Indonesian Physical Review
Volume 2 Issue 2, May 2019
P-ISSN: 2615-1278, E-ISSN: 2614-7904

Determination of Pumice Pyroclastic Density of Rinjani Mountain Eruption and its Spreading Simulation Using Hazmap Software

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ARTICLE INFO

Article History:
Received: 15-04-2019
Revaised: 29-05-2019
Accepted: 30-05-2019

Keywords:
Density; pyroclastic; simulation.

How To Cite :
Wardani, A.F., Al Hadi, K., Qomariyah, N., Minardi, S., (2019). Determination of pumice pyroclastic density Of rinjani mountain eruption and its spreading simulation using hazmap software. Indonesian Physical Review, 2(2), 75-83

DOI:
https://doi.org/10.29303/ipr.v2v2.27

ABSTRACT

Volcano represent channel of systems fluid (lava), which has a depth up to 10 km from the earth surface. One of the active volcanoes is Mount Rinjani which recorded the eruption was 9 times from 1846 to 1994. The result of the eruption of Mount Rinjani is pyroclastic rocks dominated by pumice, which accumulated at lot of areas of research that will be determined by the density value calculation method. The resulting rock density values can be used to see the spread of the volcanic eruption material with simulation software based on data Hazmap eruption in 1994. The result of this research is the density of pumice and simulated the spread of the eruption of Mount Rinjani 1994. The density of pumice is about 693 kg/m^3 and deployment simulation shows the distribution of the eruption of Rinjani to the diameter size of the fine dust (<1/16 mm) spread towards the Northwest (North Lombok) with total mass about 6,38x10^9 kg and diameter size of lapilli (2-10) mm spread around the center ofthe eruption (Mount Rinjani) with total mass about 5, 16x10^9 kg.

Introduction

Volcano is a channel system of fluid (lava) which has a depth of up to 10 km from the surface of the earth (https://id.wikipedia.org). Existence of mountains this fire spread throughout the world, however location of the most recognizable volcano is on the Pacific Ring of Fire arc formed due to friction between two plate tectonics. Volcanoes in Indonesia are part of the Pacific Ring of Fire formed in the subduction zone between the Eurasian plate and the Indo-Australian plate.

Mount Rinjani is one type A volcano in the region Indonesia, which erupted 9 times during the period of 1846 to 1994 [1]. The results of the eruption from Mount Rinjani is pyroclastic rocks that are genetically divided into three types, namely falling deposits pyroclastic, and pyroclastic flow deposits pyroclastic surge deposits.

Pyoclastic deposits are ingredients released from the volcano produced by a series of processes related to volcanic eruption. In other terms often found is scattering material (ejecta), which is a rock crust issued during the eruption volcano [2]. Group of this rock is important to learn considering Indonesia's geological conditions many volcanoes, make the presence of rocks is very common found in Indonesia, especially in active volcanic regions.

Based on its grain size, pyroclastic rock is divided into bombs if the size is greater than 64 mm; lapili (2-64 mm); and coarse dust (<2 mm). The size of the Item is the basis for selecting sample rocks in each study location which indicate they are pyroclastic rocks. Pyroclastic rocks found around Mount Rinjani are pumice. Pumice is a type of pyroclastic rock that is genetically close to extrusive rocks, but descriptively and how it occurs shows characteristics (structure and texture) similar to clastic sedimentary rock groups.

Pumice has many benefits both in industry and construction. Its application in the industrial sector tends to produce complete goods, such as paint and cement, while in the construction sector produces building materials, such as lightweight concrete aggregates. Based on these reasons, further research needs to be done pyroclastic rocks especially the pumice.

This research will be conducted determination of the density of pyroclastic rocks and its distribution simulation by means of collection of samples (pumice) at the study site, where samples for the 1994 Rinjani eruption were found at a layer of 1 m above ground level, because the 1994 eruption was considered the last eruption of Mount Rinjani. Pumice rock is then processed so that the results of the input parameters (density) are needed in the simulation.

