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ENHANCING LINEAR FEATURES IN AEROMAGNETIC DATA USING DIRECTIONAL HORIZONTAL GRADIENT AT WADI HAIMUR AREA, SOUTH EASTERN DESERT, EGYPT

Ahmed Mohammed ELDOSOUKY [1], Sayed Omar ELKHATEEB [2], Abeer ALI [2] & Sherif KHARBISH [1]

[1] *Geology Department, Faculty of Science, Suez University, Suez, 43518, Egypt.*
[2] *Department of Geology, Faculty of Science, South Valley University, 83523, Qena, Egypt.*
**Corresponding Author. Tel:+201153267202; Email address: dr_a.eldosoky@yahoo.com and/or Ahmed.Eldosouky@sci.suezuni.edu.eg. Co-authors. elkhateeb24@yahoo.com; engeopero@yahoo.com, sherifkharbish@hotmail.com.*

Abstract: The present work deals with the detection of linear features in aeromagnetic anomalies of Wadi Haimur area, South Eastern Desert (SED), Egypt, according to the directional horizontal gradient (DHG) technique. DHG is an effective tool to improve the linear features in potential data. Given the elevation and azimuth of the anomaly, it calculates sharp lateral variations in densities. Straight features perpendicular on the horizontal azimuth are enhanced, while the parallel ones become limited. It is a standard enhancement technique applied in the interpretation of geophysical data. The DHG algorithm is applied in a different azimuth from an original zero reference line (x-direction). This technique enhances linear features giving more details in the data than those interpreted from other filters. The study of the aeromagnetic anomaly of Wadi Haimur area displays five notable faults trending to NW, NE, N-S, NNW, and NNE directions. This paper introduces a horizontal gradient analysis that does not require the calculation of the vertical derivative of the field and thus is faster and has extensive application for enhancing the linear features of potential field data.

Key words: Aeromagnetic, Linear features, HGM, Directional horizontal gradient.

1. INTRODUCTION

Magnetic methods are one of the common powerful and accessible tools that assist in the identification and mapping of the surface and subsurface geology. Utilization of aeromagnetic analysis helps in explaining the problems of provincial geologic mapping, boundaries detection and structures (Eldosouky & Elkhateeb, 2018; Eldosouky, 2019; Sehsah et al., 2019; Pham et al., 2019), representation of buried contacts, position of the presumable fields of rock differentiation, mineralization (Eldosouky et al., 2017; Pham et al., 2018; Ekwok et al., 2019; Eldosouky et al., 2020) and density of sedimentary cover.

Linear feature enhancement in potential field data is very helpful as it enables dykes, faults, and other features to be presented more obviously, thus assisting the geologic understanding process (Cooper, 2003). One of these methods is to apply directional horizontal gradient (DHG), i.e. the data gradient in a given direction, in either the frequency or space domains (Cooper, 2003).

In the present study, we apply horizontal gradient magnitude (HGM) and DHG to aeromagnetic data of Wadi Haimur area, South-Eastern Desert (SED), Egypt for a better understanding and a more obvious analysis of linear features affecting the study area

2. GEOLOGY OF THE STUDY AREA

Wadi Haimur area is situated southeast to Aswan in the South-Eastern Desert (SED) of Egypt between latitudes of 22º 35' 00" and 23º 00' 00" N and longitudes of 33º 52' 50" and 34º 10' 00" E (Fig. 1).

The Northern Sudan, Egyptian Eastern Desert (EED), and western part of Saudi Arabia have been collectively named the Arabian–Nubian Shield (ANS), which is distinguished by four principal rock associations: (i) an arc association; (ii) an ophiolite association; (iii) a gneiss association; and (iv) intrusions of granite (Abdel Rahman, 1995).

