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Analysis and Interpretation of Airborne Magneticdata of G.Abu Had-G.Umm Qaraf Area, South Eastern Desert, Egypt

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I. Introduction

This paper discusses some of the guidelines used in analyzing high-resolution aeromagnetic surveys and illustrates some of the techniques and software tools used for reducing, processing and interpreting such aeromagnetic data for structural and tectonic features. Geologic structures (like ore bodies or faults) often produce small magnetic fields that distort the main magnetic field of the earth. These "anomalies" can be detected by measuring the magnetic field near the surface of the ground. By analyzing these measurements, geophysicists can learn about geologic structures, even though the structures may be concealed entirely below the earth's surface (Blakly. 1995).

The present study deals essentially with the analysis and interpretation of aeromagnetic survey data acquired. The data interpretation would be supplemented by the consideration of all available previous geological and all information works in this area. In brief the proposed study has the following main objectives:

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1- Analyzing the airborne magnetic data to define the basement rock units.
2- Mapping the surface and subsurface structures that can be shade more light on the structural setting by using 2D modeling technique.

Area is located in the southern part of the Eastern Desert of Egypt. It is about 100 km southwest Marsa Alam City. The surveyed area is bounded by latitudes 24° - 25°N and longitudes 34^0- 35^0 E with 1221 km^2 area (Fig.1). More than 95% of the area is covered by crystalline basement (igneous and metamorphic rocks). Sedimentary rocks and wadi sediments cover small region. Quaternary sand and gravel extensively cover plains and wadis. The compiled geological map shows the available information about the surface geology. Faults, joints and foliation, in addition to lithologic boundaries, are the main features controlling the dendritic drainage pattern of the area.

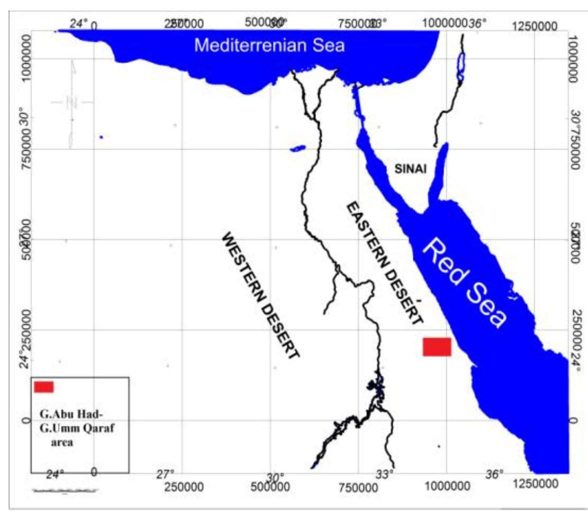

Figure 1: location map of G.Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt

II. Geological Outline

The study area is a part of the Precambrian belt in the south Eastern Desert of Egypt. Proterozoic (igneous and metamorphic) and Phanerozoic rocks are exposed in the studied area as illustrated in the geologic map (Fig. 2) that modified after EGSMA (1997 and 2001).

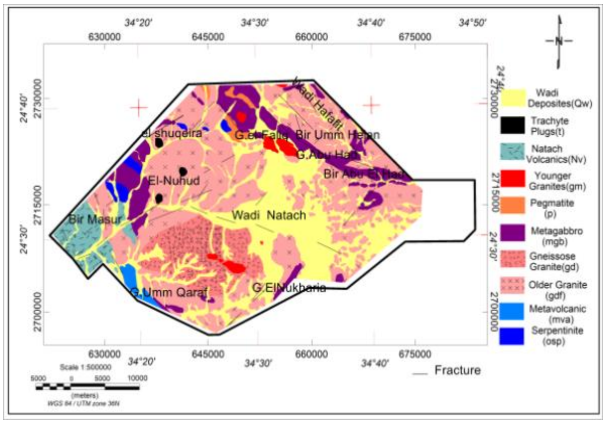

Figure 2: geologic map of G.Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt, after EGSMA (1997 and 2001)

a) Quaternary Sediments (Qw)

