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INTERPRETATION OF THE SUBSURFACE STRUCTURAL SETTING USING AEROMAGNETIC SURVEY DATA, SIWA – QATTARA AREA, NORTHERN WESTERN DESERT, EGYPT

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تفسير التراكيب التحتسطحية باستخدام بيانات المسح المغناطيسي الجوي، منطقة سيوه – القطارة، شمال الصحراء الغربية ، مصر

الخلاصة: يطبق فى هذه الدراسة عدد من التقنيات النصف آلية و الآلية لتفسير بيانات المسح المغناطيسي الجوي بمساعدة البيانات الجيولوجية لشمال الصحراء الغربية فى مصر. تم إجراء فصل بيانات شاذات المغناطيسية المختزلة إلى القطب الشمالى باستخدام تقنية فورير للتعرف على التراكيب المحلية المتبقية من التراكيب ذات الطبيعة الإقليمية . بالإضافة لتطبيق تقنية الاشتقاق الرأسى الأولى و الثانية على بيانات المسح المغناطيسي الجوي والتى تزيل تأثير المتداخلات وتعزز التراكيب السطحية و الظواهر المرتبطة بنوعية الصخور. تستخدم طريقة تحليل الإشارات للتفسير الآلى لبيانات المسح المغناطيسي الجوي حيث يتم تحديد مواقع و الشكل الهندسى التقريبي للمصادر المغناطيسية.

تم استخدام المعلومات المتكاملة والتي تم الحصول عليها من تطبيق تقنيات التفسير الكمية و الكيفية على بيانات المسح المغناطيسي الجوي بمساعدة المعلومات الجيولوجية المتاحة فى تحديد الشكل التركيبى لشكل القاعدة المركبة، ولتوضيح الإطار التركيبي الإقليمي العام لمنطقة الدراسة. وتعتبر الإتجاهات NE-SW ، E-W ، NW-SE و N-S هى الإتجاهات التركيبية الشائعة فى منطقة الدراسة.

يمكن تقسيم القاعدة المركبة لمنطقة الدراسة إلى أربعة نطاقات رئيسية مرتفعة وثلاثة أحواض تركيبية رئيسية. النطاقات المرتفعة هى مرتفع السلوم، مرتفع القطارة و مرتفع أجنس و مرتفع سيوه. الأحواض التركيبية هى : حوض مطروح و حوض فاجور– غزالات و حوض أبو غراديق، وهذه تمثل المظاهر الرئيسية لمنطقة الدراسة وهى محكومة تركيبياً. تأخذ الفوالق التى تحدد هذه الظواهر الرئيسية إتجاهاً عاماً (NE الىEW) وقد نمت هذه الإتجاهات كنتيجة للإمتداد التكتونى التركيبى العميق الذى أثر على الجزء الشمالى من مصر خلال حقبة الميزوزويك. وقد وجد من خلال الدراسة أن العمق لصخور القاعدة المركبة يتراوح بين ٠,٩ كم حتى ٤ كم.

ABSTRACT: *This study applies a variety of semiautomatic and automatic methods, for the interpretation of aeromagnetic survey data with the aid of geological data of the Northern Western Desert of Egypt. Separation of reduced to the north magnetic pole (RTP) anomalies using Fast Fourier Transformation (FFT) technique was carried out in order to identify the residual local structures from those of regional nature. In addition, the application of first and second vertical derivatives method on the aeromagnetic data effectively removes the response of the dykes and enhances earlier structural and lithological features. Moreover, the analytic signal method was used for automatic interpretation of aeromagnetic data, whereas the locations and approximate geometries of magnetic sources can be deduced.*

The integrated information, obtained from the application of different qualitative and quantitative interpretation techniques to magnetic survey data with all available geologic information, were used to portray the basement configuration and show the regional structural framework of the basement complex of the study area. The most predominant structural trends are the NE-SW, E-W, NW-SE and N-S directions. The area includes four major uplifted zones and three major basins. The four uplifted zones are Salum high, Qattara high, AGNES high, and Siwa Oasis high. While Matrouh basin, Faghur - Ghazalat basin and Abu-Gharadig basin, which represent the main features in the study area, are structurally-controlled. The fault trends, which bound these main features, are oriented in general NE to EW directions. They are developed originally as a result of the deep-seated crustal extensional tectonics that affected northern Egypt during the Mesozoic Era. The depth to basement rocks was found to range from 0.9 to 4.0 km.

1. INTRODUCTION

The area under consideration is located in the northwestern part of the Western Desert of Egypt. It is bounded by latitudes 29^o 00′ N and 31^o 20′ N and Longitudes 25^o 00′ E and 29^o 00′ E.

In order to delineate the regional structural framework of the basement rocks in the study area, suitable semiautomatic and automatic methods of magnetic data analysis were used. These involve:

a) Isolation of magnetic anomalies, using band-pass filtering.
b) First and second vertical derivatives method.
c) Analytic signal method.

2. LITHOLOGICAL AND STRUCTURAL SETTINGS

The Cretaceous marine rocks of the studied area, which lies principally to the north of Qattara Depression (Fig. 1) are generally considered one of the most important sedimentary sequences of the Western Desert of Egypt. The area is generally characterized by two major surface morphologic features. According to Abu-Al-Izz,1971, these are (a) the rocky southern Miocene plateau, with its northern portion made up of Middle Miocene-Marmarica "limestone" (Tm) and its southern portion consisting of the Lower Miocene Moghra "sandstones and gravels" (Tm), and (b) the Qattara Depression itself, which occupies the western portion of Abu-Gharadiq basin area, with its floor made up of Lower Miocene Moghra "clastics", covered by playas and shallow saline water ponds in its deepest portions and silt, loose sands and sand dunes as well as sabkhas in its shallow portions (Fig. 1). The Eocene limestone (Te) and the Oligocene clastics" (To), which are the oldest exposed rock nits in the study area, are found to crop out in the southern portions of the Miocene Plateau and the Qattara Depression.

