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Identification of Ransiki fault segment in South Manokwari Regency, West Papua Province, Indonesia based on analysis of a high-resolution of global gravity field: Implications on the Earthquake Source Parameters

Richard Lewerissa[1*], Nur Alzair [2], Laura Lapono[3]

[1] Department of Physics, Faculty of Mathematics and Natural Sciences, Papua University; Manokwari, Papua Barat, Indonesia.

[2] Department of Geological Engineering, Faculty of Mining and Petroleum Engineering, Papua University; Manokwari, Papua Barat, Indonesia.

[3] Department of Physics, Faculty of Sciences and Engineering, Nusa Cendana University; Nusa Tenggara Timur, Kupang 85148, Indonesia.

r.lewerissa@unipa.ac.id

Abstract. The province of West Papua in Indonesia is an area crossed by three major faults, including Sorong, Koor, and Ransiki, leading to the collision of Australia, the Pacific, and Eurasia. In the past, there have been strong and damaging earthquakes on these faults, manly Ransiki fault in the South Manokwari regency. Identification of the Ransiki fault segment was conducted by geological subsurface modeling using the earth gravity field of the Global Gravity Map (GGM) based on satellite measurements implicates for earthquake source parameters. The GGM is seen as a solution for the unavailability of direct measurements in the region. The gravity field analysis begins with data reduction using SRTM2gravity as modern terrain correction to obtain a complete Bouguer anomaly. Furthermore, the gravity gradient approach through vertical and horizontal gradients, analytical signal, and the tilt angle are applied to emphasize a contact or fault structures that are not visible using a 2D fast Fourier transform. Overall, the gravity gradient analysis obtained results that were compatible with the alignment of the Ransiki fault segment which direction of the northwest to south. The gravity inversion produces a geological subsurface model that clearly shows the Ransiki fault segment, associated with a low rock density distribution, thought to the Befoor formation and quaternary sediments, located between high-density rocks correlated to Arfak volcanic rocks as a basement.

Keywords: *Ransiki, Gravity field, GGMplus, ERTM2160, SRTM2gravity, active fault parameters.*

1. Introduction

West Papua Province of Indonesia is situated in the western part of Papua Island, tectonically one of the most active and complex areas in the world due to extreme deformation in the Australian, Eurasian and Pacific Plate convergence zone [1]. The geological setting at the plate boundary involves the formation and movement of microplates, ocean-forming lithosphere fractures, basins, continental-arc collisions, and so on [2]. The plate activity has consequences for the development of various major faults of West Papua, including the Sorong, Koor, and Ransiki faults, which have contributed to many earthquakes. On October 10, 2002, an earthquake with a magnitude of 7.6 occurred at a shallow depth at the southern part of the Ransiki fault, which had a dextral strike-slip focal mechanism along the fault [1]. A large and destructive earthquake also occurred near the Ransiki region on 21 April 2012, with a magnitude of 6.7 at a shallow depth, with moderate and severe damage to buildings and casualties [3].

The Ransiki region is part of the South Manokwari regency administrative area, the Manokwari regency's expansion area in 2012. This place is a district capital situated in lowlands at an altitude of 0-100 m elevation and near the coast, which is vulnerable to natural disasters, such as the earthquake and tsunami, since the place is on major fault lines the Ransiki fault. Several related studies have been conducted in West Papua, especially in the Ransiki district of South Manokwari. Milsom, (1991) was carried out measurements of gravity and terrane tectonics in the field of New Guinea (Irian Jaya) and reported that the gravity technique was an effective instrument for the study of terranes but could not be used for isolated structures. Most structural analyses of formations in western Papua have been done without regard to evidence of gravity, and there is a disparity of some degree [4]. Serhalawan & Sianipar, (2017) have researched the mechanism of earthquake sources to determine faults based on the Ransiki earthquake on the Mw 6.7 scale of 2012, which states that the Yapen Fault caused the earthquake with a sliding fault mechanism trending west-east, not caused by the Ransiki fault [3]. A fault system study at the triple junction of East Indonesia was undertaken to assess the quaternary activity and its consequences for seismic hazards. The Sorong, Koor, and Ransiki faults are used as a model for the West Papua area [1].

In line with regional planning and development, more studies are required to research geological structures such as faults as with details on the potential for geohazards in Ransiki, South Manokwari regency. Fault identification is generally limited to observing features on the surface, but fault traces may have been lost by geological processes or are covered by layers above them [5]. Our research uses the approach of the gravity method to describe this possibility, which is related to the gravity anomaly correlated with the distribution in subsurface rock density. The fault and the folding system are not only controlled by the current stress field, but also by recent stress. Hence it is crucial to define the features of these systems to obtain an understanding of the tectonic activity that is currently occurring. Geological and geomorphological elements are capable of providing valuable knowledge on the properties of geological formations. However, geophysical surveys, such as gravity and/or seismic methods, are approaches to determine subsurface structures, particularly in areas where active formations are no longer visible on the surface [6]. Furthermore, geophysical methods are considered more desirable for geohazard investigations due to its discrete and more economical nature [7], [8]. The geological structure in the region is occupied by quaternary sediments [9], which is an essential topic for the study of disasters or natural hazards.

