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Reduction to the Pole and Analytic Signal Interpretation Techniques of Magnetic Data in Equatorial Area, Ethiopia

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Abstract: ***Magnetic data interpretation in equatorial area is a very difficult task due to low intensity and direction of the inducing field. As a result the anomaly produced by such weak inducing field is not visible (low amplitude) unless appropriate enhancement techniques are applied. To minimize the effect of magnetization direction, analytic signal method was applied while; to increase the amplitude of the intensity and to transform dipole to monopole the reduction to the pole techniques were used.***

Keywords: phrases: Reduction to the pole; analytic signal; magnetization direction

1. Background

It is a kind of revenge that the earth's magnetic field intensity is influenced by the local magnetization of crustal rocks [12]; it magnetizes crustal rocks (magnetic materials) as a result its total intensity varies from the normal. This variation of intensity of the earth’s magnetic field reveals very important characteristics of the subsurface geology [9]. However, at low latitude area, due to dipolar nature of the field and is oriented approximately North-South, parallel to the surface, some features will not be visible unless appropriate filtering techniques applied. Therefore, it causes the pattern of an induced magnetic anomaly highly dependent on its orientation [1]. So that the event will not exactly above the causative body [5], [6], [2]. As a result, it is difficult to correlate the anomaly and the exact subsurface physical properties. As [1] explained the ambiguity is not only its dipolar nature, but in low latitude area its intensity is decreased almost by half to that of the intensity at high latitude area.

Therefore, different enhancement techniques are used to interpret magnetic data. Some enhancement techniques used as to enhance features associated with depth while others are associated with location (latitude). Techniques used, which are associated with depth, such that wavelength filtering, continuation, and trend analysis, are important mainly to separate the residual and regional causative bodies. The continuation of anomaly maps in to or away from the source point enhances the shallow or deep features respectively. While the reduction of anomaly maps to the pole (with special consideration of its stability) reveal the causative body immediately below the anomaly. This technique is rather seems a very good approach to minimize the complexity of the field.

This study is, actually, intended to apply the appropriate magnetic data interpretation techniques in equatorial area. Indeed, to mean appropriate is that, to minimize the complexity of magnetic data, to have a clear and undistorted data. There are different magnetic data interpretation techniques. However, roughly reduction to the pole and analytic signal methods are mostly used in equatorial area.

2. Methods

In geophysical methods, to shorten the complex information provided in the original data, different data processing techniques are implemented. In this study, as usual the removal of theoretical geomagnetic field and diurnal correction of magnetic data was made. With the aim of interpretation of near feature effects the observed magnetic data was upward continued to 1 km, to enhance the regional field, and it was subtracted from the original observed magnetic data so that to get the residual magnetic data (Fig.1) of the area with up to depth of 500 m. However, this residual map by itself does not provide us the direct relationship of the anomaly and subsurface features, it needs enhancement techniques. Therefore, analytic signal and reduction to the pole techniques were applied. From the residual map the analytic signal and reduction to the pole map were produced using 2D- Fast Fourier Transform.

2.1 Analytic signal method

The variation of Earth's magnetic field intensity is mainly affected by the magnetization direction [7], [3], [10]. Presumably with the minimum intensity and the dipole nature in equatorial area, it increases the complexity of the magnetic data. The analytic signal (total derivative) method minimizes this complexity. It does not depend on the direction of magnetization of sources rather it is related to the strength of magnetization [4], [8], [11]. The amplitude of analytic signal can be expressed as;

$$|A(x,y)| = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial y}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2} \qquad (1)$$

Where M is the observed magnetic field

2.2 Reduction to the pole

At low geomagnetic latitude magnetic data interpretation is more difficult than at high geomagnetic latitudes since anomaly maxima are not located directly over the causative bodies [13]. This interpretation technique reduce dipole field to monopole field, the anomaly is directly above the causative body as like gravity anomaly, since it assume the perfect induction for simplicity. The reduction to the pole operator can be expressed as

$$L(\theta) = \frac{1}{[\sin(I) + i\cos(I)\cos(D-\theta)]^2} \quad (2)$$

Where θ is the wave number direction.

3. Interpretation

The residual map (Fig.1) anomalies are characterized by both high and low frequencies of anomalies associated with the local magnetization distribution. It ranges from -322.8 to 278.8 nano Tesla. High magnetization is observed in the South East and North West part of the map. It is possible to observe from the map as almost East-West trending anomalies are observed. This is expected in low latitude areas where long North- South trending structures will not be visible [1]. The reduction to the pole map (Fig.2), was produced from the residual map (with IGRF = 35510.8 nano Tesla, Inclination =1.2 and Declination= 1.7), is characterized by high and low magnetic anomalies. It ranges from -496.6 – 602.2 nano-Tesla. The intensity value increases because the reduction to the pole filter is an amplitude amplifier filter. This map is exemplified by a North –South trending anomalies where this trend is not visible from the residual map because of the latitude and direction problem. The maximum in the residual map becomes minimum in the reduction to the pole map. However, to have reliable interpretation the analytic signal map (Fig.3) was produced from the residual map. Since the variation of Earth's magnetic field intensity in low latitude areas is affected by the magnetization direction, enhancement techniques that do not consider the direction of magnetization is appropriate. The amplitude of analytic signal (related to strength of magnetization of underlying rocks) of the total magnetic field produces maxima over magnetic contacts regardless of the direction of magnetization. The amplitude of the analytic signal map is high around the North, North east and south west part where the maximum and minimum boundaries are exist in the residual map. This map clearly shows the edge of magnetization distribution. It has amplitude ranges from 2-19.8 nano-Teslas per meter.