The stratigraphy of the Northem Western Desert was extensively studied by so many workers. Among those are: Said (1962), Norton (1967), Soliman and Elbadry (1970), Gezeery and Taha (1971), Norton et al. (1971), Elwoi and Abdine(1972), Abdine and Deibis (1972), Awad (1984) , Elzarka (1984) and Bayoumi and Lofty (1985).

a) The sedimentary section overlying the Precambrian basement complex arises considerably both in thickness and lithology in the studied area, being thin continental at the northern portion, and thick marine in the central and southern portions (Fig. 2**.** This figure represents a generalized stratigraphic section, showing the major stratigraphic units in the study area and their characteristic features**, (**Schlumberger ,2002).

b) The initial phase of formation of Abu-Gharadig basin appears to have started with the beginning of the first Mesozoic sedimentary cycle.

Figure (1): Geological map of the Siwa – Qattara area, Northern Western Desert, Egypt, with major structures and regional geological units (The Egyptian Geological Survey and Mining Authority, EGSMA, 1980)

<u>Legend:</u>

Te:Eocene limestone **To** : Oligo-Miocene clastics **Tm**: Miocene clastics

Tpl: Tertiary Pliocene **Qsb**: Quaternary sabkhas **Qd** : Quaternary dunes

Q : Quaternary

A slow and restricted southward transgression of the Tethyan Sea, reached Abu-Gharadig basin area, during Middle Jurassic, and formed an east-west trending local embayment. Deposition of Middle Jurassic Khatatba sandstones and shales, and Upper Jurassic Masajid limestones followed (Fig. 2).

c) During Early Cretaceous, more than 1800 metres of sediments, represented by the continental Shaltut/Kharita sandstones and shales and the shallow marine Aptian Alamein dolomites were deposited in a well pronounced east-west trending elliptical depocenter, that had been slowly subsiding along the major east-west trending fault.

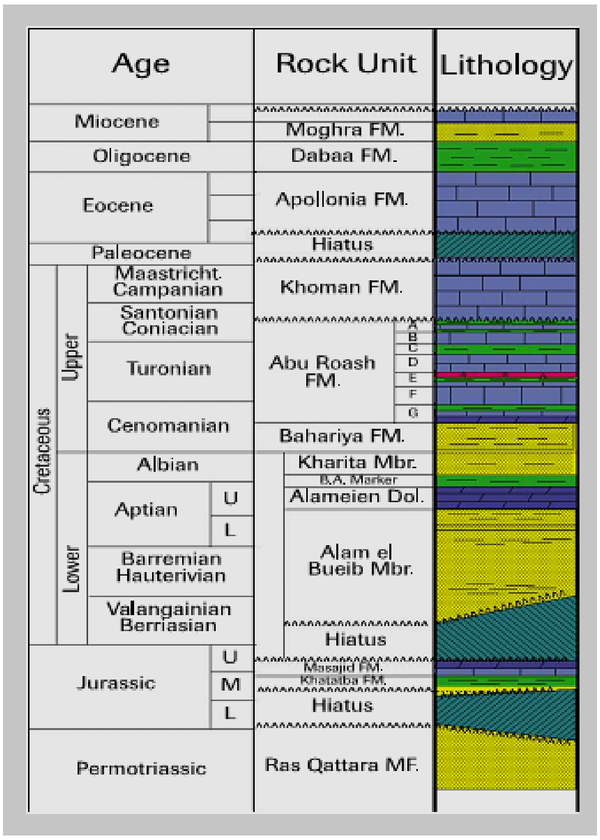

Figure (2): Generalized stratigraphic section showing the major stratigraphic units in the studied area (Schlumberger, 2002).

3. AIRBORNE GEOPHYSICAL SURVEY DATA

The area under consideration has been involved in the aerial geophysical survey conducted by Aero-service Division in 1984, Western Geophysical Company of America, and then included in the Western Atlas International Inc, Houston, Texas, USA (1989). The Mineral, Petroleum and Ground- Water Assessment Program (MPGAP) agreement number 263-0105, 28th September 1980, of the United States Agency for International Development was the basis on which this survey was conducted. Additional data were added, under amendment No. 1, to this agreement, after a recompilation of older aeromagnetic surveys over the Western Desert. Conversion of the total magnetic intensity anomaly data to the pole was accomplished in the wave number domain, using inclination and declination of the geomagnetic field of 37.7° and 2.0° for the data over the Western Desert of Egypt.

The data, shown on this map were collected during a number of different surveys and have been reduced using the parameters of the Western Desert of Egypt, with an original altitude of 1000 feet barometric and zero nT constant removed to obtain the best fit of the zero level contour across all areas, with a minimum mismatch at area boundaries. Finally, a map with a scale of 1:500000 was obtained.

4. TECHNIQUES OF ANALYSIS OF MAGNETIC DATA

In this study, three advanced techniques were used to analyze the magnetic data and as a guide for structural interpretation. These methods are filtering of the magnetic data using band-pass filter techniques (Spector, 1970; Spector and Grant, 1970), second vertical derivative (Henderson and Zietz 1949; Peters 1949, Elkins, 1951; Hospers and Rathore, 1984) and the analytic signal (MacLeod et al., 1993).

These methods were proved as efficient tools to map the locations of magnetic structures, such as faults and contacts. The same functions, that were used to locate structures, were used also to estimate source depths at the contact locations. It is usually necessary to improve the signal-to-noise ratio of the data by filtering or upward continuation prior to calculation of derivatives. In this study, these methods were applied to the filtered regional and residual magnetic components, after removing the white noise.

