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The GGMplus data analysis for Modeling of the Kelimutu volcanic subsurface

Rindi Apriliani[1], Rina Dwi Indriana[2], Udi Harmoko[3], Tony Yulianto[4]

Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Semarang[1234]

rindiapriliani@students.undip.ac.id[1];rina_dei@yahoo.com[2];udiharmoko@gmail.com[3]; tonygeoundip@gmail.com[4]

ABSTRACT

Kelimutu volcano is one of the active volcanoes on the island of Flores. This study aims to perform subsurface modeling of the Kelimutu volcano with 3D inversion modeling using the Global Gravity Model Plus (GGMplus) satellite gravity data in the form of gravity disturbance data and Earth Residual Terrain Model (ERTM2160) with a distance between measurement points of 200 m. Data processing for gravity disturbance is carried out in the form of Bouguer correction and Terrain correction, so that the complete Bouguer anomaly value is produced. Furthermore, 3D inversion modeling was carried out using Grablox 1.6e and Bloxer 1.6e software. 2D modeling results using Grablox 1.6e show that the surface of the Kelimutu volcano consists of several types of rock, namely sandstone with a rock density of 2.02 g / cc, igneous rock with a type of granite rock and andesite rock with a rock density of 2.52 g / cc to 2.80 g / cc as well as lava, basalt, diorite, and granodiorite rocks with a rock density of 2.80 g / cc to 3.2 g / cc.

Keywords: ***GGMPlus data, gravity method, Grablox 1.6e, Bloxer 1.6e, and density***

1. INTRODUCTION

Flores Island is an island located between the Sunda arc in the west and the Banda arc in the east and on the border between the Flores basin in the north and the Savu basin in the south. The existence of the island of Flores and the eastern Indonesian archipelago cannot be separated from the role of tectonic activity on the oceanic plate and continental plate [1]. The government of the island of Flores needs to review various studies related to subsurface modeling of volcanoes that are still active on the island of Flores because the level of seismicity on the island of Flores is quite high. Subsurface modeling of active volcanoes on the island of Flores can be useful for knowing the subsurface structure. Subsurface structures can be identified using geophysical methods, namely the gravity method. Gravity method is one of the geophysical methods used to describe subsurface structures based on the value of variations in the gravitational field caused by differences in density values [2]. Various gravity studies have been carried out from the Indonesian ocean to the north of the Nusa Tenggara archipelago. Research conducted by Darman [3] found that in the southern part of the Nusa Tenggara islands there was a positive anomaly that caused the formation of volcanoes due to a continuous rise and a low anomaly that formed a basin in the north. The popping process is thought to be a description of the existence of a subduction zone in the oceanic crust. The results of other studies by Hamilton [4] and Sari [5] indicate the formation of volcanoes, both active and inactive.

Previous studies that have been carried out have obtained subsurface modeling results for volcanoes on the island of Flores which are general in nature with a non-specific scope. In this study, subsurface modeling will focus on one of the active volcanoes on the island of Flores, namely the Kelimutu volcano. The data used in this study is secondary data, namely the gravity field anomaly data of the GGMplus Satellite (Global Gravity Model Plus), because the GGMplus data has advantages in terms of resolution, which is about 200 meters compared to other gravity satellites. GGMplus is the result of research from Curtin University (Perth, Western Australia) and Technical University Munich (Germany). GGMplus satellite gravity field anomaly data contains GGMplus gravity disturbance data. The gravity disturbance data is free air anomaly data, so it is necessary to make some corrections to get the complete Bouguer anomaly (ABL) value. ABL is a combination of regional anomaly and residual anomaly, so to get the value of regional anomaly and residual it is necessary to separate the anomaly. The method to separate regional and residual anomalies in this study is the Upward Continuation method. Furthermore, 3D inversion modeling was carried out using Grablox 1.6e and Bloxer 1.6e software. The modeling results are then interpreted against the subsurface model in the research area.

2. MATERIALS AND METHODS

2.1. The basic concept of gravity

The theory that underlies the gravity method is Newton's law which states that the attractive force between 2 particles having masses m_1 and m_2 , is directly proportional to the product of the two masses and inversely proportional to the square of the distance between the masses [6]. The attractive force is written systematically in equation (1):

$$\vec{F} = -G \frac{m_1 . m_2}{|\vec{r}|^2} \hat{r} \qquad \dots\dots\dots\dots\dots\dots\dots (1)$$

where F is the force acting between the two particles, while G is the gravitational force constant of 6.67×10^{-11} Nm^2kg^{-2} [6].

Gravity method is one of the geophysical methods used to describe subsurface structures based on the value of variations in the gravitational field caused by differences in density values [2].

