GEOLOGY AND TSUNAMI EXPOSURE OF PANDEGLANG, BANTEN, INDONESIA

By

WAN NUR `AFIFA BINTI WAN MUSTAPA

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

FACULTY OF EARTH SCIENCE

UNIVERSITI MALAYSIA KELANTAN

2020

CERTIFICATION

This is to certify that the dissertation entitled Geology and Tsunami Exposure of Pandeglang, Banten, Indonesia is the bona fide record of research work done by Ms Wan Nur `Afifa binti Wan Mustapa during the period from September 2019 to January 2020 under my supervision. I have read this dissertation and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation to be submitted in partial fulfilment for the degree of Bachelor of Applied Science (Geoscience) with Honours.

Main supervisor,

……

Ir. Arham Muchtar Achmad Bahar

Lecturer

Geoscience Department

Universiti Malaysia Kelantan Kampus Jeli

Locked Bag 100, 17600 Jeli, Kelantan.

Date: …….

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated and duly acknowledged. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at Universiti Malaysia Kelantan or other institutions. I grant Universiti Malaysia Kelantan the right to use the dissertation for teaching, research and promotional purposes.

……

Wan Nur `Afifa binti Wan Mustapa

Date: ……..

ACKNOWLEDGEMENT

The Final Year Project (FYP) had been a very tough and challenging task. First and foremost, Alhamdulillah and I would like to thanks to Almighty Allah for giving me strength, ideas and knowledge before, during and after of completion of this Final Year Project.

Then, I would like to extend my thanks to my supervisor in Universiti Malaysia Kelantan (UMK) and Universitas Padjadjaran (UNPAD) Ir. Arham Muchtar Achmad Bahar and DR. Teuku Yan W. Muda Iskandarsyah due to their supports and advices with enthusiasm in order to make sure all my works complete on time. Also to Pak Yudhi Listiawan along with all of Petrography's lecturer and lab assistants; Pak Kurnia Arfiansyah Fachrudin, Nouval Muamar Asrial, Mochamad Akbar Syah and Tri Bayu Pamungkas for giving information about lab study, lending geological field work tools and helping in describing and analyzing minerals in thin section.

Furthermore, special thanks to my beloved parents Wan Mustapa Wan Abdullah and Norliza Long, my brother Wan Muhammad Faizul Harith and my other siblings and aunt for their encouragement during my field work and support my needed especially in my costing during my fieldwork and report writing.

Sincerely gratitude and thanks to all of my research team Astriana Emaonang Sipranus, Akila Amirrudin, Nurul Shaadah Mohamad, and Kevin Heinrich Pesch by sharing their information about geology of Indonesia, their moral support, their help during my difficulties and the great memories along two month in Indonesia. I also grateful to all of members of Pusat Survey Geologi (PSG), Pusat Vulkanologi dan Mitigasi Bencana Geologi (PVMBG), Dr. Igan Sutawijaya from Badan Geologi and Badan Perencanaan Pembangunan Daerah Serang (BAPPEDA) for giving useful information and their help to make sure my work of the Final Year Project run properly.

My appreciation also rewarded to the special person in my life Alradhiatul Zulaikha Mohd Aljaffry for always being there when needed, give motivation and help me in my Final Year Project writing. Next, I sincerely would like to thank you for all of my friends for their sharing knowledge and giving the important information about my content in this thesis especially Muhammad Amirruddin Safwan Abd Samad, and Mahirah Mahather.

Last but not least, thanks to all of Pandeglang residents for their cooperation to me and my research team during our study in Banten, Indonesia.

GEOLOGY AND TSUNAMI EXPOSURE OF PANDEGLANG, BANTEN, INDONESIA

ABSTRACT

As the study area is prone to geological hazard phenomena geological information of Pandeglang, Banten should be updated frequently with the latest data and findings. In geology world, geological map is very crucial to researchers as it contain various geological data such as stratigraphy, structure, features and rock unit. The study area bounded by coordinate latitude of S 06˚19'06.01" to S 06˚21'48.60" and longitude of E 105˚49'06.17" to E 105˚51'48.70" . This research aims to provide an updated geological map of research area with scale 1:25000 and to produce tsunami exposure map with complete classification of tsunami exposure in Pandeglang, Banten. In order to generate geological map, exposure map and other thematic maps geological mapping is conducted. During field studies, geological data such as geomorphology, lithology, tsunami exposure and others been collected along with sampling and traversing. From the analysis and interpretation made, the study area is primarily composed of two lithologies which are Upper Banten Tuff and Alluvium. Sandstone fragment that found at the river is believed belong to Bojongmanik Formation. Three different types of exposure zone due to recent tsunami are constructed. Secondary data shows run up distance and flow depth of the tsunami are 274 m and 390 m respectively. Pandeglang is prone area to tsunami and other geological phenomena due to its geological position.

ABSTRAK

Oleh kerana kawasan kajian terdedah kepada geologi bahaya fenomena informasi geologi Pandeglang, Banten harus selalu diperbarui dengan data dan penemuan terkini. Dalam dunia geologi, peta geologi sangat penting bagi penyelidik kerana ia mengandungi pelbagai data geologi seperti stratigrafi, struktur, ciri dan unit batu. Kawasan kajian yang dibatasi oleh koordinat latitud S 06˚19'06.01" hingga S 06˚21'48.60" dan bujur E 105˚49'06.17" hingga E 105˚51'48.70". Penyelidikan ini bertujuan untuk menyediakan peta geologi penyelidikan yang diperbaharui dengan skala 1:25000 dan menghasilkan paparan peta tsunami dengan pengelasan lengkap pendedahan tsunami di Pandeglang, Banten. Untuk menjana peta geologi, peta pendedahan dan peta peta tematik geologi lain dijalankan. Semasa kajian lapangan, data geologi seperti geomorfologi, litologi, pendedahan tsunami dan lain-lain telah dikumpulkan bersama dengan sampel dan melintasi. Dari analisa dan tafsiran yang dibuat, kawasan kajian ini terutama terdiri daripada dua lithologi iaitu Upper Banten Tuff dan Alluvium. Potongan batu pasir yang terdapat di sungai dipercayai milik Bojongmanik Formasi. Tiga jenis zon pendedahan yang berbeza disebabkan oleh tsunami baru-baru ini. Data sekunder menunjukkan jarak larian dan kedalaman aliran tsunami adalah 274 m dan 390 m masing-masing. Pandeglang adalah kawasan rawan tsunami dan fenomena geologi yang lain karena kedudukan geologinya.

TABLE OF CONTENT

Content **Page**

LIST OF SYMBOL AND ABBREVIATION

%	Percentage
°	Degree
2D	Two Dimensions
BAPPEDA	Regional Planning and Development Agency
BIG	Geospatial Information
BMKG	Meteorology, Climatology and Geophysics Agency
GIS	Geographic Information System
GPS	Global Positioning System
HCl	Hydrochloric Acid
Km	Kilometer
M	Meter
PPL	Plane Polarized Light
PVMBG	Centre of Volcanology and Geological Hazard Mitigation
UMK	Universiti Malaysia Kelantan
UNPAD	Universitas Padjadjaran
WIB	Waktu Indonesia Barat
XPL	Cross Polarized Light

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The back of this study is about geology and tsunami exposure of Pandeglang, Banten, Indonesia due to Mount Krakatau eruption. The tsunami that occurred at the beginning of 2019 on the coast of Pandeglang, Banten claimed many lives. This event was quite as the tsunami was discovered due to the Avalanche of Mount Krakatau hill. Two geological phenomena that occur simultaneously are volcanic eruptions and tsunami.

The primary aim of this study is to provide an updated geological map of research area with scale 1:25000 and to determine tsunami exposure. By completing these two aims a tsunami exposure map with a complete classification of tsunami exposure in Pandeglang area can be produced. Banten or more specifically Pandeglang was chosen as study area as this site is not really been studied in detail of any researchers and event that happened early of 2019 truly pique my interest to study more what happen and what is the cause of that event. Besides, this study also goes on under mobility program moderated by Faculty of Earth Science, Universiti Malaysia Kelantan.

This study becoming more interesting as Indonesia is known as a country that active with volcanism activities and the volcanism activities itself change Indonesian structure from time to time. Insecurities of what are the aftermath and what are the causes of tsunami to occur when tsunami take place also one of why this study was conducted.

For this situation, no doubt the offender is "*Anak Krakatau*". This name may get familiar in geology world as it rise from the notorious Krakatoa well of lava, which thundered to life in 1883 which is one of the biggest emissions of current occasions. The purposes for the absence of forewarn released out by Geological Agency is because the tsunami was triggered by the avalanche of the wall of "*Anak Krakatau*". Unlike past occasions, they are activated by earthquake; recent tsunami was probably brought about by the breakdown or collapse of an offshore volcano. One conceivable significant danger rising up out of "*Anak Krakatau*" would be a tsunami activated by a breakdown of its flank, as the volcano is incompletely based on a lofty mass of the caldera coming about because of the 1883 emission (Giachetti et al., 2012).

Volcanoes are simply weakly stuck together layers of rock, where each eruption only sort of slips progressively down, so you have every one of these layers of rock that are tilted into the bearing of downhill (Mika McKinnon, 2018). It doesn't take much for a piece to loosen up. Furthermore, if that piece happens to be extensive, it can send enormous waves toward shore with almost no notice.

Moreover, this isn't the first run through this mount erupted as the burst of Krakatau, in August 1883 was a conspicuous amongst the most destructive volcanic emanation of present day history. It is assessed that in excess of 36,000 people get killed. Numerous lost their live because of intense injury from the impacts and a lot more were casualties of the waves that pursued the breakdown of the well of lava into the caldera beneath ocean level. The eruption additionally influenced the atmosphere and made temperatures drop everywhere throughout the world.

The contrast between ongoing occasion and past one of every 1883 is the place the underlying blast cracked the magma chamber and enabled seawater to contact the hot magma. The outcome is known as a phreatomagmatic occasion. The water streak bubbled, making a pad of superheated steam that conveyed the pyroclastic streams up to 25 miles (40 km) at velocities more than 62 mph (100 kph).

The emission has been doled out a rating of 6 on the Volcanic Explosion Index (VEI) and is assessed to have had the dangerous power of 200 megatons of TNT. For reasons for examination, the bomb that crushed Hiroshima had a power of 20 kilotons, about ten thousand times less hazardous as the Krakatoa emission. The Krakatoa ejection was around multiple times more unstable than the Mount St. Helens blast of 1980 with a VEI of 5.

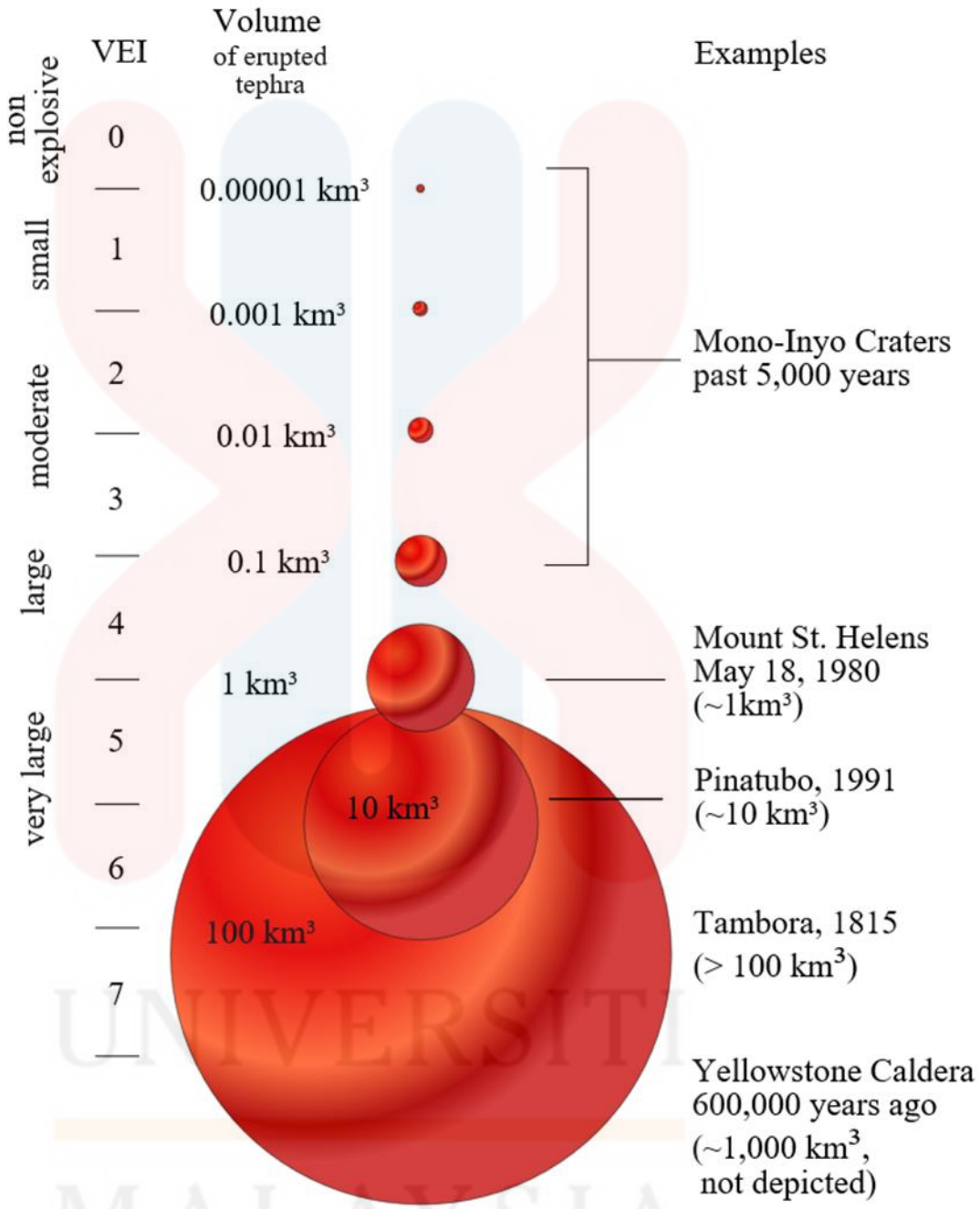


Figure 1.1: Volcano Explosivity Index.

