IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 10, Issue 3 Ser. I (May. – June. 2022), PP 30-37
www.iosrjournals.org

Modeling of the Subsurface Structure of Mount Ebulobo Based On Ggmplus Gravity Data

M. Nur Abdul Fattah Faris Wijaya)[1], M. Irham Nurwidyanto)[1], Tony Yulianto)[1]
[1]*Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Semarang*

Abstract:
Background*: The gravity method is one of the geophysical exploration methods, its application is made by measuring the acceleration of gravity below the earth's surface due to the distribution of mass density between rocks that are uniform in an area and topographic variations in the area. Earth surface. Ebulobo Volcano is located in Ngada Regency, Flores – East Nusa Tenggara. Ebulobo volcano another name Ambarombu located in the Ngada district has a stratotype of the volcano at the height of 2123 meters above sea level*.
Materials and Methods*: The gravity data in this study has an area of 10 km x 12 km with a distribution of 2530 observation points. This study aims to interpret the subsurface area of the Ebulobo Volcano based on the results of 3D inversion modeling using Grablox software.*
Results*: . The modeling results identify all the incisions providing information on the alleged location of the magma chamber at a depth of 3000 meters with a diameter of 3000 meters to 4000 meters as a warning if in the future there is an explosive eruption that affects the surface of the mountain body and the surrounding areaDensity results obtained using x-axis and y-axis incisions are from 2.15 g/cm^3 to 3.25 g/cm^3.*
Conclusion:*. The layers that make up the Ebulobo Volcano are andesite, basalt, andesite-basaltic rocks, breccia, and tuff rocks.*
Key Word*: Subsurface, modeling, Ebulobo Mountaint, gravity, CGM Plus,*

Date of Submission: 22-05-2022 Date of Acceptance: 05-06-2022

I. Introduction

Indonesia has a volcanic route with eruption hazards in the ring of fire area from Sumatra, Java, Bali, Nusa Tenggara, Sulawesi, Banda, Maluku, and Papua [1]. Volcanoes are located in the boundary zone or subduction zone between two plates that meet and collide with each other, by producing hot clouds, hot lava, volcanic ash, and various large materials that affect the atmosphere and marine volcanoes that can cause landslides, volcanic earthquakes, and even volcanic eruptions. Tsunamis. The territory of Indonesia has a total of up to 127 volcanoes scattered on various islands and one of them is Ebulobo on Flores. The Ebulobo volcano is located in the area where the three Indo-Australian, Eurasian-Pacific, and Indo-Pacific plates meet, causing various volcanic earthquakes and earthquakes before the eruption, with a stratotype and a height of up to 2,123 meters (masl). The first eruption was in 1830, generally, lava flows out during the eruption to form lava that accumulates to increase in height in a short time and there have been no previous paroxysmal eruptions, with a symmetrical body. Ebulobo volcano has an eruptive period of 3 to 58 years [2].

Ebulobo Volcano's behavior can be understood by researching structures on the subsurface of Ebulobo Volcano. One of the geophysical methods used to identify subsurface conditions is the gravity method. The gravity method consists of measuring the gravitational field between rocks. To understand the subsurface conditions of an area, the gravity method is widely used before other geophysical survey methods are carried out, because of its broad and deep (regional) nature.

Of the many methods for geophysical research, the gravity method is the most appropriate choice to determine the location of the estimated fault location, because this method provides information from differences in density contrasts of rock bodies. The fault/fault zone is indicated by the significant difference in rock density contrast [3].

Several methods of analyzing gravity data are carried out to describe subsurface structures, such as knowing the location of fault structures and identifying faults, derivative analysis can be performed. The focus of this research is the result of the anomaly value in the modeling by knowing the distribution of the density of the expected subsurface structure can be described. Then a modeling simulation is carried out from the comparison of the observed anomalies with anomalous geometry models and geological data information. Two ways of modeling simulations are made in two-dimensional and three-dimensional cross-sections to describe the state of the structure at the subsurface. From the results of the modeling simulation, it is expected to be able to

take into account the location and characteristics of the faults from the results of gravitational observations, as well as to obtain information on the structural layers below the surface

II. Material And Methods

The Research Area are Ebulobo Volcano with another name Ambarombu is located in the Ngada district. It has a Strato Volcano type with an altitude of 2123 meters above sea level. There are at least 8 eruption points and 3 lava plugs without a crater name. Its geographical location is at the coordinates of 8"48.5' South Latitude and 121"11' East Longitude. Administratively, Ebulobo Volcano is located in Ngada Regency, Flores - East Nusa Tenggara. The closest town to the Ebulobo Volcano is Boa Wae Town [3].

