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Analysis and Interpretation of Airborne Magnetic Data of Alm Agayeb area, West Dakhla Oasis, Central Western Desert, Egypt.

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Abstract: *The study area located at west Dakhla Oasis in the central part of the western desert of Egypt. It lies between latitudes 25° 23' 55" and 26° 31' 16" N and longitudes 26° 15' 24" and 27° 30' 9" E. Airborne geophysical surveys have an obvious and significant role to play in regional and detail bedrock, surface and subsurface geological mapping, mineral exploration for a wide variety of commodities and petroleum exploration. In this paper the airborne magnetic data were analyzed and interpreted by many methods such as residual- regional separation, depth estimation and modeling. Three models were applied to present the fitted subsurface structure at satisfied values.*

Keywords*: airborne magnetic, analyzed, subsurface structures, Depth, 2D, modeling.*

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I. Introduction

The study area is located at west Dakhla Oasis in the central part of the western desert of Egypt. It is limited by the latitudes 25° 23' 55" and 26° 31' 16" N and longitudes 26° 15' 24" and 27° 30' 9" as shown in figure (1). The present study aims to evaluate the surface and subsurface tectonic pattern in the studied area. It also aims to study the basement depth, relief, and tectonics to evaluate the topography of basement. These aims were achieved through the following:

- Analysis of the magnetic data using the most recent techniques and software package up to producing the magnetic maps of the study area.

- Interpretation of airborne magnetic data to map the basement tectonic setting as well as intrasedimentry structures. This interpretation will be achieved through application of the most advanced interpretation techniques including filtering, Euler Deconvolution, analytic signal, source parameter imaging, derivative, and finalized by 2-D modeling.

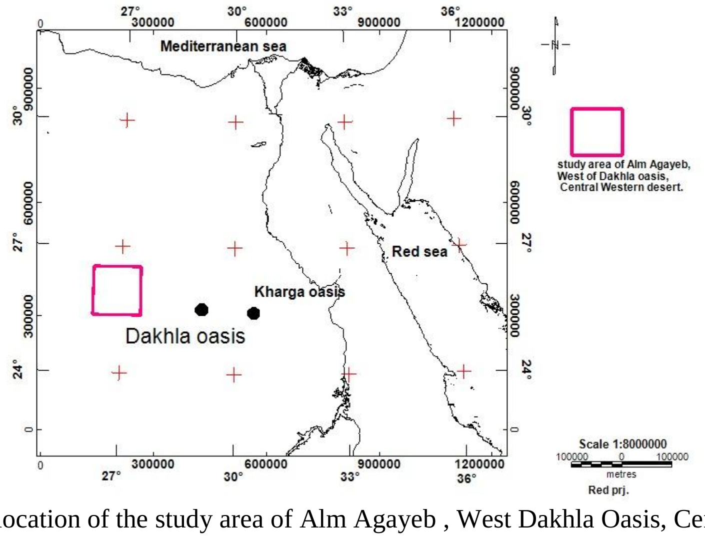

Figure (1): General location of the study area of Alm Agayeb , West Dakhla Oasis, Central Western Desert, Egypt.

II. General geology

The study area located at west Dakhla in central parts of the western desert of Egypt, gives excellent exposures of Cretaceous and Lower Tertiary. Main lithological units in the study area are shown in (figure 2) and traced from the geological map of Egypt prepared by Conoco (1987). The sedimentary rocks occupy most of the study area and ranging from Jurassic age to Quaternary. The Jurassic to Quaternary sequence include Quseir formation, Duwi Formation, Dakhla formation, Tarawan Formation , Sand sheet and Sand dunes described in the following:

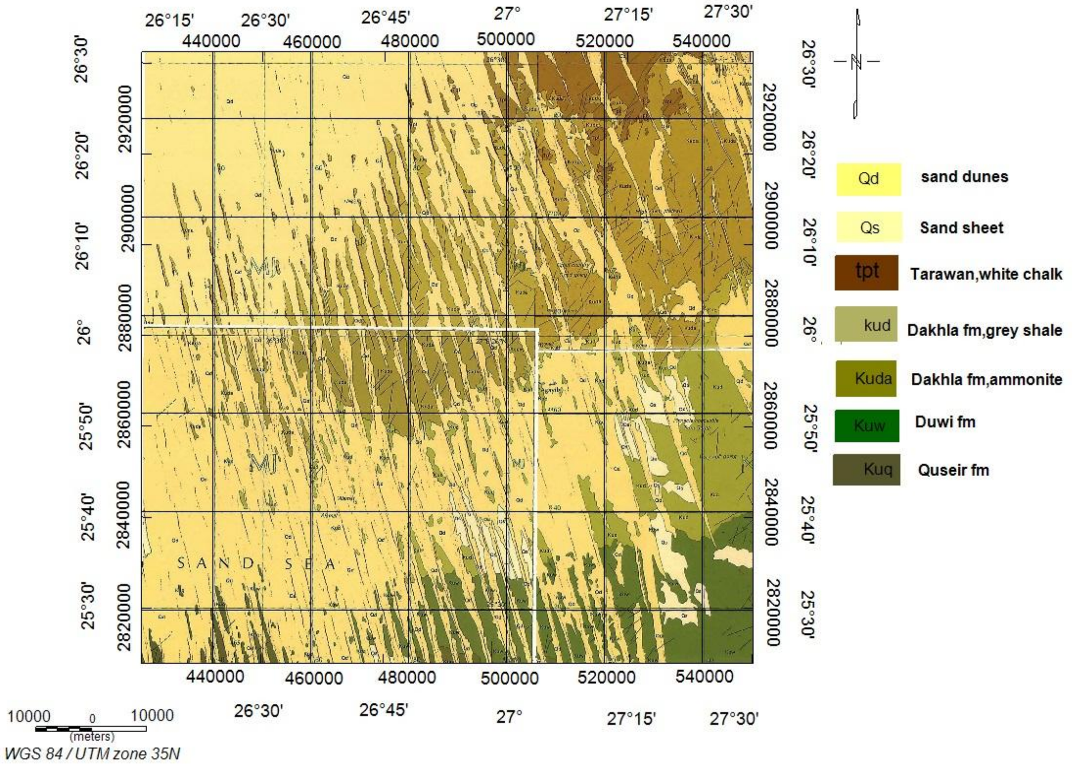

Figure (2): Geologic Map of the study area of Alm Agayeb , West Dakhla Oasis, Central Western Desert, Egypt (Conoco, 1987).

3.1. Quseir formation (Youssef 1957=Mut formation: Barthel and Herrmann-Degen 1981):
The claystone, siltstone and sandstones of the Quseir formation overlie the sandstones of the Taref formation. In general, the deposits of the Quseir formation indicate a gradual, occasionally stagnating transgression.

