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COMBINATION OF SPECTRAL ANALYSIS AND MOVING AVERAGE METHOD TOWARD RESIDUAL GRAVITY ANOMALY PROFILE TO DETERMINE BASEMENT STRUCTURE

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ABSTRACT

Basement structure is one of gravity method's main target. It can be identified from residual gravity anomaly which is superposition of gravity respons from deep anomaly body, shallow anomaly body, and near surface anomaly body. Horizontally, residual gravity anomaly changes with distance and form a wave with certain amplitude and wavelength. Basement structure, which is deep and homogenous, has long wavelength and small amplitude. Its wavelength can be identified by using spectral analysis. Discrete fourier transform was applied toward residual gravity profile data. It produced numbers of spectral amplitude and wavenumber of anomalous bodies from various depth. Spectral amplitude natural logarithmic and wavenumber were plotted and analyzed to determine the basement spectral wavenumber. In general, those data graph formed three trends, which can be interpreted as previous anomalous body. The wavelength of basement structure is calculated from intersection between deep anomalous body and shallow anomalous body trend. Afterwards, the wavenumber was used to calculate number of points which will be used on moving average process toward residual gravity anomaly profile. Smoother residual gravity anomaly curve was produced and the smoothness was proportional to number of points, which were calculated from basement wavelength. Those methods were applied toward sintetic and real data. The application toward sintetic data obtained curve which has similar pattern to the gravity respon of its basement structure. As for real data, resistivity section of MT data was used to confirm the result. Smoothed curve of real data showed similar trend with deep high resistivity body, which is usually interpreted as basement structure.

INTRODUCTION

Basement structure is one of the most important targets in geothermal exploration. It can be identified by using residual gravity data. Because of the depth, basement in general has long wavelength gravity anomaly (Telford, 1989). It can be identified along a residual gravity anomaly data profile, since gravity data amplitude are varying toward distance.

Residual gravity anomaly is superposition of anomalous body response in different depth (Telford, 1989). Unlike basement gravity anomaly, it has shorter wavelength. Long wavelength of basement cannot be observed directly from it. It should be interpreted or generated by using a certain filter.

This paper discusses about method to generate long wavelength from residual anomaly data in order to determine basement gravity anomaly response. Wavelength of those basement gravity anomaly is calculated by using spectral analysis method. The wavelength then used to construct moving average filter.

GRAVITY DATA

Gravity data which are used were residual gravity anomaly along profile from synthetic and real data. The real data is combined with resistivity section. The data can be seen in figure 1, figure 2, and figure 3.

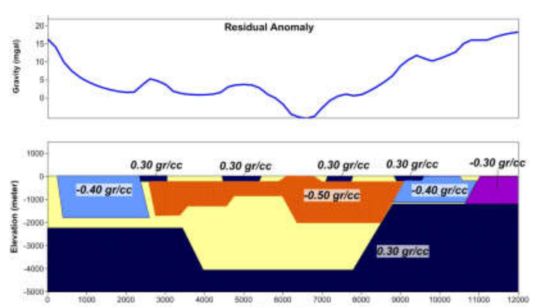

Figure 1: Synthetic model 1, derived from gravity 2D forward modeling

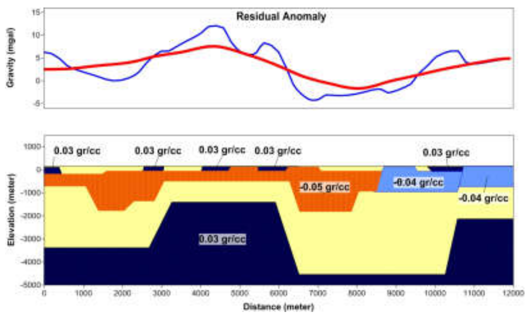

Figure 2: Syntheticmodel 2, derived from gravity 2D forward modeling

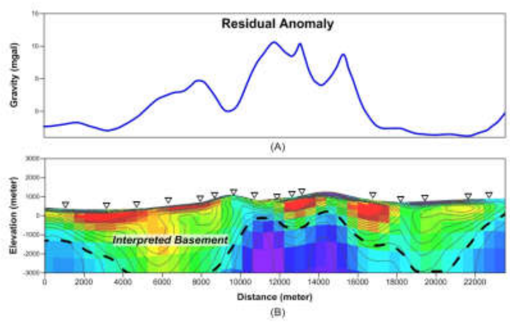

Figure 3: Residual gravity anomaly of real data (top) and resistivity section (bottom)

The synthetic data was constructed with the assortment of basement and several anomalous bodies on the top of it. The basement is the deepest body with 0.03 gr/cc density contrast. The first basement model is like a shape of a graben and the second model resemblance a horst followed by graben.

