PROCEEDINGS, 13th Indonesia International GEOTHERMAL Convention & Exhibition 2013
Assembly Hall - Jakarta Convention Center Indonesia, June 12 – 14, 2013

GEOLOGICAL STRUCTUR MAPPING USING DERIVATIVE OF GRAVITY ANOMALY

Muhammad Imaduddin[1], Suryantini[2], Prihadi Sumintadiredja[2]

[1] Magister of Geothermal Engineering, Institut Teknologi Bandung
[2] Geology Departement, Institut Teknologi Bandung

e-mail: m.imaduddin@gmail.com

ABSTRACT

Existences of the structure's plane hardly determined qualitatively with contrast of Bougeur anomaly (CBA). The problem is to determine representatively range of the anomaly values which can present the contact area using variation of anomalies.
Derivation of gravity anomaly in spatial dimension can be used to map the distribution of contact area without knowing difference of body's density quantitatively. First Horizontal Derivative (*FHD*) will indicate the presence of the contact area at the maximum or minimum value. First Vertical Derivative (*FVD*) and Second Vertical Derivative (*SVD*) will indicate the presence of the contact area at the transition zone of the maximum and minimum values, around zeros.
The combination of structures zone from two types of gravity anomaly derivatives expected to map the existence of the geological structure.
Keyword: structure, gravity, derivative, horizontal, vertical.

INTRODUCTION

The interpretation of geological structures by using Bougeur, regional, and residual anomalies still have ambiguity. Other methods can be used to detect geology structure is gradient or derivative of Bougeur Anomaly. Gradient method in the analysis of the structure are First Horizontal Derivative (*FHD*), First Vertical Derivative (*FVD*), and the Second Vertical Derivative (*SVD*).
In this study we want to represent the usefull of gravity derivation in geological structure mapping.

REGIONAL-RESIDUAL ANOMALY

Bouguer anomaly is a superposition anomaly of regional and local anomalies. Regional anomalies dominantly correspond with the general geological conditions in the relevant area. It is characterized by low-frequency anomalies. Residual anomaly correspond with local geological conditions information which has been separated from its regional conditions that contain high frequency anomalies. Anomalies that need to be separated to obtain the anomaly which is associated with the geological conditions (Figure 1).

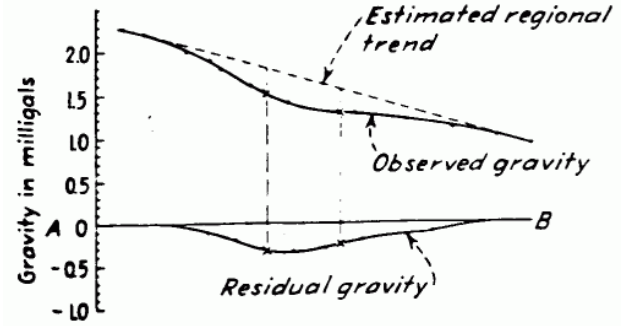

Figure 1 : Profile's illustration of residual anomaly separated from Bougeur anomaly by regional anomaly trend orde 1st.

In 2-dimensional case, the separation of residual anomaly can be solved as a simple illustration above. Complete Bougeur anomaly map is obtained from observed gravity data corrected by theoretical gravity data (Figure 2). The next image shows an example of the residual anomaly separation Bougeur anomalies using regional anomalies (Figure 4).

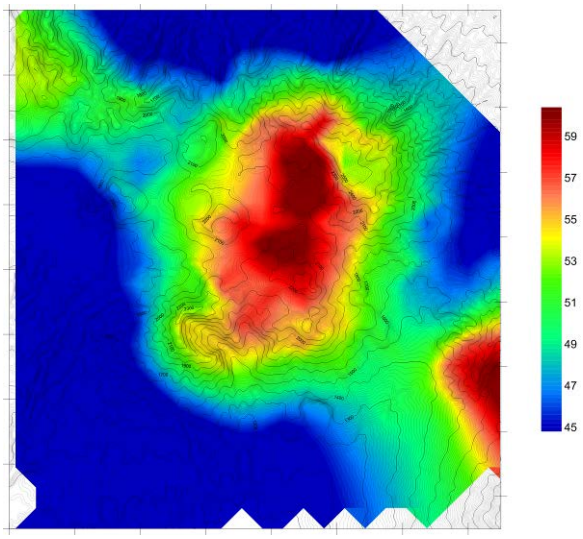

Figure 2: Complete Bougeur anomaly map.