Source: Program, V. H. (n.d.). Volcano Hazards Program Glossary - VEI. Retrieved from https://volcanoes.usgs.gov/vsc/glossary/vei.html

1.2 Problem Statement

There are several of previous studies conducted at Pandeglang, Banten but most of them are not focusing on tsunami exposure due to Mount Krakatau. Previous researchers mostly conducted their study on general geology, stratigraphy and lithology etc. on those places but not on tsunami exposure. Cause of the event is recently occurred researchers are not yet cover about this occasion unless report by Geology Agencies and authorities. Questions still abound about what caused the tsunami that hit shorelines in Banten. The absence of an incredible quake or solid volcanic eruption caused the Meteorology, Climatology and Geophysics Agency (BMKG) to at first report that the waves did not comprise a tsunami but rather were rather brought about by high tide. This unwarned tsunami brings a lot of damage to coastal communities' properties and claimed many lives. Furthermore, previous research was conducted included other areas in Banten province and this cause the study on the study area is not too detail. Through this research, it will only focus on targeted area and its aftermath due to Mount Krakatau Eruption.

1.3 Objective

1. To provide an updated geological map of research area with scale 1:25000
2. To determine tsunami exposure
3. To produce tsunami exposure map with a complete classification of tsunami exposure in Pandeglang area

1.4 Scope Study

This research will be executed on a 5km time 5km located Pandeglang Regency, Banten Province, Indonesia. Besides geological mapping, secondary data also will be used to analyze the tsunami exposure. There are several significant aspects that has to be covered in this research area such as geology, and tsunami exposure due to Mount Krakatau eruption which will be carried out along the Pandeglang coast area and on their buildings, infrastructure and land use of the affected area. All of those aspects need to be covered in order to produce geological map and other thematic maps. Although the population of Labuan area exceeded 50,000 people, questionnaires only will be distributed to those who live in the research area. This study also will study why tsunami occur without warn hit shoreline which cause lots of damage to coastal communities and land use in the research area.

1.5 Significant

This research is crucial as it will bring awareness to local communities about tsunami either cause by tremor or avalanche of volcanoes' wall. Furthermore, the result of this study can be used as preliminary data or guidance to geologist, researchers or even to authorities for their further research and as future precaution as well. Based on this research, authorities can be more alert on future occasion as Pandeglang's position itself is vulnerable towards geological hazards. This is as Pandeglang is close to mount Krakatau and subduction zone, tsunami that cause by seismic activities and by avalanche of mount's wall brings different result. Thus this study can be referred for making future decision.

1.6 Study Area

Indonesia is a well-known archipelago consist of more than of 17,000 islands extending out more than 5000 km from east to west somewhere in the range of 95 and 141 degrees E, and intersection the equator from 6 N to 11 S. It is located at the borderline of three major plates: Eurasia, India-Australia, and Pacific-Phillipine Sea.

Located on a major fault and part of the notorious volcanic zone called the "Ring of Fire", Indonesia was made from vicious seismic action that made the greater part of the 17,000 islands that structure the country today. This research will be conducted at Banten province or to be more specific, Labuan Area, Pandeglang regency, Banten province. This research also include Mount Krakatau, Krakatau is a caldera in the Sunda

Strait between the islands of Java and Sumatra in the Indonesian territory of Lampung. The position of Mount Krakatau can be referred at Figure 1.2.

Banten lies somewhere in the range of 5°7'50" and 7°1'11" south scope and 105°1'11" and 106°7'12" east longitude. The region has a region of 9,662.92 km². Banten is situated close to the Sunda Strait's vital ocean paths that connect Australia and New Zealand with Southeast Asia. For research area, the study is aligned between S 6'20"9.90 to S 6'22" 52.62 for latitude, while for longitudes are aligned in between E 105'49"43.13 to E 105'52"29.28, and can refer to the provided base map in Figure 1.3. Data collection for the specification is will be obtained in the research area.

Figure 1.2: Map of Indonesia and study area

Source: Corlinski, Virginia. (2015, August 18). *Banten*. Retrieved from https://www.britannica.com/place/Banten-province-Indonesia

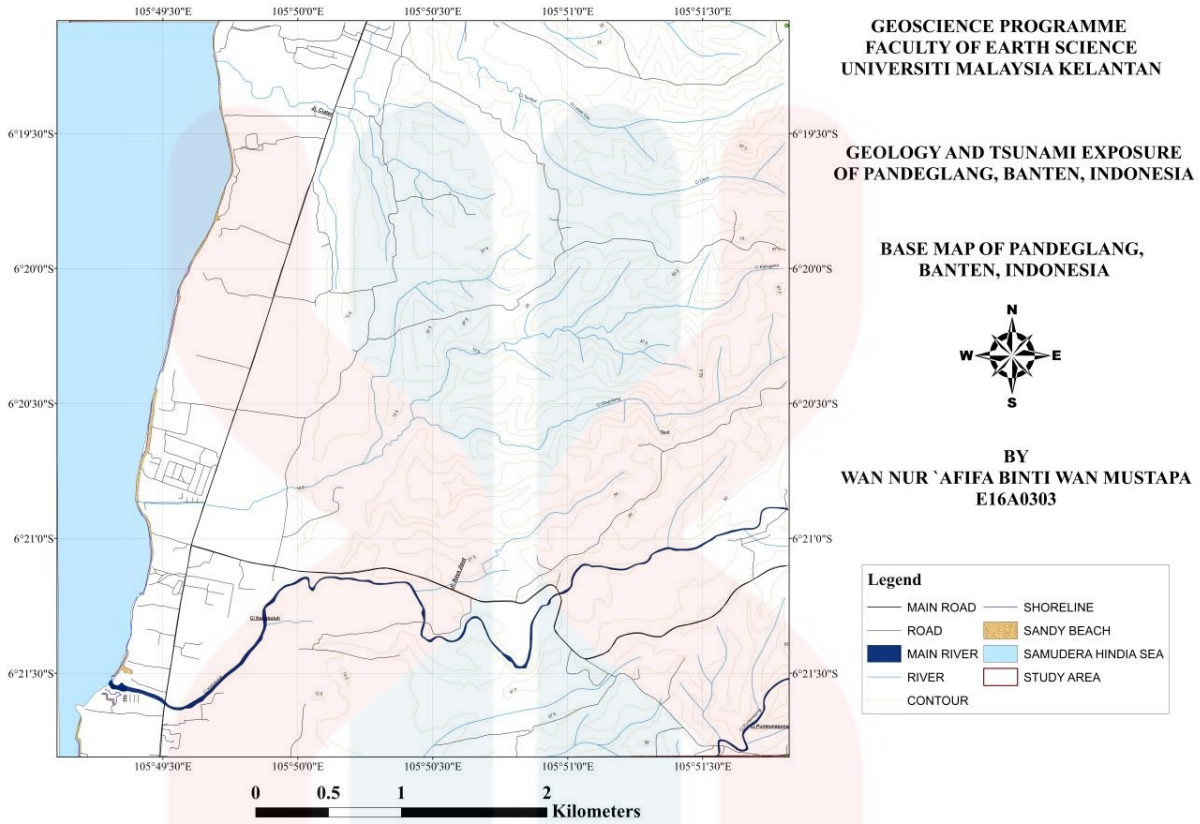


Figure 1.3: Map of research area in Pandeglang, Banten, Indonesia

a) Demography

Indonesia is comprised of in excess of 17,000 islands with over 1.9 million square miles of land, which makes it the fourth biggest nation. Indonesia has a populace evaluated at 269.54 million out of 2019, up from the 2015 gauge of 257 million. About 56.7% of Indonesia's populace lives on Java, the most crowded island. The populace thickness of Indonesia is presently at 140.08 people per square kilometer.

Indonesia has in over of 300 unmistakable ethnic and etymological clusters, spite the fact that the predominant and utmost prevailing as far as legislative issues are the Javanese at over 40% of the populace. Most Indonesians are plummeted from Austronesian-talking individuals. Another significant ethnic group is Melanesians who live on the eastern piece of the nation.

The Bantenese individual shapes the greater part in the region, framing 47% of the complete populace. The vast majority of the general populations in northern Banten are Javanese. The vast majority of the Javanese are vagrants from the focal and eastern piece of Java. The Betawi individuals lives in the Greater Jakarta territory, for example, Tangerang.

In Banten the most of the general population living are by and large rehearsing Muslims, whichever is expected to be indistinguishable from a solid Islamic social foundation. This case is likewise firmly identified with the historical backdrop of Sultanate of Banten as one of the biggest Islamic domain in the Java Island.

Next, in Banten, Sundanese is the most prevailing language. Individuals that living in Banten Province talk a Sundanese vernacular got from age-old Sundanese language. The vernacular is delegated casual or brutal layer in present day Sundanese language, using various layers as Javanese dialect.

Table 1. 1: Population of Banten Province

(Source: Wikipedia)

Western Banten totals(outside Jabodetabek)		8,349.95	3,989,527	4,708,867	5,241,185	
Tangerang Regency	Tigaraksa	1,011.86	2,781,428	2,834,376	3,154,790	0.695 (Medium)
Tangerang (city)		153.93	1,325,854	1,798,601	2,001,925	0.758 (High)
South Tangerang (city)		147.19	(b)	1,290,322	1,436,187	0.791 (High)
Serang (city)		266.71	(a)	577,785	643,101	0.702 (High)
Lebak Regency	Rangkasbitung	3,426.56	1,030,040	1,204,095	1,340,213	0.616 (Medium)
Pandeglang Regency	Pandeglang	2,746.89	1,011,788	1,149,610	1,279,569	0.620 (Medium)
Eastern Banten totals(within Jabodetabek)		1,312.98	4,107,282	5,923,299	6,592,902	
Serang Regency	Ciruas	1,734.28	1,652,763	1,402,818	1,561,401	0.639 (Medium)
Cilegon (city)		175.51	294,936	374,559	416,901	0.715 (High)
Banten totals		9,662.93	8,096,809	10,632,166	11,834,087	0.698 (Medium)

b) Road connection

The railroad organize into the territory of Banten forth 305.90 km dominant part are 'single track' where it comprised of Merak to Tanah Abang, Tangerang to Duri and Cilegon to Cigading with a sum of 141.6 km, and neglected railroads with a total164.3 km. There are five ports comprising of two developed port in Banten which is Port Ciwandan and Port Bojonegara and three ports that are not developed which containing Port of Karangantu, Port of Labuan, and Port of Bojonegara. Furthermore, the presence of Trans-Java Toll Road, this toll road function as connecting all the main cities of the Island with total distance of destination is 1,167 kilometres. This toll road is where accommodate people to travel from Merak, northwestern end of Java to Banyuwangi, the eastern end of the Island in Indonesia.

International Airport of Soekarno-Hatta broadly is the fundamental airplane terminal in Indonesia as the door passage of merchandise and travelers from inside and outside the nation. Moreover there are additionally different air terminals, for example, Pondok Cabe air terminal in South Tangerang, Budiarto Airport in Tangerang and Gorda Airport in Serang. Pondok Cabe Airport is an airplane terminal for common avionics actions; the air terminal utilized for preparing flight activity is Budiarto airport. While Gorda Airport was utilized as an armed forces airplane terminal that moderated by the Indonesian Air Force.

c) Rainfall distribution

The most elevated precipitation is around 2712–3670mm that occurs during rainy days a long time of September to May cover half region of the Pandeglang Regency, western piece and precipitation 335–453mm in the month from September to May covering half territory of the northern piece of the Serang Regency, the whole zone of Cilegon city, half zone of the Tangerang Regency and the whole region of the city of Tangerang. During drought, the most highest precipitation of 615–833 mm in April–December spread half territory of the northern piece of the Serang Regency, the entire zone of Cilegon city, half region of Tangerang Regency, northern piece and the whole region of Tangerang city, whereas the mass of least precipitation in the dry season as much as 360–486mm in the full-length of June to September half inclusion zone of southern Tangerang Regency and 15% region of southeastern Serang Regency.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section will cover the past research and it finding that lead to this study or upcoming research in future. Among the viewpoint that will cover are geology setting, regional geology, research specification and structural geology. For research specification, a study of tsunami exposure will be carried out along the Labuan beach area. This study included exposure of tsunami on coastal community's properties. Labuan located in Banten province, Indonesia and situated in South East Asia region.

2.2 Geology Setting and Regional Geology

Physiographical of this district is a piece of the western tip of Northern Java Alluvium Plain, Bogor Zone, and the Central Depression/Bandung Zone (U. & Soemantri, 2012). Besides, the morphology of this territory can be partitioned into four

units. Geomorphologies of the locale comprise mountain and volcanic cone unit, slightly undulating hilly unit, inter-mountain plain unit, and lowland unit.

For Mountain and Volcanic Cone Unit, this unit possesses the northern part of the considered region described by a few volcanic cones which comprised elevation range of 600 to 1040 m above ocean magnitude. The rivers and their channels consists a radial configuration, semi-parallel, narrow valleys by V-shape, and lofty slant.

