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Short Communcation

Modelling The Subsurface Structure of Sangeang Volcano Based on Gravity Data

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Abstract: The Lesser Sunda Islands stretch from Bali to Timor which is divided into two geologically distinct parts and formed due to the subduction of oceanic crust along the Java-Timor Trough. The northern part of the Lesser Sunda Islands, which includes Bali, Lombok, Sumbawa, Flores, Wetar, Pantar and Alor, is a volcanic arc archipelago. Mount Sangeang Api is one of the island volcanoes located on the island of Sumbawa and is geographically located at 08°11' NS dan 119° 03,5' East. Studying how the anatomy of the volcano, knowing the subsurface structure of Mount Sangeang Api and knowing the depth of its magma kitchen through 3D modelling of gravity data in the form of rock density values. The geophysical method used in this research is the gravity method. The results of 3D cross-section modelling obtained variations in subsurface rock density values. The variation of rock density value is $1{,}6\ \mathrm{g/cm^3} - 3.6\ \mathrm{g/cm^3}$. The depth of the magma kitchen ranges from 600 m above the earth's surface to 30,000 m below the surface, this depth is in accordance with the modelling limits, but based on the modelling results there is a suspicion that the depth of the magma kitchen continues to more than 30,000 m below the earth's surface. Interpretation is made by looking at the table of rock density values and the geological map of East West Nusa Tenggara, Dompu and Bima Sheets.

Keywords: Anatomy of Fire Mountain; Mount Sangeang Api; Magma Pockets; Gravity.

1. Introduction

The Lesser Sunda Islands stretch from Bali to Timor which is divided into two parts which The Lesser Sunda Islands stretch from Bali to Timor which is divided into two geologically different parts and formed by the subduction of oceanic crust along the Java-Timor Trench. The northern part of the Lesser Sunda Islands, which includes Bali, Lombok, Sumbawa, Flores, Wetar, Pantar and Alor, is a volcanic arc island, while the islands in the southern part are non-volcanic islands which include Sumba, Timor and Rote [1]. The straits along the Lesser Sunda Islands are formed by complex geological and tectonic processes that occur in this area. The islands in the Lesser Sunda region have many active volcanoes, these volcanoes are the path of the Sunda Arc mountains (Mediterranean Mountain Range) [2].

West Nusa Tenggara is one of the provinces included in the Lesser Sunda region. There are three volcanoes located in the province of West Nusa Tenggara (NTB), namely, Mount Rinjani, Mount Tambora, and Mount Sangeang Api. Sangeang Island and its surroundings are volcanic islands whose position is slightly shifted to the north of the normal series of volcanoes that stretch from west to east starting from the islands of Sumatra, Java, Bali and others. This series of volcanoes was formed from the meeting of the Eurasian continental crust and the Indo-Australian Ocean crust [3].

Anatomy of a volcano is the structure of rocks that make up the subsurface of a volcano. It is important to study and understand the structure of the subsurface of a volcano [4]. Previous research was conducted on the Sangeang Api volcano island in the East Sunda Arc, Indonesia, on the Level and Process of Potassic Magma Evolution under the Sangeang Api Volcano. It was found that the size of the magma chamber is ~6-10 km_3, the cooling rate is ~0.05° C/year, the crystal growth rate is $(2\text{-}7)\times10^{-13}$ cm/s, the mantle is Basaltic, and the continental crust is on average Andesite. Turner et al., have not studied the depth of the magma chamber [5].

This research uses the Gravity method. The objectives of this research are: (1) to find out the subsurface structure of Mount Sangeang Api based on the rock density value and

3D modeling results, and (2) determine the depth of the magma chamber of Mount Sangeang Api.

2. Literature Review

2.1 Basic Principles of the Gravity Method

The gravitational force can be described by Newton's law: the force between two particles of mass m_1 and m_2 is directly proportional to the square of the distance between the centers of mass:

$$F = \gamma(m_1 m_2/r^2)r_1 \quad (1)$$

where F is the force on m_1 m_2 is a unit vector directed from m_2 to m_1, r is the distance between m_1 and m_2 and γ is the universal gravitational constant. The value of force F in SI units is γ 6.672 x 10^{-11} $N/m_2.kg_2$ [6]. In gravity surveys, subsurface geology can be seen based on variations in the earth's gravitational field, density anomalies between subsurface rocks [7].