Our study utilizes a combination of earth gravity field models with high resolution from the Global Gravity Model plus (GGM) [10], Earth Residual Terrain Model (ERTM) 2160 [11], and the SRTM2gravity [12] for modern terrain correction of disturbance or free-air gravity anomalies in the research place. The use of earth gravity models is used as a solution because there is no direct gravity measurement data available on Ransiki at a dense scale. Geological structure identification is performed by vertical and horizontal derivative (gradient) analysis of the gravity field as well as by inversion modeling of gravity anomaly data in the study area. Geological structure identification is performed by vertical and horizontal gradients (derivative) analysis of the gravity field as well as by inversion modeling of gravity anomaly data in the study area. The derivative analysis uses a first or second degree of vertical or horizontal gradients to enhance edge effects, and also to outline possible boundaries from a gravity source [13]. Gravity inversion modeling is applied to obtain subsurface geological models capable of delineating the existence of the Ransiki fault formation as well as the bedrock density in the study region.

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This research is a preliminary study using a qualitative and quantitative evaluation of the corrected gravity anomaly of the GGMplus field of gravity data, and also an analysis of the gravity gradient in the form of vertical, horizontal, analytical signal and tilt angles from the complete Bouguer anomaly using 2D fast Fourier transform (FFT). Gravity modeling relies on Singular Value Decomposition (SVD) and Occam techniques. The goal of the results is to improve and define the boundary of the geological system of the fault covered by the layer of sediment above it so that the planning and construction of the site can pay attention to potential natural hazards.

2. Geology, Tectonic, and Gravity

According to the geological map of the Ransiki sheet issued by the Indonesian Geological Agency in 1989 [9], it was found that the geological formations of the South Manokwari regency were composed of Alluvials, Arfak volcanic rocks, Maruni limestone, Befoor formation, Kemum formation, Wai formation, Anggi granite, and alluvial (Figure 1). For the study area, the Ransiki area is dominated by tertiary alluvial (Qa), Arfak volcanic rock (Tema), and alluvial (Tqb).

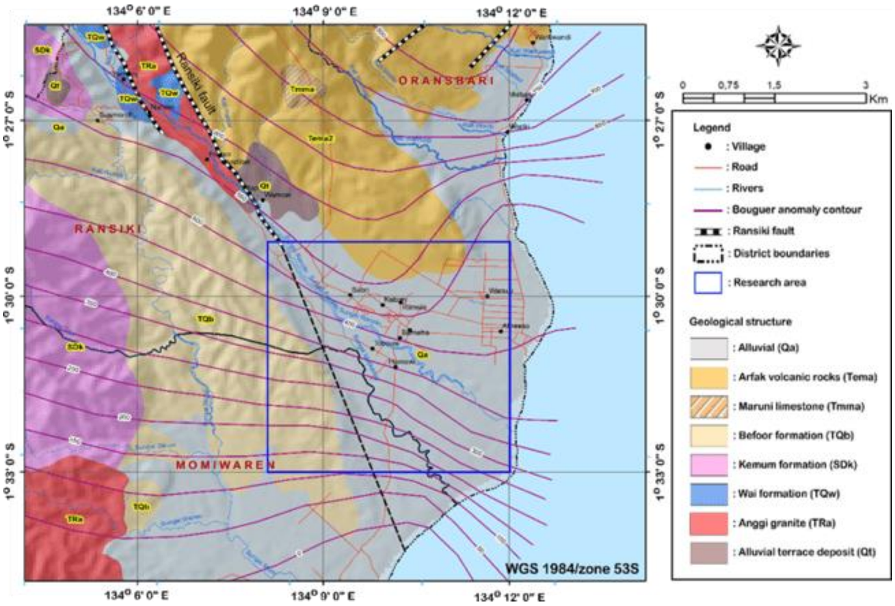

Figure 1. Geological map of the Ransiki area, South Manokwari regency [9]

The research work is included in the bird-headed zone of the Papua islands, a deformed area of active plate tectonics due to impacts between the Eurasian, Pacific, and Australian plates, and also many smaller microplates occupied by major strike-slip faults [14]. The Ransiki fault in the eastern side of the bird's head is believed to be the result of a collision between the archipelago and the Australian continent, spreading into the Bay of Cenderawasih, east of Wandamen, and linked to the Weyland overthrust in the Central Mountains [4], [14], [15]. Today, arc rock is mainly formed by the bedrock on the northern part of Papua Island, such as the eastern west of Papua, the Cenderawasih Bay, and the reefs. The North-Northwest (NNW) direction of Ransiki Fault is believed to be a dextral shear zone connecting to the Sorong fault again with Yapen Fault, which is considered to be inactive [16]. The Ransiki Fault in West Papua has a typical segment length ranging from 20 -50 km with a maximum length of 100 km [1]. Earth's gravity field measurements have been carried out on the bird's head of Papua. Milsom, (1991) conducted gravity and terrane tectonics measurements in the New Guinea region obtained during the geological mapping project of Irian Jaya by Indonesia - Australia (IJGMP), and also involved re-mapping the geology in the south and west of the Cenderawasih Bay, as well as some areas further to the east, as shown in Figure 2 [4]. Figure 2 shows that the study area is on the path of the Ransiki fault having positive Bouguer anomaly values ranging from 0 g.u to 600 g.u (1 g.u = 0.1 mGal). The highest anomaly is associated with Arfak volcanic rocks, while low anomalies are correlated with quaternary alluvial sedimentary rocks.