Furthermore, slightly undulating hilly unit possessed of young volcanic rocks. This morphological unit is described according to the arrangement of slopes which have risen between 25 m and 400 m above ocean level. The rivers and their channels have a parallel configuration, instead wide valleys with fairly lofty to practically level precipices.

The rocks that construct the Intermountain Plain Unit possess of different kinds of young volcanic rocks. This Intermountain Plain Unit has risen between 500 m to 616 m over ocean level, meanwhile Lowland Unit developed by vast plain with range of elevation within 0 m to 25 m. This topographical unit is composed mostly of alluvium deposits whichever comprise of clay, mud, gravel, sand, and pumice granules(U. & Soemantri, 2012).

2.3 Structural Geology

The geological structure around research study is demonstrated via the appearance of lineaments exhibit a north-south heading. Structure on young volcanic

rock of lower Banten tuff is a distinguishing proof can well be observe which it comprising of tuff breccia, tuff, pumice agglomerate, sandy tuffs, and lapilli tuff. It appears that the lineaments are persistently up-through into alluvium. It ought to likewise be considered that the developments of Tertiary rocks around there are most likely brought about by structural activities (U. & Soemantri, 2012).

2.4 Stratigraphy

The sedimentation process in the study area began since the late Miocene results in the deposit of sandstone, marl, and clay stones deposited in the land environment to the shallow sea known as the Bojongmanik Formation. Bojongmanik Formation known as the oldest formation there and persued by Cipacar Formation, Bojong Formation, Young Volcanic rocks and and the one that is the least old among all are Beach sediments and Alluvial (Lumbanbatu et al., 2012).

2.5 Krakatau Explosion

Vulnerability of tsunami or tsunami exposure is a condition that is ascertain by physical, social, economic, and environmental factors or processes that result in decreased ability to deal with it. How large a community, building, service or area will

be damaged or disturbed by the impact of a hazard, which depends on the conditions, the type of building materials and infrastructure, and its proximity to a dangerous or disaster-prone area.

In tsunami hazards has a different level of exposure. The level of vulnerability is an important thing to know as one of the factors that influence the occurrence of event, because a new disaster will occur if "danger" occurs in "vulnerable conditions. The tsunami hazard catastrophe map is required by the government and the public people to comprehend about their locale on the status of the tsunami vulnerable or risk disaster.

The authorities would decide evacuation plan and assessed the physical and foundation improvement in a sheltered region, particularly for the hazard zone as indicated by the outcomes in tsunami exposure map. Besides, tsunami exposure map is utilized as a kind of perspective for district advancement arranging zone that can limit the person in question, physical and financial pulverization.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This section intends to talk about the materials and methods that being used and conducted amid the research. In this section also will summarize all the preliminary study, work at the study are, laboratory works and data analysis in a flowchart in Figure 3.1.

3.2 Material

In conducting this study there are several materials will be used.

Basic Materials:

- Garmin Portable Global Positioning System (GPS)
- Brunton or Suunto compass
- Geological Hammer

- Hand Lenses
- Topographic Map
- Measuring Tape
- 0.1 Mol Hydrochloric Acid (HCl)
- Sealed sample bag
- Field book and stationery
- Camera or Smartphone

Laboratory Specific Instrument and Software:

- Polarizing Microscope
- GIS software
- Stereonet
- GeoRose
- Sedlog
- Google Earth

Mapping devices: Geological field is about apparatuses. What instruments are fitting to use in the field. Geologist should think about the devices, it will be simpler on the off chance to know what the correct apparatuses to be used in the field. The instruments are:

Global Positioning System (GPS) is use to ascertain the research area, to comprehend current position and the guide of heading amid the investigation. GPS working with arrange framework. Next, Geographical compass: It's utilized to quantify the heading of strike-plunge, slant and auxiliary topography. There are numerous sorts of compass, for example, Brunton compass, Topochaix-Universal compass, and some more. Be that as it may, we more often than not utilizing Brunton compass.

Then, to collect sample for lab work, geological hammer is use in the research, there are two kind of hammer which are Tip point and Chisel point where used for crystalline rocks or hard-rocks and for sedimentary rocks or delicate rocks respectively. Geographical loupe or hand lenses: It's utilized to detail-watched the rock. The rocks possessed numerous full scales until smaller scale minerals and materials. That is the reason we have to utilize it. Hand lenses also were used to ascertain the grain size of the rock apart from depicts the rock.

The map can be topographic map or thematic maps. It is utilized to make cross for track, make a limit of lithology, and to compose all of field information Topographic map functions as a manual for passage to a specific area and distinguish coordinates. Estimating the dimension of part of exposed bedrock will utilize the measuring tape.

Hydrochloric acid (HCl) is utilized prior to carbonated rock like limestone, when work in carbonate fields, HCl will be used to utilize it to recognize the carbonate rocks and non-carbonate rocks. On the off chance that there is carbonate, it will bubble yield fizzing sound. In Indonesia, completely Java Island, carbonate fields are plenteous in Southern Mountain zone, Kendeng zone, Rembang zone. Sealed sample bag will be used for the most part for the sampling reason it needed to spare and keep the sampless. It ought to be solid, water and tear resistant, and sufficiently enormous for samples that has at any rate hand-specimen measure.

A field notebook and stationery will be used to write down all perception highlights amid hands on work. It is utilized to compose all of information and make a sketch. Keep the field notes from water, flame, and anything which will make your lose the information. Furthermore, the uses of camera or smartphone to snap image of geological features, outcrops, sample and others during field observation. It also acts as tool to take documentation in the field. Each sketch will be better on the off chance that documentation been taken. It's utilized to know the other non-land information at the field.

Lastly, in analyzing data certain software will be used such as Google Earth, ArcGIS 10.2, Stereonet, GeoRose and Sedlog which will help access satellite and aerial imagery geological data, create geological map, tsunami exposure map and other thematic maps, rose diagram and lithology.

3.3 Methodology

For this section, method for methodology for the research will be discussed. Without the correct technique, the study will nowise achieve its goal. This part will cover the initial study, process in hands on work at the field work and laboratory work that will be conducted.

3.3.1 Preliminary Study

This resembles an underlying beginning of the investigation. This procedure is principally to gather beginning thought or issue articulations for the examination territory. The information could be spread from numerous perspectives that incorporate lithology, sedimentology, stratigraphy, silt structure, and fossil science information. The correction of set up information additionally encourages the scientist to see better the hypothesis likewise clear things up about issue proclamation for the exploration. The past investigation additionally gives an indication or a proposal about the past examination particularly the reveal geography highlights

3.3.2 Data Collection

a) Geological and Tsunami Mapping

The purpose of geological mapping is to afford an updated geological map of research study while tsunami mapping will be conducted to generate tsunami exposure map. This both mapping should be done amid the research being conducted. Geological and tsunami mapping are crucial method in order to accomplish the first and third objective of this study respectively.

Topography map; base map function as the base information of geological attribute during doing research in the study area. Through geological mapping, different information can be collected and those data can be used to cover several aspects such as geomorphological features, drainage pattern, structural geology, lithology, tsunami exposure effects and all those field related data will be processed in GIS based platform to generate other thematic maps.

Field observation for geological mapping include depicting the rock characteristics such as texture, grain size, color and some other noticeable characteristics. This information will be taken from fresh outcrops to guarantee the accuracy of rocks data as rocks composition and features can be altered due to weathering as the time goes.

b) Interview and Questionnaire

Other than geological and tsunami mapping, survey and interview also will be conducted along the Labuan beach area. This includes field observation on buildings, infrastructures, and land use of the affected area due to Mount Krakatau eruption. Questionnaires also will be used in this research. Questionnaires will be distributed to random coastal communities in order to quantifying the tsunami exposure on their properties. From this method, a tsunami exposure map will be produced with a complete classification of tsunami exposure in Labuan area.

3.3.3 Data Processing

a) Laboratory

Laboratory works solely focused on thin section analysis. Thin section is a laboratory preparation of a rock, mineral or soil sample by utilizing a polarizing petrographic microscope, electron microscope, and electron-microprobe. An exceptionally thin sample is taken out from the rock sample using diamond saw and being cut in flat shape.

Furthermore, cut sample will be mounted on a glass slide. Then it will be grounded smooth with fine abrasive grit until the sample is 30 micrometer thick. This will include the Michel-Levy impedance color chart. Microscope with two filters, cross polarizes and a polarizing filter will be utilized. Both filters, will demonstrate the properties of the mineral that contains at the slight area test once the thin section sample is put at the right angle. This will gather information from petrography viewpoints as various minerals as an alternate mineral's properties.

b) Geological and Tsunami Map Preparation

A geologic map depicts the geologist's observations and inferences about the surface distribution, geometry and structure of the various rocks and sediments in the area. Data that been collected from research area will be inserted into software where each of the software will creates different result. GeoRose will indicate the direction of the forces, sedlog will yield the lithology of study area, stereonet are useful visualizing structural data and identifying trends in two dimensions (2D). All of these collected data from both study area and generated from software will be used to produce geological map and tsunami exposure map by using GIS tool.

3.3.4 Data Analysis

a) Geological Map

Geological analysis is one of the basic works in the geographical field. Geological mapping is one topographical information introduction that is most equipped and is utilized for different purposes either for science or investigation of common assets. A geographical map is a map that comprises of land data of the external layer of earth crust; they are a variety of lithology, circulation of geologic structure, stratigraphy and geomorphology. Every data on the map can be read by colors and symbols. Particularly, geological map rely upon its scale, and the thickness and precision of perceptions in the field.

b) Tsunami Exposure

Once all of the data accumulation has been done, the data should be preceded. The purpose of tsunami exposure map is to analyze the tsunami disaster at Pandeglang, Banten. This map will helps in identifying and give awareness of risky region to public people. Furthermore, it also will be useful for authorities and communities on how to

avoid their belongings, infrastructures, buildings and land use from serious damage when tsunami hits them again.

3.2.5 Map Analysis and Interpretation

After all of data been collected and process, those data will be analyzed. This analyzation will lead to result, hence fulfill the objective of the research. For this study, all information particularly new obtained data will be plot into a geological map of 1: 250000 scale. Each new detail will include and the new elucidation will be concluded from this information investigation. Sampling thin section likewise will be broke down to the recognized features to recognize each and every sample. This incorporates the sedimentary structure acknowledgment, and tsunami exposure of affected area.

3.2 Research Flowchart

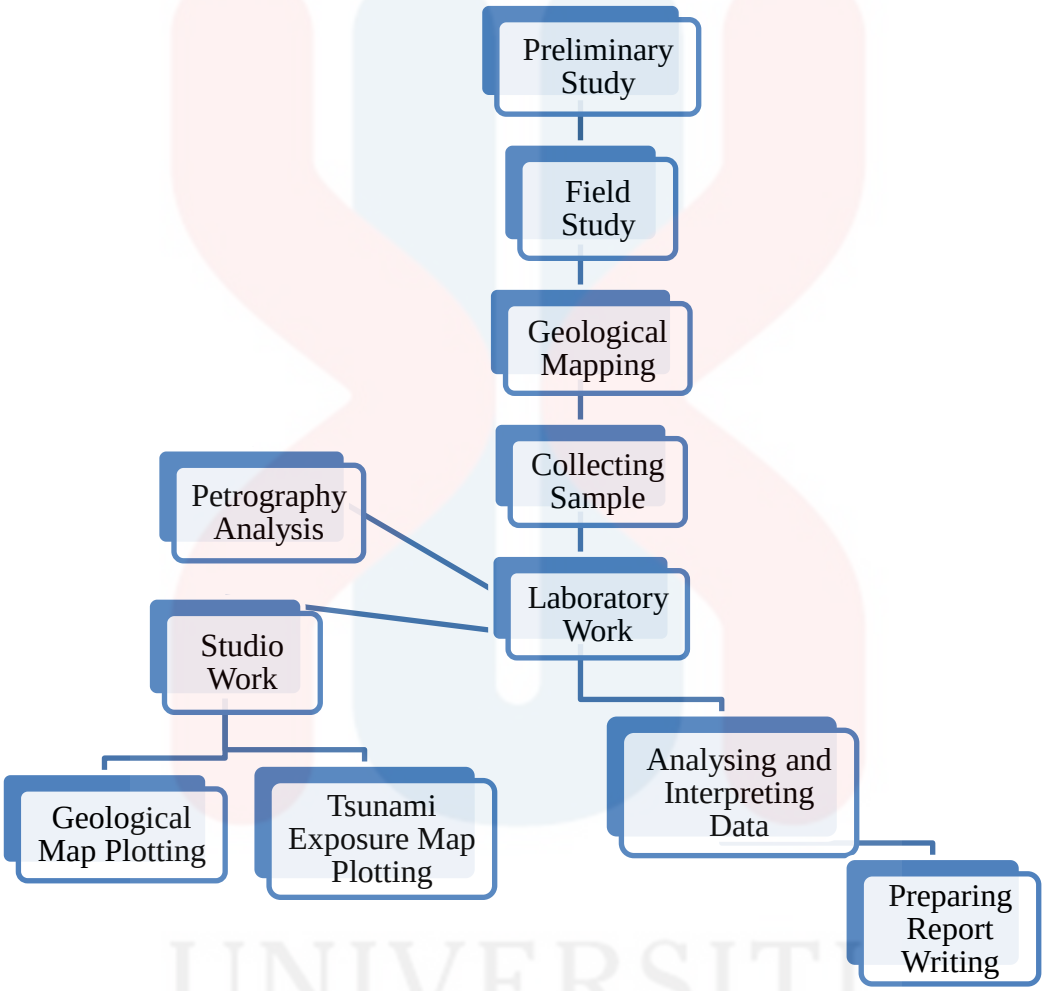


Figure 3.1: Flowchart of research methodology

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This section will cover about mapping part; geological exposures which involve geomorphology, lithostratigraphy, structural geology and petrography analysis of the research area.

i. Accessibility

There are two main roads in this study area which are Jl. Ciater and Jl. Raya Jiput – Caringin. Besides, lots of residential roads available that connected with main roads which make local life easier. Those roads used by local and outsider as way in and out from Banten such as Cilegon, Sumatera, Jakarta, Bandung and even to Soekarno Hatta airport. Pandeglang is one of well – known tourism attraction places in West Java and because of that lots of tourist from oversea or even from Indonesia itself would come to this place during holiday or

New Year eve. This occasion would because roads become busier from usual day. As this site is near to the shore sea route also been used by certain people.