High anomaly presence in the center of map which can be caused by intrusion. Contour pattern shown caldera closure as margin of high anomaly (Figure 2). Generated regional anomaly map (Figure 3) proves the intrusion is dome-shape covers in the middle of caldera closure.

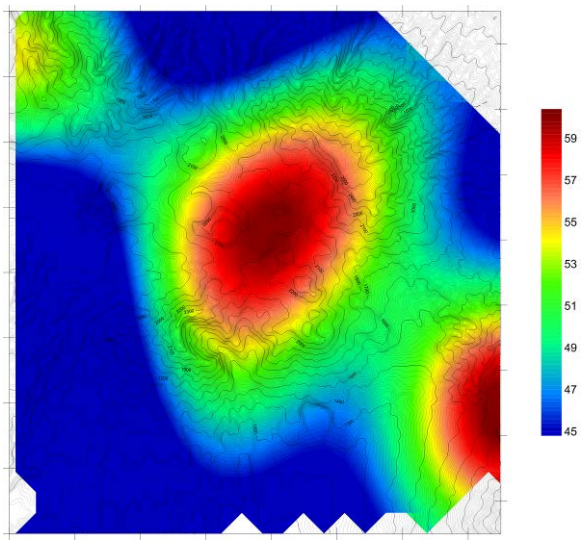

Figure 3: Regional anomaly map extract from bougeur anomaly using low pass filtering.

Residual anomaly map (Figure 4) shows low anomaly at the center of map. This anomaly is obtained by reduction of high anomaly of regional map. Low anomaly indicated geothermal reservoir zone. It is known that reservoir area have lower density than surrounding rocks.

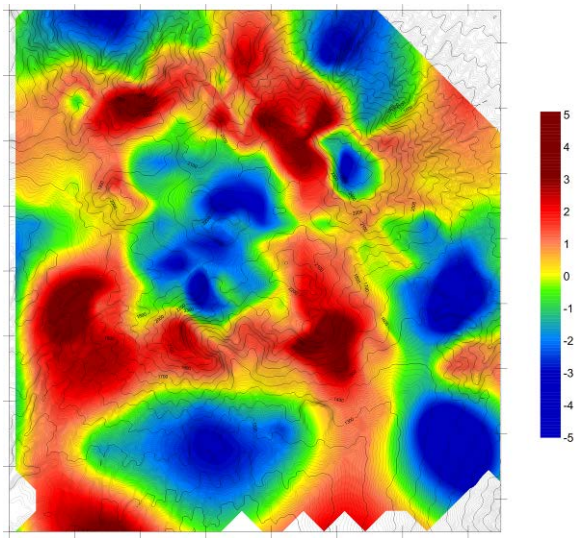

Figure 4: residual anomaly map extract from bougeur anomaly map (Figure 2) reduced by regional anomaly map (Figure 3).

DERIVATIVE OF BOUGEUR ANOMALY

Forward modeling using Geomodel (freeware) can generate the respons of *(a)* residual anomaly, *(b)* First Horizontal Derivative (*FHD*), and *(c)* First Vertical Derivative (*FVD*) from *(d)* possible geological structure with differences of body's contrast density.
Generated respons for reverse fault model shown in Figure 5 and Figure 6. Other model is normal fault model and its respons in Figure 7 and Figure 8.
Residual anomaly (Figure 5-a and Figure 7-a)is a respon which is obtain from the existing model(Figure 5-d and Figure 7-d). The respons is a function of distance from surface to the anomalies body which is subsurface located.
First horizontal derivative (*FHD*) indicate a magnitude's change of residual anomaly as a function of lateral distance. Maximum or minimum value of *FHD* indicate the existing of geological structure plane (Figure 5-b and Figure 7-b). In 2-dimensional case, *FHD* map is extracted from CBA map using gradient function.
First vertical derivative (*FVD*) indicate a magnitude's change of residual anomaly as a function of vertical distance. Real *FVD* measured at same position with different elevation. FVD indicate the existing of geological structure plane around zeros value.
In same case Second Vertical Derivative (*SVD*) also indicate the same pattern with *FVD*. Difference between *FVD* and *SVD* is absolute maximum and minimum value of *SVD* is higher than *FVD*. Therefore, *SVD* easily indicate fault type than *FVD* (Table 1). In 2-dimensional case, *FVD* and *SVD* can be approximated using horizontal derivative, even real *FVD* didn't acquired.