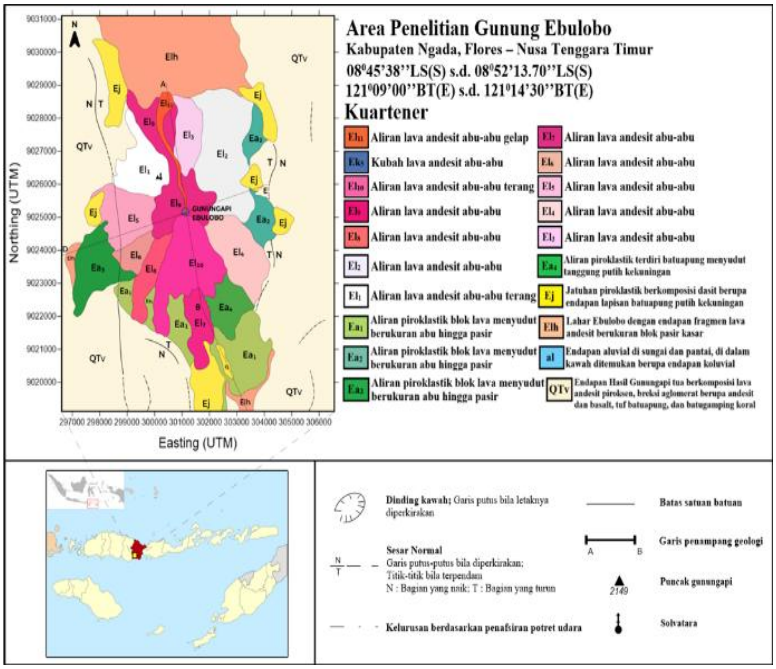

Figure 1. Geological Map of Mount Ebulobo [3]

Basic Principles of Gravity Method

Newton's law of gravity is the basis of the theory of gravity. Newton's law of gravitation explains that the magnitude of the force between two objects that attract each other with masses m1 and m2, which are spaced r apart, is inversely proportional to the square of the distance and directly proportional to the product of the two masses. In Figure 2 Newton's law of gravitation is illustrated as follows [4].

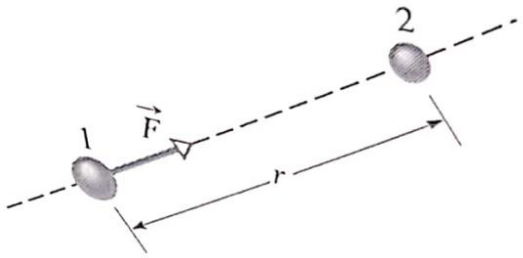

Figure 2. The attractive force between particle 1 and particle 2.

Procedure methodology

This research was carried out from March to July 2021. The data used in this study is secondary data in the form of GGMplus which contains longitude, latitude, and Free Air Anomaly The geographical position of the research area is at coordinates 08°45'38" South Latitude (S) to 8° 52'13.70" South Latitude (S) and 121o09'00" East (E) to 121°14'30" East (E) This data has a distribution of 2530 observation points with an area of 10 km x 12 km. The applications used in this research are Ms. Excel 2013, Google Earth Pro, Ms. Visio 2013, Global Mapper 18, Oasis Montaj, Surfer11, Magpick, Grablox, and Bloxer. In this study, qualitative interpretation was carried out using horizontal gradient and vertical gradient methods. The quantitative interpretation was also carried out for the distribution of density values over a 2-dimensional (2D) cross-section.

The quantitative interpretation was also carried out to see the layers that make up Mount A pi Ebulobo by looking at the results of modeling in 3 dimensions (3D)

III. Result

The Complite of Bouguer Anomaly in the research area are shown in Figure 3. The range of Bouguer anomaly values ranging from 68 mGal to 116 mGal is the result of RBD at a depth of 2800 meters when compared to a complete Bouguer anomaly without RBD. Bouguer anomaly values range from 90 mGal to 150 mGal. The maximum value of the Bouguer anomaly was reduced from 150 mGal to 116 mGal, while the minimum value of the Bouguer anomaly was reduced from 90 mGal to 68 mGal. The distribution range of the Bouguer anomaly consists of three types, namely, the high Bouguer anomaly value, the medium Bouguer anomaly value, and the low Bouguer anomaly value. The distribution of high Bouguer anomaly values extends and the coverage area is quite wide in the north, east, and west of the study area. The distribution of moderate Bouguer anomaly values has yellow to green markings. The distribution of low Bouguer anomaly values has very little coverage area because the blue color is only visible in the southeast and southwest parts of the study area. In the complete Bouguer anomaly before in the flat area in the Mount Ebulobo area, it shows a low anomaly and after in the flat the results get a middle anomaly to high anomaly which explains that the Mount Ebulobo area is occupied by medium density rocks such as andesite-basaltic and high density such as basalt and lava with basalt composition.

