GEOLOGY AND LANDSLIDE SUSCEPTIBILITY OF PATUK AREA, GUNUNG KIDUL, YOGYAKARTA, INDONESIA

by

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APPROVAL

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

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DECLARATION

I declare that this thesis entitled " **GEOLOGY AND LANDSLIDE SUSCEPTIBILITY ANALYSIS OF PATUK AREA, GUNUNG KIDUL,YOGYAKARTA, 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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GENERAL GEOLOGY AND LANDSLIDE SUSCEPTIBILITY OF PATUK AREA, GUNUNG KIDUL, YOGYAKARTA, INDONESIA

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ABSTRACT

Abstract: Research was conducted around Patuk area in Gunung Kidul, Yogyakarta, Indonesia that was approximately 25km^2 and the coordinates of the study area is 110°28´ to 110°31´0´´E at the longitude and 7°51´ to 7°54´0´´S at the latitude. The purpose of this study is to update the geological map of this study area in the scale of 1:25000, to analyse the impact probability and impact of landslide in the study area and also to analyse the landslide susceptibility analysis for cut in the study area using the ArcGIS software. The study area composed of three main lithological unit that is sandstone unit, volcanic breccia unit and also limestone unit. Based on the weightage overlay method in the ArcGIS software, the susceptibility of landslide in the study area was determined. Five parameters have been chosen in determining the landslide susceptibility that is slope, lineament density, the type of lithology, drainage density and also the type of soil in the study area.The weightage and score for each parameters had been assigned based on the references from the previous study. Five maps from each of the parameters have been produced and in the end the landslide susceptibility map of the the study area was made by overlaying all of the five maps. The zone of the susceptibility was divided into three that is the low susceptibility zone, moderate susceptibility zone and also the high susceptibility zone and it was later determined that slope is the most influenced to the landslide hazard because of the location of the study area itself that located on the hilly and mountainous area.

Keywords : Weightage ; ArcGIS ; Yogyakarta ; Landslide Susceptibility ; Weighted Overlay Method

GEOLOGI UMUM DAN KERENTANAN TERHADAP TANAH RUNTUH DI KAWASAN PATUK,GUNUNG KIDUL, YOGYAKARTA, INDONESIA

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ABSTRAK

Abstrak: Penyelidikan dijalankan di sekitar kawasan Patuk di Gunung Kidul, Yogyakarta, Indonesia yang terletak kira-kira 25km2 dan koordinat kawasan kajian adalah 110°28' hingga 110°31'0"E di bujur dan 7°51' hingga 7°54'0"S di latitud. Tujuan kajian ini adalah untuk mengemas kini peta geologi kawasan kajian ini dalam skala 1: 25000, untuk menganalisis kebarangkalian kesan dan kesan tanah runtuh di kawasan kajian dan juga menganalisis analisis kerentanan longsor untuk memotong kawasan kajian menggunakan perisian ArcGIS. Kawasan kajian terdiri daripada tiga unit lithologi utama iaitu unit batu pasir, unit breccia gunung berapi dan juga unit batu kapur. Berdasarkan kaedah 'overlay' berwajaran dalam perisian ArcGIS, kecenderungan tanah runtuh di kawasan kajian telah ditentukan. Lima parameter telah dipilih untuk menentukan kecenderungan tanah runtuh yang merupakan cerun, kepadatan garis lurus, jenis litologi, ketumpatan saliran dan juga jenis tanah di kawasan kajian. Anggaran dan skor untuk setiap parameter telah diberikan berdasarkan rujukan dari kajian terdahulu. Lima peta dari setiap parameter telah dihasilkan dan pada akhirnya peta kerentanan terhadap tanah runtuh di kawasan kajian dibuat dengan melimpah semua lima peta. Zon kerentanan itu dibahagikan kepada tiga iaitu zon kerentanan rendah, zon kerentanan sederhana dan juga zon kerentanan yang tinggi dan kemudiannya ditentukan bahawa cerun adalah yang paling terpengaruh dengan bahaya tanah longsor kerana lokasi kawasan kajian itu sendiri yang terletak di kawasan pergunungan dan bukit.

Kata kunci : Pemberat ; ArcGIS ; Yogyakarta ; Kerentanan Terhadap Tanah Runtuh ; Kaedah 'Overlay' Berwajaran

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LIST OF ABBREVIATIONS

km^2	Kilometer square
mm	Millimeter
GIS	Geographical Information System
NE - SW	Northeast - Southwest
E - W	East - West
N - S	North - South
PDZ	Principle Displacement Zone
OAF	Old Andesite Formation
GPS	Global Positioning System
PPL	Plane polarised light
XPL	Cross polarised light
S	Stations
HCl	Hydrochloric Acid
E	East
S	South
$CaCO_3$	Calcium Carbonate
Pl	Plagioclase
Am	Amphibole
Bt	Biotite
Qtz	Quartz
Ol	Olivine
Opq	Opaque

Hb	Horneblende
M	meter
Cm	Centimeter
Wi	Weightage
Sij	Score

LIST OF SYMBOLS

°	Degree
’	Minutes
’’	Seconds
%	Percent
<	Less than
>	More than
$\sum$	Sum

CHAPTER 1

INTRODUCTION

1.1 General Background

Landslide susceptibility analysis is one of the most important analysis that need to be done in every developing country especially the Asia country because it will give a bad effect and catastrophe if geological hazard such as an earthquake. For a country such as Indonesia, earthquake is one of the common natural disaster and it is the major cause of the slope instability that eventually triggering coseismic landslides. This problems have been faced throughout the history when humans and nature disrupted the balance of the nature soil slopes. Slope usually occurs either naturally or it is engineered by human. The increasing in demand for the engineered cut and fill slope on construction project has increased the need in understanding more about the analysis landslide possibility that may occurs without the proper understanding in the problem. The understanding in the geology, hydrology, and the properties of soil and rock itself is vital to applying the landslide susceptibility analysis properly.

1.2 Problem Statement

The area of interest that is believed to be the prone area that always associated with landslide and also rock fall problem as the Patuk road in Yogyakarta, Indonesia area located at mountainous area with many steep slopes and also always crowded with people that using the road. The hazard occurs due to the natural phenomenon and also because of the human action without a proper safety measures. The unstable cut slope and also the lose of the cohesion of soil can lead to the cut slope failure hence can be a disaster to the people around the area such as the loss of life and also property loss. In preventing this disaster, lanslide susceptibility analysis need to be done for human precaution and also implementing several methods to prevent or reducing the occurrences of landslide hazard. The geological map of this area also need to be updated as they are already outdated and most of it did not perfect yet.

1.3 Research Objectives

The objective of this research is:

i) To establish an updated geological map of the lithology in the study area with the scale of 1: 25000.

ii) To analyse the landslide susceptibility analysis for cut in the study area using the ArcGIS software.

1.4 Study area

Study area simply meant by the specific area of concern for which the research will be done at and data will be analysed in a map. Figure 1.1 shows the location of the study area.

1.4.1 Location

The study area of the research is in Patuk area, Bantul, Yogyakarta, Indonesia. The distance of the study area for the general geology studies which is at the Patuk area is about 5×5 km^2 which the covers about 25 km^2. The coordinates of the area are 110° 28´ to 110° 31’’ 0´´E at the longitude and 7° 51´ to 7° 54´0´´S at the latitude.

Patuk is a sub-district in the district of Gunung Kidul, Special Province of Yogyakarta. This sub-district located about 16 km from Wonosari that is the capital district of Gunung Kidul Regency to the northwest by the national road road segment of Yogyakarta-Wonosari city. The center of the of the governmet is located in the Patuk village.The study area is easily accessible as the road connection is highly distributed around the location of the study area.

The boundary of territories can be divided into four territories that is on the north territory, south territory and also the west territory. On the north territory, there are Gedangsari sub-district, Prambanan sub-district and also Piyungan sub-district while on the south location there are Playen sub-district and the Dlingo sub-district. On the west territory, there are Piyungan sub-district.

The location of this area is quite strategic because it passes Jalan Yogyakarta - Wonosari so that its economic activity is relatively advanced. Its inhabitants mostly become farmers because the area has relatively fertile soil. In this area there are also some Hindu community heritage sites such as shrines. One of them is in the hamlet Payak, Srimulyo. Figure 1.1 shows the map of Yogyakarta while figure 1.2 shows the map of the study area.

Figure 1.1: Map of Yogyakarta

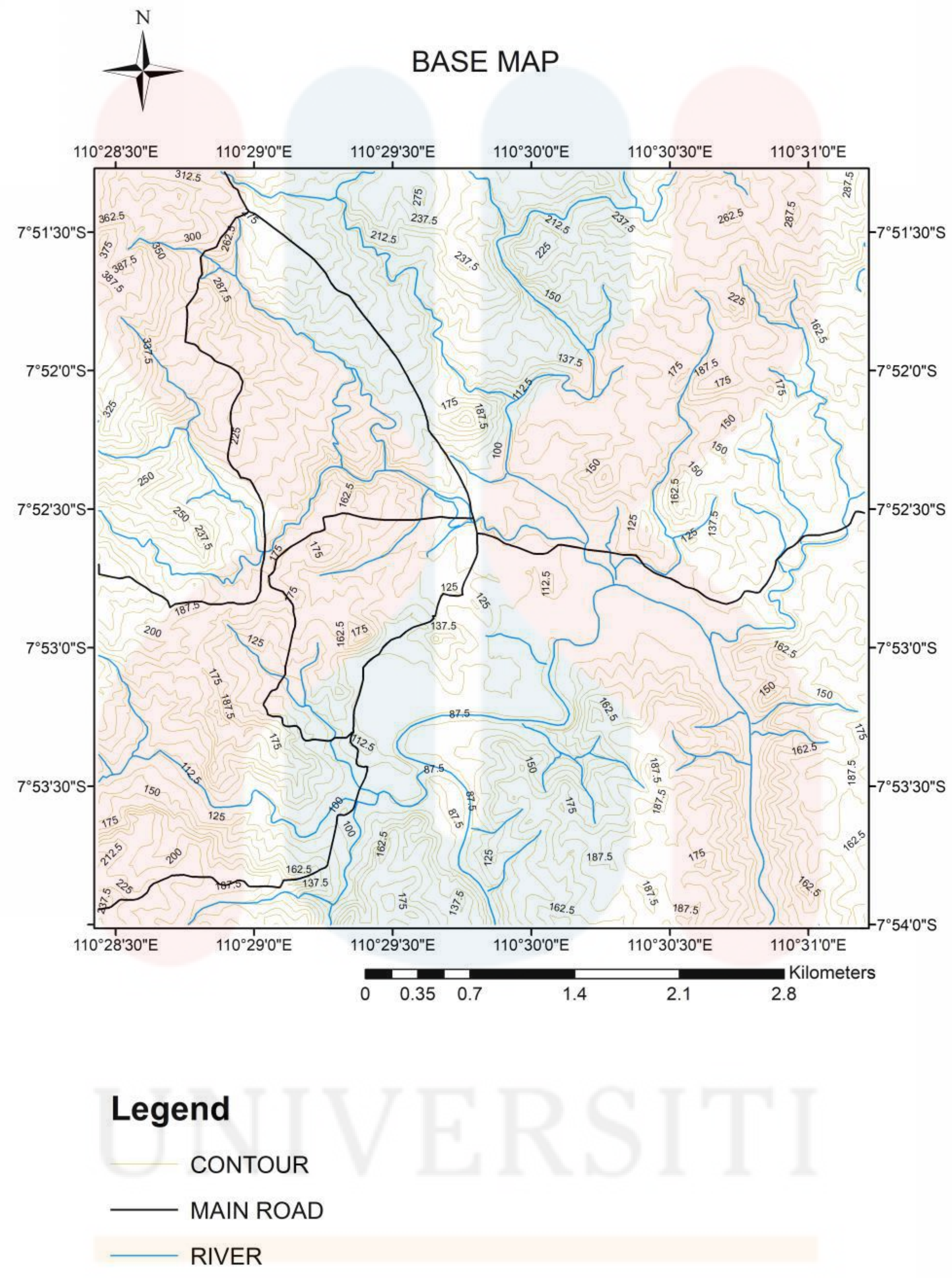


Figure 1.2 : Map of the study area

1.4.2 Demography

In Yogyakarta, Javanese are the largest population of the native people. However, the living cost in Yogyakarta is relatively lower to be compared with the living cost in Jakarta. Yogyakarta has a large number of tourists that contribute to the economy. In the Gunung Kidul Regency, there are a total of 722 479 people that are consist of 348 825 of male and 373 654 of female and respectively.

Gunung Kidul Regency consist of 18 district and the location of my study area is located at the Patuk district. The total population of the Patuk area is 32 460 that are divided to 15 817 male and 16 643 of female. The number of population may increase or decrease due to the migration process that in to the study area or out from the study area. The table 1.1 below shows the total of population in Gunung Kidul regency in the year of 2016.

Table 1.1 : Total population of Gunung Kidul regency according by gender (Badan Pusat Statistik Kabupaten Gunung Kidul)

District	Gender		
	Male	Female	Total
Panggang	13 588	14 772	28 360
Purwosari	9 895	10 818	20 713
Paliyan	14 917	16 193	31 110
Saptosari	17 646	19 012	36 658
Tepus	16 248	17 862	34 110
Tanjungsari	13208	14280	27 488
Rongkop	13 853	14 920	28 773
Girisubo	11 256	12 476	23 732
Semanu	26 632	28 710	55 342
Ponjong	25 731	27 542	53 273
Karangmojo	25 109	27 053	52 162
Wonosari	41 146	43 111	84 257
Playen	28 146	30 153	58 299
Patuk	15 817	16 643	32 460
Gedangsari	18 453	19 266	37 719
Nglipar	15 383	16 373	31 756
Ngawen	16 448	17 380	33 828
Semin	25 349	27 090	52 439
Gunung Kidul	**348 825**	**373 654**	**722 479**

1.4.3 Rainfall Distribution

Based on the rainfall distribution data from Badan Pusat Statistik Kabupaten Gunung Kidul that is from the year of 2010-2016, it shows that in 2015 and 2016 the amount of rainfall distribution increase significantly in comparison with the previous year. The data in the month of January 2016 shows that the rainfall distribution in Gunung Kidul regency is 4 386 mm while in the same month in 2010 the rainfall distribution is only 226.17 mm.

It can be observed that in the month of January to May, the rainfall distribution is higher compare with the rainfall distribution in the month of June to October. In the period of time is considered as the drought season where all of the river in the area will start to dry. So, in the certain area there will be frequent distruption of the water supply due to the shortage of water. But in the month of November to December, the rainfall distribution increase and the trend of the rainfall distribution are relatively the same in the year of 2010 to 2016. Table I.2 shows the rainfall distribution of Gunung Kidul regency in 2010 to 2016.

Table 1.2 : Total of Rainfall Distribution in Gunung Kidul Regency in 2010-2016 (Badan Pusat Statistik Kabupaten Gunung Kidul)

Month	Rainfall Distribution (mm)						
	2010	2011	2012	2013	2014	2015	2016
January	226.17	357.06	442.78	499.78	387.94	6 364	4 386
February	265.11	408.33	322.39	296.11	332.78	4 450	6 695
March	125.17	325.81	397.50	168.83	108.22	6620	4 628
April	126.67	241.24	158.50	198.78	179.89	5 695	4 391
May	109.67	134.20	73.11	172.78	63.89	1 423	2 282
June	36.67	-	0.92	334.17	56.50	193	3 597
July	1.72	-	-	131.67	59.56	11	1 172
August	0.50	-	-	0.06	0.83	-	1 478
September	0	-	-	0.06	-	-	3 795
October	56.19	43.17	78.44	245.28	220.11	1 642	6 510
November	101.38	256.78	227.35	245.28	220.11	1 642	6 510
December	126.31	389.39	399.25	374.17	471.78	3 222	5 471

1.4.4 Land Use

The Special Region of Yogyakarta lies in the southern central part of Java, one of the most densely populated islands in the world. In general, the morphology of Yogyakarta can be classified into two areas that are physiographically different. These two areas are specifically barren mountainous regions and fertile lowlands. Majority of the territory of Yogyakarta is dominated by the mountainous regions including the areas of Mount Merapi that is located due north, the mountain range of Seribu due east and due west are the hilly areas.

This morphology creates a natural boundary for Yogyakarta which is surrounded by Central Java. In the centre part of Yogyakarta, the remaining regions are dominated by the lowlands. These lowlands are mostly covered by young volcanic soil which is also known as regosol. These lowlands regions are densely populated in Java due to the occurrence of two flowing rivers namely the Progo and Opak which contributes to the high soil fertility of the area.

Most of the lands in Special Region of Yogyakarta is used for agriculture. As stated by Badan Pertahanan Nasional, as per the year 2018, approximately 94.46282 Ha are used for the purpose of agriculture. In the study area, it is mostly covered by the teak tree plantation where it covered in almost 50% of study area. There are also paddy field and corn field that covers around 20% of the study area. In this area, it is major use of the area was used for the agriculture and plantation. Figure 1.3 shows the teak tree plantation, figure 1.4 shows the corn field and the figure 1.5 shows the paddy field in the study area respectively.

Figure 1.3 : Teak tree forest

Figure 1.4 : Corn field in the study area

Figure 1.5 : Paddy field plantation

1.4.5 Social Economic

The social economic in Yogyakarta is where they give priorities to the traditional value. This related closely to their historical background where they also have a high tolerance for each other. Ideology, education, health and birocracy are the important factors for the modernizations. In term of the economics of Yogyakarta, the domestic production increasing per years. Their economics heavily relies on the tertiary sectors such as wholesale and retail trade, transportation and warehousing, tourism, information and communication sector, insurance and financial services, real estate, corporate services, government administrations and also education services.

1.4.6 Road Connection

The location of the study area is highly accessible as the road connection of the area is well developed. This makes the journey to the study area is very easy and convenient. Motorcycles are the most suitable transportation that can be used in collecting data as the road system is good.Yogyakarta has an absolute extensive transportation system of public transportation. The accessibility is a major departure point for inter-city and to other cities.

The most common transportation used by the Yogyakarta natives are motorcycles as their personal transportation and also at a high number of Yogyakarta residents used their own automobiles. Yogyakarta also has a good and well developed highway system. Ringroad is one of the highways and overpasses including the Janti Overpass and Lempuyangan Overpass. Overall, the accessibility in Yogyakarta is in good development which aids the residents to move to other places easily.

In the study area, in the rural areas such as in the village they are connected with the village roads that connects most of the places in the village area. In the farm or at the plantation site, there are small road that was made by the villagers themselves in order to make them easier in doing their daily activities. Figure 1.6 shows the accessibility of the road in Yogyakarta obtained from the google maps. Figure 1.7 shows the small road in the study area while figure 1.8 shows the village road in the study area.

Figure 1.6 : Accessibility of road in Yogyakarta (Google Maps)

Figure 1.7 : Small road in the study area

Figure 1.8 : Village road in the study area

1.5 Scope of study

This research is about the analysis and assessment of the landslide susceptibility that associated with the rock and soil properties of the study area that is in Patuk, Yogyakarta. The GIS specification method such as landslide susceptibility analysis is conducted in order to determine the probability in the occurrences of landslide in the study area. Further study on the geological prospect of the study area is important to understand the content of rock thus can give information about the rock structure and also the rock mass strength that may affected the landslide to occur.

This research also includes the rock sampling method that is the collection of the rock sample and of the study area. Different rock are collected and analysed later in laboratory work to conduct the petrographic analysis. Petrographic study is conducted to support the determination of the composition either chemical or physical composition of the lithology accurately.

1.6 Research Importance

This research prospect will be helpful to determine the landslide susceptibility of the Patuk area as it is a landslide prone area. Moreover, this research project will also important as it will also give information and understanding about the general geology for the future research. This research is important due to the previous outdated geological map so an updated geological map of the area will be produce at the end result of this research proposal that is believe to be beneficial to enhance previous research. The result of the landslide susceptibility analysis then will be obtained by using the ArcGis software.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will more focus on the geological part and the research specification part. In the geological review it will cover included several topics such as the regional geology and tectonic setting, the structural geology and also stratigraphy. All of these reviews are related to the study area that is in Indonesia especially in Yogyakarta area. From the previous study from B.N. Kresna Citrabhuwana et al, 2016 had stated that there are joint and fault that make the area prone to slope instability.

The next part is the research specification part which is the in the research interest of the remote sensing & GIS method that is the landslide susceptibility analysis of the Patuk area in Yogyakarta, Indonesia. The more detailed discussion about the research specification such as the determination of the lineament density map, the soil type map, the slope map, drainage pattern density map and also properties of lithology and rock.

2.2 Regional Geology and Tectonic Setting

The Indonesian archipelago a complex collection of the continental blocks, volcanic arcs and involved the complex subductions and old and young basins (Gorsel, 2016) . The basements of the formations are metamorphic rock that being intruded by the formations of plutonics. In Sumatra Island, the oldest rock are gneiss, schist and quartzite where the schist usually contains gold. They form the backbone of the island and it is along the mountain chain that runs parallel to the west coast.

The other series of rock is slates below and limestone above where it lies unconformably upon the older rocks that indicate it belongs to the Upper Carboniferous. There are no Permian beds found and the deposits of Mesozoic have been found in the East Sumatra that is the upper part of the basin of Kwalu. The tectonic settings of Indonesia are Indonesia forms the southeastern extremity of the Euro- Asian lithospheric plate.

It is constrained by the northward- moving Indo- Australian and the Westward- moving Pacific plate. It is certainly one of the most complex active tectonic zones on earth. The subduction zone that occurs around the Euro – Asian plate that called Sunda trench. Most of the volcanoes in Indonesia are part of the Sunda arc, extending from Northern Sumatra to the Banda Sea. In the region of the eartquakes, the plates of the Indo – Australia moves towards northeast that results in oblique convergence at the Sunda trench (Gorsel, 2016).

The oblique motion partitioned into thrust faulting that occurs on the plate-interface and involves slip directed perpendicular to the trench and strike-slip faulting. The name of the fault is Sumatran fault where it is divided into three that is southern segments, central segments and also northern segments. The Sumatran Fault

System probably dated from the middle Miocene and the opening of the Andaman Sea and it runs the length of the Barisan Mountain, a range of uplifted basement blocks, granitic intrusions and tertiary sediments topped by Tertiary- recent volcanics.

The Indonesian region is one of the most seismically active zones of the earth where Indonesian region has many dormant, active and potential for volcanic eruptions. Indonesia has a structure where a typical island-arc structure with physiographic features of a deep oceanic trench, a marginal basin, a volcanic inner arc and a geo-anticline belt. It is estimated that Indonesia has over 400 volcanoes in which approximately 100 are active volcanoes.

2.3 Structural Geology

The major structures in Indonesia were formed by the tectonic processes in Indonesia. The Great Sumatran Fault is a dextral strike- slip fault along Sumatra Island is the most prominent fault in the west of Indonesia. The formation of this fault zone is closely related to subduction zone in the west of Sumatra. Another major structural feature is Palu – Koro fault that formed in the central part of Indonesia. This fault run across the central part of the Sulawesi Islands and it is extended offshores to the west across the straits of Makassar and ends in the Mangkalihat Peninsular in Borneo.

Opak fault can be found on the border of the parallel fault on the eastern margin but on the western side there is no any faulting in Yogyakarta. The western fault is covered by the younger sediments and even though the eastern and western parts of Yogyakarta have the same conditions, both of the parts still have the different lineament densities and trends. Based on a survey by Barianto in 2009, the

NE-SW fault in the western margin and E-W fault which is buried in the northern margin is can be observed (Smyth, 2005).

The western margin is controlled by NE-SW, N-S and E-W faults from south to the north of Yogyakarta. The E-W fault from the western part of the Menoreh Mountains to the eastern part of the Kebo- Butak Mountains can be observed. This known as a normal fault which can precisely say as a sinistral fault. During the middle Miocene, the Jonggrangan Formation, Sentolo Formations, Oyo Formations and Wonosari Formations have similar sedimentation environments with different elevations. These differences evidenced by different uplifts which the western block are the highest uplift.

2.4 Stratigraphy

In this subtopic, the general stratigraphy of Indonesia and the precise stratigraphy of the study area is studied. The stratigraphy of the western part of Indonesia is dominated by Cenozoic age formations ranging from Paleogene to Quartenary. Minor Mesozoic and Paleozoic formations were found in places while the Devonian limestones were found in Telen River, East Kalimantan, as fragments within Paleogene clastic sediments. In comparison, Eastern Indonesia has generally older stratigraphy compare to Western Indonesia. The stratigraphy of Eastern Indonesia ranges from Permian to Tertiary.

The early Cenozoic sandstones above the oldest sediments increases in volcanic materials in the recording of the southern Mountain Arc (Smyth, 2005) . Throughout the late Oligocene to early Miocene a thick sequences of volcanic and epiclastic rocks found due to the explosive volcanic activity (Smyth, 2005) . The volcanism was terminated in the early Cenozoic by the short-lived early Miocene

Semilit super eruption event that causes the entire southeast region of Sundaland was lifted during this period.

In the middle Miocene to late Miocene the volcanic activity is reduced while from the late early Miocene to middle Miocene, the carbonate range can be found in this period (Smyth, 2005). Lunt (2009) proposed an unconformity recorded in a late Miocene tectonic event that had created a new series of basins which filled by erosion of structural highs in Central Java. Other than that, a major tectonic event in the late Pliocene and Quaternary caused the uplifting of Java and the deposition is widespread Pliocene and Quaternary sediments in the offshore area.

