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Inversion Modelling 3D Gravity for Hydrocarbon Identification at Sanggau, West Borneo

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Abstract. Inversion modelling 3D in gravity is applied on Sanggau Quadrangle, West Borneo. Subsurface modelling by gravity methods has ambiguity, to solve this ambiguity invers modelling 3D has been applied to anomaly bouguer map with measurement of depth by spectral analysis. Invers modelling 3D use inversion method of singular value decomposition (SVD) and inversion Occam. Anomaly bouguer show low anomaly between -83.5 mGal to 184 mGal in the north and south of map, middle anomaly between 184 mGal to 315 mGal in the middle of the map, high anomaly has values between 346.5 mGal to 544.7 mGal in North-East. Spectral analysis have result of the regional depth 30.381 km. Invers modelling 3D has result the model that have RMS 0.063 and 0.02. Invers modelling 3D shown large thickness of sandstone with density 2.35 g/cc at Kayan High Land, Ketungau Low Land, and Kapuas Low land, that potential for hydrocarbon. Volume sandstone on Sanggau is predicted about $\leq$ 50892.19384 km^3. The result of the model give preliminary information of model concept on estimated potential hydrocarbon.

1. Introduction

Indonesia is one country that has a large hydrocarbon potential. The potential of large hydrocarbon is meaningless if no exploration and exploitation is carried out. The presence of hydrocarbon is spread in various regions in Indonesia, one of which is in Melawi Basin which is characterized by a very small petroleum seepage located 40 km east of Sanggau city, near the eastern edge of Sanggau, West Borneo [1]. The gravity method is used because it has the ability to distinguish the density of a rock from an anomalous source to its environmental density. The presence of a non-uniform density distribution can show the shape of the subsurface structure of a research area [2].

The problems that arise in making the subsurface structure model in the gravity method is the ambiguity which means that it is influenced by the depth and density of the rock. The nature of ambiguity can be above by spectrum analysis for depth estimation and determination of rock density based on geological stratigraphy and 3D inversion data modeling of complete bovine anomalies. 3D modeling on gravity methods is still rarely carried out, so to find out the 3D model of subsurface structure 3D inversion is carried out so that rock density can be obtained and can predict volumetric from a rock in the study area. This study aims to identify the potential of hydrocarbon in Sanggau

Sheet, West Borneo using the 3D inversion model method on a complete bovine anomaly map based on the data sheets of the sheets of the Sanggau gravity spectrum, West Borneo.

2. Methods

The research area is located in the northwestern part of West Kalimantan Province, precisely between the equator 01°00' L.U. and 109.30'-111.00 B.T. The data in the study were data obtained from the results of digitization of bougeur anomaly maps belonging to the Pusat Survei Geologi. Data is presented in the form of bougeur anomaly contour map with minimum curvature gridding method. Spectrum analysis was performed on bougeur anomalies by digitizing bougeur anomalies using several trajectories.

The sampled anomaly is then performed by Fourier Transform to convert the spatial domain into a frequency domain. Fourier transform is done using Fast Fourier Transform (FFT) algorithm using MATLAB software. Spectrum analysis is carried out by transforming the Fourier path determined on the contour map of Complete Bouguer Anomaly. The results of the Fourier transform which as described in Eq. (1) [3]:

$$S(f) = \int_{-\infty}^{\infty} S(t)e^{-i2\pi ft}\, dt, \tag{1}$$

$j = \sqrt{-1}$. The spectrum is derived from observed potential gravity which as described in Eq. (2) [4]:

$$F(U) = \gamma\mu F\left(\frac{1}{r}\right), \text{ and } F\left(\frac{1}{r}\right) = 2\pi\frac{e^{|k|(z_0 - z_1)}}{|K|}, \tag{2}$$

$z_1 > z_0$. $|k| \neq 0$, U is the gravity potential, μ is the mass density anomaly, γ is the weight constant and r is the distance.

Three-dimensional modeling is carried out using linear inversion techniques with the singular value decomposition method to obtain linear solutions. The subsurface structure modeling is carried out using three-dimensional (3D) inversion technique using Grablox 1.6 [5] software so that it will produce a 3D density section. The Grablox 1.6 software combines two inversion methods namely Singular Value Decompotion (SVD) and Occam inversion which are processed sequentially [6].