3.2. DUWI Formation (Youssef 1957: =Phosphate Formation:Awad &Ghobrial 1965):
The Duwi Formation is a phosphate –bearing unit that occupies a stratigraphic position at the top of Quseir formation and underlies the Dakhla formation.

3.3. Dakhla formation:
Dakhla formation consists of shale, marl and clay intercalations of calcerous, sandy and silty beds. It forms the major thickness of the succession that overlies the Duwi formation and underlies the Paleocene limestone beds along the scrap face of south Kharga to Abu Minqar.

3.4. Tarawan Formation (Awad & Ghobrial 1965).
Tarawan formation marks a hiatus on the top of the underlying Dakhla formation. The occurrences of this bed are due to a regression of the sea during middle to late Paleocene. White chalk grading into limestone, impure limestone or dolomite in areas where Paleocene sediments are deposited (Issawi, 1972).

3.5. Sand sheet
Sand sheet forms the Arabian desert .They probably owe their flatness to wind scour which was limited by the depth of water table(Haynes 1982).The sand sheets had been traditionally classified among the Eolian deposits by most authorities (Sandford 1935 , Bagnold 1933, Said 1957 ,Haynes 1980, Maxwell 1982).

3.6.Sand dunes:

Sand dunes cover about 20 % of the total area under discussion.Occasional inter-dune corridors expose Trawan or Dakhla formations . The extension of this sand mass invades in discontinuous narrow belts at the western side of Dakhla depression.

4. Airborne Survey Specification

By the 30th of January, 2015. The Airborne Geophysics Department (AGD) of the Nuclear Materials Authority used Kharga as operation bases. AGD carried out a high-resolution aeromagnetic survey over West Dakhla region; Central Western Desert of Egypt. The primary objectives of the project are to acquire high-resolution airborne Gamma-Ray spectrometric data with 100 m terrain clearance and aeromagnetic data over the proposed survey area and to process the data in a manner which conforms to the accepted industry standards of excellence and safety, to a high standard. The flight line spacing was 4000 m oriented N-S direction and Tie line spacing was 10000 m with nominal flying elevation 1000 m ASL.

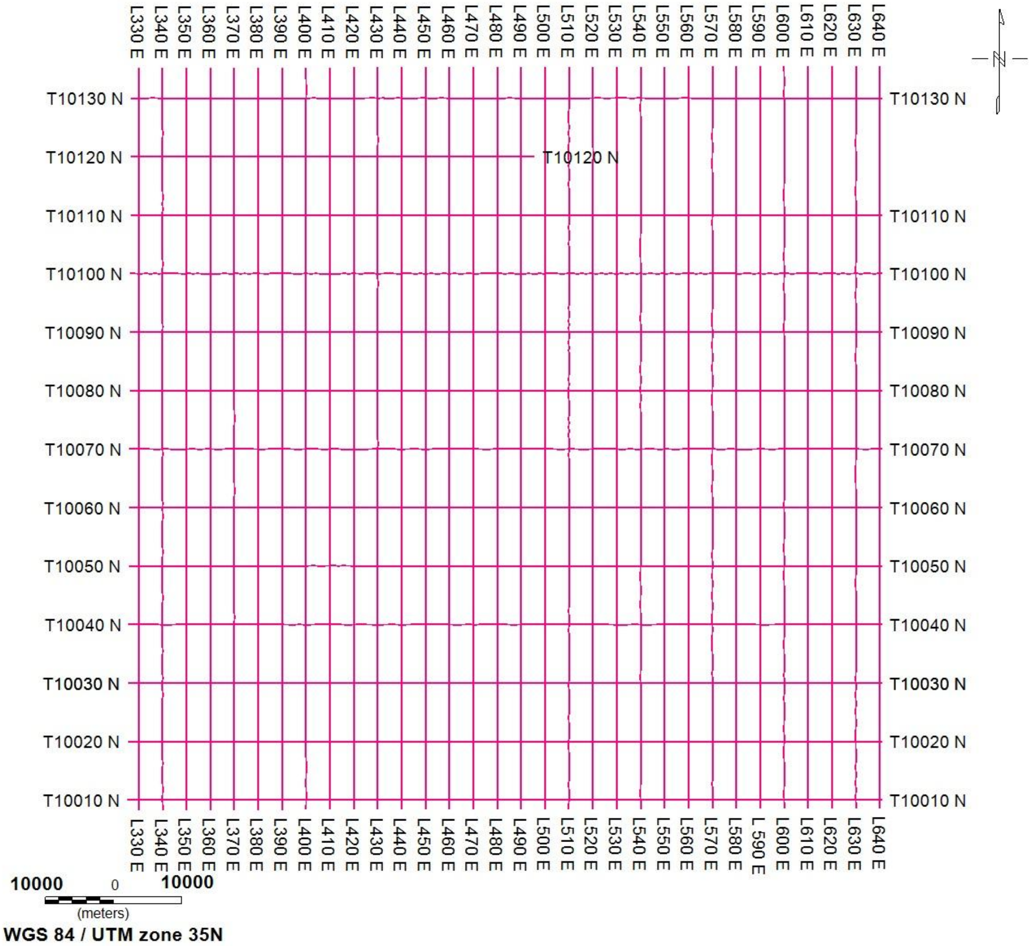

Figure (3): survey lines of the study area of Alm Agayeb , West Dakhla Oasis, Central Western Desert, Egypt.

4.1. Reduction to the North Magnetic Pole

Since the inclination of the earth's magnetic field, the magnetic anomalies show positive and negative responses together. These minima and maxima are generally offset from the center of the causative body along the magnetic meridian. The method of reduction to the pole (RTP) is used to remove this effect, so data appear as observed at the pole, where the magnetic field is vertical. Figure (4) show Reduction to pole (RTP) map that resulted from total magnetic intensity map. According to the frequencies and amplitudes of magnetic anomalies, the RTP map could be subdivided into three zones. The first zone is characterized by low magnetic values that represented by blue to green color and ranging from 100 nT to 269 nT that encountered in the northeastern part, at the center and at the southeastern part with some spots at the west of the area. The second zone is characterized by intermediate magnetic values that spread all over the area, represented by yellow to orange color and ranging from 274 nT to 330 nT. The third zone is characterized by high magnetic values that encountered at the northwestern corner, at the center and at the southwestern corner of the area with some spots at the east and this zone is appeared with red to magenta color and ranging from 360 nT to 640 nT.

