DEPTH ESTIMATION OF AEROMAGNETIC DATA OF GOMBE, NORTH EASTERN NIGERIA, USING THE METHOD OF ANALYTIC SIGNAL

V.C. Ozebo, J.A. Olowofelaand B.A Agboluaje

Federal University of Agriculture, Abeokuta, Nigeria

Email: chidioz2001@yahoo.com.

ABSTRACT

This research was carried out using an aeromagnetic data which records variation in the magnitude of the earth's magnetic field in order to detect changes in the properties of the underlying geology. The aeromagnetic map was digitized and analyzed using reduction to pole method. The depth of the magnetic source of the region was determined using Analytic Signal. The graphs of the magnetic intensity against distance shows that there are sizeable quantities of different magnetic deposit structures on the location. The highest depth to the surface of magnetic source is 15.5km while the lowest depth is 1.0km. A magnetic exploration expedition of Gombe, Northeast Nigeria, therefore, is a worthwhile venture, going by the findings in this study, especially the availability of different magnetic structures in the area.

Key Words: Aeromagnetic data, Analytic signal, Gombe, Reduction to the pole, Aeromagnetic map.

1.0 Introduction

An aeromagnetic survey is a common type of geophysical survey carried out using a magnetometer aboard or towed behind an aircraft. The principle is similar to a magnetic survey carried out with a hand-held magnetometer, but allows much larger areas of the Earth's surface to be covered quickly for regional reconnaissance. The aircraft typically flies in a grid-like pattern with height and line spacing determining the resolution of the data (and cost of the survey per unit area).

Magnetic data can be used to obtain the following: the direct detection of structural trends or geological provinces, the determination of specific anomaly source by inversion of data, the detection and analysis of specific anomaly source by trial and error, the estimation of depth to basement, etc.

Many methods have been developed based on the horizontal and vertical derivatives to process magnetic anomalies. Roest et al[1] suggested a method to estimate the direction of the body magnetization with limited success. Ates and Kearey [2] developed a new method to estimate the direction of body magnetization and presented its application to the potential field anomalies of the Worcester Graben area in South Central England. Bilim and Ates [3] compiled a computer program to estimate the direction of the body magnetization using the root-mean square method based on the method of [2].The data from magnetic survey can be interpreted by estimating source depth or locations[4]; consequently, many processing algorithms have been proposed to enhance the estimation. Spector and Grant [5] develop the spectral method for computing the average depth of a set of source. Their approach was based on the inspection and analysis of the slope of the power spectrum. Thompson[6] proposed a method based on the equation of homogeneity of Euler applied to 2D profiles which was later generalized by [7] for 3D structure.The Euler deconvolution allows the location of the sources to be determined and can be applied to both gravity and magnetic data.

The magnitude of the total gradient or analytic signal peaks directly over a contact with arbitrary dip though it is an estimator. The breath of the peak however, allows estimation of the depth to the source. All the above methods may be applied to either gridded data or profiles. A number of automatic profile processing methods (reviewed by [6]) combine source location and depth estimation, while Naudy [8], employs the prism and thin- plate models approach.

Roest and Pilkington [9] correlated the amplitude of the total gradient of the magnetic field and the horizontal gradient of the pseudo gravity and also examined the correlation in structure between the total gradient and pseudo-gravity computed numerically from magnetic rock types. Haney and Li [10] developed a wavelet based method for 2D data sets. These are just a few examples of work that has been done in this area and each of the methods carry with them strengths and weaknesses.

Magnetic anomalies are the differences between measured magnetic values and the values predicted from the model of earth core field. They are caused by variation in magnetization of underground crystal rocks. Total magnetic anomaly map record the components of local anomalies in the direction of the Earth main field. The force of the Earth is not very strong, but it is large enough to magnetize (Reeves [11]).

The reduction to pole (RTP) operation computes, from the observed magnetic field, the vertical magnetic field that would be observed if the magnetization were also vertical (Baranov [12]) in an effort to rid magnetic anomalies of the complicating patterns due to the oblique angles of magnetization and anomaly projection.

With the advent of fast Fourier Transform (FTF), most work has been treating this problem as a simple filtering operation performed in the wave number domain by multiplying the Fourier transform of the observed magnetic field with the RTP operator in the wave number domain (Bhattacharyya, [13]).