Singular Value Decompotion Inversion (SVD) is a technique of reducing a matrix into two matrices. The following is a mathematical equation regarding the inversion of the Singular Value Decompotion which as described in Eq. (3) [7]:

$$A = USV^T, \tag{3}$$

U is left orthogonal matrix, S is diagonal matrix, V is right orthogonal matrix, and T is transpose matrix. Occam inversion is an inversion technique by utilizing model roughness [8].

3. Result and Discussion

The pattern of the Sanggau bougeur anomaly, Kalimantan shown in Figure 1 has a range of bougeur anomalies around -83.5 mGal to 544.7 mGal. High anomaly patterns are spread in the east and south of the study area. Low anomalous patterns are concentrated in the north and southeast of the study area. The anomalies found in the bougeur anomaly map are divided into three parts, namely: low anomalies, moderate anomalies and high anomalies. The low anomalies have a range between -83.5 mGal to 184 mGal is described in blue to green. Medium anomalies have a range between 184 mGal to 315 mGal with green to yellow. High anomalies have a range between 346.5 mGal to 544.7 mGal with red to light purple. The anomaly source cannot be determined based on the bougeur anomaly value. This is because the value of the bougeur anomaly is superposition or a combination of gravity anomalies due to shallow (residual) rocks and rocks in (regional).
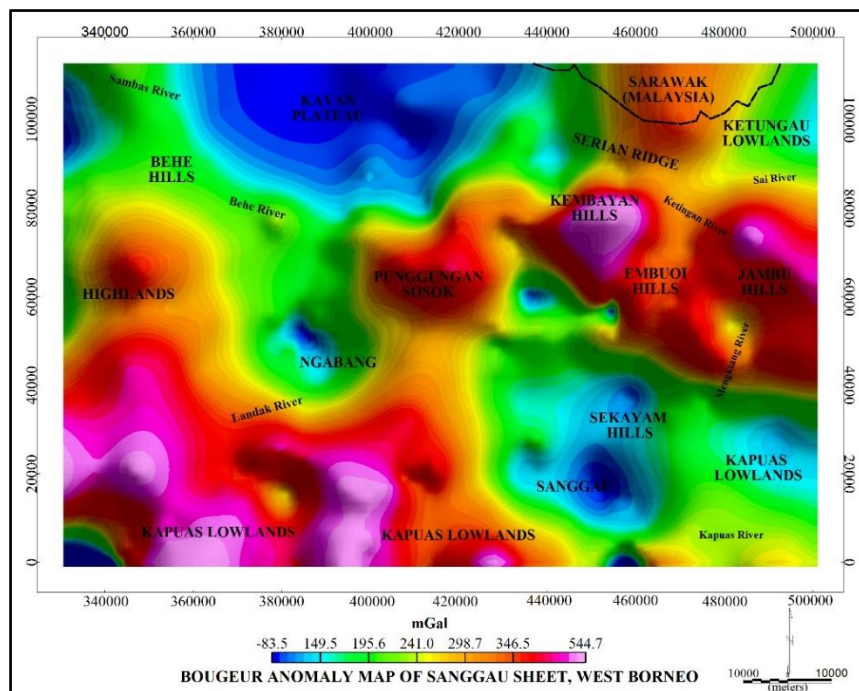
Figure 1. Map of the Sanggau Sheet Bougeur Anomaly, West Borneo.