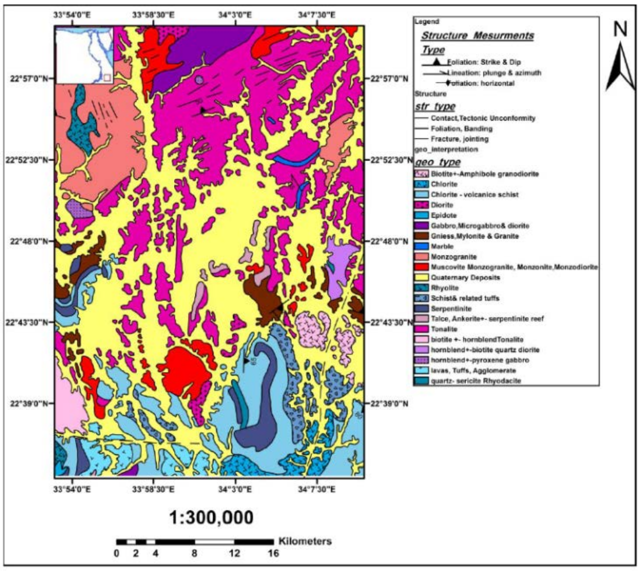

Figure 1. Location and geology of Wadi Haimur area.

Wadi Haimur region is a section of the Precambrian belt in the SED of Egypt (Fig. 1). Three different rock units are distinguished: ophiolites, gneisses and granites. The amphibolites, which form the principal rock type of the ophiolitic rocks, were formed in a back-arc setting (Abd El-Naby, 1998), while the granites are associated with collision-related magmatism. The gneisses of Wadi Haimur area are described to have a sedimentary origin. Compositions of amphibole and muscovite indicate that the gneisses relate to a low-pressure metamorphic facies progression (Abd El-Naby, 1998). Relationships between the prevailing features of Wadi Haimur metamorphic sequence (amphibolites, metagabbros, and hornblendites) and metamorphic soles underneath ophiolites (Searle & Cox, 1999) suggest such an origin for Wadi Haimur rocks.

Abd El-Naby et al. (2000) studied Wadi Haimur area and concluded that Wadi Haimur–Abu Swayel region revealed the remnants of back-arc oceanic crust that causes a metamorphic bottom underneath an allochthonous ultramafic source, which was overthrust as a hot body.

3. DATA AND METHODOLOGY

3.1. Horizontal gradient (HG)

HG derivative maps are simple and instinctive products to exhibit the anomaly texture of magnetic maps and to delineate discontinuities in the anomaly pattern. Cordell et al., (1985) stated that the one dimension of the horizontal derivative can be acquired in the space domain by subtracting the first value (x_1) from the third one (x_3) or by subtracting two consecutive values; the resultant value will represent the midway point (Δx) between these two values as:

$$\frac{\partial f(x)_{1.5}}{\partial(x)} = \left[\frac{f(x)_3 - f(x)_1}{2\Delta x}\right] \qquad (1)$$

$$\frac{\partial f(x)_2}{\partial(x)} = \left[\frac{f(x)_2 - f(x)_1}{2\Delta x}\right] \qquad (2)$$

The HG algorithm can be applied to different angles from an original zero reference line (x-direction) to generate directional horizontal gradient (DHG) maps.

3.2. Horizontal gradient magnitude (HGM)

Horizontal gradient magnitude (HGM) approach (Blakely and Simpson, 1986; Nassreddine & Haydar, 2001) is conceivably the most simplistic method to determine the locations of magnetic contact and depths because it does not require the consideration of vertical derivatives but only the two first-order horizontal derivatives of the domain. Thus, for a grid of magnetic field value T (x, y), the HGM is expressed by:

$$HGM = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2} \qquad (3)$$

4. RESULTS AND DISCUSSION

In this work, aeromagnetic data is employed to analyze the structural trends of the studied region. To achieve this, the reduced to the pole (RTP) map (Aero-Service, 1984) was enhanced (Fig. 2). RTP map of the study area (Fig. 2) shows magnetic highs and lows (positive and negative anomalies) ranging from -115.4 to 323.6 nT. It is clear to notice that the northern part shows magnetic highs while magnetic lows are dominant the southern part.

The DHG algorithm is applied to RTP dataat various angles from an original zero reference line (x-direction) to generate DHG maps. The used angles are 0º, 22.5º, 45º, 67.5º, 90º, 112.5º, 135º and 157.5º.

Figure 3a shows the DHG of Wadi Haimur area with an angle of 0º from the reference line (x-direction) representing the N-S direction. This figure (3a) maps well the locations of the N-S trend affecting the study area and illustrates that it was scattered by NE and NW directions. While the DHG with an angle of 22.5º (Fig. 3b) illustrates that the NNW direction has small traces in the study area.

