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Geological Structure Identification Using GGMplus Satellite Gravity Data in The Area Surrounding Mount Tampomas

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ABSTRACT

Satellite gravity provides a new alternative in geological exploration with several advantages, such as low operational cost and large covering area. GGMplus satellite gravity data provide better accuracy for several applications such as lithology or fault identification. Satellite gravity provides a new alternative in geological exploration with several advantages, such as lower costs, broader area coverage, and easily accessible data. Mount Tampomas is one of the areas that has geothermal prospects and a mountain area that has many types of rock formations and faults. This research has been conducted using GGMplus satellite gravity data in the Mount Tampomas area to obtain the second vertical derivative (SVD) and identify the fault distribution in the area. The GGMplus Gravity Acceleration data was corrected and filtered to obtain SVD structures in the area. The structure in this area is dominantly trending northwest-southeast and west-east. The area around Mount Tampomas forms a structure in the form of a caldera. In addition, there are also structures trending north-south at coordinates 81500-82000 E. Some of these structures were overlaid with a geological map to see the suitability of the processed data with the geological conditions that have been studied. The comparison is done by overlaying the structure of the interpretation results and the contour of the value 0 from the Second Vertical Derivative (SVD) data so that we get four fault structures that correlate with the geological map, three calderas, and one lineament that correlates with the lineament map.

Keywords: Mount Tampomas, GGMplus, gravity method, geological structure.

INTRODUCTION

Satellite gravity is currently an alternative in initial exploration and research activities. Satellite gravity has several advantages over conventional gravity measurement methods because of its low cost and extensive area coverage, so it can be used to identify faults or rocks regionally [1]. Moreover, many obstacles are experienced when conducting field measurements, such as difficult access to research sites, limited personnel, and government policies. One of the satellite gravity data with more accuracy than earlier satellite gravity is the GGMplus satellite gravity data with a data density of up to 200 m [2]. Therefore, with more accuracy, GGMplus could provide better resolution for several applications such as lithology determination, fault identification, geothermal prospection, etc.

Located in the northern part of Sumedang Regency, Mount Tampomas has geothermal prospects or a Geothermal Working Area (GWA) with many geological structures, such as calderas and faults. The geothermal field is usually related to the occurrences of both surface and deep geological structures. Therefore, further studies need to be conducted to determine the occurrences of geological structures in this area.

This study processed Second Vertical Derivative (SVD) Residual data using GGMplus satellite gravity data. The aim is to compare the existing structures on the Geological Map and the Lineament Map of Mount Tampomas with the resulting structure from interpreting the SVD Residual Anomaly data [3]. Furthermore, the SVD-interpreted structure could provide information about another concealed fault in the Mount Tampomas area.

Mount Tampomas is an inactive mountain classified as a young Quaternary volcano. It is located in the Sunda arc, which was formed by the subduction of the oceanic plate from the Cretaceous to the present [3]. Figure 1 explains the rock formations in the research area and their lithology [3].

The Mount Tampomas area's geomorphology consists of six units: the lava flow ridge unit, the volcanic foot plain unit, the pyroclastic flow ridge unit, the lava dome unit, the lava flow ridge unit, and the volcanic residue sediment hill unit [4]. The lava flow ridge unit is the dominant geomorphological unit in this area, occupying around 38.9% of the total study area.

The lineament map of Mount Tampomas shows four calderas surrounding it, formed by past volcanic eruptions. The map of Mount Tampomas's geological structure (lineament) can be seen in Figure 2. The lineament has a dominant northeast-southwest and northwest-southeast trend with a total length of approximately 83 km.

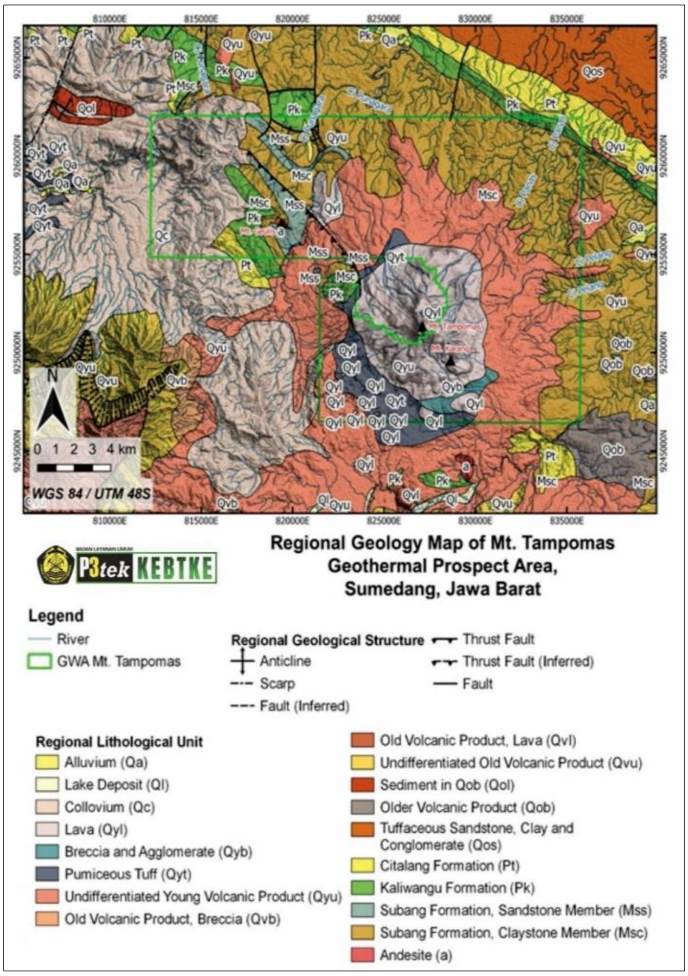

Figure 1. Geological Map of the Study Area [3]