Next is the Sambipitu Formation. Sambipitu Formation occurs in the Early Miocene until the Middle Miocene and it is composed of sandstone that is adjacent to shale, siltstone, claystone and locally can be found conglomerates and breccia (Lauti D. Santy, 2007) . The lower part of the Sambipitu Formation is silicyclastic in contrast to the upper part that consists of more carbonate material and the carbonate material increases gradually upward from the formation. Based on the previous study, it was determined that the Sambipitu Formation as a marine depositional environment which influent by the turbidity currents (Lauti D. Santy, 2007).

All of the calcareous sediments in Sambipitu Formation heve been overlain by all the volcanic rock units and are grouped into many formations that is Oyo Formations, Wonosari Formations and Kepek Formations. Nglanggeran Formation is composed of volcanic breccias, tuffs or volcanic sandstone, agglomerates with poorly bedding, pillow lava flows of andesitic to basaltic andesite and autoclastic and hyaloclastic breccia in composition (Djoko Mulyanto, 2009). In the geological time scale, the formation is placed at the age of Early to Middle Miocene.

2.5 Historical Geology

The geological history of Yogyakarta is it is known as the pull-apart basin that was addressed as Opak-Muria Fault whereas also known as the Principle Displacement Zone (PDZ) of Java Island. The releasing bend and the response of trans-tension deformations of sinistral strike-slip movement defined the Yogyakarta depression. There are five periods referring to the regional volcanism event of the Old Andesite Formation (OAF) to the geological history of Yogyakarta pull-apart basin in the Paleogene to present.

The five periods are from oldest to the youngest event which is from the cretaceous-Paleocene basement, Middle-Late Eocene pre- OAF, Oligo-Miocene OAF, Middle-Late Miocene Post OAF and Pliocene-Holocene syn-orogenic. The compression tectonic event in the Middle- Miocene resulted of the new subduction due to the plate re-organization of Indo-Australia oceanic crust movingly slowly to the north direction builds the volcanic arc comprising the formations of Kebo-Butak, Semilir and Nglanggran Formations.

The Yogyakarta city and the province are considered as a system where the geological phenomena distinctively dominate all the natural processes. The continuous subduction of the Indo-Australia plate Oceanic Plate from the South in the direction below the Eurasia Continental Plate not only resulted in the formation of the active Merapi volcano and it is also brought about the formations of the mountainous morphology of volcanic and carbonate rocks (D. Karnawati, 2006).

Yogyakarta city situated at the centre of the province, in the middle part of Yogyakarta valley which is extending from the north to the south. The valley is a graben that was filled by the Merapi laharic flows while to the west, a dome of andesitic breccia and lava flows with the intensive fault formation occurred. According to the (D. Karnawati, 2006) , in the eastern part of the province, it is a steep mountain of carbonaceous - volcanic rocks as well as limestone with karst landscape are exposed.

2.6 Research Specifications

In determining the landslide susceptibility analysis in the area, there are several of methods that can be employed and used. For details, slope stabilization method involves specialty of construction techniques that must be understood and modelled in a realistic way. The analysed must be based on a model that accurately represents site subsurface conditions, ground behaviours and also the applied loads.

Usually, slope stability analysis is used to contribute to the safe and economic design of excavations, embankments, earth dams, landfills and also spoil heaps. The evaluations are concerned with identifying critical geological, material, environmental and economic parameters that will affect the project as well understanding the Mother Nature, magnitude and the frequency of the potential slope problems.

According to B.N. Kresna Citrabhuwana et al, the road in Piyungan, Yogyakarta is a road that crosses a hilly topography that causes its sides bounded by quite steep cliffs or slopes. Based on the analysis, some slopes around the study area have a really high potential to move and the movements can be classified into rock fall, debris fall and rock slide with the sliding planes being categorized as the planar and wedge (B.N. Kresna Citrabhuwana, 2016).

Slopes composed of hard rock and coherent rock that are usually characterized by the occurrence of stress that is different from the slopes occupied by a weathered rock or weathered soil. Based on Price (2009), the slope of soil is much weaker than the slope of rock. The stability of the slope is occupied by soil and it is totally influenced by the shear strength of the soil while it often triggers the potential of the occurring of an avalanche (S.B. Kusumayudha, 2016).

Next in determining the landslide susceptibility in the study area, the remote sensing and Geographical Information System (GIS) was used. Based on Punyatoya Patra (2010), remote sensing is obtaining the information about the Earth's land and the water surface by using the reflected or emitted electromagnetical energy. Remote sensing is one of the widest sense in detecting and recording the radiation of electromagnetic from the target areas in the field view of the intrument's sensor. Figure 2.1 shows the stages of remote sensing in analysing data.

Geographical Information System(GIS) is a computer based information system that attaches with varieties of qualities and characteristics to the location of geographical and it assist in the decision and planning making (Punyatoya Patra,2010). The users of GIS can expect support from the system in entering the georeferenced data to analyse it in variety of ways and producing output such as maps from the data. Figure 2.2 shows information that is sored as theme layers with each layer linked to a common spatial feature referenced to a specific location.

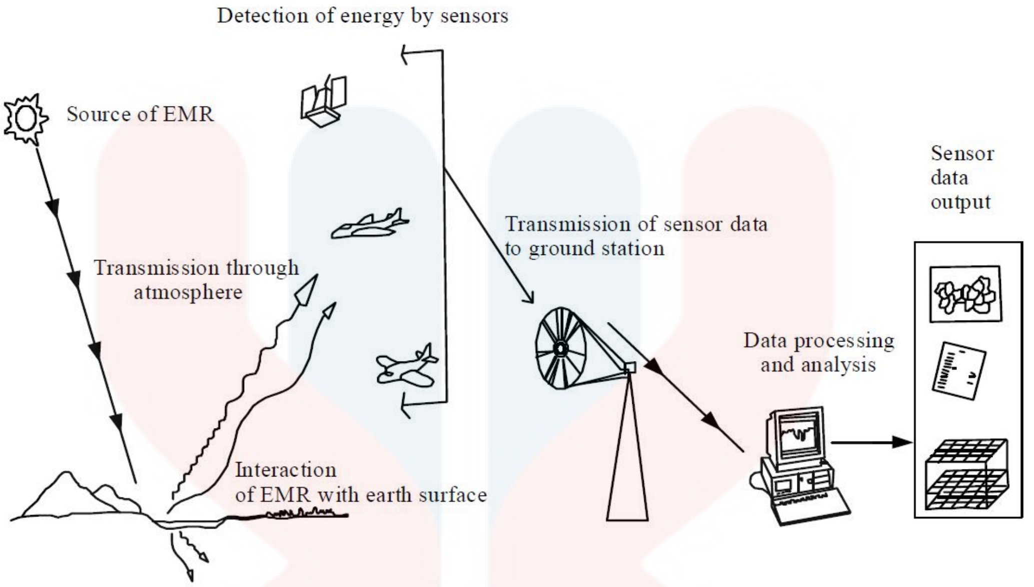


Figure 2.1 : Stages of Remote Sensing

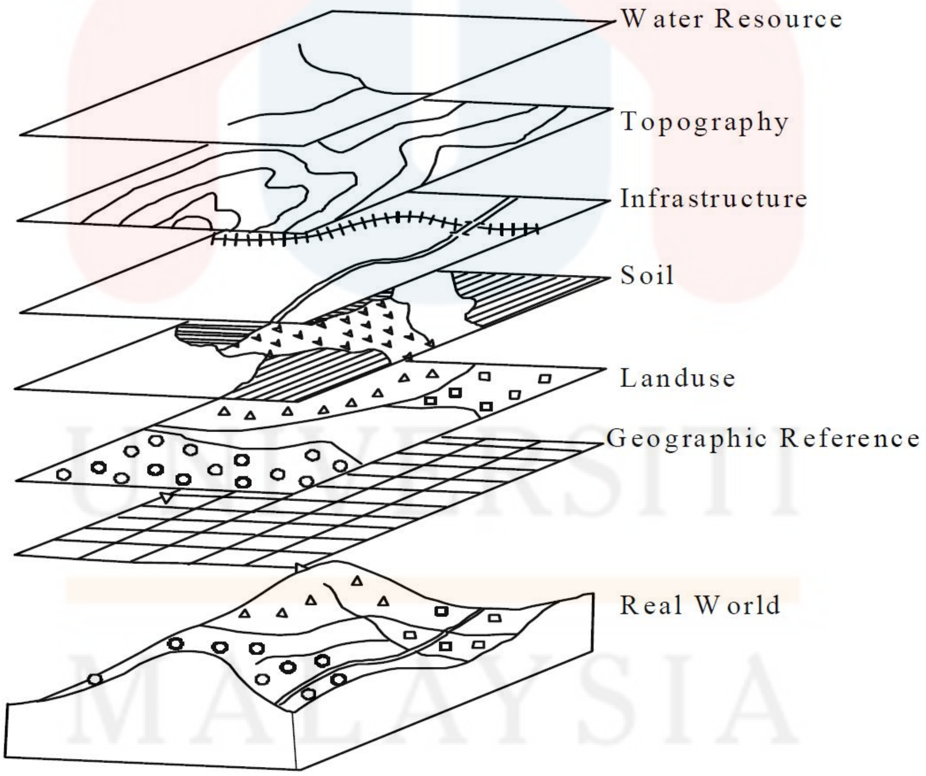


Figure 2.2 : Information that is stored as theme layers with each layer linked to a common spatial feature referenced to a specific location

Based on Himan Shahabi (2015), landslide suscetibility mapping has been made possible because of the accessibility and the remote sensing data variety also thematic layers as causative data factors in using GIS. Based on the records, the main causes of frequent landslides occurring in the Southeast Asia slope is due to seasonally dry periods, steep hill slopes, excessive rainfall intensities and also the unstable soils.

Landslide susceptibility is the propensity of rock or soil in producing various types of landslides (Christos Chalkias et al, 2014). In the study made by Christos Chalkias et al, (2014), elevation, slope aspect, lithology, land cover, mean annual precipitation and peak ground acceleration has been identified as the landslide-conditioning factors. Among all of the parameters that had been mentioned, elevation and the slope aspect had been determined as the most important conditioning factors.

Based on Gang Piao et al, (2013), landslide susceptibility is an attempt to derive spatial variation of area based-slope failure probability or instability at a regional scale. They had categorized the factors that triggering the landslide to the prepatory factors such as the lithology and geomorphology, and the triggering factors such as the seismicity, rainfall, land covers and also the anthropogenic causes.

CHAPTER 3

MATERIALS AND METHOD

3.1 Introduction

In this chapter, it is focused on the materials and methods that was used in this research. The materials that was used in this research was list wisely as shown in Table 3.1 because its play an important role in conducting geological mapping. For the method, to get the precise result, method was carefully studied on the previously research, and organized every steps properly and follow the step until the right result obtained.

In methodology section there are two type of method that is a quantitative method and also qualitative method. Quantitative research data is the data produced that are always numerical and they are analysed using mathematical and statistical methods while on the other hand, qualitative research is any which does not involve numbers or numerical data. Qualitative analysis results in rich data that gives an in-depth picture and it is particularly useful for exploring how and why things have happened. In this research, the type of method that will be used is the mix of the qualitative analysis and quantitative analysis.

The methods that was used in carrying out the study is the preliminary studies, field study, laboratory work, data analysis and interpretation and also report writing. After the preliminary research is done, the writing of literature review is carry out as well as site selection. During the field mapping or studies, there are two things need to be done which are geological mapping and engineering geological mapping. The

GIS study also carry out to determine the geomorphology of the study area such as drainage pattern and topography as well as lineament.

3.2 Materials

3.2.1 Global Position System Equipment (Garmin 62s)

GPS showed in Figure 3.1 is a navigation system based on the satellite consists of the satellites in space, monitoring stations on earth and GPS receivers. The functions of GPS equipment are used in positioned one’s position, recording traverse track, operated the interval of traverse track recording, measuring elevation, and storing the sampling location.

Figure 3.1 : Global Positioning System (Garmin 62s)

3.2.2 Compass

Compass is use to get the directional degree measurements (azimuth) based on the Earth’s magnetic field, measure strike and dip value of the exposed outcrop, and used in following traverse line in order to go to the pointed point as it can be set to the planned direction. Picture of compasses showed in Figure 3.2. The most common type of compass used is Brunton compass and Suunto compass.

(a) (b)

Figure 3.2 : suunto compass(a), brunton compass (b)

3.3.3 Measuring Tape

Measuring tape is used to measures the actual size of the lithology and structures as well as taking the measurement of the bed thickness and the grain size. It also used to measure the geometry of slope and the geometry of the slope failure. Figure 3.3 shows the type of measuring tape used.

Figure 3.3 : Measuring tape

3.2.4 Geological Hammer

There are two type of geological hammer, pointed-tip rock hammer and chisel-tip rock hammer. Pointed-tip rock hammer has a long pick-like end that usually used for the harder rock such as igneous rock and metamorphic rock. The long pick-like end useful in inserted into the cracks for levering out loose rock and digging through a thin soil cover. The chisel-tip rock hammer has a chisel-shaped blade that commonly used for sedimentary rock and sediments. The chisel end is useful for splitting the layers of sedimentary rocks, trimming rocks and digging soils and sediments. These two types of geological hammer are both important in rock sampling in the field and presented in Figure 3.4.

(a) (b)

Figure 3.4 : Tip-point geological hammer (a), Chisel geological hammer (b)

3.2.5 Hand Lens

The hand lens is used to make the initial analysis of the rock samples in the field based on the rock types, colour, mineral compositions, textures and structure properties such as folding, foliation, intrusions or layering that cannot seen by naked eyes before the detail analysis and observation carry out in the laboratory. Figure 3.5 shows the type of hand lens that while performing the geological mapping.

Figure 3.5 : Hand lens

3.2.6 Polarizing Microscope

It is commonly used for the study of rocks and minerals in the field of geology and petrography. For the observation of the rocks or minerals, a thin section of the particular sample has to be done. This microscope has three objectives with different magnification which are 4x, 10x and also 40x . Figure 3.6 shows the type of polarizing microscope that was used.

Figure 3.6 : Polarizing microscope

3.2.7 Geographical Information System (GIS) Software

The obtained data in shapefile was then being used to produce map such as the base map of the study area, the slope map, the drainage pattern map, the watershed map and also the topographical map. Figure 3.7 shows ArcGIS software that was used in making all the maps.

Figure 3.7 : ArcGIS software

3.2.8 GeoRose Software

GeoRose software is used to plot the structural geology rose diagram by entering the strike, dip and dip direction of structure such as joint, fault, fold, lineament and bedding. The rose diagram can be in full circle or semi-circle

3.2.9 Sample Bags

The common sample bag used is the transparent plastic bag with a resealable zip lock. It is uses to store the rock or soil sample from field. The label tag that consists information like coordinate, sample number, date and time is necessary for each sample on the sample bags. Figure 3.8 shows the sample bags that was used in sampling the sample that was taken in the field.

Figure 3.8 : Sample bags

3.3 Method

3.3.1 Preliminary Study

Preliminary studies is the study of research contains information that needs to be verified. Conducting preliminary research involves choosing a topic that is interesting and give initial overview of the study area that was done by observation of topographic map and references from the library and internet. The reference of the researches was obtained from the journal or bulletin that related to the research title and study area. Well carried out of preliminary study can give a better information about the site that is going to be visited. It is required as part of a planning application or used as part of a pre-purchase assessment. This is based on the geomorphological of the study area and the research for the analysis of the landslide susceptibility at the study area.

3.3.2 Field Study

The main purpose of doing field study is to get detail information about the study area such as lithology, geomorphology at the area, stratigraphy, structural geology and others that related to the study area for further interpretation. The methodology that was used was geological mapping by collecting the data such as joint, strike and dip, also collect the outcrop samples at the study area used for laboratory test purpose, and while traverse the road it tracking by using geological positioning system (GPS). The data and information obtained from the field study was used to produce geological map of the study area.

Traverse is also used to gather information and data in the study area on foot where some of the places in the study area cannot be travel by using the other means of transport. It is the best way in collecting data that are essential to the result and observation of the slope stability analysis of the study area as the study area can be covered wholly and more details interpretation of the study area can be made.

3.3.3 Sampling

The sample of rocks that had been collected from the site need to be sampled to determine the types of rock in the study area. It is essential to see the distribution of rocks that can be used in determining the strength of rock and the suitability of railway project at the study area itself.

3.3.4 Laboratory work

The laboratory work that had been done in completing this research is in making the thin section sample. The sample of rock that had been taken in the field was brought to the laboratory to produce the thin section. Based on the thin section, the petrography analysis will the continued in analysing the content of mineral of the rock sample. In petrographical analysis, polarizing microscope was used in determining the mineral content that is under plane polarise light (PPL) and cross polarise light (XPL).

3.3.5 Data analysis and Intrepretation

a) Petrography

The analysis and interpretation of the rock samples are carried out with the study of petrography which is based on the observation of the thin section. The thin section made will be observed under the petrographic microscope. The type of minerals, distribution of minerals, textures and colour of the thin section are determined under the microscope.

b) **Force analysis by the structural data**

The structural data such as the orientation, strike and dip value is obtained from the discontinuities like fault, folding, bedding surface, foliation and the shear zone. The force analysis by and interpretation is based on the structural data collected from the field.

Dynamic analysis seeks to reconstruct the orientation and magnitude of the stress field by studying set of structures, typically fault and fractures (Fossen, 2010). The rose diagram is use to plot the orientation of force and the direction of the force.

c) **Landslide Susceptibility Inventory**

For the creation of Landslide Susceptibility inventory, the specific parameters that was identified during the analysis such as the slope geometry, the drainage density analysis, the lineament density analysis, the watershed analysis and also the topographical analysis. All of these parameters was important in determining the weightage of landslide susceptibility in the study area.

d) **Field Work Data Analysis**

The data that had been gathered through traversing method then need to be analysed. The first analysis of data is in the field where the data is analyse that is about the lithology of the study area, the types of rocks and also the structures of geology that present at the study area. It is very important as it takes cost and time if the data that had been analysed is wrong because the site needs to be revisit to get the accurate data value.

3.3.6 Report Writing

All the geological data collected from the field and preliminary research was gathered to make the interpretation. Thesis writing constructed according to the chapter provided. Chapter one consists of introduction this research. The second chapter is the literature review and the third chapter is material and method was used in this study. Chapter four is the general geology and the fifth chapter contain result and discussion of specification for landslide susceptibility analysis. The last chapter which is chapter six is the conclusion and suggestion for this research in the future research. Figure 3.9 shows flowchart of the research methodology.

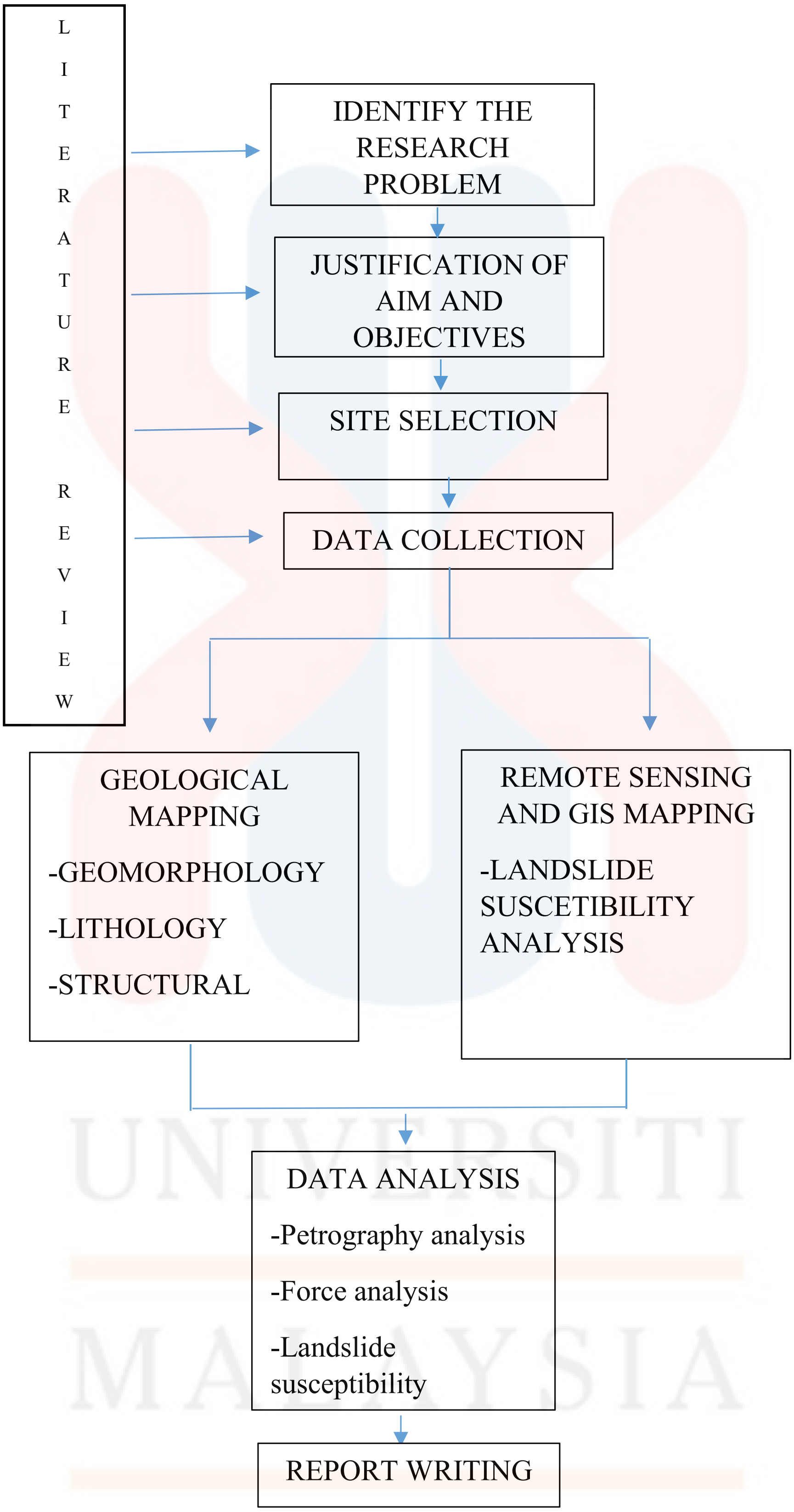


Figure 3.9 : Flowchart of the methodology of the research project

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

General geology is one of the most important chapter that includes the geomorphology, stratigraphy, structural geology and historical geology of the study area. All of the data were obtained by the observation in the field and also from the analysis of data in the laboratory. The study area has been accessed by traversing as it is dominated by the plantation and also forest area.

Geomorphology is the study about the landform and its processes that related to the origin of the Earth and also the Earth's evolution. Geomorphology includes the study of the topography, drainage pattern and also the weathering process of the area. Stratigraphy is the branch of geology that concerned with the order and the relative position of strata and their relationship to the geological timescale.

Stratigraphy involved the lithostratigraphy, biostratigraphy, chronostratigraphy, sequence stratigraphy, seismic stratigraphy and also magnetostratigraphy but the most concerned part in this paper is on the lithostratigraphy part. The thin section of the lithologies is done and the identification of the rock and the analysis of the mineral is carried out. The analysis of petrography is used in identifying the type of lithologies an also in constructing the geological map of the study area.

Structural geology is carried out by the analysis of structure found on the outcrops such as fault, joint, fracture and fold. The structural mechanism was done to determine the major forces that deformed in the study area. Part of the historical geology also discussed about the historical formation of the study area. In this part covered the sequence of the lithology found and also the history of deformation during the formation of the area.

The geological mapping is very important in geology to describe in detailed the process that had occurred in the study area, the type and also the formation of the rocks. Figure 4.1 shows the traverse map that was conducted through geological mapping of the study area. The traverse map shows the location of the observation, sampling and measurement on structural during the field mapping. Table 4.1 shows the activities that being done in every station.