Residual gravity anomaly of real data in figure 3 is often led to misinterpretation since the curve trend not so similar compared to the high anomaly in resistivity section, which is in general interpreted as basement. For example, in distance 5000 to 8000 m, the high resistivity, which is interpreted as basement, shows descending trend, but the residual gravity data shows upside trend.

METHODS

The gravity profile data was processed by using two methods, spectral analysis and moving average.

Spectral Analysis

Spectral analysis has been widely applied to determine depth of anomalous body (Njandjock, 2006). It is done by analyzing a graphic representing power spectral versus wave number provides an estimation of the mean depth around which the sources are distributed (Moral, 2000). In most case, the graph could be distinguished as three segments, which were represented mean depth of anomalous body.

Power spectral and wave number were generated by using Discrete Fourier Transform (DFT) toward gravity data profile. Discrete fourier transform provide spectral amplitudes (Smith, 1999). The spectral amplitudes were converted into power spectral by converting it into its natural logarithmic number.

In spectral analysis of residual gravity anomaly profile, the regional segment is interpreted as power spectral of basement structure, since basement structure is the deepest anomalous body which is contained in residual gravity data. The wave number was then calculated from intersection of regional and residual segment. Furthermore, those wave number was converted to wavelength which would be used to construct moving average filter.

Moving Average Filter

Moving average filter construct output by averaging number of points of input data (Smith, 1999). Since the data were separated by a certain distance, number of points cover total distance which could be called as filter band. The filter band are adjusted so that they covered the wave number of the basement. The basement wavelength, which was obtained from spectral analysis, was divided by data distance to obtain number of points.

RESULTS AND ANALYZIS

Power spectral and wavelength graph from each model are shown at figure 3, figure 4, and figure 5.

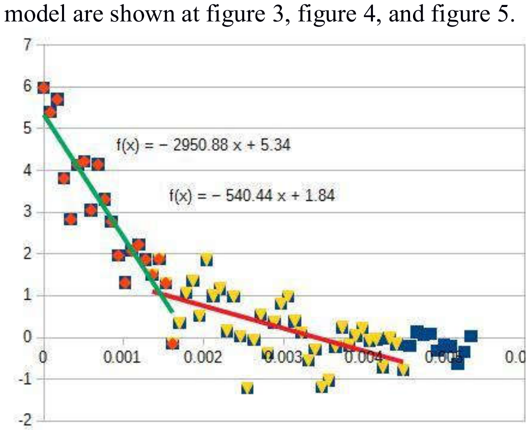

Figure 4: Power spectral vs wavelength of synthetic model 1

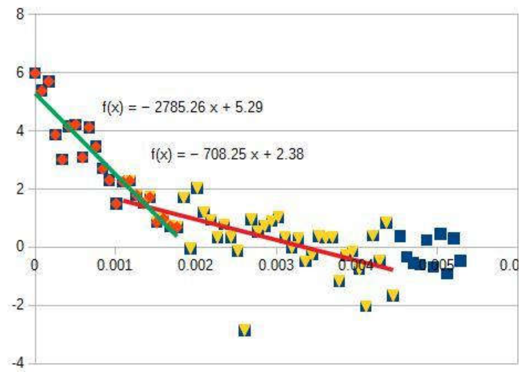

Figure 5: Power spectral vs wavelength of synthetic model 2

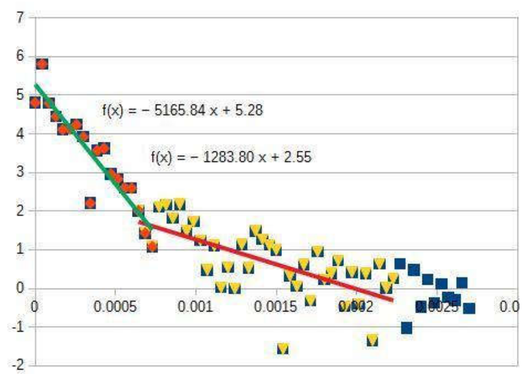

Figure 6: Power spectral vs wavelength of real data

Y axis represents power spectral and x axis represents wavenumber. In general, all of the graphs have three segments. The first segment from the left is interpreted as power spectral of basement structure. It has the largest gradient. The second one is interpreted as power spectral of anomalous body above it. Each segment trend line was calculated by using linear least square. Wave number of the basement is wave number value at intersection point of those trend line. The basement wavenumber of synthetic model 1 is 0.00145, synthetic model 2 is 0.0014, and real data is 0.00093.

