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SEPARATION OF REGIONAL AND RESIDUAL ANOMALIES USING *GGMPLUS* GRAVITY DATA IN PANTI SUB-DISTRICT, WEST SUMATRA

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Abstract

This study addresses the limited application of GGMPlus satellite gravity data for regional and residual anomaly separation in geothermal exploration within Indonesia. The research aims to separate and analyze gravity anomalies to elucidate subsurface geological structures in Panti District, Pasaman Regency, West Sumatra. A quantitative-descriptive approach with an exploratory design was employed, utilizing secondary gravity data from the GGMPlus model comprising 4,537 measurement points at 200-meter intervals. Data processing involved Bouguer correction, Fourier transformation, and the application of a bandpass filter using Oasis Montaj software. The complete Bouguer anomaly in the study area ranges from –37.5 to –25.6 mGal. Frequency-based separation yielded regional anomalies ranging from –37.3 to –25.8 mGal, while residual anomalies varied between –0.77 and 0.72 mGal. The residual anomalies are interpreted as responses from shallow subsurface features, including sedimentary rocks and potential geothermal reservoirs. In contrast, the regional anomalies are associated with deeper geological structures, such as faults and intrusive bodies. These findings demonstrate that frequency-domain filtering provides an effective means of enhancing the interpretability of satellite-derived gravity data in geothermal investigations. The study confirms the utility of GGMPlus data and spectral filtering techniques in delineating subsurface targets and improving geophysical assessments for geothermal resource exploration.

Keywords: GGMPlus; Bouguer Anomaly; Bandpass Filter; Regional Anomaly; Residual Anomaly; Geothermal Exploration

INTRODUCTION

Energy demand in Indonesia continues to experience a significant increase along with population growth, infrastructure expansion, and expansion of the industrial and transportation sectors. Energy has a strategic role in supporting national development and improving people's quality of life(Khasmadin & Harmoko, 2021). However, until now, the national energy supply is still dominated by non-renewable fossil fuels. This dependence on energy sources has implications for increasing supply instability, rising energy costs, and environmental impacts such as greenhouse gas emissions and ecosystem degradation (Meilani & Wuryandani, 2010).

One of the most promising renewable energy sources in Indonesia is geothermal energy. Geologically, Indonesia is located in the Pacific Ring of Fire, which is characterized by the presence of hundreds of active volcanoes, large fault systems, and high tectonic activity. These conditions create a geothermal system that is widely spread from the western to the eastern tip of the archipelago. Data shows that there are more than 300 locations of geothermal potential in Indonesia with huge estimated energy reserves (Aulia et al., 2022; Hakim et al., 2022). However, the utilization of this potential is still limited, mainly due to the lack of adequate subsurface data, especially in tectonically active areas with minimal exploration, such as Panti District, Pasaman Regency, West Sumatra.

In the context of geothermal exploration, information on subsurface geological structures plays an important role. The presence of faults, fractures, intrusive rocks, and hydrothermal alteration zones are important indicators in geothermal systems. Therefore, geophysical methods such as gravity (gravimetry) are used to detect variations in rock density that can be associated with these structures (Telford et al., 1990). Gravity measures variations in the Earth's gravitational acceleration caused by density contrasts in the subsurface. In geothermal systems, density changes can occur due to fracturing, the presence of alteration rocks, or magma intrusion, all of which are important in the development of geothermal resources.

The advancement of satellite technology, particularly through the GGMPLUS gravity model which integrates GRACE, GOCE, and EGM2008 data, has enabled more cost-efficient and wide-coverage geophysical exploration (Hirt et al., 2013). Advances in satellite technology have expanded the scope of geophysical exploration in a more cost-efficient manner. The GGMPLUS gravity model is one of the leading satellite products, as it combines data from GRACE, GOCE, and EGM2008 and high-resolution topographic corrections (Hirt et al., 2013). With a resolution of up to about 200 meters, GGMPLUS is very suitable for regional-scale geological mapping, including for early geothermal exploration in areas that do not yet have adequate ground survey data (Prida Mazzaluna & Catur Wibowo, 2024)

In the interpretation of gravity data, the separation of anomalies into regional and residual components is an important step to make the information obtained more focused. Regional anomalies reflect large and deep structures such as basins and bedrock, while residual anomalies reflect local variations such as shallow faults or shallow intrusions that are highly relevant in geothermal systems (Novianti et al., 2024). Therefore, the use of filtering techniques, especially bandpass filters, is an effective method to separate gravity signals based on a specific depth or wavelength scale.

Anggraeni (2021) showed that the application of filtering to gravity data can clarify the boundaries of geological structures in areas with complex tectonics. However, similar studies in Indonesia generally still use land survey data with limited coverage, and rarely utilize high-resolution satellite data such as GGMPLUS.The study by Resta et al. (2025), for example, has not integrated spectral analysis in the frequency domain for gravity anomaly separation. Moreover, there is no comprehensive study that applies the bandpass filter method specifically to GGMPLUS data for the Panti region located in active fault zones.