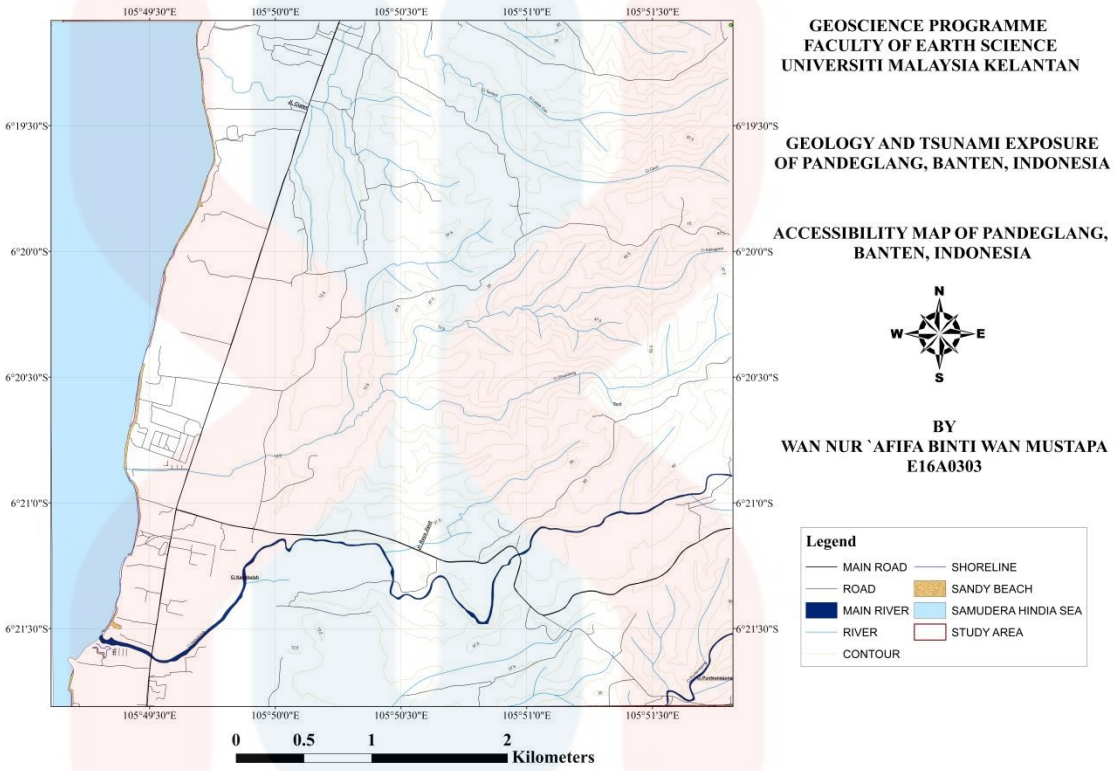


Figure 4.1: Accessibility map of Pandeglang

ii. Settlement

Research area is dominated by residential area. Pandeglang is famous for their Carita Beach and due to this there lots of tourism center been established to accommodate tourists. These situations give job opportunities to local communities as villa keeper or even as resort workers. This is as the tourism center are mostly own by Jakarta citizen and they are not living there.

iii. Forestry

Pandeglang Regency mostly covered by thick orchard that own by both local and outsider citizen. In this research area can be said that populated by vegetation. Furthermore, most of Banten area being covered by ancient volcanic soil during 1883 explosion occasion. As result, volcanic deposits can be developed into some of the richest agricultural lands on earth. This can be the answer for high vegetation in study area.

Figure 4.2: Vegetation area in research area

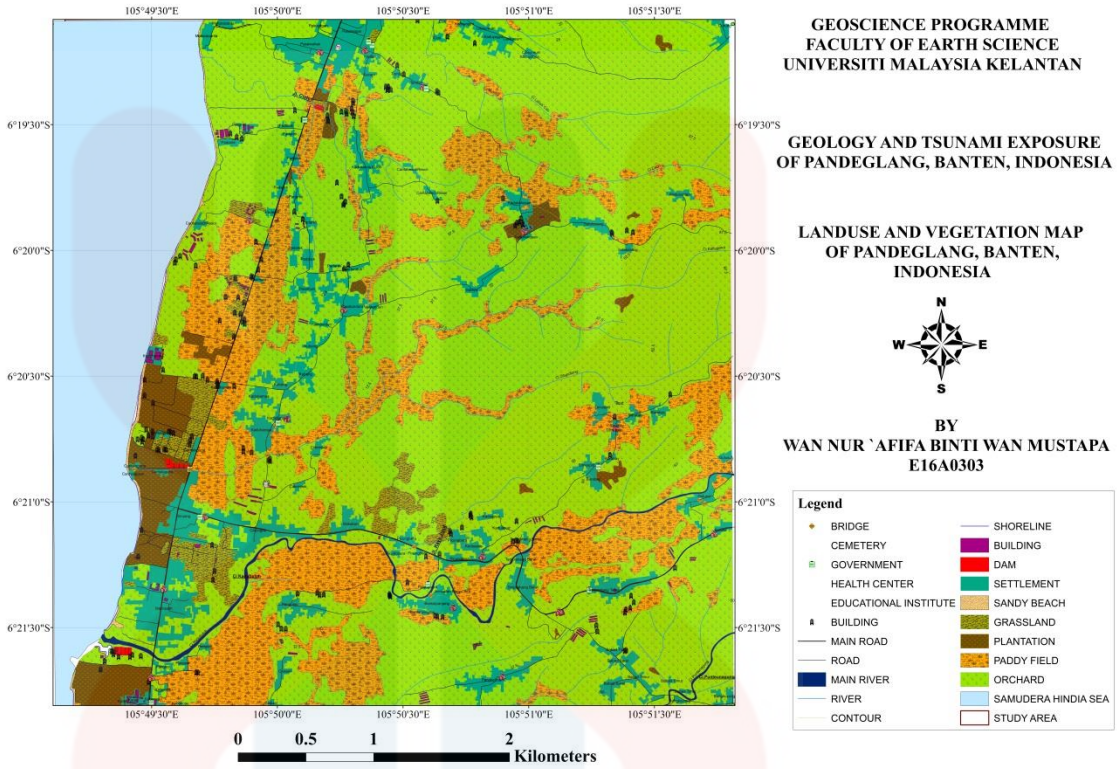


Figure 4.3: Land use and vegetation map of Pandeglang

iv. Traverse

In geological mapping, traverse is a crucial part that should be done in order to obtain result or information about study area. During traverse every particular detail will be observed in order to know the research area structural geology, lithostratigraphy, locality and about tsunami exposure.

Traverse is done by walking and by riding motorcycle and it take about 4 days to complete the geological mapping. The study area that measured 5km x 5km was covered from south to the north of study area. There two location that have outcrop in this box. It is difficult to find exposed outcrop as most of places

in study area are being excavated either for construction or for plantation. From those two location, rock sample that be obtained are lithic tuff and sandstone. Lithology of research area is Upper Banten Tuff and Alluvial and its geomorphology study is quite hard to be done as there are no high elevation places that can be used to observe morphology of study area. But geomorphology study can be completed by studying 3 dimensional map if research area.

Figure 4.4: One of residential road used in Carita, Pandeglang

Figure 4.5: Forest route in Carita, Pandeglang

4.2 Geomorphology

Geomorphology is the investigation of landforms, their processes, structure and sediments at the surface of the Earth. Study incorporates observe landscapes to work out how the earth surface processes, for example, air, water and ice, can shape the landscape. Landforms are created by disintegration or deposition, as rock and sediment is eroded by these earth-surface processes and transported and deposited to various territories. The distinctive climatic conditions produce various suites of landforms. The landform might be tectonic and structural in inception and even because of volcanic processes, for example, volcanic eruption and molten interruption; igneous intrusion. Earthquake likewise triggers the change of geomorphology in a zone. Landforms are sorted by trademark physical traits.

Research area is dominated by flat area as it is situated near the ocean. The highest elevation in study area is 87.5m while the lost elevation 12.5m above sea level. The research area morphology is mostly flat area as in consist of coastal alluvial plain and slightly undulating hills. The coastal alluvial plain is a region where the deposition processes still occur till today as it near the shore. The deposition occurs as deposits come from ocean brought by wave and also by deposition of deposits from channels. Geomorphology study is aspire to interpret the surface condition of study area based on obtain data during geological mapping and from 3 dimensional map.

4.2.1 Geomorphological Classification

Geomorphological classification is function as categorization and depiction of the nature, source and evolution of landforms. The crucial system of this characterization is that a geomorphic unit can be characterized dependent on its origin and process, on its general structure and landform. In study area there are two type of unit of geomorphology that can be identified which are coastal alluvial plain and slightly undulating hills. Due to high vegetation and population in study area geomorphology of research area cannot be studied clearly, geomorphology of research area are shown below in Figure 4.3 using 3 dimensional map.

1) Coastal Alluvial Plain

Coastal alluvial plains shape when streams shipping residue; sediment from hilly zones arrive at low altitude and store a huge extent of their dregs load. This happens because of a diminishing in stream inclination, which decreases sediment transport limit. The degree of coastal alluvial plain is controlled in enormous part via ocean level, and alluvium deposited during past occasions of low ocean level. This unit of morphology covered about 20% of study area which is from the shoreline until 1 – 2 km to residential area. Furthermore, deposition process for this unit is still ongoing and its elevation is ranging from less than 12.5m to 37.5m. Even it is near to the shoreline, residents still make a living there.

2) Slightly Undulating Hills

Slightly undulating hills unit consist of young volcanic rocks. This morphological unit is portrayed by order of slopes which have extended upward between 25m and 400m above sea level. This unit covers more than half of area in the box which means that the study area is dominated by slightly undulating hills. In slightly undulating hills region inhabited by the most of the residents, there still some of parts of places where undergoing excavation process to build villagers houses. Other than villagers this unit also filled by high vegetation.