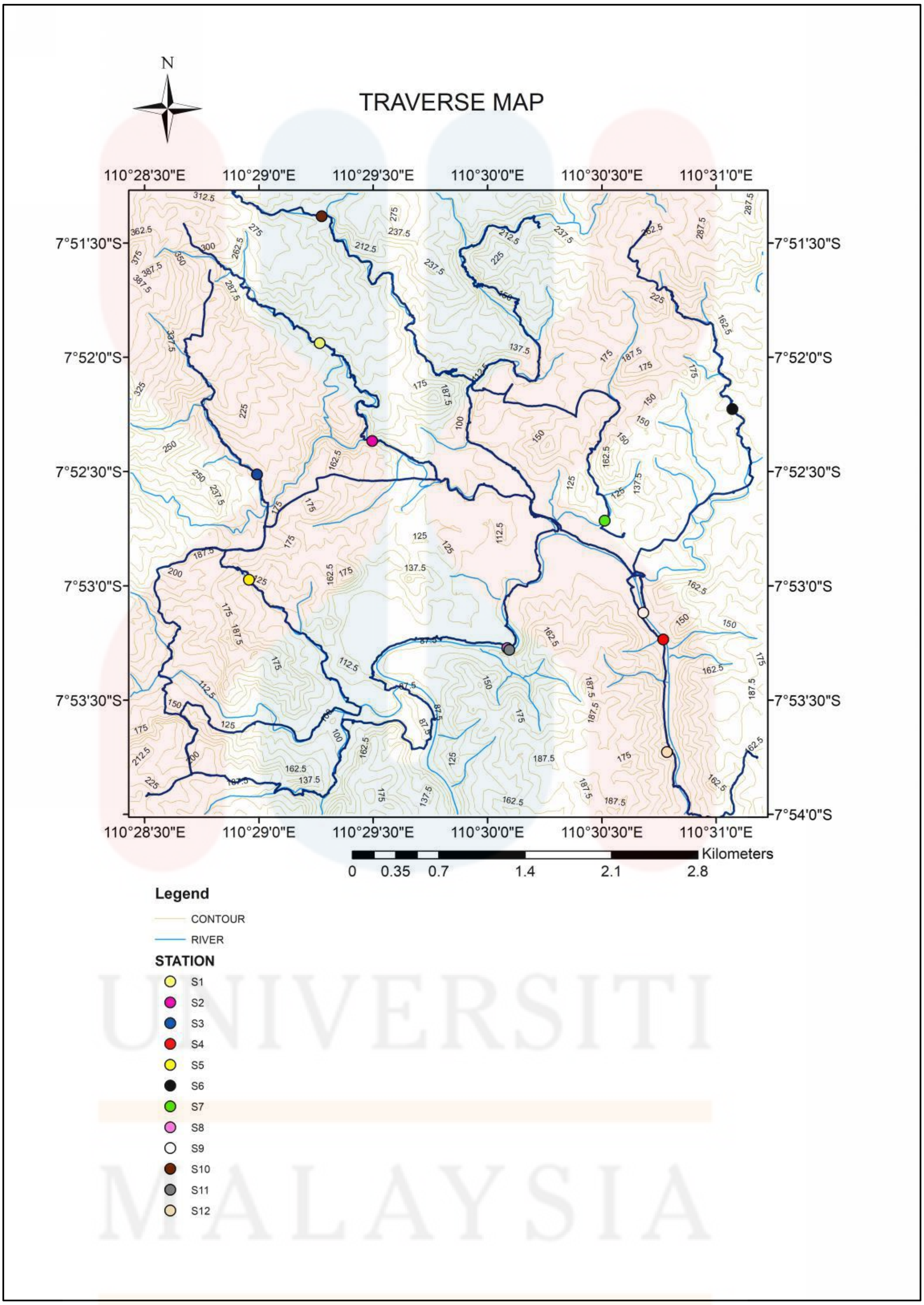


Figure 4.1 : Traverse map in the study area

Table 4.1 : Activities at each stations

Station (S)	Coordinates	Observation/Activities
S1	110° 29′ 15.16′′E 7° 51′ 56.254′′S	Andesite outcrop
S2	110° 29′ 557′′ E 7° 52′ 22.068′′S	Unconformity of volcanic breccia outcrop
S3	110° 28′ 59.715′′E 7° 52′ 30.672′′S	Breccia outcrop
S4	110° 30′ 46.083′′ E 7° 53′ 13.879′′ S	Interbedded of sandstone with claystone
S5	110° 28′ 57.335 ′′E 7° 52′ 58.683′′ S	Tuff outcrop
S6	110° 31′ 4.931′′E 7° 52′ 13.829′′S	Interbedded of sandstone and claystone
S7	110° 30′ 30.888′′E 7° 52′ 42.939′′S	Sandstone outcrop of Sambipitu Formation
S8	110° 30′ 5.257′′E 7° 53′ 16.442′′S	Bedding of the Limestone outcrop of the Oyo Formation
S9	110° 30′ 40.795′′E 7° 53′ 6.914′′S	Observation of the geological structural that is an anticline fold
S10	110° 29′ 16.327′′E 7° 51′ 22.587′′	Observation of the geological structure that is a faulting
S11	110° 30′ 6.051′′E 7° 53′ 16.577′′S	Observation of the geological structural that is a syncline
S12	110° 30′ 47′′E 7° 53′ 43.523′′S	Observation of the geological structure that is the syncline.

4.2 Geomorphology

Geomorphology is the scientific study of the origin and evolution of the topographic and bathymetric features that created by physical and chemical processes operating at or near the Earth's surfaces. The major type of landforms included mountains, hills, plateaus and plain. The geomorphology of the Earth can be made up by either endogenic or exogenic processes. The endogenic process that can create landforms is related to volcanism, diastrophism and earthquake while exogenic processes referred to the aggradation.

Mountain is the large landform in form of a peak that rises high to its surrounding area. Plain is a landform that has flat area commonly occurs as lowland. Fluvial is a morphology formed by the processes and deposits of rivers and streams. From this, it can seek the understands about why landscapes look the way they do, understand landform history and dynamics and also can predicts changes through a combination of field observation through the mapping. Figure 4.2 show the fluvial morphology in the study area while figure 4.3 show the hilly landform in present in the study area. Figure 4.4 shows the landform at the study area mostly composed of undulating and hilly area. In this chapter, geomorphology consist of observation and analysed topography map of landform, and drainage pattern.

Figure 4.2 : Fluvial morphology

Figure 4.3: Hilly landform of the study area

Figure 4.4: Undulating and hilly area landform

4.2.1 Topography

Topography is the arrangement of the physical distribution of the Earth's surface such as shape and elevation. The topography of a particular area can show by the topographic map which included the elevation of the area. The topography if the study area can be divided into three part that is mountainous part, hilly area and also the undulating area. Based on the figure 4.5, the majority of the study area is consisting of the undulating area and hilly area.

The elevation of the study area ranging from the lowest that is from 50 meter to the highest elevation of 450 meter. The pattern of topography that shows the lines of the contour is very close means the topography is high and steep. However, the line of the contour that far away means the topography is low area. The highest elevation of the study area can be seen at the northwest of the study area where the highest elevation is 450 meters.

The mountain landform, which has mean elevation more than 300 m, covered 10% of study area. The hill landform has mean elevation range from 150 m to 300 m, covered 25% of study area. The undulating area has mean range elevation 50 m to 150 m, covered 65% of the study area. Geomorphology analysis is done at the study area.

The type of rocks that found in the area are known based on contour pattern. For the study area, the mountainous area has the characteristic of igneous rock or volcanic rock. Furthermore, the hilly and undulating area shows the characteristics of sedimentary rock.

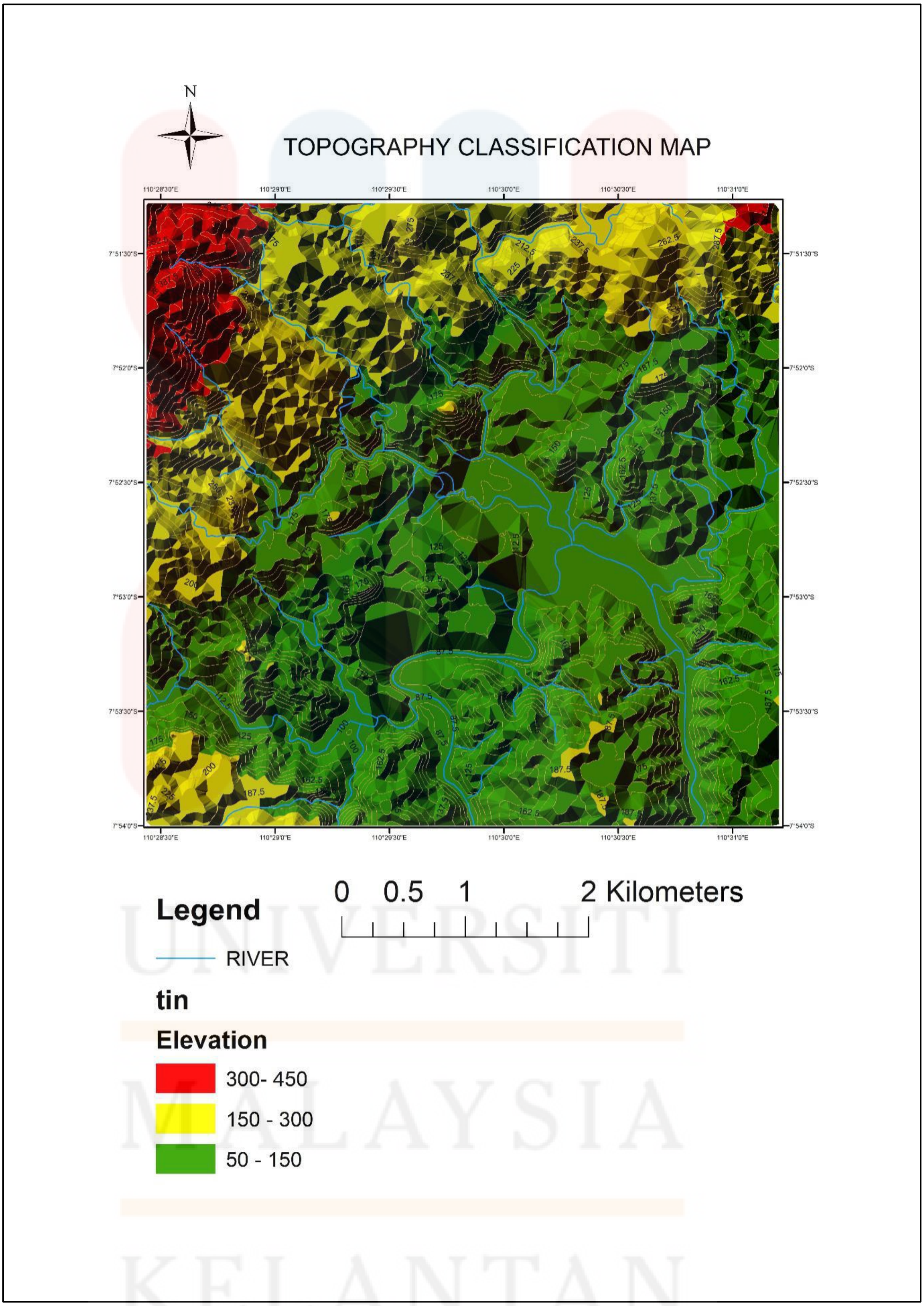


Figure 4.5 : Topographical map of the study area

4.2.2 Drainage pattern

Drainage pattern is the arrangement of streams on the surface of Earth by drainage system. Geologic and topographic factors of the rock beneath the Earth reflected the drainage pattern as well. The drainage pattern included dendritic, parallel, trellis, rectangular, radial, centripetal and deranged pattern. Dendritic drainage pattern is the most common drainage pattern found on the surface of Earth.

There are five types of drainage patterns that can be observed in the study area such as the parallel, trellis, rectangular, dendritic and internal drainage patterns. Parallel drainage pattern is a river pattern that caused by steep slopes with only some relief. This type of pattern frequently developed on uniformly sloping and dipping rocks beds. It is also developed in the regions of parallel elongated landforms for examples like the outcropping resistant rock bands. In the study area, the lithology found are sandstone, claystone and also volcanic breccia.

Trellis drainage pattern formed by the sedimentary rocks that have been folded or tilted. Then, the folded sedimentary rocks will then be eroded to varying sizes degrees depend on the strength itself. The lithology that can be found in the trellis drainage pattern in the study area is sandstone, claystone and also limestone. Next is the rectangular drainage patterns. It is generally developed in the places where the joint of the rock forms a rectangular pattern.

The weathered and eroded rocks along the joints, fractures and faults thus the collected runoff water in such long and narrow fissures that resulting from the weathering and erosion of joints then will form numerous small rills. It can be observed from the study area that in the rectangular pattern drainage pattern, the type of lithology that can be found is mostly sandstone.

Dendritic drainage pattern is one of the most common drainage patterns that develop in the area where the rock in the area beneath the stream can be eroded easily in all direction. The shape of the dendritic drainage pattern looks like branching shape of tree roots. Ritter (2006) stated that the dendritic drainage pattern develops in areas underlain by homogeneous material. The tributaries join to the larger streams at acute angle (less than 90 degrees). The type of lithology that found in the study area is sandstone, claystone and also volcanic breccia.

The last one is the internal drainage patterns. Internal drainage patterns is a type of drainage patterns that has a very little surface expression displayed with internal drainage. It is a subterranean drainage system that is characterized by caves and sinkhole. Internal drainage is generally developed by soluble rocks such as carbonates.

Watershed can be defined as the area or ridge of land that separates the waters to flow to different basins, rivers or seas. Ridges and hills that separate two watersheds called as the drainage divide because of its character. The watershed also consists of streams, reservoirs, lakes and wetlands and all the underlying groundwater. Figure 4.6 shows the drainage pattern map of the study area.

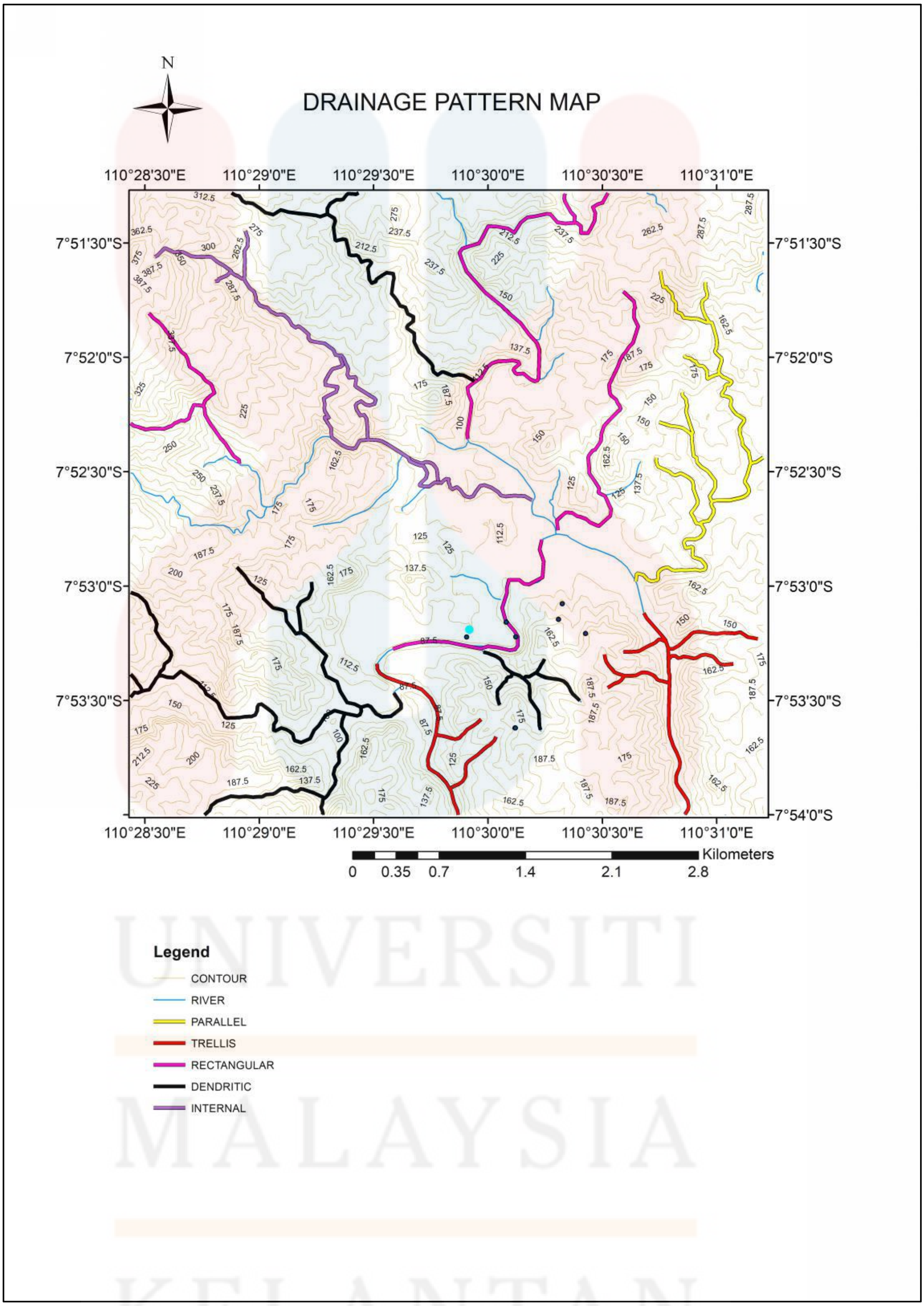


Figure 4.6 : Drainage pattern map of the study area

4.2.3 Weathering Process

Weathering is defined as the breakdown of rock, soils and minerals through the contact with Earth's atmosphere, waters and sometimes biological organism. Weathering is the process that occurs in in-situ place which means on site or in the same place with no movement. The process of weathering that takes place on rock is different for every rock depend on their properties and mineralogy content. This process is more active in wet condition and environment with high temperature. Weathering is divided into three types, which are physical weathering, chemical weathering and biological weathering

Physical weathering that is also known as the mechanical weathering is the weakening and breaking down of the rocks without the changing in the chemical composition of the rock. It is then also followed by the disintegration due to the physical and or the mechanical forces including the actions on the rock by abrasion and also the crystal growth. Example type of physical weathering is exfoliation that occurs as cracks develop parallel to the land surface a consequence of the reduction in pressure during uplift and erosion.

Chemical weathering also known as decomposition is the breakdown of rock by chemical mechanisms. It changes the chemical composition of the rocks usually through carbonation, hydration, hydrolysis and oxidation. Chemical weathering alters the composition of the rock material toward surface minerals such as clays. These chemical processes required water and it occurs rapidly at higher temperature.

Biological weathering is disintegration of rocks as a result of the action by living organisms. Plant and animals have a significant effect on rocks as they penetrate or burrow into the soil respectively. Some plants and trees grow within the fractures in the rock formation and make the crack wider and deeper that eventually disintegrate the rocks. Figure 4.7 shows the biological weathering process that occurs in the study area.

Figure 4.7 : Biological weathering process in the study area

4.3 Stratigraphy

Stratigraphy is the study of the characteristics of layered rocks, relationships between the layered rocks and the relative and absolute ages of the rocks. Lithostratigraphy is one of the sub-discipline of stratigraphy which concern on the of the study of the rock layer. It usually use to describe the relationships between the formations of igneous or sedimentary rocks.

4.3.1 Lithology Unit

In the study area, there are three main lithology units which are the limestone unit, volcanic breccia unit and also the sandstone unit. The limestone unit consist of the limestone and sandstone while the volcanic breccia unit consist of volcanic breccia, tuff, sandstone and also claystone. In the sandstone unit, there are sandstone that are interbedded with claystone. As can be seen in the lithological map, the age of the rock has been arranged in the older to younger age that is from volcanic breccia unit, sandstone unit and limestone unit respectively.

The lithology unit at the study area also can be divided into the formation of the area that is the Oyo Formation, Nglanggeran Formation and Sambipitu Formation. The oldest Formation is the Nglanggeran Formation then follows by the Sambipitu Formation and the youngest formation is the Oyo Formation. Based on the stratigraphic column, the limestone unit have the colour from greyish white to dark gray and dark brown colour.

The texture is clastic with sand and silt size that is compose from carbonate material with the calcite vein. Next, the sandstone unit has the colour from greenish gray to white yellowish with the texture of clast with fine to medium sand size. In certain area in the study area, the sandstone is sometimes interbedded with the claystone. For the volcanic breccia unit, it has the colour from dark gray to dark colour for example black colour. The texture is clastic with pebble to sand size, andesite fragment, tuff matrix and the silica matrix. Figure 4.8, figure 4.9 and figure 4.10 shows the lithological map, the stratigraphic column and the geological map of the study area respectively.

