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STRIPPING FILTER IMPLEMENTATION FOR INTERPRETATION TIME-LAPSE MICROGRAVITY DATA KAMOJANG FIELD 2006-2007

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ABSTRACT

Filter stripping equation were derived from a prims model that was developed from Cordell's (1985) and Aina's (1994) equations. Simulation of synthetic data at filter stripping uses parameters of a model giving a large error. Therefore, filter stripping needs to be modified. The modification is done by adding a weighted factor (Ω) in the filter stripping equation. Weighted factor (Ω) range from 0.3 -0.7 related to complexity of object model. Growing complicated object model then weighted factor value getting smaller, and also do on contrary. Result show the addition of weighted factor can reduce error to 20-50%.

Implementation stripping filter can separate microgravity anomalies as a result of reservoir mass deficit due to exploiting of vapor and or addition of reservoir mass from geothermal injection wells from gravity anomaly as result of lowering of water table. Deficit district (dry-out) is show by negative microgravity time-lapse anomaly (-) and addition mass of injection water at reservoir (recharge) is show by positive microgravity time-lapse anomaly (+). Negative microgravity time-lapse anomaly is represented as negative change of density anomaly (-) and positive microgravity time-lapse anomaly (+) is as positive change of density.

Based on time-lapse anomaly microgravity maps between period of July 07 to June 06, negative concentration anomaly locates in western field that is around rim structures. This can be related to activity of production wells in the area. Based on 3D cross section map at depth of 1100 m (+400 m asl), this area is represented by negative density from – 0.02 up to – 0.04 gram/cm^3. This also proves that injection amounts through injection well in the area is not effective. Positive anomaly is represented by accumulation of injection water from injection well and or accumulation of water meteoric flowing through faults.

INTRODUCTION

In general, estimates and residual anomaly separation and regional anomalies in the gravity method is divided into four approaches. First, the graphical approach, is the simplest method, which regional trend anomalies manually drawn from the profile data. The second, least-squares fitting by using a low-order polynomial of the observational data. Approach to applying a digital filter-3 on observational data for the gravity anomaly separate wavelength (λ) associated with the field length of the regional gravity anomaly with a short wavelength. The approach to the stripping-4 is a method. This method uses a very different approach than the three previous methods, which are based on detailed geological knowledge of the field of research in detail. Geologic unit known to be calculated and deducted against gravity field observation data. This method was first used by Hammer (1963). Then filtering stripping developed by Cordell (1985), further lowered by other methods by Aina (1994) and used with 3D inversion approach by Li and Oldenburg (1998).

If the shallow and deep sources produce wavelengths overlapping (overlapping), then filtering based on the wavelength (λ) will not be effective. Something like this happened in the case of geothermal field monitoring. Gravity anomaly due to shallow sources (groundwater lowering) produces long wavelengths, while gravity anomaly due to deep source (mass change in reservoir) produces short wavelength. This study offers a filtering solution with a modified method of stripping to separate time-lapse gravity anomaly between shallow sources and deep sources in the geothermal field monitoring.

METHODS OVERVIEW

Time-lapse microgravity has been used as one of the monitoring techniques in the geothermal field. Gravity measurements performed repeatedly with a period of time, so-called time-lapse microgravity. This method is based on the phenomenon of density changes caused by exploitation of the masses and injection in geothermal reservoirs.

Thus, time-lapse anomaly is the difference between the value of gravity within a certain time period, as in Equation (1).

$$\Delta g(x,y,z,\Delta t) = g(x,y,z,t2) - g(x,y,z,t1) \qquad (1)$$

The difference is the value of gravity as an indication of density changes that occur over a period of time (t2-t1) specific. Positive anomaly indicates the addition of fluid density due to the addition of a rock, and otherwise negative anomaly indicates a reduction in density due to the fluid that comes out of the rock is due to exploitation.

Source of the anomaly can be highly variable and overlapping. Where, the measured surface gravity anomaly is a super-position of the source of these anomalies. To calculate the gravity anomaly due to the source of the anomaly, the filtering is the ultimate solution.