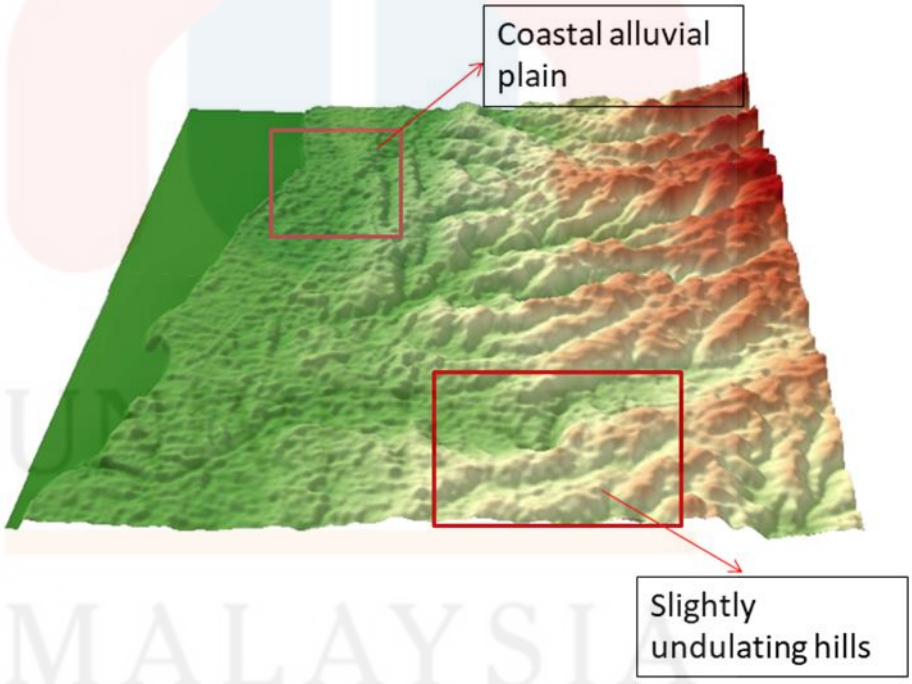


Figure 4.6: 3 dimensional map of geomorphology of Pandeglang

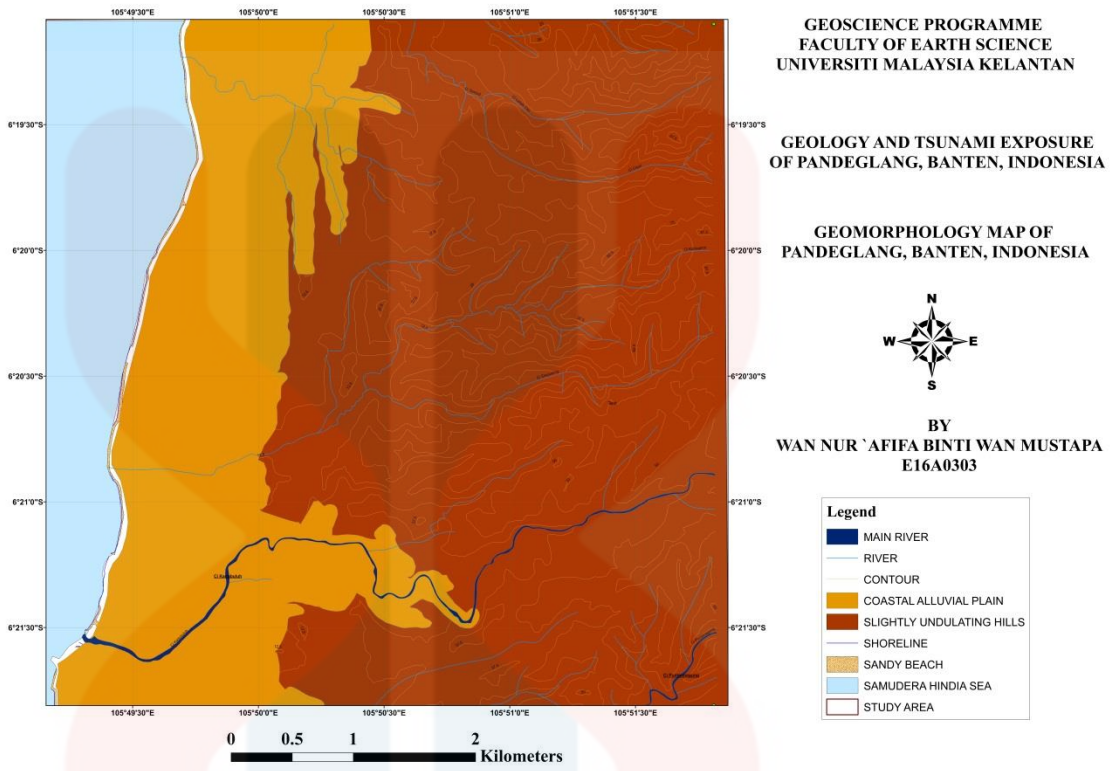


Figure 4.7: Geomorphology map of Pandeglang

4.2.2 Weathering

Weathering is the breaking down or dissolving of rocks and minerals on earth surface. When a rock has been separated or broken down from its original location, a process called disintegration transport the bits of rocks and minerals away. These two processes always change the rough landscape of Earth. Weathering erodes open surfaces as time goes by. The length of exposure frequently adds to how vulnerable a stone is to weathering. Rocks, for example, lavas, that are immediately covered underneath other type of rocks are less vulnerable against both weathering and erosion than rocks that are exposed to weathering agents, such as wind and water.

Furthermore, weathering is divided into three different processes which are mechanical, chemical and biological weathering. Biological weathering, in which living or once living beings take part in this process, also can be a part of the other first two forms.

The weathering and erosion product finally will accumulate and produce a certain landscape. Along the shoreline from north to south and vice versa black sand can be found in variety of grain size. According to discussion with Dr Igan Sutawijaya, volcanoes expert, those black sand is type of metallic mineral that came from any four ancient volcanoes located towards east outside of the study area.

The research area consists of quaternary volcanic rocks and this type of lithology got more tendencies to undergo weathering and erosion. As time goes by those volcanoes eroded and undergoes weathering processes and metallic mineral is transported through available channels. Some of the mineral deposited in the rocks body while on their way to lower gradient area; along the beach. This can be proof by the discovery of metallic mineral; hematite in the thin section of lithic tuff.

Figure 4.8: Metallic deposit along the shoreline

4.2.3 Drainage Pattern

Drainage pattern is an outcome made by stream disintegration after some time that uncover characteristics of the sort of rocks and geologic structures in a landscape area drained by streams.

Drainage pattern is the pattern generated by the streams, rivers, and lakes in a specific drainage basin. They are manipulated by the topography of the land, regardless of whether a certain area is overwhelmed by hard or soft rocks, and the inclination of the land.

From the river distribution in research area there are two type of drainage pattern identified; dendritic pattern and sub – parallel pattern. Drainage analysis is use in useful

in structural and rock interpretation, particularly in area of low relief. For dendritic pattern, where is by far the most familiar, this pattern is form in regions where the rock or unconsolidated substances underneath the stream has no specific texture or structure and can be broken down similarly effectively in all directions. Examples would be granite, gneiss, volcanic rock, and sedimentary rock that have not been folded or disturbed. In this case, the existence of volcanic rock in research area make the presence of dendritic pattern is possible.

Drainage patterns generally are subdivided into basic and modified basic. In this case, there is a modified basic pattern that can be identified in research area which is sub parallel. Parallel or sub – parallel drainage formed on sloping surfaces. This type of drainage is common in terrain with homogenous rocks. Progression of parallel rills,

gullies or narrow channels are commonly seen on gently inclining surface.

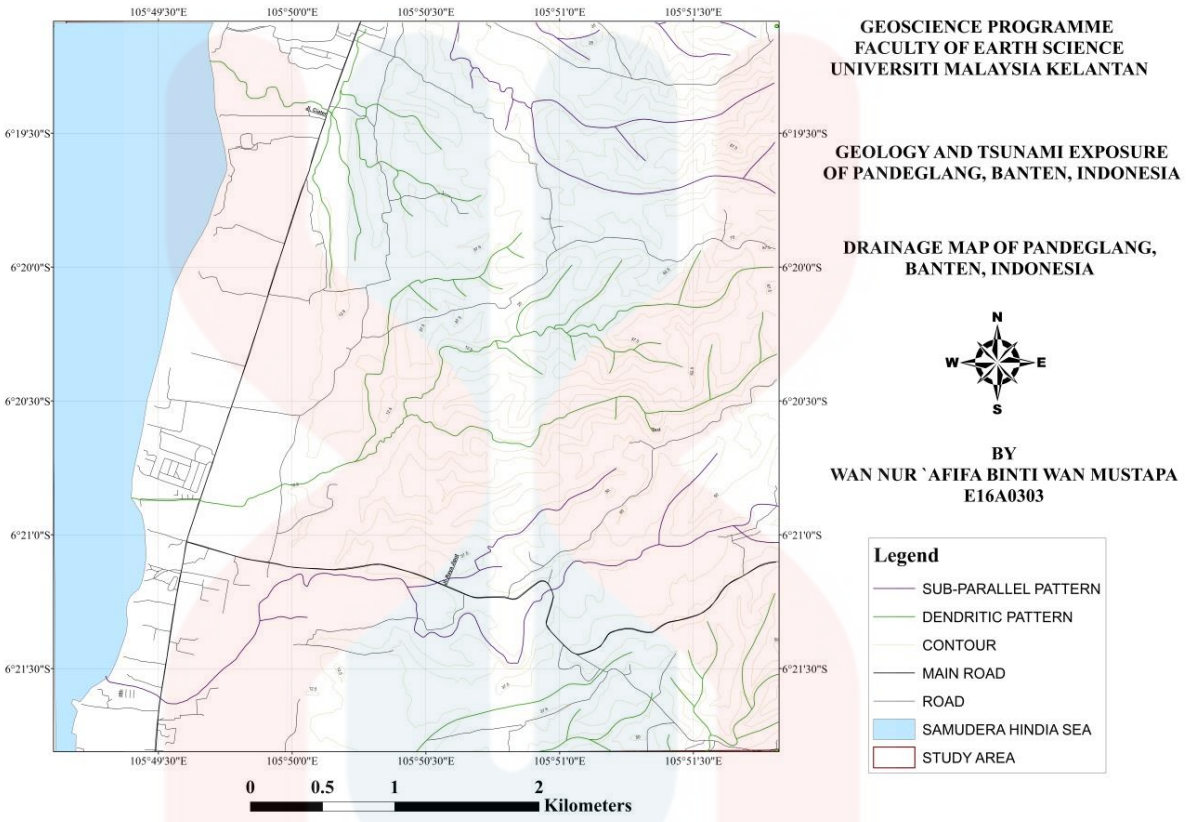


Figure 4.9: Drainage pattern map in Pandeglang

4.3 Lithostratigraphy

Lithostratigraphy is a sub-control of stratigraphy, the geographical science affiliated with the study of strata or rock layers. Major focuses incorporate geochronology, relative topography, and petrology. Lithology of rock in study area can be determined in more detail by examining thin section under polarized microscope. Each thin section will focus on each of minerals that present by using both plane polarized light (PPL) and cross polarized light (XPL). Commonly a stratum will be principally igneous or sedimentary identifying with how the rock was developed.

4.3.1 Stratigraphy

As known, stratigraphy is the study of stratum or also known as layered sedimentary rocks. There are several of principles that geologist will discuss when it comes to stratigraphy. According to Steno (1669) there are four stratigraphic laws which are original horizontality, lateral continuity, superposition and cross – cutting relations. When rock is first deposited, all of them are in horizontal bedding. But as time goes by, after those rocks exposed towards variety of forces those sedimentary rocks are no longer in their original position as they has been tilted from their original position. For superposition the rocks layer are in older layering to younger layering which is from the bottom to upwards.

Next, in cross – cutting relationship if a body or discontinuities cuts over a stratum, it more likely that it must have been formed after that stratum. Lastly lateral continuity is where material forming any strata was continuous over the surface of the earth unless some other solid bodies stood in the way.

Research area consist of two different stratigraphic unit which are alluvium and volcanic rock; lithic tuff. Those are both from Quaternary period. Alluvium is a unit which still undergoes deposition processes and this fact make it much younger that lithic tuff unit. From geological mapping a fragment of sandstone been found at the riverbank that drifted from somewhere else and from discussion with one of petrology lecturer from Universitas Padjajaran (UNPAD), Pak Kurnia Arfiansyah there is possibility that the drifted sandstone might be separated from its original body. From our assumption there is sandstone unit layered beneath lithic tuff unit but it not exposed on the surface.

Formation of Bojongmanik is the oldest rock exposed in Pandeglang and it composed of sandstone and calcareous sandstone with marl and clay interpolated with lignite and sandy tuff (Lumbanbatu et al, 2012), this may answer the discovery of sandstone fragment at the river. Because of the formation is the oldest one so it's reasonable that the rock unit is not appearing on the surface. Lithic tuff unit even it is not young as alluvium unit but it is still at Quaternary age and some part of it lies under alluvium unit layer.

4.3.2 Lithic Tuff

This rock unit occupies most of the research area. While geological mapping being conducted, outcrop of this unit is very difficult to be found as most of the region is already been excavated for buildings and for agriculture purposes. Fortunately one place is exposed while being excavate for house renovation with coordinate reading S 06˚21'48.60'' E 105˚51'38.49'' which exposed lithic tuff layer. Other than that there is other outcrop at the river with coordinate reading S 06˚21'48.31'' E 105˚51'32.4'' but it is highly weathered until if being hammered the rock may shatter. Both of location is shown in Figure 4.6 and Figure 4.7.

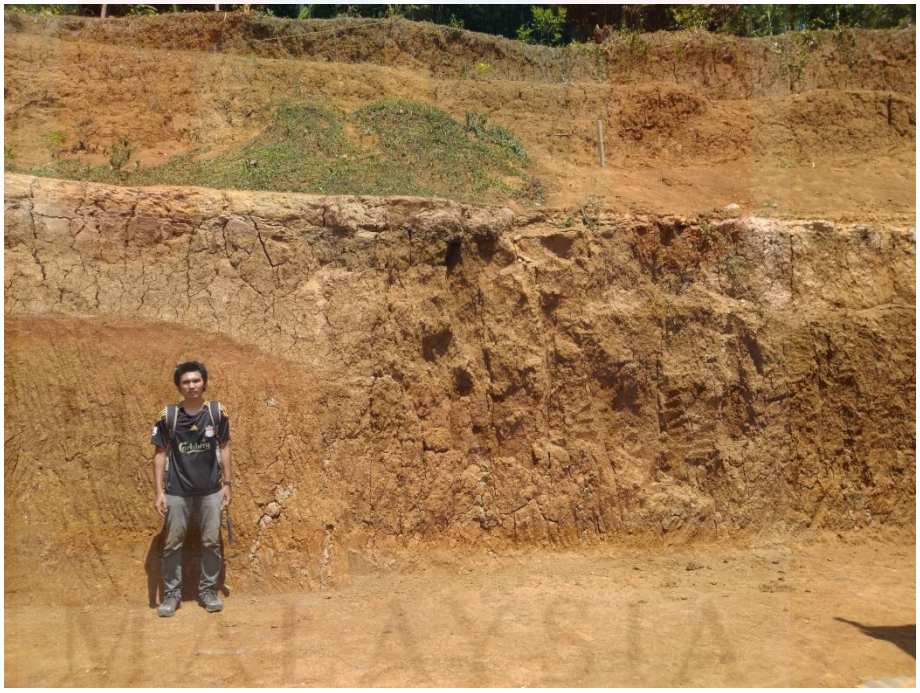


Figure 4.10: Location of first outcrop, Lithic Tuff

Figure 4.11: Location of second outcrop, fragment of Sandstone

4.3.3 Alluvium

This rock unit covered about 1 – 2km of area from the shore line towards east of research area. As stated above this unit still undergoes deposition processes that occur from both marine and fluvial channel. Beach and alluvial can be seen distributed along the west coast of the research area. The lithology if this unit consists of gravels, pebbles, clays, muds, pebbles of pumice. Pumice can be seen deposited nearby the beach as result of recent tsunami.

