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AEROMAGNETIC GEOPHYSICAL INVESTIGATION IN EL-FAIYUM DISTRICT, WESTERN DESERT, EGYPT

By
M.M. EL-AWADY,* H. EL-ETR,** and A. BAKRAH***
** Faculty of Science, Tanta University.*
*** Faculty of Science, Ain Shams University.*
**** Water Supplies Department, Tanta.*

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ABSTRACT

The present paper deals with the interpretation of the aeromagnetic survey executed over the Faiyum area, Western Desert, Egypt. Qualitative as well as quantitative interpretation of the aeromagnetic data were carried out to obtain more information about the crystalline basement structure and the local structure in the sedimentary section. The analysis of the constructed magnetic maps which include the total intensity map, the vertical map, the regional map, the residual map, the second vertical derivative map and the downward continuation maps serve as basis for revealing the structural pattern of the basement complex, and the shallower structures. In connection with a quantitative interpretation by 2-dimensional model bodies a structural map for the basement was constructed.

INTRODUCTION

Magnetic methods of geophysical prospecting are based mainly in the measurement of small variations in the earth's magnetic field. This field is affected by variation in the distribution of magnetized (polarized) rocks. Magnetization (polarization) corresponds, in importance, to display in gravitional prospecting. However, both the magnetic and gravitional methods make use of the potential field.

Magnetic data could also be used the determination of the depths to the basement surface. Sedimentary rocks are of low magnetic properties and are generally considered to be nonmagnetic. Meanwhile igneous basement rocks are sufficiently magnetic. An aeromagnetic map is a reflection of the differences in the magnetic properties of the underlying sedimentary and basement rocks. Therefore, determining the depth to the surface of the basement is generally equivalent to determining the thickness of the sedimentary section. Since oil basically occurs only in sedimentary rocks, a reliable determination of the configuration of the basement rocks gives a measure of the size and shape of basins of sedimentation.

A total area of approximately 3528 km^2, extending between maximum Lat. 29°10′ N to 29° 50′ and Long 30° 20′ E to 31° 10′E, is covered. (Fig. 1).

The aeromagnetic map of the area under investigation accordingly was used to help in the identification of the regional basement configuration.

The interpretation of aeromagnetic maps tends to be qualitative rather than quantitative. Recently, several improved techniques have been used for the analysis of the magnetic intensity maps which leads to quantitative interpretation.

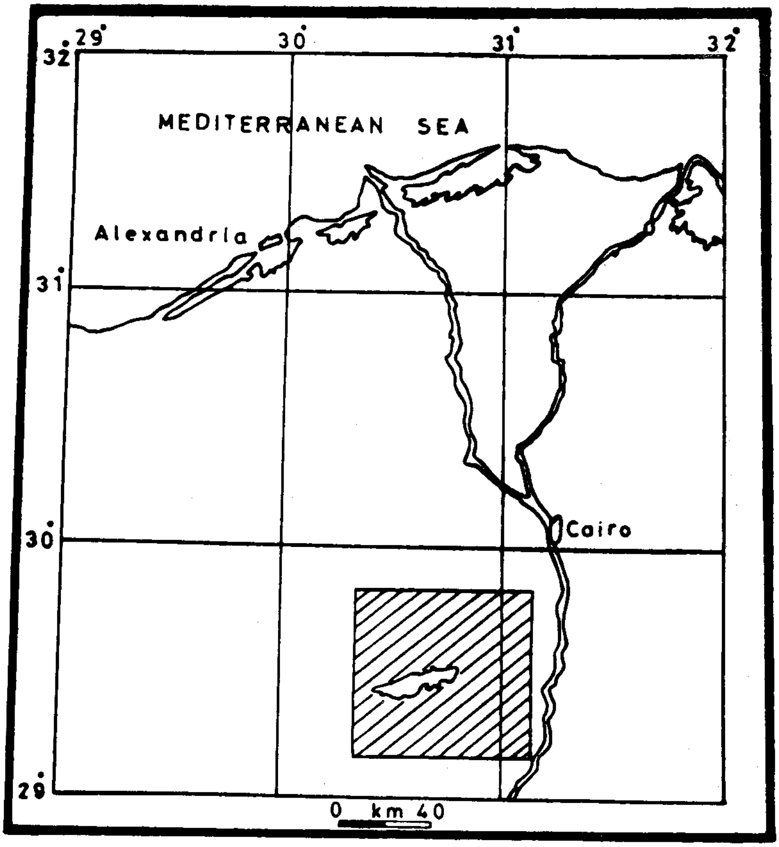

Figure 1 Location map of the area under investigation.

BASIC CONCEPTS

The following basic concepts must be taken into consideration in using magnetic (or gravity) data:

(a) The interpretation is not a clear-cut process which can be relied upon for a unique answer but instead, it is subject to numerous limitations which decrease as the independent information increase, such as those obtained from drill holes, regional geology and structures.

(b) The interpretation must also fit into the imagination of the geologists. Frequently, the magnetic and gravity methods of prospecting supply results permitting several solutions when analyzed by the geophysicts alone; but can be very much limited when a geologist includes only those having a reasonable degree or probability.

Based on the foregoing sensible statements, the authors set up their analysis on an aeromagnetic map for the area under investigation meaured by Pan American Oil Company, Western Desert.

Control analysis on the observed aeromagnetic data included the following:

(a) Datum lining using the least square method in which a base flight line network is constructed for datum lining. The three tie lines (bases) and the four flight lines used in the construction of the base net are corrected for both the diurnal variation and the instrument drift. Any closure errors which are due partly to the diurnal variation and the instrumental drift, and partly to errors in positioning and height keeping as well as the instrumental errors were taken into consideration in the usual way.

(b) A correction which is mainly designed to remove the broad effects caused by the earth's main magnetic field, the change of which depends on the geographical position, has been also taken into consideration. A zero line for the normal field of each line is taken in such a way that the sum of the positive areas equals that of the negative ones. In a calm zone on the profile, the points of equal values of the normal field of the flight lines are connected together to get the gradient contours. The gradient map and, in turn, the magnetic gradient in both directions was calculated.