Panti sub-district has a strategic tectonic position, located around a large fault zone associated with volcanic and geothermal activity in the West Sumatra region. The geothermal potential in this area is still not optimized due to limited subsurface data. Gravity analysis can provide initial clues about the presence of important structures such as faults, fractures, or rocks with high-density contrast that may serve as conduits for hydrothermal fluids (Blakely, 1996). As such, This approach is not only useful for energy exploration, but also relevant for mitigating geological risks such as earthquakes and ground motion.

This research aims to apply the bandpass filter method to the GGMPLUS satellite gravity data to separate regional and residual anomalies in Panti sub-district. This separation is expected to reveal subsurface geological structures that are indicative of potential geothermal systems. By utilizing signal processing techniques in the frequency domain, data interpretation becomes more accurate and focused, especially in identifying shallow structures that play a role in geothermal systems. This approach represents a novel application of high-resolution satellite gravity data in geothermal exploration within Indonesia.

METHODS

1. Type of Research

   This research uses a descriptive quantitative method with an exploratory approach. The quantitative method was chosen because the data used is in the form of numbers from satellite gravity anomaly measurements that are analyzed through mathematical and statistical methods. The descriptive approach is used to describe the spatial distribution pattern of regional and residual gravity anomalies, while the exploratory approach is used to reveal previously unknown subsurface geological information
2. Research Design

   This research design is a case study-based exploratory study. The case study was conducted in Panti Sub-district, Pasaman Regency, West Sumatra, which was chosen because it has unique geological characteristics and has not been widely explored using satellite gravity data. This design allows in-depth analysis of local geological phenomena by utilizing high-resolution secondary data from satellites.

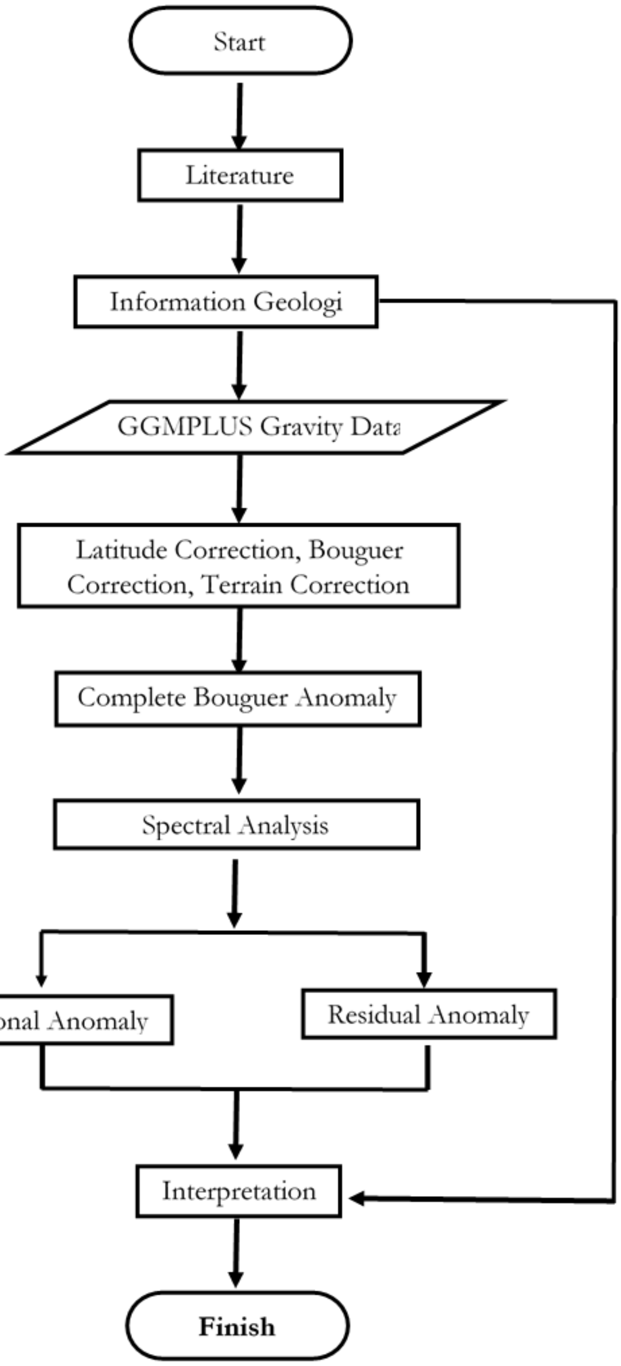

Figure 1Research Flowchart

3. Participants and Sampling Techniques

The unit of analysis in this study is the gravity data point from the GGMplus satellite model, which covers the Panti sub-district area. GGMplus data is a remote sensing product that provides global gravity information with wide area coverage and high resolution. The main advantage of this satellite data is its ability to provide comprehensive data without the limitations of geographical access or difficult terrain conditions (Pail et al., 2011).

