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Interpretation of the Subsurface Structure of Batanta Island Using Gravity Method and 2D Modeling

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ABSTRACT

Batanta Island in Raja Ampat, West Papua, is located in an active tectonic zone dominated by fault structures and igneous rock intrusions, thus possessing significant geological potential. This research aims to identify the subsurface structure of the island using the gravity method that has undergone drift, tidal, topographic, and Bouguer corrections, followed by regional-residual component separation. 2D modeling with GM-SYS software was used to construct geological cross-sections based on rock density distribution. Results show the presence of several main units, including massive lava, breccia, Quaternary deposits, and high-density intrusion bodies (±3.00 g/cm³) that are interpreted as diorite. An active fault zone and lithological boundary were also found, which serve as the main controllers of geological structure. These findings indicate the presence of mineralization potential and complex geological dynamics, and serve as an important initial contribution to further geological exploration on Batanta Island and its surroundings.

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1. INTRODUCTION

Subsurface geological exploration is one of the important aspects in understanding the geodynamic conditions of a region [1], particularly in areas that have mineralization potential as well as tectonic complexity [1], [2], [3], [4]. Geophysical methods, especially the gravity method, have been widely used as an initial approach to interpret variations in subsurface density and hidden geological structures, particularly in regions with limited surface access [5];[6].

Batanta Island, located in the northwestern part of West Papua Province, is part of the Raja Ampat archipelago and lies within an active tectonic zone influenced by the interaction of the Pacific Plate and Indo-Australian Plate [4]. Geologically, this region is estimated to have potential fault structures and igneous rock intrusions that play an important role in metal mineralization systems. However, limited surface data and difficult geographic conditions make direct survey methods less efficient for understanding subsurface structures in detail [4].

The gravity method becomes one of the effective solutions to address these problems [7];[8];[9];[10]. The working principle of this method is to measure variations in Earth's gravitational acceleration that are influenced by changes in rock density below the surface [7];[9]. By performing data corrections (drift, tidal, topographic, Bouguer), followed by separation of regional and residual components, information about geological structure can be obtained indirectly yet with sufficient accuracy [2];[5];[6];[8].

Several previous studies have demonstrated the effectiveness of 2D gravity modeling in identifying fault systems and intrusions associated with mineralization zones. Gravity interpretation using 2D forward modeling is capable of mapping the presence of thrust fault structures and lithological contacts below the surface clearly [6];[11]. This technique has also proven efficient in complex geological conditions as well as areas with limited access.

Based on these considerations, this research aims to identify the subsurface geological structure of Batanta Island using a 2D gravity data modeling approach. This study is expected to provide useful preliminary information for natural resource exploration activities, particularly in mapping fault systems and intrusions that may be associated with mineralization potential in the research area

2. RESEARCH METHOD

This research was conducted in the Batanta Island region, Raja Ampat Regency, West Papua Province. This island is part of a complex geological area in the transition zone between the Indo-Australian Plate and the Pacific Plate, characterized by the presence of fault structures and intrusive rocks. The data used in this research consisted of Bouguer

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anomaly data from corrected gravity surveys, as well as regional geological maps as lithological references. This research was conducted through the following stages:

2.1 Collection and Correction of Gravity Data: Gravity data was corrected for the following factors:

- Drift correction: to eliminate the effect of time-related changes in the gravimeter instrument.
- Tidal correction: to eliminate the effect of gravity fluctuations due to the interaction of the moon and sun.
- Topographic correction (Free-air and Bouguer correction): to eliminate the effect of elevation and topographic mass around the measurement point.
- Terrain correction: performed if the terrain is sufficiently complex (optional if high-resolution DEM data is available)."

Figure 1. Research Location, Batanta Island

2.2 Separation of Regional and Residual Components

- Separation is performed to distinguish local anomalies (shallow structures) from regional trends (deep structures).
- Filtering is carried out using polynomial fitting of a specific order or moving average method.
- The results of this separation are used as the basis for interpreting local anomalies associated with subsurface geological structures.

