GEOLOGY AND DEPOSITIONAL ENVIRONMENT OF SAMBIPITU FORMATION IN BUNDER AREA, GUNUNG KIDUL REGENCY, INDONESIA

by

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

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DECLARATION

I declare that this thesis entitled "Geology and Depositional Environment of the Sambipitu Formation in Bunder Area, Gunung Kidul Regency, Indonesia",is the result of my own research except as cited in the references .The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

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

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GEOLOGY AND DEPOSITIONAL ENVIRONMENT OF THE SAMBIPITU FORMATION IN THE BUNDER AREA, GUNUNG KIDUL REGENCY, INDONESIA.

ABSTRACT

Yogyakarta situated in the Central Java and the city is located only 30km from Merapi volcano area. The study area is located at the Bunder, Patuk Village, Gunung Kidul Regency,Special Provine of Yogyakarta, Indonesia. The geology, sedimentary structure and sedimentary facies need to be updated for the accuracy information and data of geology in Bunder area especially in determine their depositional environment. The objective of this study is to update a geological map of the area with scale of 1:25,000, to determine the deposition environment of the Sambipitu formation and also to analyse the sedimentary facies in the study area. The methods used in this study consist of two parts. The first is making lithostratigraphic columns from the combination observation of field work and laboratory .Second, petrographic observations from the rock sample to determine the composition of the constituent facies and lithological..At the upper part of the study area, it occurred pyroclastic-epiclastic rock and the alternation between sandstone with claystone, tuffaceous sandstone -siltstone with fragment tuff and limestone. The alternation of packestones and wackestones with marls also can be found in the Bunder area at the lower part of the study area.Based on the previous stratigraphic measurement data and analysis of association ichnofossil groups, the interpretation depositional environment from Lower Sambipitu Formation to Upper Sambipitu Formation shows the fluctuation of seawater level due to transgression and regression process in submarine fan.

Keywords: Depositional environment, Sambipitu Formation, sedimentary rock facies and lithostratigraphy, submarine fan.

GEOLOGI DAN PEMENDAPAN PERSEKITARAN FORMASI SAMBIPITU DI KAWASAN BUNDER, KABUPATEN GUNUNG KIDUL, INDONESIA.

ABSTRAK

Yogyakarta terletak di Jawa Tengah dan bandarnya terletak hanya 30 km dari kawasan Merapi volcano.Kawasan kajian terletak di Desa Bunder, Kecamatan Patuk , Kabupaten Gunung Kidul, Provinsi daerah istimewa Yogyakarta, Indonesia.Objektif kajian ini adalah untuk mengemaskini peta geologi kawasan tersebut dengan skala 1:25,000, seterusnya adalah untuk menentukan persekitaran pemendapan pembentukan Formasi Sambipitu dan juga untuk menganalisis fasies sedimennya.Antara metode digunakan dalam kajian ini terdiri daripada dua bahagian. Pertama,menghasilkan set lithostratigrafi daripada pemerhatian gabungan kerja lapangan dan penelitian di makmal.Kedua, pemerhatian petrografi dari sampel batu yang diambil untuk mengidentifikasikan fasies sedimen.Dari segi komposisi taburan batuan,bahagian atas kawasan kajian terdapat batuan pyroclastik-epiclastik dan juga terdapat pertukaran antara batuan tanah liat dengan batu pasir tufan ,batu pasir tufan dengan siltstone dan dengan sedikat fragmen dari tufa dan batu kapur.Silih ganti packstones dan wackstones dengan marls juga boleh didapati dalam kawasan selatan Bunder.Berdasarkan data pengukuran dan analisis persatuan ichnofossil kumpulan stratigrafi sebelum, alam sekitar tafsiran pengenapan daripada Lower Formasi Sambipitu kepada Upper Formasi Sambipitu menunjukkan fluktuasi naik dan turun muka air laut iaitu proses transgresi dan regresi dan menunjukkan kawasan submarin fan.

Kata Kunci; Pemendapan Persekitaran,Formasi Sambipitu,fasies batuan sedimen dan lithostratigrafinya,submarin fan.

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LIST OF ABBREVIATIONS

Cal	Calcite
Cm	Centimetre
Cpx	Clinopyroxene
XPL	Cross polarized light
E	East
Ft	Feet
GIS	Geographic Information System
GPS	Global Information System
Hbl	Hornblende
Km	Kilometer
km^2	Kilometer per square
mm	Milimetre
m	Metre
Mya	Million years ago
N	North
Opq	Opaque mineral
Pl	Plagioclase
PPL	Plane polarized light
S	South
W	West

LIST OF SYMBOLS

^{0}	Degree
^{0}C	Degree Celcius
=	Equals
%	Percentage
$\sigma 1$	Maximum Principle Stress
$\sigma 3$	Minimum Principle Stress

CHAPTER 1

INTRODUCTION

1.1 General Background

Indonesia located in Southeast Asia which lay between the two famous oceans, the Indian Ocean and the Pacific Ocean. An about 8,844 of the island in Indonesia and 922 of the island was inhabited which comprises Sumatra, Jawa, Borneo (known as Kalimantan in Indonesia), Sulawesi, and New Guinea, according to the government of Indonesia .Most of these islands mountainous, with peaks ranging between 2,000 and 3,800 meters (6,562 and 12,467 ft) meters above sea level. Jawa lies between Sumatra to the west and Bali to the east. Jawa is about 138,800 km^2 with a population of over 141 million and dominates with their politically, economically and culturally.

There are several parts of UNESCO world heritage sites in Jawa and the famous historical building such as Borobudur Temple, Prambanan Temple, Sangiran Early Man Site. The volcanic eruption had close information of the result of Jawa formed and well known as the 13th largest island in the world .In Indonesia, Jawa also categorized as one of the largest by landmass. Along the island, there are a series of volcanic mountains formed due to the fact that Indonesia has relatively occurred by the tectonic and volcanic activities. Due to the plate of Eurasian, Indo-Australian, Pacific, and Philippine Sea Plate Eurasian, the volcanic mountain lies on the convergence of the plates. It is about 5,500 km long of the fault of the Sunda which called as mega-thrust fault that the Pacific Plate is thrusting north-eastward towards

the sub-ducting Sunda plate. According to the Ashari and Pandita (2005), there is a lot of volcanic activity in Central Jawa, the volcanic activity started from Formation of Kebo-Butak and about to end in Nglanggeran Formation. Specification in this study is depositional environment in Bunder Village, Patuk District, Gunung Kidul Regency, Special Province of Yogyakarta, Indonesia. The depositional environment will determine due to the facies occurrences that relate to the physical and biological process in the study area.

1.2 Study Area

In Jawa, the main city and most popular city in Jawa Island is Yogyakarta which the capital of the Yogyakarta Special Region. Wonosari is the nearest town rather than Yogyakarta and the Sambipitu area located in between the two locations which about in the Yogyakarta-Wonosari Km-13 Sambipitu Wonosari, Yogyakarta. Along the main road side, the area consists of the main river named as Oyo's river.

Based on Figure 1.1, the city of Yogyakarta coordinate is 7° 47' 49.4448" South and 110° 22' 13.9044" East, meanwhile for the study area, the coordinate is 7 ° 53 '20 730 " South and 110 ° 32' 17 180" East From the observation, the study area located in the eastern of the Jawa and near with the coastal area.

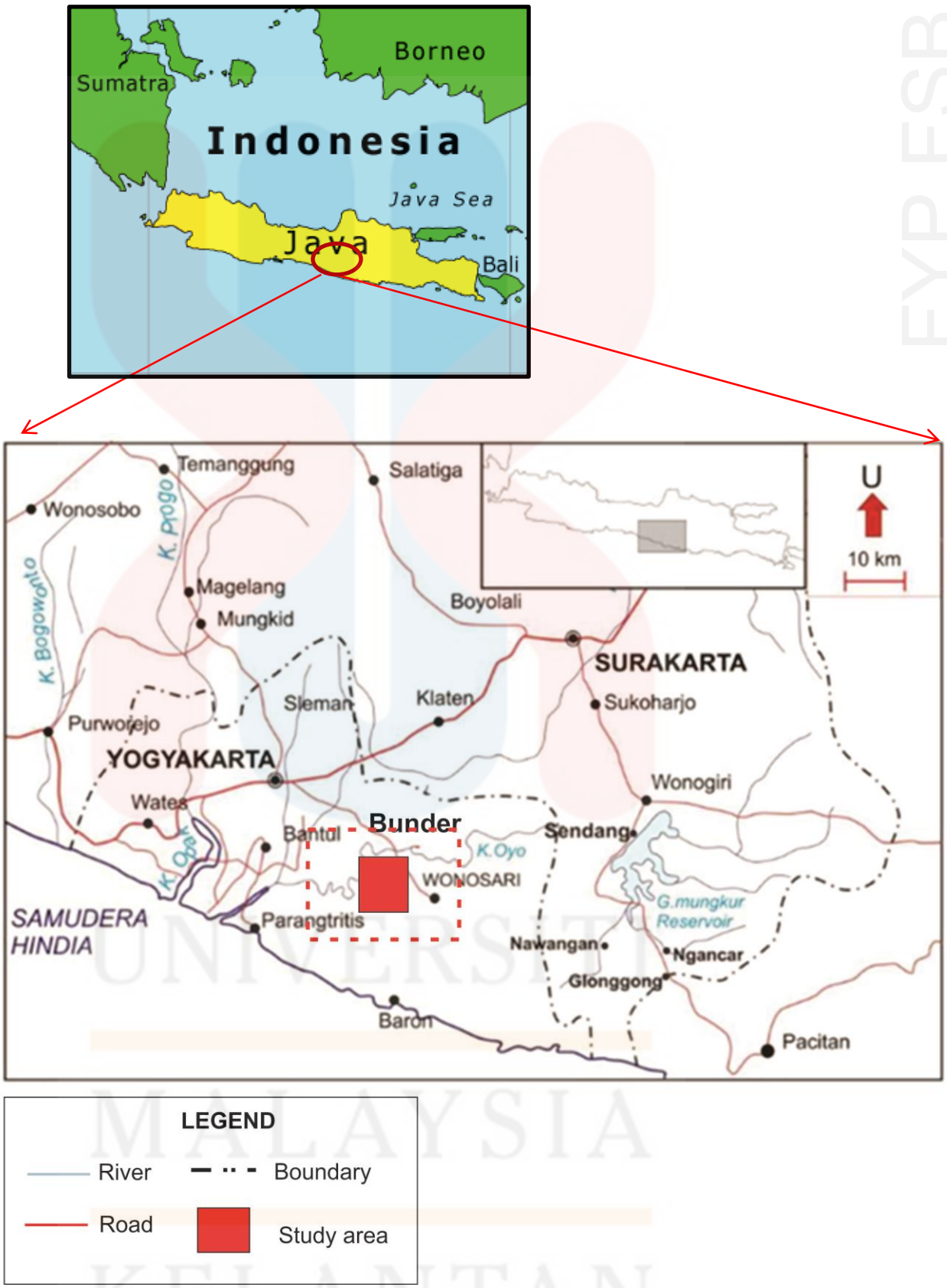


Figure 1.1: Jawa Island and Bunder, Yogyakarta, Indonesia (Surono, 2013)

1.2.1 Demography

The barriers of the mountains and the sea have protected the character and traditions of many groups of ethics. From Figure 1.2, in Indonesia, the people distribution collected by their ethnic group which Jawanese, Sundanese, Malay, Batak, Madurese, Betawi and others. Indonesia's largest ethnic group was constituted by the Javanese (40.1%) roughly about one-third of the total population. In the regions of the central and eastern part of Jawa, mostly the part covered by the agricultural area. For Jawa's western region, including the city of Bandung, is the homeland of the Sundanese (15.5%) which the second largest ethnic group in Indonesia. Next, the ethnic of Madurese (3.0%) located northeast of Java, Indonesia's third largest ethnic group which this ethnic raise cattle for cultivating wet-rice paddies. In the east of Java, the constituted by Balinese that historically they are the only non-immigrant practitioners of Hinduism. Roughly, the Jawanese work in paddy cultivation at the study area.

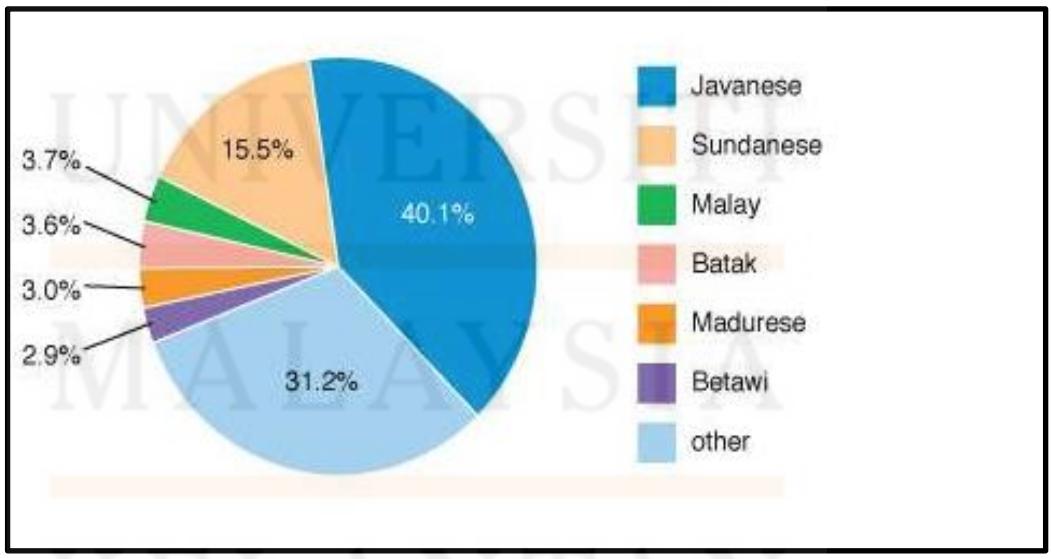


Figure 1.2 : Distribution of ethnic composition in Indonesia (Mohamad,2010)

1.2.2 Rainfall

The study area nearby Ngalang area, as shown in Figure 1.3 below, the climate in this area is tropical climate which the non-arid climate in which all twelve months and no freezing of the topographic features. The average annual temperature of Ngalang is 25.9 °C which about 1965 mm of precipitation falls annually. The least amount of rainfall occurs in September. The average in this month is 30 mm. With an average of 332 mm, the most precipitation falls in January. The graph in Figure 1.4 shows the maximum temperature per month for Ngalang area state is 26.6°C which in October while the minimum in July average temperature is 25.0°C.

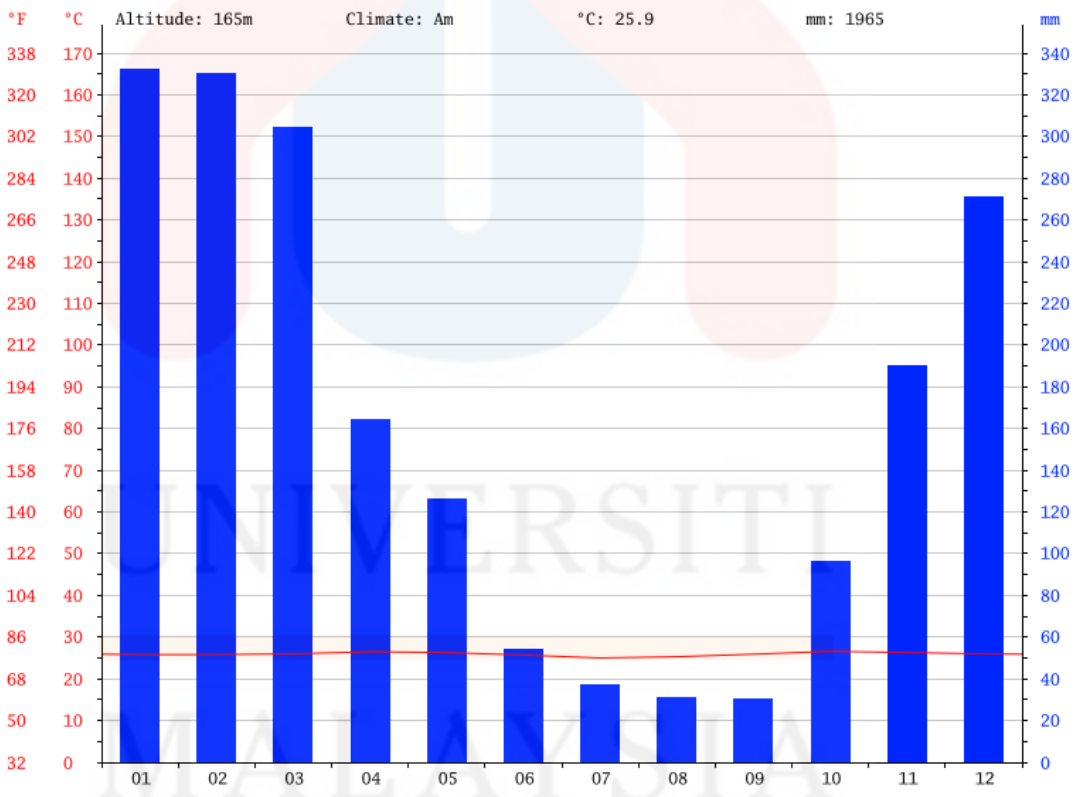


Figure 1.3 : Climate graph of Ngalang state (Source: climate-data.org, 2015)

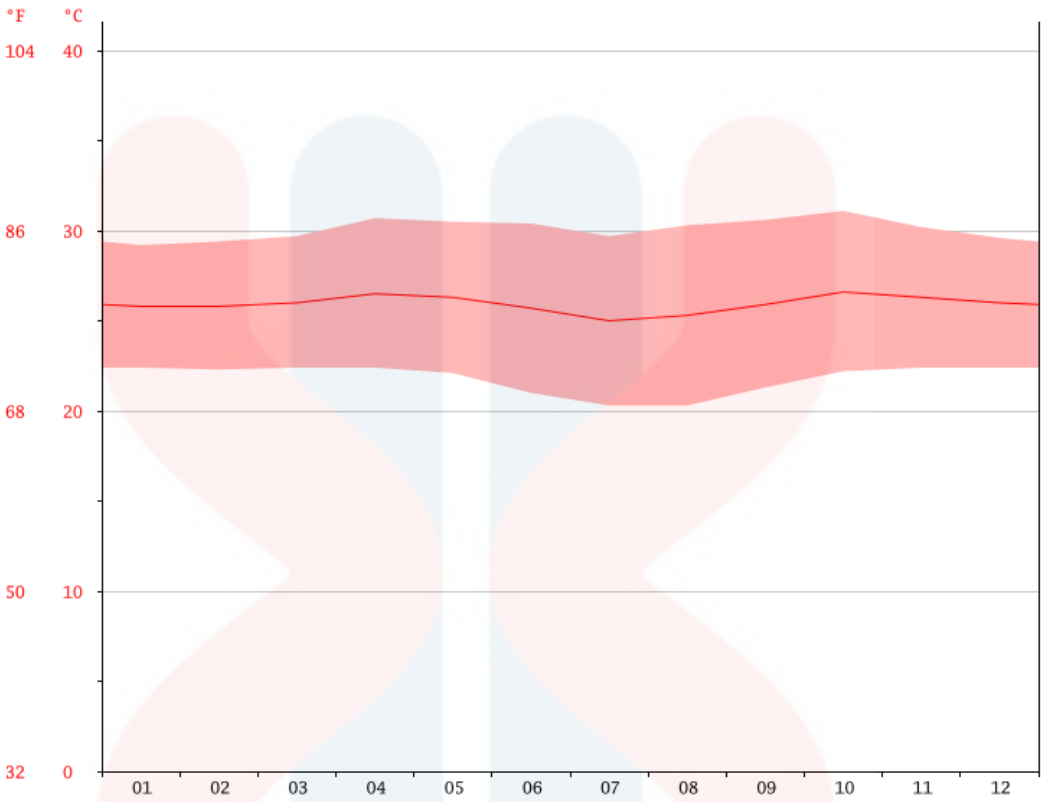


Figure 1.4: Graph of average temperature in Ngalang per month (source: World Meteorological Organization, 2015)

1.2.3 Land Use

Almost 55% of the study area covered with orchard area and some part of agricultural where paddy main work for citizens. Figure 1.5 shows that agricultural activity at lowlands area such as the river area. The preserved forest located in the north area of the study area.

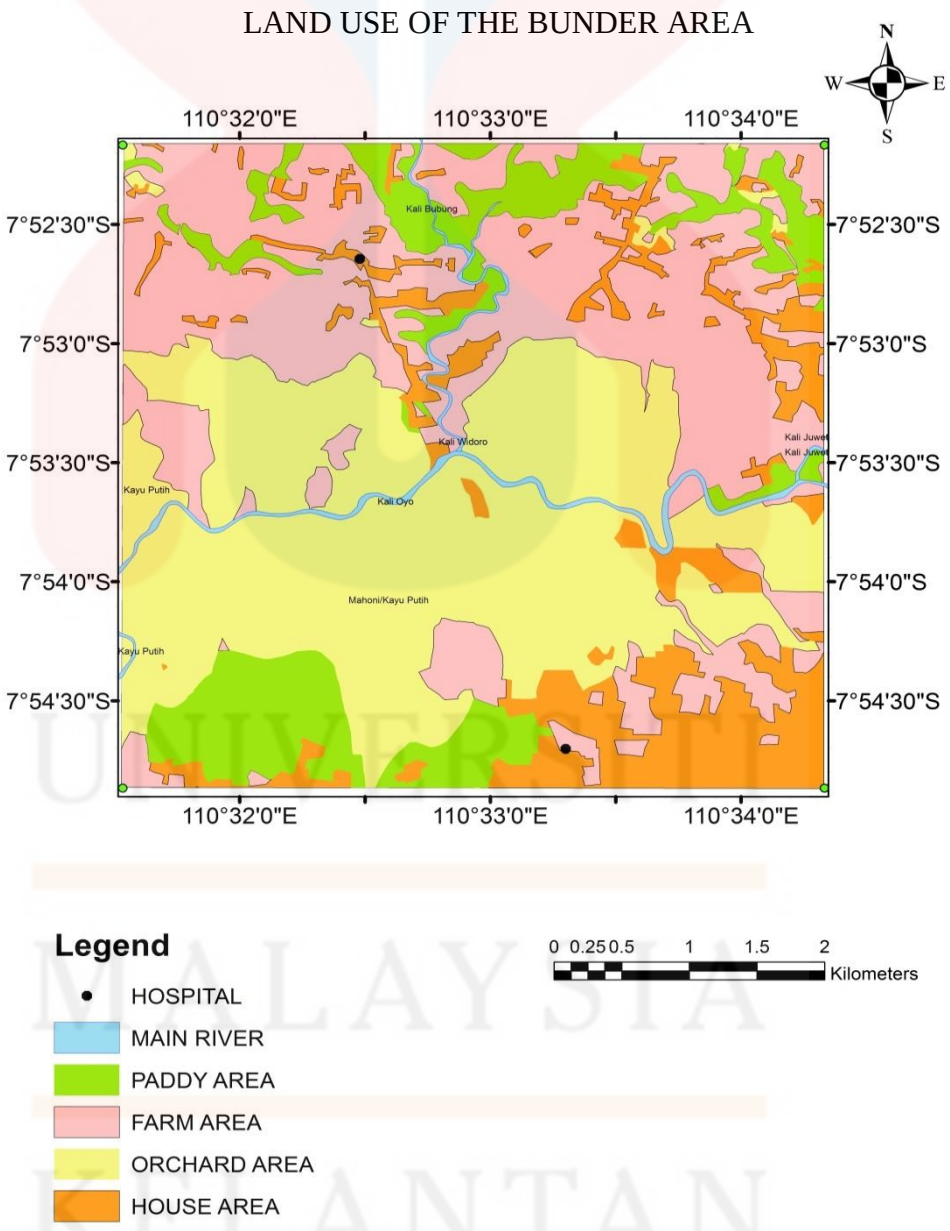


Figure 1.5: Landuse map of Bunder area, Indonesia (Geospatial, Indonesia, 2011)

1.2.4 Social Economic

Special Province of Yogyakarta (3.133km^2) known with their major economic sector of vegetation. Special province Yogyakarta‘s topography is covered with the province’s lowland and at the north area is the highland which bordering Central Jawa at the foothill of Gunung Merapi.

Bunder and Sambipitu area was a famous place for paddy field which available for the citizen in the area to work due to the land suitable for paddy cultivation and for food agriculture. The flat area shows the suitability for agriculture activity. For the information, the main food for peoples in the Sambipitu area is rice. Therefore, the paddy field widely occurs in this area and the worker comes from ethnic of Jawanese.

1.2.5 Road Connection

Figure 1.6 : Main road of Yogyakarta area that connects Bunder and Sambipitu area.

The study area has several ways to access. For example, in Yogyakarta, there is a way to go to the study area using the main route such as “Jalan Sambipitu-

Yogyakarta". Thus, the study area can be accessed easily due to their public transport. There are many types of public transportation, such as Inter-city Bus, Metromini Bus, Trans Bus, School Bus, and Campus Bus. Meanwhile, the common form of public transportation for long trips is bus and train, usually located in between cities and district.

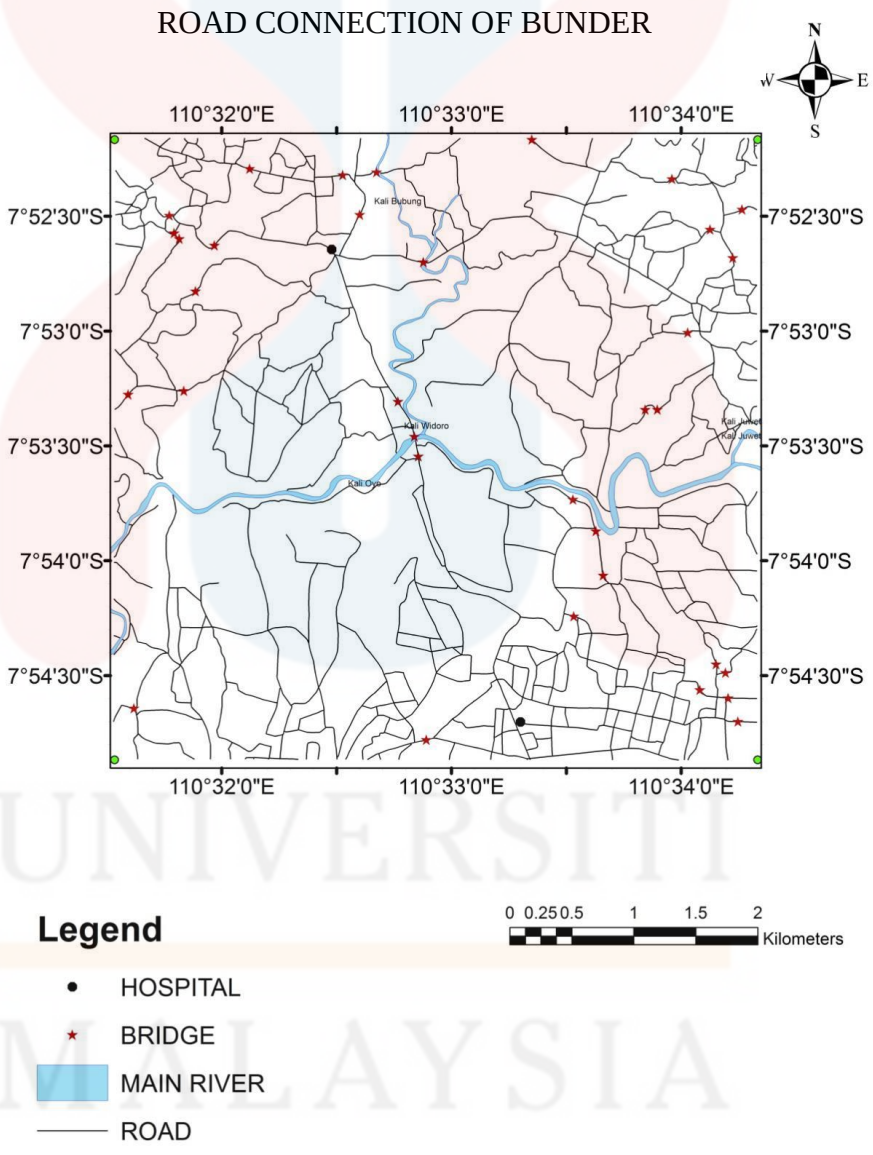


Figure 1.7. : Road Connection map shows the main road used by the locals. (Geospatial Indonesia, 2011)

1.3 Problem Statements

This will focus on the formation of structural and sedimentary rock of the Bunder area in the special province of Yogyakarta, Indonesia. The first problem, the outdated of the geological map of the study area needs more and details on the lithology unit and others geology structures. This study needs more information regarding the sedimentary structure and structural geology information previous of study in the special province of Yogyakarta specifically based on the study of fossil instead of the structure of geology. In order to realize changes in the geology of due to the geological process, the data of geology need to be updated. Besides, need accurate data of sedimentary facies so that can improve the depositional detail data of the sedimentary facies in the study. In addition, the rocks in the Bunder area not clearly exposed because of the chemical, physical and biological weathering process occurred on the surface of the rocks.

The weathering process had difficulties to observe and analyse rocks. The paddy area field that has been evolved can affect the geology in the study area. So, a proper of the identification of the rock and the thin section should be conducted. The thin section activity and the observation of petrography important in order to determine the texture and mineral occurred.

1.4 Objective:

I. To update a geological map of the Bunder area with the scale 1:25,000

II. To analyse the sedimentary facies in the Bunder area.

III. To determine the depositional environment of the Sambipitu formation in the study area.

1.5 Scope of Study

In this study, the depositional environment will be determined in the Bunder area by the analysis of the rock characteristic and the present of fossils in the area. Thus, the studies also focus on the sedimentary lithology and sedimentary structure rather than palaeontology study. The reconstruction of the depositional environment had been done by combining the sedimentary lithology and sedimentary structure. Based on the previous study, mostly sedimentary structure occurred at the upper part of the study area and there abundance of ichnofossil at the Sambipitu formation. So, the camera will be used to capture all the structures occur on the surface of outcrop and the rock samples were brought to the laboratory for petrographic observation in order to get the accurate information about the rock unit.

1.6 Significant of Study

This study more focuses to increase the depth of knowledge in the litho-stratigraphy method. Besides, the update of the geological map is produced in order for further details and enhancing the knowledge of geology in the Bunder area especially for the geologists and university students. Next, the depositional environment needed in industry especially construction because it can provide the information and details use in natural development in the area. Moreover, for the stratigraphic measurement, it must include of lithological description, analysis of physical properties and observation of sedimentary structures in order to get more finding in strata and the sedimentary structure. Petrographic observation is conducted in the thin-section samples to determine the composition of the constituent facies and lithological.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review is about any information of data and historical background that come from the previous research. So, in this chapter, the issue or any statement that related to the research area of Indonesia especially in Bunder area in Gunung Kidul, Yogyakarta.

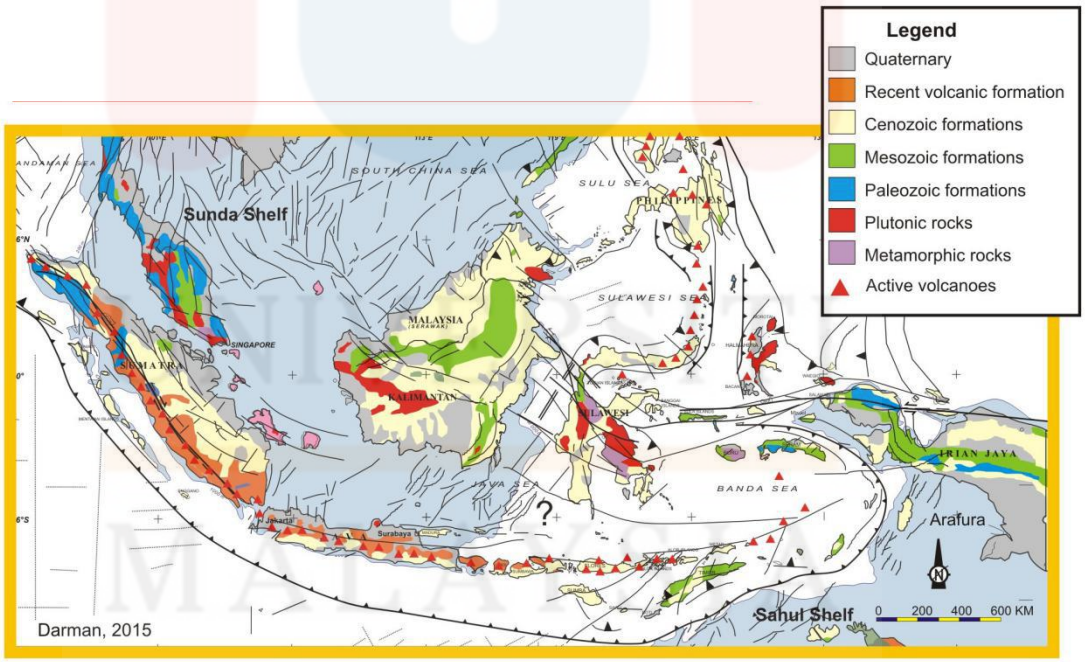


Figure 2.1: Regional Geology of Indonesia (Darman, 2015)

The information related to the regional geology of Indonesia and the sedimentary formation was essential in finding the rock distribution of the study area.