2.2 Gravity Anomaly

Earth's gravity has only one direction, namely vertical. Gravimeter is a tool that can effectively respond only to the vertical component of the gravitational attraction and anomalous mass [8]. The effect of the gravitational field of anomalous mass, with horizontal and vertical components on the local gravitational field can be represented in a vector diagram. Gravity on the mass at point m with a distance r from the mass. Gravity with Δg_r in the direction of m which can be seen from the following equation

$$\Delta g_r = \frac{G_m}{r^2} \quad (2)$$

Since only the vertical component is measured, the gravity anomaly Δg due to the mass is

$$\Delta g = \frac{G_m}{r^2}\cos\theta \quad (3)$$

2.3 Bouguer's anomaly

The ultimate end result of gravity data correction is the Bouguer anomaly, which should correlate only with lateral variations in the density of the upper crust and is of most interest to geophysicists and applied geologists [9]. The Bouguer anomaly is the difference between the observed gravity values (gobs), adjusted by the sum of all the necessary corrections, and at some base station (g_1). The variation of the Bouguer anomaly should reflect lateral variations in density, so that high-density features in low-density media should give rise to positive Bouguer anomalies. Conversely, low-density features in higher-density media should give rise to negative Bouguer anomalies [10].

2.4 Geophysical Modeling

Modeling parameters in geophysics are used to indicate the subsurface geological conditions. surface. Modeling is a process of estimation and modeling parameters based on data observed on the earth's surface [11]. Inverse Modeling in this modeling the model is obtained directly from the data. The basis of inversion modeling and its process can be described as in Figure 1, but for the model modification mechanism to obtain a better match between calculation data and observation data is done automatically. Inversion modeling can also be said as data fitting because the process seeks a model that produces a response that fits the observation data [12].

3. Method

3.1 Time and Place

This research was conducted at the Geophysics Laboratory (Advanced Physics) Faculty of Mathematics and Natural Sciences, University of Mataram. Data processing began in October 2022 to January 2023. The location of data collection was on Sangeang Api Volcano Island. The route that can be taken from the nearest city, namely Bima City to the research location or Mount Sangeang Api via the Bima Wera Cross Road. Geographically located at 08o11 'LS and 119° 03.5' BT.

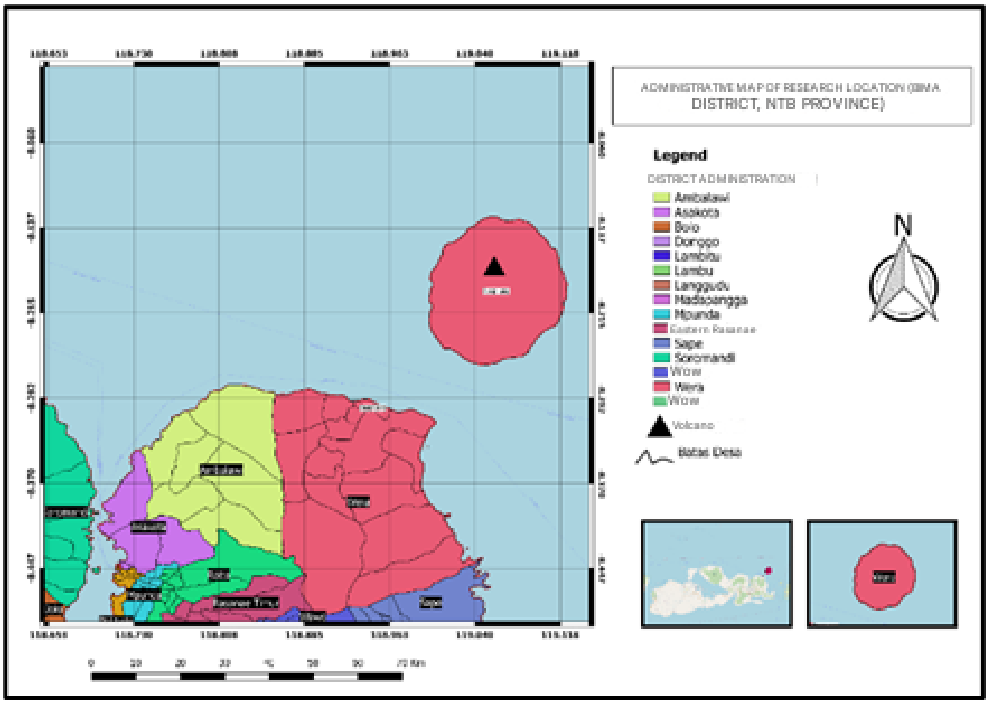

Figure 1. Map of research location on Mount Sangeang Api, Wera District, Bima Regency, Sumbawa Island, West Nusa Tenggara Province.