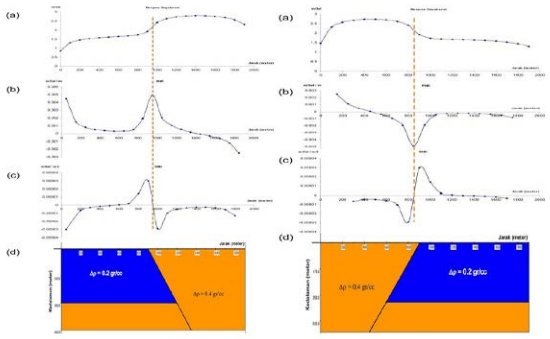

Figure 5 : (a) residual gravity anomaly, (b) FHD, (c) FHD generated from (d) reverse fault model

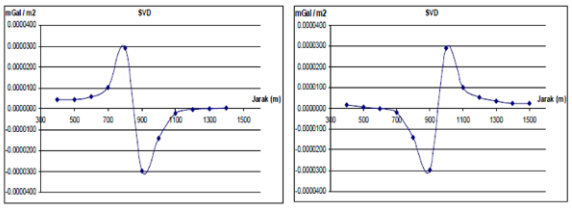

Figure 6 : SVD from Figure 5(d)

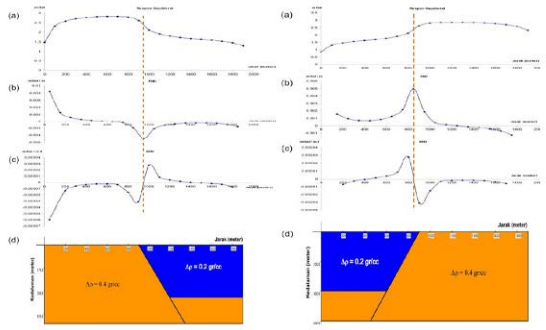

Figure 7 : (a) residual gravity anomaly, (b) FHD, (c) FHD generated from (d) normal fault model

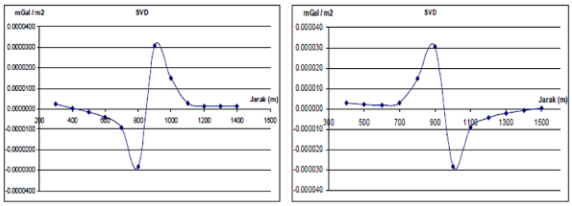

Figure 8 : SVD from Figure 7 (d)

Table 1 : relationship between fault type and gravity derivative application.

Fault type	Plane position		Indicator
	FHD	*FVD*	*SVD*
reverse	Max / Min	zero	|maks|<|min|
normal	Max / Min	zero	|maks|>|min|

Maximum and minimum lineament pattern at *FHD* map (Figure 9) indicate an existances of geological structure. This lineament also being cross-checked with zeros lineament on *FVD* map (Figure 10). If both of these condition are true, then the existences of geological structures are considered valid. A valid geological structure from both maps shown with black line on both maps.

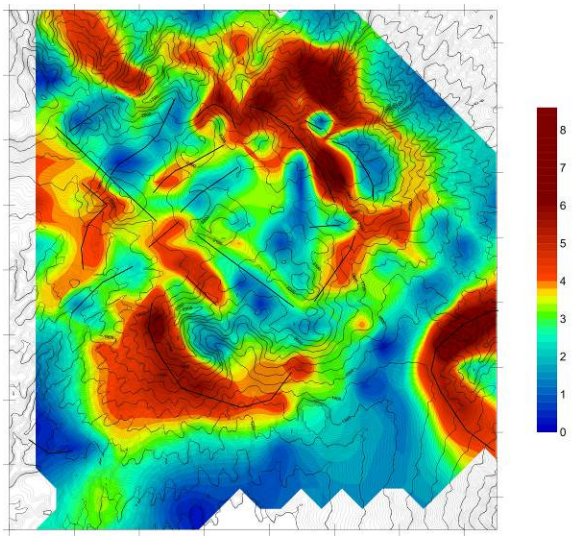

Figure 9 : FHD Map extracted from complete Bouguer Anomaly map (Figure 2)