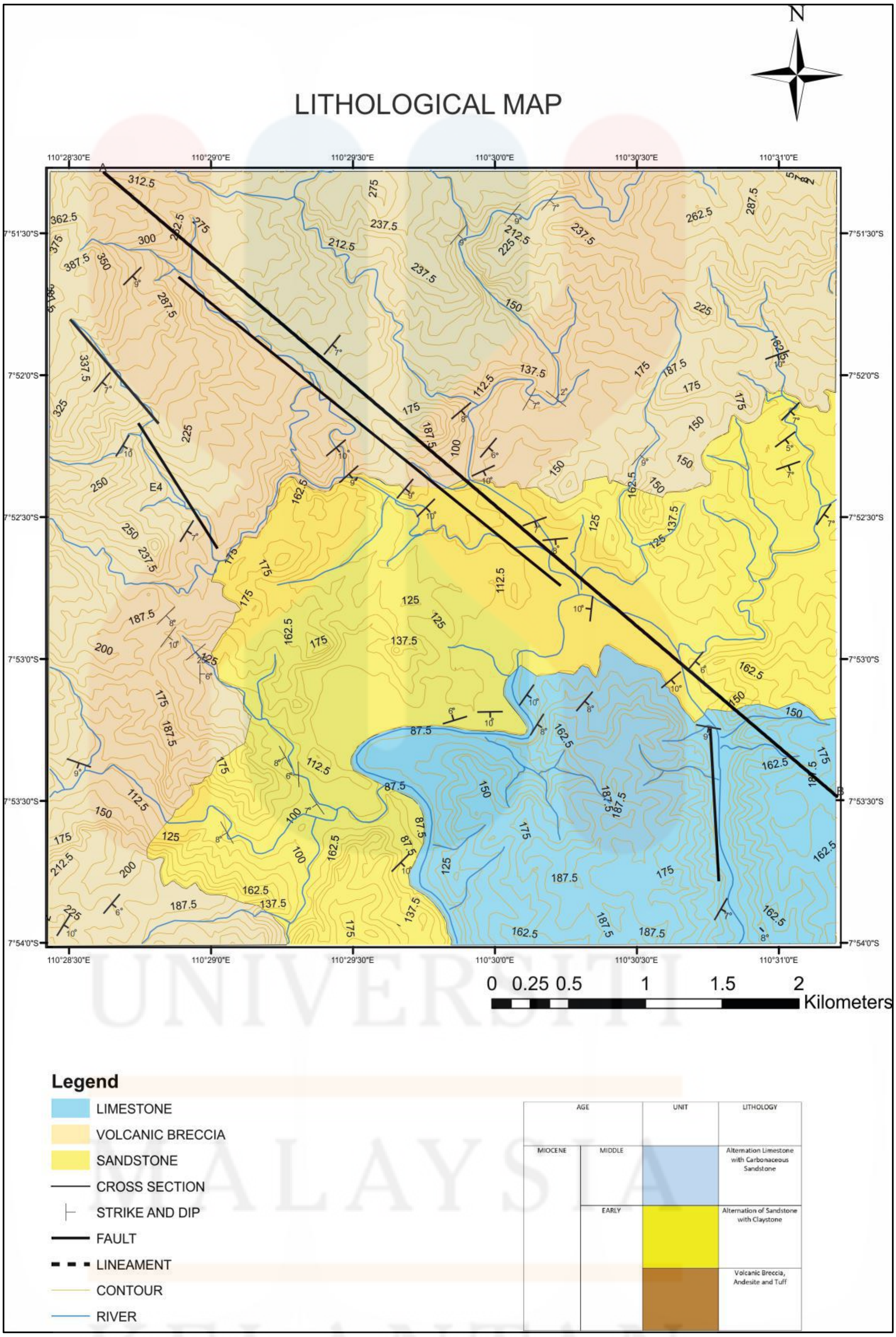


Figure 4.8 : Lithological map of the study area

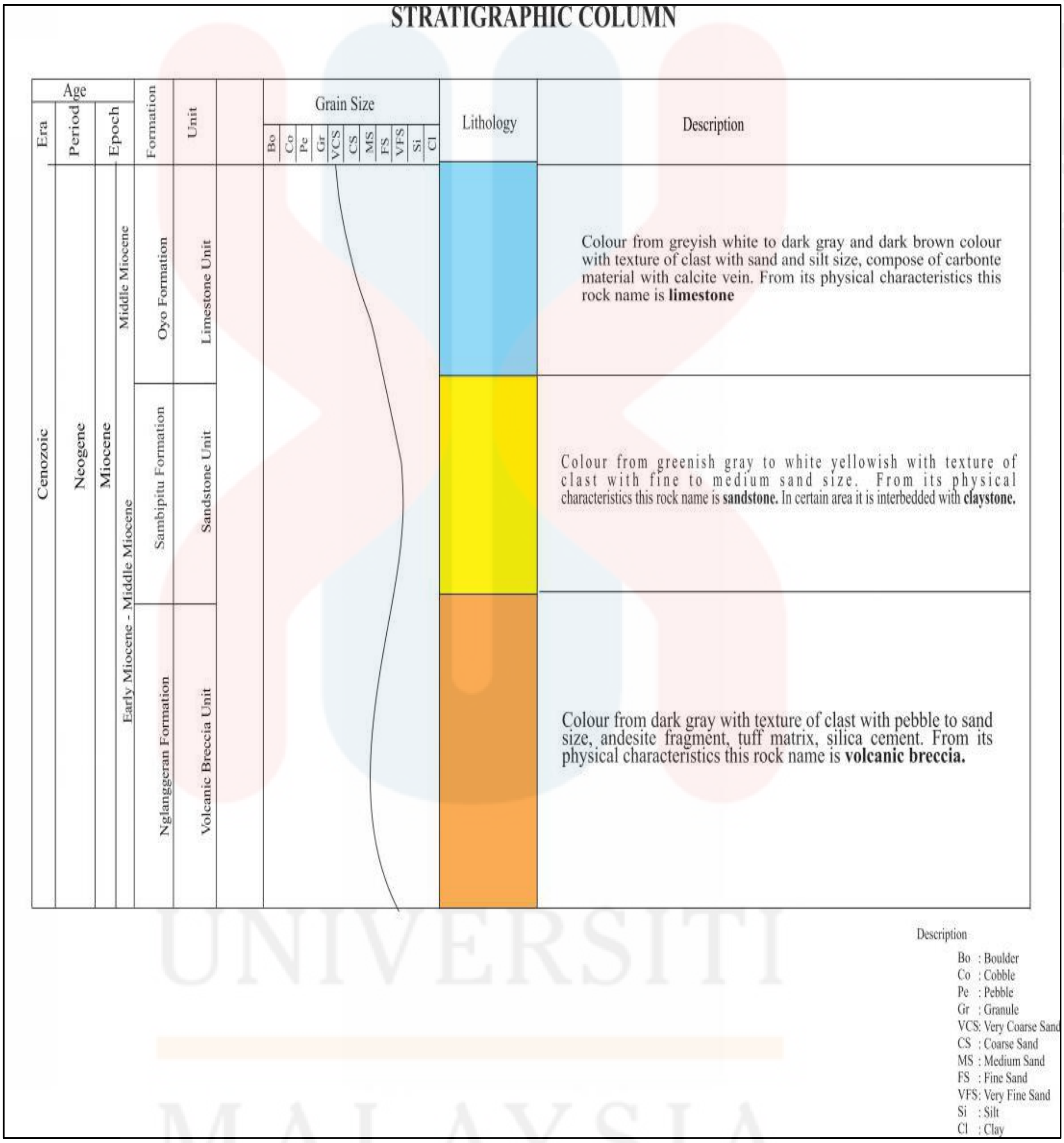


Figure 4.9 : Stratigraphic column of the study area

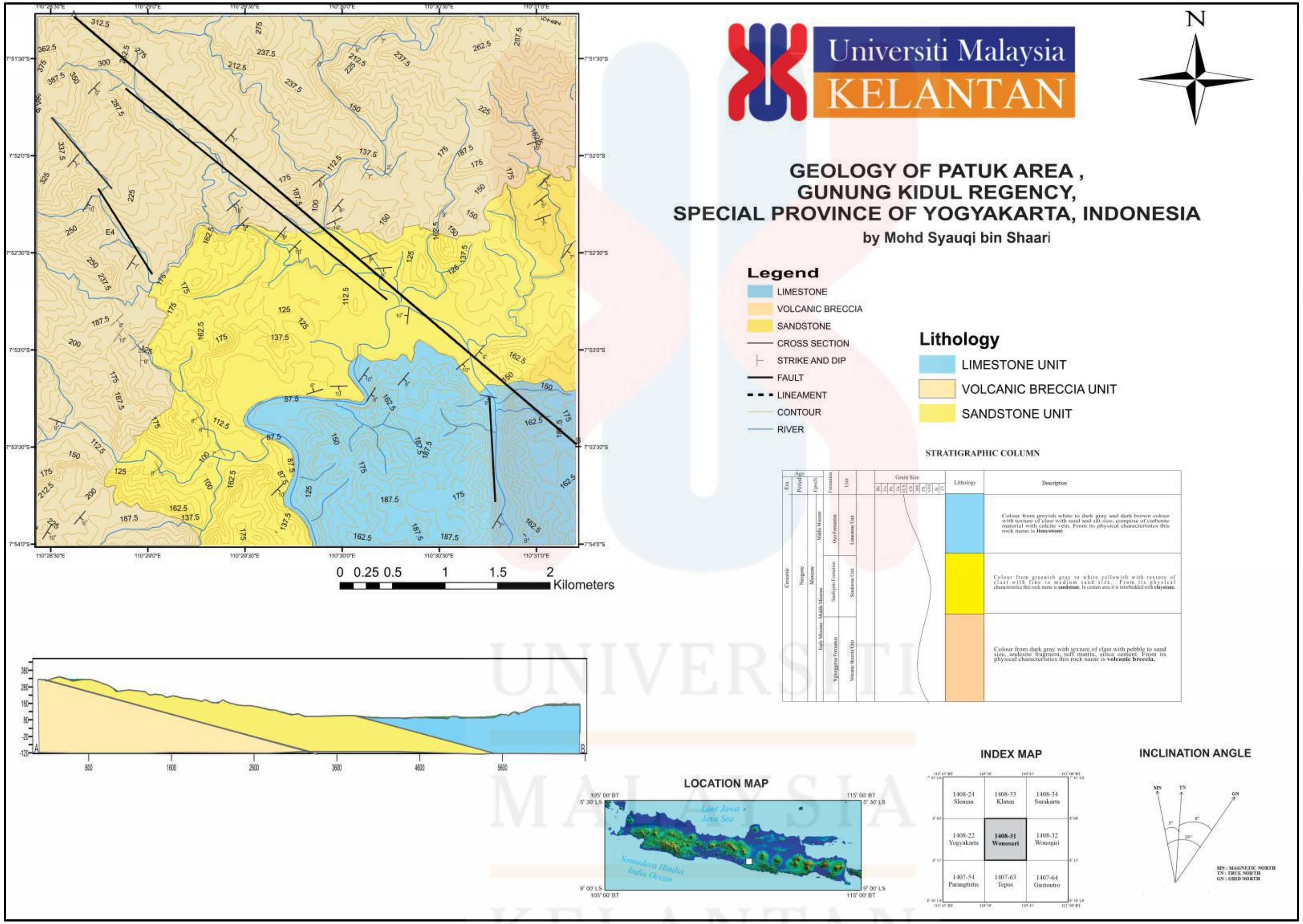


Figure 4.10 : Geological map of the study area

4.3.1.1 Andesite

Andesite rock is an extrusive rock that have an intermediate composition between rhyolite and basalt. It is identified as an andesite rock from the hand specimen that had been taken from the study area as mapping was done. The location of the outcrop was marked at the coordinates of 110° 29′ 15.16′′E 7° 51′ 56.254′′S that is at the station 1.

For the hand specimen, the colour of the rock is dark gray colour with grain size is from fine size to medium size grain. The texture of the rock is smooth texture and there is no fossil found when the thin section is observed under the microscope. Andesite did not react when it is test with the hydrochloric acid (HCl). Figure 4.11 shows the hand sample of andesite rock taken in the study area.

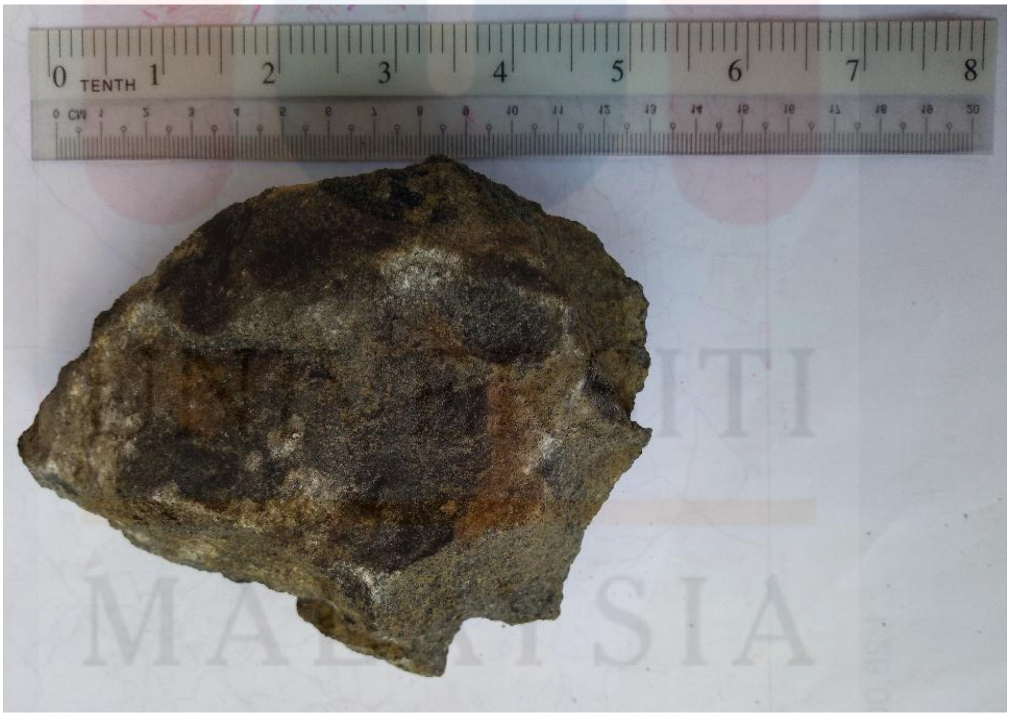


Figure 4.11 : Hand sample of andesite (Coodinates : 110° 29′ 15.16′′E 7° 51′ 56.254′′S)

4.3.1.2 Volcanic Breccia

Volcanic breccia are grouped into three group based on the process of fragmentation that is autoclastic, pyroclastic and also epiclastic. Autoclastic volcanic breccia form from internal frictional processes acting during movement of semisolid or solid lava. It includes the flow breccia and intrusion breccia while pyroclastic breccia is produced by volcanic explosion and includes vulcanian breccia, pyroclastic flow breccia, and hydrovolcanic breccia.

Epiclastic volcanic breccias results from the loose volcanic material transportation that is from epigene geomorphic agents or by gravity. It includes laharic breccia, water-laid volcanic breccia, and volcanic talus breccia. The outcrop is located in the station 3 with the coordinates of 110° 28´59.715´´E 7° 52´ 30.672´´S. The outcrop was found in the river with a very large dimension.

Based on the hand specimen, it can be observed that the colour is light grey in colour. The grain size is fine to medium grain size and the texture of the rock is rough. There is no fossil found when the thin section is observed under the microscope. Volcanic breccia did not react when it is test with the hydrochloric acid (HCl). There are also can be found the interbedded layer between volcanic breccia and sandstone in the study area. Figure 4.12 shows hand sample of volcanic breccia while figure 4.13 shows the outcrop of volcanic breccia that is interbedded with sandstone in the study area.

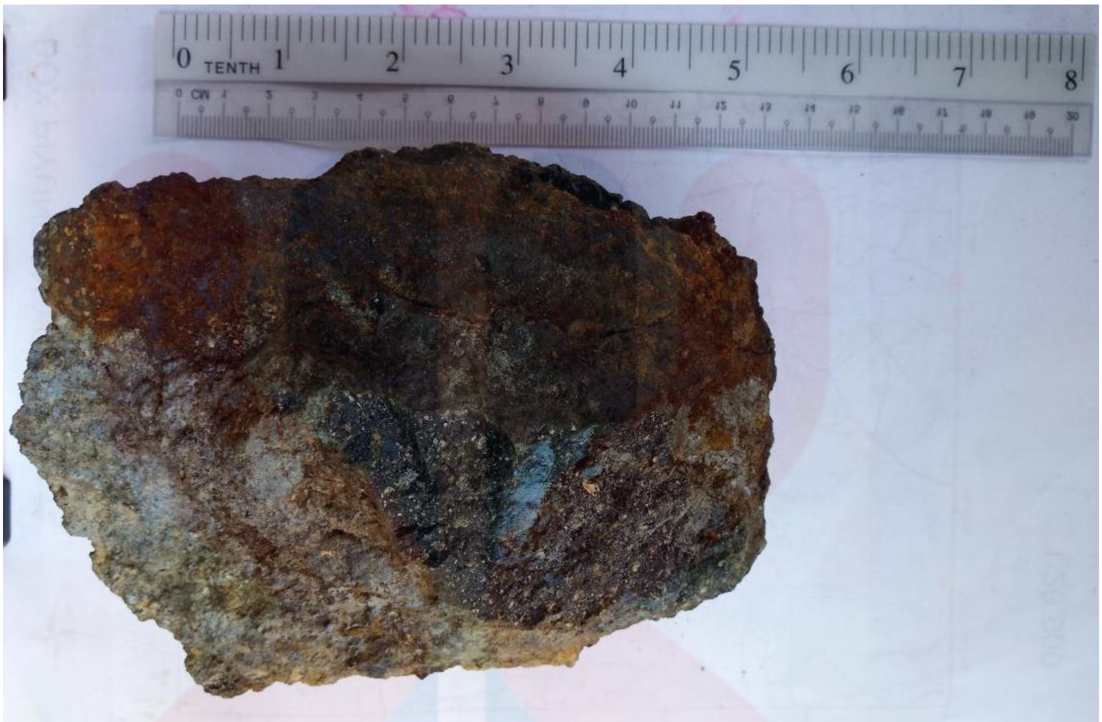


Figure 4.12 : Hand sample of volcanic breccia (Coordinates : 110° 28´ 59.715´´E 7° 52´ 30.672´´S)

Figure 4.13 : Outcrop of volcanic breccia interbedded with sandstone

4.3.1.3 Sandstone

Sandstone is a type of sedimentary rock that composed of the sand-size grain of mineral, rock, or organic material. It contains the cementing material that functions as the binding of the sand grain together and it may contains a matrix of silt- or clay-size particles that occupy the spaces between the sand grains. It is one of the most common sedimentary rocks and its always can be found in the sedimentary basins throughout the world.

The sandstone outcrop was found at station 6 with the coordinates of 110° 30´30.888´´E at the longitude and 7° 52´ 42.939´´S at the latitude. The outcrop was found near the Oyo river that have a dimension of 4 meters in height and about 20 meters in lengths. Based on the hand specimen, the colour of the sandstone is greyish in colour while the grain size is the sand size that is from fine to medium grain size. There is no fossil found whether thin section is observed under the microscope. Sandstone did not react when it is test with the hydrochloric acid (HCl). Figure 4.14 shows the hand sample of sandstone taken in the field and figure 4.15 shows the outcrop of the sandstone in the study area.

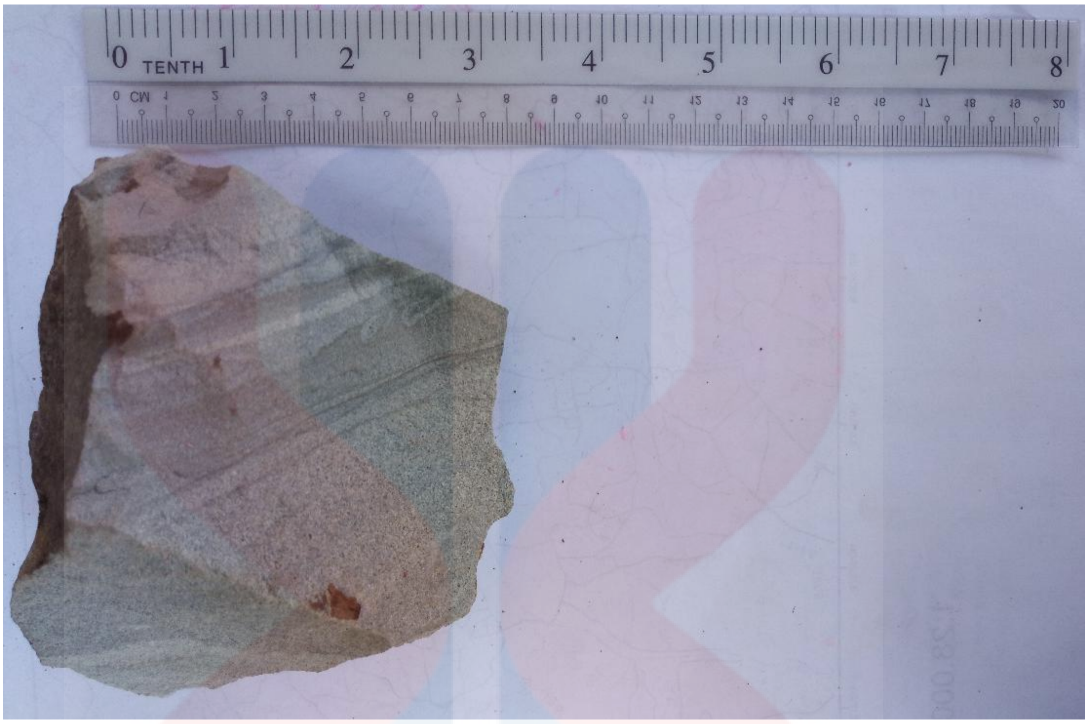


Figure 4.14 : Hand sample of sandstone (Coordinates: 110° 30′30.888′′E ,7°52′42.939′′S)

Figure 4.15 : Outcrop of sandstone in the study area

4.3.1.4 Tuff

Tuff is relatively a soft and porous rock that is usually formed by the compaction and cementation process from the volcanic ash and dust. It was formed by the chemical deposition of calcite, or calcium carbonate, or silica from water as sinter. Tuffs may be grouped as vitric, crystal, or lithic when they are composed principally of glass, crystal chips, or the debris of preexisting rocks, respectively.

The location of the outcrop is at the station 5 with the coordinates of 110° 28′ 57.335′′E at the longitude and 7° 52′ 58.683′′ S at the latitude. The outcrop was found in the forest of teak tree plantation that have a dimension of 1 meter in height and around 5 meters in length. The colour based on the hand specimen that had been taken at the study area was white in colour and there is no fossil found when the thin section is observed under the microscope. Figure 4.16 shows the hand sample of tuff taken from the study area.

Figure 4.16 : Hand sample of tuff (Coordinate: 110° 28′ 57.335′′E,7° 52′ 58.683′′ S)

4.3.1.5 Claystone

Claystone is one of the sedimentary rock type that is composed primarily of the clay-sized particles. It is not laminated and it is easily split into thin layers, such rocks that show cleavage roughly parallel to the bedding plane often are classed as clay shales. The claystones that are massive and blocky are called mudstones.

The location of the outcrop was found at station 4 with the coordinates of 110° 30´46.083´´ E on the longitude and 7° 53´ 13.879´´ S on the latitude. The outcrop was found interbedded between sandstone and also claystone and the diameter of the outcrop was 3 meters in height and also around 10 meters in the length. The colour was brownish to reddish in colour and the grain size is fine grain. It has a smooth texture and there is no fossil found when the thin section is observed under the microscope. Figure 4.17 shows the hand sample of claystone taken in the field in the mapping process while figure 4.18 shows the outcrop sandstone in the study area.

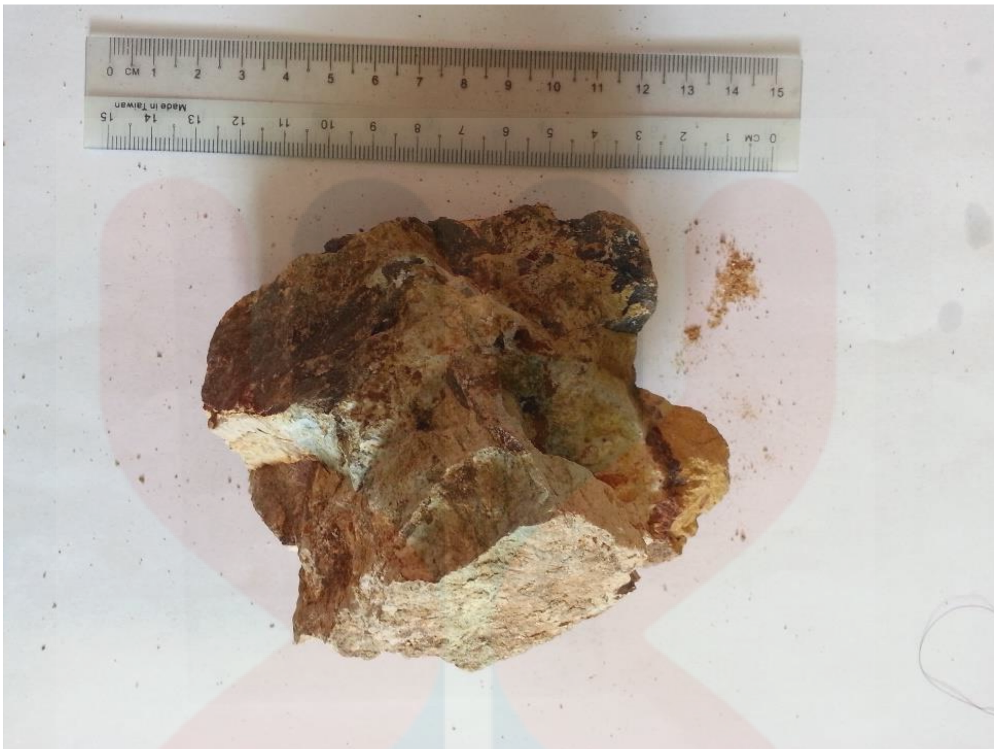


Figure 4.17 : Hand sample of claystone (Coordinate : 110° 30′46.083′′ E, 7° 53′ 13.879′′ S)

Figure 4.18 : Outcrop of claystone in the study area

4.3.1.6 Breccia

Breccia is a term used for or clastic sedimentary rocks that are composed of large angular fragments that is more than two millimeters in diameter. The spaces between thee large angular fragments filled with a matrix of smaller particles and also with mineral cement that functions to binds the rock together. It is forms when the the broken , angular fragments of most rock and minerals accumulate and it is usually form at the base of an outcrop where mechanical weathering debris accumulates.

The outcrop was found at station station 3 with the coordinates of 110° 28′59.715′′E at the longitude and 7° 52′ 30.672′′S at the latitude. It was found in the river where it is interbedded layer of breccia and also with sandstone. The diameter of the outcrop is 3 meters height and around 10 meters length. Based on the hand specimen, it can be observed that the colour is dark colour with angular fragment and rough texture. The grain size is medium to coarse grain and there are no present of fossil found when it observed under the microscope. Figure 4.19 shows the hand sample of breccia that was taken in the study area while figure 4.20 shows the outcrop of breccia that are interbedded with sandstone.

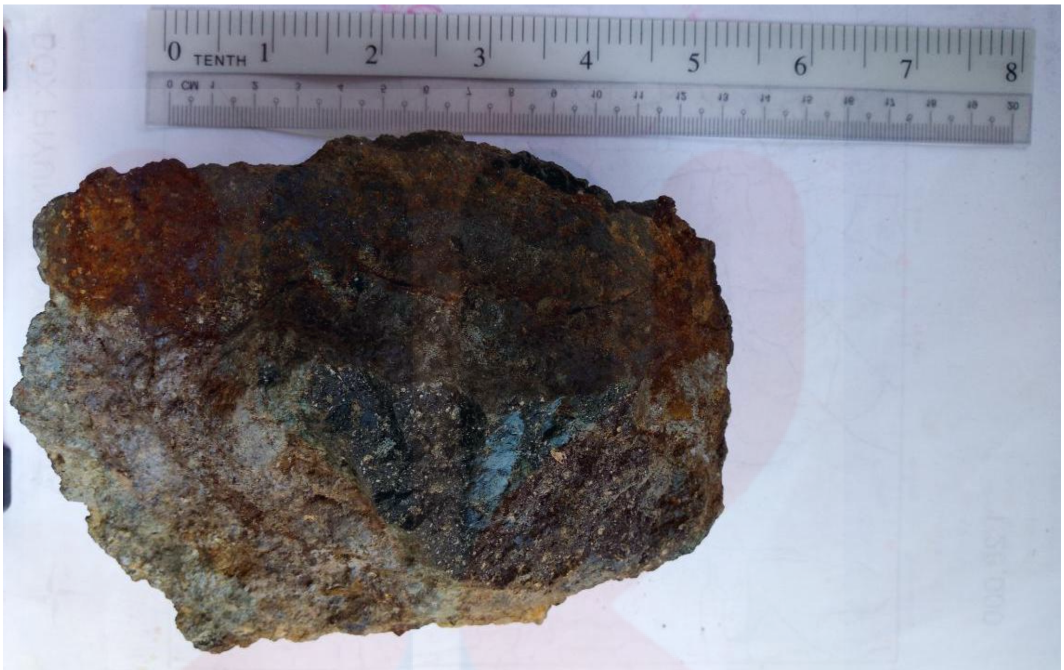


Figure 4.19: Hand sample of Breccia (Coordinates : 110° 28´59.715´´,7° 52´ 30.672´´S)

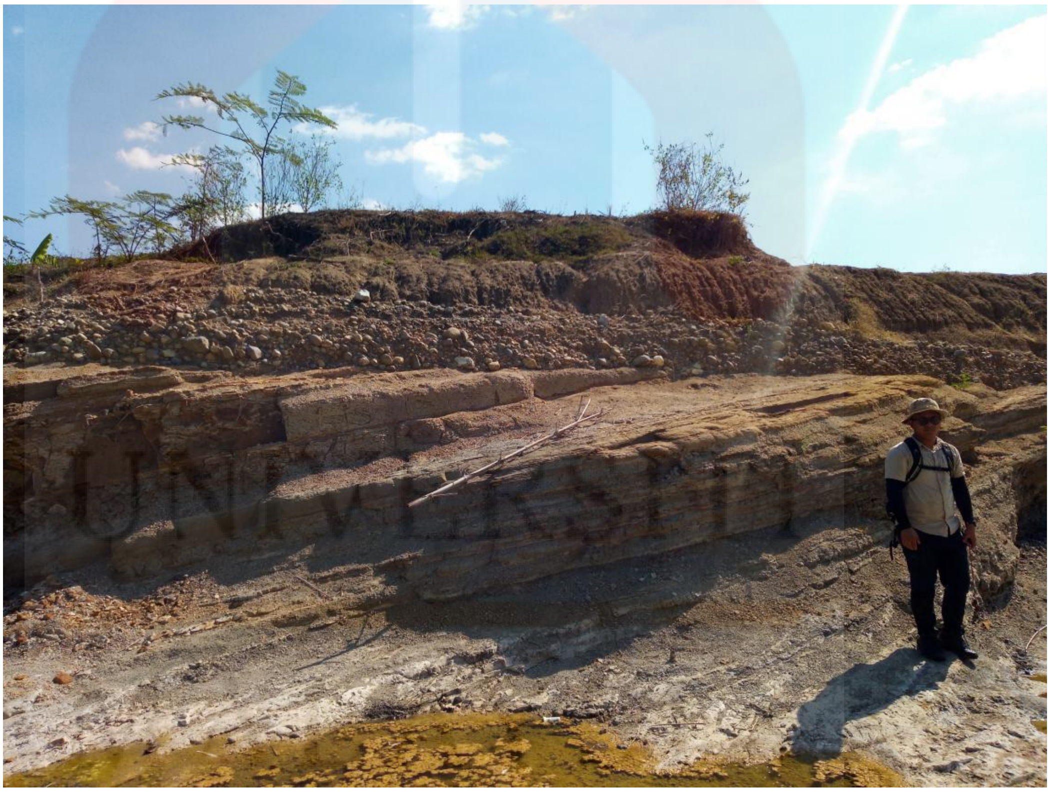


Figure 4.20 : Outcrop of breccia interbedded with sandstone

4.3.1.7 Limestone

Limestone is one of the sedimentary rock composed mainly of calcium carbonate ($CaCO_3$) that is in the form of the calcite mineral. It is commonly forms in the clear, warm, shallow marine waters. It is usually an organic sedimentary rock that forms from the accumulation of shell, coral, algal, and fecal debris. It is also can be a chemical sedimentary rock that formed by the process of precipitation of the calcium carbonate itself from lake or the ocean.