The parameters will be input data on simulation processing is the diameter, density, total eruption mass and eruption column height, and wind speed and direction data when the eruption occurs. In addition to sample data, researchers added other rock data (sand and scoria) which are other pyroclastic rocks in the area. The final result of this study is the value of pumice density and contour maps of mass deposits of pyroclastic rocks resulting from the simulation of the 1994 Mount Rinjani eruption.

Conducted a study of the Colima (Mexico) volcanic eruption scenario using Hazmap, and the results were contours as below [3]. Data input from the modeling are rock type, rock diameter, total mass, and eruption column height. Type of rock in the form of pumice, scoria, lytic and crystal with a total eruption mass of 2.36×10^{11} kg, and column height of about 25 km.

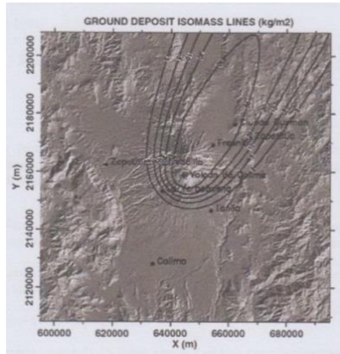


Figure 1. Fallout deposit of 1913 Colima eruption reconstructed using the HAZMAP model [3].

From 1896 to 1994 Mount Rinjani was recorded as having erupted 9 times with products such as lava and pyroclastic fall. Composers of pyroclastic flow deposits are dominated by pumice fragments, besides that there are also lithic fragments and scoria. Pyroclastic fall deposits are widespread in the top part of the caldera arranged from sand-sized pumice to gravel and lytic, dirty white, scoria fragments are generally blackish gray in color, in some places there is good graded bedding [1].

Theory and Calculation

Geologically, the NTB region is composed of Quaternary to Tertiary rocks which are dominated by volcanic rocks and Alluvium (resent). Tertiary rocks on the island of Lombok consist of quartz sandstone sandstone, claystone, breccia, lava, tufa with limestone, limestone and dacitic lenses. Whereas for Quaternary rocks consists of intersections of side breccia and lava, breccia, lava, tufa, pumice and lava breccia. The distribution of rocks is displayed in the form of a geological map in Figure 2.

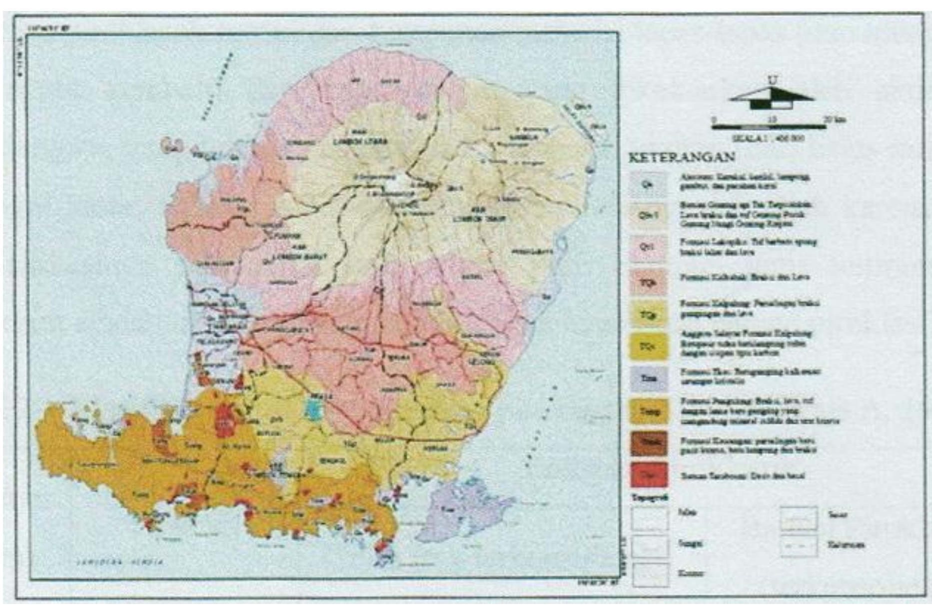


Figure 2. Lombok island Geological map [4]

Pyroclastic rocks are clastic textured volcanic rocks produced by a series of processes related to volcanic eruptions, where the constituent material is deposited and consolidated before experiencing transportation (reworked) by water or ice [5]. In its activities rock results from volcanic activity can be in the form of lava flows as classified in igneous rock or in the form of explosive products from material that is solid, liquid or gas contained in the stomach of the mountain.

