GEOLOGY OF BAYAT AREA AND RESISTIVITY STUDY FOR GROUNDWATER POTENTIAL IN GUNUNG KIDUL, YOGYAKARTA, INDONESIA.

by

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

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APPROVAL

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

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DECLARATION

I declare that this thesis entitled " **GEOLOGY OF BAYAT AREA AND RESISTIVITY STUDY FOR GROUNDWATER POTENTIAL IN 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.

Signature : ....

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Date :

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GEOLOGY OF BAYAT AREA AND RESISTIVITY STUDY OF GROUNDWATER POTENTIAL IN GUNUNG KIDUL, YOGYAKARTA, INDONESIA.

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ABSTRACT: Generally, the study area consists of two regencies that is Bayat and Gunung Kidul. The study area can be divided into three which are Jiwo hills, alluvial plains and Gunung Kidul (Southern Mountain). The Jiwo hills area located in the north part of the study area and alluvial plains that are located in the centre part of the study area have abundant groundwater resources as the area had undergone a series of intrusion which leads to the existence of complex geological structures. Alluvium is a good groundwater recharge hence, there are abundant of water wells in the villages that are located in these areas. On the other hand, the Gunung Kidul Regency (Southern Mountain) dominantly consists of steep slopes that hardens the process of groundwater exploration despite the lithology of the area that is dominated by sedimentary rocks which are also a good groundwater recharge.The purpose of this study is to update the geological map of the study area and also to investigate the groundwater potential in Gunung Kidul area using the vertical electrical sounding (VES) method which involves resistivity as the main parameter. In the Gunung Kidul area, three resistivity lines were conducted and based on the lithological factors, it can be interpreted that there is a good groundwater resource that could be useful for domestic uses for the locals. This groundwater exploration is necessary due to the lack of water wells and groundwater resource in the area.

Keywords: Yogyakarta; geological map; geophysical survey; groundwater; resistivity.

GEOLOGI DI KAWASAN BAYAT DAN KAJIAN RESISTIVITI BAGI POTENSI AIR BAWAH TANAH DI GUNUNG KIDUL, YOGYAKARTA, INDONESIA.

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ABSTRAK: Kawasan kajian ini meliputi dua kawasan iaitu kawasan Bayat dan juga Gunung Kidul. Pergunungan Jiwo terletak di bahagian utara kawasan kajian dan tanah rata aluvium mendominasi di bahagian tengah kawasan kajian. Kedua-dua kawasan ini mempunyai banyak sumber air bawah tanah kerana kawasan ini pernah mengalami beberapa intrusi yang mengundang kepada kewujudan struktur geologi yang kompleks di kawasan tersebut. Tanah aluvium adalah sejenis tanah yang memiliki ciri ciri akuifer yang baik dan hal ini menjadikan kawasan tersebut mempunyai banyak telaga air yang berpunca daripada air bawah tanah. Kawasan Gunung Kidul mempunyai litologi yang amat berpotensi sebagai akuifer tetapi geomorfologi dikawasan ini didominasi oleh kawasan cerun yang curam yang menyukarkan eksplorasi air bawah tanah dijalankan. Kajian ini dijalankan bagi tujuan mengemaskini peta geologi terdahulu yang telah dibuat di kawasan kajian. Selain itu, kajian ini juga telah dijalankan bagi mengkaji potensi kewujudan air bawah tanah di kawasan Gunung Kidul dengan menggunakan kaedah vertical electrical sounding (VES) yang menjadikan sebagai parameter utama. Bagi kajian ini, tiga garis resistiviti telah dijalankan di kawasan Gunung Kidul kerana kawasan ini mempunyai potensi air bawah tanah yang tinggi yang boleh digunakan sebaiknya oleh penduduk sekeliling. Kawasan Gunung Kidul mempunyai telaga air bawah tanah yang kurang jadi kajian air bawah tanah ini amat diperlukan.

Kata kunci: Yogyakarta; peta geologi; kajian geofizik; air bawah tanah; resistiviti.

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LIST OF ABBREVIATIONS

1-D	One-dimensional
2-D	Two-dimensional
Bt	Biotite
Chl	Chlorite
DIY	Daerah Istimewa Yogyakarta (Special Region of Yogyakarta)
Fds	Feldspar
GDP	Gross Domestic Product
GRDP	Gross Regional Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
Ha	Hectares
HCl	Hydrochloric Acid
km	kilometres
km^2	kilometre squared
m	metres
mm	milimetres
mya	million years ago
NE	Northeast
NW	Northwest
Opq	Opaque
PPL	Plane-polarized Light
Plag	Plagioclase
Qtz	Quartz
RMS	Root Mean Square
S	South
v	Version
VES	Vertical Electrical Sounding
XPL	Cross-polarized Light

LIST OF SYMBOLS

°	Degree
'	Minutes
"	Seconds
%	Percent
>	More than
σ	Sigma
Ωm	Ohm-meter

CHAPTER 1

GENERAL INTRODUCTION

1.1 General Background

The title of this research is ‘Geology of Bayat Area and Resistivity Study for Groundwater Potential in Gunung Kidul, Yogyakarta Indonesia’. Geographically, Bayat is located in Klaten which is a district located in Yogyakarta, Indonesia which is a home to many beautifully unique landform, geological phenomena, and also rare earth materials. Indonesia is a country with a tropical climate which experiences a humid type of weather throughout the year. The district of Klaten in the city of Yogyakarta is one of many areas in Indonesia that experiences a humid climate. This humid climate is known as a Tropical Monsoon that undergoes a short period of dry season and the remaining months will experience monsoon rains. This leads to a high probability of groundwater potential in Bayat area as groundwater can undergo natural occurrence by rain, snow and surface water.

Groundwater is defined as water that naturally appears beneath the Earth’s surface in soil pore spaces, fractures of rocks and many more. Approximately, 20% of the world’s supply of fresh water originated from groundwater which is roughly around 0.60% of the amount of water of the whole world inclusive of the permanent ice and oceans. Groundwater is a significant resource which acts as a large natural and long-term reservoir that can mitigate the shortage of surface water, especially during the times of draught. This is because groundwater can be naturally replenished by surface water from streams, precipitation and rivers when the recharge reaches the water table.

Geophysical survey especially using resistivity method is a common survey that is conducted in search of groundwater potentials. The vertical electrical sounding (VES) method are used to detect and map subsurface layers of lithology by displaying its resistivity values in resistivity profiles. This is also called as resistivity profiling. Vertical electrical sounding method requires the measurement of apparent resistivity of rock and soils to act as depth. Soil resistivity is a crucial purpose of permeability, porosity, ionic content of pore fluids and clay mineralization. The rudimentary principle for the resistivity method is the injection of current into the ground current and potential electrodes. This current causes a potential difference in the ground that can be measured using a separate pair of electrodes. Using the parameters of the electrical survey, the voltage can later be converted into an apparent resistivity value.

1.2 Study Area

a. Location

The study area is located in the area of Bayat, in the district of Klaten, Yogyakarta, Indonesia. The total area of the study area is 25 km^2 that is 5 km by 5 km specifically. The coordinates of the study area is from 7° 46’ 30”S to 7° 48’ 30”S for the latitude and 110° 37’ 30” to 110° 40’ 0” for the longitude. Figure 1.1 shows the location of the study area and Figure 1.2 shows the base map of the study area.

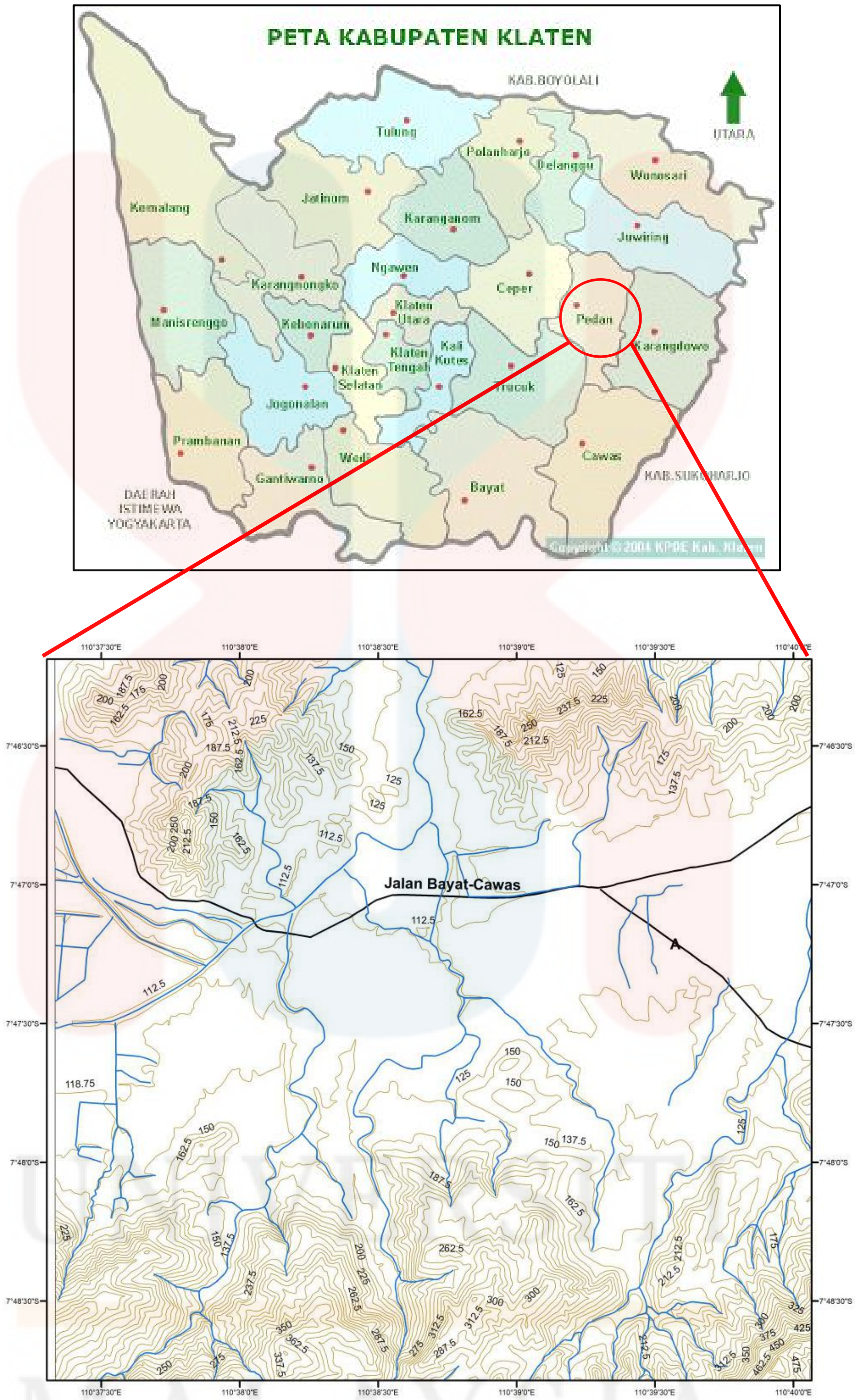


Figure 1.1: The location of the study area.

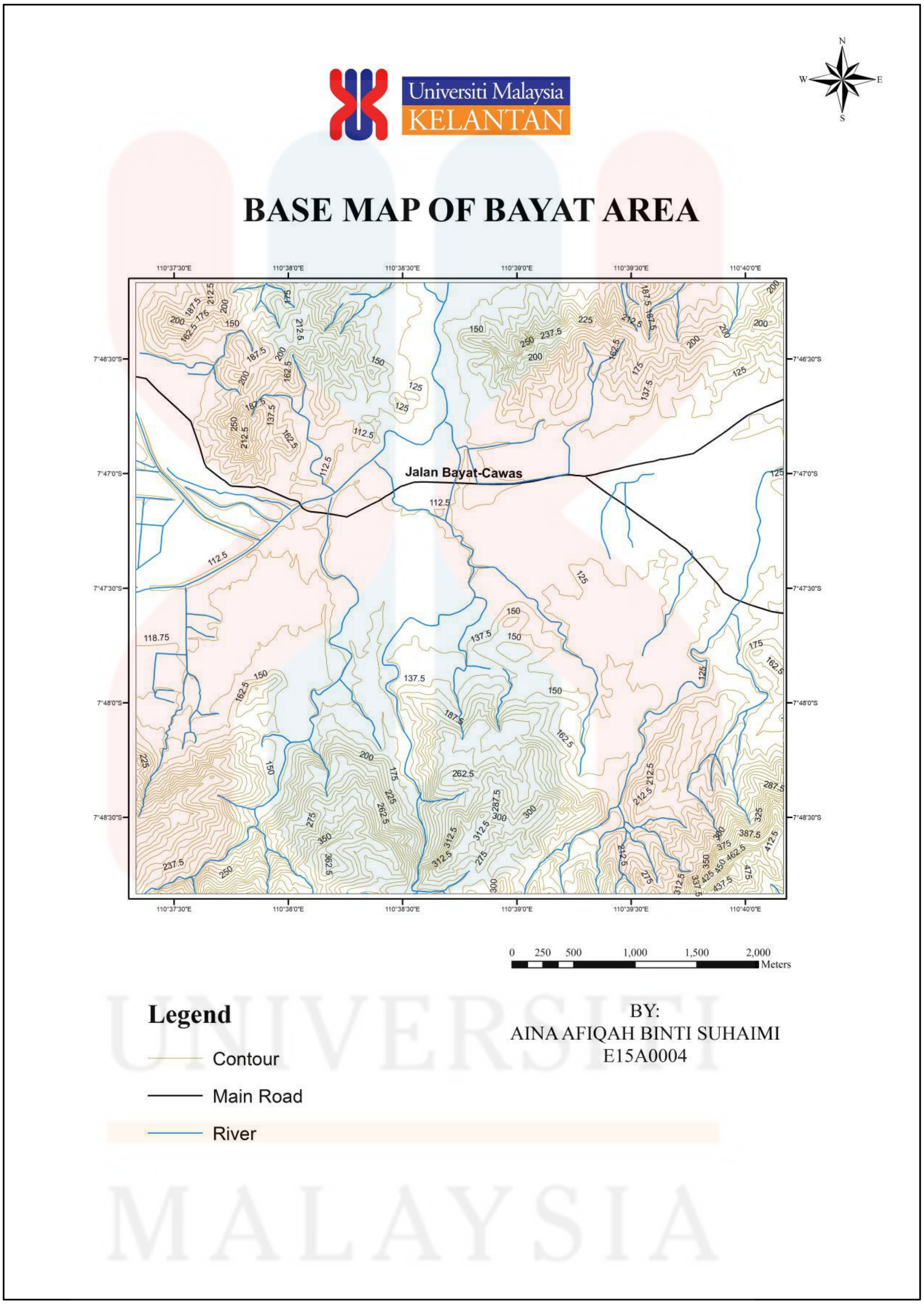


Figure 1.2: The base map of the study area.

b. Accessibility

The study area is dominated with flat plains in the centre part and hills on the north and south part. It is convenient to get to the study area as there is a main road that connects to the study area. This main road also connects the flat plains with the hilly areas as it is located in the centre part in between the two hilly areas. The name of the main road is Jalan Bayat-Cawas. Furthermore, there are many small roads that are interconnected with the main road which makes the area highly accessible. The study area is surrounded with villages and settlements. These roads bring convenience to the locals to travel everyday. Figure 1.3 shows a small road of a village in the study area.

Figure 1.3: A small road of a village in the study area.

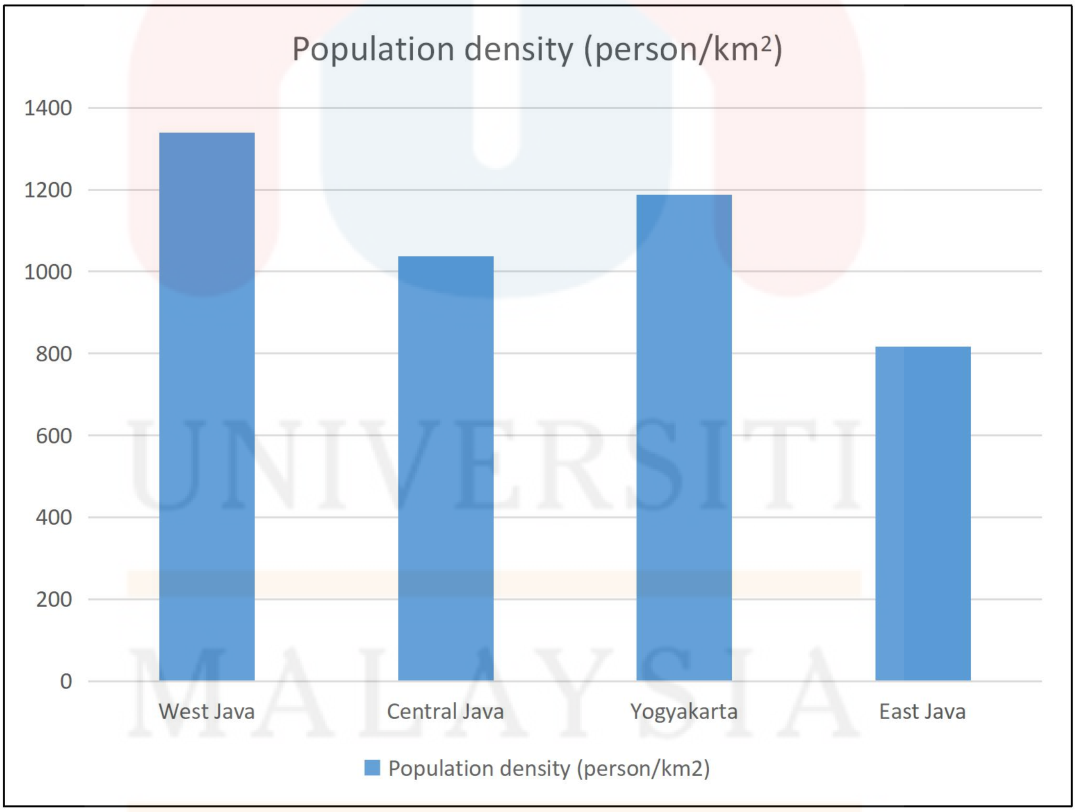
c. Demography

The city of Yogyakarta is an administrative part of the Yogyakarta Special Region (DIY) which has the status of a province in Indonesia. The regencies of Bantul and Sleman have population densities far higher than the surrounding countryside (over 1,500 per square kilometer) and are effectively dormitory communities of the greater area of Yogyakarta. Within the greater Yogyakarta area lies the city of Yogyakarta called Kota Yogyakarta. Yogyakarta Special Region are made up of 4 regencies and 1 city namely, Yogyakarta City. The 4 regencies are Kulon Progo with the capital of Wates, Sleman with the capital of Sleman, Bantul with the capital of Piyungan and Gunung Kidul with the capital of Wonosari.

The majority population in Yogyakarta is consisting of the Javanese ethnic. Yogyakarta is known as a home to a huge number of learning institutions such as schools and universities. This city also has a relatively low living cost as compared to other Indonesian cities hence, it attracts a significant number of students from all over Indonesia. As a consequence, there are many other Indonesian ethnic groups living in Yogyakarta, especially from eastern parts of Indonesia. There are some foreigner communities in the city, which is mainly composes of foreign students.