Spectral analysis is carried out for estimating the depth of shallow (residual) and rock (regional) rocks. The results obtained from the spectrum analysis in the form of window width (N) that will be used in the separation of anomalies based on wave numbers and average depth of density contrast between relatively low densities and relatively high densities so that it can be estimated residual and regional anomaly sources. The trajectory anomaly used in this study is 15 trajectories for spectrum analysis. Spectrum analysis using 15 paths because to get the overall anomaly from bougeur anomaly is shown in Figure 2. Each track, anomaly is sampled per 2000 meters.
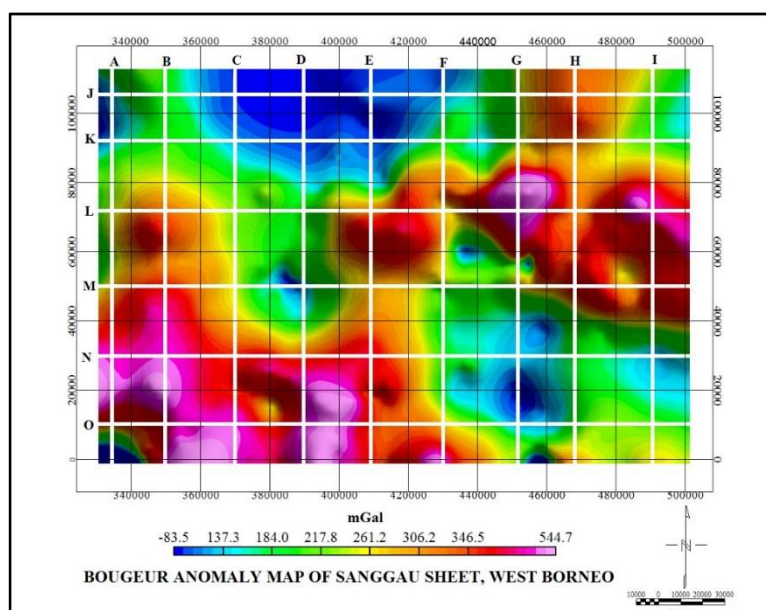

Figure 2. Trajectory of Spectrum Analysis on Bougeur Anomalies.

Trajectory spectrum analysis graph A is shown in Figure 3. The graph shows the plot of the price of the natural logarithm of anomalous energy (*A*) to wave number (*k*). Blue data shows the regional zone (inner zone). Red data shows the residual zone (shallow zone). The *kc* value is the cut wave number (k cutoff) which separates the two zones with a value of *kc* = 0.12 cycle / km.
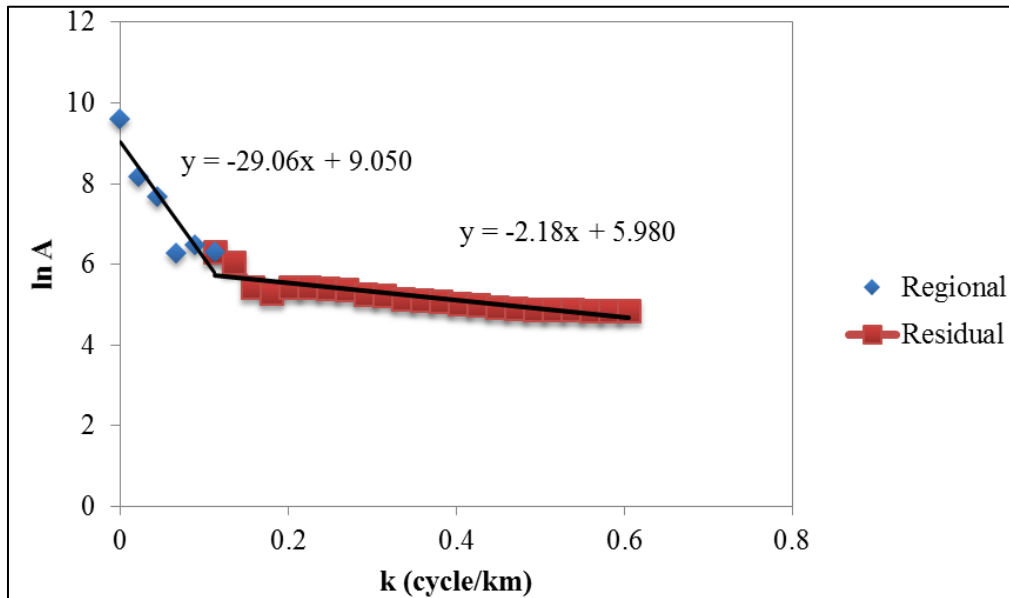

Figure 3. Trajectory Spectrum Analysis Graph A.

