Source Location and Depth Estimation from Digitized Aeromagnetic Data Acquired from a Basement Complex Formation

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Abstract

Locations and depths to magnetic contacts were estimated from the total intensity magnetic field using horizontal gradient magnitude (HGM), Analytic signal amplitude (ASA) and local wavenumber (LWN). The digitized magnetic data of Ibadan area, south-western Nigeria were analyzed to estimate depths to magnetic sources as well as source locations. The results obtained showed a shallow depth range limit for the HGM and LWN while the ASA method overestimated shallow source depths when compared with HGM and LWN functions.

Keywords: Horizontal gradient magnitude, analytic signal, local wavenumber, source location, source depth, aeromagnetic data.

Introduction

Most geophysical data like aeromagnetic data are interpreted to determine the locations, depths and forms of the sources responsible for the observed magnetic anomalies. The process of determining the location and depth of a magnetic source from gridded potential field data begins with the construction of a function from the data such that the function peaks over the magnetic source. Examples of such functions are analytic signal amplitude (ASA), local wavenumber (LWN) and the Horizontal gradient magnitude (HGM). (Nabighian, 1972, 1984; Roest *et al.,* 1993).

In this study, a digitized aeromagnetic data of Ibadan area, south western part of Nigeria as obtained by Nigerian Geological Survey Agency in 2009 were employed to determine the locations and depths to sources using the ASA, LWN, and HGM methods.

Theory:

(a)   The Analytic signal amplitude

The analytic signal or total gradient is formed through the combination of first order horizontal and vertical gradients of the magnetic anomaly. The analytic signal is independent of magnetization direction and the direction of the Earth's magnetic field. (Milligan and Gunn, 1997). The function used in this method is the analytic signal amplitude (ASA) defined by:

$$\text{ASA } (x, y) = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2 + \left(\frac{\partial T}{\partial Z}\right)^2} \quad \text{(Roest and Pilkington, 1992)}$$

Where $\left(\dfrac{\partial T}{\partial y}\right)$ is the vertical gradient of the field.

(b) The Horizontal gradient magnitude

The horizontal gradient magnitude (HGM) method (Blakely and Simpson, 1986, Nasreddine and Haydar, 2001) is perhaps the simplest approach of estimating magnetic contact locations and depths because it does not require the calculation of vertical derivatives but only the calculation of the two first-order horizontal derivatives of the field.
Thus, for a grid of magnetic field value T (x, y), the HGM is given by:

$$\text{HGM } (x, y) = \sqrt{\left(\frac{\partial T}{\partial x}\right)^2 + \left(\frac{\partial T}{\partial y}\right)^2}$$

Where $\dfrac{\partial T}{\partial x}$ and $\dfrac{\partial T}{\partial y}$ are the field gradients in the x (East) and y (North) directions respectively.

(c) The Local Wavenumber

The local wavenumber k(x, y) is given by:

$$k (x, y) = \sqrt{\left(\frac{\partial \theta}{\partial x}\right)^2 + \left(\frac{\partial \theta}{\partial y}\right)^2} \quad \text{and}$$

$$\theta = \frac{\dfrac{\partial T}{\partial Z}}{\sqrt{\left(\dfrac{\partial T}{\partial x}\right)^2 + \left(\dfrac{\partial T}{\partial y}\right)^2}}$$

Where θ is the local phase of the total field, (Thurston and Smith,1997)

Location of the Study Area

The study was carried out in Ibadan area of Oyo State, South western Nigeria. The area is located within longitude 3^0 $30^{'}$ E to 4^0 $00^{'}$ E and latitude 7^0 $00^{'}$ N to $7^0 30^{'}$ N covering an area 55km X 55km, which is 3,025 square kilometers. The location and contour maps of Ibadan area are shown in Fig. 1 and Fig. 2 respectively.

Geological Set up

The area falls within the basement complex of South-western Nigeria characterised by the basement complex rocks of the Precambrian age consists of various granites and the metasedimentary rocks (Adetoyinbo *et al.,* 2010). Ibadan area is composed of biotite granitic