The Province of Yogyakarta that is known as the Special Region of Yogyakarta is located in the middle-southern part of Java Island. The province has administrative boundaries with the Province of Central Java in the northern, western and eastern part, while in the southern part, Yogyakarta has a border with Indonesian/Indian Ocean or in local words "Laut Selatan". The total provincial area of Yogyakarta is about 3,186.25 meter squared. Yogyakarta is located in the Java Island. Demographic information that is the population density in West Java, Central Java, Yogyakarta and East Java is described in Table 1.1.

Table 1.1: Population density of 4 provinces of Yogyakarta in 2016.



(Source: Badan Pusat Statistik, 2016)

d. 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. Figure 1.4 shows an image of the forestry in the study area that includes teak tree and banana tree. Figure 1.5 shows the plantation planted by the locals in the alluvial plain.

Figure 1.4: Forestry in the study area.

Figure 1.5: Plantation in the alluvial plain of the study area.

e. Social economic

Majority of the population in Yogyakarta, especially in rural areas, are engaged in agriculture. As a matter of fact, agriculture has been the largest contribution to the regional income. Historically, sugarcane was an example of the most intensively cultivated crop. According to Geertz (1963), in the year 1920, more than 30% of the lowland regions was utilized by the locals for sugarcane cultivation. It was one of the highest ratio recorded in Java. Due to the expulsion of foreign plantations that occurred after independence, sugarcane is no longer the most cultivated crop in Yogyakarta. After the expulsion, rice replaced sugarcane as the most planted crop in the low-lying regions of Yogyakarta. Rice was and still is the fundamental food of the Javanese. Besides rice, there are secondary crops such as maize, cassava, peanuts and soybeans which are planted in the irrigated areas. However in mountainous area, they are the dominant crops.

Economic activities in Yogyakarta are mainly concentrated on commercial services with about 23% of the total Gross Regional Domestic Product (GRDP). It is then followed by the agricultural sector which is about 19%. A detail of Yogyakarta's GDP information is illustrated in Figure 1.6.

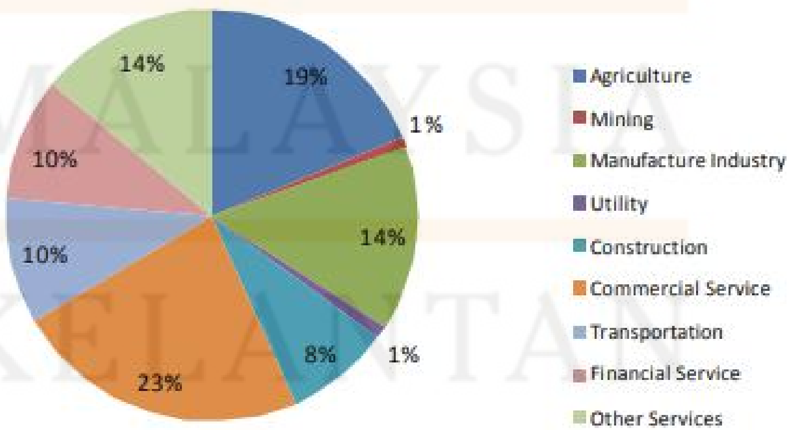


Figure 1.6: GRDP in several sectors of Yogyakarta Province in 2014.

1.3 Problem Statement

The Earth undergoes a lot of major and minor natural processes which leads to multiple changes of the Earth surface. Due to these natural processes, the general geology of Bayat, Klaten also might undergo some changes throughout the year. Therefore, an update of the geological map of the study area is necessary as the geological information of the study area might have changed and these changes could affect the study.

The Capital City of Yogyakarta Special Region Province that is Yogyakarta has undergone a rapid development in all sectors. The population growth and development of urban activities require more water supply for the society. The high density of population in Yogyakarta and the physical condition of land that is mostly dominated by sandy soil has the potential of enhancing groundwater pollution (Kamulyan, 2014). This is due to the insufficient sources of treated domestic wastewater hence, searching for a new potential zone of groundwater would be necessary.

1.4 Objectives of Study

1) To update the geological map of the study area.

2) To investigate the groundwater potential in Gunung Kidul area using the vertical electrical sounding (VES) method.

1.5 Scope of Study

The study is conducted in an area located in Bayat, Klaten, Yogyakarta. The total area of the study area is 25 km^2 (5 km x 5 km). There are two major parts that will be investigated in this study. Geological mapping will be conducted in order to study on the general geology of the study. Geological mapping is conducted to understand the overall geology of the study area. Secondly, the search of groundwater potential area will be conducted using the vertical electrical sounding (VES) method. The geological mapping is conducted first in order to study geology of the area. This is to make the search for suitable location for groundwater potential easier based on the lithological factors.

1.6 Significance of Study

Generally, geological mapping is conducted to produce a geological map. A geological map is a map that provides fundamental data for understanding processes affecting a region of Earth in both past and present days. This information is very significant for geologists because to find, protect and safely extract natural geological resources such as groundwater, petroleum, sand, metals, etc. A geologic map portrays the distribution of the rocks and sediments that are most likely to contain these natural resources. Geophysical investigation involves simple methods of study made on the surface in order to investigate the detail of the subsurface detail. Geophysical survey is very significant because of their success in solving a vast variety of problems. Few applications of geophysical survey using the electrical resistivity method are to determine the depth to bedrock or groundwater, map stratigraphy, estimate landfill thickness, and many more.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Globally, Indonesia is the largest archipelagic state that is a home to five main islands and approximately 300 smaller islands. The five main islands are Sumatra, Papua, Sulawesi, Kalimantan and Java. The archipelago is located in between two large oceans namely, the Pacific Ocean and the Indian ocean. Indonesia also connects two continents which are the Asian and Australian. Indonesia has a total area of 9.8 million km^2, of which more than 7.9 million km^2 are under water (Winoto, n.d.). Java Island is one of Indonesia's main island that is dominantly formed due to the events of volcanic. Due to these volcanic events, an east-west spine is formed along the island by a chain of volcanic mountains. The offshore continuance of the Gunung Sewu plateau is the eastern province comprises of flat lying Miocene limestones in outcrop while an angular Base-Miocene unconformity occurs in the western province. Klaten is one of the many districts located in Yogyakarta. Due north, the district of Klaten borders on Boyolali Regency. In the east side, it bounds the Sukoharjo Regency and Wonogiri Regency. Klaten acts as a boundary for the Special Region of Yogyakarta to the south and west.

The study area also comprises of the Gunung Kidul Regency. Located on the island of Java, Gunung Kidul is one of the many regencies of the province of Yogyakarta and is located in the southeast part. This Gunung Kidul regency is bounded by the Yogyakarta city to the north west, Bantul Regency to the west side, Sleman Regency to the north east and the Indian Ocean to the south. Gunung Kidul Regency is located in a karst region. Karst region is a difficult geography for farmers and this contributes to considerable poverty in the area due to water shortages.

2.2 REGIONAL GEOLOGY AND TECTONIC SETTING

On the south of Central Java lies the South Central Java basinal area. During a major present day, this South Central Java basinal area lies on the northern side of bathymetric basin that lies between the Java's volcanic arc and its outer ridge that is non-volcanic which also acts as a boundary to the Java Trench that is located on the north side. This area is categorized as outer arc basin in a wide tectonic setting. Also, it is a feature of megatectonic that are connected with the other island arc systems and may differ considerably in the sense of its complexity.

2.3 STRATIGRAPHY

The study area are generally classified under three formations namely, Kepek Formation, Kebo Formation and Butak Formation. The lithology of the study area is dominated by alluvium. Kepek Formation is said to be aged within Late Miocene to Early Pliocene (Blow, 1969). Meanwhile, the final research shows that Kebo Formation and Butak Formation are said to be aged within Late Oligocene to Late Miocene (21.0-26.55 mya). Generally, Kepek Formation comprises of the iteration of carbonate clay stone and limestone is Kebo Formation is an intermediate between sandstone and sandstone pebbles that are interbedded with few other lithologies such as silt rock, clay, tuff and shale. Some of the sandstone and clay stone have the characteristics of a limestone. Conglomerates and breccias of various polymic composition are also found. The centre part of this formation is dominated by sandstone gravels. Butak Formation is a formation that overlaps Kebo Formation and its lithology consists of polymic breccia that is interbedded with sandstone, sandstone gravels, claystone, and siltstone or shale. The petrographic of Formasi Butak shows that its fragments are dominated by volcanic materials such as basalt, plagioclase, andesite, tuff, quartz and a little bit of claystone).

2.4 STRUCTURAL GEOLOGY

Java Island inhabited an active margin of two plates interaction between Eurasia continental plate and Indian oceanic plate which, since Cretaceous, have converged. Due to this inhabitant, the basement of Java Island comprises of both Eurasian continental crust (northern West Java and Central Java) and intermediate acreted terrane (southern Western Java, southern Central Java and East Java). In Java, it is possible if there are some micro-continents such as those in the Jampang and Bayat areas. There are Previous published studies that are conducted on structural geology of Java Island using various kinds of methods. The result of the previous research done by Pulunggono and Martodjojo in the year 1994, these two have grouped Java Island into three groups of specific structural trends. These three structural trends are known as Meratus Trend, Sunda Trend and Java Trend (Pulunggono and Martodjojo, 1994). In addition to those three, an investigation by using gravity data interpretation shows that there is an addition to those three trends and that is Sumatra Trend.

The existence of the structures with Sumatra Trend is also supported by seismic data (Pramono et al.,1990; Gresko et al., 1995; Ryacudu and Bachtiar, 2000). The structures with Sumatra Trend mainly exist in West Java area and disappear to the east of Central Java area. On the other hand, the structures of Meratus Trend dominate the structural grains of northern East Java (Satyana and Darwis, 2001) and getting reducing and disappearing to the west of Central Java. Central Java occupies the transition area of structure between the Meratus and Sumatra Trends.

The age of formation of these three structures are Late Cretaceous for Meratus Trend, Late Cretaceous to Paleocene for Sumatra Trend Eocene to Late Oligocene for Sunda Trend and Early Miocene for Java Trend. The structural grains of Meratus, Sumatra and Sunda Trends are normally comprises of normal and strike-slip faults. Differ from these three structral grains, Java Trend comprises of thrust-reverse fault. All structural grains on Java can be related to north-south compression due to the crust subduction of the Indian Ocean (Situmorang et. al., 1976). Based on a number of interpretations, conclusively, Central Java indentation is a structural segmentation forming re-entrants. This is caused by the two major Paleogene wrench faults in western Indonesia with opposing trends and slips which are met to each other in southern Central Java.

2.5 HISTORICAL GEOLOGY

Generally, Central Java is made up of two sedimentary basins that are said to be aged during Neogene. The outline of the structural geology of these basins are determined during tectonic activities of the Late Oligocene such as a phase of folding, faulting, and volcanism. The depositional environment of the basins was interpreted as deep marine due to the clastics of deep marine facies found in the basins. Based on the records of seismic and stratigraphic, it can be said that there are three major Neogene tectonic activities that are regionally significant to Central Java. These three tectonic events are a minor Early Miocene event, a Mid Miocene event and a Late Pliocene event. Though they are considered significant, none of these events has contributed to the deformation of the offshore Neogene. The deeper part of the outer arc basin that is the south part of Central Java shallows steadily towards north. Based on seismic records, the records portray that a ridge of basement and a basin filled with sediment are traversed before reaching the coastline of Java. According to Bolliger & De Ruiter (1974), a simplified mega-structural sense can be considered as part of the "southern mountains" of west and east Java.

On the south of Nusa Kambangan ridge, there is a depression trending east-west called the western basin and it contains over 10 000 feet of sediment that is not deformed. Further south, there is an extensive high platform and this platform is said to be located in between the western basin and the slope that belongs to the present day outer arc basin. The central province of Central Java is the result of extension of the Kebumen Basin on land. This is classified by two factors namely, the greater thickness of Neogene and also the absence of distinct unconformity at the base of the Miocene. A broad and deeper basement ridge separates the Miocene basin and the outer arc basin. The province that is located on the east side of Central Java is the offshore continuation of the Gunung Sewu plateau which is located at the south of Yogyakarta. The plateau of Gunung Sewu is dominated by flat lying limestone in outcrop that is aged during Miocene. Most parts of the coastal regions of eastern south Java up until Lombok Island are involved in the domination of the limestone plateau. Large carbonate build-ups that is a strong indication of the existence of limestone is discovered in the offshore area. For the province located in the west side, an angular unconformity of the Base Miocene has occurred.

2.6 GROUNDWATER

Groundwater is undeniably one of the most precious natural resources to all living things. Its continual availability and good natural quality makes it a significant source of water supply for both rural and urban areas of any country (Todd and Mays, 2005). Approximately 22% of the Earth's total freshwater is the groundwater and it comprises of about 97% of all liquid freshwater available which is used for human consumption (Foster, 1998). The usage of unsustainable groundwater is clearly increasing especially in evolving countries (Todd and Mays, 2005) such as Ethiopia. Alluvial plain is generally a level plain that has a gentle slope and land surfaces that is slightly undulated. Alluvial plains are commonly surrounded with alluvial type of deposits such as sand, silt and clay materials. Alluvial plain is well known as a zone of good groundwater potential due to its naturally good capacity of recharging. Since alluvium is the dominant lithology of the study area, it can be said that there are plenty of alluvial plains within the study area that have a high potential of groundwater (Murugesan, Krishnaraj, Kannusamy, Selvaraj, & Subramanya, 2011).

VERTICAL ELECTRICAL SOUNDING (VES)

Groundwater exploration by using a geophysical method is known as groundwater geophysics. Geophysical investigations or geophysical surveys are carried out on the Earth's surface to search for potential zones of groundwater by observing some physical characteristics such as resistivity, conductivity, magnetic, electromagnetic, radioactive phenomena and many other characteristics. Generally, geophysical methods consist of measurement of signals from either natural or induced phenomena of the physical properties of subsurface formation. Geophysical investigations are able to identify the anomalies or differences in physical properties beneath the Earth surface. The main aim of groundwater exploration is to identify the indicators that could locate the zones that have high potential of groundwater. Geophysical methods such as the electrical, gravity, magnetic and seismic methods are very significant in solving many problems especially problems regarding hydrogeology. For decades now, the electrical resistivity surveys have been used in hydrogeological, mining and geotechnical investigations. On top of that, based on the recent research, this method is also used for environmental surveys. Each electrical property is the basis for a geophysical method.

Basically, groundwater exploration is an investigation of the formations that is found underground in order to understand the process of hydrologic cycle, to study about the quality of groundwater and also to identify the nature, type and number of aquifers beneath the surface (Arefayne Shishaye & Abdi, 2015). There are various methods available for groundwater exploration. An exemplar of the many methods is surface geophysical survey namely the vertical electrical sounding (VES) method. The vertical electrical sounding (VES) method is a 1-D resistivity method that delineates the differences in the electrical properties of geologic materials and also provides significant information of the deep surface despite the minimum amount of equipment used in this method. VES is one of the oldest techniques and also one of the least costly method used in order to obtain resistivity data per unit depth. Although it is the least costly resistivity method, it happens to be quite flexible and resourceful for preliminary subsurface surveying since it requires minimal equipment. Notwithstanding the fact that there are variety of 1-D electrical resistivity method such as TDEM, the data collected are more responsive to general electrical structure in vertical electrical sounding method. With VES method, the high resistivity contrasts are better resolved.

Vertical electrical sounding is one of the methods that is classified under the electrical resistivity imaging method. Vertical electrical sounding (VES) is one way that could provide valuable information on the vertical successions of the subsurface geo-materials in terms of their resistivity values and individual thicknesses (Arefayne Shishaye & Abdi, 2015). This method is efficient and effective for groundwater exploration because it is not time consuming, and does not require too much cost. In the vertical electrical sounding method, the distance between the current electrodes and the potential electrodes is increased systematically hence, providing information on subsurface resistivity from greater depths. The spacing of electrodes can be increased about a central point. This will result in a vertical electric sounding (VES) that is modeled to create a 1-D geo-electric cross section. Recent advances in technology allow for rapid collection of adjacent multiple soundings along transects that are modeled to create a 2-D geo-electric cross-section. The cross-section is very beneficial for mapping both the vertical and horizontal variations in the subsurface. Forward and inverse modelling computer software is used to model the variation of resistivity with depth. All data analysis and data interpretation are however, done according to the basis of direct currents. Theoretically, for some simple cases, the distribution of potential is related to the distribution of the ground resistivities. As for other more complicated resistivity distributions, analysis and interpretation are commonly done based on the basis of empirical methods.

CHAPTER 3

MATERIALS AND METHODS

3.1 INTRODUCTION

Geological mapping and geophysical surveys will be conducted in the study area in search of groundwater potential zones in the area. The geological mapping will be conducted in order to study and identify the geological features such as its lithology and also geological structures. For geological mapping, basic mapping equipments will be used. The basic mapping equipments are namely a Brunton compass, a Global Positioning System (GPS), a hand lens, a geological hammer and also a bottle of hydrochloric acid (HCl).

As for the geophysical survey, the vertical electrical sounding (VES) method will be carried out by using a resistivity meter called the McOHM Model 2115. 2 current electrodes and 2 potential electrodes will be connected to the resistivity meter that is set up on a straight line on a flat area with a changing spacing between them

. The common electrode configuration that is used for a groundwater potential survey is the Schlumberger configuration hence, the Schlumberger configuration is likely to be used in this research. The resistivity lines will be conducted on relatively flat areas as these areas are discharge areas that has a high potential of accumulation of groundwater. In order for the resistivity survey to function well and to minimize the errors in the data obtained, the survey will also be carried out at open spaces that are free or located far enough from construction sites, building structures and any obstacles. In general, the flow of the research is represented in Figure 3.1 below.