2.3 2D Modeling (Forward Modeling)

- Model profiles are created based on gravity measurement profiles (example: Line_1.geosoft_gmsys2d).
- GM-SYS software (Geosoft Oasis Montaj) is used to construct subsurface cross-section models.
- Input parameters consist of:
  - Initial density values for each rock layer (referring to literature data and/or geological assumptions).
  - Initial geometric shape of rock layers based on geological map interpretation or anomalies.
- The model is adjusted iteratively so that the calculated anomaly curve approaches the observation curve.
- Error tolerance is adjusted until a minimum residual value can be achieved (<1 mGal is generally considered good).

2.4 Geological Interpretation: The model results are then interpreted geologically, including:

- The presence of faults, folds, or lithological contacts.
- The possibility of magma intrusion based on high-density anomalies.
- The relationship between rock layers and regional geological configuration.

2.5 Validation of Interpretation

- Model interpretation is compared with geological map data and published regional structural patterns.
- If available, integration is performed with other data such as satellite imagery or other geophysical data (magnetic, seismic, etc.)

3. RESULT AND DISCUSSION

3.1. Bouguer Anomaly Map

Bouguer anomaly (BA) (Figure 1. Research Location, Batanta Island) is the difference between measured gravity values after being reduced to a specific reference plane and the theoretical gravity value at that point, which reflects variations in rock density below the ground surface [1];[9]. This value can then be separated into regional and residual anomalies for further interpretation. In the research area, the Bouguer anomaly map shows an anomaly value distribution ranging from ±124.6 mGal to 155.4 mGal, with a sufficiently clear lateral variation pattern. However, research in other regions in Indonesia shows varying anomaly

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ranges, for example in Manokwari (West Papua) the Bouguer anomaly values range from 4 mGal to 96 mGal [6], in Central Sulawesi between 31 mGal to 56 mGal [2], and in Tojo Una-Una between -70 mGal to 210 mGal [3]. The anomaly variation pattern, particularly the northwest–southeast elongated pattern as mentioned, can reflect the direction of main geological structures in the area, such as regional faults or elongated tectonic zones [6];[12]. Nevertheless, research in the Batanta Island research area itself identifies faults that generally trend Northeast–East to Southwest–West and the Sorong Fault System which extends West-Westsouthwest [12].

A zone with high anomaly (specific value 145 mGal) in the central to northeast portion of the research area indicates the presence of high-density rock mass [9]. In this region, intrusive rocks or basement rocks such as basaltic igneous rocks (for example 3.03 g/cm³), andesite (for example 2.53 g/cm³), gabbro (2.90 g/cm³), or diorite (for example 2.75 g/cm³) and metamorphic rocks (for example phyllite up to 4.7 g/cm³) are commonly found [6];[7];[11]. Batanta Island itself is dominated by igneous rocks as basement rock [4];[12]. The increase in anomaly values in this zone can also be associated with geological uplift due to tectonic activity [8]. On Batanta Island, rocks are indeed uplifted along with faulting and northward uplift that may still be occurring to the present day. Additionally, Dayang Limestone is also known to have undergone uplift and tilting due to basaltic intrusion from the Batanta Volcanic Formation [12].