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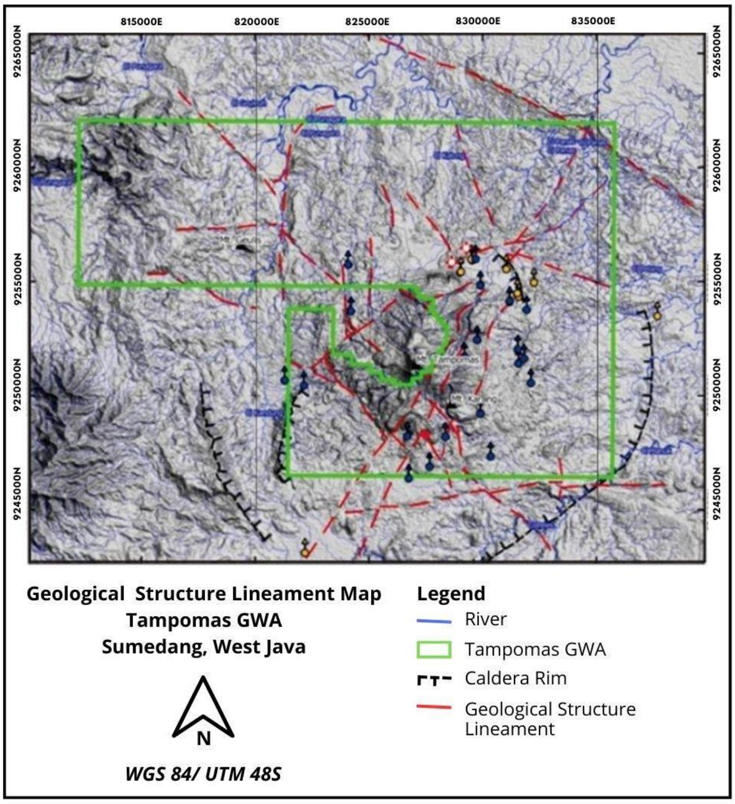

Figure 2. The Geological Structure (lineament) Map [4]

METHODOLOGY

In general, the gravity method shows the contrast of the gravitational field in an area [5]. Gravity can identify faults, subsurface tunnels, basins, mineral veins, subsurface rocks, intrusions, and basement depths [6]. The approach for fault identification uses SVD analysis. The data processing is given as follows.

The gravity data taken from the GGMplus website was gravitational acceleration data. Therefore, the data correction carried out is as follows: (1) latitude correction makes corrections due to the difference in the Earth's radius at the equator and the poles [7]; (2) free air correction to bring the measurement gravity value closer to the gravity value at sea level (mean sea level) [8]; (3) Bouguer correction to eliminate mass effects between the datum and the observation point [9]; (4) Terrain correction needs to be done because the Bouguer correction approach uses an infinite horizontal slab, even though the earth's surface is not flat, but adjusts the topography. So, this correction needs to be made [10]. After passing these corrections, we get a complete Bouguer anomaly.

Geological structure analysis in this study is based only on the second derivative of the residual Bouguer anomaly. Therefore, residual anomaly extraction was carried out from the complete Bouguer anomaly. After the complete Bouguer anomaly value has been obtained, spectrum analysis is carried out to obtain the boundary between regional and residual anomalies [11]. Spectrum analysis was carried out by taking several sections of the complete Bouguer anomaly map and plotting the sections with the Fourier transform (Figure 3).

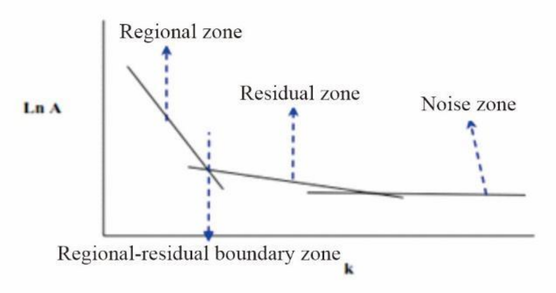

Figure 3. Spectrum Analysis [11]

After obtaining the regional and residual anomaly boundaries, the complete Bouguer anomaly data is filtered by moving averages to produce regional anomalies. The window width of the moving average filter is obtained from the following equation [12].

$$N = \frac{2\pi}{k_c \Delta x} \quad (1)$$

where N is the window width, k_c is the regional and residual zone boundary in the wavenumber domain, and Δx is the spacing of the slices used. A moving average filter is carried out with the following equation [13].

$$\Delta g_{reg}(i,j) = \frac{(\Delta g(i-n,j-n)+\cdots+\Delta g(i+n,j+n))}{N} \quad (2)$$

where Δg_{reg} is the regional anomaly value, and n is (N-1)/2. The complete Bouguer anomaly is a combination of residual anomalies and regional anomalies. So, to get the residual anomaly value, the following equation is used [14].

$$\Delta g_{res} = \Delta g - \Delta g_{reg} \quad (3)$$

where Δg_{res} is a residual anomaly, and Δg is complete Bouguer anomaly.

