

ESTIMATION OF SEDIMENTARY COVER THICKNESS BY USING SPECTRAL ANALYSIS OF GRAVITY ANOMALIES

Daariimaa Badarch, Baatarchuluun Tsermaa *

School of Arts and Sciences, National University of Mongolia, Ulaanbaatar Mongolia

ABSTRACT

In this paper, power spectrum analysis has been used for estimating the depth of geological interfaces. The computer code was tested for synthetic models and implemented to gravity survey data to estimate the thickness of sedimentary cover of several Meso-cenozoic basins of Mongolia. The depth estimation results of the basins' sedimentary cover were in good agreement with other prior geological and geophysical interpretation results of the study areas.

Keyword: Gravity anomaly; Power spectrum; Fast Fourier transform

*Corresponding author. Tel.: +976 9660 0446

E-mail address: baatarchuluun@num.edu.mn

1. Introduction

Power spectrum analysis is a powerful tool to estimate the mean depth of the geological interfaces considering the log of power of the Bouguer gravity anomaly spectrum as a function of wavenumber/frequency assuming uncorrelated rock density contrast of causative sources (Spector and Grant, 1970). It is particularly well suited to analysis of potential field maps and profiles. The spectrum of gravity anomaly due to layered source is separated into multiple line segments in wavenumber/frequency domain that can be interpreted in terms of mean depth of the interface.

The interpretation of the gravity and magnetic data is preferred in frequency domain because of simple relation between various source models and field. The estimation of the depth of anomalous sources is usually carried out by Spector and Grant (Spector and Grant, 1970) method and its variants in frequency domain (Bhattacharyya, 1966; Naidu, 1968; Spector and Grant 1970). B.K.Bhattacharyya (1977) and A.R.Bansal (2013) also studied and

interpreted the gravity anomalies of the area using rectangular prismatic bodies.

The estimation of sedimentary cover depth of continental basins is of interest for petroleum resources prospecting and exploration. In order to estimate depth of geological interfaces it is preferred using Fourier transform spectral analysis because there is simple relation between causative body parameters and potential fields.

In this paper, we have synthetically generated gravity anomaly of prismatic bodies with certain geometrical and physical parameters and numerically estimated the depth of the top and bottom interfaces of the bodies in order to assess viability of *the our subroutines which use two-dimensional Fourier transform and spectral analysis. The software has been utilized to evaluate the sedimentary cover thickness of the Uulbayan, Tuvshinshiree and Tamsag basins of Mongolia using Bouguer gravity anomaly maps of the areas. This spectral approach is based on the assumption* that interfaces are essentially horizontal with some small relief. The depth

estimation results of the basins' sedimentary cover were in good agreement with other prior geological and geophysical interpretation results of the study areas.

2.Methodology

Potential field anomaly due to subsurface geological objects contains indispensable information which will be the most important factor for geophysical interpretation process. Especially, potential field anomaly distribution caused by 3D prismatic bodies can be used as a representative of some subsurface geological structures. So, we've written computer codes to calculate gravity Bouguer anomaly distribution due to prismatic bodies with known geometrical and physical parameters. Assuming a group of prismatic sources distributed over the subsurface topography, the gravity power spectrum of the group of bodies

reveals a quasi-linear relationship between the wavenumber and the power spectral density. The spectrum of gravity anomaly due to layered source is separated into multiple line segments in wavenumber/frequency domain that can be interpreted in terms of mean depth of the interfaces.

Let us consider a prismatic body with vertical extent, as shown in Figure 1(a). The coordinates of the corners of the top surface are $(-a, -b, h_t)$, $(a, -b, h_t)$, (a, b, h_t) and $(-a, b, h_t)$. The horizontal dimensions of the body parallel to the x_0 and y_0 axes are $2a$ and $2b$, respectively.