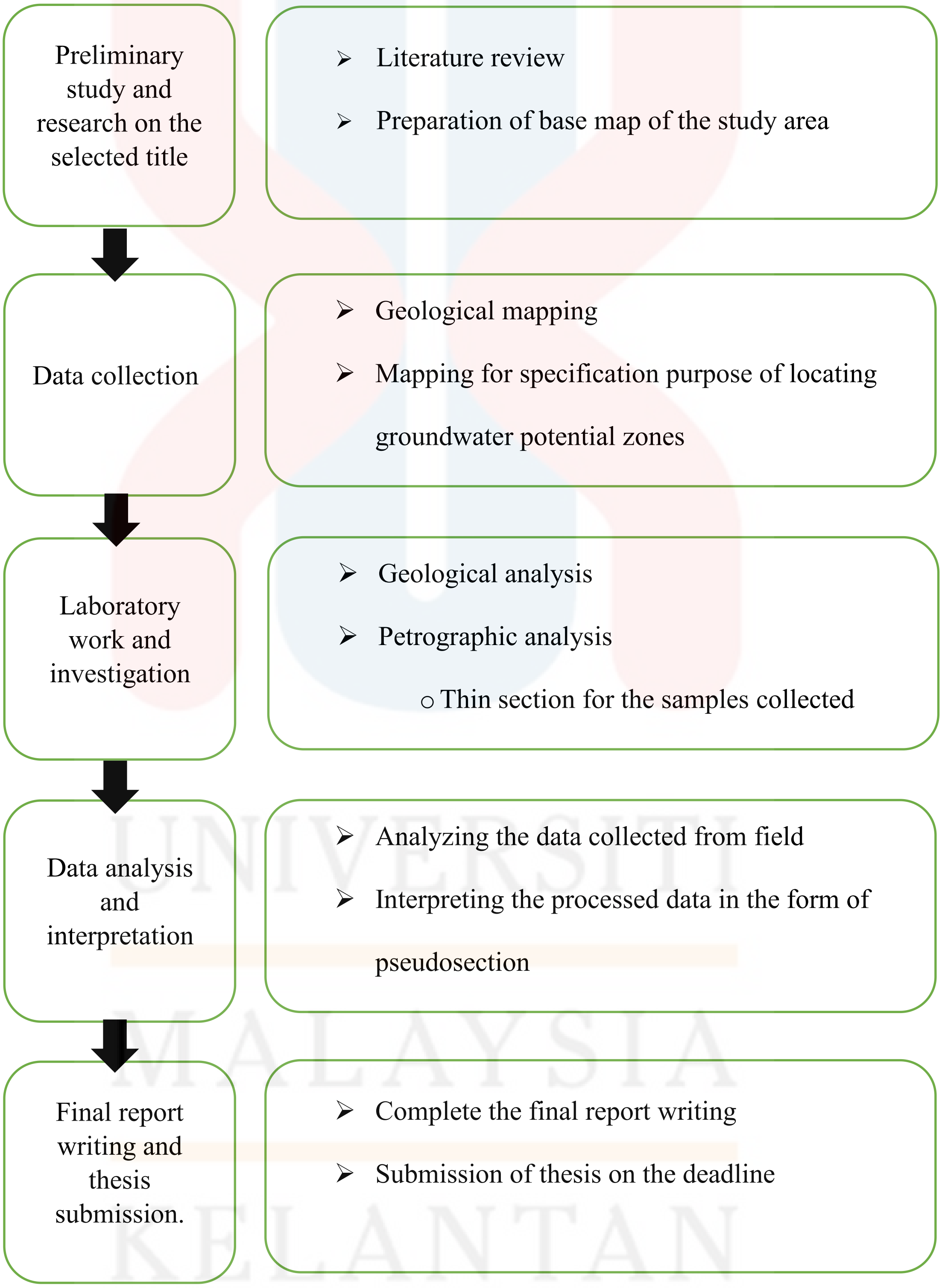


Figure 3.1: The research flow chart of how the study is conducted.

3.2 MATERIALS / EQUIPMENT

For geological mapping, the materials and equipment used are basic geological mapping equipment. These basic mapping equipment are namely a Brunton compass, a Global Positioning System (GPS), a hand lens, a geological hammer and also a bottle of hydrochloric acid (HCl). This bottle of hydrochloric acid (HCl) is to test for the presence of calcite in rocks. When the hydrochloric acid reacts with calcite from rocks, it will reacts and produce bubbles. Table 3.1 shows the images and uses of basic geological equipment.

For the 1D vertical electrical sounding survey that will be conducted for the specification, the geophysical equipment that will be used are a resistivity meter called McOHM Model 2115, 2 current electrodes, 2 potential electrodes, 2 sets of 250 m cables, crocodile clips, cable connectors and power supply. Figure 3.2 shows the VES equipment taken during the vertical electrical sounding (VES) survey.

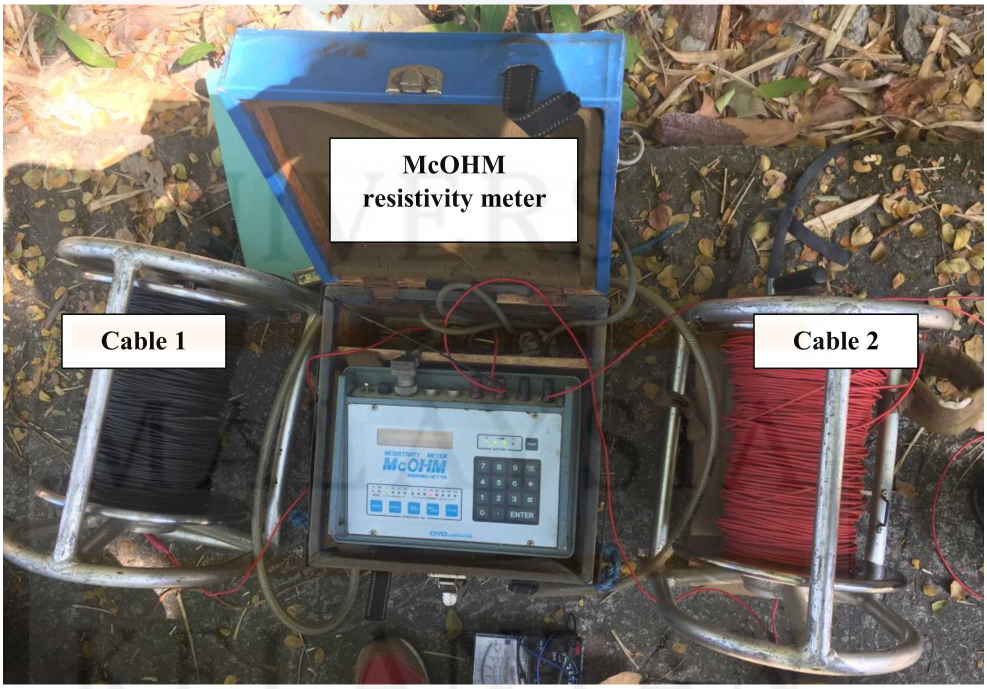


Figure 3.2: VES equipment on field.

Table 3.1: Basic geological equipment and their uses.

Equipment	Uses
 **Brunton compass**	A brunton compass is commonly used to get directional degree measurements (azimuth) of geological features. It is also useful in measuring the dip and strike of an outcrop on field.
 **Global Positioning System (GPS)**	A GPS is a device used to determine the location and position of something on Earth. For geologists, it is useful in locating geological features on Earth by providing the latitude, longitude and altitude.
 **Hand lens**	A hand lens is a small magnifying glass commonly used by geologists to take a closer look at rocks. hand lens help geologists to take a closer look at the texture of rocks, to identify the minerals and fossils in rocks. Hand lenses are usually equipped with 10x magnification power.
 **Geological hammer**	A geological hammer is used by geologists to split and break down rocks. Splitting and breaking rocks are necessary to get a fresh and less weathered part of rocks for further identification.

3. 3 METHODOLOGY

3.3.1 Preliminary studies

As the first step in conducting a research, a preliminary study is first conducted. A preliminary study can be defined as an initial exploration of issues related to a proposed quality review or evaluation. A variety of sources have been used in order to carry out this preliminary study. The main sources are books and the Internet. The Internet is used widely in collecting the data from the previous researches that have been done. For the geology part, recent journal papers and previous geological maps that are published are also very beneficial for preliminary study.

3.3.2 Field studies

This research is focused on two major assessments that are the general geology of Bayat and resistivity study for groundwater potential in Gunung Kidul, Yogyakarta. Both of these assessments are conducted on field. Traversing and geological mapping are carried out in the field to study the general geology of the study area such as lithology, topography, morphology, drainage pattern and geological structures, historical geology that can be found in the study area.For the investigation of groundwater potential in Gunung Kidul area, geophysical survey specifically, the 1-D vertical electrical sounding (VES) method is carried out. The McOHM Model 2115 resistivity meter is connected to 2 current electrodes and 2 potential electrodes which are laid out on a straight line with a changing spacing between the electrodes within the study area. Three survey lines are selected for this study by considering the topography of the study area. The resistivity lines are arranged in flat or low-lying areas which are potential groundwater discharge areas.

3.3.3 Laboratory work

The laboratory work mainly consist of the preparation of thin sections for every sample that is collected on field. Rock samples are brought to the lab for laboratory investigation. The various samples of rock units are taken for thin section. Thin section can be defined as a thin, flat piece of material prepared for examination with a microscope, in particular a piece of rock about 0.03 mm thick, or, for electron microscopy, a piece of tissue about 30 nm thick. The thin section will be analysed under a laboratory microscope. By conducting a thin section analysis, the mineral content in every sample are identified and the naming of rocks are done. Below are the steps on how a thin section is prepared.

Step 1: Preparation of the glass slide

The glass slide that will be used for the rock sample must be flat to ensure the rock section end up with a constant thickness. This is done by frosting the slide which helps to remove the thick spots on the slide and adjusts the slide face to be parallel to the face of the grinding wheel. Once the setting up is done, the second wheel from the left is turned on and some water from one of the bottles is sprayed on the wheel until it is completely wet. Then, a little bit of abrasive is sprinkled on it. A corner of a glass slide is carefully dragged on the left side of the wheel and once a small amount has ground away, the glass slide is prepared.

Step 2: Frosting the glass slide

The glass slide must be frosted or grind to flatten it out and roughen the surface so that the epoxy can bind well. A clean slide that is not frosted is placed on the slide holder of the cut-off saw. The slide holder of the grinder is wiped clean and the section is placed on the grinder holder. The vacuum is turned on to check if the slide is firmly held. The control is turned and when it reads about 70, the motor is turned on. The control is slowly turned until the slide is in contact with the grinding wheel. The control wheel is advanced gradually about three ticks from the contact value and it is left to be grind for a while to ensure complete and even grinding. The vacuum is then turned off. The removed slide is dried.

Step 3: Cutting the slab

A slab of the a rock sample is cut along the marked line using the slab saw. Firstly, the sample is clamped in the holder making the marked line parallel to the saw blade. A crank handle is then attached to square protrusion on tray. The tray is winded about 11 turns away from the saw blade and the crank handle is then removed. The cover is closed to ensure the sides and bottom are tucked inside the lip. Then, the cutting process began. After the switch is turned on, the knob is then turned until the weight begins to fall. Once the cut is done, the blade is turned off and the moving weight is stopped. The crank handle is removed and the cover is closed.

Step 4: Cutting the chip

The size of the slab need to be reduced slightly smaller than a thin section. For this purpose, a special rock-cutting blade is used. The water is started by using the valve above and to the right of the saw. Using the switch, the blade is then started. The slab is placed on the platform and moved into the blade. After the chip is cut, the side from which the think section is cut is first polished to remove marks from the saw blade.

Step 5: Gluing the slide to the chip

The chip is heated up by placing it on one of the hot plates with the polished side up. A batch of epoxy is then mixed. A small batch have about approximately 2 grams of epoxy and 1 gram of hardener. These materials must be well mixed. Once it is all well mixed, a few drops is spread across the top of the warmed chip. The epoxy must let to penetrate fully into porous rocks before spreading more epoxy. When no more epoxy soaks into the rocks, the slide is placed with the frosted side down on the epoxy. The slide is moved around to squeeze out extra epoxy and to achieve a constant thickness. The slide is then sit to cure roughly about 20-30 minutes.

Step 6: Cutting off the chip from the slide

A blank glass slide is placed on the grinder and the water is turned on to the cut-off saw. The slide is then placed in the cut-off saw and the vacuum is turned on to hold it. When the saw motor is turned on, the handle is used to move the chip into the blade. Once the chip is cut off the slide, the chip is retrieved from the water tray and set aside. The vacuum and saw motor is then turned off and the vacuum is break. The slide is removed from the saw once the hissing stopped.

Step 7: Grinding your slide to the correct thickness

A blank glass slide is place on the cut-off saw to block the vacuum. The water is turned on to the grinder. The slide is then placed on the grinder and the vacuum and grinder motor are turned on. The control is gradually advanced about 15 ticks below the zero value until the slide is in contact with the grinding wheel. The slide is finally removed and mineral identification is done.

3.3.4 Data processing

In this research, data processing are conducted using two software. The first one is ArcGIS software. ArcGIS is a software that is widely used in the production of maps. Therefore, all types of maps especially the geological map, that are involved in this research are produced by using ArcGIS software. In order to process the data obtained from the geophysical survey, the software that is used is the PROGRESS v 3.0. PROGRESS v 3.0 is a common software that is widely used in the process of interpreting geophysical resistivity method. By using this software, the data is presented in a resistivity profile that shows the vertical layers of the Earth. This software also portrays the resistivity value and depth of every layer along with the amount of layers below the sounding point surface.

3.3.5 Data analysis

After the completion of data collection and data processing, the data analysis will take place. Data analysis and data interpretations will be carried out after all the data from preliminary study, field work and laboratory analysis are completed and gathered together. Based on all the data that have been collected and processed, interpretations and conclusion can be made by correlating the data to each other. The interpretation for the groundwater potential zone in the study area are done by referring to the resistivity profiles.

CHAPTER 4

GENERAL GEOLOGY

4.1 INTRODUCTION

On Chapter 4, the topic that will be emphasized is regarding the general geology of the study area. As stated in Chapter 1, the study area is located in Pedan area, Special Region of Yogyakarta, Indonesia. General geology can be divided into four particular parts which are the geomorphology of the study area, the stratigraphy of the study area, the structural geology of the study area and also the historical geology of the study area.

The study area has a total area of $25km^2$ which is 5km by 5km. A total of 14 days were taken in order to complete the general geology mapping of the study area. In general, the study area can be accessed easily due to the existence of the main road and the small roads that are interconnected within the study area. Most parts of the hilly forest areas are accessible and off road tracks can be discovered in the area. Only small part of the hilly areas are hard to be accessed especially in the steep areas located in West Jiwo hills and the Southern Mountain. Figure 4.4 shows the traverse map during the 14 days of mapping. It can be estimated that almost 90% of the study area has been covered.

The high accessibility in the study area is due to the presence of settlements within the area as Bayat is an area that is surrounded by many villages and settlements. Approximately it can be said that 80% of the study area is covered with settlements except for the steep areas in Jiwo hills. Figure 4.1 shows an example of the high accessibility in the study area. The villages in the study area are commonly connected with small roads as shown in Figure 4.1. The study area is also surrounded with forestry and plantation which somehow becomes the main source of income for the locals. The study area is mostly covered with paddy field especially at the centre part of the Bayat and Gunung Kidul. The alluvium is also used by locals to grow various types of vegetables. There are also other plantation discovered in the study area such as teak trees, bamboo trees, banana trees, corn fields and sweet potatoes.

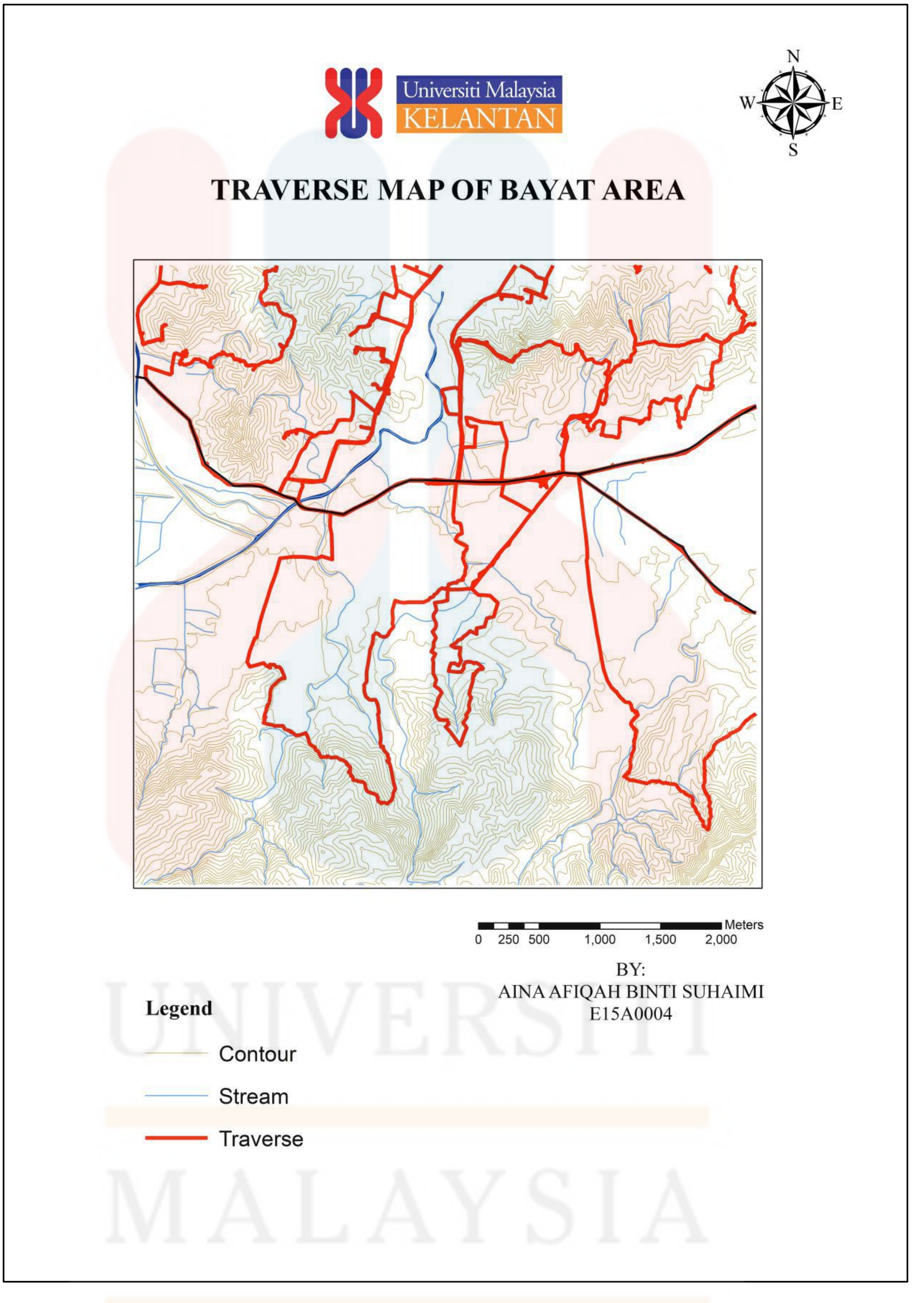


Figure 4.1: Traverse map of the study area.

4.2 GEOMORPHOLOGY

Geomorphology can be defined as the study of the physical features or landform such as hills, rivers and flat plains on the surface of land of the Earth (Hudgett R. J.). Landforms are Earth's observable features that can be found everywhere on Earth. Landforms are variable from a few factors such as size and lifespans. For the size factor, landforms could exist not only from molehills to mountains but also to massive plates of tectonics. The lifespans of landforms also vary from days to millenia and even to eons. In general, geomorphology is a scope of study that enquire into the landforms and its processes that leads to its formation. In order to have a firm understanding of genesis and evolution of any landform, the form, processes and the interconnection between them should be known.

4.2.1 Geomorphologic classification

Geomorphologically based on the elevation, the study area can be divided into two types of landforms that are flat plains and hilly areas. The study area is dominated by flat plains followed by the hilly areas. The hilly areas can be divided into two subclasses which are the second and the third subclass. It cannot be classified in the first subclass because the highest elevation in the study area does not exceed 500 meters above sea level.

Flat plains of the study area are located at the centre part. These flat plains are dominated by alluvial deposits. The alluvial plains in the study area are located in the centre part and they separate the two other landforms which are the Jiwo hills and the Southern Mountain. Other feature that can be found in the alluvial plain is alluvial fan. As the name implies, an alluvial fan is a fan-shaped or a cone-shaped sedimentary deposit that is built up by water bodies such as streams and rivers. However, if a fan originates from the flow of debris, it is usually called as a colluvial fan or a debris cone.