A second vertical derivative (SVD) filter is carried out from the residual anomaly obtained. The second vertical derivative is a filter to view vertical anomalies with the second derivative. SVD is commonly used to identify faults in the gravity method. SVD with a value of zero is considered to be a response from the subsurface structure. The SVD calculation is carried out based on the Laplace equation which is given as follows [15]:

$$\nabla^2 g = 0 \quad (4)$$

$$\frac{\partial^2 g}{\partial x^2} + \frac{\partial^2 g}{\partial y^2} + \frac{\partial^2 g}{\partial z^2} = 0 \quad (5)$$

$$\frac{\partial^2 g}{\partial z^2} = -\frac{\partial^2 g}{\partial x^2} - \frac{\partial^2 g}{\partial y^2} \quad (6)$$

Gravity data which has a regular grid, SVD anomalies can be derived using the convolution equation which has the following equation [16]:

$$\Delta g_{svd}(\Delta x, \Delta y) = \iint_{-\infty}^{\infty} \Delta g_{res}(x,y) F(x - \Delta x, y - \Delta y)\, dx dy \quad (7)$$

F is the Second Vertical Derivative filter. The Second Vertical Derivative (SVD) filter is performed with several types of convolution operator matrices, as shown below (Table 1-3). From the several SVDs carried out, SVD results were taken that were considered good in identifying geological structures in the study area.

Table 1. SVD Henderson dan Zietz type [17]

SVD Matrix				
0,0000	0,0000	-0,0838	0,0000	0,0000
0,0000	1,0000	-2,6667	1,0000	0,0000
-0,0838	-2,6667	-17,0000	-2,6667	-0,0838
0,0000	1,0000	-2.6667	1,0000	0,0000
0,0000	0,0000	-0.0838	0,0000	0,0000

Table 2. SVD Elkins type [18]

SVD Matrix				
0,0000	-0.0833	0,0000	-0.0833	0,0000
-0.0833	-0,6667	-0,0334	-0,6667	-0.0833
0,0000	-0,0334	-1,0668	-0,0334	0,0000
-0.0833	-0,6667	-0,0334	-0,6667	-0.0833
0,0000	-0.0833	0,0000	-0.0833	0,0000

Table 3. SVD Rosenbach type [19]

SVD Matrix				
0,0000	-0.0416	0,0000	-0.0416	0,0000
-0.0416	-0,3332	-0,7500	-0,3332	-0.0416
0,0000	-0,7500	4,0000	-0,7500	0,0000
-0.0416	-0,3332	-0,7500	-0,3332	-0.0416
0,0000	-0.0416	0,0000	-0.0416	0,0000

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The data used in this research is GGMplus satellite gravity data. The data obtained is Gravity Acceleration (Figure 4) and Elevation (Figure 5) data in the Mount Tampomas research area. The area used is the same as the area on the geological map in Figure 1.

After making corrections, a complete Bouguer anomaly map is obtained as follows (Figure 6). From the complete Bouguer anomaly, spectrum analysis and moving average filters were carried out to obtain regional anomaly maps and residual anomaly maps as follows (Figure 7 and Figure 8). So, the residual anomaly uses 4 different types of filters. Namely, the SVD calculation uses equation 5, and the SVD calculation uses a convolution approach with 3 different filters [17–19]. Several SVD results were obtained as follows (Figure 9).