3.2 Work Procedures

The literature study conducted was by reading scientific sources about the research location to be able to determine the formulation of the problem, and the importance of this research being conducted. In addition, in this literature study stage, researchers also studied the processes of data collection to data processing and related theories to facilitate the research process that leads to the research objectives. The purpose of this study is to determine the 3D modeling of the subsurface structure of Mount Sangeang Api with Gravity data. This literature study was conducted to study in more depth the Gravity method based on sources and/or references that are relevant to the research. These references are in the form of Books, Articles and Scientific Journals.

3.3 Data Retrieval

Satellite imagery gravity anomaly data can be accessed on the website by Morawski et al. [13]. Technical University of Munich (Germany). The data accessed is secondary data in Excel format with a distance of 200 m [14]. The data was taken at coordinates 08o11 'LS and 119° 03.5' BT, namely at Mount Sangeang Api, Sumbawa Island, NTB.

3.4 Data Analysis

The processed data is gravity anomaly data from the Mount Sangeang Api area, Wera District, Bima Regency, West Nusa Tenggara Province.

a. Performing bouger correction on free air anomaly data. The goal is to eliminate the influence of the mass between the measurement point and the spheroid reference point to obtain a complete bouguer anomaly map.
b. Performing terrain correction to eliminate the influence of excess and deficient mass around the measurement point which results in a reduction in the measured gravity value to obtain results in the form of a complete Bourger anomaly map with the help of Geosoft software.
c. Separation of deep (regional) and shallow (residual) anomalies using the upward continuation method.
d. Map making was done with the help of Geosoft and Surfer 13 software.
e. 3D modeling of complete Bouguer anomaly values with the help of UBC Grav3D software

Data interpretation is done by matching the rock density values with the rock density values based on the rock density value table in the Telford 1990 book. Matching the results with the regional geological map.

4. Result and Discussion

4.1 Earthquake Hypocenter Relocation Results Data Validation Using the Double Difference Method

The results of data processing produce a complete Bouguer anomaly map as output. The complete Bouguer Anomaly Map is a map that describes the distribution pattern of subsurface rock density [15]. The results of data processing produce a complete Bouguer Anomaly map as output. The complete Bouguer Anomaly Map is a map that describes the distribution pattern of subsurface rock density.

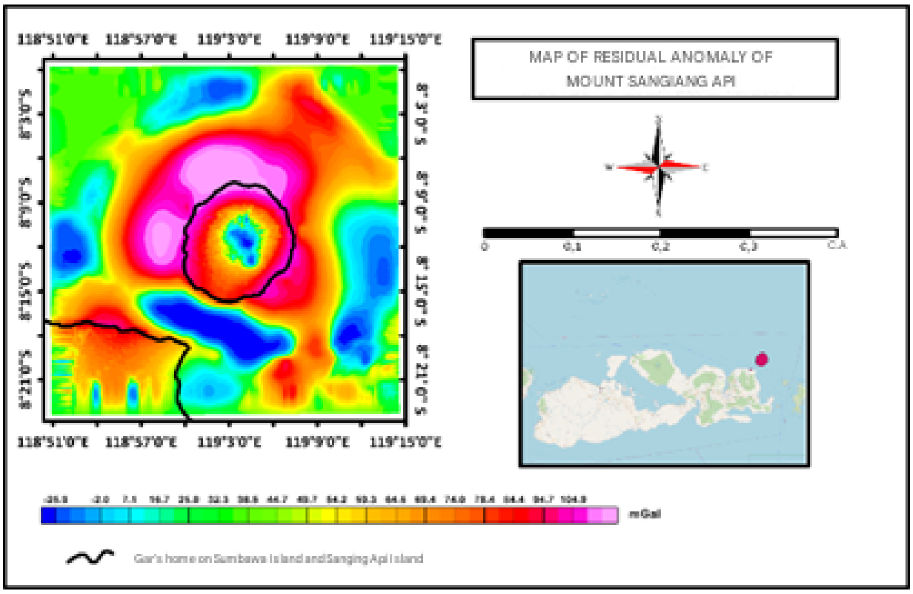

Figure 2. Complete Bouguer Anomaly Map of Mount Sangeang Api

The results of the Bouguer anomaly mapping can be seen in (Figure 2). The color differences found in the complete Bouguer anomaly map indicate variations in the Bouguer anomaly values research location. The difference in complete Bouguer anomaly values on the map is marked by the difference in color that can be seen on the color scale. The variation in bouguer anomaly values ranges from negative to positive. Negative anomaly values range from -25 mGal to 0 mGal, and positive anomaly values range from 0 mGal to 104.9 mGal.

