PAPER • OPEN ACCESS

Modeling of subsurface based on gravity data with second vertical derivative (SVD) and euler deconvolution optimazitation

To cite this article: Kania Pinasti Soleha *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **311** 012065

View the article online for updates and enhancements.

Modeling of subsurface based on gravity data with second vertical derivative (SVD) and euler deconvolution optimazitation

Kania Pinasti Soleha[1,*], Accep Handyarso[2], Dini Fitriani[1] and Eddy Supriyana[1]

[1] Geophysics Departement, University of Padjadjaran, Jl. Raya Bandung Sumedang KM.21 Sumedang, Indonesia
[2] Centre of Geological Survey – Geological Agency, Jalan Dipenogoro no.57 Bandung, Indonesia

E-mail: kania14001@mail.unpad.ac.id

Abstract. The purpose of this study is to estimated the mean depth of bedrock in the Sahul Basin and identification of subsurface geological of the research area. The study contucted in Sahul Basin, which is associated with a basins in Papua New Guinea that has been proven to produce oil and gas, with the adjacent geographical location, is expected to have the same play concept. The analysis that used in this research is Second Vertical Derivative (SVD) to know the geological structure, Euler Deconvolution to get depth solution, and Forward Modelling 2D for information of the subsurface. The results of the study have shown that the average depth of bedrock is more than 3500 meters, and structur that developed of the research area are strike slip fault, normal fault, and reverse fault, that occured due to the compression force between Australian Continental Plate and Pacific Ocean Plate.

1. Introduction

The Sahul Basin is located in the most Eastern-Southern province of Papua, associated with the basin in Papua New Guinea who have been proven to produce oil and gas. The adjacent geographical location is expected to have the same play concept with the basins in Papua New Guinea. One of the geophysical methods used as preliminary studies of oil and gas exploration is the gravity method. To obtained a better subsurface model data optimization has been done by applying Euler Deconvolution analysis to get depth values solution and Second Vertical Derivative (SVD) is used to find out the structures in the area of research.

2. Methodology

This paper discusses the estimate of the bed rock by involving Euler Deconvolution to get spread of depth solution and identification of the structure existence in Sahul Basin area by involving analysis Second Vertical Derivative (SVD). Those analysis are expected to provide a good agreement related subsurface model in the study area and interpretation of gravity methods is based on two-dimensional forward modelling. The flowchart of methods used in this study is shown in Figure 2.

---

* To whom any correspondence should be addressed.

2.1 Second Vertical Derivative (SVD)

Fault delineation using gravity data is based on the anomaly enhancement approach such as Second Vertical Derivative (SVD). The equation used is the following Laplace equation (Blakely 1996). The second vertical derivative (SVD) technique is one of several methods of removing the regional trend in order to calculate the second vertical derivative using Fast Fourier Transform (FFT). This technique is used in to bring up the local anomalies which was intended to find out the discontinuity of subsurface, in particular faulting. Reviewed theoretically, this technique was derived from the Laplace's equation:

$$\nabla^2 \Delta g = 0 \tag{1}$$

$$\frac{f^2(\Delta g)}{f z^2} = -\left(\frac{f^2(\Delta g)}{f x^2}\right) \tag{2}$$

Using the above equation, we can be known that the second vertical derivative of an anomalous gravity surface is equal to the negative of the horizontal second-order derivative. Equation 2 is then used to calculate the SVD anomaly pattern from the gravity data obtained.

2.2 Euler Deconvolution

The position and depth of gravity source is an important parameter in data interpretation. In oil exploration, it is used to determine the position and depth of the basement. Euler's inversion is a method for studying the position and depth of the source or often called Euler Deconvolution [1]. Euler Deconvolution is a 3D estimation of the source position, and is a method that requires no prior knowledge of the source of anomalies. Euler Deconvolution is an estimate of the horizontal and vertical position of the source. In this case, the source geometry is assumed by an interpreter. The result of Euler Deconvolution is an approximate map of the source position [2]. Thompson (1982) shows Euler's homogeneity relationship written:

$$(x - x_o)\frac{\partial T}{\partial x} + (y - y_o)\frac{\partial T}{\partial y} + (z - z_o)\frac{\partial T}{\partial z} = N(B - T) \tag{3}$$

where (x_o, y_o, z_o) is the position of the source with the total field T detected at (x, y, z). The total field has a regional value B. The degree of N homogeneity can be interpreted as Structural Index (SI). Structural Index is a function of the geometry of the object causes the depth. The index is too low giving a depth too shallow, while if too high value gives the estimated depth too deep [3].