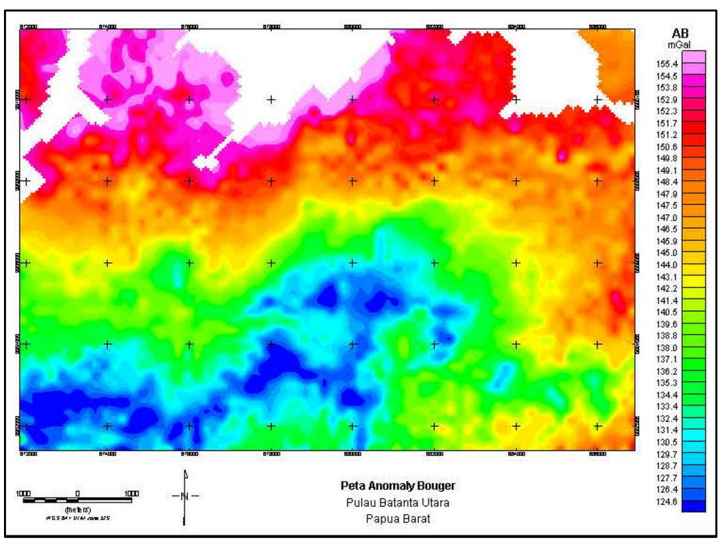

Figure 2. Anomaly Bouger

Conversely, zones with low anomaly values (specific value ≤135 mGal) in the western and southeastern portions of the map indicate the presence of low-density rocks. This can be interpreted as Quaternary deposits such as alluvium (for example 2.3 g/cm³), soil (1.3 g/cm³), shale rocks (1.72 g/cm³), clay rocks (1.6 g/cm³), or sand rocks (between 1.2

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g/cm³ to 2.6 g/cm³) which are generally found at the surface [6];[7];[8]. The decrease in anomaly values can also reflect sedimentary basins or filling of loose material such as alluvial deposits and Tertiary/Quaternary sediments through surface sedimentation processes [6], [7];[8];[9].

Morphologically, the map showing tightly spaced anomaly contours at several locations, particularly at the boundary between high and low anomaly zones, indicates high gravity gradients [6];[9]. This phenomenon typically represents sharp density contrasts below the surface, which can be caused by the presence of lithological boundaries, active faults, or intrusion bodies that cut through sedimentary rock layers [1];[10]. This anomaly pattern indicates the presence of magmatic arcs and Paleogene–Neogene intrusions that are widely found on Batanta Island and its surroundings. The presence of high Bouguer anomalies in the central part of the island very likely reflects part of an intrusion system or magmatic basement rock that is not yet fully exposed at the surface.

3.2. Residual Anomaly and Interpretation

After Bouguer correction, the next stage in gravity data analysis is to separate the anomaly components into two main parts: regional anomaly and residual anomaly [5];[9]. This separation is important to understand whether an anomaly is caused by large-scale deep structures (regional), or small-scale shallow structures (residual).

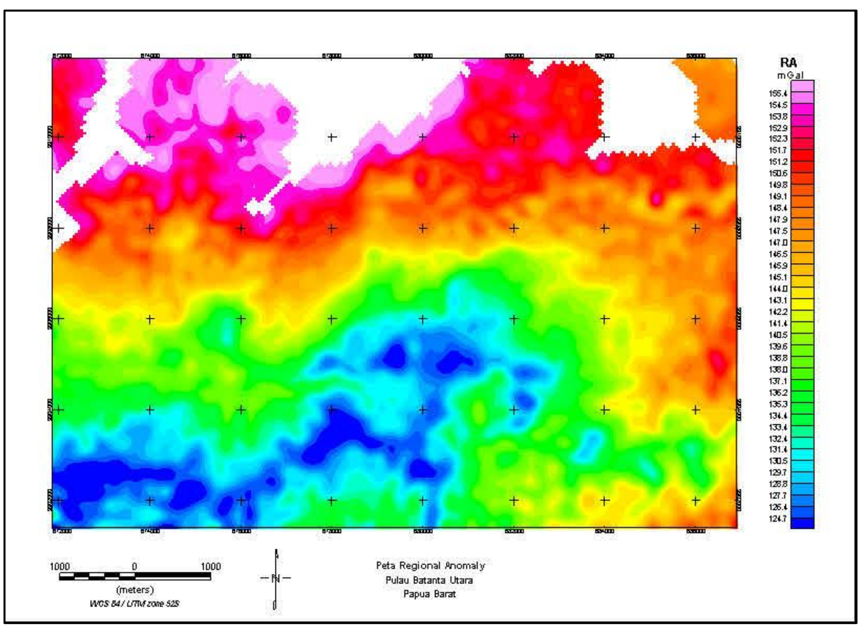

Figure 3. Regional Anomaly

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The regional anomaly (Figure 3. Regional Anomaly) is obtained through data smoothing methods using a second-order polynomial approach, which is designed to capture large-scale trends in gravity values over a wide area [5]. On this map, anomaly values appear more homogeneous and smooth, reflecting the effect of relatively deep and gently dipping subsurface structures. In the Batanta Island study area, the regional trend shows a tendency for anomaly values to decrease from the center toward the west and southeast, indicating variations in deeper crustal density or basement rock topography that tends to decrease in those directions.