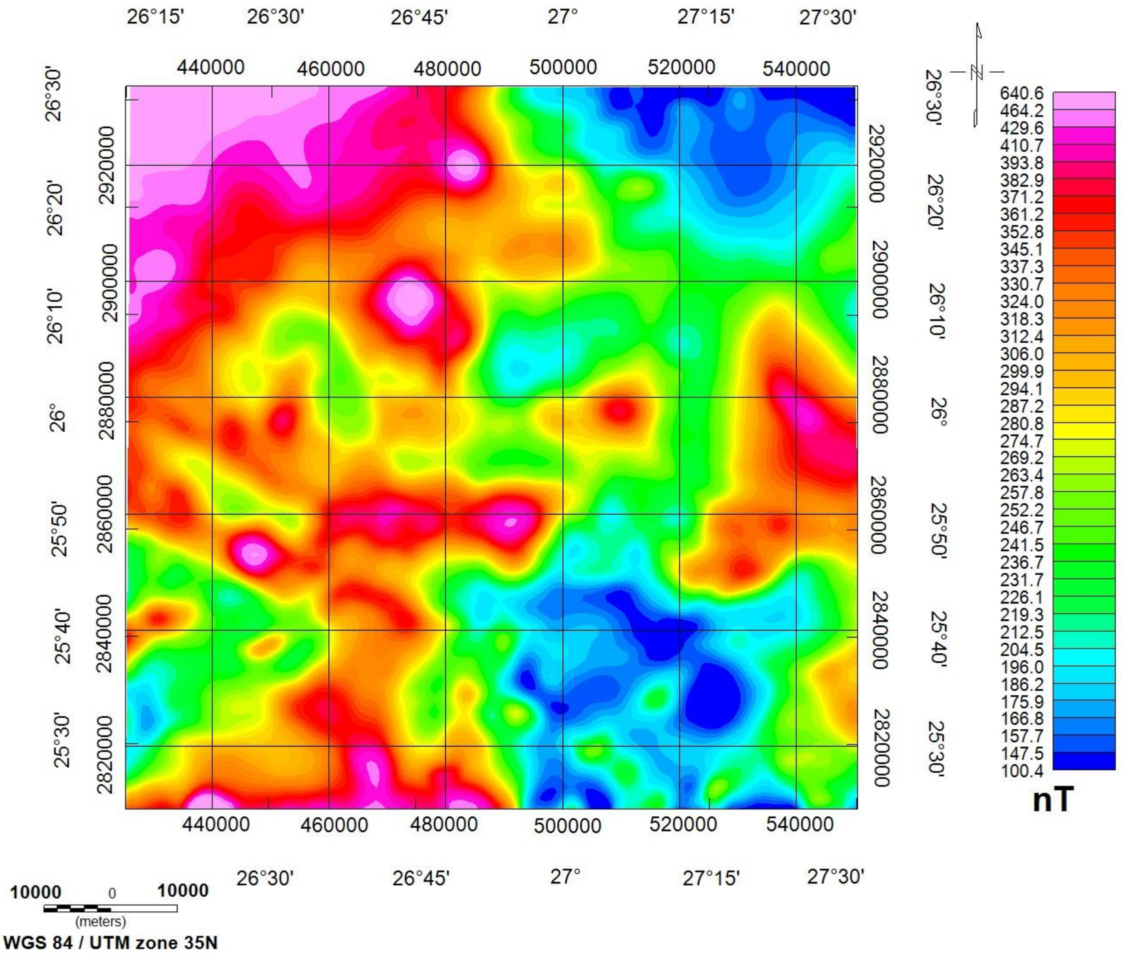

Figure (4): Reduced to The North Magnetic Pole (RTP) of the study area of Alm Agayeb , West Dakhla Oasis, Central Western Desert, Egypt.

4.3. Computation and Analysis of the Energy (Power) Spectrum

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 Gaussian filler technique is used in this study. It is the separation procedures are designed to separate broad deeper variations " regional" from sharper local variation " residual" magnetic anomalies. In another words, the magnetic map is split into two parts, the regional and the residual magnetic component maps. The residual map attention on weaker features, which are obscured by strong regional effects on the original map .The energy decay curve (figure 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. Figure (5) shows two different components as straight-line segments, which decrease in slope with increasing frequency. There are three levels of sources: deep sources, intermediate sources and shallow sources .The slopes of the segments yield estimates of the average depths to magnetic sources. Regional-intermediate separation was at 0.03 frequencies, the average depth of deep-seated (regional) magnetic component maps ranges from to 5000 m to 7000 m. The intermediate-shallow separation was at 0.1 frequencies, the average depth of shallow (residual) magnetic component maps ranges from 3000m to 5000 m.

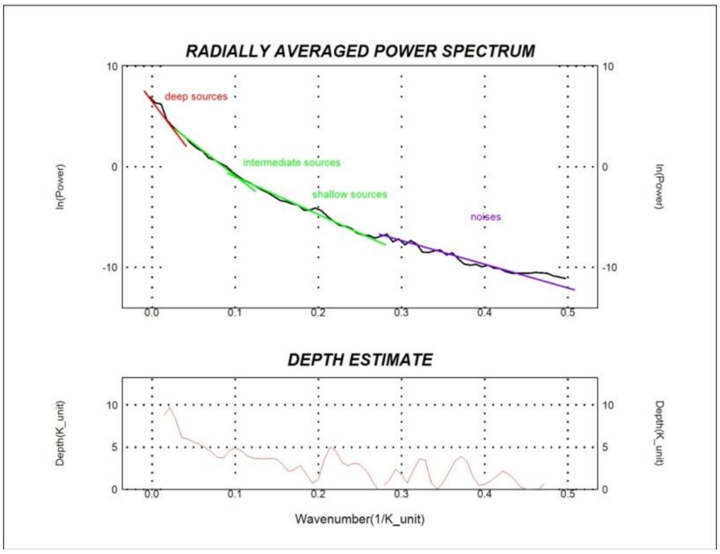

Figure (5): Radially Averaged Power Spectrum and Depth Estimate of the RTP Magnetic.

4.4. Residual Magnetic Component Map

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 (figure6). 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 (figure 6) shows that, it is characterized by the following features:

1. Presence of broad negative magnetic zones concentrated at southern half 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, these anomalies ranging from -33.9 nT to -4 nT .
2. 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. These high anomalies spreading all over the map, but concentrated at the center extending to the south of the map and ranging from 6.2 nT to 81 nT.

