IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 6, Issue 4 Ver. I (Jul. – Aug. 2018), PP 01-10
www.iosrjournals.org

Power Spectral Analysis and Edge Detection of Magnetic Data of Migori Greenstone Belt, Kenya

Odek Antony[1], Githiri John[2], K'Orowe Maurice[2], Ambusso Willis[3]
[1]*Chuka University, Physical Sciences Department, P.O. Box 109-60400, Chuka*
[2]*Jomo Kenyatta University of Agriculture and Technology, Physics Department*
[3]*Kenyatta University, Kenya, Physics Department*
Corresponding Author: Odek Antony

Abstract: *With the continuous extraction of minerals in Migori greenstone belt, exploration is currently evolving from surface based exploration to subsurface exploration. This necessitates a good understanding of the geophysical features in the subsurface which are likely to have a direct bearing on the distribution of minerals. In this study, the measured total magnetic field data was subjected to cleaning process to remove perturbations which are not of geophysical interest, and later enhanced by removing long wavelength anomalies which are as a result of regional magnetic trend. Power spectral analysis of geologically constrained magnetic intensity field data was then conducted, in order to obtain the limiting depth of the anomaly causative bodies. Edge detection techniques were then employed on the delineated magnetic field intensity anomalies trending WNW-ESE along the belt. The power spectral analysis shows bodies of high magnetic field intensity from the ground surface to a limiting depth of approximately 400 m. The anomalous region is bounded by two major faults along rivers Migori and Munyu. Integrating the 2-D inversion of magnetic field intensity data and the geology of the area, the magnetic field perturbation is associated with banded iron formations which act as the host for the minerals.*

Keywords: *Magnetic, Anomalies, Migori Greenstone belt, Inversion, Minerals*

Date of Submission: 30-06-2018 Date of acceptance: 17-07-2018

I. Introduction

1.1 Depth estimation and Edge detection techniques

Magnetic survey of Migori greenstone belt was conducted with an aim of approximating the depth of the anomaly causative bodies and delineating the productive parts of the belt. Limiting depth as a parameter under investigation, does not only give the approximate depth of the anomaly causative bodies but also acts as a start up parameter for further indirect interpretation. In this study, limiting depth was obtained by the use of power spectral analysis, it quantifies the property that the magnetic anomalies decay rapidly with distance from the source. Also, due to the wide nature of this belt, it was necessary to locate the productive parts of the belt by enhancing the anomaly features and their edges. This was done by applying tilt derivative and analytical signal edge detection techniques.

1.2 Geological and tectonic setting

Migori greenstone belt runs west-northwest to east-southeast between Lake Victoria and the Great Rift Valley. The belt is squeezed between the diapiric migori granite batholith to the south and a felsic volcanic succession to the north. The structure of the Migori greenstone belt appears to reflect diapiric movements of the migori Granite batholith. The geology of the area (Figure 2) consists of Archean greenstone belt that surrounds Lake Victoria. The Archean rocks in this area are principally of the Nyanzian system, the Kavirondian system and the post-Kavirondian granites that surround Lake Victoria (Shackleton, 1946). The history of gold mining in this area, especially the history of Macalder mine, situated to the north-west of Migori town indicates the potential this area has for mineral production. In the vicinity of Macalder mine, gold occurs mostly in concordant quartz veins, some of which crop out and are worked by artisanal miners as shallow opencast workings (Ngira exploration works, 2009). An explorer may need to know that systematic exploration is usually based on some conception of general or generic setting. In this case an ability to define host structures or units as well as vein location and orientations, coupled with the facility to discriminate mineralized from unmineralized terrain is required.

Study conducted by Shackleton (1946), deduced that the Macalder mine area consisted of sulphide replacement veins. He also described the rocks in the vicinity to be having a regional foliation trending west-northwest and steeply dipping to the north or south. He reported evidence of graded bedding and cleavagebedding relations east of the mine in a south dipping sequence. According to this research the whole belt is sandwiched between Migori granite in the south and porphyritic andesites in the north. The area is also injected with dykes and sheets of granite and quartz-porphyries and sills of epi-diorite and delorite. Recent geological study conducted by Ichangi (1993) concludes that the belt is a Zn-Cu-Au-Ag massive sulphide deposit, with numerous gold occurrences restricted to the greenstone belt. In mapping the area and defining the lithofacies, he has divided the rocks into formations and adopted modern stratigraphic nomenclature in naming the lithostratigraphic units. According to him, a considerable economic potential for gold exist in Migori as the type of gold mineralization, volcanogenic massive sulphides, is the most common and widespread in other Archeancratons. (Ngira exploration works Ltd, 2009)

1.3 Study area

The study was conducted within Migori county located on the Western part of Kenya (Figure 1). It covered Kehancha, Masaba, Nyanchabo, Migori, Mukuro, Masaba and Macalder.

