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APPLICATION OF SOME ADVANCED INTERPRETATION TECHNIQUES IN DEPICTING THE STRUCTURAL SETTING OF WADI ABU-HAD AREA, NORTHERN EASTERN DESERT, EGYPT, USING AEROMAGNETIC DATA

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تطبيق بعض تقنيات التفسير المتقدمة فى تحديد الوضع التركيبى لمنطقة وادى أبو حاد، شمال الصحراء الشرقية، مصر، باستخدام المعطيات المغناطيسية الجوية

الخلاصة: تهدف الدراسة الحالية إلى تحليل وتفسير معطيات المسح المغناطيسى الجوى لمنطقة وادى أبو حاد بشمال الصحراء الشرقية، مصر. تقطع المنطقة العديد من الوديان الجافة التى غالبا ما تأخذ اتجاهى شمال– شرق وشرق شمال شرق، وتتغطى المنطقة بالصخور النارية والمتحولة فيما عدا الجزء الشرقى منها الذى تغطيه الصخور الرسوبية. تم التوصل إلى التفسير التركيبى لمعطيات المسح المغناطيسى الجوى من خلال تطبيق بعض تقنيات التفسير المتقدمة التى تهدف إلى تحديد التراكيب المغناطيسية وتعيين أعماقها. تشمل تلك التقنيات: المشتقة الرأسية الثانية والتحليل الموجى والعدد الموجى الموضعى. أوضحت التراكيب المغناطيسية المفسرة أن منطقة الدراسة تتأثر بمجموعة من الفوالق تأخذ الإتجاهات الرئيسية: شمال – جنوب وشمال شمال غرب وشمال – غرب وشمال – شرق وشرق شمال شرق. إضافة إلى ذلك، فإن الجزء الشرقى من المنطقة يغطى بنطاق شاسع ذى خواص مغناطيسية منخفضة والتى تجعل من المحتمل إمتداد جذور الجسم المسبب له إلى أعماق بعيدة مما يوضح أن صخور القاعدة فى هذا الجزء من المنطقة عميق. أظهرت الأعماق والميول التى تم حسابها بطريقة العدد الموجى الموضعى أن الجزء الشرقى من المنطقة أكثر عمقاً من الأجزاء الأخرى بالمنطقة وتتراوح تلك الأعماق بين ٥٢٥ إلى ١٦٠٥ مترا، بينما تأخذ إتجاهات الميول وجهات شمال – شرق وشمال شمال الشرق وشمال شمال الغرب وجنوب الغرب.

ABSTRACT: *The present work deals with the analysis and interpretation of airborne magnetic survey data of Wadi (W.) Abu-Had area, northern Eastern Desert of Egypt. This area is traversed by several wadis, mainly with NE and ENE directions, and comprises igneous and metamorphic rocks, with the exception of its eastern part, which is mainly covered by sedimentary rocks.*

Structural interpretation of the aeromagnetic data was achieved through the application of some advanced interpretation techniques that delineate the magnetic structures and estimate their depths. These techniques include second vertical derivative (SVD), analytic signal (AS) and Source Parameter Imaging (local wave number) (SPI).

The interpreted magnetic structures reveal that the area is dissected by a set of faults trending mainly in the N-S, NNW, NW, NE and ENE directions. Moreover, the eastern part of the studied area, is occupied by a broad belt of low magnetic relief, which suggests a deep- rooted causative mass which indicates a deeping of the basement rocks. The estimated depths and dips using (SPI) method show that the eastern part is deeper than the other parts of the study area. The depths were found to range from 525m to 1605m and they are oriented in the NE, NNE, NNW and SW directions.

INTRODUCTION

The Wadi Abu-Had area is located in the northern part of the Eastern Desert of Egypt, some 60 km to the north of Hurghada city on the Red Sea coast. It is enclosed between latitudes 27° 32´ 30″N and 27° 43´ 30″ N and longitudes 33° 00´ E and 33° 15´ E. I t has a rectangular shape, with its longer side of about 25 km and its shorter one of about 20 km, and thus covering an area of about 500 km^2 (Fig. 1). The general outline of the topography of the study area shows that it is mainly covered by basement complex rocks forming relatively rugged, highly-dissected Precambrian terrain running parallel to the Red Sea Coast. The maximum elevation attained is 1120 m at Gabal (G.) Idid Elgedan, while the lowest mountain peak is that at G. Abu-Had (510 m). The eastern side of the area is covered with sedimentary rocks forming hills and ridges of low to moderate topography (Fig. 2).

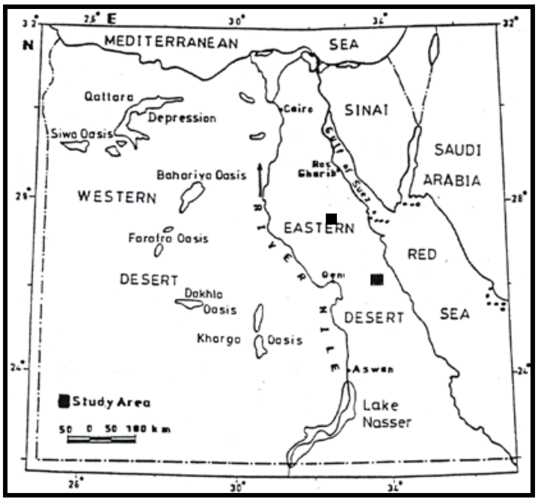

Fig. (1): Map of Egypt showing the location of Wadi Abu-Had area, northern Eastern Desert, Egypt.

The area under study is traversed by several wadis, mainly with NE and ENE directions, and the drain eastwards to the Red Sea (Fig. 2).