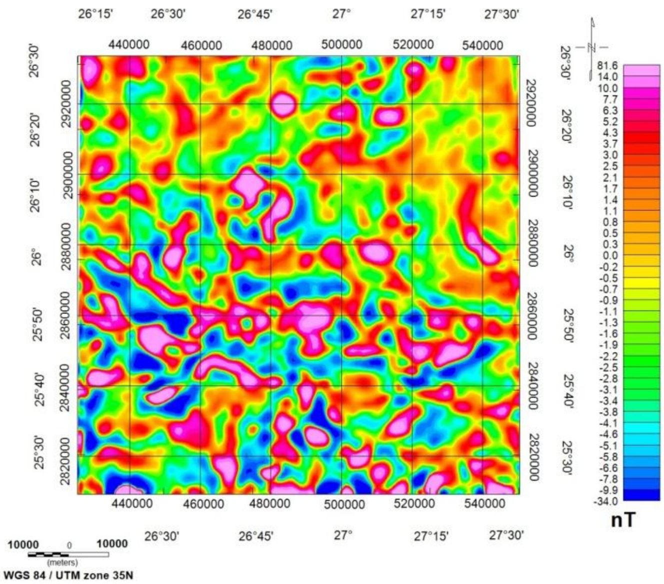

Figure (6): Residual magnetic component, of the study area of Alm Agayeb , West of Dakhla Oasis, Central Western Desert, Egypt.

4.5. Regional Magnetic Component Map

The regional magnetic component map (figure 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 northeastern , southeastern parts with spot at the south western corner of the map that trending E-W and NW-SE .They covered with Tarawan formation, Dakhla formation, Duwi formation ,Dakhla formation dark grey shale , Quaternary Sand dunes and Quaternary sand sheet. Their amplitudes range from 131 nT to 218 nT.

2. Positive magnetic anomalies (high zones). They covered the northwestern part trending NE-SW trend and at the southwestern part of the map extending E-W and their amplitudes range from 386 nT to 584 nT and they are covered by Quaternary sand dunes, Dakhla formation ammonite hill member and Quseir formation. Also positive values are located the east and at the center trending NW-SE and E-W.

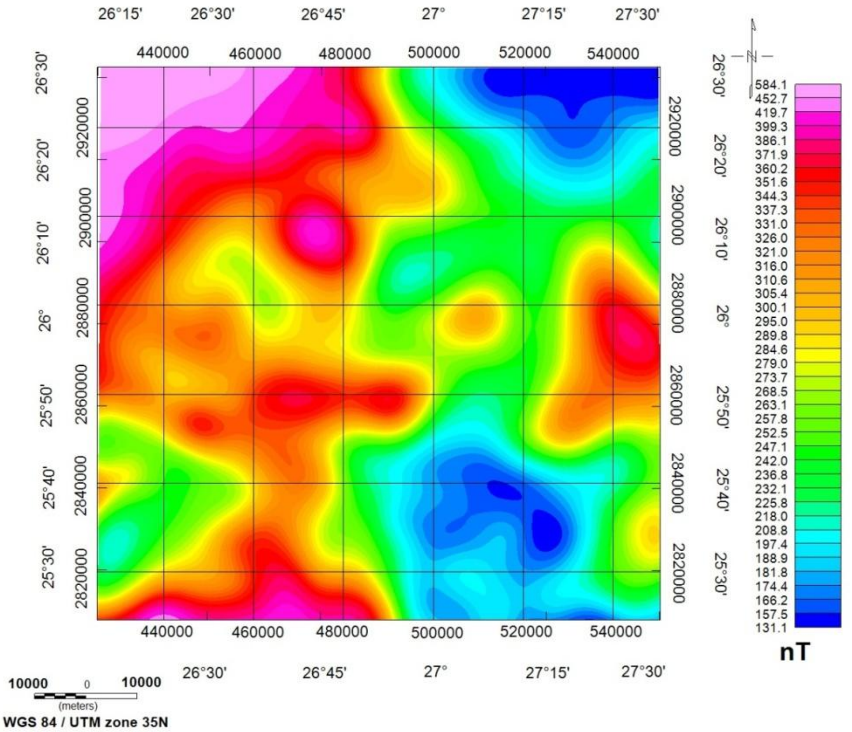

Figure (7): Regional magnetic component, of the study area of Alm Agayeb , West Dakhla Oasis, Central Western Desert, Egypt.

III. Discussion of the Magnetic Depth Calculations

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. 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.

In this paper, 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). The three techniques AS, SPI and Euler results re closed to each other (figures 8, 9 & 10) respectively. 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.

From combination of the three maps, this will be shown two main zones of depths (figure 11). The first zone is characterized by deep depths that trending NW-SE and NW-SE and found at the eastern parts to northwestern parts and some spots at the southwestern corner which ranged from 4195.3 m to 5628.3 m for SPI method, from 4290.1 m to 5696.9 m for AS method and ranged from 4256.2 m to 5781.1 m for Euler method. The second zone has shallow depths that trending NW-SE presented at the west to southeastern parts. These low values of depths range from 290 m to 1636.2 m for SPI method, from 277.4 m to 1683.5 m for

AS method and from 245.6 m to 1346.8 m 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.

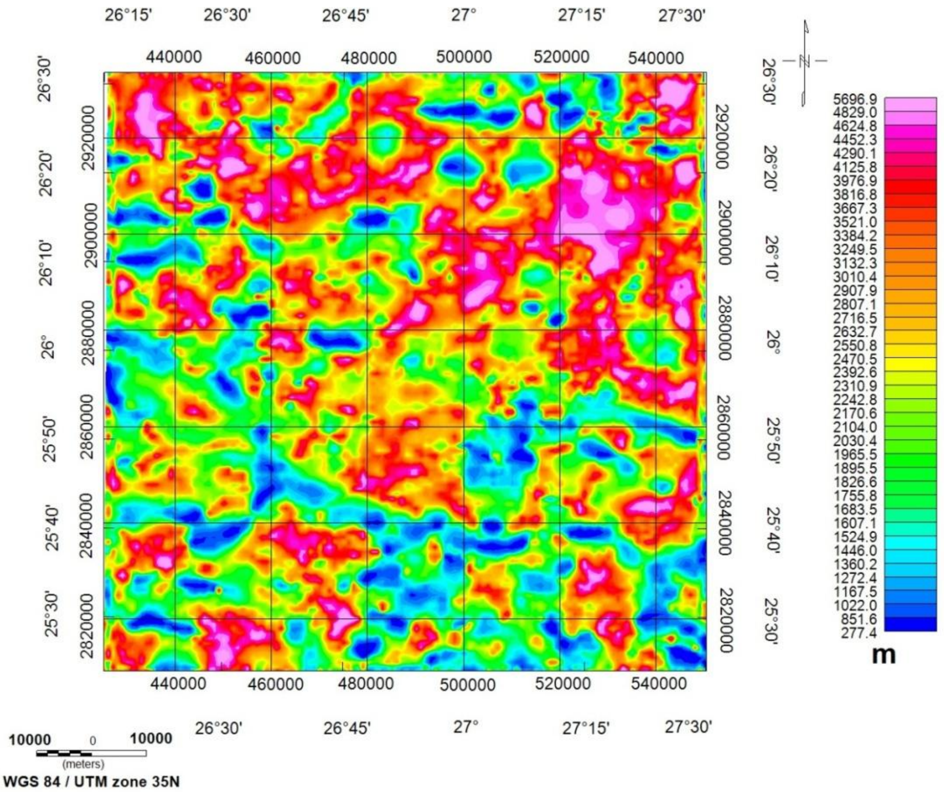

Figure (8): Depth to magnetic basement as calculated using analytical signal (AS) of the study area of Alm Agayeb ,West Dakhla Oasis, Central Western Desert, Egypt.