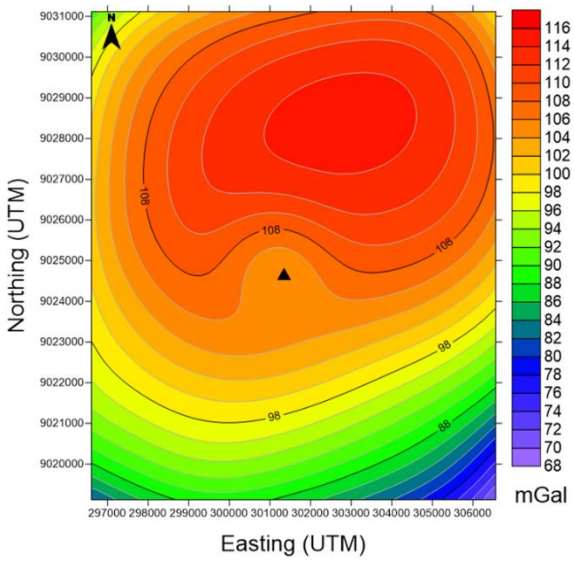

Figure 3. Complete Bouguer Anomaly

The range of Bouguer anomaly values ranging from 68 mGal to 116 mGal is the result of RBD at a depth of 2800 meters when compared to a complete Bouguer anomaly without RBD. Bouguer anomaly values range from 90 mGal to 150 mGal. The maximum value of the Bouguer anomaly was reduced from 150 mGal to 116 mGal, while the minimum value of the Bouguer anomaly was reduced from 90 mGal to 68 mGal. The distribution range of the Bouguer anomaly consists of three types, namely, the high Bouguer anomaly value, the medium Bouguer anomaly value, and the low Bouguer anomaly value. The distribution of high Bouguer anomaly values extends and the coverage area is quite wide in the north, east, and west of the study area. The distribution of moderate Bouguer anomaly values has yellow to green markings. The distribution of low Bouguer anomaly values has very little coverage area because the blue color is only visible in the southeast and southwest parts of the study area. In the complete Bouguer anomaly before in the flat area in the Mount Ebulobo area, it shows a low anomaly and after in the flat the results get a middle anomaly to high anomaly which explains that the Mount Ebulobo area is occupied by medium density rocks such as andesite-basaltic and high density such as basalt and lava with basalt composition.

Upward continuation is used to find the anomalous value of internal objects. The *upward continuation* is carried out by *trial and error* to see the trend of the contour pattern of the lift at a certain height. In this study, a height of 3000 m, the regional anomaly can be shown in Figure 4 and the resisual anomaly can be shown in Figure 5.

