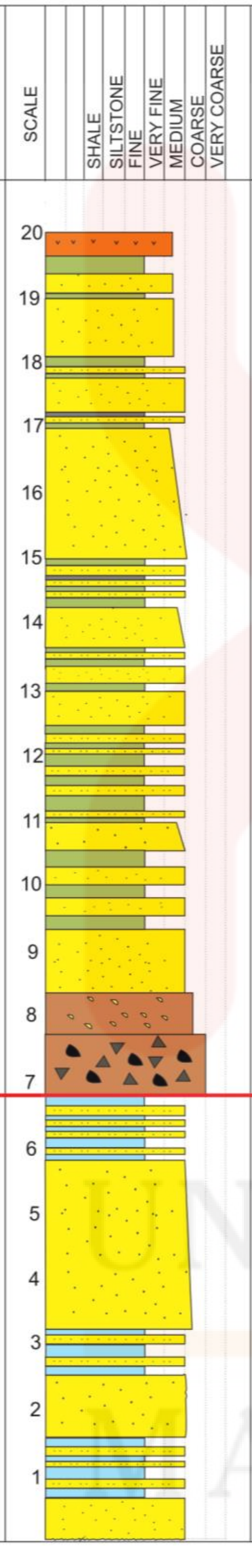
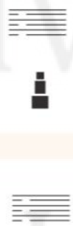
APPENDIX 3

