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Estimation of depth to the bottom of magnetic sources (DBMS) using modified centroid method from Aeromagnetic data of Central India

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Summary

The estimation of the depth to the bottom of magnetic sources (DBMS) from the aeromagnetic data is always a challenge. The conventional centroid method of depth estimation from magnetic data assumes random uniform uncorrelated distribution of sources and to overcome this limitation a modified centroid method based on fractal distribution has been proposed. We applied this new method to the aeromagnetic data of the Indian region and selected 29 overlapping blocks of dimension 200 km by 200km covering different parts of the central India. Shallower values of DBMS are found for the western and southern portion. The depths to the bottom of magnetic sources correlate well with other geophysical results in the region.

***Keywords**: Curie depth, aero-magnetic, Central India, Modified Central Method, Fractals*

Introduction

The internal sources of geomagnetic field mostly lie in crust and core because generally mantle behaves non- magnetic. The liquid outer core contributes a lot due to complex hydrodynamic processes and the associated magnetic field is known as main field (Blakely, 1995). The main field can be modeled by spherical harmonic analysis and removed as a regional field before analyzing the magnetic field. The residual field represents the magnetic field mainly due to the crust which contains information right from the surface of the crust up to a particular depth where the ferromagnetic minerals looses its magnetism, in certain conditions called as Curie depth. In this manuscript we prefer DBMS rather than Curie depth as these depth values may represent either a tectonic or a temperature boundary. If the DBMS represent a thermal boundary, it can provide information on the thermal structure of the Earth's crust, an important parameter to understand wide variety of geo-processes and rheological/rock-physics parameters in the crust. The direct measurements of the heat flow is restricted only to very shallow depth and limited data is available because of the cost of the measurement and no techniques are available for very deep drilling. Therefore the DBMS, if representing a thermal boundary can provide indirect evidence/proxy heat flow of a given region. The shallower DBMS corresponds to higher heat flow in the region. Several studies have been conducted to study the variation of the DBMS/Curie depths in regions around the world (Ross et al., 2006; Bhattacharyya and Leu,1975; Espinosa-Carden˜a and Campos-Enriquez, 2008; Tanaka et al., 1999; Okubo et al., 1985; Okubo and Matsunaga, 1994; Rajaram et al., 2009; Chiozzi et al., 2005; Dolmaz et al., 2005; Trifonova et al., 2009; Bansal et al., 2011).

In this study, we are estimating the DBMS for the Central India for fractal distribution of sources. An aeromagnetic map of Central India, at an altitude of 1.5km, was compiled by Rajaram and Anand (2003), using data collected at different altitudes and epochs. The compiled dataset is suitable for regional studies (Rajaram et al., 2009). For the present analysis, we selected 29 blocks of 200km X 200km, with a 50 % overlap covering different geological entities of Central India. The dimension of 200km by 200km was also found suitable for estimating the DBMS for the Germany and Northeastern Austria (Bansal et al., 2011). The aeromagnetic map over the central India is shown in figure 1.

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Methodology

The magnetic anomalies may be interpreted in space or frequency domain. The interpretation in frequency domain becomes easy because the convolution operator change to multiplications. The centroid method is mostly used method in frequency domain. In this method the DBMS are calculated in two steps: (1) estimate the top depth of the deepest magnetic body and (2) centroid depth of the deepest magnetic body. Then top depth and centroid depths are used to compute the DBMS. In this method top depth (Zt) and power spectral density (P(k)) are related as(Spector and Grant, 1970):

$$\ln(P(k)) = A - 2k Z_t \tag{1}$$

Where A, k are constant and wavenumber, respectively.

The top of anomalous body is obtained as half of the slope of straight line fitted to the log of power spectral density versus wavenumber.

The centroid depth (z) can be related to the power spectral density as follows (Okubo et al., 1985):

$$\ln\left(\frac{P(k)^{1/2}}{k}\right) = A_1 - |k| z \tag{2}$$

where A_1 is a constant. Finally the DBMS can be computed as:

$$Z_b = 2Z_0 - Z_t \tag{3}$$

The conventional centroid method assumes random and uncorrelated distribution of sources whereas in the real situations the source distribution follows random fractal distribution of sources.

Bansal et al. (2011) suggested a modified centroid method for real random fractal distribution of sources. The method is having many advantages over the convention centroid method. In the conventional centroid method many workers either filter the data before depth estimations or discard few points corresponding to high wavenumbers because otherwise the DBMS are unrealistic very deep. The filtering and discarding few points are a subjective approach. The modified centroid method does not require pre filtering of the data and less subjective than the conventional approach.

In this method central depth of the anomalous body is related to the power spectral as follows:

$$\ln\left(k^{\beta}\frac{P(k)}{k^2}\right) = A_2 - 2kZ_0 \tag{4}$$

Where β and A_2 are scaling exponents and constant, respectively. In the modified centroid method top depth value can be related as:

$$\ln(k^{\beta} P(k)) = A_3 - 2kz_t \tag{5}$$

Finally the DBMS can be calculated using equation 3. In Bansal et al. (2011) approach two parameters: depths and scaling exponents are required to be estimated from the power spectral density. The depth and scaling exponents are having high correlation and simultaneous estimation of these parameters from the inversion method produces unrealistic values. Therefore Bansal et al. (2011) suggested the fixing of scaling of exponent in advance equal to one which is also followed in this study.