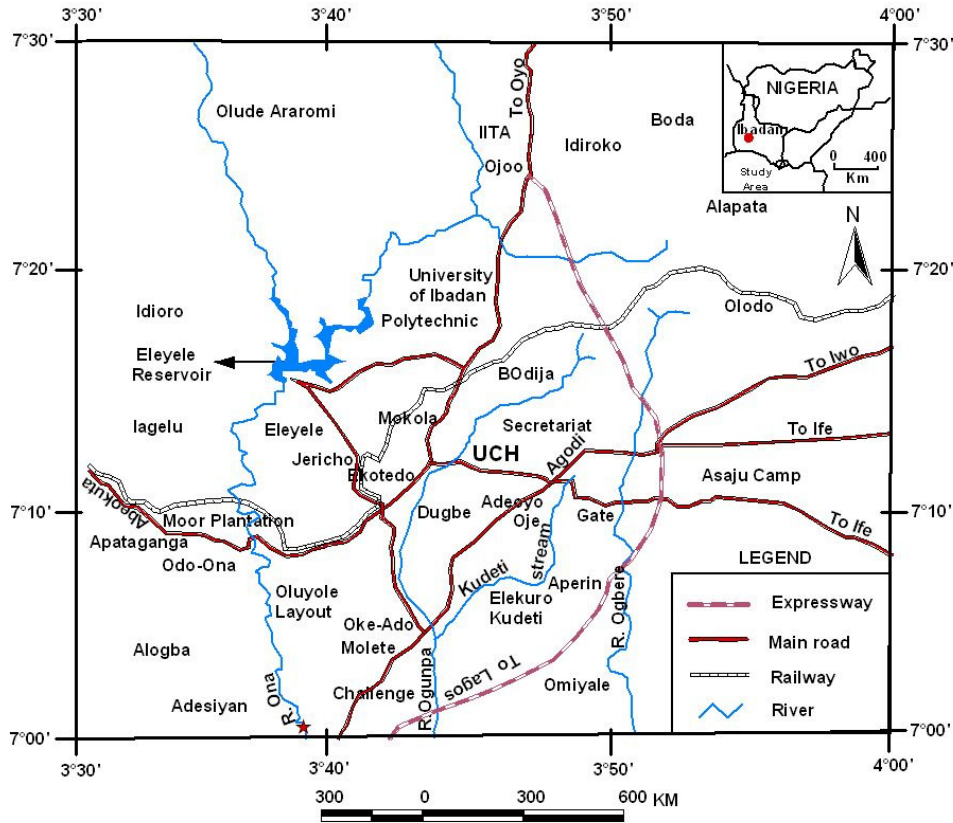gnesis; migmatite biotite gneiss; biotite muscovite granite; hornblende granite and Schists (Fig. 3).

Fig. 1: Location map of ibadan area.

Result and Discussion

Result:

Source Locations and Depth:

The location and depth solutions are shown in Figs. 4a, b and c for the HGM, LWN and ASA respectively. Using a maximum standard error of 35% on each of the methods, depths were computed for the sources from the total intensity field of the study area. The results obtained from the HGM revealed depth range limit of 0.588-2.310 km. while the AS gave an estimated depth to the magnetic sources to range from 0.263-4.28 km. LWN method revealed an estimated depth to range from 0.607 -2.480 km.

For each of the diagrams, the centre of each circle coincides with the location of a maximum for that function, while the diameter of the circle is proportional to the depth estimated for the source at that point.
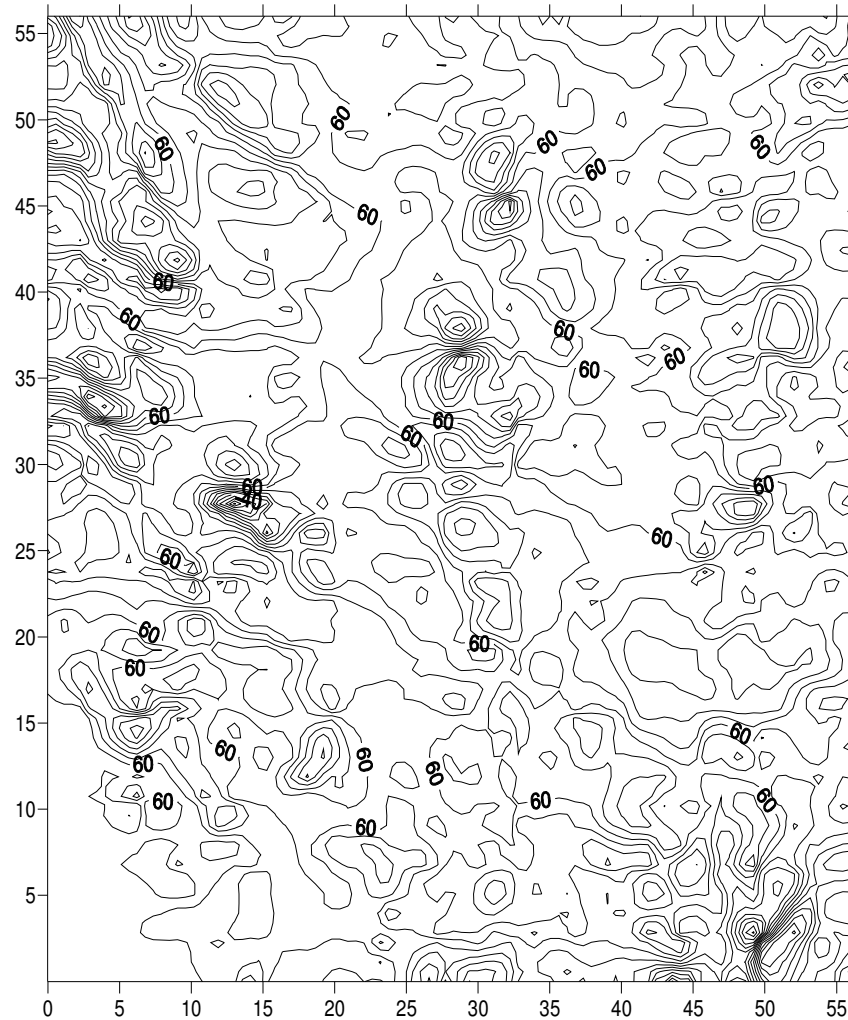
Fig. 2: Contour map of Ibadan area.