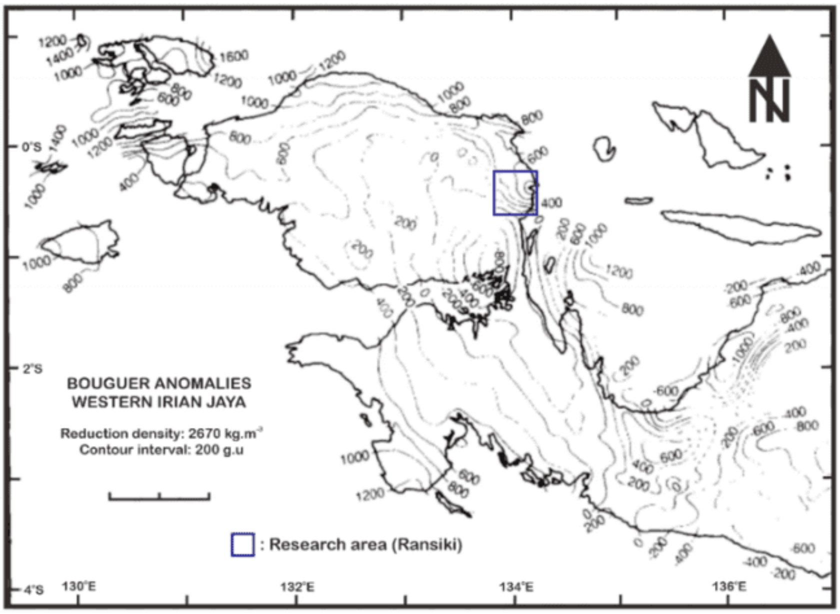

Figure 2. Bouguer anomaly in West Irian Jaya (West Papua) in gravity units (g.u) with an interval of 200 g.u = 20 mGal [4]

3. Methodology

3.1. GGMplus Gravity Data Reduction

This research examines the major strike-slip fault in Ransiki district, South Manokwari, West Papua, Indonesia at coordinates: 134.133° E - 134.199° E and 1.547° S - 1.477° S (Figure 3).

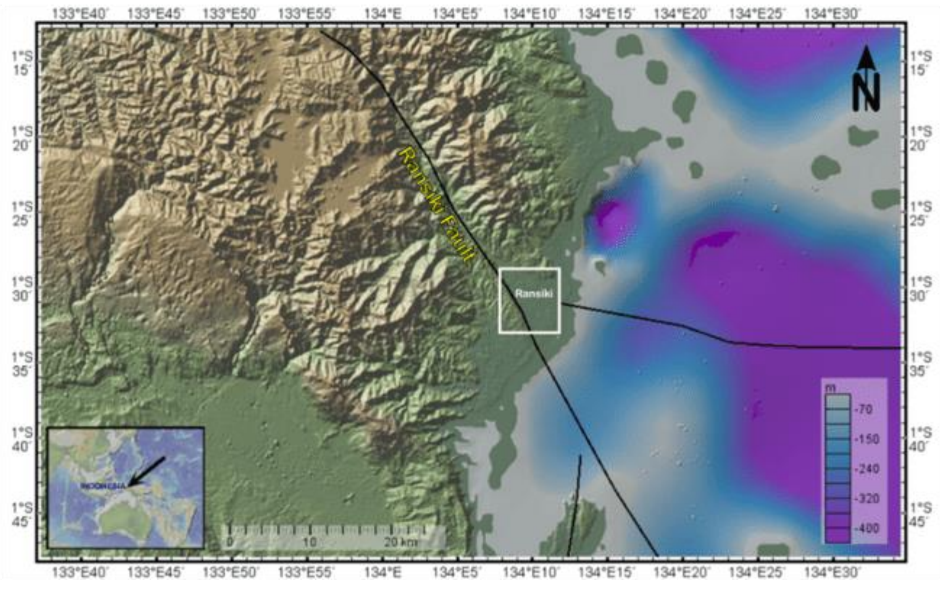

Figure 3. The study area of Ransiki district in South Manokwari regency, West Papua, Indonesia

The reduction of the earth-gravity field starts with the extraction of gravity data for the West Papua area from GGMplus (S05E130), ERTM2160 (S05E130), and SRTM2gravity (S02E134) developed by Curtin University, Perth, Australia. The global high-resolution field of gravity is very useful in several areas, such as exploration, potential field of geophysics, climate, and marine level change analysis. GGMplus is a high-resolution earth-gravity model for local scales on land and islands encompassing an area of ± 60° latitude with a spatial grid of 7.2" (~220 m) [10]. This model results from three gravity measurements, including the GOCE/GRACE gravity satellite, the 2008 EGM model, and topographic gravity. GGMplus is useful in applying geophysics and exploration as a new data source for in-situ reduction of detailed gravity surveys, mineral searches without calculating needed, and reduction of time-consumption [10], [17].

Earth Residual Terrain Model (ERTM) 2160 is a short-scale earth gravity field generated by forward gravity modeling using the SRTM of the global topographic approach. The model has a spatial scale equal to the harmonic spherical coefficient of up to 2160 degrees used to create a small range of GGMplus gravity map from 10 km to 250 m [11]. SRTM2gravity is a modern gravity field correction reflecting earth gravity force from the global topographic mass of ~28 billion computational points. The territory is covered by all land in the -60° to 85° geographic latitude range with a spatial resolution of 90 m. This model specifically incorporates Bouguer shell effect and all residual gravitational field effects on the Bouguer shell. As a result, the model reflects the cumulative signal of gravity provided by the global topographic mass [12]. Gravity anomaly data extraction in the Ransiki region was performed using the Matlab listing software developed by the developer. In addition, we use the GNU Octave program to modify and extract data. The GGMplus model used is a disturbance anomaly model equivalent to free air anomaly data, also ERTM2160 in the form of digital elevation model (DEM) data with a spatial grid of 7.2 "(220 m). The SRTM2gravity model is a full-scale gravity for modern terrain correction with a 3" (~ 90 m) spatial scale.