Application to the aeromagnetic data of Central Indian region

We selected 29 overlapping blocks of dimension 200 km by 200 km covering different geological parts of the central India from latitude (18 to 22°N) and longitude (78 to 85°E). The region consists of Deccan volcanic province, Godavari Graben, Bastar Craton, Eastern Ghat Mobile belt, Singbhum Craton, Mahandi Graben, and Central India tectonic zone. The central part of each block is represented by a filled square in Figure.1. The power spectrum of each block is computed using the fast Fourier transform (FFT). A first-order trend is removed from each block, and grids are expanded by 10% using the maximum entropy method to make the edges continuous. The depth values are then computed from the radial-averaged power spectra using equations 4, 5, and 3. An example of depth computed using modified centroid method is presented in figure 2 and 3 for four blocks.

The DBMS obtained for all blocks are also shown in figure1 at the centre of block. The calculated dept to bottom of the magnetic sources varies from 19 to 43km. The shallowest DBMS are seen towards the south western part of the study region, with the depth values variations from 19 to 28 km covering part of the Deccan volcanic province. The shallower DBMS may be indicates high heat flow. The deepest DBMS of 43km is found over the Chattisgarh basin. The DBMS over a small part of Easern Ghat Mobile belt, Bastarn craton and Singhbhum varying from 30 to 35 km correlate well with the depth values obtained by Rajaram et al. (2009). In some of the areas we found a mismatch with the values of Rajaram et al. (2009) because they have used large block size of 5 degree by 5 degree covering many geological entities therefore the DBMS are representing combined effect. Our deeper DBMS correlates well the Moho depth in the region.

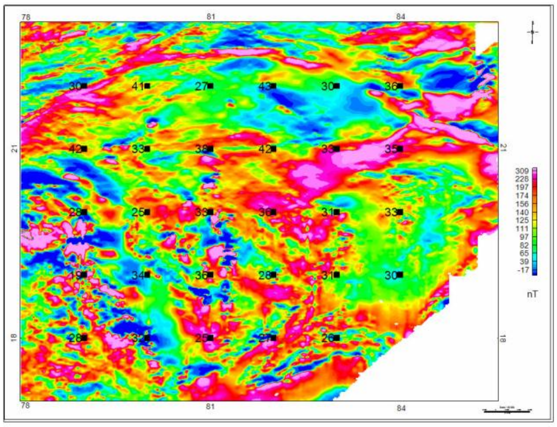

Figure 1: The aero-magnetic anomaly map of central India and the DBMS obtained for each blocks are shown at the centers

Conclusions

We found modified centroid method more robust for estimating the DBMS from the aeromagnetic data of the central India. The shallower DBMS are found for the Deccan traps and mobile belts. The DBMS in the region varies from 19 to 43 km. The deeper DBMS are correlating with the Moho depths.

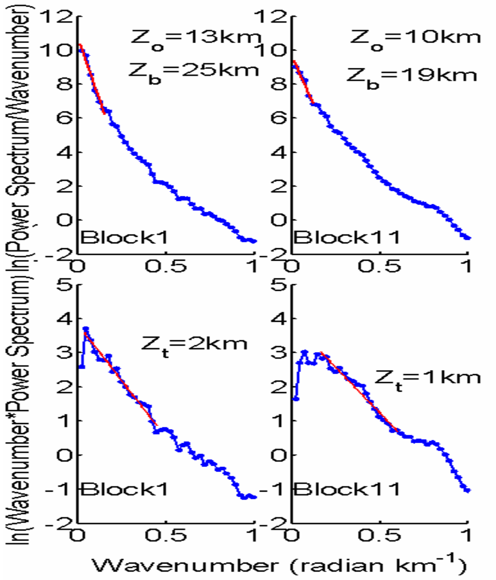

Figure 2: An Example of depth estimation for blocks 1 and block 11. The upper and lower portion indicate the estimation of centroid and top depth, respectively.

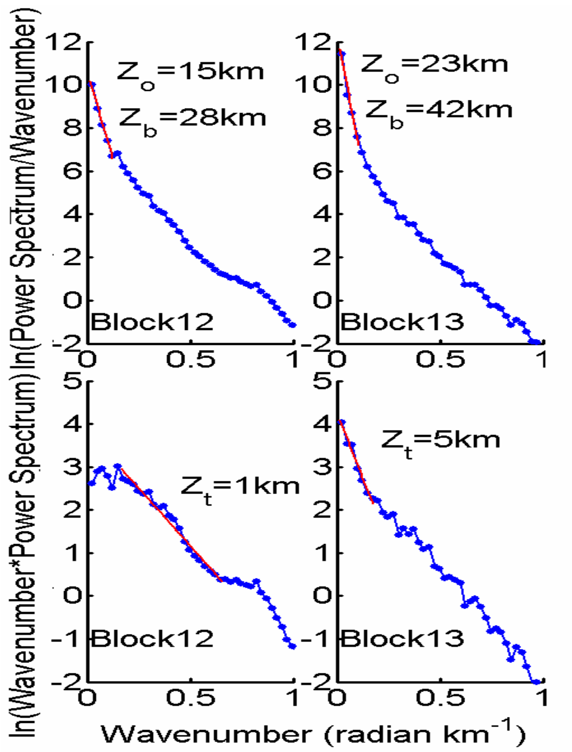

Figure 3: An example of the DBMS estimations for the blocks 12 and 13, the top and bottom portion indicate centroid and top depth estimation, respectively.

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