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Subsurface Analysis on Ranu Grati Lineaments with Satellite Gravity Data

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Abstract: The lineaments with NE-SW direction formed by the Umbulan Spring, Banyubiru Spring, and Ranu Grati Maar in Pasuruan Regency indicate a geological structure. This structure is predicted to play a role in forming these springs and maar. Therefore, a study was conducted to identify the presence of these geological structures using the GGMPlus satellite gravity data. The data used in this study were 945 points with spacing intervals of about 200 to 300 meters. Satellite gravity data needs to be corrected so that the Complete Bouguer Anomaly (CBA) value is obtained, which can be used to determine the distribution of density contrast values in the research area. Gridding is done by using a Second Vertical Derivative (SVD) filter to determine existing fault that results in the lineaments of the two springs and maar based on the second derivative value from CBA. It was found that the range of interpolated CBA values in the study area was around 143 mGal to 150 mGal. SVD analysis indicates existing a fault plane exists through Umbulan Springs, Banyubiru Springs, and Ranu Grati Maar with E-W direction.

Keywords: Geological Structure; Satellite Gravity; Second Vertical Derivative

Introduction

Umbulan Spring, the largest spring in Indonesia, is a unique hydrogeological phenomenon on the northern side of the Bromo-Tengger Volcanic Complex (Fajar et al., 2021). Administratively, this spring is located in the Pasuruan Regency, with coordinates of 7°45′34.94″ S 112°56′3.65″ E and a debit of 3500 L/s. Based on the genesis of spring formation, Umbulan is a type of spring that is formed due to a fault (Rengganis & Seizarwati, 2015). The North Pasuruan fault zone surveyed shows the presence of a South-North graben forming the Pasuruan Plain (Marliyani, 2016; Toulier et al., 2019). In addition to the Umbulan Spring, the Banyubiru spring and the Maar Ranu Grati are considered to form a lineament. Physiographically, this lineament lies in the Ngawi and Quaternary Mountains Sub-zone, which includes the Solo and the Kendeng Zone (van Bemmelen, 1949).

Based on the Geological Map, the Umbulan Spring is located in the Middle Quarter Volcanic Formation, which consists of volcanic breccia, tuff, lava, agglomerates, and lahars (Santosa & Suarti, 1992). However, the result of geoelectrical measurements shows that the rocks making up the Umbulan Spring are sand, tuffaceous sand, breccia, sandy breccia, sandy tuff, and tuff (Tatas et al., 2014). On the other hand, the Banyubiru Spring and the Ranu Grati Maar are included in the Rabano Tuff Formation, which consists of sandy tuff, floating tuff, tuffaceous breccia, and fine sandy tuff (Santosa & Suarti, 1992). It should be noted that Maar is formed from hydromagmatic eruptions driven by a direct interaction between magma and water, such as groundwater, sea, or rivers (Sottili et al., 2012). Therefore, the two springs considered as lineament could be called structural springs due to faults based on the lithology of the rock forming the springs.

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In determining the presence of geological lineament, the Satellite Gravity method is used to map the distribution of subsurface rock density values due to the differences in gravitational field values from one observation point to other points (Hinze et al., 2010; Kamto et al., 2021; Lestari et al., 2023; Pratama et al., 2023). Gravity anomaly became important object to identify gravitational anomaly in the research area related to rock density and structural geology (Abdullah et al., 2022; Bychkov et al., 2021; Nafian et al., 2022; Sanjaya et al., 2023). Gravity method is based on Newton`s Law of Gravity which states that two objects are mutually attracted because of the object's gravitational field (Ansari & Abouelmagd, 2020; Qin, 2022; Wei et al., 2023). By using First Horizontal Derivative (FHD) and Second Vertical Derivative (SVD) analysis, the Gravity method data can show geological feature anomalies so that they can detect the geological structures (Darmawan et al., 2021; Dewanto et al., 2022; Yanis et al., 2022; Yusvinda et al., 2021). Significant changes in anomaly values are generally controlled by the presence of faults beneath the surface (Sota, 2011). Therefore, the Satellite Gravity method in this research with SVD analysis was used to prove the presence of the lineament between Umbulan Spring, Banyubiru Spring, and Ranu Grati Maar.