4.1. Filtering

To separate the regional and residual components of the magnetic data, the two-dimensional power spectrum curve was calculated from the reduced to the north magnetic pole (RTP) magnetic map (Fig. 3), using Fast Fourier Transformation (FFT) technique (Spector, 1970; Spector and Grant, 1970).

The power spectrum curve (Fig. 4) shows two linear segments that are related to regional and residual magnetic components at average depths of 4.0 and 0.9 km respectively. Moreover, the analysis of power spectrum curve shows that the deep -seated magnetic component frequency varies from 0.0 to 0.1 wave number/km. Meanwhile, the near-surface magnetic component frequency ranges from 0.1 to 0.9 wave number/km. These bands of frequencies were used through the band-pass filter technique to produce the regional and residual magnetic component maps (Figs. 5, 6).

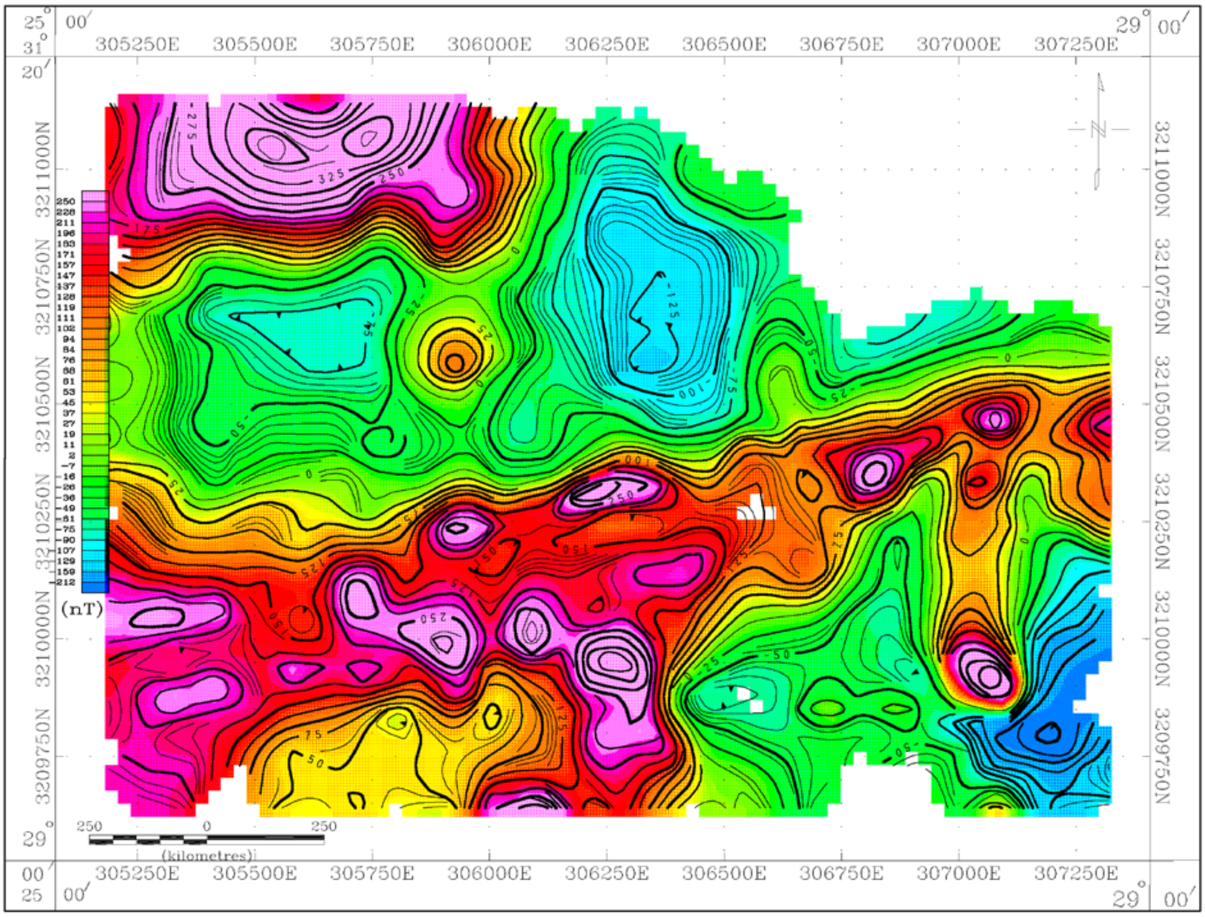

Figure (3): Reduced to the north magnetic pole (RTP), total magnetic intenrvicesity map of Siwa – Qattara Area, Northern Western Desert, Egypt (Aero-service, 1984).

Figure (4): Power spectrum curve of the RTP magnetic map. of Siwa – Qattara Area, Northern Western Desert, Egypt