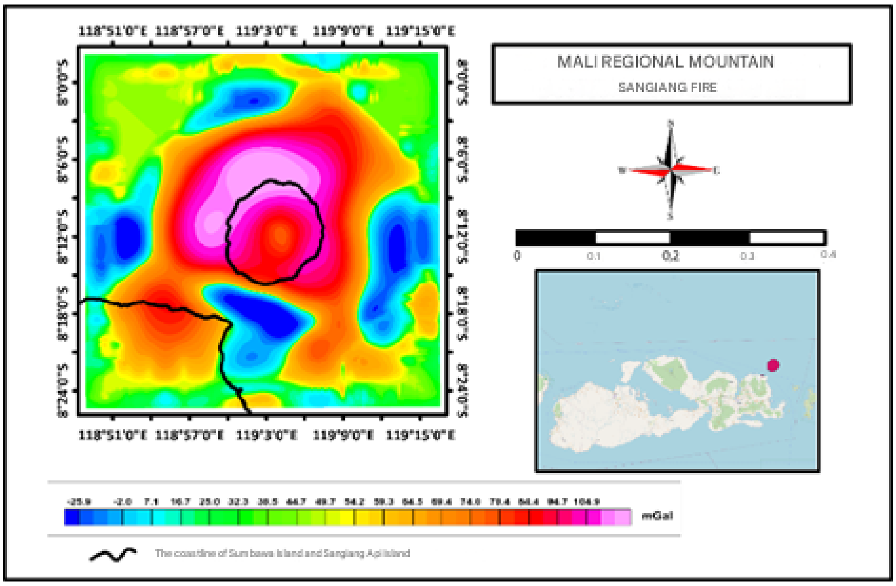

Figure 3. Regional Anomaly Map

The results of the upward continuation lifting (Upward Continuation) carried out at an altitude of 3,000 meters, then obtained a Regional anomaly map (Figure 3). Several variations in the height of the upward continuation lifting (Upward Continuation). The regional anomaly values obtained range from -25 mGal - 105 mGal. This can be seen from the color variations on the regional anomaly map (Figure 4), information on color variations can be seen in the color scale box listed on the regional anomaly map (Figure 4).

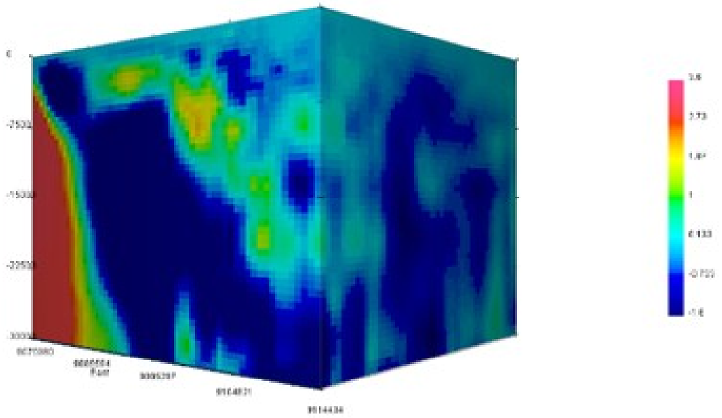

Figure 4. 3D Modeling of East and North Views

The results of the three-dimensional modeling performed (Figure 4) on the complete Bouguer anomaly data. The cross-section of the three-dimensional modeling is composed of blocks (Mesh) with a depth of 0 km - 30 km from the earth's surface. The blocks (Mesh) with a size of 663 m (X, Y) and 600 m (Z) at one block. On the X axis consists of 58 Mesh, on the Y axis consists of 53 Mesh and on the Z axis consists of 50 Mesh. The results of the West - South view modeling can be seen in (Figure 5) and the results of the East - North view modeling can be seen in (Figure 5). The 3D modeling process obtained an error of 5%.