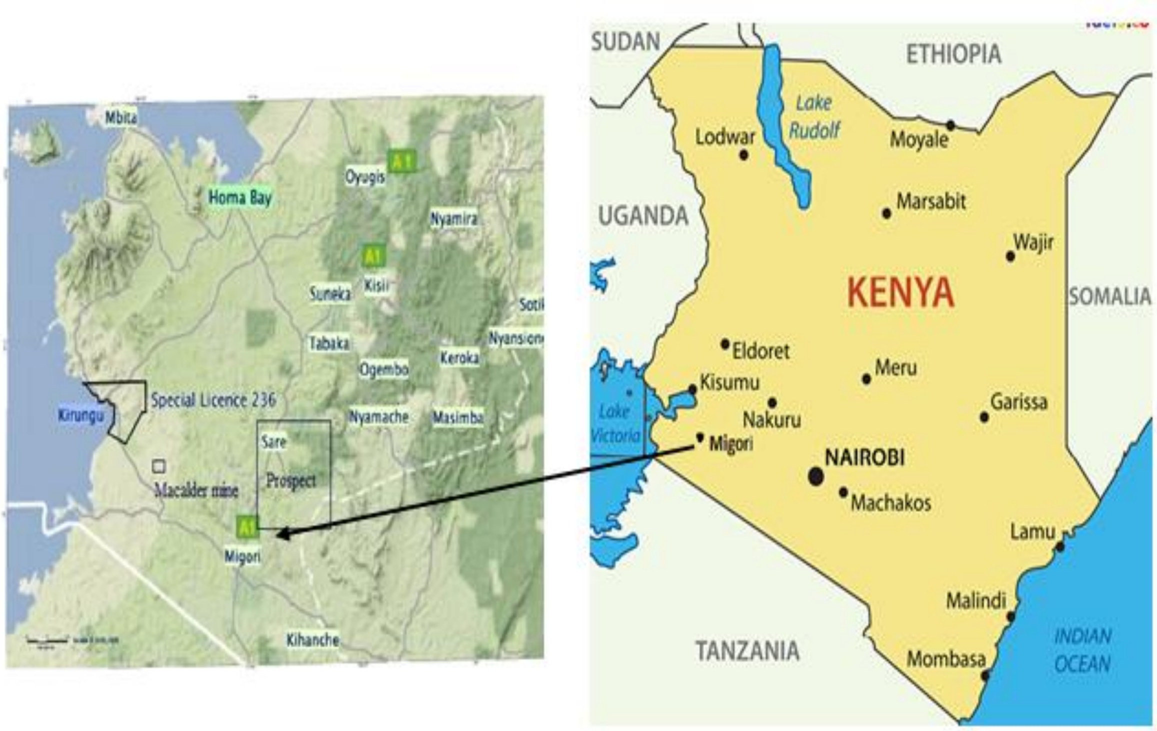

Figure 1: Topographic map of the study area (Ogola, 1987)

1.4 Magnetic technique

Magnetic survey method can provide comprehensive structural, genetic and target evaluation and achieve site discrimination in terms of potential economic deposits (Leaman, 1992). Magnetic data is acquired with the goal of determining variations in the magnetic field intensity. This physical property can be interpreted in terms of lithology and/ or geological processes and their geometric distributions can help delineate geological structures and used as an aid to determine mineralization and subsequent drilling target (Philips *et al.*, 2010).

The magnetic field B due to the pole of strength m at the same distance r is defined by equation 1, (Keary *et al.*, 2002).

$$B = \frac{\mu_0 m}{4\pi \mu_R r^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where μ_0 and μ_R are magnetic permeability of vacuum and relative magnetic permeability of medium separating the poles respectively. The total field anomaly (ΔB) due to both horizontal and vertical components is given by equation 2 which is related to susceptibility as in equation 3

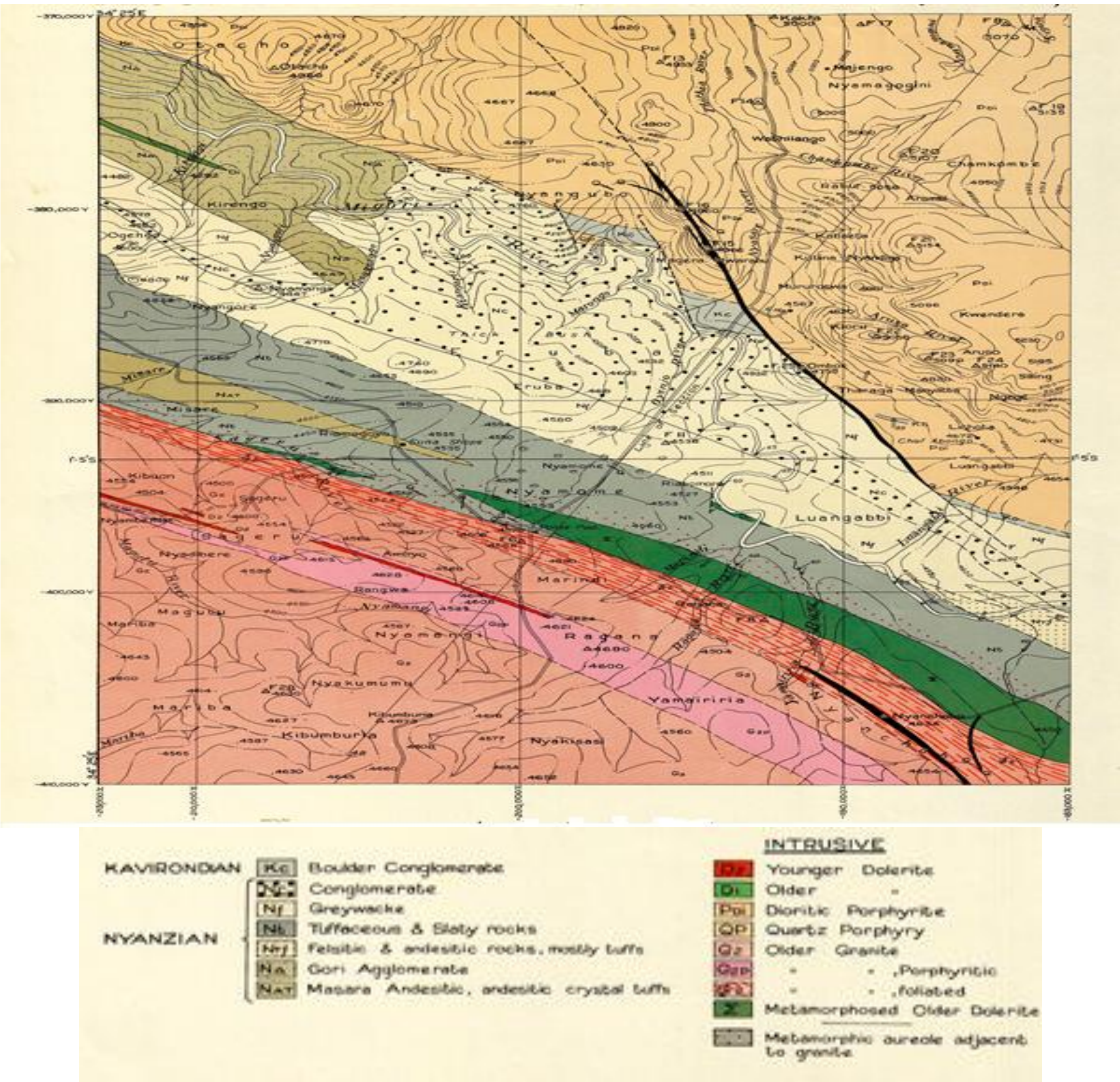

Figure 2: Local geology of Migori greenstone belt (Shackleton, 1946)

$$\Delta B = \frac{-\mu_0 mz}{4\pi r^3}\sin I + \frac{\mu_0 mx}{4\pi r^3}\cos I \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 2$$

$$\mu_0 = \frac{\mu}{k+1} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 3$$