Pyroclastic rocks are very different in texture with igneous rock, if igneous rock is the result of freezing directly from magma or lava, so from the liquid phase to the solid phase with the end result consists of a collection of crystals, glass or mixture of both. While pyroclastic rocks consist of a set of loose material (and possibly reunited) from materials released by volcanic activity, in the form of solid materials of various sizes (from fine to very rough, even can reaching the size of a lump). Therefore the classification is based on grain size and type of grain.

Analysis of the distribution of pyroclastic rocks using the contour interpolation method. Contour interpolation methods are either interpolation methods other than visual, numerical, and graphic [6]. Input of the Hazmap 2.4.4 software is a variable of mass and density.

Mass is the nature of an object that explains the strength of the object's resistance to resisting changes in speed, and SI units for mass are kilograms (kg). Objects of the same size can have different weights and masses, this difference is characterized by other characteristics, namely density. Density (ρ) of a substance or object defined as mass per unit volume [7], which is getting higher the density of an object, the greater also the mass of each volume.

$$\rho = \frac{m}{V} \tag{1}$$

Where m is a mass (kg), ρ is a density ($kg.m^{-3}$) and V is a volume (m^3) respectively.

Hazmap is a computer program for simulation of volcanic particles by point discrete source and to get a deposit suitable soil. Hazmap 2.4.4 is based on a simple physical model describe transportation and sedimentation volcanic particles (lapili and ash) from one source or more.

Spread of particles in the atmosphere influenced by turbulent diffusion and movement wind, while falls are influenced by speed determination generated from gravity and air resistance. For make it in a computational model, then a simple assumption is made, the distance from the column eruption (for example several times the eruption column), Ci particle concentration with determination speed Vs, and j can be described with mass determination equation:

$$\frac{\partial C_j}{\partial t} + \omega_x \frac{\partial C_j}{\partial x} + \omega_y \frac{\partial C_j}{\partial y} - v_{s,j} \frac{\partial C_j}{\partial z} = K_x \frac{\partial^2 C_j}{\partial x^2} + K_y \frac{\partial^2 C_j}{\partial y^2} + K_z \frac{\partial^2 C_j}{\partial z^2} \tag{2}$$

Where (x, y, z) is spatial coordinate, t is a time, (w_x, w_y, w_z) is a wind velocity component and K_x, K_y, K_z is coefficient of diffusion, which is constant assumed, respectively.

Determining of particle concentration (Cj) could be done using gauss distribution as shown in the Equation (3).

$$C(x,y,z,t) = \frac{1}{4\pi Kt} exp\left[\frac{(x - x_0 - \omega_x t)^2 - \left(y - y_0 - \omega_y t\right)^2}{4Kt}\right]\delta\left(-z_0 + v_{s,j}t\right)^2 \tag{3}$$

Equation (2) explain the distribution of particle at the horizontal plane with velocity Vs with final position of mass distribution $\left(\vec{x}_{GI} = (x_{Gi}, y_{Gi})\right)$ and variation of mass distribution on the land (σ_{Gi}^2) is:

$$\vec{x}_{Gi} = \vec{x}_{0i} + \sum_k \omega_k \Delta t_k \tag{4}$$

$$\sigma_{Gi}^2 = 2K \sum_k \Delta t_k \tag{5}$$

Where i identify the layer source point, k shows the number of general layers between the source point and the ground, wk wind speed horizontal layer k; $\vec{x}_{0i}$ is a coordinate horizontally from the source points i and Δt_k are residence time of particles in layer k ($\Delta tk = (z_k - z_{k-1}/v_{s,k})$).