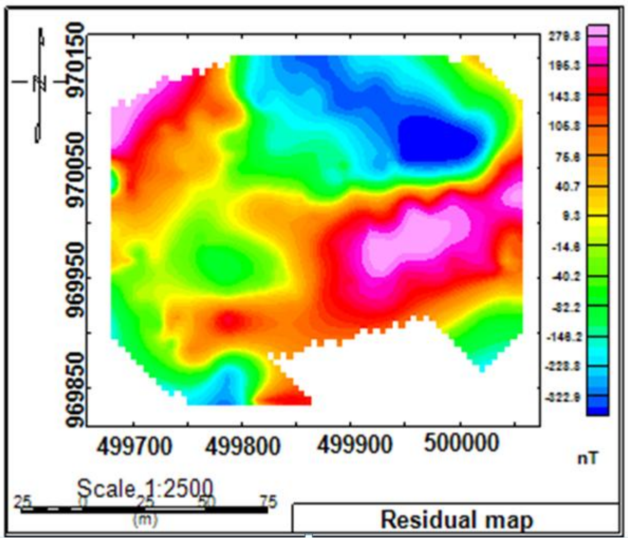

Figure 1: Residual map produced from subtracting Upward continued magnetic data from the observed magnetic data

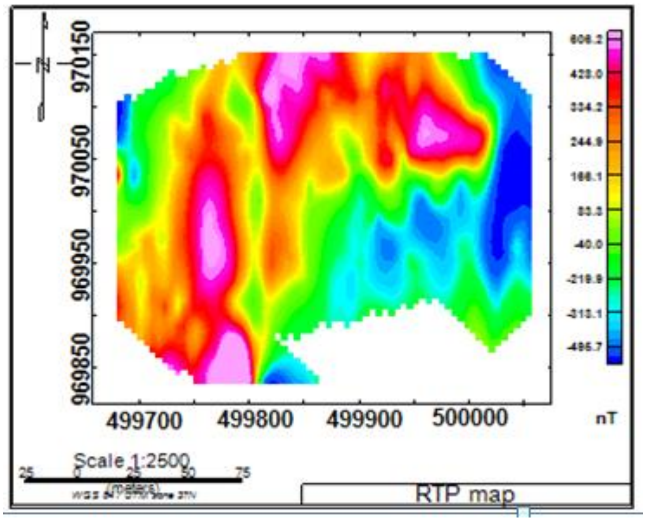

Figure 2: Reduction to the pole map produced from the residual map

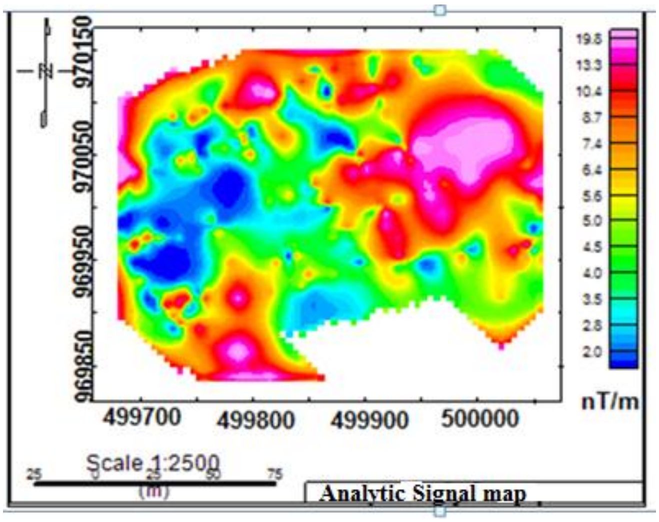

Figure 3: Analytic signal map produced from the residual map

4. Conclusion

In this paper, the reduction to the pole and analytic signal methods were applied to magnetic data. Both interpretation techniques are appropriate to reduce the complexity of the magnetic data. The reduction to the pole map showed highlights of anomaly bodies trending in the North- South direction. But these anomalies were not seen in the residual map of the area probably due to the direction of magnetization and low intensity of Earth’s magnetic field around the equator. It has high intensity value relative to the residual magnetic data due to the effect of the filter, it amplifies the amplitude. In the analytic signal map the edges of anomalous bodies are clearly observed. This technique is not depending on the inducing field direction so that the anomalies peak is distributed immediately above the source body.

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