II. Data acquisition

Ground magnetic data was collected from 425 stations established over an area of approximately 200 km^2 bounded by the latitudes 34˚15'E -34˚40'E and longitudes 0˚55'S – 1˚12'S in Migori, Macalder and Kehancha areas, with station and profile spacing of approximately 300 m and 1 km respectively. Total magnetic field intensity measurements were taken using Proton precession magnetometer. Variations in the earth's magnetic field intensity which did not result from the differences in magnetic intensity of the underlying rocks which includes instrumental drift and geomagnetic field were corrected from the ground survey data. Drift correction was done by having a base station which was preoccupied periodically in the day. A drift curve was plotted and readings made in other stations assumed to have a linear drift as fitted base readings. Using the drift rate each reading was corrected to what it would have read if there were no drift. The localized magnetic anomalies caused by rocks are superimposed on the normal magnetic field of the earth. The geomagnetic field exhibits irregular variation in both orientation and magnitude with latitude and time. The International Geomagnetic Reference Field (IGRF) which defines theoretical undisturbed magnetic field at any point on the Earth's surface was used to remove from the magnetic data those magnetic variations attributed to this theoretical field.

Shaded colour contour map of the resulting magnetic field intensity variations (Figure 3) was drawn using Geosoft Oasis Montaj program

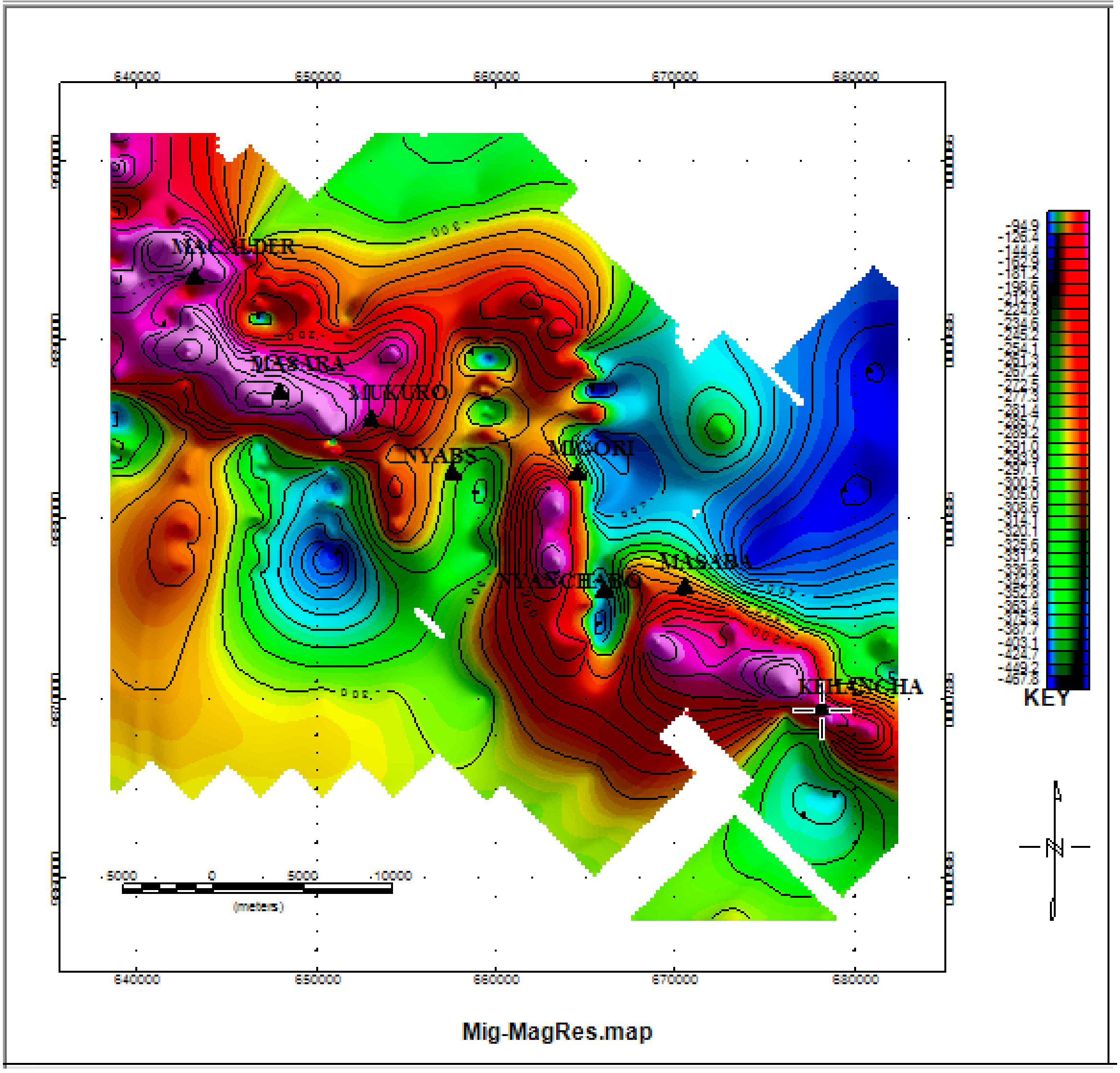

Figure 3: Shaded colour complete Bouguer anomaly contour map of Migori greenstone belt**.**