In Jawa, there is Paleocene-Neogene volcanism with the formation of pillow lavas basalt to basaltic andesite in composition. Alternating basaltic to andesitic lava flows, breccia, and tuff refer to the strata stage of volcanism which calls as construction period of composite volcanoes. After that, it will follow the destructive phase, producing pumice that rice in pyroclastic breccias, lapilli and tuff of high silica andesite composition (Bronto, 2009)

2.2 Regional Geology and Tectonic Setting

Based on Figure 2.1 above, the regional geology and tectonic setting is a study of interpretation and to determine the paleo-environment of the certain part of the area that was constructed after involving with great forces of tectonic forces.

According to Rudi (2013), the subduction resulted of the island of Jawa and melting process of the Australian-Indian plate beneath the Eurasian plate along the Jawa trench (Figure 2.1). The melting crust has risen as volcanoes and, along with subsequent sedimentation, created in Jawa. Therefore, on the surface lithological variation consists of Cenozoic rocks of volcanic rocks, clastic sediments, and uplifted corallin limestone.

The terrible effect due to the earthquake in Yogyakarta, Indonesia, May 27, 2006, causes the damage to buildings and homes and also the cracked of ancient temples of Prambanan. Even though the Richer scale only shows the relatively small which is 5.9 but it really gives a big impact in the area. The geologist state that the reason is perhaps the condition of the house itself and the other reason is loose

alluvial deposits which cover the plains of Yogyakarta which has increased earthquake waves due to the alluvial characteristics. (Gendoet, 2007)

2.3 Stratigraphy

Stratigraphy can be defined as the details of rock succession and concerned on the order of the position of the strata with relation to the geological timescale. Stratigraphy frequently used in the study of sedimentary rock and volcanic rock which consist of bedding. It also give the information on the order of the event that happened to them.

From the Figure 2.2,Surono stated that Sambipitu formation in the Sambipitu area overlie Nglanggeran formation in Jawa and mostly the rock are usually grey but can vary due to the weathering process. The most common will be found is tuff and agglomerate due to the volcanic composition. Based on the figure, the Semilir, Nglanggaran, Sambipitu, Oyo, Wonosari aged from Early Miocene to Late Miocene. Sambipitu formation was form early in the Miocene and the age of formation being proved by the sedimentary structure of the study area.

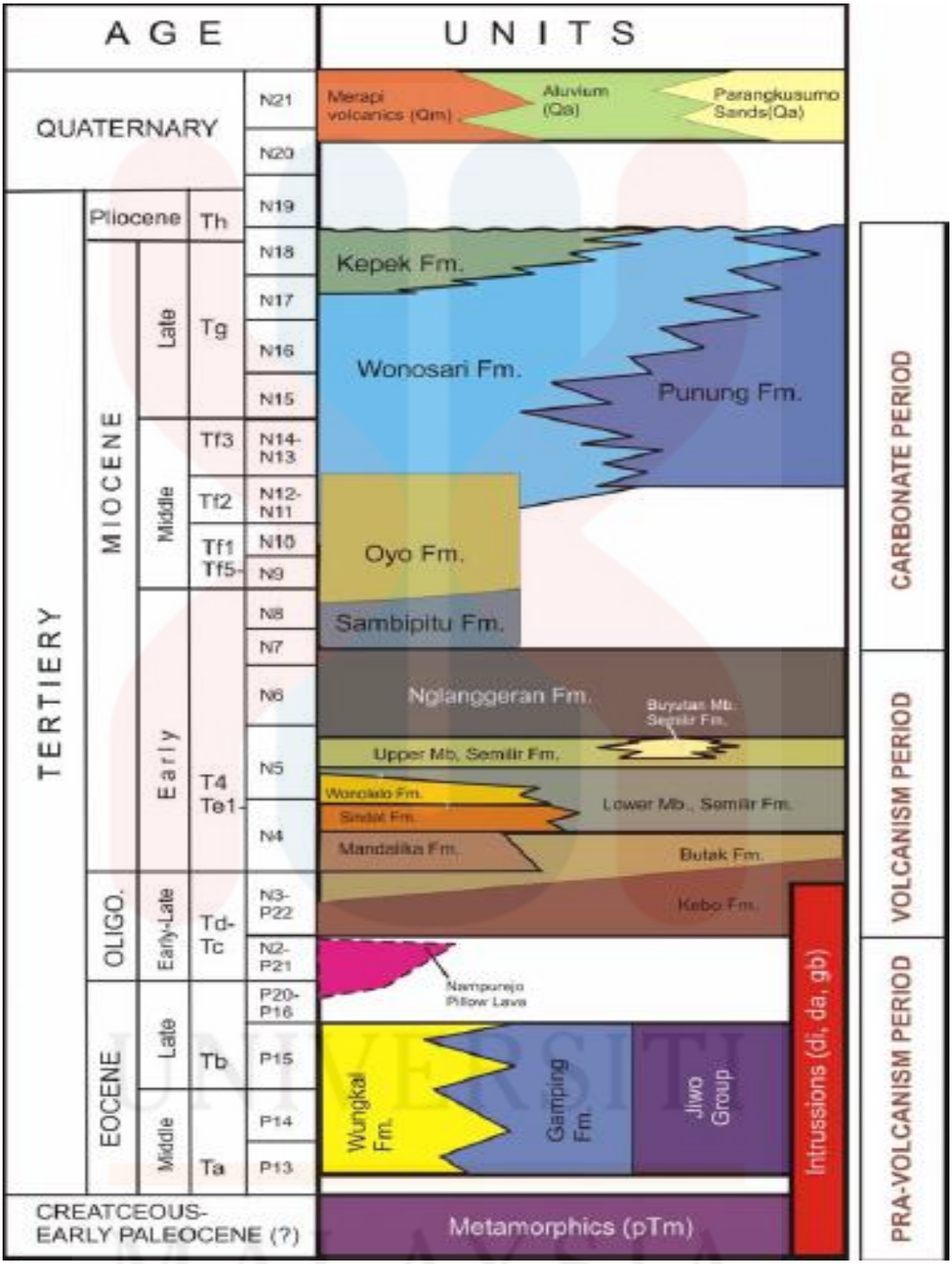


Figure 2.2 : Stratigraphy of the central part of Southern Mountain,Jawa,Indonesia (Surono, 2013)

For the basic information, the sedimentary environment can be studied by the formation of the sediment and resultant deposit which refer to the principle of uniformitarianism. It is the key to the past environment and relates to the origin of

the ancient sedimentary rock. The environment actually follows the surface of the earth. Salley, 1970 said that the part of the earth which is physically, chemically and biologically distinct form the adjacent areas. So, in the laboratory work, all the parameter should be concerned. The physical parameter will refer to the direct or variation of wind, flowing water and the weather. Next, for the chemical parameter, it will refer to the composition of water in the sedimentary environment and the geochemistry of the rock through the catchment area of the terrestrial environment.

Besides, for the biological parameter of the sedimentary environment, the flora and fauna will be discovered and observe. Flora will over grazing deforestation or over cultivation that can increase the rate of erosion and increase the rate of deposition elsewhere. For the fauna, in the marine environment, the present of skeleton contribute the sediment formation and mostly can be found in carbonate rocks and organic reefs. (Salley, 1970)

2.4 Historical Geology

The Indonesian formed over the past 300 million years by reassembly of fragments rifted from the Gondwana supercontinent that arrived at the Eurasian subduction margin. The result of Cenozoic subduction and collision at this margin refer to the present day geology of Indonesia.(Hall,2002).Regarding to the Central Jawa of Island's Jawa, the volcanic activity started at the time of Formation Kebo-Butak. According to Ashari and Pandita (2015), Nglanggeran Formation is expected of the peak of volcanic activity and began to decline with the deposition of

Sambipitu Formation This formation abundance of ichnofossil and the turbidite dominated at the Nglanggeran Formation.

The depositional environment can be interpreted by using the sedimentary structure found within the study area through the aspect of sedimentology and through the aspect of palaeontology which we try to interpret by the fossil found in the study area. Sambipitu Formation related to the stratigraphic position, between syn-volcanism and post- volcanism periods. The coarser sediments are often rich in displaced shallow that occur of marine larger foraminifera and benthic. (Akmaluddin, 2012)

2.5 Structural Geology

In earth science field, the geological features essentially will be discussed on structural geology. Thus, all the structure either secondary or primary structure occur in the study area have been observed. For the structure deformation, all the strike and dip of the titled rock must be considered because the magnitude and the direction of the forces involved in the deformation. The acting of the tectonic forces result of the folding, lineation, fault or join in the study area. (Racey, 2009)

Prasetyadi, 2011 shows the geological structures in the study area are dominated by faults. The northeast-southwest which consist of 16 faults and north-south consist of 14 faults, which are the direction of the. The remainder of faults is trending in northwest-southeast and west-east directions. Based on Figure 2.3 and

Figure 2.4, the fault and dyke occurs at the Nglanggeran area which the area located near the Bunder area. In addition, the northeast-southwest and north-south faults are dominated by sinistral faults and a few of them are reactivated as normal faults.

Figure 2.3: Nglanggran dike in K. Ngalang. (Prasetyadi, 2011)

Figure 2.4: Fault in Trembana, Bayat. Note scratch horizontal fault line intersects the line of dip slip (Prasetyadi, 2011).

Besides, Figure 2.5 shows the area consist of karst morphology previous research stated the area might occur of the sinkholes structure because there are area of limestone karst landforms of non-tropical regions are dominated by planar surfaces. The karst for the Sewu morphology is necessary as sinoid profiles of the limestone hills and the slope profiles of Sewu karst hills are mainly convex because result of differential spacing of horizontal fractures in the limestone mass.(Tjia,2013)

Figure 2.5: Sinoid karst hills of the Wonosari-Punung limestone ((Tjia, 2013)

2.6 Depositional Environment of Sambipitu.

This research was focusing on the depositional environment of clastic sedimentary rocks at the Sambipitu area in Wonosari, Indonesia. From the previous study, the geological map shows that this area composed of limestone, marly tuffaceous limestones, conglomeratic limestone, tuffaceous sandstone, and siltstone. The compositions and the depositional environment indicate the rock characteristics, especially through their texture and structure occurrence. The stratigraphic

measurement includes the lithology description, analysis of physical properties and observation of sedimentary structures will be easy to study in this area.

The area of the Sambipitu that will be cover is about 25km^2. Sambipitu area divided by five formations which are Sambipitu Formation, Oyo Formation, Bubung Formation, Wonosari Formation, Kepek Formation, and each formation consist of different rock and the own lithology. Regarding the Sambipitu formation,its occur of alteration of calcareous sandstones and calcareous siltstone, and for the formation of Oyo, it had an alteration of packestones and wackestones with marl. Kepek Formation occurs of rock like grainstones, rudstones, packstones, and oncolites. (Barianto, 2017)

Lauti, 2007 had been stated that Sambipitu formation has been known to have a diverse facies distribution, so this place is interesting to study the sedimentology and stratigraphy. The reconstruction faces and depositional environment on Sambipitu Formation and the lower limit has been done in Oyo Formation, Ngalang and surrounding area, Gunung Kidul District, Yogyakarta. Thus, from the observation and interpretation depositional environment of Sambipitu Formation, the depositional environment was the shows the transgression area which occurs the zone of tidal and the upper offshore.

CONTOUR MAP OF BUNDER

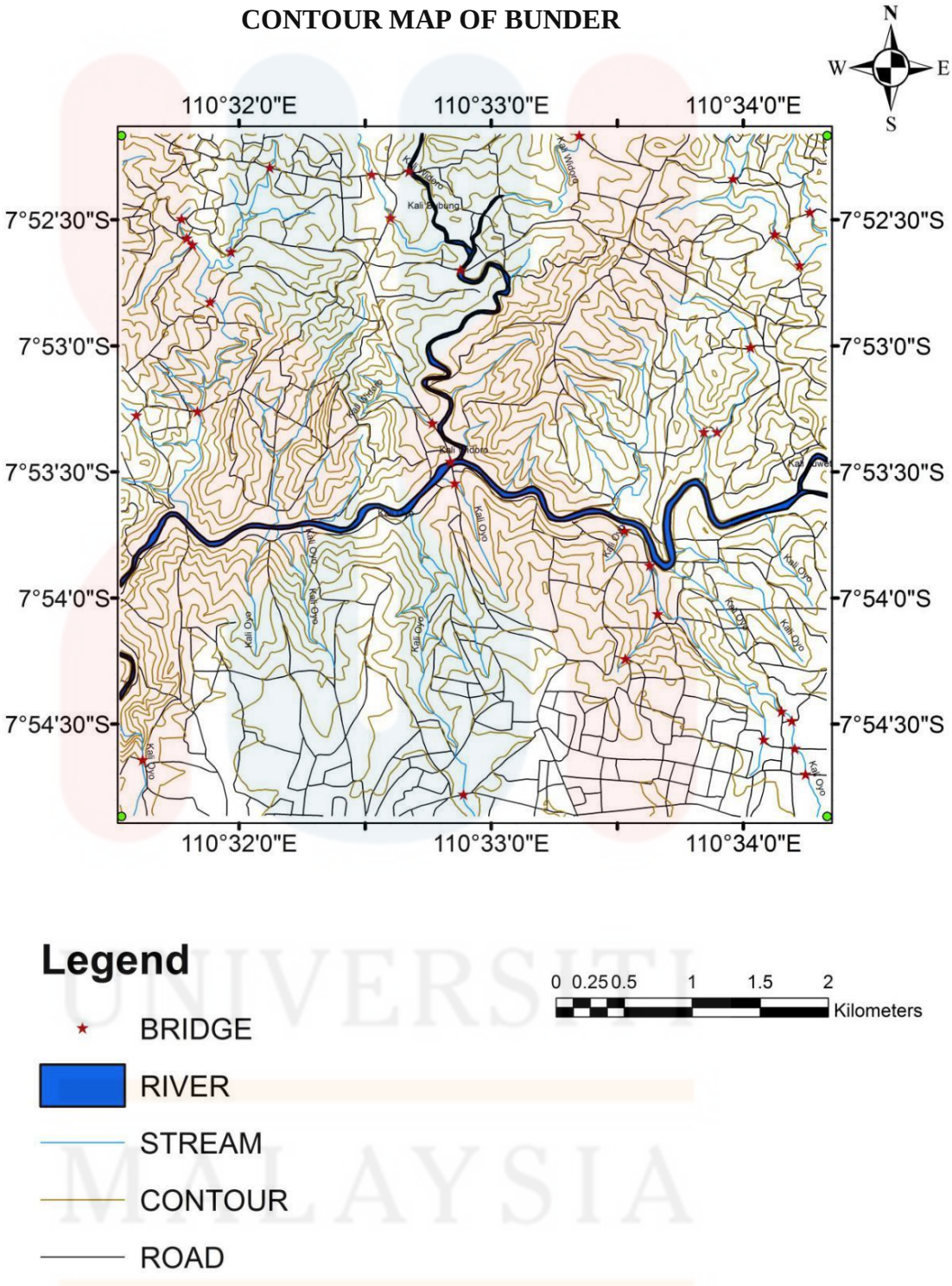


Figure 2.6: Base map of Bunder area (Geospatial Indonesia, 2011)

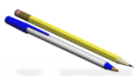
CHAPTER 3

MATERIALS AND METHOD

3.1 Introduction

Chapter 3 will discuss the material and methodology will be used in this research. The discussion will start with preliminary studies and details on materials and methods that involve fieldwork and laboratory investigations. In the figure 3.1, the important material was discovered in this research.

3.2 Materials and Equipment

 Plastic sample : Use to collect the sample of fresh rock form the outcrop for further analysis in lab.	  Note and Pencil: Use to save the data or any kind of information during the field work	 Chisel: For more delicate splitting especially when handling with the fossil in the outcrop
		

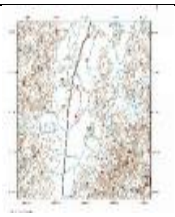
Geological Hammer: The basic things in geological field mapping because it is used to take a sample from outcrop when collecting the sample. It must knock by a proper technique in order to get a perfect sample and this tool essential to the indiscriminate bashing of the rock to get the fresh face of rock.	Brunton Compass: It is also used to determining direction especially to take the strike and dip. Besides, if Global Positioning System (GPS) was not functioning, the compass can be used to detect our location on the map.	GPS:It is a satellite-based navigation system. It is involves satellite, monitoring station on the earth and the GPS receivers. It is used for GPS to locate the position, mapping lithology, tracking structures, measuring elevation, and saving the sampling point.
 Hydrochloric Acid (HCL) : It is used to distinguish the most common carbonate rocks, dolomite, and limestone. When we test, a frizzy sound will be heard when carbonate minerals are present.	 Software ArcGIS 10 : used to provide a visual representation of data and can interpret the data in a proper way. It is also important to construct the geological map.	 The base map can provide information in the three-dimensional shape of the landscape by representing contour with lines on a two-dimensional map.
 Camera: It is an important material to capture, outcrops or any geological features	 Hand lens: Use to find the mineral crystal that cannot be observed by naked eye.	 Microscope: Use in thin section for petrography analysis.

Figure 3.1: Tools and materials used in this research

3.3 Methodology

There are certain methods need to be use in order to conduct this research. First was the data collection which contents of preliminary study and field work followed by data processing and data analysis.

3.3.1 Preliminary Studies

The primary study will be conducted by geological mapping to gather the information from the research area such as in form geomorphology analysis, structural geology, and sampling. Then, the information will be gathered by referring to the previous research study such as journals, books, articles, and newspaper. The revision of previous researchers related to the topic and study area is done before going to the field. The literature review is important as it helps to review certain elements such as historical geology, regional structure, and tectonic setting. This process will give a clear view of the concept of structural analysis research.

3.3.2 Geological mapping and field studies

Geological mapping will be conducted in the study area which is Bunder area that will consider and analyse the geomorphology, structural geology, stratigraphy and lithology. Observations of outcrops in each locality will be done to identify the type of lithology, structures that presence in the study area. Identification of the contact between the lithology, determining the boundary of each lithology, lineament analysis will be conducted. While conducting the fieldwork, the sample of the rocks

will be collected for further analysis. This basic geological mapping is needed to fulfil the first objective which is to produce a detailed geological map of study area.

In addition, the geological structure will be observed and the observation must be related with the lithology, geomorphology, structural geology, sedimentology and the stratigraphy in the site. In the data collection, we must collect any information as details as we can, for example, the strike and dip measurement. In the data collection also we must avoid any errors or ambiguity to make sure our analysis can be obtained in good information of the distribution of data. So, make sure all the measurement and instrument is in a good condition.

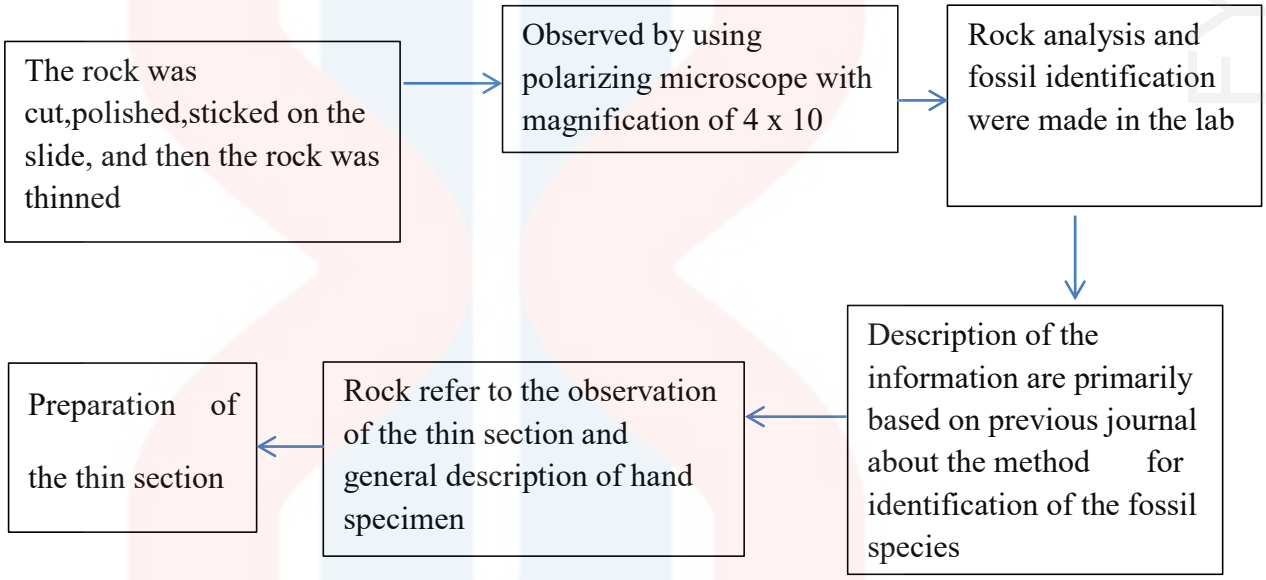
3.3.3 Laboratory Work

The rock samples will be further studied during this process. This method will require the thin section process. It will involve the petrographic section studies. The thin section will provide the information of the rocks include the type of mineral content and the exact name of the rock based on the mineral composition. This process will be done by using the petrographic microscope.

In the laboratory investigation, after the sampling process, the laboratory work should be done. In this method, a petrography analysis will be done which we collect all of the samples from the field and proceed for thin section preparation. Petrography is the important step in determining the depositional environment because the texture and specific criteria of the rock can be observed and the information will be more accurate rather than observation from the field. This method also acts as a core data in order to deal with critical information of the origin

and history of the rock. Table 3.1 shows the process of thin section for the rock samples conducted in this research:

Table 3.1: The process of thin section and observation



Laboratory investigation is required in order to study the characters and the type of rock. The steps involved in the preparation of thin section are sectioning, vacuum impregnation, grinding, cementing, grinding and polishing. First, rock saw is used to cut the sample and the dimension of the chip must be smaller than the glass slide. The thin section will be cleaned and vacuum impregnation to fill the available pores to consolidate the sample materials.

Next, the grinding process will produce a flat and smooth surface. Hold the ground surface against the light 45^{o} to make sure the chip surface is ground flat. The sample needs to be clean and dry before cementing process. Third, the mounted chip will again be cut into the thickness of 0.05 mm and proceed for polishing, After the preparation of thin section, examine it under the petrographic microscope for identification the mineral composition and the texture of the rocks.

3.3.4 Data Processing

In this study, the raw data and the data collection large and complex. We gain a lot of raw data and the data collection is large, and complex, so to the number of operations needs to be performed in specific way and stored in digital form .In order to perform the complex data of operation, data in the digital form easy to allow the data conversion into the different form.

Geographic Information System (GIS) is the tool that mostly will be applied in all procedure in this study especially to construct the geological map because it can produce geospatial data. In the processing process, the data that had been collected from the field either primary or secondary data, the data will be collected to be the input into the GIS.

3.3.5 Data Analysis and Interpretation

Data analysis and interpretation is important method after the data collection have been done. This consideration of the analysis will predict either the data is qualitative or quantitative data. Generally, the data that had been collected mostly qualitative data because the research a general statement and the categories of the data have their relation each other. Regarding the analysis, the data identification will be easier to explain and the future prediction can be made because the data will provide a lot of information.

In this research, the specification more in geology and depositional environment. Thus, the analysis and interpretations important because from the occurrences of the active fault will affect the soil structure and collapse, meanwhile, in the distribution of the sedimentary structure in the study area provide the information for the ancient environment.

In the progress, the function of the data analysis help to improve the information of the details get from field or lab. It is because the tracing and identifying the problems will be identify and remove it. Data analysis and interpretation, in the end, help improve processes and identify problems. It advices to find as many as details data to high the accuracy of the data.

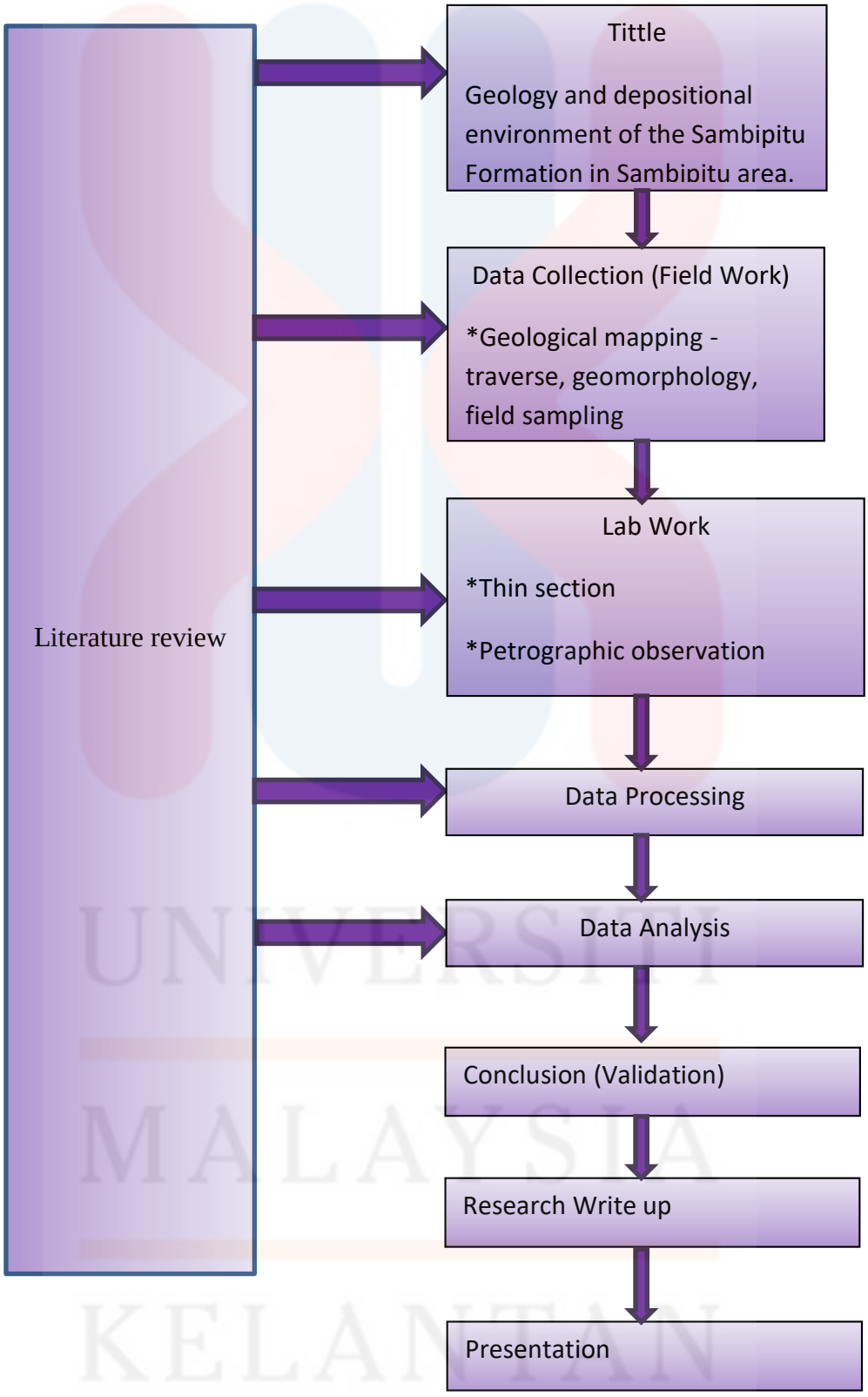
Software analysis such as geo-rose's software will be used to complete the joint analysis by adding the strike value reading from the fieldwork thus it will present the direction of the greatest force acted on that particular area. Stereonet will be used to plot the data of fault and fold. Two types of features will be generated on the stereonet, a line which will be plotted by trend and plunge and a plane that will be plotted by strike and dip value reading. A line will be plotted as a point and a plane plotted as a great circle. By using the ArcGIS software a geological map of the study area will be produced. The faults that present in the study area analyzing by using the dynamic analysis. The analysis will help in producing the direction of the forces of the fault in the research area. The deformational history of the study area can be reconstructed and explained if there are any new finding of structural geology in the Bunder area.

3.3.6 Research writes up

The final method in this research is report writing which all the important and crucial information about the geology and depositional environment have been gathered in the book or other multimedia. This research writes up must follow the guideline of Final Year project that has been provided. The proper way when making the writing will make your research easy to understand and served in a good arrangement. When writing the research, the specific activity of the research need to be discussed and the information on the geological map will be collected in table and figures diagrams.

3.4 Flow Chart

Table 3.2: Shows the flow chart for Final Year Project



CHAPTER 4

GEOLOGY

4.1 Introduction

Geology is the study of geology deformation due to the process, structure, origin, and features. In this chapter will discuss the geology information in the Bunder area and also part of Bunder area covered approximately about 25km^2. This part will cover the geomorphology, lithostratigraphy, petrology, geological structure and geological history which based on the observation, the sample of rock and the data analysis. Historical geology also will be discussed for the geological processes that resulted change the earth's landform, on geomorphology topic. The information mostly observes from the field and from the sample that has been collected for the lab work study and observation especially on the petrographic observation. The arrangement of the map will start from the topography map or also call as the base map in the study area, geomorphology map which provides the landscape of the area, traverse map, drainage map, and all the geology information will be discussed in this chapter. The geological map of the study area with a scale of 1:25,000 needs the information of geology in the Bunder area in order to update any information that related to the geology.

4.1.1 Accessibility

The base camp located at Plosodoyong‘s village in Ngalang which the beautiful environment and scenery. The location from the base camp to the study area takes about 5 km and about 4 km to the Sambipitu’s town and 7 km to the Bunder’s town by motorcycles. This area more prefers for a motorcycle because it will be easier and fast.

The study area consists of two type of road which main road and the small road. Mostly, the small road created by the villagers and difficult for big vehicles to access because people there prefer to walk meanwhile the main road suitable for big and small vehicles such as motorcycles, cars, or buses. The area also consists of two main towns such as Sambipitu and Wonosari. Alfa Mart was the nearest market in Bunder and small market which makes the area easy to access by peoples, and the main actually the way that connected Sambipitu to Jogjakarta town. Jogjakarta town famous in Indonesia which rich of their good culture, traditional craft and tourism places which the area of focus for villagers and tourists. Therefore the main road in Bunder was important for villagers to the Jogjakarta‘s town.

The connection from place to place quite easy to access due to the economic activities of the villagers which they made the small road from their house to the crops which also for me easiest for geologist’s student or researchers to access to the outcrop. For the communication, the line coverage totally good but if the places far from the telecommunication system, it might face with the slow line of the connection system.

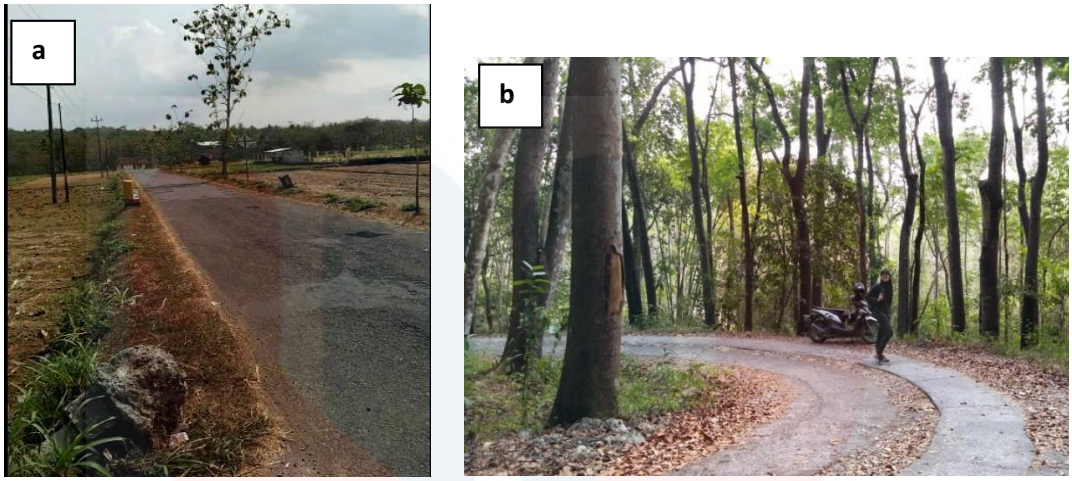


Figure 4.1 (a) The common road used by villagers and (b) the small road at the study area

4.1.2 Settlement

The study area located at the Bunder which one of the parts in Gunung Kidul regency and the population in the place increase year by year. The citizen at the Bunder majority occupied by a farmer. But certain places in Bunder and Sambipitu especially in town state, the peoples sell something likes foods, drinks and other daily needs for their sources income. Bunder area covered the middle part of the study area and Sambipitu area covered at the south part. In the study area also divided by many villages which provided many facilities for peoples such as the schools, police stations, clinics and the also the recreation places.

