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ESTIMATION OF DEPTH TO MAGNETIC SOURCE BODY USING SOURCE PARAMETER IMAGING AROUND THE SCHIST BELT AREAS OF KANO, NORTH WESTERN NIGERIA

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Abstract

Depth to the magnetic source bodies in the study area was estimated. This depth is of utmost importance in magnetics. Source Parameter Imaging (SPI) method, which employs the relationship between source depth and the local wave number of the observed field, was used for this purpose. It is an easy method and also has the advantage of being able to estimate the depth of a model-independent body. The regional field was separated from the observed field to obtain the residual field using least square method and the residual field was used for the SPI analysis. The result of the SPI analysis shows that the depth to the magnetic source bodies in the study area is generally shallow ranging from 94.624 m to 754.266 m with an average of 424.445 m. However, depth to the regions with mineralization favorability ranges from 94.624 m to 341.412 m with an average of 218 m this result agree with similar works carried out in Nigerian basement complex.

Keywords: *Regional-residual separation, Schist belt, Source Parameter Imaging.*

1.0 Introduction

Solid Minerals are important resources to every country. They are particularly important for Nigeria owing to over-dependence on petroleum which whenever its price falls in the international market, the repercussion is always a huge stress on all spheres of the economy.

Shehu *et al.,* [1] carried out a reconnaissance study to map out the potential mineral zones in the study area. They, however, did not give any estimate of the depth of the anomalous body. A geoelectric study was carried out by Bagare [2] at Alajawa artisanal mining site in Shanono area (western Kano). This study, although focused on a relatively small area, could serve as a base upon which further studies would be established. More so, the depth to which investigation is made is always subjective in resistivity surveys and depth to the mineralization zone could be higher than what the surveyor has chosen. Hence the need for other geophysical methods, such as potential field methods, for depth investigation as recommended in his report.

Estimation of depth to the anomalous body is one parameter that is always necessary in mineral exploration to give a fair idea about depth to miners. Graphical, eulerdeconvolution, spectral analytic and wernerdeconvolution methods as used by [3], [4], [5] and [6] respectively are some available techniques for this task.

Source Parameter Imaging (SPI) technique developed by [7] and improved by [8] has two advantages: first, the depths can be displayed on an image depending on the model assumed (fault, dike or horizontal cylinder); second, depth of a model independent body can also be estimated.

In this paper, the SPI technique is used in estimation of depth to the magnetic source body around the schist belt area of Kano State with special emphasis on model independent body.

Location of the study area

The study area is bounded within latitudes $11^0 30'$ N to $12^0 30'$ N and longitudes $7^0 30'$ E to $8^0 30$ E. It covers western parts of Kano and eastern parts of Katsina States. More about the location of the study area is given by [1].

Theory of SPI

SPI employs the relationship between source depth and local wavenumber of the observed field data and it is based on complex analytic signal. Nabighian[9] wrote the complex analytic signal as

$$A(x,z) = |A|e^{j\theta} \quad (1)$$

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where x and z are Cartesian coordinates for the horizontal and vertical directions perpendicular to strike respectively, $|A|$ is the amplitude of the analytic signal, θ is its phase and j is imaginary number.
The local wavenumber k is defined by [10] as

$$k = {}^{\partial\theta}/_{\partial x} \quad (2)$$

where θ is as defined above and is given as

$$\theta = \tan^{-1}\left\{\frac{{}^{\partial M}/_{\partial z}}{{}^{\partial M}/_{\partial x}}\right\} \quad (3)$$

where M is the magnitude of the anomalous total magnetic field.
[7]and[8] therefore, wrote the first- and second-order local wavenumbers k_1 and k_2 respectively as

$$k_1 = \frac{\partial}{\partial x}\tan^{-1}\left[\frac{\partial M}{\partial z}\Big/\frac{\partial M}{\partial x}\right] \quad (4)$$

$$k_2 = \frac{\partial}{\partial x}\tan^{-1}\left[\frac{\partial^2 M}{\partial^2 z}\Big/\frac{\partial^2 M}{\partial z \partial x}\right] \quad (5)$$

Equations 4 and 5 are used to determine the most appropriate model and depth estimate of any assumption about a model.
[8] used the expressions for the magnetic anomalies due to sloping contact, dipping sheet and long horizontal cylinder as given by [9], [11] and [12] respectively in equations 4 and 5 to arrive at

$$k_1 = \frac{(n_k+1)h_k}{h_k^2+x^2} \quad (6)$$

$$k_2 = \frac{(n_k+2)h_k}{h_k^2+x^2} \quad (7)$$

where n_k is the SPI structural index (subscript k = c, t or h) and $n_c = 0$, $n_t = 1$ and $n_h = 2$ for the contact, thin sheet and horizontal cylinder models respectively and h_k is the depth to the source body
Using the pointer given by [8], a model-independent local wavenumber which we have called k_o in this work was calculated from $k_2 - k_1$ to obtain

$$k_o = \frac{h_k}{h_k^2+x^2} \quad (8)$$

The position x = 0 defines the source location and k_o, k_1 or k_2 has a maximum value at this position. The model-independent depth can thus be estimated from

$$h_k = \frac{1}{k_{max}} \quad (9)$$

k_{max} being the value of k_o at $x = 0$.

Methodology

The data and analysis carried out are discussed here.

Data

The aeromagnetic data used for this research were obtained from the work of [1]. They used four sheets numbering 56, 57, 79 and 80, representing the study area to produce the Total Magnetic Intensity (TMI) map (Figure 1). The data were extracted using Geosoft Oasis Montaj Software.