The hilly areas are located both in the north part and the south part of the study area. The highest elevation of this type of morphology is 487.5 m above sea level while the lowest elevation is 112.5 m above sea level. The hilly areas in the north part can be classified into two parts that are East Jiwo and West Jiwo. Both of these are classified under the Jiwo hills. East Jiwo and West Jiwo is separated by a river that is believed to be a newly developed river and known as the New Dengkeng River (Kali Dengkeng Baru).

Figure 4.2 shows a topography map that is classified based on its elevation. It can be classified into three types of topography namely, flat plains, second subclass of hill and third subclass of hill. As shown in the topography map, the study area is dominated by flat plains which have the elevation from 100 m to 180 m above sea level.

The hilly area with elevation from 180 m to 340 m can be classified as the third subclass of hill which presents a very smooth and gentle topography. The main characteristics of this type of landform are they possess a low slope gradient (8-15%) and low altitude. The shape and form are very irregular but generally can be considered as an undulating topography. These type of hills usually show broad rounded crests.

Hills with the elevation ranging from 340 m to 420 m can be classified as the second subclass of hill. The second subclass of hill embraces hills with a large variety of slope steepness., length, shape and lithology. The elevation is moderate ranging from 300 meters and above. Its slope gradient is very variable, ranging from moderate steep to sloping. Slopes are generally straight with rounded crests but the relief shape change very often according to the lithology. Hills on metamorphic and plutonic formations show sharp crests. Sedimentary hills usually have more smooth relief usually showing rolling topography. Accumulation of debris on the foot slopes are common.

A slope map is shown in Figure 4.3. Slope can be defined as a measure of steepness or the degree of inclination of a geological feature relative to the horizontal plane. Normally, slope is expressed as a percentage, an angle or a ratio. Therefore, a slope map portrays the degree of inclination of the slopes in the study area. By referring to the slope map, the slopes have been categorized into five classes of slope gradient that is expressed in percentage. The slope gradient classification is done by referring to the Van Zuidam slope classification as shown in the Appendix I. Based on the slope classification of Van Zuidam, majority of the study area is dominated by 0-2% of slope gradient which is classified as flat plains. The Jiwo Hills area at the north part of the study area is dominated by hills with slope gradient of 5-15% which is classified as medium slope. The Gunung Kidul area that is located due south of the study area, are dominated by hilly areas with slope gradient of more than 40% which is classified as steep slope.

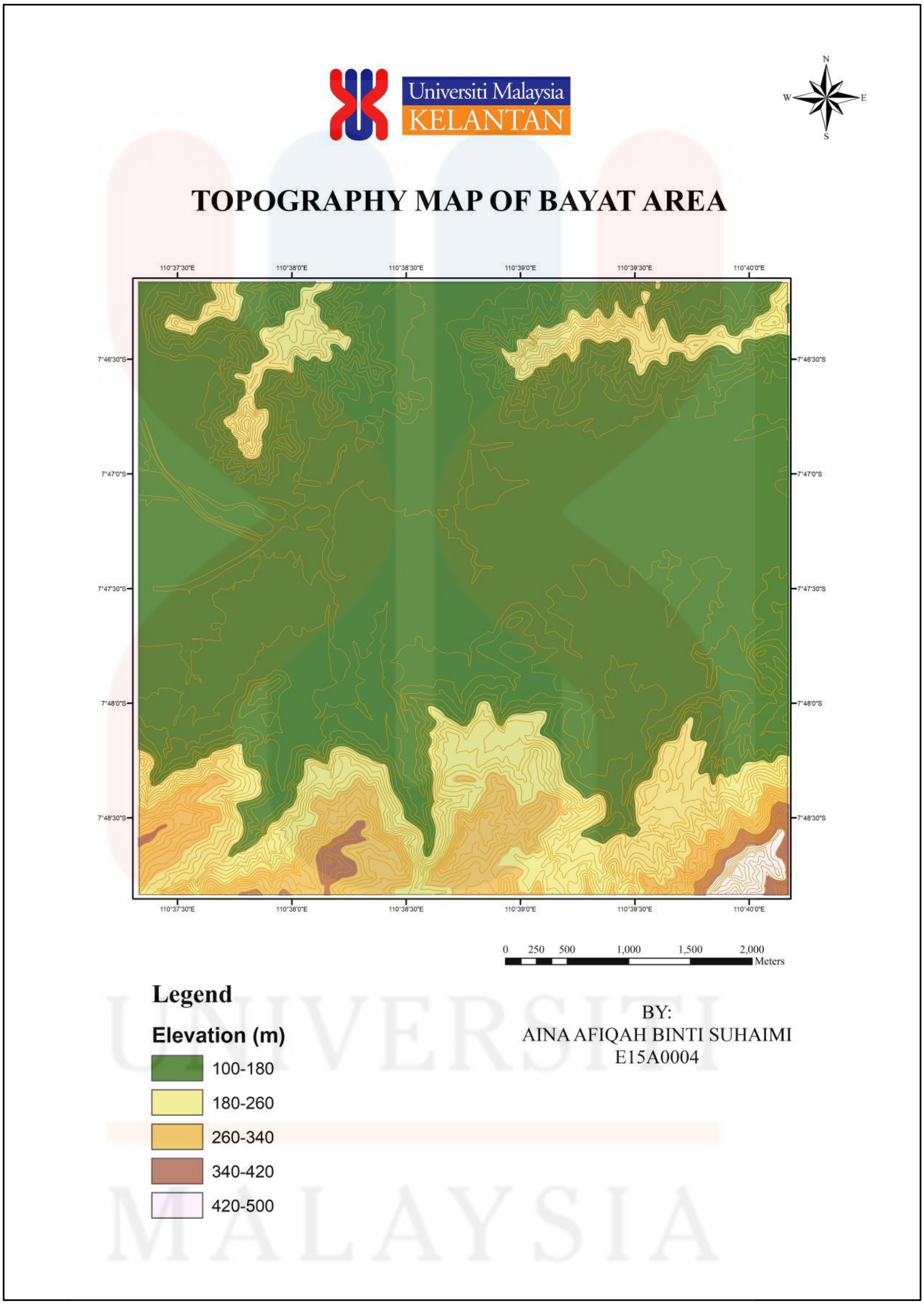


Figure 4.2: Topography map of the study area.

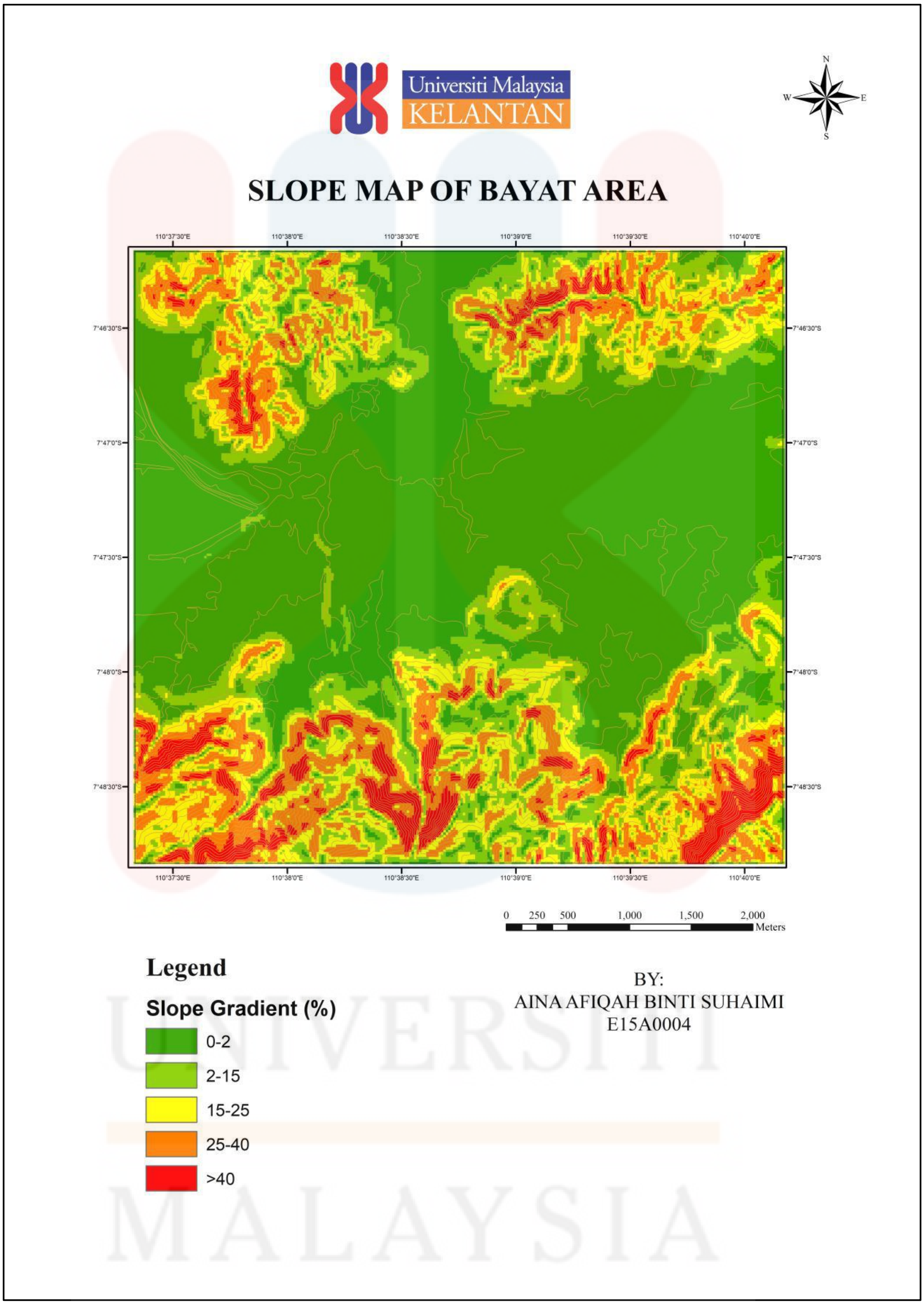


Figure 4.3: Slope map of the study area.

4.2.2 Weathering

In geology, weathering is a process of breaking down of rocks, soil and minerals as well as wood and artificial materials through contact with the Earth's atmosphere, water and biological organisms. Weathering occurs in situ which literally means it occurs in the same place, with little or no movement. Weathering is different from erosion as erosion involves the movement of rocks and minerals by agents such as water, ice, snow, wind, waves and gravity which are then transported and deposited in other locations.

Generally, weathering process can be distinguished into three types on the basis of nature of agencies which bring about weathering. The three types of weathering are physical weathering, chemical weathering and biological weathering. Physical weathering of rocks is a mechanical process which is brought by a number of factors, such as temperature, wind and water. The temperature factor causes breakdown of rocks in several ways such as differential expansion, exfoliation and frost action. The water factor causes breakdown of rocks in several ways like rain, running water, wave action, glacier formation and wind.

The second type of weathering is chemical weathering. Chemical weathering causes disappearance of original rock minerals either completely or partly. In this process, secondary products may be formed from the protoliths. Presence of moisture and air is very essential in chemical weathering hence it is less effective in deserts. Examples of chemical weathering are solution, hydrolysis, oxidation, reduction, carbonation and hydration.

Last but not least is the biological weathering. Biological weathering can be defined as the weakening and subsequent disintegration of rock by plants, animals and also microbes. In fact, many organisms play important roles in the weathering of rocks through physical and chemical means. Important organisms that are concerned with the decomposition of rocks are lichens, bacteria, fungi, plants, nematodes and other soil microbes. Lichens and some other organisms with the presence of moisture will secrete carbonic acid which will eventually corrodes the rock.

In the study area, the common type of weathering that can be discovered is biological weathering and chemical weathering. Most outcrops especially in the forest areas are biologically weathered. The presence of roots on the surface of rock exerts a considerable pressure by which rocks are broken down into smaller fragments. The root exudates which are secreted by the plants also weaken the rocks and weather them into a smaller extent. Figure 4.4 shows an example of biological weathering found in the study area.

Figure 4.4: Biological weathering in the study area.

The second type of weathering found in the study area is chemical weathering. The specific name of this chemical weathering is spheroidal weathering. This spheroidal weathering is discovered in the igneous intrusion area. Spheroidal weathering can be defined as a type of chemical weathering that occured in bedrocks that has joints which then results in the formation of layers of extremely weathered rock that is commonly spherical or concentrical in shape.

This formation is known as saprolite. Further physical erosion that acted on the saprolite will then cause the concentric layers to peel off as concentric shells that looks like a peeled onion hence, spheroidal weathering are commonly known as onion skin weathering. Rounded boulders that is also called corestones are usually the result of this type of weathering. Figure 4.5 shows the corestones of the spheroidal weathering and Figure 4.6 shows the image of the result of physical erosion of the spheroidal weathering that were taken on field. This spheroidal weathering is commonly occurred in diabase or diorite in the study area. Its occurrence is in jointed rocks that contains plagioclase. When plagioclase reacted with water, clay mineral is formed and this leads to the construction of weathering layers that looks like an onion skin.

Figure 4.5: Corestone of the spheroidal weathering in the study area.

Figure 4.6: Weathered layers that look like an onion skin.

4.2.3 Drainage pattern

Drainage systems vary in every area. An area drained by a single river is called its drainage basin. The main river of an area along with its tributaries forms a drainage pattern. Theoretically, the pattern that is formed dependent on the relief and the rocks that make up the surface of the area.

In the study area, there are two divergent drainage patterns that can be found as shown in Figure 4.7. The first drainage pattern found in the study area is the dendritic drainage pattern. A dendritic drainage pattern occurs when the tributary systems subdivides headway like the limbs of a tree. These patterns usually form in horizontal sedimentary or in intrusive igneous rocks where the rock mass is reasonably homogeneous. The study area is dominated by dendritic drainage pattern. Dendritic drainage pattern can be found in the centre part of the study area.

The second drainage pattern in the study area is the rectangular drainage pattern. This pattern is sometimes called as rectangular dendritic or angular dendritic. It is a modified version of the dendritic pattern, characterized by abrupt, close to 90 degree, changes in stream direction and distinct obtuse or acute angles of stream juncture. This pattern is usually caused by jointing or faulting of the underlying bedrock, it is usually associated with massive, intrusive igneous and metamorphic rocks. It is discovered at the west side of the study area. This rectangular drainage pattern can be found on the west side of the study area.

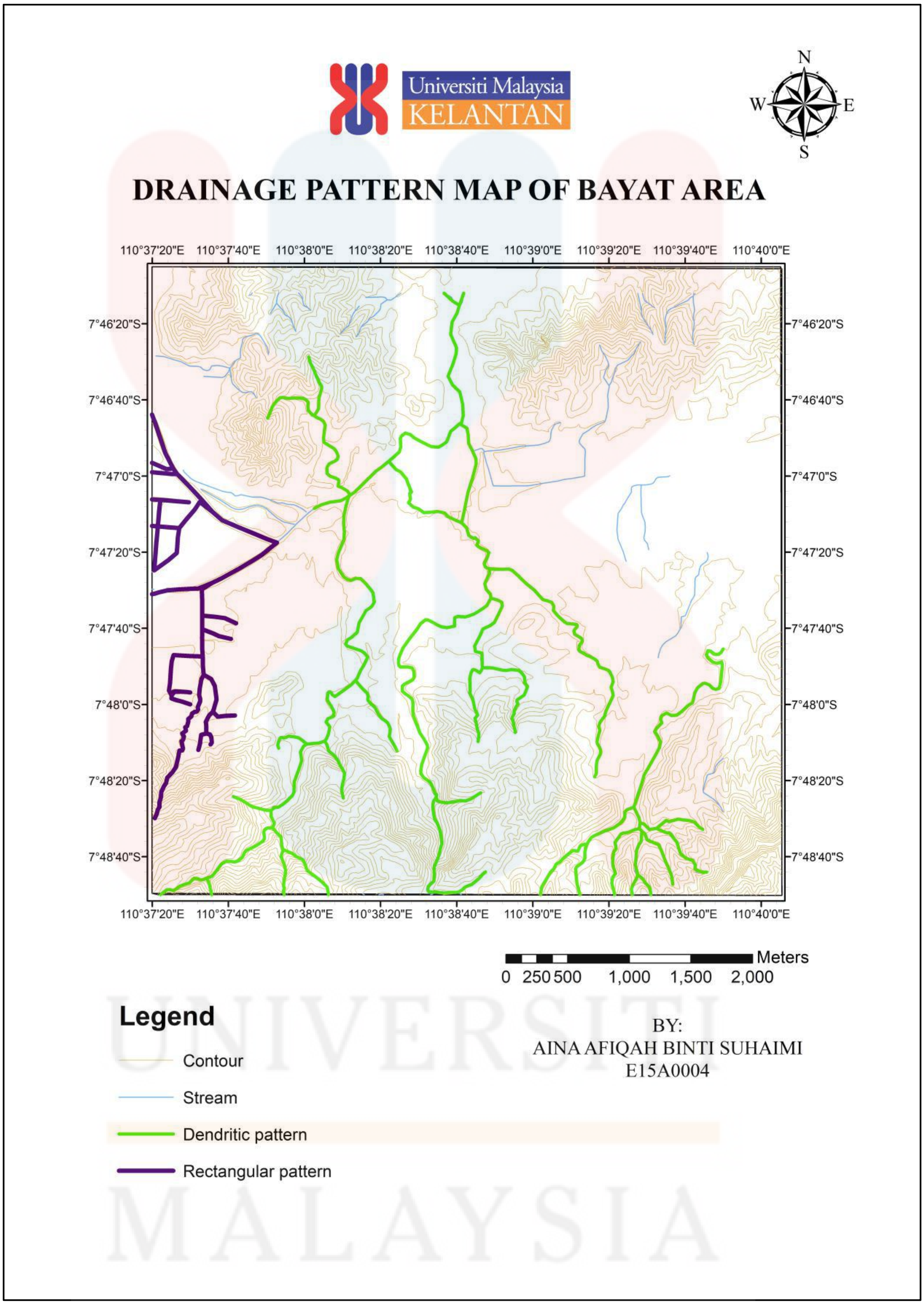


Figure 4.7: Drainage pattern map of the study area.

4.3 STRATIGRAPHY

4.3.1 Rock Unit

Stratigraphy is a branch of geology which studies rock layers that is geologically known as strata and layering also known as stratification. It is primarily used in the study of sedimentary and layered volcanic rocks. Stratigraphy has two related subfields that are lithologic stratigraphy or lithostratigraphy, and biologic stratigraphy or biosratigraphy. A stratigraphic column is a representation used in geology and its sub-field of stratigraphy to describe the vertical location of rock units in a particular area. A typical stratigraphic column shows a sequence of sedimentary rocks, with the oldest rocks on the bottom and the youngest on top.

In the study area, the schist-phyllite unit is the oldest rock unit that is aged in Early Oligocene in the period of Paleogene. The second oldest rock unit in my study area is the tuffaceous sandstone unit that is aged roughly around Early Oligocene followed by the younger volcanic clastic sandstone unit that is aged on the Late Oligocene. The igneous rock intrusion that occurs in the Jiwo hills are said to be aged in the Middle Miocene. The youngest rock unit in the study area belongs to quarternary deposits that are the alluvium deposits.