2.3 Forward Modelling 2D

Forward Modelling is a method of interpretation that estimates sub-surface density by making the first geological subsurface objects or is a process of calculating data from theoretical result that will be observed on the surface of the earth if the model parameters are known. At the time of interpretation, look for a model produce suitable and fit responses with observational data, so it is expected that the model condition can represent approximate the actual situation.

This modelling is done by making a cross section of the selected Bouguer anomaly was selected by taking some of the path representing the study area. The gravity model anomaly of the subsurface model is called calculated (cal) gravity anomaly measurement result called observed (obs) anomaly. The subsurface model is constructed in such a way that the gravity anomaly of the model corresponds to the gravity anomaly of the measurement. At this stage geological information is needed, relating to the research area, and the depth values estimation of the area of spectral analysis results and Euler Deconvolution.

3. Result and Discussion

3.1 Gravity Bouguer Anomalous of Research Area

Bouguer anomaly map of gravity is shown in Figure 3 shows the range of anomaly value range from -4.9 to +37.1 mGal. The Sahul Basin can be grouped into three different anomalies:

- High anomalies that have a range of values between +27.2to +37.1 mGal spread over the west and north of the study area. The high anomalies in the west of the study area are thought to be cause by the influence of lithologic rocks in the Arafura Sea, so the rocks area dominantly based on the continental crust, while the high anomalies in the northern part of the study area are thought to be due to the influence of uplift of the Papuan fold belt.
- Medium anomalies that has the range between +7.9 to +27.2 mGal. These anomalies generally occupy the central of the study area and spread to the northeast and northwest. Medium anomalies in the study area are thought to be due to transition rocks between height and lowness, with the lithology of alluvium deposits and river deposits.
- Low anomalies that have a range from -4.9 to +7.9 mGal, are spread on the eastern part of the study area. The low anomaly in the eastern part of the study area, is where the Ely River is, so it is suspected that the sediment deposition in this section is thicker.

3.2 Spectral Analysis

Spectral analysis to know depth of deep and shallow discontinuities. The depth of the discontinuity plane in this case is the slope value (gradient) of the spectral power log (ln Amplitude) of frequencies. On the Bouguer anomaly map of the Sahul Basin area made twenty path runs vertically and horizontally which is expected to represent the whole of the area of research.

The values obtained on the twenty trajectories are averaged. That shows the average value of the dept of the regional discontinuity is 16.94 km, the result is interpreted as the mean depth of the boundary plane of the Mohorovic layer while the average depth of field residual discontinuity is 3.43 km, the depth of the residual anomaly interpreted as boundaries between zones of basement with sedimentary rocks.

3.3 Regional and Residual Anomalies

The regional anomalies of the study area are shown in Figure 4. In general, regional anomalies show patterns that are not much different from the Bouguer anomaly patterns, this is because regional anomalies have a major effect on Bouguer anomaly with values ranging from -4.7 to 36.5 mGal. The residual anomaly is shown in Figure 5, where the residual anomaly map shows the pattern of anomalies are more complex anomaly pattern than the regional anomaly, because it illustrates anomalous patterns with shorter wavelengths which reflecting the shallower anomaly effect of anomalous object, this anomaly is characterized by high frequencies.

3.4 Second Vertical Derivative (SVD)

The SVD anomaly pattern also shows the offset or net-slip shift of the Southeast-Northwest anticline ridge, indicates a structure of strike slip fault with Southwest-Northeast direction This is in accordance with the theory of faulting Anderson, where there is an intersection between the two structures that form the letter "X" pattern [5]. There are some patterns of Strike Slip fault with Southwest-Northeast direction formed caused due to compression ot the Australian Plate with the Pacific Ocean Plate.