The research population criteria are all gravity coordinate points in the study area of Panti District, Pasaman Regency, West Sumatra Province which is bounded by the coordinates of 00°15'38.992" - 0°23'11.630" North latitude and 100°1'24.974"-100°10'11.630" East longitude. Data selection was done through purposive sampling, selecting the most representative and high-quality data points. The amount of data used is 4537 points with a distance between points of 200 meters, which allows for wide coverage and high accuracy in anomaly mapping (Kamto et al., 2021).

4. Instruments and Data Collection Techniques
   a. Research Instruments
      1) Matlab: For extraction and preprocessing of GGMplus gravity data.
      2) Global Mapper: For geographic to UTM coordinate conversion and data input generation.
      3) Surfer: For data visualization in the form of gravity contour maps.
      4) Oasis Montaj: For gravity data correction, Bouguer anomaly processing, Fourier transform, and filtering.
      5) Microsoft Excel: For tabular data processing, correction calculations, and descriptive statistics
   b. Data Collection Technique
      1) Data Extraction

         The processed gravity data is secondary data obtained from GGMPlus satellite data which is then extracted using Matlab based on the research area boundaries. The amount of data obtained from GGMPlus is 4537 data with a space between measurement points of 200 meters (Mardiyah et al., 2024). The research observation point is limited to coordinates from 00°15'38.992" - 0°23'11.630" North Latitude and 100°1'24.974" - 100°10'11.630" East Longitude.
      2) Coordinate Conversion

         After extraction, the coordinate data that was originally in the geographic system (latitude-longitude) was converted into the UTM (Universal Transverse Mercator) system using Global Mapper software. The aim was to facilitate the plotting, correction and spatial analysis of the gravity data.

3) Data Correction

Corrections are made to the gravity data to obtain the Complete Bouguer Anomaly (CBA) value. This correction is important to remove external influences that are not directly related to the subsurface structure. The types of corrections made include:

- Latitude Correction

  Latitude correction is done because the shape of the earth is not perfectly round, so there is a difference between the radius of the earth at the poles and the equator. Gravity is stronger at the poles than at the equator due to the Earth's oblateness. Because of this difference, latitude correction greatly affects the amount of gravity in an area. Systematically, the topographic gravity field anomaly can be expressed in the form of the following equation:

$$g_{\varphi} = 978032.700\,(1 + 0.0053024\,sin^2\varphi - 0.0000058 sin^2 2\varphi) \qquad \textit{Equation 1}$$

- Free Air Correction

  Free air correction is a correction due to differences in the height of the measuring point by ignoring the mass between the measuring point and the measurement reference plane. Free air correction can be calculated using the formula:

$$FAC = 0.3086\ X\ h \qquad \textit{Equation 2}$$

  Description: FAC: Free Air Correction (mGal/m), h: Height of measuring point (m)

- Terrain Correction

  Taking into account the topographic effects around the measurement point using DEM (Digital Elevation Model) data. This correction aims to eliminate the effects of external terrain and obtain the true gravity anomaly valu (Mahadi. Tian Aprilia Aksa et al., 2020).

- Bouguer Correction

Bouguer correction is used to remove the influence of surrounding subsurface rock mass. By making Bouguer correction, it can determine the height difference between the observation point and the datum plane and consider the density of the rock mass around the observation point. The amount of correction value can use the equation:

$$BC = 0.04192\rho h \qquad \textit{Equation 3}$$

Where: BC= Bouguer correction (mgal), h = height of measurement station (meters), ϱ= averagerock density (g/cm^3), G= the universal value of gravity $(G = 6.67 \times 10^{-11} Nm^2kg^{-2})$.

The complete Bouguer anomaly is the result of the superposition of regional anomalies, residuals and noise. Positive values in the Bouguer Anomaly represent large density contrasts in the subsurface, usually found at the bottom of an ocean. Whereas, negative values in Bouguer Anomalies occur due to small density differences found during gravity surveys on land. A positive Bouguer anomaly represents a large density contrast in the subsurface, usually found at the bottom of an ocean. Negative Bouguer anomalies are due to small density differences found during gravity surveys on land (Kearey et al., 2002).

- Separation of Regional Anomalies and Residuals

The Bouguer anomaly is a gravity anomaly that has been corrected for topographic effects as well as a combination of regional and residual anomalies. This reflects that the Bouguer anomaly can be broken down into two components, the regional anomaly and the residual anomaly. This relationship is important for understanding the variation of rock density in the subsurface. Through Bouguer correction and spectrum analysis, the Bouguer anomaly has been analyzed obtained Bouguer anomaly and regional anomaly values (Sihombing et al., 2024)

All correction processes were performed using Oasis Montaj software and Microsoft Excel.