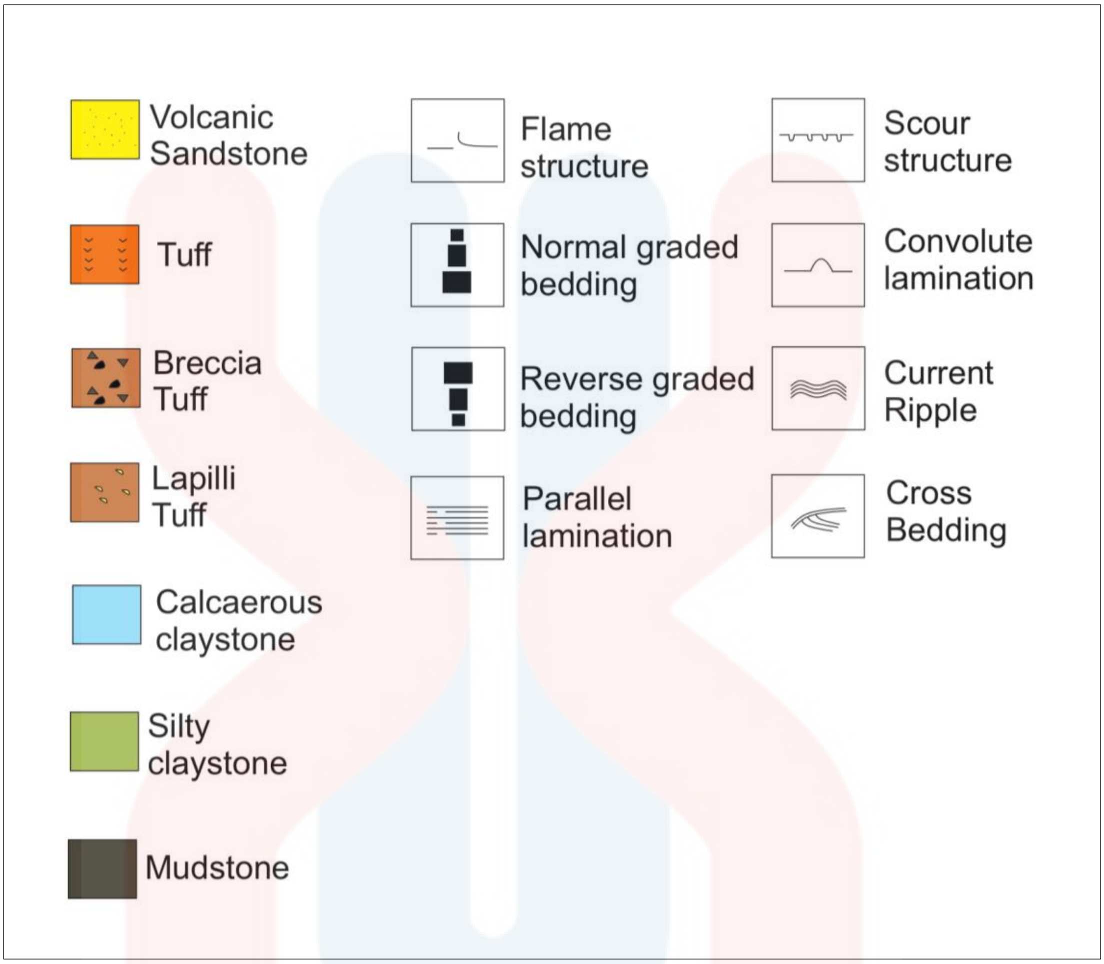

SCALE
SHALE
SILTSTONE
FINE
VERY FINE
MEDIUM
COARSE
VERY COARSE
Sedimentary Structure
Description
Depositional Environment
SEMILIR (SUBUNIT-5)
100
99
98
97
96
95
94
93
92
91
90
Tuff appear in white colour and fine to very fine grain. it occur as massive bed. The tuff seem to compact and hard.
parallel lamination, parallel lamination and cross bedding present
Deep Marine (Upper fan)
SEMILIR (SUBUNIT-4)
89
88
87
86
85
84
83
82
81
Graded bedding, parallel lamination can be observed on volcanic sandstone the bed continue from previous section of subunit-4.
Deep Marine (Upper fan)

	SCALE / SHALE / SILTSTONE / FINE / VERY FINE / MEDIUM / COARSE / VERY COARSE	Sedimentary Structure	Description	Depositional Environment
SEMILIR (SUBUNIT-4)			Some of volcanic sandstone is dark grey, coarse grain with small tuff ash particles, while some volcanic sandstone white range from medium to fine grain. The were parallel lamination, flame structure and cross bedding	Deep Marine (Upper Fan)

Unit	SCALE (SHALE, SILTSTONE, FINE, VERY FINE, MEDIUM, COARSE, VERY COARSE)	Sedimentary Structure	Description	Depositional Environment
SEMILIR (SUBUNIT-4)	59–60		The volcanic sandstone has coarsening upward. The volcanic rock is dark grey in colour and has coarse texture. it has some tuff ash particles.it has scour structure	Deep Marine (Upper Fan)
SEMILIR (SUBUNIT-3)	41–59		At this level it has volcanic sandstone which continue from the previous section. The volcanic sandstone has fining upward sequence. it appear in white colour. The the of of this section tuff fine to very fine texture present and there are some mudstone interbedded within tuff. At this section the bed has gradational contact from one bed to another bed. it appear in massive bed. The mudstone and tuff has sharp contact. A complete Bouma sequence structure such as graded bedding, convolute lamination, current ripple, parallel lamination and cross bedding appear in outcrop.	Deep Marine (Upper Fan)

	SCALE / SHALE / SILTSTONE / FINE / VERY FINE / MEDIUM / COARSE / VERY COARSE	Sedimentary Structure	Description	Depositional Environment
SEMILIR (SUBUNIT-3)			The breccia tuff or also known as pebbly volcanic sandstone is appear very coarse white tuff fragment range 1-2.5 cm. It decreases the grain size and the fragment as it fining upward. At this part it also consist of lapilli and volcanic sandstone. The lapilli appear greyish blue colour and has coarse grain while volcanic sandstone is white in colour and medium grain There were carbonceous siltstone and claystone can be founded interbedded in volcanic sandstone. Parallel lamination are present.	Deep Marine (Upper Fan)
SEMILIR (SUBUNIT-2)			White tuff with fine grain texture and the grain size increase where volcanic sandstone found at the top of larger of subunit 2. The volcanic sandstone is white In colour	

		Sedimentary Structure	Description	Depositional Environment
SEMILIR (SUBUNIT-2)			Composed of Tuff breccia, Lapilli Tuff, valcanic sandstone and tuff. Tuff breccia whitish grey in colour with tuff fragment range 0.2-0.5mm coarse grain. Lapilli tuff greyish blue in colour and has medium to coarse grain. There were carbonceous siltstone and claystone can be founded interbedded in volcanic sandstone. The volcanic sandstone appear in white colour with medium grain. Some of Bouma sequences present in the beds such as parallel lamination, current ripple	Deep marine (Middle fan)
SEMILIR (SUBUNIT-1)			Volcanic sandstone massive bed with light grey colour which has medium to fine grain,black lamination with siltstone grain, carbonaceous siltstone interbedded with calcaerous claystone. Parallel lamination in volcanic sandstone.	Deep marine (Middle fan)


Volcanic Sandstone
Tuff
Breccia Tuff
Lapilli Tuff
Calcaerous claystone
Silty claystone
Mudstone
Flame structure
Normal graded bedding
Reverse graded bedding
Parallel lamination
Scour structure
Convolute lamination
Current Ripple
Cross Bedding