Tectonic Investigation In Relation To Gravity Anomalies In Northeastern Sinai, Egypt.

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S U M M A R Y

The purpose of this work is to solve problems of tectonics investigations making use of the relatively cheap gravity survey. This is preferred to the costly seismic survey which have failed in such detections specially in areas of complex structural history. (Linsser 1967 p. 480, P. 485 Paragraph 1 - 4).

Computer programs used to determine the depth at which faults had acted as well as their throws. The structural pictures at the basement surface have been selected seperately at both the 15,000 and 1,000 feet depths.

Two selected tectonics maps have been constructed by transforming the available Bouguer gravity data the first at Z=15,000 feet and the second at 1,000 feet. They show the following characters; i) Longer extension of the tectonic elements; ii) Greatly displaced blocks, reaching 1170 mts (about 3840 feet); iii) Hinge faults; iv) Predominantly NW - SE direction and less pronounced NE - SW direction of the tectonic elements.

INTRODUCTION :

The area under investigation lies in the northeastern corner of Sinai roughly between Lat. 30° 20, and 31° 30 and Long 33° 30 and 34° 40 (Fig. 1).

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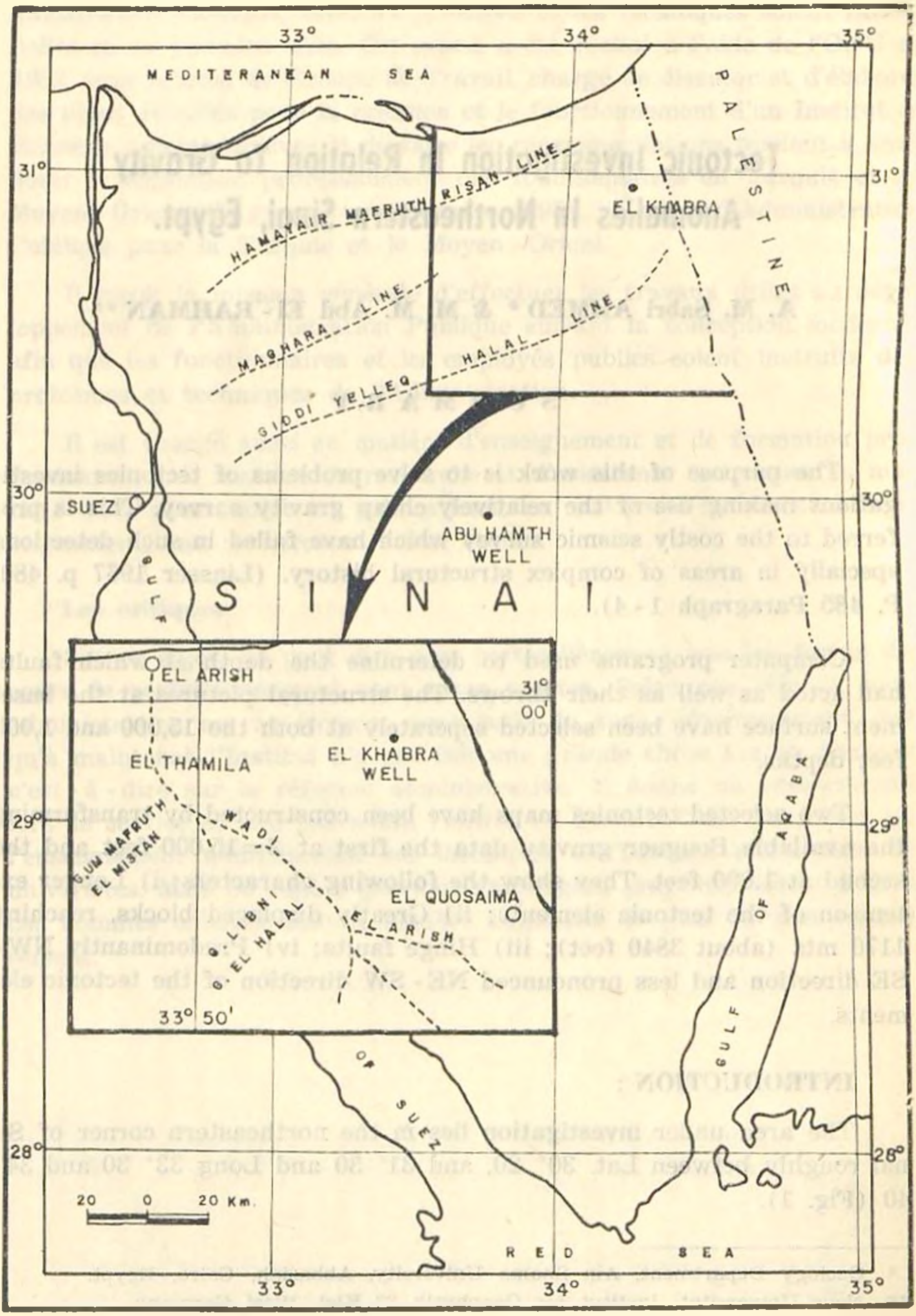