4) Fourier Transform

Fourier transformation is performed on CBA data to obtain spectrum analysis, which is then used in the separation of regional and residual anomalies using the Bandpass filter method (Nur Aziz et al., 2023). In the data processing process using Oasis Montaj software, the Radially Averaged Power Spectrum (RAPS) of the direction- independent spectrum analysis is displayed in 1D form (Karunianto et al., 2017)

5) Visualization and Interpretation

After the Complete Bouguer Anomaly (CBA) data was obtained through a series of corrections, visualization was performed using Surfer software. This visualization produces contour maps depicting the distribution of gravity anomalies within the study area. The colors on the map are used to show the variation of gravity acceleration values, where blue to purple colors represent low values, while yellow to red colors indicate high values. These contour patterns provide an initial indication of the potential presence of geological structures such as faults or rock intrusions. Furthermore, interpretation is based on spectrum analysis of the Fourier transform results on the CBA data. This stage aims to separate regional anomaly components originating from deep and large-scale geological structures, and residual anomalies reflecting shallow structures such as local fractures or faults. The separation is done with the bandpass filter method, so that information from different depths can be analyzed separately and in more detail.

c. Previous Studies

The use of GGMPlus satellite gravity data and software such as Oasis Montaj, Surfer, and Matlab has been widely applied in geophysical research, especially to identify subsurface structures. One of the relevant studies was conducted by Mardiyah et al. (2024)) in a study entitled Identification of Gorontalo Fault by Utilizing High Resolution Satellite Gravity Data. The study used data from GGMPlus processed with Matlab and Oasis Montaj to calculate the full Bouguer anomaly and separate regional and residual anomalies through spectrum analysis. The results successfully identified active faults based on contrasting gravity anomaly patterns.

Meanwhile, (Althafunnisa et al., 2024) used a similar approach in Southeast Sulawesi. With the help of Surfer and Oasis Montaj software, they managed to map subsurface density variations and identify regional geological structures from satellite gravity anomalies.

These studies show that the integration between GGMPlus data and geophysical software is able to provide accurate and efficient subsurface interpretation results, especially in areas that are difficult to reach by direct field surveys.

5. Analysis Technique

Data analysis in this study uses a quantitative approach by applying signal processing techniques to separate gravity anomaly components based on spatial frequency. The Complete Bouguer Anomaly (CBA) data obtained from the GGMPlus satellite was first corrected using Oasis Montaj software to remove the influence of topography and terrain effects. Next, the data is analyzed using a bandpass filter method that serves to separate regional and residual anomalies based on a specific spatial frequency range.

Filtering was performed using Oasis Montaj software to apply the Fourier transform and implement the bandpass filter effectively. Furthermore, correction and further data processing using Oasis Montaj facilitated data analysis and visualization. Visualization of filtered contour maps was done using Oasis Montaj for spatial interpretation of the anomalies. Visualization of the results in the form of contour maps is done with Surfer, while interpretation is done based on the filtering results to identify potential subsurface geological structures.

6. Time and Duration of Research Process

   This research was conducted over two months, from January to February 2024. In January, data collection, extraction, and processing including correction were carried out. using Matlab and Oasis Montaj. Subsequently, in February, analysis, interpretation of results, and preparation of the final report and publication were carried out. The duration was optimized to ensure efficiency while maintaining research quality.

RESULTS

1. Topography of the Study Area

   The research area is located in Panti District, Pasaman Regency, West Sumatra Province, with coordinate boundaries of 00°15'38.992" to 00°23'11.630" North latitude and 100°1'24.974" to 100°10'11.630" East longitude. Based on topographic data, the average elevation of this region is 610.84 meters above sea level. There are 4,537 observation points with a distance of about 200 meters between points. This topographic data is used as the basis for gravity correction, particularly Bouguer and terrain correction.

Figure 2 Topographic map of the study area

2. Complete Bouguer Anomaly Pattern

The results of data processing show the Complete Bouguer Anomaly (CBA) value. Next, a contour map is made using Oasis Montaj software by inputting the latitude and longitude values in UTM coordinates obtained from GGMPlus satellite data and the CBA value. The griding process is carried out to produce a Complete Bouguer Anomaly map.

Based Figure 3, CBA values range from -37.5 mGal to -25.6 mGal, divided into three main zones, namely low, medium and high anomalies, with different spatial distribution. Low anomalies (-37.5 to -31.3 mGal) are dominant in the southeast region, characterized by dark blue to light green colors. Medium anomalies (-31.3 to - 28.4 mGal) are scattered in the north and northeast with a light green to orange color. High anomalies (-28.4 to -25.6 mGal) are found in the northeast and northwest with red to pink colors. Negative anomaly values indicate low density rocks (e.g. sediments), while positive anomalies indicate higher density rocks (e.g. intrusions or faults).