Data processing begins by verifying the satellite data used, which compars with the gravity field measurement data carried out in West Papua province by the Indonesian geological agency and the IJGMP project [4]. Furthermore, the three types of data are processed to obtain the complete Bouguer anomaly by correcting a free-air anomaly in the form of reduction with full-scale gravity data (terrain correction). SRTM2gravity model contains the total gravity effect of the global topographical mass, so the full-scale gravity (terrain correction) product can be directly reduced to disturbance or free air anomalies to obtain the complete Bouguer anomaly value in the study area. Furthermore, it does not require correction of the spherical Bouguer shell, because it is implicitly included in the product of full-scale gravity [12].

3.2. Regional and residual anomalies separation

This study focuses on the Ransiki fault zone, which preserves sediment associated with residual anomalies so that the complete Bouguer anomaly includes the difference between regional and residual anomalies. Regional anomalies are commonly affected by large and deep structures, while residual anomalies are caused by small and shallow formations [18], [19]. The separating process for regional and residual anomalies is calculated using a frequency filtering technique, using a low-pass filter to pass low-frequency anomalies associated with regional anomalies, while high-frequency anomalies are eliminated. A single filter ring with a boundary susceptible inner and outer ring radius is used in low-pass and high-pass filters.

3.3. Gravity gradients

Vertical and horizontal gradients are intended to describe the boundaries of geological structures and source objects buried in gravity or magnetic field map [20]. Vertical gradient (derivative) is applied to delineate the edges of the gravity anomaly. This technique is commonly used to highlight near-surface geological features, and to raise the large wavenumber element of spectrum, where zero values of vertical gradient (VG) normally corresponds to the geological boundary [21]. The mathematical equation for vertical gradient can be written as:

$$VG = \frac{\partial g}{\partial z} \tag{1}$$

A horizontal gradient is used to calculate the rate of change in the potential plane in *x* and *y* directions [22]. In addition, a horizontal gradient is used to detect the difference in density or susceptibility to potential field model. This technique is useful for delineating shallow or deep sources relative to vertical gradients, adequate only for shallow structures [23]. The horizontal gradient of gravity data in the directions *x* and *y* is expressed as follows:

$$HG\,(x, y) = \sqrt{\left(\frac{\partial g}{\partial x}\right)^2 + \left(\frac{\partial g}{\partial y}\right)^2} \tag{2}$$

g is a gravity anomaly, which in this study used the complete Bouguer anomaly data in the Ransiki area, South Manokwari regency. The vertical and horizontal gradients of Bouguer anomaly are powerful for the determination of subsurface formations including faults or contacts body represented by the highest value of horizontal gradient and the zero of vertical gradient [6].

To delineate geological structures such as contacts and faults in the research work, an analytical signal of gravity data was used according to Poisson's relation between magnetic and gravity fields. This limitation can be calculated for the maximum amplitude magnitude of the analytical signal [24], [25]. The analytical signal of observation gravity data is generated by 3D sources can be written as [26], [27]:

$$A_s(x, y) = \sqrt{\left(\frac{\partial g}{\partial x}\right)^2 + \left(\frac{\partial g}{\partial y}\right)^2 + \left(\frac{\partial g}{\partial z}\right)^2} \tag{3}$$

where $A_s(x, y)$ is amplitude of analytic signal at position (*x*,*y*), *g* is the gravity observed in the plane (*x*,*y*), and $\left(\frac{\partial g}{\partial x}, \frac{\partial g}{\partial y}\right)$ is horizontal gradient or derivative, and $\frac{\partial g}{\partial z}$ is vertical derivatives in the *z*-component. The analytical signal from the gravity field is obtained using FFT approach in the frequency domain [28].

The tilt angle (*TA*) method was introduced by Miller and Singh, 1994, used to identify structural boundaries from various sources with varying depths [29]. The tilt angle is a ratio between vertical and horizontal derivatives with a range from -90° to 90°. The equation of *TA* can be expressed as [21]:

$$TA = tan^{-1}\left(\frac{VG}{HG\,(x, y)}\right) \tag{4}$$

The value of *TA* is positive above the source, zero or close to zero when it is at the source boundary, and negative on the outside of sources [20], [21]. The process of calculating a vertical, horizontal, and tilt angle gradients is displayed in the frequency domain through a 2-D FFT approach. The gravity gradient is equal to the multiplication of gravity with the wavenumber along the derivative direction in a Fourier domain [30], [31]. The Fourier transform represents the sum of the sine and cosine at different spatial frequencies or wavenumbers (k_x and k_y) which are based on a data range (*Dx* = max (*x*) - min (*x*)) and (*Dy* = max (*y*) - min (*y*)) and data sampling (*dx* and *dy*) along the *x* and *y* directions.

3.4. 3D gravity inversion modeling

Subsurface modeling according to the gravity data inversion in the Ransiki area was performed using Grablox and Bloxer tools for model editing and visualization. Grablox is built on a 3D rectangular block, where the main blocks represent the subsurface volume of the gravity survey site, which is separated into small blocks with small volumes. The procedure of inversion was followed the Singular Value Decomposition (SVD) and Occam methods. The SVD is an unconstrained inversion with adaptive damping, while Occam performed to smoothing model using Lagrange multiplier and Roughness parameters [32]. The Lagrange multiplier is a function that minimizes data errors, while the Roughness is a discontinuity parameter. Occam inversion provides a smoot model similar to SVD inversion [32]. The RMS error between the response of the model and the observation data is written as [33]:

$$RMS_d = \sqrt{\frac{1}{M}\sum_{i=1}^{M}\left(\frac{d_i - y_i}{\Delta d}\right)^2} \quad (5)$$

where Δd = maximum gravity data (d_{max}) - minimum gravity data (d_{min}) used for data scale. The initial reconstruction of the model starts with an area of ± 50 km^2. The initial model was established by spatial discretion including 30 small blocks in W-E, 30 small blocks in N-S, and 5 layers with a maximum depth of 2 km. Additional margins are used to eliminate edge effects during the inversion process.