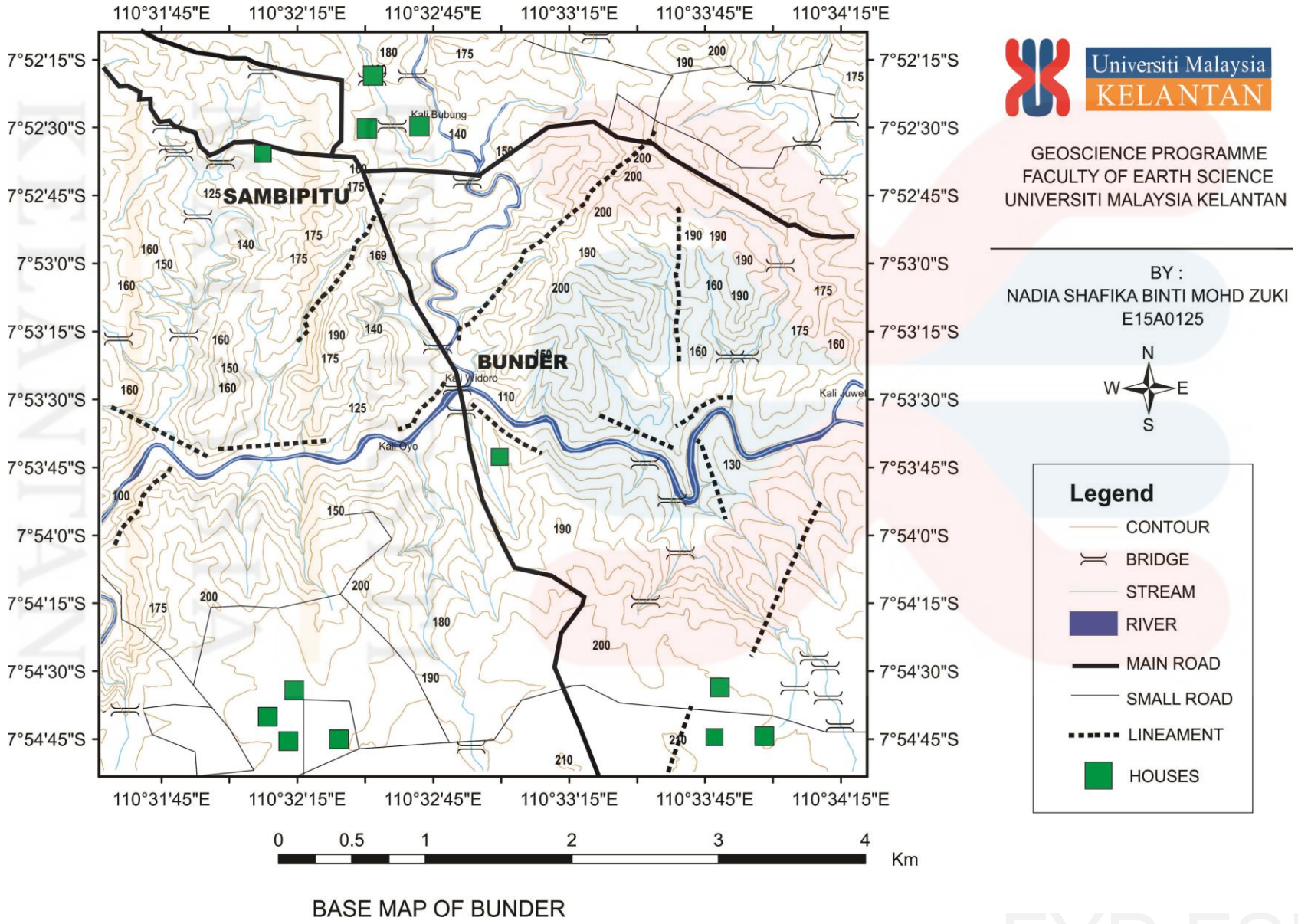


Figure 4.2 : Base map of Bunder area

4.1.3 Vegetation

The socio-economic activity in the study area are vegetation such as corn, tomatoes, potatoes, chilies, cucumber and many more and they sell their vegetation and foods in the market. The vegetation area covered mostly in the study is and the other half was a part of the rural region. By the time of the dry season, the certain vegetation will be twisted to vegetation because some of the vegetation not suitable in a high amount of sunlight and need more water to grow and cannot be adapted for the dry season. For example, the paddy field area needs more water to produces the rice but in the dry season, the farmer will be twisting paddy field to the nuts vegetation because of the nut vegetation no need a lot of water for growth.

In the study area also consists the 'Kayu Jati' tree and "Kayu Putih" tree plantation which economically for peoples in Central Java, Indonesia. For the Kayu Jati, the villagers use the wood to build the house and create a bonfire and the wood also can build a bridge to cross the river meanwhile the Kayu Putih will be extracted for the productivity of the Kayu Putih oil which can produce unique aroma and has the colour of light green liquid which has so many advantages for discomfort of our body especially to release stomach-ache, bloated stomach, nausea or itchiness due to insect bite such as mosquito. The grasses also act as the most important for the vegetation area which the villagers collect the grass for food for cows and goats. In Indonesia, the production of milk, ice cream, or cheese came from cows or goats that fed the grass.

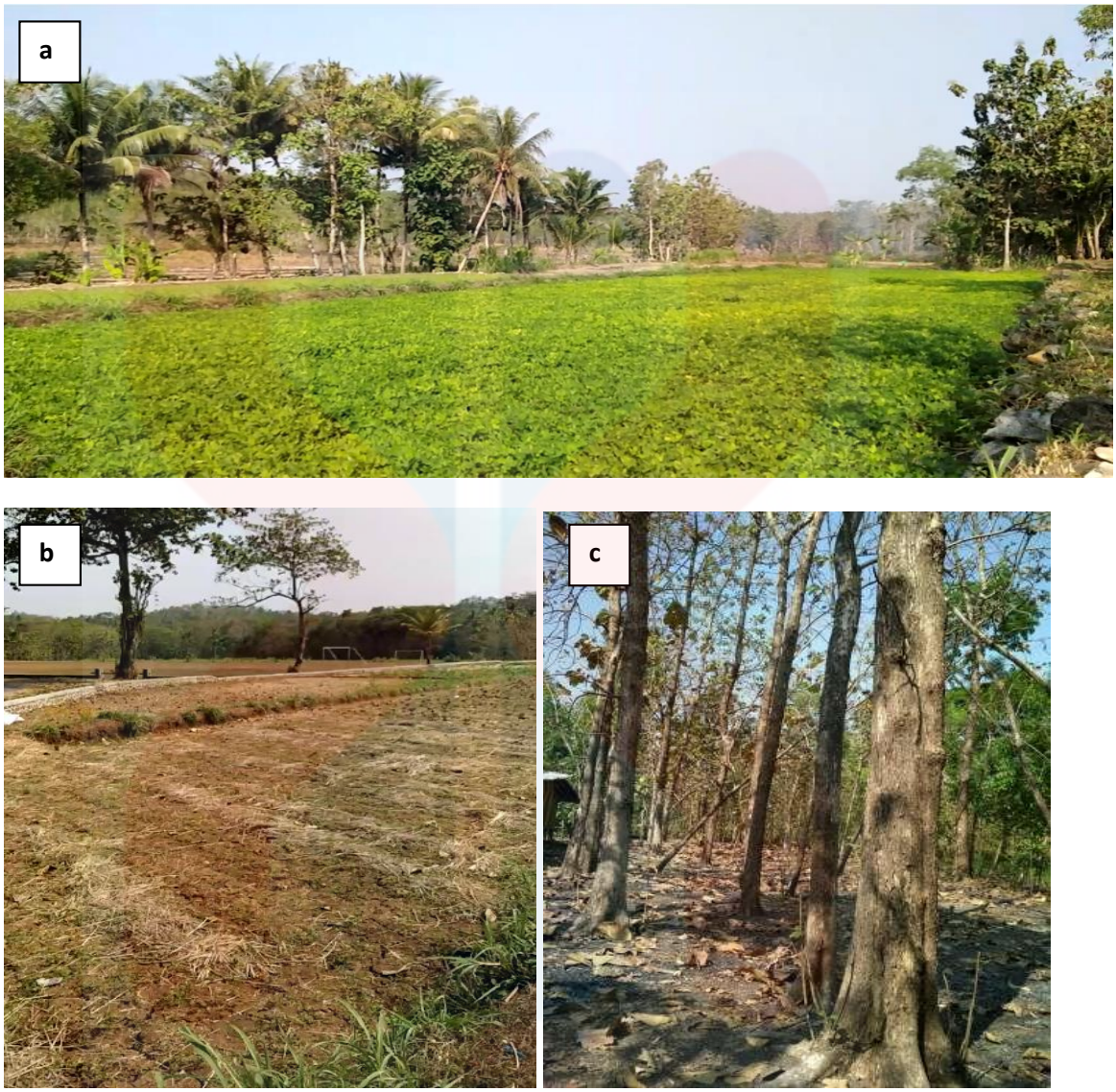


Figure 4.3 (a) Nut vegetation ,(b) havested paddy field and (c) Kayu Jati's tree

4.1.4 Traverse and Observation

The geological mapping in the study area was covered by traversing and observing all the information about geology information. Then collect the sample of the rock and measured the data dimension of the outcrops. The traverse was the crucial method in mapping which it can route and give the direction especially the direction to the contact of the formation to another formation. Before going to the field, the traverse must decide on the base map to limit the times and give the effect to the field

work. For the general geology of Bunder, it might take 10 days to collect the data and observed the geology structure roughly and other information related to of the geology.For the study area, information about the general geology takes about 9 days because at the southern part of the area covered by the housing area and less information about the geology due to the construction and difficult to find the outcrops.

Commonly, the classification of contour on the base map had been made and was classified by the landscape area which is the hilly area and flat area. This observation important because it the strategy for field work and makes the efficient work. The observation of the geological structure, sedimentary structure and other major structure of geology had been measured. The crucial information needs to be observed was the lithology boundary which the shows the changes form of the characteristics of rocks. By the contour map or topographic map, the identification can easily be made.

Every track was recorded and the waypoint had been marked if any geology structure or outcrop found. The Global Positional System(GPS) was one of the geography tools that had been used to mark the coordinates and trace others location and give details such as elevation, contour, strike dip magnitude, and the azimuth.

The covered area for traverse for the study area was 90% and all the details of geology were collected in the books and had been copied in the laptop to avoid the missing data.

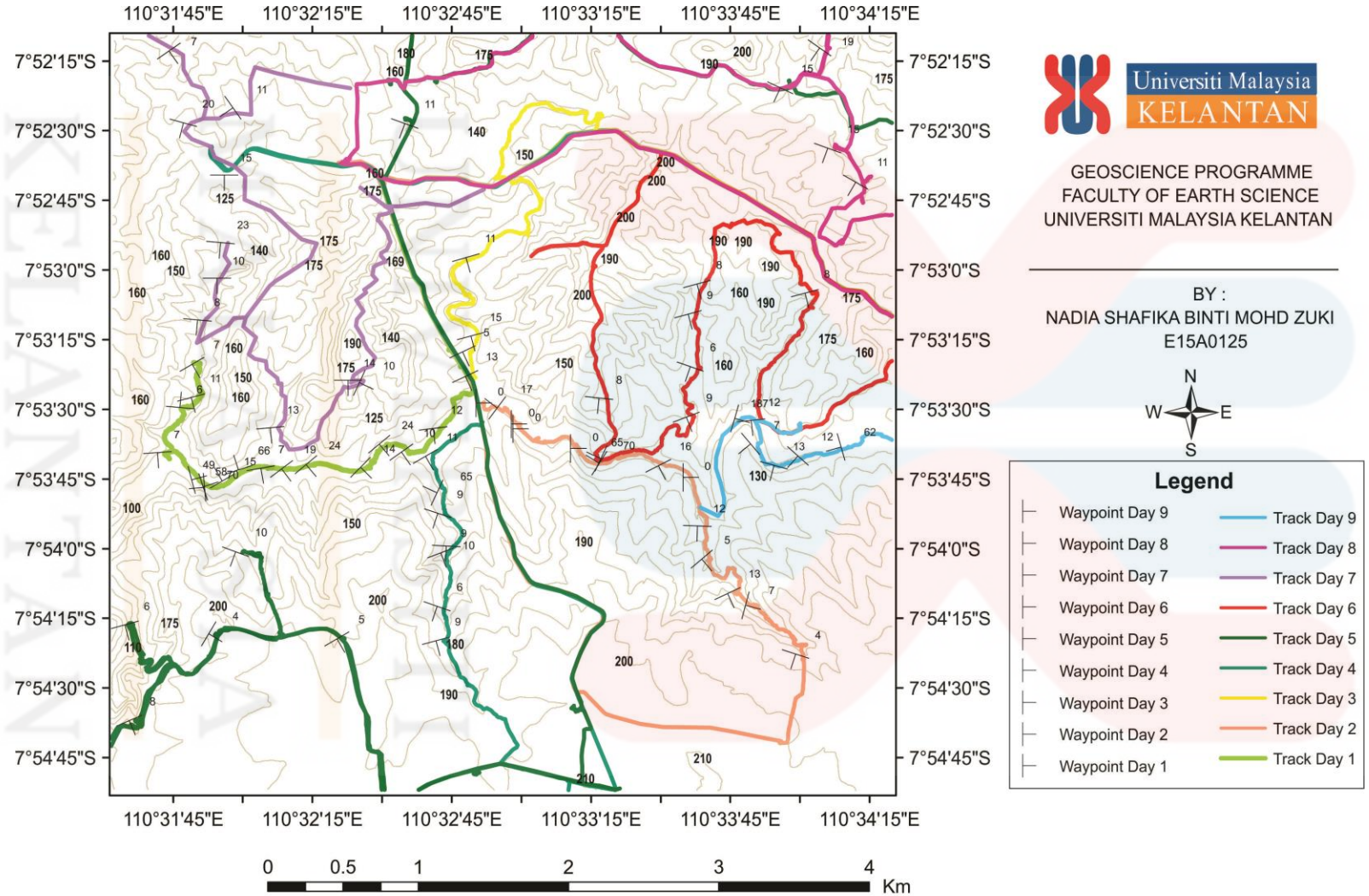


Figure 4.4: The traverse map

4.2 Geomorphology

Generally, the geomorphology shows the changing of geology landform, the drainage pattern of the study area, the floodplain area, and the watershed which the flow of water from the land after the rainfall. Geomorphology map shows the distribution of the different landform due to their different resistance and rock characteristics. It also related to the physical, chemical and biological weathering process. For the land development, the geomorphology map was important for the review on construction and further details on the interest area either suitable for construction or might takes some precaution to build the housing or construction area.

4.2.1 Geomorphic Classification

The landform of the surface in the study area mostly experienced by the complex structure, the forces occurred and result from the different landform. The study area has the morphology which divided by the hilly and flat landscape. At the top of the mountain, the morphology was observed and sketches, the classification of the hill were determined due to the level resistance of the rock type. The five landforms form there which at the right side and at the middle part of the Bunder area. From there, we can classify the resistance of the hills of Gunung Kidul area and the most resistance hill was Gunung Kidul Karst. We also found the housing area and tiny cottages and the vegetation that we can saw from the top such as paddy field, corn, nut and many more.

The hilly landscape can be found at the Northern part meanwhile the Southern part covered by the flat landscape. The southern part dominant of sedimentary rock and the Northern part composed of pyroclastic and epiclastic rock which the rock resist for the weather even rainy seasons or summer seasons.

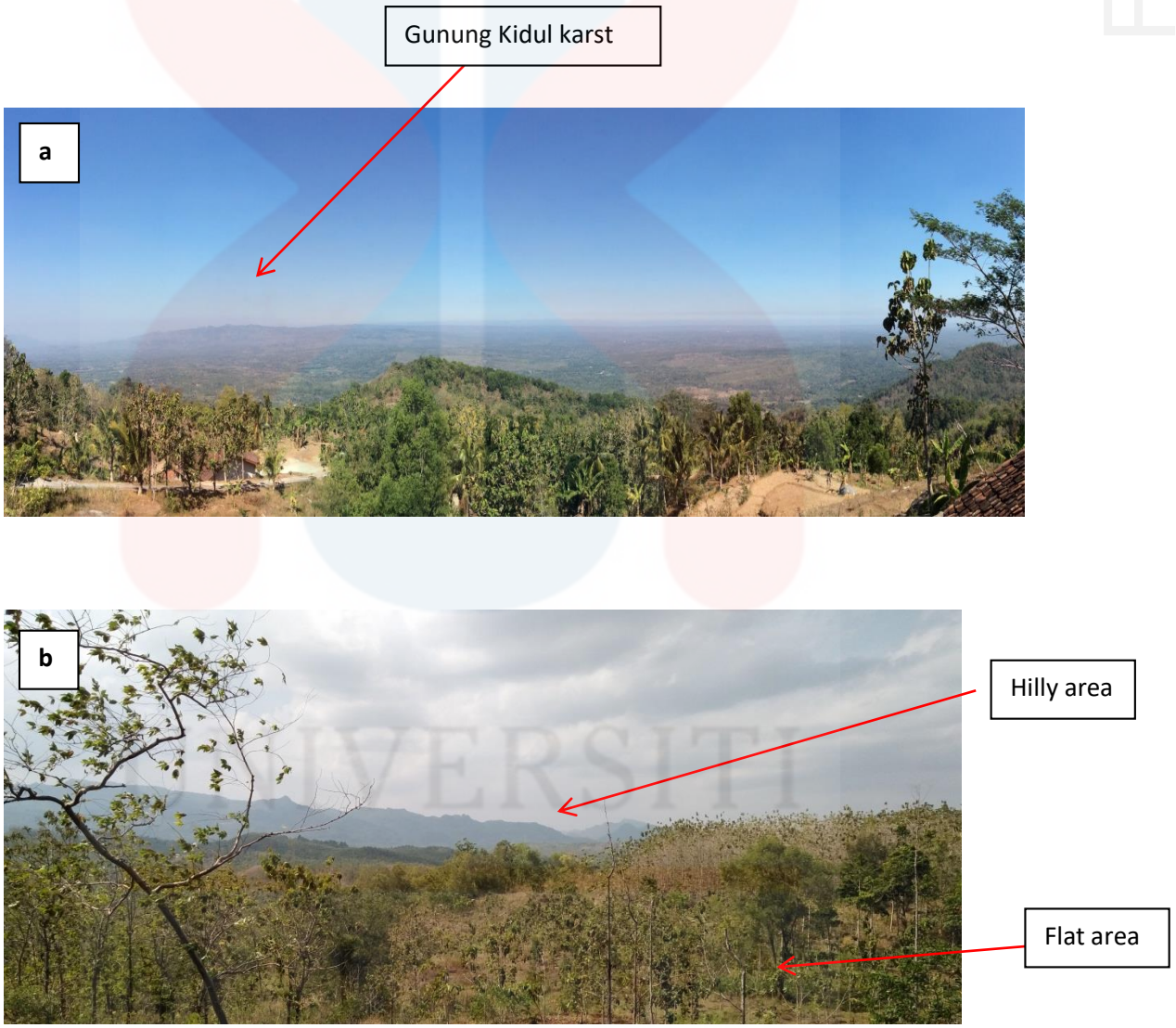


Figure 4.5 : (a)Panorama was taken from the top of Gunung Kidul Embung Mountain and (b) panorama taken from the flat area of Bunder

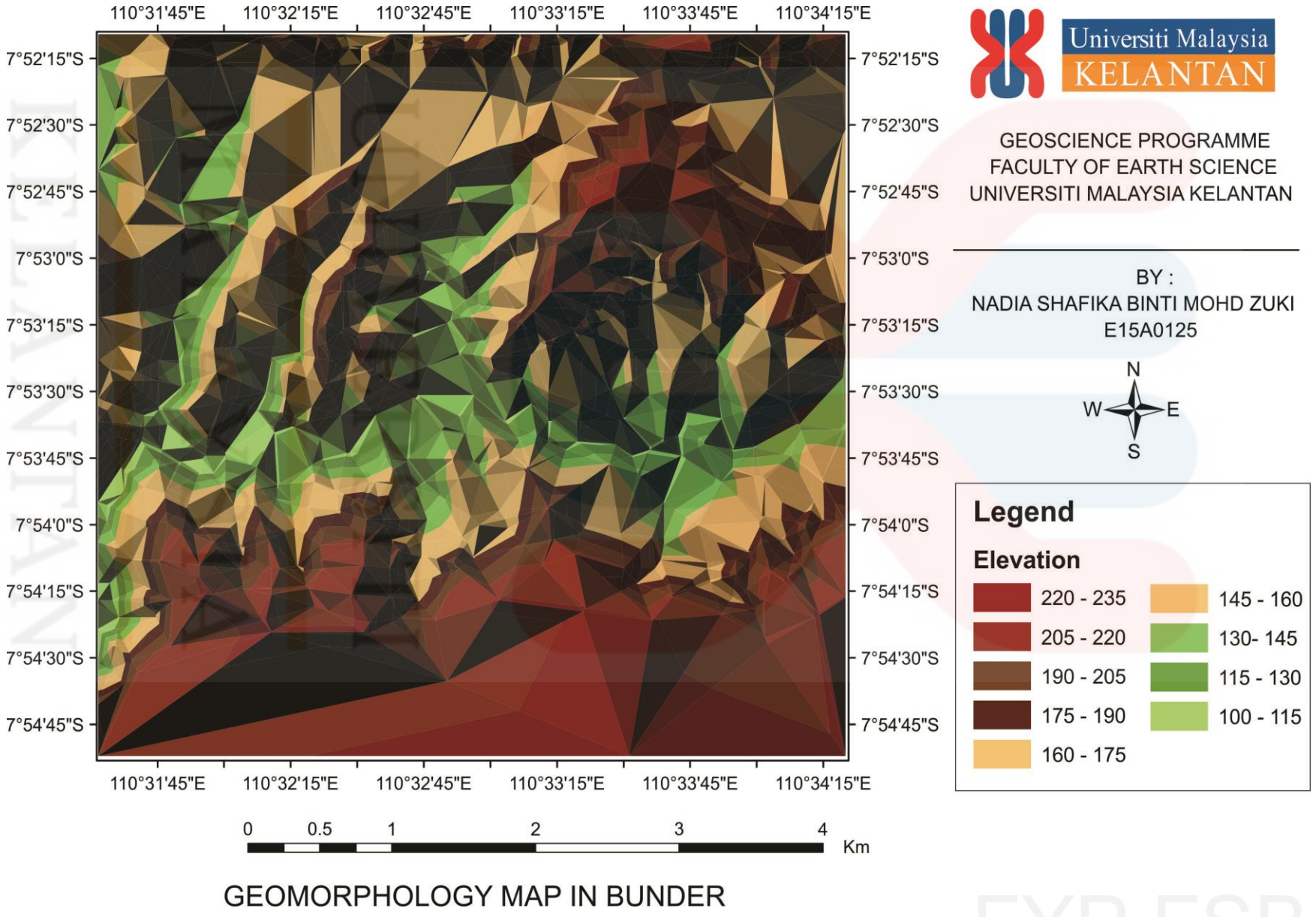


Figure 4.6: The geomorphology map in Bunder

4.2.2 Weathering

Weathering process divided into three parts which physical, chemical and biological weathering. Physical weathering defines as the rock break during the mechanical process while chemical weathering refers to the formation of iron oxide or calcite mineral. Regarding the iron oxide, the oxidation of iron in react with oxygen and thus it changed the composition of the rocks meanwhile biological weathering refers to the plant root that penetrates through the rock or algae produced chemicals that help break down the rock.

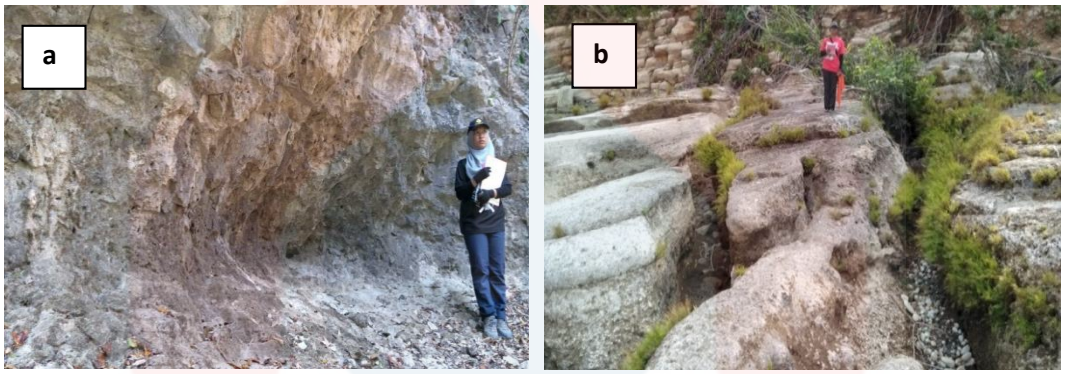


Figure 4.7: (a) Physical and chemical weathering and (b) biological weathering

Base on Figure 4.7 (a), the physical weathering and chemical weathering occurred which located at the coordinated with latitude S $07^0$53’27.52’’ and longitude E $110^0$31’50.62’’, elevation 122m. The physical weathering refers to the erosion due to the dissolution of water meanwhile the chemical weathering due to the acidic rainwater can also react with non-silicates especially carbonated rock will undergo chemical weathering when the react with rainwater and produce the carbonic acid which the acid can in a rock or soil. For instance, carbonic acid can dissolve as calcite mineral so that all constituents go into solution.

Mostly the outcrop found at the Southern part is weathered due to the physical and biological weathering which biological weathering might from the vegetation area. It may affect our result and quite tough to find any structures there. Physical weathering may be influenced by the rainfall and biological weathering more on the living organisms or the root plants on the surface of rock will make the rock easily go broke.

For instance, the crack or gaps between rock due to the roots grow which they exert pressure and the force make the rock easy to break or crack. The weathered of the plant or other organic vegetation ill undergo the chemical weathering process which can make the rock crack. It because the decomposition will release carbon dioxide that chemically breaks down rock into soil when present of carbonic acid.

4.2.3 Drainage Pattern

Drainage pattern in the study area consist of parallel and dendritic type. Dendritic pattern known to be homogeneous rock occur along the river that made up of limestone which can occurred because of erosion by running water that develops in regions that underlain by same identical material that made it has the same weathering resistivity. The limestone is the major rock that found along the river. Rock has different resistance and will affect the stream pattern on Figure 4.8, the pattern due to the limestone which has high resistance in a dry climate but not in a wet area like river, sea or lakes. Parallel pattern drainage of the river shown by the area which the steep slope has some relief. The stream's line was straight due to the steep slope flowing into the main river in the same direction. It formed by from the hilling landscape to the flat landscapes and resulted to the few tributaries. From the

map of drainage, the hilly landscape occurred at the centre of the study area. For the stage of the main river, the river has V-shaped which shows that the river had advance erosion. The V-shaped valleys that cause the rock types must be impervious and non-porous. The mud crack and floodplain also found along the river and stream.

Figure 4.8: (a) Stream pattern due to erosion in tuffaceous limestone and (b) mud-crack along the side of the rock

Mudcrack important to determine the depositional environment because it was the indicator to shows the environment experienced the transition change of climate or the temperature change from fluid condition to dry environment. The sediment fill the crack with the mud texture of sediments. Any layer of layer of fined sandstone or thinly layered limestone in this study area give clues as for how they formed. As the thinly layered limestone probably marine in origin, but some clues such as mud-crack suggest that they could have formed near land. If you find lots of mud cracks, the depositional environment might wet and dry environment due to the transition of that environment and related to the tidal activity.

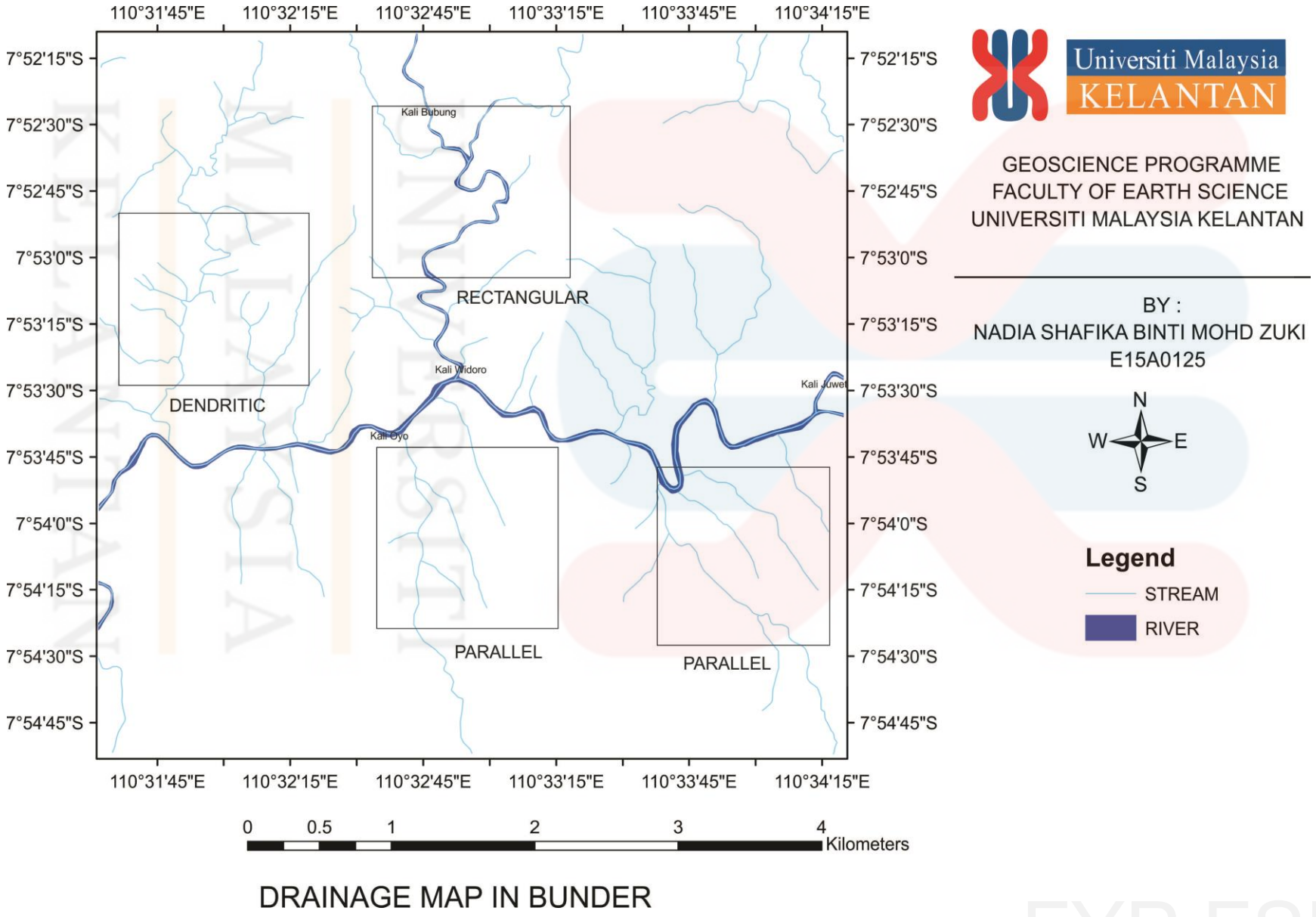


Figure 4.9: Drainage map in Bunder

4.3 Litho-stratigraphy

The sedimentary rock mainly abundance in the Bunder area such as calcareous sandstone, sandy tuff, marl, and siltstone, which almost ¾ of the part covered by sedimentary rock. About ¼ part left to stand for pyroclastic and epiclastic rock at the lower Sambipitu formation which has occurred in the upper part of the study area.

In the study area, it is consists of andesitic lava (pyroclastic rock),epiclastic breccia(Tuff, breccia pumice, sandstone, lava, claystone), interbedded sandstone and claystone, tuffaceous calcareous sandstone, and tuffaceous limestone(wackestone, packstone, and rudstone).

4.3.1 Stratigraphic Position

The oldest unit in the study area is the volcanic unit consist of pyroclastic and epiclastic rock. The sandstone unit is the second oldest and followed by the limestone unit which the youngest unit in the study area. The andesitic lava and the epiclastic breccia show the contacts and categorize as the volcanic unit and the oldest unit in the study area. Next, the sandstone unit that categorizes by various types which the second oldest unit is the massive sandstone followed by sandstone interbedded and claystone, sandy tuff, calcareous tuffaceous sandstone, and alternation wackestone and packestones.

