Subsurface Significance of Gravity Anomalies in Kharga Area, Egypt A.R.E.

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ABSTRACT

The present study is mainly devoted to the critical analysis of the geophysical data, including the gravity anomalies and the drill hole infarmations in Kharga area for better understanding of its subsurface structural features that has economic potentiality.

Such a critical analysis revealed that the regional structural setting of the area is generally consists of major faulted blocks. These faults had affected the basement complex and the overlying sedimentary succession by throws having different magnitudes ranges between 50 to 250 meters. Some of the faults which were detected from the residual - anomaly map indicate the presence of two fault trends striking *NW—SE* and *NE—SW* parallel to the Gulf of Suez and Gulf of Aqaba respectively. It is concluded that the maximum thickness of the sedimentary succession overlying the basement complex which recorded in the area is about 950 meters.

INTRODUCTION

The studied area is located in the Southern part of the Western Desert of Egypt between latitudes 24° 38′ 07″ N and 25° 40′ 30″ N and 30° 28′ 00″ E and 30° 46′ 00″ E which included in the Kharga Depress-

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ion (Figure 1). The Kharga Depression is a prominant topographic feature with its elevations above the sea level. Figure (2) shows the topographic contour map of the studied area compiled from the elevations of the gravity stations previously measured to construct the Bouguer-anomaly map. This area is generally considered among the most important localities of the Western Desert as a potential reservoir of the groundwater. Groundwater have been found in many wells in Kharga area.

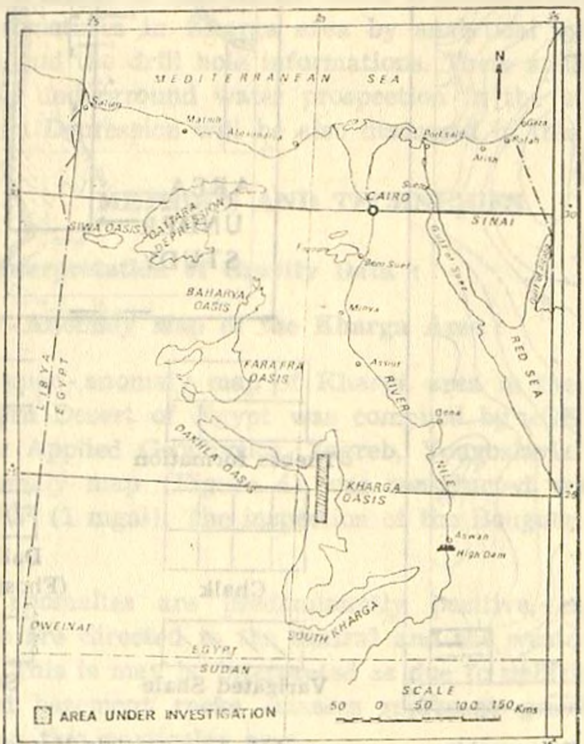

Fig. 1. — Location Map of the Studied Area.

The origin of the Kharga Depression represents a matter of contraversy for a long time as well as all the other depressions in the Western Desert of Egypt (Qattara, Siwa, Bahariya, Dakhla and Farafra). Many authors (Said, 1962; Ghobrial, 1967 ... etc) believe that these depressions were the result of wind action as a main eroding agent together with the climatic changes and heavy rains. On the other side, Knetsch and Yallouse (1955) stated that these depressions are intimately connected with tectonic deformations and fractures.

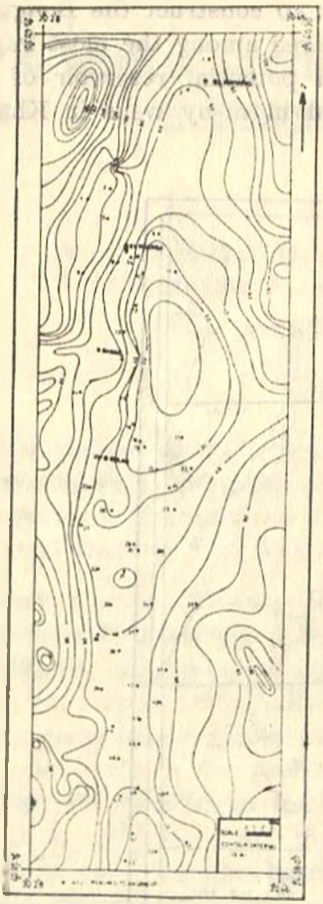

Fig. 2. — Topographic Map of the area under study.