The gravity effect at a point $(x_0, y_0, 0)$, due to the volume v_0 occupied by the prismatic body with a uniform distribution of density ρ , is given by

$$\Delta g(x_0, y_0, 0) = G\rho \int_{v_0} \frac{z}{[(x_0-x)^2+(y_0-y)^2+z^2]^{3/2}} dv_0 \tag{1}$$

The Fourier transform of $\Delta g(x_0, y_0, 0)$ is defined as

$$F_g(u, v) = \int_{-\infty}^{\infty} \int \Delta g(x_0, y_0, 0) e^{-i(ux_0+vy_0)} dx_0 dy_0 \tag{2}$$

where u and v are the angular frequencies in *radians/unit* spacing along x_0 and y_0 axes, respectively.

A combination of from Erdelyi et al. (1954) yields the following:

$$2\pi e^{-zk} = \int_{-\infty}^{\infty} \frac{z}{[x_0^2+y_0^2+z^2]^{3/2}} e^{-i(ux_0+vy_0)} dx_0 dy_0 \tag{3}$$

Where:

$$k^2 = u^2 + v^2$$

Now, with the help of equations (1) to (3), we have

$$F_g(u, v) = 2\pi G\rho \int_{v_0} e^{kz-iux_0-ivy_0} dv_0. \tag{4}$$

For the given prismatic body, we can now express (4) in the following form:

$$F_g(u, v) = -\frac{2\pi G\rho}{uvk} e^{-kh} [e^{-i(ua+vb)} - e^{-i(ua-vb)} - e^{-i(-ua+vb)} + e^{-i(-ua-vb)}] \tag{5}$$

In the case of a prism with vertical extent, let us assume the depths to the top and the bottom of the body to be h_t and h_b , respectively. Then, with the help of (5), we can write the Fourier transform $F'_g(u, v)$ of the gravity effect due to the body as

$$F'_g(u, v) = F_g(u, v)|_{h=h_t} - F_g(u, v)|_{h=h_b} \tag{6}$$

Let us now consider the power spectrum (i.e. the square of the Fourier amplitude spectrum) of the gravitational field intensity anomaly over single rectangular block (Spector and Grant, 1970).

$$P_{(k)} = |F_g(u, v)|^2 \tag{7}$$

Our calculation of is based on statistical methods of depth determination from the radial power spectrum of the gravitational field (Spector and Grant, 1970).

$$P(k) = C_1 e^{-2|k|h_t} (1 - e^{-(h_b-h_t)})^2 \quad (8)$$

Where C_1 is a constant. Equation (8) can be further simplified to compute the centroid depth h_0 of the gravity effect from the low wavenumber part of the power spectrum as

$$\ln\left(\frac{P(k)^{1/2}}{k}\right) = C_2 - |k|h_0 \quad (9)$$

Where \ln is natural logarithm and C_2 is a constant. Equation (7) is also simplified to compute the top of sources h_t by assuming that the signals from the sources tops dominate the power spectrum:

$$\ln(P(k)) = C_3 - 2|k|h_t \quad (10)$$

The centroid and depth to the may be related to the depth to the bottom of gravity bodies h_b as:

$$h_b = 2h_0 - h_t \quad (11)$$

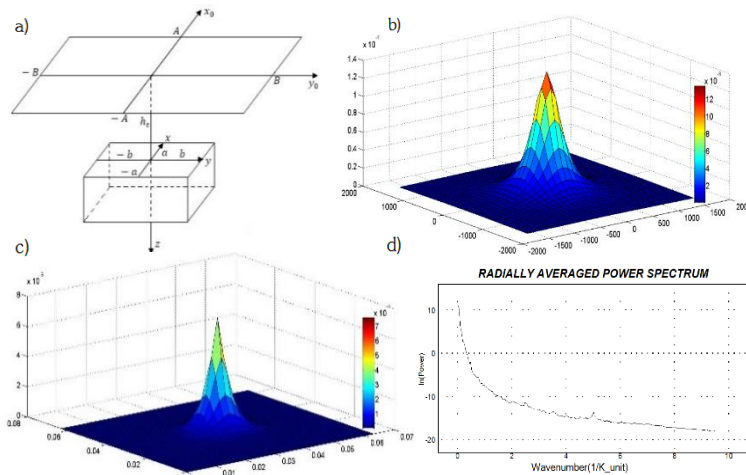


Fig. 1. a) A schematic of the causative prismatic body and the coordinate system, b) The gravity anomaly map, c) The Fast Fourier Transform of the gravity anomaly, d) Power spectrum of the gravity anomaly