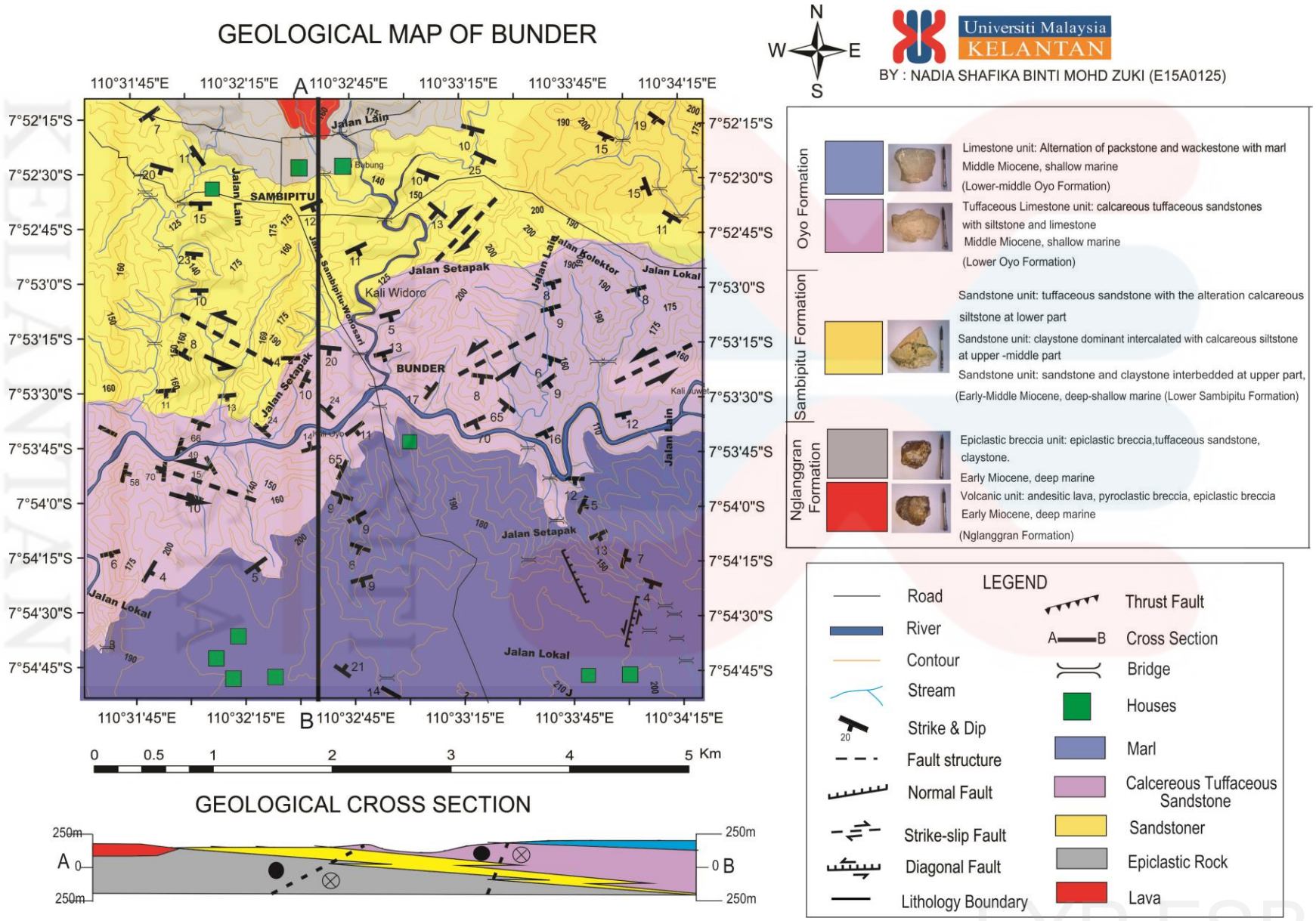


Figure 4.10: The geological map in Bunder

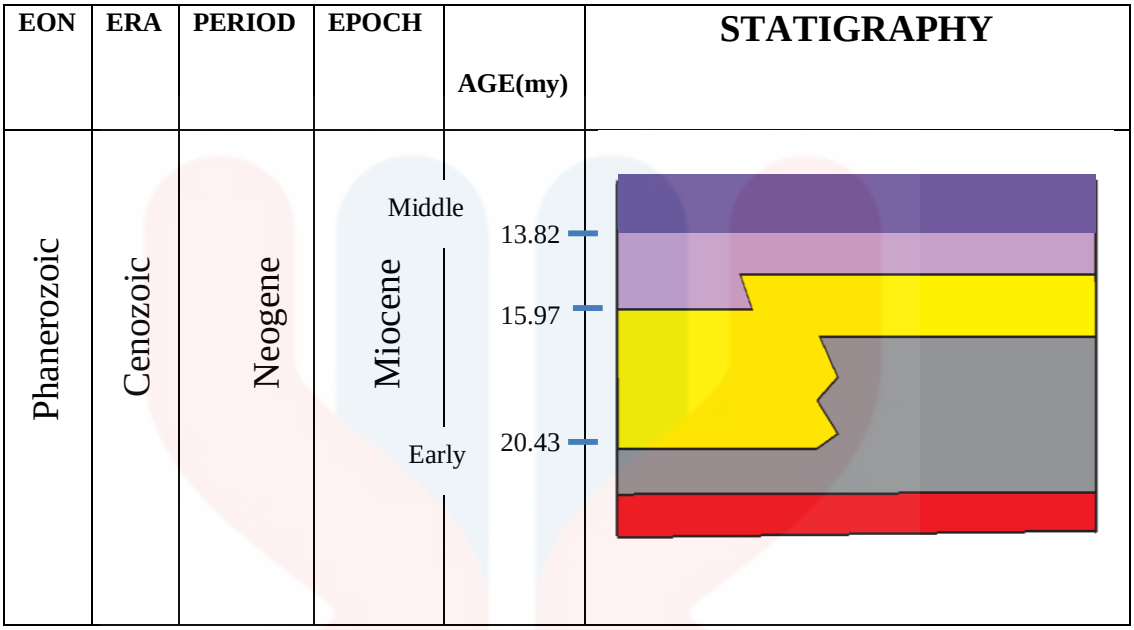
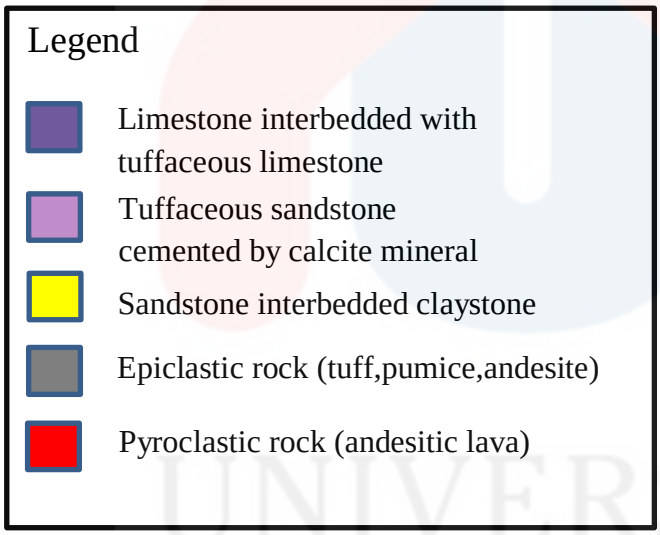


Figure 4.11: The litho-stratigraphy unit in Bunder



4.3.2 Unit Explanation

The lithology units were explained starting from the oldest and youngest unit of rock. The shaped contact between the units shows the interaction between the formations and mostly there has the interfingering connection between the formations. In petrographic observation, the more detail of the composition of the rock was explained. Instead of composition it also contains of the geology structure and mainly the sedimentary rock consists the sedimentary structure which indicator with the depositional environment.

4.3.2.1 Lava Unit

A. Andesitic lava

The pyroclastic rock is the oldest rock found in the Bunder area. The area begins with the Upper Nglanggeran Formation with Lower Sambipitu Formation. Both formations give the characteristic of interfingering each other. Lava or andesitic lava refers to the rock that may not too far from the source of eruption and the sample of hand specimen prove that the rock was the andesitic lava due to high silliclastic groundmass. The compositions are andesite and little grain of ash pyroclastic. The area for the exposed is about 100 m length and the colour was grey to dark grey. The igneous structure of auto-breccia exposed on the surface of this outcrop. The structure due to the cooling process of magma when suddenly in contact to the surface which the crack of surface of lava look like breccia .The area exposed about 70m for length below the small bridge at the North-West area.

Through the observation using microscope, the sample CODE 1 shows mineral which mostly feldspar colourless and light brown in PPL, meanwhile, it have

twinning with extinction of 20 ^{0}in XPL. The mineral composed such as plagioclase, quartz and, clinopyroxene.

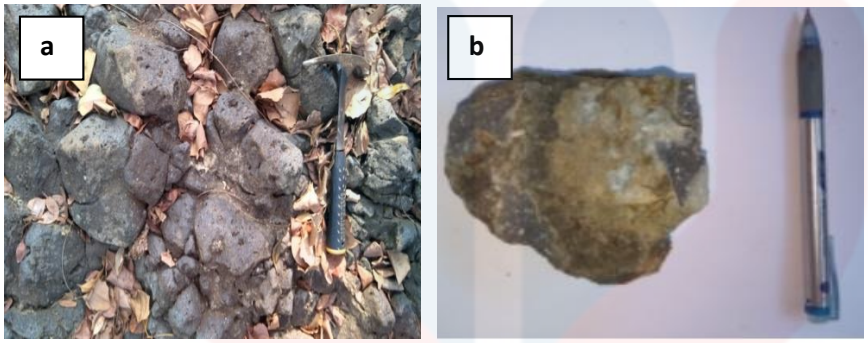


Figure 4.12: (a) The pyroclastic rock exposed shows the auto-breccia structure and (b) The sample of pyroclastic rock .Coordinate CODE 1 NAD510 (S 07^{0}52'19.45'',E 110^{0}32'32.61'') with elevation 131m

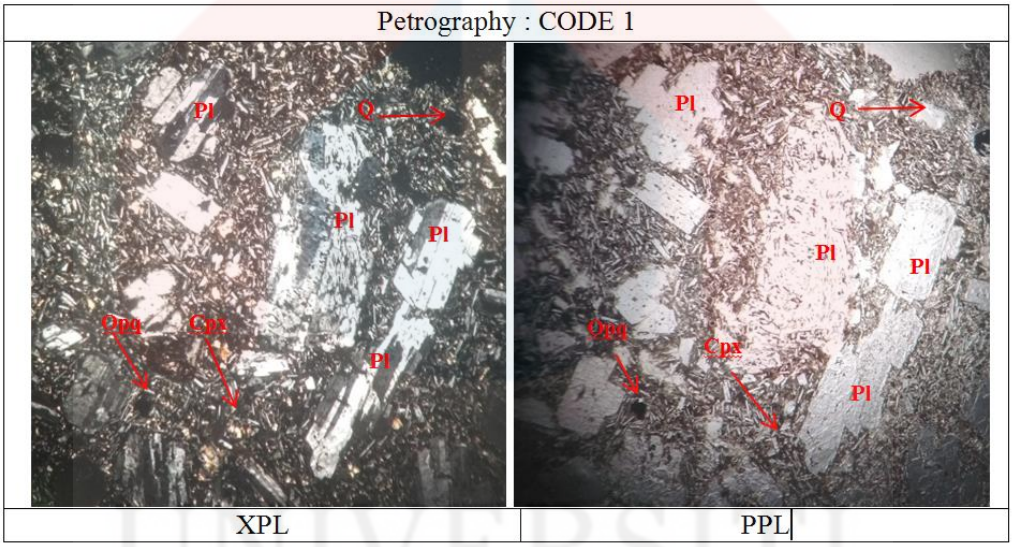


Figure 4.13 Shows the petrographic information with hand specimen of Code 1

Mineralogy/Fossil Of Description		
Composition of Mineral	Amount %	Description of Optical Mineralogy
Pl : Plagioclase	65	Have twinning and high relief in XPL and colourless under PPL. Extinction about 20 ^{0}
Opq : Opaque mineral	10	Opaque mineral black colour in PPL and XPL
Q : Quartz	10	Identified by low relief under PPL and colourless to greyish in XPL and have cleavage
Cpx : Clinopyroxene	15	Brownish colour in PPL and dark brown in XPL.

4.3.2.2 Volcanoclastic- Epiclastic Unit

B. Conglomerate and breccia

It composed of conglomerate and breccia. The epiclastic rock was formed by the transportation along the river flow and deposited after deposition process settles down, the fragments are bound together by mineral cement or by matrix particles which filled the spaces between fragments. In the outcrop composed of breccia and conglomerate, mainly, the rock was the volcanic rock product with the composition are sandstone, breccia pumice, andesite conglomerate, breccia, and tuff. The colour was grey to light grey and the fossil does not occurred and the fragment of tuff and andesite clearly observe and measure which the diameter about 3-5cm.

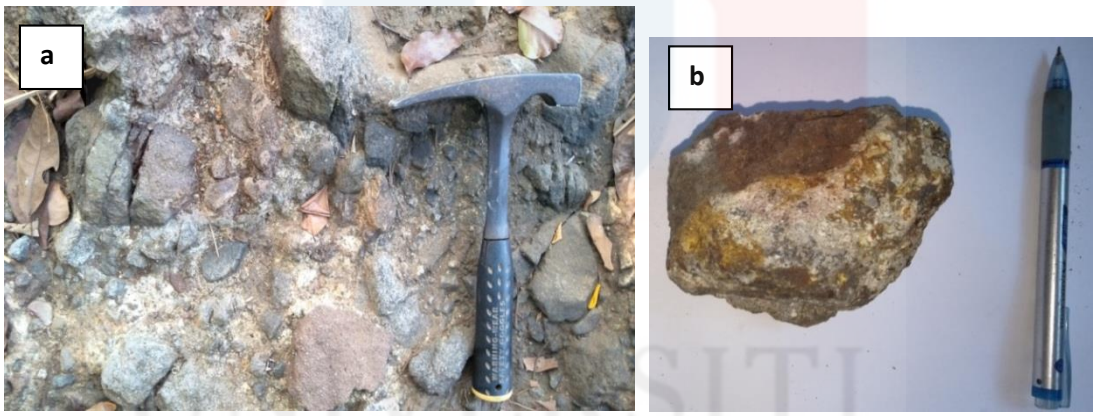


Figure 4.14: The outcrop of epiclastic rock .Coordinate CODE 2 NAD5C9 S $07^0$52’25.11’’, E $110^0$32’33.45’’ with elevation 131m

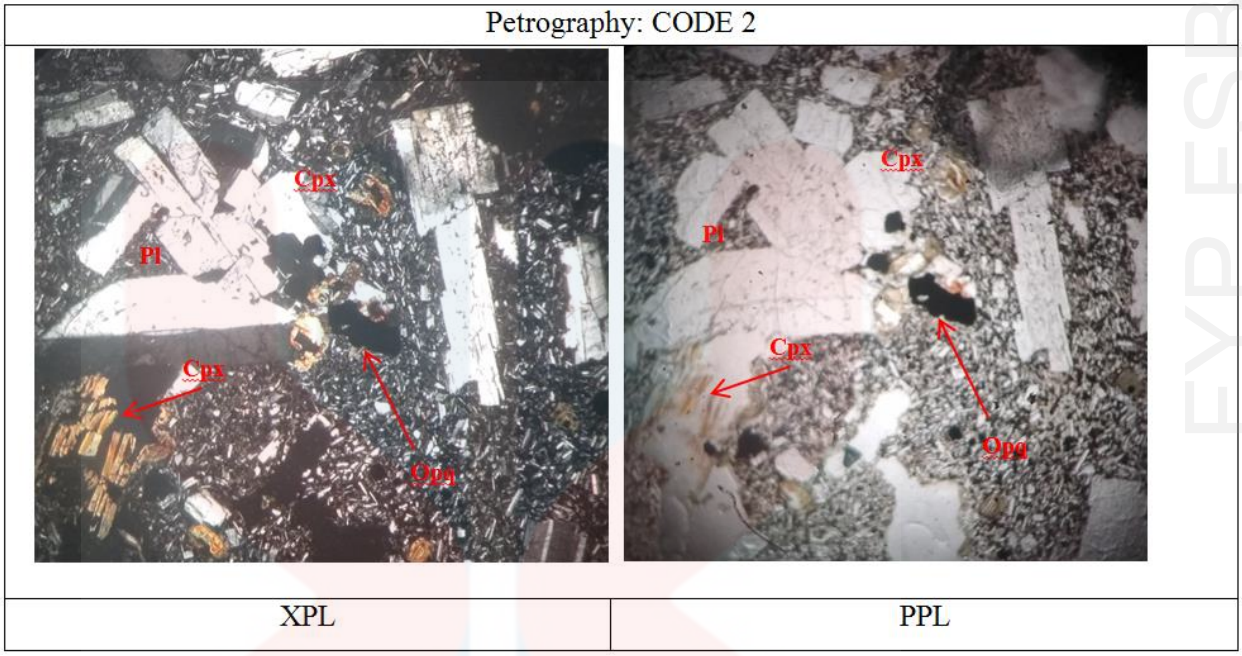


Figure 4.15 : The petrographic information with hand specimen of Code 2

Mineralogy/Fossil Of Description		
Composition of Mineral	Amount %	Description of Optical Mineralogy
Pl : Plagioclase	55	High relief and elongate shape and twinning in XPL. Extinction about 35 ^{0}
Opq : Opaque mineral	15	Opaque mineral black colour in PPL and XPL
Q : Quartz	5	Identified by low relief under PPL and colourless to greyish in XPL
Cpx : Clinopyroxene	25	Brownish colour in PPL and dark brown in XPL with sub angular shape. In XPL, the silver shining colour appear.

C. Lapilli Tuff

In the map of the study area, the lapilli tuff distributed at North-East area. Commonly, the rock overlaid the sandstone, tuffaceous sandstone. The rock typically light grey colour with the fill of tuff composition that creamy colour. The rock formed when the high temperature exerted to make the increase of high pressure to force the rock move upward to the mouth of the volcano. Mostly the composition

andesite and rhyolite. The simultaneous rapid cooling and rapid depressurization resulted in the foamy configuration of pumice rock.

Based on Figure 4.16, the grey colour to light grey and the fossil does not occur in the sample. The fragment of tuff clearly observes and measure which the diameter about 1-2cm. The white colour of tuff fills the pores and the dense clast of product volcanic shows in the rock in dense texture. The clast well sorted in textures of grain and fragments. The curve-planar surface of the large white pumice clast(arrow).The groundmass can be categorized as lithic sandstone with the product of volcanic and common mineral such as quartz and feldspar.

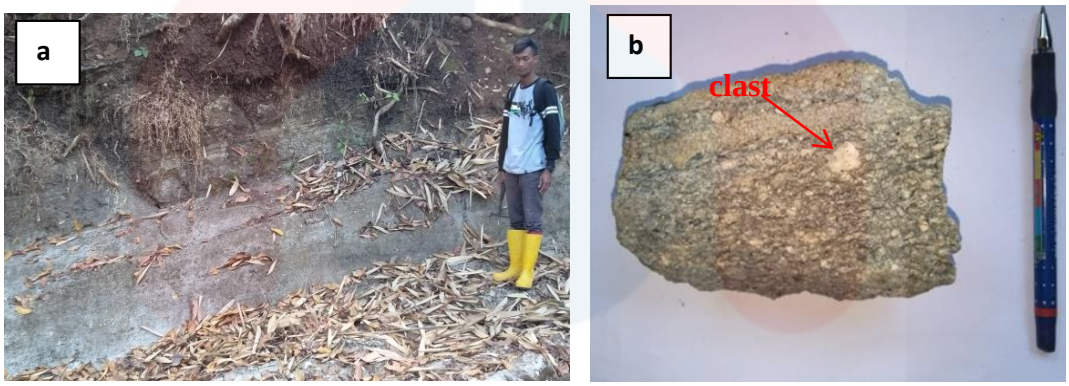
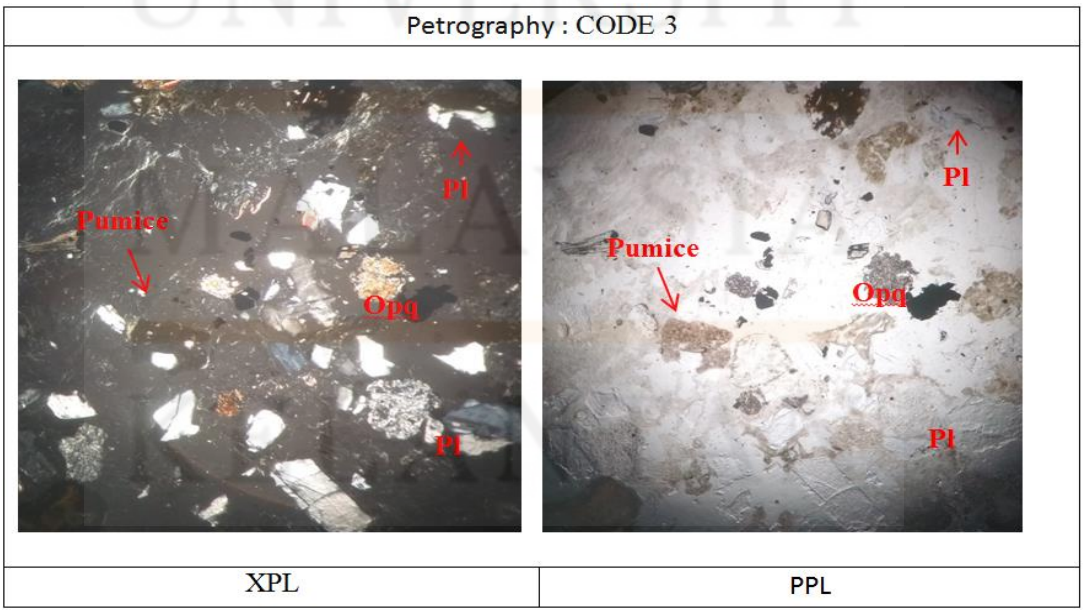


Figure 4.16 The outcrop of lapilli tuff exposes. Coordinate CODE 3 NAD512 (MS 3) (S $07^0$52’18’’,E $110^0$33’58’’)with elevation 130 m



Mineralogy/Fossil Of Description		
Composition of Mineral	Amount %	Description of Optical Mineralogy
Pl : Plagioclase	30	Have twinning and high relief in XPL and colourless under PPL. Extinction about 40 ^{0}
Opq : Opaque mineral	15	Opaque mineral black colour in PPL and XPL
Q : Quartz	10	Identified by low relief under PPL and colourless in PPL/while in XPL the mineral turn to black colour.
Cpx : Clinopyroxene	15	Brownish colour in PPL and dark brown in XPL with subangular shape.In XPL,the silver shining colour appear.
Pumice	30	Pumice is beige brown in PPL and dark brown in XPL

Figure 4.17: The petrographic information with hand specimen of Code 3

4.3.2.3 Sandstone Unit

The unit from the middle to Upper Sambipitu Formation Sandstone is made up of very fine or fine-grained about 1/16 mm – 2mm and mostly the mineral of quartz will presence. The groundmass will be found such as silica, carbonates, clay or iron oxides. In this area mostly carbonate that cemented the mineral.

A. Arkose sandstone

The arkose rock classifies by QFL ternary diagram which the feldspar must have or move than 25^{0} and also quartz mineral. The grain from fine to very fine grained and light grey colour and weathered on the surface of the oxide. It also cemented by calcite by in little amount.

In using the microscope, the groundmass mostly siliceous sandstone and small amount of calcite cement. The mineral of quartz also appeared which prove high resistant. The mineral found such as clinopyroxene, quartz, plagioclase, and opaque mineral. The opaque mineral black in colour in PPL and XPL.

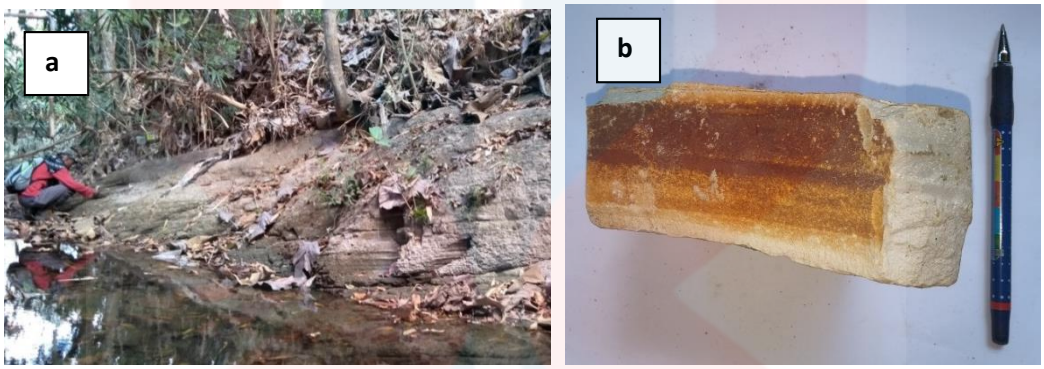
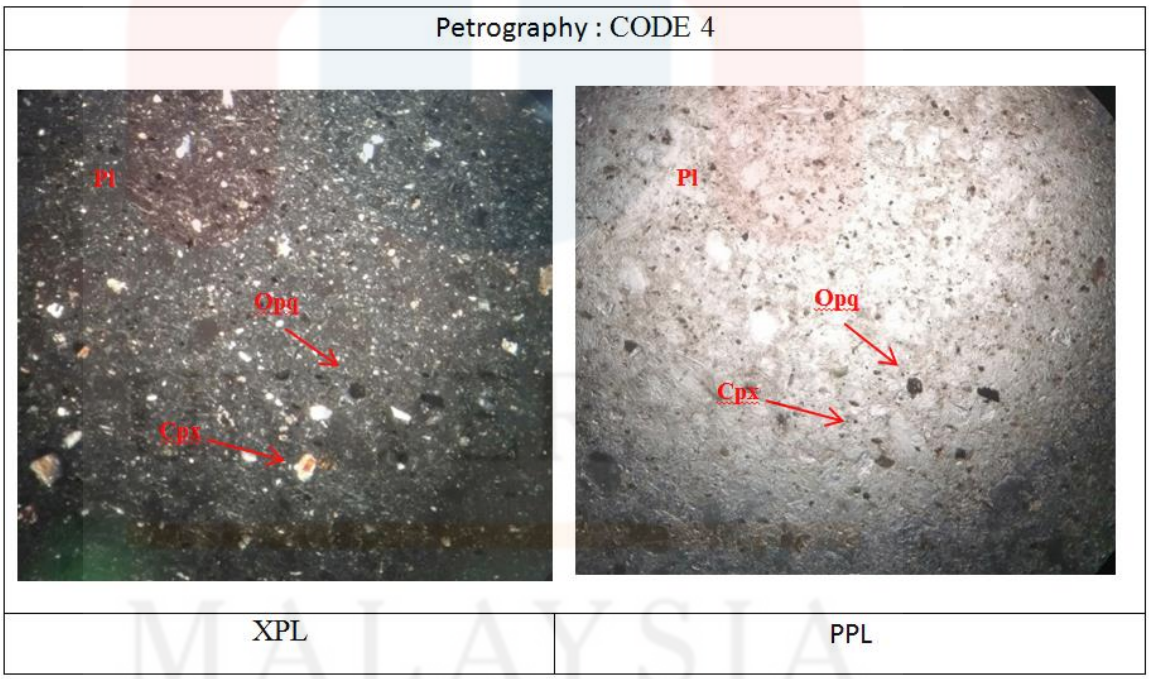


Figure 4.18 Shows the outcrop of arkose sandstone interbedded with tufaaceous sandstone. Coordinate CODE 4 NAD6C 8 (S $07^0$52'50.08'', E $110^0$31'57.12'') with elevation 130 m



Mineralogy/Fossil Of Description		
Composition of Mineral	Amount %	Description of Optical Mineralogy
Pl : Plagioclase	40	Have twinning and high relief in XPL and colourless under PPL. Extinction twinning about 45 ^{0}
Opq : Opaque mineral	15	Opaque mineral black colour in PPL and XPL
Q : Quartz	15	Identified by low relief under PPL and colourless in PPL/while in XPL the mineral turn to black colour.
Cpx : Clinopyroxene	30	Brownish colour in PPL and dark brown in XPL with sub-angular shape. In XPL, the silver shining colour appeared.

Figure 4.19: The petrographic information with hand specimen of Code 4

B. Tuffaceous sandstone

Medium-grained tuffaceous sandstone interbedded with fine-grained tuffaceous sandstone. The alternating sandstone have different thickness which the fine-grained sandstone thick about 10 cm, the colour more dark brown than the medium sandstone, meanwhile the medium-grained about 5 cm and bright yellow-white colour. Coordinates located at latitude S 07^{0}53'20.30'' and longitude E 110^{0}31'50.71'' with elevation 124m.The sandstone reacts with the hydrochloric acid (HCl) shows that the rock cemented by the calcite mineral. Both of the rock was moderate of compactness, the trace fossil occurred on the surface bedding. The sedimentary structure and trace fossil indicate the depositional environment, the turbidite system at the Widoro's river believed to form at the shallow marine based on the Mutti's Turbidite Facies Theory (Mutti et al., 2007).

In the observation using a microscope, the beige to light brown colour in PPL mostly appeared. It is hypocrystalline by its crystallinity texture and the groundmass as lithic tuffaceous sandstone. The minerals found plagioclase, opaque mineral, quartz, clinopyroxene and occur fossil foraminifera which the planktonic fossil which mostly found in the west area.

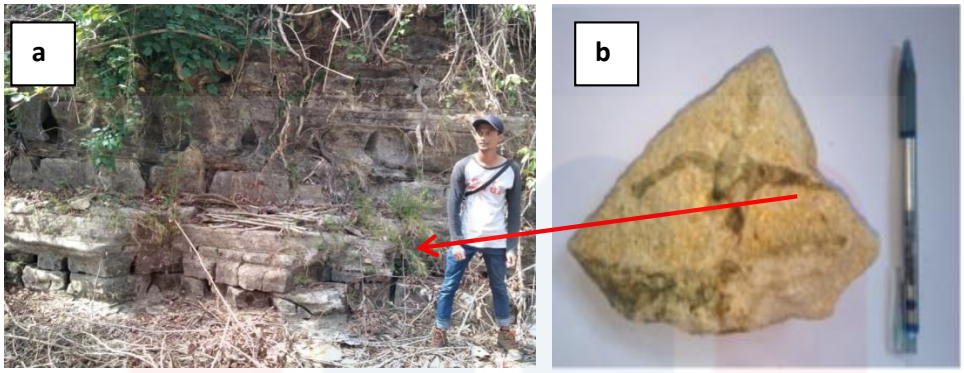
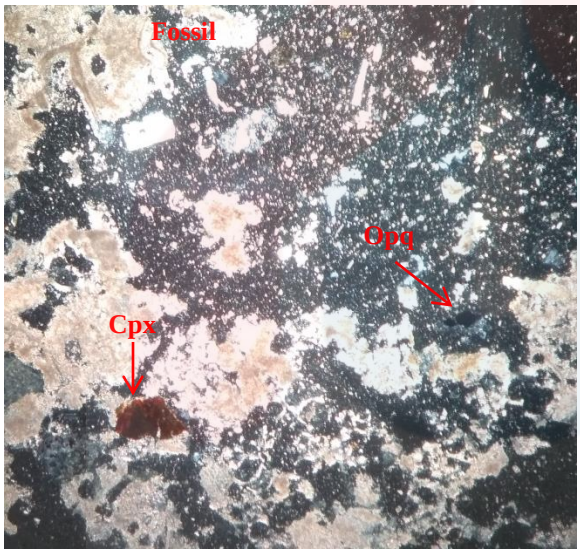
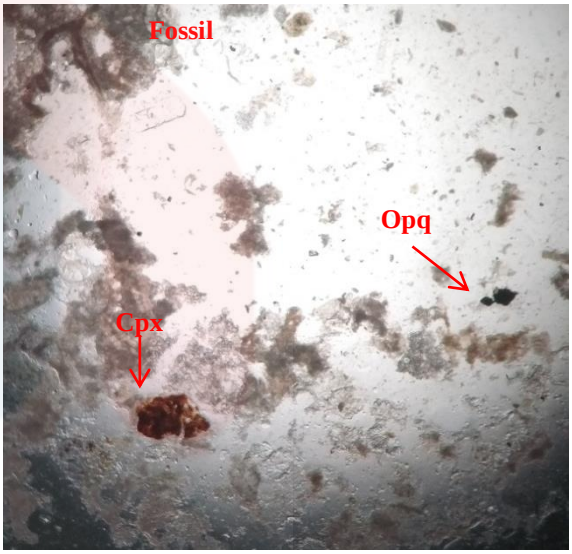


Figure 4.20 (a)The sandstone outcrop which fine-grained sandstone interbedded with medium – grained with fine-grained sandstone sample and (b) hand specimen of fine-grained sandstone.Coordinates CODE 5 NAD1C1 (S $07^0$53’15.20’’,E $110^0$31’30’’) with elevation 130 m

Petrography : CODE 5	
	
XPL	PPL

Mineralogy/Fossil Of Description		
Composition of Mineral	Amount %	Description of Optical Mineralogy
Pl : Plagioclase	20	Have albite twinning and moderate relief in XPL and colourless under PPL. Extinction about 40 ^{0}
Opq : Opaque mineral	10	Opaque mineral black colour in PPL and XPL
Q : Quartz	10	Identified by low relief under PPL and colourless in PPL/while in XPL the mineral turn to black colour.

Cpx : Clinopyroxene	20	Brownish colour in PPL and XPL but more darker and high relief in XPL, subangular shape. In XPL, the silver shining colour appeared.
Fossil	40	Abundance of benthic and planktonic forams fossil.

Figure 4.21: The petrographic information with hand specimen of Code 5

C. Calcareous siltstone

The rock composition between the clay grain sizes to sand. The colour was lightly creamy and overlaid the tuffaceous sandstone. The bedding thickness for calcareous siltstone about 10 cm-15cm.

In the observation using the microscope, cream in colour in PPL and light brown shows in XPL. It is hypocrystalline by its crystallinity texture and the groundmass as lithic tuffaceous sandstone. The minerals found plagioclase, opaque mineral, quartz, and calcite There also occur of fossil foraminifera such as *Globigerinid* sp. and *Orbulina* sp. *Globigerinid* sp. shows the structure of foraminifera more chamber meanwhile the Orbulina only one chamber structure in petrographic observation.