Schist-phyllite unit is dominantly found in the north part of the study area. The Jiwo Hills area are dominated by this unit. The schist-phyllite unit differs by the mineral content. As for the schist, it can be generally divided into three namely, mica schist, chlorite schist and graphite schist. In the schist-phyllite unit, the outcrops are dominated by low-grade metamorphic rocks. The common metamorphic rocks found in the area are phyllite, mica schist and marble. Foliation is a common structure found in this unit. The schist-phyllite outcrop is normally grey to dark brown in colour with fine to medium-grained texture. Figure 4.8 shows an outcrop in the schist-phyllite unit. The schist-phyllite unit also comprises of igneous rock intrusion that are interpreted as diorite. Figure 4.9, 4.10 shows the hand samples of schist and marble respectively.

Figure 4.8: Outcrop in a schist-phyllite unit.

Figure 4.9: Hand sample of a schist.

Figure 4.10: Hand sample of a marble**.**

The second oldest rock unit in the study area is tuffaceous sandstone unit. Tuffaceous sandstone can be found at the east side of the study area. This tuffaceous sandstone unit is classified under the Nampurejo Member. Nampurejo Member is a member of Kebo Formation with dominant lithology of tuffaceous sandstone and tuff, intercalated with diorite. The grains are composed of volcanic fragments, quartz and plagioclase. Figure 4.11 shows an outcrop dominated by tuffaceous sandstone and Figure 4.12 shows the hand sample of tuffaceous sandstone.

Figure 4.11: Outcrop in tuffaceous sandstone unit.

Figure 4.12: Hand sample of a tuffaceous sandstone

The volcanic clastic sandstone unit is the third oldest unit of rock found in the study area. It is discovered in the south part of the study area underlying the sandstone unit that is in the Gunung Kidul Regency. The volcanic clastic sandstone unit is dominated with coarse-grained sandstone with intercalation of siltstone, tuff and volcanic breccia. Figure 4.13 shows the image of an outcrop found in the volcanic sandstone unit in the study area while Figure 4.14 shows a hand sample of a volcanic sandstone.

Figure 4.13: Outcrop in volcanic clastic sandstone unit.

Figure 4.14: Hand sample of a volcanic clastic sandstone.

Next is the sandstone unit which is the fourth oldest rock unit in the study area. It is discovered at the south part of the study area overlying the volcanic clastic sandstone unit. The sandstone unit is dominated with alternation of sandstone and siltstone, that is intercalated with claystone and tuff. The grain size of the sandstone is ranged from fine-grained to very fine-grained. Figure 4.15 shows the outcrop found in the sandstone unit and Figure 4.16 shows the hand sample of the sandstone.

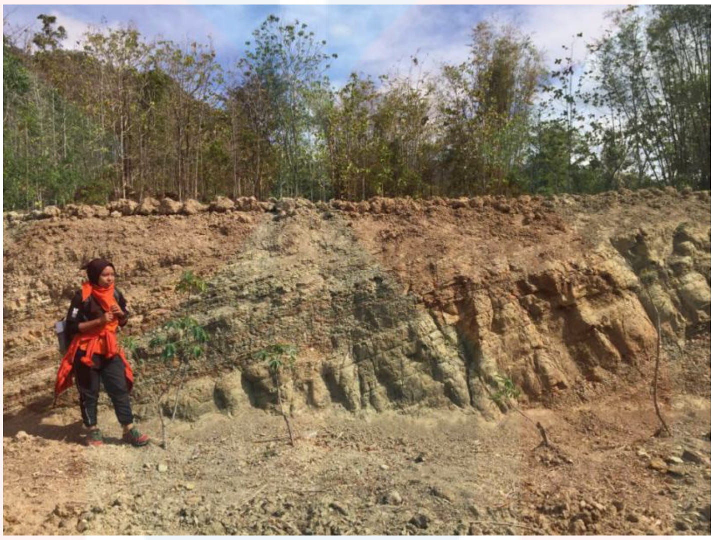


Figure 4.15: Outcrop in sandstone unit.

Figure 4.16: Hand sample of a sandstone.

The younger rock unit than all the four rock units mentioned is the diorite unit. This unit is an igneous intrusion that occurred in the study area and it is interpreted to be diorite. This unit is dominantly made of speckled black and white in colour but is usually dark-coloured. Diorite is holocrystalline with phaneritic texture. Plagioclase and hornblende are commonly the main phenocryst. Figure 4.17 shows the outcrop of the diorite unit and Figure 4.18 shows a hand sample of a diorite.

Figure 4.17: Outcrop in diorite unit.

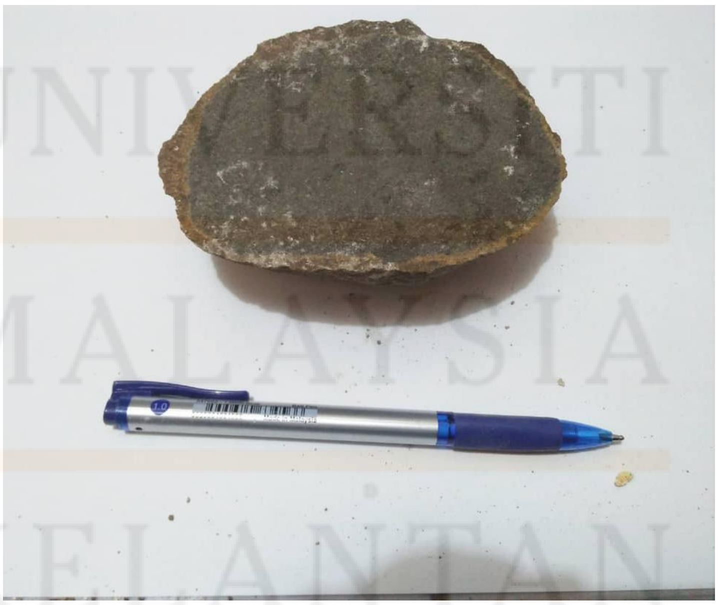


Figure 4.18: Hand sample of a diorite.

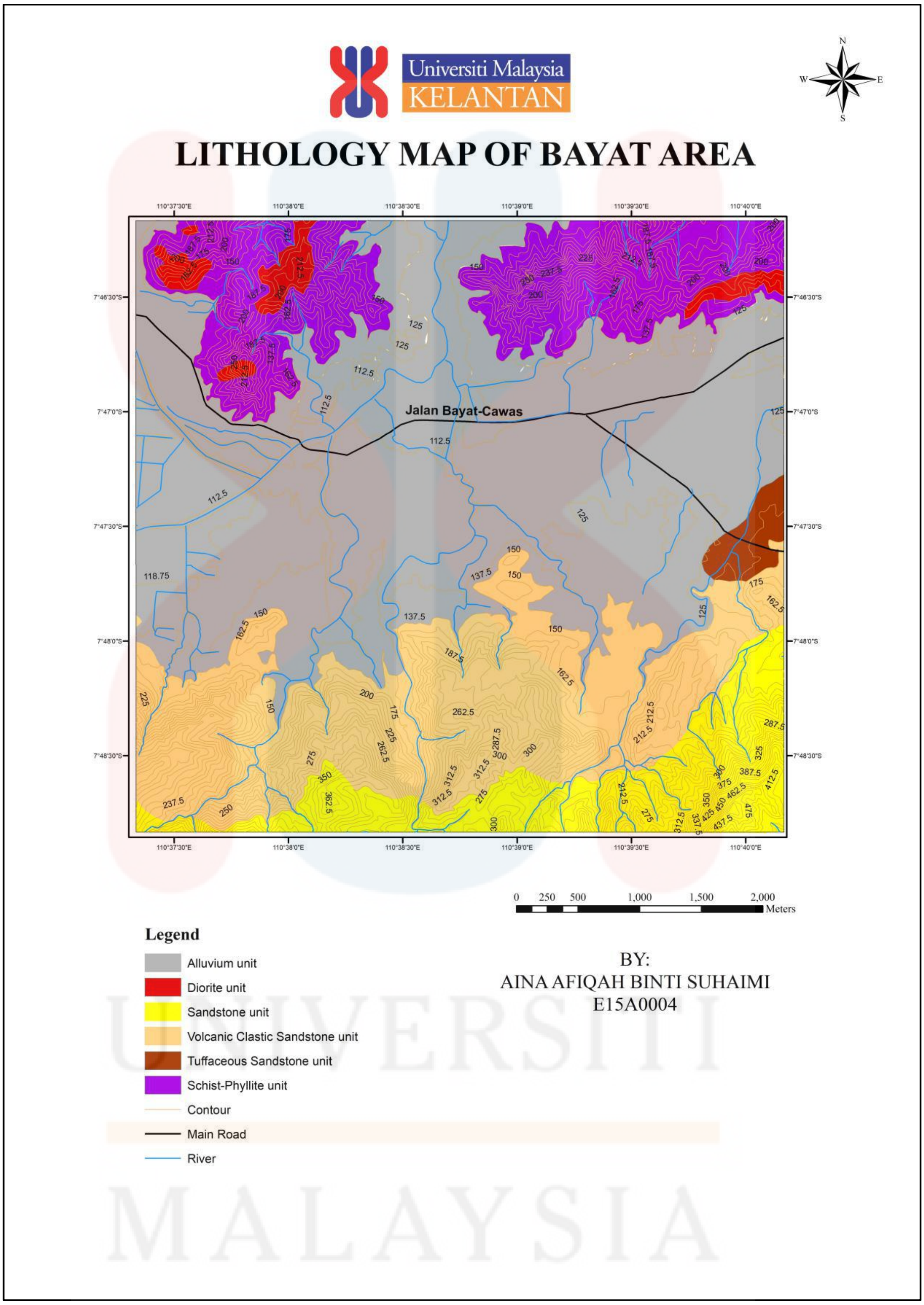


Figure 4.19: Lithology map of the study area.

4.3.2 Stratigraphy column

A stratigraphic column can be defined as a representation used in geology and its sub-field of stratigraphy to describe the vertical location of rock units in a particular area. A stratigraphic column is constructed to study the chronological sequence of scattered strata of different places and to interpret the geological history of the Earth as a whole from the forgoing data. The bottom part of a stratigraphic column starts from the oldest rock unit followed by the younger rock unit above it. Stratigraphic column follows the younging order in which within normal sedimentary strata, the lower bed is older than the upper bed. Figure 4.20 shows the stratigraphic column of the study area that is constructed by using the software CorelDRAW X7.

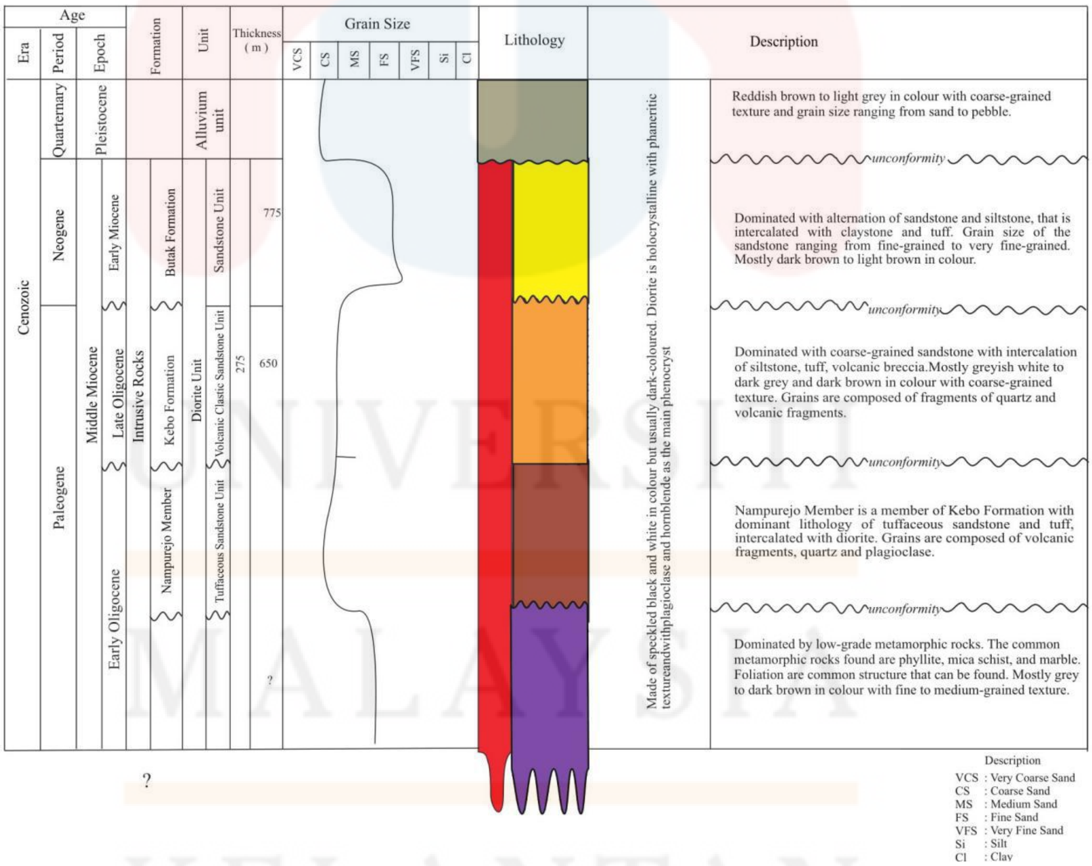


Figure 4.20: Stratigraphic column of the study area.

4.3.3 Petrographic analysis

Petrographic analysis is an analysis done in the laboratory by using a petrographic microscope. A petrographic microscope is a type of optical microscope that is widely used especially in petrology in order to identify the minerals in thin sections that will somehow helps to identify the type of rocks. The thin sections are observed under cross polarized light (XPL) and plane polarized light (PPL) under various magnifications such as 4X10 and 10X0.25.

The petrographic microscope provides two types of polarized light that are the plane-polarized light and cross-polarized light. As the name implies, the plane-polarized light (PPL) means the light that is used has a plane polarization that is caused by a polarizer. When light interacts with a provided thin section, the polarization of certain fraction of light may change which then results in scattering of minerals. As soon as the cross-polarized light (XPL) is used after the PPL, the real PPL will be distinguisehd and will be replaced with the light that has a perpendicular orientation. Figure 4.21 below shows an image of petrographic microscope with the label of its body parts. Table 4.1, 4.2 and 4.3 shows the petrographic analysis for schist, tuffaceous sandstone and volcanic clastic sandstone respectively.

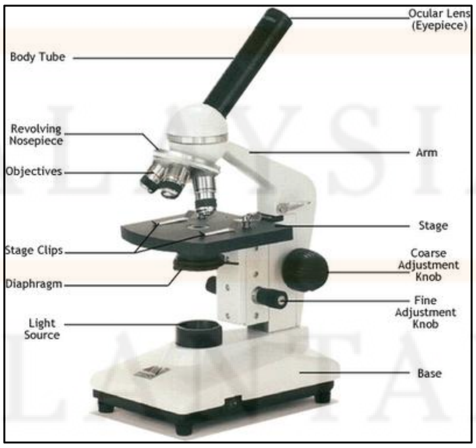


Figure 4.21: A labeled image of petrographic microscope

Table 4.1: Petrographic analysis of schist.

Location	:	Jiwo Hills
Rock Name	:	Schist
Colour	:	Greyish-white
Texture	:	Coarse-grained, sparkling
Mineral		Description
Chlorite	:	Chlorite is pleochroic usually colourless, pale green. Twinning is common but often difficult to recognize.
Biotite	:	Under PPL, biotite is usually dark green, brown, or black, has a pale brown color. Similar to muscovite, biotite displays high interference colors in XPL.
Quartz	:	The rollover displays the same grain under plane polarized light. Poor cleavage is visible in both polarized light.
Opaque	:	Appears in black colour in both XPL and PPL. It has an anhedral shape with a high relief and no pleochroism.
Description The thin section has a colour of greyish white incision and it also has the green colour due to the presence of chlorite. This rock has a hypocrystalline texture where it consists of a mixture of crystals and glass. This rock has an obvious sets of foliation. The minerals are elongated on the foliation. The minerals that can be interpreted from the observation are feldspar, chlorite, quartz, biotite and opaque minerals. This rock is interpreted as schist.		
Photo		

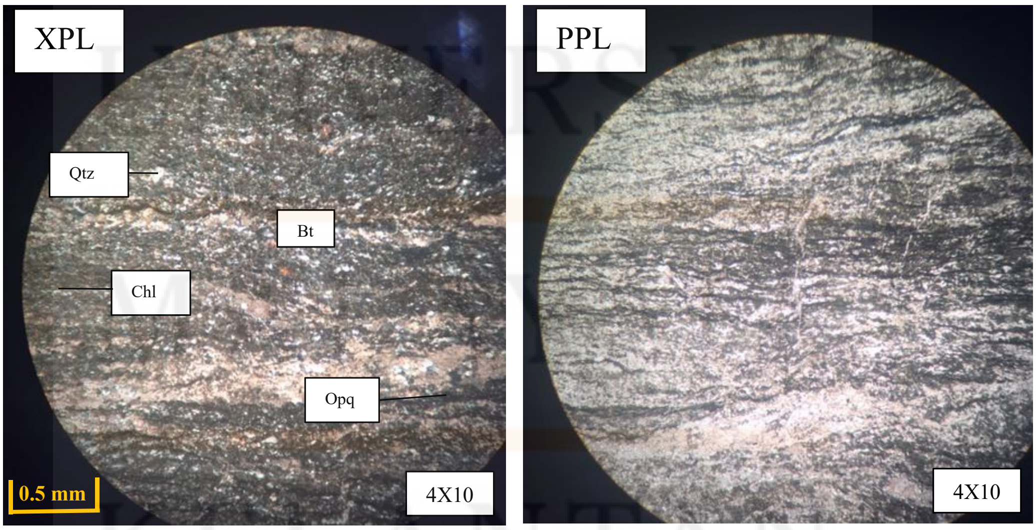
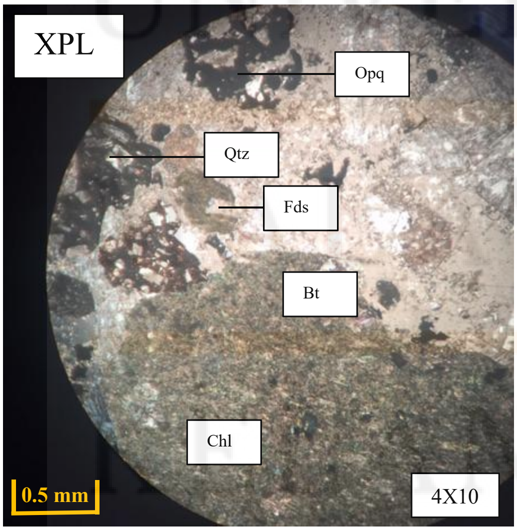


Table 4.2: Petrographic analysis of tuffaceous sandstone.