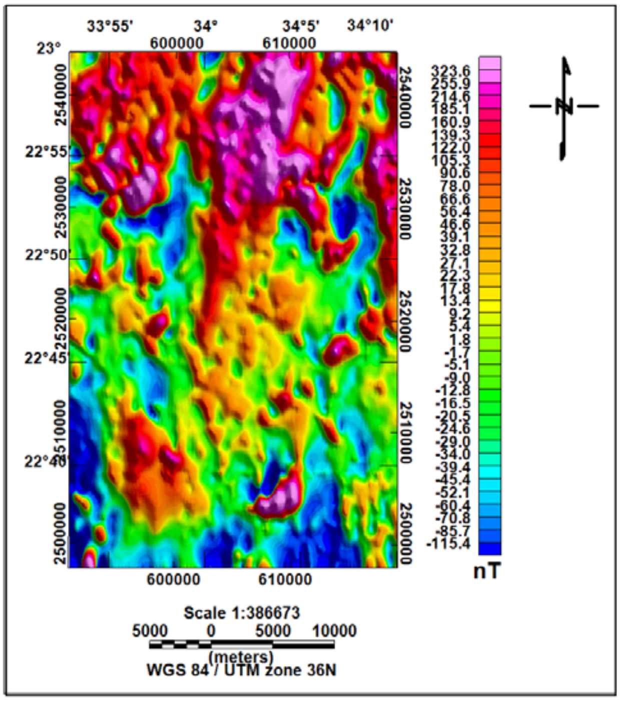

Figure 2. RTP map of Wadi Haimur area.

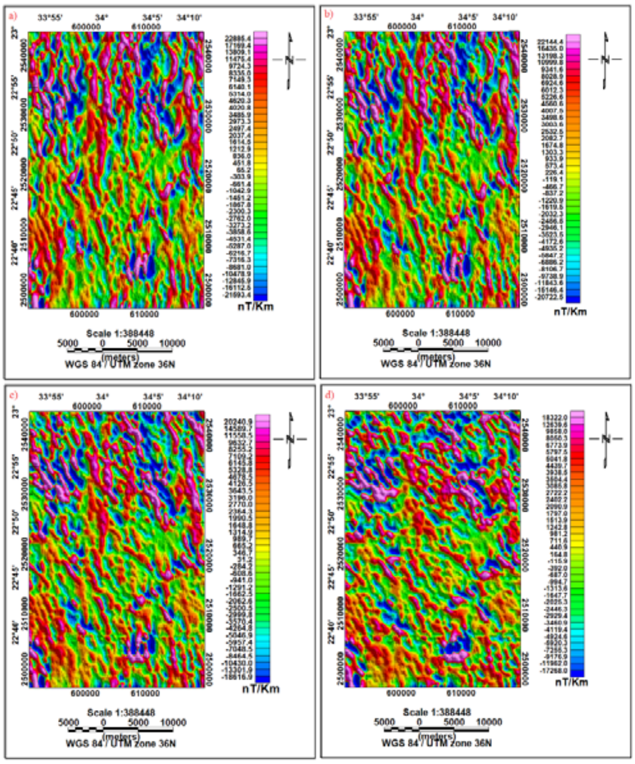

Figure 3. The DHG-RTP of Wadi Haimur area with an angle from the reference line (x-direction) of: a) 0º; b) 22.5º; c) 45º; and d) 67.5º.

The DHG with an angle of 45º (Fig. 3c) which is related to NW direction shows that this one is the predominant structural trend affecting the study area and is scattered by the NE direction. The WNW direction can be traced in the southern part of the study area where the DHG of 67.5º was applied (Fig. 3d).