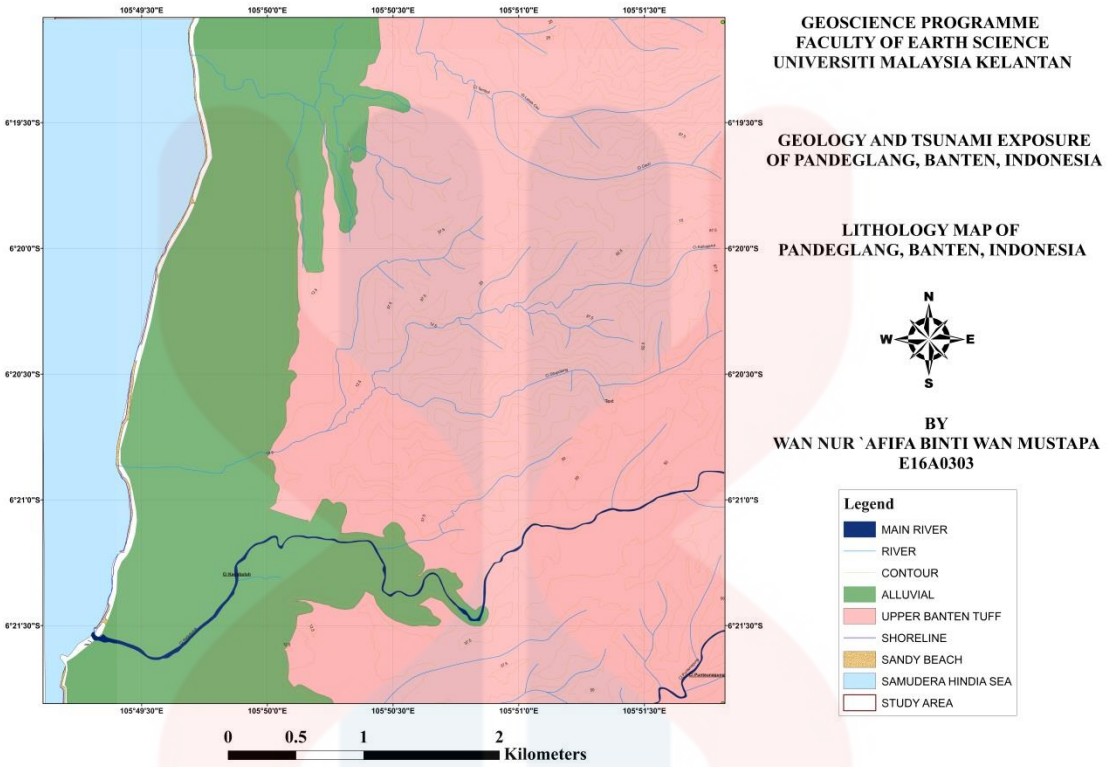


Figure 4.12: Map of rock type in Pandeglang

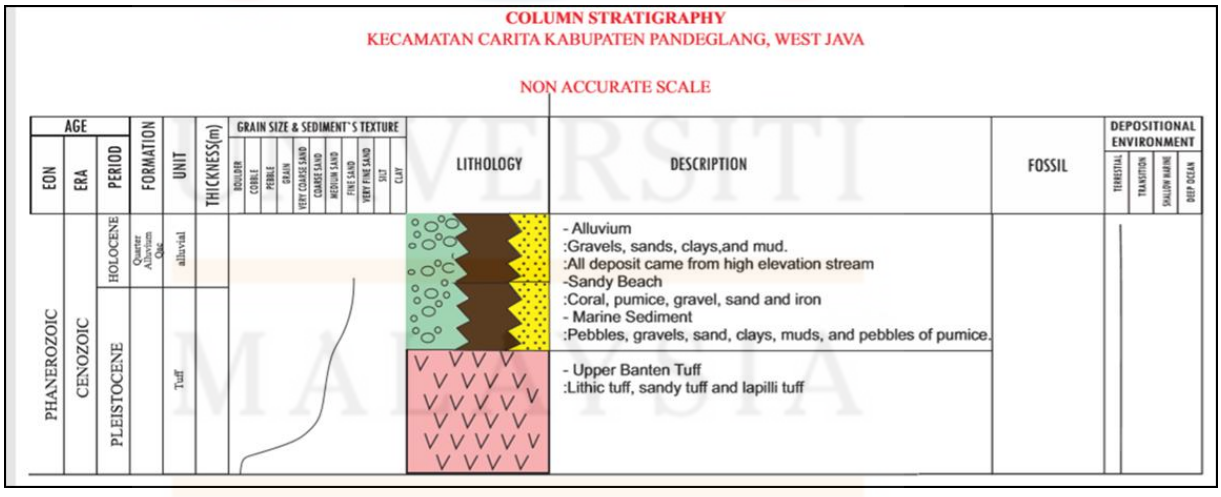


Figure 4.13: Stratigraphy column

4.4 Structural Geology

Structural geography is the investigation of the surface deformation and deformation of subsurface of the Earth and other planetary bodies. This deformation reflects past evolution in local and regional stress and strain, and can be utilized to remake past crustal developments and dynamics. This comprehension of the dynamics of the stress field can be connected to significant occasions in the geologic past; a shared objective is to comprehend the structural development of a certain region as for regionally wide – ranging patterns of rock deformation because of plate tectonics.

Research area consists of Quaternary rocks; alluvium and volcanic tuff and alluvium especially is still undergoes deposition and geological processes. And as we know that volcanic rocks doesn't have any structure. Tuff also can be grouped either as sedimentary or even an igneous rock.

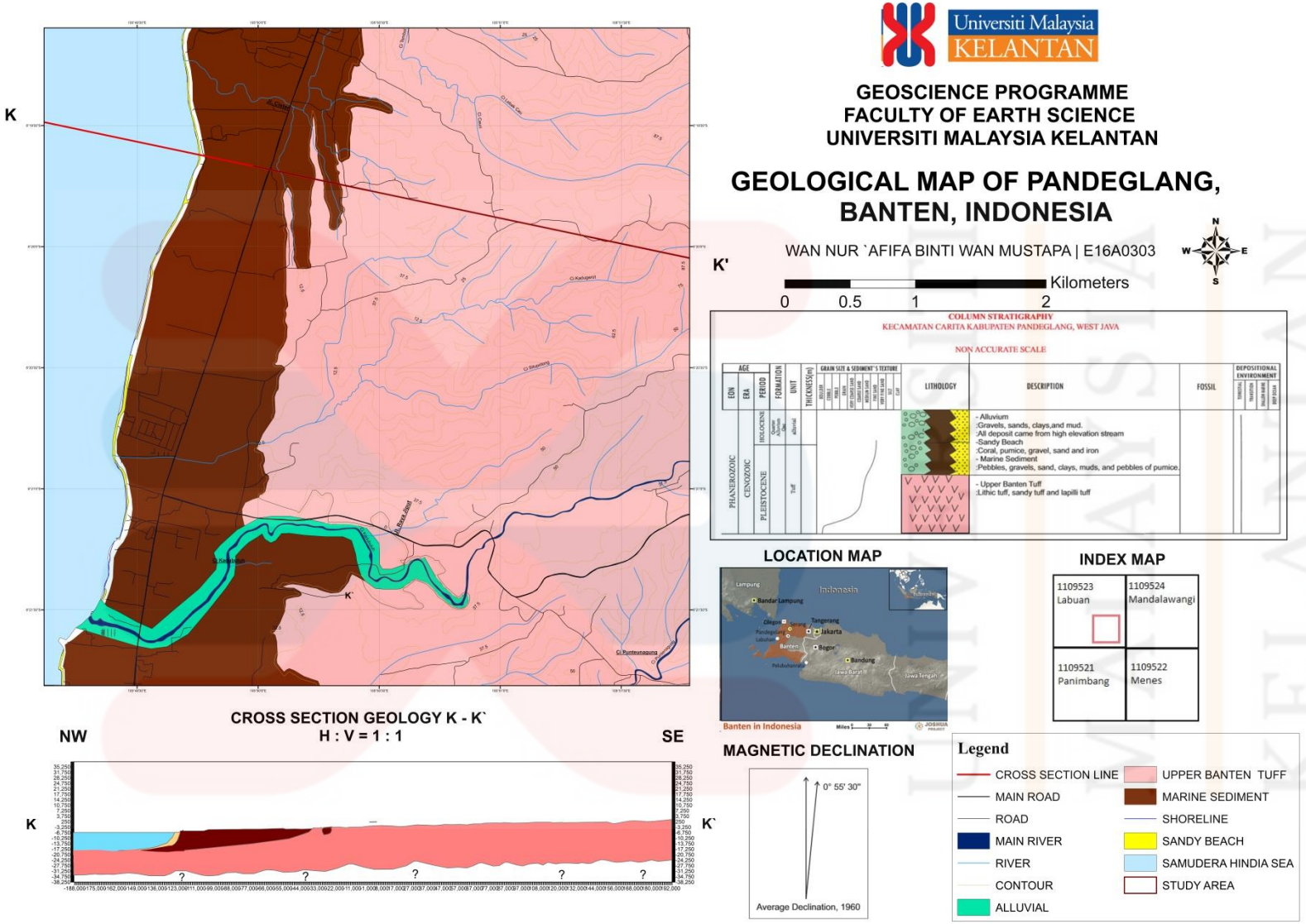


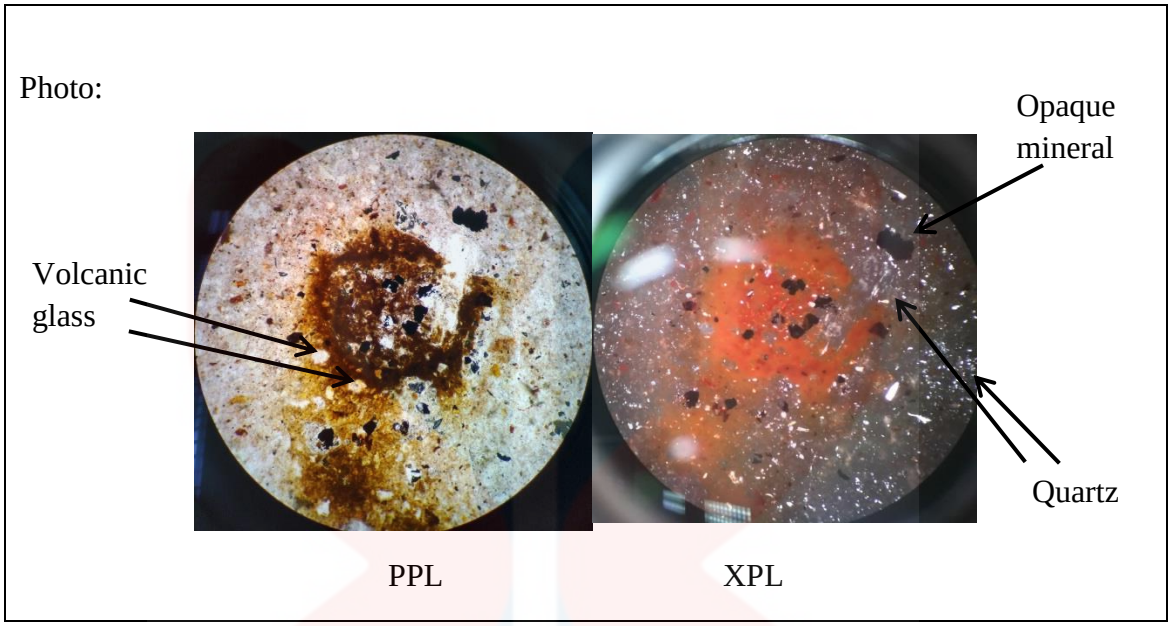
Figure 4.14: Geological map of research area

4.5 Petrography Analysis

I. Sample WNA_T1

Table 4.1: Description of optical mineralogy

Location: Behind resident's house Coordinate: S 06˚21' 48.60'' , E 105˚51'38.49'' Elevation: 35m Name of rock: Lithic Tuff Type of rock: Pyroclastic rock		
Mineralogy description		
Composition of Minerals	Amount (%)	Description of Optical Mineralogy
Weathered Lithic Fragment	20%	Color: Dark brown Shape: Anhedral Pleochroism: None Cleavage: None Twinning: Absent Relief: High
Volcanic Glass	60%	Color: Colorless Interference color: Black Shape: Anhedral to subhedral Pleochroism: Low Cleavage: None Twinning: Absent Relief: Low
Quartz	10%	Color: Colorless Interference color: White to gray Shape: Anhedral Pleochroism: None Cleavage: Conchoidal fracture Twinning: Absent Releif: Low
Other mineral	10%	Opaque mineral