The location of the outcrop is at station at station 8 with the coordinates of 110° 30′ 5.257′′E at the longitude and 7° 53′ 16.442′′S at the latitude. It is found all the way along the Oyo river and the formation is in the Oyo Formation. The diameter of the outcrop is 2 meters in height and also 20 meters in the length. Based on the hand specimen that had been taken in the study area, the colour of the limestone is white in colour and the texture is smooth texture. The grain size is very fine to fine grain and there are no present of fossil found when it observed under the microscope. Limestone react when it is test with the hydrochloric acid (HCl) and produce bubble. Figure 4.21 shows the outcrop of sandstone in the study area.

Figure 4.21 : Outcrop of limestone in the study area (Coordinates : 110° 30´ 5.257´´E, 7° 53´ 16.442´´S)

4.3.2 Petrography analysis

Petrography is the study of mineralogy that focuses on detailed description of rocks. The science of petrography is largely based on the study of the appearance of thin, transparent sections of rocks in a microscope fitted with polarizers. Petrography analysis is describing the rock minerals by using microscopic features that used polarizing or petrographic microscope that have plain and crossed polarized lighting condition.

4.3.2.1 Andesite

Based on the observation of the thin section under the microscope, andesite is rich with plagioclase mineral and it is also contain biotite and also amphibole. The characteristics of the plagioclase mineral is it is white in colour and it has a perfect cleavage and a one good cleavage that nearly met at 90° angle. The birefringence of plagioclase is 0.012-0.013 and it has an incline extinction. The colour of biotite is brown in colour in the thin section and it has single perfect cleavage to produce thin flexible sheets or flakes.

The relief is moderate and the birefringence is 0.028 - 0.08. the extinction of biotite is straight. Amphibole can be observed as a dark brown in colour in the thin section and it has a perfect cleavage. The relief is moderate while the the birefringence is 0.2. Amphibole has an inclined extinction. Table 4.2 shows the composition of mineral with the percentage of each mineral. Figure 4.22 and 4.23 shows the thin section of andesite under cross polarised (XPL) and also plane polarised (PPL).

Table 4.2 : Mineral composition of andesite

Composition of mineral	Percentage of mineral (%)
Plagioclase	50
Amphibole	35
Biotite	15

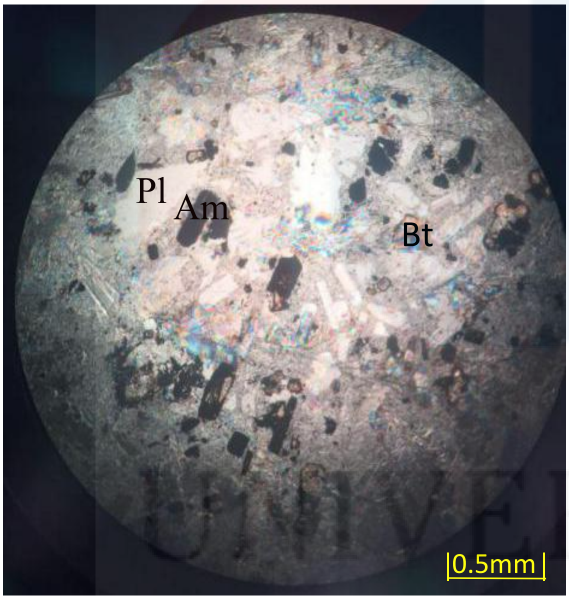


Figure 4.22 : Andesite under XPL

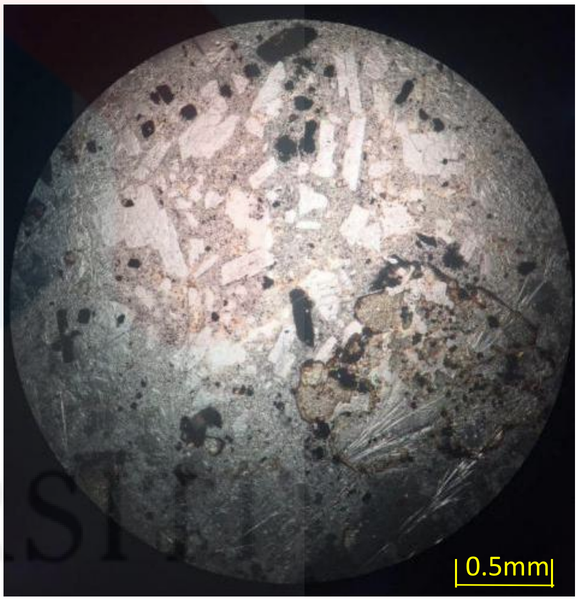


Figure 4.23 : Andesite under XPL

4.3.2.2 Volcanic Breccia

In the thin section under the microscope, it can be observed that it is composed of quartz mineral, biotite, olivine and also the opaque mineral. For the quartz mineral, the colour that can be observed from the thin section that it is clear in colour and it has no cleavage. It has a relatively low birefringence that is 0.009 and also low relief. Next is olivine. Olivine has a greenish clour under the microscope and it is moderate in the relief. The birefringence of olivine is around 0.035 to 0.051. The extinction of olivine is straight while the refractive index of olivine is 1.635 to 1.875. There are also opaque mineral that can be observed in the that maybe can magnetite or graphite mineral. Table 4.3 shows the composition of volcanic breccia mineral while figure 4.24 and 4.25 shows the thin section of volcanic breccia under microscopic condition in XPL and also PPL.

Table 4.3 : Mineral composition of volcanic breccia

Composition of mineral	Percentage of mineral (%)
Quartz	35
Biotite	25
Olivine	15
Opaque	25

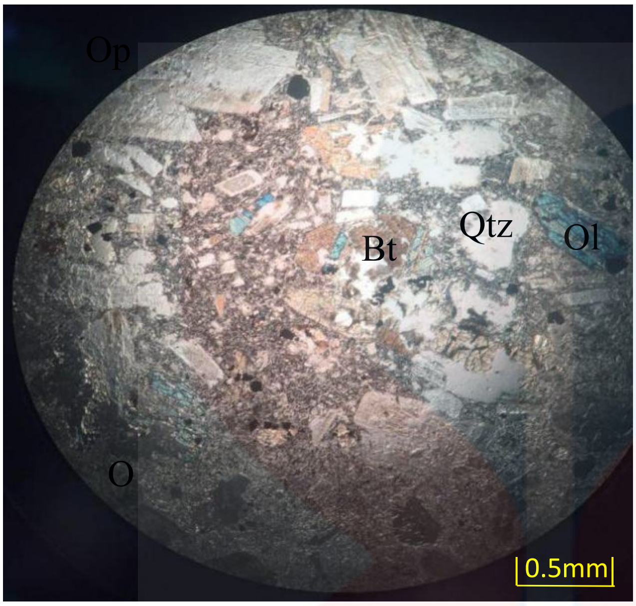


Figure 4.24: volcanic breccia under XPL

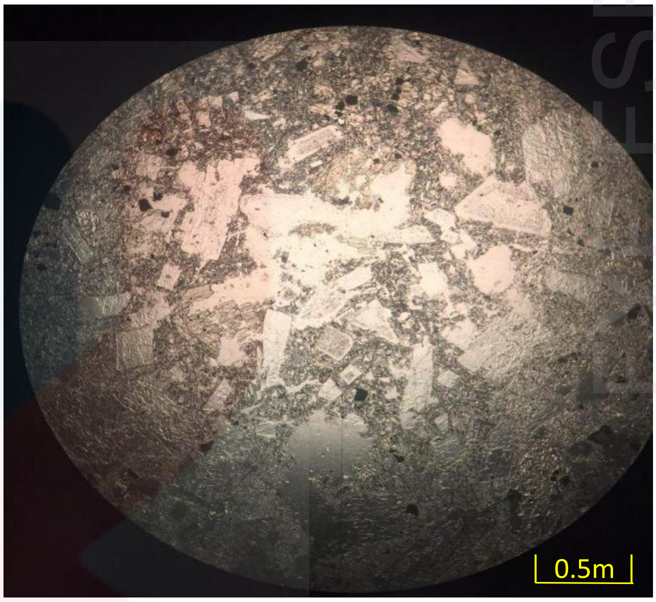


Figure 4.25: volcanic breccia under PPL

4.3.2.3 Sandstone

Based on the observation of the thin section sample, it can be observed that the mineral of sandstone consists of quartz, biotite, plagioclase, horneblende and also opaque mineral. It is dominant with the quartz mineral where it can be seen having the clear in colour. The birefringence of quartz is 0.009 and it is lack in the cleavage and also twinning. The next mineral is plagioclase mineral that is grey in colour in the thin section and it has a poor cleavage in this thin section. The birefringences of plagioclase is about 0.007 to 0.013.

Next is the horneblende mineral. It can be observed in the brownish colour and if has a moderate in relief. The refractive index of horneblende is 1.61 to 1.76 and the birefringence is 0.02. It has an inclined extinction while the interferences colour is second to third order. There are also opaque mineral in that can be observed in the thin section as shown in the figure 4.26 and also figure 4.27. Table 4.4 shows the mineral composition of sandstone with the percentage of the mineral.

Table 4.4 : Mineral composition of sandstone

Composition of mineral	Percentage of mineral (%)
Quartz	35
Biotite	25
Plagioclase	15
Horneblende	10
Opaque	15

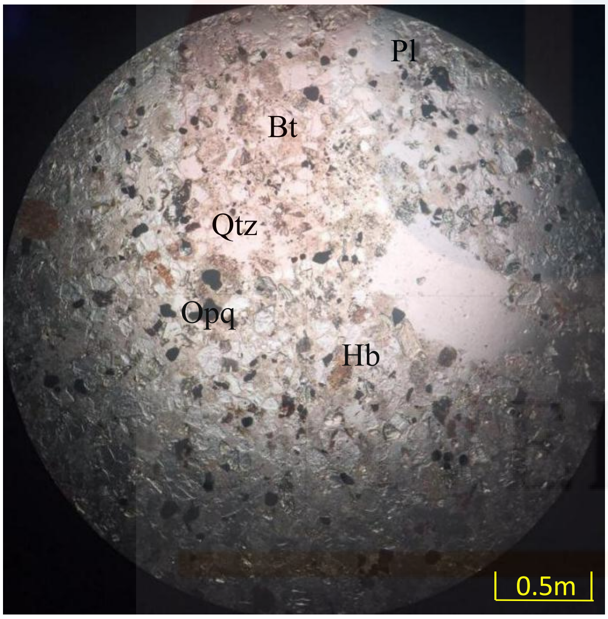


Figure 4.26 : Sandstone under XPL

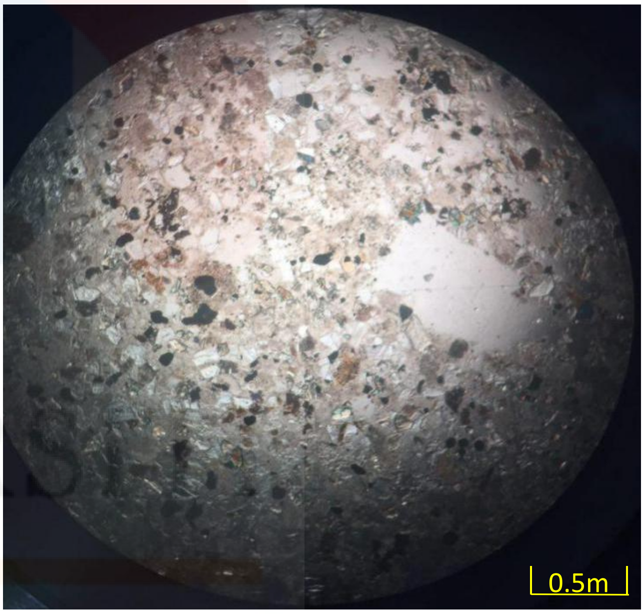


Figure 4.27 : Sandstone under PPL

4.3.2.4 Tuff

Based on the observation of the sample from the thin section, it can be observed that it is composed of plagioclase, biotite and also opaque mineral. The biotite mineral can be observed in the brownish in colour and it has a moderate relief. The refractive index is 1.53 to 1.696 while the birefringence of biotite in this thin section is 0.04. it has a straight extinction angle and the interferences colour is second to third order. Table 4.5 shows the mineral composition and the percentage of mineral of tuff while figure 4.28 and figure 4.29 shows the thin section of tuff in microscopic condition.

Table 4.5 : Mineral composition of tuff

Composition of mineral	Percentage of mineral (%)
Plagioclase	25
Biotite	40
Opaque	35

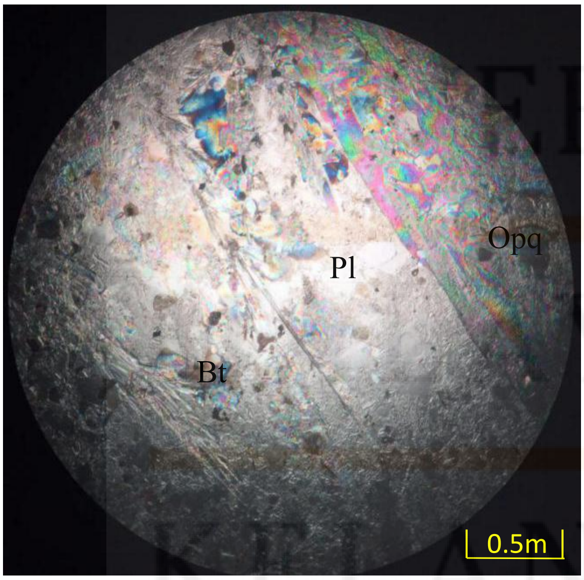


Figure 4.28 : Tuff under XPL

Figure 4.29 : Tuff under PPL

4.3.2.5 Breccia

Based on the observation of the thin section, it can be observed that the mineral composition of breccia is composed of quartz and also plagioclase mineral. The quartz mineral can be seen in clear in the colour while the plagioclase mineral is greyish in colour. The birefringence of quartz is low that is 0.004 and it also has a low relief. Plagioclase has the birefringence of 0.010 and the relief is also low. Table 4.6 shows the mineral composition off breccia while figure 4.30 and figure 4.31 shows the microscopic condition of tuff in XPL and PPL condition respectively.

Table 4.6 : Mineral composition of breccia

Composition of mineral	Percentage of mineral (%)
Quartz	70
Plagioclase	30

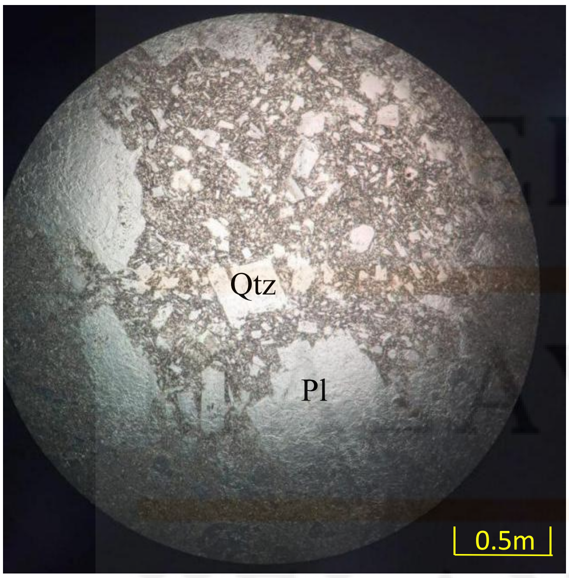


Figure 4.30 : Breccia under XPL

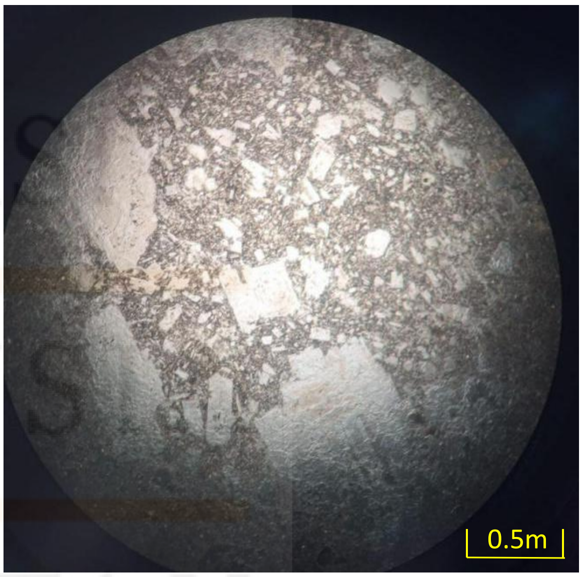


Figure 4.31 : Breccia under PPL

4.3.2.6 Limestone

Based on the observation from the thin section sample, it can be observed that the mineral composition of limestone is consists mainly of calcite. Based on the thin section in figure 4.32 and 4.33, it can be observed that the calcite mineral is white in colour. It has a poor cleavage as can be seen in the figure below.

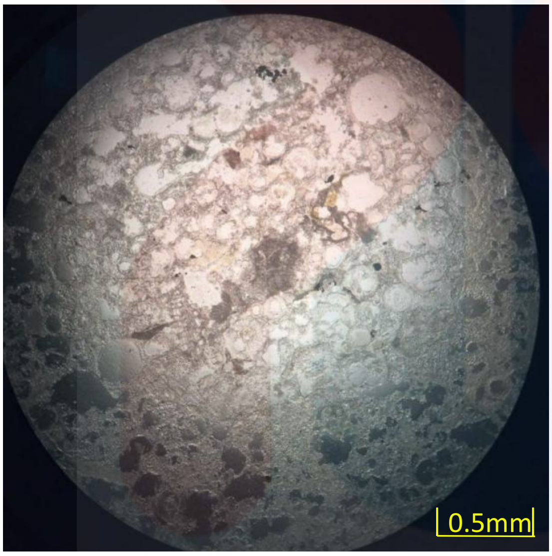


Figure 4.32 : Limestone under PPL

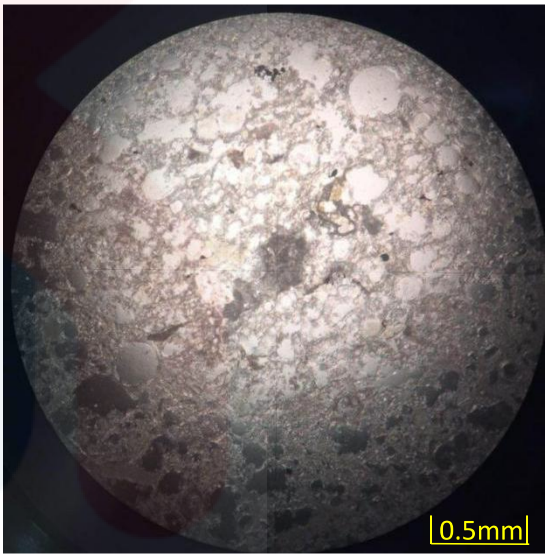


Figure 4.33 : Limestone under XPL

4.4 Structural Geology

Structural geology is the study of three dimensional distribution of rock unit with respect to their deformational histories. Structural geology is important to use as measurements of present day rock geometries to investigate the information about the strain and stress in the rocks to seek and explored about the past history of the Earth.

Structural analysis for this study area was done by geological field mapping. The geology structure consist at the study area was carefully observed for further interpretation. Based on geological field mapping, a few structure have been found near study area.

4.4.1 Lineament Analysis

Caran et al. (1981) defined lineament as a pattern in a photograph, map or model of earth's surface or subsurface of earth which is stratigraphically, structurally or geophysically defined that must be linear, continuous, well expressed and related to features of the solid earth. Fault zones, igneous intrusions, shear zones, valley, fault or fold-aligned hills, streams and coastlines contributed to lineaments.

Lineament can be observed from the aerial photograph, satellite image, terrain map and geological map. Lineament is categorized into two types which are positive lineament and negative lineament. According to Mohd Hashim and Akhir (2010), ridge and range present the positive lineament while negative lineament represent by streams, faults and valleys. The figure 4.34 below shows the lineament map of Patuk area in Yogyakarta, Indonesia.

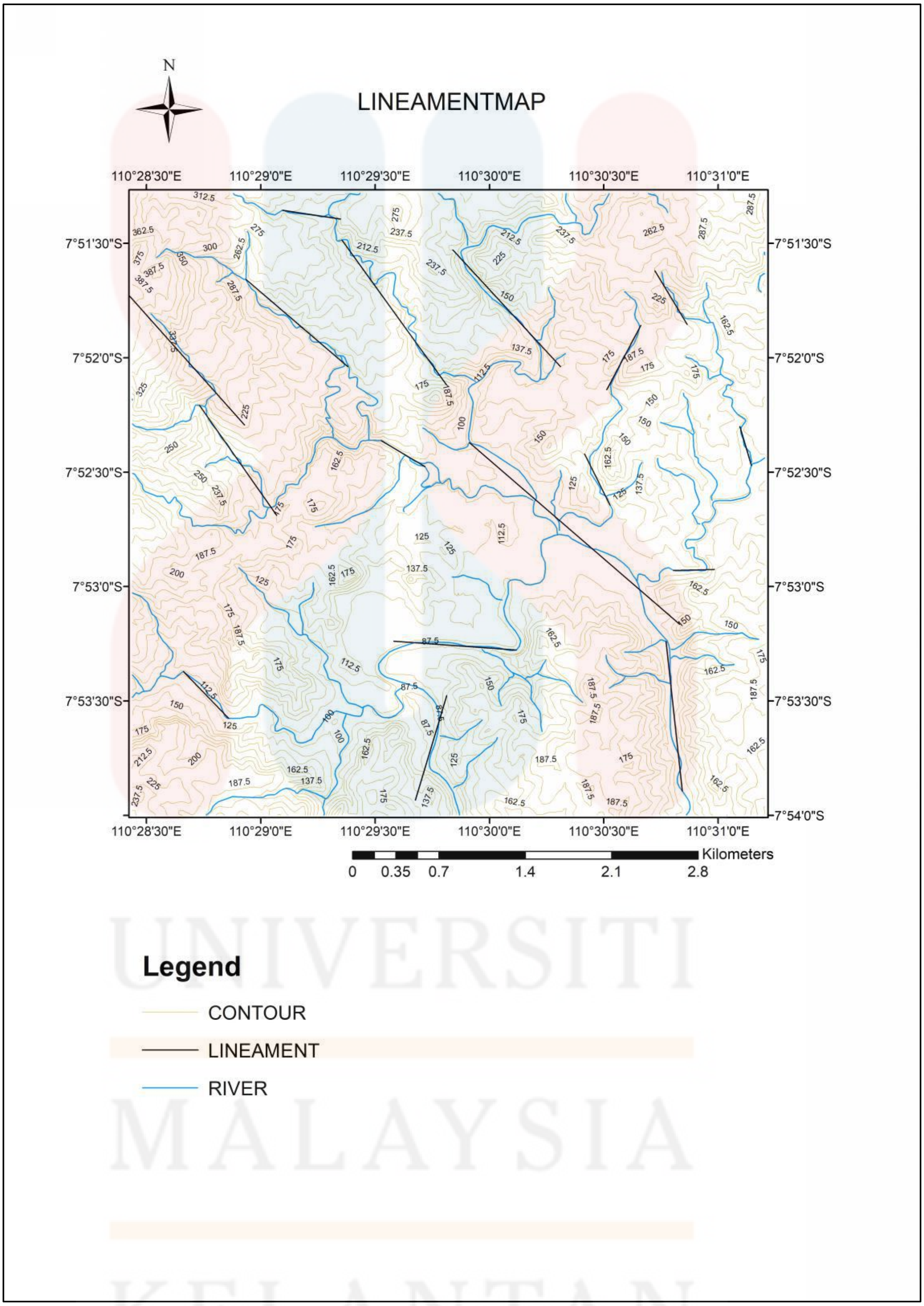


Figure 4.34 : Lineament map of the study area

4.4.2 Folding

Fold is one the geologic structure formed by the deformation. It is results when flat-lying or other undeformed surface is wrapped or deformed into an undulating geologic structure. When two tectonic plates are collide, fold is created on the Earth's crust. Normally folding occurs beneath the Earth where rocks are ductile than at the shallow depths or at the surface. The type of fold included anticline, syncline, monocline, chevron, recumbent and plunging fold.