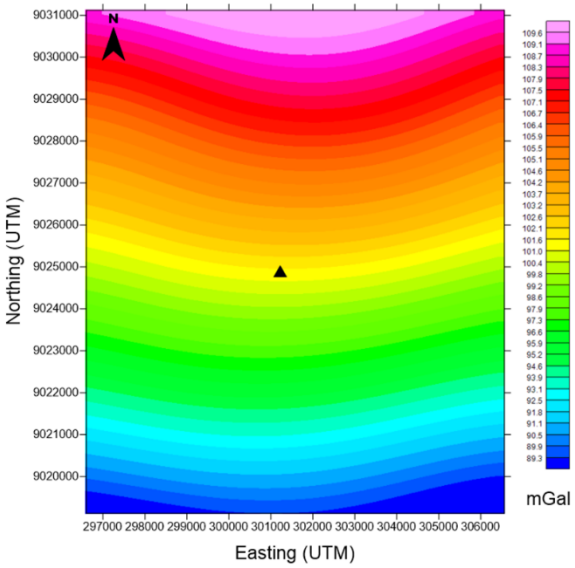

Figure 4. Upwarded Anomaly

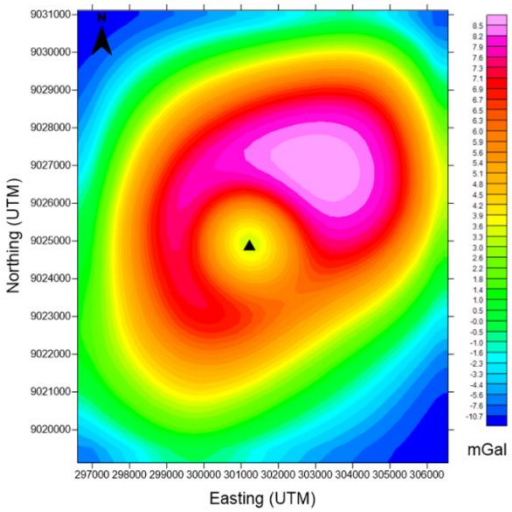

Figure 5. Residual Anomaly

Residual anomalies produce information about the condition of shallow rocks different from the response anomalies of deep bodies which explain the condition of deep rocks. There was a significant decrease in the value of the variation in the value of the shallow response anomaly. The values obtained range from -10.7 mGal to 8.5 mGal. The residual Bouguer anomaly map is dominated by high residual anomaly values whose area surrounds the body of the Ebulobo Volcano and is centered in the northeast and southwest of the summit, presumably due to the shallow response of the breccia rocks. The moderate anomaly value, which is characterized by light green and yellow colors circling the outside of the high zone of Ebulobo Volcano and around the summit of Mt., is thought to be due to the response of andesitic lava flows. Low anomaly values are concentrated in the southeast and northwest of the study area which is characterized by a dark blue color with a range of -10.7 mGal to -1.5 mGal presumed from the response of andesite lava rock, tuff and tuff pumice.

Quantitative interpretation is done by making subsurface modeling using *Grablox* and *Bloxer*, by entering the response value of shallow objects that have been reduced to a flat plane. Subsurface modeling is carried out using 6 incision paths on local anomaly contours flat field. This was done to see the subsurface structure of Ebulobo Volcano.

IV. Discussion

Figure 6 is the result of 2D modeling of the A-A' incision with the surfer. The range of density values obtained is 2.25 g/cm^3 to 3.25 g/cm^3. The 2D model of the A-A' incision is at Y = 9025,793. This A-A' incision passes through the sedimentary rock formations of Old Volcano (QTv), Ebulobo pyroclastic fall (Ej), 11 Ebulobo lava flow (El11), 9 Ebulobo lava flow (El9), 1 Ebulobo lava flow (El1) and 2 Ebulobo lava flow (El2). Ebulobo volcanic rock is the bedrock of volcanism with a rock composition consisting of lava with basalt, andesite, and basalt composition. Andesite rock has a density range of 2.40 g/cm^3 to 2.80 g/cm^3 seen in the surface area with the central area of Mount forming two paths towards the center of the earth and the area below a depth of 3000 meters, the A-A' incision is dark green to yellow. In the A-A' section, medium to high-density rocks dominates the modeling results. Lava has a density range of 2.80 g/cm^3 to 3.00 g/cm^3 seen at the west end and east end of the A-A' incision with a depth of 1000 m to 5,000 m can be identified as lava rock which is characterized by red color. Basalt rock has a density range of 2.70 g/cm^3 to 3.30 g/cm^3 in the A-A' section. Basalt rock with reddish-yellow color is seen spread over an area of 1000 m to 5,000 m in the west and east. In the A-A' section, there is a fault-based on geological information, there is a decrease in density from 2.7 g/cm^3 to 2.55 g/cm^3 with a tendency toward the fault line from South-North, this is proven in previous studies conducted by [6] stated that all visible structures have a south-north trend. In the A-A' section, there is a low-density contrast at a depth of 3000 meters with a diameter of approximately 3000 to 4000 meters which indicates the area of the magma chamber of Ebulobo Volcano is suspected to have a more specific ratio than the location of the depth of the magma chamber in the study [7] with the average depth of the magma chamber. Volcano on the island of Flores at 6 km. From the estimation of the location of the magma chamber, it is supported by data from [4] that the symmetrical shape of Ebulobo Volcano and the lava dome in the summit crater which functions as a rock cap would be very dangerous if an explosive eruption occurred.