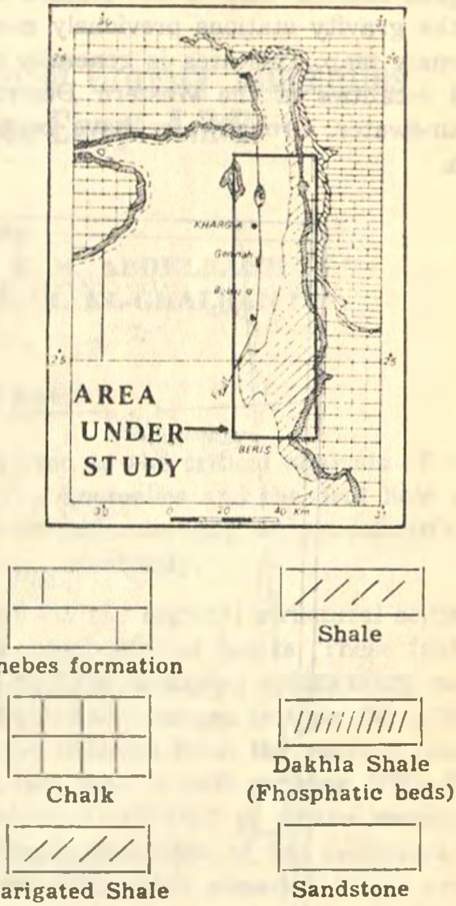

Fig. 3. — Geolgic Map of Kharga Oasis (after said, 1962).

According to the study of the geological map of Kharga area (Figure 3) and different publications (Said, 1962; Ghobrial, 1967; ... etc) as well as the drill hole data (El-Ghalban, 1980), the greater portion of the Kharga Depression is covered with sand dunes and the oldest outcrops belong to the Cretaceous age (mainly consists of Nubian Sandstone). The Cretaceous rocks are overlain with a small section of Lower Eocene and a thin section of Recent - Pleistocene rocks. All the sedimentary section with an average thickness about 800 meters lies unconformably above the Pre - Cambrian basement complex (mainly of granitic composition changing into green rock in some localities).

Structurally Kharga Depression was complicated by three fault groups having different trends (Said, 1962; Ghobrial, 1967): A long *N—S* (East - African) trend, *E—W* (Tethyan) trend and *NW—SE* (Erythrean or African) trend.

The main target in the present work is to emphasize in detail the subsurface structures in Kharga area by analytical evaluation of the gravity data and the drill hole informations. These structures are very important for underground water prospection in the area. The origin of the Kharga Depression will be also discussed in this work.

METHODS AND TECHNIQUES

Qualitative Interpretation of Gravity Data :

1) Bouguer - Anomaly Map of the Kharga Area :

The Bouguer - anomaly map of Kharga area in the Southern part of the Western Desert of Egypt was compiled by «GEOFIZIKA» the Company for Applied Geophysics, Zagreb, Yougoslavia in 1961. This Bouguer - anomaly map (Figure 4) was constructed with contour interval 10 $\mu m/5^2$ (1 mgal). The inspection of the Bouguer - anomaly map reveals that :

1. The anomalies are predominantly positive, especially those which are directed to the central and the western part of the area. This is may be interpreted as due to uplifting of the deep seated basement rocks (masses represent gravitational sources) in this particular area.

2. The regional anomaly features are complicated in several localities as shown by the presence of several irregularities exhibited by the contour pattern of such anomalies, particularly in the form of noses. Interpretation of such features is consecutive the fact that the gravity field must have been affected by anomalous bodies of shallow and deep seated origins.

3. The gravity anomalies are marked with variations in both magnitudes and trend patterns. The most conspiceous of all are the

positive and negative large anomalies nearly occupying most of the area with a marked domallike shape. The western flank of the negative broad anomaly is characterized by steep gradient. This steep gradient feature may be due to faults striking nearly in $N-S$ direction. The remainder high gravity gradients are also noticed in several localities with different trends and magnitudes mainly in $NE-SW$, $NW-SE$ and $E-W$ directions.