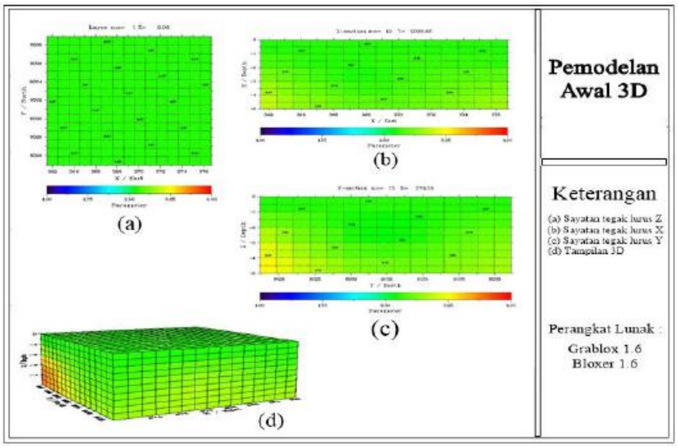

Fig. 1. The initial 3D Modeling of Grablox 1.6e software

According to Sunaryo [7] in the gravity method, what is studied is the variation in rock density below the surface, so that what is observed in its implementation is the difference in gravity from one observation point to another. Measurements in this method are carried out on the value of the vertical component of the acceleration due to gravity somewhere. The value of gravitational acceleration can be influenced by several factors, such as: differences in degrees of latitude, the position of the earth in the solar system, differences in altitude, variations in rock mass density, and other factors.

3. RESULTS AND DISCUSSION

3.1 Initial model

The researc area modeled in this modeling is about 15 km to the X axis, 15 km to the Y axis, and the depth of the targeted model is 5 km to the vertical Z axis. The modeling is done using Grablox 1.6, Bloxer, and Surfer 13 software. , with the input used is the complete Bouguer anomaly value. Grablox 1.6 software works on the principle of combining two inversion methods, namely Singular Value Decomposition (SVD) inversion and Occam inversion which are processed sequentially (Hjelt, 1992). The initial model in this modeling is that the X-axis is divided into 15 blocks (nx), the Y-axis is divided into 15 blocks (ny), and the Z-axis is divided into 10 blocks (nz) so as to produce 2250 blocks. Fig. 1. (a) is an image of the section display perpendicular to the Z axis which represents 10 incisions that can show variations in rock density at each depth. Figure 1. (b) is an image of an incision perpendicular to the X-axis representing 15 incisions that can provide information on the density and depth of the model in the transverse direction. Fig.1. (c) is an image of an incision display perpendicular to the Y axis representing 15 incisions with information on the density and depth of the model in the longitudinal direction. Figure 1. (d) is a three-dimensional display image of the initial modeling results in Bloxer 1.6 software.

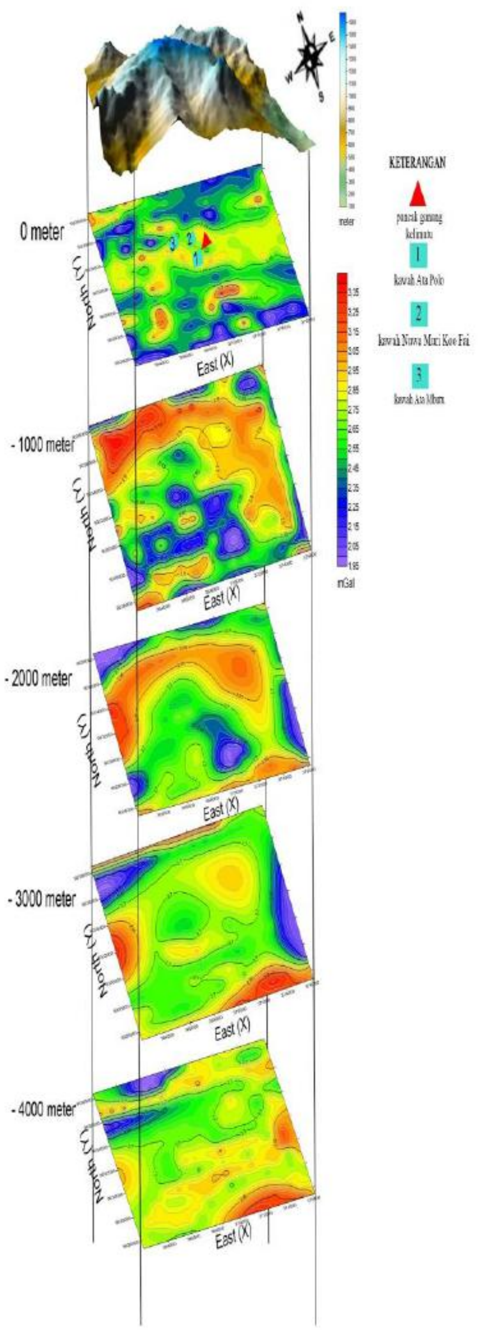

Fig. 2. The incision of the Kelimutu volcano base on gravity data analysis

The results of this initial modeling will then be used for the subsurface modeling process by making incisions using excel.