Figure 7 is the result of 2D modeling of the B-B' incision with the *surfer software*. The range of density values obtained from Figure 8 is 2.25 g/cm^3 to 3.25 g/cm^3. The 2D model of the B-B' incision is at Y = 9025,390. This B-B' incision passes through sedimentary rock formations of Old Volcano (QTv), Ebulobo pyroclastic fall (Ej), 11 Ebulobo lava flow (El11), 9 Ebulobo lava flow (El9), 5 Ebulobo lava flow (El5), 2 Ebulobo lava flow (El2), and pyroclastic flow 2 (Ea2). Ebulobo volcanic rock is the bedrock of volcanism in rock composition consisting of lava with basalt, andesite and basalt composition. In the B-B' section, there is a low-density contrast at a depth of 3000 meters with a diameter of approximately 3000 to 4000 meters which shows the suspected magma chamber area of Ebulobo Volcano has a more specific ratio than the location of the magma chamber depth in the study [7] with the average depth of the magma chamber. Volcano on the island of Flores at 6 km. From the estimation of the location of the magma chamber, it is supported by data from [4] that the symmetrical shape of Ebulobo Volcano and the lava dome in the summit crater which functions as a rock cap would be very dangerous if an explosive eruption occurred.

2D modeling of the C-C' incision with the surfer software. The C-C' 2D model is at Y = 9024,178. The range of density values in the C-C' incision ranged from 2.25 g/cm^3 to 3.25 g/cm^3. At the C-C' section, it passes through the sedimentary rock formations of Old Volcano (QTv), 4 Ebulobo lava flows (El4), 5 Ebulobo lava flows (El5), 6 Ebulobo lava flows (El6), 8 Ebulobo lava flows (El8), 10 Ebulobo lava flows. Ebulobo flow (El10), pyroclastic flow 2 (Ea2), pyroclastic flow 3 (Ea3) and Ebulobo lava (Elh). Ebulobo volcanic rock is the bedrock of volcanism with rock composition consisting of lava with basalt, andesite, and basalt composition. In the C-C' section, there is a fault-based on geological information, there is a decrease in density from 2.7 g/cm^3 to 2.55 g/cm^3 with a tendency toward the fault line from South-North, this is proven in previous research conducted by [6] stated that all visible structures have a south-north trend. In the C-C' section, there is a low-density contrast at a depth of 3000 meters with a diameter of approximately 3000 to 4000 meters which indicates the area of the magma chamber of Ebulobo Volcano is suspected to have a more specific ratio than the location of the depth of the magma chamber in the study [7] with the average depth of the magma chamber. Volcano on the island of Flores at 6 km. From the estimation of the location of the magma chamber, it is supported by data from [4] that the symmetrical shape of Ebulobo Volcano and the lava dome in the summit crater which functions as a rock cap would be very dangerous if an explosive eruption occurred.

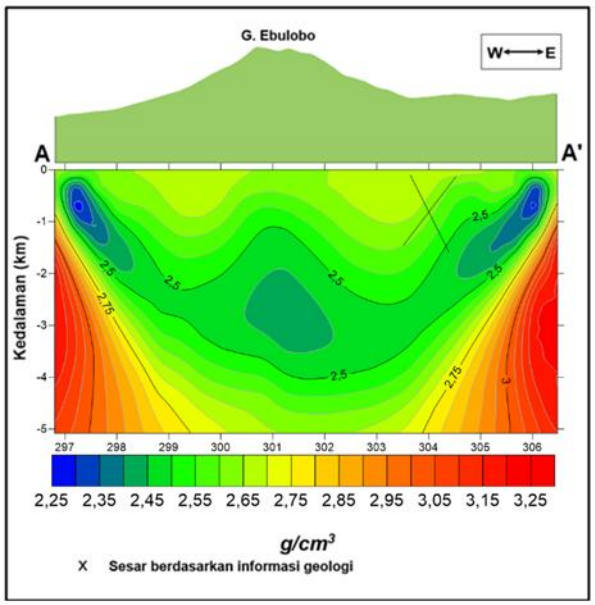

Figure 6. Modelling the A-A' incision

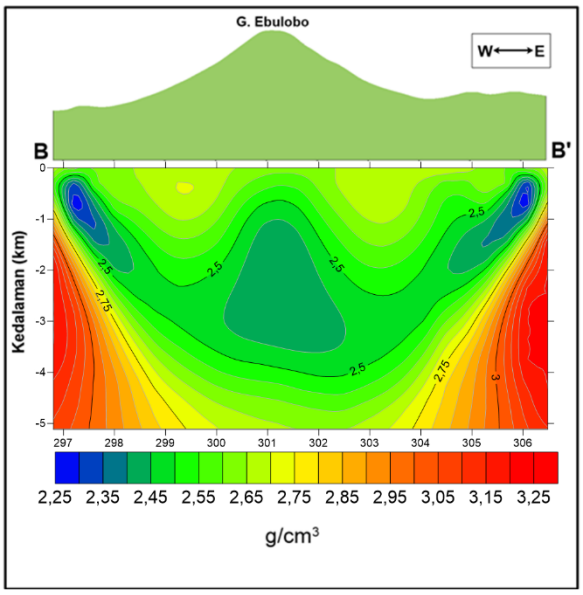

Figure 7. Modelling the B-B' incision.