Location	:	Nampurejo Member
Rock Name	:	Tuffaceous sandstone
Colour	:	Dark green and brown
Texture	:	Fine-grained
Mineral		Description
Chlorite	:	Chlorite is pleochroic usually colourless, pale green. Twinning is common but often difficult to recognize.
Feldspar	:	Under XPL, feldspar colour is mostly greyish white. Yellow interference colours generally imply a thick section. No twinning.
Biotite	:	Under PPL, biotite is usually dark green, brown, or black, has a pale brown color. Similar to muscovite, biotite displays high interference colors in XPL.
Quartz	:	The rollover displays the same grain under plane polarized light. Poor cleavage is visible in both polarized light.
Opaque	:	Appears in black colour in both XPL and PPL. It has an anhedral shape with a high relief and no pleochroism.
Description The thin section has a colour of green and brown incision and it has a hypocrystalline texture where it consists of a mixture of crystals and glass. The minerals that can be interpreted from the observation are chlorite, feldspar, biotite, quartz and opaque minerals. Since this rock is tuffaceous, it also consists of volcanic ash which originates from the Mount Merapi. This rock is interpreted as tuffaceous sandstone.		
Photo		



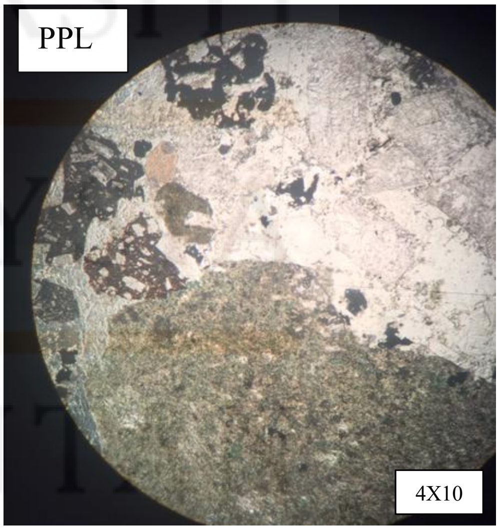


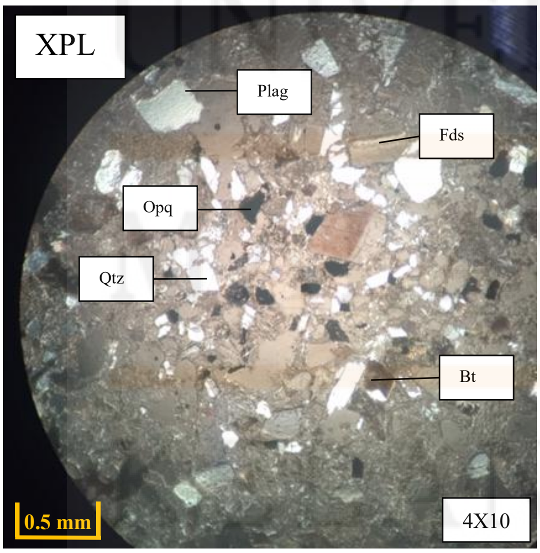
Table 4.3: Petrographic analysis of volcanic sandstone.

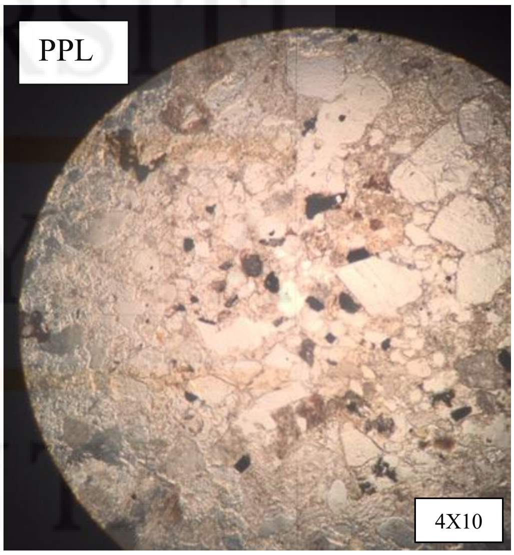
Location	:	Gunung Kidul (Kebo Formation)
Rock Name	:	Volcanic sandstone
Colour	:	Dark brown
Texture	:	Coarse-grained
Mineral		Description
Feldspar	:	Under XPL, feldspar colour is mostly greyish white. Yellow interference colours generally imply a thick section. No twinning.
Biotite	:	Under PPL, biotite is usually dark green, brown, or black, has a pale brown color. Similar to muscovite, biotite displays high interference colors in XPL.
Quartz	:	The rollover displays the same grain under plane polarized light. Poor cleavage is visible in both polarized light.
Plagioclase	:	Appears shiny and greyish in colour under XPL.
Opaque	:	Appears in black colour in both XPL and PPL. It has an anhedral shape with a high relief and no pleochroism.

Description

The thin section has a colour of brown incision and it has a hypocrystalline texture where it consists of a mixture of crystals and glass. The minerals that can be interpreted from the observation are feldspar, biotite, quartz, magnetite and opaque minerals. Since this rock is volcanic, it also consists of volcanic ash which originates from the Mount Merapi. This rock is interpreted as volcanic sandstone.

Photo





4.4 STRUCTURAL GEOLOGY

Structural geology is the study of the three-dimensional distribution of rock units with respect to their deformational histories (Twiss et al,.). The main objective of structural geology is to use the geometry measurements of the present-day rock in order to discover the information about the deformation history of the rocks. The geometry measurements are important for classifying the flow paths followed by particles during deformation. Due to the deformation that occurred on Earth, structural geology is also important to understand the stress field that is a result of the observed strain and geometries. The understanding of the dynamics of the stress field is somehow important in knowing the important past events. When the past geologic events are known, it is easier to understand the evolution of structural geology in a particular area.

A lineament is a linear feature in a landscape which is an expression of an underlying geological structure such as a fault. Typically a lineament will comprise a fault-aligned valley, a series of fault or fold-aligned hills, a straight coastline or indeed a combination of these features. Fracture zones, shear zones and igneous intrusions such as dykes can also give rise to lineaments (Twiss et al,.). Lineaments are often apparent in geological or topographic maps and can appear obvious on aerial or satellite photographs.

There are plenty of geological structures that can be found in the study area. In the north part of the study area that is the Jiwo hills area that is dominated by metamorphic and igneous rocks, structures such as foliation and veins are very common. As for the south part of the study area that is the Gunung Kidul area, the common geological structures are bedding, lamination, joints and fault.

A) Foliation

At the north side of the study area that is dominated by metamorphic type of rock which is the schist-phyllite unit, foliations can be easily found on the outcrops. Foliation is defined as a pervasive planar structure that results from the nearly parallel alignment of sheet silicate minerals and or compositional and mineralogical layering in the rock (Nelson S. A.). In simpler words, it can also be defined as monotonous layers found in metamorphic rocks. Usually, the formation of foliation is due to shear force or differential pressure. Shear forces are pressures that act on body of rock which pushes different sections of the rock in different directions. On the other hand, differential pressure occurs when the pressure coming from one direction is higher than the others which means the layers that are formed is in parallel to the shear direction or perpendicular to the direction of higher pressure. The study area is dominated by foliated metamorphic rocks due to the series of deformation that acted on the area. Figure 4.22 shows the foliation found on metamorphic rocks in study area.

Figure 4.22: Foliation on metamorphic rocks in the study area.

B) Bedding

Other structural geology that can be discovered in the study area is bedding. Bedding is a sedimentary structure that separates the sediments into layers that differ in several factors such as textures, colour, composition, weathering characteristics or by partings that is the small gaps between adjacent beds (Earle S.). In the lithostratigraphic unit classification, a bedding is classified as the smallest unit of division. The size of bedding vary from a centimetre to several metres. A layer of bed is distinguishable from the layers above and below it by the type of rock, the mineral content and also the size of particle. The “bedding” term is usually used to describe sedimentary strata but however, it is acceptable for volcanic flows or layers of ash. The existence of bedding acts as an indicator of the changes in depositional processes that occurred in a specific location. In the study area, bedding is commonly found in the Southern Mountain as it is dominated by sedimentary and volcanic rocks. Figure 4.23 shows the sedimentary bedding in study area.

Figure 4.23: Sedimentary bedding in the study area.

C) Fault

On top of that, fault can also be found in the study area. Fault, in geology, is a planar or gently curved fracture in the rocks of the Earth's crust, where compressional or tensional forces cause relative displacement of the rocks on the opposite sides of the fracture (Rafferty J. P.). Faults vary in length that ranges from a few centimetres to many hundreds of kilometres, and various displacement ranging from less than a centimetre to several hundred kilometres along the fracture surface that is known as the fault plane. In some cases, the movement is spread over a fault zone that is made up of individual faults that occupy a belt that is hundreds of metres wide. The geographic spreading of faults also vary due to tectonic movements causing some large areas may have none and some other areas are disturbed by numerous faulting. Faults may also vary in its direction due to the forces acting on it. Faults may be vertical, horizontal or inclined at any angle.

There are two types of faults that are found in the study area and they are normal fault and reverse fault. Normal fault and reverse fault are known as dip-slip faults. They experience vertical movement, in line with the dip of the fault. They are identified by the relative movement of the hanging wall and foot wall. In a normal fault as shown in Figure 4.24, the hanging wall moves downwards relative to the foot wall. They are caused by extensional tectonics. This kind of faulting will cause the faulted section of rock to lengthen. In a reverse fault as shown in Figure 4.25 the hanging wall moves upwards relative to the foot wall. They are caused by compressional tectonics. This kind of faulting will cause the faulted section of rock to shorten.

Figure 4.24: A normal fault found in study area.

Figure 4.25: A reverse fault found in study area.

D) Vein

A vein or a quartz vein to be exact is a distinct sheetlike body of crystallized quartz within a rock. Veins form when mineral constituents carried by an aqueous solution within the rock mass are deposited through precipitation. The hydraulic flow involved is usually due to hydrothermal circulation. Veins are classically thought of as being the result of growth of crystals on the walls of planar fractures in rocks, with the crystal growth occurring normal to the walls of the cavity, and the crystal protruding into open space. This certainly is the method for the formation of some veins. However, it is rare in geology for significant open space to remain open in large volumes of rock, especially several kilometers below the surface. Thus, there are two main mechanisms considered likely for the formation of veins which are open-space filling and crack-seal growth. Figure 4.26 shows the quartz vein found in Jiwo Hills part of the study area.

Figure 4.26: Quartz vein found in Jiwo hills area.

E) Joint

A joint is a fracture dividing rock into two sections that have not moved away from each other. A joint sees little or no displacement. Joints push out in various directions, usually vertically. They can have smooth, clean surfaces, or they can be scarred from sliding against another joint. Joints usually occur as sets, with each set made up of joints that are parallel to each other. Figure 4.27 shows an underground outcrop that is located in the upper part of the Gunung Kidul that consists of a series of joints. Table 4.4 shows the joints data collected on field. Figure 4.28 shows a rose diagram constructed that interprets the force that acted on the outcrop that results in the deformation of the outcrop. The rose diagram was plotted by using a geological software called GeoRose. Based on the rose diagram, it can be said that the pressure and tectonic forces came mostly from the northeast side at the angle of 15°. The highest force is concluded as sigma 1 ($\sigma 1$). Sigma 3 ($\sigma 3$) will always be perpendicular to sigma 1 hence, sigma 3 is interpreted coming from the northwest side.

Figure 4.27: Joints that are found on an outcrop in Gunung Kidul.

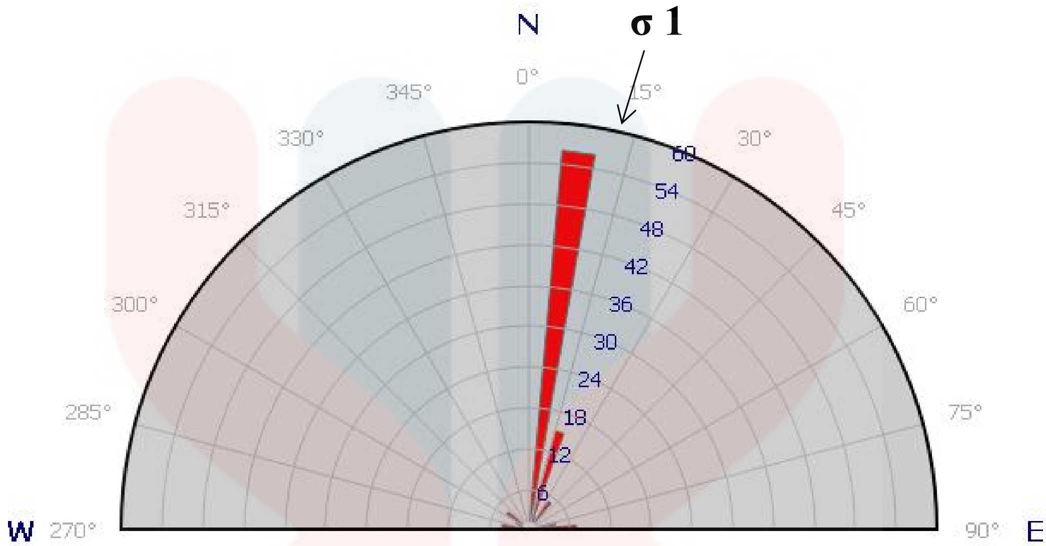


Figure 4.28: Rose diagram of the joints data collected on field.

Table 4.4: Joints data collected on field.

Range	**Frequency**
181-190	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ I
191-200	~~IIII~~ ~~IIII~~ ~~IIII~~
201-210	II
211-220	~~IIII~~
251-260	IIII
261-270	~~IIII~~ II
271-280	IIII
281-290	I
291-300	II
301-310	~~IIII~~

4.5 HISTORICAL GEOLOGY

The study area covers two specific areas that are Bayat and Gunung Kidul. Jiwo Hills is located in Bayat and Gunung Kidul is also known as Southern Mountain. Historically, the building of Jiwo Hills was generated by uplifted basement rocks and Jiwo Hills also have undergone a few series of intrusion of igneous rock bodies. Metamorphic rocks like schist, phyllite and marble are common and mostly made up the basement of Jiwo Hills. Among these three metamorphic rocks, it can be said that phyllites are the most predominant rocks found in the area but typically they are highly weathered. Quartz veins and calcite veins are commonly found elongating in their foliations. According to Bothé (1929), the age of the basement rocks are assumed to be at the age of Cretaceous based on a finding of a large foraminifera fossil, Orbitolina in the area.

Wungkal-Gamping Formation is a formation that overlies these basement rocks. As the name implies, Wungkal-Gamping Formation consists of two different members, namely the Wungkal Member that is located at the bottom part and the Gamping Member that is located above it. However after a very long time, the Wungkal-Gamping Formation is gradually replaced by the Kebo-Butak Formation. The lithology at the bottom part of the Kebo-Butak Formation are mostly composed of sedimentary rocks such as sandstone, claystone, siltstone and also tuffaceous sandstone. This lithology is dominantly found in Gunung Kidul. According to a research done by Husein and Sari (2011) that discovered some fragments of basaltic pillow lava at the bottom part of this formation, it is interpreted that magmatic activities has occurred during the deposition of Kebo-Butak Formation. The many series of igneous intrusion that occurred in Bayat are said to produce diabase, diorite and andesite (Surono et al., 2006).

CHAPTER 5

RESISTIVITY STUDY FOR GROUNDWATER POTENTIAL

5.1 INTRODUCTION

The title of specification for this Final Year Project is "Resistivity Study for Groundwater Potential in Gunung Kidul, Yogyakarta, Indonesia". As the title implies, the method that is used for this study is 1-D electrical resistivity method that is called Vertical Electrical Sounding (VES). Vertical electrical sounding method is one of the most commonly used method in geophysical survey especially for groundwater exploration. Generally, this method is used to describe the condition beneath the Earth surface by identifying the resistivity value from every layer of rock inside the Earth as every distinct rock layer possess different resistivity values. Electrical energy is flowed into the Earth layer through two potential electrodes. The resistivity values can be calculated by knowing the value of the potential energy supplied.

The basis of this method is the Earth is assumed to be isotropically homogenous. By applying this assumption, the resistivity value obtained is the real resistivity value and is not dependent on the electrode spacing. The data that is obtained on field are the resistivity values beneath the Earth surface. Vertical electrical sounding (VES) method is applied by using an artificial electrical current that is injected into the Earth through the electrodes. By applying this very method, it is able to produce a variation of change in resistivity values both horizontally and vertically hence, this method is highly effective for explorations conducted in a shallow environment.

In vertical electrical sounding method, there are two measuring techniques namely, electrical resistivity mapping and sounding (drilling). Electrical resistivity mapping method is to study the variation of resistivity values of the distinct layers beneath the Earth surface horizontally. Therefore, this method is set up by using a fixed distance of electrode spacing for all of the sounding points on the Earth surface. The electrical resistivity sounding technique is conducted to study the variation of rock resistivities vertically hence, it is also called as vertical electrical sounding (VES). The measurement at one sounding point is conducted by changing the electrode spacing accordingly from time to time. The electrode spacing begins with a small spacing and it will be increased gradually. Figure 5.1 below shows the cross section of how the potential and electrical energy spreads beneath the surface that explains the concept of Vertical Electrical Sounding (VES) method. Figure 5.2 shows the electrode spacing for 1-D Schlumberger array by using vertical electrical sounding method. Figure 5.3 shows two images of euipment setup on field.

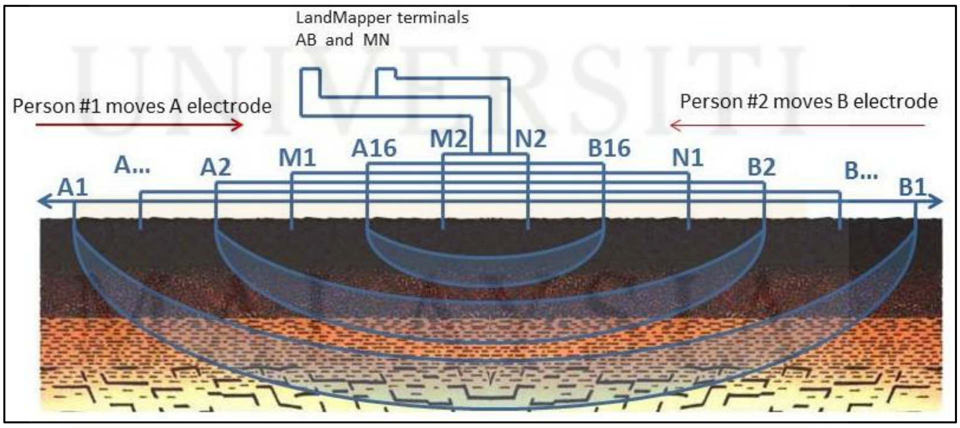


Figure 5.1: Cross section of the spreading of electrical and potential energy using VES.

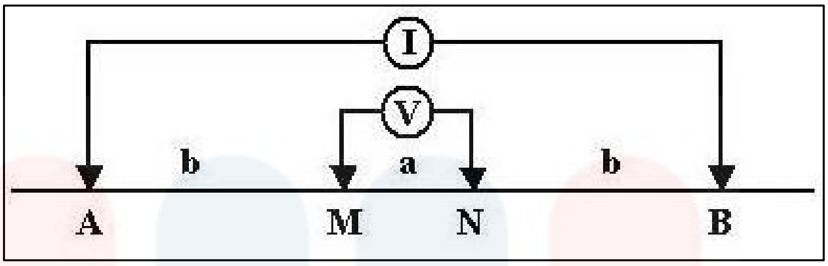


Figure 5.2: Electrode configuration for 1-D Schlumberger array for VES.

Figure 5.3: Equipment setup on field.

5.2 FIELD DATA AND INTERPRETATION

Three resistivity lines were set up in three distinct location in Tancep, Gunung Kidul. The first line labelled as P1 is set up at the coordinates of 7°48'15.45" and 110°40'27.75" while the second line, P2 is set up at 7°48'17.82" and 110°40'24.56". the last resistivity line, P3 is set up at the coordinates of 7°48'11.32" and 110°40'30.97". All of these three resistivity lines are approximately in parallel to each other. The raw data of each line P1, P2 and P3 that were collected on field are shown in Appendix II, Appendix III and Appendix IV.