Accordingly, the south-north gradient amounted to 3.07 γ/Km., and the west-east gradient resulted is +1.09 γ/km.

(c) The datum level of the flight lines was determined by consideration of the base net and its regional gradient map.

The analysis of anomalies in the area is generally based on the aeromagnetic data shown in the map in terms of the prevailing subsurface geologic conditions. This analysis is almost exclusively emperical. The deductions and inferences, particularly in term of geology and structure of the basement complex are basically drawn on the size and configuration of the aeromagnetic anomalies.

Accordingly, the study of the aeromagnetic map of the the area indicates that most of the observed anomalies show different trend patterns as well as relatively sharp gradient. This indicates:

(a) a basement relief, since any sudden change in the magnetic contour spacing over an appreciable distance suggests a discontinuity in the basement dept, (b) lithologic variation within the basement complex itself, or (c) both.

The distribution of the magnetic materials within the sedimentary section, e.g., in the form of basaltic flow, sills and dikes, might also have a bearing on the magnetic relief of such observed anomalies.

The phase of interpretation of the total intensity magnetic field in this work is primarily qualitative in nature.

Aeromagnetic pattern of the area under consideration consists of small low amplitude local anomalies superimposed upon larger broader anomalies. The combined effect of these anomalies and the regional gradient of the geomagnetic field produced the "observed aeromagnetic field". Nonmagnetic strata overlying the magnetic igneous rocks do not affect the total intensity field in the area under investigation.

Topographic relief of the dissected basement surface or small local variation susciptibility of the igneous cause many small magnetic highs and lows.

Larger contrasting tectonic units, such as faulted igneous blocks, produces broader and larger highs and lows.

Basaltic sills and dikes which are known to be present in the sedimentary cover produce complex magnetic patterns or anomalies of higher amplitude than what is conventionally known for the sedimentary rocks.

On the basis of the above mentioned principles, the anomalies represented in the maps of utmost importance if they are described on the basis of the following parameters: (a) areal extent of the anomaly, (b) amplitude in gammas, (c) gradient, and (d) shape.

QUALITATIVE STUDY OF THE AEROMAGNETIC FIELD

Total intensity, residual, regional, second derivative and down continuation maps were prepared and analyzed. The following section describes the characteristics of each.

1. The Total Intensity Map:

A close look at the total intensity map of the studied area (Fig. 2), shows that the lowest value is located in an elongated anomaly ENE of Birket Qarun (unit A-3) oriented EME to E-W. Gradient is rather steep. Southwest of this lake (unit B-1) is another anomaly oriented northwesterly. South and southeast of the lake are two other anomalies oriented east northeast and northeast respectively. Gradient in these later three anomalies is rather gentle.

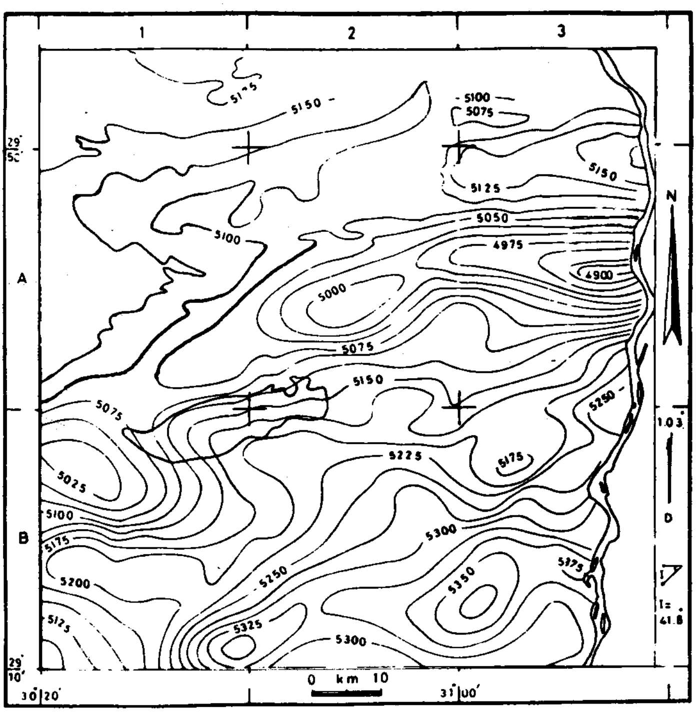

Figure 2. Simplified aeromagnetic total intensity map of El-Faiyum district. After Pan American Oil Company, 1974. Flight altitude 450 barometric meters. Flight interval 310.45 kms and contour interval (C.I.) 25 Gammas. (Original C.I. is 5 gammas and original scale of map is 1:100,000).

2. Residual Map:

Residual total intensity map (Fig. 3) was prepared using Henderson and Zietz (1949) method. It is characterized by the presence of several anomalies with different amplitudes, shapes, and orientations. They are also characterized by possessing different values of gradient indicating the presence of anomalous bodies at different depths. The gradient is quite gentle in eastern part of Qarun Lake, whereas it is higher in the other parts of the study area.