Method

This study used 945 satellite gravity data from Global Gravity Model Plus (GGMPlus) since it can detect observation gravity values. Satellite gravity data have geoid undulation interval between 200 to 300 meters from 60° LN - 60° LS (Hirt et al., 2013). The study has 44 km^2 areas with various morphology, which are steep areas in the south and sloping areas in the north study area. The satellite gravity data distribution is shown in Figure 1.

Complete Bouguer Anomaly (CBA) was determined from several satellite gravity data corrections. Kriging gridding method was applied in CBA anomaly to interpret 2-D profile, which the data weighting is based on the distribution and correlation of the satellite gravity data (Kanda, 2018; Mulugeta et al., 2021; Omollo & Nishijima, 2023). Second Vertical Derivative (SVD) filter was used to make shallow anomaly effects from residual influence and to determine the geological structure boundary in this location (Yulistina, 2017). SVD value is obtained from CBA value derivative to spatial data distance, so it can be used to identify a fault from contiguous maximum and minimum anomaly values (Dewanto et al., 2022). The second derivative has a clear and good figure because this filter emphasizes shallow anomaly over regional anomaly (Elkins, 1951).

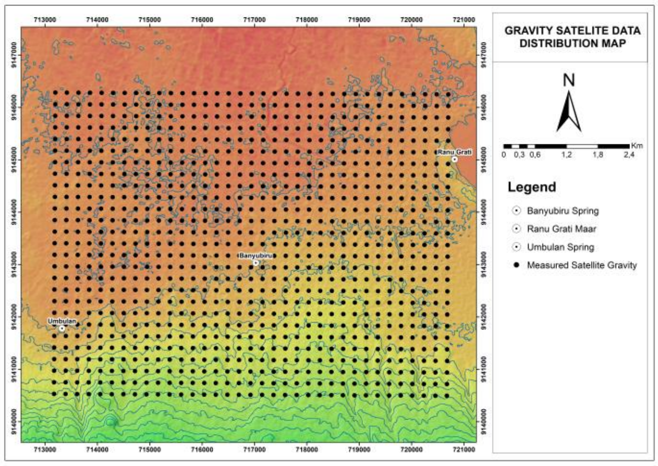

Figure 1. Satellite gravity data distribution in study area.

Result and Discussion

As a result, from satellite gravity data correction, the distribution value of Complete Bouguer Anomaly (CBA) is figured out in Figure 2 as 2-D profile.

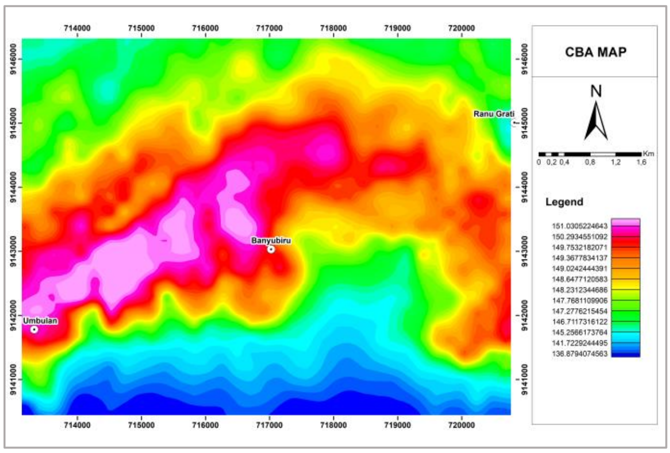

Figure 2. Complete Bouguer Anomaly (CBA) from satellite gravity data maps.

From that map, very low value of gravity anomaly distributes in the south and low value distribute in the north study area, that is around 143 mGal. Meanwhile, the center study area has a high value of gravity anomaly around 150 mGal, which distribute in E-W direction. These maps have great representative grades because the satellite gravity data interval does not need to interpolate so far.