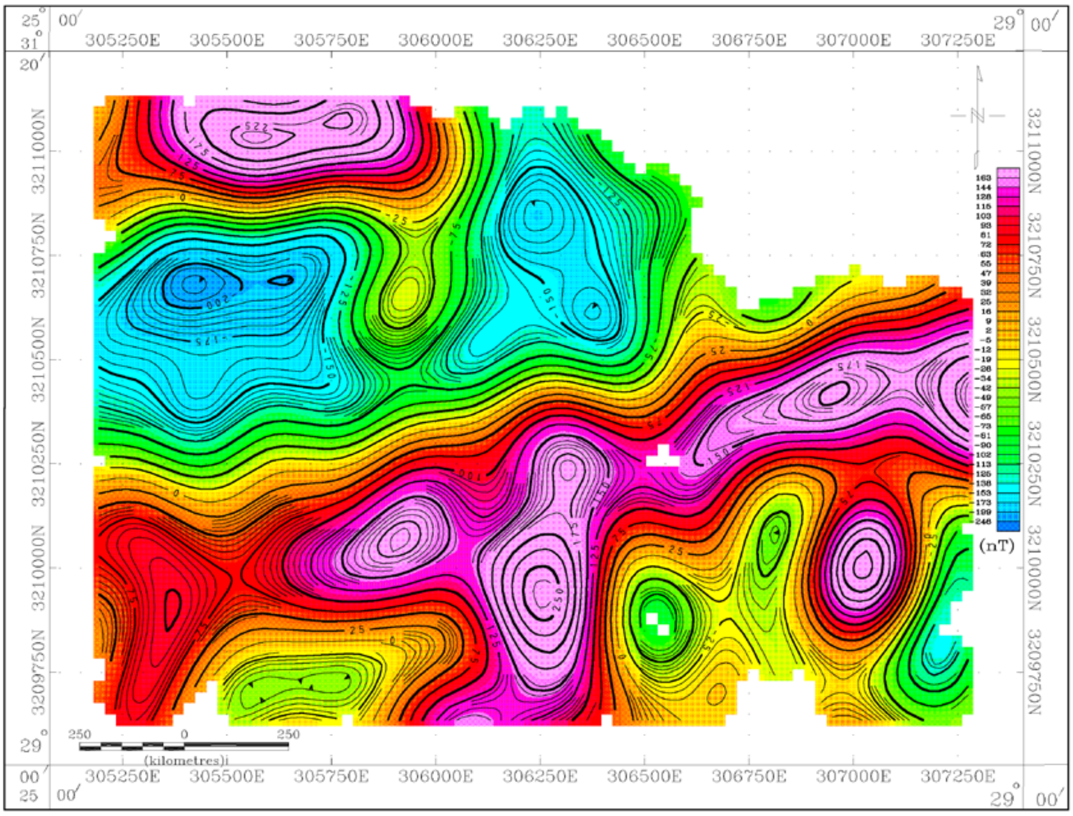

Figure (5): Filtered reduced to the north magnetic pole regional magnetic component map of Siwa – Qattara Area, Northern Western Desert, Egypt

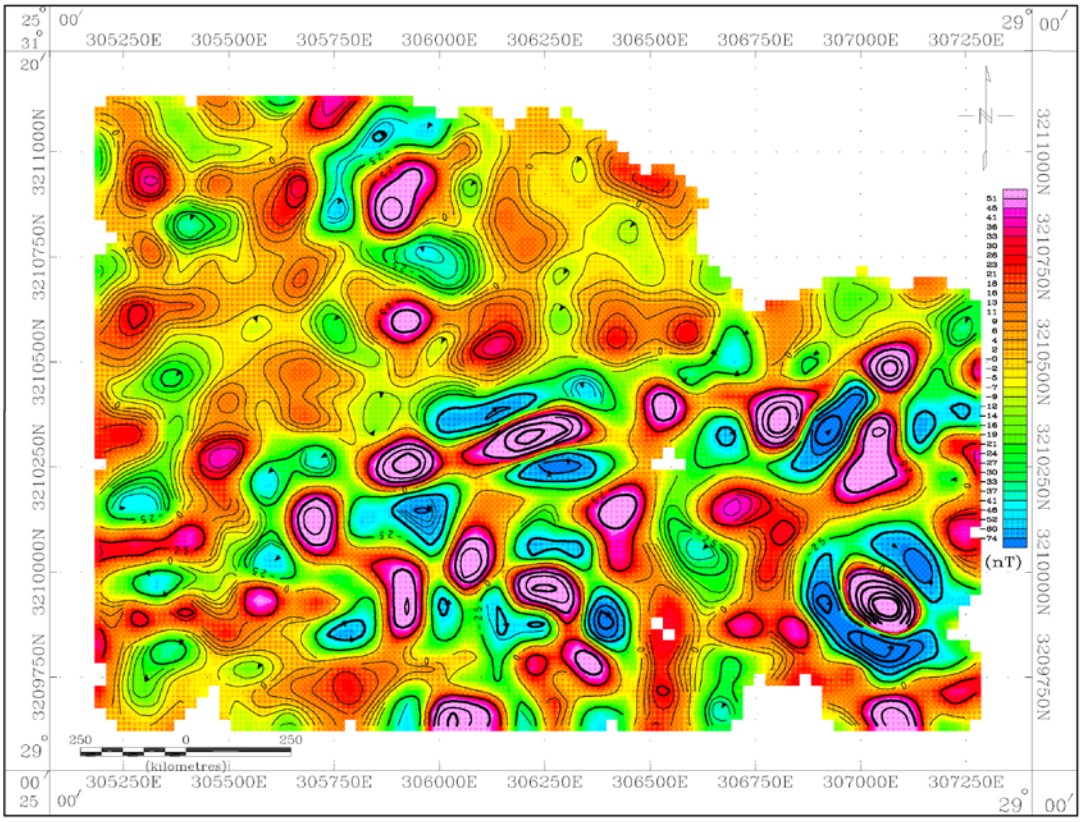

Figure (6): Filtered reduced to the north magnetic pole residual magnetic component map of Siwa – Qattara Area, Northern Western Desert, Egypt.

4.2. First and Second vertical derivative (FVD) and (SVD)

First and Second vertical derivatives (SVD) amplify gradually short-wavelength structures at the expense of long-wavelength structures. SVD maps, accentuate gradients along edges of shallow potential field sources. Hence, they are used to locate edges of potential field bodies and emphasize sources at shallow depths (Dobrin and Savit, 1990). The calculations may be carried out in the space domain or in the frequency domain.

The features of interest on the second vertical derivative (SVD) map are the maxima and the zero contours. The closed zero contours on these maps outline the potential field body, Henderson and Zietz, (1949), Peters 1949, Elkins, 1951; Hospers and Rathore, 1984. These ascertained that the spacing of the grid lines did not significantly affect the locations of the zero, maximum, and minimum values of the curvature for the theoretical bodies. However, smaller grid spacing resulted in a more accurate delineation of the curvature.