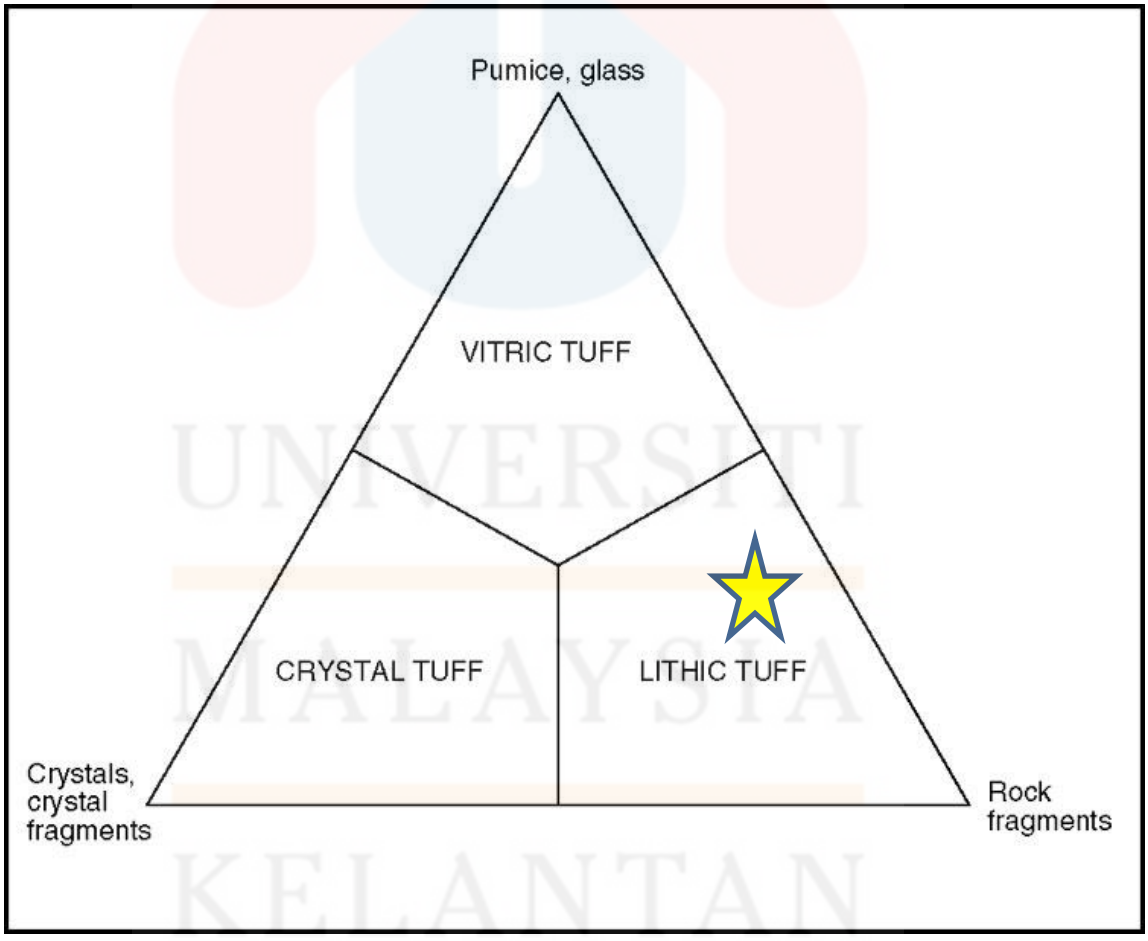
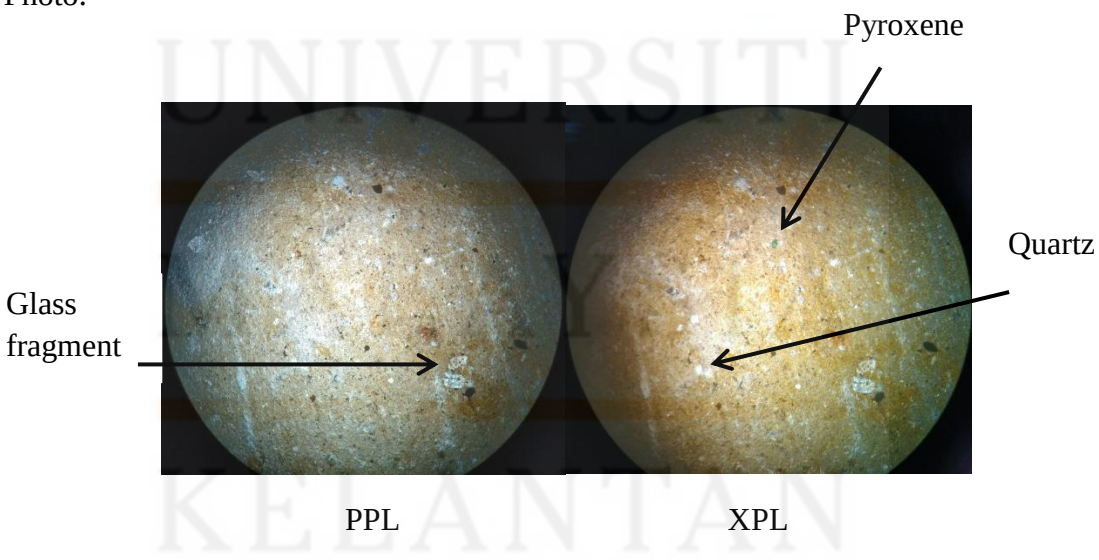


Figure 4.15: Classification of pyroclastic rock (Schmid, 1981)

II. **Sample WNA_S1**

Table 4.2: Description of minerology

Location: At the river Coordinate: S 06˚21'48.31'' , E 105˚51'32.4'' Elevation: 31m Name of rock: Sandstone Type of rock: Sedimentary rock		
Mineralogy description		
Composition of Minerals	Amount (%)	Description of Optical Mineralogy
Quartz	20%	Color: Colorless Interference color: White to gray Shape: Anhedral Pleochroism: None Cleavage: Conchoidal fracture Twinning: Absent Relief: Low
Pyroxene	3%	Color: Colorless Interference color: Yellowish to olive-green Shape: Euhedral Pleochroism: Weak Cleavage: ½ direction Twinning: Perpendicular to cleavage planes Relief: High
Other minerals	77%	Glass fragment, opaque mineral, matrix
Photo:  		

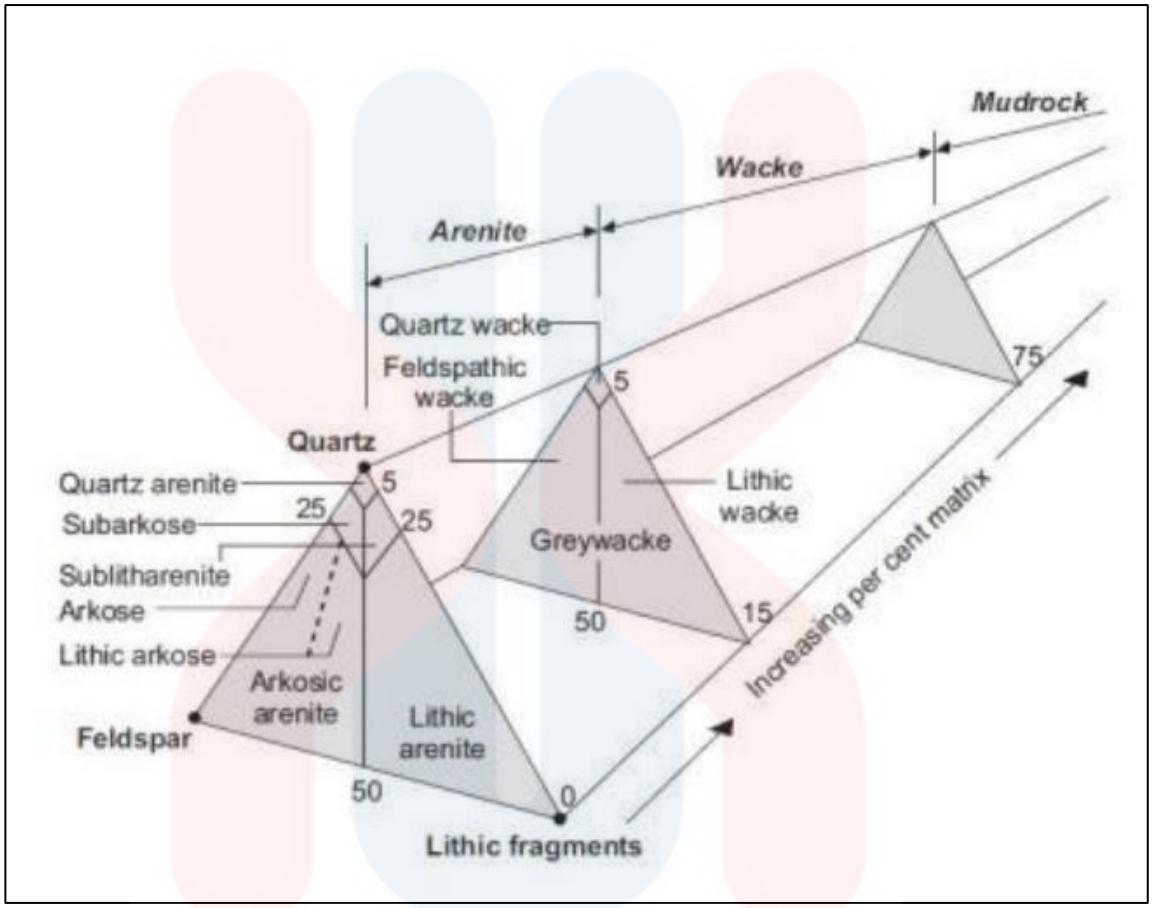


Figure 4.16: Classification of Sandstone (Pettijohn, 1975

CHAPTER 5

TSUNAMI EXPOSURE OF PANDEGLANG, BANTEN, INDONESIA

5.1 Introduction

This section will explain more on tsunami exposure of Pandeglang, Banten, Indonesia. This title is chosen as the specification in this study in order to study more about the tsunami exposure towards coastal community and their properties. Pandeglang is situated near to infamous volcano; Krakatoa that claimed many lives during 1883's occasion, and also located near to the subduction zone.

This research is conducted to investigate the aftermath of the Avalanche of Mount Krakatoa hill that occurred at the beginning of 2019, which two geological phenomena occur simultaneously; volcanic eruptions and tsunamis. The data for this section is gathered during geological mapping and also by secondary data that acquired from Regional Planning and Development Agency (Bappeda), Centre of Volcanology and Geological Hazard Mitigation (PVMBG) and Geological Agency.

Figure 5.1: Distance of research area from source of the tsunami; Krakatoa

(Source: Google Earth)

5.2 Tsunami Signature

While geological mapping being conducted along the shoreline from north to south there are significant prove are left behind by the recent occasion that take place at the beginning of 2019. Those affected properties are divided into three (3) different types which are possibly damaged, damaged and destroyed and exposure zone being created based on those 3 types of destructions. While at research is tsunami run up distance can be observed had range of 500 meter which is the tsunami does not even reach to the main road.

From observation during field, vegetation or big trees which are strong and stable enough gives huge contribution and act as resistance in tsunami run up distance where the momentum and energy of the tsunami will be reduced. This is why the tsunami cannot reach too far from the shoreline and due to this lots of residents does not notice or even know that tsunami have struck their shoreline that night.

During the research, most of the tourist spot; villa, homestay, resorts, and residents properties that situated near the shoreline are destroyed. Then, only few of them being repaired while others being abandoned unrepaired by their owners. Towards south the pattern of tsunami that struck the coastal area is slightly difference as the tsunami is assume to hit Tanjung Lesung first before the wave repel or bounce back and hit the shoreline headed towards north.

Figure 5.2: Villa that damaged due to the tsunami

Figure 5.3: Unrepaired villa in study area

Figure 5.4: Destroyed villa found in research area

Figure 5.5: Abandon resort in study area

Figure 5.6: Vegetation that available near the shoreline

Other than tourist spot, there are also got presence of vegetation near the beach and most of them also destroyed in that occasion but during study was conducted those plants that affected were already been fixed by their owners and in good condition. Casualties that occur in the study area are Carita; 71 (dead), 102 (injured) and 0 (missing), Labuan; 17 (dead), 80 (injured) and 2 (missing). Field observations showed that in several locations there were collapsed vegetation patterns that can give directions for the arrival of a tsunami with a geological compass tool. The direction of the tsunami that measured by geological compass is N 110˚E.

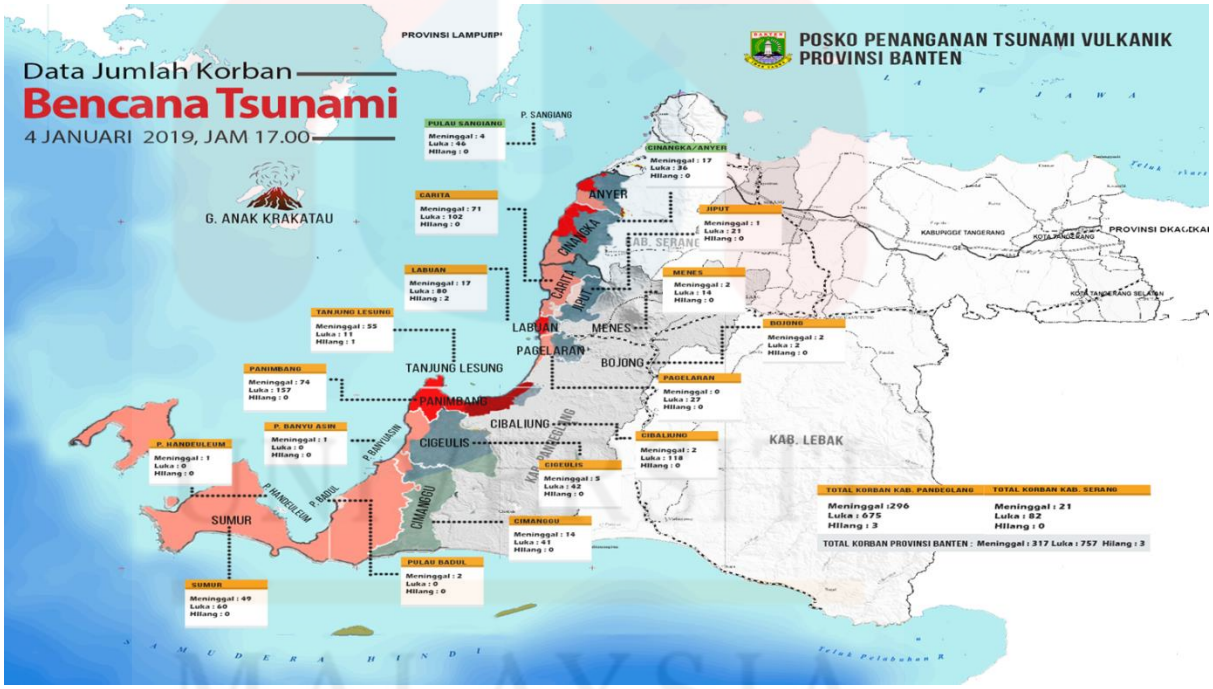


Figure 5.7: Data of casualties

(Source: Bappeda Provinsi Banten)

5.3 Tsunami Characteristic

From field observation and topography map, beach in the Pandeglang can be observed and classified as gently sloping beach. Slope at this area is less than 10˚ and height difference between land and sea level is less than 3 m.