The range of density values in Figure 10 ranges from 2.2 g/cm^3 to 3.25 g/cm^3. The 2D model of the D-D' incision is at X = 300.434. In the D-D' section, it passes through the sedimentary rock formations of Old Volcano (QTv), 1 Ebulobo lava flow (El1), 8 Ebulobo lava flows (El8), 9 Ebulobo lava flows (El9), 10 Ebulobo lava flows (El10), 11 lava flows Ebulobo (El11) and Ebulobo lava (Elh). Ebulobo volcanic rock is the bedrock of volcanism with a rock composition consisting of lava with basalt, andesite, and basalt composition. Andesite rock has a density range of 2.40 g/cm^3 to 2.80 g/cm^3 seen in the surface area with a central area of Mount forming two paths towards the center of the earth and an area below a depth of 3000 meters D-D' incision dark green to yellow can be identified as andesite rock. In the D-D' section, medium to high-density rocks dominates the modeling results. Lava has a density range of 2.80 g/cm^3 to 3.00 g/cm^3 seen in the North and South of the D-

D' section with a depth of 1000 m to 5,000 m can be identified as lava rock which is characterized by red color. Basalt rock has a density range of 2.70 g/cm^3 to 3.30 g/cm^3 in the D-D' section. Basalt rock with reddish-yellow color is seen spread over an area of 1000 m to 5,000 m in the north and south. In the D-D' incision, there is a fault-based on geological information, there is a decrease in density from 2.7 g/cm^3 – 2.55 g/cm^3 with a tendency toward the fault line from South-North, this is proven in previous research conducted by [6] stated that all visible structures have a south-north trend. In the D-D' section, there is a low-density contrast at a depth of 3000 meters with a diameter of approximately 3000 to 4000 meters which indicates the area of the Ebulobo volcano is suspected to have a more specific comparison of the depth of the magma chamber in the study [7] with the average depth of the magma chamber. Volcano on the island of Flores at 6 km. From the estimation of the location of the magma chamber, it is supported by data from [2] that the symmetrical shape of Ebulobo Volcano and the lava dome in the summit crater which functions as a rock cap would be very dangerous if an explosive eruption occurred.