Hansen and Pawlowski [14], however, developed an elegant method in which Wiener filtering technique is used to form a regularized RTP operator. Keating and Zerbo [15] emphasized the need of better reproduction of the data as a factor for improved RTP results. They used an ad hoc method of iterative refinement to obtain a better fit between the observed data and the data calculated from the RTP field.

Despite this very considerable body of methods, there remained a need for fast means of processing a magnetic grid to drive trends and estimates in an automatic or semiautomatic manner. The qualitative process reasserts itself on the basis of the mapped gravity and magnetic data alone, by the interpolation and extrapolation of modeled features into regions that do not benefit from modeling well control. In his way, body geometries can be more accurately defined on a map-wide basis, more precise xyz location of bodies determined, and interfering bodies better recognized for what they are.

Gombe State is part of the central Nigeria highlands; but the flat landscape in the northern and southern parts of the state have isolated hills. While the elevation of the plain is at about 600m above sea level, the hills reach between 700m and 800m.Gombe State is geologically a part of the Upper Benue Trough, although the state is an entity of its own, the Gongola Trough. As such, the state constitutes a majorsedimentary basin, with a fill of about 6,000m of Cretaceous Tertiary Sedimentary rocks. These rocks are well exposed throughout the state.Carter et al. [16] recognized the various formations which were described as a sedimentary sequence covering a considerable area around Gombe Township comprising the Bima formation, Yolde formation, PindigaShales, Gombe Sandstone and the Kerri Kerri formation. To the Southwest of Gombe Township, the sedimentary rocks overly the Basement Complex rocks.

The objective of this study is to determine the depth to magnetic source, through the interpretation of the anomalies of an aeromagnetic map of Gombe, using the method of analytic signal.

2.0 Methodology

According to Roest et al [1], the analytic signal of the magnetic anomaly M of 3D source can be defined as a complex vector

$$AS(x,y) = \frac{\partial M_x}{\partial x}x + \frac{\partial M_y}{\partial y} + i\frac{\partial M_z}{\partial z} \text{. . . . .} (1)$$

wherei is a complex number and *x*, *y* and *z* are the unit vectors in *x*, *y* and *z* directions, respectively.
In the frequency domain (1) may be written as follows [1]

$$I.F\ A\ (x,y) = h\nabla F(M) + I_Z \nabla F(M) \text{. . . . .} (2)$$

The real and imaginary parts of (2) being the horizontal and vertical derivatives respectively, form a Hilbert transform operator *i(h.k)*|*k*| as follows:

$$h\nabla F\nabla|M| = i\frac{h.k}{|M|}Z\nabla F|M| \text{. . . . .} (3)$$

Where$\nabla = ik_x x + ik_y y + |k|z$, represent the gradient operator in frequency domain, with *k*= *(k,k)* the wave number, *h*=*x*+*y* and *i*=*x*+*y*+*z*. The amplitude of the analytic signal in 3D is then given by the formula:

$$|AS(x,y)| = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial y}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2} \text{. . . . . .} (4)$$

For a thin sheet-like body, the location of the source in the horizontal plane can be deduced from the positive peaks of the maximum amplitude of the analytic signal, and the source depth can be estimated as the half width at half maximum of the amplitude of the analytic signal.

The data was collected from an aeromagnetic map numbered 152 that covers the town of Gombe and was produced by the Geological survey of Nigeria. The flying over the region was completed in January 1975 and final maps completed in April 1975. The data were collected on a scale of - 1: 100 000 and has an average magnetic inclination of I = 7^0 in the North and I= 4^0 in the south.

The aeromagnetic map of the study area was first digitalized with the aid of a wide transparent tracing paper. The map area was divided into 55x55 grids. The rows and columns of the grid help divide the map into X and Y coordinate axes.
Analytic Signals were obtained in figures for each profile and the graphs were then plotted to determine the depth for each profile which was estimated as half of the width at half maximum of the analytic signal curve.

2.1 *Analysis and Interpretation*

From the positive peak of the maximum amplitude of the analytic signal, the source depth can be estimated as the half width at half maximum amplitude of the analytic signal. The amplitude of analytic signal will always be positive because it involves the square of the variation of the magnetic anomalies with direction. The width of the signal will correspond to their position on the horizontal axis, from where the depth to magnetic source can be estimated as:

$$\text{Estimated Depth} = \frac{X_2 - X_1}{2}$$

where $X_2 - X_1$ corresponds to the width at maximum amplitude.