Conversely, the residual anomaly map (Figure 4. Residual Anomaly) depicts the component of gravitational anomaly that remains after the regional effect is removed. This anomaly is more local in nature and highly sensitive to shallow density variations (<2 km). Residual anomaly values in the study area range from approximately –2.5 mGal to +2.3 mGal, with a non-uniform distribution showing several zones of sharp change. This pattern reflects the presence of shallower geological structures (depth < 2 km) such as shallow intrusions, faults, weathering, or contrasting lithological boundaries.

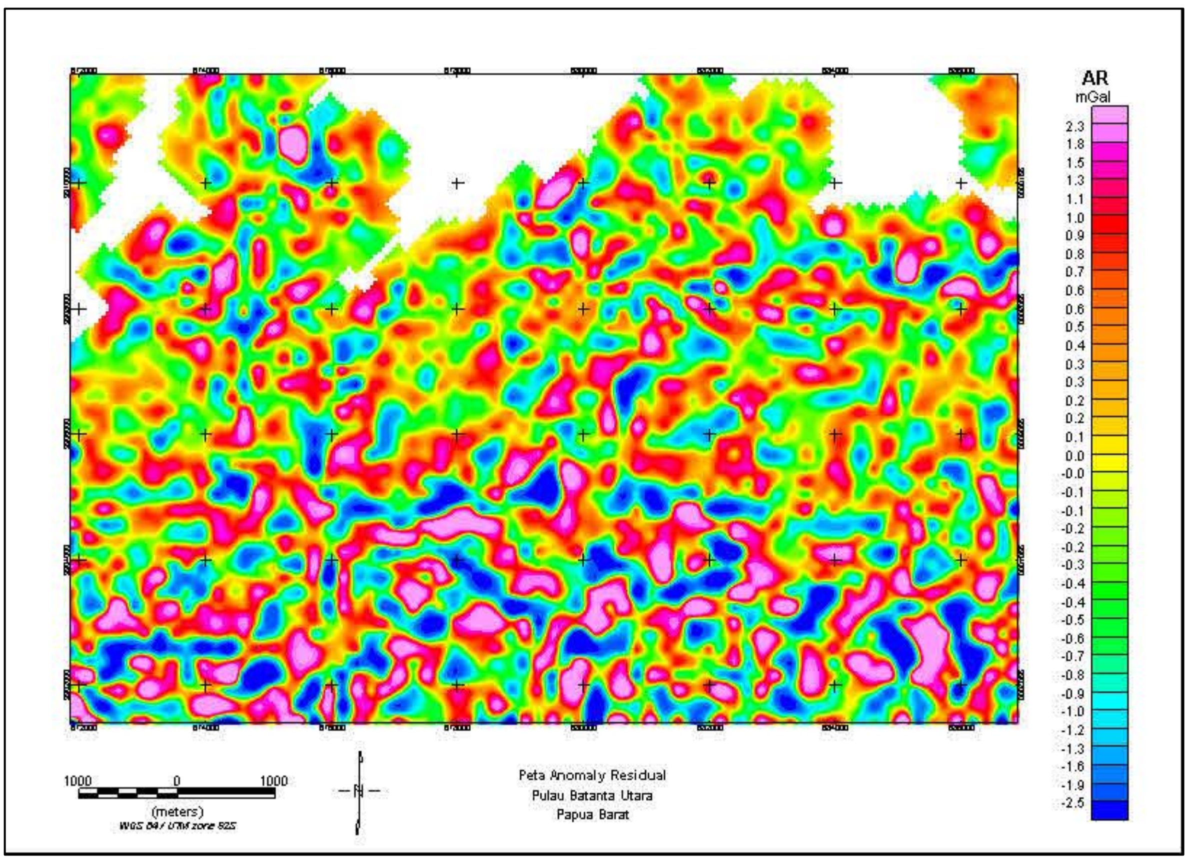

Figure 4. Residual Anomaly

Zones with high residual anomaly values, particularly in the central portion of the profile, are very likely associated with the presence of igneous intrusion bodies such as diorite or monzonite that have high density and cut through lighter volcanic rock units. Meanwhile, zones of negative anomalies that appear in the western and eastern portions of the profile indicate the presence of weathered material, such as altered tuff, Quaternary deposits, or fault zones filled with loose material, which have lower density.