The method discussed in the previous sections have been tested with both gravity anomalies due to various prismatic bodies. The gravity anomalies are computed on different geometrical parameters of causative prismatic body and the study areas using Eq. (1). Fourier transform of the anomaly had been done by Eqs. (2), (5) and the depth of top and bottom interfaces of the body were estimated from the

calculated power spectrum $P(k)$. In order to assure persuasiveness of the computer code we have presented the comparisons between the model depth parameters with that of calculation results in Table 1. According to the comparisons, the numerical estimation results of the depth were within the calculation error range to the initial model depth.

Table 1. Comparison between model parameters and numerical results

№	Study area dimensions, m		The depth to top interface of the model body, m	Numerical estimation results of the depth to top interface, m
	X	Y	h	h_t
1	3200	3200	50	49.1
2	3200	3200	100	102.2
3	3200	3200	150	150.3
4	3200	3200	250	250.1
5	3200	3200	300	303.4

The results shown in Table 1 proves that our computer code works well with the gravity anomaly maps from causative prismatic bodies to estimate the geometrical parameters of the model. Consequently, we've applied the code to the gravity anomaly data of some Mesozoic basins of eastern Mongolia (Uulbayan, Tuvshinshiree and Tamsag-Bayangovi basins) to evaluate the depth of interface between the sedimentary cover and the basement.

3. Results and Discussion

The study areas, Uulbayan, Tuvshinshiree and Tamsag basins, commonly expressed as a negative residual anomaly in the gravity maps (Fig. 2a, 3a, 4a).

According to the depth estimation, the sedimentary cover thickness of the Uulbayan basin was approximately 1.3 km. The sedimentary cover thickness was estimated as 1.4 km for the Tuvshinshiree basin. The two basins have similar geological conditions and that was reflected in the thickness estimation results.

For the Tamsag-Bayangovi basin's case, one of the deepest basins of Mongolia, the sedimentary cover thickness was estimated approximately 3.1 km and the result was in good agreement with other survey results including drillhole logging and geophysical interpretations.

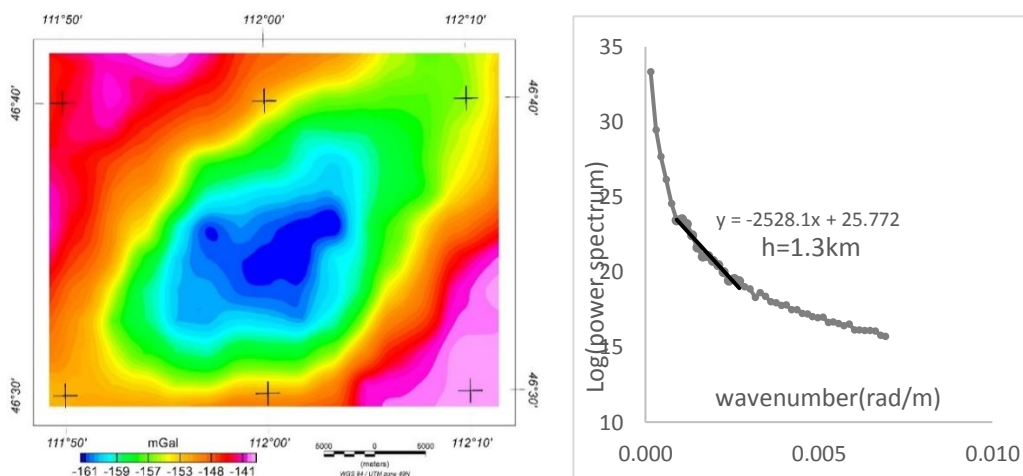


Fig. 2. a) Gravity anomaly map, b) Power spectrum versus wavenumbers for calculating depths, Uulbayan basin