After the complete data is collected from field, all of the data will be transferred into the PROGRESS v 3.0 software. The software will display the data in the form of graph. The bad datum or bad data that is detected by the software will be eliminated in order to get the most minimum root mean square (RMS) that cannot exceed 10% for each line. The bad datum may be caused to several factors such as noise from the surroundings and other technical problems. Once the data has achieved the desirable root mean square it will display a resistivity profile that indicates the layers beneath the surface with its resistivity reading. The data that has been processed by the software for line P1, P2 and P3 are shown in Appendix V, Appendix VI and Appendix VII respectively.

Based on the interpretation by referring to the resistivity profile of line P1, the layers of rock can be classified into eight layers. The first layer which is at 0m depth, the interpreted lithology is sandstone with the resistivity value of 13.64 Ωm. The second layer is classified as siltstone at 3.86 m depth and resistivity 2.65 Ωm. At depth 6.69 m beneath the Earth surface, sandstone is discovered with the value of resistivity 13.71 Ωm. Siltstone is discovered at depth 17.12 m until 25.47 m with the resistivity values ranging from 0 Ωm to 10 Ωm. Groundwater potential is located at depth 34.49 m with the value of resistivity 18.11 Ωm and it is considered as a shallow potential aquifer. Tuffaceous sandstone is discovered at depth 58.34 m until 88.75 m with high resistivity values ranging from 50 Ωm to 100 Ωm. Table 5.1 shows the data interpreted for line P1 and Figure 5.4 shows the resistivity profile for line P1.

Table 5.1: The data interpretation for line P1.

Layer	Depth (m)	Resistivity (Ωm)	Lithology
1	0.00	13.64	Sandstone
2	3.86	2.65	Siltstone
3	6.69	13.71	Sandstone
4	17.12	7.50	Siltstone
5	25.47	1.85	Siltstone
6	34.49	18.11	Groundwater potential
7	58.34	61.46	Tuffaceous sandstone
8	88.75	75.55	Tuffaceous sandstone

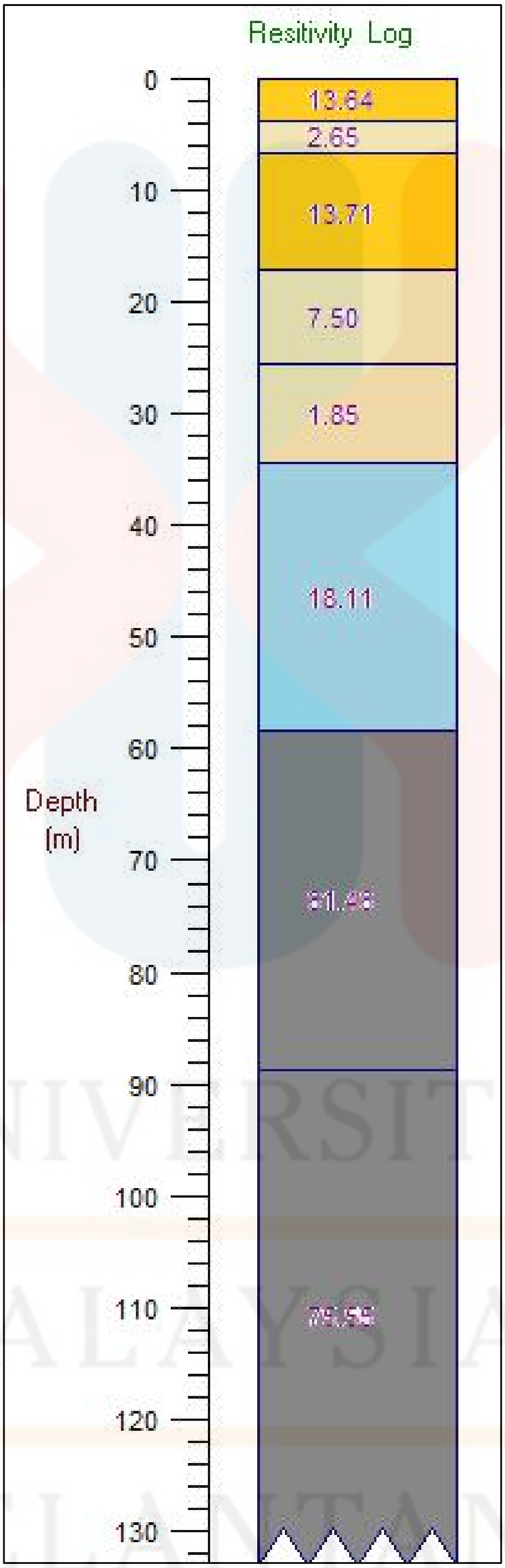


Figure 5.4: Resistivity profile for line P1.

As for resistivity line 2 that is labeled as point P2, at depth 0 m with resistivity value of 7.20 Ωm, the lithology is interpreted as siltstone. The second layer at depth 1.54 m, it can be said as fresh water potential with 18.29 Ωm resistivity value. It is not considered as groundwater because it is located near the Earth surface and very shallow. At depth 4.15 m up until 47.77 m, the lithology can be classified as alternation of sandstone and siltstone. Sandstone possess a much higher resistivity value than that of siltstone. Groundwater potential is located at depth 61.31 m beneath the Earth surface with resistivity value of 18.46 Ωm. It is considered as a deep potential aquifer. The last layer that is tuffaceous sandstone, is located at 81.70 m with 51.84 Ωm resistivity value. Table 5.2 shows the data interpreted for line P2 and Figure 5.5 shows the resistivity profile for line P2.

Table 5.2: The data interpretation for line P2.

Layer	Depth (m)	Resistivity (Ωm)	Lithology
1	0.00	7.20	Siltstone
2	1.54	18.29	Fresh water
3	4.15	13.27	Sandstone
4	8.81	3.80	Siltstone
5	20.36	13.00	Sandstone
6	47.77	0.39	Siltstone
7	61.31	18.46	Groundwater potential
8	81.70	51.84	Tuffaceous sandstone

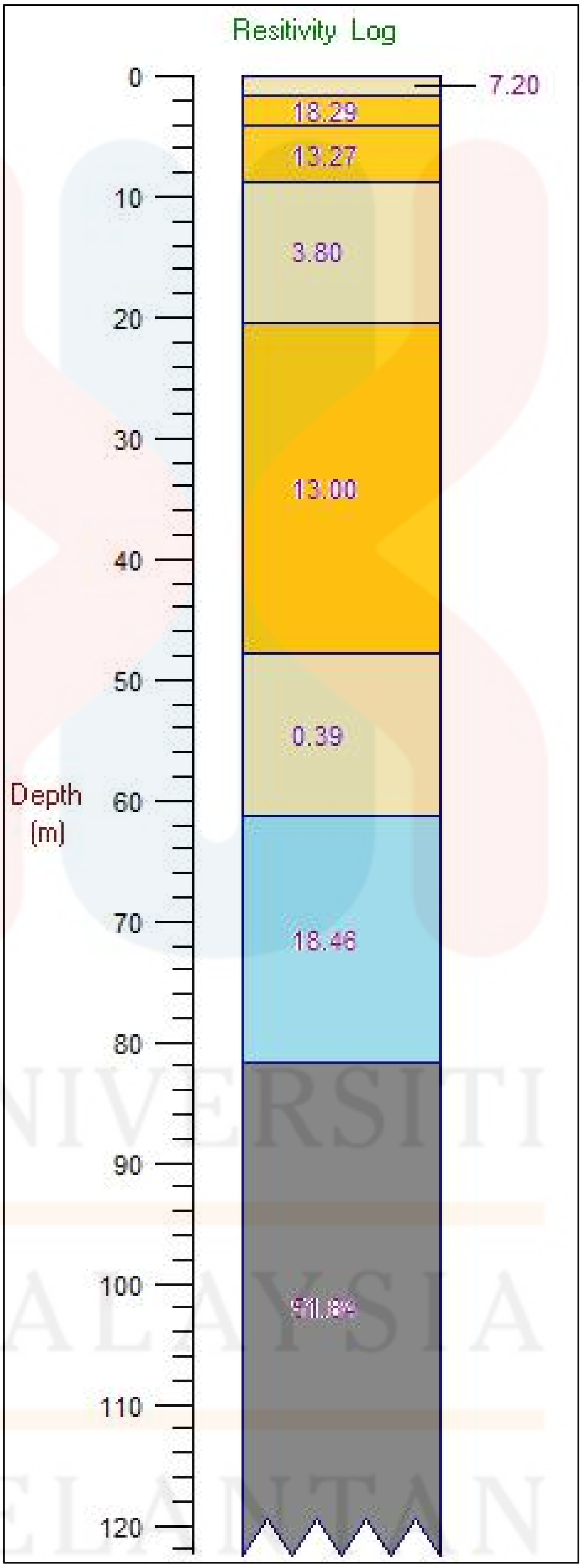


Figure 5.5: Resistivity profile for line P2.

The third resistivity line, point P3 is classified into seven layers. The first layer is sandstone at 0 m depth with 14.73 Ωm resistivity value. Siltstone is discovered at depth 2.70 m to 13.01 m below the Earth surface with resistivity values ranging approximately from 0 Ωm until 10 Ωm. The potential of groundwater is located at depth 26.70 m with resistivity value of 16.33 Ωm and is considered as a shallow aquifer. The last layer that is the tuffaceous sandstone is located at 76.21 m with 52.56 Ωm resistivity value. Table 5.3 shows the data interpreted for line P3 and Figure 5.6 shows the resistivity profile for line P3.

Table 5.3: The data interpretation for line P3.

Layer	Depth (m)	Resistivity (Ωm)	Lithology
1	0.00	14.73	Sandstone
2	2.70	1.99	Siltstone
3	3.70	7.27	Siltstone
4	13.01	7.07	Siltstone
5	26.70	16.33	Groundwater potential
6	56.07	1.74	Siltstone
7	76.21	52.56	Tuffaceous sandstone

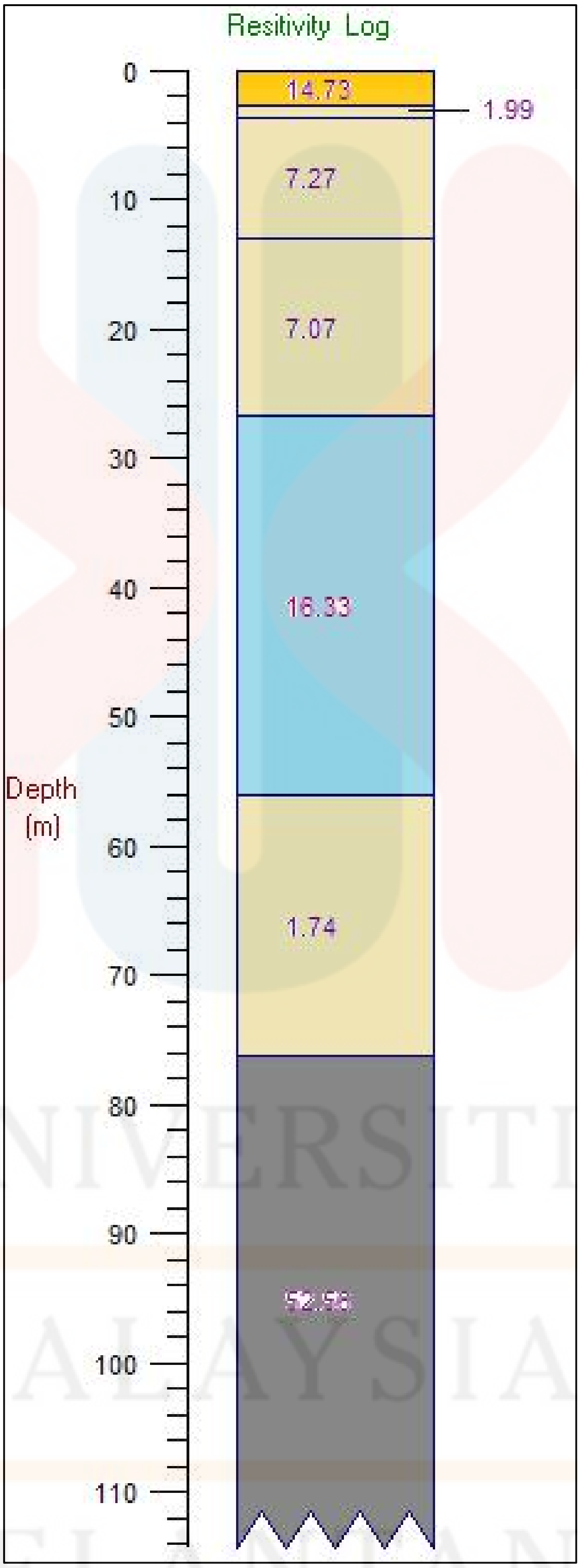


Figure 5.6: Resistivity profile for line P3.

Based on the interpretation and assumptions made on the three resistivity lines (P1, P2, P3) set up in Tancep, Gunung Kidul, the three resistivity lines can be correlated to each other. The correlation of line P1, P2 and P3 is shown in Figure 5.7.

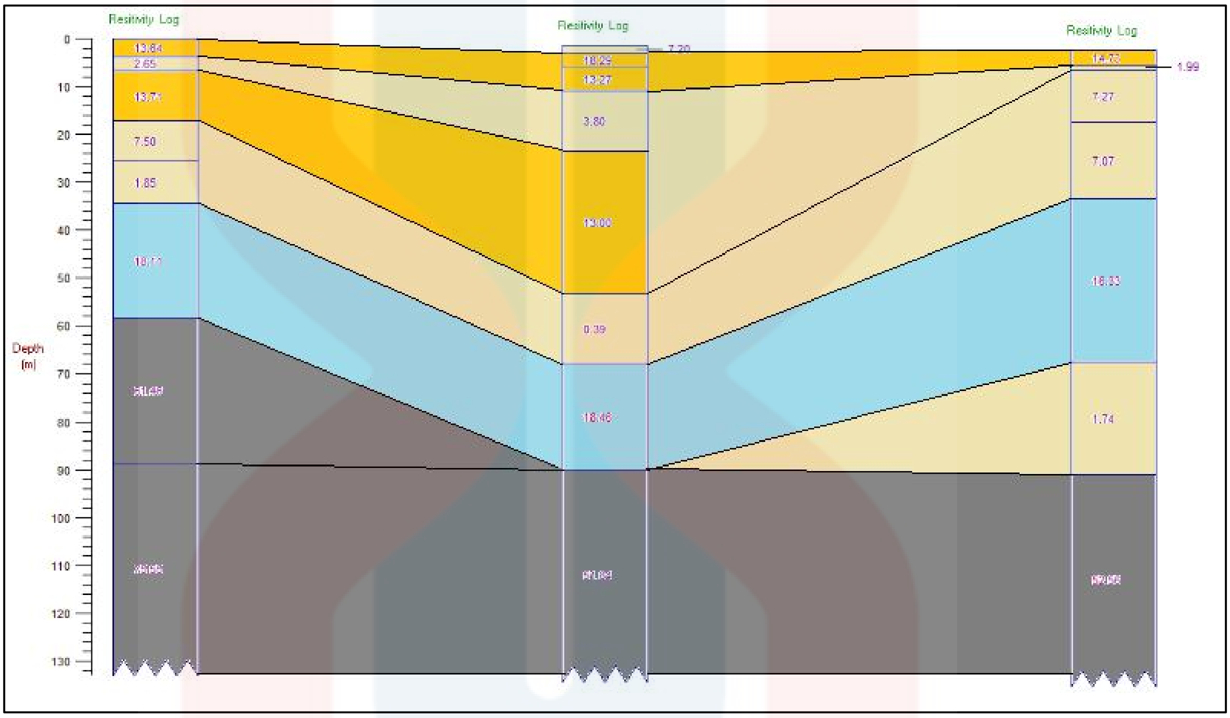
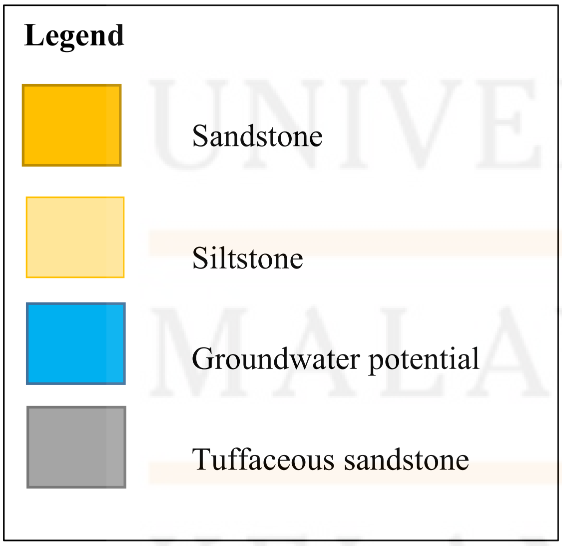


Figure 5.7: The correlation made from line P1, P2 and P3.



CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

In conclusion, there are two main objectives of this research that are to update the geological map of the study area and also to investigate the groundwater potential in Gunung Kidul area using the 1-D resistivity method namely the vertical electrical sounding (VES) method. To achieve the first objective, a geological mapping is conducted in the study area for fourteen days. From the field and lab work that has been done, the lithologies that are found in the study area are alluvium, diorite, sandstone, volcanic clastic sandstone, tuffaceous sandstone and also schist-phyllite. As shown in Appendix VIII, a geological map of the study area is conducted by using the scale 1:25000.

Based on the result obtained from the resistivity study conducted in Gunung Kidul, it can be said that the area has groundwater potential based on the lithology of the area which is dominated by sedimentary rocks. Groundwater potential in Gunung Kidul area is located within 15-20 Ωm and is usually discovered at depth 20 m to 40 m for a shallow aquifer and up to 60 m for a deep aquifer.

Bayat and Gunung Kidul are areas that have a number of groundwater wells. This is due to the large amount of settlements within the area. Therefore, for further study and upcoming research, it is recommended that a research on geochemistry of groundwater or monitoring groundwater quality is to be conducted in the area as it has many groundwater wells.