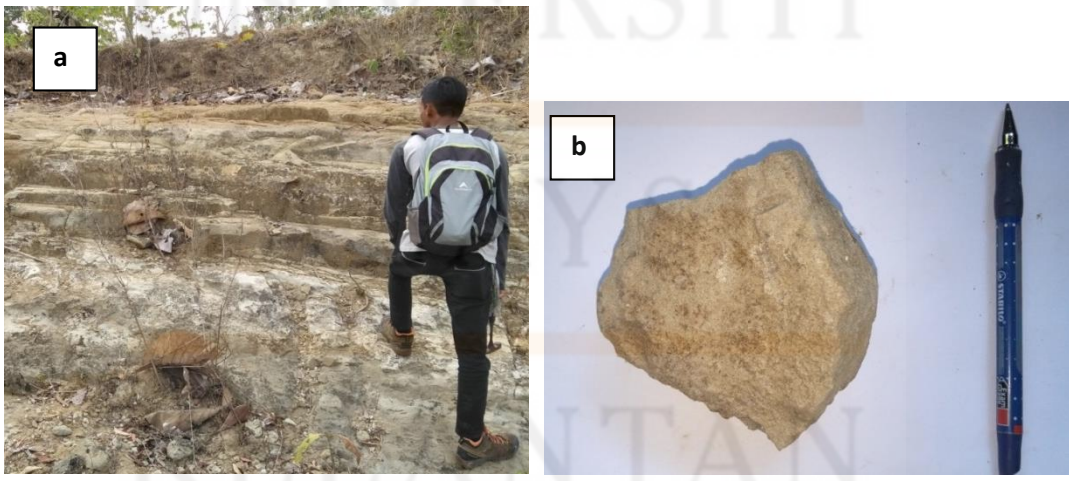
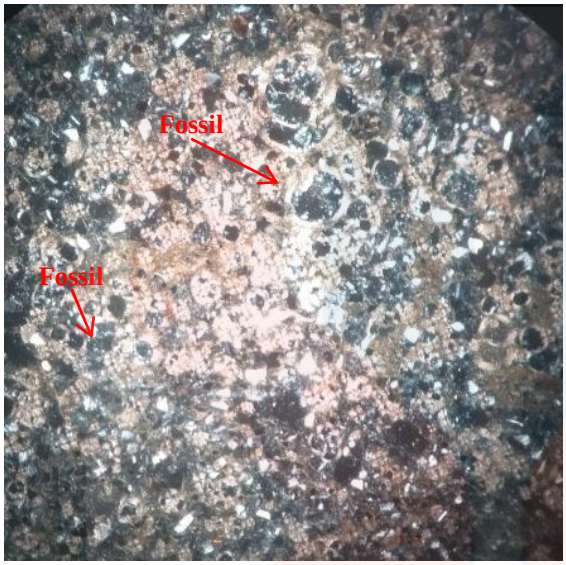
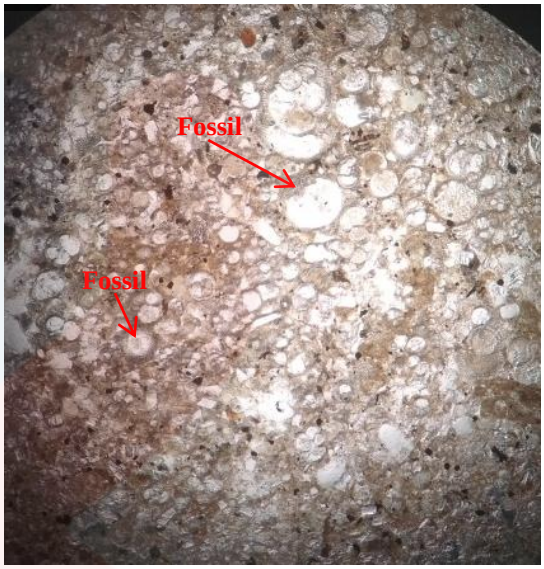


Figure 4.22: (a) Shows the outcrop of sandstone interbedded with tuffaceous siltstone and(b) hand specimen of tuffaceous siltstone. Coordinate CODE 6 NAD8C2 (S $07^0$52’54’’,E $110^0$34’06’’) with elevation 130 m

Petrography : CODE 6	
	
XPL	PPL

Mineralogy/Fossil Of Description		
Composition of Mineral	Amount %	Description of Optical Mineralogy
Pl : Plagioclase	15	Have twinning and high relief in XPL and colourless under PPL. Extinction of twinning about 15 ^{0}
Opq : Opaque mineral	10	Opaque mineral black colour in PPL and XPL
Q : Quartz	15	Identified by low relief under PPL and greyish colour /while in XPL the mineral turn to black colour.
Cal-Calcite	20	Calcite colourless in PPL and pearly shades in XPL
Fossil	40	Abundance of foraminifera fossil which are *Globigerinid* sp. and *Orbulina* sp.

Figure 4.23 : The petrographic information with hand specimen of Code 6

4.3.2.4 Tuffaceous Limestone Unit

A. Tuff Limestone

Tuffaceous limestone mainly found at the eastern and western part of the study area. The rocks in light brown cream, compactness moderately. The grain size fine to medium and composed of lithic tuffaceous sandstone. It is the sedimentary rock that the tuff which dominant of sandstone and it was cemented of the calcite. Rock that contains 50% of lithic tuff in carbonate rock can consider as tuffaceous limestone due to the composition of carbonate rock.

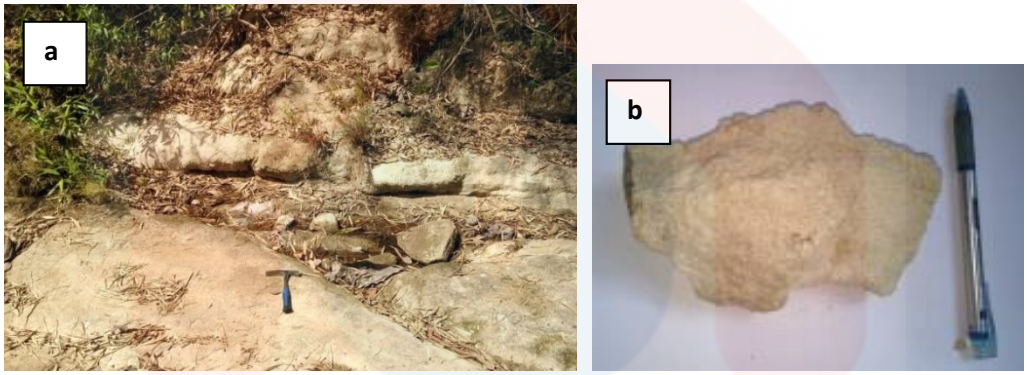
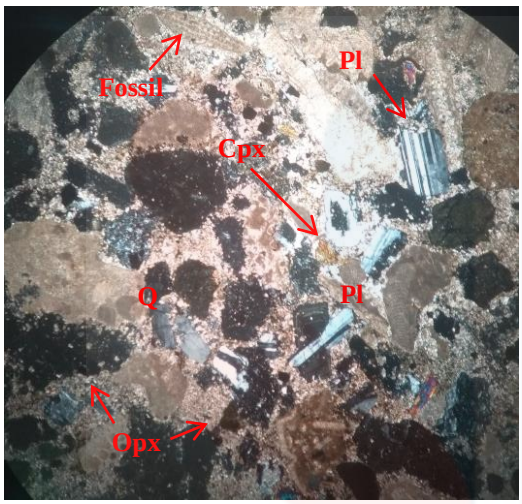
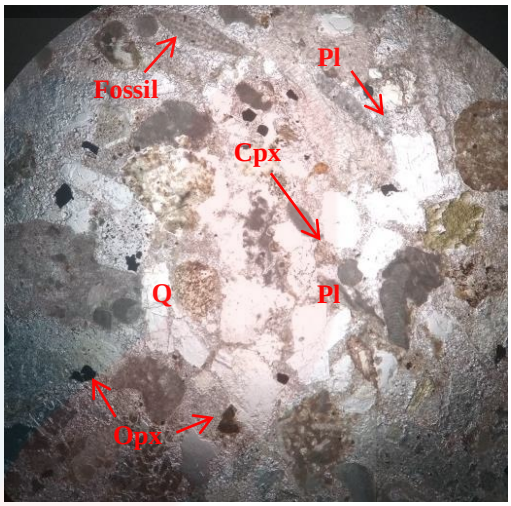


Figure 4.24 : (a) The tuffaceous limestone outcrop and (b) hand specimen of tuffaceous limestone. Coordinates CODE 7 S $07^0$53'20.30'', E $110^0$31'50.71'' with elevation 124m.

In microscope observation, the plagioclase colourless in PPL and have twinning extinction about 39^0. It is hypo-crystalline by its crystallinity texture and the groundmass composed of calcite and plagioclase minerals. The minerals found plagioclase, opaque mineral, calcite and occur fossil foraminifera (*Globigerinidae* sp.)

Petrography : CODE 7	
	
XPL	PPL

Mineralogy/Fossil Of Description		
Composition of Mineral	Amount %	Description of Optical Mineralogy
Pl : Plagioclase	10	Have twinning and high relief in XPL and colourless under PPL and euhedral shape. Extinction about 39 ^{0}.
Opq : Opaque mineral	10	Opaque mineral black colour in PPL and XPL
Cpx : Clinopyroxene	5	Was brownish colour in PPL and XPL but more darker and moderate relief in XPL. In XPL,the silver shining colour appeared.
Cal-Calcite	25	Calcite colourless in PPL and pearly shades in XPL
Fossil	50	Content such as foraminifera and coral fossil.

Figure 4.25: The petrographic information with hand specimen of Code 7

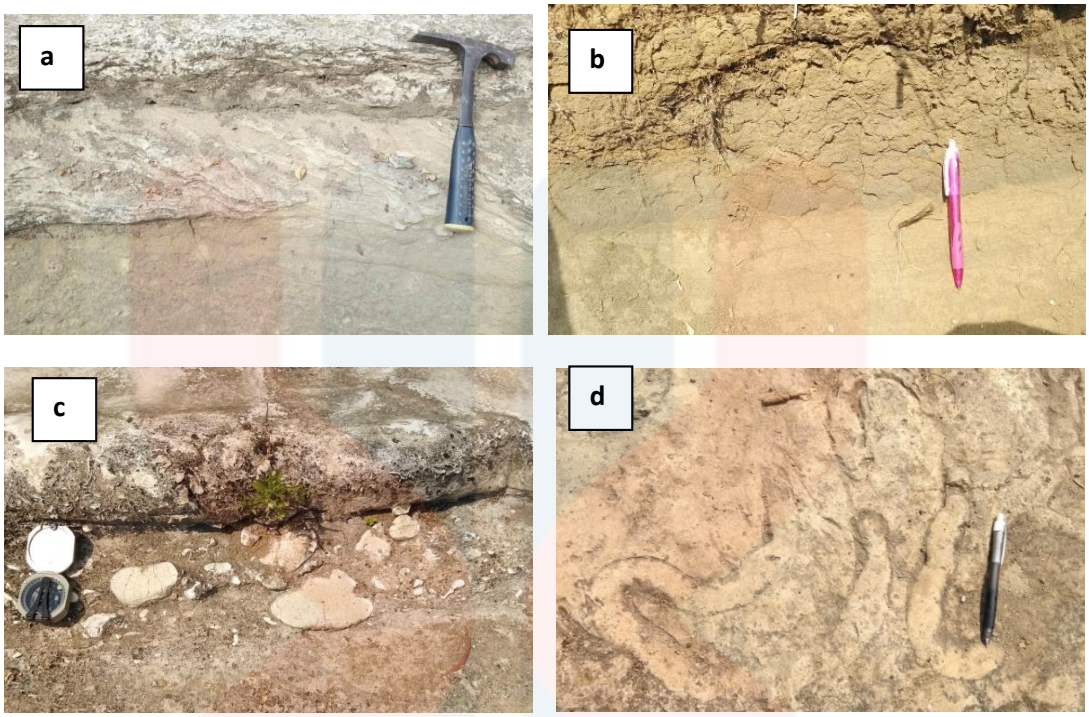


Figure 4.26 : (a) Cross bedding, (b)Cross lamination ,(c)Breccia pumice and (d)Bioturbation

Ichno-fossil also known as trace fossil shows the kinds of feeding traces, tracks, footprints, and burrows. Burrows are tubes or holes of varying diameter, length, configuration, and composition excavated or constructed by organisms, chiefly worms, crustaceans, or molluscs, along with a bedding plane or penetrating the bedding. To get information of organism ancient activity or the type of paleo-ecosystem, the analysing of fossil should be as the consideration.

Figure 4.26 (a) shows the cross bedding in the tuffaceous sandstone and intercalated with limestone. Limestone typically found in carbonate rock which contains of calcite mineral and possible of occurrences of the fossils. Typically the limestone beds at Bunder about 5 cm to 30 cm thick. On the beds surface, there is the presence of joints caused by the complex structure which the major fault of sinistral strike-slip fault. However, the joints cannot be seen clearly because the outcrop is highly weathered.

In the field, bedding in the outcrop will be observed and identify in order to mark and identify the geologic and sedimentary series. It called as a sedimentary rock because of the bedding structure deposited in layer by layer. In the general information of lithostratigraphic unit, the bed ranging from centimetre to meters. There are various ways to differentiate the bed of the sedimentary rock regarding their size of grain and the alternating of the bedding's colour. Due to the interpretation of the environment in Bunder, the structure of cross-bedding as the indicator or support the statement that the depositional environment forms in tidal flats.

Cross-bedding formed when the sandstone was deposited on the slope area and overlie or underlie the flat area. In Figure 4.14 (a) the cross-bedding underlie the planar bedding of limestone's rock and laid down on a sloping surface which supports interpreting that the depositional environment was water environment.

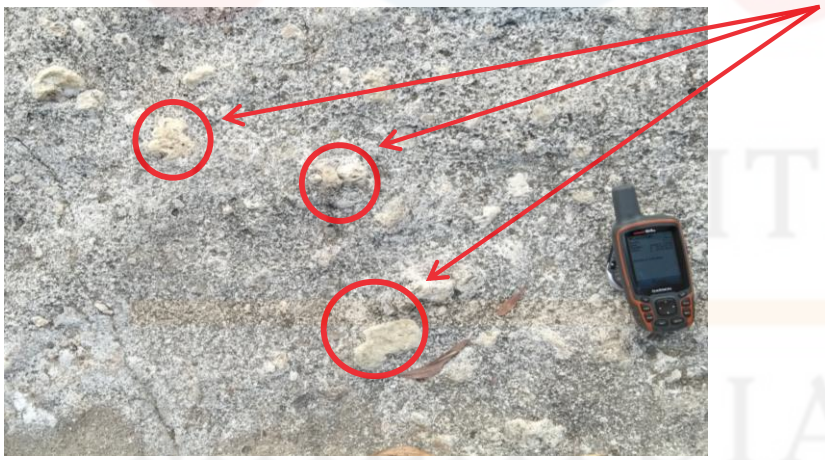


Figure 4.27 : Inclusion of limestone fragments

The structure due to the law states that clasts or fragment in a rock are older than the rock itself . Then the inclusions must be older than the formation that contains them.In the figure above,the limestone's clast might from the previous

limestone formation either Gamping Wungkal Formation or Jaten Formation.The clasts were transported by the river and deposit at the Tuffaceous Sandstone of Sambipitu Formation.

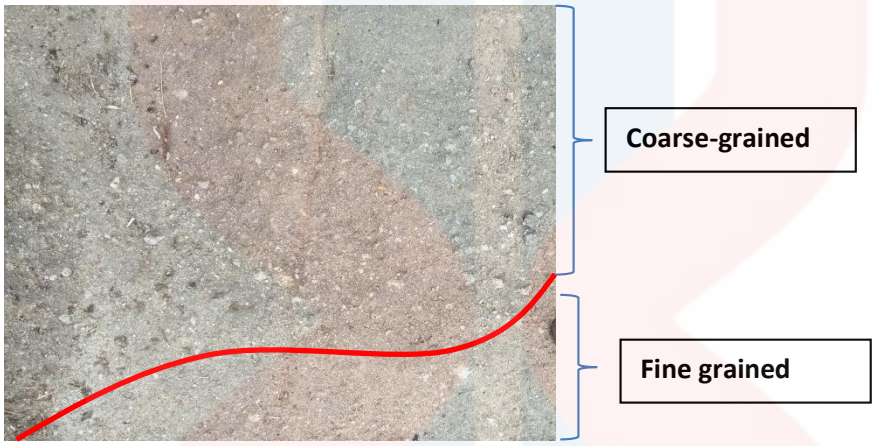


Figure 4.28 : Reverse graded bedding at coordinate S $07^0$53'10.28'',E $110^0$32'45.06''

The change in grain known as graded bedding which divided by two type which normally graded bedding or inverse / reverse graded bedding geology, in reverse or inverse grading the bed coarsens upwards and the bed fining upward known as normal bedding. The characteristics of this type of grading are relatively shown that the sediments deposited by grain flow and debris flow. Reverse graded bedding occur when the turbulence activity occurred.

4.3.2.5 Limestone Unit

Limestone not so pure due to the interfingering formation.It also gives the differentiation of the amount of matrix surrounding the grains. The percentage of calcium carbonate must more than 50 %.The reaction of the rock with hydrochloric acid shows the calcite principal. The reaction like the frizzy which the dissolution occurred. The Dunham system always shows the classification for limestone based

on their grain size and texture such as mudstone, wackestone, packestone, grainstone, and boundstone.

A. Rudstone interbedded with wackstones

Based on Figure 4.29 (b) rudstone composed of plagioclase and calcite which shows the crystal in XPL and colourless in PPL. The calcite fill in the space of fossils. Based on Figure 4.29 (c), the grey colour shows the wackestone. The mud supported the carbonate rock which the grains must higher than 10%. The wackestone bedding thickness about 10-15 cm meanwhile rudstone only intercalated which about 8-10cm. It is light grey in colour and very compact. Rudstone's colour of hand specimen is light grey due to the fossiliferous structure and coarser grain measurement. The tuff fragment about 2-3cm diameter.

In microscope observation, both of rock have plagioclase with twinning and colourless in PPL. Its composed plagioclase, calcite, opaque mineral and fossil of planktonic foraminifera. It also consists of small amount of tuff fragment and abundance of forams fossil. Meanwhile, the wackestone composed the same mineral as rudstone but the high amount of calcite mineral and not an abundance of fossil forams.

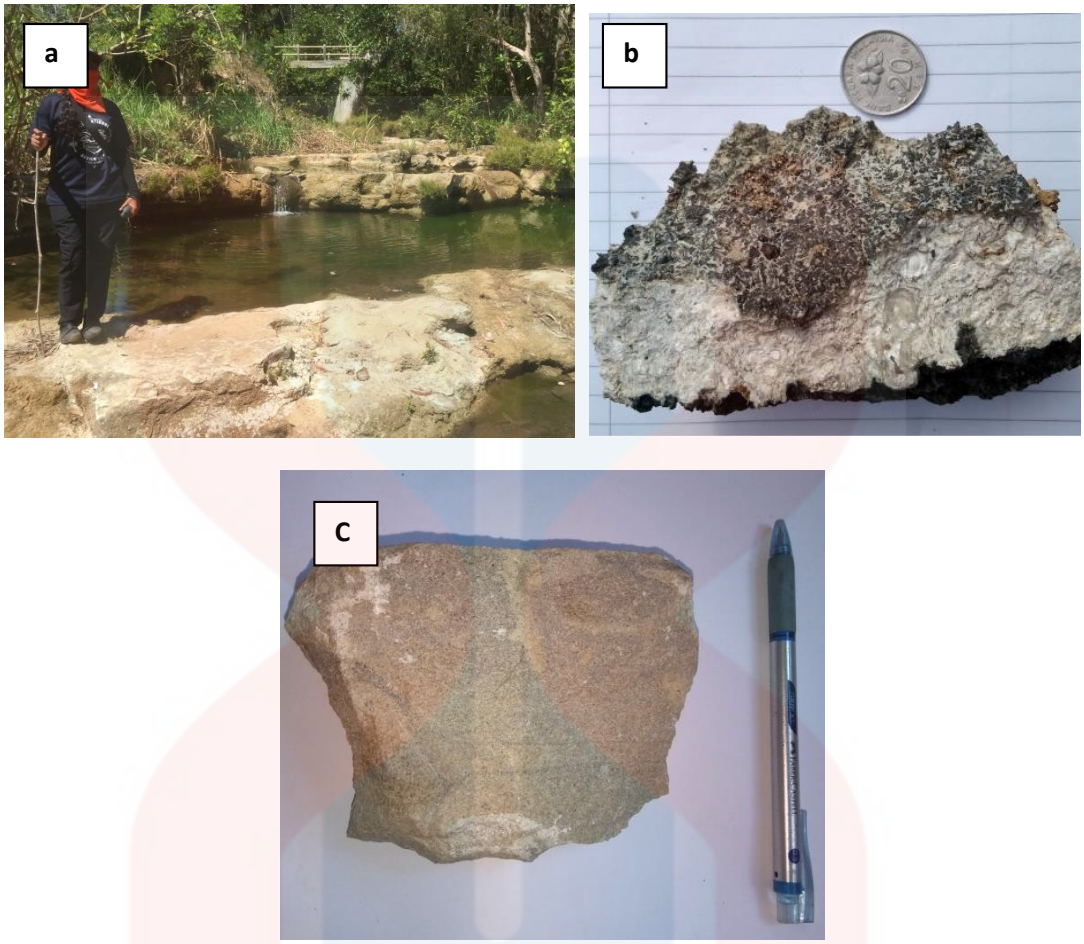
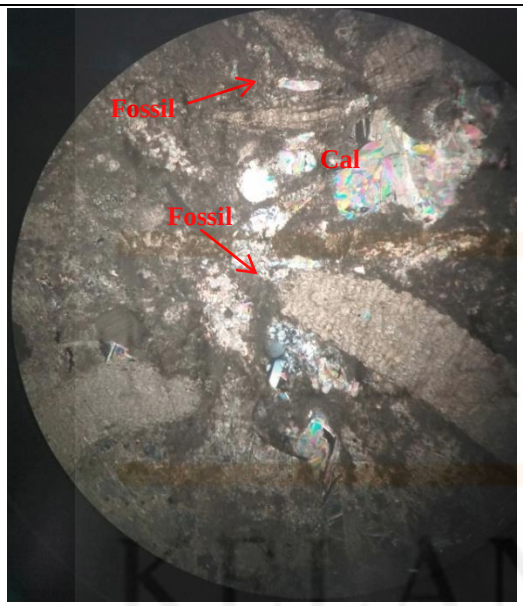
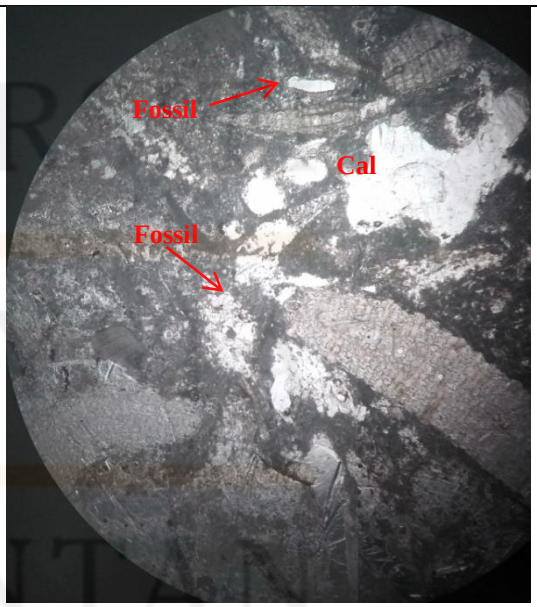
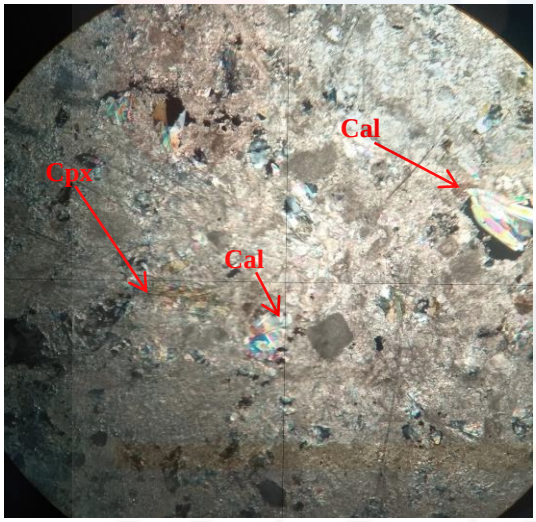
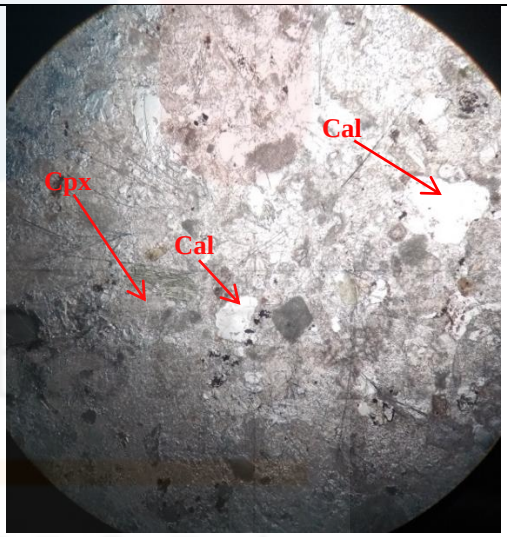


Figure 4.29: (a) The tuffaceous limestone outcrop (b) CODE 8, hand specimen rudstone c). CODE 9, hand specimen of wackstone. Coordinates S 07^{0}53'41.51'', E 110^{0}33'18.48'' with elevation 130m

Petrography : CODE 8	
	
XPL	PPL

Mineralogy Of Description		
Composition of Mineral	Amount %	Description of Optical Mineralogy
Pl : Plagioclase	5	Have twinning and high relief in XPL and colourless under PPL and euhedral shape. Extinction about 12^0
Opq : Opaque mineral	10	Opaque mineral black colour in PPL and XPL
Cpx : Clinopyroxene	5	Was brownish colour in PPL and XPL but more darker and moderate relief in XPL.In XPL,the silver shining colour appeared.
Cal-Calcite	30	Calcite colourless in PPL and pearly shades in XPL
Fossil	50	Content such as foraminifera and coral fossil.

Figure 4.30: The petrographic information with hand specimen of Code 8

Petrography : CODE 9	
	
XPL	PPL

Mineralogy Of Description		
Composition of Mineral	Amount %	Description of Optical Mineralogy
Pl : Plagioclase	5	Have twinning and high relief in XPL and colourless under PPL. Extinction of twinning about 15^0
Opq : Opaque mineral	10	Opaque mineral black colour in PPL and XPL

Cpx : Clinopyroxene	15	Brownish color in PPL and XPL but more darker and high relief in XPL, subangular shape.In XPL,the silver shining colour appeared.
Cal-Calcite	60	Mostly calcite due to the crystal colour and colourless in PPL
Q : Quartz-	10	Identified by low relief under PPL and greyish colour /while in XPL the mineral turn to black colour.

Figure 4.31: The petrographic information with hand specimen of Code 9

B. Marl-Limestone

It refers to the amount of calcium carbonate that the composition usually silts. In marl, the calcite must be the dominant mineral compared other minerals like dolomite or siderite. The colour light cream yellow and the thickness bedding about 70cm and have the bedding of tuffaceous limestone overly the marlstone bedding. The high of compactness and difficult to break the rock. In microscope observation, the texture medium grained and the groundmass composed of tuffaceous siltstone. The rock composed such as plagioclase, calcite, opaque mineral and fossil. The fossil of *Orbulinea* sp. Of foraminifera because only have one chamber structure and a small amount of *Globigerinidae* sp. The calcite which colourless in PPL and crystal colour in XPL.

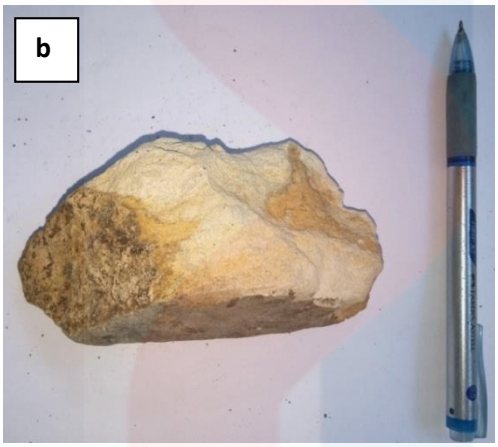
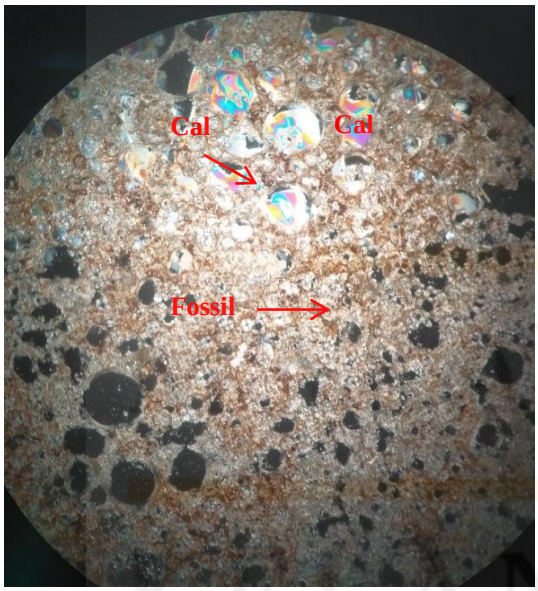
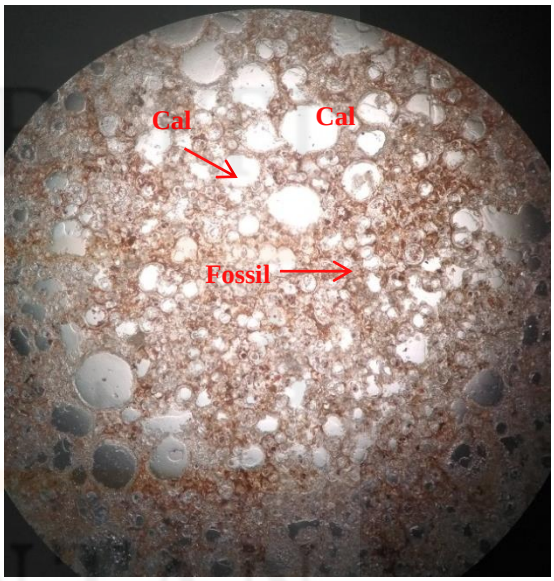


Figure 4.32: (a) The tuffaceous sandstone with marl outcrop and (b) hand specimen of marlstone. Coordinates CODE 10 NAD5C4 (S $07^0$54’37.20’’,E $110^0$31’37.21’’) with elevation 131m.

Petrography : CODE 10	
	
XPL	PPL

Mineralogy Of Description		
Composition of Mineral	Amount %	Description of Optical Mineralogy
Pl : Plagioclase	10	Plagioclase high relief and elongate shape and twinning in XPL. Extinction about 20 ^{0}.
Opq : Opaque mineral	10	Opaque mineral black colour in PPL and XPL or metal oxide mineral that cannot pass through it or pyrite.
Cal-Calcite	40	Calcite colourless in PPL and pearly shades in XPL
Fossil	40	Content such as foraminifera and coral fossil.

Figure 4.33 : The petrographic information with hand specimen of Code 10

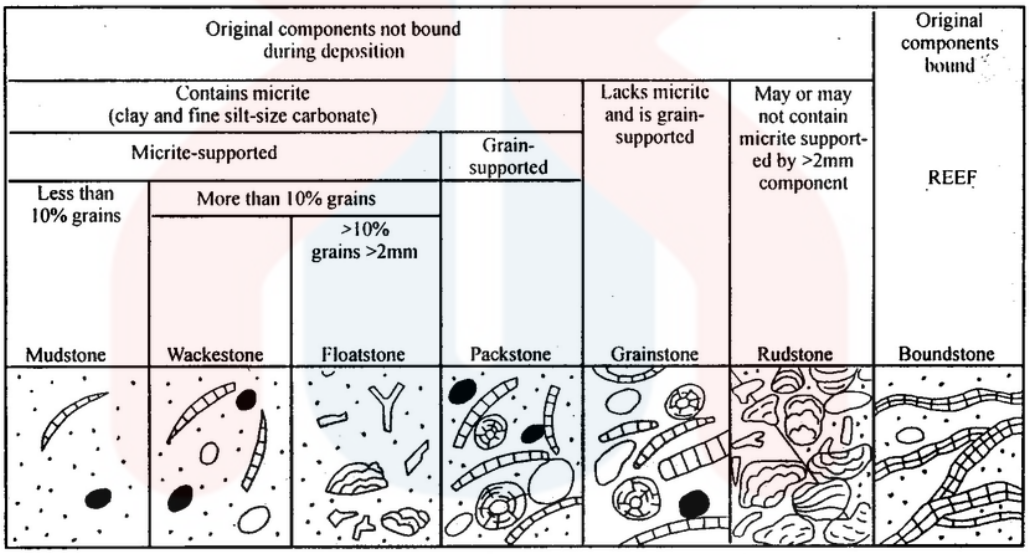


Figure 4.34: Dunham's Classification on carbonate rocks (Source: Dunham, 1962)

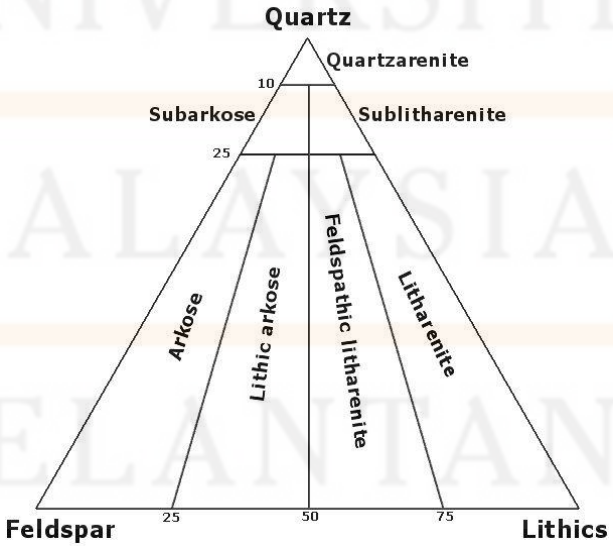


Figure 4.35: QFL diagram for Folk's sandstone classification

Based on the Dunham's classification in Figure 4.34, it showed a way of describing the composition of limestone, meanwhile, Folk's classified for sandstone due to the matrix that cemented the composition in the rock. Regarding the carbonate rock, the micritic claystone also found which interbedded with calcerous tuffaceous sandstone. Most of the samples in tuffaceous limestone consist about 70 % of calcite mineral. Folk's classification shows in QFL diagram which the composition of the quartz, feldspar and lithic or also called rock fragment identified. QFL ternary diagram classified base on the quart, feldspar, and lithic composition. The classification of sandstone in the QFL diagram also used in the sample of sandstone unit of Sambipitu Formation.