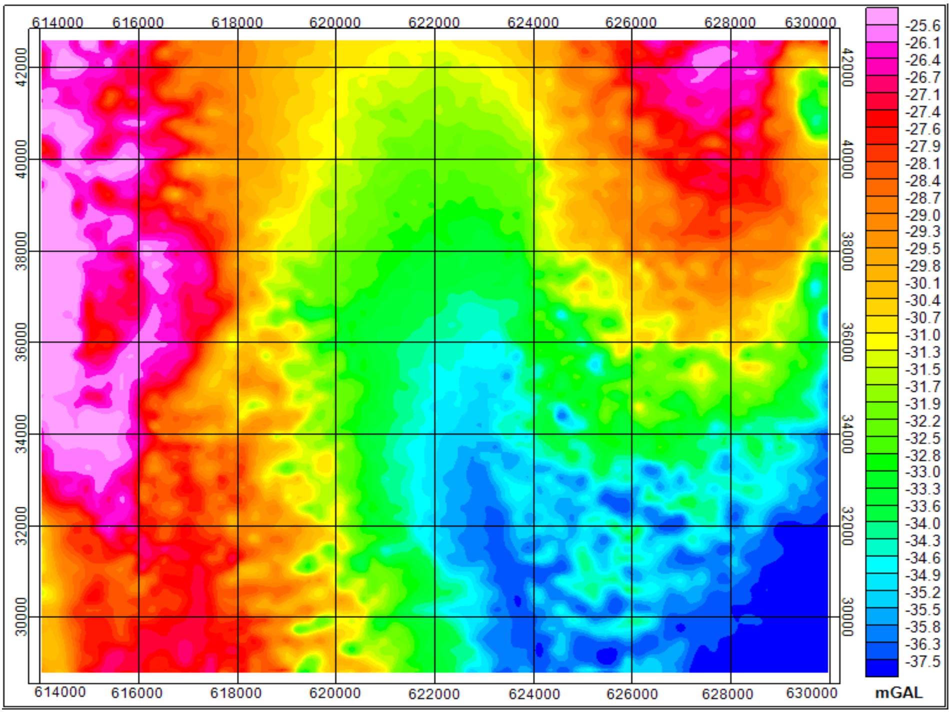

Figure 3 Complete Bouguer Anomaly Map in Panti Area

3. Parasnis Method Density Estimation

To support the CBA analysis, the Parasnis method is used to calculate the estimated rock density. Based on the linear relationship between Free Air Anomaly and elevation, the average density value is obtained $\rho = 2{,}6619\ g/cm^3$. According to Wildan et al. (2017)) the Parasnis method density estimate is obtained from the gradient of the line equation. Linear between the Free Air Anomaly value and elevation multiplied by 0.04193 (the value of the determination of the difference in the height of the Earth's gravity). With the estimated density value, the Bouguer correction can be done

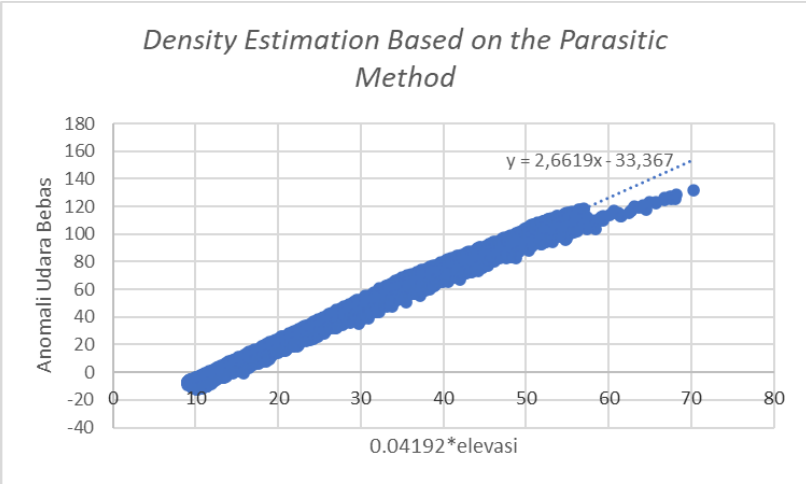

Figure 4 Density Estimation Based on the Parasnis Method

Negative anomaly values indicate that the density of rocks in the subsurface is relatively low, while positive anomaly values indicate higher density rocks. The larger the gravity anomaly value, the denser the subsurface rock structures such as faults or fractures. However, the Bouguer anomaly cannot directly determine the presence of geothermal heat, but only shows the pattern of variation in anomaly values in an area.

4. Spectrum Analysis

Spectrum analysis is performed in one dimension on a cross-section of the Bouguer anomaly data. The aim is to estimate the depth of regional anomaly sources and residuals using the Fourier transform. This process uses the RAPS (Radial Average Power Spectrum) curve, which allows identification of the depth of the discontinuity field through the RAPS curve. The RAPS curve consists of several main components, namely regional anomalies, residual anomalies, and noise (Kusmita et al., 2023) . Each component can be analyzed to estimate the depth of the anomaly source by calculating the slope of the RAPS curve. The depth is obtained from the formula where the slope is the slope of the line on the RAPS curve.