3.2.1. Model 2D Forward

Two-dimensional modeling (Figure 5. Cross-Sectional Model) was performed on a gravity measurement profile approximately 8,000 meters long in the Batanta Island area. This model was developed based on the complete Bouguer anomaly curve that has undergone correction and regional-residual anomaly separation. The subsurface cross-section was constructed using GM-SYS software, with a horizontal scale of 50,273 and vertical exaggeration (VE) of 1.03. The resulting model shows good fit between the observed and calculated curves, with a residual error value of 0.374 mGal, which is within the very good tolerance range for gravity studies.

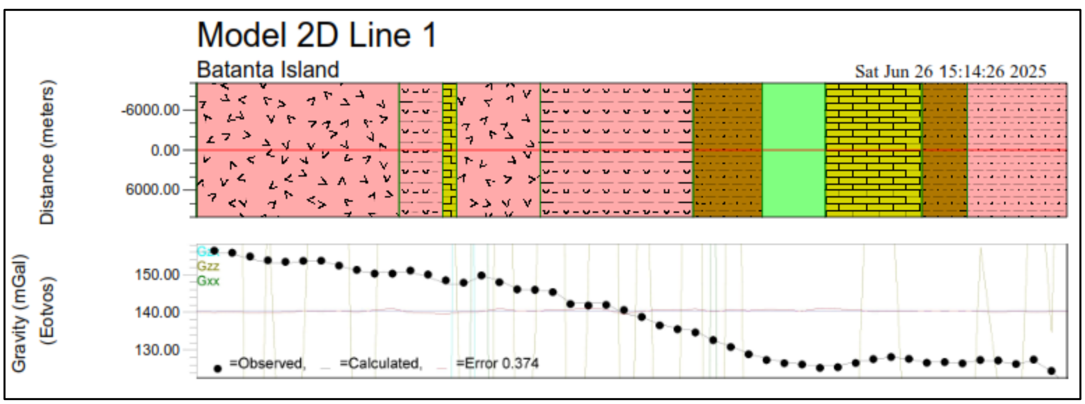

Figure 5. Cross-Sectional Model

The modeling results display a complex subsurface geological configuration (Figure 6. Subsurface Structure Profile) consisting of several rock units with varying density. The upper portion of the cross-section is dominated by a lava breccia unit (ρ ≈ 2.80–2.90 g/cm^3), which is associated with past volcanic activity. This unit outcrops over most of the surface and has a massive geometry extending horizontally. Below it, there is a massive lava unit (marked in the model as Temb Lava and Tmpwa) with higher density, approximately 2.90–3.00 g/cm^3. This unit fills most of the middle to lower subsurface structure and exhibits more compact and homogeneous characteristics.

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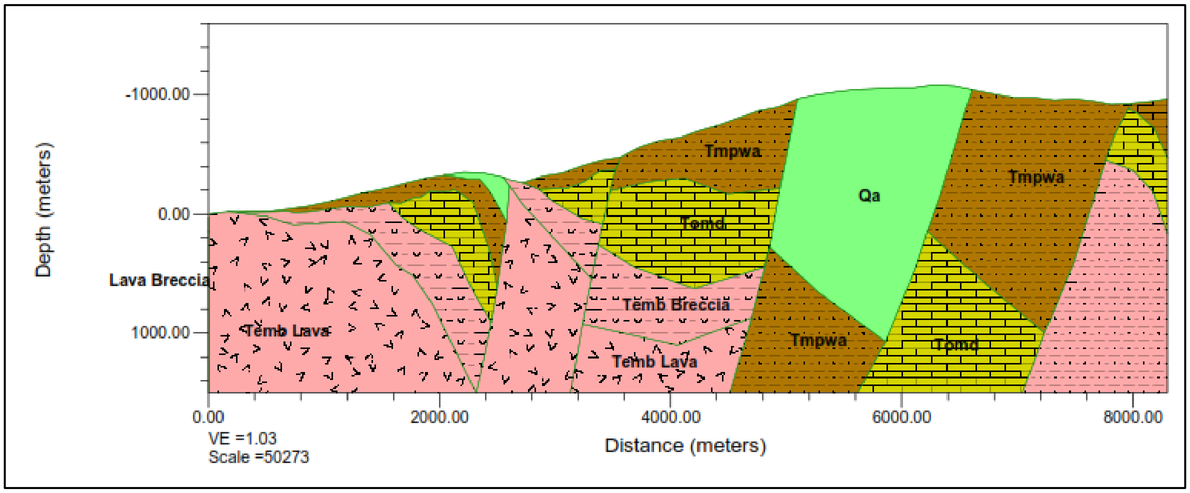