Because of linearity in the equation for mass determination, the total mass on the ground is calculated as the sum of each source point and speed determination, Equation (3) can be rewritten as:

$$M_G(x,y) = \sum_{j=1}^{N_{v_S}} \sum_{i=1}^{N_{sources}} \frac{M_i f_j}{2\pi\sigma_{Gi}^2} exp\left[-\frac{(x - x_{Gi})^2 + \left(y - y_{Gi}\right)^2}{2\sigma_{Gi}^2}\right] \tag{6}$$

Where Nvs, shows the total of class speed determination, M_i; number of masses which is emitted from the source point in the i layer ($\sum_i M_i = M_{total}$, with the total mass entered in the system) and f_j is a fraction masses who have speed provisions class j ($\sum_j f_j = 1$)[8].

Method

This research was conducted in the North Lombok area with 4 research location points as presented in Figure 4. While the research stages are described as the diagram in Figure 5.

Figure 3. Location of data acquisition

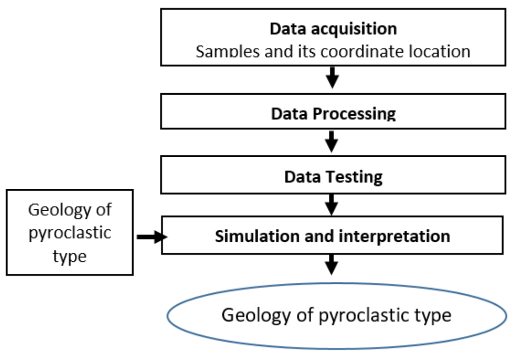


Figure 4. The research stages

Result and Discussion

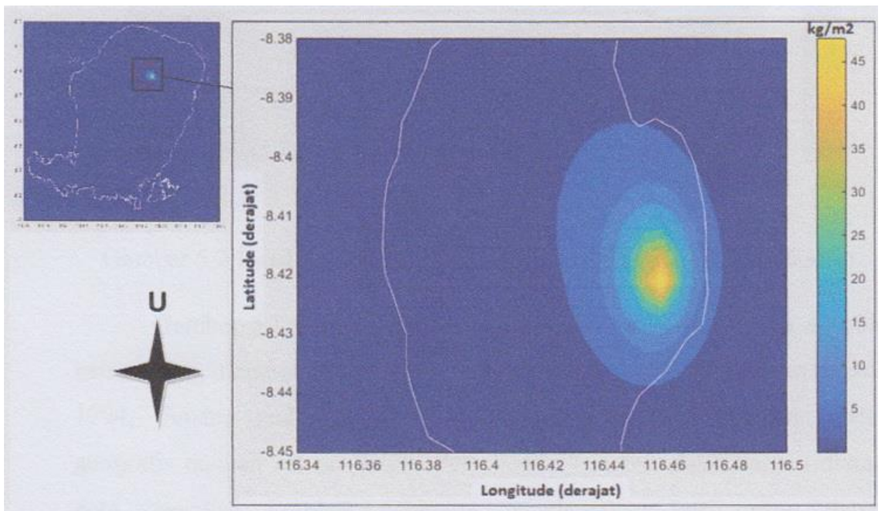
Calculation of rocks (pumice) is done by using rock density (mass / volume) equations in the study area, while the results of the calculations can be seen in Table 2 below:

Table 1. Results of Calculation of Rock Density

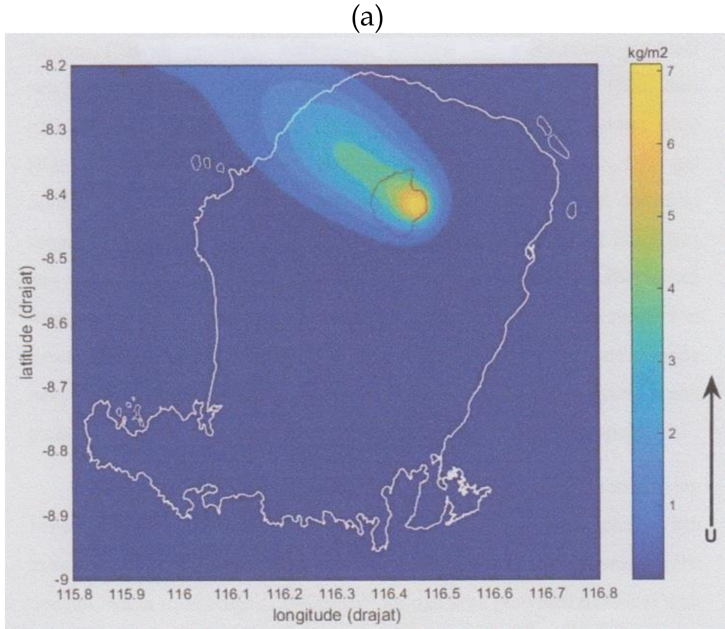
Location	sieve size(mm)	mass(g)	volume (ml)	density (kg/m³)
PANTAI TEBING	>10	25.8	50	516
	4 - 10	225.9	300	753
	2 – 4	324.2	440	737
	<2	534.7	730	732
LOKOK MEANG	>10	49.7	50	994
	4 - 10	169.8	185	918
	2 – 4	136.1	150	907
	<2	515.7	560	921
SAMBIK BANGKOL	>10	73.6	120	613
	4 - 10	209.2	360	581
	2 – 4	157.3	270	583
	<2	223.7	400	559

SANJAJAK	>10	93.4	165	566
	4 - 10	229.6	410	560
	2 – 4	89.4	160	559
	<2	64.7	110	588

Table 1. above shows the value density of rock samples at the study site, where this density value will be used in simulation of the spread of eruption results in 1994 in Hazmap-2.4.4 software.



(a)



(b)

Figure 5. Results of the 1994 Rinjani Eruption Simulation for (a) diameter (2-10) mm and (b) diameter less than 1/16 mm.

Calculation this rock density is obtained from mass results and the volume of rock samples that have been sifted at each research site, but the results of the sieve less than 2 mm is not used because of its size so small that it cannot be ascertained as pumice which is the sample research. The results of the sieve are then used to calculate rock density each location and average yield of density be the final value of the density of the surrounding rock 693 kg/ m^3. The final result of the rock spread simulation can be shown in the Figure 5.

Figure 5(a) is the final result of processing data that shows spread of pyroclastic rocks that are on Lombok based on the data obtained with the diameter of the rock according to the sieve used. In the picture shows spread rock deposits at the center of the eruption with the mass value of the deposit highest around (37 – 47) kg/m^2 spread around the center of the eruption and the lowest value around (5 – 17) kg/m^2 spread around Mount Rinjani (mountain crater), while Figure 6(b) is a spread simulation with smaller rock diameter (<1/16 mm). More rock spread clearly heading northwest with value the highest mass deposit is around (5.5 - 7.2) kg/m^2 which are spread around Mount Rinjani and the lowest value is around (0.7- 3.5) kg/m^2 many spread northwest and partly to the southeast. In the second the picture above is the lowest mass value of the deposit which is shown in blue shows unaffected areas mountain eruption, this happens because of the spread of at the atmospheric particles is affected by wind direction, which is in the study the direction of the wind is to the northwest of the center eruption.

Figures 5(a) and 5(b) are map of the mass contour of the rock deposit shows the simulation of the resulting rock spread eruption of Rinjani 1994, where on the x-axis and the y-axis describes the geographical position in units of degrees. Map of the contour depicted on the coastline map of Lombok so get results that can indicates the position of the mass deposit at Lombok Island.

The simulation results in the form of the mass of total deposits from the eruption of Mount Rinjani in 1994 which is about 5.1593×10^9 kg for data rocks sieve diameter (2-10) mm and about 6.3851×10^9 kg for rock diameter size of <1/16 to the total mass eruption 1.0420×10^{10} kg and direction of distribution in the direction of the wind (northwest). Differences in the simulation value with the actual value of the total mass due to rock deposition events not only influenced by land wind speed, but also influenced by several things such as the topography of the area or cracks around Mount Rinjani.

Conclusion

Based on the calculation and distribution of analysis that has been done, it can be concluded that: almost of Rinjani eruption material distributed in the northwest. Direction of material distribution mainly dependent to direction and speed of the wind and influenced by several things such as the topography of the area or cracks around Mount Rinjani.

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