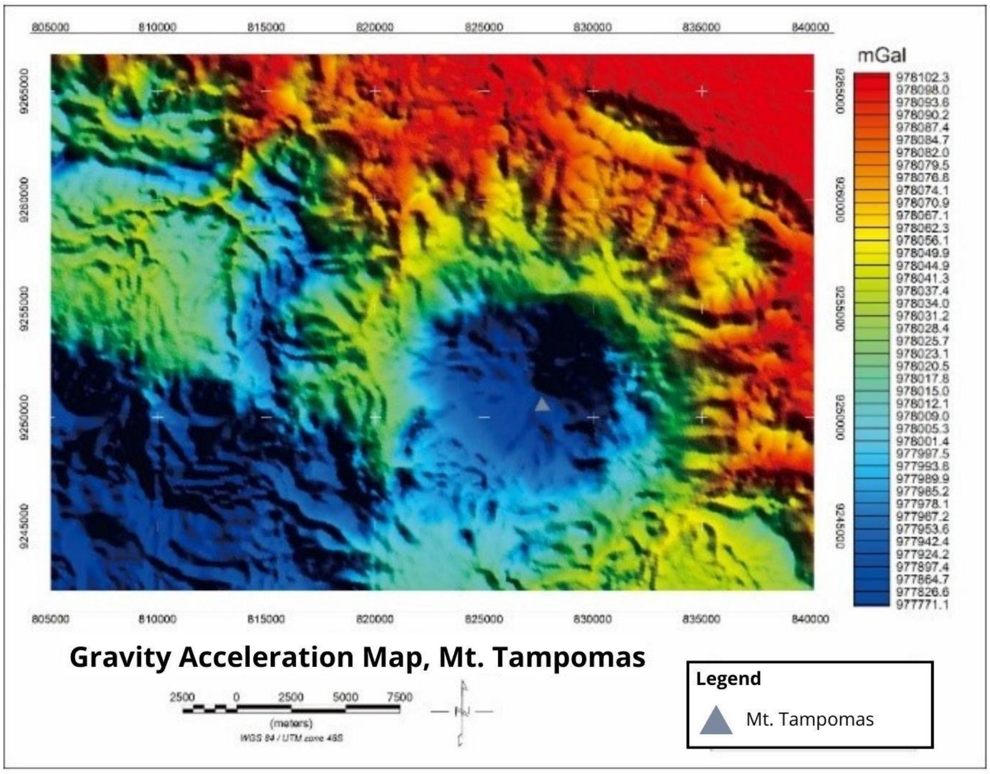

Figure 4. Gravity Acceleration Map

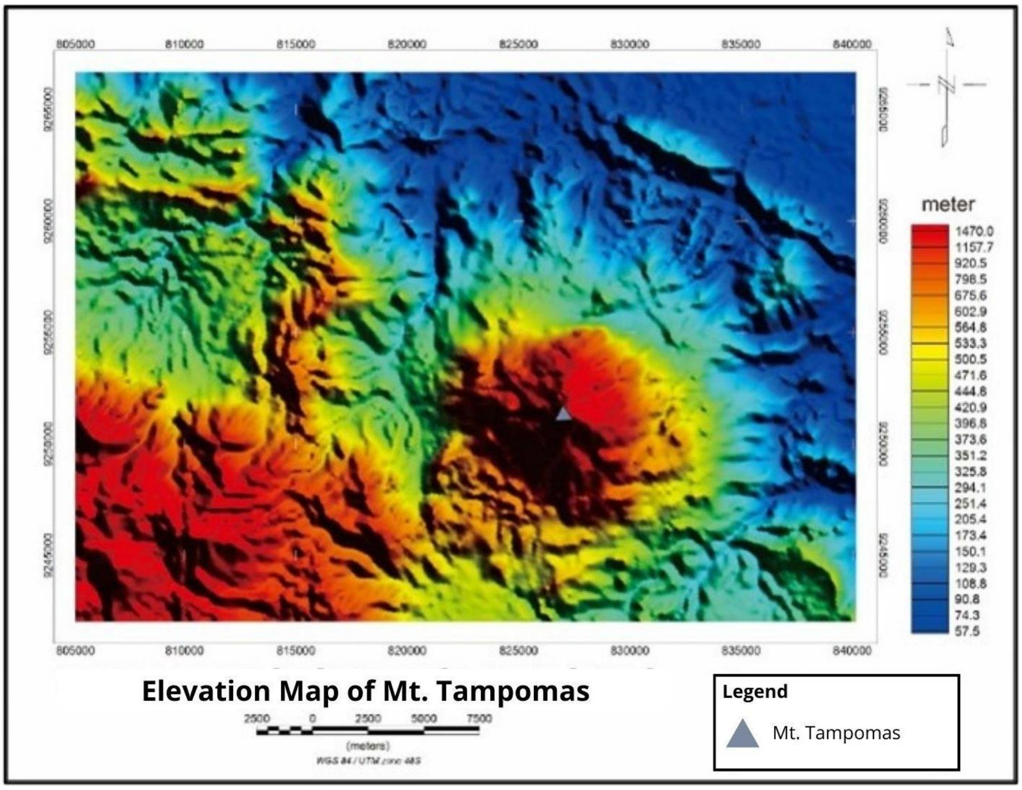

Figure 5. Elevation Map