Fig. 1 A map showing location of area under investigation.

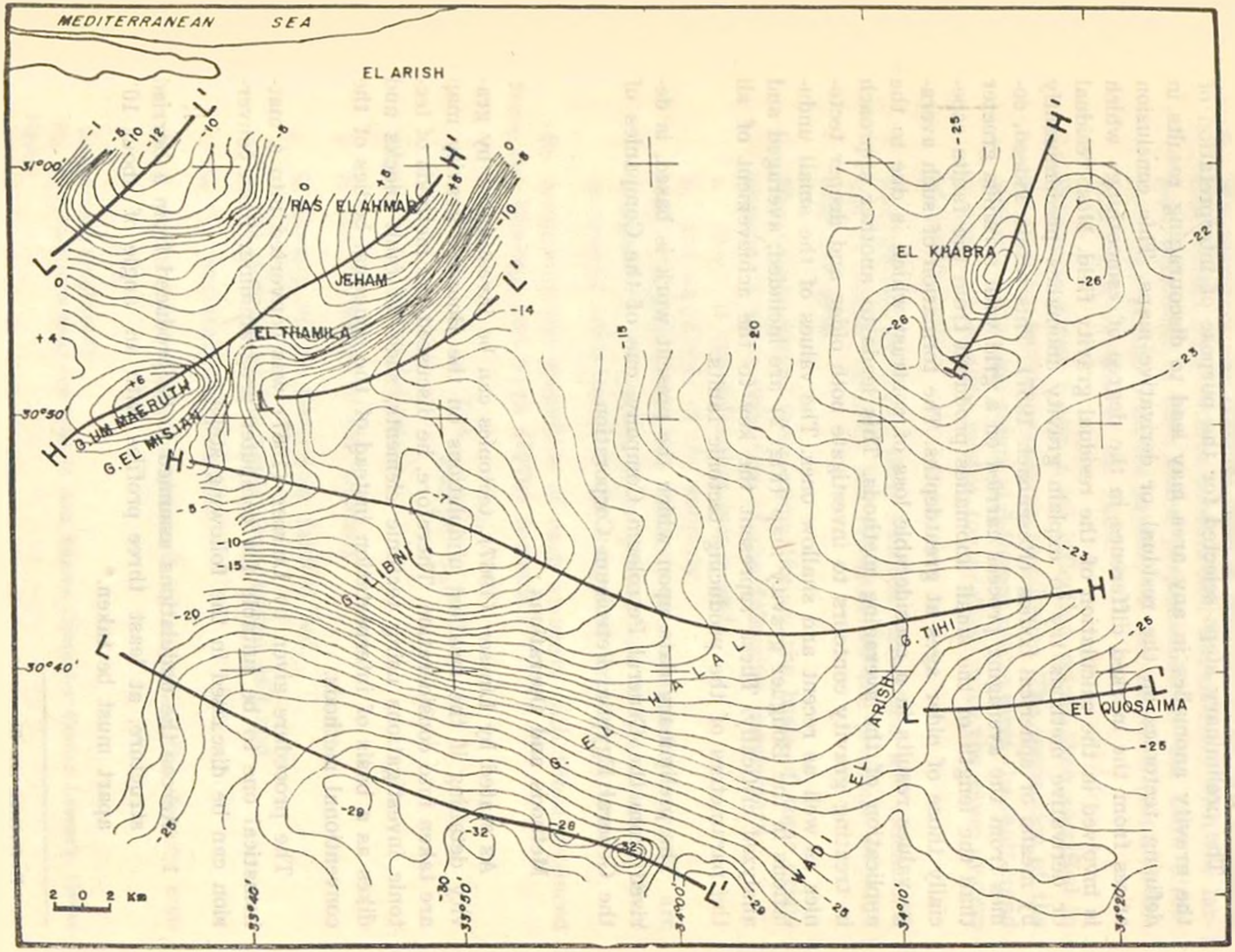

Fig. 2 Bouguer anomaly map of El Arish El Quosaima area, northeast sinai.

The preliminary steps selected for the purpose of interpretation of the gravity anomalies in any area may lead to discouraging results in defining tectonics on the residual or derivative maps. This conclusion arises from the marked difference in the degree of «smoothing» which is involved in the calculation of the residual gravity field. Most residual or derivative methods try to explain gravity anomalies predominantly by means of spherical bodies (Rosenbach 1957). This result, indeed, comes from the averaging process carried on a grid with a radius greater than the length of the small anomalies produced from the faults especially those of older ages at greatdepths. The formation of such average values results in a considerable loss of contrast which is due to the application of the averaging methods. This leads to another approach in treating gravity contours to investigate both older and deeper tectonics as well as recent and shallow ones. The values of the small undulations in the Bouguer gravity map (Fig. 2) are included, averaged and analyzed critically. These represent the key to the achievement of all the parameters of the producing tectonic faults.

The preliminary data upon which the present work is based, is derived from the General Petroleum Company, one of the Companies of the General Egyptial Petroleum Corporation.

Methods and Operations :