4. Results and Discussion

4.1. Free air and Complete Bouguer anonalies in Ransiki area

The result of GGMplus data extraction for the West Papua zone indicates that the free-air anomaly in the Ransiki area of South Manokwari is positive, ranging from 49.10 mGal to 92.80 mGal. High anomalies are found in the northern and western areas of the study, while moderate to low anomalies are usually observed in the central and southern areas of the study (Figure 4a). The distribution of free air anomalies primarily follows the topographic elevation model, varying from -4 m to 254 m based on the ERTM2160 model (Figure 4b), where high anomalies are correlated with high topography, and vice versa. The SRTM2gravity full-scale gravity model for terrain correction in the Ransiki area produces anomalies between 14.39 mGal and 39.92 mGal. This terrain correction model also follows the elevation pattern, where it is high value in the mountains or hills of the north and west, low in the middle to the south (Figure 4c). The effect of terrain in mountainous areas greatly affects the anomalous value of free air and makes it very varied and irregular [17].

The difference between the value of free-air anomaly and the full-scale gravity (terrain correction) produces a complete Bouguer anomaly in the Ransiki, which is a positive values ranges from 28.82 mGal to 53 mGal. In general, the anomaly pattern is southwest to the northeast with a low anomaly in the southwest, increasing to the east of the Ransiki area (Figure 4d). According to the Ransiki sheet of geological map [9], we compared with Bouguer anomaly results from field measurements by the geological research and development center in 1989, anomaly value and pattern match are obtained, where the resulting regional Bouguer anomaly ranges between 200 $\mu m.s^{-2}$ (20 mGal) to 600 $\mu m.s^{-2}$ (60 mGal) with contour intervals of 50 $\mu m.s^{-2}$, trending southwest-northeast (Figure 1). Bouguer anomaly of Ransiki area also corresponds to the results of gravity and terrane tectonic measurements in the New Guinea region with a contour interval of 200 g.u (20 mGal), as shown in Figure 2 [4]. Geologically, the high Bouguer anomaly in the northern part is correlated with the Arfak Volcanic Rock (Tema), the moderate anomaly aligned with the Befoor Formation (Tqb), whereas the low anomaly indicates the quaternary sedimentary rock (Qa). The Ransiki fault on the complete Bouguer anomaly map is not clearly described, so further analysis is needed to confirm the structure in the form of anomaly separation and gradient analysis of the anomaly.

4.2. Residual and regional anomalies

This research aims to study and enhance the Ransiki fault zone associated with sedimentary layers that may close the fault path in the study area so that anomalous separation of residual and regional anomalies is required in the complete Bouguer anomaly data. Low pass filter technique is used to achieve regional anomalies, then the differential between the complete Bouguer anomaly and the regional anomaly is a residual anomaly. Regional anomalies is positive with a range between 29.31 mGal and 56.63 mGal, which increased in value from southwest to northeast (Figure 5a). The regional anomaly pattern is close to the complete Bouguer anomaly, then it is presumed that deep and large structures below the surface have a strong effect on the gravity anomaly in the Ransiki region. The location of the fault structure of Ransiki is not visible in the regional anomaly.

