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# Estimation of fractal parameter and Curie point depth of magnetic sources using de-fractal approach in East Azarbaijan Province, Iran

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**Summary**

The East Azarbaijan geothermal area is located in northwest of Iran, which hosts several hot springs. It is situated mostly around the Sabalan and Sahand mountains. The Sabalan and Sahand geothermal area is now under investigation for the geothermal electric power generation. It is characterized by high thermal gradient and high heat flow. In this study, our aim is to determine the fractal parameter and top and bottom depths of the magnetic sources. A modified spectral analysis technique named "de-fractal spectral depth method" is developed and used to estimate the top and bottom depths of the magnetized layer. A mathematical relationship is used between the observed power spectrum (due to fractal magnetization) and an equivalent random magnetization power spectrum. The de-fractal approach removes the effect of fractal magnetization from the observed power spectrum, and estimates the parameters of the depth to top and depth to bottom of the magnetized layer using iterative forward modelling of the power spectrum. This approach is applied to the aeromagnetic data of the East Azarbaijan Province. The obtained results indicated variable magnetic bottom depths ranging from 9.8 km to about 16.8 km. In addition, the fractal parameter was found to vary from 1.6 to 3 within the study area.



## Introduction

The interpretation of potential fields is generally carried out in the frequency domain due to (1) simplicity in the implementation of signal processing tools, and (2) easy and concise characterization of potential field signals caused by a large variety of source models. In the frequency domain, the geophysical source parameters such as density have been assumed as uncorrelated distribution. To the contrary, source distribution of the physical parameters is correlated following the scaling or fractal laws.

Fractal source distributions have power spectra proportional to $k_{\beta}$, where $k$ is the wave number (i.e. length of the wave vector) and $\beta$ denotes the respective fractal parameter. This has been discovered by the detailed analysis of the densities and susceptibilities of several borehole data around the world including the German continental deep drilling program in southeastern Germany. The fractal parameter reflects the proportion of long and short wavelength variations of a signal. The higher the value of the fractal parameter, the stronger is the relative intensity of the long wavelength variations of the signal.

The main objective of the current work is to develop an algorithm for estimation of the fractal parameter using a de-fractal spectral analysis of the aeromagnetic data from the study area in order to determine the bottom depths of magnetic sources. This approach for analysis of magnetic data assumes that the observed power spectrum is equivalent to the random magnetization model multiplied by the effect of fractal magnetization. It is believed that the de-fractal method can reduce the ambiguity related to the selection of fractal parameter to provide an estimate of bottom depths of magnetic sources more reasonable than the estimates using conventional methods. However, the ability of the de-fractal method has not been verified so much in practical exploration applications. Hence, in this work, an attempt has been made to use this approach to remove the effect of fractal magnetization from the power spectrum of real magnetic data to have a reasonable depth estimate of magnetic sources.

**Methodology and Approaches**

In the last four decades, variations on several methods have been proposed and applied for estimation of the bottom depths (zb) of magnetic sources using azimuthally averaged Fourier spectra of magnetic anomalies. The mathematical formulae of these methods are based on assumptions of flat layers with particular distributions of magnetization, namely: 1) random (uncorrelated) magnetization models or 2) self-similar (fractal) magnetization model. The idea of using models with fractal magnetization distribution comes from the concept of self-similarity.

The de-fractal method is based on the assumption that the observed power spectrum is adequately represented by a simplification of the fractal magnetization power spectrum where the magnetization in the x and y directions is fractal and is constant in the z direction. In this case, the observed power spectrum is equivalent to the result of power spectral density of the random magnetization model multiplied by k-α. Having removed the fractal effect, one can treat the resulting de-fractal power spectrum as though it was the power spectrum of a random magnetization model. The present approach can be considered as a correction to the power spectrum of the magnetic field for the fractal distribution of magnetization.

**Results and Conclusions**

In this work, we have determined the bottom depths to magnetic sources using de-fractal spectral analysis method. This method applies a transformation to the observed magnetic field based on an estimated fractal parameter such that the power spectrum resembles the power spectrum that would be generated by a random magnetization distribution. The advantages of this method are that the range of the feasible de-fractal parameters can be estimated, and the bottom depths of the magnetic sources or anomalies are obtained based on simultaneously estimating the depth values from the centroid method and visual inspection of the forward modeling of the spectral peak. The method has been applied to 50% overlapping 11 blocks having 100 * 100 square km dimensions of aeromagnetic data in Ardabil area. As a result, the fractal parameter has been determined between 1.6 and 3 The obtained results also indicate that the bottom depths of sources of the magnetic anomalies vary from 9.8 km to about 16.8 km.