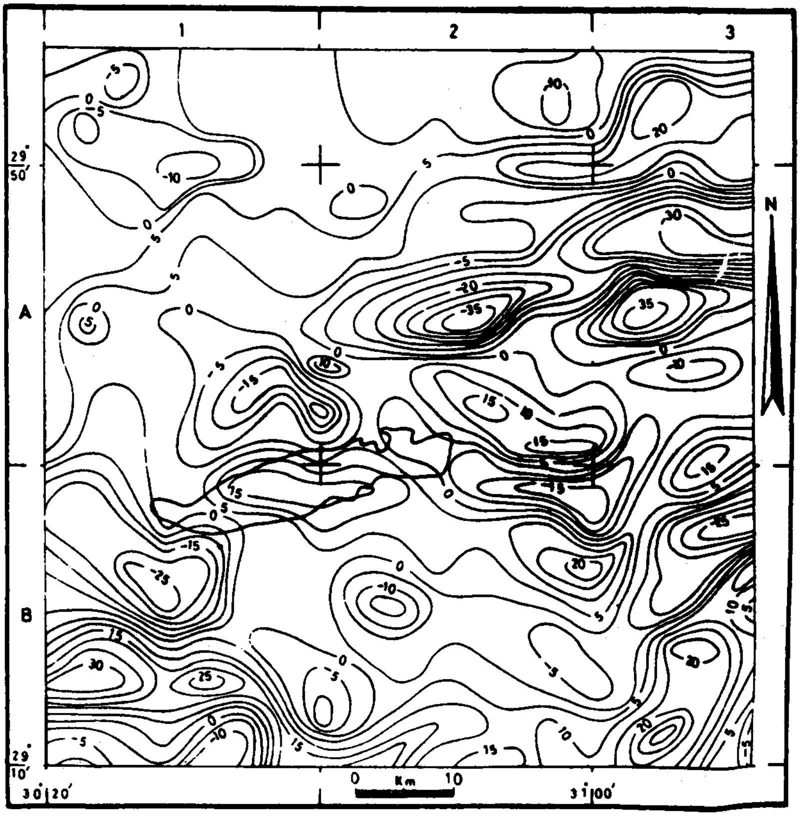

Figure 3. Residual anomaly map of the aeromagnetic field. Contour interval 5 Gammas.

3. Regional Map:

The regional map (Fig. 4), prepared by Griffin's (1949) method, correlated well with the total intensity and the vertical intensity maps. It shows four elongated to circular closures of different amplitudes. Highest value is reported in the southeast corner of the map (unit B-3) and it grades steeply in a NNW direction. The lowest values are located along an ENE oriented line located just to the north Birket Qarun. West of the Lake lower than average anomaly is located. Gradient is rather gentle in the northwestern corner of the map(A-1).

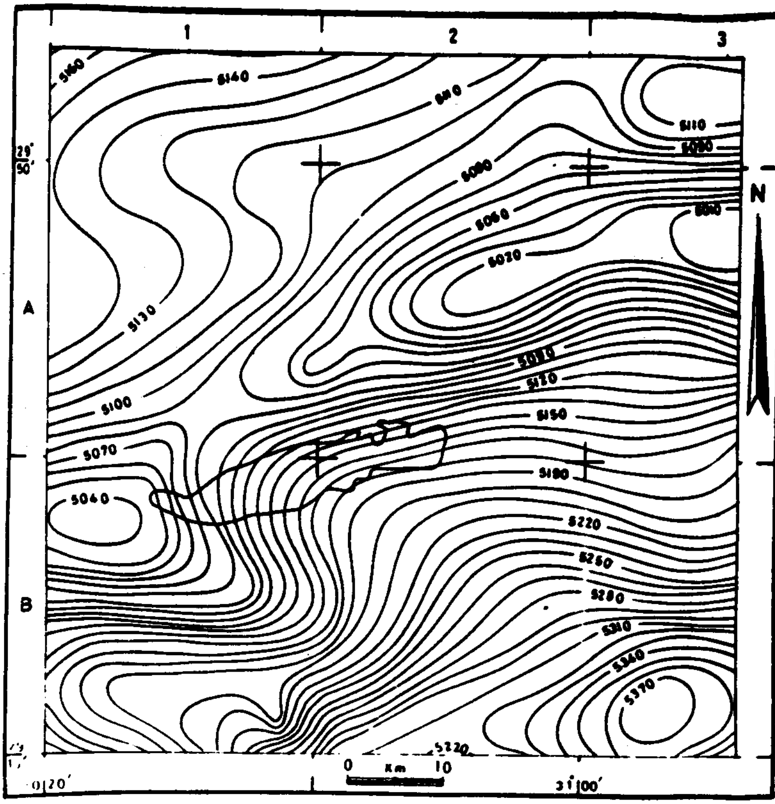

Figure 4 Regional anomaly map of the aeromagnetic field. Contour interval 10 Gammas.

4. The Vertical Intensity Map:

The vertical intensity map (Fig. 5) bears the same gentle signature of the original anomaly map. Values range from 3600 gamma (southeast corner) to 3340 just west of Birket Qaren. Gradient in the northeastern part of the map is quite gentle in this case too.

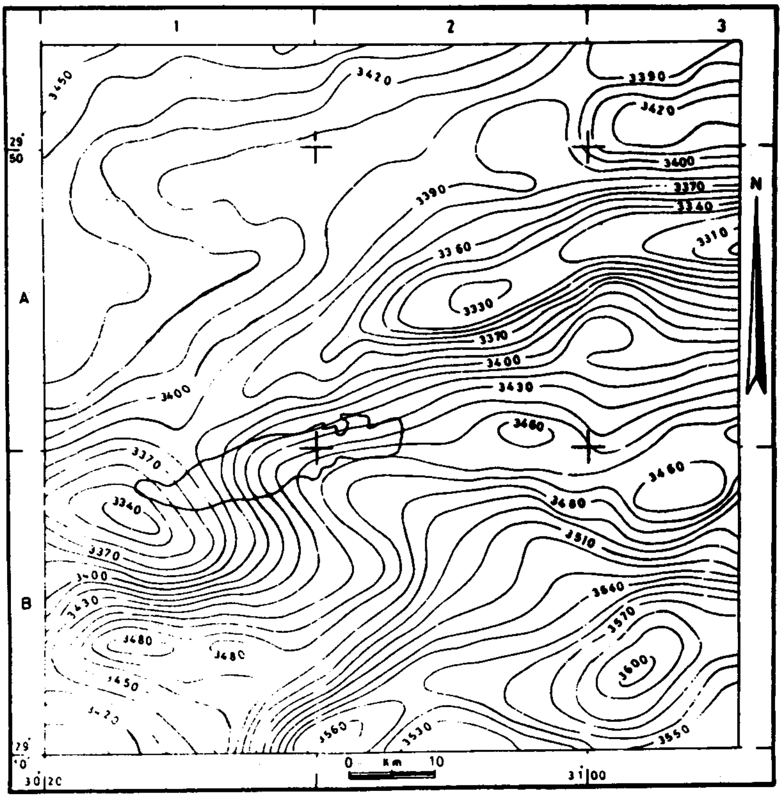

Figure 5. Vertical anomaly map of the aeromagnetic field. Contour interval 10 Gammas.