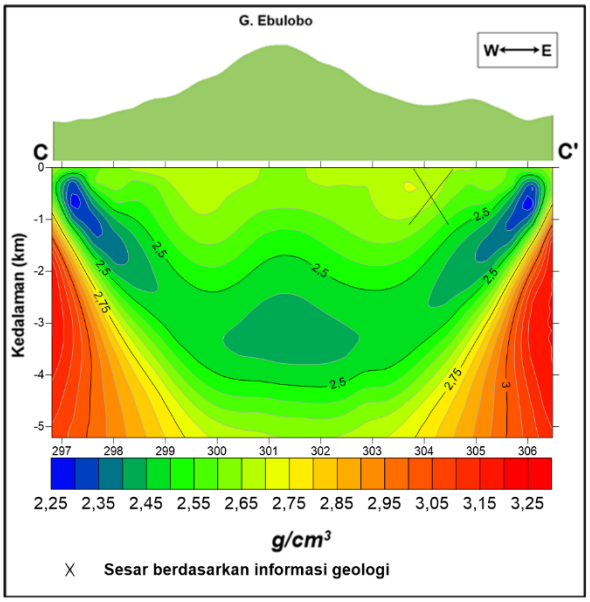

Figure 8. C-C' incision Modelling

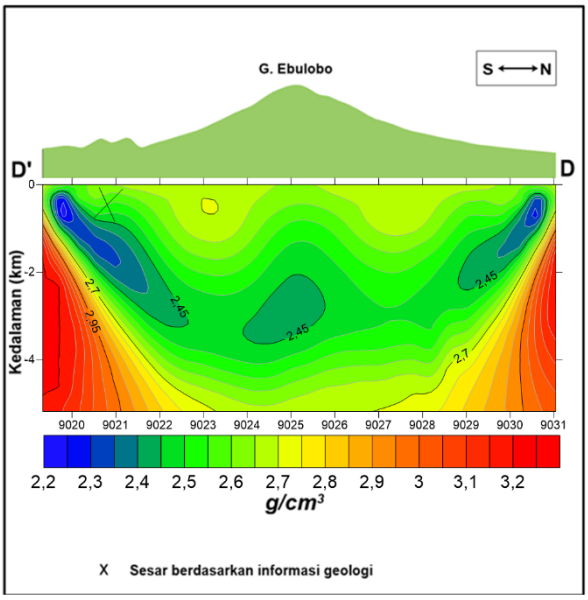

Figure 9. D-D' incision modelling

Modeling results for the E-E' incision are shown in Figure 10. The results of the 2D modeling of the E-E' incision are divided into 3 categories, namely rock density with high value, rock density with medium value, and rock density with low value. The 2D model of the E-E' incision is at X = 301,240. The range of E-E' incision modeling results ranged from 2.15 g/cm^3 to 3.25 g/cm^3. At the E-E' section, it passes through the sedimentary rock formations of Old Volcano (QTv), 3 Ebulobo lava flows (El3), 8 Ebulobo lava flows (El7), 9 Ebulobo lava flows (El9), 10 Ebulobo lava flows (El10), 11 lava flows Ebulobo (El11), Ebulobo lahar (Elh), pyroclastic flows (Ea1) and Ebulobo pyroclastic fall (Ej). In this incision, it cuts exactly Mount Ebulobo in a south-to-north direction. Ebulobo volcanic rock is the bedrock of volcanism with a rock composition consisting of lava with basalt, andesite, and basalt composition. On the contour of the E-E' incision, it is seen that there is a low-density contrast at a depth of 3000 meters with a diameter of approximately 3000 to 4000 meters which indicates the area of the magma chamber of Ebulobo Volcano is suspected to have a more specific ratio than the location of the depth of the magma chamber in the study [6] with an average depth Volcanic magma chamber on the island of Flores at 6 km. From the estimation of the location of the magma chamber, it is supported by data from [4] that the symmetrical shape of Ebulobo Volcano and the lava dome in the summit crater which functions as a rock cap would be very dangerous if an explosive eruption occurred.

Incision modeling 2D modeling F-F' incision with surfer software are shown in Figure 11. The 2D model of the F-F' incision is at X = 302,047. The range of density values obtained from Figure 4.34 is 2.2 g/cm^3 – 3.25 g/cm^3. In the F-F' section, it passes through the sedimentary rock formations of Old Volcano (QTv), 2 Ebulobo lava flows (El2), 4 Ebulobo lava flows (El4), 7 Ebulobo lava flows (El7), 9 Ebulobo lava flows (El9), 10 Ebulobo lava flows.