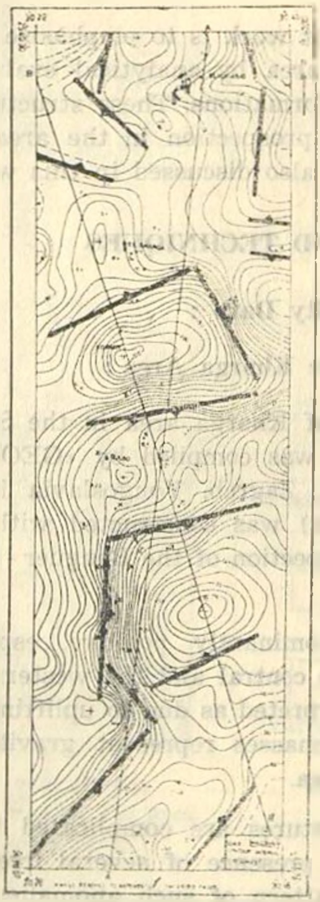

Fig. 4. — Bouguer anomaly Map.

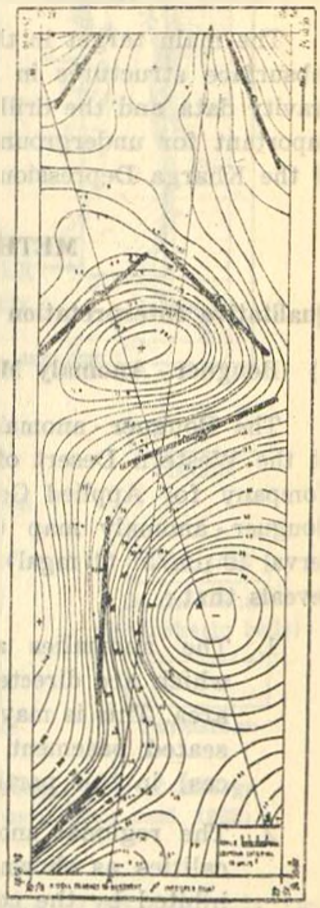

Fig. 5. — Regional anomaly Map.

4. The Bouguer - anomaly map of the Kharga area has several well defined relatively minor anomalies occupying several parts of the mapped area with different shapes.

5. The qualitative analysis of the Bouguer - anomaly features in terms of subsurface geological conditions in the area under study as a whole expose that :

   a) the structural setting of the basement complex is entangle by the presence of major *N—S*, *NE—SW*, *NE—SE* and *E—W* trending tensional normal fault zones and probably have their effects on the overlying sediments, and it can be stated that the major and local gravity anomalies as well as the sttep gradients represent different types of grabens and horsts, with variable intensity.

   b) it also seems quite possible than only major faults have tectonic effects as deep as the basement complex, however it can be stated that many of the minor faults complicate either the basement surface or the sedimentary succession.

   c) density variations within the basement igneous rocks in this particular area have great effect on the gravity field.

   d) comparing the Bouguer - anomaly map (Figure 4) and the topographic contour map (Figure 2) reveals a good correlation; the Kharga area is occupied mostly by positive gravity anomalies. This coincidence gives clue for further geophysical concerning the origin of the Kharga Depression and its possible consequences in neotectonics. Neutectonis is the science dealing with various tectonic process taking place in Early Cenozoic with the result that they rejuvenate ancient or produce new, often buried forms fully or partially developed on the earth's surface or hidden beneath it, which characteristic features were given by Vyskocil and Kopecky, 1974.

Considerable horizontal and vertical movements of crustal microblocks were proved (Vyskocil and Kopecky, 1974; Van Den Berg, et al., 1975; Krs, 1978; Marcak, ... etc). The movements of these microblocks are controlled by the dynamics of lithospheric plates or microplates. However, one would except even vertical recent movements in this particular area. This could be proved by establishing a separate project, which would study these movements by geodetic survey of high accuracy.

In order to delinate structures of interest from the observed gravity data more precisely, the residual anomaly map must be used. However, through interpretation of the second vertical derivative maps, small and shallow geologic features can be detected. It should be mentioned here that these derivative maps do not eliminate the familiar ambiguity in potential field but they just an effective - technique in subtracting the regional component from the total field.

2) Regional, Residual and Derivative Anomaly Maps of the Kharga Area :

The regional and residual anomaly maps were constructed by the Griffin's method (1949) with different grid spacing. The second vertical derivative maps were constructed by the Elkins' method (1951). These previously mentioned fields were calculated using the general formula :

$$V = \frac{1}{m \cdot s^n}\left(K_1 g_1 + K_2 \sum_1^4 g_i(s) + K_3 \sum_1^4 g_i(s\sqrt{2}) + K_4 \sum_1^8 g_i(s\sqrt{5})\right) \quad (1)$$

where s is the grid spacing, m, n and K are constants (coefficients) characterizing the chosen calculating method, g_1 is the value of the given field at the calculating point, and $g_i(s)$, $g_i(s\sqrt{2})$ and $g_i(s\sqrt{5})$ are the sum of the values of the given field on the circles of the radii s, $s\sqrt{2}$ and S, $s\sqrt{5}$ respectively.