As stated by Linsser (1967), tectonics can be investigated by gravity detailing if the smallest undulations on the Bouguer gravity map are taken into consideration. Therefore, he discussed the methods of tectonic investigations using tectonic elements, such as fault blocks and dikes as a basis of interpretation instead of the spherical bodies of the conventional methods.

The procedure given by Linsser (1967) was converted into a mathematical one to be suitable for computer programming. Such conversion can be discussed in the following steps :

1. Across the undulations assumed to be produced from a burried structure, at least three profiles with an angle of about 10° apart must be taken.*

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* Reference no. 3.

2. The effect of the regional field is removed from the anomalies represented on the three profiles and the anomaly with the largest amplitude is then taken perpendicular to the fault direction. The position, on the profile, of the inflection point, determines the location of the fault.**

3. Practicing steps 1 and 2, all inflection points then specified in the profiles having maximum amplitudes. The connection of the different inflection points at different places gives the fault trend in this area for the profile (or profiles) with the same system of undulations.

4. The tectonic elements, their location; directions, and extensions, can be shown up upon the repetition of the previous steps all over the area.

5. The separation of these anomalies on the basis of their origin requires a clear definition of the following parameters :
   a. Slope at the inflection point; and
   b. the amplitude of the anomaly.

   Once the parameters are defined; two computer programs* are designed for comparing these parameters of the measured field anomalies with those of the computed «master curves».