$$Depth = \frac{Slope}{4\pi} \qquad \text{Equation 4}$$

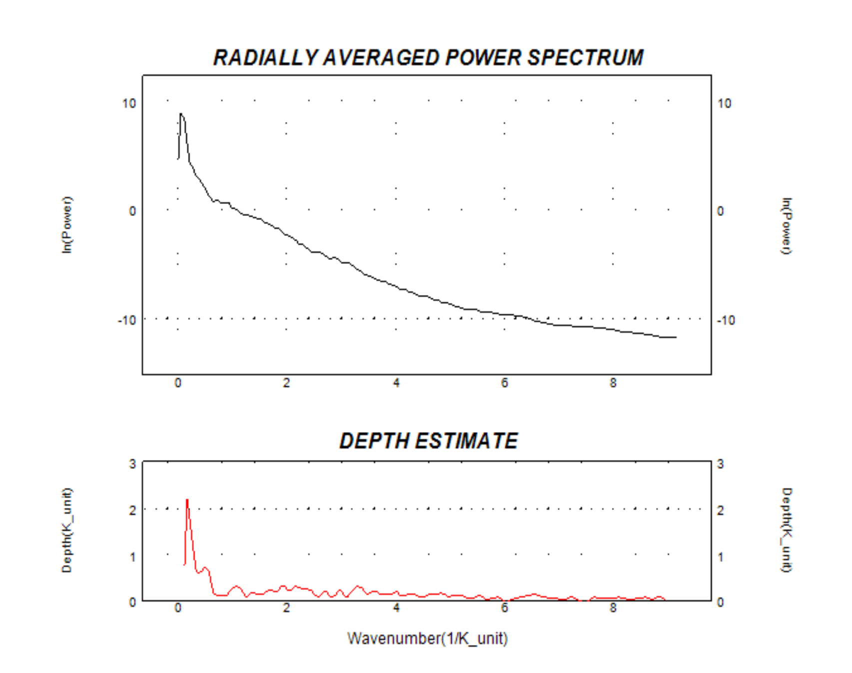

Figure 5   Radially Averaged Power Spectrum (RAPS) Curve

5. Separation of Regional Anomaly and Residual Anomaly

   Anomaly separation is performed with a Bandpass filter to distinguish regional anomalies originating from sources of greater depth from residual anomalies originating from shallow depths. The result of this anomaly separation is a regional map and a residual map.

   a) Regional Anomaly Map

      Figure 6 shows the regional anomaly map which has a smooth contour pattern with a value range of -37.3 mGal to -25.8 mGal. The contours of the regional anomaly map are similar to the CBA map, but smoother. This low anomaly indicates the presence of rocks with relatively low density, This zone has the potential to become a geothermal reservoir because sedimentary rocks tend to be porous and can store hot fluids.

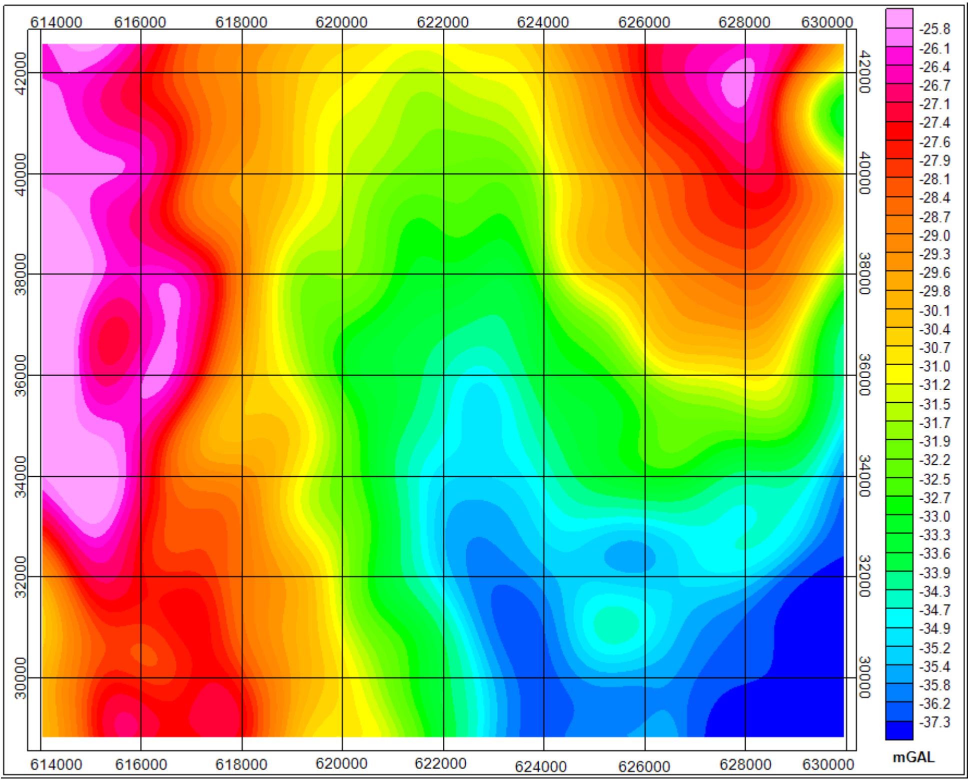

Figure 6 Regional Anomaly Map of Panti Region

b) Residual Anomaly Map

The residual anomaly map in Figure 7 has a smaller range of values, from -0.77 mGal to 0.72 mGal, with low anomalies in the southeast and high anomalies scattered in some areas. These residual anomalies are more spatially variable and allow identification of local geological features such as faults, fractures or shallow intrusions. In the study area, low residual anomalies dominate the southeast, indicating the presence of low-density sedimentary rocks, while high anomalies are scattered in several areas that are thought to be related to tectonic activity.