It is usually recommended to construct several maps of different grid spacing and then few selected from them are used in the interpretation. The chosen maps should be in concordance with the available data (drill hole data, structures, denities ... etc). In this study the maps of grid spacing $2\sqrt{5}$ Km for the regional residual and second vertical derivative maps are used in the interpretation (Figures 5, 6 and 7).

Quantitative Interpretation of Gravity Data :

The quantitative interpretation of the gravity anomalies will be carried out along two profiles *AA'* and *BB'*, crossing the studied area in a *NE—SW* and *NW—SE* directions respectively as shown in Figures 4, 5 and 6, which intersect the major structures in Kharga area. A very simple two dimensional a density models along these profile are shown in Figures 8 and 9 respectively. The method of trial and error was used for the solution of the inverse problem. The exact positions of the inferred faults are detected from the residual anomaly map (Figure 6) at the inflection points between positive and negative residual anomalies as usual. The values taken from the wells spuded at the basement located on the profiles are considered to be a fixed reference points. The depths to the basement in few nearby wells are projected also on the profiles in order to get an accurate model. The upper boundary of the model is plotted from the topographic contour map (Figure 2). The relative residual effect was calculated from the plate formula :

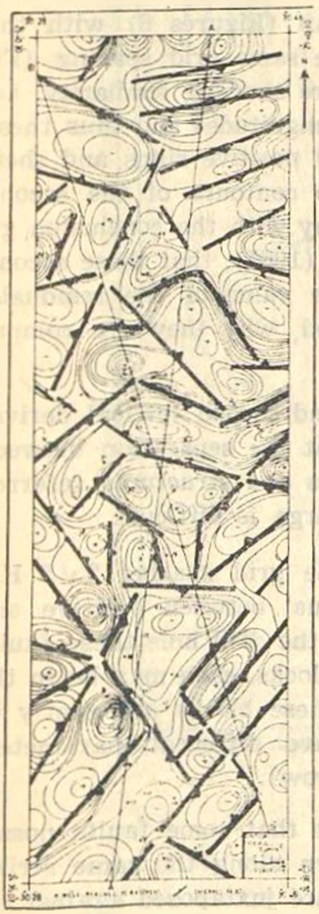

Fig. 6. — Residual anomaly Map.

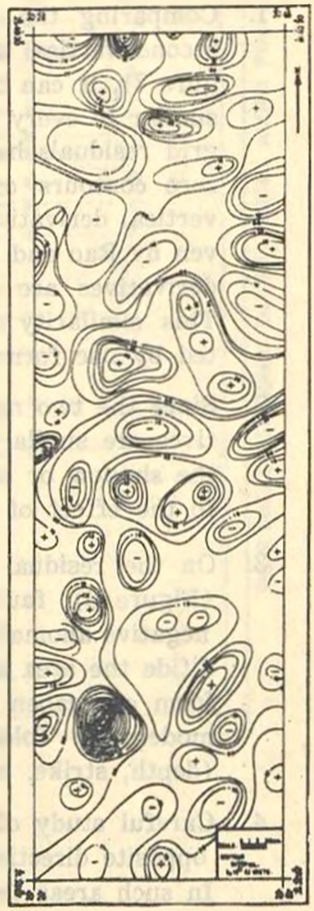

Fig. 7. — Second vertical derivative anomaly Map.

$$\Delta g = 2\pi f \, . \, \Delta \sigma \, . \, \Delta h \qquad (2)$$

where Δg and Δh are the difference in gravity residuals and depth values between two points, f is the univeral gravitational constant and $\Delta \sigma$ is the denstiy contrast. An average density conttrast equal 0.35 Mg/m^2 (gm/cm^3) between the basement complex and the sedimentary succession was used (Tealeb, et al., 1980).

CONCLUSIONS AND DISCUSSIONS

Authors picked out the following points of interest through analyses of the previously mentioned data :

1. Comparing the residual - anomaly map (Figures 6) with the second vertical derivative may of the same grid spacing (Figure 7), it can be stated that they are showing similarity, i.e. similar in every aspect except their magnitudes and thus these grid residuals have both negative and positive signs and their zero contours coinside with the zero contours of the second vertical derivative which is in harmony with the conclusion given by Rao and Radhakrishnamurthy (1965), that these second derivatives are entirely represent the value of the residuals. This similarity may be also explained, why they are computed by one formula.