4.4 Structural Geology

In the observation of geological information, the Bunder area occurred by the complex structure. The geological structure can be found mostly strike-slip fault left lateral and also the auto-breccia structure that form when the lava cooled suddenly while the below part of lava still in liquid state. In addition, vein, joint, drag fold also can be found in this area especially at the Southern part of the study area. The structure resulted from the tectonic activity and the uplifting process. Generally, to study structural geology, identification of lineament on the map was the important things before going to the field. The lineament was the straight line or curve line in a landscape which is an expression of an underlying geological structure as indicators such as a fault due to the contour or topography.

4.4.1 Lineameant Analysis

Lineament analysis of Bunder area analysed based on lineament map. Based on lineament map in Figure 4.36, North-East direction shows the dominant lineament distribution and mostly the lineament easily to find along the river because the river flow direction can give information about the fault due to the tectonic activity. Dominant distribution direction indicates the paleo-stress direction.

From the lineament, structures such as folding and faulting are predicted on the map and analysed on field study. The dominant structures found are folding and faulting. The data collected is interpreted and it showed that the folding happens before faulting. Type of fold found at the Southern part of Bunder area was drag fold. Fold experienced by ductile rock and the fault happen because it has exceeded the ductility of the rock. There are quite huge numbers of fault found along the traverse from the Northern part of Widoro's river to the Southern part of the river. Instead of that, the anticline and syncline also found in limestone outcrop. The faulting and folding found to give the pieces of evidence of the lineament observed on the terrain map. Interbedded of different lithology also indicates the presence of structures in between the bedding.

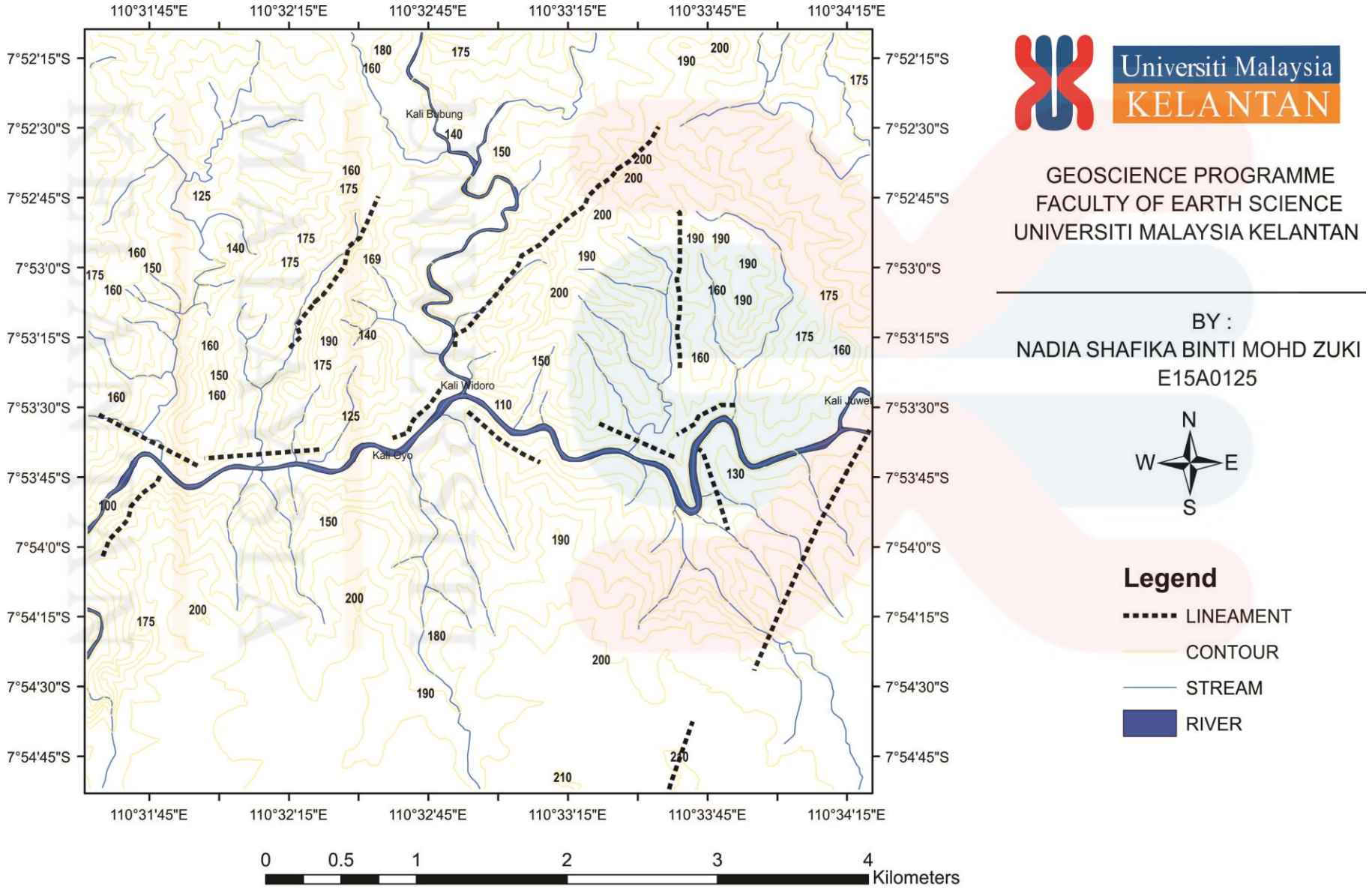


Figure 4.36: The lineament map

4.4.2 Fault

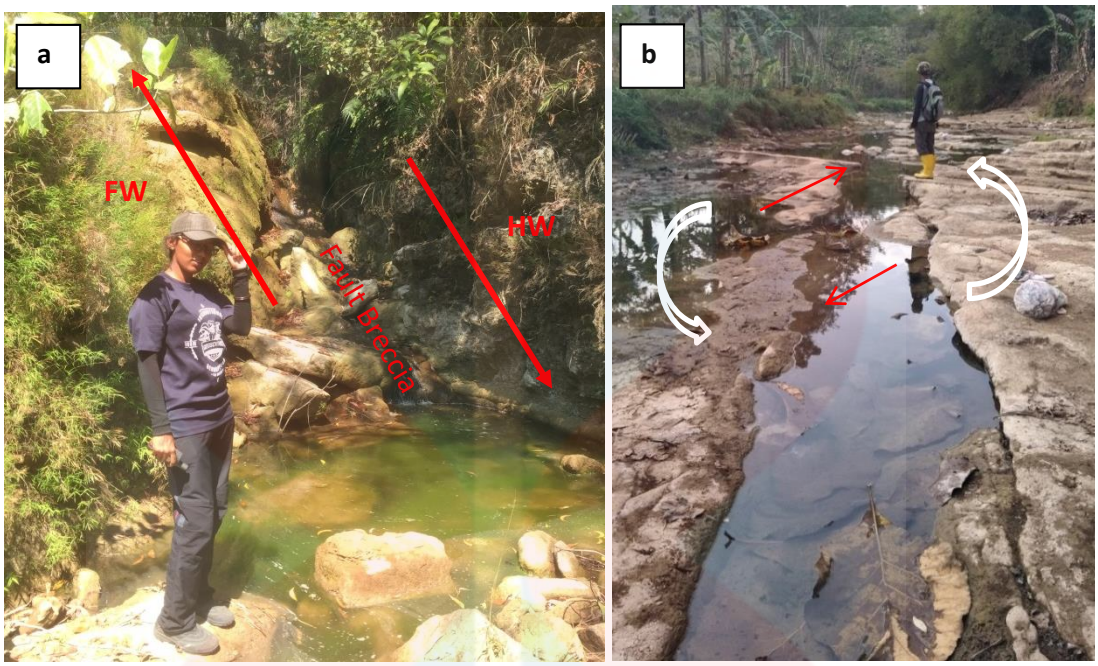


Figure 4.37 : (a) Normal fault and (b) Strike slip-trust fault and normal fault (Oblique fault)

The fault was the secondary structure which important for the geologist to understand. It is actually come from the brittle rock and break in the rock that makes up the earth crust which the rock being offset. Based on Figure 4.37 (b) above , coordinate S $07^0$53'22.86'', E $110^0$32'49.53'' with the elevation 126 m, the outcrop seeing undergoes fault which normal fault with trend and plunge value S 44 ^{0}E/19 ^{0}. The normal fault which occurs when the movement of the side of the plane either hanging wall or footwall moves down relatively follow the dip of the fault. Fault breccia is formed when the rock fragments or mineral debris accumulate at the fault plane or it looks like the broken rock with the angular shape produced along the fault plane that slides each other during faulting. It was not transported very far from the fault plane. Oblique fault in Figure 4.41 (b) shows that the strike-slip fault dextral and followed by the normal fault. The combination of shearing and compressional forces exerted surround the rock and basically, the fault will have some component

of both dip-slip either normal fault or reverse fault. The figure below shows the stereonet for the strike-slip (dextral).

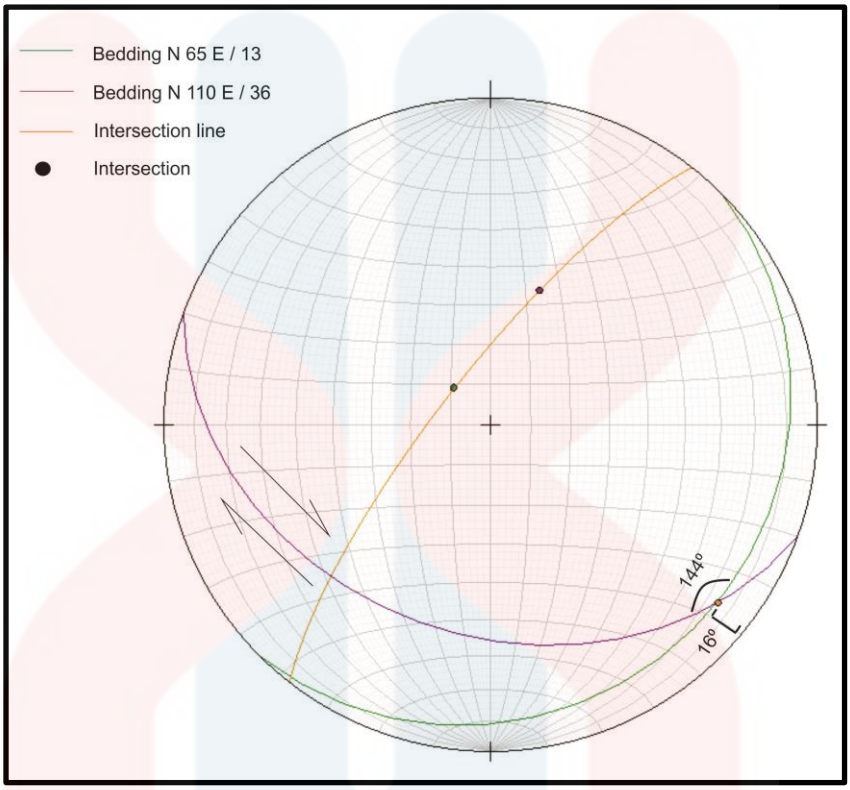


Figure 4.38: Stereonet strike slip fault (dextral) occur in oblique fault

4.4.3 Joint

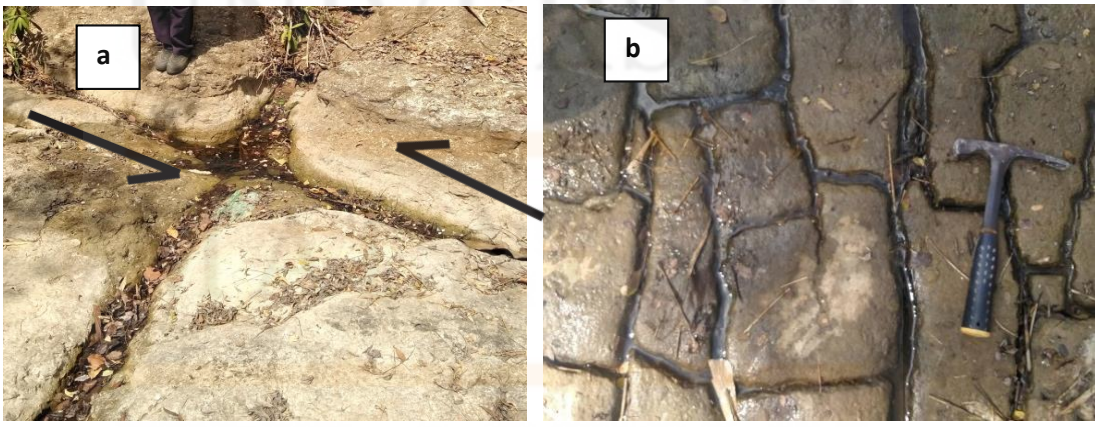


Figure 4.39: (a) Conjugate joint and (b) Orthogonal joint

Joints structure mostly found in carbonate rocks of the study area. The joints show the result that the bedrock or the outcrop undergoes the weathering process and

the erosional process. The process and the joints structure affect the landform of the surface of the earth, change the topography and morphology of the earth's surface. From this location of Figure 4.39, we found the two type of joint which extensional joint and shear joint. The conjugate joint shows the 'X' shape that been created by the tectonic activity due to the movement of the rock layer by the maximum and minimum forces. Joint is the easy structure to found at Bunder and mostly joint structure occur on the tuffaceous sandstone.

Next,when the rock compressed and is formed of a crack that was called the shear joint which an emerging shear plane. (Merriam Webster, 1828).However, the extensional joint was the planes of separation on which no shear displacement has taken place. Joint can easy to find by looking at the straightening fracture which the extensional were not really straight meanwhile the shear joint have the sharp straight structure of fracture. Stress exceeds might give the limit of compressive stress causes the rock in a brittle manner. So in this area, we observed that the continued deformation may occur due to their additional joint sets.

Table 4.1 : Joint reading in tuffaceous sandstone

Bearing	Frequency	Bearing	Frequency	Bearing	Frequency
0° - 10°		121° - 130°	II	241° - 250°	II
11°- 20°		131° - 140°		251° - 260°	
21°- 30°		141° - 150°		261° - 270°	II
31° - 40°		151° - 160°	II	271° - 280°	
41° - 50°	III	161° - 170°	IIIII I	281° - 290°	IIII
51° - 60°		171° - 180°	II	291° - 300°	
61° - 70°		181° - 190°		301° - 310°	IIII
71° - 80°		191° - 200°		311° - 320°	II
81° - 90°		201° - 210°	I	321° - 330°	IIII IIIII I
91° - 100°		211° - 220°		331° - 340°	IIIII I
101° - 110°		221° - 230°		341° - 350°	IIIII IIIII IIIII III
111° - 120°		231° - 240°		351° - 360°	II

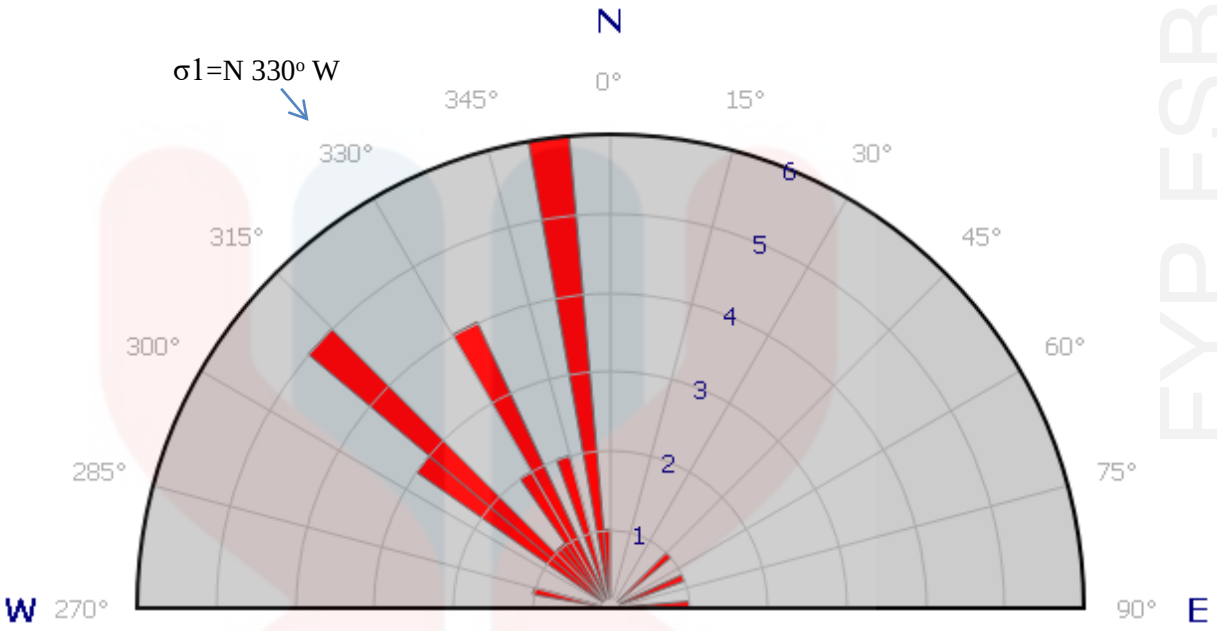


Figure 4.40: Shows the rose diagram .From the measurement of frequency of joints, most of the joint set trend 300^0 and 360°. Therefore, the principal stress of α_1 is assumed from N 330° W.

Table 4.2 : Joint reading in tuffaceous limestone

Bearing	Frequency	Bearing	Frequency	Bearing	Frequency
0° - 10°		121° - 130°	IIIII	241° - 250°	II
11°- 20°		131° - 140°	IIIII IIIII II	251° - 260°	
21°- 30°		141° - 150°	II	261° - 270°	
31° - 40°	III	151° - 160°	IIIII	271° - 280°	
41° - 50°	I	161° - 170°	IIIII IIII	281° - 290°	
51° - 60°		171° - 180°	IIIII IIIII I	291° - 300°	IIIII I
61° - 70°		181° - 190°	IIIII I	301° - 310°	III
71° - 80°		191° - 200°		311° - 320°	IIIII II
81° - 90°	II	201° - 210°	IIIII IIIII IIIII I	321° - 330°	
91° - 100°	II	211° - 220°	IIIII IIII	331° - 340°	
101° - 110°	III	221° - 230°	IIII	341° - 350°	
111° - 120°		231° - 240°	III	351° - 360°	II

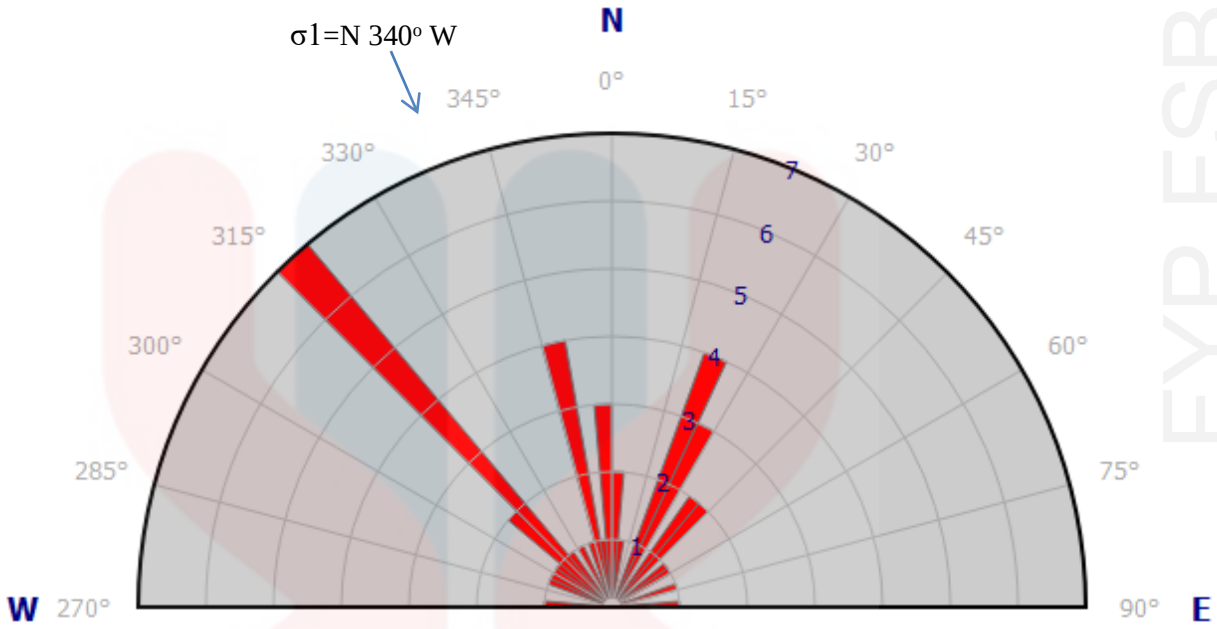


Figure 4.41: Shows the rose diagram .From the measurement of frequency of joints, most of the joint set trend 310^0 and 360^o. Therefore, the principal stress of σ1 is assumed from N 340° W.

From both figure of joint, the maximum principal forces (σ1) from North-West. Regarding the figure of conjugate joint, the minimum forces (σ3) can be identified at the field as it perpendicular to the maximum principal forces (σ1).The stereonet objectives for the geometry projection for joint structure so that the analysis can be more precise and accurate.

4.4.4 Fold

Fold is the structure to shows the rock in ductile and deformed due to stress and pressure exerted. When the colliding between two plates, as they are forced exerted, they tend to bend or make some pattern in the rock. (Horridson, 2016). Folding can be varying in size which can be as big as mountain and as small as microscopic photo. There were many type of fold such as anticline, syncline, and drag fold which can be found at the southern part of the study area.

4.4.4.1 Syncline Fold

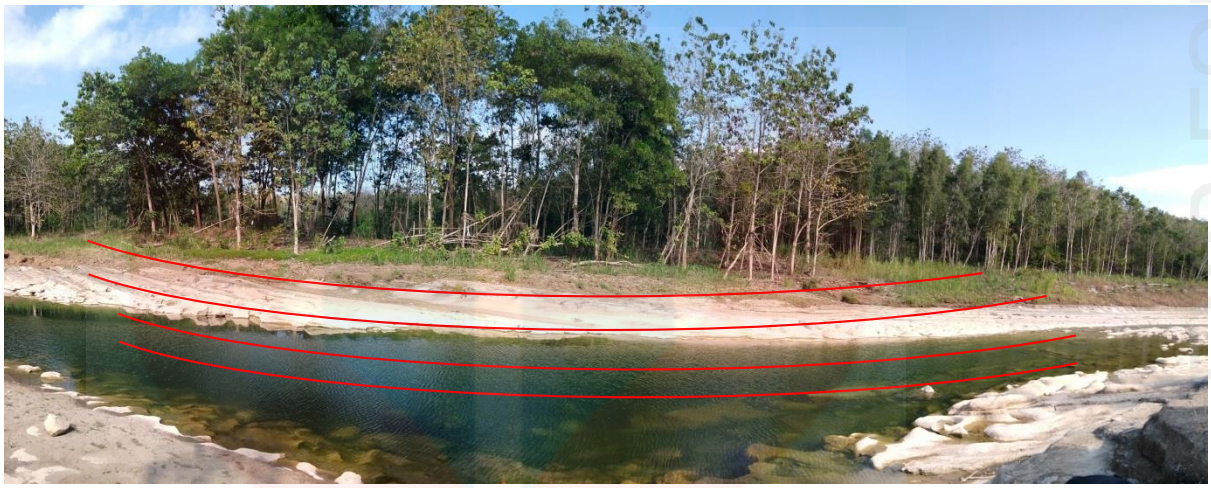


Figure 4.42: The fold was found at coordinate with latitudes S $07^0$53’39.30’’ and longitude E$110^0$31’43.26’’ with elevation 107 m.

Syncline fold found at the river bank, typically the Downward fold same as the synclines fold are typically a downward fold (synform), Syncline is the older rock layers are found in the centre (along the axis) of the fold which closely related to the anticline ,this also related to the named of synform. Strike and dip measurement were measured to gain more data about the tilting angle from the horizontal of the bedding. More data give the accuracy and details about the formation structure. The syncline fold occurs at the meandering river, that alternating of tuffaceous sandstone with grain-limestone

4.4.4.2 Drag Fold

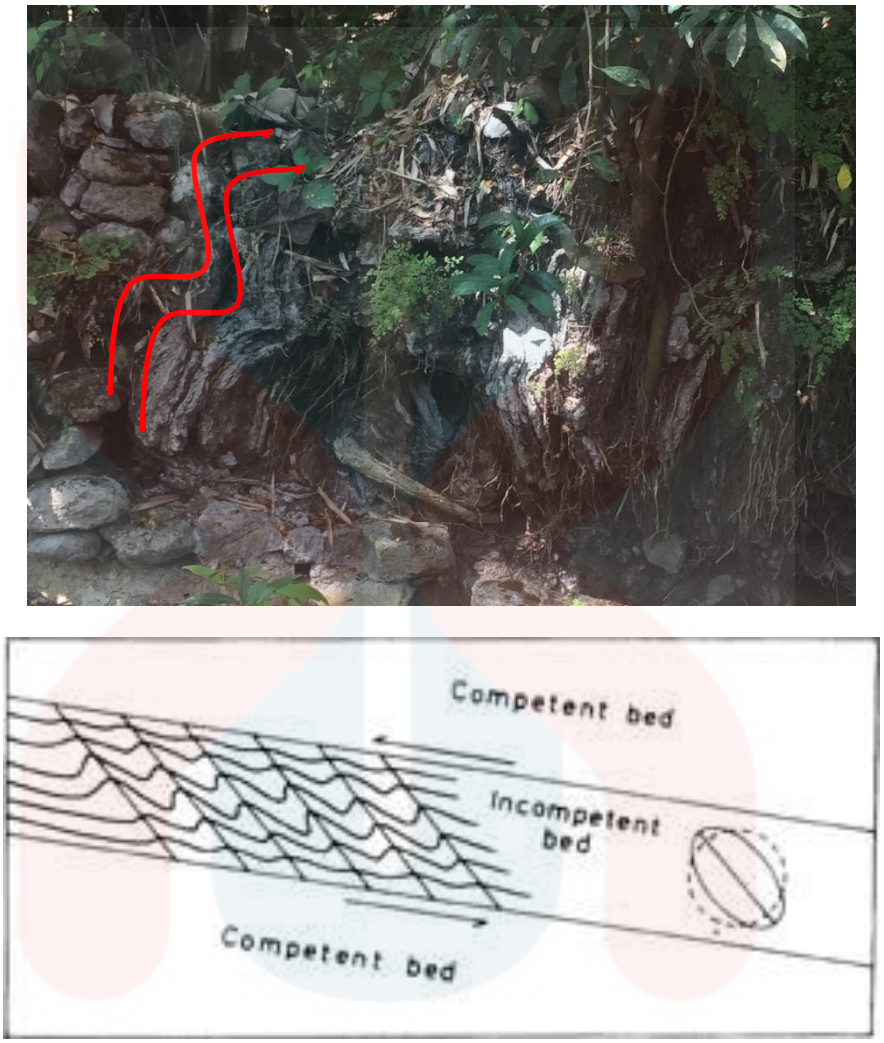


Figure 4.43: The drag fold

The drag fold develops due to the shearing and dragging effect and minor geological fold produced in soft or thinly laminated beds lying between harder or more massive beds in the limbs of a major fold. The incompetent rocks are the rock which has the characteristic weak and soft. This characteristic or features resulted of rocks that in turn are sandwiched between thick competent beds.

4.4.5 Vein

Figure 4.44: The vein structure

Quartz vein is commonly found in limestone area. The precipitation due to the cycles of groundwater chemistry and it also evident by subtle changes in dissolved magnesium .Groundwater typically related with the limestone and groundwater carry dissolved silica. The silica crystallization accelerated due to the high pressure and temperature. Crystallization is dramatically accelerated and the precipitation of quartz and calcite is actually quite common.

Based on figure above, there is intrusion process occurs. From observation, the intrusion is quartz vein because the mineral that intrude does not react with HCl. Based on the Figure 4.44, the structure of quartz veins cut the bed and through the bedding of rocks. The vein occurs on the surface of thick bedded of the tuffaceous limestone and about 20 m long on the flat surface of limestone bedding.

4.4.6 Auto breccia

Figure 4.45: Well outcrop exposed shows the auto-breccia structure of pyroclastic rock (Andesitic lava)

Auto breccia is the igneous rock structure that forms from the magma. The structure happened because of the cooling process when the magma in contact with the surface and flow as lava when the surface of lava break up caused difference temperature between the rock and the surface make the rock broke into the angular shape and the look like breccia fragment. The magma gets incorporated into the lava flow, but the magma below it still in liquid state. The structure only occurs on the surface and the magma below the outcrop exposed does not have the structure as well as the magma that in contact to the surface.

Based on the outcrop of the study area, the auto breccia occurs on the andesitic lava. The boundary of Sambipitu Formation and Nglanggeran Formation. Actually the andesite lava equivalent of diorite which the colour of the rock not too dark and variable, but typically grey that lighter coloured than basalt rock.

4.4.7 Cleavage

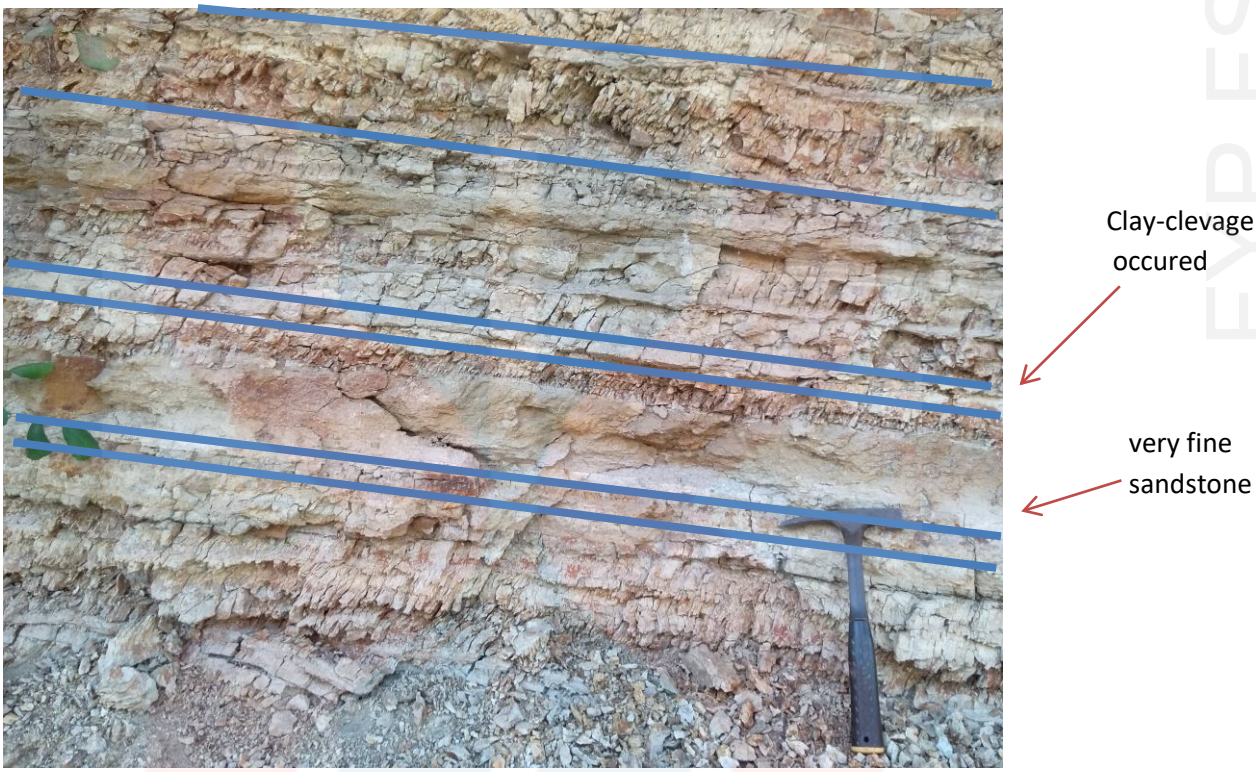


Figure 4.46: Slaty cleavage of claystone alternating with sandstone

Cleavage is the common structure in clay or siltstone shows the line crack with no movement features. The pressure solution related to the cleavage structure and the degree of the deformation with the rock determines the kind of feature of the cleavage. The alternating of claystone and very fine sandstone give information that the environment was tidal due to the regressions and transgression process which the clay deposited first when the high tide to low tide process and followed by very fine-grained sandstone. The colour of very fine sandstone brown meanwhile for claystone the colour shows the light beige brown.

4.4.8 Potholes

Figure 4.47: Potholes along the Oyo river

Potholes in this tuffaceous sandstone streambed were probably formed by the long-term erosive action when the water reacts with the carbonate formed the carbonic acid, the carbonic acid will dissolve the mineral such as feldspar or calcite into solution. This result for the rock poorly cemented and made of the broken shell or other coral species. The observation of the potholes coordinates with latitude S $07^0$53’10.28’’, E $110^0$32’45.06’’.