Filter Stripping and Modification

Stripping approach was first used by Hummer (1963) to improve the interpretation of gravity data by utilizing the concept of old and new geological information from the new drill data by reducing the gravity anomalies of the layers that are not desirable to raise the target anomaly.

In 1985, Cordell through layers of equivalent Green (Green's equivalent layer) cut a filter in the wave number domain for separating potential field anomalies shallow sources and deep sources. A filter operation stripping for shallow source anomalies expressed as follows:

$$G_s(k) = F(k).G(k) \qquad (2)$$

where Gs (k) is the Fourier transform result of the anomalous shallow source, G (k) is the Fourier transform result of the anomalous total source and S (k) is the filter stripping. Cordell (1985) gives the form of filter stripping as follows:

$$F(k) = 1/[1+ \alpha\exp(-2\pi|k|\xi)] \qquad (3)$$

where α is the contrast ratio of the physical properties average (density or susceptibility) of the deep source to the shallow source, k is the wave number and ξ is the vertical distance between the deep source and the shallows source.

Furthermore, Aina (1994) formulate Cordell stripping filter for vertical gradient magnetic anomalies to the model dike and stated as follows:

$$F(k) = 1/[1+ W.\ B(k).\alpha \exp(-2\pi|k|\xi] \qquad (4)$$

a shape similar to the filter essentially stripping Cordell with additional functions B (k) is the function of the ratio of the thickness and lateral boundaries of the deep to the shallow source.

Simulation filtering using formula Aina (1994) subsequently realized on synthetic models. The use of filter stripping Aina (1994) it still gives an error filtering large enough. So modified filtering stripping then done. Modifications gave with the weighting factor (Ω) in the numerator equation Aina (1994). So the equation (4) becomes:

$$F(k) = 1/[1 + \Omega.A.B(k)\exp(-2\pi|k|\xi)] \qquad (5)$$

where $A = \dfrac{\rho_d}{\rho_s}$, $B = \dfrac{1-e^{-kt_d}}{1-e^{-kt_s}}$, $\xi = h_{td} - h_{ts}$ dan $k = (u^2+v^2)^{1/2}$

Weighting factor (Ω) is right for a particular model can improve filtering a very significant error. Modification filtering stripping the weighting factor (Ω) aims to optimize the separation of the target response gravity anomaly from the total anomalies. The test sensitivity parameters stripping filter (A, B, and ξ) the results of the error filtering and weighting factor (Ω) is done for each object model.

RESULTS AND DISCUSIONS

From the test results it can be concluded that the stripping filter modified with the addition of weighting factor (Ω) on the parameters A and B show a more optimal filtering stripping. Weighting factor (Ω) range from 0.3 - 0.7, dealing with the complexity of the model objects. The modification is done by adding a weighted factor (Ω) in the filter stripping equation. Weighted factor (Ω) range from 0.3 -0.7 related to complexity of object model. Growing complicated object model then weighted factor value getting smaller, and also do on contrary. Result show the addition of weighted factor can reduce error to 20-50% (Zaenudin, 2009a, 2009b).

Furthermore, stripping filter will be used to separate time-lapse microgravity anomalies due to shallow anomaly with deep anomaly from the total anomaly in geothermal field monitoring. Shallow anomly caused groundwater lowering (in unconfined aquifers) and deep anomalies caused by the addition or subtraction of the mass of the geothermal reservoir. Stripping filtering results are expected to maximize the appearance of the deep anomalies in the target analysis.

Filtering Stripping Implementation on Time-Lapse Microgravity Kamojang 2006-2007

To minimize time-lapse microgravity anomalies due to groundwater lowering, filtering stripping do to the total time-lapse microgravity anomaly, so the rest is time-lapse microgravity anomalous due to changes in the mass of the geothermal reservoir. Filtering parameters extracted from parameter Kamojang field for each measurement period, in which the parameters of the shallow anomaly sources: changes in the shallow aquifer layer thickness (ts) is estimated from the change in water table of groundwater, which is calculated from local rainfall. The addition of groundwater causes positive changes in density and conversely groundwater lowering causes negative density changes.