It is commonly classified according to the attitude of their axes and the cross sections that are perpendicular to the trend of the fold. An axis of the fold is the intersection of the axial plane with one of the strata of which the fold is composed while in the simpler types of fold, the axis s horizontal or gently inclined, it may be steeply inclined or even vertical. Plunges is the angle of inclination the axis, as measured from the horizontal.

In the study area there are minor folds that can be observe present near the Oyo river. The location of the outcrop is at the station 9 with the coordinates of 110° 30′ 40.795′′E at the longitude and 7° 53′ 6.914′′S at the latitude. It is an anticline folding which have the attitude of 158° of the strike and 9° of the dip angle. The dimension of the outcrop is around 5 meters in the height and 10 meters in the length.

The outcrop of the folding structure is consist of sedimentary rock that is sandstone. The formation of the fold is maybe due to the high pressure or stress that exerted to the rock body until deformation of the rock occurs. The next location of the folding is at the coordinates of 110°28'54.187"E at the longitude and 7°52'55.501"S at the latitude with the elevation of 110m. The dimension of the outcrop is 2 meters in the height and 5 meters in the length. The strike and dip value is 178°/60°. Figure 4.35 and figure 4.36 shows the structure of folding that found in the study area.

Figure 4.35 : Folding structure in the study area (Coordinates :110° 30′ 40.795′′E, 7° 53′ 6.914′′S

Figure 4.36 : Folding structure in the study area (coordinates:110°28'54.187"E ,7°52'55.501"S)

4.4.3 Joint

Joint is a break or fracture of natural origin in the continuity occurs in a layer or body of rock that lacks any visible or measurable movement parallel to the surface plane or fracture. Joint is divided into two forms, joint set and joint system. Joint set is a group of joint that is parallel, evenly spaced joints that can be observed through mapping and analysis of orientations, spacing, and physical properties while joint system composed of two or more intersecting joint sets.

A joint analysis had been done in the study area where there are presence of the joint structure. The location of the joint structure that had been observed is at 110°30'19.395"E at the longitude and also 7°52'45.325"S at the latitude. The joint analysis was done in identifying the direction of forces acting based on fracture on rocks. A 100 readings of strike had been taken on the volcanic breccia outcrop that had been found at the study area.

Based on the rose diagram in the figure 4.37, it can be observed that the principal stresses is from the north east direction and also comes from the southwest direction. The principal stresses indicate that the most of the stress come from the direction that is also called as a major stress. The reading that have been recorded is shown at the figure below also with the rose diagram of the joint analysis. Table 4.7 shows the value of joint's readings that had been measured in the study area while figure 4.38 shows the joint set at the volcanic breccia outcrop in the study area.

Table 4.7 : 100 readings of joints

70°	70°	70°	70°	70°	70°	70°	100°	100°	100°
100°	100°	100°	60°	60°	60°	60°	60°	60°	60°
120°	120°	120°	120°	120°	120°	120°	220°	220°	220°
220°	220°	220°	220°	100°	100°	50°	50°	50°	150°
150°	150°	150°	150°	117°	117°	117°	117°	125°	125°
125°	125°	125°	125°	119°	119°	119°	119°	119°	119°
70°	70°	70°	70°	70°	70°	70°	60°	60°	60°
60°	60°	250°	250°	250°	250°	250°	250°	245°	245°
245°	245°	245°	245°	227°	227°	227°	227°	280°	280°
280°	280°	280°	280°	253°	253°	253°	253°	253°	253°

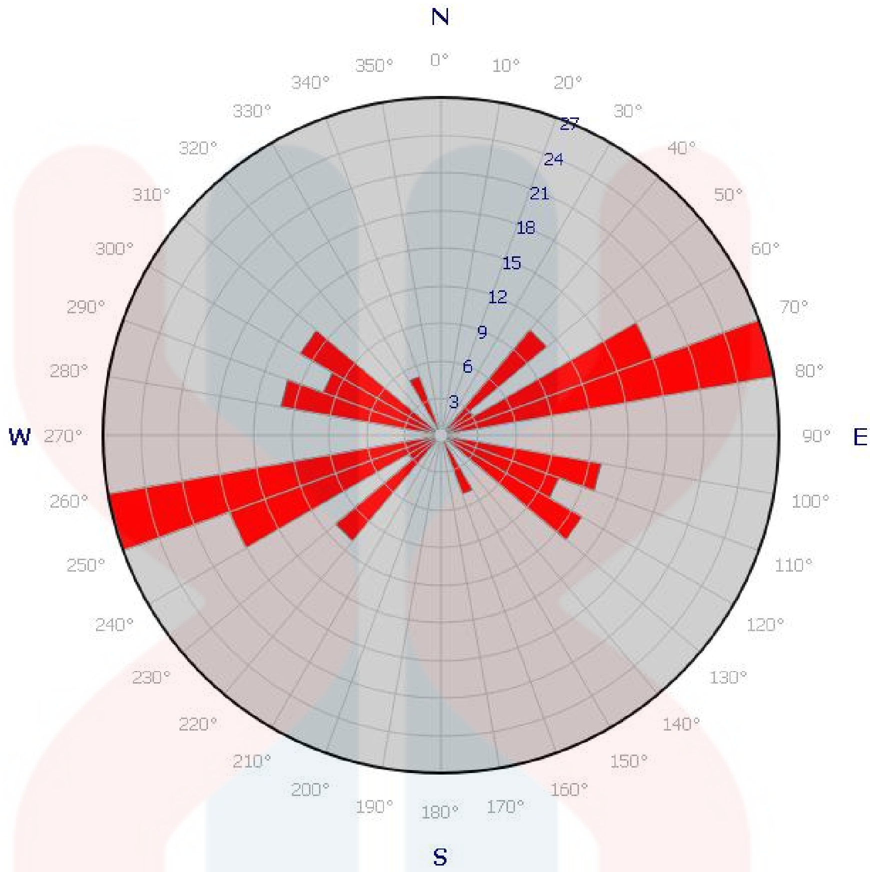


Figure 4.37 : Rose diagram of the joint analysis

Figure 4.38 : Joint sets in the study area (coordinates :110°30'19.395"E, 7°52'45.325"S)

4.4.4 Faulting

Fault is defined as the fracture zone between the rocks. Fault allowed the blocks to move in relative to each other. The occurrences of fault may occur rapidly or it may occurs in the form of earthquake. It can be classified into several types included dip-slip fault, strike-slip fault, oblique-slip fault, normal fault, reverse fault, and thrust fault. Fault can be formed at all types of rocks due to the deformation. The type of fault that can be found in the study area is normal fault and also the strike slip fault. The strike and dip of the fault is taken.

Normal fault occurred when there is a tension applied and pull apart the rock. The hanging wall moved downward relative to the footwall. The normal fault can be found at station 10 where the coordinate is 110° 29′ 16.327′′E at the longitude and 7° 51′ 22.587′′S at the latitude with the elevation of 254m. The figure 4.39 below shows the normal fault that had been found in the study area with the label of the direction. The strike and dip for the normal fault is 78°/5.

Next is the strike-slip fault. Strike-slip fault is the vertical fractures where most of the blocks have moved horizontally. There are two types of strike-slip fault that is called sinistral and dextral. Sinistral strike-slip fault is when the far sides of the blocks move to the left while dextral strike-slip fault is when the far sides of the blocks moves to the right. In the study area, the type of the strike-slip fault is the sinistral stike-slip fault as the as the far sides of the blocks move to the left.

The coordinates of the sinistral strike-slip fault is 110°30'5.193"E at the longitude and 7°53'11.014"S at the latitude. It is found on the sandstone outcrop in the river with the strike and dip of 179°/10° with the elevation of 102m. Figure 4.40 shows the sinistral strike-slip fault that had been found in the study area. There are also dextral strike-slip fault that can be found within the study area. The location of the fault is 110°30'13.651"E at the longitude and 7°51'59.982"S at the latitude with the elevation of 132m. The structure is found on the volcanic breccia outcrop with the strike and dip value of 280°/80°. Figure 4.41 shows the dextral strike-slip fault that can be found in the study area.

Figure 4.39 : Normal fault structure in the study area (Coordinates : 110° 29′ 16.327′′E, 7° 51′ 22.587′′S)

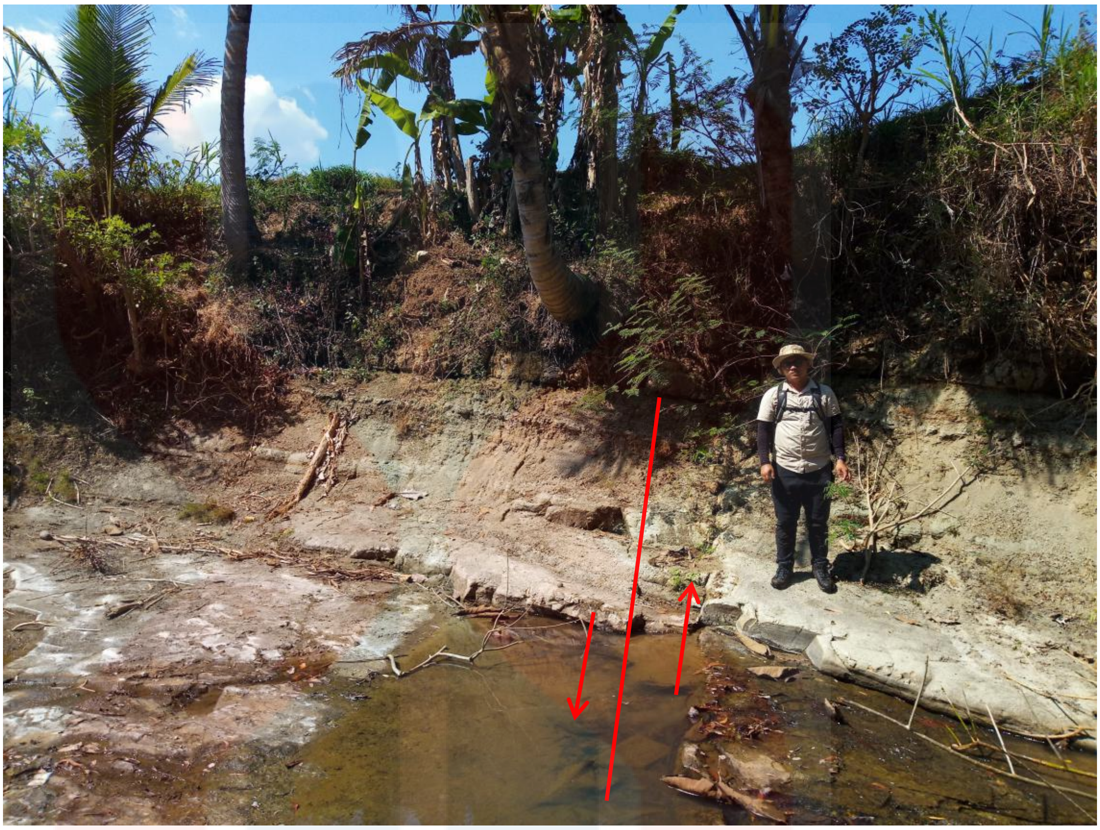


Figure 4.40 : Sinistral strike-slip fault (Coordinates : 110°30'5.193"E, 7°53'11.014"S)

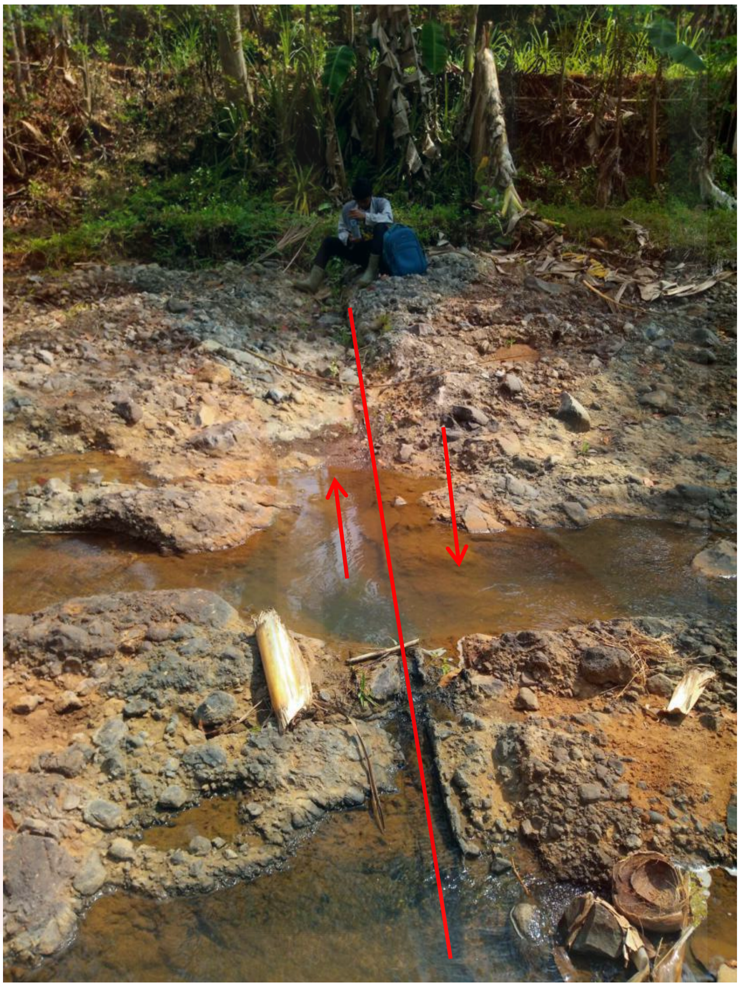


Figure 4.41 : Dextral strike-slip fault (Coordinates : 110°30'13.651"E, 7°51'59.982"S)

4.4.5 Convolute bedding

Convolute bedding structures forms when complex folding and crumpling or the beds lamination occurs. Usually, this type of lamination occurs in the fine or silty sands and usually it is confined to only one rock layer. The convolute laminations can be found in flood plain, delta, point bar and also intertidal-flat deposits. The size is generally in the range from 3cm to 25cm but there are also larger formations that have been recorded that is up to several meters length. Figure 4.42 shows the structure of convolute bedding in the study area.

In the study area, there are convolute bedding structures that can be observed that located at the coordinates of 110°29'54.811"E at the longitude and 7°53'11.754"S at the latitude with the elevation of 111m. This convolute bedding structures was found on the sedimentary rock that is sandstone. It can be observed that there are also laminations that are around 2cm in size. This structures may indicate that the location once a channel from a delta or a flood plain.

Figure 4.42 : Structure of Convolute bedding (Coordinate : 110°29'54.811"E, 7°53'11.754"S)

4.5 Historical Geology

Historical geology included the origin and formation of the geological features and Earth. In the study area, there are three lithological unit that is the volcanic breccia unit, sandstone unit and also the limestone unit. Volcanic breccia unit is under the Nglanggeran Formation while sandstone unit is under the Sambipitu Formation and Limestone unit is under the Oyo Formation. The name of the formation was originally from the most distinct features for example the Nglanggeran Formation was originated from the ancient volcanic of Nglanggeran while Oyo Formation was from the Oyo river.

Under Sambipitu Formation, the type of lithologies consists of fine grained volcanic siltstone, volcanic claystone and also sandstones. The rock unit contains calcareous materials in the upper part and this formation is about 230m thick. The lithology found in Sambipitu Formation in the study area is sandstone, claystone and also tuff and it is categorised as the sandstone unit because the dominant lithology that was found is sandstone. It is the second oldest unit and the age is in the early miocene.

In Nglanggeran Formation, the lithologies is composed of volcanic breccias, tuffs or volcanic sandstone, agglomerates and lava flows of andesitic to basaltic andesite in composition. The total thickness of the formation is about 530m. In the geological time scale, the formation is placed at the age of Early to the Middle Miocene. In the study area, the lithology found is volcanic breccia and andesite and also tuffs. It is then categorised as the volcanic breccia unit because of the dominance in the volcanic breccia in the study area. It is the oldest in the age between Oyo and Sambipitu Formation.

Next is the Oyo Formation. In the Oyo Formation, the lithologies comprises of tuffaceous marl, andesitic tuff and also conglomeratic limestone. In the study area, limestone and carbonaceous sandstone had been found and it is named as limestone unit because of the dominance in the presence of limestone in the location. Based on the age, it is the youngest in the age that is in the middle of Miocene period in the geological time scale.

The subduction and significant volcanism ceased beneath Java from about 90 Ma to 45 Ma (Hall et al, 2009,2011). in the middle Eocene, the subduction resumed when Australia began to move northwards (Hall, 2009). In the same period, at the east java, the oldest Eonozoic sediments were reported (Lelono,2000) and the rocks units deposited unconformably on the basement rocks. The early Cenozoic sandstones above the oldest sediments increases in volcanic materials recording of the southern Mountain Arc (Smyth,2005). Across the east Java and the east Java Sea, there is an intra- Oligocene that caused by the sea level changes (Matthews, 1995)

CHAPTER 5

LANDSLIDE SUSCEPTIBILITY ANALYSIS

5.1 Introduction

In this chapter, the research specification that is the landslide susceptibility analysis of the study area that is in the Patuk area will be discussed and determined. In determining the landslide, there are five landslide causative factors such as the density of lineament, density of drainage, type of lithologies, type of soil and also slope were extracted and later analysed. Then by using the average weight-age score method, the landslide susceptibility of the area later was determined. Table 5.1 shows the weightage of the parameters that have been selected in determining the landslide susceptibility.

Table 5.1: Weightage of landslide causative- factors

No.	Parameters	Weightage (Wi)
1	Slope	10
2	Lineament Density	9
3	Lithology	7
4	Drainage Density	5
5	Soil type	4

5.2 Results and Discussion

5.2.1 Slope

Slope is one of the most important parameters in determining the landslide susceptibility in the study area. It is because the stability form the basis for the frequency and and also the intensity of the hazard study**.** Generally, this study area located on a mountainous area that is in the Gunung Kidul regency and the undulating landform of this study area highly affected on the degree of slope.

The majority of the degree of slope in this area are steep and it is divided into three groups that is low degree slope (<5°), high degree slope that consists of 6° to 75° of slope and also very high degree of slope that is slope degree of higher than 75° of slope. The weightage score for the slope is divided to three that is from one to three score that is 3 for the factor that has the greater influence and 1 for the smaller influence of landslide occurrences. Table 5.2 shows the analysis of the slope parameters with the weightage and score while Figure 5.1 shows the slope map of the study area.

Table 5.2 : Weightage and Score (Slope)

No.	Slope (°)	Weightage (Wi)	Score (Sij)	(Wi x Sij)
1	<5	10	10	100
2	<75	10	8	80
3	>75	10	4	40

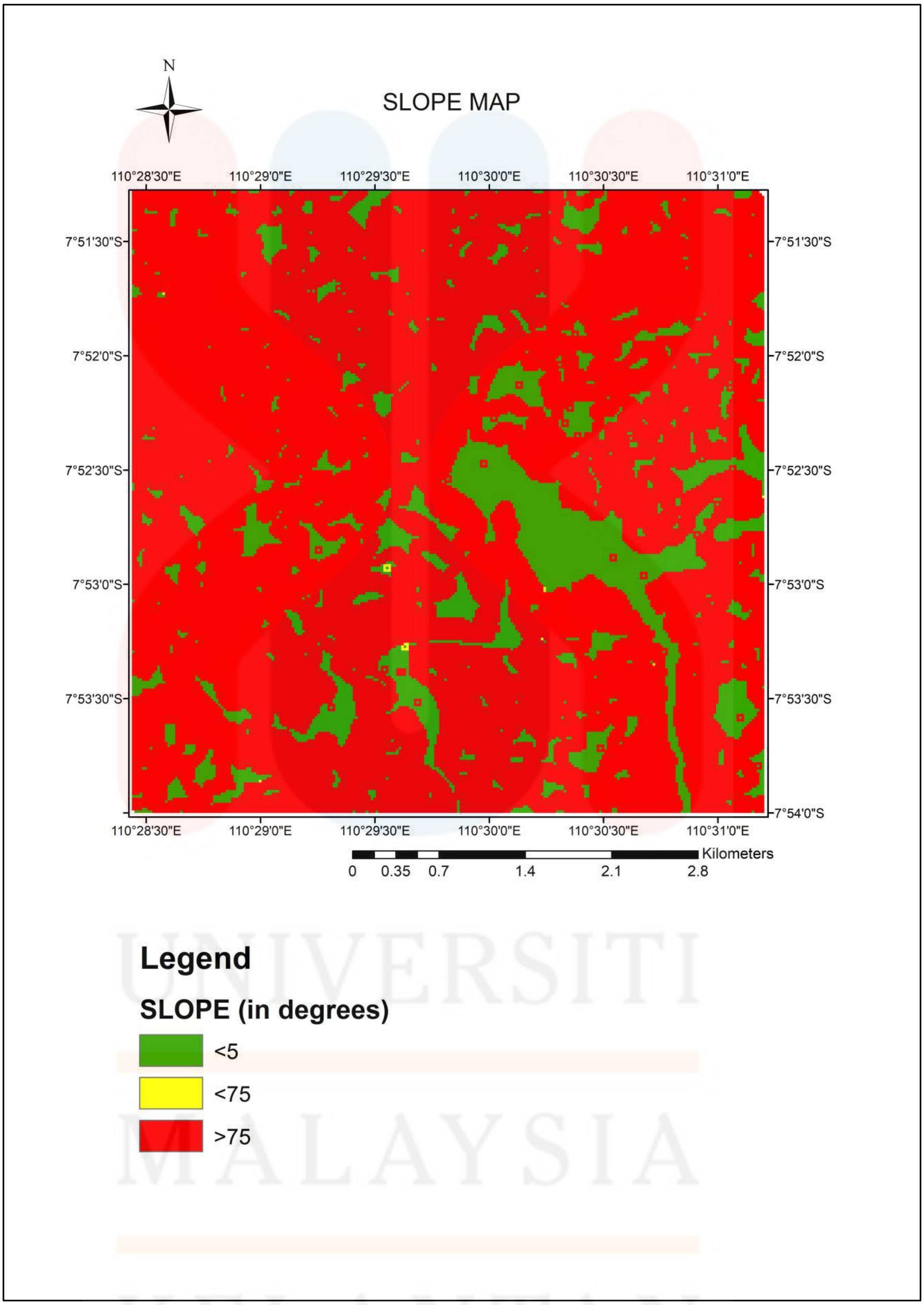


Figure 5.1 : Slope map of the study area

5.2.2 Lineament Density

Lineaments is the structurally controlled linear features that can be identified by the relatively linear alignments. Lineaments indicates that there are the presence of the faulting and fracturing that resulting in the increased of the secondary permeability and porosity.By measuring the density of the lineament, the susceptibility of landslides hazard can be determined.

There are 3 groups of lineaments that are recognized in the study area that is low group, moderate group, and also the high group. The low group is the lowest influence to the landslide susceptibility while the high group influenced the most to the landslide occurrences. The weightage of lineament density is 9 and will be multiply by the score that is shown in the table 5.3 below.

Table 5.3 : Weightage and Score (Lineament Density)

No.	**Lineament Density**		**Weightage (Wi)**	**Score (Sij)**	**(Wi x Sij)**
1	Low	0-270	9	8	72
2	Moderate	270-540	9	6	54
3	High	540-810	9	4	36

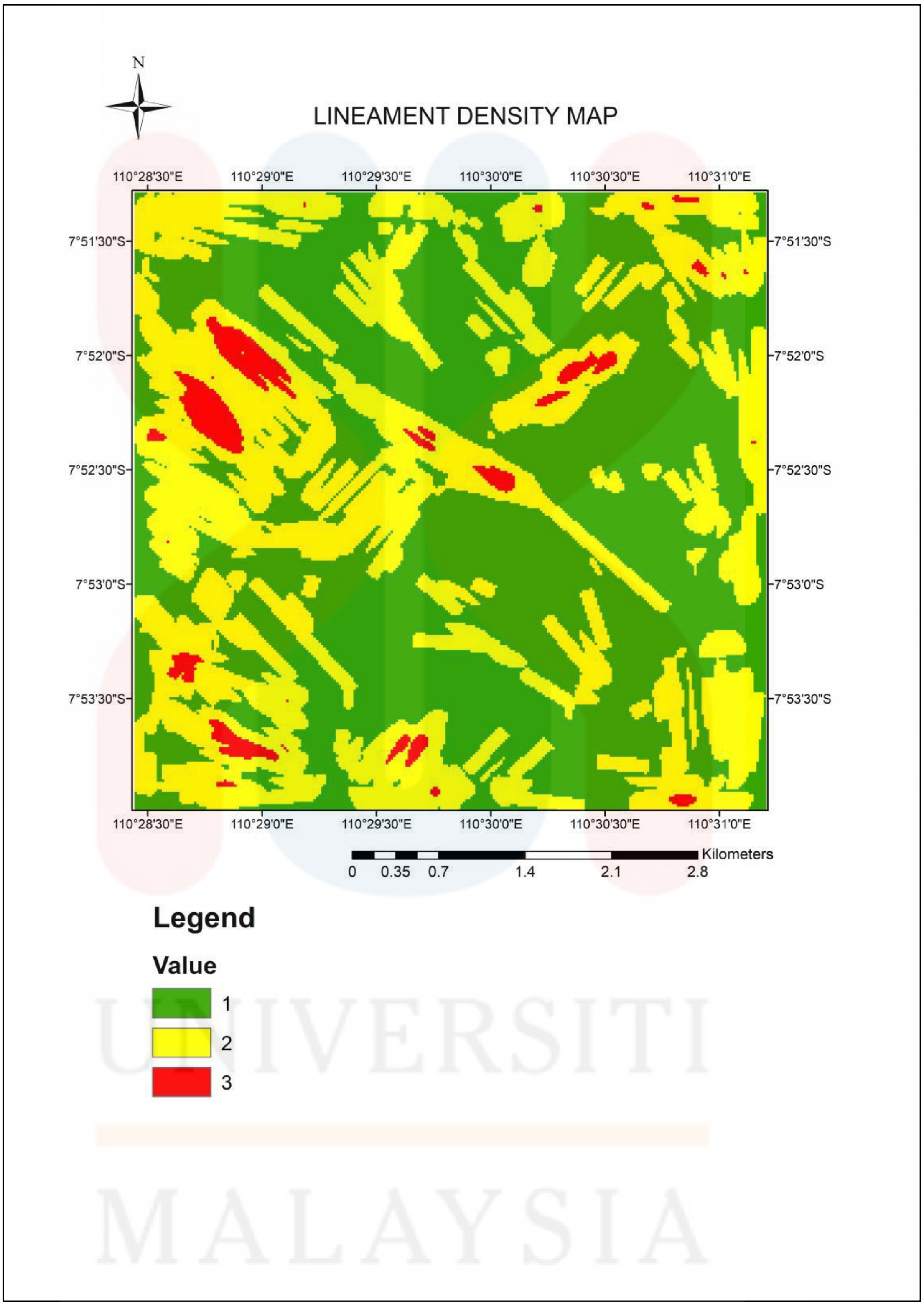


Figure 5.2 : Lineament Density of the study area

5.2.3 Lithology

Lithology of the study area may also play an important role in determining the susceptibility of landslide occurrences in the area. This is because the differences in the lithologies will also influenced whether the area are prone to landslides or it is low vulnerability of the hazard. The rock type in the study area falls in the period of Early to Middle Miocene period and there are also the present of the folding structures and also faulting structures.