The results of the spectrum analysis of the trajectory *A* obtained by the value of *kc* is 0.12 cycle / km. The distance between spaces at the measurement point (Δx) is known to be 5 km, so that the estimated width of the window which as described in Eq. (4):

$$N = \frac{2\pi}{k_c.\Delta x} = 6.28 \; x \; \frac{1}{0.12 \; x \; 5} = 10.47 \tag{4}$$

Window width value (N) in spectrum analysis of path A is 10.47 so that if rounded to 11 with *kc* value is 0.12 cycle / km based on differences in trends between regional zones and residual zones. This means that the window width value data (N) which has a value of k less than 0.12 cycles/km is considered a regional zone, meaning that the inner rock zone and k value of more than 0.12 cycles/km are considered as residual zones meaning shallow rock zones.

In spectrum analysis, in addition to estimating the width of the screening window, it also produces the estimated value of the discontinuous depth in the regional zone and residual zone. Gradients in a straight line indicate depth estimates. The gradient of the residual trend line is the first discontinuous boundary field with a value of 2.18 km. The regional trend line gradient is the two discontinuous boundary plane with a value of 29.06 km.

Spectrum analysis on track A through path O produces estimated values of residual anomalies and regional anomalies as shown in Table 1. The depth of residual anomalies is about 1.978 km to 3.413 km so the average depth estimate of the study area is 2.622 km. This depth estimation is associated with sedimentary rock. Based on research conducted found that the depth of Indonesian sediments was estimated to range from 2 km to 4 km with an average sediment thickness estimated at 3 km [9].

The estimated depth of regional anomalies and residual anomalies are obtained from the results of spectrum analysis. Anomalies that have a low value indicate the response of rocks in (regional zones). The regional depth obtained based on the analysis of the trajectory of the trajectory A to the O trajectory, the lowest depth is 19.52 km and the deepest depth is 45.56 km. The average depth of the

regional zone is 30,831 km. Anomalous sources at these depths are thought to come from the field of moho discontinuity which is a transition between the layers of the earth's crust and the earth's mantle.

Table 1. Table Estimation the depth of the results of spectrum analysis

No.	Trajectory	Depth (km)	
		Regional	**Residual**
1	A	29.06	2.18
2	B	28.3	2.398
3	C	19.52	1.978
4	D	25.94	2.556
5	E	36.14	2.568
6	F	20.27	2.387
7	G	23.95	2.94
8	H	45.56	3.413
9	I	36.96	3.014
10	J	42.41	2.88
11	K	30.37	2.282
12	L	23.39	2.224
13	M	34.83	3.229
14	N	34.81	2.445
15	O	30.96	2.8382
	Average	30.831	2.622

The results obtained from the spectrum analysis are the window width (N) and the cut wave number (k cutoff). The cut-wave number value (k cut-off) has different results-different from the 15 sampled ones. The lowest cut wave (k cutoff) is 0.10 cycle / km with the window width (N) is 12.56 and the highest cut wave number (k cutoff) is 0.16 cycle / km with the window width (N) is 7.87. Based on 15 trajectories selected, the average value of cut wave number (k cutoff) is 0.13 cycle/km with the window width (N) is 10.21.

The inversion process of bougeur anomaly map was carried out using Grablox 1.6 software with a bougeur density value of 2.67 g/cc and a range of parameters between 1-4 g/cc. The inversion process is carried out with several optimization stages namely basic optimization (Base), density (density), Occam density (Occam-d), height of block (Heights) and Occam block height (Occam-h). The inversion results obtained have an RMS of 0.063 and the RMS model is 0.020, and Lagrange is 1. The inversion results in the form of a 2D density cross section at each depth and then combined into a 3D model using Voxler software. From the inversion results, bougeur anomalies map was obtained to a depth of <30,831 km. The 3D density model can represent rock density in the Sanggau Sheet which is correlated with rock types based on geological maps. The results of inversion can be seen in Figure 4.
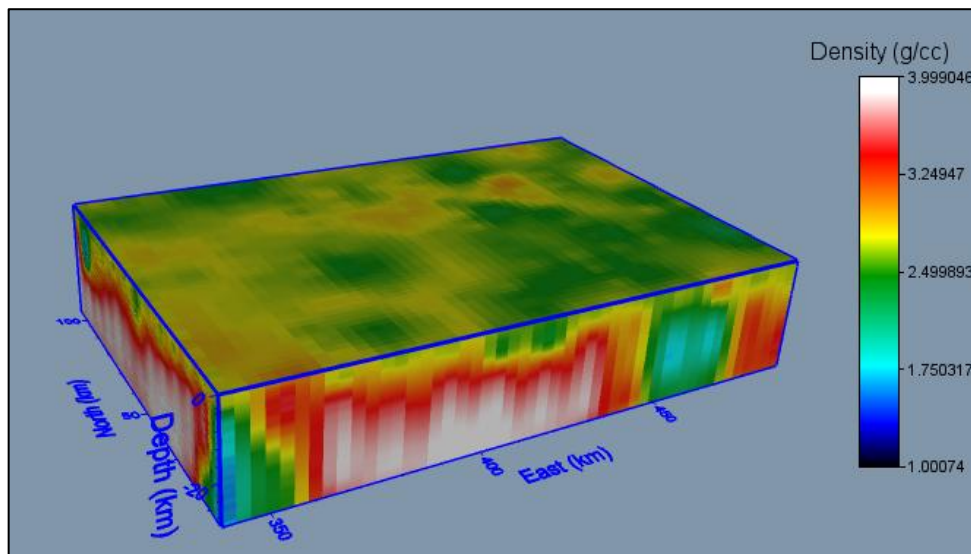
Figure 4 Model cross section of the surface of the Sanggau sheet.