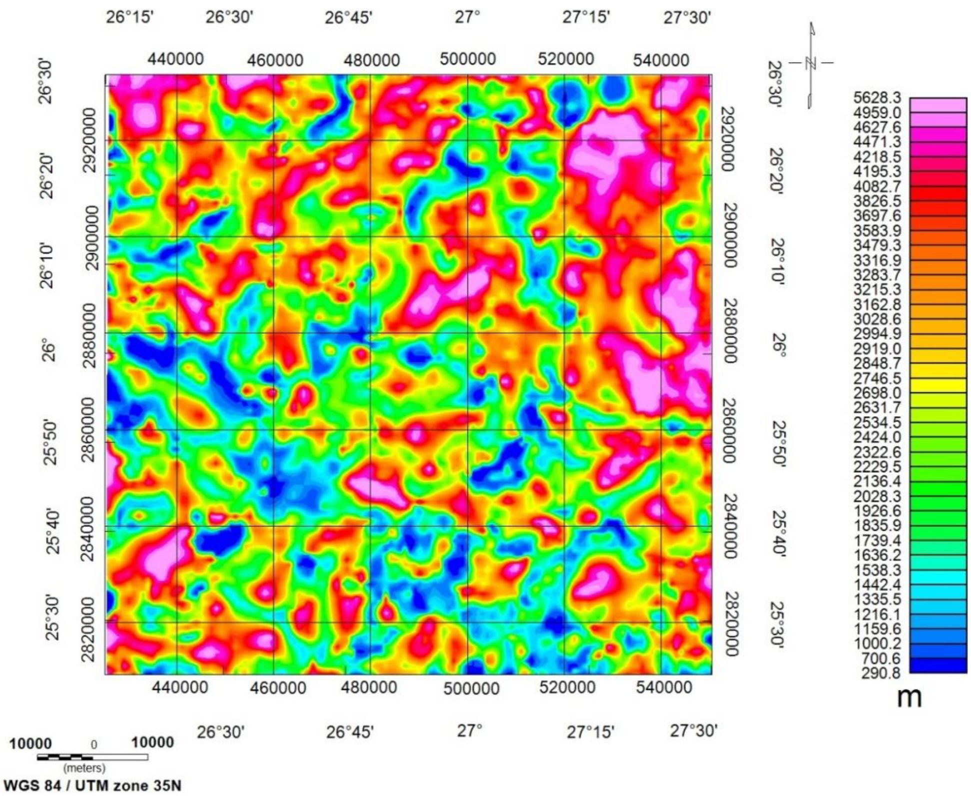

Figure (9): Depth to magnetic basement as calculated using source parameter imaging (SPI) of the study area of Alm Agayeb , West Dakhla Oasis, Central Western Desert, Egypt.

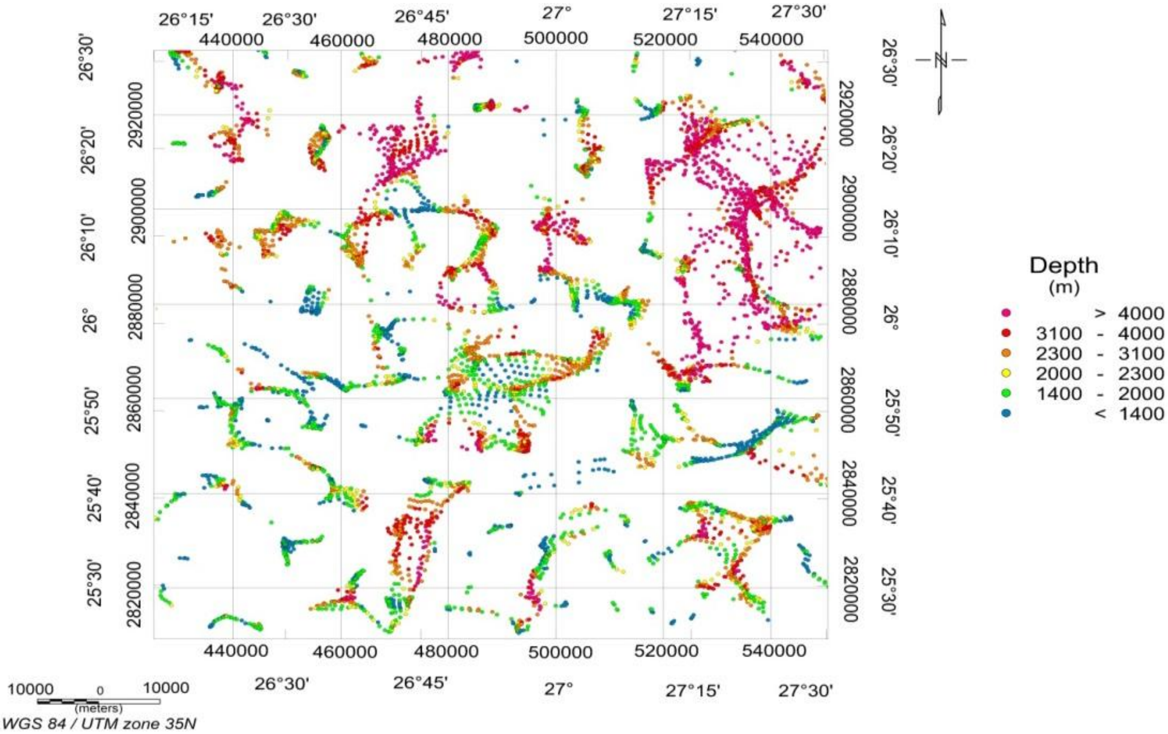

Figure (10): Depth to magnetic basement as calculated using Euler of the study area of Alm Agayeb , West Dakhla Oasis, Central Western Desert, Egypt.