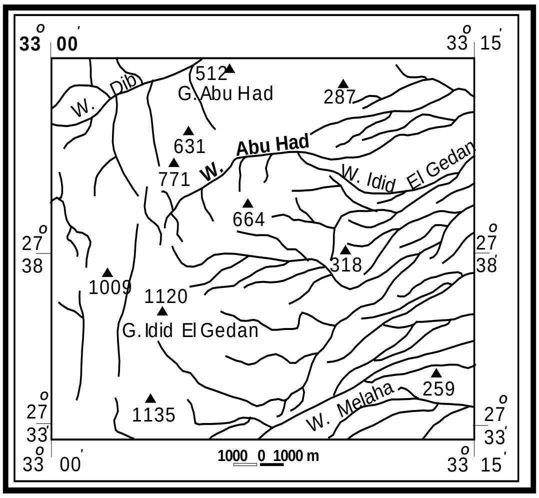

Fig. (2):Topographic map showing the main features of Wadi Abu-Had area, northern Eastern Desert, Egypt. W. = Wadi, G. = Gabal, ▲ = Triangulation point

Among the numerous large and major wadis dissecting the study area, are W. Dib, W. Abu-Had, W. Idid Elgedan and W. Melaha in the northern part of the Eastern Desert of Egypt. Fig.(3) Presents the false-colour composite Landsat Satellite Multispectral Scanner (MSS) photo map of the study area, published by the Egyptian Remote Sensing Centre (ERSC Atlas, 1992), with the same scale as the geologic map in order to reveal some extra lithologic and structural features.

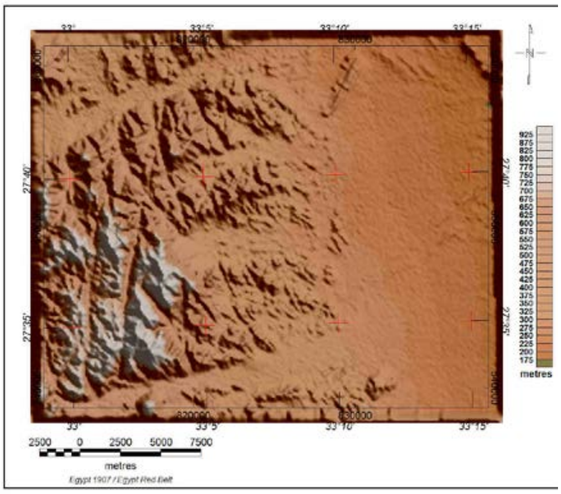

Fig. (3): False colour composite Landsat image, Wadi Abu-Had area, Northern Eastern Desert, Egypt.

In 1983, the Eastern Desert was included in an airborne spectral radiometric and magnetic surveying programme (including the study area), carried out by Aero-Service Division, Western Geophysical Company of America. The aerial magnetic survey was conducted using Varian (V-85), with a sensitivity of 0.1 nT airborne magnetometer. The measurements were taken along a system of equally-spaced NE-oriented flight lines 1.5 km apart, at a nominal flight altitude of 120 m ground clearance. Tie lines were flown perpendicularly in a NW-SE direction, at 10 km intervals.

AIM OF THE STUDY

The present study is an attempt to make use of the available aeromagnetic survey data, as a main source of information, aided by the geological knowledge to figure out the gross structural framework of W. Abu-Had area and to define the significant structural trends that are responsible for the structural development of its geological units. The application of various methods and techniques of interpretation and analysis to the aeromagnetic data in such an area that is characterized by widely varying lithological rock units and structures, would permit the elucidation of near-surface and deep-seated lithological and structural configuration of the study area. The ultimate goal of the present research work is to use the acquired results as an aid to mineral exploration in this area, since its structural conditions seem to play a significant role in the localization of mineralization of the radioactive and accompanying non-radioactive ore deposits in the area. In order to pursue these objectives, the total aeromagnetic map reduced to the north pole (RTP) was subjected to some advanced methods of analysis, including second vertical derivative (SVD), analytic signal (AS) and Source Parameter Imaging (local wave number) (SPI).

SURFACE GEOLOGY

The investigated area is dominated by the presence of igneous and metamorphic rocks of the basement complex, with the exception of its eastern part, which is mainly covered by sedimentary rocks. Both the crystalline and sedimentary rocks are generally traversed by several Wadis filled with Quaternary sediments. Accordingly, the various rock formations constituting the area under consideration show a wide range in their relative geological ages and structural-tectonic stages that took place from Early Precambrian to Cenozoic. The distribution of the different rock types exposed in the study area is shown on the compiled geological map (Fig. 4) prepared mainly from the work of Francis (1972) and the geological map of Qena quadrangle published in 1981 at scale 1:500,000, by the Egyptian Geological Survey and Mining Authority (EGSMA). A brief description of these rock units is given hereafter, starting with the oldest.

Metasediments:

These sediments represent the oldest rocks recorded in the study area. They are of limited distribution and cropping out mainly near the mouth of

W.Abu-Had, forming a small elongated exposure in the central western part of the study area. They start with a basal coarse polymictic conglomerate, followed upwards by rocks of an originally silty mudstone to greywacke composition (Francis, 1972).

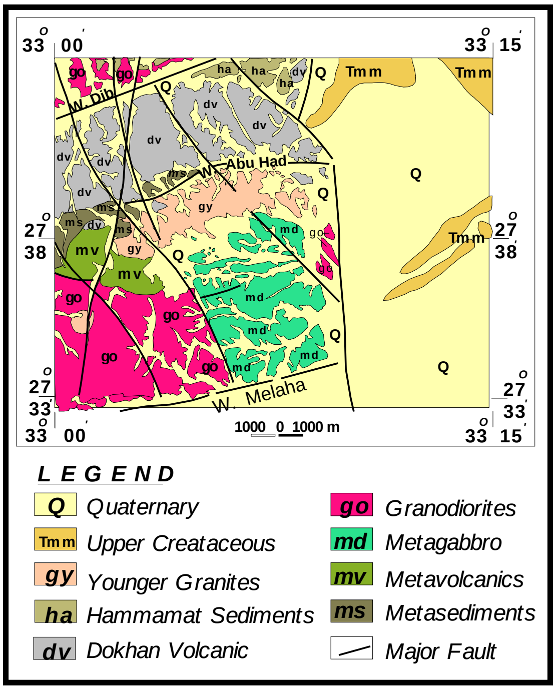

Fig. (4): Compiled geological map, Wadi Abu-Had area, northern Eastern Desert, Egypt (Francis, 972; EGSMN, 1981).