4.5 Historical geology

The historical geology of the study area started in the Early Miocene and Middle Miocene. The study area consists of three parts of formation which Nglanggeran Formation, Sambipitu Formation, and Oyo Formation. The relationship between the boundaries of the formation is interfingering each other of the formation. The size of grains, percent of the minerals content, colour of the rock was determined in order to

differentiate the units of rock. As mentioned, the Bunder area composed of the complex structure due to the tectonic moves and under the changer pressure and forces which comes in many directions that resulted in the fold, and fault. Lower Permian where the low grade of metamorphism process formed in the region.

From the lithostratigraphy, the rock units were divided into 5 different unit which started between the early Miocene and the middle Miocene. Roughly will be discussed the rock unit from the lower Sambipitu formation, middle Sambipitu Formation and Upper Sambipitu formation. The sandstone unit will be discussed more in Chapter 5.

There are many sedimentary structures in the study area which can be the indicator for the ancient depositional environment. The energy level in the environment was turbulence which indicates that the place was a submarine fan. Sequence stratigraphy analysis indicates that the areas sequences were dominated mainly by submarine fan complexes introduced in the low stand stages and pelagic sediments deposited during the transgressive and high stand stages.

The volcanic rock was the oldest formation in the Bunder area. The formation from the volcanic activity either produces the pyroclastic or ash fragment or debris. The volcanic rock in the study area such as tuff, breccia pumice, andesitic lava, and conglomerate.

Next, for the sandstone unit which it consists of claystone interbedded with fine-grained sandstone, siliceous siltstone, tuffaceous sandstone, calcareous sandstone, and calcareous siltstone. The trace fossil mostly abundance shows the burrow of worm organisms. The outcrop mostly weathered and dark brown to light brown. The colour of the rock gives in details about the environment when the deposition

occurred. From the previous research, the inclusion information involved of the tuff fragment which forms from the volcanic rock and had been transported and deposited while the fine-grained sandstone cemented the tuff fragment. By referring the Figure 4.16 using the same concept of inclusion, at coordinate S $07^0$52'50.96'', E $110^0$33'01.64'', the limestone fragment was found in the Sambipitu Formation that undergoes the transportation by the river flow and deposited with the sandstone in the Sambipitu Formation. The presence of limestone fragment in the Sambipitu formation was the new findings in this research which from the previous study, they only found the tuff fragment in Sambipitu Formation.

Limestone units consist of tuffaceous limestone, marl, wackestone,packestone, and mudstones .The outcrop mostly light grey colour and fossils were abundances. For instance, the colour of the rock sample thinly bedded limestone in Oyo formation lighter than the thick-bedded limestone. It indicates that the thinly bedded limestone deposited in the calm water which deeper water level than the thickly bedded limestone. The thickly bedded limestone has the darker colour due to the in contact with the surface and weathered. This phenomenon slightly refers to the tidal movement in the marine environment. The Dunham's classification was used to determine the limestone rock's name by determining the percentage of certain minerals.

CHAPTER 5

DEPOSITIONAL ENVIRONMENT OF SAMBIPITU FORMATION IN BUNDER AREA

5.1 Introduction

Depositional environment is the study of the ancient environment and the origin of the rock that deposited through the surrounding mechanism. The different environment gives the characteristic of the rock deposited. This chapter will cover about the petrographic for the sandstone rock deposited along the Widoro's river and the measuring section was conducted and recorded bedding by bedding about 200 m height. There were several samples collected and had been done for petrographic.

5.2 Petrography of rock sample

In chapter 4, the petrographic of the samples Code 1 until Code 10 will be discussed. First of all, the unit start with the sandstone and limestone that significance in this chapter due to the sedimentary structure and the fossil abundance within the rock clues for facies analysis. The petrography of the rock discusses about the mineralogy and the fossil composition. Roughly, the mineral of quartz, feldspar and other mineral had been identified by the petrographic study. The other mineral such as pumice, pyroxene, and calcite also needs in the petrographic study to make the comparison between the rock samples. It had been observed through the electron microscope in the lab of Universiti Malaysia Kelantan. After observation, the data plotted on a ternary diagram of classification sedimentary rock and also QFL ternary diagram for sandstone classification.

5.3 Measuring Section

The geological history was important because the information was used by people to be more careful and for the constructor for development, the geology information was important for their safety and good environment. The way to understand it by the measurement and record all the information geological structure. This need a good integrity to make the data and information more precious and useful especially for further study on the depositional environment of Sambipitu Formation.

In order to determine the depositional environment, the findings of indicator or sedimentary structure were the most crucial thing to be considered. At the study area, even though the outcrop was difficult to found due to the weathering process, there are many findings of sedimentary structures found while doing measuring section infield and also the microfossils found in the petrographic observation. Generally, sediment made of the fractured and weathered rock and when it undergoes lithification process, where the compaction and cementation happened and the sediment as sedimentary rock. In term of geomorphology, the river, shallow water, sea, lakes made up of sedimentary rock which the rock transported and deposited at the area by time.

The deposition occurs due to the weathering process which it broke the rock while the transportation due to the mechanical process which it brought the rock from one location to another and the space between the location considerate by the energy level. The sedimentary structures which indicated the type of the ancient environment were found. In addition, the presences of fossil in the sedimentary rock will also the most important information in order to determine the history of the

environment. The sedimentary will be covered in this content such as the bedding plane direction, the palaeontology information, the mineral contents, minor structure of sedimentary rock.

The measuring section was conducted after the geological mapping has been done because from the mapping the best places and more significance for measuring section will be identified in order to record and observe the precise information in the lithology section. It had been done along the Widoro's river at the Bunder area. The characteristic of sedimentary structure or other primary structure was determined in the measuring section log or lithology section. The measuring started from the southern part of the study area with coordinates S07^{0}52'19.45'' E 110^{0}32'31.77'' elevation 131m and end at the coordinate S 07^{0}52'19.45'', E 110^{0}32'31.77''. The outcrop mostly weathered so that the bedding measurement bed to bed was conducted along the Widoro's river for the detail information in the measuring section. It begin at the boundary formation of Nglanggeran Formation and Sambipitu Formation at the Northern part of the map and ended at the Boundary Formation of Sambipitu Formation and Oyo Formation with the older part of formation to the younger part of the Formation which the boundary between the Nglanggeran with Sambipitu and Sambipitu with Oyo Formation was determined in the study area.

The measurement starts from the Lower part of Sambipitu Formation through the middle part of Sambipitu Formation and Upper part of the Sambiptu Formation. Based on the lithology facies unit, Sambipitu Formation and Nglanggeran Formation interfingering each other. It means that the mixture of rock between both formations.For instances, the tuff fragment of Nglanggeran found in the tuffaceous sandstone of Sambipitu Formation. Sambipitu formation also interfingering of Oyo Formation that carbonated limestone found in tuffaceous sandstone .The relationship

for both formations give the difficulties to make the boundary section on geological and lithology map due to the mixing composition of the rock unit. So, the way that had been conducted was by the finding the trace or body fossil planktonic and benthonic foraminifera. For example, at the upper Sambipitu Formation, the trace fossil benthonic abundance compared to the lower part and middle part and the increasing about 40% of calcite mineral.

5.3.1 Interpretation of lithology along the Widoro's river in Bunder area.

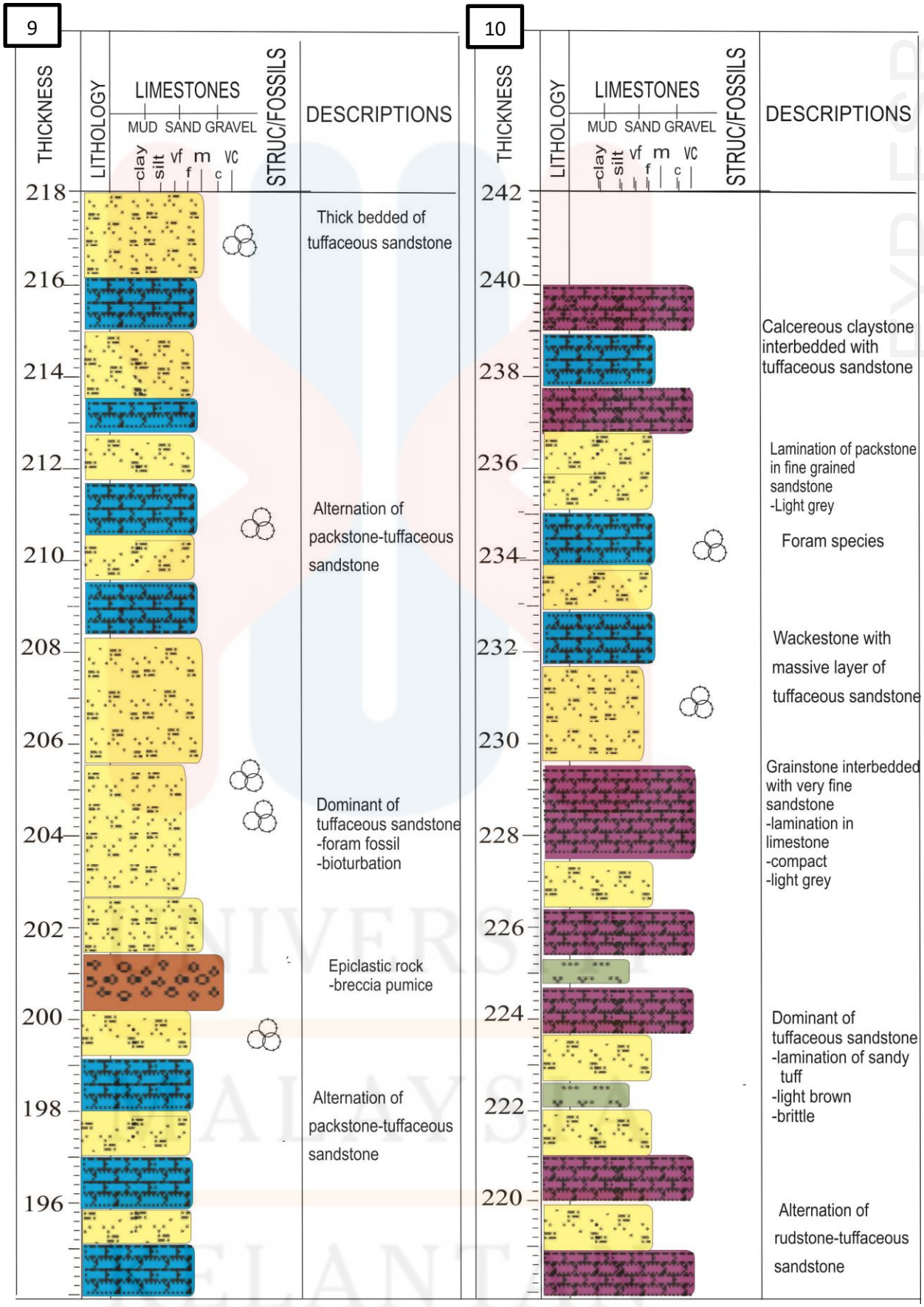
Figure 5.1 (a)Lower Sambipitu' formation outcrop ,(b) Middle Sambipitu's formation outcrop and (c)Upper part of Sambipitu Formation in Bunder

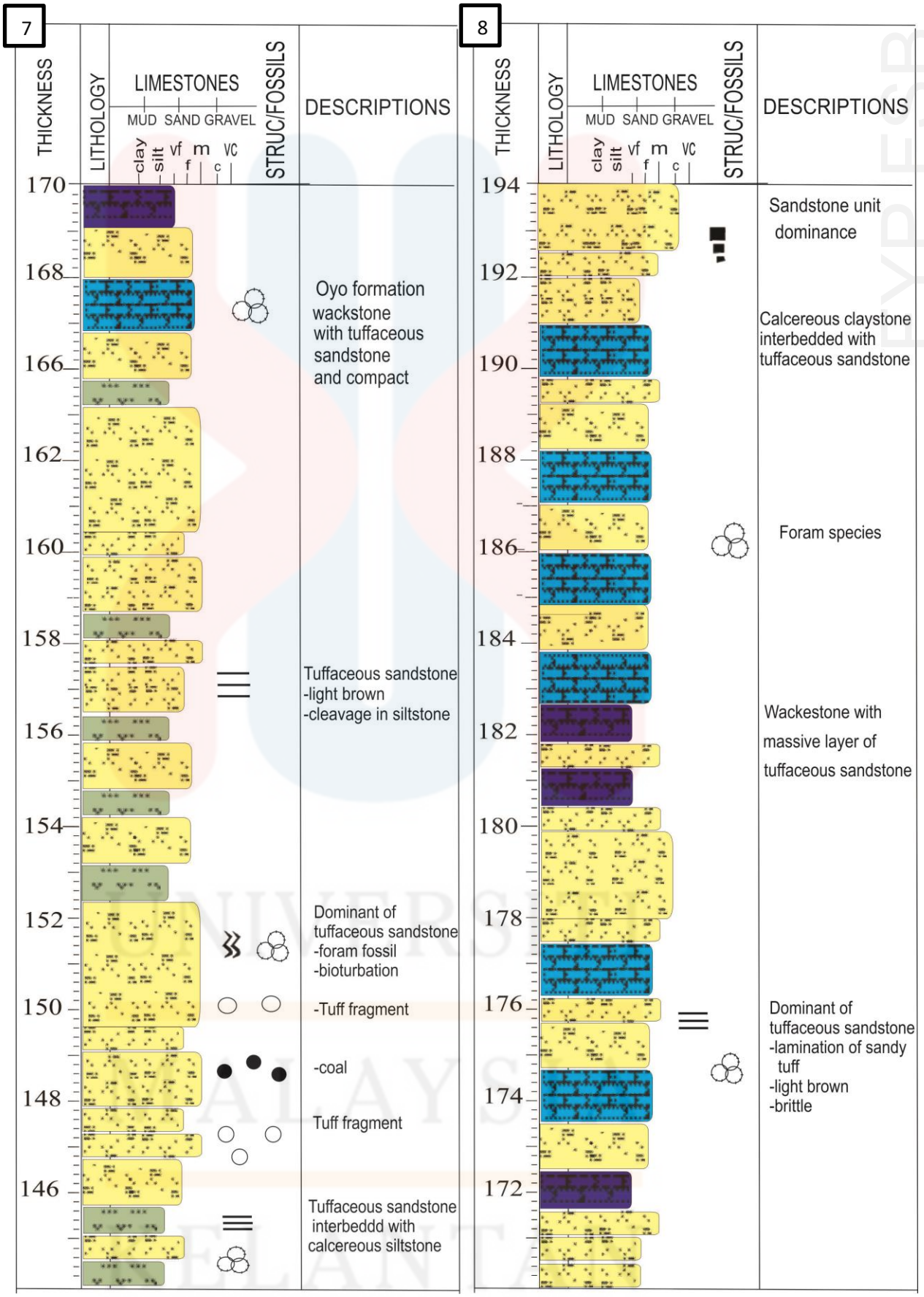
Figure 5.1 (a) of Lower Sambipitu Formation, it's composed of pyroclastic-epiclastic rock (conglomerate, breccia, tuff, sandstone, quartz) and auto-breccia also occurred at lava part occurred. The sorting of the rock well sorted due to the transportation by the river and the turbidite happened due to the different energy level experienced by the rock. From the petrographic, the fossil of foraminifera found at the Lower Sambipitu Formation. The bioturbation also can be found in the Calcareous Tuffaceous Sandstone. The observation of the measuring section for Lower Sambipitu Formation at thickness 0 meters until 60 m (Figure 5.2).

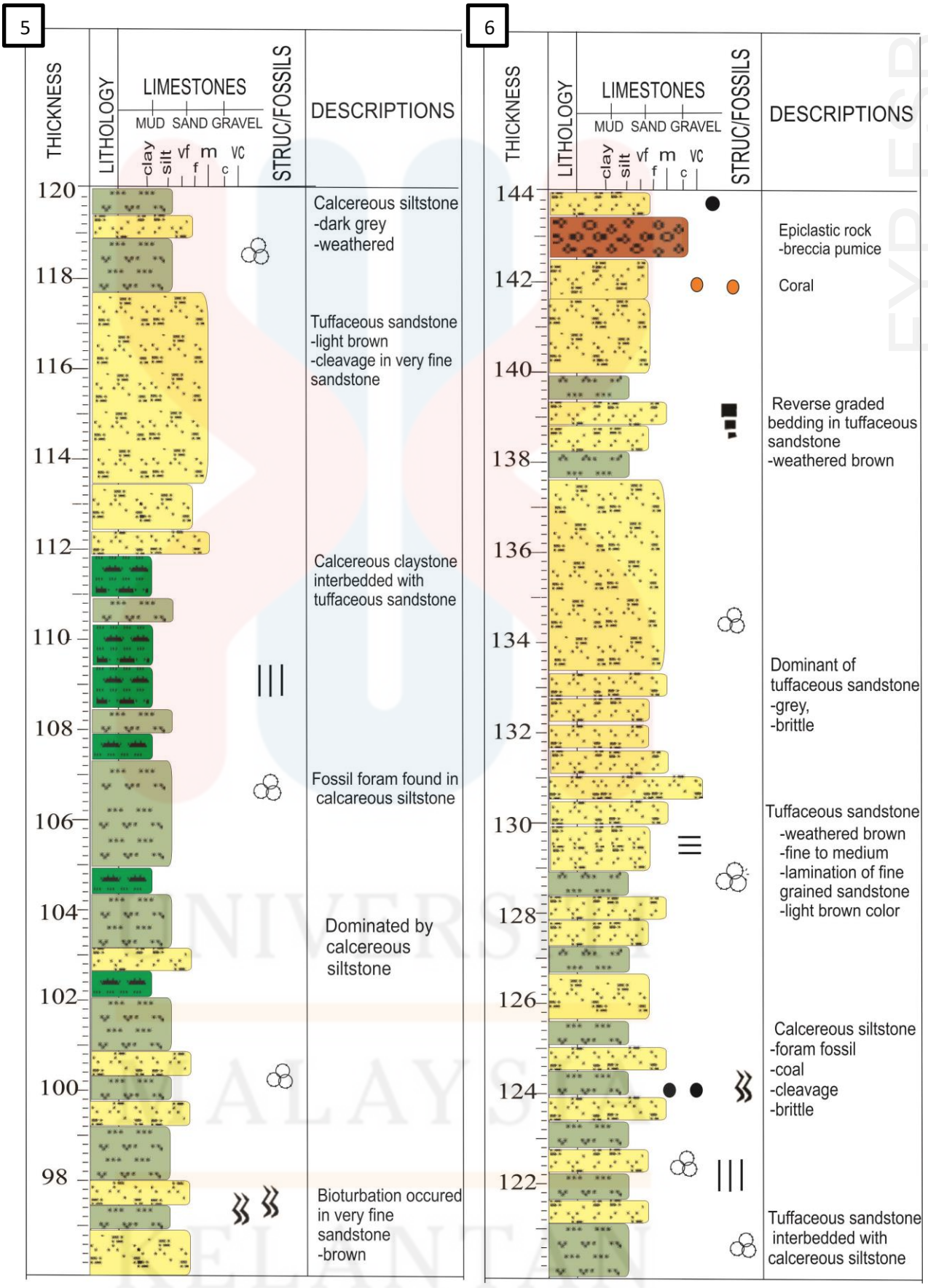
Figure 5.1 (b) of the Middle Sambipitu Formation composed alternation of calcareous tuffaceous sandstone with claystone and the massive tuffaceous sandstone interbedded with siltstone. The bioturbation, at S $07^0$52'34.02'', E $110^0$32'56.60'', the coal was found but not abundance. Lamination and normally graded bedding can be found in the same location. Cleavage found in the claystone which shows that the rock brittle while some forces in contact for this cases, the compaction during the deposition of sediment. The observation for Middle Sambipitu Formation at the thickness 60 meters until 180 m (Figure 5.2).

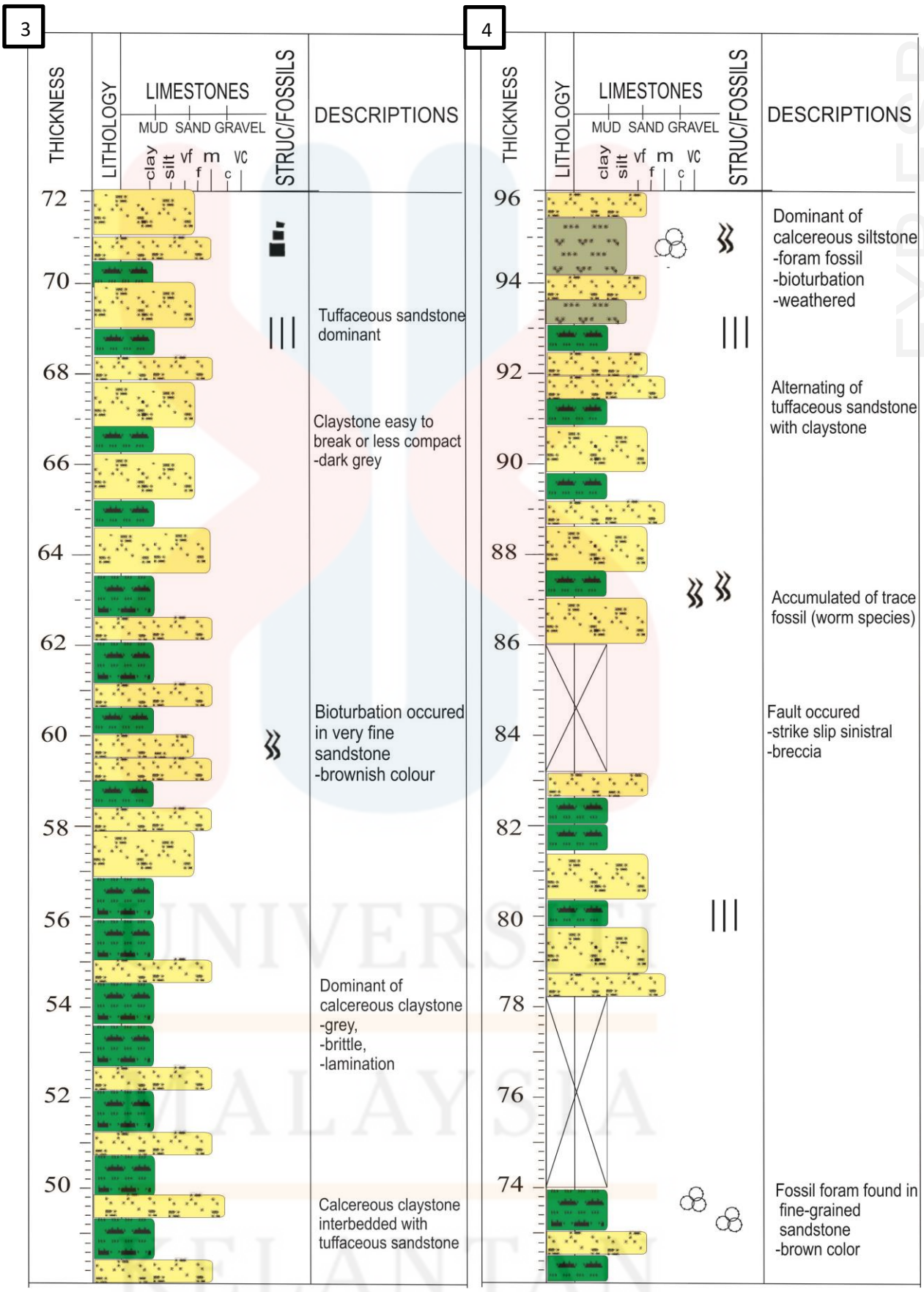
Besides,based on Figure 5.1 (c) ,Upper Sambipitu Formation refer to the composition of lithic which calcite that cemented the fragment of clastic rock in Sambipitu Formation. Mostly composed of wackestone and packestone rock and the complex structure occurred. It because of the formation interfingering with the Lower Oyo Formation composition carbonates rock. The cross lamination can be found which dip and strike N 80^o E / 15^o.In this location, the fossil foraminifera abundance and the rudstone or fossiliferous rock interbedded with calcareous tuffaceous sandstone. The observation of the measuring section for Middle Sambipitu Formation at thickness 180 meters until 240 m .For the conclusion of the

measuring section along Widoro's river, the exact boundary separates the section of lower, middle and upper Sambipitu Formation cannot be identified accurately due to the interfingering mechanism between the Sambipitu Formation with Oyo Formation. For the details in bedding layer interpretation, the figure below shows the lithology set of measuring section along the Widoro's river. The section starts from 0m to 240m of thickness bedding follow their age from older to younger formation.(*start at page 98).


9
THICKNESS
LITHOLOGY
LIMESTONES
MUD SAND GRAVEL
clay silt vf f m c vc
STRUC/FOSSILS
DESCRIPTIONS
218
216
214
212
210
208
206
204
202
200
198
196
Thick bedded of tuffaceous sandstone
Alternation of packstone-tuffaceous sandstone
Dominant of tuffaceous sandstone
-foram fossil
-bioturbation
Epiclastic rock
-breccia pumice
Alternation of packstone-tuffaceous sandstone
10
THICKNESS
LITHOLOGY
LIMESTONES
MUD SAND GRAVEL
clay silt vf f m c vc
STRUC/FOSSILS
DESCRIPTIONS
242
240
238
236
234
232
230
228
226
224
222
220
Calcereous claystone interbedded with tuffaceous sandstone
Lamination of packstone in fine grained sandstone
-Light grey
Foram species
Wackestone with massive layer of tuffaceous sandstone
Grainstone interbedded with very fine sandstone
-lamination in limestone
-compact
-light grey
Dominant of tuffaceous sandstone
-lamination of sandy tuff
-light brown
-brittle
Alternation of rudstone-tuffaceous sandstone


7
THICKNESS
LITHOLOGY
LIMESTONES
MUD SAND GRAVEL
clay silt vf f m c vc
STRUC/FOSSILS
DESCRIPTIONS
170
168
166
162
160
158
156
154
152
150
148
146
Oyo formation wackstone with tuffaceous sandstone and compact
Tuffaceous sandstone -light brown -cleavage in siltstone
Dominant of tuffaceous sandstone -foram fossil -bioturbation
-Tuff fragment
-coal
Tuff fragment
Tuffaceous sandstone interbeddd with calcereous siltstone
8
THICKNESS
LITHOLOGY
LIMESTONES
MUD SAND GRAVEL
clay silt vf f m c vc
STRUC/FOSSILS
DESCRIPTIONS
194
192
190
188
186
184
182
180
178
176
174
172
Sandstone unit dominance
Calcereous claystone interbedded with tuffaceous sandstone
Foram species
Wackestone with massive layer of tuffaceous sandstone
Dominant of tuffaceous sandstone -lamination of sandy tuff -light brown -brittle


5
THICKNESS
LITHOLOGY
LIMESTONES
MUD SAND GRAVEL
clay silt vf f m c VC
STRUC/FOSSILS
DESCRIPTIONS
120
118
116
114
112
110
108
106
104
102
100
98
Calcereous siltstone
-dark grey
-weathered
Tuffaceous sandstone
-light brown
-cleavage in very fine sandstone
Calcereous claystone interbedded with tuffaceous sandstone
Fossil foram found in calcareous siltstone
Dominated by calcereous siltstone
Bioturbation occured in very fine sandstone
-brown
6
THICKNESS
LITHOLOGY
LIMESTONES
MUD SAND GRAVEL
clay silt vf f m c VC
STRUC/FOSSILS
DESCRIPTIONS
144
142
140
138
136
134
132
130
128
126
124
122
Epiclastic rock
-breccia pumice
Coral
Reverse graded bedding in tuffaceous sandstone
-weathered brown
Dominant of tuffaceous sandstone
-grey,
-brittle
Tuffaceous sandstone
-weathered brown
-fine to medium
-lamination of fine grained sandstone
-light brown color
Calcereous siltstone
-foram fossil
-coal
-cleavage
-brittle
Tuffaceous sandstone interbedded with calcereous siltstone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THICKNESS
LITHOLOGY
LIMESTONES
MUD SAND GRAVEL
clay silt vf f m c VC
STRUC/FOSSILS
DESCRIPTIONS
72
70
68
66
64
62
60
58
56
54
52
50
Tuffaceous sandstone dominant
Claystone easy to break or less compact -dark grey
Bioturbation occured in very fine sandstone -brownish colour
Dominant of calcereous claystone -grey, -brittle, -lamination
Calcereous claystone interbedded with tuffaceous sandstone
4
THICKNESS
LITHOLOGY
LIMESTONES
MUD SAND GRAVEL
clay silt vf f m c VC
STRUC/FOSSILS
DESCRIPTIONS
96
94
92
90
88
86
84
82
80
78
76
74
Dominant of calcereous siltstone -foram fossil -bioturbation -weathered
Alternating of tuffaceous sandstone with claystone
Accumulated of trace fossil (worm species)
Fault occured -strike slip sinistral -breccia
Fossil foram found in fine-grained sandstone -brown color

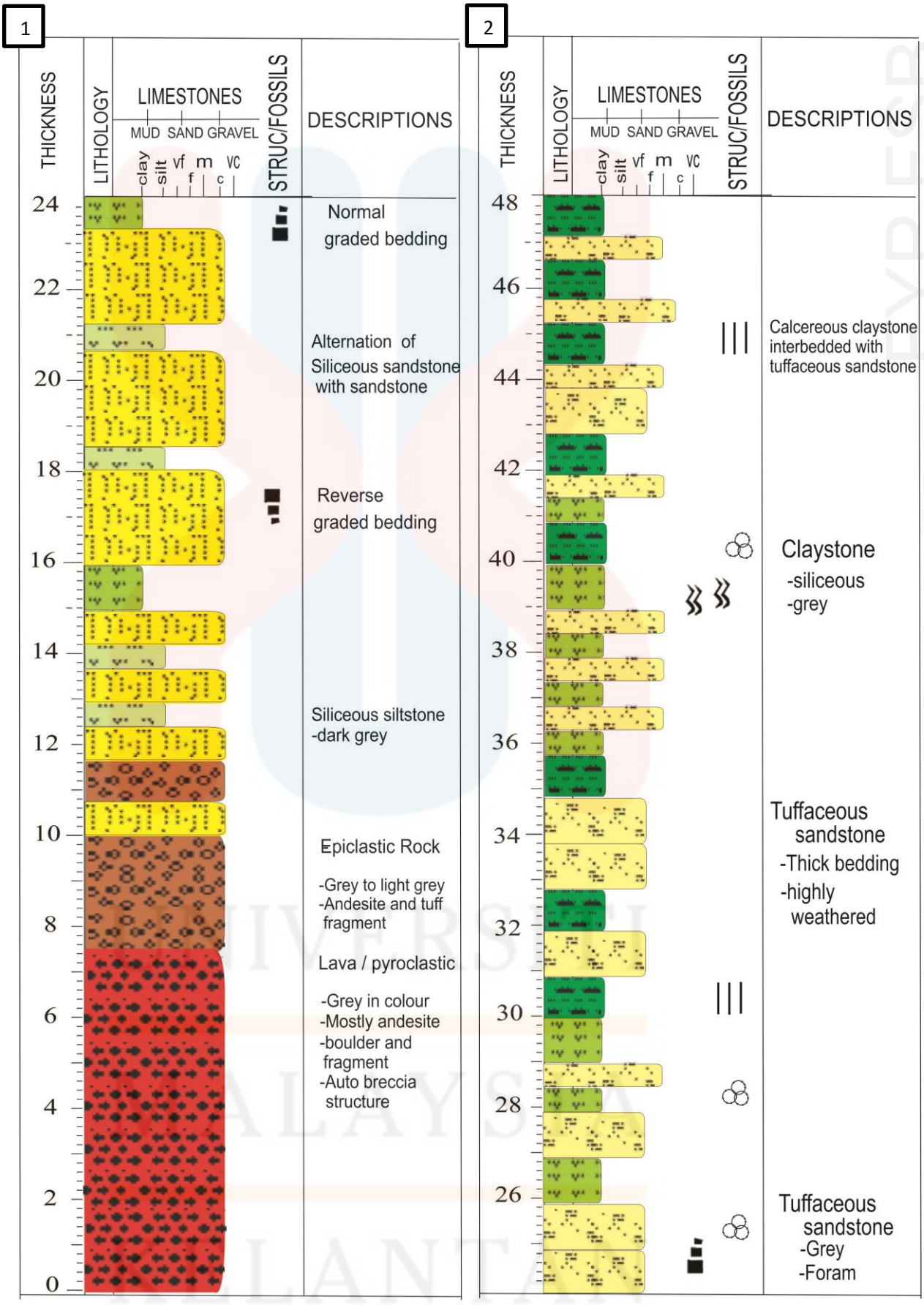

Figure 5.2: Lithostratigraphy of measuring section along the Widoro's river (Thickness from 0m until 240m)