3.5 Euler Deconvolution

The Euler Deconvolution Map (Figure 7) shows the solution of the source position as a circle with a depth proportional to the diameter. The result of Euler Deconvolution is correlated with the result of spectral analysis to make the subsurface section and obtained a similar solution for the depth of the

source position, on spectral analysis obtained the average depth for the basement is 3500 meters, this is also supported by sediment depth map data that shows areas of research had a sediment thickness of 3000 meters – 4000 meters.

3.6 Forward Modelling

Trajectories are made on the Bouguer anomaly map that can represent the research area. Forward modeling in this research assumed consist of two types of rocks in the first layer is sedimentary rock with the value density of 2.5 g/cm^3 and on the second layer is basement with the value of the density 2.8 g/cm^3.

The determination of density value of each layer is done by linking the lithology of the constituent rock with the appropriate density value. Therefore the sediment layers above the basement are thought the lithologies of sandstone, carbonaceous shale, silt rock, carbon, and conglomerate that has a density of 2.5 g/cm^3, and tend to thickened towards the Northeast. Then for the basement laye of basement that form the continental plate from the continent of Australia is estimated to have an average density of 2.8 g/cm^3 [5], and thought to be the a modio dolomite rock. Basement generally basically silt toward Batannafo from west of research area.

The three gravity profiles are constructed from a perpendicular path to the direction of the anomaly stance represented by the AB, CD, and EF paths (Figure 8) for subsequent modeling.

3.6.1 Cross Section AB Anomaly

The structure contained in the path AB is indicated is a horizontal fracture, a rising fracture, and a fault down, so that the formation of Horst and Graben in the area.

3.6.2 Cross Section CD Anomaly

The modeling of the subsurface structure in the path of the CD shows that there is an indication of normal fault and reverse fault resulting the existence Horst and Graben in the area.

3.6.3 Cross Section EF Anomaly

This trajectory resulted the thickening of sediments to the south of the study area that was not very significant when compared to the path AB, this is due to the caused the path passage through the Sigul big river, so the possibility of sediment deposits is greater. As well as sedimentation to the west of the study area that has a high gravity anomaly value that is suspected to be caused by the southern part of Indonesia is covered by Australian continental rocks. The structure that develop on the path is a normal fault.

4. Conclusions

- Based on the data of sediment thickness, processing with spectral analysis, and futher analysis using Euler Deconvolution, it was found that basement in the Sahul Basin area has an average depth is more than 3500 meters.
- The subsurface model on the third lap on the Sahul Basin has been made shows the presence of basement was towards to the Southwest of the research area and thickening of sediment to the Northeast. The structure that developed in the study area is strike slip fault, this is indicated by the SVD anomaly pattern which indicates the offset or net-slip shift of the anticline ridge with a Southwest-Northeast. In addition, there is a reverse fault and normal fault that resulted formation of Horst and Graben in the Sahul Basin, this is caused of a compression between the Australian Plate with the Pacific Ocean Plate.

References

[1]   Fan, M., & Wu, Y. (2011). *Euler deconvolution method of gravity anomaly based on wavelet analysis*. *2011* International Conference on Multimedia Technology, 305–308. https://doi.org/10.1109/ICMT.2011.6002024

[2]   Melo, F. F., Barbosa, V. C. F., Uieda, L., Oliveira Jr., V. C., & Silva, J. B. C. (2013). *Estimating the nature and the horizontal and vertical positions of 3D magnetic sources using Euler deconvolution*. Geophysics, 78(6), J87–J98. https://doi.org/10.1190/geo2012-0515.1

[3]   Keating, P. B. (1998). Weighted Euler deconvolution of gravity data. Geophysics, 63(5), 1595–1603. https://doi.org/10.1190/1.1444456

[4]   Agency, G., & Resources, M. (2012). Tectonostratigraphy of the Southern Part of Papua and Arafura Sea , Eastern Indonesia Tektonostratigrafi Papua Bagian Selatan dan Laut Arafura , Indonesia Bagian Timur, 7(3), 167–187.

[5]   Handyarso, A. and Saleh, H.H., 3, 2017, STRIKE-SLIP FAULT IDENTIFICATION BENEATH OF THE WIRIAGAR OIL FIELD, Scientific contributions Oil and Gas, 40 (3) pp, 133-144. DOI: 10.29017/SCOG.40.3.133-144.