Detritus, sands, gravels, pebbles, cobbles and boulders are distributed all over the area and constitute the surficial cover in the main Wadis. They are generally formed by the weathering of the different types of rocks. Quaternary deposits are represented by wadi deposits (alluvial sediments) along the courses of wadis such as Wadi Natach at the centre of the studied area and Wadi Hafafit at NE part of the area. Also there are wadies at south, north and central parts.

b) Trachyte plugs (T)

They are represented by trachyte plugs and sheets. They have exposure like spots at the west of the area. These trachyte plugs are located at El-Nuhud; they are fine-grained, massive and vary in coulor from dark grey to grayish brown.

c) Natash volcanics (Nv)

These volcanics are well exposed west of the area. They are basic to acidic alkaline, undeformed volcanic rocks. Wadi Natash volcanics acquired their name from the type locality, Wadi Natash, located at the western border of the basement complex at the South Eastern Desert of Egypt. They were extensively erupted during the upper Cretaceous associated with the regional uplift preceding the northern Red Sea rifting. Surface manifestation of these volcanics is cropped out in separate locations in the study area as alkaline basalts and numerous of small trachytic intrusions (Hashad, et al., 1982).

d) Younger Granites (gm)

The younger granitic rocks (alkali feldspar granites) are outcropping in northern and southern parts of the studied area with small exposure. The majorities of these intrusions are rounded or elongate parallel to the direction of the Red Sea and possess relatively sharp contacts with the surrounding rocks. The younger granites are exposed in the eastern side of G. El Faliq, Naslet Abu Gabir as well as northeast W. Abu Gherban. They are characterized by low to moderate topography (375 m), cover about 95 km2, constituting some 45 in vol. % of the total exposed basement rocks and form elongated mass in NW-SE direction(Mostafa, 2013).

e) Pegmatite (P)

Pegmatite occurs as steeply dipping bodies of variables size. These rocks are very coarse grained mainly observed in the older granites near the contact with ophiolitic mélange. They are mainly composed of milky quartz, plagioclase with small pockets of mica. Also all the granitoid rocks of G. El Faliq are cut and crossed by several pegmatite bodies. These bodies are trending (NNE-SSW) and ranging in length from 50 m to several meters. Also, they occur as pockets or lenses (10-20 m in length) at the margin and the core of the gneisses rocks as well as ophiolitic mélange (Mostafa, 2013).

f) Metagabbro (mgb)

It is undifferentiated Intrusive metagabbro. It is exposed as limited outcrops at the western and northeastern parts of the studied area. It is composed of heterogeneous assemblage of rock types. They are mainly metamorphosed basic rocks including gabbro, norites, delorites, and basalts, in which the igneous textures are partly preserved.

g) Gneissose Granites (gd)

Gneissose granites are highly mylonitized and dissected by several faults mostly oriented to NW-SE directions. They show a well developed planer banding, gneissosly and folding. Small size quartz and pegmatitic veins are common and seem to be developed from the gneiss through mobilization and crystallization.

h) Older Granites (gdf)

They are exposed as wide outcrops located around Wadi Hafafit at the northwestern and eastern parts and represented a wide exposure of G. Umm Qaraf at the southern part of the area.

It occupies the extreme eastern side of the G. El Faliq. Also they have a wide exposure around G. Umm Qaraf. It occurs along the contact between the ophiolitic mélange and the younger granites. The older granites are characterized by relatively low to-medium topography. In hand specimens they are whitish in colour and characterized by medium to coarse grained and obvious biotite flakes (Mostafa, 2013).

i) Acidic metavolcanics (mva)

It is Intermediate to acidic metavolcanics and metepyroclastics. It is exposed in a small part in the area at the southwestern part. The metavolcanics constitute a pile of regionally-metamorphosed submarine lava flows of alternating basic, intermediate and acidic compositions.

j) Serpentinite (osp)

The ophiolitic rock in the area under study represented by Serpentines (osp), talc carbonates and related rocks. Serpentinite, essentially formed after harzburgite and to a lesser extend after dunite and lherzolite, are frequently transformed into talc-carbonates particularly along thrust fault and shear zone. Outcrops are located as few masses at the west. Serpentinite at G. Faliq area occurs either as huge masses or small masses at the western part of the studied area (Fig.2).