First Vertical Derivative (FHD) results a first derivative value distribution of CBA, and Second Vertical Derivative (SVD) used at FHD value to results a second derivative of CBA to spatial data distance. Figure 3 showing a distribution of SVD value.

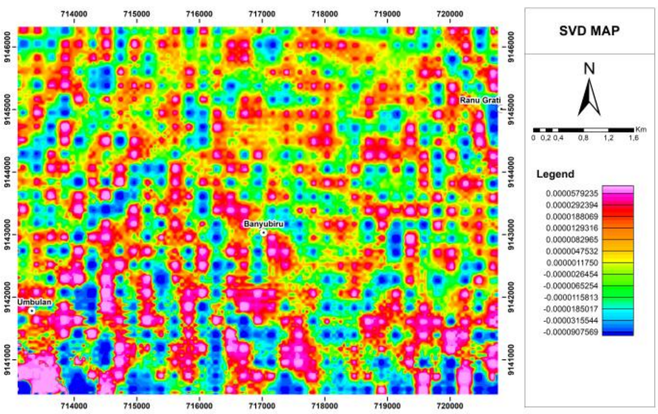

Figure 3. Second Vertical Derivative (SVD) from CBA maps.

Based on this map, SVD value starts from -0.0000907 mGal/m² until 0.0000597 mGal/m². Distribution of SVD value shows a high value in the center study area, which have E-W direction. Fault plane interpretation must follow contrast value from one data to another data. Slicing in SVD value was applied to get second derivative value curve, which can be used to indicate fault plane in study area. For this reason, slicing must be perpendicular with the direction of the fault plane indication, as in Figure 4.

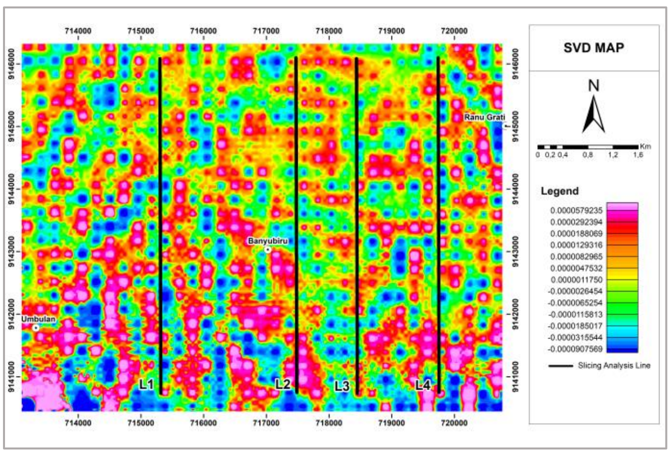

Figure 4. Second Vertical Derivative (SVD) from CBA slicing maps.

Maximum and minimum extreme values from the second derivative value curve are indicators for fault plane analysis. The curve analysis result is shown in Figure 5 and this interpretation is shown in Figure 6. Indicate fault plane exists in the center study area through Umbulan Springs, Banyubiru Springs, and Ranu Grati Maar with E-W direction. Moreover, some lineament indicated around the fault plane is estimated as a weak zone from this fault plane. Fault exists with springs because this geological structure makes a fracture in impermeable layer and confined aquifer so water can move up to the surface through that fracture (Kodoatie, 2012). In maar formation, faults make fractures to magma intrusion, which possible to meet an aquifer system and occur an explosion because the water in the aquifer getting hotter. The crater because explosion will fill by water from that aquifer.