Moving average result of synthetic model 1 can be seen in figure 2. The wavelength which is calculated from respective wave number is 4333.23 m and covered by 47 number of points. The result of moving average filter using 47 number of points toward synthetic model 1 is represented as red curve in figure 7 (B). It has long wavelength and have similar pattern with basement anomaly with correlation coefficient 0.967. The short wavelength of the data is reduced. For example, local peak of the data from distance 0 to 2000 meter. Its peak is considerably high, around 15 mgal and 1500 m wide, but it is reduced into around 5 mgal in accordance with regional wavelength.

Moving average result of synthetic model 2 can be seen at figure 8. The model basement wavelength is 4488 mand covered by 49 number of points. The result of moving average filter using 49 number of points is represented as red curve in figure 8 (B). The correlation coefficient between moving average curve and basement anomaly curve is 0.80. Undulations of gravity anomaly data are removed. The filter produces smooth data curve similar to

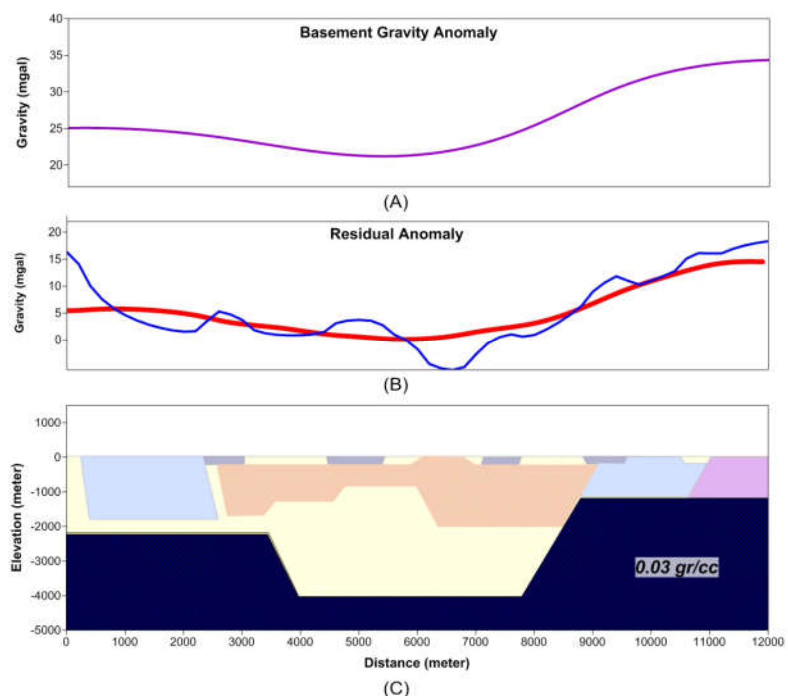

Figure 7: Moving average result of synthetic model 1 using 47 number of points. (A). Gravity anomaly of basement body with 0.03 gr/cc density. (B). Gravity anomaly of synthetic model 1 (blue curve) and moving average result (red curve). (C). Synthetic model 1.

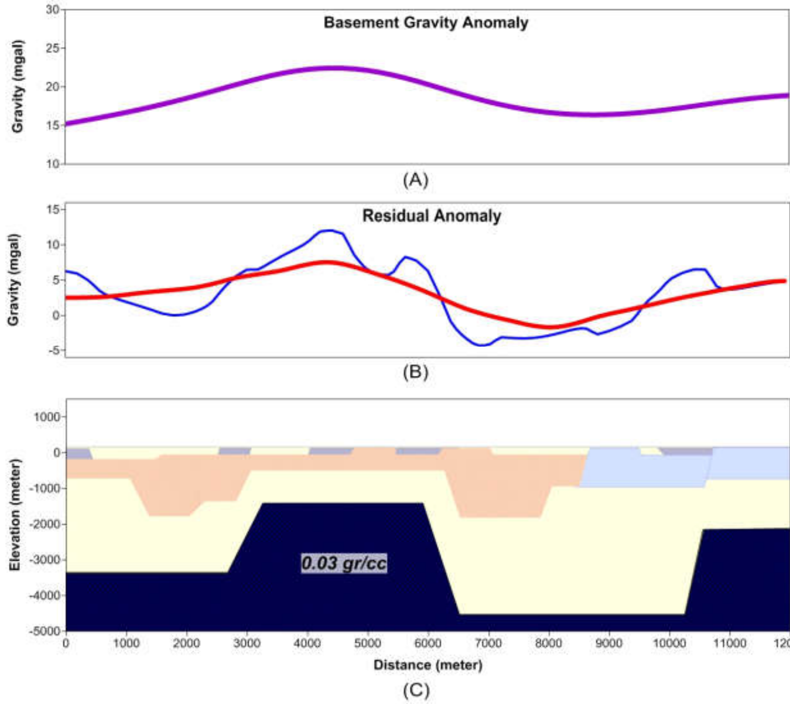

Figure 8: Moving average result of synthetic model 2 using 49 number of points. (A). Gravity anomaly of basement body with 0.03 gr/cc density. (B). Gravity anomaly of synthetic model2 (blue curve) and moving average result (red curve). (C). Synthetic model 2.