Metavolcanics:

The metavolcanics in the study area occupy two relatively small separate outcrops at the upper reaches of W. Abu-Had to the north of G. Idid Elgedan. They are almost massive, thick, sheet-like bodies, composed of intermediate to basic volcanic tuffs and flows, which have been subjected to regional metamorphism.

Metagabbro-Diorite Complex:

These rocks are more developed than the before-mentioned two units, and occurr in the central part of the study area, between W. Abu-Had and W. Melaha. Francis (1972) believed that these rocks were probably derived from the metavolcanics (and probably also the metasediments) through the interaction between the granodiorite magma and these older rocks. They occupy zones, intermediate in position, between the metamorphic rocks and granodiorites, with irregular boundaries.

Granodiorites:

The granodiorites are well developed in the study area and are encountered mainly in its southwestern part, to the north of W. Melaha, and in a small exposure located in the northwestern corner, north of W. Dib. These rocks are medium to coarse grained, strongly sheared and intruded by several dykes, mainly of basaltic composition. They are ranging in composition from adamellites to quartz diorites and sometimes granites, but the majority is granodiorites (Elramly, 1972).

DokhanVolcanics:

These rocks represent the second episode of volcanism in the stratigraphic succession of Egypt (Heikal and Ahmed, 1983). They are a thick sequence of slightly metamorphosed intermediate to felsic volcanic rocks, composed mainly of successive sheets of lavas and pyroclastics, within which 15 m thick of rhyolites are recorded. The bulk composition of lavas is mainly andesite and rhyodacite (Heikal and Ahmed, 1983). They are the most dominant rocks in the study area and crop out in a large segment between W. Abu-Had and W. Dib in its northern part.

Hammamat Sediments:

Hammamat sediments are represented in the study area by a small exposure, located in its northern part, to the south of G. Abu-Had. They are found in intimate association with Dokhan volcanics, and essentially composed of immature and poorly-sorted breccia, sandstones, siltstone and conglomerate (Stern, et al., 1984). They represent the latest stage of sedimantation in the Precambrian of Egypt (El-Shazly, 1977).

Younger Granites:

These rocks are mainly represented by intrusive granites possessing relatively sharp contacts with the surrounding rocks and are followed by the formation of pegmatites, aplites, felsites and quartz veins. They have been emplaced over a wide range of time, however, most varieties are believed to have formed by the end of Late Precambrian times (El-Shazly, 1964 and 1977). Yuonger granites are well-developed in the study area and mainly represented by ENE elongated outcrop located south of W. Abu-Had. These granites are composed of quartz and perthitic orthoclase in nearly equal amounts, together with oligoclase and biotite. Accessory minerals include zircon, zoisite, clinozoisite and iron oxides (Francis, 1972 and Dardir & Abu-Zeid, 1972).

UpperCretaceous-Lowe Tertiary Sediments:

These rocks are formed of intercalations of shales, marls, sandstones, chalky limestone and limestone with flint concretions and phosphate bands (Mazhar et al., 1979). They are occuring in the eastern side of the mapped area, forming elongated patches mainly with NE extenstion.

Quaternary Sediments:

These are the youngest sediments recorded in the study area. They are occupying the eastern margin of the area and constitute the surficial cover in the main wadis and their tributaries. They are formed of loose sands, gravels, pebbles, cobbles and boulders.

STRUCTURAL SETTING

The structural pattern of the basement rocks of W. Abu-Had area is the result of combined effect of successive earth movements that took place since Precambrian times and is expected, therefore, to be most complicated. The complexity of the structure of the study area is tightly related to the regional structures in the northern Eastern Desert of Egypt. Dardeir and Abu-Zeid (1972) and Francis (1972) studied the area of the Eastern Desert between Lat. 27^0 00 and 28^0 00´ N, including the study area. They stated that, faults represent the main important structural features affecting the study area and almost all of them are of the normal type, with their planes either vertical or steeply inclined.

Francis (1972) divided the major faults traversing the study area into two main groups of transverse and longitudinal types. The first (transverse) group includes those faults with an ENE to NE trend, normal to the Red Sea axis. The major faults of this group are those running along W. Dib, W. Abu-Had and W. Melaha, as far as the area under study is considered. The second (longitudinal) group includes all faults having N-S, NNE and NNW trends. Some of the major faults of this group which cross the whole length of the area from north to south have a NNW trend and change their direction towards the northwards. Due to the active role of these faults, a very conspicuous uplifted block represented by the Red Sea basement mass is formed and bordered from the west and east by structural depressions filled by sediments.

STRUCTURAL GEOMORPHOLOGY

The study area is intervened by several Wadis of different widths and lengths. The geomorphology of the area is greatly influenced by various structures, beside lithology of the diverse rock types. The Wadis pattern in the study area is one of the most salient physiographic features showing the effect of prevailing structures on the morphology and their mutual interaction. The fault lines as traced from both the geological map (Fig. 4) and composite landsat image (Fig. 3) as well as the wadi lines (courses) as traced from the topographic map (Fig. 2), both were statistically analyzed with respect to their number and length proportions. The results of these studies are given in (Fig.5), which shows the resultant frequency rose diagrams for the two different types of trend directions of the fault lines and wadis courses respectively. The relation between fault lines and the courses of main Wadis in the study area shows the effect of faulting on the distribution pattern of the courses of Wadis. This relation is given on Table(1) and is illustrated in (Fig.5), according to their main directional trends, number and length proportions.