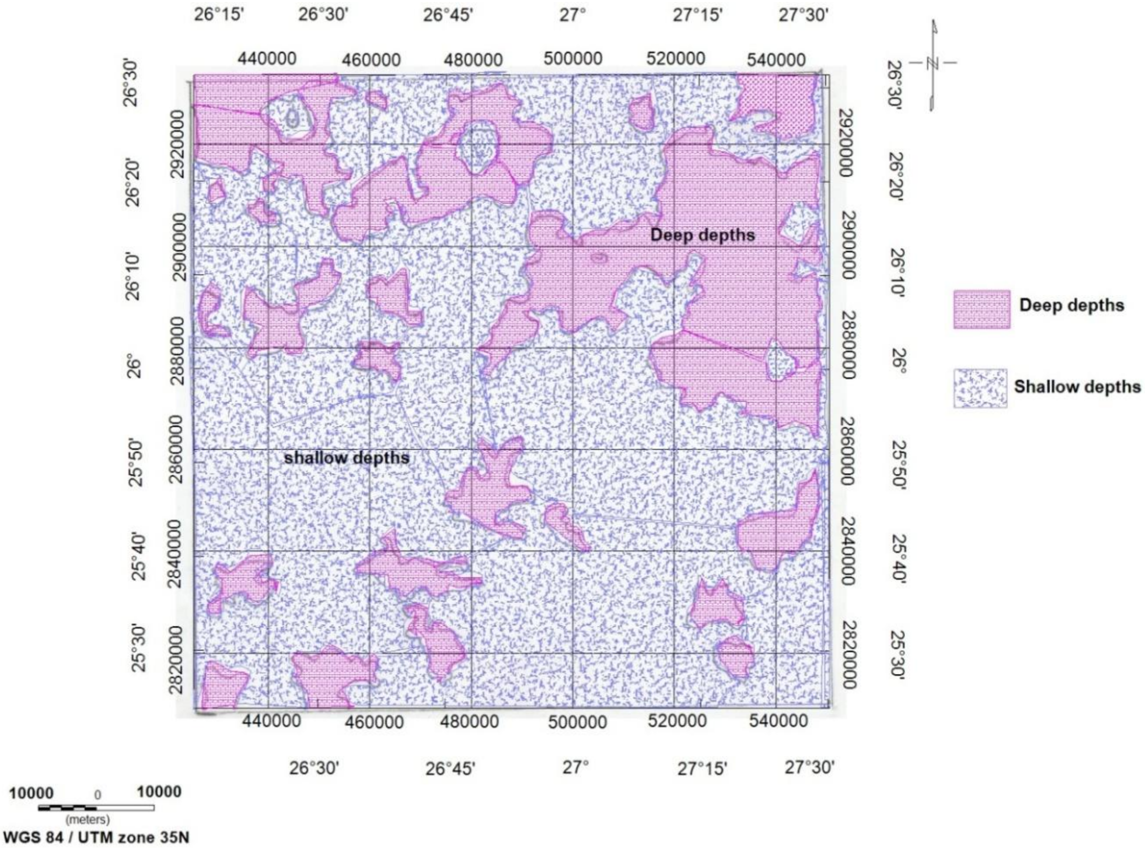

Figure (11): The main depths zones which resulted from the calculated depths and lineation on TMI map.

IV. Interpreted Magnetic Basement Tectonic Map

The basement tectonic relief map (figure 12) constructs through the integration interpretation of the magnetic maps. It shows two distinguish regions of different structure. The first region located in the west side of the study area extending to the southeastern part that is dominated mainly by a set of faults oriented in NW-SE and N-S trend. The second regions located in the eastern part extending to the west and center of the study area. It comprises a set of faults oriented in NW-SE and NE-SW trend.

Figure (12) shows the deep-seated structural features of the study area, which dissect in the subsurface, these lineaments are integrated as swell and trough belts intervened by faults with varying trends The results (locations and depths) obtained from the analysis of depth maps, RTP, regional, residual and horizontal gradient and edge detection maps were compared and integrated to construct the basement tectonic map. The deep-seated structures (regional faults), interpreted from the regional map, are displayed in bold black lines.

Black lines are indication for the composition change resulted from structure displacement or magma distribution and formation. Close inspection of the interpreted structure map reveals that, the area is affected by sets of deep seated and near-surface structural lineaments oriented in NW-SE, NE-SW, N-S and E-W directions. The NW-SE (Red Sea) trend is more strongly developed than the other identified trends. It represents the prevailing tectonic trend in the area, and played an important role in the formation of its tectonic framework. It was noticed that this trend is greatly responsible for the formation of the major basin that trends in the same direction and occupies the western and southeastern parts of the area. The near-surface lineaments (residual effects), shown in blue lines, were traced by the application of the analysis methods to the residual component map.