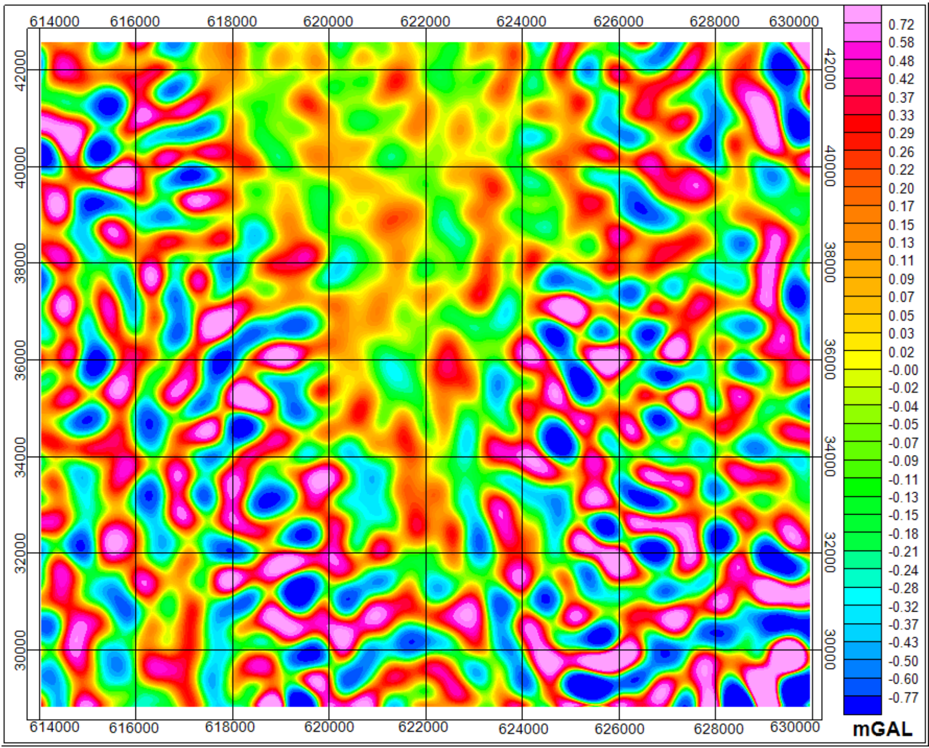

Figure 7 Residual Anomaly Map of Panti Region

6. Anomaly Pattern Interpretation

   The low anomaly may be caused by rocks with low density values (sedimentary rocks). The morphology of the site shows that in the north to the east and west there are suspected geothermal sources as indicated by the low anomalies. Geothermal sources are associated with volcanic activity. While the high anomaly is suspected to be a tectonic process that causes the formation of breakthrough rocks that break through to the surface and the presence of volcanic volcanic rocks.

DISCUSSION

This research successfully answered the research question regarding the characterization of subsurface structures and geothermal potential in Panti District, Pasaman Regency, West Sumatra Province. With topographic data collected from 4,537 points and a distance of approximately 200 meters between points, a sufficient database was obtained for gravity anomaly analysis using the Complete Bouguer Anomaly (CBA) method. The analysis results showed negative to moderately negative gravity anomaly values, divided into three main zones based on the range of values from -37.5 mGal to -25.6 mGal. These negative anomalies indicate the presence of low-density rocks, typical of sedimentary rocks and geothermal reservoir zones, while high anomalies reflect denser rock structures such as faults and intrusions (Mulyadi & Munandar, 2023) .

These results are consistent with the research by Mardiyah et al. (2024)in the Gorontalo area, which also utilized GGMPlus gravity data and Matlab and Oasis Montaj software to map active faults through anomaly separation using spectrum analysis. This approach enabled us to reveal subsurface structures based on gravity anomaly contrasts, reinforcing the relevance of using satellite gravity data to identify hidden geological features. Similarly, Althafunnisa et al. (2024) demonstrated that the combination of GGMPlus and software such as Surfer and Oasis Montaj can map rock density variations and regional geological structures in Southeast Sulawesi, consistent with the methods applied in this study.

Table 1 below summarizes the distribution of Bouguer anomaly zones in the Panti region, showing a close relationship between dominant locations and geological interpretations:

Table 1 Distribution of Bouguer Anomaly Zones in Panti Area

Anomaly Zone	Value Range (mGal)	Dominant Location	Interpretation
Low	-37,5 to -31,3	Southeast	Sedimentary rock, low density, geothermal potential
Medium	-31,3 to -28,4	North and Northeast	Transition zone between sedimentary and igneous rocks
High	-28,4 to -25,6	Northwest and Northeast	Intrusive or volcanic rocks, high density

The principle of the relationship between rock density and gravity anomaly values forms the basis for gravity geophysical interpretation. Rocks with low density cause a mass deficit and produce negative anomalies, while rocks with high density cause a mass surplus and produce positive anomalies. Therefore, gravity anomaly maps can be used as an initial indicator of subsurface density distribution, which is important in geothermal exploration. This is in line with the study by Restiana et al. (2023) in Dompu Regency, West Nusa Tenggara, which emphasizes the importance of anomaly separation in identifying geothermal prospect zones with greater precision.