5. The Second Vertical Derivative Map:

The second vertical derivative map (Fig. 6) is prepared by the method of Henderson and Zietz (1949). It is characterized by a large number of small elongated to rounded closures. Highest values are reported in southeast and southwest corners as well as ENE Birket Qarun. Values range from 5 to — 10, and lowest values in ENE Birket Qarun and in the northwestern part of the map.

6. The Downward Continuation Maps:

The importance of the downward continuation methods of the geomagnetic field arises from great difficulties in the anomaly separation. Coincidence of such anomalies on their causative bodies depends on the shape and direction of the geomagnetic field and these in turn depend upon:

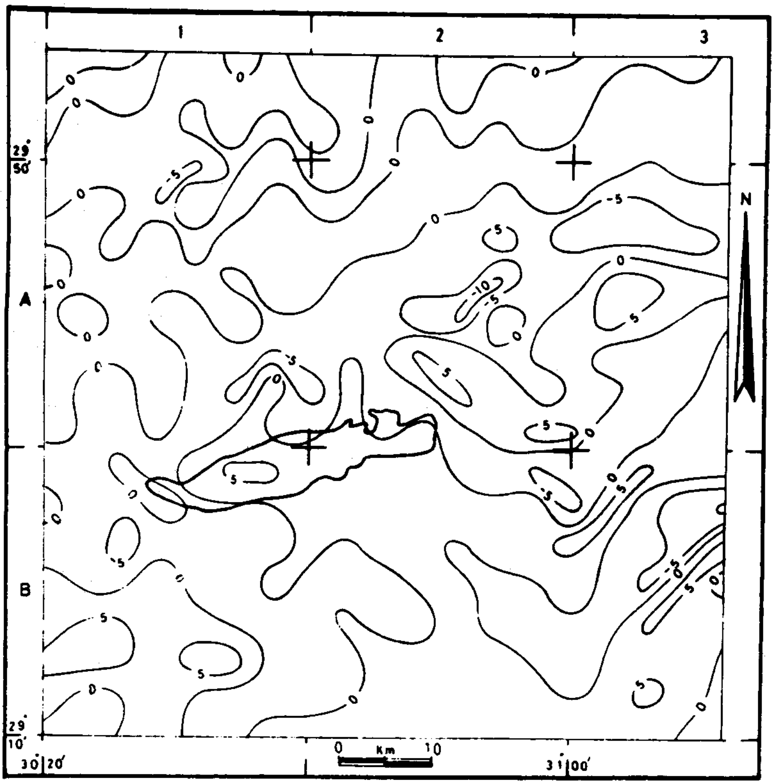

Figure 6: Second vertical derivative map of the total manegtic intensity field. Contour interval 5 Gammas per Sq km.

a) the strike of the structural elements and b) the direction of the magnetization.

The continued geomagnetic field at different depths gives the structural trends as well as the susceptibility contrasts between the sedimentary section (on no or minimum susceptibilities) and the basement (of high susceptibilities) or depth inside the basement if the susceptibilities contrast permit.

The downward continuation technique is carried out in the area under investigation using Hendersons's method (1960). Four different maps were construction at depths of 1.5, 2.5, 3.5 and 4.5 kms below the ground surface. The maps are shown in Figures 7, 8, 9, and 10 respectively. The structural features represented on those maps are slightly different and for this reason each such maps is herein treated separately.

a. 1.5 km Map:

The aeromagnetic data map continued to a depth of two kilometers (1.5 kms below datum) Figure 7 prepared by Henderson's (1960) method, shows that the lowest value is located in an elongated anomaly (unit A-2 and above A-3) oriented northeast. Gradient is rather steep. Southwest of this anomalyis an elongated anomaly (unit A-1) oriented NE to E-W. Gradient is rather gentle. Highest value is reported northeast of Birket Qarun (unit A-2) in elongated two anomalies oriented NWW. Southeastern Birket Qarun, area is characterized by three high amplitude. Elongated anomalies (unit A-3) and (B-4) oriented NE and E-W respectively. Gradient is rather gentle.

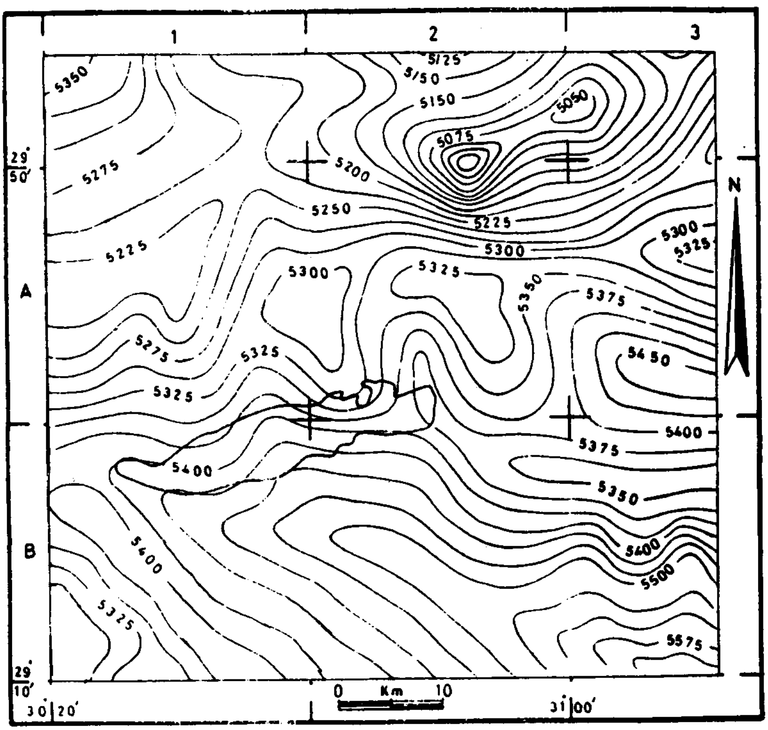

Figure 7. Aeromagnetic data map continued to a depth of two kilometers (1.5 km below datum) contour interval 25 Gammas.