Discussion:

From the results obtained using these three gradient techniques, it showed that the estimated depth limit to shallow sources by both HGM and LWN methods are relatively close (0.588 km. and 0.607 km. respectively). However, the AS method overestimated the depths to shallower sources and thus revealed smaller depth limits (0.263km) for the shallow sources, when compared to the other methods.

Conclusions

The location and depth to magnetic contacts has been estimated from the maxima of the HGM, LWN and ASA functions of the total intensity magnetic data. The results of this study have shown that the estimates of depth limit to shallow magnetic contact by HGM and LWN methods are relatively close and comparable. The ASA method overestimated the depth to the shallow sources and revealed a smaller depth for the shallow sources.
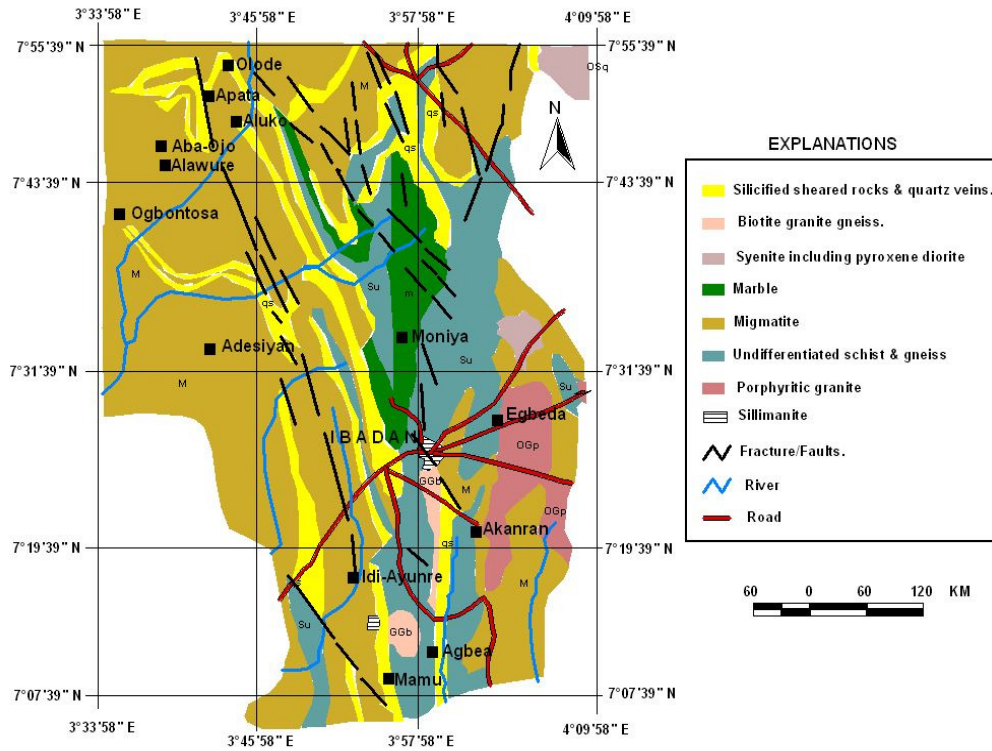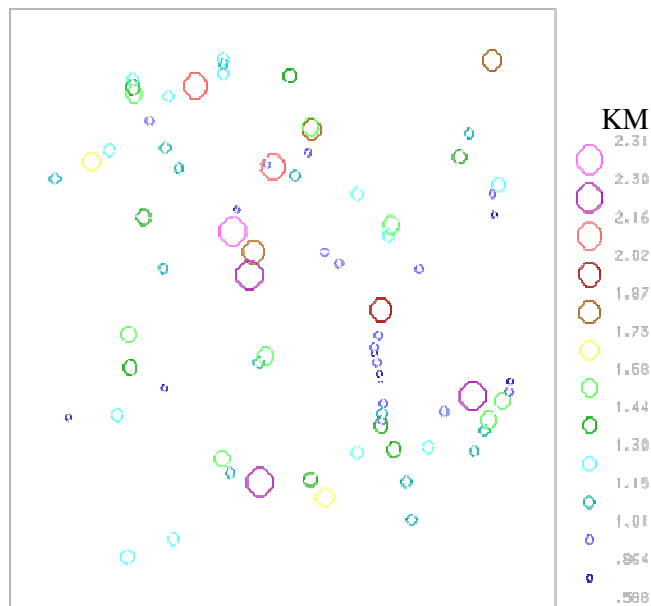
Fig. 3: Geological map of the study area.