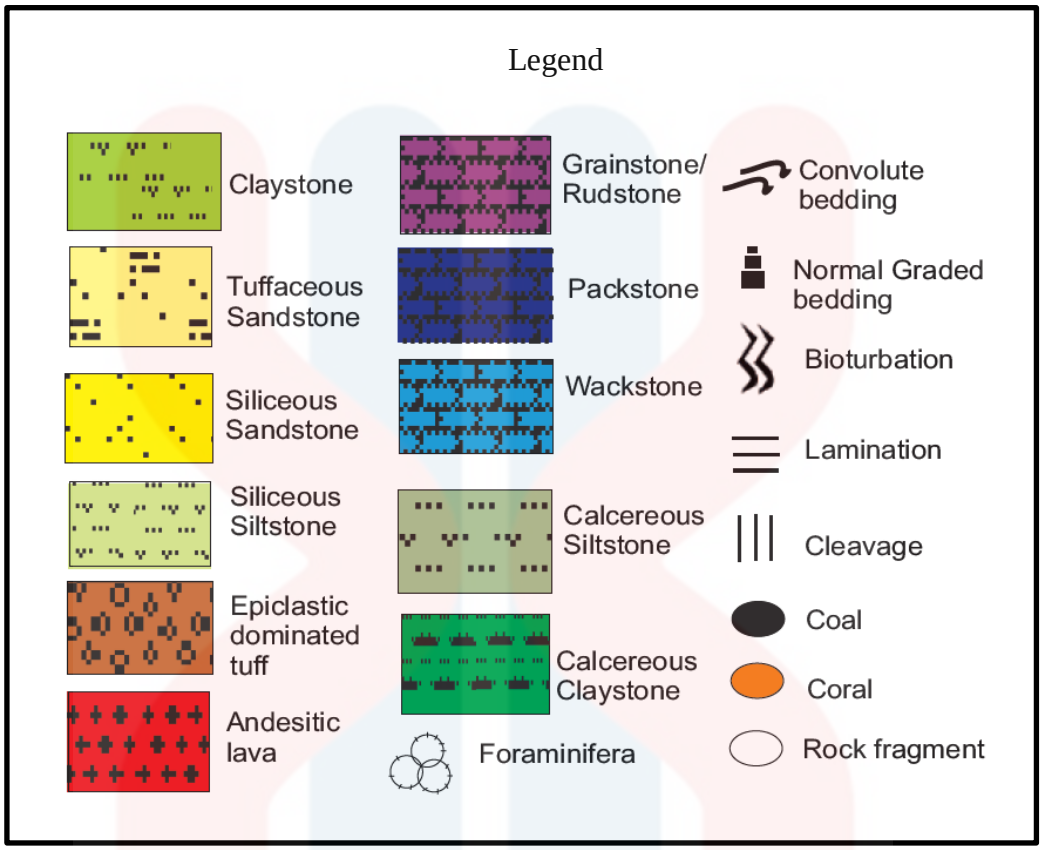

Figure 5.3: Legend lithology set of measuring section

5.4 Facies Analysis

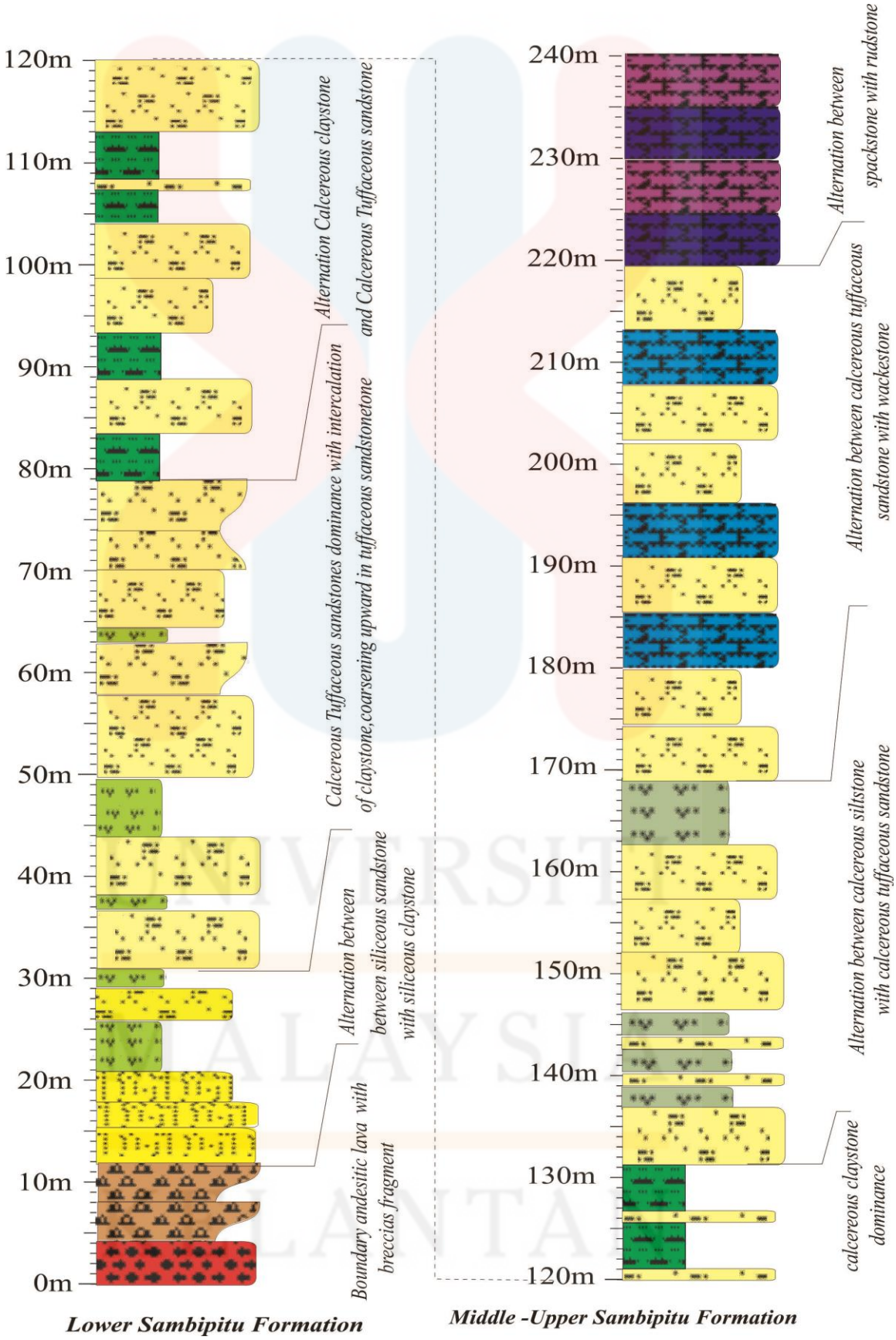

Figure 5.4 : Litholog of facies analysis along Widoro's river

Based on the Figure 5.4,the analysis of facies was identified and there are eight different facies association which andesitic lava with breccia fragment, alternation between siliceous sandstone and siliceous claystone, domination of calcareous tuffaceous sandstone with intercalation of claystone, alternation calcareous claystone with calcareous tuffaceous sandstone, domination of calcareous claystone intercalation of tuffaceous sandstone, alternation between calcareous siltstone with calcareous tuffaceous sandstone, alternation between calcareous tuffaceous sandstone with wackestones, and alternation between packstones and rudstones. All of these facies will be group based on the Lower, Middle and Upper Sambipitu Formation.

5.4.1 Lower Sambipitu Formation

There are four different facies which andesitic lava with breccia fragment (0m – 12m), alternation between siliceous sandstone and siliceous claystone(10m – 30m), domination of calcareous tuffaceous sandstone with intercalation of claystone (30m – 80m), and alternation calcareous claystone with calcareous tuffaceous sandstone (80m – 120m). The andesitic lava and breccia mostly come from Nglanggeran Formation, the light grey colour exposed on the lava outcrop. It is consists of a small amount of agglomerate and the breccia fragments (tuff, sandstone and other product of volcanic)The diameter fragment about 4-10 cm and the tuff fragment dominance in this facies. The trace fossil looks like wormhole were found abundance in claystone, and also in calcareous tuffaceous sandstone with the thick bedding about 7-metre dominance intercalated with claystone about 1 meter. The fossil definitely lives in the tidal zone. The colour for calcareous sandstone dark

brown to grey while claystone more to light brown. The cleavage can be found at the sandstone bedding. The sedentary structures that were found such as reverse graded bedding and normally graded bedding. Reverse graded bedding when the very fine-grained sandstone deposited at the top of fine-grained bedding while normally graded bedding vice versa. The fining upward and coarsening upward of grain size carry out in this facies due to the tidal .The depositional of this facies is upper fan in submarine fan which the interpretation supported by the conglomerate and thinned bedded found.

5.4.2 Middle Sambipitu Formation

In this part, the facies calcareous claystone (thick bedded) intercalation of tuffaceous sandstone and the alternation between calcareous siltstone with calcareous tuffaceous sandstone. The grained size about fine to medium grain sizes. The thickness of calcareous claystone is increasing that shows the change in energy of the water moderately. The abundance of foraminifera can be found in calcareous siltstone. The alternation between the bed of sandstone and claystone is based on wave action. (Nichols, 2009).The high energy level was effect by wave action and when the energy level becomes low, the mudstone deposited.

There were body fossil and trace fossil found within the calcareous siltstone. The mollusc found shows that the but not in a perfect body due to the precipitation of carbonate with water. The trace fossil of Planolites abundance and there also the microfossil of *Globorotalia Menardii* and *Orbulina Universa* that can found through observation by microscope.

The sedimentary structure identified as normally graded bedding,cross-bedding, cross lamination, erosional surface, and also the bioturbation. The cross lamination found in the siltstone bedding while the bioturbation mostly found on the surfaces bedding of tuffaceous sandstone. The colour of siltstone and sandstone slightly change in beige brown. The depositional of this facies is mid fan of the submarine fan which the interpretation supported by the massive sandstone interbedded with claystone.

5.4.3 Upper Sambipitu Formation

The lithologies facies that were found such as the alternation between calcareous tuffaceous sandstone with wackestones, and alternation between packstones and rudstones. The color of calcareous tuffaceous limestone dark brown in colour and the grain sizes from moderate to coarse. The bedding associated with the fossil and ichnofossil. The ichnofossil abundance and the coral of body fossil were found in the bedding of rudstones whereas the thick bed about 10 centimetres. Wackestone, packestone, and rudstones are the limestone that varies of grain sizes. The thick of bed of limestone rock increasing from the Middle Sambipitu Formation to the Lower Sambipitu Formation.

Roughly, there are three types of fossils that were found which foraminifera and coral. The microfossil of foraminifera has been observed. The fossil of foraminifera mostly occurred in, middle and upper Sambipitu Formation and dominantly in middle to upper Sambipitu Formation in calcareous tuffaceous sandstone and tuffaceous limestone (wackestone). Next, the ichnofossils also found on the surface of the outcrop. Ichnofossil tells that the organism living in the rock left

their trace or their activity on the surface of rock or vertically which cross the bedding. Mostly, the ichnofossils in the Widoro's river horizontally exposed on the surface bedding. This gives the record and detail in order to determine the depositional environment due to the behaviour of the organism. There are many different structures of ichnofossils such as the structure of tracks, trails or burrows. The depositional of this facies is lower fan transition of the Lower Oyo Formation which the depositional is shallow water and continental reef. The interpretation supported by the fossil found and the coarsening upward of grain size facies.

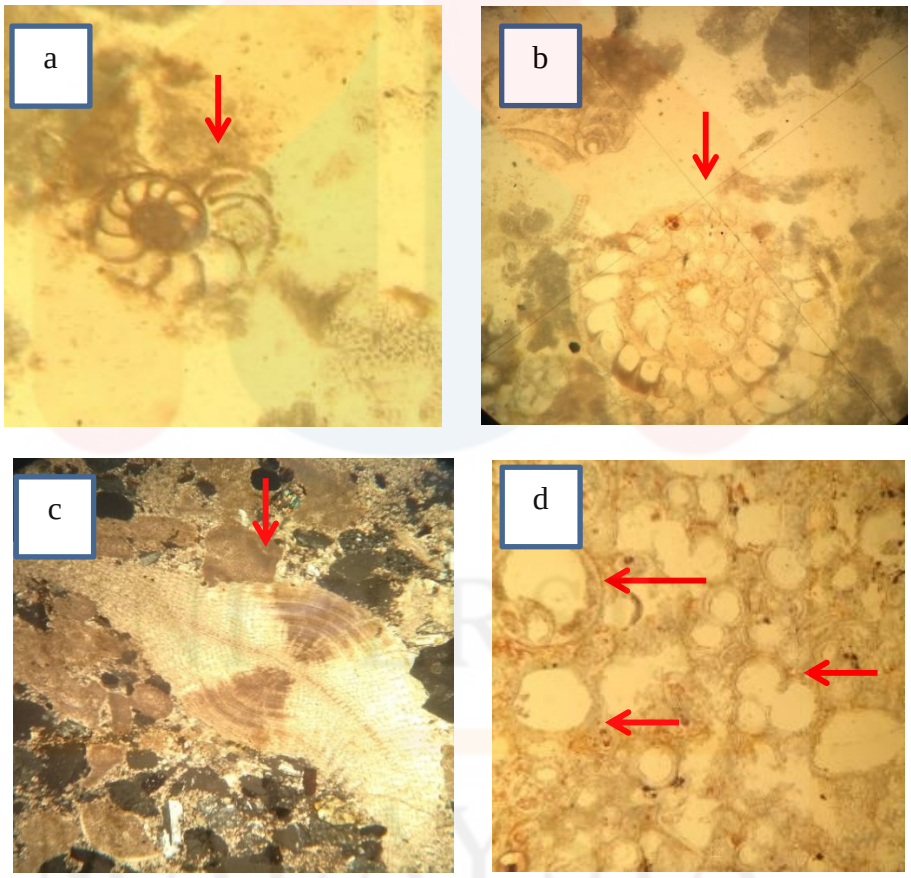

Figure 5.5 : Foraminifera fossil in the petrographic observation which (a) *Anomalina* sp., (b)*Ammonite* sp.,(c)benthic foraminifera *Linderina* sp and (d) Planktonic foraminifera of *Globorotalia Menardii* and *Orbulina Universa.*

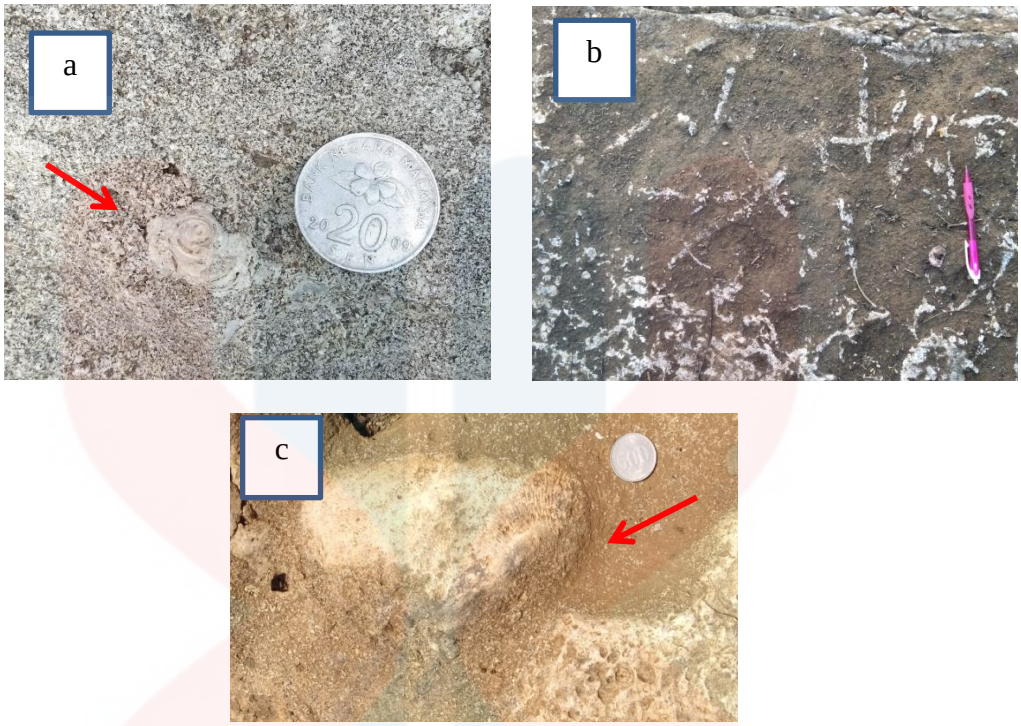

Figure 5.6 : (a) Mollusc fossil found in the very coarsed tuffaceous limestone ,(b) The ichnofossil of *Planolites* sp. and (c) coral foundin the limestone bedding(rudstone and wackestones)

5.5 Suggestion of depositional environment

By the measuring section observation, the facies of the sediment deposition in the deep to shallow water and erosion in the carbonate depositional system. Carbonate will shut down at times of low stand because of the continental shelf undergoes karstification process. Mostly the sand-rich of turbidite occur in tuffaceous sandstone. The turbidite structure which changes the grain size of the particle of rock. Regarding the tidal, the process of regression and transgression may result in the rapid landward translation of facies which the condense succession are deposited when the continental shelf starved sediment.

The succession of deposition of rock from the lithology set shows the fining upward and coarsening upward. Fining-upward shows that the environment deep water or calm water meanwhile the coarsening upward shows that the environment shallow

water and the alternate each other reflects the repetitive tendency of the energy level of the deposit. From the large scale of stratigraphy log, the coarsening upward dominance which shows the environment from lower Sambipitu Formation to the Upper Sambipitu Formation was deep water to shallow water. From the fieldwork and petrographic observation, the indicator of sedimentary structure support that the environment was influent by the tidal activity and the environment, the sand-rich turbidites system develop the submarine fan on the slope and the basin floor.

5.6 Model of suggested depositional environment

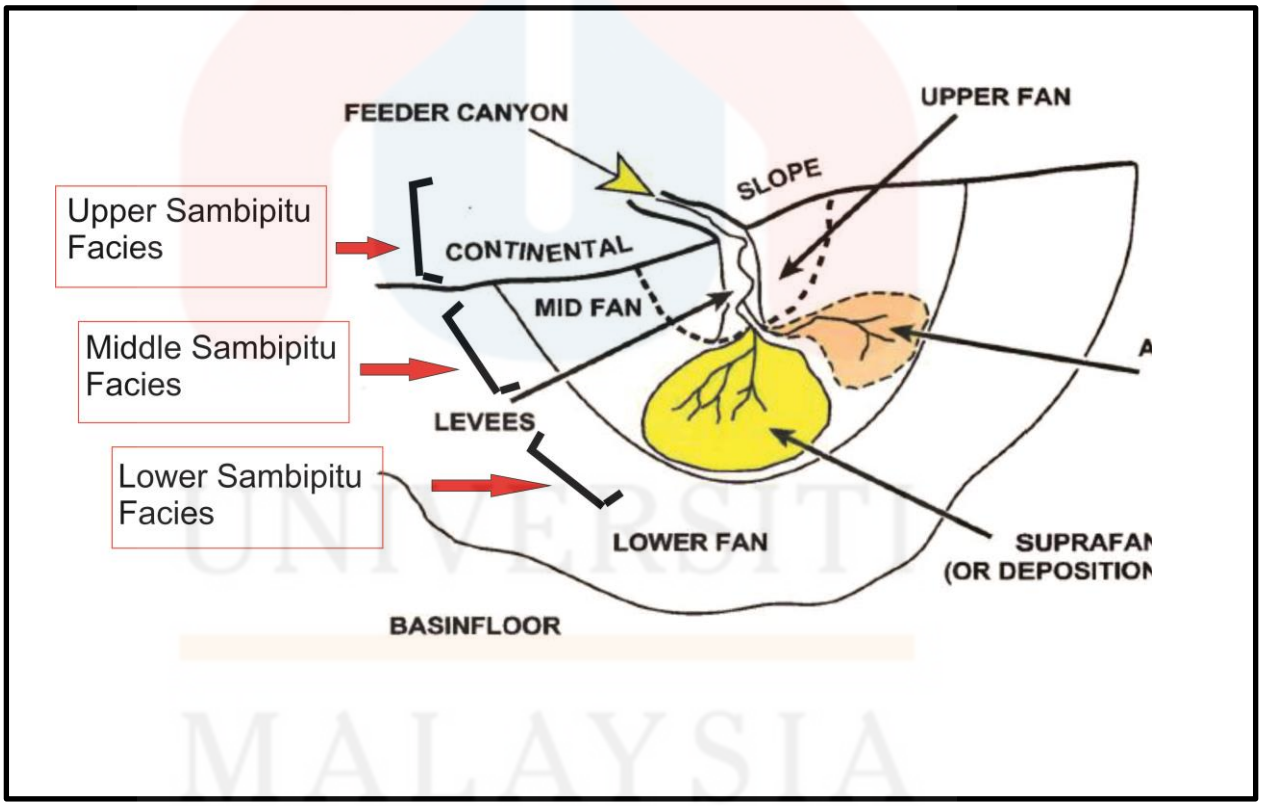

Figure 5.7 Submarine fan morphological features (Andrew, 2010)

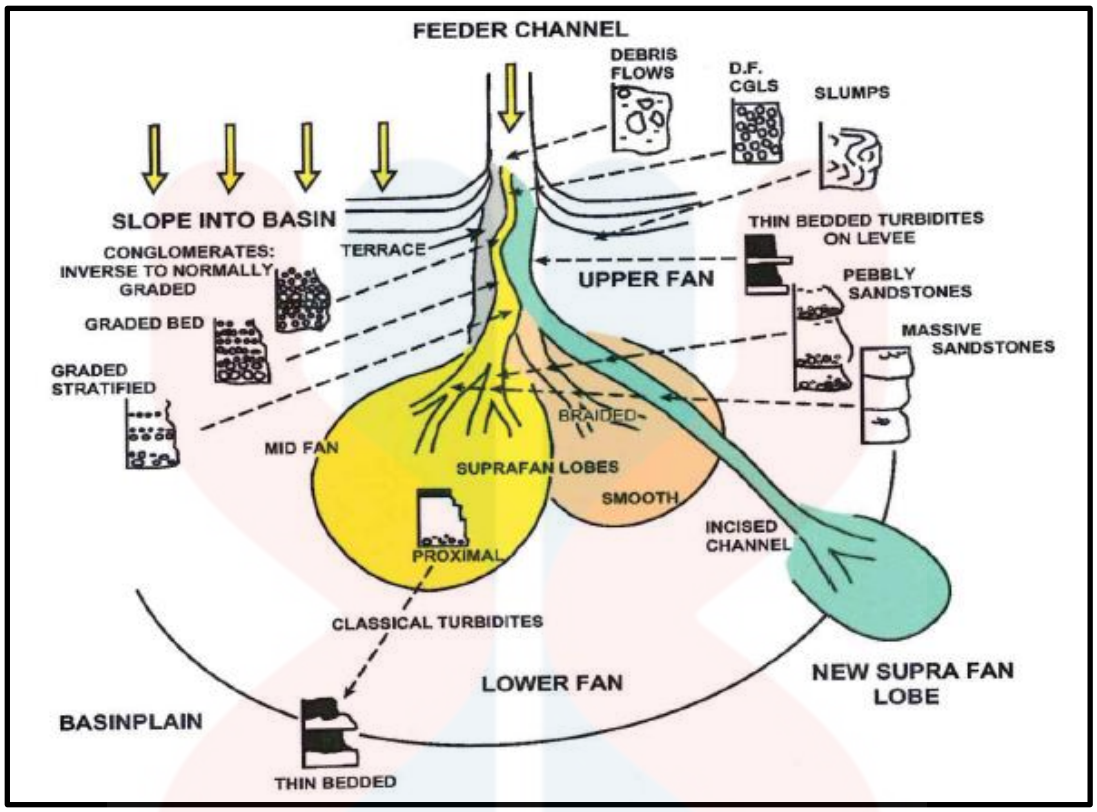

Figure 5.8 Submarine fan facies association (Andrew, 2010)

Based on Figure 5.4, all the sedimentary structure can indicate the depositional environment. On the slope, composed of the clastic materials and the density current was the main process of the deposition. Mostly, the deposition at the origin of slope fan system which these deposits contain major hydrocarbon formation explained by geoscience community. Submarine fan influenced by source area, climatic condition, sea level position, and tectonic movement. The clastic sediment incorporated on the shelf which depends on the relative sea-level position. From figure 5.4, the thickness change from proximal to distal and at the feeder channel, sediment will start to flow from the steep wall. This activity will form the levees to the channel axis. When the materials move to downslope, the sediment starts to accumulate. So, the depositional in Bunder, along the Widoro's river is Submarine fan and the grain size coarsening upward support the environment in deep to shallow water.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

As a conclusion, all the data and observation shows the importance of geology's knowledge to produce a geological map, lithology and the decision by making the type of depositional environment of the study area. As the study area is located in the Bunder village, Gunung Kidul, Indonesia and mostly occurs of complex structures, especially along the river.

The hilly landscape can be found at the Northern part meanwhile the Southern part covered by the flat landscape. The southern part dominant of sedimentary rock and the Northern part composed of pyroclastic and epiclastic rock. Besides, the drainage pattern mostly dendritic pattern due to the erosion by running water that develops inhomogeneous regions.

There are several types of lithology units such as lava,epiclastic rock, massive tuffaceous sandstone interbedded by claystone, sandy tuff, and also limestone. The measuring section conducted along the Widoro's river from North to South and the contact boundary between Nglanggeran Formation and Sambipitu Formation, Sambipitu Formation and Oyo Formation were found. The relation between formations is interfingering due to the fossil occurs and the composition of the tuff fragment in carbonate rock. Deposition in a shallow marine environment sensitive to changes in sea level so that will be easier to locate the transition state.

Mostly strike-slip fault left lateral found in the study area and also the auto-breccia structure that forms when the lava cooled suddenly while the below part of lava still in liquid state. The structural geology that can be found such as a vein, joint, fault, and drag fold. Meanwhile, the sedimentary structure, facies analysis, and trace fossil indicate the depositional environment, the turbidite system at the Widoro;'s river is believed to form at shallow marine based on the Mutti's Turbidite Facies Theory. There are some problems which the data of geology information less at the southern part of the study area due to the housing area and difficult to find the exposed outcrop.

6.2 Recommendation

There are some suggestions that are identified to enhance the research and add up some details of the lithology of Sambipitu Formation. First, conduct a test laboratory of isotope where it will chemically identify the properties and characteristics of the rock so that the inclusion unknown of limestone fragment in the Sambipitu Formation can be identified from which formation either Jaten Formation or Gamping Wungkal Formation. Next, need more details and comparison of palaeontology information between Sambipitu Formation and Oyo Formation in the Bunder area.

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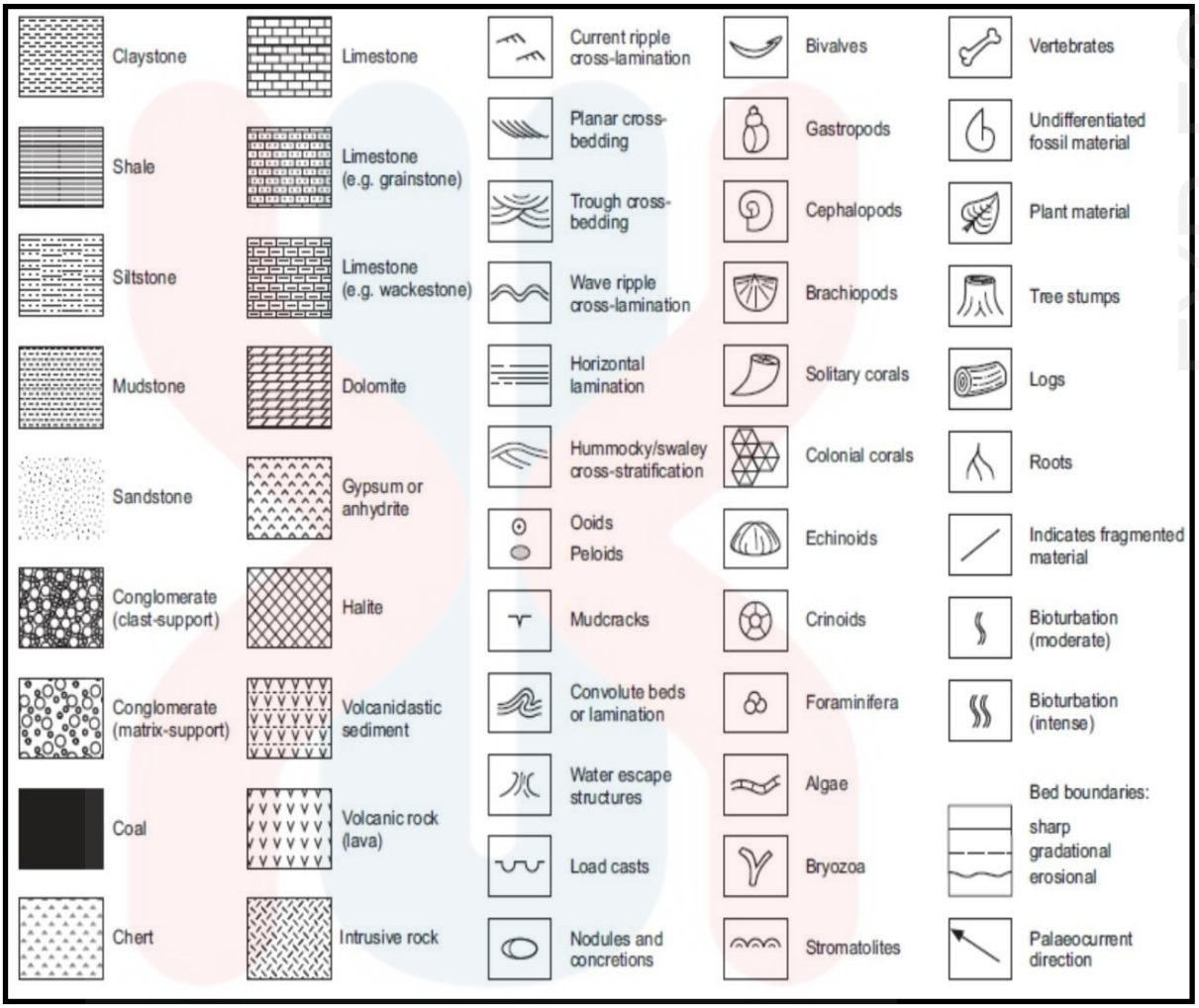
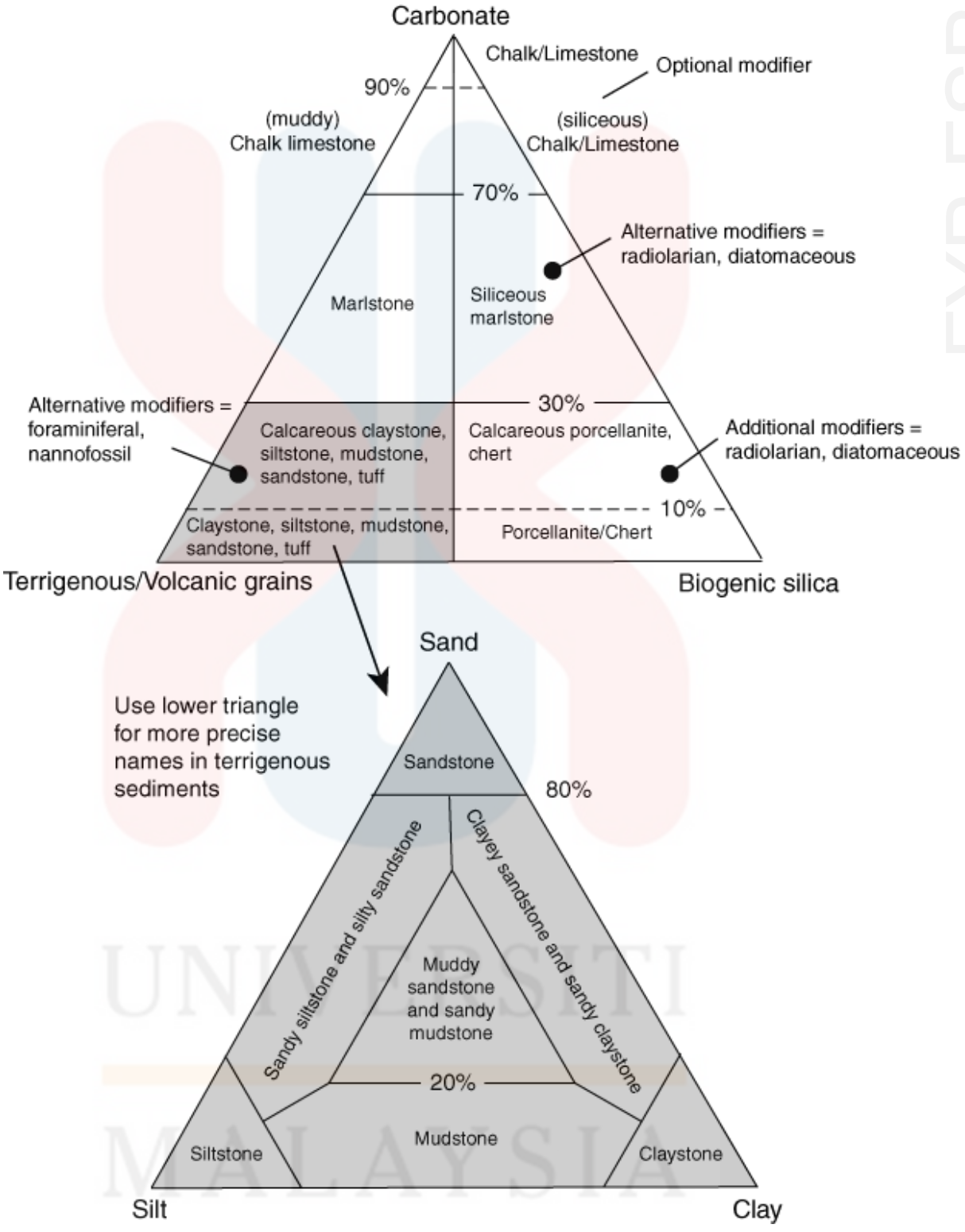
APPENDICES



APPENDIX A : Examples of patterns and symbols used on lithology (Federal Geographic Data Committee, (2006)



APPENDIX B : Classification of sandstone ‘s rock