b) 2.5 kms Map:

The aeromagnetic map continued to a depth of three kilometers (2.5 below datum) Figure 8 prepared by Henderson (1960) method, shows that the lowest value is located in 2 elongated anomalies (north unit A-3 and unit 2-2) oriented N-S and NW

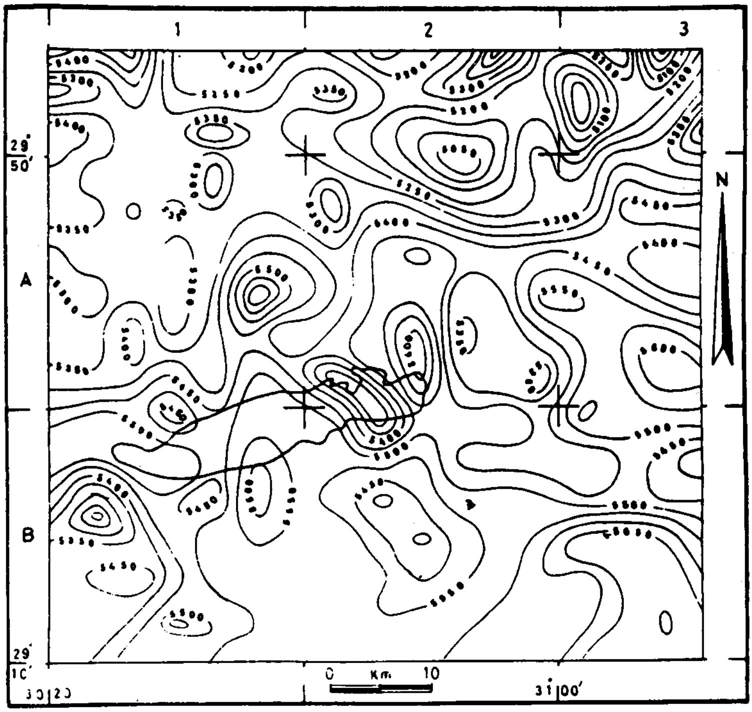

Figure 8. Aeromagnetic data map continued to a depth of three kilometers (2.5 km below datum). Contour interval 50 Gammas.

respectively. Gradient in the first is rather steep and in the second is rather gentle. Southwest of Birket Qarun, a circular anomaly of lowest value is located (unit B-1), oriented NW. Gradient is rather steep. Highest value is reported in an anomaly north of Birket Qarun (unity A-1), oriented NE, and a second located northeast of Birket Qarun (unit - 2) oriented NNW. Gradient in both is rather steep. North-east of the central part of Birket Qarun (unit A-2 and B-2) is an elongated anomaly, oriented northwesterly. Gradient is rather steep.

c) 3.5 kms Map:

The aeromagnetic map continued to a depth four kilometers (3.5 kms below datum) Figure 9 prepared by Henderson (1960) method, shows that the lowest value is located in 2 elongated anomalies (above unit A-3 and unit A-3) oriented NNE and NW respectively. Gradient in both is rather steep. Northeast of Birket Qarun (unit A-2), there is a circular anomaly that have a low amplitude and is oriented northwesterly. Gradient is rather gentle. East of Birket Qarun (unit A-2) an elongated anomaly is located, oriented NNW to NW. Gradient is rather gentle. Southwest of Birket Qarun (unit B-1) is located an elongated to circular anomaly of lowest value oriented NW.

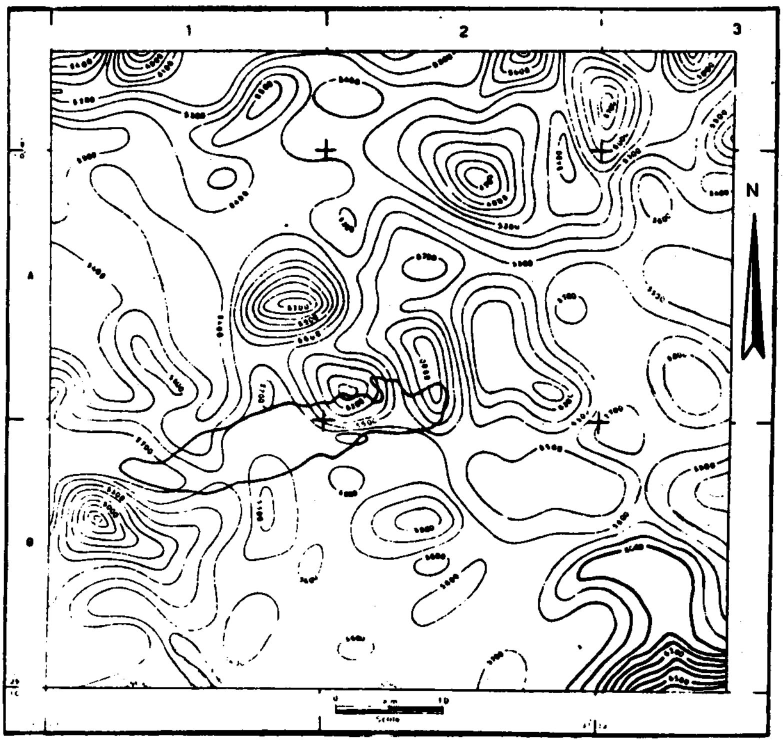

Figure 9. Aeromagnetic data map continued to a depth of four kilometers (3.5 km below datum). Contour interval 100 Gammas.

