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

By Asmaa Abubakr Mahmoud Azzazy

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1. Location, Morphology and Regional Geology

The area is mountainous. More than 95% of the area is covered by crystalline basement (igneous and metamorphic rocks). Sedimentary rocks and wadi sediments covers 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. The drainage net is crossing the basement terrain. The compiled geological map (Fig. 1) shows the available information about the geology and structure of the area under consideration.

II. Geological Outline

The study area is a part of the Precambrian belt in the south Eastern Desert of Egypt (Figure 3). Proterozoic igneous and metamorphic and Phanerozoic rocks are exposed within a geological map of the area illustrated in (Figure 1) from Conoco map (1987). The rock units exposed in the study area could be arranged into four main groups; from older to younger units:

1. Pre-Pan-African rocks (gneisses and migmatites).
2. Pan-African ophiolites and island-arc assemblage (serpentinites, metagabbros, metavolcanics and metavolcaniclastics).
3. Cordilleran-stage associations (different types of granites).
4. Quaternary sediments.

Gneisses are the oldest Precambrian rocks in the study area, as highly fractured weathered hills. They are composed of leucocratic and melanocratic medium to high grade metamorphic rocks of gneiss, granite gneiss, schist and amphibolite (Stern, 1994). These Pre-Pan-African rocks that were remobilized at high-temperature deeper levels and occur largely in the form of two rock unit as gneisses and migmatites assemblage.

In general, the Precambrian shield in the Eastern Desert is divided into three domains according to distinctive structural and tectonic characteristic; these domains separated by mega-shears. Garson and Krs(1976), Stern and Hedge (1985) and El Gaby et al (1988). They are divided Precambrian shield in the Eastern Desert into three structural domains namely: the North Eastern Desert (NED), the Central Eastern Desert (CED), and South Eastern Desert (SED) domains (Figure 4).

The three domains are separated by two ENE WSW striking fundamental fault zones namely Safaga - Qena zone, that separates the NED from CED domains and Marsa Alam - Aswan fault zone, which separates the CED from SED domains. CED is structurally characterized by NNW steeply dipping ductile shear zones and ENE deep-seated faults.

During the Pan-African time, sediments of the continental arc, outer arc, and/or magmatic arc derivation, was deposited along an active continental margin in a basin floored by oceanic crust. The continental margin assemblage (schists and paragneisses) was deformed during and after its deposition. It was mixed with the ophiolites forming ophiolitic mélange assemblage (Harris, 1983).

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III. AIRBORNE SURVEY SPECIFICATION

a) Flying Pattern

Airborne Geophysics Department of the Egyptian Nuclear Materials Authority (NMA) conducted a comprehensive airborne high resolution geophysical 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. AGD has used its best efforts to start operations at that time figure (2).

b) Aircraft

The Nuclear Material Authority (NMA) geophysical survey aircraft (Fig., 3) is a twin-engine Beechcraft B200SE (Turbine engines) equipped with a multi-sensor airborne geophysical survey system. This system comprises a high resolution magnetometer and a high sensitivity multi-channel gamma-ray spectrometer. Communication instruments installed on the aircraft are Collins products. This Aircraft has the Egyptian registration No. SU-BNJ.
A Novatell DL-3 Global Positioning System (GPS) was used on-board to provide positioning control during the survey. The system determines the absolute position of the aircraft in three dimensions, resulting in a position sampling accuracy of better than 3.0 m. On the other hand, a Novatell DL-4 base station GPS system, with a position sampling accuracy of better than 3.0 m., was also used for the subsequent flight path recovery. The base station system was located at the operation base (Hurghada, north east Red Sea coast) to monitor GPS satellite correction data. Records from the GPS base station were used with the aircraft GPS files to determine the differential correction (DGPS) to the flight path.

c) Airborne Magnetometer

A Picoenvirotech MMS-4 Airborne Cesium Magnetometer system was used in conducting the survey area. The system utilizes a split-beam, optically-pumped Cesium vapor magnetic sensor, which is sampled at 0.1 seconds and has an in-flight sensitivity of 0.001 nT. The sensor capabilities guarantee correct sampling of high magnetic gradient zones. The total field intensity range of this instrument is approximately 15,000 to 105,000 nT. The magnetometer sensor is mounted in a rear stinger. A magnetic compensator is used to remove the low frequency effects of the aircraft magnetic field during normal flight maneuvers.

d) Base Station Magnetometer

A digitally-recording Smart Mag Cesium magnetometer of the model SM-4, having a resolution 0.01 nT, complete with data logger is used as a base station for monitoring and recording the geomagnetic diurnal and other time varying field. This magnetometer was calibrated and operated continuously throughout the survey production near the survey area (Luxor). This base station setup location was chosen to be free of magnetic noise, away from steel objects, vehicles and electrical power lines, which could interfere with recording of the magnetic field diurnal variation. To ensure high quality magnetic data, time Synchronization of both the ground and airborne magnetometers were adjusted to ±1 second or better using GPS real-time signals. The digital data from this monitor was used in correcting the acquired airborne magnetic data.