III. Airborne Survey Specification

Airborne Geophysics Department of the Egyptian Nuclear Materials Authority (NMA, 2012), Exploration Division conducted a comprehensive airborne high resolution magnetic survey, over G.Abu Had-G.Umm Qaraf, South Eastern Desert, Egypt,. Along flight-lines oriented in NE-SW direction using 250m line spacing for central and east area but 1000 m for the north and west area meanwhile the tie-lines oriented in NW-SE direction using 1000 m line spacing for all the area. Nominal flying elevation was 100m above ground surface. The airborne geophysical department (AGD) of the nuclear materials authority began operations by the beginning of 19 Jan, 2012 until March 2012.

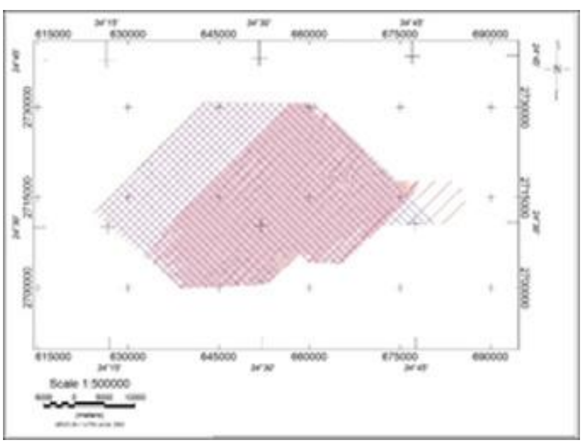

Figure (3): survey lines over South Eastern Desert, Egypt

IV. Total Magnetic Intensity Map(TMI)

The careful examinations of the TMI map (Fig. 4) showed that, the investigated area is characterized by the presence of numerous groups of shallow positive and negative magnetic anomalies of varying wavelengths, amplitudes, sizes, as well as magnitudes. The variation in magnitude of amplitudes and wavelength of these magnetic anomalies may reflect changes in the composition of geologic rocks and their depths, respectively. Meanwhile, the differences in sizes of the anomalies reflect the sizes of the various intrusions. The apparent correlation between the magnetic features of the TMI map and the compiled geological map of the area was found to be generally good. The main effected trends at TMI map are northwest-southeast trend located all over the area.

According to the magnetic characters, frequencies and amplitudes of the magnetic anomalies, the TMI map could be subdivided into three zones (Fig.46). The first zone (Zone-1) is characterized by low to very low magnetic values of high frequencies. It ranges from -4327to -202 nT at the northern and western parts of the map. (Zone-1) is recorded over younger granite, Natach volcanic and parts of older granites rocks. The main trend of this level is Northwest-Southeast and North-South trend (Fig. 5).

The second zone (Zone-2) occupies the central and eastern portion of the study area. It has irregular low to intermediate magnetic anomalies in different directions, reflecting different magnetic sources. The intermediate amplitudes range between -202 and -10.9 nT. Geologically, this zone is covered by wide portion of older granites and trending East-West trend (Fig. 5).

The third zone (Zone-3) represents the high amplitude and dense frequency of magnetic field. It characterized by strong positive anomalies with amplitudes ranging between -10.9 nT to 3968 nT, with large variation between them. It occupies parts of the west and south of the area. Geologically, this zone is covered by the, parts of metagabbros, pegmatite and serpentinites. The southern anomalies may be related to the basic and ultrabasic roots of basement rock extended at high depth and appear at the southern part of the Eastern Desert. This configuration of positive anomalies may be attributed to relatively deep-seated low relief basement structures. This suggests that the TMI anomalies are strongly influenced by the regional tectonic.