Gradient is rather steep. Highest value is reported in two anomalies, one circular north of Birket Qarun (unit A-1) oriented E-W and has a rather steep gradient. The second is located north of the north-east part of Birket Qarun (unit A-2), it is an elongated anomaly oriented NNW. Gradient is rather gentle. Southeast of Birket Qarun (unit B-2), elongated to circular anomaly of high value is located, oriented E.W. Gradient is rather gentle.

d) 4.5 kms Map:

The aeromagnetic data map continued to a dpeth of five kilometers (4.5 kms below datum) Figure 10 prepared by Henderson's (1960) method, shows that the lowest value is located in 2 elongated anomalies (north unit A-3 and A-2), oriented NNW and NW respectively. Gradient is rather steep. Northeast of Birket Qarun (unit A-2) an elongated anomaly of low value is located oriented NNW to NW. Gradient is rather gentle. Above the northeast side of Birket Qarun (unit A-1 and unit a-2), an elongated anomaly having a low value is located, oriented NW to E-W. Gradient is rather steep. Southwestern of Birket Qarun (unit B-1) another elongated to circular anomaly of low value is oriented NW to E-W. Gradient is rather steep. Highest value is reported in two anomalies, one north of Birket Qarun (unit A-2) oriented NNW and has a rather gentle gradient and the second is located north of the northeast side of Birket Qarun (unit A-2). This latter anomaly is elongated in shape, and is oriented NNW. Its gradient is rather steep. Southwest of Birket Qarun (unit B-2), a circular anomaly of high value is located, oriented E-W. Gradient is rather gentle.

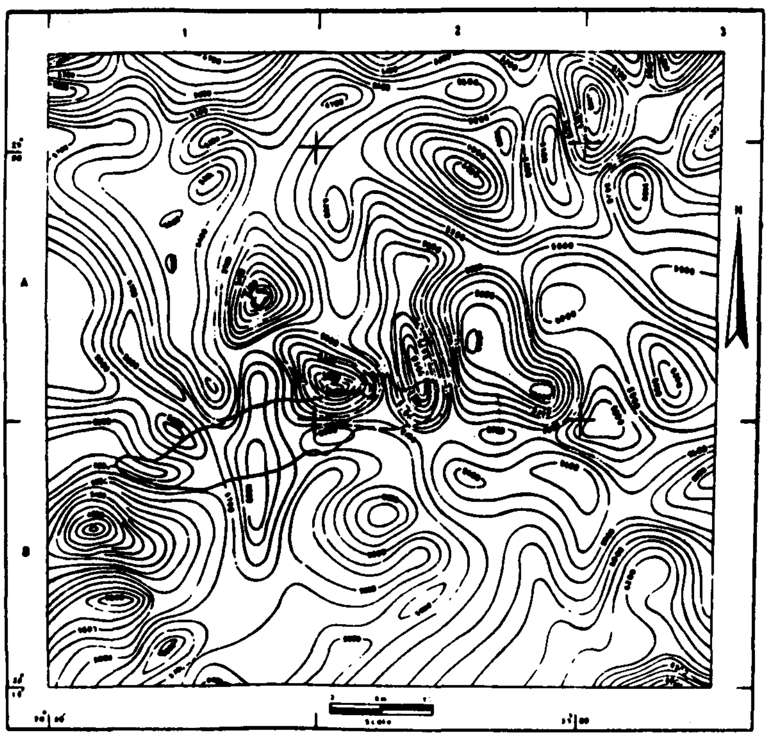

Figure 10. Aeromagnetic data map continued to a depth of five kilometers (4.5 km below datum). Contour interval 100 Gammas.

BASEMENT STRUCTURES DEDUCED FROM AEROMAGNETIC DATA

In view of the results obtained fom the previously mentioned techniques and methods of interpretation, it becomes possible to construct a structural map of the basement and a map of the shallower structures in the area under investigation (Fig. 12 and 13) respectively.

Available drill hole information in the area are not sufficient for getting a complete and reliable picture of the structural features of the basement surface. A total of eight deep wells are available only. The basement rocks were encountered in just three of these wells, viz: Kattania-l well, Wadi Rayin-l well and Abu Roash-l well at depths of 3761 m, 1265 m and 1890 m respectively. The other five deep wells are distributed all over the area under investigation (Fig. 11) and include Gebel Rissu-1 well, WD 19-1