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APPENDIX I

Slope Gradient (%)	Classification
0-2	Flat
2-15	Low slope
15-25	Medium slope
25-40	High slope
>40	Steep

APPENDIX II

DATA PENGUKURAN TAHANAN JENIS METODA SCHLUMBERGER

Koordinat : 7°48'15,45"; 110°40'27,75" Point :P1

No.	AB/2 (m)	MN/2 (m)	I (mA)	V (mV)	R (ohm)	K	Tahanan Jenis (ohm-meter)
1	1	0.5	850	4410	5.188235294	2.357142857	12.23
2	2	0.5	855	975	1.140350877	11.78571429	13.44
3	3	0.5	785	392.6	0.500127389	27.5	13.75
4	5	0.5	800	122.5	0.153125	77.78571429	11.91
5	7	0.5	879	58.6	0.066666667	153.2142857	10.21
6	10	0.5	788	21	0.026649746	313.5	8.35
7	10	2.5	822	101.8	0.123844282	58.92857143	7.30
8	12	2.5	865	56.4	0.065202312	86.58571429	5.65
9	15	2.5	921	39.5	0.042888165	137.5	5.90
10	17	2.5	625	24.2	0.03872	177.7285714	6.88
11	20	2.5	573	14.6	0.02547993	247.5	6.31
12	25	2.5	309	5.8	0.018770227	388.9285714	7.30
13	30	2.5	260	3.7	0.014230769	561.7857143	7.99
14	40	2.5	857	6.4	0.007467911	1001.785714	7.48
15	40	10	876	17.7	0.020205479	235.7142857	4.76
16	50	10	800	8.4	0.0105	377.1428571	3.96
17	60	10	700	5.6	0.008	550	4.40
18	70	10	707	4.7	0.006647808	754.2857143	5.01
19	80	10	700	4.1	0.005857143	990	5.80
20	90	10	646	2.5	0.003869969	1257.142857	4.87
21	100	10	753	2.6	0.003452855	1555.714286	5.37
22	100	25	808	6	0.007425743	589.2857143	4.38
23	120	25	509	2.7	0.005304519	865.8571429	4.59
24	150	25	412	1.9	0.00461165	1375	6.34
25	170	25	335	1.6	0.004776119	1777.285714	8.49
26	200	25	451	1.5	0.003325942	2475	8.23
27	220	25	459	1.1	0.002396514	3003	7.20
28	250	25	625	1.5	0.0024	3889.285714	9.33

APPENDIX III

DATA PENGUKURAN TAHANAN JENIS METODA SCHLUMBERGER

Koordinat : 7°48'17,82"; 110°40'24,56" Point : P2

No.	AB/2 (m)	MN/2 (m)	I (mA)	V (mV)	R (ohm)	K	Tahanan Jenis (ohm-meter)
1	1	0.5	685	2189	3.195620438	2.357142857	7.53
2	2	0.5	675	460	0.681481481	11.78571429	8.03
3	3	0.5	552	192.1	0.348007246	27.5	9.57
4	5	0.5	457	78.1	0.170897155	77.78571429	13.29
5	7	0.5	450	32.2	0.071555556	153.2142857	10.96
6	10	0.5	558	19.8	0.035483871	313.5	11.12
7	10	2.5	566	102.2	0.180565371	58.92857143	10.64
8	12	2.5	431	51.2	0.118793503	86.58571429	10.29
9	15	2.5	344	26.5	0.077034884	137.5	10.59
10	17	2.5	377	23.6	0.062599469	177.7285714	11.13
11	20	2.5	543	23.4	0.043093923	247.5	10.67
12	25	2.5	409	9.3	0.022738386	388.9285714	8.84
13	30	2.5	353	5	0.014164306	561.7857143	7.96
14	35	2.5	360	2.9	0.008055556	766.0714286	6.17
15	40	2.5	435	2.9	0.006666667	1001.785714	6.68
16	40	10	488	14	0.028688525	235.7142857	6.76
17	45	10	650	14.4	0.022153846	302.5	6.70
18	50	10	540	9.6	0.017777778	377.1428571	6.70
19	60	10	517	6.6	0.012765957	550	7.02
20	70	10	533	5.4	0.010131332	754.2857143	7.64
21	80	10	416	3.3	0.007932692	990	7.85
22	90	10	536	2.8	0.005223881	1257.142857	6.57
23	100	10	466	1.7	0.003648069	1555.714286	5.68
24	100	25	578	5.6	0.009688581	589.2857143	5.71
25	120	25	587	3.3	0.005621806	865.8571429	4.87
26	150	25	631	2.6	0.004120444	1375	5.67
27	170	25	530	1.6	0.003018868	1777.285714	5.37
28	200	25	632	1.4	0.00221519	2475	5.48

APPENDIX IV

DATA PENGUKURAN TAHANAN JENIS METODA SCHLUMBERGER

Koordinat : 7°48'11,32"; 110°40'30,97" Point : P3

No.	AB/2 (m)	MN/2 (m)	I (mA)	V (mV)	R (ohm)	K	Tahanan Jenis (ohm-meter)
1	1	0.5	700	4400	6.285714286	2.357142857	14.82
2	2	0.5	665	774	1.163909774	11.78571429	13.72
3	3	0.5	691	324.2	0.469175109	27.5	12.90
4	5	0.5	698	90.9	0.130229226	77.78571429	10.13
5	7	0.5	462	24.2	0.052380952	153.2142857	8.03
6	10	0.5	519	10.5	0.020231214	313.5	6.34
7	10	2.5	521	38.2	0.073320537	58.92857143	4.32
8	12	2.5	190	10.3	0.054210526	86.58571429	4.69
9	20	2.5	511	9.6	0.018786693	247.5	4.65
10	25	2.5	474	5.9	0.012447257	388.9285714	4.84
11	30	2.5	516	4.8	0.009302326	561.7857143	5.23
12	35	2.5	483	3.4	0.007039337	766.0714286	5.39
13	40	2.5	544	3.1	0.005698529	1001.785714	5.71
14	40	10	637	15	0.023547881	235.7142857	5.55
15	45	10	516	8.2	0.015891473	302.5	4.81
16	50	10	414	5.7	0.013768116	377.1428571	5.19
17	60	10	300	3	0.01	550	5.50
18	70	10	259	2.5	0.00965251	754.2857143	7.28
19	90	10	576	2.7	0.0046875	1257.142857	5.89
20	100	10	310	1.2	0.003870968	1555.714286	6.02
22	120	10	361	1.2	0.0033241	2247.142857	7.47
23	120	30	222	2	0.009009009	707.1428571	6.37
24	150	30	374	1.6	0.004278075	1131.428571	4.84
25	170	30	580	2.2	0.003793103	1466.666667	5.56
26	200	30	388	1.2	0.003092784	2048.095238	6.33
27	220	30	588	1.5	0.00255102	2488.095238	6.35
28	250	30	313	0.7	0.002236422	3226.666667	7.22

APPENDIX V

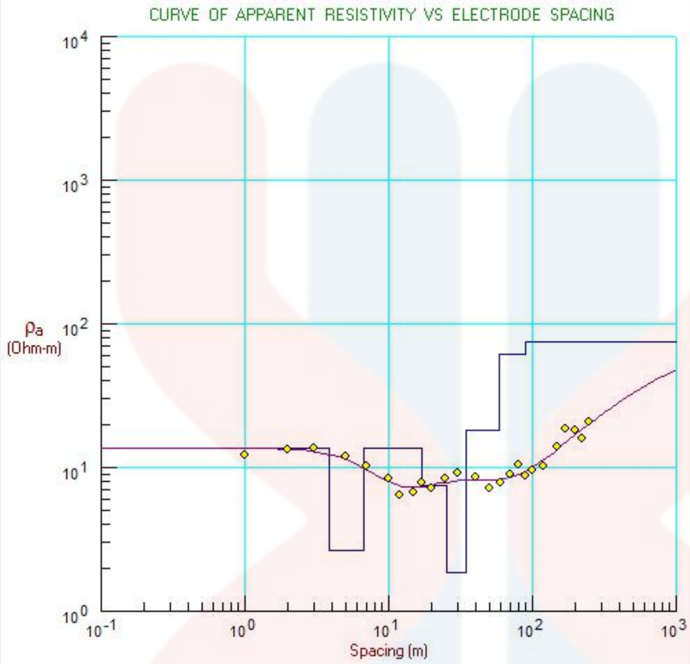


TABLE OF INTERPRETED DATA

No.	Spacing (m)	Observed Data (Ohm-m)	Calculated Data (Ohm-m)	Error (%)
1	1.00	12.230	13.609	11.2720
2	2.00	13.440	13.403	-0.2779
3	3.00	13.750	12.933	-5.9400
4	5.00	11.910	11.368	-4.5538
5	7.00	10.210	9.654	-5.4494
6	10.00	8.350	7.942	-4.8833
7	12.00	6.463	7.439	15.1127
8	15.00	6.749	7.275	7.8045
9	17.00	7.870	7.361	-6.4593
10	20.00	7.218	7.580	5.0255
11	25.00	8.350	7.917	-5.1870
12	30.00	9.139	8.113	-11.2335
13	40.00	8.556	8.208	-4.0627
14	50.00	7.118	8.203	15.2377
15	60.00	7.909	8.289	4.8124
16	70.00	9.005	8.530	-5.2816
17	80.00	10.425	8.919	-14.4511
18	90.00	8.754	9.428	7.7021
19	100.00	9.652	10.024	3.8527
20	120.00	10.115	11.370	12.4096
21	150.00	13.972	13.522	-3.2167
22	170.00	18.710	14.949	-20.1008
23	200.00	18.137	17.019	-6.1602
24	220.00	15.867	18.345	15.6172
25	250.00	20.561	20.249	-1.5150
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				

LEGEND

Sounding Point : jono tancep 1

Electrode Configuration : Schlumberger

RMS (Root Mean Square) : 9.3410 %

Model Parameters

Layer	Depth	Resistivity
1	0.00	13.64
2	3.86	2.65
3	6.69	13.71
4	17.12	7.50
5	25.47	1.85
6	34.49	18.11
7	58.34	61.46
8	88.75	75.55
9		
10		
11		
12		

Description :

◇ = Observed Data

— = Calculated Data

⊓⊔ = Model Parameters

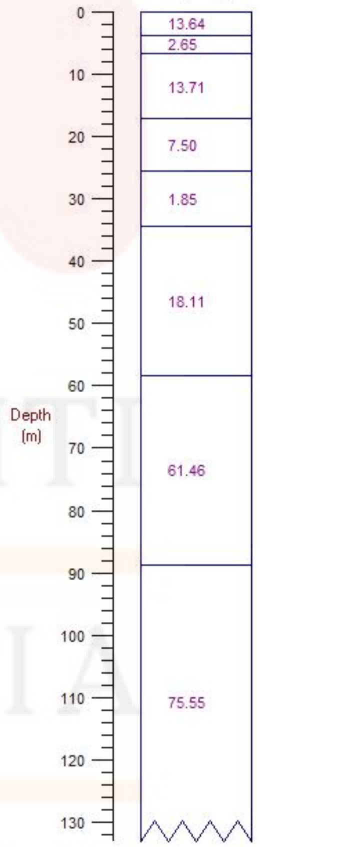
ρ_a = Apparent Resistivity (Ohm-m)

Spacing = Electrode Spacing (m) : AB/2

Depth = Depth of Layer (m)

Resistivity = True Resistivity of Layer (Ohm-m)

Resitivity Log



APPENDIX VI

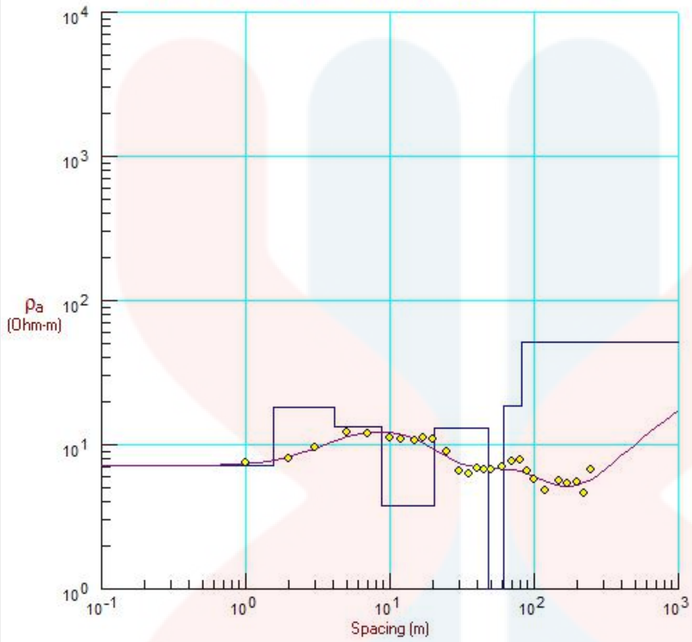


TABLE OF INTERPRETED DATA

No.	Spacing (m)	Observed Data (Ohm-m)	Calculated Data (Ohm-m)	Error (%)
1	1.00	7.530	7.387	-1.8969
2	2.00	8.030	8.252	2.7665
3	3.00	9.570	9.439	-1.3722
4	5.00	12.290	11.295	-8.0988
5	7.00	11.960	12.137	1.4819
6	10.00	11.120	12.181	9.5389
7	12.00	10.968	11.774	7.3497
8	15.00	10.764	10.898	1.2388
9	17.00	11.079	10.269	-7.3158
10	20.00	10.846	9.385	-13.4664
11	25.00	8.985	8.235	-8.3492
12	30.00	6.607	7.515	13.7393
13	35.00	6.272	7.122	13.5656
14	40.00	6.790	6.936	2.1575
15	45.00	6.730	6.862	1.9618
16	50.00	6.730	6.835	1.5662
17	60.00	7.051	6.795	-3.6288
18	70.00	7.674	6.694	-12.7732
19	80.00	7.885	6.523	-17.2763
20	90.00	6.599	6.307	-4.4274
21	100.00	5.705	6.075	6.4762
22	120.00	4.866	5.643	15.9635
23	150.00	5.665	5.227	-7.7300
24	170.00	5.365	5.132	-4.3447
25	200.00	5.475	5.221	-4.6516
26	220.00	4.636	5.395	16.3770
27	250.00	6.694	5.772	-13.7815
28				
29				
30				
31				
32				
33				
34				
35				

LEGEND

Sounding Point : jono tancep 3
Electrode Configuration : Schlumberger
RMS (Root Mean Square) : 9.1598 %

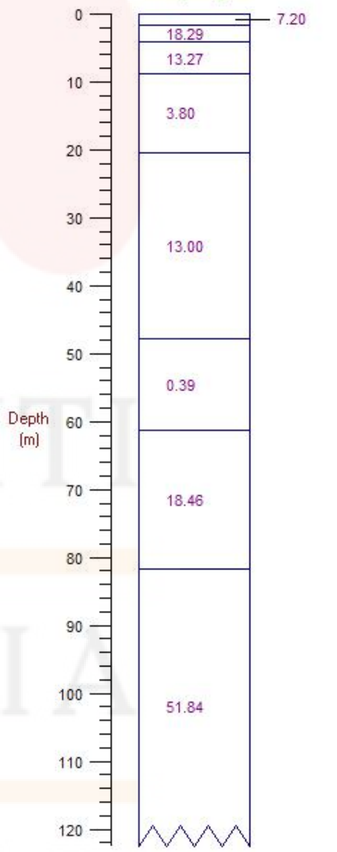
Model Parameters

Layer	Depth	Resistivity
1	0.00	7.20
2	1.54	18.29
3	4.15	13.27
4	8.81	3.80
5	20.36	13.00
6	47.77	0.39
7	61.31	18.46
8	81.70	51.84
9		
10		
11		
12		

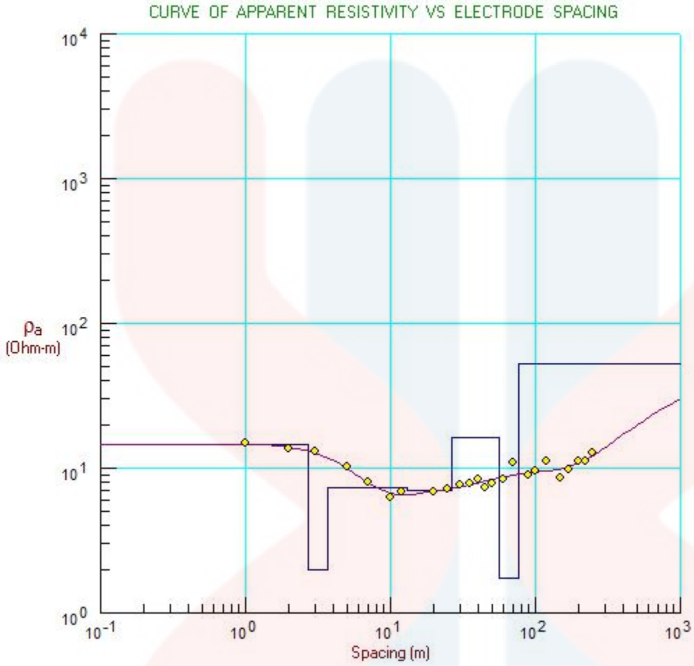
Description :

◆ = Observed Data
— = Calculated Data
⊓⊔ = Model Parameters
ρa = Apparent Resistivity (Ohm-m)
Spacing = Electrode Spacing (m) : AB/2
Depth = Depth of Layer (m)
Resistivity = True Resistivity of Layer (Ohm-m)

Resitivity Log



APPENDIX VII



LEGEND

Sounding Point : jono tancep 2

Electrode Configuration : Schlumberger

RMS (Root Mean Square) : 7.0979 %

Model Parameters

Layer	Depth	Resistivity
1	0.00	14.73
2	2.70	1.99
3	3.70	7.27
4	13.01	7.07
5	26.70	16.33
6	56.07	1.74
7	76.21	52.56
8		
9		
10		
11		
12		

Description :

- ◇ = Observed Data
- ― = Calculated Data
- ⊓⊔ = Model Parameters
- ρ_a = Apparent Resistivity (Ohm-m)
- Spacing = Electrode Spacing (m) : AB/2
- Depth = Depth of Layer (m)
- Resistivity = True Resistivity of Layer (Ohm-m)

Resitivity Log

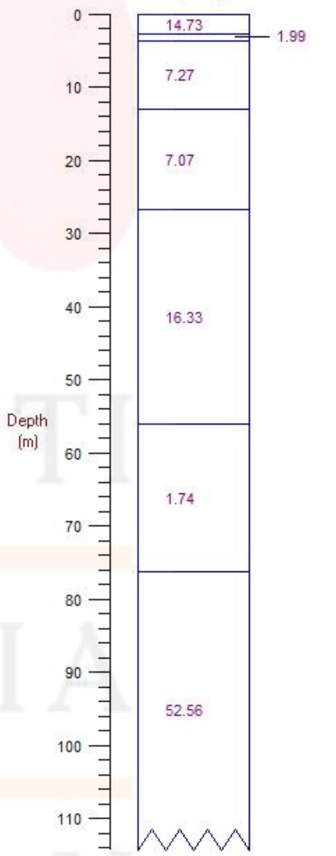


TABLE OF INTERPRETED DATA

No.	Spacing (m)	Observed Data (Ohm-m)	Calculated Data (Ohm-m)	Error (%)
1	1.00	14.820	14.625	-1.3146
2	2.00	13.720	14.003	2.0652
3	3.00	12.900	12.804	-0.7453
4	5.00	10.130	9.924	-2.0305
5	7.00	8.030	7.921	-1.3534
6	10.00	6.340	6.755	6.5454
7	12.00	6.883	6.594	-4.2001
8	20.00	6.824	6.905	1.1849
9	25.00	7.103	7.167	0.8978
10	30.00	7.676	7.420	-3.3340
11	35.00	7.910	7.667	-3.0799
12	40.00	8.380	7.906	-5.6547
13	45.00	7.263	8.133	11.9854
14	50.00	7.836	8.343	6.4645
15	60.00	8.304	8.700	4.7589
16	70.00	10.992	8.968	-18.4104
17	90.00	8.893	9.296	4.5302
18	100.00	9.512	9.397	-1.2148
19	120.00	11.279	9.564	-15.2024
20	150.00	8.570	9.895	15.4640
21	170.00	9.845	10.222	3.8357
22	200.00	11.208	10.874	-2.9808
23	220.00	11.244	11.395	1.3434
24	250.00	12.784	12.262	-4.0844
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