2. Since the two maps of the residual and second vertical derivatives are similar, it can be stated that the separation between the shallow or near surface structures and structures referred to the effect of the basement in Kharga is difficult.

3. On the residual - anomaly map of the grid spacing $2\sqrt{5}$ Km (Figure 6), faults are located as usual between positive and negative anomalies with the help of the drill hole these faults difide the area into several tectonic blocks, each may be in the form of graben or horst. Rocks in these blocks are gently to moderately folded. These faults have different parameters (depth, strike, extension, dip and throw).

4. Careful study of these faults, reveals that some faults posses opposite directions of the downthrown along the same strike. In such areas the basins or grabens are juxtaposed against the

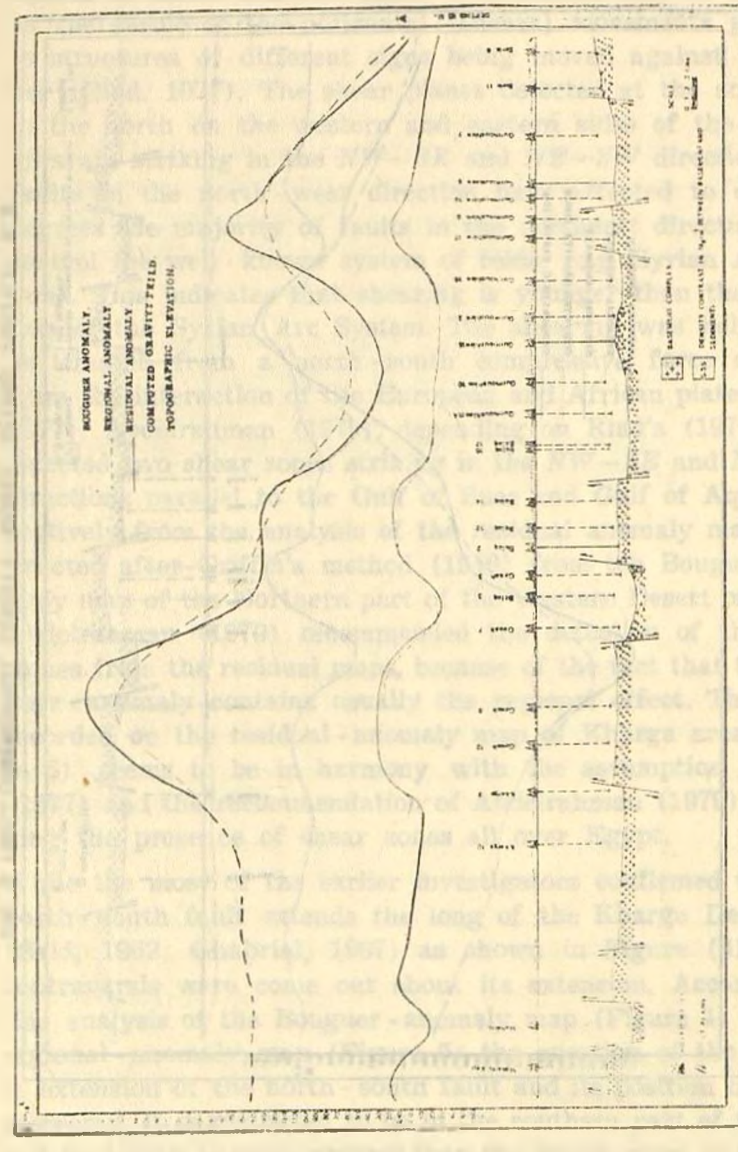

FIG. 8 TWO DIMENSIONAL DENSITY MODEL ALONG PROFILE A-A'