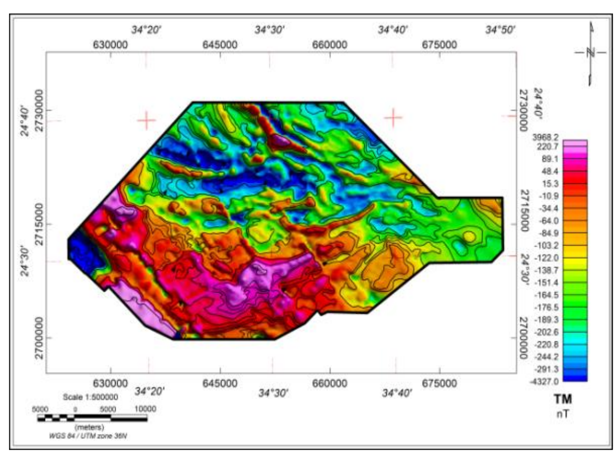

Figure (4): Total Magnetic Intensity Field, G.Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt.

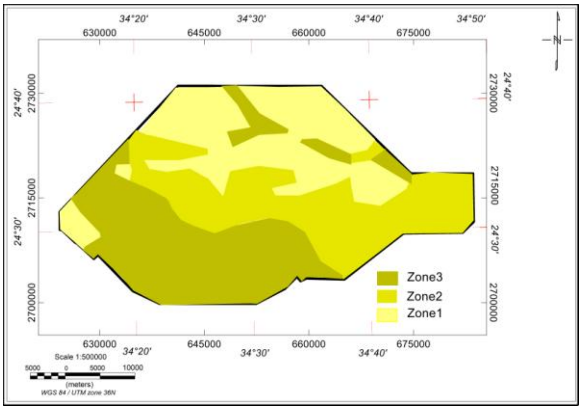

Figure (5): Magnetic Zones Map G.Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt.

V. Spectral Analysis and Regional-Residual Separation

There are many techniques to separate regional and residual magnetic component from magnetic map. Spectral analysis is the best of these techniques which is based theoretically on a Fast Fourier Transform (FFT). The method of frequency analysis is most appropriate, since it provides better resolution of shallow sources. Fourier spectral analysis has become a widely used tool for interpretation of potential field data, especially for depth estimation. This approach has been developed by many workers (Spector and Grant 1970). The energy decay curve (Fig.6) includes linear segments, with distinguishable slopes, that are attributed to the contributions in the magnetic data from the residual (shallower sources), as well as the regional (deep sources). The presentation of the method depends on plotting the energy spectrum against frequency on a logarithmic scale. Figure.6 shows two different components as straight-line segments, which decrease in slope with increasing frequency. The slopes of the segments yield estimates of the average depths to magnetic sources. Regional-residual separation was done at 0.15 frequencies. The depth of deep-seated (regional) magnetic component maps ranges from 500m to more than 1000 m and that of near-surface (residual) magnetic component ranges from 150m to 500m.

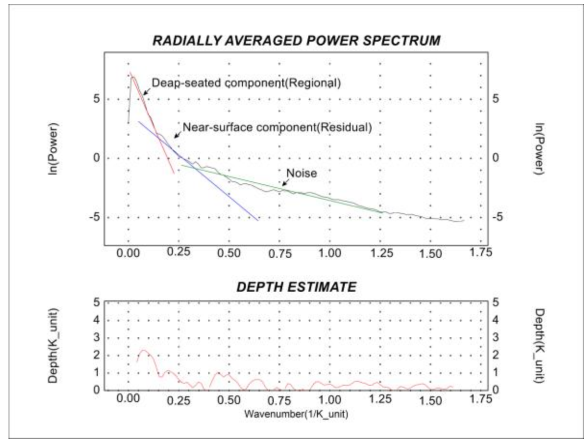

Figure (6): Power spectrum of magnetic data showing the corresponding averaging depths, of G.Abu Had-G.Umm Qaraf area, south Eastern Desert, Egypt.