From (Fig. 5) and Table (1) the following can be deduced as far as the statistically-significant peaks are concerned:

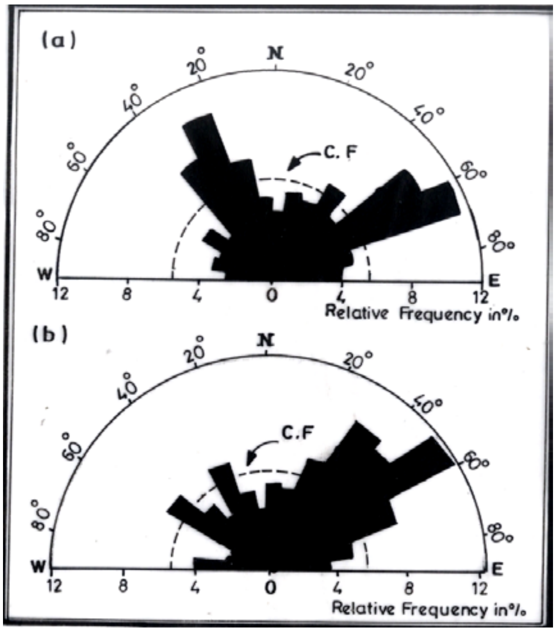

Fig. (5): The resultant frequency rose diagrams of: (a) the fault lines and (b) the main Wadis, according to their main directional trends and length

1- The N-S, WNW and NNW trends of faults are grater than their corresponding wadis both in number and length proportions, which may indicate that these faults are mainly cutting through rock exposures rather than controlling wadis.

Table (1): Relation between the main directional trends and the number and length proportions of the fault lines and Wadi courses, Wadi Abu-Had area, northern Eastern Desert, Egypt.

Trend direction	Faults		Wadis	
	Number (%)	Length (%)	Number (%)	Length (%)
N-S	9.87	10.06	7.81	7.53
NNE	11.25	13.30	12.62	13.22
NE	13.96	14.73	21.81	22.45
ENE	17.36	15.81	14.94	15.67
E-W	10.66	8.28	9.63	10.84
WNW	9.25	9.07	6.80	6.37
NW	8.34	7.84	10.66	9.09
NNW	19.31	20.91	15.73	14.83
Total	100.00	100.00	100.00	100.00

2- The NE and NW trends of wadis are greater in number and length proportions than their corresponding faults. This may suggest that these wadis are not controlled by tectonics and are mainly formed by natural erosion processes.

3- The NNE, ENE and E-W trends of faults have nearly comparable number proportion and to a lesser extent length proportion with their corresponding wadis. This may reveal that most of the wadis belonging to these trends are in their majority structurally controlled and are affected by the fracture system prevailing in the area.

RESULTS AND INTERPRETATION

Qualitative Interpretation:

The RTP aeromagnetic map (Fig. 6) of the study area is a reflection of the horizontal contrast in magnetic properties of the underlying rocks. The magnetic expression of various structural features depends on the existence and intensity of such magnetic contrasts. The distincteness, with which such features appear on the map, is clearly dependent on the character and composition of these rocks.

The first impression from looking at the RTP map (Fig. 6) indicates that it does not agree well with the surface lithologies, as given on the compiled geological map (Fig. 4) and the correlation between both was perplexing to some extent. However, in some instances, a well-defined magnetic gradient (representing a contact or a fault) would transgress several geologically-mapped rock units. One of the explanations for this discrepancy would be that the magnetic effect of the local (or near-surface) and the regional (or deep-seated) geological features is different and not conforming. It was found that strong magnetic anomalies of near-surface (or shallow) origin obscure the relatively weaker effects associated with deeper structures and vice versa. Therefore, variations in the magnetic character, observed on the RTP magnetic map, define the surface configuration and composition of the underlying magnetic basement rocks rather than the rocks exposed on the surface.

Close inspection of the RTP aeromagnetic map (Fig. 6) shows that the area under study is characterized by numerous major and minor positive and negative magnetic anomalies of varying wavelengths and amplitudes. Such variations may be due to inhomogeneities in the composition of basement rocks and diversities in their depths. Based on the variations in the character of magnetic anomalies, it was possible to group the RTP magnetic map into four different zones having various magnetic characters.

The first magnetic zone (zone I) is located at the area of W. Dib in the north western corner of the study area. It is represented by strong negative magnetic anomalies of limited areal extent, having nearly E-W direction. The low magnetic character of this zone suggests a down-faulted block occupying the area of W. Dib. This opinion is supported by the coincidence of this magnetic low zone with what is known geologically as W. Dib syncline (Francis, 1972). On the surface, it is associated with granodiorites and Hammamat sediments.

The second magnetic zone (zone **II**) occupies the area located to the south of W. Abu-Had and northeast of G. Idid Elgedan. It is characterized by the presence of localized high-amplitude negative magnetic anomalies of relatively low frequency. This zone is associated with rocks of granitic composition. The linear shape of the positive magnetic anomalies bounding this zone from all sides suggests tabular shapes of their causative magnetic bodies. The high- amplitude and low frequency nature of this low magnetic zone may reflect its association with near-surface acidic to intermediate sources.

The third magnetic zone (Zone **III**) is met at the southeastern corner of the study area, along W. Melaha. It is represented by a broad strong negative magnetic anomalies associated with Quaternary and Upper Cretaceous-Tertiary sediments. These anomalies are characterized by their large areal extent, long wavelengths and low magnetic reliefs, particularly to the east. It could be interpreted as a structural low or a down-faulted block. The nature of these anomalies indicates that there is a deepening in the basement surface southeastwardly.

The fourth magnetic zone (zone **IV**) occupies the main bulk of the central, western and northeastern parts of the study area. It extends as a major belt across the study area, trending nearly in a NE to ENE direction.

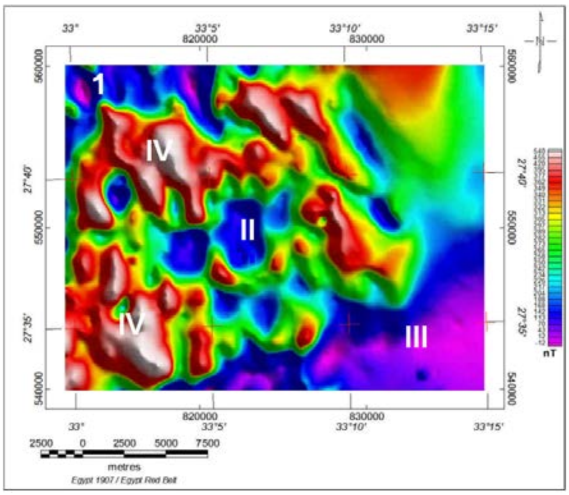

Fig. (6): Reduced to the pole (RTP) aeromagnetic map, Wadi Abu-Had area, Northern Eastern Desert, Egypt (III Number of the interpreted magnetic zone.).