Methods and equations for calculating the second vertical derivative values from uniformly gridded potential field data are given by Henderson and Zietz (1949), Peters (1949) and Vacquier et al., (1963).

The second vertical derivative technique was applied to the regional component of the reduced to the pole magnetic data to amplify short-wavelength structures and to emphasize edges of magnetic sources in the Potential Field data.

The result of the SVD computed from the regional magnetic component is displayed in figure 7. The edges from the SVD function could map the deep-seated magnetic structure of the study area. These structures are trending mainly in NW, NNW, NE, and NS directions.

4.3. Analytic Signal

The 3-dimensional analytic signal is a powerful data processing technique which eliminates problems encountered due to remnant magnetization and data from low magnetic latitudes. It further turns both negative and positive anomalies into a positive response which is directly above the magnetic source.

It is independent of the remnant magnetization and direction of the inducing field. The 3-D magnetic analytical signal amplitude is related to the magnetic contrast of the underlying rocks. The map of the analytical signal can be used to outline the edges of magnetic sources. The analytic signal is normally derived from the three orthogonal gradients of the total magnetic field using the expression:

$$|A(x, y)| = [(dT/dX)^2 + (dT/dY)^2 \; (dT/dZ)^2]^{1/2}$$

Where A(x, y) is the amplitude (or the absolute value) of the analytic signal at (x, y) and T is the observed magnetic field at (x, y). The amplitude of the 3-d analytic signal of the total magnetic field is positive regardless of the direction of magnetization; the amplitude being proportional to the magnetization contrast of the underlying rocks. Thus the 3-D analytic signal shows the edges of magnetic bodies, which if these edges represent rock contacts, can be roughly interpreted as a “pseudo-geology” map if the magnetic units outcrop.

The most conspicuous feature of the analytical signal map (Fig. 9) is the presence of a group of positive magnetic anomalies as well as many associated negative ones, which are aligned in alternating manner. This indicated different types of intrusions having various lithologic compositions (acidic, intermediate and basic). It could be concluded that the causative bodies of most of these anomalies are dykes like bodies with no deep root i.e. either outcropping or existing at shallow depths beneath the surface. It is very noticeable that the contact between the basement and sedimentary rocks is well pronounced and visible on the analytical signal map (Fig. 9).

A well-defined boundary with appreciably different degrees of magnetic relief can be easily traced in this contact zone. This may reflect a contrast between the magnetic properties of rocks along the opposite sides of this boundary and indicate also the existence of faults.

The western to northeastern part of the study area, which is represented on the surface by Quaternary sediments, is occupied by a broad belt of moderate to strong negative magnetic anomalies having nearly NE-SW direction and characterized by their long wavelength and low magnetic relief, particularly to the north, which suggests a deep-root for the causative mass.

The nature of these anomalies indicates that there is no deepening in the basement surface northwestwardly. A set of great faults could be interpreted from the analytical signal map (Fig. 9). These faults are running mainly in NE-SW, E-W, and N-S directions.

5. INTERPRETED BASEMENT SHAPE MAP

The results obtained from these three methods were compiled and integrated to construct the interpreted basement shape map, (Fig. 10). Close inspection of this map (Fig. 10) reveals that the area is affected by four sets of structural lineaments oriented in NW-SE, NE-SW, NS and E-W directions.

Therefore, examination of this map (Fig. 10)) illustrates that the study area is characterized mainly by the presence of two intersecting sets of NNW-SSE to NW-SE and NNE-SSE to NE-SW trending major faults as in (Tab. 1 and Fig. 11).

Besides, it can be seen from the basement shape map that the studied area includes four uplifted zones and three major basins.

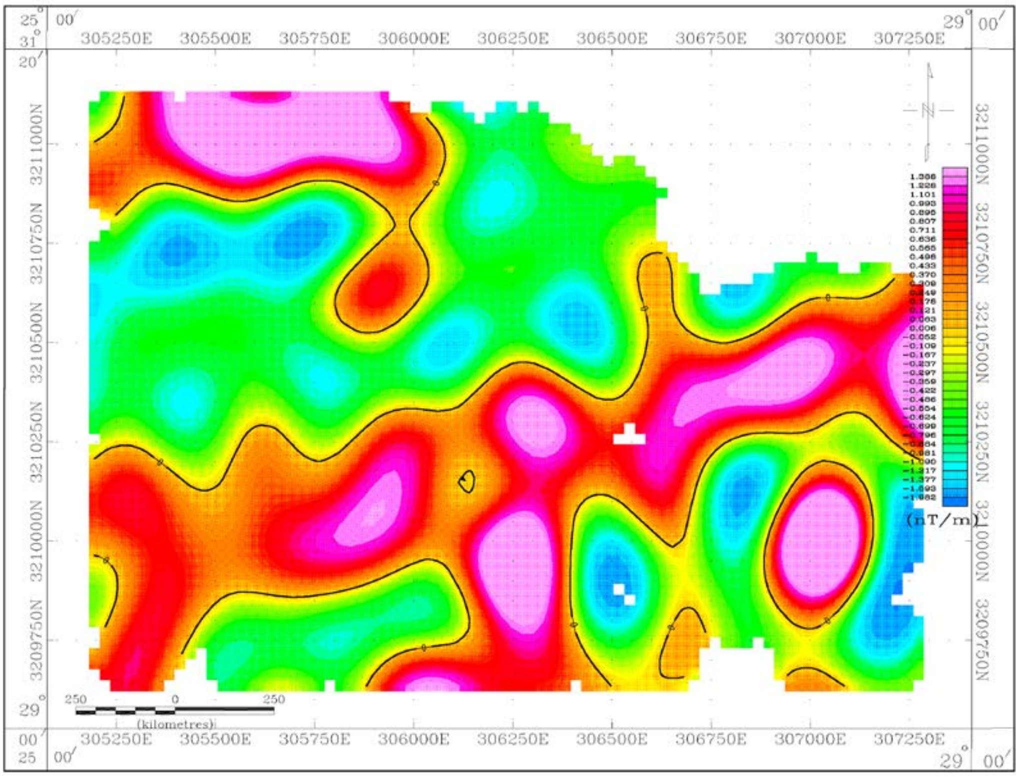

Figure (7): First vertical derivative (FVD) computed from the regional magnetic component, overlain by the picked zero FVD value (in black.) of Siwa – Qattara Area, Northern Western Desert, Egypt.