basement gravity anomaly curve. The most notable anomaly change is shown from distance 6000 m to 9000 m. The descending anomaly trend in gravity response is quite low amplitude and have long band, about 3000 m. But it is still reduced by the filter, so the output curve has higher amplitude and smoother anomaly. It is probably the descending trend of basement gravity anomaly descends even more was caused by low density anomalous body above it, so it was removed.

Moving average result of real data can be seen at figure 9. It is compared with resistivity section. Basement is interpreted from resistivity section, the structure with high resistivity. The interpreted basement is represented by dash line.

Basement wavelength value of the data is 6756.11 m and is covered by 37 number of points. The filter produces smooth curve which is represented by red curve in figure 9 (A). Interpreted basement of resistivity data is very undulating compared to moving average curve, since gravity anomaly of the basement should have long wavelength. The resistivity basement form like horst or intrusion structure in the middle of the section. Furthermore, the moving average curve shows similar pattern with the basement. When the basement has

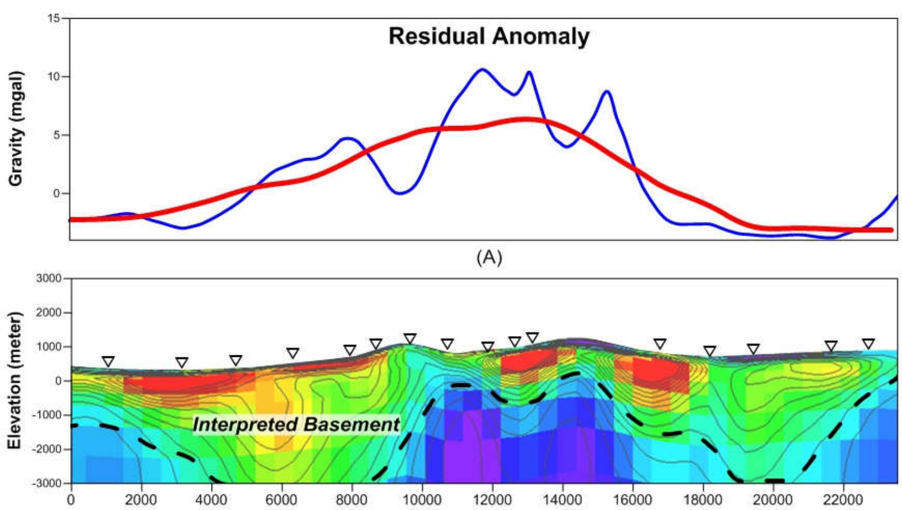

Figure 9: Moving average result of real data residual gravity anomaly using 37number of points compared to resistivity section. (A). Residual gravity anomaly of real data (blue curve) and moving average result (red curve). (B)Resistivity section of real data with interpreted basement (dash line).

ascending trend, the moving average also has the same pattern, unlike the residual gravity anomaly which show some differences in pattern toward basement structure. For example, at the distance of 5000 to 8000 m, the basement shows descending trend but the residual curve shows ascending trend. Moreover, at the distance of 8000 to 1100 m, the basement shows ascending trend but the residual curve shows descending trend. Those condition might cause misinterpretation of the data. All of those unsuitable trends were removed by corresponding filter.

All of the three models show good result, that curve which is produced by moving average filter show similar trend toward basement structure. It is possible that moving average filter pass the curve with equal or longer wavelength. Narrow undulation, even though it has large amplitude, will be reduced to the point where it is suitable toward desired trend.

Although filtered curve shows similar trend, they have different amplitude range. For example, in model 1, basement gravity anomaly hasamplitude range from 15 to 25 mgal, while moving average result have amplitude range from 1 to 15 mgal, same as with the residual data amplitude range. This is happened because moving average filter just smooth the curve not restore the superposition component. Residual gravity anomaly is the superposition of basement gravity anomaly which has high amplitude and other anomalous body which has lower amplitude. So, the residual gravity anomaly has obviously lower amplitude range compared to basement's.

CONCLUSIONS

Combination of spectral analysis and moving average data can produce curve which is similar to basement trend. It removes local undulation which might cause misinterpretation. Although it produces similar pattern, the moving average curve have different amplitude range compared to basement gravity anomaly curve.

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