The magnetic intensity signature was then subjected to total horizontal derivative (THDR) data filtering technique; which is highly suitable in isolating and enhancing anomaly features for mapping shallow basement structure and mineral exploration targets. It does not only accentuate and concentrates the structural features, but also accentuates potential leftover noise from levelling in the data (Geosoft Oasis Montaj program). Therefore the undesirable striation and high frequency noise was simultaneously filtered using a low pass Butterworth filtered (Figure 4). THDR is defined as;

$$\mathrm{THDR} = \sqrt{\left(\frac{\delta f}{\delta x}\right)^2 + \left(\frac{\delta f}{\delta y}\right)^2} \quad \ldots\ldots 4$$

Where THDR is the total horizontal derivative, f is the magnetic or gravity field, $\frac{\delta f}{\delta x}$ and $\frac{\delta f}{\delta y}$ are the first derivatives of the field f in the x, and y directions. This result was later compared with the vertical derivative

(Figure 5) which gives a good correlation in terms of the distribution of the high magnetic field intensity anomalies.

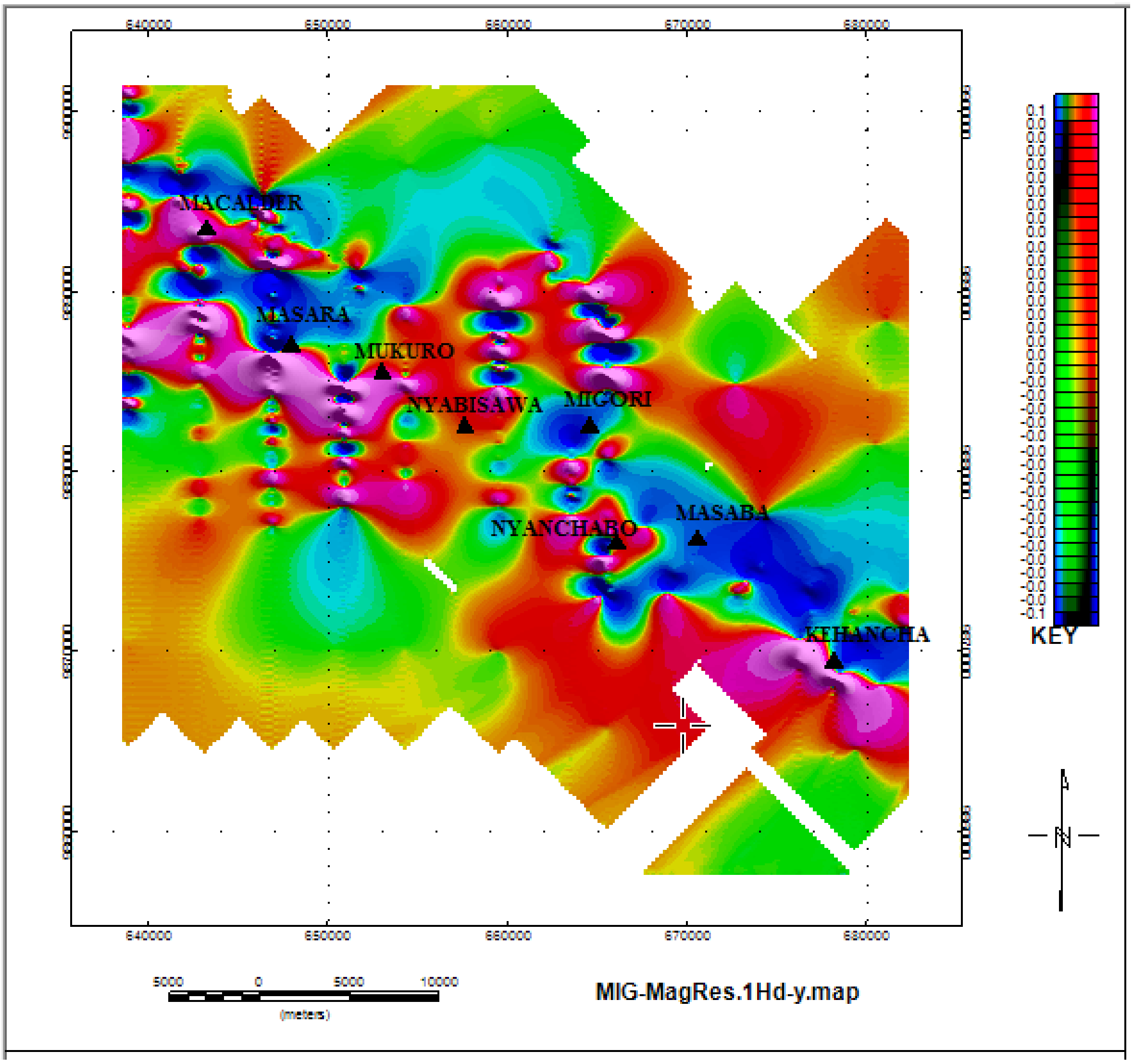

Figure 4: Shaded colour total horizontal derivative (THDR) of the residual magnetic field of Migori greenstone belt

III. Spectral power analysis

The quantitative interpretation of the magnetic field intensity data involved both direct and indirect methods, limiting depth is one of the most important parameters derived by direct interpretation and it may be deduced from magnetic anomalies by making use of their property of decaying rapidly with distance from the source. This effect may be quantified by computing the power spectrum of the anomaly; the log-power spectrum has a linear gradient whose magnitude is dependent upon the depth of the source (Spector and Grant, 1970). Such techniques of spectral analysis provide rapid depth estimates from regularly-spaced digital field data.