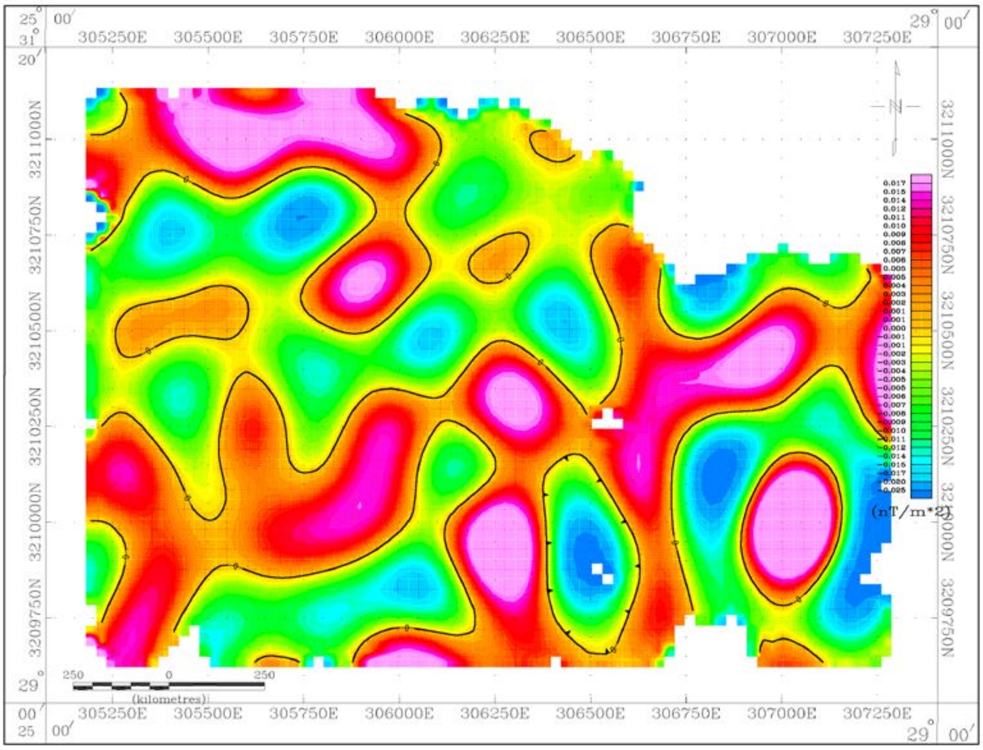

Figure (8): Second vertical derivative (SVD) computed from the regional magnetic component, overlain by the picked zero SVD value (in black.) of Siwa – Qattara Area, Northern Western Desert, Egypt.

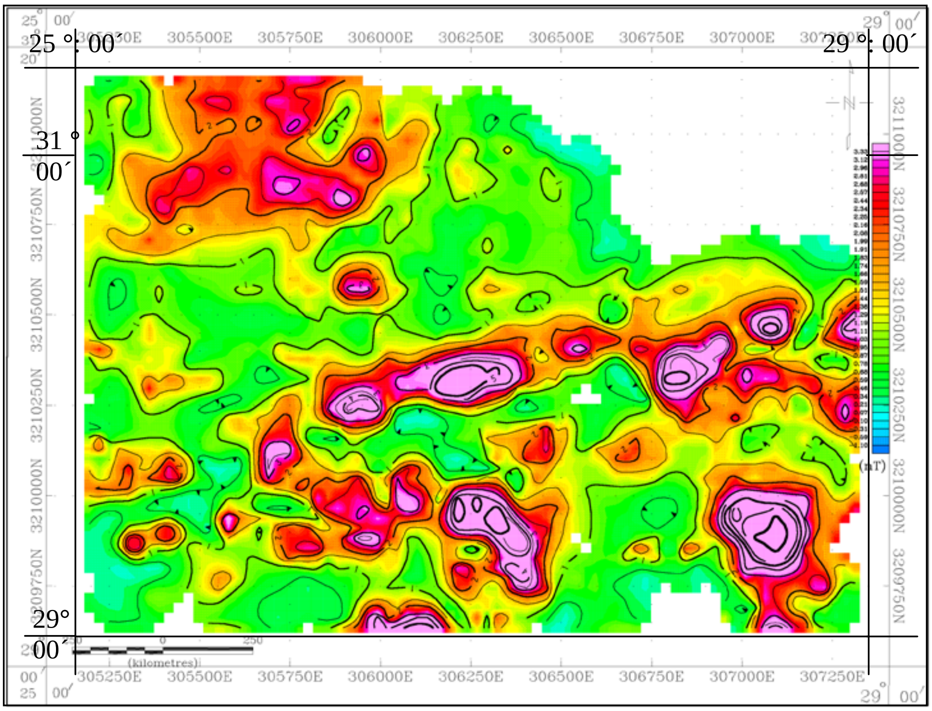

Figure (9): Analytical signal map computed from the reduced to the north magnetic pole (RTP), total magnetic intensity map of Siwa – Qattara Area, North Western Desert, Egypt.