Before the tsunami, there was a continuous eruption of Mount Krakatau volcano since June 2018 and fluctuated but there was no significant increase in intensity. The tsunami that occurred on 22 December 2018 is estimated to have been triggered by an avalanche or the fall of part of the body and material of the Mount Krakatoa (flank collapse) especially in the southern and southwest sectors. Satellite image data from BPPT confirms this assumption with an area of avalanche of about 64 hectares. This occasion is capable to produce regional tsunamis that can represent hazard to coastal ecosystems and human settlements near the beach (Ludwig, K.A et. al, 2018)

According to Supartoyo and Deden (2019) tsunami that occur on 22nd December 2018 in Sunda strait region happened without any early warning from authorities and without being preceded by signs tsunami will occur. This occasion befall at night (21.30 WIB) on weekend where most of the coastal communities that live and attend the festival near the shoreline are unaware of what are going to happen. Due to lack of awareness of what going to struck them and resulted in considerable causalities. The tsunami struck Banten, yet in addition South Lampung. The tsunami occasion had bringing about a calamity in the Sunda Strait area, conveying in excess of 431 died in Lampung and Banten.

The tsunami incident was recorded by the Agency's tidal stations Geospatial Information (BIG) with appearance time and first wave height information. The measurement results of the tsunami hit the coast of Banten Province shows high immersion on land (Flow Depth) the highest is 390 cm in Kampung Sumur, Sumberjaya Village, Sumur District, and Regency Pandeglang. The farthest distance from the tsunami to the land (Run up Distance) is 274 m Banyuasih Village, Cigeulis District, Pandeglang Regency (Supartoyo & Deden, 2019).

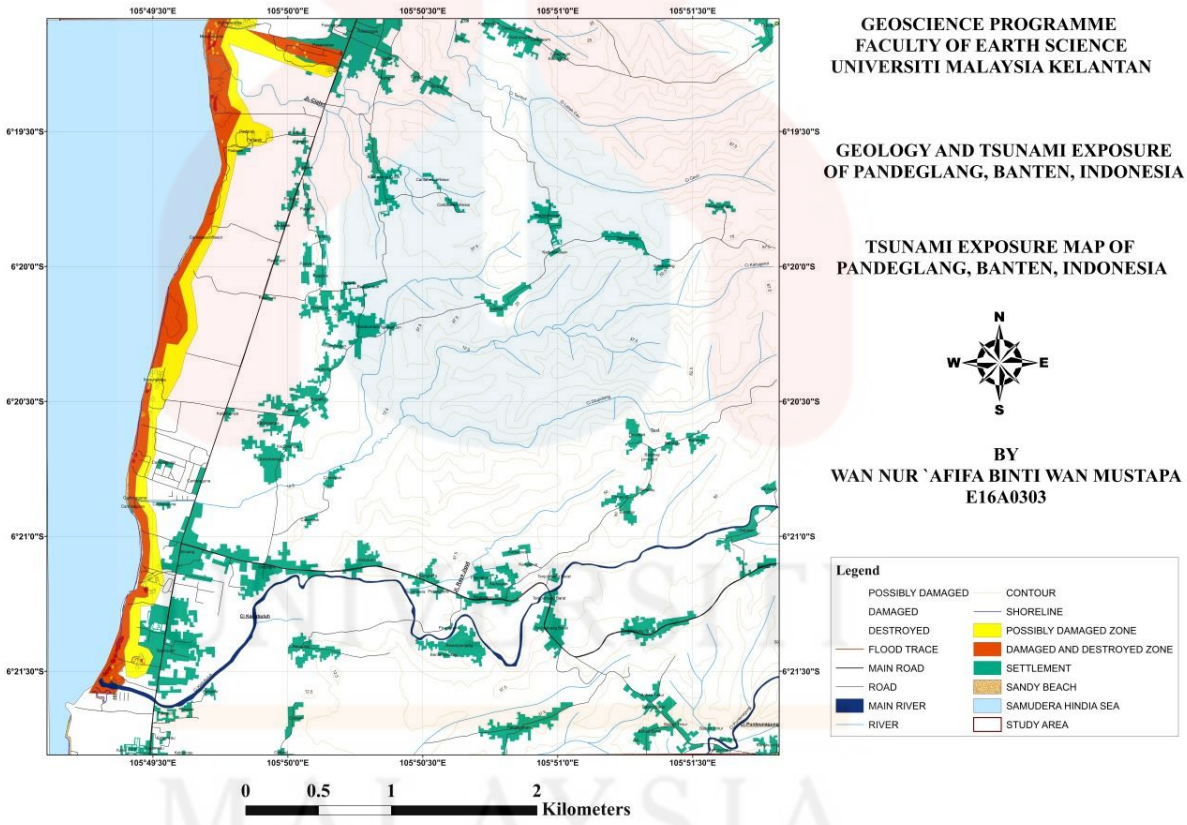


Figure 5.8: Tsunami exposure map of Pandeglang, Banten, Indonesia

5.4 Discussion

From the research that have been conducted on tsunami exposure of Pandeglang, Banten, Indonesia conclusion can be made that Sunda Strait beach in Banten province is a tsunami-prone area sourced from the landslide Mount Krakatoa hill body, Mount Krakatoa hilll eruption material and Strait subduction / megathrust zones Sundanese located in the south of Banten. The characteristics of the beach in the Sunda Strait of the Banten area are generally sloping beaches with a slope of less than 10˚. Ramps are rarely found beach barriers in the form of beach walls or beach embankments and vegetation, so they are prone to tsunamis. But in this episode vegetation, buildings and big trees which available along the shoreline helps in reduced the tsunami intensity and its run up distance. Therefore the tsunami is prevented from spread out in larger scale and many lives are safe from this occasion.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

All things considered, each one of the data and perception shows the significance of geology's knowledge to generate geological and other thematic maps including the study of tsunami exposure in research area. As the research area is situated in Pandeglang, Banten, Indonesia and close to the subduction zone and Krakatoa volcano the tendency for geological hazard phenomena to happen is high.

As observed, the slightly undulating hills covered the Eastern part of the study area while towards West coastal alluvial plain can be found which ended at the shore. Furthermore, there are two different types of lithologies which are Upper Banten Tuff and Alluvium. These lithologies are located towards Eastern and Western part of study area respectively. Other than that, the drainage pattern that can be observed in research area are dendritic and sub-parellel pattern that developed by erosion of water that flow in inhomogeneous territory for dendritic while sub-parallel formed due to steep slopes , the straight and quick-flows streams, with only several tributaries, and all of the streams flows in same direction.

Research area consist of two stratigraphic unit that aged Quaternary period which are alluvium and volcanic rock; lithic tuff. The discovery of sandstone fragment along the river may belong to Bojongmanik Formation as one of this formation's compositions is sandstone. Bojongmanik Formation is the oldest formation exposed in Pandeglang.

Through geological mapping which done for specification on tsunami exposure, the result that can be achieved is three different zones; possibly damaged, damaged and destroyed can be constructed on affected area. This research also shows that Pandeglang is prone area for tsunami due to its geological position.

6.2 Recommendation

There are several of suggestions that can be made in the research area for future's sake. More research should be made on study area and nearby area so that future researcher can use them as guidance for further investigation especially on lithology details tsunami analysis. The study on tsunami exposure due to Mount Krakatoa should be heightened to ease researchers' future investigations.

The tsunami mitigation should be implemented in research area by built barrier at the shoreline so that the strength or momentum of tsunami can be reduced as well as properties damages. Indonesia government also can follow the precautionary steps made by Japan such as practice tsunami drill upon villagers and make steel gate that can

blocked the tsunami water from reach residents area. Tsunami landform data and map of tsunami hazard prone areas issued by the Geology Agency to be used at the next stage, namely rehabilitation and reconstruction. Coastal community should be exposed to application that can make them more aware about geological phenomena happened around them.

REFERENCES

Asia. (n.d.). Retrieved from https://www.citypopulation.de/php/indonesia-banten-admin.php?adm2id=3601120

Azly, E. (2018, December 24). Anak Krakatau avalanche caused Sunda strait tsunami. Retrieved from https://en.antaranews.com/news/121511/anak-krakatau-avalanche-caused-sunda-strait-tsunami

Bagley, M. (2017, September 14). Krakatoa Volcano: Facts About 1883 Eruption. Retrieved May 5, 2019, from https://www.livescience.com/28186-krakatoa.html

Burkett, V.R., Davidson, M.A. (Eds.), (2012.) Coastal Impacts, Adaptation and Vulnerability: A Technical Input to the 2012 National Climate Assessment, p. 150. Cooperative Report to the 2013 National Climate Assessment. http://downloads.usgcrp.gov/NCA/technicalinputreports/ Burkett_Davidson_Coasts_Final_.pdf.

Figure 2f from: Irimia R, Gottschling M (2016) Taxonomic revision of Rochefortia Sw. (Ehretiaceae, Boraginales). Biodiversity Data Journal 4: E7720. https://doi.org/10.3897/BDJ.4.e7720. (n.d.). doi:10.3897/bdj.4.e7720.figure2f

FURNEAUX, R., (1964,) Krakatoa. Prentice-Hall, Inc., Engiewood Cliffs, N. J., 224 pp. GORSHKOV, G. S., (1959,) Gigantic Eruption of the Volcano Bezymianny. Bull. Volcanol., ser. 2, 20, p. 77-109, plates. HARKRmm~, D. and PRESS, F., 1967, The Krakatoa Air-sea Waves: an Example of Pulse Propagation in Coupled Systems

Geologic mapping (UGM). (n.d.). Retrieved from https://wiki.aapg.org/Geologic_mapping_(UGM)

Giachetti, T., Paris, R., Kelfoun, K., Ontowirjo, B., & Pascal, B. (2012). Tsunami hazard related to a flank collapse of Anak Krakatau Volcano , Sunda Strait , Indonesia. 79–90

HARKRmm~, D. and PRESS, F., (1967,) The Krakatoa Air-sea Waves: an Example of Pulse Propagation in Coupled Systems

Ludwig, K.A., Ramsey, D.W., Wood, N.J., Pennaz, A.B., Godt, J.W., Plant, N.G., Luco, N., Koenig, T.A., Hudnut, K.W., Davis, D.K., and Bright, P.R., 2018, Science for a risky world—A U.S. Geological Survey plan for risk research and applications: U.S. Geological Survey Circular 1444, 57 p., https://doi.org/10.3133/cir1444.

Lumbanbatu, U. M., Hidayat, S., & Poedjopradjitno, S. (2012). Potensi Bencana Pelulukan Di Daerah Labuhan Kabupaten Pandeglang Provinsi Banten. Jurnal Geologi Dan Sumberdaya Mineral, 22(2), 115–130. https://doi.org/10.33332/JGSM.2012.V22.2.115-130

METZGER, E., 1884, Gleanings from the Reports Concerning the Eruption of Krakatoa. Nature, London, 29, p. 240-244

Patton, J., Stein, R., & Sevilgen, V. (2018). Sunda Strait tsunami launched by sudden collapse of Krakatau volcano into the sea. *Temblor*. doi:10.32858/temblor.001

Penanggulangan Bencana Tsunami Selat Sunda. (2019, november). Badan Perencanaan Pembangunan Daerah. Banten, Indonesia.

RUSSELL, F. A. R. and ARCHIBALD, E. D., (1888,) On the Unusual Optical Phenomena of the Atmosphere, 1883-1886, Including Twilight Effects, Coronal Appearances, Sky Haze, Coloured Suns, Moons, etc. Part 4, p. 151- 463. Ln: The eruption of Krakatoa, and Subsequent Phenomena, Report of the Krakatoa Committee of the Royal Society, G. J. SYMONS Ed., Harrison and Sons (Printers), Triibner and Co. (Publishers), London, 494 pp.

Science, E. (n.d.). *Analysis of tsunami disaster map by Geographic Information System (GIS): Aceh Singkil-Indonesia Analysis of tsunami disaster map by Geographic Information System (GIS): Aceh Singkil-Indonesia*. https://doi.org/10.1088/1755-1315/56/1/01200

Soils from Volcanoes. (n.d.). Retrieved November 4, 2019, from http://volcanology.geol.ucsb.edu/soil.htm

supartoyo, d. j. (2018). Tsunami Tanggal 22 Desember 2018 di Pantai Banten.

U., B. L. M., & Soemantri, P. (2012). Quaternary Geological Phenomena in Labuhan Area , Pandeglang Regency , Banten Province. Indonesian Journal on Geoscience, 7(4), 211–226. Retrieved from http://ijog.bgl.esdm.go.id

Yurtoğlu, N. (2018). Http://www.historystudies.net/dergi//birinci-dunya-savasinda-bir-asayis-sorunu-sebinkarahisar-ermeni-isyani20181092a4a8f.pdf. *History Studies International Journal of History,10*(7), 241-264. doi:10.9737/hist.2018.658