By comparing the amplitude of each anomaly with those produced from the Sharma and Vyas (1970) formula,

$$\delta = \frac{g}{2\pi G\,(\sigma_r - \sigma_0)}$$

Where δ is the displacement,

g is the amplitude of the anomaly,

σ_r is density of the lowermost faulted bed,

σ_0 is the density of the uppermost faulted bed and

G is the gravitational constant;

the fault throw could easily be obtained by adjusting the density con-

** Determined graphically.

* The computer programs are kept in Ain Shams Computer Center Library, Cairo, Egypt.

trast $(\sigma_r - \sigma_0)$, between the uppermost and lowermost faulted layers. The value $(\sigma_1 - \sigma_0)$ ranges between 0.5 and 1.0 gm/cc.* Other parameters of the same faults involved to obtain their throws can be evaluated if the depth at which the disturbance due to the fault is determined.

This is possible upon comparing the measured field anomaly parameters with those computed by Geldart Gill and Sharma (1966), taking wide ranges of parameters (e.g. the depth of burrial Z to the fault ranges from 1 to 20 K. ft. and so also the thickness T of the faulted bed). The density contrast takes values from 0.1 to 2.0 gm/cc and the horizontal distance **X**, which is occupied by the computed curve, ranges between +2 and −2 K. ft. on both sides of the point of inflection. Therefore, we compare each of the field curves with 8000 computed curves (master curves).

In such method the master curves are identical in both shape and amplitude with the field curves and the program assigns parameters Z, T and of the compared master curves.**

The fault dip (or dip of the fault plane), is also variable and can be introduced in the computer program based on Geldart, Gill and Sharma (1966), considering the gravity, effect of the fault based on its displacement, density contrast between the faulted bed and its surrounding, and the dip of the fault plane. Sharma and Vyeas (1970), however, concluded that the dip of the fault plane has no influence on the gravity effect due to the fault. Therefore, computer programs are based on the special case «vertical fault».

For plotting a tectonic map from these programs one can proceed as follows :

1. Consider both fixed density contrast (for a given area) and the depth Z. The density contrast must be adjusted at any level Z in the two programs for selecting the optimum displacement, and the same density contrast for selecting the optimum depth Z to the fault.*

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* Abd El Rahman, 1974.

** Reference no. 3.

* The principle can be understood from Grant and West 1965 page 250 paragraph 9-9 (Interpretation theory in applied Geophysics).

2. Select all faults at this level and plot them on a new plate after identifying their location, direction, and extension which are previously determined for each element. On the basis of the two steps just mentioned, a template of tectonic framework at any level (Z) within the earth is constructed.

The complete solution for the problem of the tectonic investigation based on the above prodedure starts with the critical analysis of the Bouguer anomaly map where a number of fault tectonics with their directions are proposed on the basis of small undulations of the contours whose shapes and amplitudes suggest more than one type of faults.

These are :

1. First order undulations of smaller amplitudes indicating deeper and older tectonics. This type can be traced to a large extension.
2. Second order undulations of larger amplitudes indicating shallower and recent tectonics and having different lengths.
3. In between, there is a third type of intermediate origin wherever, the fault trend is determined by the direction of its segments. The depth and location are also suggested.

RESULTS

The tectonic framework in El Arish - El Quosaima area as indicated by anomalous features in the map (Fig. 3) can be summarized as follows :

1. Fault F_1 extends from north of Gebel Um - Mafruth towards the southeast crossing the area north of Libni, beyond which the fault branches into three faults trending ENE - WSW (F_3), nearly E - W (F_9) and NW - SE branch (F_1).
2. Fault (F_2) crosses the area southwest of Libni, Abrieq El Halal.
3. Another Fault F_3, trends NW - SE traversing El Hilal body and bending towards south at Wadi El Arish, Southeast of El Halal.
4. Fault F_4 located at the northwestern part of the surveyed area, represents a well - defined structure. It extends from the area