SALUM

Figure (10): Interpreted basement shape map from aeromagnetic data compiled with location of Oilfields from Schlumberger in Western Desert Gas Project Company, 2002 in Siwa – Qattara area, North Western Desert, Egypt.

<u>Legend</u>:

Contact: **Anticlinal axis:** **Synclinal axis:**

Oilfield: **Gasfield:** **Fault:**

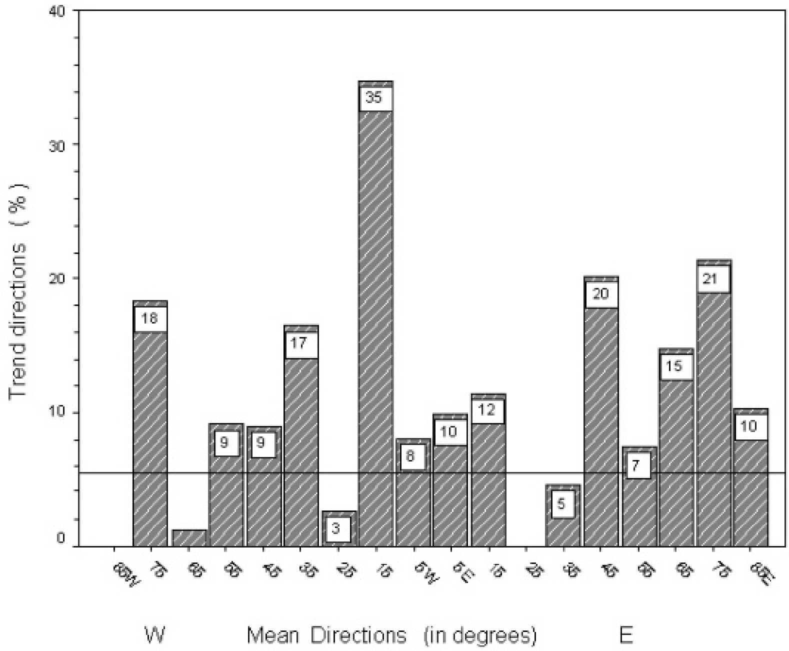

Figure (11): Bar chart showing the different trends (Length %) of the interpreted basement shape map, Siwa – Qattara area, Northern Western Desert, Egypt.

Table (1): Showing calculated statistical values of different trends (Length %) of the interpreted basement shape map, Siwa – Qattara area, Northern Western Desert, Egypt.

No.	Category (Azimuth)	L(%) E	L(%) W
1	0◦-10◦	9.9	8.1
2	10◦-20◦	11.5	34.8
3	20◦-30◦	-	2.6
4	30◦-40◦	4.5	16.5
5	40◦-50◦	20.2	9
6	50◦-60◦	7.4	9.1
7	60◦-70◦	14.8	1.3
8	70◦-80◦	21.4	18.4
9	80◦-90◦	10.3	-

The four uplifted zones are Salum high in the very northwestern portion of the studied area, Qattara high that extends from southwestern portion to northeastern portion , AGNES high in the southeastern portion of the studied area, and Siwa Oasis high in the southwestern portion of the studied area started at the Paleozoic Era, and Shushan high in the western portion of the studied area. The three major basins are:Abu-Gharadig basin in the extreme southwestern portion of the studied area extending beyond the area of investigation that started in the Middle Jurassic beginning of the first Mesozoic sedimentary cycle, whereas a transgression of the Tethyan Sea reached abu-Gharadig basin area during Middle of Jurassic and formed an east-west trending basin, Cretaceous Matrouh basin in the northern portion of the studied area that started at the Mesozoic and Faghur - Ghazalat basin in the western portion of the studied area.

6. SUMMARY AND CONCLUSIONS

The present study is mainly devoted to the critical analysis of all available geological and aeromagnetic survey data in the Siwa – Qattara area, Northern Western Desert, Egypt. The main physical features of the study area include Salum highs to the west, Siwa Oasis to the south, Qattara depression in the central portion and Abu-Gharadig basin that lies principally to the east of the Qattara depression,

This work presents the application of a variety of semiautomatic methods, for the interpretation of aeromagnetic survey data on the basis of geological data of the area under study. Three analytical techniques were applied to airborne magnetic data to map the location and depth of the magnetic contacts as an aid to structural interpretation.

Separation of the reduced to the north magnetic pole (RTP) anomalies using Fast Fourier Transformation (FFT) technique was carried out in order to identify residual local structures from those of regional nature. Besides, the application of first and second vertical derivatives method on the aeromagnetic data effectively removes the response of dykes and enhances earlier structural and lithological features. Finally, the application of analytic signal method led to deduce the locations and approximate geometry of magnetic sources.

The examination of the interpreted regional structure fabric map can lead to see that the study area is characterized mainly by the presence of two intersecting sets of NE-SW and N-S to NNW-SSE trending major faults. The results indicate that the most two predominant structural trends are the NW-SE and NE-SW directions. The depth to basement rocks was found to range from 0.9 to 4.0 km.

The studied area includes four uplifted zones and three major basins. The four uplifted zones are: Salum high in the very northwestern portion, Qattara uplift that extends from southwestern portion to northeastern portion, AGNES high in the southeastern portion, and the Shushan high in the western portion.

The three major basins are: Abu-Gharadig basin in the extreme southwestern portion, extending beyond the area of investigation that started in the Middle Jurassic beginning of the first Mesozoic sedimentary cycle. Meanwhile, a transgression of the Tethyan Sea reached Abu-Gharadig basin area during Middle Jurassic and formed an east-west trending basin, Cretaceous Matrouh basin in the northern portion that started in the Mesozoic, and Faghur and Ghazalat basin in the western portion of the studied area.

Siwa Oases, Qattara Depression and Abu-Gharadig Basin are structurally controlled. The fault trends, which bound the main structural features in the study area, are oriented in general NE to E-W direction, that developed originally as a result of the deep crustal extensional tectonics that affected northern Egypt during Mesozoic Era.