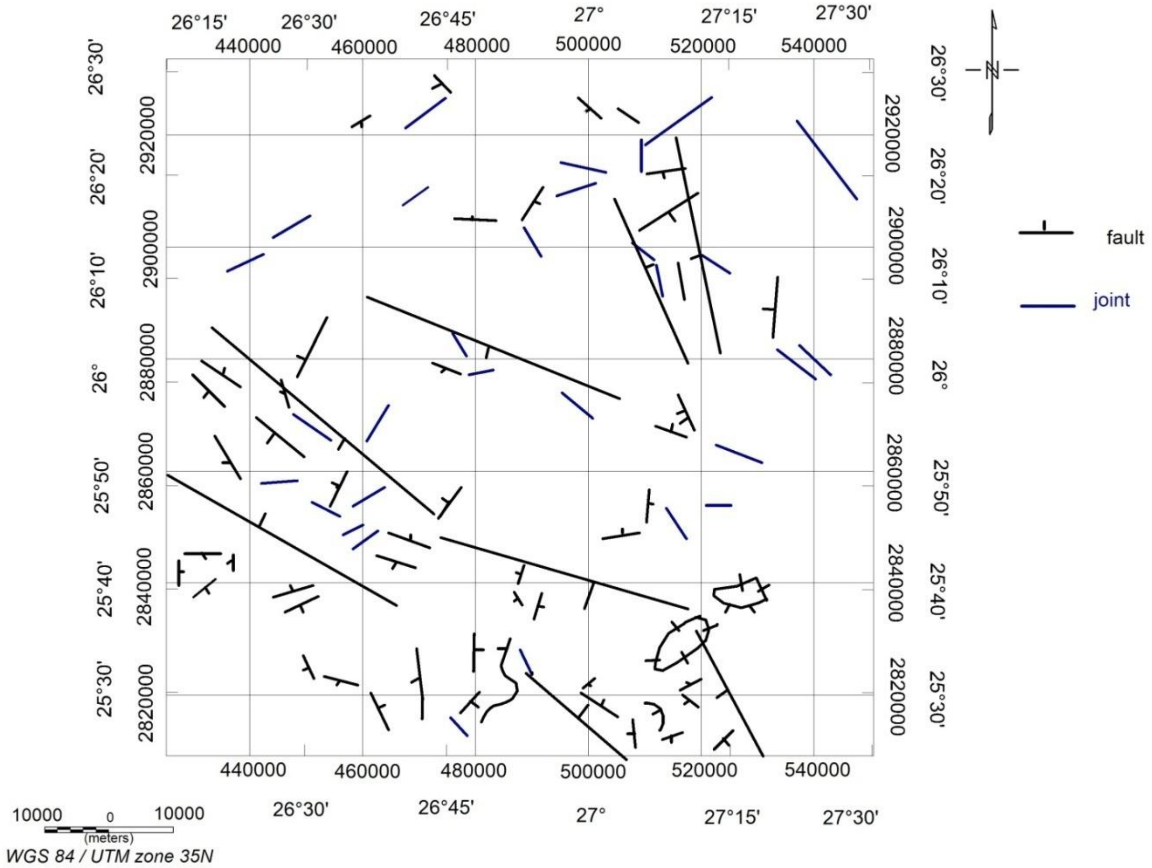

Figure (12): Structural tectonic map of the study area of Alm Agayeb , West Dakhla Oasis, Central Western Desert, Egypt.

V. Modelling Technique

The two dimentional modelling is simple way to imagine the subsurface structure. The following 2-D model explains profile A-AA, B-BB and C-CC figure (13). Forward modelling involves creating a hypothetical geological model and calculating the geophysical response to that earth model. GM-SYS is a modelling program which allows interactive manipulation of the geologic model and real time calculation of the magnetic or gravity response (Geosoft, 2010). We have 9- blocks with magnetic susceptibility ranging from 0.002 c.g.s to 0.003 c.g.s.

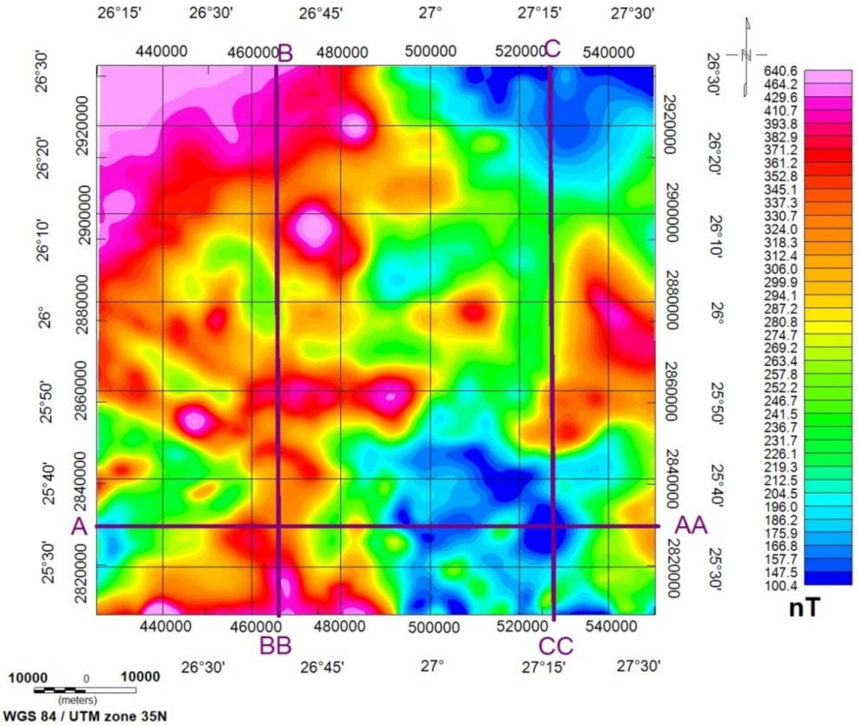

Figure (13): Location of 2-D model drawn at reduced to The North Magnetic Pole (RTP) of the study area of Alm Agayeb at west of Dakhla Oasis, Central Western desert, Egypt.

7.1. Two-Dimensional Magnetic Modelling of Profile A-AA

Model A-AA was taken at E-W direction figure (14). Close examination of the modelled profile A-AA show an excellent fit between the observed and calculated anomalies with error reach 0.942. The magnetic susceptibility values were assumed to be between 0.002 to 0.0026 c.g.s. There is an intersection point with B-BB Model at depth 1816 m with magnetic susceptibility = 0.0026 c.g.s , and another intersection point with model C-CC at depth 4300 m with magnetic susceptibility =0.002 c.g.s. . Group of blocks are represented the subsidence basement blocks such as block number (1), (2), (3), (4). They are given susceptibility values of 0.0024, 0.0026, 0.002, 0.0022, c.g.s units respectively.

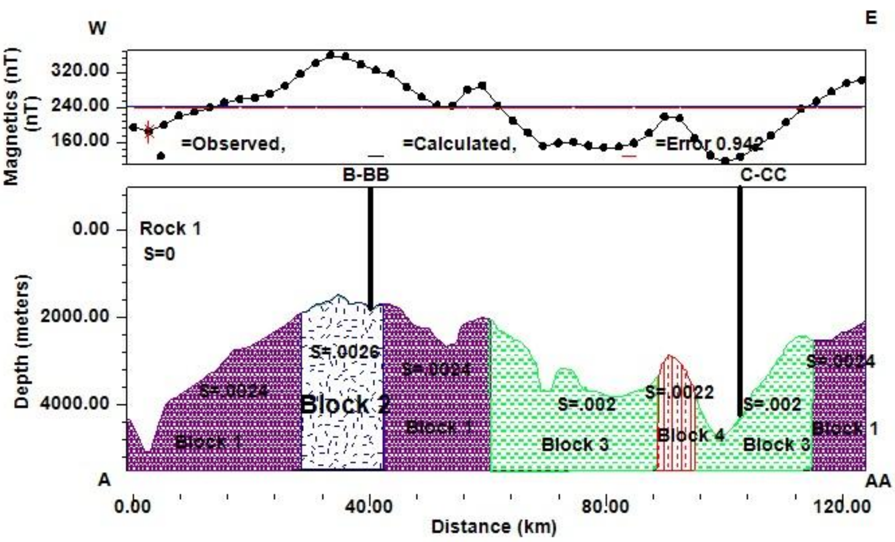

Figure (14):2-D modelling of profile (A-AA) drew at reduced to The North Magnetic Pole (RTP) of the study area of Alm Agayeb at west of Dakhla Oasis, Central Western desert, Egypt.