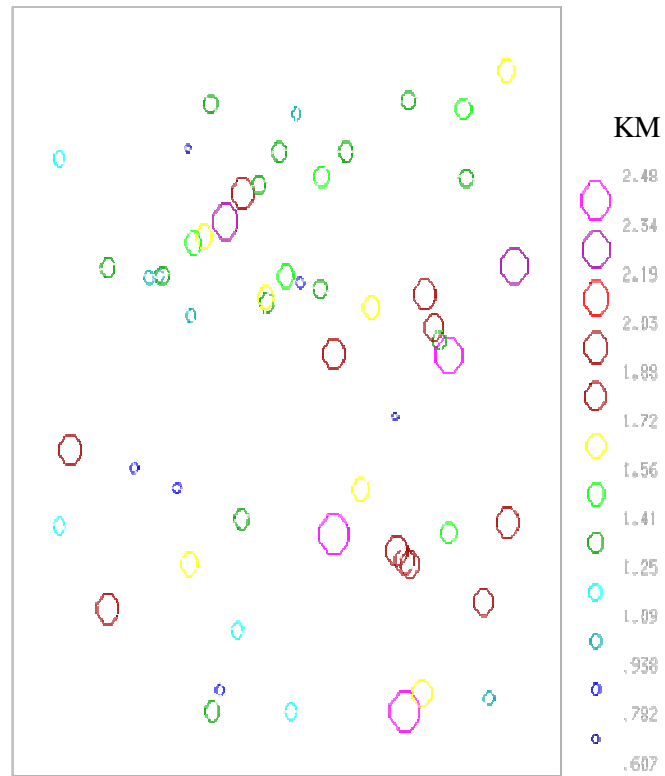**Fig. 4A:** Depths and source locations from HGM.
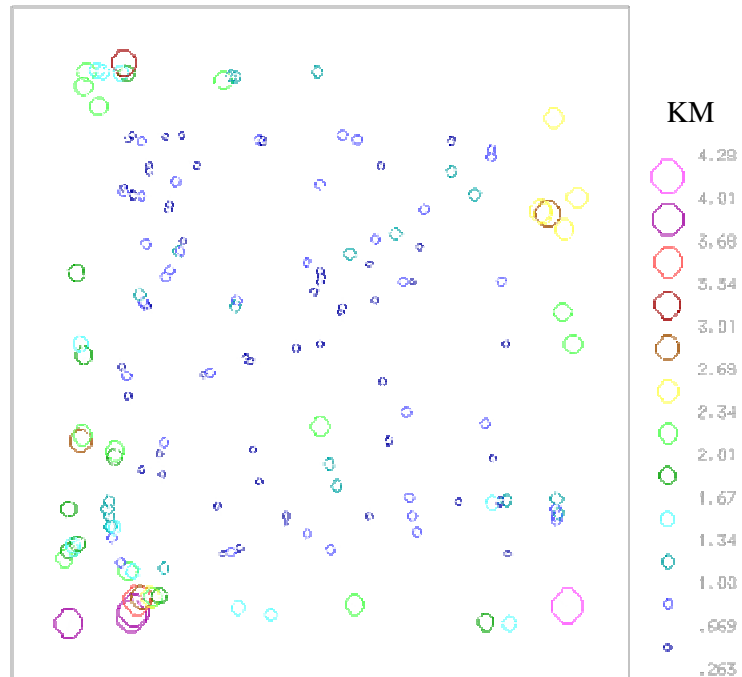
Fig. 4B: Depths and source locations from LWN.

Fig. 4C: Depths and source locations from ASA.

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