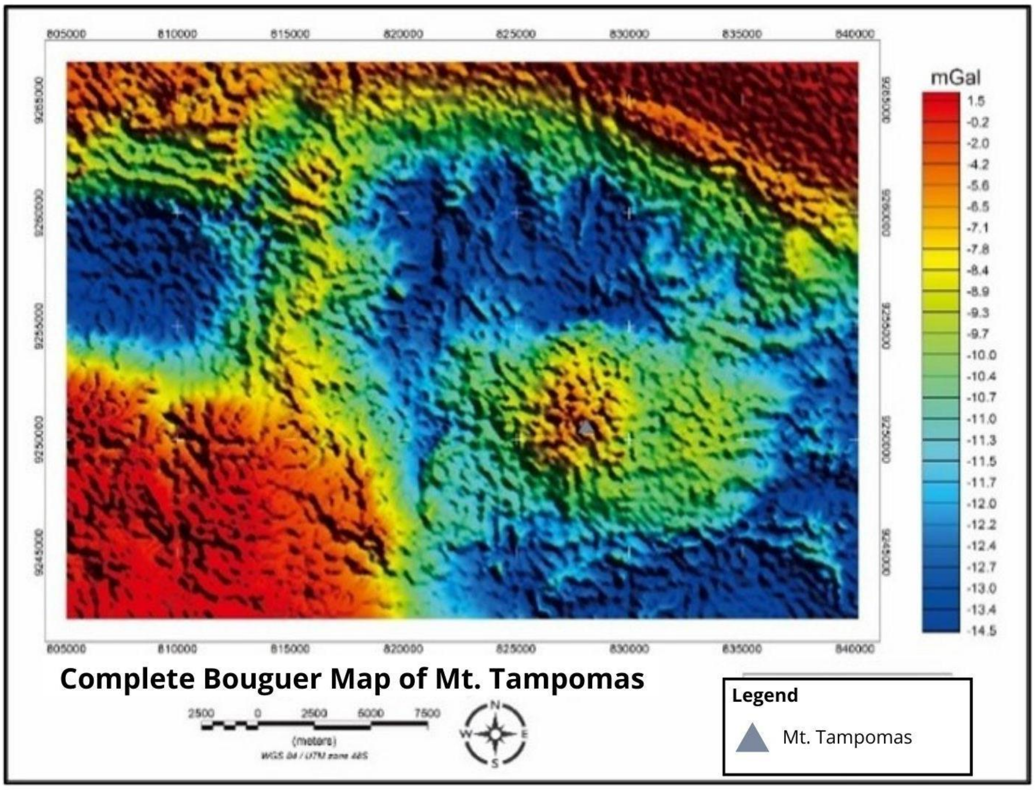

Figure 6. Complete Bouguer Anomaly Map

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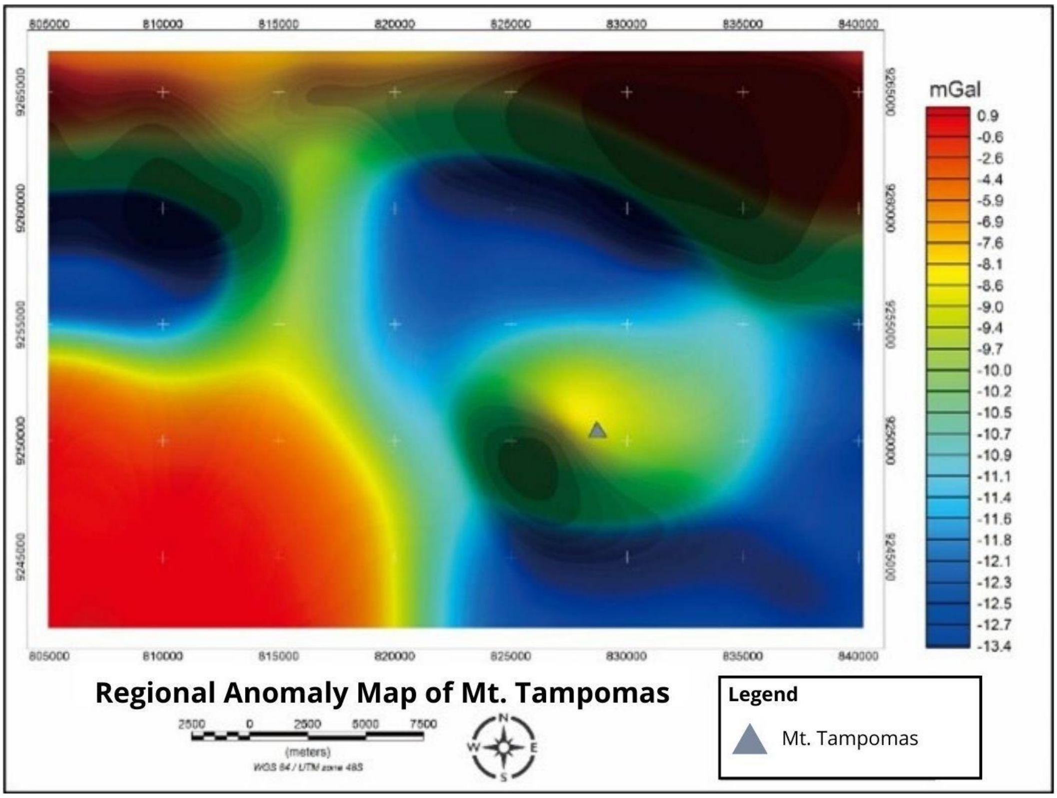