On the surface, it is associated with different types of rocks including granodiorites, metagabbro-diorite complex, Dokhan volcanics and Quaternary sediments.

This zone is composed of numerous groups of positive magnetic anomalies that vary greatly in their frequencies and amplitudes. The low-frequency nature and relatively-moderate amplitudes of these positive magnetic anomalies may suggest their association with deep-seated intermediate to basic sources. The most conspecious feature of this zone is that most of the anomalies are aligned in a NNW or nearly N-S trend. There are sets of faulting systems and various types of intruding dyke swarms trending in these two directions (NNW & N-S) and recognized as surface geologic features (Francis, 1972). It is worth mentioning that, this high amplitude belt zone suggests an uplifted structure that coincides with what is known geologically as an anticlinal fold occupying the area between W. Dib and south W. Melaha syncline (Francis, 1972). It is very noticeable that the extreme NE extension of this zone is represented by an incomplete, large areal extent and long-wavelength anomaly, which indicates a deepening of the causative basement masses in this direction.

Quantitative Interpretation:

1- Computation and Analysis of the Energy (Power) Spectrum:

Limiting depth is the most important parameter by direct interpretation, and this may be deduced from magnetic anomalies by making use of their property of decaying rapidly with distance from their causative sources (Kearey and Michael, 1994). This effect can be quantified by computing the power spectrum of the anomaly as it can be shown, for certain types of source bodies, that the log-power spectrum has a linear gradient, whose magnitude is dependent upon the depth of the source (Spector and Grant,1970). Such technique of spectral analysis provides rapid depth information on a system of anomalies, i.e., a group of bodies, estimated from regularly-spaced digital field data. So, it is frequently used to determine the average depth to the basement more accurately than the traditional methods of depth computation in most cases (Curits and Jain, 1975).

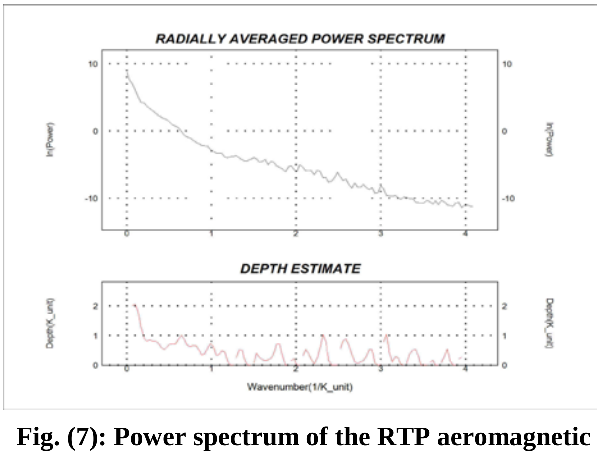

Fig. (7): Power spectrum of the RTP aeromagnetic survey data, Wadi Abu Had area, northern Eastern Desert, Egypt.

In the present study, the Fast Fourier Transform was applied on the RTP aeromagnetic survey data to calculate the energy spectrum (Fig. 7). Consequently, two major contributions of the aeromagnetic map were found to be coming mainly from two sets of sources at two main average levels (interfaces). The first contribution is estimated at 1.0 km depth below the measuring level, which represents the residual magnetic effects of the near-surface magnetized sources. Meanwhile, the other contribution is estimated at 2.0 km depth, representing the regional magnetic effects of the deeply-seated magnetized sources.

2- Separation of Magnetic Anomalies:

There are several methods to get an excellent resolution of the effects of the deep-seated magnetic bodies from that of the near-surface ones. Some of these methods are graphical, while the modern methods are analytical. In the present study, the band-pass filter technique (Geosoft, 1994) was applied on the RTP aeromagnetic data for separation of magnetic anomalies. Once a Fourier transform has been created, the application of a filter is quite straight-forward. Low-pass filters pass the long-wavelength anomalies (broad slow changes in the potential field data), typically attributed to deep-crustal or subcrustal sources and are termed the regional field. High-pass filters pass the short-wavelength anomalies (residual), usually associated with shallow features (Dobrin and Sovit, 1990).This process of filtering resulted in the construction of two maps, one for the residual aeromagnetic-component (Fig.8) and the other for the regional aeromagnetic-component (Fig. 9) at the two assigned interfaces, 1.0 km and 2.0 km, respectively.

The RTP residual magnetic-component map (Fig. 8) focuses attention on weaker features that are obscured by strong effects in the original map (Reford and Sumner, 1964). This map demonstrates in detail, several positive and negative magnetic anomalies having nearly semicircular and elongated shapes with irregular boundaries, and is characterized by their relatively high frequencies and short wavelengths. As expected, the residual magnetic anomalies are of higher resolution than both of the RTP and regional magnetic maps and shows to a much lesser extent- the same general magnetic features as that observed on both. Nevertheless, it can demonstrate more about the magnetic-rock types, their contacts and their over-all magnetic structural features, particularly at the near-surface level. This residual map (Fig. 8) clearly defines the sudden and abrupt changes in the magnetic relief, always accompanying the shallow-seated (near-surface) geological features and/or bodies reflecting the supra-basement structures. This map clearly shows the characteristic linear magnetic anomalies associated with near-surface structures, which are characterized by low to moderate amplitudes and semi-continuous features. These structures either reach the ground surface or lie at a very shallow depth. Three major structural trends could be deduced from the residual magnetic map (Fig 8 t). These trends are recorded mainly in the NNW NNE and N-S directions, and represent the dominant near-surface structural lineaments that prevail in the study area.