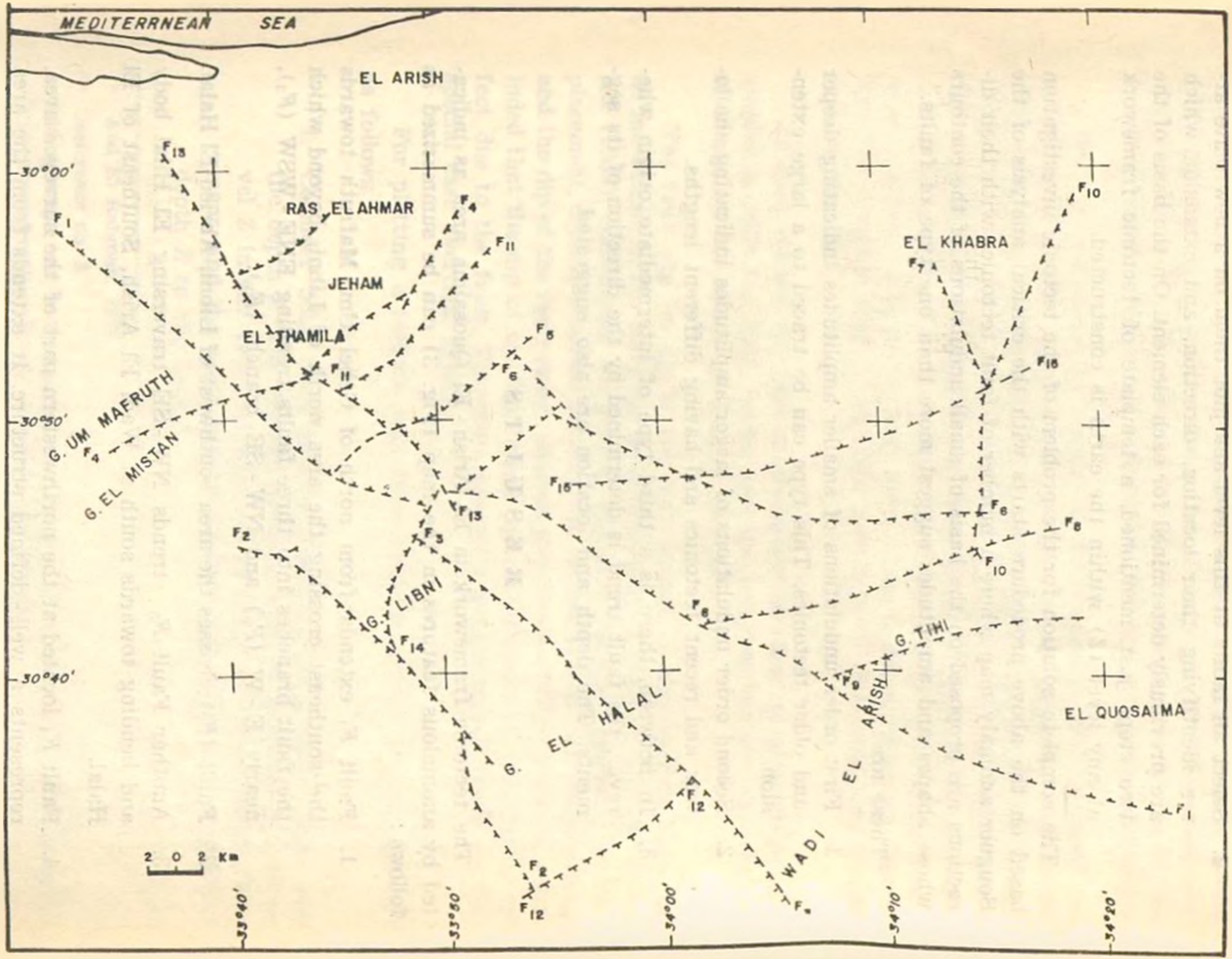

Fig. 3 Approximate structural pattern of expected basement surface of El Arish El Quosaima area (linsser's technique 1967).

between El Mistan - Um Mafruth towards the northeast, bounding the Thamila, Jeham Resan El - Aneiza, and Ras El Ahmar - El Lahfan uplifts, affecting the geological exposures as well as the gravity anomalies.