Figure 7. Regional Anomaly Map

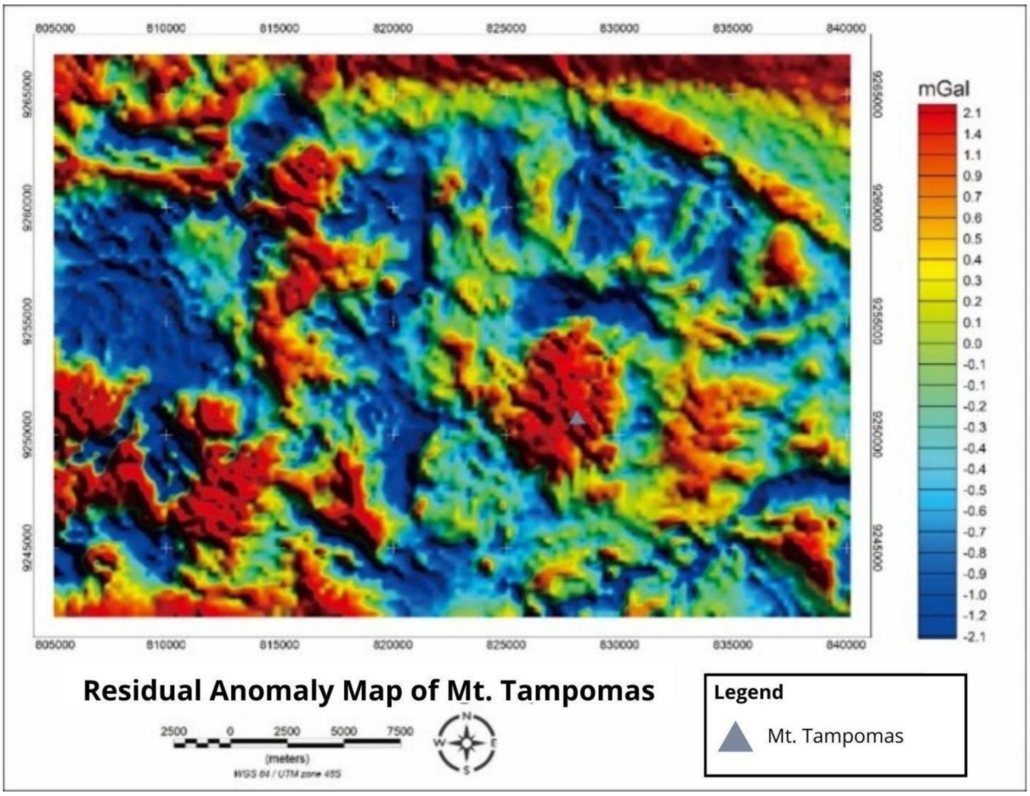

Figure 8. Residual Anomaly Map

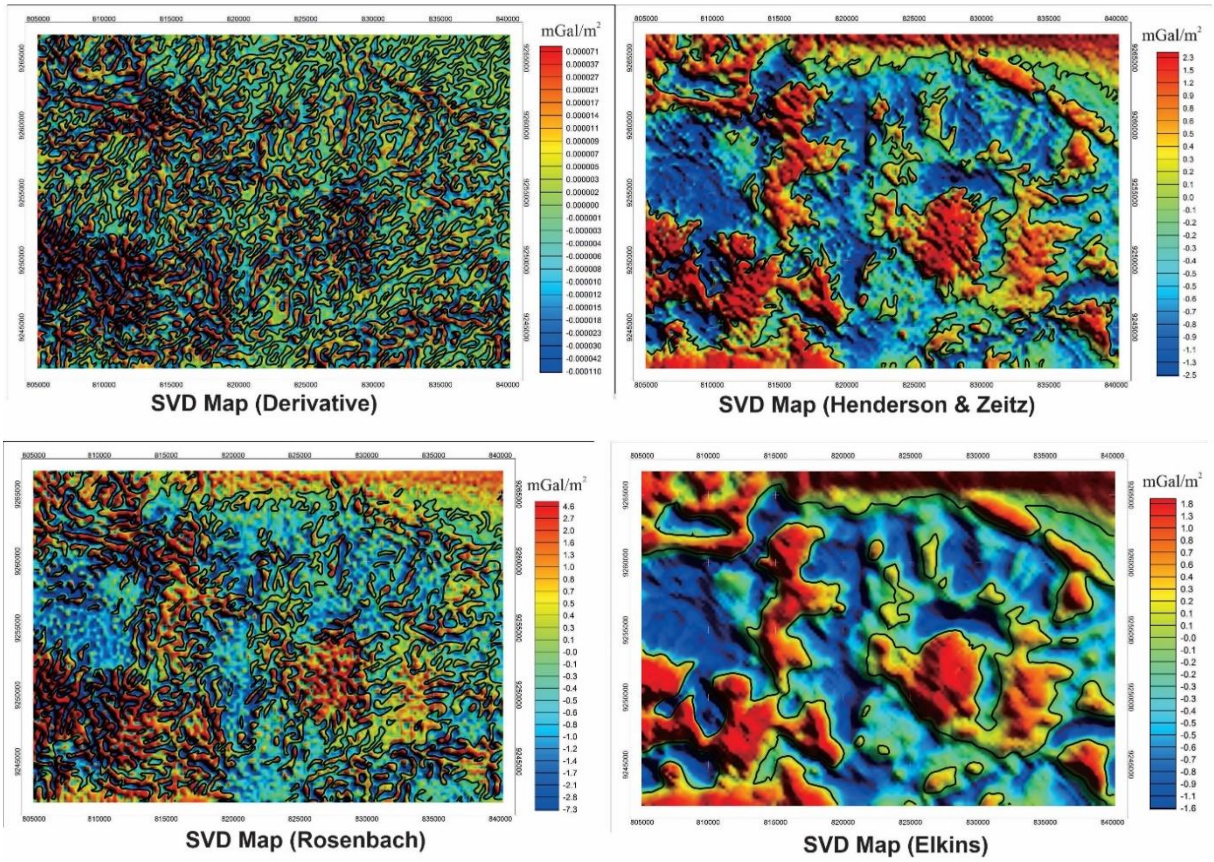

Figure 9. SVD results are based on each type.