a) *Residual Magnetic Component Map*

Qualitative and quantitative interpretation can be made more objective by constructing the residual maps of the observed field. Residual maps have been used by geophysicists to bring into focus local features, which tend to be obscured by the broader features of the field (Ammar et al., 1983). The construction of the residual map is one of the best known ways of studying a potential map quantitatively, where the measured field includes effects from all bodies in the vicinity (Fig.7). The residuals focus attention to weaker features that are obscured by strong regional effects in the original map (Reford and Sumner, 1964).

The investigation of the residual magnetic component map (Fig. 7) shows that, it is characterized by the following features:

1. A good similarity to the geologic map at north with anomalies have northwest-southeast and east-west trend which may suggest that, most of the basement rocks in the area, responsible for the magnetization, are either cropping out on the surface or buried at shallow depths like metagabbro and pegmatite intrusions.
2. Presence of broad negative magnetic zones located at southwestern and west parts of the map differing in their shapes and trends. They may reflect different compositions of the basement rocks at the subsurface or shallow basins due to subsiding. These zones are dissected by high frequency irregular and linear anomalies of shallower magnetic sources.
3. Some of the magnetic anomalies are of large areal extent. These anomalies are of moderate to high amplitudes with high magnitudes and high to low frequencies, suggesting that, the magnetic bodies, responsible for the magnetization, are extended at depth.

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b) Regional Magnetic Component Map

The regional magnetic component map (Fig.8) at the assigned interface is the result of removing the residual effects from the TMI map, where the separation procedures are designed to separate broad regional variations from sharper local anomalies. This map could be described as follows:

1. Negative magnetic anomalies (low zones) located in southwestern part of the map extended from northern to southern and far northern parts of the studied area. They covered with, Natach volcanic and granites trending NW-SE and E-W. Their amplitudes range from -990 to -7 nT.
2. Positive magnetic anomalies (high zones). They covered the northern part trending NW-SE trend and found as mass extend in southern part and their amplitudes range from 17.2 nT to 2179 nT and they are covered by pegmatite and parts serpentinite. Also positive values are located at the western part trending NW-SE trend which is covered by serpentinites, metagabbros, parts of older granites and metavolcanics. The anomalies at the southern parts are related to the deep root of basic and ultrabasic rocks.

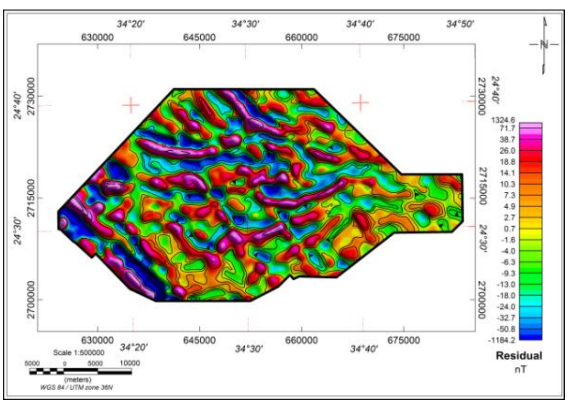

Figure (7): Shaded color contour map of the residual magnetic component, G.Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt

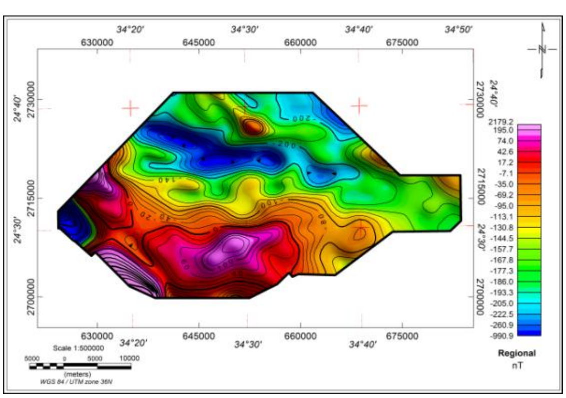

Figure (8): Shaded color contour map of the regional magnetic -component, of G.Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt

VI. Discussion of the Magnetic Depth Calculations

Depth estimation tools are mainly based on a specific algorithm that highly governs the estimated results. Derivation of the algorithm of each method depends on different constraint parameters. For example, Euler deconvolution is mainly constrained by the structural index of the source body, while the power spectrum is constraint by the spectral window of the FFT and the fitting method, and the 2-D modeling is constraint by the magnetic susceptibility of the subsurface layers. The constraint parameters of the applied tools in this study were also reasonably detected because the nature and geometry of the source body is well known. Knowing the source geometry made it possible to constrain the suitable structural index and accordingly estimate well its depth parameter. Although imaging the subsurface geological sources using maps form is advantageous, it was preferred in this paper to interpret the magnetic data in profiling form to avoid the negatives of interpolation used in maps which is believed to reduce the accuracy.

In this work, three advanced techniques were used to analyze the magnetic data as a guide for structural interpretation and basement configuration. These methods are analytical signal (AS), Euler technique and source parameter imaging "SPI" (Thurston and Smith, 1997). These methods are proved as efficient tools to map the location of magnetic structures such as faults and dykes. Magnetic depth estimation is one of the important steps in the quantitative interpretation of magnetic data to help providing useful information about the source body.

The three techniques SPI, AS and Euler results are closed to each other (Figs. 9, 10and 11 respectively). The maps of the depths help us very much to lineate the general structures of basement surface. In this study we applied the Euler method using the structural index (SI≈0) for contact or step and (SI≈1) for sill or dykes (Thompson, 1982 and Reid et al., 1990), since the main objective is to map the faults and contacts. Despite of generating scattered solutions, using structural index very near to zero is the way for better estimation of depth and location of the contact/fault. The estimated depths and locations using Euler methods were compared with that estimated using the SPI methods and the consistent solutions get the highest consideration in the interpretation.

From combination of the three maps, the NE-SW trend show shallower depth presented at the central to eastern parts. The depths at the two zones are related to the results which are calculated at the three methods. The first zone is characterized by deep depths which ranged from -278 to more than-580 for SPI method, from-225 to more than -695 for AS method and ranged from-360 to more than -800 for Euler method.

The second zone has shallow depths. These low values of depths range from -278 to -110 for SPI method, from -225 to -101 for AS method and from -360 to -129 for Euler method. This zone found from east to central parts. The shallow depths have main trends N-S, NE-SW and NW-SE trends.

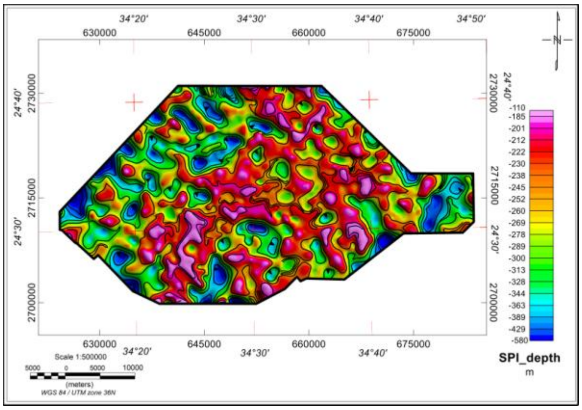

Figure (9): Depth to magnetic basement as calculated using source parameter imaging (SPI), G.Abu Had-G.Umm Qaraf area, south Eastern Desert, Egypt