Figure 6. Subsurface Structure Profile

Interestingly, in the central portion of the cross-section there is a body with rounded to semi-lensoid geometry with high density (ϱ ≈ 2.95–3.10 g/cm³) that is interpreted as an igneous intrusion body, possibly diorite or monzonite (marked as Temd in the model). This body is located at a depth of approximately 1,000 to 2,000 meters and correlates directly with the highest gravity anomaly values above it. The presence of this intrusion is very important because in addition to being a source of positive anomaly, it can also serve as a control center for geological structure and hydrothermal mineralization pathways.

The lightest unit in the model is Qa, which represents Quaternary deposits or weathering material with density between 2.40–2.50 g/cm³. This unit is found at the uppermost part of the model and is distributed unevenly, particularly in the western portion of the profile. Additionally, there are several narrow vertical zones that cut across rock layers, characterized by sharp changes in geometry and extreme density contrasts. These zones are interpreted as thrust faults or active strike-slip faults, and may serve as pathways for subsurface fluid migration.

3.2.2. Discussion

The 2D gravity model of the profile on Batanta Island reveals a subsurface configuration controlled by volcanic lithology and intrusion, consistent with the regional geological (Figure 7. Regional Stratigraphy of Sorong Sheet (Red Box: Research Location), Modified from Amri, et al., 1990) conditions of western Raja Ampat. In the upper part of the model, the Tmpwa unit (Waigeo Limestone) is exposed, which is widely distributed as a surface-forming rock [4]. This unit has intermediate density (approximately 2.80–2.90 g/cm³), and in the model appears to fill the western and eastern portions of the profile asymmetrically. This lithology reflects products of Quaternary–Tertiary volcanic eruptions and shows varying thickness, between 300 to 800 meters.

Below this volcanic unit, a unit of Lava and lava breccia that is more compact and massive has been identified, marked by increased density and lateral spreading in the central portion of the cross-section. These rocks are possibly associated with andesite lava or older basalt deposits, and indicate lava flow pathways that froze in situ or around eruption centers. The contact between Temb Lava and Tmpwa is quite sharp in several locations, indicating a stratigraphic boundary or structural zone such as a fault [12].

The most interesting part of this profile is the presence of the Tomd intrusion body, which appears in the central portion of the model with high density (±3.00 g/cm^3), forming a rounded-lensoid geometry and pushing upward. Based on its position and density, this intrusion is interpreted as diorite, which regionally is known to outcrop on Batanta as part of the Oligocene–Miocene pluton. This intrusion reaches depths of approximately ±1,000–2,000 meters and plays a major role in generating positive gravity anomaly values at the surface. The presence of this intrusion is also possibly associated with hydrothermal mineralization processes commonly found in magmatic arc systems.

At the uppermost surface portion, the model shows the presence of the Qa unit, namely Quaternary deposits such as sandstone, clay, or conglomerate, with relatively low density (2.40–2.50 g/cm^3). This unit is limited in distribution in the western portion of the profile and possibly occupies valleys or lowlands. Additionally, the model also shows vertical zones that cut across rock layers, interpreted as thrust faults or strike-slip faults, marked by displacement of lithologic geometry and striking density differences. This structure is suspected to be a pathway for uplift and fluid migration that could also be related to metal mineralization systems.