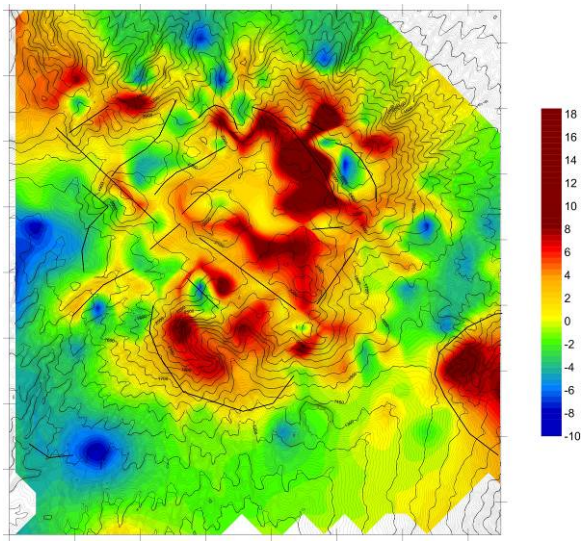

Figure 10 : FVD Map extracted from complete Bouguer Anomaly map (Figure 2)

In SVD map, Distribution of absolute maximum value are higher than absolute minimum value (Figure 11). Thus, at this area normal fault are dominantly exist. Simply, the slope of geological structure trend to maximum value.

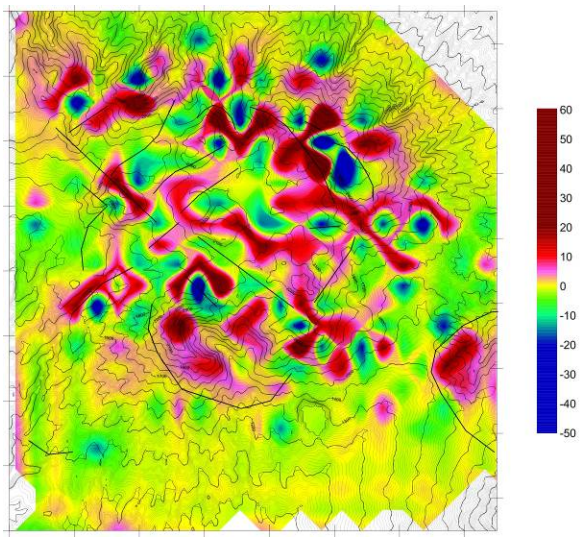

Figure 11 SVD Map extracted from complete Bouguer Anomaly map (Figure 2)

VALIDATING USING TOPOGRAPHY, STRATIGRAPHY UNIT ANALYSIS AND MAGNETOTELLURIC

Topography map also can indicate the existence of geological structure (Figure 12). Valley or river, contour shifting, and caldera rim are indicator of geological structure at the surface. Lineament pattern from ridges and river shown also indicate of volcanostratigraphy unit which is usually bound by dendritic river's pattern. Matching geological structures as an outcome from gravity derivative analysis found at some feature in topography map. A caldera rim at north and south side is located right on arch-shaped structure. The other lineament also found right on valleys and contour shifting feature. Some lineaments also found right on contact of volcano-stratigraphy unit. Volcano-stratigraphy unit shown by green lines (Figure 13) and white lines (Figure 15 and Figure 15).

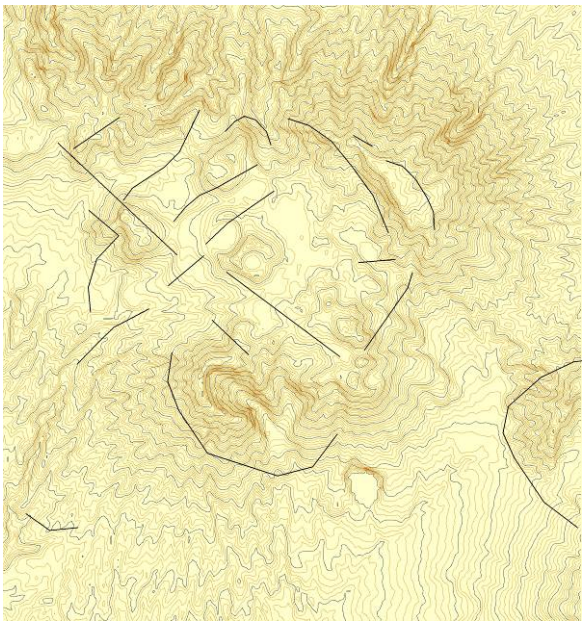

Figure 12 : Topography map and interpreted geological structure (black lines) as an outcome from gravity derivative analysis.