IV. PROCESSING OF AIRBORNE MAGNETIC DATA

a) Building Database

The OASIS Database is essentially a file that contains all the data from a single survey project. Database files have extension .GDB. Unlike conventional relational databases, an OASIS database is an object-oriented database that stores Earth Science data in a form that allows the fast access to data and efficient storage demanded in applications that deal with very large volumes of data. The OASIS database provides us with the functionality required to run complex routines rapidly and efficiently. With the airborne geophysical modules, we can import multichannel data from large surveys. We can then process it by editing, flight-path recovery, cartographic projections, noise and spike removal, lag and heading corrections, base-station and tie-line leveling and other reductions to produce a final data set. After processing data in OASIS environment, we have the option of gridding it to create images or creating a variety of custom map products.

OASIS database is unlimited in the volume of data that it can manage and process, and there are no limits in its ability to evolve with the addition of new functions and processes. After importing each survey flight into the database, the corrected GPS positions were merged for each successive flight.

b) Pre-Levelling

i. Magnetic Base Station Correction

Most diurnal errors, if not all, can often be corrected by establishing a magnetic base station at a fixed ground location. The base station site located away from any natural or man-made magnetic sources, and tested to insure that the background magnetic field is relatively constant. A digital recording base station
magnetometer was set up at the site and the magnetic field is measured continuously during the course of the survey, at a rate of 60 times per minute.

The recorded base station readings were entered into a GEOSOFT diurnal correction table file, which contains columns of date, time and a diurnal correction. The table lookup will use linear interpolation between times to determine a correction for any required time.

ii. Heading Correction

A heading correction corrects data for systematic amplitude shift in the data that is a function of the direction of the travel for a survey line. This is most often required in magnetic surveys because the survey aircraft produces a magnetic field that changes based on survey direction. Heading corrections are normally included as part of the aircraft compensation corrections that are performed automatically by the survey data acquisition system. Improperly compensated surveys, may still require a heading correction as part of data processing.

iii. Parallax / Lag Correction

A lag correction corrects data for the distance shift between the measurement sensor and the positioning sensor. The time it takes for the sensor to move to the position of the aircraft, which is a function of the aircraft speed and the distance between the aircraft and the sensor, is known as the lag. A lag correction subtracts the lag (in fiducials) from the start fiducial of the data channel in the database.

iv. IGRF Correction

The International Geomagnetic Reference Field (IGRF) is a mathematical representation of the earth’s main magnetic field due to sources in the core. This model is updated every five years based on magnetic observations from base stations located throughout the world. The magnetic survey data were corrected for the IGRF by subtracting the IGRF model values at each point in the survey.

The earth’s magnetic field intensity will vary naturally as the earth rotates in the ionosphere of the sun. This variation is called “diurnal”, because the variation has a natural period of one day.

One characteristic of these types of error in data is that they vary slowly with respect to the information that is of interest. The most obvious effect of such errors is that they vary slowly with respect to the information that is of interest. The most obvious effect of such errors is that they vary slowly with respect to the information that is of interest.

The time variations at the base station location will be assumed that the same at the location of the moving sensor at the same time. This is acceptable for small surveys, but this assumption can be poor for larger airborne surveys where the recording base station is often located far from the actual survey site. In such situations, it will be necessary to also perform tie-line leveling.

ii. Tie-Line Leveling

After all known systematic errors correction have been made, tie-line leveling procedures can be used to perform final leveling of the data. Tie line leveling basically involves two steps. First, tie lines are leveled by looking at the differences at the crossing lines of all survey lines. This assumes that there are a sufficient number of crossing lines to properly model the tie-line error, which is further assumed to be a single base level shift or some higher order polynomial surface. After tie lines have been leveled all survey lines are adjusted to match the tie values at their intersection.

Following is a summary of steps required:

1) Leveling Tie Lines: To level the tie lines, we assume that the difference between the tie line and all crossing survey lines can be used as an estimate of the diurnal error along the tie-line. Provided there are many crossing survey lines, it is not unreasonable to assume that the tie line should, on average, match the crossing lines. Any single line may be out of level, but the average of all lines should follow the correct tie line. Then, the statistical leveling procedure will fit to zero order (level shift), to the crossing differences and apply that surface as a correction to the tie lines.

The tie line intersection table is produced. This table file tabulates every intersection between tie lines and regular survey lines. It includes the exact ground location of the intersection point, the tie line and survey line numbers, the cross differences, the horizontal gradient and the cross level.

To level the tie lines, first extract intersections along each line. Given cross line intersection differences, the system will calculate a trend surface that best fits the observed differences, then adjust the survey line to the trend. This is mainly used to level tie line if the...
crossing survey lines can be assumed to represent a statistical sampling of the correct field during the tie line flight. After running statistical levelling, the tie lines can be assumed to be correctly leveled and will form the base on which to tie the regular survey lines. We should now recreate the intersection table again.

2) Leveling Normal Lines: Leveling survey lines involves correcting each survey line to match the level at each tie line. This procedure assumes that the tie line values are correct where they cross survey lines. The cross-gradient value may also be helpful for evaluating the quality of a specific tie point. The larger the horizontal gradient, the greater the uncertainty in the tie point.