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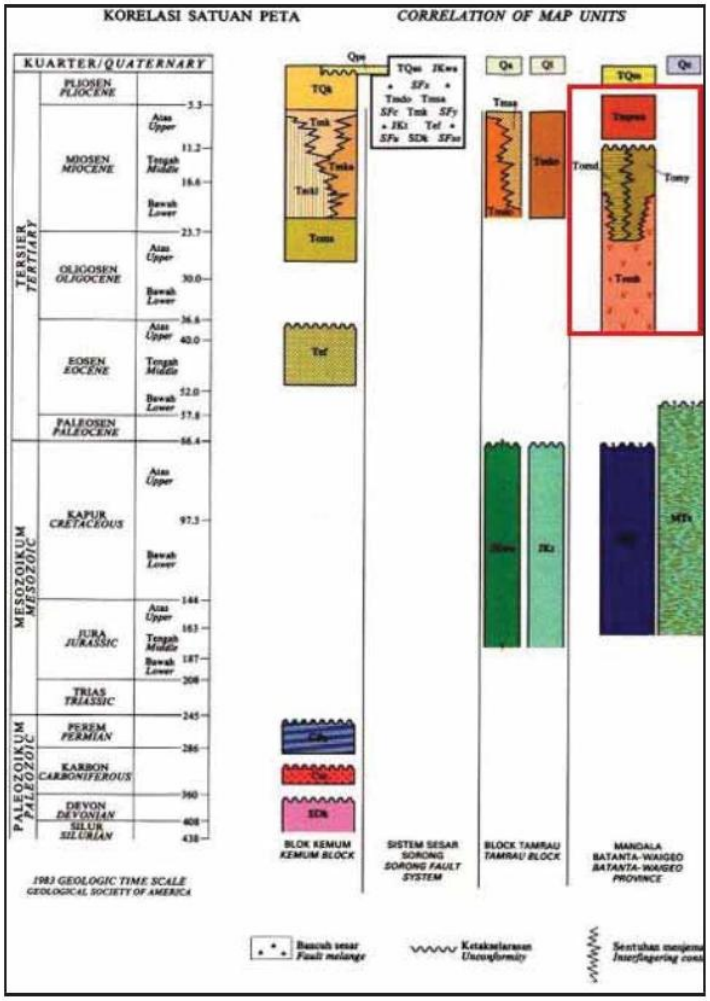

Figure 7. Regional Stratigraphy of Sorong Sheet (Red Box: Research Location), Modified from Amri, et al., 1990

Geological interpretation based on this profile model reinforces the assumption that Batanta Island is composed of a volcanic rock system that has undergone intrusion and deformation. The diorite intrusion at intermediate depth, which cuts through lava and tuff units, serves as an important indicator of magmatic dynamics in this region. The presence of faults, intrusions, and volcanic rocks demonstrates a complex structural system with potential to be a location for metal mineralization accumulation, especially if supported by post-intrusion hydrothermal activity.

4. CONCLUSION

This research aimed to identify the subsurface geological structure of Batanta Island using a 2D gravity data modeling approach. The results of the analysis show consistency with initial expectations, where important geological structures such as active faults, lithological contacts, and high-density igneous intrusion bodies interpreted as diorite or monzonite at depths of 1,000–2,000 meters were successfully revealed. The presence of intrusions and faults strengthens the suspicion of a complex geological system potentially related to metal mineralization. Furthermore, the variations in rock density and geometry displayed in the subsurface cross-section model also provide a clear picture of the geological dynamics of Batanta Island, which is located in an active tectonic zone.

The development prospects from the results of this research are very open, both in the context of mineral resource exploration and in the development of regional geological models. Further studies are recommended to integrate other geophysical methods such as magnetic or seismic, as well as field validation to strengthen model interpretation. The results of this research can serve as an important initial reference for exploration activities and geological mapping in the Raja Ampat region and its surroundings.

REFERENCES

[1] Khamada, Aufar Farrell, et al. "Identifikasi Area Potensi Deposit Mineralisasi Emas Sesar Semangko Daerah Ngambur Provinsi Lampung Berdasarkan Analisis Derivatif Data Gaya Berat Ggm Plus". Journal Online Of Physics, vol. 9, no. 2, Apr. 2024, pp. 87-93, doi:10.22437/jop.v9i2.29898..