It originates from the mathematical distinction existing between periodic waveforms that repeat themselves at a fixed time period T, and transient waveforms that are more repetitive. By means of the mathematical technique of Fourier analysis any periodic waveform, however complex, may be composed into a series of sine (or cosine) waves whose frequencies are integer multiples of the basic repetitive frequency 1/T, known as fundamental frequency. The higher frequency components, at frequency of n/T (n=1, 2, 3 ...) are known as harmonics. A periodic waveform can be expressed either in time domain (expressing wave amplitude as a function of time) or in the frequency domain (expressing amplitude and phase of its constituent sine wave as a function of frequency). These spectra known as line spectra, are composed of a series of discrete values of the amplitude and the phase components of the waveform at set frequency values distributed between 0 Hz and the Nyquist frequency. Transient waveforms do not repeat themselves, that is, they have an infinitely long period (infinitesimally small fundamental frequency 1/T→0) and consequently harmonics that occur at infinitesimally small frequency intervals to give continuous amplitude and phase spectra rather than the line spectra of the periodic waveforms. However it is imposible to cope analytically with spectrum containing an infinite number of sine wave components (Keary *et al.*, 2002).

Fourier transformation of digitized waveform is readily programmed for computers, using a fast Fourier transform (FFT) algorithm as in the Cooley-Tukey method (Brigham, 1974). FFT subroutins can thus be routinely built into data processing programs in order to carry out spectral analysis of geophysical waveforms. Fourier transformation can be extended into two dimensions (Rayner, 1971), and can thus be applied to a real distribution of data such as gravity and magnetic contour maps. Figure 6 below shows computed power spectrum of the magnetic anomalies of Migori greenstone belt.

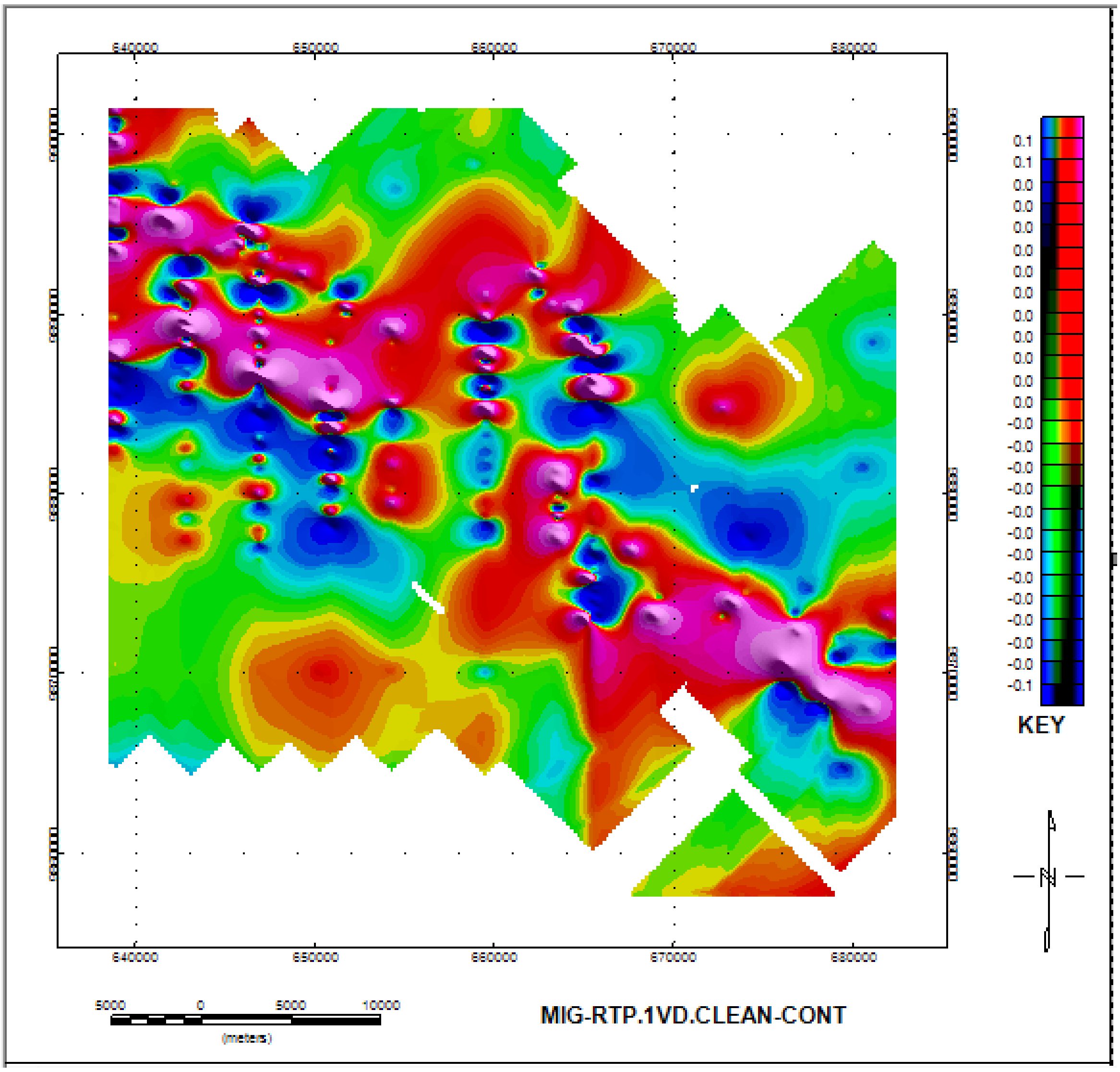

Figure 5: First vertical derivative of the residual magnetic field of Migori greenstone belt