Geologically, the lithologies of the study area were divided into three lithological unit that is the volcanic breccia unit, sandstone unit and also limestone unit and they were assigned to the score of 1, 6 and 2 respectively. The weightage for lithology have been assigned as 7 due to the influenced of it to the landslide susceptibility. Table 5.4 and Figure 5.3 shows the weightage and score of the type of lithology and the lithological map respectively.

Table 5.4 : Weightage and Score (Lithology)

No.	**Lithology Class**	**Weightage (Wi)**	**Score (Sij)**	**(Wi x Sij)**
1	Sandstone	7	6	42
2	Limestone	7	2	14
3	Volcanic Breccia	7	1	7

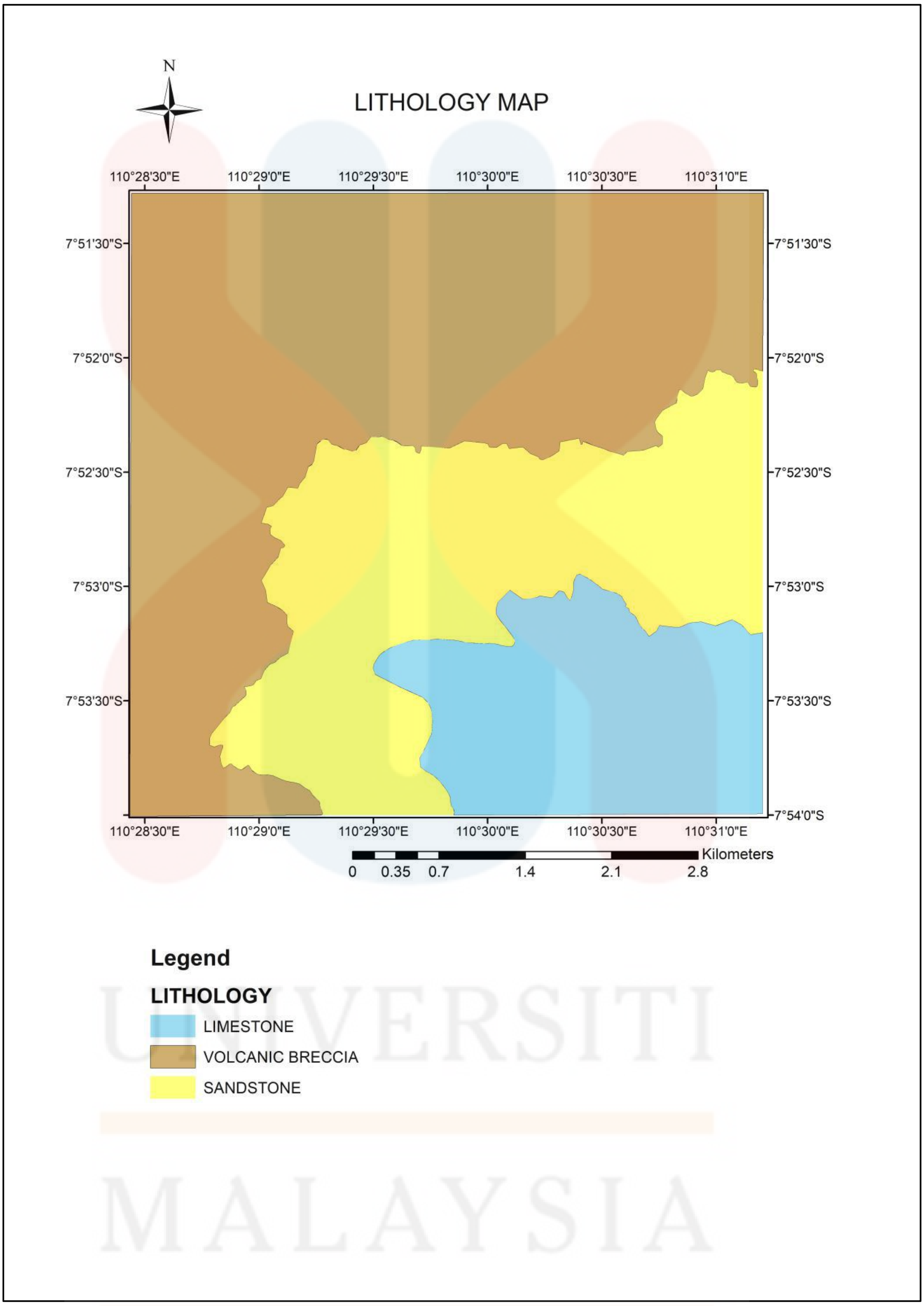


Figure 5.3 : Lithological map of the study area

5.2.4 Drainage Density

Drainage Density indicates the closeness of the spacing of the streams and it is a detrimental key factor for a water to travel from source to sink (Horton, 1945). it is also an inverse function of infiltration so when the decrease in the rainfall infiltration, the surface runoff tends to be concentrated. Based on the drainage density, the extent of the debris flow, seepage and also the possible consequences of the landslides occurrences can be determined better.

In the study area, the drainage density is classified into three categories that is low, moderate and also high group of drainage density. High drainage density values are highly favourable for the surface runoff hence it also indicate the higher possibility of the landslide occurrences. Higher score are assigned to the area with the higher drainage density as shown in the table 5.5. Figure 5.4 shows the drainage density map of the study area.

Table 5.5 : Weightage and score (Drainage Density)

No.	**Drainage Density**		**Weightage (Wi)**	**Score (Sij)**	**(Wi x Sij)**
1	Low	0-455	5	8	40
2	Moderate	455-911	5	6	30
3	High	911-1367	5	4	20

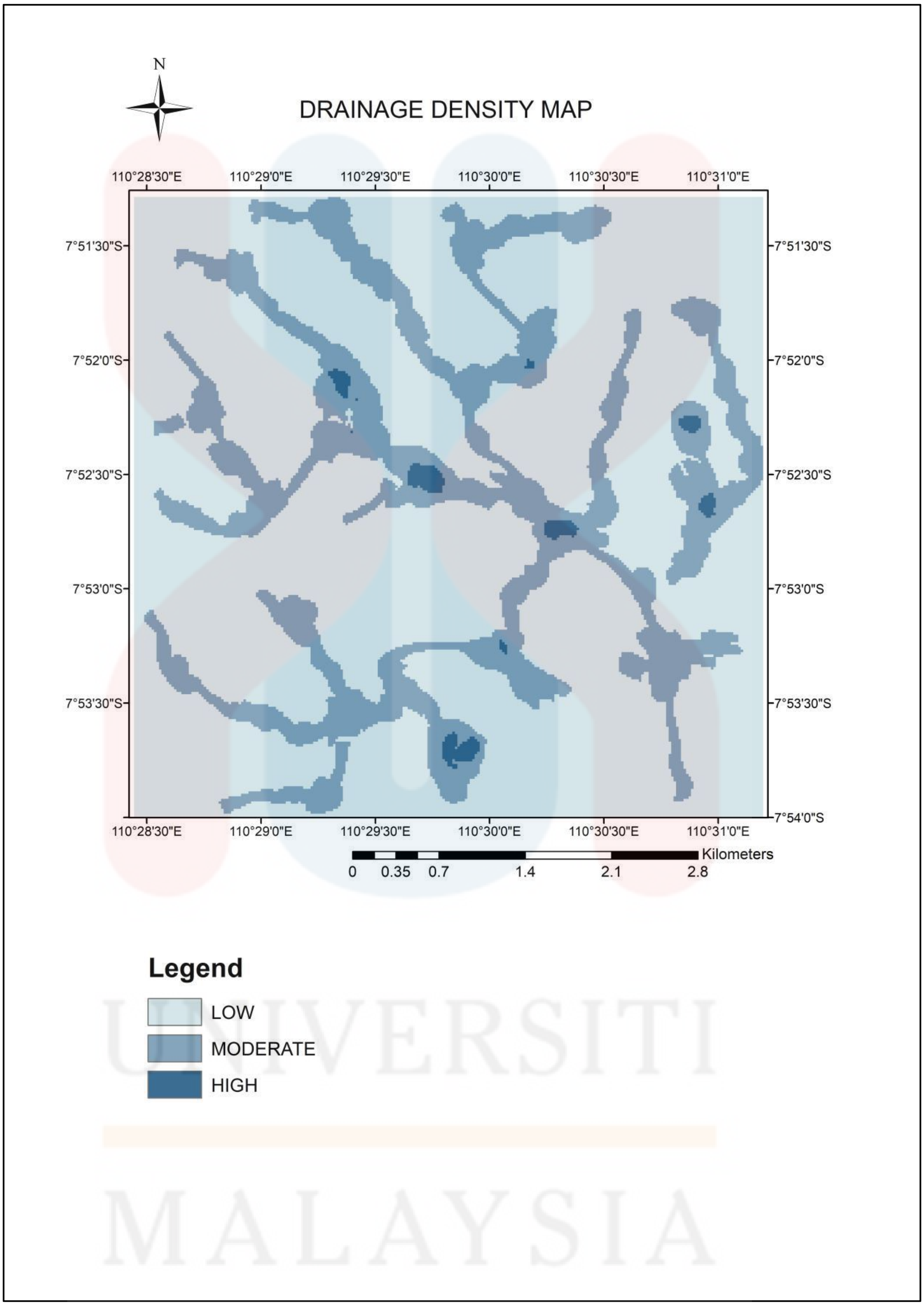


Figure 5.4 : Drainage density map of the study area

5.2.5 Type of soil

The soil type in area was important as it controls the water amount that able to infiltrate into the soil hence the water amount who becomes flow (Nichols and Wong, 2005). The probability of landslides occurrences increases when decrease in soil infiltration capacity which causes the increases in the surface runoff. When water supplied exceeds the soil's infiltrations capacity, it will moves down slope as runoff on sloping land that can lead to landslide hazard (Lowery et al, 1996)

There are three type of soil that comprised of gravelly loam, gravelly clay, calcareous loam, loam soil and calcareous clay on the moderate slope, gravelly loam, gravelly clay, clay and loam soil on the gentle slope and also clay, gravelly loam on the steep slope. The weight are assigned as 4 for the soil type based on the influenced to landslide hazard. Table 5.6 shows the score and weightage and score for the type of soil while figure 5.5 shows the type of soil map in the study area.

Table 5.6 : Weightage and score (Soil Type)

No.	Soil Type	Weightage (Wi)	Score (Sij)	(Wi x Sij)
1	Clay,Gravelly Loam - Steep slope	4	8	32
2	Gravelly Loam, Gravelly clay, Clay, Calcareous loam, loam soil, calcareous clay - moderate slope	4	6	24
3	Gravelly loam, gravelly clay, clay loam soil - gentle slope	4	4	16

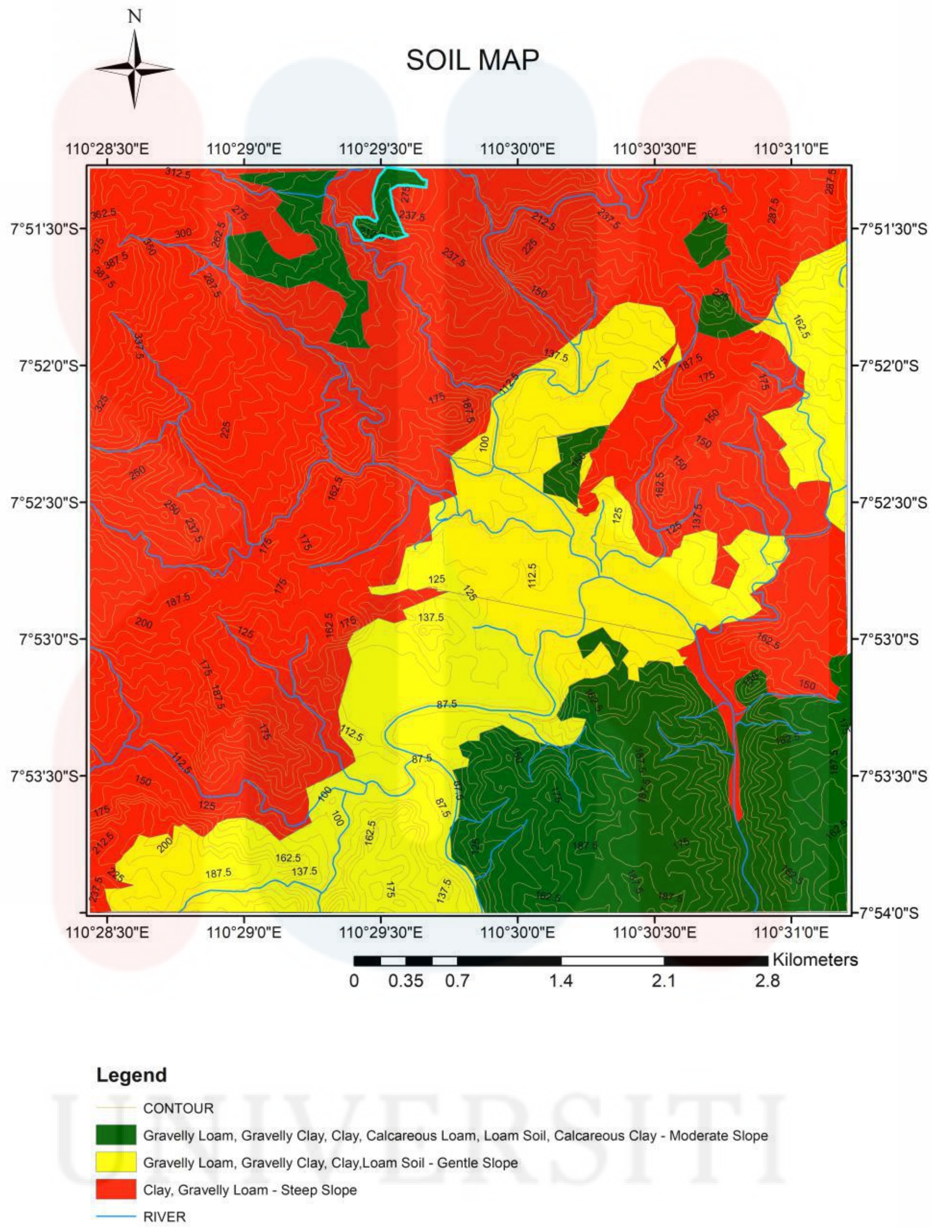


Figure 5.5 : Type of soil in the study area

5.2.6 Landslide Susceptibility Analysis

A map was generated to show the areas that are susceptible to landslide in three classifications that is low hazard area. Moderate hazard area and also high hazard area. The susceptibility of the landslide hazard was prepared by using weighted overlay index method on the GIS platform. Five parameters of the landslide causative - factors have been chosen by referring to the previous study that is slope, lineament density, lithology, drainage density and also type of soil.

$$s = \frac{\sum wisij}{\sum wi} \qquad 5.1$$

Each of the parameters have been assigned of each weightage respectively and it is later calculated by using the equations that was shown in the above 5.1 equation. Based on the figure 5.6, it can be observed that the majority of the study area has a moderate susceptibility of landslide that covers around 80% of the study area and the 15% of the study area is consist of low susceptibility of landslide hazard while 5% more is high susceptibility to landslides.

In general, the degree of landslides increased with the decreased in the drainage density and also the lineament density. Slope is one of the most parameters in the landslide susceptibility analysis since the stability of the slope form the basis for the frequency and intensity of the occurrences of landslides. The steeper the slope the more the tendency for instability it will be. Particularly, the hilly and mountainous region has the more chances of landslides occurrences because of the of the higher slopes and that concludes why the study area was dominance with moderate susceptibility area. The moderate susceptibility of landslide means that there are high chances of the landslides hazard if the parameters such as the slope did not cut properly.Table 5.7 shows the susceptibility class for the landslide hazard in the study area.

Table 5.7 : Susceptibility of landslide hazard in the study area

Susceptibility Class	**Risk**	**Area percentage (%)**	**Cumulative Area Percentage**
Low Zone	0-50%	15	15
Moderate Zone	50%-75%	80	95
High Zone	> 75%	5	100

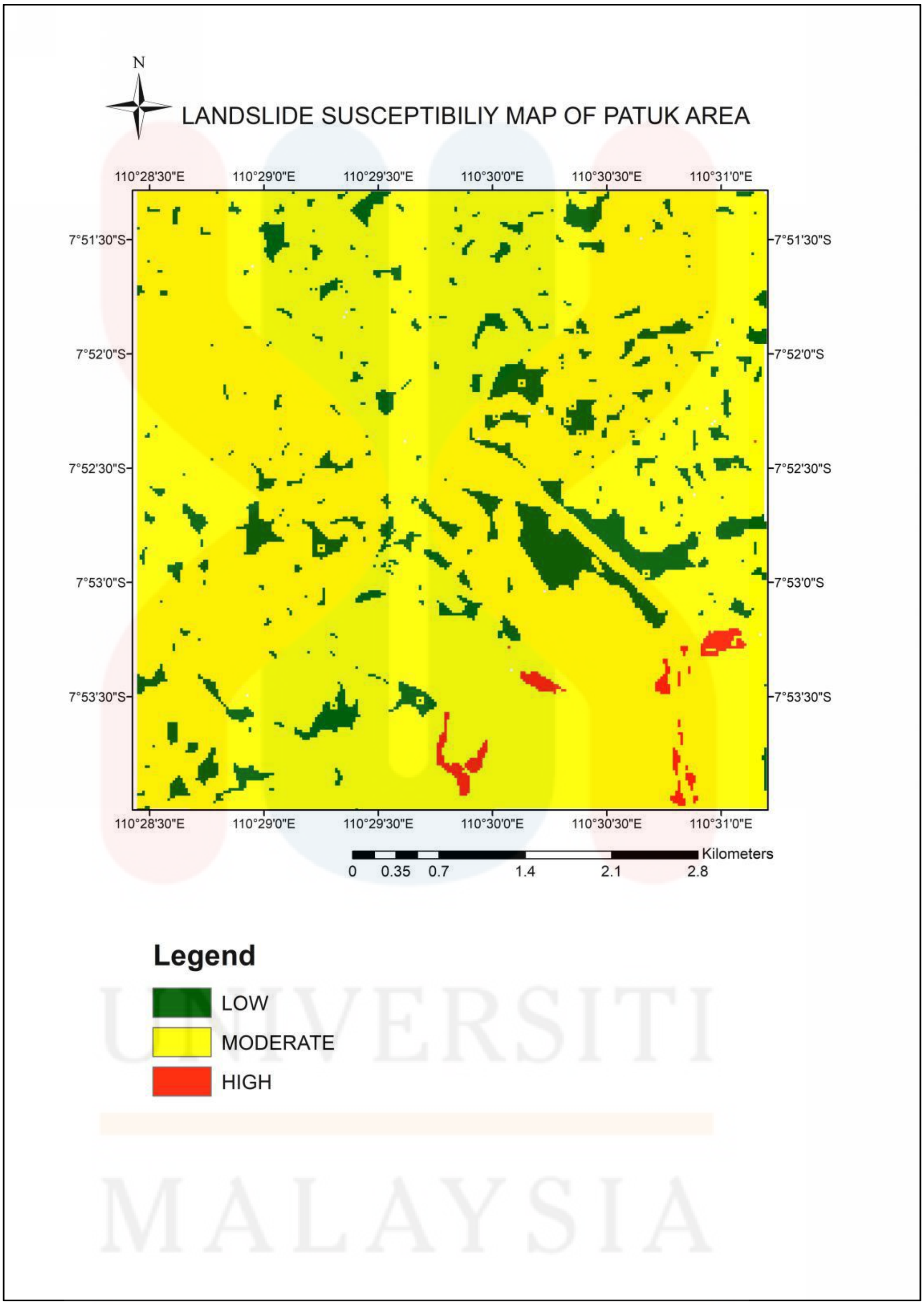


Table 5.6 : Landslide Susceptibility Map of Patuk Area

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

As for the conclusion, after this research was finished, the geological map of the Patuk area was updated in the scale of 1:25000. the lithology had been divided into the three units of lithologies that is the sandstone unit, the volcanic breccia unit and also the limestone unit. The structural analysis, geomorphology form, drainage pattern and stratigraphy of the study area were obtained through geological mapping activity.

In the research specification part that is the landslide susceptibility mapping of the study area, a map have been generated that is the map of landslide zonation map of the Patuk area. It has been divided into three class of zone that is low class zone, moderate class zone and also the high class zone. By using the weighted overlay method in the GIS platform, five parameters had been chosen that is slope, lineament density, lithology, drainage density and also the type of soil map.

Generally, the study area have been divided into three class of area that susceptible to the landslides hazard that is low susceptibility of landslide hazard, moderate susceptibility of landslide hazard and also high susceptibility of the landslides hazard. The area also have been divided into percentages that is the majority of the study area are consists of moderate susceptibility that is 80% of the study while the low and high susceptibility of study area is divided into 15% and 5% respectively.

Particularly, based on five parameters that have been chosen, slope is the highest influenced to the landslides hazard because the stability of slope form the basis frequency for the occurrences of the landslides hazard. The location of the study area that is on a mountainous and hilly area make it more prone to the occurrences of the landslides.

6.2 Recommendation

Based on the current research, the recommendations for the next study is that in the geological mapping itself, it should be start earlier so that the problem such as the insufficient in the collection of data can be avoided. The general knowledge in mapping also need to be improved that is in the mapping knowledge and also in another field of the geological knowledge such as the structural geology and also the lithologies of the study area.

In the specification part, it is advised in the next study to use different type of parameters such as the type of vegetation, the slope aspect and also the geomorphology of the study area. It is because the different type of parameters used may give different result then the result can be compared to know what parameters influenced most to the landslide susceptibility to the study area.

The landslide susceptibility analysis was recommended to be done by using the ArcGIS software because it is a simple software that can determined the landslide susceptibility in a study area. As for the result of the landslide susceptibility, it is advisable to the construction in the study area to be done properly as the area have a high probability of occurrences in landslide hazard. It is for the safety of the people and also to prevent life and property lost.

REFERENCES

Abubaker Ezabti, Verka Jovanovic, (2015). GIS and Remote Sensing Application in Geological Mapping and 3D terrain modelling : A case study in Eghei uplift, Libya, *Geographic Information Systems, SYNTHESIS,* 615 - 619.

Al. Awadhi, T., Al - Shukili, A. & Al- Amri Q (2011). The use of remote sensing & geographical information systems to identify vegetation : The case of Dhofar Governorate, *Geography Departmene, Sultan Qaboos University, Oman*.

Birl Lowery and William J. Hickey (1996). Soil Water Parameter and Soil Quality, *Soil Science Society of America. USA.*

B.N. Kresna Citrabhuwana, S. B. (2016). Geology and Slope Stability Analysis using Markland Method on Road Segment of Piyungan - Patuk , Sleman and Gunungkidul Regencies, Yogyakarta Special Region, Indonesia . *International Journal of Economic and Environmental Geology*, 42-52.

Barianto, D. H. (2009). Structural Analysis using Landsat TM, Gravity Data and Paleontological Data from Tertiary Rocks in Yogyakarta, Indonesia. 65-77.

Caran, C. S., Woodruff Jr, C. M., & Thompson, E. J. 1981. Lineament Analysis and Inference of Geologic Structure--Examples from the Balcones/Ouachita Trend of Texas. *Geological Circular 82-1*, 59-69.