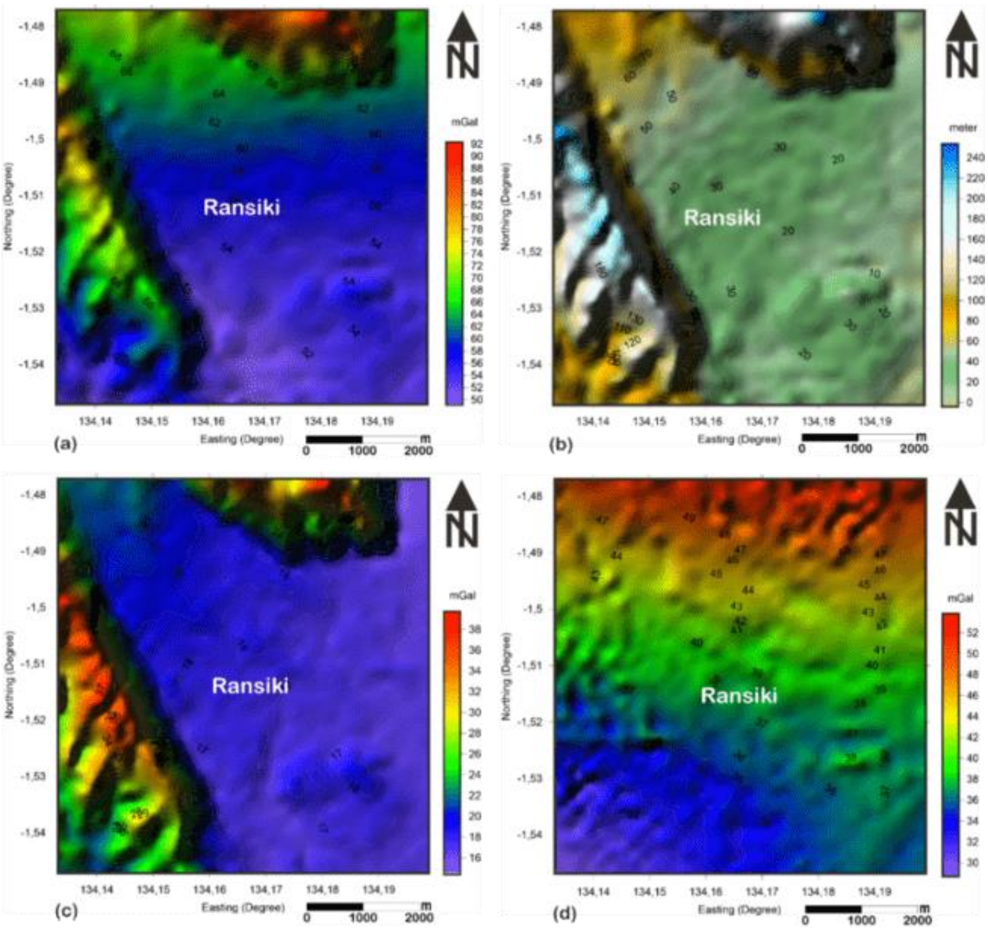

Figure 4. (a) Free air anomaly based on the GGMPlus model; (b) Digital Elevation Model (DEM) based on ERTM 2160 model; (c) terrain correction based on the SRTM2GRAVITY model (d) Complete Bouguer anomaly in the Ransiki area, South Manokwari Regency, Indonesia

Residual anomalies are often more complex relative to complete Bouguer and regional anomalies with values varying from -2.88 mGal to 2.28 mGal, high anomalies in the form of circular spots distributed all across the research location. In this anomaly, the Ransiki fault began to appear and was identified to be associated with a low negative value trending northwest to the south (Figure 9b). In this anomaly, the Ransiki fault began to appear and was identified as being associated with a low negative value in the northwest direction to the south (Figure 5b). Low anomaly values may correlate with weak or crushed zones associated with low density distribution of rock, because of the effect of tectonic activity in West Papua. Watkinson and Hall, (2017) state that the asymmetrical location of the Ransiki River near the Ransiki fault gap supports extensional activity along the fault [1]. To emphasize the structure of the Ransiki fault near the surface, further analysis was provided in the form of an interpretation of the Earth's gradient of gravity from the complete Bouguer anomaly.

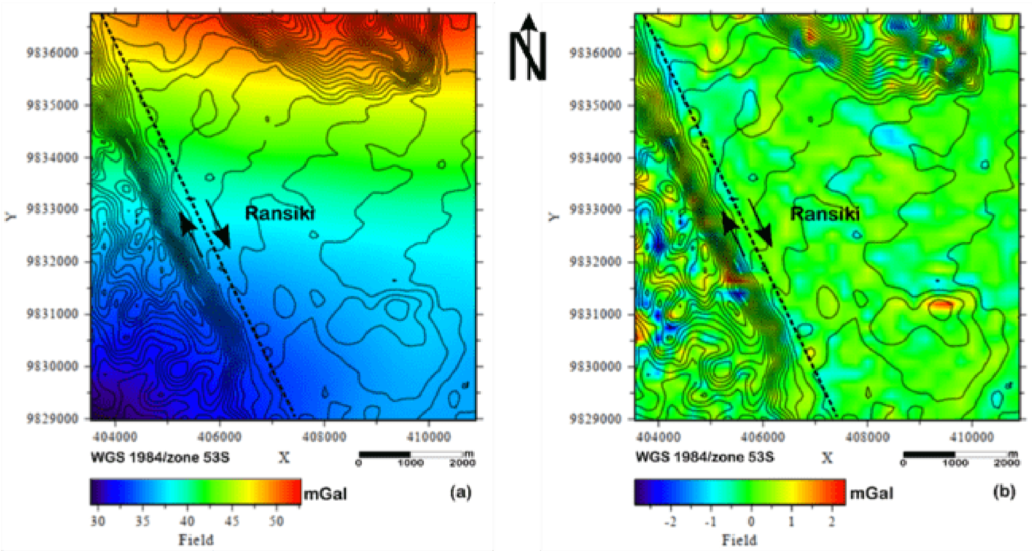

Figure 5. (a) Regional anomaly of the Ransiki area; (b) Residual anomaly of the Ransiki area

4.3. Gravity gradients analysis

Analysis of the gravity gradient of vertical, horizontal gradients, analytical signal, and tilt angles is carried out to sharpen and increase the boundaries of the anomaly source and geology structures in Ransiki. The vertical gradient is negative to positive between -0.012 mGal/m to 0.010 mGal/m (Figure 6a). The fault structure or geological contact is visible on the vertical gradient map, associated with zero values on the anomaly map. The horizontal gradient is positive of 0.00016 mGal/m to 0.01019 mGal/m (Figure 6b).

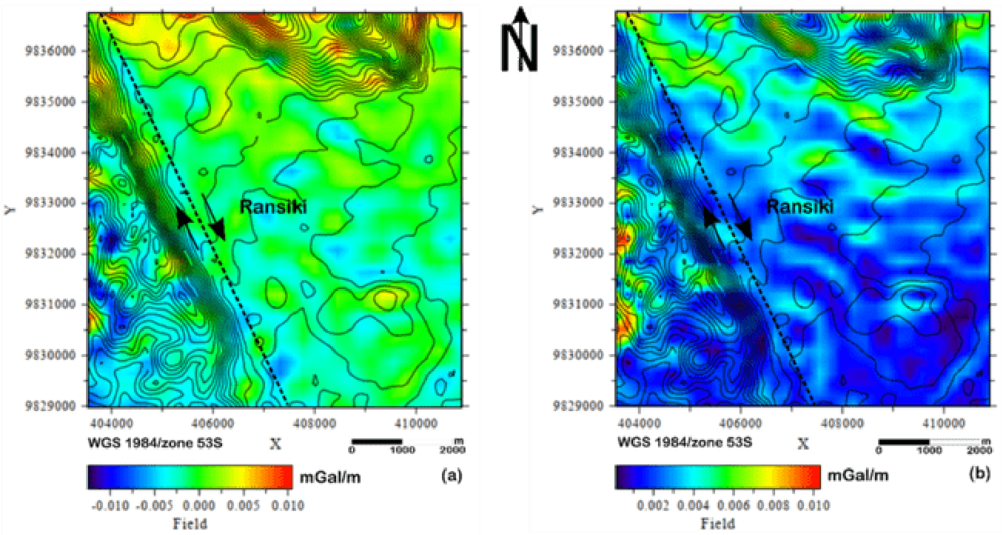

Figure 6. Gradient analysis of Complete Bouguer Anomaly in Ransiki area; (a) Vertical gradient, (b) Horizontal gradient.