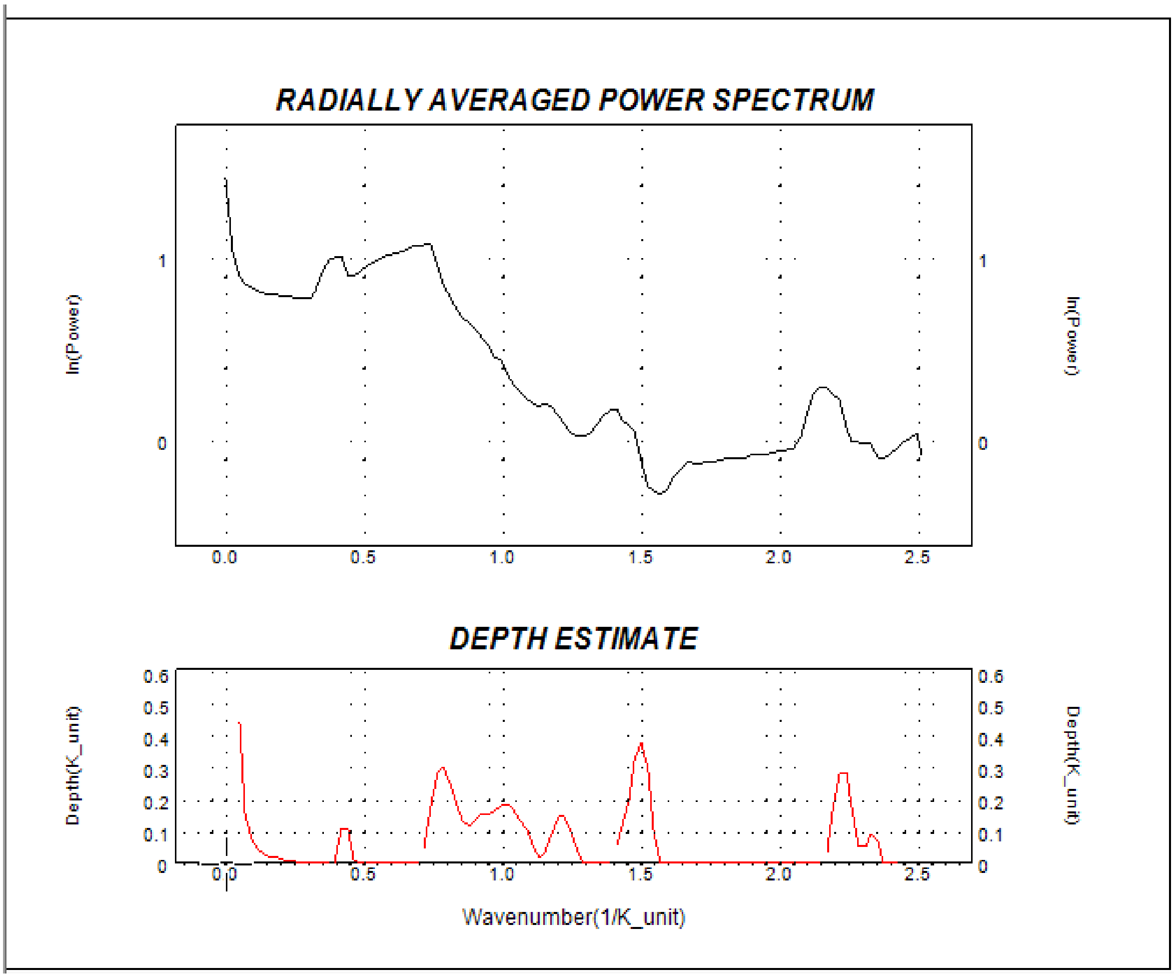

Figure 6: Computed power spectrum of the magnetic anomalies of Migori greenstone belt

IV. Edge detection methods

A number of edge detection methods are currently being applied in the interpretation of magnetic data, the choice of the method to be applied depends on the estimated depth of the anomaly causative body. In this study, power spectral analysis was first computed in an attempt to obtain the limiting depth of the causative body. Shallow structures of limiting depth of about 400 m were delineated, this informed the choice of tilt angle derivative (TDR) and analytical signal (AS) edge detection techniques. The two techniques give good resolution at shallow depths.

4.1 Tilt angle derivative (TDR)

TDR is used for enhancing the anomaly causative body features including its edges, it is applicable in mapping shallow basement structures and mineral exploration targets (Geosoft Oasis Montaj, 2007). It produces positive values directly above the sources, negative values away from the sources and a zero value over or close to the source edges and therefore can be used to trace the edges (Miller and Singh, 1994). It is given by equation 5

$$TDR = tan^{-1}\left[\frac{VDR}{THDR}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

Where VDR is the vertical derivative and THDR is the total horizontal derivative. It can further be expressed in terms of the magnetic or gravity field (f) and the first derivative of the field f in the x, y and z directions $\frac{\delta f}{\delta x}$, $\frac{\delta f}{\delta y}$ and $\frac{\delta f}{\delta z}$ respectively as;

$$TDR = tan^{-1}\left[\frac{\frac{\delta f}{\delta z}}{\left(\frac{\delta f}{\delta x}\right)^2 + \left(\frac{\delta f}{\delta y}\right)^2}\right] \quad \text{...6}$$

The amplitude of TDR range between –π/2 to +π/2 radians regardless of the amplitude of the vertical or the absolute value of the total horizontal gradient (Salem *et al*., 2008). Figure 7 shows the shaded colour map of the TDR of Migori greenstone belt.