Once all level differences have been established, running the spline levelling will adjust the data by adding the differences at each point that a difference value is defined. Spline interpolation is used to correct data values between different points.

d) Data Presentation

i. Gridding of the Geophysical Data

The airborne spectral gamma-ray and magnetic measurement locations are irregularly distributed. This is mainly due to the intensive sampling along flight lines in comparison with the relatively low sampling density between the flight lines. A consequence of this is that gridding (interpolation) procedures may lead to serious degradation of the data. The data were gridded to a very fine grid interval (50m for spectrometric data and 250m for the magnetic data) using cubic-spline interpolation. Without this interpolation, the resulting images would have blank spaces between the flight lines. These spaces hamper colour perception and make interpretation more difficult (Duval, 1983 and Geosoft, 1995).

ii. Reduction to North Magnetic Pole

The careful examinations of the RTP 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. Meanwhile, the differences in sizes of the anomalies reflect the sizes of the various intrusions. According to the magnetic characters, frequencies and amplitudes of the magnetic anomalies, the RTP map could be subdivided into three zones.

The first zone (Zone-1) is characterized by low to very low magnetic values of high frequencies. It ranges from -594 to -224 nT at the southwestern and western part of the map. (Zone-1) is recorded over some wadi sediments, parts of weathered younger granites rocks. The main trend of this level is North-South trend.

The second zone (Zone-2) occupies the southern and eastern portion of the study area. It has irregular intermediate magnetic anomalies in different directions, reflecting different magnetic sources. The intermediate amplitudes range between -200 and -123nT. Geologically, this zone is covered by some wadi sediments, granites, metavolcanics and melanocratic medium to high grade metamorphic rocks.

The last zone (Zone-3) represents the high amplitude and dense frequency of magnetic field. It characterized by strong positive anomalies with amplitudes ranging between -72 nT to 843 nT, with large variation between them. It occupies the western, centre of the area. Geologically, this zone is covered by the granites and leucocratic, melanocratic medium to high grade metamorphic rocks.

iii. Calculation of Power Spectrum and Regional-Residual Separation

There are many techniques to separate regional and residual magnetic component maps from a RTP 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.

![Figure (4): Reduced to North Pole Total Magnetic Intensity Field, G.Abud-Had-G.Umm Qaraf area, South Eastern Desert, Egypt](image-url)
especially for depth estimation. This approach has been
developed by many workers (Spector and Grant 1970). The energy decay curve (Fig.5) 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. (Fig.5) is shown 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 at 0.25 km. The depth of deep-seated (regional) magnetic component maps range from 420m to 500 m and the near-surface (residual) magnetic component ranges from 100m to 250m.

![Power spectrum of magnetic data showing the corresponding averaging depths, of G.Abu Had-G.Umm Qaraf area, south Eastern Desert, Egypt](image)

**Figure (5)**: Power spectrum of magnetic data showing the corresponding averaging depths, of G.Abu Had-G.Umm Qaraf area, south Eastern Desert, Egypt

iv. **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., 1988). 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.6). The residuals focus attention to weaker features that are obscured by strong regional effects in the original map (Reford and Sumner, 1964).

v. **Regional Magnetic Component Map**

The regional magnetic component map (Fig.7) at the assigned interface is the result of removing the residual effects from the RTP 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 corner, northeastern corner and east part. They covered with the quaternary deposits, ophiolitic rocks and metavolcanic rocks, and their amplitudes range from -606 to -21 nT. It could be suggested that, remnant magnetization is associated with this zone, which may be also interpreted as structural lows or synclines.

2. Positive magnetic anomalies (high zones). They covered the northern part trending NW-SE trend and found as mass extend in eastern part and their amplitudes range from -21 nT to 2287 nT. Also positive values are located at the centre part trending NE-SW trend.

![Shaded color contour map of the RTP residual magnetic component, G.Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt](image)

**Figure (6)**: Shaded color contour map of the RTP residual magnetic component, G.Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt
vi. Discussion of the Magnetic Depth Calculations

The SPI and AS result are close to each other (Figs. 8 and 9). Meanwhile, Euler method shows little difference (Fig. 10). The maps of the depths help us very much to lineate the general structures of basement surface. At the three maps, the NE-SW trend show more shallow 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 -429 to -278 for SPI method, from -451 to -225 for AS method and ranged from -471 to -360 for Euler method.

The second zone has shallow depths. These low values of depths range from -278 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 (8)**: Depth to magnetic basement as calculated using source parameter imaging (SPI), G.Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt

**Figure (9)**: Depth to magnetic basement as calculated using analytical signal (AS), G.Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt
vii. **Modelling Technique**

The two-dimensional modelling is a simple way to imagine the subsurface structure. The following 2-D model explains a profile D (figure 11).

**Figure (10)**: Depth to magnetic basement as calculated using Euler, G.Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt.

**Figure (11)**: Location of 2-D model drawn at Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt. The resulting model shows an image that two faults affected this profile and show the lateral change in lithology.

**Figure (12)**: 2-D modelling of Abu Had-G.Umm Qaraf area, South Eastern Desert, Egypt.

**REFERENCES**


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