On this gradient, the boundaries of the geological structure are correlated with the moderate or intermediate amplitude values. The analytical signal of Bouguer anomaly data in the Ransiki region was positive of 0.00036 mGal/m to 0.1274 mGal/m (Figure 7a). The gradient tilt angle provides more complex information when compared to the vertical and horizontal gradient anomaly maps. The tilt angle values ranged from -87.513° to 84.416°, with a predominance of positive angles in the north, and negative in the southern part (Figure 7b). The Ransiki fault structure in the tilt angle model corresponds to zero or close to zero. The zero contour of angle is usually located near to the boundaries of the sources body [29].

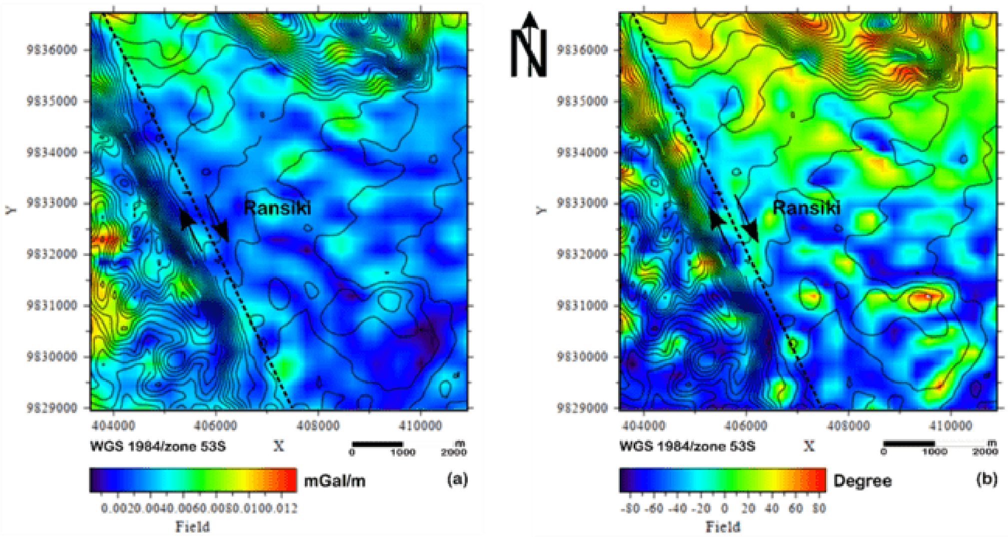

Figure 7. Gradient analysis of Complete Bouguer Anomaly in Ransiki area; (a) The analytical signal, (b) Tilt angle.

4.4. Gravity data inversion and Fault Parameters Interpretation

The purpose of the gravity inversion modeling of global gravity data in the Ransiki Area is to classify subsurface structures associated with the main Ransiki fault line in the field. The inversion process for the complete Bouguer anomaly is performed by optimizing three essential physical parameters, including base, density, and geometry of the block. Base optimization is performed to increase the coefficient of second-order polynomials associated with regional anomalies. Density value and block geometry optimization are carried out to obtain a density distribution model of subsurface rock, which is expected to be capable of describing the Ransiki fault model which is filled by a layer of sediment on the surface. According to the SVD approach, optimization results in an RMS error value of 0.06. Occam density and block optimization generally produce smoother results than SVD with a data RMS error of 0.02 and model RMS error of 0.006. These findings show a very high degree of fitting between measurement and calculation of gravity anomaly data.

The horizontal subsurface model regarding the effect of the inversion of gravity in the Ransiki region is shown in Figure 8a, in the depth of 750 m (Figure 8b), and also the basement (Figure 8c) while the 2.5D model intersecting the Ransiki fault is shown in Figure 8d. The total rock density of the gravity inversion modeling is 2.67 gr.cm^{-3}. Figure 8a shows that the study area is dominated by high-density rock (blue color), which is spread evenly over almost the entire region. The high rock density is related to the Arfak volcanic rocks as a basement created during the Upper Eocene to the Middle Miocene [9], [14]. The composition of Arfak volcanic rocks consists of tuff, agglomerate, lava, breccia, andesite, basalt, and gabbro, which are parts of igneous rock with an average density ranging from 2.61 gr.cm^{-3} to 3.03 gr.cm^{-3} [34], [35]. The layer above the basement is thought to be a Befoor formation with a composition of sandstones, mudstones, conglomerates, marl, and volcanic rocks that occurred during the Pliocene [9]. In general, this layer has a rock density that is relatively lower than that of Arfak volcanic rock (light blue color).

The younger layers above the Befoor formation are thought to be alluvial and littoral deposits of quaternary sediments consisting of mud, sand, gravel, peat, and plant matter. Figure 8b shows a 2.5D cross-section profile that intersects the Ransiki fault segment in the South Manokwari district.

According to the model, it can be seen clearly that the alignment of the Ransiki fault segment from the northwest to the south is associated with the distribution of low rock density (in green) between high-density rocks. This zone is thought to be a zone of destruction due to the extension or compression of tectonic plates in the birds head of Papua [1], [14].