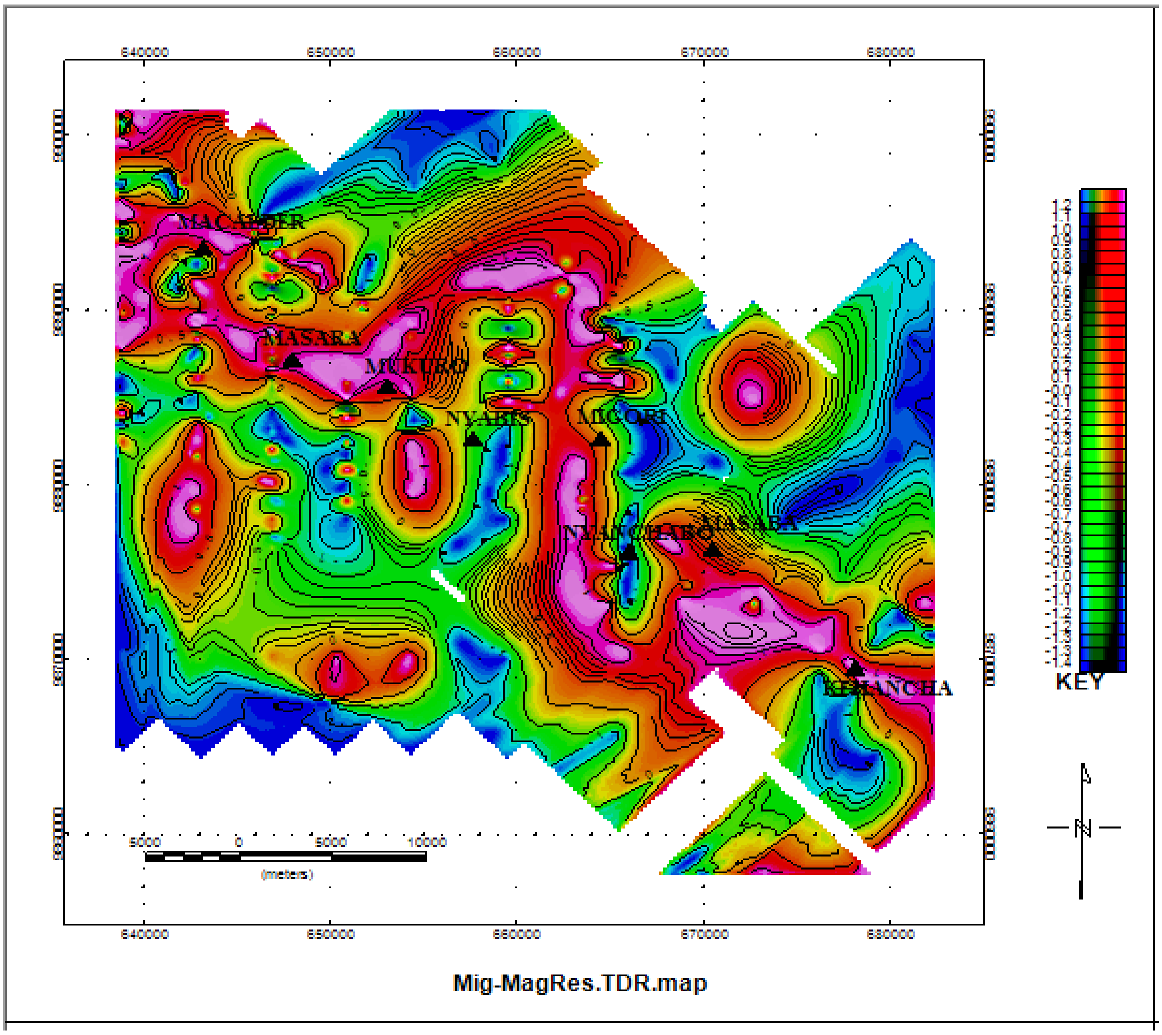

Figure 7: Shaded colour map of tilt angle derivative (TDR) of the magnetic anomalies of Migori greenstone belt

4.2 Analytic signal (AS)

Analytic Signal (Figure 8) is a very useful technique for delineating edges of shallow magnetic sources given that the amplitude of the analytical signal peaks over the magnetic sources (Cooper, 2009). The fact that it is independent of magnetization direction in the 2D case, makes it more appropriate in determining magnetic parameters from magnetic anomalies (Li, 2006). However, it suffers from the assumption that near surface structures can be characterised adequately by step models. It is defined as equation 7

$$AS = \sqrt{\left(\frac{\delta f}{\delta x}\right)^2 + \left(\frac{\delta f}{\delta y}\right)^2 + \left(\frac{\delta f}{\delta z}\right)^2} \quad \text{...}$$

.....7

Where, $\frac{\delta f}{\delta x}, \frac{\delta f}{\delta y}, \frac{\delta f}{\delta z}$ are the first derivatives of the total magnetic field in the x, y and z directions (Roest *et al*, 1992)