The input is in the form of 3D modeling data from Grablox in (.*dat) format. The incision path is carried out by making 5 incisions in the direction of the Z axis at a depth of 0 meters, 1000 meters, 2000 meters, 3000 meters, and 4000 meters to determine the distribution of rock density below the surface of the Kelimutu volcano.

The result of subsurface modeling (fig.2) being used to interpret the distribution of rock density and rock types. Interpretation of rock density distribution and rock types for the complete

Table 1 The density of various types of rock

Rock type	Density range (g/cm^3)	Average (g/cm^3)
Sediment rocks		
Overburden		1.92
Soil	1.2 – 2.4	1.92
Clay	1.63 - 2.6	2.21
Gravel	1.7 – 2.4	2.0
Sand	1.7 – 2.3	2.0
Sandstone	1.61 – 2.76	2.35
Shale	1.77 – 3.2	2.40
Limestone	1.93 – 2.90	2.55
Dolomite	2.28 – 2.90	2.70
Sedimentary rocks (av.)		2.50
Igneous rocks		
Rhyolite	2.35 – 2.70	2.52
Andesite	2.4 – 2.8	2.61
Granite	2.50 – 2.81	2.64
Granodiorite	2.67 – 2.79	2.73
Porphyry	2.60 – 2.89	2.74
Quartz diorite	2.62 – 2.96	2.79
Diorite	2.72 – 2.99	2.85
Lavas	2.80 – 3.00	2.90
Diabase	2.50 – 3.20	2.91
Basalt	2.70 – 3.30	2.99
Gabbro	2.70 – 3.50	3.03
Peridotite	2.78 – 3.37	3.15
Acid igneous	2.30 – 3.11	2.61
Basic igneous	2.09 – 3.17	2.79
Metamorphic rocks		
Quartzite	2.50 – 2.70	2.60
Schists	2.39 – 2.90	2.64
Graywacke	2.60 – 2.70	2.65
Marble	2.60 – 2.90	2.75
Serpentine	2.40 – 3.10	2.78
Slate	2.70 – 2.90	2.79
Gneiss	2.59 – 3.0	2.80
Amphibolite	2.90 – 3.04	2.96
Eclogite	3.20 – 3.54	3.37
Metamorphic	2.40 – 3.10	2.74