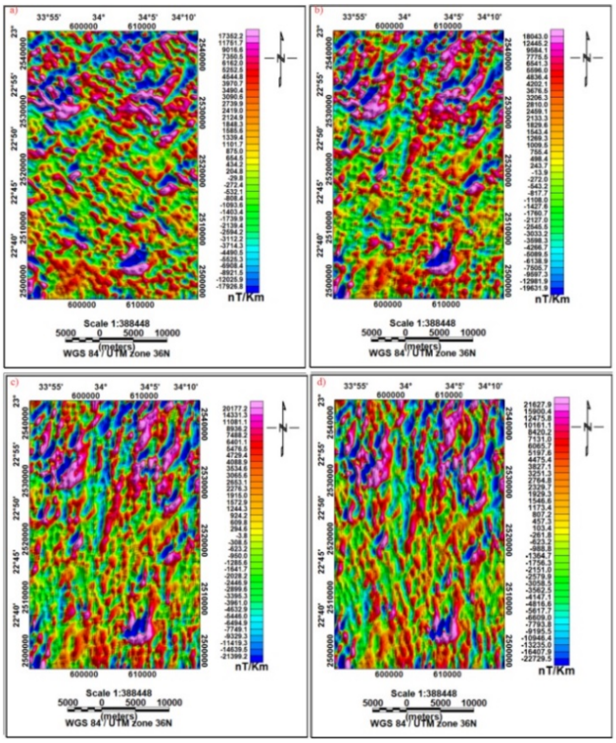

Figure 4. The DHG-RTP of Wadi Haimur area with an angle from the reference line (x-direction) of: a) 90º; b) 112.5º; c) 135º; and d) 157.5º.

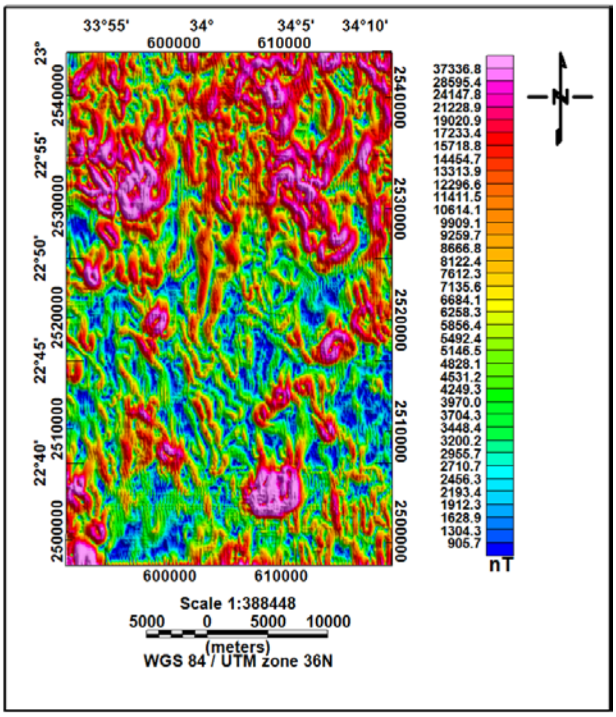

Figure 5. Horizontal gradient magnitude (HGM-RTP) map of the study area.

The DHG of Wadi Haimur area with angles from the reference line (x-direction) of 90º, 112.5º, 135º and 157.5º to the RTP data as shown in figure 4 (a, b, c, and d). These DHG maps represent the E-W, ENE, NE and NNE directions respectively. The E-W and ENE directions have a limited effect on the study area appears the southern part of the map (Figs, 3a, and 3b respectively).

Equation 3 was applied to the RTP data to estimate the HGM map as shown in Figure 5. From the HGM-RTP map one observes that the faults/boundaries are located at the maxima of the HGM. The most obvious structural trends are the NW, N-S, and NE directions. Comparison of HGM results with those of DHG showed that the DHG results have more details for trend analysis. The detailed structural features obtained from DHG technique, than the trends that dectecetd and obtained from HGM map, can be interpreted according to Grauch (1987) who stated that the horizontal gradient magnitude identifies only the faults that have a vertical extension. On the other hand, the DHG can detect faults and geologic boundaries that have both vertical and horizontal extensions.

5. CONCLUSION

The present work deals with the interpretation of the magnetic anomalies at the Wadi Haimur area, South Eastern Desert (SED), Egypt, caused by the distribution of surface and subsurface geologic formations and their structures. The application of directional horizontal gradient (DHG) method to magnetic data is used in interpreting the structural directions of Wadi Haimur area. The DHG delineated faults/boundaries that have no clear evidence on the HGM map and cannot be identified by geologic mapping. The results of the present work lead to a better understanding of structures and stresses directions controlling Wadi Haimur area, which can be used in similar districts for trend and structural analysis purposes.

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