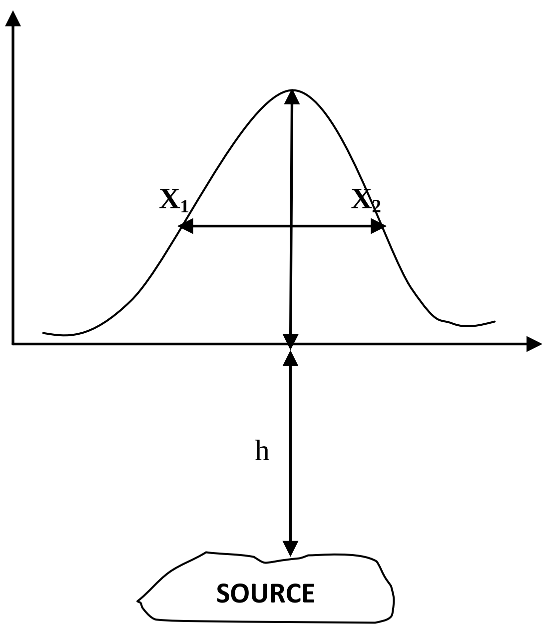
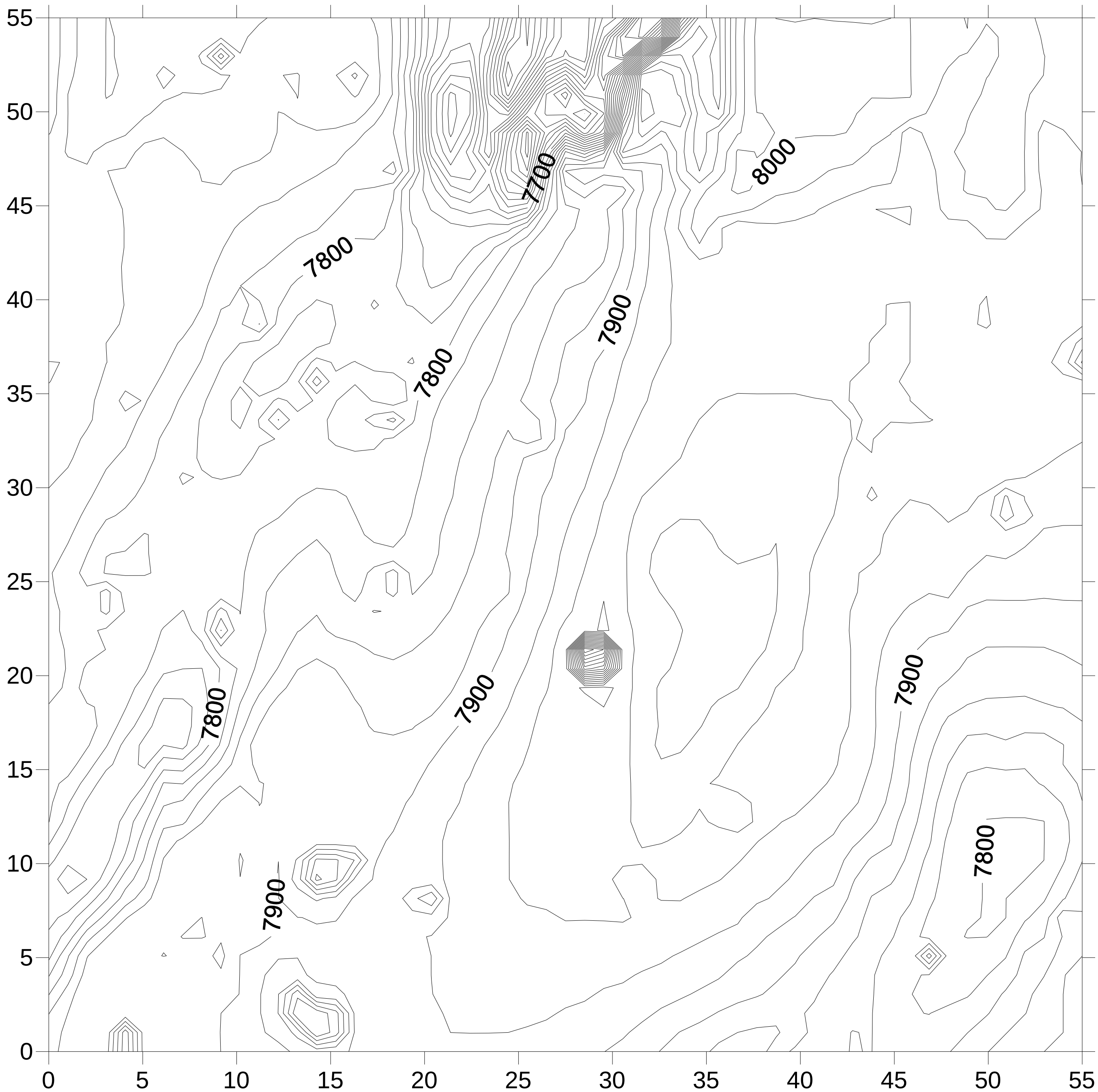