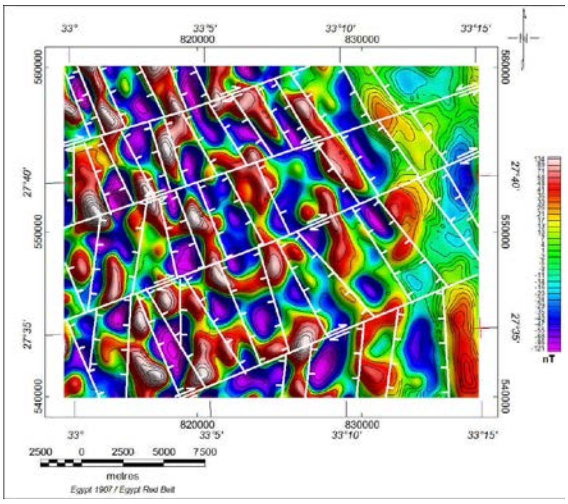

Fig. (8):Residual aeromagnetic map with interpreted residual (near-surface) magnetic basement structural lineaments, Wadi Abu-Had area, northern Eastern Desert Egypt.

The RTP regional aeromagnetic-component map (Fig. 9) is the result of the removal of the near-surface magnetic effects from the recorded total magnetic intensity field.

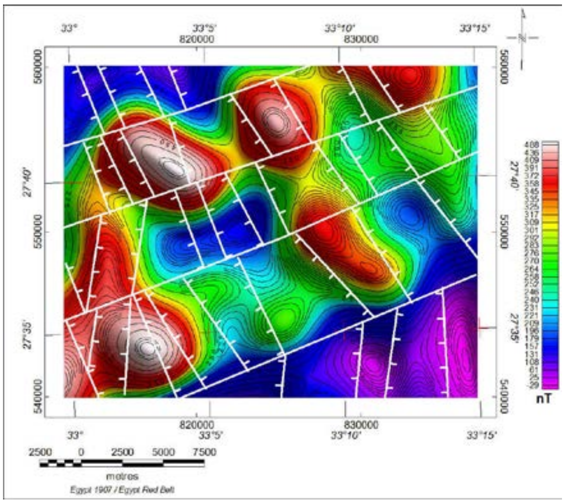

Fig. (9): Regional aeromagnetic map with Interpreted regional (deep-seated) magnetic basement structural lineaments, Wadi Abu-Had area, Northern Eastern Desert, Egypt.

This map was found to resemble to a great extent- the aerial RTP magnetic map (Fig. 6) as concerning the magnetic character of anomalies, i.e., their wavelengths, amplitudes, groupings of anomalies and trend patterns. This similarity may indicate that the sedimentary cover possesses low or negligible magnetization. Therefore, the deep-seated structures play the most important role in defining the general structural framework of the study area. The regional magnetic-component map (Fig. 9) shows nearly the same number of high and broad magnetic anomalies. These anomalies are characterized by their high magnetic amplitudes.

The shapes of some of these anomalies are somewhat rounded, while others are to some extent- elongated. These anomalies acquire sharp contacts in various degrees with the surrounding magnetic features. The sources of these anomalies may be due to basic to ultrabasic intrusions. The NNW trend -as the main structural trend- beside the ENE, NW and NE trends, which are defined clearly on the regional magnetic-component map (Fig. 8). This feature supports the idea that these fault trends possess deep-seated effects.

3- Second Vertical Derivative (SVD):

Vertical derivatives amplify short-wavelength information at the expense of long-wavelength one. On the total field anomaly maps, these shallower anomalies appear as short wavelength anomalies on top of broader, deeper anomalies. These broader anomalies will be filtered out using a second vertical derivative, which accentuates gradients along edges of shallow magnetic sources. Hence, they are used to locate edges of magnetic bodies and emphasize sources at shallow depths (Dobrin and Savit, 1990). The second vertical derivative map often delineates geological contacts and structures better than the original magnetic anomalies.

In the present work, the second vertical derivative (SVD) was computed for the RTP magnetic data of the study area. The obtained SVD map (Fig. 10) shows subtle anomalies more clearly and emphasizes minor features on the expense of major ones, so it shows better resolution of some superimposed anomalies. This map indicates alternative positive and negative magnetic anomalies and some high amplitudes with great obvious gradients, reflecting major faults, as well as other small amplitudes and gentle gradients indicating smaller-displacement faults. The SVD map can assist in interpretation of the residual map. The similarity between both maps is expected, because both maps depend on the curvature of the anomalies (Dobrin, 1976). Close investigation of the SVD map (Fig. 10) and the residual magnetic component map (Fig. 8) indicates that there is a great similarity between both of them, concerning the relief of general features, the gradients of contours, the areal distribution and trends of magnetic anomalies. The similarity of these two maps supports each other and gives a good support for the presence of very shallow to near-surface causative bodies. On the other hand, the broad magnetic anomalies, observed on the RTP aeromagnetic map (Fig. 6), are still recorded on the regional map (Fig.9) and not indicated on both the residual and SVD maps (Figs. 8 and 10) respectively. This may indicate that the origin of these anomalies may be associated with deep-seated basement bodies and not with shallower ones.

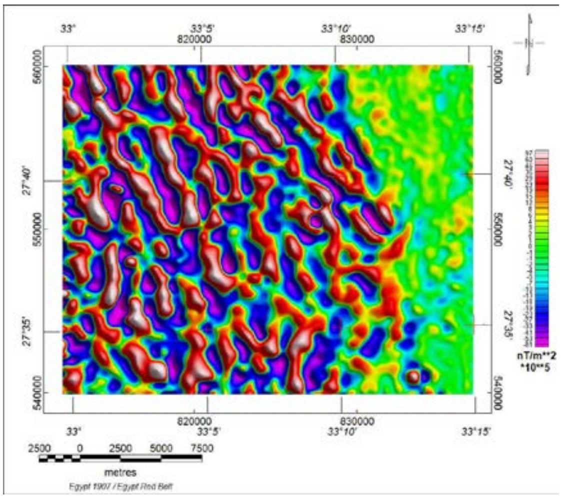

Fig. (10): Second vertical derivative (SVD) map, Wadi Abu-Had area, northern Eastern Desert, Egypt.