RESULTS AND DISCUSSIONS

The SVD results show that the Elkins-type SVD map is clearest in showing the continuity of zero-value SVD. Henderson & Zietz-type is also clear enough but not clearest. Rosenbach-type and normal derivatives are too noisy and can't show the continuity of zero-value SVD. Therefore, this study interprets the geological structure based on the Elkins-type SVD map to identify the geological structure.

The SVD structure can be determined by looking at the zero-contour lineament in the SVD data. This study used the Elkins-type SVD filter to convert the residual gravity data into SVD data. SVD data that has been obtained has a value range of -2 to 4 mGal. On the SVD Residual Anomaly Map of Mount Tampomas (Figure 9) that has been created, the black contour line shows that the area has a residual anomaly value of 0 mGal/m^2. In contrast, the white line is the SVD structure obtained from the interpretation results (Figure 10).

The SVD structure in this area is dominantly trending northwest-southeast and west-east. The area around Mount Tampomas shows several circular structures interpreted as calderas. In addition, there are also structures trending north-south at coordinates 81500-82000 E. These SVD structures were overlaid with a geological map to see the suitability of the processed data with the geological conditions that have been studied.

The SVD structure was overlaid with the lineament map of the study area to see its conformity with the lineament map (Figure 10) and overlaid with the geological map to see its compatibility with the geological structure (Figure 11). The white line

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represents the SVD structure. Meanwhile, the yellow line is the SVD structure related to the lineament map.

Three calderas correlate with the lineament map seen in the image above. SVD data can see the caldera due to differences in rock density due to eruption debris. As for the lineaments in the study area, there is only one lineament related to the SVD structure, located in the northeastern part of the research area.

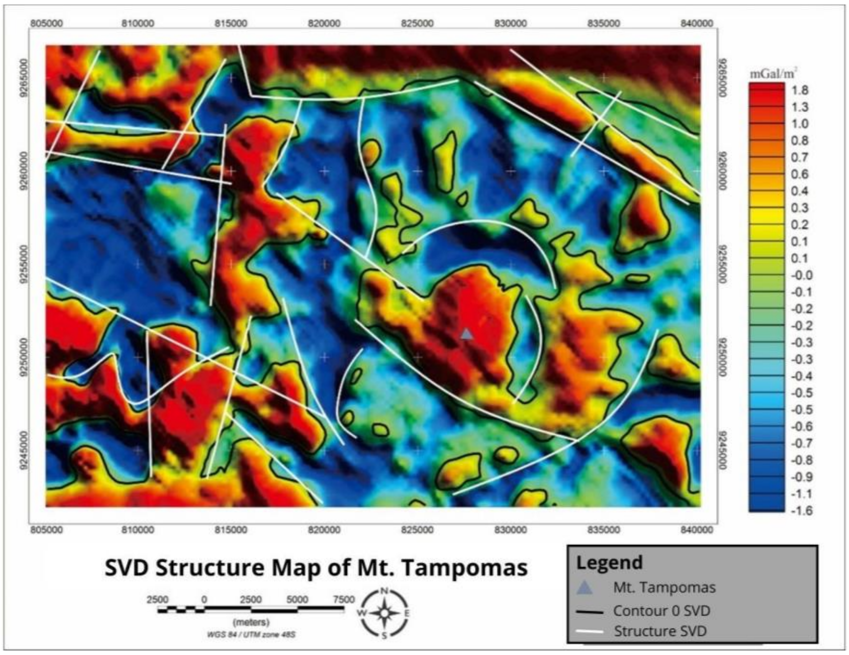

Figure 10. SVD structure map.