Sandstone density has a range between 1.6-2.81 g/cc indicated by the green volume. However, to determine the volume of sandstone by evenly descending, it obtained 2.35 g/cc. Sand volume density of 2.35 g/cc is estimated to be 417251.3314 ≤Volume isovalue ≤ 50892.19384 km³ is predicted to form the Kayan Plateau, Lowland Mungle and Kapuas Lowland is shown in Figure 5.
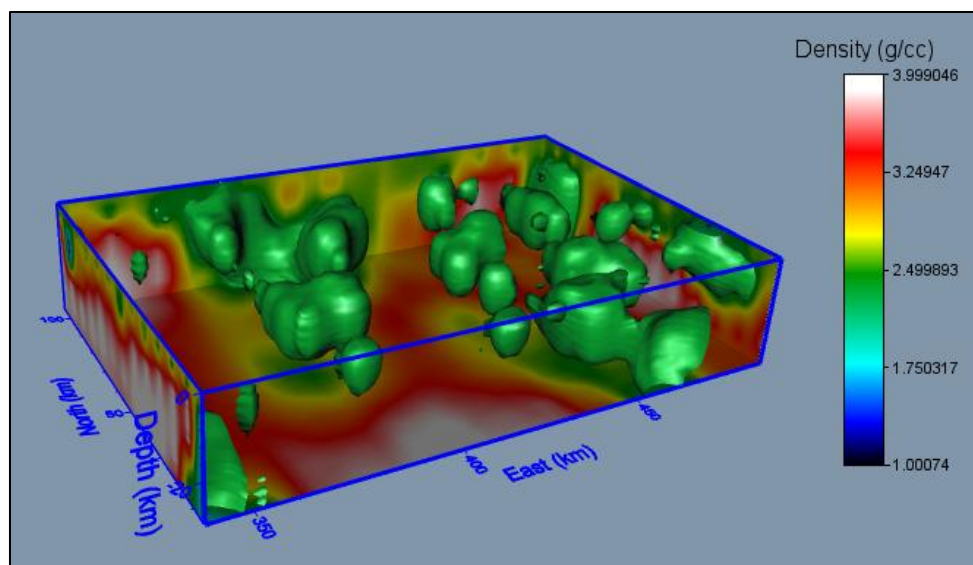

Figure 5. Volumetric sandstone 3D models.

4. Conclusions

Anomaly bouguer show low anomaly between -83.5 mGal to 184 mGal in the north and south of map, middle anomaly between 184 mGal to 315 mGal in the middle of the map, high anomaly has values between 346.5 mGal to 544.7 mGal in North-East. Spectral analysis have result of the regional depth 30.381 km. Invers modelling 3D has result the model that have RMS 0.063 and 0.02. Invers modelling 3D shown large thickness of sandstone with density 2.35 g/cc at Kayan High Land, Ketungau Low Land, and Kapuas Low land, that potential for hydrocarbon. Volume sandstone on Sanggau is predicted about ≤ 50892.19384 km³. The result of the model give preliminary information of model concept on estimated potential hydrocarbon.

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