Based on the literature review and measurement of the wells, unconfined groundwater depth average in Kamojang field is 5-10 m. Based on the calculation of the relationship between rainfall and groundwater lowering, groundwater was found that the change in period of July 2007-June 2006 amounted to +0.40 m. Changes density in shallow aquifer ($\Delta\rho s$) due to reduction in groundwater mass is multiplication of fluid density rock with the porosity of the rock layers. With density water 1 gr/cm3 and porosity sandstone or volcanic lake sediment 30%, the change in density due to the addition or subtraction shallow groundwater is 0.30 gr/cm3.

Changes in the density of reservoir is multiplying density mass of fluid in the reservoir with the porosity. With the density of reservoir fluids is 0.26 gram/cm3 and the average reservoir porosity is 7%, the change in the density reservoir is 0.02 gram/cm3. The size reduction of groundwater models is 5.25 km x 6 km and area model of mass reduction on geothermal reservoir at 3.75 km x 4 km. The size of reduction groundwater lowering greather than mass reduction in the reservoir. In addition to the reservoir mass reduction is localy, because mass reduction occurs in production wells in vapor-dominated geothermal systems (vapor-dominated) more 'heat pipe' is vertically upwards rather than horizontally.

Filtering time-lapse microgravity anomaly between the time period of July 2007-June 2006 allegedly by stripping filter parameters as follows: ρd = -0.02 gr/cm3; ρs = +0.30 gr/cm3; hd = 700 m, hs = 5 m ; td = 200 m, ts = +0.40 m. Based on the analysis of the subsurface anomaly sources, for the period, an anomalous object layers with shallow groundwater level rise (ts = +) due to the addition of groundwater due to seasonal, resulting in a positive change in the density (ρs = +).

The deeping layer consists of two distribution source of the anomaly, the positive anomalies in the South, a negative anomaly in the middle of the field and the North field. Filtering is done separately. Of these parameters is the amplitude spectrum stripping filter. Weighting factor (Ω) used in the northern part of the southern section 0.4 and 0.6.

Figure 1 shows the time-lapse microgravity anomaly in the time period June 2006-July 2007.

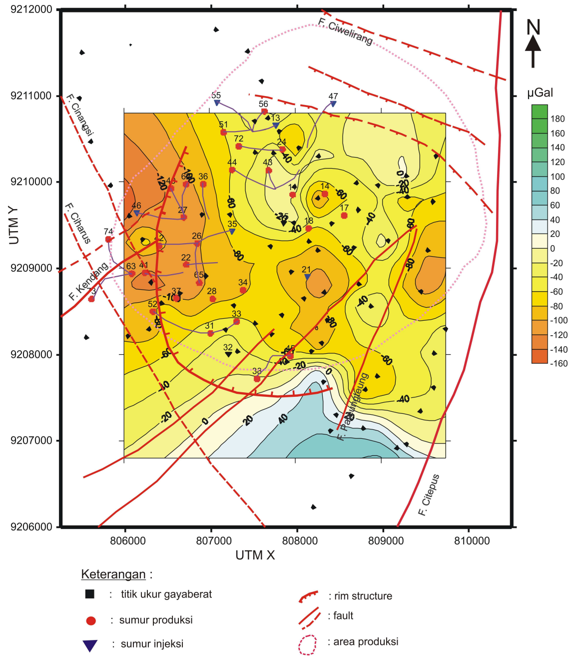

Figure 1 : Time-lapse microgravity Kamojang period July 2007-June 2006 period

Figure 2 shows time-lapse microgravity June 2006-July 2007 after filtering. Anomaly in the dominance of negative anomalies. Only the southern part of the field who have a positive anomaly.