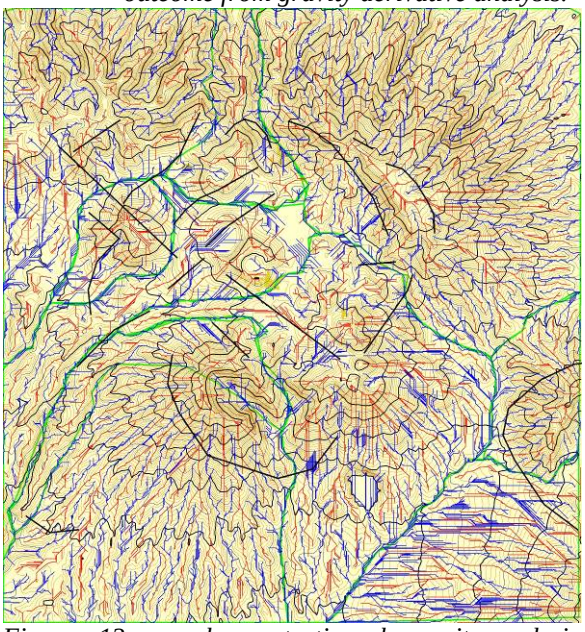

Figure 13 : volcano-stratigraphy unit analysis generated from topography map

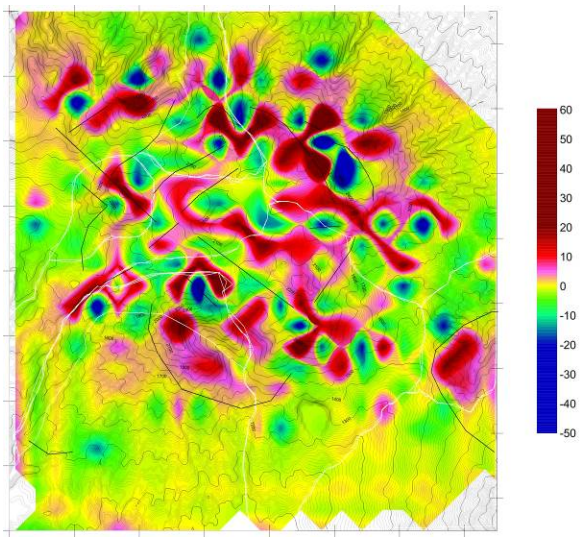

Figure 14 : Integrated structure interpreted with volcano-strahtigraphy unit analysis

Another data which can be used to validate geological structure is isodepth resistivity map which is sliced from magnetotelluric model.at 500 meter below sea level (Figure 15). An arch-shaped structure are exactly located at contrast of high resistivity at north or low resistivity at south with medium resistivity range (10 ohm-meter). A lineaments also separate high or low resistivity body. Identical separated body indicate an existence of fault.

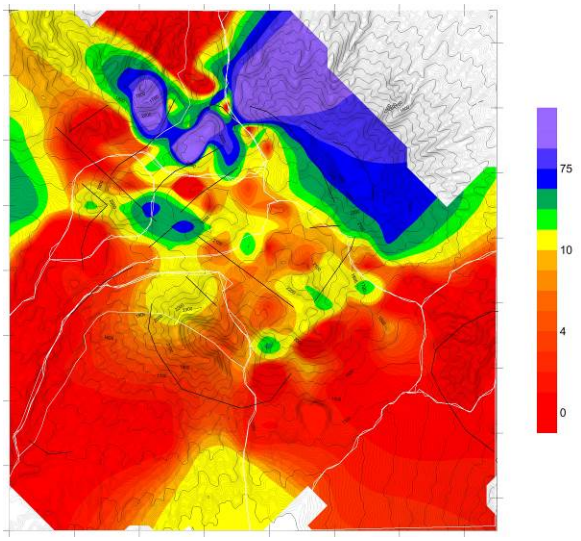

Figure 15 : Integrated Integrated structure interpreted with volcano-strahtigraphy unit analysis and isodepth magnetotelluric -500 mdpl

SUMMARY

A combination of maximum value on *FHD* map and zero value on *FVD* map can obtain an existence of geological structures. If a geological structure is a fault, fault types, reverse fault or normal fault, can be determined by *SVD* map.