[2] R. Mutia, M. Mardani, S. Fathia, and T. Kusmita, "Identifikasi Sesar dengan Menggunakan Metode Gaya Berat (Studi Kasus: Sulawesi Tengah)," *JRFI*, vol. 3, no. 2, pp. 1–6, June 2023, doi: 10.33019/jrfi.v3i2.3552.

[3] A. K. Maimuna *et al.*, "Analisis Anomali Gaya Berat Menggunakan Metode SVD dan Pemodelan 3D - Studi Kasus Gempa di Kepulauan Togean, Kabupaten Tojo Una-Una, Sulawesi Tengah," vol. 19, no. 01, 2021.

[4] F. K. Rohmala, "Analisis Lingkungan Pengendapan Formasi Batugamping Dayang Distrik Batanta Utara, Kabupaten Raja Ampat, Provinsi Papua Barat," *Lembaran Publikasi Minyak dan Gas Bumi*, vol. 54, no. 3, pp. 127–148.

[5] S. Supriyadi, K. Khumaedi, S. Sugiyanto, and F. Setiaswan, "Pemisahan Anomali Regional dan Residual Data Gayaberat Studi Kasus di Kota Lama Semarang," *PERJ*, vol. 1, no. 1, p. 29, Aug. 2019, doi: 10.21580/perj.2019.1.1.3927.

[6] A. Zaenudin and S. Yulistina, "Studi Identifikasi Struktur Geologi Bawah Permukaan Untuk Mengetahui Sistem Sesar Berdasarkan Analisis First Horizontal Derivative (FHD), Second Vertical Derivative (SVD), Dan 2,5D Forward Modeling Di Daerah Manokwari Papua Barat," *JGE*, vol. 4, no. 2, pp. 173–186, Jan. 2020, doi: 10.23960/jge.v4i2.15.

[7] T. Agustina, Muliddin, and Kasman, "Studi Kajian Literatur: Struktur Bawah Permukaan Menggunakan Metode Gaya Berat dibeberapa Daerah Indonesia," *Einsteins: Research J. of. Applied Physics*, vol. 1, no. 2, pp. 63–69, Apr. 2023, doi: 10.33772/einsteins.v1i2.180.

[8] R. Kurniasih, Y. Arman, and R. Perdhana, "Identifikasi Struktur Bawah Permukaan Cekungan Pembuang Daerah Kalimantan Tengah Berdasarkan Data Gaya Berat," *Prism. Fis.*, vol. 10, no. 1, p. 8, June 2022, doi: 10.26418/pf.v10i1.52209.

[9] Y. R. Liana, T. M. M. Wea, W. Syarifah, S. Supriyadi, and K. Khumaedi, "Analisis Anomali Bouguer Data Gaya Berat Studi Kasus di Kota Lama Semarang," *JRST*, vol. 4, no. 2, p. 63, Sept. 2020, doi: 10.30595/jrst.v4i2.6301.

[10] D. A. Pramadhana, S. T. Rinanda, and Y. D. Haryanto, "Studi Karakteristik Sesar Bawean (Wilayah Laut Utara Jawa) menggunakan Analisis Turunan dengan Data Gaya Berat," *sosial*, vol. 3, no. 1, pp. 39–53, Jan. 2025, doi: 10.62383/sosial.v3i1.587.

[11] L. Rista, O. Ivansyah, and R. Adriat, "Identifikasi Struktur Bawah Permukaan Geologi Karangsambung Terhadap Terobosan Dyke dan Sill Menggunakan Metode Gaya Berat," *Prism. Fis.*, vol. 7, no. 1, p. 1, Mar. 2019, doi: 10.26418/pf.v7i1.30499.

[12] F. K. Rohmala, "Geologi Dan Analisis Lingkungan Pengendapan Formasi Batugamping Dayang Distrik Yensawai Dan Sekitarnya, Kabupaten Raja Ampat, Provinsi Papua Barat," Skripsi, Universitas Papua, Manokwari, 2021.