7.2. Two-Dimensional Magnetic Modelling of Profile B-BB

The profile B-BB was taken at N – S direction figure (15). The modelled profile B-BB shows an excellent fit between the observed and calculated anomalies with error reach 0.837. The magnetic susceptibility contrast values were assumed to be between 0.0024 c.g.s to 0.003 c.g.s. There is an intersection point with model A-AA at depth 1816 m with magnetic susceptibility = 0.0226 c.g.s. . Group of blocks are represented the subsidence basement blocks such as block number (1), (2), (5), (6) and a(7) . They are given susceptibility values of 0.0024, 0.0026, 0.003, 0.0028 and 0.0027 c.g.s units respectively.

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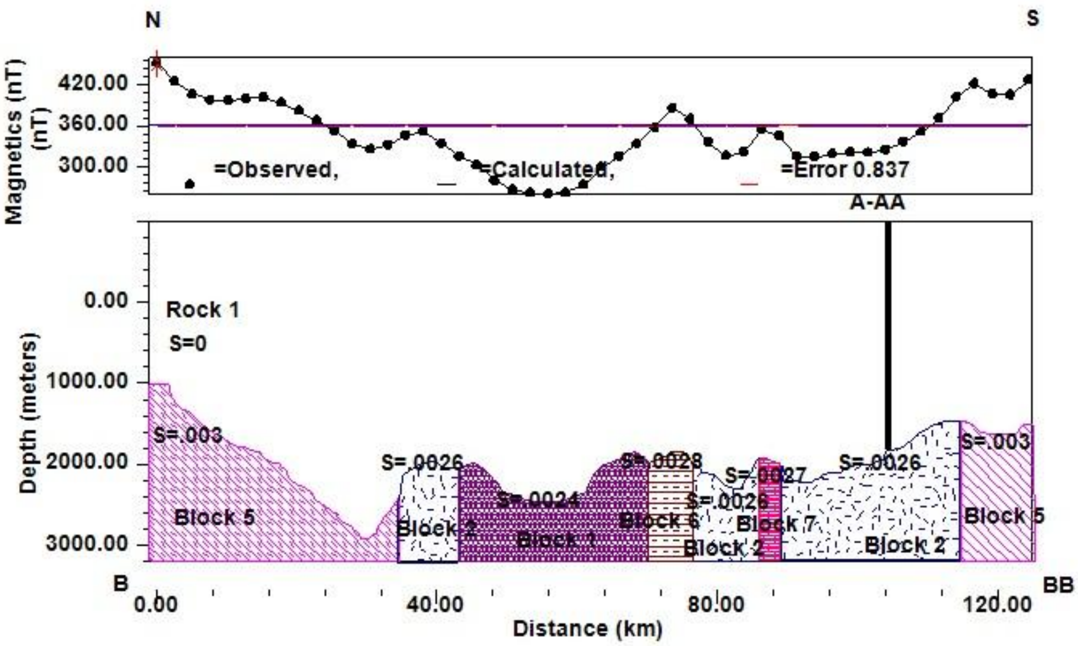

Figure (15):2-D modelling of profile (B-BB) drew at reduced to The North Magnetic Pole (RTP) of the study area of Alm Agayeb at west of Dakhla Oasis, Central Western desert, Egypt.

6.3. Two-Dimensional Magnetic Modelling of Profile C-CC

Modelled profile CC was taken at N-S direction (figure16). The model passed the same interception point with model A-AA at depth 4300 m with magnetic susceptibility = 0.002 c.g.s. magnetic susceptibility values were assumed to be between 0.002 c.g.s to 0.0028 c.g.s. Group of blocks are represented the subsidence basement blocks such as block number (2), (3), (6), (8) and (9) . They are given susceptibility values of 0.0026, 0.002, 0.0028, 0.0025 and 0.0023 c.g.s units respectively.

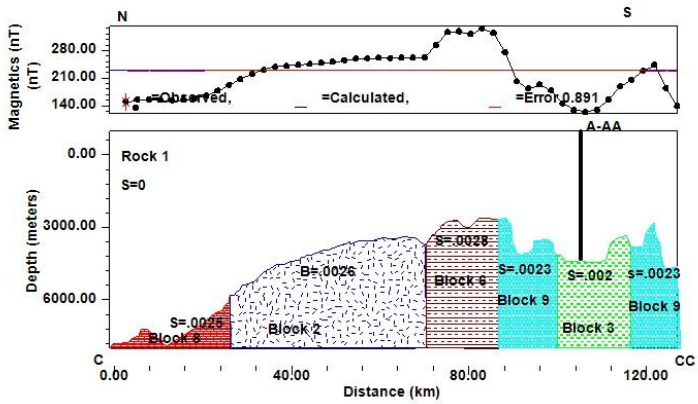

Figure (16):2-D modelling of profile (C-CC) drew at reduced to The North Magnetic Pole (RTP) of the study area of Alm Agayeb at west of Dakhla Oasis, Central Western Desert, Egypt.

VI. Conclusion

Results obtained from the qualitative and quantitative interpretation techniques applied to the aeromagnetic data of the studied area have been used in conjunction with all available surface as well as subsurface geological information to construct the tectonic map of the area which illustrates the structure configuration of the buried magnetic basement rocks .

As a result of quantitative magnetic modeling the following conclusions were obtained:

1. the deep-seated structural features of the study area, which dissect in the subsurface, these lineaments are integrated as swell and trough belts intervened by faults with varying trends The results (locations and depths) obtained from the analysis of depth maps, RTP, regional, residual maps were compared and integrated to construct the basement tectonic map. The deep-seated structures (regional faults), interpreted from the regional map, are displayed in bold black. The basement tectonic relief map (figure 54) constructs through the integration interpretation of the magnetic maps. It shows two distinguish regions of different structure. The first region located in the west side of the study area extending to the southeastern part that is dominated mainly by a set of faults oriented in NW-SE and N-S trend. The second regions located in the eastern part extending to the west and center of the study area. It comprises a set of faults oriented in NW-SE and NE-SW trend.

2. It was evident that the modeled basement rocks show a wide range of magnetic susceptibility ranges between (0.002 c.g.s. to 0.003 c.g.s.) units which indicates a great lateral variation in the lithologic composition of the crystalline basement rocks across the studied area.

3. The high structures within the studied area are generally associated with basement blocks of higher magnetic susceptibility values where the susceptibility of the basement rocks forming these high structures , this suggests that these structures may have related due to intrusion of mantle type basic material into the crystalline basement rocks.

Meanwhile, the major basinal areas seem to be associated with a relatively acidic basement rocks.

4. Modeling of magnetic profiles shows only the regional tectonic framework, but in order to interpret adequately all the detailed structures within an area, the filtered residual magnetic anomalies should be considered as a prequisite for modeling the residual magnetic anomalies associated with local geologic structures.

Acknowledgments

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

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