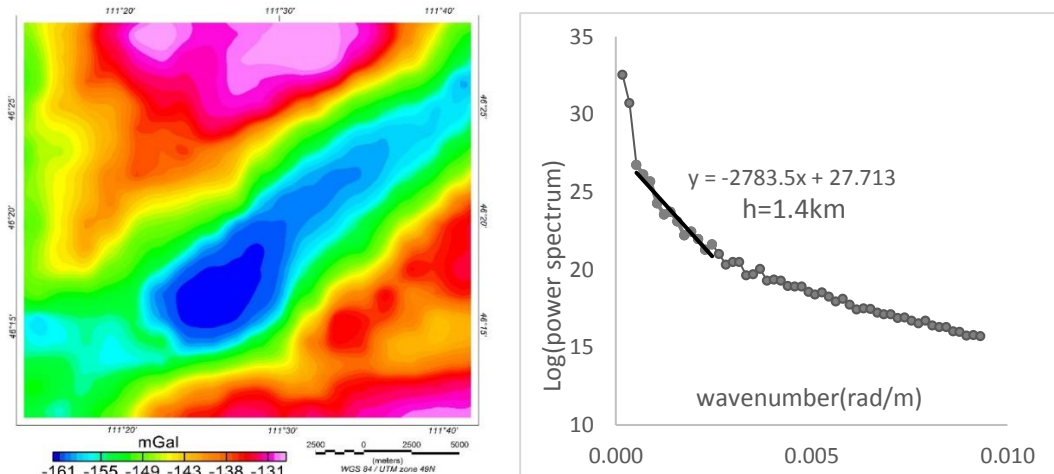


Fig. 3. a) Gravity anomaly map, b) Power spectrum versus wavenumbers for calculating depths, Tuvshinshiree basin

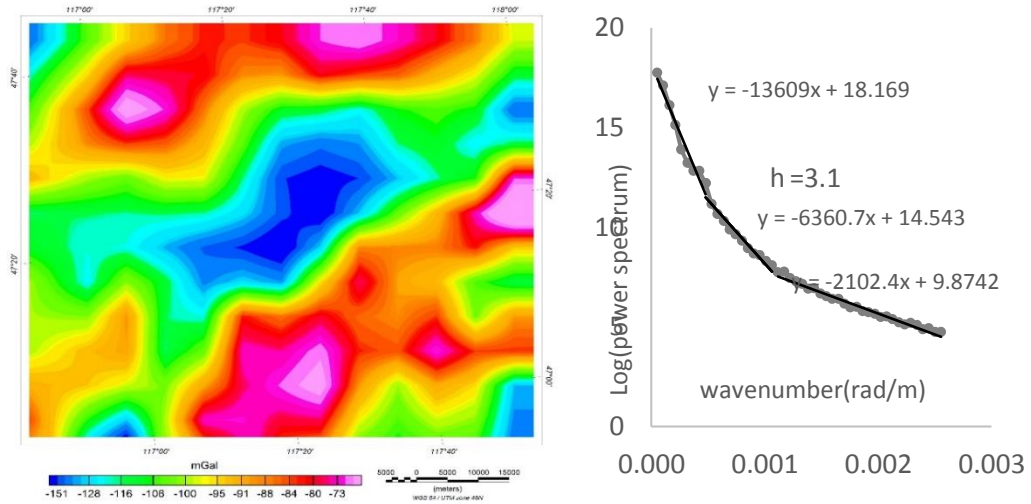


Fig. 4. a) Gravity anomaly map, b) Power spectrum versus wavenumbers for calculating top and bottom depths of the Tamsag-Bayangobi basin

4. Conclusion

Fourier transform spectral analysis is a powerful tool to estimate the mean depth of the geological interfaces using potential field data. The interpretation of the gravity and magnetic data is preferred in frequency domain because there is simple relation between various source models and field.

According to the depth estimation, the sedimentary cover thickness of the Uulbayan,

Tuvshinshiree and Tamsag-Bayangovi basins are 1.3 km, 1.4 km and 3.1 km, respectively.

The depth results were in good agreement with other survey results including drillhole logging and geophysical interpretations.

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