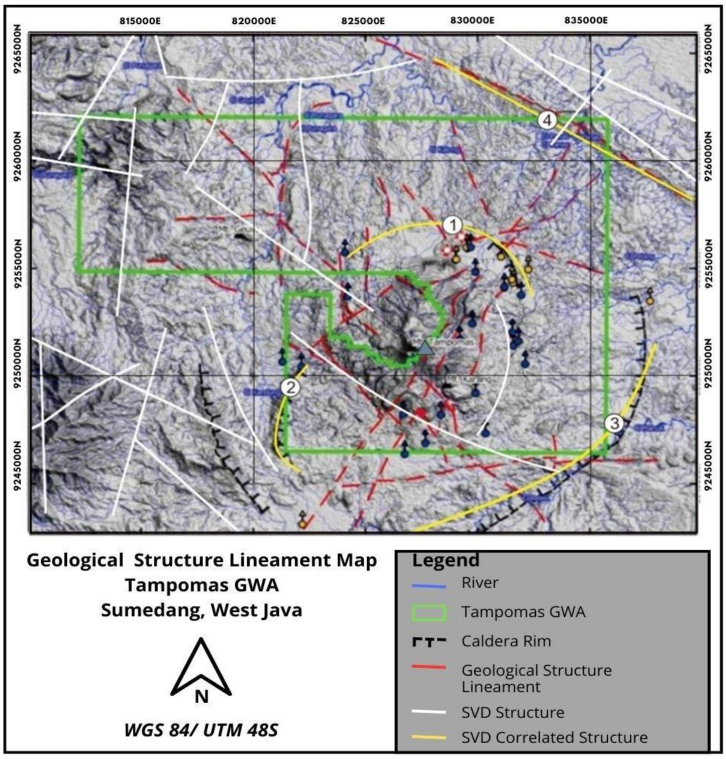

Figure 11. Overlay of SVD structure with lineament map.

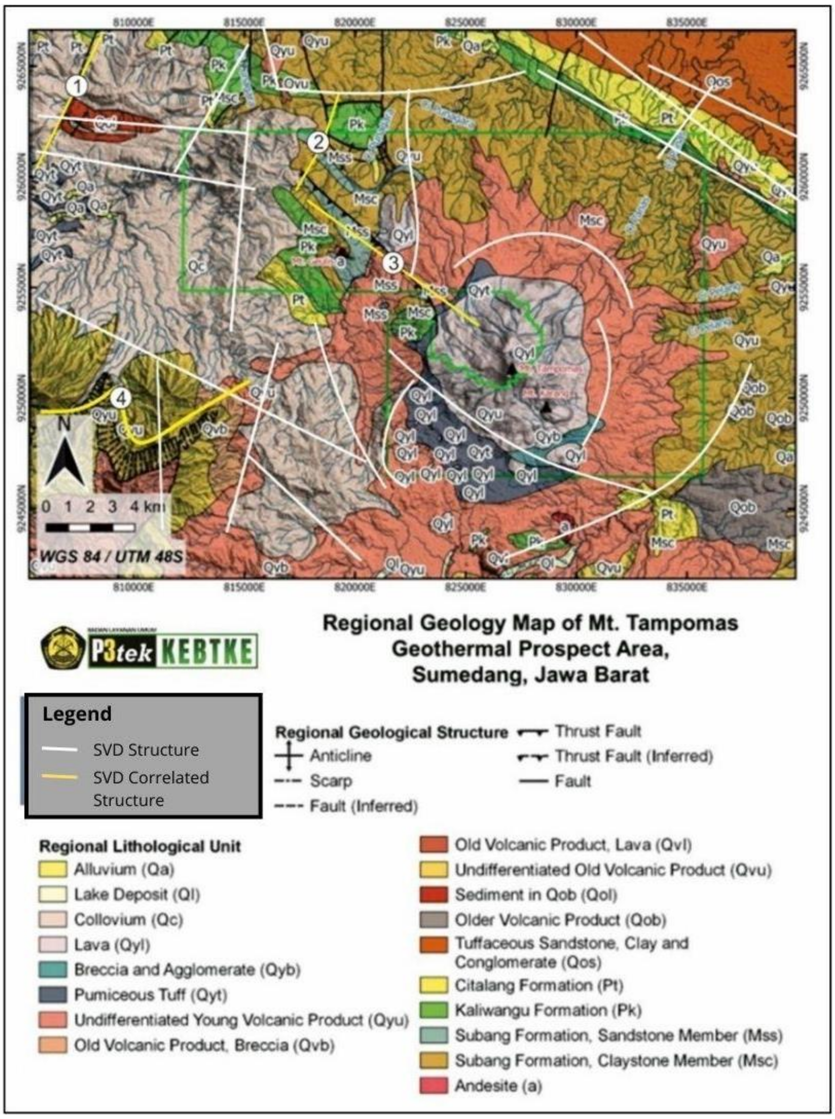

Figure 12. Overlay of SVD structure with geological map (modified from Mesker (2008) [3]).

Four structures correlate with the structures on the geological map. The first structure is in the northwest of the study area. This structure trends northeast-southwest and is located in the Kolovium Formation (Qc). The second structure is north of the research area in the Kaliwangu Formation (Pk). The Kaliwungu (Pk) Formation is going down with the Subang Formation (Msc) around it. The third structure is related to the reverse fault located on the northwestern part of Mt. Tampomas. This structure is oriented northwest-southeast. The fourth structure is the scarp or ladder fault system. Located in the southwestern part of the research area. The four structures are significant from this region's stratigraphy and geological cross-section. So, this structure can be seen in the gravity data. Gravity data can’t see some structures. It could be the structure is not major enough and does not show a significant contrast in gravity values.

Most manifestations in this area are passed by structures, either by SVD structures that correlate with the geological map or by SVD structures that do not correlate.

CONCLUSION

The SVD structure from GGMplus Gravity data shows its relationship in trends and morphology with the structure found on the Mount Tampomas area's geological map and lineament map. Four SVD structures related to the research area's geological map and the lineament map have a northwest-southeast trend in both type and direction. Geological structures in SVD can be used as a reference for depicting a complete subsurface model.

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