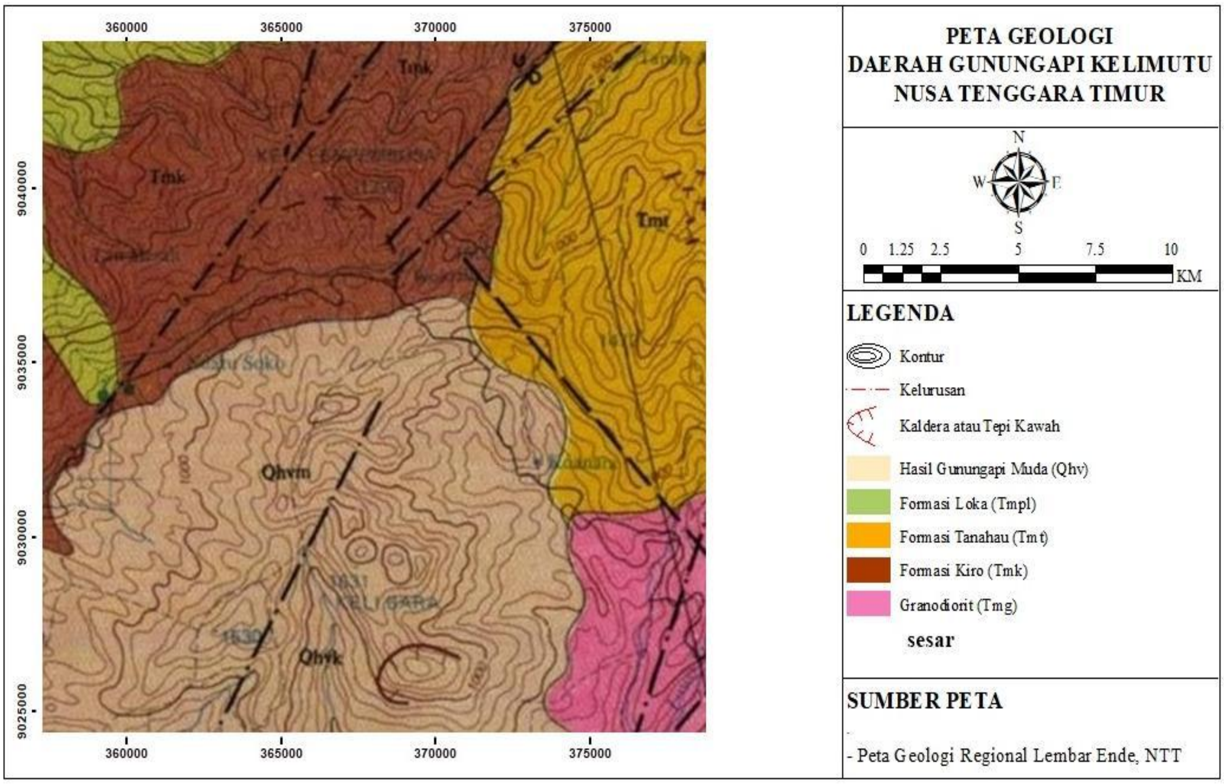

Fig. 3. Geological Map of the Research Area cut from the map Sheet Ende

Bouguer anomaly value modeling results is carried out based on information and geological data of the research area based on the geological map of the Ende sheet in (Fig.3) [8] and density data.

The first layer carried out at a depth of 0 meters showed variations in density values ranging from 2.55 g/cc to 2.76 g/cc. Layers with a low density of 2.55 g/cc are interpreted as forming 3 craters and interpreted as andesite and granite rocks. Layers with a high density value of 2.76 g/cc are interpreted as igneous rock which is a product of a volcano in the form of granodiorite. The average density for rock density in the first layer is 2.63 g/cc.

The second layer is carried out at a depth of 1000 meters with a rock density between 2 g/cc to 3.2 g/cc. Low rock layers between 2 g/cc to 2.4 g/cc are interpreted as sandstone. The results of low density are in the southern and western parts of the study site, while for rocks with high density values of 2.82 g/cc to 3.2 g/cc are interpreted as lava, diorite, and basalt rocks that cross from the west to the east. . The average density for rock density in this second layer is 2.68 g/cc.

The third layer at a depth of 2000 meters has a rock density between 2 g/cc to 3.2 g/cc. Low rock layers ranging from 2 g/cc to 2.52 g/cc in this layer are located slightly to the east, south, and west of the study area which are interpreted as andesite and granite rocks. The high rock layer, which is between 2.82 g/cc to 3.2 g/cc which is located across the west to the east is interpreted as igneous rock consisting of lava rock, basalt, and diorite. The average density for rock density in this third layer is 2.70 g/cc.

The fourth layer, which is carried out at a depth of 3000 meters, has the same value range as the third layer, which is between 2 g/cc to 3.2 g/cc. Low rock layers of 2 g/cc to 2.50 g/cc located in the east and across the southwest to the north of the study area are interpreted as sandstone and granite. The high rock layers of 2.83 g/cc to 3.2 g/cc can be interpreted as igneous rocks consisting of lava rock and diorite which are located in almost part of the study area. The average density for rock density in the fourth layer is 2.72 g/cc.

The last layer, namely the fifth layer which was carried out at a depth of 4000 meters, had the same value range as the third and fourth layers, which ranged from 2 g/cc to 3.2 g/cc. Low rock layers in this layer, which are between 2 g/cc to 2.52 g/cc which are located slightly in the east and southwest to the north, can be interpreted as a group of andesite and granite rocks. The high rock layer in the fifth layer, which is between 2.83 g/cc to 3.2 g/cc which is located in almost all research areas, can be interpreted as the dominating rock types, namely lava and basalt. The average density for rock density in this layer is 2.76 g/cc.

The three-dimensional model made as a whole from the first layer to the fifth layer has a density variation ranging from 2 g/cc to 3.2 g/cc with the average density of each layer from the first layer to the fifth layer, which is between 2.63 g/cc. cc to 2.76 g/cc. The color scale of each layer shows the variation in density values in each minor block. This variation in density values can also indicate that the thickness of the material making up the subsurface structure has different shapes and sizes. Overall, the rock density values that have been carried out from the first layer at a depth of 0 meters to the fifth layer at a depth of 4000 meters show that each layer has an increase in the average density value. Most of the rock types from the first layer to the fifth layer below the Kelimutu volcano are sedimentary rock types such as sandstone and igneous rocks such as andesite, basalt, granite, lava rock, and diorite and granodiorite rocks. All of these rocks are the result of the Kelimutu volcano or the overflow from the cold lava of the Kelimutu volcano.

4. CONCLUSION

Subsurface structure modeling with 3D inversion modeling using Grablox software results that the surface of the Kelimutu volcano consists of several types of rock, namely sandstone with a rock density of 2.02 g/cc, igneous rock with granite rock type and andesite rock with a rock density of 2.52 g. /cc to 2.80 g/cc as well as lava rock, basalt rock, diorite rock, and granodiorite rock with a rock density of 2.80 g/cc to 3.2 g/cc.

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