To estimate the depth of the anomaly source and separate regional and residual components, Fourier transformation was performed on the CBA data and analyzed using the Radial Average Power Spectrum (RAPS) curve. The RAPS curve enables the identification of dominant frequency spectra associated with specific depths based on the slope of each spectral segment. A gentler slope indicates a deeper (regional) anomaly source, while a steeper slope indicates a shallower (residual) anomaly source. In the context of this study, the RAPS analysis in Figure 4 was able to identify the average depth of the regional anomaly source as ±9.7 km and the residual anomaly source as ±1.2 km, which supports the separation process using a bandpass filter. These results reinforce the effectiveness of bandpass filters in the separation process, as also applied by Abdul Basid (2012) in a geophysical study in Songgoriti, Batu City.

The anomaly separation results produced two main maps: the regional anomaly map and the residual anomaly map. The regional anomaly map displays smoother contours and a broader distribution pattern of anomalies, reflecting large-scale geological structures such as bedrock, large intrusions, and regional alignments. These characteristics are important in understanding the tectonic setting and the potential migration pathways of hydrothermal fluids from the deep zone. Meanwhile, the residual anomaly map displays more complex and localized contour patterns, reflecting the presence of shallow geological structures such as minor faults, fractures, and alteration zones associated with geothermal systems.

The distribution of low residual anomalies is found dominantly in the north, east and west of the Panti area, indicating the presence of low density rocks at shallow depths. This can be interpreted as an indication of hydrothermal alteration zones or porous rocks that have undergone weathering and interaction with geothermal fluids. The residual map also shows anomalous alignments that can be associated with fault patterns, providing important information in determining more precise drilling target locations. Table 2 summarizes the characteristics of the two anomalies.

Table 2 Characteristics of Regional Anomalies and Residuals in the Panti Research Area

Parameters	**Regional Anomalies**	**Residual Anomaly**	**Parameters**
Value Range (mGal)	-37.3 to -25.8	-0.77 to 0.72	Value Range (mGal)
Contour Pattern	Smooth	More details and spatially variable	Contour Pattern
Source Depth	In (structure big)	Shallow (structure local)	Source Depth

The main contribution of this research lies in the successful separation of anomalies that clarify the differences between regional structures and local features, which are very important in evaluating geothermal potential. This approach not only improves the accuracy of interpretation but also reinforces the results that have been shown in various previous studies in various regions of Indonesia. This advantage is very relevant for the development of renewable energy in the future.

Practically, the results of this research have important implications for geothermal energy development, particularly in the early exploration stage. Information on the distribution of gravity anomalies, relative density values, and the depth of anomaly sources can be used to guide the location of exploratory drilling more efficiently and accurately. This contributes to the development of more economical and sustainable renewable energy. Local governments and energy industry players can utilize these results in formulating strategic policies for geothermal resource management.

However, this study has several limitations. First, although the number of observation points is relatively dense, their distribution is not entirely homogeneous across the study area, which may affect the spatial resolution of gravity modeling. Second, the use of gravity data from the GGMPlus satellite has limitations in terms of vertical and horizontal resolution, so some local geological details may not be well identified. Third, external factors such as atmospheric effects, local magnetic fields, and imperfect topographic corrections may also affect the accuracy of the final results.

To improve the quality of future interpretations, it is recommended that field data be acquired directly using high-precision gravimeters and integrated with other geophysical data such as magnetic, seismic, and geochemical data. The application of machine learning-based data processing techniques and 3D inversion modeling is also expected to produce more realistic subsurface visualizations and support more effective geothermal energy exploration.

CONCLUSION

Research in Panti Sub-district, Pasaman Regency, successfully mapped the gravity anomaly pattern through Complete Bouguer Anomaly (CBA) analysis with values ranging from -37.5 mGal to -25.6 mGal. Three main zones were identified: a low anomaly zone indicating the presence of low density rocks and indications of potential geothermal sources, a medium zone as a transition, and a high anomaly zone associated with intrusive rocks and tectonic activity.

The separation of regional and residual anomalies using the bandpass filter method provides a deeper understanding of the depth of the anomaly source. Regional anomalies reflect large-scale deep geological structures, while residual anomalies reflect shallow local variations, such as fractures, faults and sedimentary rocks that have the potential to become geothermal reservoirs. This separation proves crucial in detecting geological features that are not directly identified in the full Bouguer data.

The limitations of this study include the limited resolution of the satellite data and the relatively large distance between observation points (about 200 meters), so the details of the anomalous variations may be less detailed. In addition, the influence of topography and noise on the data can also affect the interpretation results.

Future research is recommended to collect field gravity data with higher coverage and resolution, and incorporate other geophysical methods such as magnetic and seismic to validate these findings. The development of a three-dimensional model based on regional and residual anomaly data is also expected to provide a more complete picture of the subsurface structure and geothermal potential in Panti sub-district.

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