As a framework, these major faults and other minor ones are integrated to give the structural picture at 15000 feet depth as follows :

a. A Garben (as shown in Fig. 3) occupies the area north of Gebel Um Mafruth and extends to the Southeast through the area north of Libni cutting through, Gebel El Halal to end at El Quesaima. This great graben has surface reflections especially at the area of Gebel El Halal as a system of faults parallel to its trend (NW - SE) and crossing the body of El alal as small grabens and horsts.

b. A second Graben extends perpendicular to the first one (NE - SW direction) and occupies the area just southeast of El Thamila uplift. This graben is bordered by the faults F_4 and F_5.

c. A third Graben occupies the south western area of the map to the southwest of Um Mafruth - Libni El - Halal. Its general trend is NW - SE. This graben is caused by the faults F_2 and F_5.

d. A fourth Graben lies west of El - Quosaima.

e. A fifth Graben occupies the area of Wadi - El Arish south. It is caused by parts of the faults F_3 and F_{12}.

A system of horsts separated by the previously described faulted grabens is shown in Fig. 3 and can be summarized as follows :

i. The first Horst occupies the area of Um Mafruth and extends Southwestwards to Gebel Libni into the southern portion of Gebel El Halal.

ii. The second Horst occupies the northern and northeastern part of the map area where - Ras El Ahmar - Thamila - Jeham are represented as an elevated block extending eastwards to El Khabra area. This block is truncated by a small graben at the south of El - Thamila - Jeham blocks and at the west of El Khabra area.

The second tectonic map shown in Fig. 4 has the following general characteristics :

