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Graben Structure Identification Using Gravity Method

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Abstract. Graben (trench) is a natural expanse that is lower in altitude compared to its surrounding which is caused by normal faults shift. Changes in rock density can be identified to obtain the subsurface rock structure. Gravity method is a basic method yet very effective in determining subsurface rock structure. Identification of graben structure is the main focus of this research in order to identify the natural resources which may be available under the ground. Research work was performed in various locations in Bogor and according to our analysis using 2D Talwani model, the average density at the surface is 2.5 gram/cm³. 2D modelling results show a fault structure at rocks with relative direction West-East. The fault is forming an extension block faulting which makes the area a graben. In general, the cross-section profile of the model indicates rock layer structure made from limestone rocks (2.75 gr/cm³), sands, flakes, limestone (2.5 gr/cm³), volcanic sediment layer sandstone (2.3 gr/cm³), and clay layer and similar (2.00 – 2.10 gr/cm³).

1. Introduction

Tectonic plate activities have been affecting changes in geological structure physically in earth’s crust and it appears in the West Java landscape. Tectonic force does continuously press, pull, bend, and fracture the rocks in lithosphere [1]. Subduction zone in the south of Java that is continuing to Sumatera contributed to tectonic compression that forms Meratus, Sunda, and Java Pattern. Bogor Basin, which in Middle Eocene - Oligocene was a front basin of magmatic arc, changed its structure into rear basin of magmatic arc in Early Miocene – Pliocene [2], and it formed a lot of thrust faults and creases.

Graben (trench) is a natural expanse that is lower in altitude compared to its surrounding which is caused by normal fault shift [3] Changes in rock density can be identified to obtain the subsurface rock structure. Gravity method is a basic yet very effective tool in determining subsurface rock structure. Some researchers identified graben with gravity method yet [4, 5]. Identification of graben structure is the main focus of this research in order to identify the natural resources, which may be available under the ground.

Uneven density distribution under the earth surface can be caused by the available geological structure. Contribution of the structure to the difference in gravity acceleration on earth surface is very
low, compared to its absolute value. The difference is also contributed by observation’s point position in earth surface, since earth is not a perfect sphere and earth’s relief varies.

Gravity method is an investigation method in geophysics that is based on the variety of gravity acceleration on earth’s surface. This method is used to identify and describe rocks lithology geological structure and subsurface structure depending on varied earth’s gravity which is caused by difference in various rocks’ density.

This research uses gravity data analysis to determine subsurface structure of fault patterns which focus in a slicing model. This is done because geophysics geology survey has not been done before in the area, so there is very limited information about the area. The slicing model is very unique to be observed because it is expected to have a normal fault block structure pattern as expanded fault. Generally, the area is formed by volcanic rocks, sediment rocks, and intrusive that can form a hydrocarbon reservoir. In research area, there is a high contrast of rock density and complex fault structure, which is predicted to be a hydrocarbon manifestation [6].

One technique that will help in interpreting the depth of the source of gravity anomaly is upward continuation that is supported by spectral analysis information in the slicing which will be tested. The purpose of the analysis is to give effective information about geological structure that will be analyzed. Thus, it is our hope that this method can be used to help collecting information about subsurface geological structure in Bogor Basin, West Java.

2. Methods

Research Centre for Geotechnology LIPI carried out data acquisition using point closed looping method. By applying some necessary corrections on the collected data, a complete Bouguer anomaly contour map was succeeded in showing some anomalies in the field (see Figure 1). The map was created by using 169 data points data which was symbolized by ‘+’ sign on the map.

![Figure 1. Complete Bouguer anomaly map](image_url)

To separate noise, residual, and regional information, spectral analytic method is used in this research (see Figure 3 and Figure 4). The spectral analysis used is upward continuation method that converts potential field data measured on a certain surface level into values, which reflect data as if
measured at higher surface level (see Figure 2). Upward continuation will show anomalies that are caused by shallow sources. To simplify modelling, GMSys 2D software that is based on 2D Talwani method will be used using interactive forward modelling. This modeling is performed by predicting the geometrical form of subsurface that will be correlated with geological structure.

3. Result and Discussion

This Complete Bouguer Anomaly Map has anomaly value in a range between 26 until 66 mGal, with general pattern in the form of closed and open basin with varied value. This distribution map describes shallow and deep subsurface structure. Differences of Bouguer anomaly value are marked with colour gradation, where each colour represents certain anomaly value.

Regional anomaly is associated with general geological condition of the area, characterized by low frequency anomaly. Bouguer anomaly can also be considered as a resultant/accumulation of subsurface rocks structure’s influences which consist of anomalies caused by shallow, medium, and deep geological structure, including adjacent and mutually interacting structures that cause overlap anomaly as shown on the map.

The research area is an area of interest because it belongs to high anomaly group. The low anomaly is probably caused by the presence of faults that causes the area to be depressed and lower than its surrounding. The high anomaly, on the other hand, is caused by the availability of solid/compact material in the area.

In this research, contour map produced with upward continuation is not significant compared to Complete Bouguer anomaly map (ABL). This happens because the contour on ABL map is qualitatively smooth. Fixed and relatively far distance between measurement points (750 m effectively) and using only one slicing section model may contribute to the effect, which also contribute to a linear distribution in map-gridding processing phase (statistical computation).

Spectral analysis results show that the source of regional anomaly is at 1769.5-meter depth, residual anomaly source at 132.29-meter depth, and noise source at 17.7-meter depth (see Figure 2). Based on the result, limit of depth value of residual-regional anomaly is between 1558.508 and 2805.314 m, which show a high anomaly pattern caused by the presence of normal fault block structure pattern. The result from spectral analysis and upward continuation information are needed in objectively subsurface interpretation AA’ slicing model (see figure 5). From the result of separation filtering, it can be concluded that the higher the continuation then the deeper the regional anomaly and the more shallow the residual one.

![Figure 2. Spectral analysis from gravity data](image-url)

There is a coherent relation between the analysis results of gravity data using upward continuation with spectral as control data information in assisting the interpretation of gravity subsurface geological
structure, considering that both analytical methods are subsurface potential field data analysis application [7].

Figure 3. Regional anomaly map with upward continuation

Figure 4. Residual anomaly map with upward continuation

Positive anomaly that form heights and closed basin is predicted as a result of interaction between horst-graben caused by normal fault (rifting) in West-East direction. Rocks layer
from simulation in this trajectory is interpreted against average of rock density in research area, which is \( 2.507647059 \text{ gr/cm}^3 \approx 2.5 \text{ gr/cm}^3 \). Based on the result, basement rock (red body layer), predicted to be sedimented and then covered by sediment from Quaternary volcanic, which has density between \( 2.14–2.52 \text{ gr/cm}^3 \). This might be true if the type of the rocks is sand rock.

![Figure 5. 2D slicing section model of research area](image)

4. Conclusions
The source of regional anomaly according to continuation result and spectral analysis information is at depth range between 1558.508 until 2805.314 meter. The model’s section cut as shown in Figure 4 has rock layer structure that consists of limestone (2.75 gr/cm\(^3\)), sand, flakes, limestone (2.5 gr/cm\(^3\)), volcanic sediment layer and sandstone (2.3 gr/cm\(^3\)), and clay and similar (2.00–2.10 gr/cm\(^3\)).

References
[5] Emilson Pereira Leite and Naomi Ussami, 2006, Linear inversion of a negative gravity anomaly in