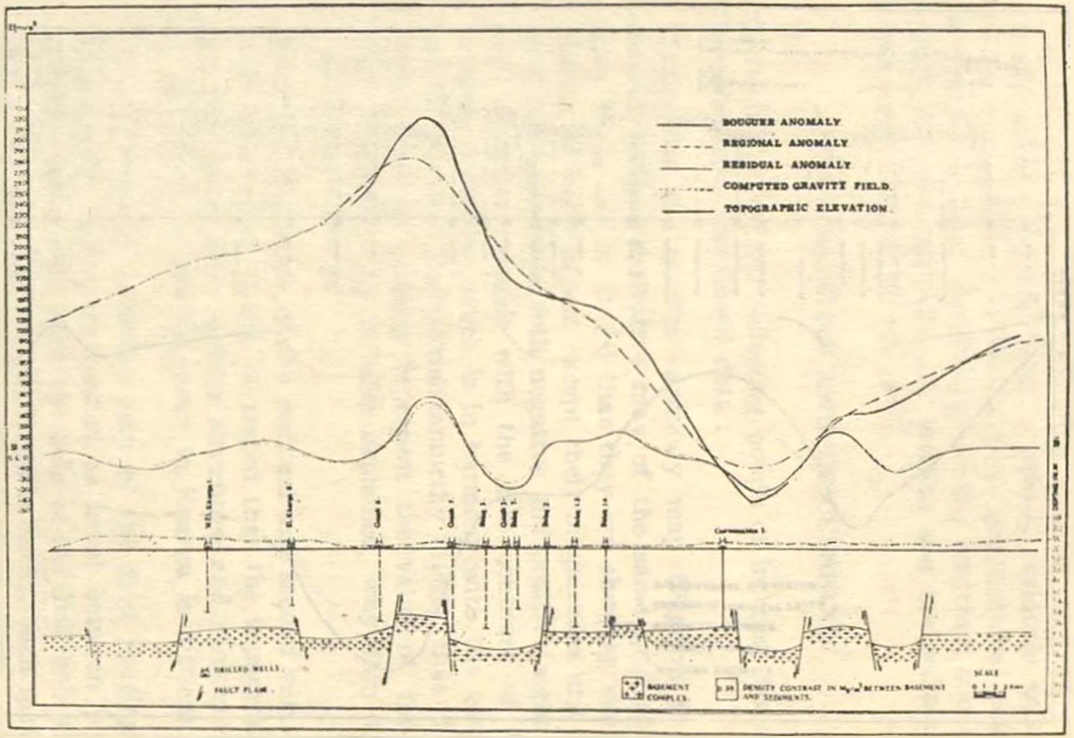

FIG 9 TWO—DIMENSIONAL DENSITY MODEL ALONG PROFILE B-B̄.

uplifts or horsts and vice versa. This feature may be explained as the result of the horizontal (shears) movements give rise to structures of different signs being moved against each other (Riad, 1977). The shear planes detected at the south and to the north on the western and eastern sides of the Kharga area are striking in the *NW—SE* and *NE—SW* directions. The faults in the north - west direction have affected to different degrees the majority of faults in the northeast direction (that control the well - known system of folds, (e.g. Syrian Arc System). This indicates that shearing is younger than the formation of the Syrian Arc System. The shearing was believed to be created from a north - south compressive force resulting from the interaction of the European and African plates (Riad, 1977). Abdelrahman (1979), depending on Riad's (1977) trial, detected two shear zones striking in the *NW—SE* and *NE—SW* directions parallel to the Gulf of Suez and Gulf of Aqaba respectively from the analysis of the residual anomaly map, constructed after Griffin's method (1949) from teh Bouguer - anomaly map of the Northern part of the Western Desert of Egypt. Abdelrahman (1979) recommended the detection of the shear zones from the residual maps, because of the fact that the Bouguer - anomaly contains usually the regional effect. The faults recorded on the residual - anomaly map of Kharga area (Figure 6) seems to be in harmony with the assumption of Riad (1977) and the recommendation of Abdelrahman (1979) concerning the presence of shear zones all over Egypt.

5. While the most of the earlier investigators confirmed that the north - south fault extends the long of the Kharga Depression (Said, 1962; Ghabrial, 1967) as shown in Figure (3), many contraversis were come out about its extension. According to the analysis of the Bouguer - anomaly map (Figure 4) and the regional - anomaly map (Figure 5) the question of the accurate extension of the north - south fault and its position had been answered. It is restricted to be in the southern part of the area and its length is much shorter than the length given in the previously mentioned publications.

6. From the interpretation of the two profiles (Figures 8 and 9) the following conclusion can be deduced :

A) The thickness of the sedimentary successive overlying the basement complex ranges from about 500 meters to more than 950 meters.

B) The sedimentary succession is generally folded and is braid by systems of normal dipping faults. Step faults, horsts and grabens are characteristic structural features of the area. All of these faults affect the basement complex as well as the sedimentary succession with different throws is the intersection of the observed residual anomaly with ranges from 50 to 250 meters.

C) An interesting point of these two-dimentional density models is the intersection of the observed residual anomaly with the calculated one above the control points (wells) indicating that these models were accurately calculated and showing best fit.

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