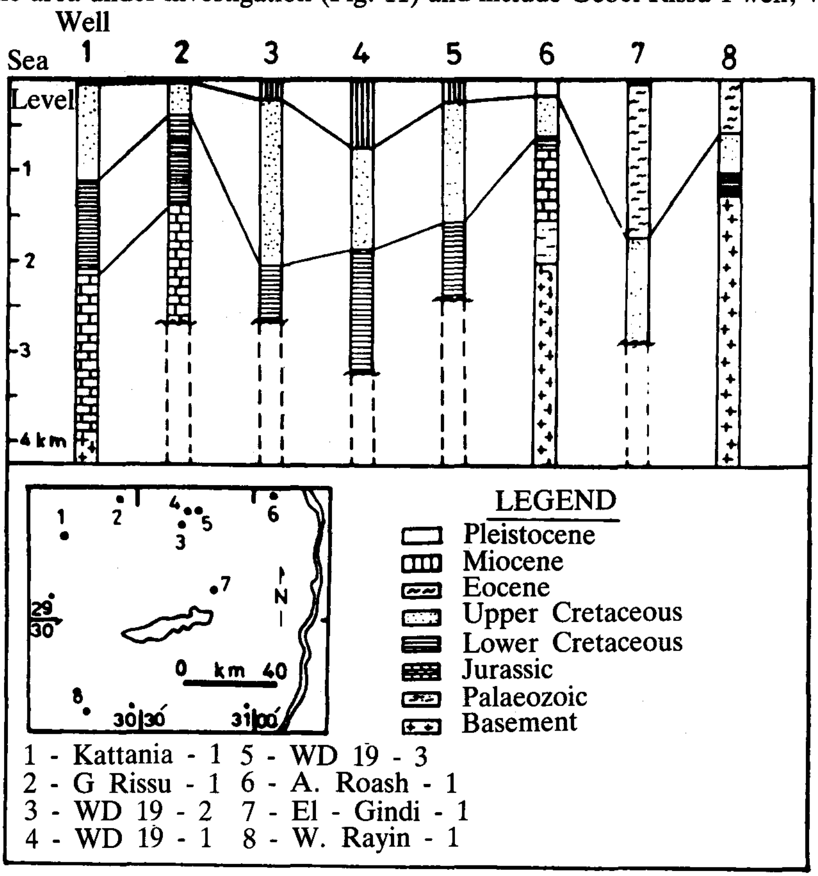

Figure 11. Subsurface stratigraphic correlation based on drillhole data. Insert map shows the location of wells studied.

well, WD 19-2 well, WD 19-3 well and El-Gindi-l well. Drilling in Gebel-Rissu-l well was stopped upon reaching the lower Jurassic formations at a depth of 2680 meters. Wells designated WD 19-2, WD 19-3 and WD 19-1 were stopped in Lower Gretaceous rocks at depths of 2665 m, 3231 m and 2448 m respectively.

Table 1
The results of depth estimation of the basement surface in the area under investigation.

Unit Area	Gravity and Magnetic Previous data	Peter's (1949) method	Koulomzine and Lamontagne's		Average
			Symmetrical	Asymmetrical	
A - 1	3.23 km	3.125 km	—	—	3.2 km
A - 2	2.25 km	3.75 km	2.800 km	—	2.9 km
B - 2	1.50 km	1.625 km	1.584 km	1.53 km	1.6 km
B - 3	325 km	2.875 km	3.404 km	3.20 km	3.2 km
B - 3	2.25 km	2.25 km	—	—	2.3 km

El-Gindi-1 well was stopped in Upper Gretaceous formations at a depth of 2929 meters.

Beside the controlling drill holes, the two quantitative methods of Peter (1949) and Koulomzine and Lamontagne (1970) were applied for the determination of the depth of different anomalies in the area as shown in Table (1). The results of depth estimation in the area under study are shown in Figure 12. Accordingly, the results obtained show that the basement varies in depth from about 1.6 km near Wadi Rayin-1 well in the southwestern portion of the area (unit B-1), to about 3.2 km near Kattania-1 well at the northwestern portion of the area (unit A-1) and from 2.3 km in the southwestern portion of the area (unit B-3) to about 1.8 kn in Abu Roash-1 wel in the northeastern portion of the area (north of unit A-3). The depth is about 2.9 km near El Gindi-well (unit A-2). So the average depth to the basement surface in the area under study range between 2.5 km and 3 km.

Figure 12 shows the interpreted basement structures. A total of 22 faults is reported; of these 10 rank, on reliability basis, as first order faults and 12 as second order ones. The faults are distinctly preferred in orientation; prevailing trends being northeast to east northeast and west northwest. The northeasterly faults are mainly of the first order but the west northwesterly faults are, on the contrary, of second order.

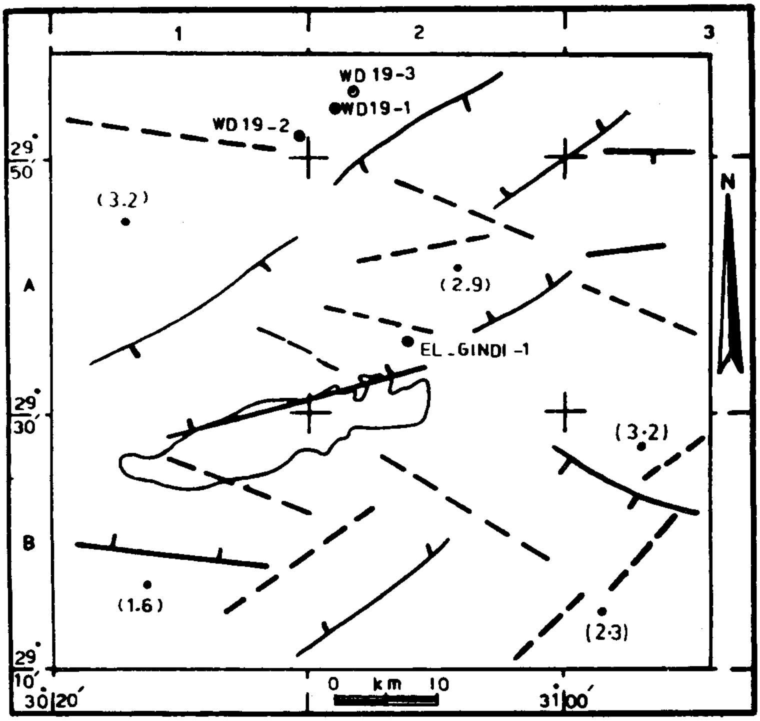

Figure 12. Basement structure deducted from aeromagnetic data. First order faults are shown in solid lines and second order faults in dashed lines.

The former set is evidently grouped in three belts; the first (2 faults) runs in units A-l and A-2 and has a southeasterly downthrow. The second belt (3 faults) runs in the northern part of unit B-1 (touching the northern rim of Birket Qarun), A-2 and A-3, The belt has a northwesterly downthrow. So, the first and second belts from a kind of northeasterly trending regional graben that traverses the northern half of the study area. The third belt is much subdued and is expressed by fire individual faults in units B-2; and B-3 of these four rank as second order.

The west northwesterly faults are also grouped in three belts, the first of which is larger and is better defined. It comprises 3 seconds order faults and extends in units A-3, and A-2 and A-1. The second belt (2 faults, one of which is first order and the other second order) is located northeast of Birket Qarun in units B-3 and A-2. The third belt (2 second order faults) traverses the eastern end of Lake Qarun. A single second order fault of this group traverses also the western end of the Lake.