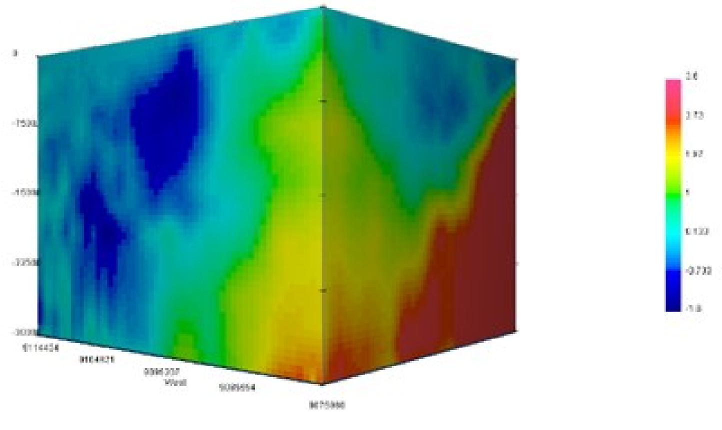

Figure 5. 3D Modeling of West and South Views

The 3D model depicts the subsurface structure in the research area according to the area of the research data covering the entirety of Mount Sangeang Api and the sea around Sangeang Api Island [16]. The alleged distribution of subsurface magma from Mount Sangeang Api is not only vertical down a straight line with the magma outlet above the surface. Therefore, it is necessary to conduct modeling with a wide area coverage so that it can be known how wide the distribution of subsurface magma pockets is. Indication of the existence of a magma pocket refers to research (Turner et al. 2003). The existence of a magma pocket can be known by performing a cut (Slice) on the results of 3D modeling according to the block volume (Mesh) arranged in the 3D modeling cross section. The results of the 3D modeling cross section Slice obtained information in the form of depth on the (Z) axis with a range of 600 m - 30,000 m from the earth's surface [17].

The estimated magma chamber depth limit is the limit of the modeling data depth in this study. Based on the modeling results, it is estimated that the depth of the Sangeang Api volcano magma chamber is still more than 30,000 m below the surface. The results of the analysis show that there are differences in the results of this study with previous studies (Research conducted by Turner, et al. in 2003, referring to the bibliography). This occurs because of the differences in the methods used, so that different results are obtained [18]. Interpretation of subsurface rock structures in the research area based on geological maps. Based on geological information, it is known that the research area consists of young volcanic rocks (Qv) from active volcanoes (Mount Tambora and Mount Sangeang Api) and Sangeang volcanic rocks (Qvsn). Young volcanic rocks (Qv) are Lava Breccia, Lava, Bombs, and Lapilli. Furthermore, Sangeang volcanic rocks are Andesite, Andesite Olivine, Basalt, Glass, and Pumice.

Table 1. Variation of Subsurface Rocks based on 3D Modeling Cross-Section

Density (g/cm^3)	Depth (m)	Types of Rocks
1.7 - 1.94	600 – 30.000	Magma
1.94 – 2.8	0 – 30.000	Andesite Breccia
2.8 – 3.67	1.800 – 30.000	Basalt Lava
3.67 – 4.54	3.000 – 30.000	Qursa Diorite
4.54 – 5.4	4.200 – 30.000	Igneous Rock Basalt
5.4 – 6.27	4.800 – 30.000	Andesite

5. Conclusions

Based on the results of data analysis and 3D modeling of Mount Sangeang Api Gravity data, the following conclusions can be drawn: (1) The results of 3D modeling show that the variations in the subsurface rock structure of Mount Sangeang Api consist of Andesite, Breccia, Basalt, Lava, Qursa Diorite, Igneous Rock and Basalt. (2) The depth of the magma chamber is estimated to be from 600 m to 30,000 m below the surface. There are 2 pockets of magma below the surface. (3) First Magma Pocket. The depth of the first magma pocket is 600 m from the surface to 3,600 m, with a volume of $2{,}08 \times 10^{-11}$. (4) 2nd Magma Pocket. The depth of the second magma pocket is from 6,000 m to 30,000 m, with a volume of 3.16×10^{-12}.

The suggestions that can be conveyed from the results of this study are: (1) It is necessary to carry out direct measurements or exploration so that comparisons of results can be made. (2) Research or exploration needs to be carried out using other geophysical methods so that the results can be used as a comparison.

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