Figure 1.0 Illustration of the half-width estimation of the depth.

The depth ***h*** of the source is therefore given by:

$$\boldsymbol{h} = \frac{(\boldsymbol{X_2 - X_1})}{\mathbf{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{5})$$

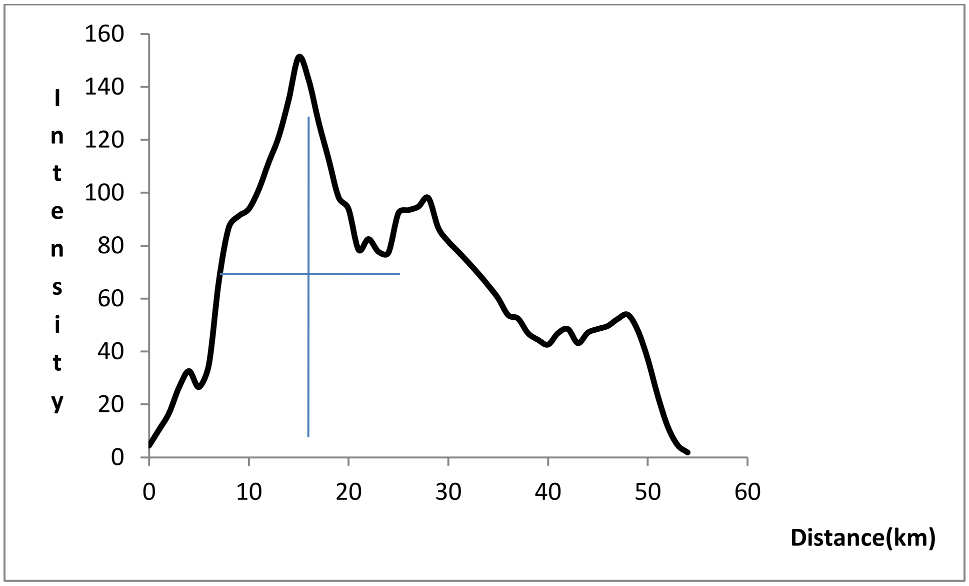


Scale: 1: 100,000

Figure 2.Digitized map of Gombe, the Study Area.

3.0 Results and Discussion

A total of 55 profiles were plotted from the data extracted from the 55 x 55 grid of the aeromagnetic map. Five of the profiles,for want of space, randomly selected are hereby presented.