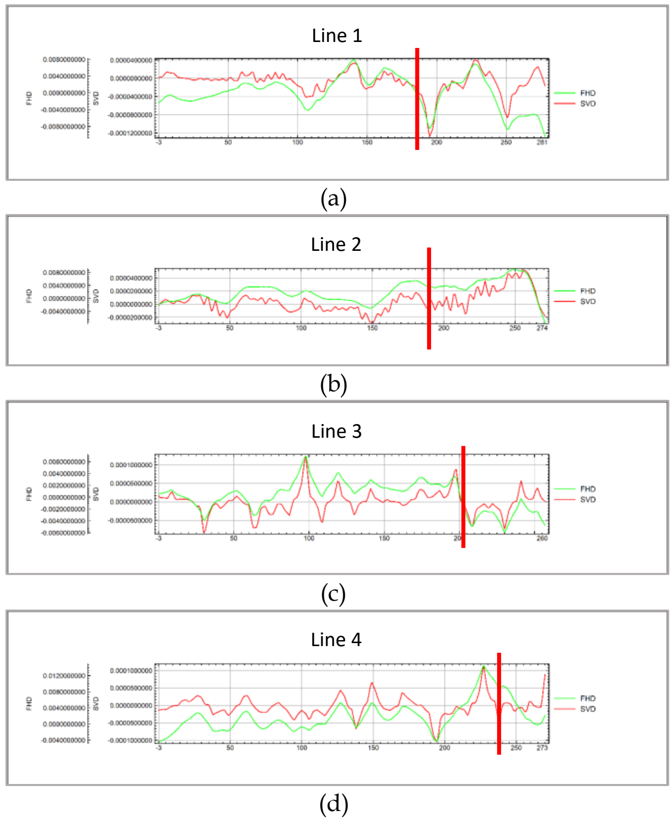

Figure 5. Second Vertical Derivative (SVD) from CBA slicing curve of (a) Line 2 (b) Line 4 (c) Line 5 (d) Line 6.

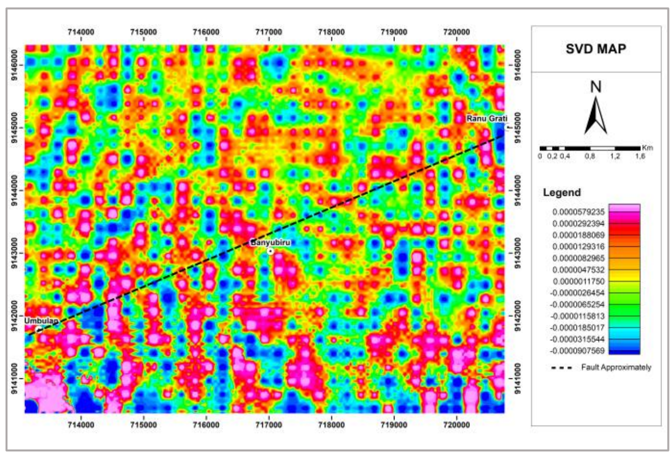

Figure 6. Fault indication based on Second Vertical Derivative (SVD) curve.

Conclusion

The analysis result using the Second Vertical Derivative (SVD) from CBA value on satellite gravity that resulting gravity anomaly around 143 mGal to 150 mGal. Data result indicates a fault in the SW-NE direction, which has a lineament from the Umbulan Spring area to the Ranu Grati Maar area. This lineament shows that the fault caused the emergence of Umbulan Spring and Banyubiru. In addition, magma intrusion from the Bromo Volcano complex can pass through the fault, which can form a maar due to the contact between the intrusion and the aquifer in the area. This research is fundamentally from further research that combined geology and geophysical data that would be representative condition of geoscience aspect in the research area.

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Author Contribution
Dhea Pratama Novian Putra and M. Haris Miftakhul Fajar have conceptor role in this research. Dhea Pratama Novian Putra, M. Haris Miftakhul Fajar, Dwa Desa Warnana, and Amien Widodo collected satellite gravity data, also processing and analysis. Dhea Pratama Novian Putra, M. Haris Miftakhul Fajar, Amien Widodo, Faqih Ulumuddin, and Syabibah Zakiyya Zukhrufah interpreted processing result and writing article draft. Faqih Ulumuddin and Syabibah Zakiyya Zukhrufah doing validation and research administration.

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Conflicts of Interest
The authors declare no conflict of interest. This research is an original research article, which is not used any forbidden and restricted data that will create any conflict.

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