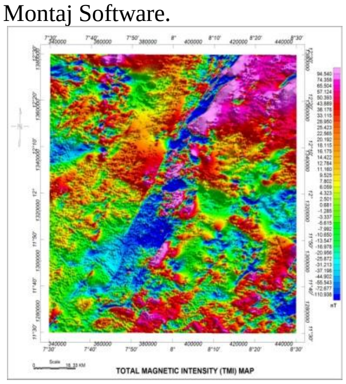

Figure 1. Total Magnetic Intensity Map of the study area [1]

Regional-Residual separation

Regional-Residual separation is generally carried out on potential field data (e.g. magnetic and gravity) to separate long wavelength anomalies of the regional field which are attributed to deep and large-scale sources from the shorter wavelength features constituting the residual field, which arise from shallower, small scale sources [13].

Agocs [14] presented various methods by which regional-residual separation can be carried out, one of which is the least square method where a best fit (regional) is made to the observed data according to:

$$Z(x, y) = Ax + By + C \quad (10)$$

where Z would be the computed value of the regional for the coordinates x and y. A, B and C are constants to be determined. The residual R would be

$$R = B - Z \quad (11)$$

where B is the observed field. The residual map is shown in Figure 2.

The advantage of this method as pointed out by [13] is that it is simple to implement and computationally none-intensive.

Following the least square method, A, B and C in equation (10) were found to be 0.0001789, 0.0002761 and -432.299 respectively

The depth estimate is made to the regions where the residual anomalies originate. Hence, R in equation (11) corresponds to M in equations 3, 4 and 5. The SPI map is shown in Figure 3.

The residual and SPI analysis and mapping were carried out using Geosoft Oasis Montaj.

Results and Discussion

The results of the analysis and their discussion are presented here.

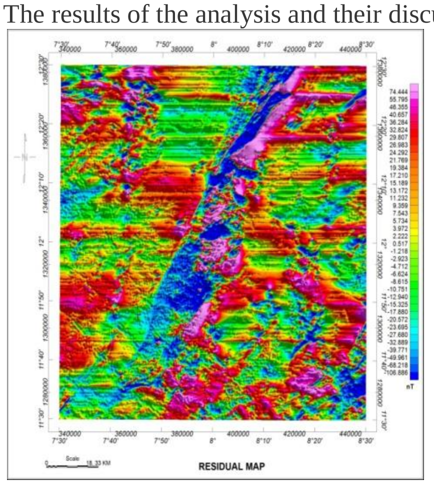

Figure 2. Residual Map of the study area

Figure 4 shows the residual map. The regional field which is the contribution from deep seated bodies has been removed. When compared to TMI map in Figure 1, it shows a spatial distribution of the reduced anomalies ranging from -106.886 nT to 74.444 nT. This tells us that deep seated bodies contributing to long wavelength anomalies have been removed

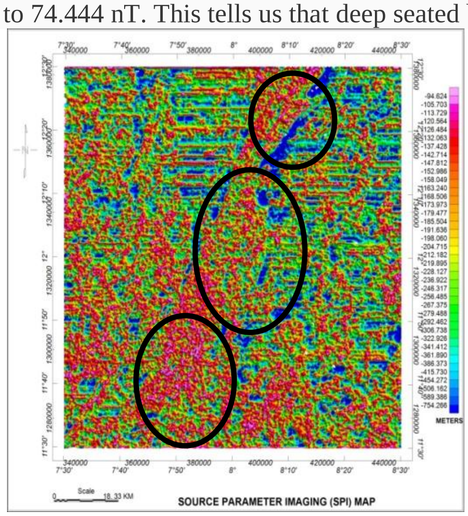

Figure 3. SPI Map

Result of the SPI map (Figure 5) gives a fair idea of the depth to magnetic source bodies. It shows that the depth of the source bodies in the area is generally shallow ranging from 94.624 m to 754.266 m with an average of 424.445 m. However, depth to the regions with mineralization favorability (in circles) ranges from 94.624 m to 341.412 m with an average of 218 m. This result contains the 184 m obtained by [2].

Our depth results agree with the results of similar magnetic studies done in some other parts of Nigerian Basement Complex. Nur*et a.l*,[15] got 60 m to 1,200 m for shallow sources around middle Benue; Nwogbo[16] obtained 70 m to 630 m for shallow sources from spectral analysis of upper Benue; Anudu*et al.*,[3] got 230 m to 760 m for shallow sources around Wamba in Nasarawa State; Muhammad *et al.*,[5] obtained 0.1km to 800 m in the Katsina area.

Conclusion

In this study, SPI technique was used in estimating the depth to mineralization zones to be in the range of 94.624 to 341.412 m with an average of 218 m. Location with high mineral favorability is bounded within longitudes 7º 51ʾ E to 8º 12ʾ E and latitudes 11º 46ʿ N to 12º 30ʾ N in the NE – SW directions.

Knowledge of the location and depth of possible mineralization zones is of utmost importance to miners; needless to say it must be the first investigation to be carried out. As such, studies of this nature are expected to guide the activities of miners who intend to explore the area for economic minerals.

The airborne magnetic data obtained from NGSA prove reliable. This is because the results of the analyzed data contains that of the experimental work [2] carried out in a small location of the entire study area. This fact gives us confidence on other results obtained in this study.

Characterization of the anomalous zones and subsequent determination of the actual minerals present are the next line of action and we hope to probe into them in further studies through ground follow-up.

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