. Figure 3. Analytic Signal for Profile 5

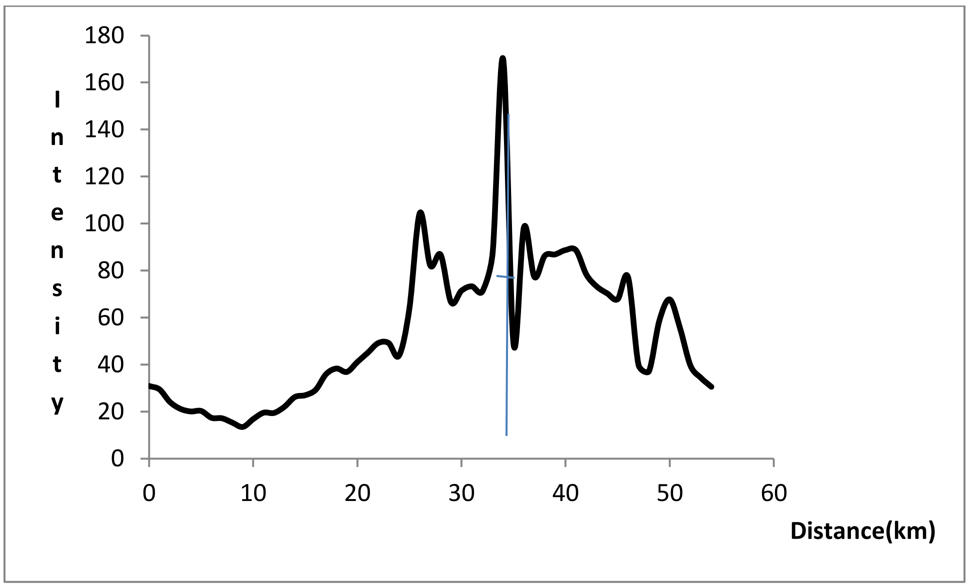


Figure 4. Analytic Signal for profile 18

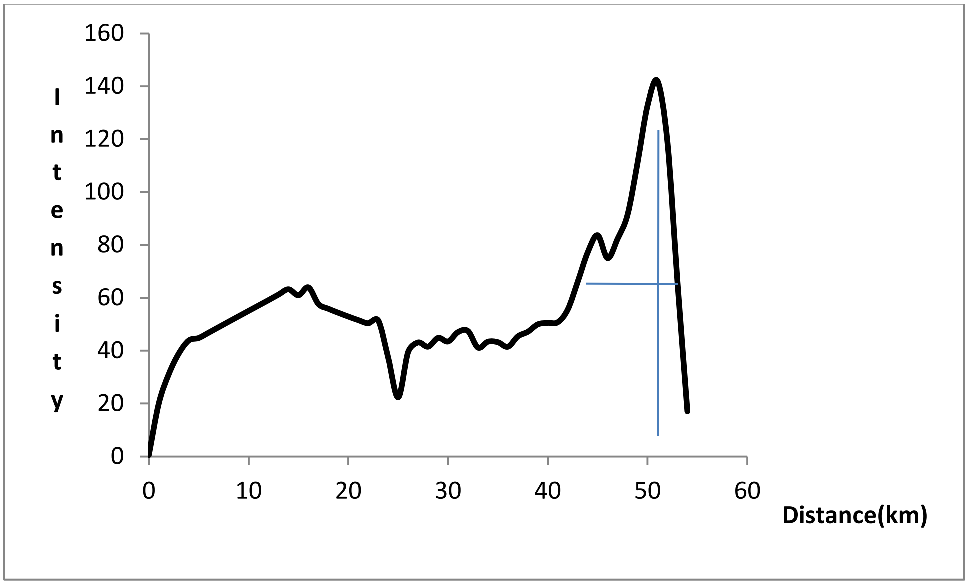


Figure 5, Analytic Signal for profile 24

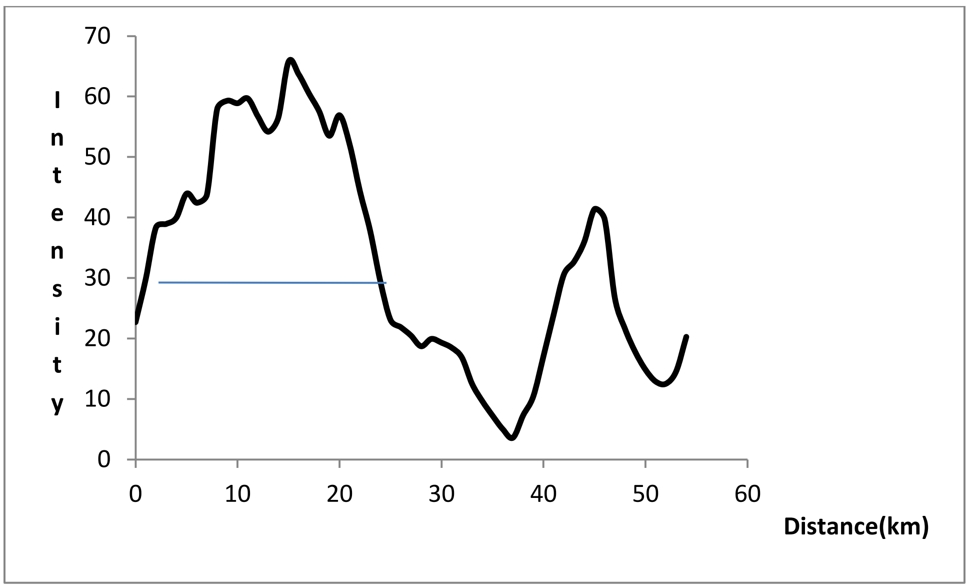


Figure 6, Analytic Signal for profile 38

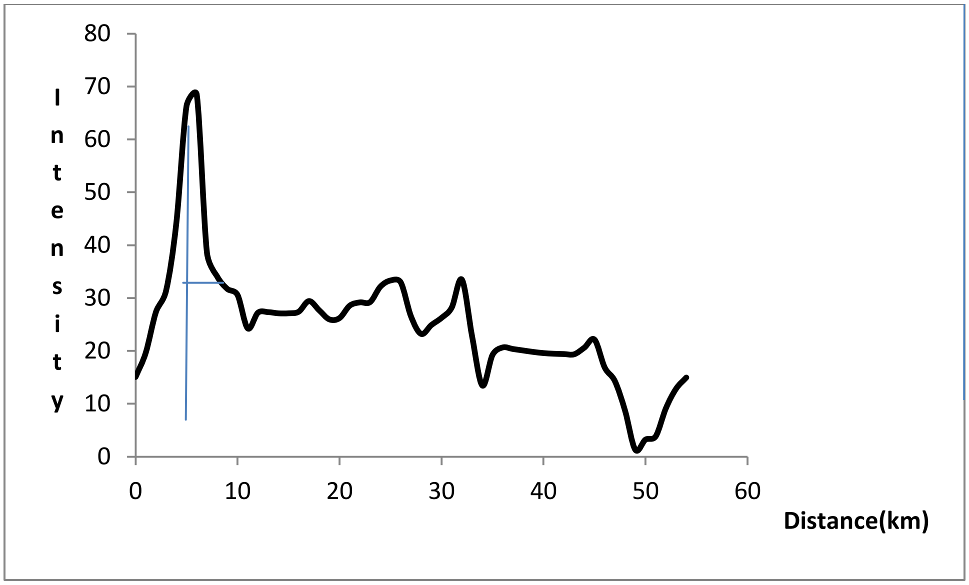


Figure 7, Analytic Signal for profile 47

Table 1.0 presents the approximate depth of each profile for the entire 55 profiles considered in this study. It can be observed that the estimated depths range from 1.0km to 15.5 km. The high value depths correspond to the deep sited structures, while the low values may represent some anomalous bodies of local magnetic features, which may be of economic importance.. The deep rooted features may also be the site of the magnetic basement of the study area. We can also infer from the results that there are sizeable quantities of different magnetic deposit structures on the location.

4.0 Conclusion