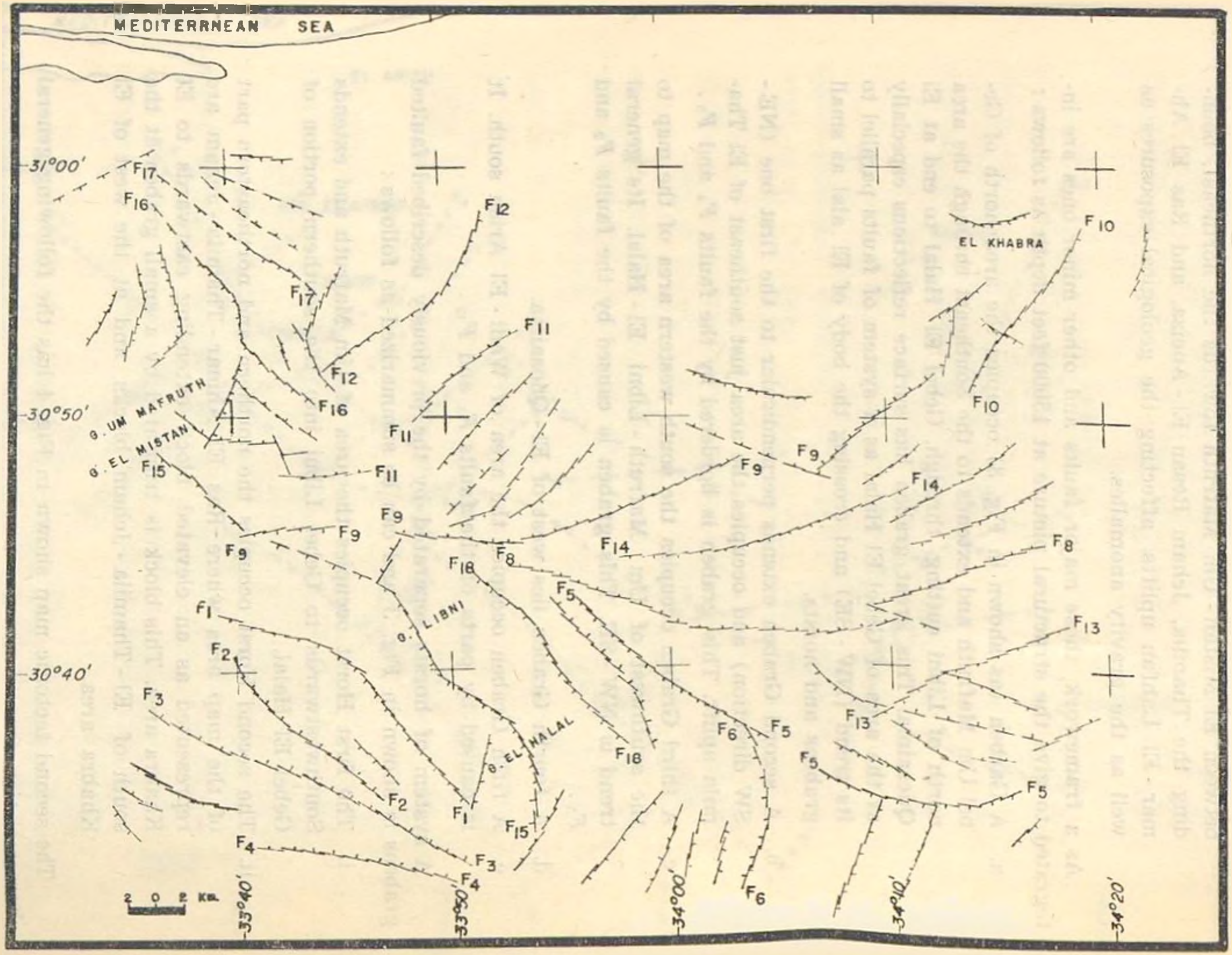

Fig. 1. Tectonic Map of El Arish El Quosaima Area selected at 1000 feet Depth (Lins sei's Technique 1967).

1. Small extension of the tectonic elements.
2. Low values of fault throws. The maximum throw of the majority of fault displacements has values less than 500 mts.
3. Hinge type faults.
4. The structural elements trending NE - SW are more pronounced near the surface (Fig. 4) than at depth (Fig. 3).

However, the random distribution of these elements combined is difficult to imagine. The dominant trend of the large segments to the northwest of the surveyed area is NW - SE, whereas the NE - SW trend is inconspicuous. At the southwestern part of the area, the predominant trend is NW - SE, while in its eastern part is NE - SW.

In comparison, this map (Fig. 4), represents a slightly different picture from that drawn for the depth of 1,5000 ft (Fig. 3). In the northeastern part of the surveyed area, the major trend at the shallow level is the NE - SW. Another direction having a trend NW - SE on the deeper level presents great difficulties in interpreting the relationship between the elements at different depths. Despite the predominance of small surface reflections of the deeper tectonics, one can suggest that the NE - SW trend is of older age. It was later affected by the NE - SW tensile stresses producing NW - SE faults and complicating the picture.

CONCLUSIONS

From the quantitative analysis of the Bouguer Anomalies of the area of El - Arish El - Quousaima (northeastern Sinai), one can reach the following conclusions :

1. Faults are the main structural elements controlling the tectonic pattern in this area, whereas folds are less conspicuous. Faults are generally of either the hinge or the normal type.
2. Fold structures with axes trending NE - SW; such as the elongated domes of Um Mafruth, Resain, Liboni, and El Halal, are older in age than NW - SE faults. These are related to block movements and their surface reflections are in the form of horsts and grabens.
3. The general structural pattern of the area is divide dinto two groups determined through the coincidence between the results

from the different quantitative methods and the gravity detailin method at certain depths as follows :

a. A shallow group separated from the residual gravity picture, shallow continuation picture (1 Km. spacing), and also from the representing tectonic detected by gravity detailing at 1000 ft. The trends of the recorded faults are NE - SW. N - S, E - W and NW - SE.

b. A deep group separated at 15000 ft (by the gravity detailing methods) has structural trends of mainly NW - SE. N - S and E - W directions, resembling those described by the continuation field method at 5 Km spacing.

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