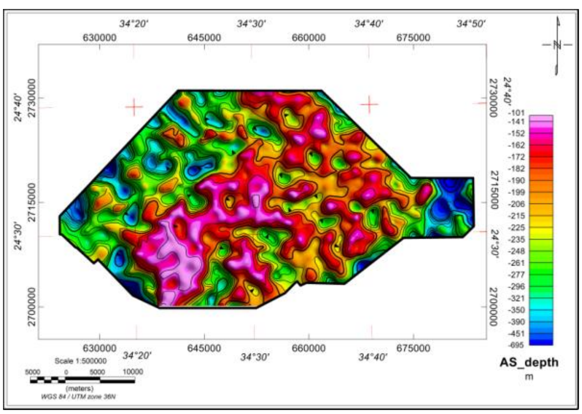

Figure (10): Depth to magnetic basement as calculated using analytical signal (AS), G.Abu Had-G.Umm Qaraf area, south Eastern Desert, Egypt

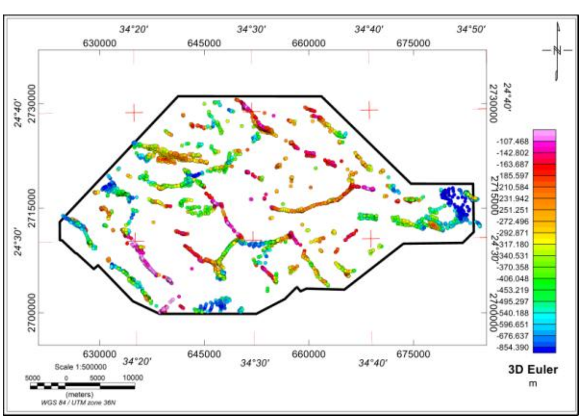

Figure (11): Depth to magnetic basement as calculated using Euler, G.Abu Had-G.Umm Qaraf area, south Eastern Desert, Egypt

VII. Modelling Technique

The two dimentional modelling is simple way to imagine the subsurface structure. The following 2-D model explains profile AA`,BB` and CC` (figure 12).

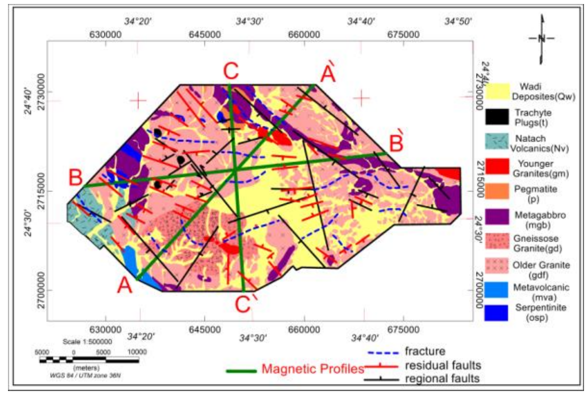

Figure (12): location of 2-D model drawn at Abu Had-G.Umm Qaraf area, south Eastern Desert, Egypt

a) *Two-Dimensional Magnetic Modelling of Profile AA`*

Model AA` was taken at southwest-northeast direction. Close examination of the modelled profile AA` show an excellent fit between the observed and calculated anomalies with error reach 2.78. The magnetic susceptibility values were assumed to be 0.00045 metavolcanic rocks, 0.0043 for metagabbro, 0.00042 for gneissose granites, 0.0004 for older granites and 0.00042 for younger granite for this model. There is may be basement effect of 0.002 magnetic suscibtability. The profile was affected by the faults which appeared at the structural tectonic map.(Fig. 13).

b) *Two-Dimensional Magnetic Modelling of Profile BB`*

The profile BB` located at west-east direction. The modelled profile BB` shows an excellent fit between the observed and calculated anomalies with error reach 0.5. The magnetic susceptibility contrast values were assumed to be 0.0.0004 for older granites, 0.0043 for metagabbro and 0.00045 for metavolcanics rock. We assumed that the magnetic susceptibility for Natach volcanic is 0.029 (Fig. 14). The basement effected bed has magnetic susceptibility of 0.002.This model show faults locations as found at the tectonic map. At this model the Natach volcanic intrusion are located at the west side.