The results from this study clearly showed the variations along profiles in the surface of magnetic basement across the study area. The analytical signal amplitude revealed the depths of the deeper magnetic features and the shallower magnetic sources. These may also correspond to the regional and the residual magnetic anomalies of the study area. The results obtained in this study also demonstrate the suitability of the analytical signal method in estimating the depth to the magnetic source from aeromagnetic data.

TABLE 1.0: VALUES OF THE ESTIMATED DEPTH FOR EACH PROFILE.

PROFILE	DEPTH (km)
1	7.0
2	6.0
3	9.5
4	7.5
5	9.5
6	12.5
7	7.0
8	13.5
9	11.0
10	15.5
11	11.5
12	12.0
13	10.5
14	5.5
15	15
16	14.5
17	16
18	1.0
19	4.5
20	3.5
21	5.0
22	5.0
23	4.0
24	5.0
25	4.0
26	5.5
27	4.0
28	3.5

29	1.0
30	3.0
31	5.0
32	3.0
33	4.0
34	2.5
35	3.0
36	3.5
37	11.5
38	11.0
39	15.0
40	12.5
41	14.0
42	14.0
43	12.5
44	7.0
45	12.0
46	5.0
47	3.0
48	3.0
49	11.5
50	10.0
51	11.0
52	11.0
53	11.0
54	10.0
55	2.0

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