The Cretaceous marine rocks of Abu-Gharadig Basin, which lie principally to the east of the Qattara depression and are considered one of the most important sedimentary sequences of the Western Desert of Egypt in terms of petroleum potentials **(**Schlumberger, 2002). Comparison between the results obtained from previous works of Schlumberger ; 2002 taking in consideration the oilfields with green circles and the compiled and interpreted basement shape map (Fig.11) as a result of this work indicate that, both of them agree in the following:(a) Matrouh Cretaceous basin in the central portion of the studied area has many oilfields (b) Faghour and Ghazalat basin in the western portion has moderate number of oilfields, in addition, (c) Abu-Gharadig basin in the southeastern portion has moderate number of oilfields and the interpreted basins boundary is very close to the oilfields boundary .

From the results of this work, it is recommended to pay more attention to the basinal area that lies to the west of Qattara depression as it is considered an extension of Cretaceous marine rocks of Abu-Gharadig basin in terms of petroleum potentials. Also pay more attention to the southeastern portion of matrouh Cretaceous basin on the central portion of the studied area.

REFERENCES

Abdine, A.S. and Deibis, S., 1972, Lower Cretaceous Aptian sediments and their oil prospects in the Northern Western Desert, Egypt. Eighth Arab Petroleum Congress, Algeria, pp. 143-155

Abu-Al Izz, M.S., 1971, Landforms of Egypt. Translated by Y.A. Fayed. The American University in Cairo Press, Cairo, Egypt.

Aero Service, 1984, The Mineral, Petroleum and Ground-Water Assessment Program agreement

Number 263-0105, 28th September, 1980 of the United States Agency for International Development. Egypt, for the Egyptian General Petroleum Corporation, Cairo, Egypt. Aero-Service Houston, Texas, USA.

Awad, G.M., 1984, Habitat of oil in Abu-Gharadig and Fayum Basins, Western Desert, Egypt. Bul. 88, No. 5, pp. 564-573.

Bayoumi, A.I. and Lotfy, H.I., 1989, Modes of structural evolution of Abu- Gharadig Basin, Western Desert of Egypt as deduced from seismic data. Journal of African Earth Sciences. Great Britain Vol. 9, No. 2, pp. 273-287.

Dobrin, M.B., and Savit, C.H., 1990, Introduction to geophysical prospecting. McGraw-Hill Book Co., New York, 749 p.

Eaton, G.P., 1979, Regional geophysics, Cenozoic and geologic resources of the Basin and Range province and adjoining regions. In: Basin and Range Symposium Rocky Mountain Association of Geologists and Utah Geological Association, Edited by Newman, G.W., and Geode, H.D. pp. 11-39.

Egyptian Geological Survey and Mining Authority "EGSMA", 1980, Geological map of Egypt, Scale 1:000,000, EGSMA, Cairo, Egypt.

Elkins, T.A., 1951, The second vertical derivative method of gravity interpretation. Engel, A. E. J., Dixon, T. H., and Stern, R. J., 1980. Late Precambrian evolution of Afro-Arabian crust from ocean arc to carton. Geol. Soc. Am. Bull., Vol. 91, No. (1), pp. 699-706.

Elowi, M. and Abdine, S., 1972, Rock unit's correlation chart of the Northern Western Desert, Egypt, Wepco Petroleum Company.

El-Shazly, E.M., 1966, Structural development of Egypt, U.A.R. The Geological Soci. of Egypt, 4th Annual Meeting, Cairo, An Extended Abstract, pp. 30-88.

El-Zarka, M.H., 1984, The application of facies parameters and mapping techniques to exploration of the subsurface Lower Cretaceous of the Qattara Depression, Western Desert, Egypt. Journal of Petroleum Geology, Vol. 7, `pp. 277-302.

Gezeery, N. and Taha, I., 1971, Contribution to the stratigraphy, tectonics and oil shows in Abu-Gharadig Basin, Western Desert, Egypt. Ninth Annual Meeting, Geological Society of Egypt, Cairo, Egypt. pp. 207-217

Henderson, R.G. and Zietz, I., 1949, The computation of second vertical derivatives of geomagnetic fields. Geophysics, Vol. 13, pp. 508-516.

Hospers, J. and Rathore, J.S., 1984, Interpretation of aeromagnetic data from the Norwegian sector of the North Sea. Geophysical Pros. V. 32, pp. 929-942.

Norton, P., 1967, Rock stratigraphic nomenclature of the Western Desert, Exploration Department, Report No. 4, Pan American Oil Company, Cairo, Egypt.

Norton, P. Hagras, M. and Abdallah, A.M., 1971, Progress report on rock stratigraphic units in the central part of the Western Desert of Egypt. Ninth Annual meeting, Geological Society of Egypt, Cairo, Egypt.

Peters, L.J., 1949, The direct approach to magnetic interpretation and its practical application. Geophysics, Vol. 14, pp. 290-320.

Said, R., 1962, The Geology of Egypt, Elsevier Publishing Company, Amsterdam, The Netherlands.

Schlumberger/Baker Hughes Company, 2002, Case study: Prestack depth migration

improved fault location definition in west Abu-El-Gharadig, Northwestern n Desert, Egypt,

Soliman, S.M. and Elbadry, O., 1970, Nature of Cretaceous Sedimentation, Western Desert, Egypt AAPG Bulletin, Vol. 54, No. 12, pp. 2340-2370.

Spector, A., 1970, Aeromagnetic map interpretation with the aid of digital computers. The 7th Annual Meeting of the C. I. M., Toronto, Canada, Vol. 64,27 p.

Spector, A. and Grant, F.S., 1970, Statistical model for interpreting aeromagnetic data. Geophysics, Vol. 35, No. 2, pp. 293-302.