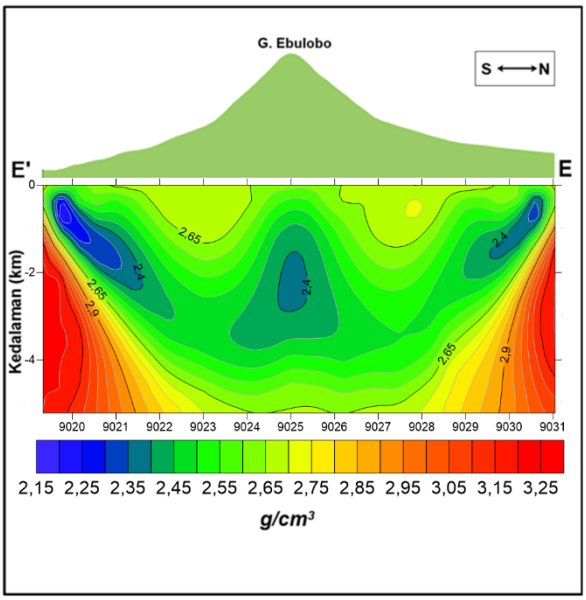

Figure 10. Modeling of the E-E' incision. Subsurface

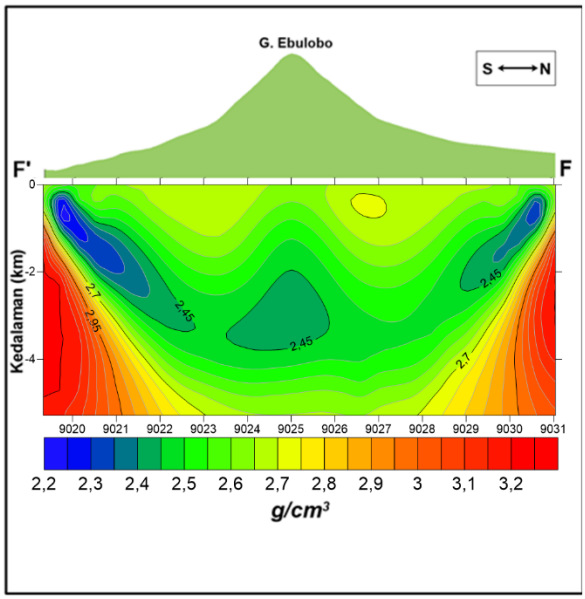

Figure 11. Modeling of the F-F' incision. Subsurface

Ebulobo (El10), Ebulobo lahar (Elh), pyroclastic flows (Ea4), and Ebulobo pyroclastic fall (Ej). Ebulobo volcanic rock is the bedrock of volcanism with a rock composition consisting of lava with basalt, andesite, and basalt composition. Andesite rock has a density range of 2.40 g/cm^3 to 2.80 g/cm^3 seen in the surface area with a central area of Mount that forms two paths towards the center of the earth and an area below a depth of 3000 meters F-F' incision dark green to yellow can be identified as andesite rock. In the F-F' section, rocks with medium to high density dominate the modeling results. Lava has a density range of 2.80 g/cm^3 to 3.00 g/cm^3 seen in the north and south of the F-F' section with a depth of 1000 m to 5,000 m can be identified as lava rock which is characterized by red color. Basalt rock has a density range of 2.70 g/cm^3 to 3.30 g/cm^3 at the F-F' section. Basalt rock with reddish-yellow color is seen spread over an area of 1000 m to 5,000 m in the north and south. In the F-F' section, there is a low-density contrast at a depth of 3000 meters with a diameter of approximately 3000 to 4000 meters which shows the suspected magma chamber area of Ebulobo Volcano has a more specific comparison of the depth of the magma chamber in the study [2] with the average depth of the magma chamber. Volcano on the island of Flores at 6 km. From the estimation of the location of the magma chamber, it is supported by data from [2] that the symmetrical shape of Ebulobo Volcano and the lava dome in the summit crater which functions as a rock cap would be very dangerous if an explosive eruption occurred.

Figure 12 shows the results of modeling on the z-axis with a depth of 0 meters, 1000 meters, 2000 meters, 3000 meters and 4500 meters, respectively. Based on these results, the constituent layers of Ebuobo Volcano are andesite rock, breccia rock, basalt rock, andesite-basaltic rock, and tuff rock.

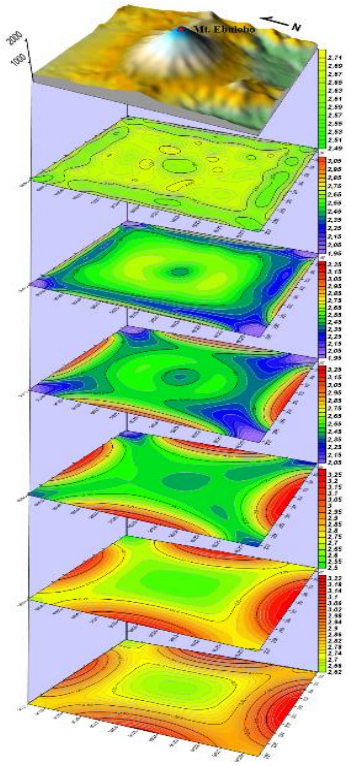

Figure 12. Modeling of the Z-axis incision

V. Conclusion

The result of subsurface modeling of Ebulobo Volcano gives a density response from 2.15 g/cm^3 to 3.2 g/cm^3. The density response value is similar to the geological information in the study area which contains andesite rock with a density range of 2.4 g/cm^3 – 2.8 g/cm^3, basalt rock with a density range of 2.7 g/cm^3 – 3.3 g/cm^3., breccia with a density range of 2.6 g/cm^3 – 2.8 g/cm^3, lava with a density range of 2.8 g/cm^3 - 3 g/cm^3, and tuff with a density range of 2.3 g/cm3 – 2,5 g/cm3. Fault indications based on geological information can also be identified in the A-A', C-C', and D-D' incisions at a depth of 0 m – 1500 m with a density value of 2.7 g/cm^3 – 2.55 g/cm^3 from Grablox modeling results. marked by contrast of medium to low-density, density with a tendency towards the fault line from South-North. The modeling results identify all the incisions providing information on the alleged location of the magma chamber at a depth of 3000 meters with a diameter of 3000 meters to 4000 meters as a warning if in the future there is an explosive eruption that affects the surface of the mountain body and the surrounding area. The layers that make up the Ebulobo Volcano are andesite, basalt, andesite-basaltic rocks, breccia, and tuff rocks.

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