Watkinson and Hall in 2017 conducted research on quarternary faults in eastern Indonesia and found that the Ransiki fault zone has a segment length of between 20 – 50 km and a width less than 1000 meters with a class of tectonic activity from maximum to minimum [1]. Moment tensor analysis from the global CMT catalog of large earthquakes in the Ransiki fault zone in 2002 with a magnitude of 7.5 Mw obtained strike and dip angle in the first nodal plane of 60° and 83°, while in the second nodal plane, 329° and 86° [36].

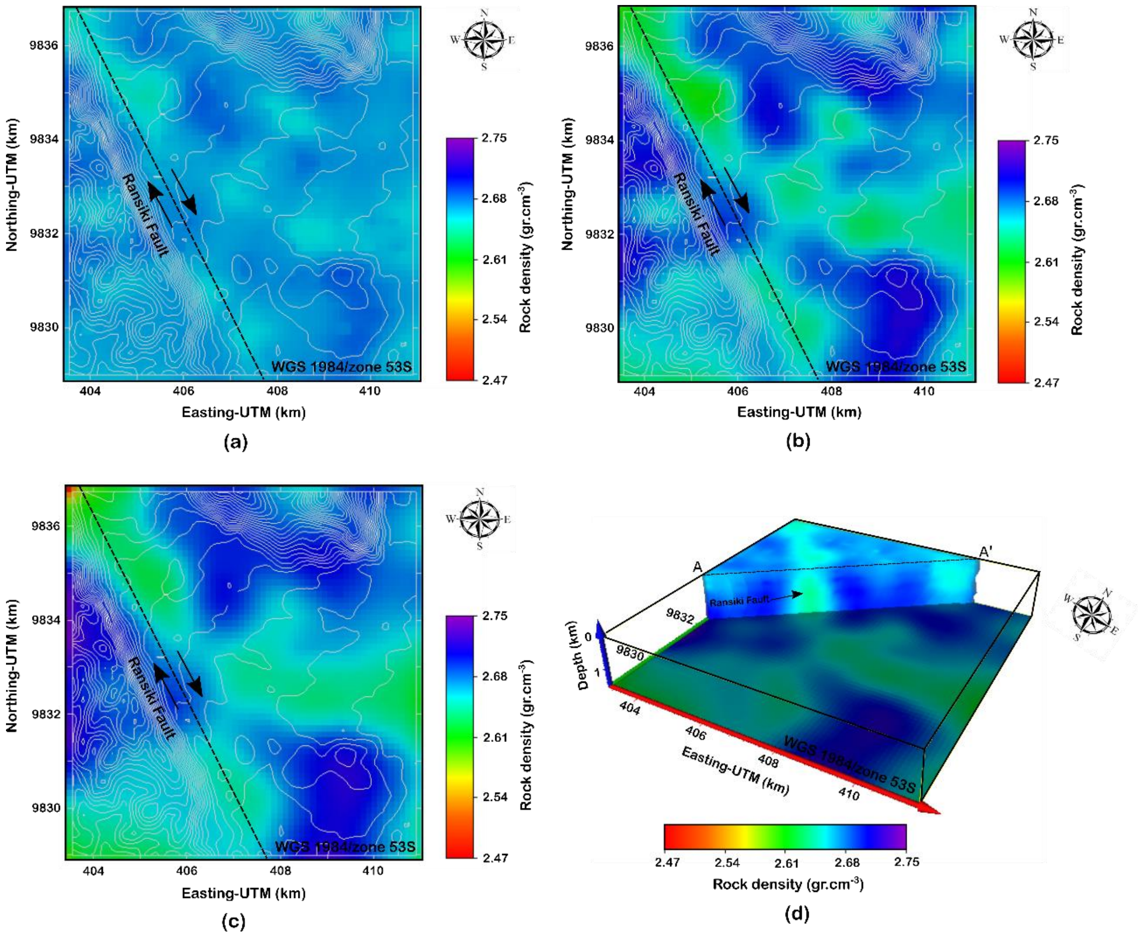

Figure 8. Rock density distrbution according to 3D gravity inversion in Ransiki area (a) horizontal layer at the surface; (b) horizontal layer at the depth of 750 m; (c) horizontal layer at the 1.5 km as the basement; (d) 2.5D cross section perpendicular to the Ransiki fault. Fault wide zone is less than 1000 meters.

5. Conclusion

The use of a high-resolution GGM global gravity field corrected by the SRTM2gravity model to identify the Ransiki fault structure in the South Manokwari Regency, West Papua, Indonesia has shown significant results defining the subsurface layer as a fault line in the study area. Qualitative interpretation through the study of gravity gradients (derivatives) in the form of a vertical, horizontal, analytical signal, and tilt angle gradients of complete Bouguer anomalies indicates an increase in the visibility of the boundaries of anomalous sources of fault systems in the Ransiki region of South Manokwari with northwest to south orientation. The Ransiki fault is correlated with zero values in the vertical gradient and maximum values in the horizontal gradient and analytical signals, whereas the tilt angle provides zero or near-zero degree of fault structures. Quantitative analysis based on gravity inversion models offers a subsurface model of the Ransiki fault segment according to the Arfak volcanic rock with a high rock density as a basement, while a fault line coincides with a low density that is usually correlated with the Befoor formation and Alluvial deposits, which are the extension zone in the birds head of Papua island.

Acknowledgments
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Author Contributions
R.L and L.L have formulated concepts and designs for the collection and processing of gravity data. A.N has evaluated the geological of Ransiki area, South Manokwari regency. R.L has also examined the principle of gravity and its gradients, then gravity inversion modeling.

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