Christos Chalkias, Maria Ferentinou, Christos Polykretis, (2014). GIS-Based Landslide Susceptibility Mapping on the Peloponnese Peninsula, Greece. *Geosciences,* 176-190.

Chudamani Joshi, Jan De Leeuw, Iris C. Van Duren. (2006). Remotely sensed estimation of forest canopy density: A comparison of the performance of four methods, *International Journal of Applied Earth Observation and Geoinformation,* Volume 8, 84 - 95.

D. Karnawati, S. P. (2006). Geology of Yogyakarta, Java: The Dynamic Volcanic Arc City. *The Geological Society of London*, 363-370.

D.G., P. (2009). *Engineering Geology Principle and Practice* . Springer.

Djoko Mulyanto, S. (2009). Pengaruh Topografi dan Kesarangan Batuan Karbonat Terhadap Warna Tanah Pada Jalur Baron-Wonosari Kabupaten GunungKidul, DIY. *Forum Geografi*, 181-195.

Fossen, H. (2010). Structural Geology and Structural Analysis. *Structural Geology*, 1-18.

Gorsel, J. V. (2016). Bibliography of The Geology of Indonesia and Surrounding Areas. *Bibliography of Indonesian Geology*.

Hall, R. (2009).Thw Eurasian SE Asian Margin as a modern example of an accretionary Orogen, in Cawood, P.A. and Kroner, A, eds, Accretionary Orogens in Space and Time, Volume 318: Geological Society of London Special Publication, 351-372.

Hall, R. Clements, B. and Smyth, H.R. (2009). Sundaland: Basement character, structure and plate tectonic development: Proceedings Indonesian Petroleum Association, *33rd Annual Convention*.

Hall, R. (2011). Australia- SE Asia collision: plate tectonics and crustal flow in Hall. R, Cottam, M.A. and Wolson, M.E.J. eds, The SE Asian Gateway : History and Tectonics of the Australia - Asia collision, Volume 355: *Geological Society of London Special Publication*, 75 -109.

Himan Shahabi, Mazlan Hashim, (2015), Landslide susceptibility mapping using GIS-based statistical models and Remote sensing data in tropical environment, *Scientific Reports.*

J. Nichol and M.S. Wong (2005), Satellite remote sensing for detailed landslide inventories using change detection and image fusion, International Journal of Remote Sensing, volume 26, 1913-1926.

Lauti D. Santy, A. K. (2007). Ichnologi dan Sedimentologi untuk Pemodelan Fasies Sedimentasi Pada Formasi Sambipitu - Oyo, Pegunungan Selatan, Yogyakarta. *Makalah Workshop Yogya*, 205-229.

Lunt P. Burgon G., B. (2009). The Pemali Formation of Central Java and equivalents : Indicators of Sedimentation on an active plate margin. *Journal of Asian Earths Sciences*, 100-113.

Lelono, E.B. (2000). Palynological study of the Eocene Nanggulan Formation, Central Java, Indonesia [Ph.D. thesis], *University of London*.

Matthews, S.J. and Brandsden, P.J.E. (1995). Late Cretaceous and Cenozoic tectonostratigraphic development of the East Java Sea Basin, Indonesia: Marine and Petroleum Geology, Volume 12, 499-510.

Mohd Hisham, Mohd Muzamil, Akhir, Juhari Mat.Lineament mapping using Landsat TM image in the eastern part of Gua Musang-Cameron Highland road. Malaysia.

Mulyanigsih, S. (2016). Volcanostratigtraphic Sequences of Kebo-Butak Formation at Bayat Geological Field Complex, Cetral Java Province and Yogyakarta Special Province, Indonesia . *Indonesian Journal on Geoscience*, 77-94.

Punyatoya Patra, (2010. Remote Sensing and Geographical Information System, *The Association for Geographical Studies ,* 1-27.

Gang Piao, Ping Lu, Marco Scaioni, Shuying Xu, Xiaohua Tong, Tian Tian Feng, Hangbin Wu, Wen Chen, Yixiang Tian, Weian Wang, Rongxing Li. (2013), Landslide Investigation with Remote Sensing and Sensor Network: From Susceptibility Mapping and Scaled-down Simulation towards *in situ* Sensor Network Design, *Remote Sensing*, 4319 - 4346.

Richard J. and Lisle. (2011). basic Geological Mapping, Fifth Edition. *Wiley-Blackwell a John Wiley & Sons, Ltd. Publication.*

Ritter, M.E., (2006)*The Physical Environment: An Introduction to Physical Geography*.Available from: http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/title_page.html [Accessed 12 June. 2018]. [Google Scholar]

Robert E. Horton, (1945). Erosional Development of Streams and Their Drainage Basins ; Hydrophysical Approach to Quantitive Morphology, *Geoscience World* , 275 - 370.

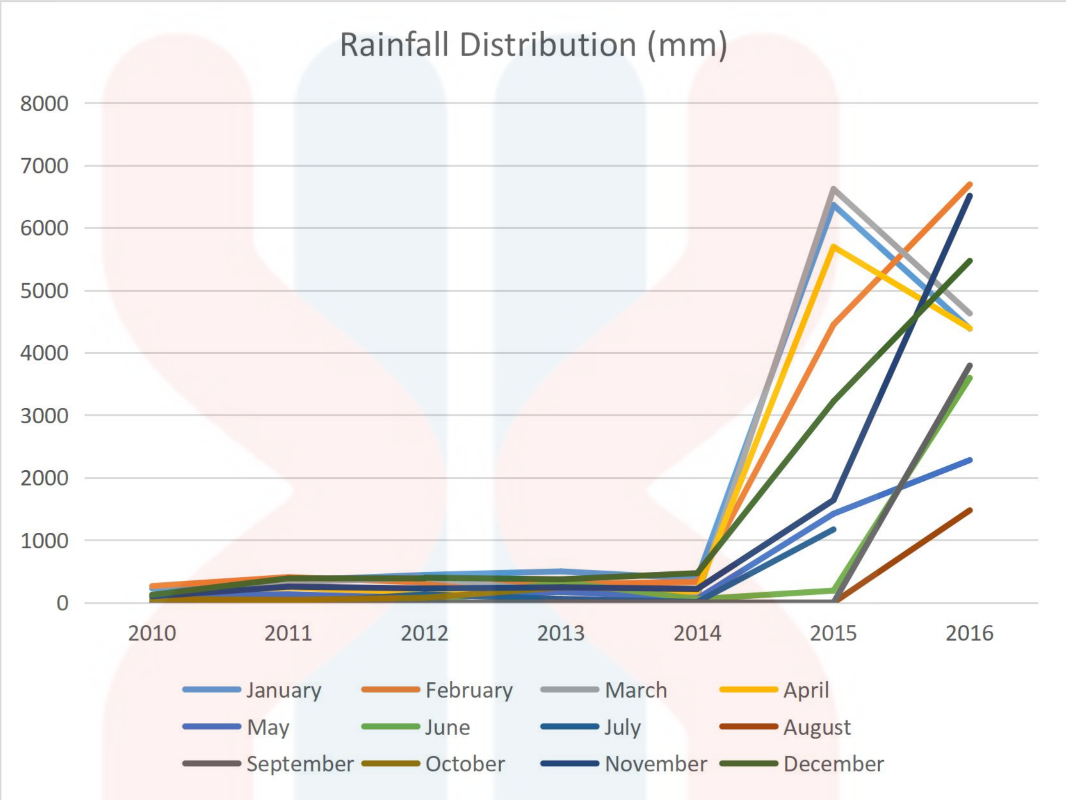
Shantanu Sarkar and Debi Prasanna Kanungo (2017). GIS Application in Landslide Susceptibility Mapping of Indian Himalayas, *Research Gate,* 211 - 219.

S.B. Kusumayudha, A. C. (2016). Correlation between Tectonic Environment and Characteristics of Mass Movements (Landeslides): A Case Study from Java, Indonesia. *Journal of Geologic Resources and Engineering* , 51-62.

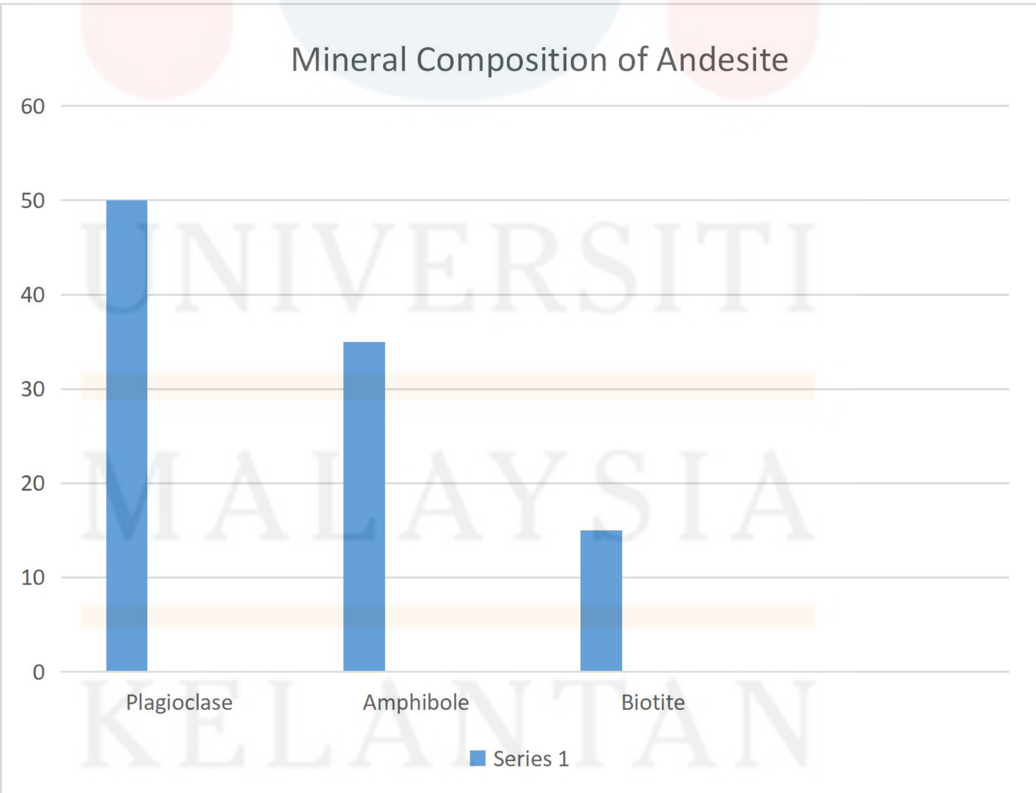
Smyth, H. (2005). *Eocene to Miocene basin history and volcanic history in East Java, Indonesia.* University of London .

Surajit Murasingh, Ramakar Jha, Sirisha Adamala (2018). Geospatial technique for delineation of groundwater potential zones in mine and dense forest area using weighted index overlay technique. Groundwater for Sustainable Development, Volume 7, 387 - 399.

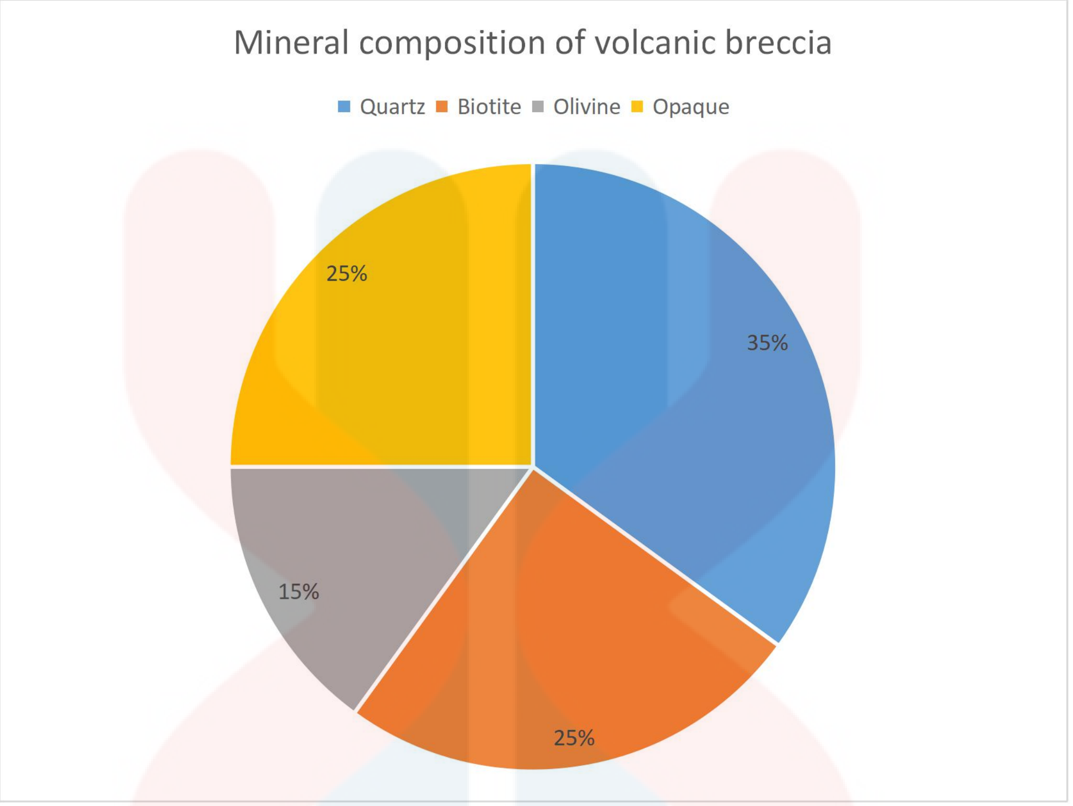
APPENDICES

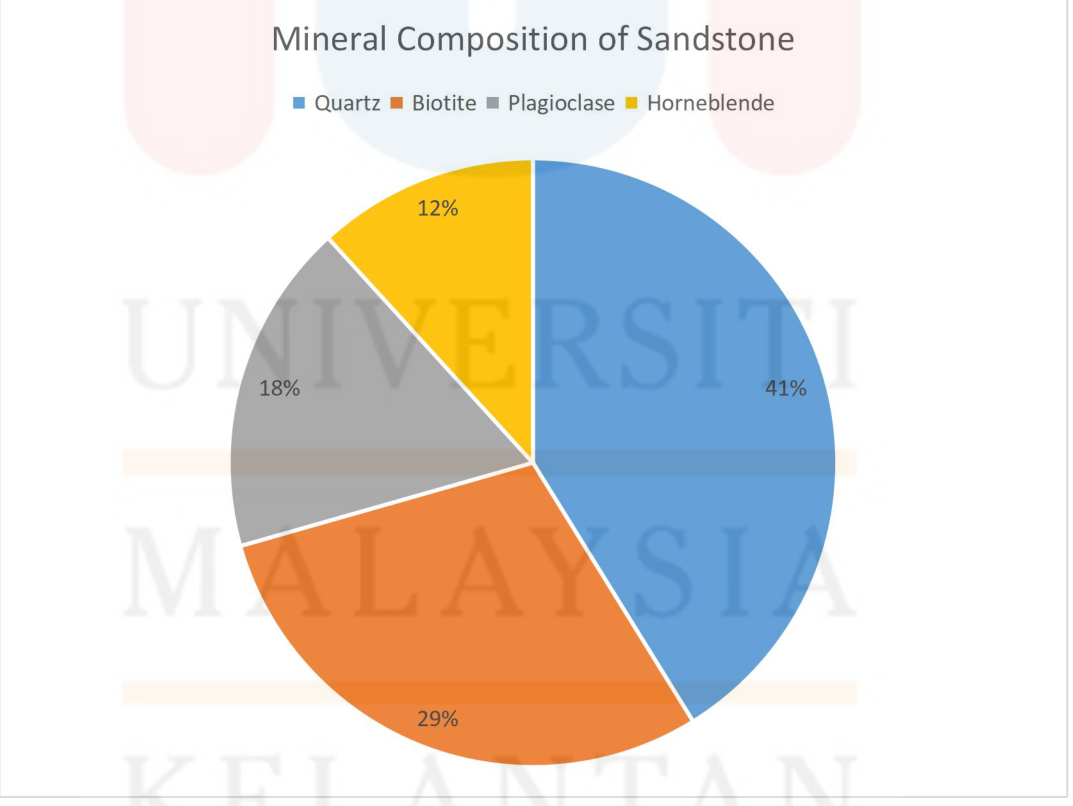


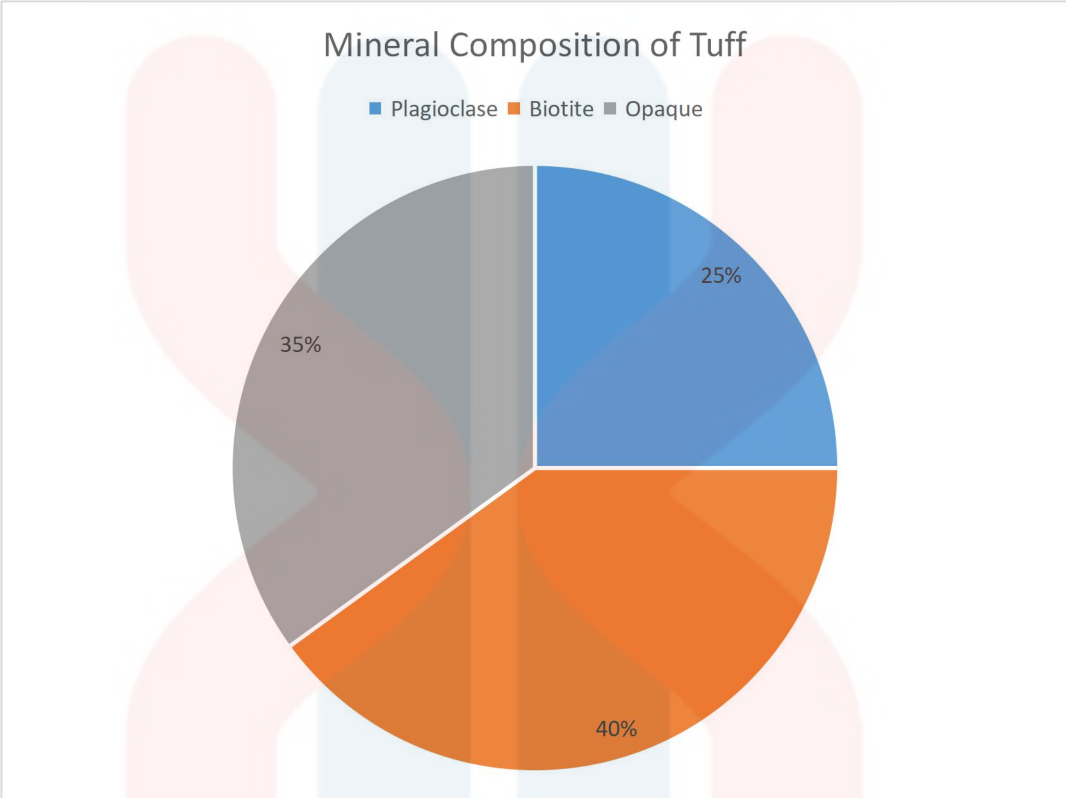
Rainfall Distribution (mm)
8000
7000
6000
5000
4000
3000
2000
1000
0
2010
2011
2012
2013
2014
2015
2016
January
February
March
April
May
June
July
August
September
October
November
December

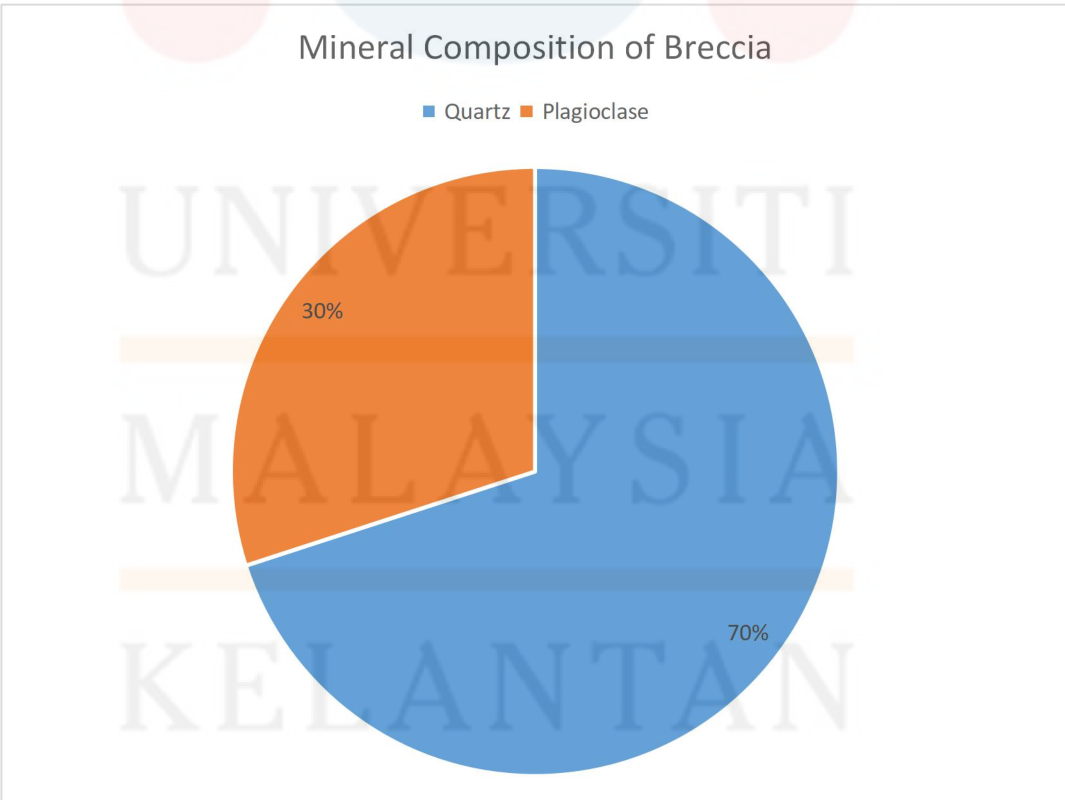


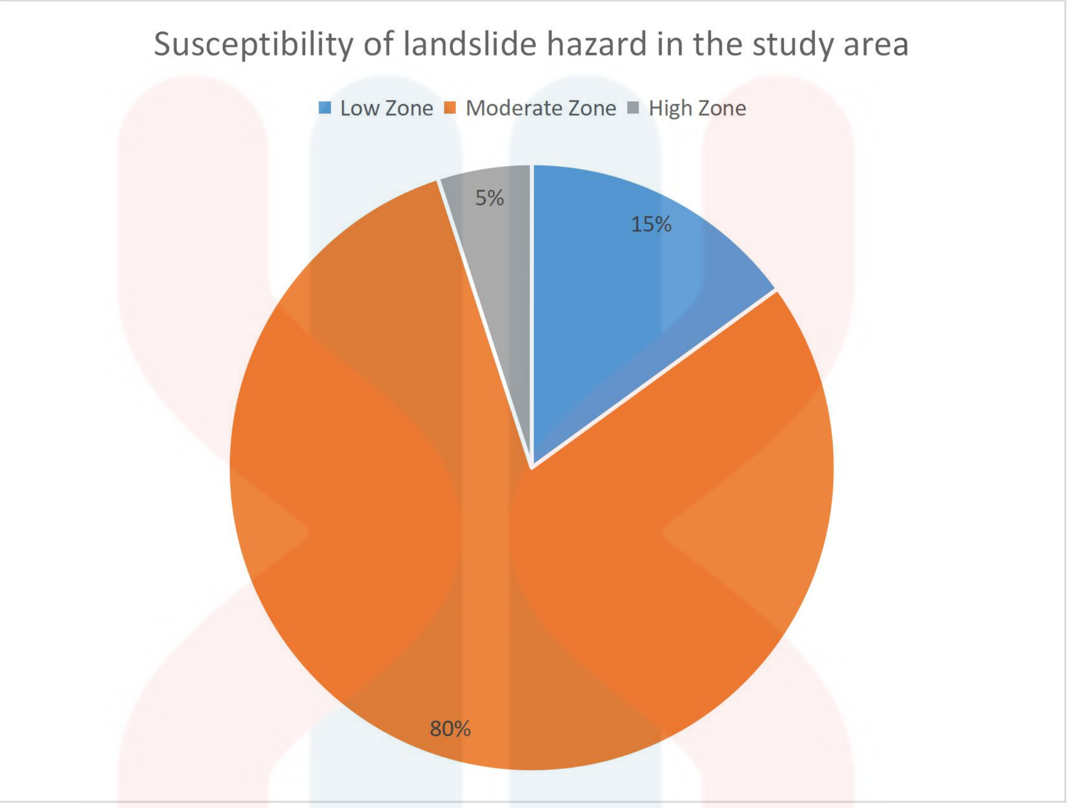
Mineral Composition of Andesite
60
50
40
30
20
10
0
Plagioclase
Amphibole
Biotite
Series 1


Mineral composition of volcanic breccia
Quartz
Biotite
Olivine
Opaque
25%
35%
15%
25%


Mineral Composition of Sandstone
Quartz
Biotite
Plagioclase
Horneblende
12%
18%
41%
29%


Mineral Composition of Tuff
Plagioclase
Biotite
Opaque
25%
35%
40%


Mineral Composition of Breccia
Quartz
Plagioclase
30%
70%



Susceptibility of landslide hazard in the study area
Low Zone
Moderate Zone
High Zone
5%
15%
80%