The eastern part of the study area, as seen on the SVD map (Fig. 10), shows a different magnetic character than the rest. This part is characterized by the presence of a group of magnetic anomalies with low frequencies, large areal extent and low magnetic relief, which may reflect their association with deep-seated sources. On the surface, this part is occupied by Quaternary and Upper Cretaceous-Tertiary sediments. The SVD map illustrates nearly the same structural magnetic lineaments that are obvious also on the residual map. These lineaments are trending in three major directions including mainly N-S, NNW and NNE ones.

The individual anomalies were isolated and identified with theoretical models for the shapes of their source bodies. With the use of appropriate proportionality constants, tabulated as A, B and C indices by Vacquier et al. (1963), the measured distances from the second vertical derivative maxima to the zero contour lines can be converted to depths to the tops of the buried causative magnetic bodies. It corresponds very closely to Peter's length (Peters, 1949; Dobrin, 1976; Hospers and Rathore, 1984).

4- 3D Analytical Signal (AS) Map:

The 3-dimensional analytical signal is a powerful data processing technique which eliminates problems encountered due to remanent magnetization and data from low magnetic latitudes (Roest et al., 1992). It further turns both negative and positive anomalies into a positive response, which is directly above the magnetic sources. It is independent of the remanent 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, where the analytical signal of the total magnetic field reduces the magnetic data to anomalies whose maxima mark the edges of the magnetized bodies. At low latitudes, an extensive source body will have stronger analytical signal at their north and south edges (Macleod et al., 2000). Thus, the 3-D analytical signal shows the edges of magnetic bodies, which if these edges represent rock contacts, can be roughly interpreted as"pseudo-geology" map, if the magnetic units outcrop.

The most conspicuous feature of the analytical signal map (Fig.11) is the presence of a group of high magnetic anomalies as well as many associated low ones, which are aligned in alternating manner. This feature indicates 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 dyke-like bodies, without deep roots, 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.11). A well-defined boundary with appreciably differtent degrees of magnetic relief can be easily traced along this contact zone. This may reflect a contrast between the magnetic properities of rocks along the opposite sides of this boundary and indicate the existence of a major fault. The eastern part of the study area, which is represented on the surface by Quaternary sediments, is occupied by a broad belt of low magnetic anomalies having nearly N-S directions and are characterized by their long wavelengths and low magnetic reliefs, particularly to the north, which suggests a deep-root for the causative mass. The nature of these anomalies indicates that there is a deepening in the basement northwardly. A set of great faults could be interpreted from the analytical signal map (Fig.11). These faults are running mainly in N-S, NNW, NW and NE directions.

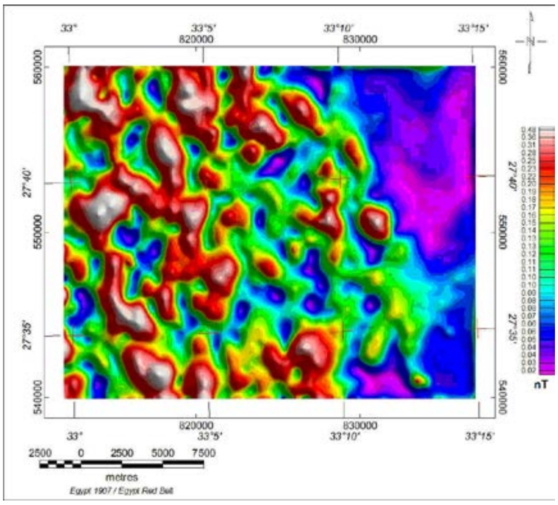

Fig. (11): Analytical signal (AS) map, Wadi Abu-Had Area, northern Eastern Desert, Egypt.

5- Magnetic Trend Analysis:

Statistical analysis of the trends for both the surface and near-surface features as well as the deep-seated structural lineaments could reveal the structural framework, which is responsible for the tectonic development of the study area. Trends of the magnetic anomalies and of the steep magnetic gradients that separate different magnetic anomalies were marked and traced. The interpreted trends are represented by peaks exceeding the significant frequency on the frequency distribution curves given in Fig. (12), as traced from the RTP, residual magnetic and regional maps (Figs. 6, 8 & 9 respectively). The various peaks recorded in this figure represent the strikes (trends) of different magnetic trends in the area under consideration. The relative magnitudes of such peaks are regarded as a reflection of the magnitude and frequency of deformation resulting from different stresses that took place at different geological times. As a result of the application of this technique, five main trends were proved to be significant and affected the study area. These trends are sorted from the strongest to the weakest as: NNW, NW, NE, N-S and ENE.

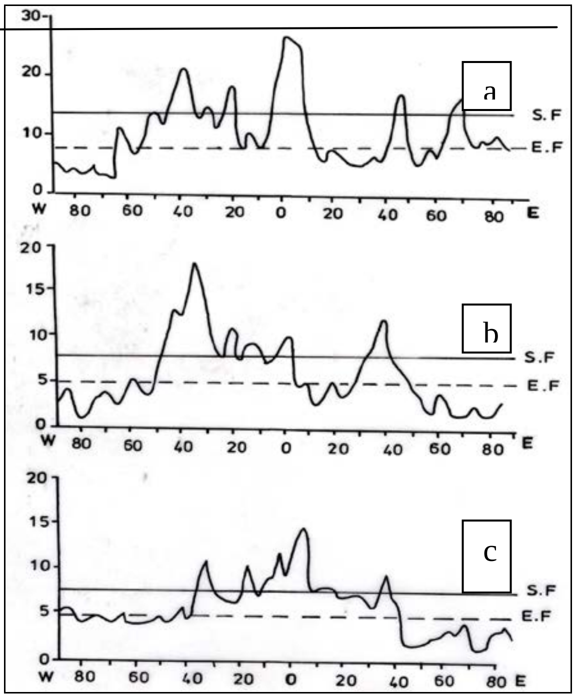

Fig. (12): Frequency distribution curves of the statistically analyzed aeromagnetic trends, Wadi Abu-Had area, northern Eastern Desert, Egypt: (a) RTP map (b) regional-component map (c) residual-component map.