Figure 13 shows the shallower structures deducted from the downward continuation of magnetic data to a depth of 1.5 km below the surface of ground. The pattern reported includes 28 first order faults and four second order ones. The pattern is closely similar to that reported for the deeper basement structures (Fig. 11). The number of faults, however, is understandably higher for the formers than the latterns. The pattern of the shallow faults is also preferred and has virtually the same orientation as the deeper basement faults. Precisely, The orientations are distinctly northeasterly and north-westerly to west northwesterly. The northewesterly faults run in two belts located in the northwestern and south-eastern corners of the study area. The former belt is formed of five first order faults and the latter of eight first order faults.

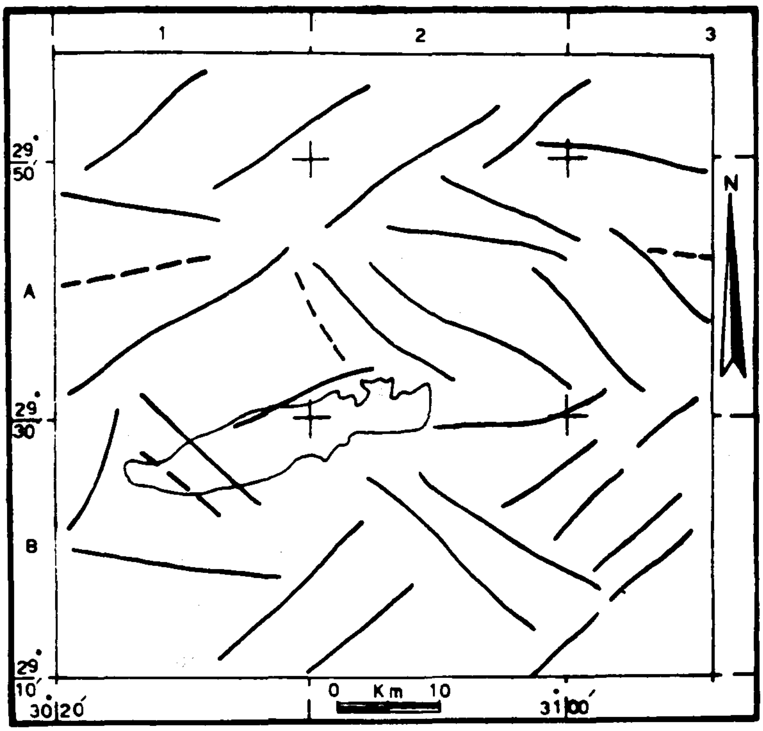

Figure 13. Shallower structure deducted from aeromagnetic data. First order faults are shown in solid lines and second order faults in dashed lines.

The central part of the area is dominated by the northwesterly to west northwesterly belt of faults. This belt is oriented northeasterly however being sandwiched between the two formerly described belts. Two west north-westerly faults traverse the northeasterly belt located in the southeastern corner of the map.

SUMMARY AND CONCLUSION

From above, it can be readily observed that the source of the magnetic anomalies as shown in the downward continuation maps at depths of 1.5 and 2.5 kms lie actually within the depth range of sedimentary section.

On the other hand, regarding the other two downward continuation maps of depths 3.5 and 3.5 kms as far as the importance and relationship of their anomalies to the regional and local geologic conditions of the area are concerned, one can easily indicate that the different anomalies represented on both maps are of the type, magnitude, areal extent and distribution that are expected to arise from geologic conditions at or near the basement. These are usually characterized by well defined anomalies having considerable reliefs, sizes and different polarities compared with those reliefs, sizes and polarities of anomalies that define the distribution of the magnetic field at a level that is either far below or high above the basement surface.

Summing up all the previous results about the analysis of the downward continuation maps lead to definite conclusions which can be summarized as follows:

1.Northeast, northwest and eastwest major anomaly trend of high and low amplitudes are shown to affect the area under study. The northeast trends has mainly the N 55° direction, while the northwest has mainly the N 85°W direction. Both trends affect more the continuation levels of 1.5 and 2.5 kms. The east-west trends has mainly the N 85°E and N 55° W direction and is more obvious at the continuation level of 2.5 kms.

2. The intensity of the northeast and northwest continuation anomalies represented by the number and length of major axes of anomalies, shows a maximum value at the continuation level of 2.5 kms which is the maximum depth of the basement rocks in the area. The east-west trend, on the other hand, has maximum intensity at the continuation level of 2.5 kms which is the average basement depth in the area.

3. The main structural features within the area are in the form of high and low structures as well as faulting. The highs and lows are mainly in the form of uplifted and downfaulted blocks within the basement. The main trends of such structures are NE, NW and E-W.

4. The comparative study of the subsurface geologic conditions described from the continuation maps indicates that most of the structural features of the crystalline basement configuration are represented mainly by the continuation anomalies within the range of spacing 3.5 and 4.5 kms.

5. It is evident that the basement surface is characterized by several arching and saggings in the form of ridges, uplifts, and structural lows as well as zones of dislocations having different areal extensions, relief, and are oriented either northeasterly or north-westerly. Block faulting is likely the most pronounced prevailing structural style. Vertical actuating mechanism is envisioned.

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دراسة جيوفيريقية لشدة المغناطيسية الكلية بمنطقة الفيوم بالصحراء الغربية - مصـــر

محمـــد العوضي حســـن العنز أحمـــد بـــكره

تضمنت هذه الدراسة بمنطقة الفيوم تحليل نوعي وكمي لشدة المغناطيسية الكلية للتعرف على تفاصيل شكل سطح القاعدة والتعرف على تراكيبها والتراكيب الموجودة في القطاع الصخري الرسوبي الذي يعلوها . ولقد وجد أن العمق المحسوب لسطح صخور القاعدة في اجزاء منطقة البحث المختلفة متفق مع نتائج الحفر ووجد أن متوسط هذا العمق يتراوح بين ٥ر٢ و٣ كيلومتر .