c) *Two-Dimensional Magnetic Modelling of Profile CC`*

Modelled profile CC` was taken at north- south direction (Fig.15). The model passed the same interception point with model AA` and model BB`. The magnetic susceptibility values were assumed to be 0.0043 for metagabbro, 0.00042 for younger granite rocks, 0.0004 for older granites and gneissose granite rocks. Magnetic susceptibility values were assumed to be 0.003 for pegmatites and it was assumed to be 0.002 for basement rocks.

The resulted models show that an image that two faults affected this profile and show the lateral change in lithology. At this model we suppose that the effect of magnetic susceptibility was because of the surface basement rock or their changes in composition and structure.

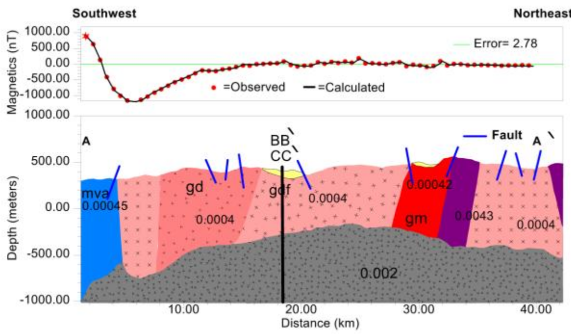

Figure (13): 2-D modelling of profile (AA`), .Abu Had-G.Umm Qaraf area, south Eastern Desert, Egypt

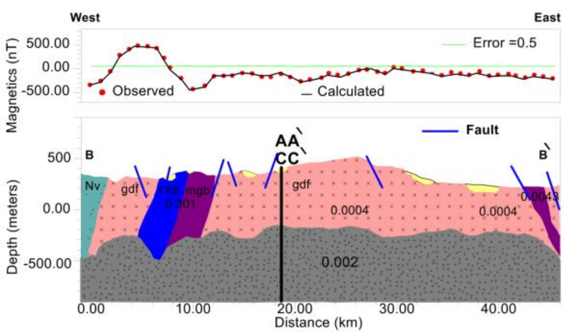

Figure (14): 2-D modelling of profile (BB`), Abu Had-G.Umm Qaraf area, south Eastern Desert, Egypt

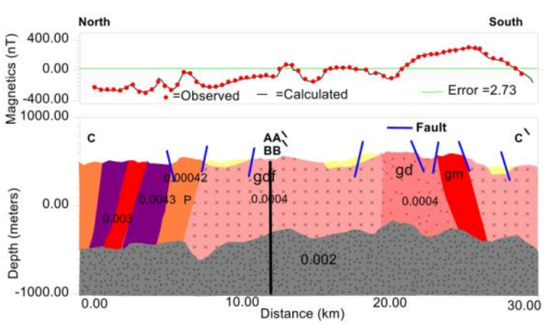

Figure (15): 2-D modelling of profile (CC`).Abu Had-G.Umm Qaraf area, south Eastern Desert, Egypt

The resulted models show that an image that two faults affected this profile and show the lateral change in lithology. At this model we suppose that the effect of magnetic susceptibility was because of the surface basement rock or their changes in composition and structure.

VIII. Conclusion

The reduced to pole (RTP) magnetic map was separated using Gaussian technique into two magnetic components named: regional and residual magnetic components. The SPI and AS result are closed to each other. Meanwhile, Euler method shows little difference. The maps of the depths help us very much to lineate the general structures of basement surface. 2D magnetic modelling was carried out along three profiles AA`, BB` and CC` oriented in SW-NE, W-E and N-S trends respectively.

IX. Acknowledgments

The assistance of Nuclear Materials Authority (NMA) for provision of the area survey data is gratefully acknowledged. To Airborne Geophysics Group (NMA) for their help during the course of this work.

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