It is evident from this result that, most of the outlined interpreted magnetic structural lineaments (IMSL) at the near-surface level are still highly recognized on the deep-seated one. Consequently, it can be stated that, most of the observed structures of the exposed basement rocks seem to be controlled by the concealed structures of the underlying basement rocks. This may offer strong evidence to the reactivation of the older structural trends throughout successive periods of the tectonic history of the study area.

6- Source Parameter Imaging (Local Wavenumber*) (SPI) Method*:

The Source Parameter Imaging (Local wavenumber) is a technique that is based on the extension of a complex analytical signal to estimate magnetic depths. The original SPI method (Thurston and Smith, 1997) works for two models: a 2-D sloping contact or a 2-D dipping thin-sheet.

One more advantage of this method is that the interference of anomaly features is reducible, since the method uses the second-order derivatives. In practice, the method is used on gridded data by first estimating the direction at each grid point. The vertical gradient is computed in the frequency domain, and the horizontal derivatives are computed in the direction perpendicular to the strike using the least-squares method.

The values of the depths which are estimated by the (SPI) method are presented as a depth contour map (Fig. 13), which can assist in the interpretation of the basement structural map. This map reflects shallower depths at the central and western parts of the study area, which correspond to the uplifted blocks of the basement rocks (Fig. 13). They posses average depths ranging between 221 m and 496 m. Meanwhile, the deeper parts are associated with the subsided blocks, which are located at the eastern and southwestern parts of the study area. This result is close to that obtained from the analytic signal map (Fig .12). They posses depths ranging between 525 m and 1605 m which correspond to Quaternary sediments as shown in the geological map (Fig. 4), and Wadi Idid Elgedan and Wadi Melaha as indicated in the topographic map (Fig. 2).

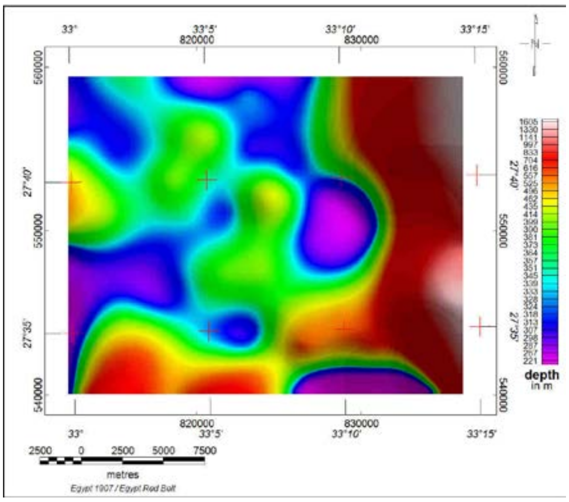

Fig. (13): SPI depth contour map, Wadi Abu-Had Area, northern Eastern Desert, Egypt.

Source Parameter Imaging (SPI) (Fairhead et al, 2004) is a profile or grid-based method for estimating magnetic source depth, and some source geometries the dip and susceptibility contrast. The method utilizes the relationship between source depth and the local wavenumber (K) of the observed field, which can be calculated for any point within a grid of data via horizontal and vertical gradients.

Philips et al. (2006) proposed a method of analyzing the local wavenumber to derive estimates of source depth and structural index. This method looks at the peaks of in terms of both the amplitude and curvature, and a depth estimate that is independent of structural index. The structural index can in fact be estimated from the data, and the estimate of structural index can provide a means of discriminating between reliable and spurious depth estimates.

Close inspection of the structural map (Fig. 14) reveals that the area is affected by sets of deep-seated and near-surface structural lineaments with the strike oriented along NW-SE trend and the direction of dip as NE and SW. It is noted that this trend is greatly responsible for the formation of the major basin that trends in the same direction and occupies the western and southwestern parts of the area.

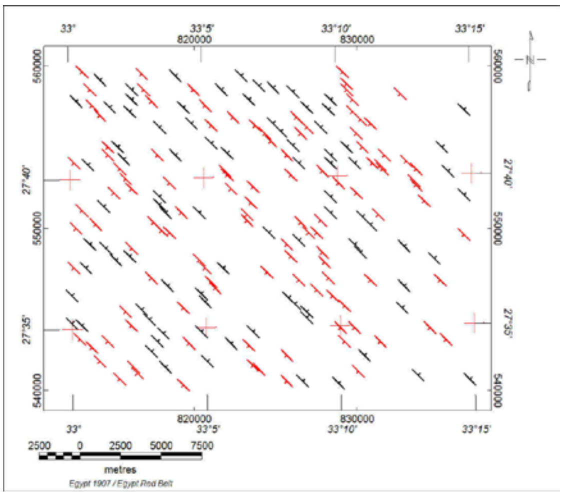

Fig. (14): Structural - trend map as deduced from (SPI),Wadi Abu-Had area, northern Eastern Desert, Egypt.

CONCLUSIONS

Integration of the analysis techniques was applied to airborne magnetic data to map the location and depth of the magnetic source edges, as an aid for structural interpretation. These techniques are the Second Vertical Derivative (SVD), Analytical Signal (AS) and the Local Wave Number (SPI).

Based on the results of both linear structures and magnetic data interpretation, five main trends proved to be significant and affected the study area. These trends are sorted from the strongest to the weakest as:, NNW, NW, NE, N-S and ENE.

It is evident from this result that, most of the outlined interpreted magnetic structural lineaments (IMSL) at the near-surface level are still highly recognized on the deep-seated one. Consequently, it can be stated that, most of the observed structures of the exposed basement rocks seem to be controlled by the concealed structures of the underlying basement rocks. This may offer strong evidence to the reactivation of the older structural trends throughout successive periods of the tectonic history of the study area.

The depths estimated using SPI method show that the shallower ones at central and western parts of the study area, correspond to the uplifted blocks of the basement rocks. They possess average depths ranging between 221 m and 496 m. Meanwhile, the deeper parts are associated with the subsided blocks, which are located at the eastern and southwestern parts of the study area. This result is close to that obtained from the analytic signal map. They possess depths ranging between 525 m and 1605m northeast.

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