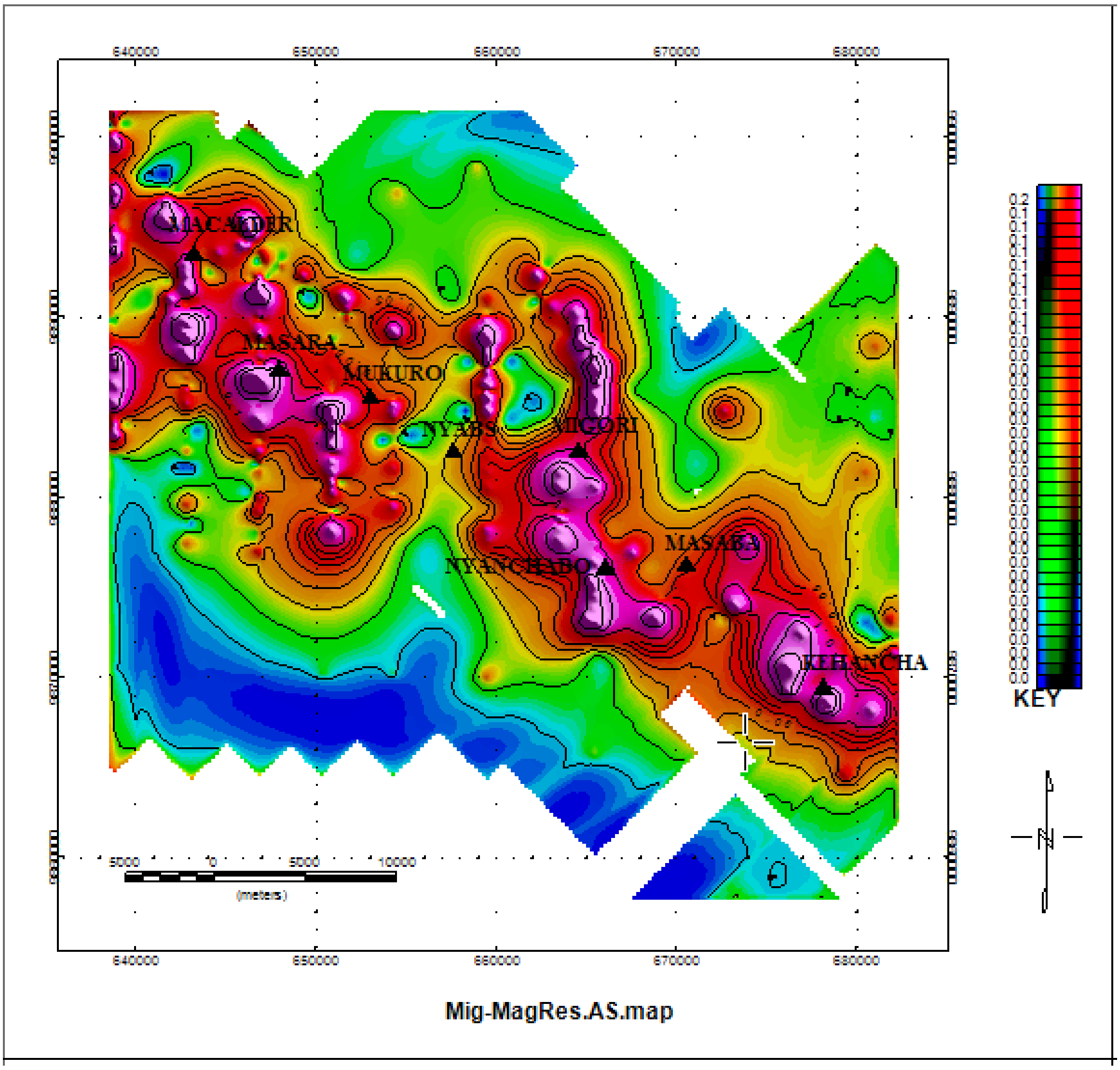

Figure 8: Shaded colour analytic signal of magnetic anomalies of Migori greenstone belt

V. Discussions and Conclusion

The total magnetic field intensity over Migori greenstone belt delineates high magnetic anomalies over the causative structures trending ESE-WNW from Kenya-Tanzania border through Kehancha, Masaba, Nyanchabo, Migori, Mukuro, Masara, all through to Macalder. The anomalies peak at Kehancha, Masara and Macalder, regions that have witnessed a lot of artisan mining using opencast method. The magnetic highs are sandwiched by the high magnetic intensity gradients that are interpreted as fault lines. In order to better interpretation of these sources power spectral analysis technique was used to estimate the depth of the causative bodies and both tilt angle derivative (TDR) and analytic signal (AS) were used for edge detection. The computed power spectrum of the magnetic anomalies (Figure 6) gives a depth of approximately 400 m as the limiting depth of the causative bodies, with some anomalies featuring at shallow depths of about 100 m. From both TDR and AS results, the width of the productive parts of the belt ranges from approximately 6000 m at Kehancha and slightly widens towards Masara and Macalder to approximately 15000 m (Figure 7 and Figure 8). The causative structures are associated with granitic intrusive characterised by the banded iron formations.

VI. Recommendation

We are grateful to National Commission of Science, Technology and Innovation (NACOSTI) and Chuka University both of Kenya for their financial support. We are also grateful to both Jomo Kenyatta University of Agriculture and Technology and Kenyatta University for availing research equipment and technical support. We also recognize Ministry of mining, Kenya for the data analysis program.

References

[1]. Brigham E.O. (1974). *The First Fourier Transform.* Prentice-Hall, New Jersey.

[2]. Cooper G.R.J. (2009). Balancing images of potential field data. *Geophysics*, **74** (3), L17-L20.

[3]. Geosoft (Oasis Montaj) *program, Geosoft mapping and Application system*. Inc. Suit 500, Richmond St. West Toronto, ON Canada N5S1V6. User's Manual 2007.

[4]. Ichangi D.W. (1993).Lithostratigraphic setting of mineralization in the Migori segment of the Nyanza Greenstone Belt, Kenya.*In: Proceedings of the fifth conference of the geology of Kenya.*Nairobi, Kenya.

[5]. Kearey P., Michael B., Ian H. (2002). *An Introduction to Geophysical Exploration*. 3rd edition. London: Blackwell Scientific publications.

[6]. Leaman D.E. (1992). Gold exploration and use of magnetic method in Northern Tasmania. *Bulletin Geological Survey*. Tasmania.**70**: 149-160.

[7]. Li X. (2006). Understanding 3D analytical signal amplitude. *Geophysics*, **71** (2), B13-B16.

[8]. Miller H.G., Singh V. (1994). Potential field tilt-a new concept for location of potential field sources. *Jour of Appl. Geophysics*, **32**, 213-217.

[9]. Ngira Exploration Works Ltd, (2009). *A geological overview of the licence area for Ngira exploration works Ltd*. Ngira.

[10]. Ogola J.S., 1987. Mineralization in the Migori Greenstone belt.Macalder Western Kenya *Geological journal* **22**, (Thermatic Issue): 25-44.

[11]. Philips N., Nguyen T.N.H., Thomson V., Oldenburg D., Kowalezyk P. (2010). 3D inversion modelling, integration and visualization of airborne gravity, magnetic and electromagnetic data *Advanced Geophysical Interpretation centre*, Vancouver, B.C. Canada.

[12]. Rayner J.N. (1971). *An Introduction to spectral analysis*. Pion, England.

[13]. Roest W.R., Verhoef J., Pilkington M., (1992). Magnetic interpretation using the 3-D analytical signal. *Geophysics,* **57** (1), 116-125.

[14]. Salem A., Williams S., Fairhead D., Smith R., Ravat D. (2008). Interpretation of magnetic data using tilt angle derivatives. *Geophysics*, **73**, L1-L10.

[15]. Shackleton R.M. (1946). Geology of Migori Gold belt and adjoining areas. *Geological survey of Kenya,* Mining and Geological Department Kenya, Rept. **10**: 60.

[16]. Spector A., Grant F.S. (1970). Statistical models for interpreting aeromagnetic data. *Geophysics* **35**, 293-302.

IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) is UGC approved Journal with Sl. No. 5021, Journal no. 49115.

Odek Antony ." Power Spectral Analysis and Edge Detection of Magnetic Data of Migori Greenstone Belt, Kenya.IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) 6.4 (2018): 01-10.