Time-lapse microgravity anomaly between July 2007 - June 2006 had a negative value greater than earlier periods, presumably because this period has the longest period (12 months). Greater negative anomaly illustrates that more mass reduction for a longer period of time. The addition of mass through injection wells KMJ-35 and KMJ-46 in the western part of the field has not been effectively offset the reduction in mass. Likewise, the activity of reinjection in the North through injection wells KMJ-13, KMJ-47 and KMJ-55 has not been able to reduce the mass deficit. In the middle of the field activities reinjection through injection wells KMJ-21 has not been effective in reducing the deficit, causing the mass of negative anomalies -70 μGal.

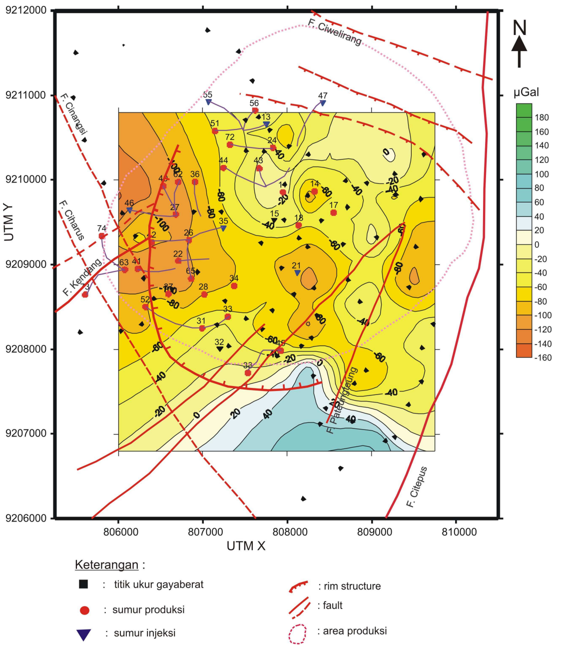

Figure 2: Map of anomalous geothermal reservoir over time-lapse microgravity Kamojang period July 2007-June 2006 results filtering

This anomaly is also due KMJ-21 injection wells are injection wells, so the addition of a measured mass of the surface is relatively small.

CONCLUSIONS

1. Mathematical modeling and simulation stripping filtering where the filter parameters using the parameters of the object model, showed considerable filtering errors. Modified by the addition of weighting factor (Ω) on the parameters A and B show a more optimal filtering.
2. Value weighting factor (Ω) best between 0.3 to 0.7. Weighting factor can reduce errors (error) filtering of 20% -50%, where the error estimate of the parameters A and B on the results of filtering larger than ξ parameter estimation errors.
3. The results of the implementation of filtering stripping can reduce gravity anomaly due to changes groundwater. Time-lapse microgravity anomaly filtering results for the period Juli'07-Juni'06 showed large negative anomaly (-80 μGal) which is adjacent to West-field around the rim structure, thought to be related to the activity of production wells with large production capacity (70.16 kg / s).
4. Inversion results show a negative density change with ranging from -0.02 to -0.04 gram/cm3 in the West, shows the mass reduction of the reservoir at a depth of 1100 m. It is proved that the number of injections in the area is less effective. Changes density positive showed accumulation of fluid into the reservoir through injection wells and faults in the field.

REFERENCES

Aina, A. (1994) : A simple of Cordell's stripping filter, *Geophysics*, 59, 488-490.

Cordell, L. (1985) : A stripping filter for potential-field data, 55th Annual International Meeting, *SEG, Expanded Abstracts*, 217-218.

Hammer, S. (1963) : Deep gravity interpretation by stripping, *Geophysics*, 28, 369-378.

Li, Y. dan D.W. Oldenburg (1998) : Separation of regional and residual magnetic field data, *Geophysics*, 63, 431-439.

Zaenudin, A., (2009 a) : Filter Stripping yang Dimodifikasi untuk Pemisahan Anomali Gayaberatmikro Antar Waktu Akibat Penurunan Muka Air Tanah dan Perubahan Massa Reservoir, Studi Kasus Lapangan Panasbumi Kamojang, Disertasi, ITB, 2009.

Zaenudin, A., (2009 b) : Modifikasi Filter Stripping untuk Memisahkan Anomali Gayaberat Dangkal dan Dalam, Prosiding PIT HAGI 2009, p: 28-31, Yogyakarta 2009.