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BASEMENT TECTONIC AND DEPOCENTERS DISTRIBUTION IN SINAI PENINSULA, EGYPTE

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ABSTRACT

The present work deals with analysing and processing some available geophysical data for evaluating subsurface geologic structural features of probable economic interest.

Quantitative interpretation of gravity and magnetic anomalies has been studied using several techniques to delineate the structural elements and estimate the average depths to the basement complex.

An average denisty contrast equal to 0.25 mg / cm^3 was calculated between the basement rocks and the sedimentary section.

The residual component of the Bouguer anomaly map of the area was evaluatd. Its values was transformed also into basement depths along a number of profiles.

The results obtained from the above techniques as well as geological informations from drilled wells in the area, were used to construct a tectonic basement maps.

The maps show three folding systems, one of which has been well known before, namely the Syrian arcs of Northern Sinai while the other two include the folding up to the basement area, of an axis trending nearly NNW - SSE and that south of Wadi Sidri near the Gulf of Suez; that related to the major fault striking roughly NW - SE and which shows obviuos horizontal right lateral displacement. Also, four major system of faulting trending ENE - WSW, NNW - SSE, NE - SW and E - W, ten major basins in the form of grabens (G) and ten major uplifts in the form of horsts (H) are emphasized.

INTRODUCTION

The studied area is of 64.000 Km^2. It is mainly divided to four different geomorphological and structural units : Northern, Central, Southern and West Sinai rift area.

Northern Sinai comprises three structural units (Shata, 1966 ; El-Kerdany, 1962). They are the Mediterranean fore shore area north Sinai strongly-folded area and north Sinai fractured trubutaries starting from El-Igma plateau southwards and terminating in the Mediteranean sea northwards.

The central part of Sinai is covered by subhorizontal Mesozoic Tertiary sediments (Said, 1962 ; Smith, 1984), changed to more complex structure towards the north. It was shaped largely by E - W folding, faulting and subsequent erosion.

The southern part of Sinai is covered by Pre-Cambrian igneous and metamorphic rocks (Said, 1962 ; El-Shazly *et al.*, 1974 ; Smith, 1984) through which are distributed several high mountainous peacks including G. Katherina (2637 m), G. El-Thabt (2438 m), G. Musa (2285 m) ... etc. Several wadis including Baba, Wadi Sidri, Wadi Firan and Wadi Isla drain the igneousmetamorphic rocks into El-Qaa plan westwards.

On the eastern side of the mountainous block the wadis drain more or less directly into theGulf of Aqaba.

The area of southern Sinai is flanked by two rift systems related to the opening of the Red Sea : The Suez graben and the Aqaba-Dead sea rift. In the western part the structural sections of the Gulf of Suez show about 2 - 5 kms of mainly Tertiary sediment overlying the Pre-Cambrian basement. The Gulf of Aqaba occupies the southern part of Dead sea rift, which is apart of the Syrian - African Rift system. It is a major shear zone (Girdler, 1985).

The present study is mainly based on the Bouguer gravity map (Fig. 1) and the Aeromagnetic map (Fig. 2) as the main obtained from subsurface data colected from drilled wells in the area and the previous geological publications.

In order to evaluate the subsurface geologic structural features and the tectonics affected the area, qualitative and quantitave interpretation techniques were applied on the Bouguer gravity and Aeromagnetic maps. This was achieved by

1) Using a simple analytical technique, it was possible to calculate

the density contrast between the basement and the overlying sedimentary rocks. The calculations were fulfilled on the measured gravity values together with the basement depths known from the drill wells reached to the basement.

2) Isolation of residual gravity anomalies, Fig. 3, using the above calculated density contrast, by removing the regional component due to the change in the thickness of the earth's crust. The resulting component is considered to be arising from the effect of the structures on the basement surface.

3) The basement depths were determined using the gravity and aeromagetic anomalies and several selected techniques.

4) A basement relief and a tectonic maps were prepared using the intergrated results obtained from the previous techniques.

GEOLOGY

The geological map, shows several geological units. These are grouped into the following units starting from the oldest to the youngest : Pre-Cambrian, Cambrian, Carboniferous, Triassic, Jurassic, Cretaceous, Paleogene (Paleocene, Eocene) Neogene (Miocene) and Quaternary (Pleistocene, Holocene). The phanerozoic volcanic rocks divided into dyke-like volcanics of early paleozoic age, basalts of Triassic age, alkaline volcanics of late-Creatceous age and basalts of Mid-Tertiary age.

Pre-Cambrian rocks : It occupies the southern part of Sinai peninsula. An important belt of metamorphic rocks were found in the central part of the pre cambrian area and another less important belt were found in the western side, the granodiorite and basic grey-white granites are predominant to the south and east while the pink acidic granites are predominant towards the north west.

Cambrian rocks : It is found as Sarabit El-Khadem formation which is essentially formed of sandstones.

Carboniferous rocks : It is represented as follows from the bottom to the top, Adedia formation (S . S), dolomite-limestone clay Um Bogma formation and ou Zarab formation (S. S). Triassic rocks has been found as Araif El-Naga formation in the same type locality already known in Sinai peninsula.

Triassic rocks are delineated in three formation, namely Bir Maghaara formation (clay and L. S), Safa formation (S . S and coal) and masajid formation (L . S).

Cretaceous is divided into malha and Lagma formations (early cretaceous sandstones), Falliq formation (L.S), Yelleq formation (dolomite) and Suder formation (chalk).

Paleocene is found as one unit named Geble Bodhiya formation (Marl, Shale and L . S).

Eocene rocks are classified into Geble Serai formation, Darat formation Khaboba formation and Tanka formation (L . S, shale, marle and flint).

Miocene rocks are of particular important for petroleum and gypsum ; anhydrite resources, It is divided into early Miocene Gharandal group (shale and S.S) and Middle Miocene Ras Mallab group (evaporites). Quaternary is classified into one pliestocene unit and ten Holocene units, Fig (4) Distinction has been carried out between deluvial deposits with their source rock indicated from alluvial deposits have been distinguished according to their lithology into Sandy Limy, chalky or clayey, dolomitic or undifferentiated, moreover, sebkhas and areas with salt crust have been distinguished.

GRAVITY AND MAGNETIC MAPS

The gravity and magnetic maps of the area were subjected to qualitative and quantitave interpretation techniques.

The qualitative analysis is an attempt to get an idea about the characteristic of the causative bodies, depending on form, shape, trend, differences in amplitude, change or discontinuity of direction and extension of anomalies. The recorded anomalies are considered to be due to folding, faulting or dike-like sources, since the area is affected by Gulf of Suez, Gulf of Aqaba and Syrian arc tectonics.

Three folding systems have been recorded on these maps, namely the Syrian arcs of northern Sinai, folding northern to the basement rocks and that south of Wadi Sidri.

The Syrian arcs are mostly trending in NE - SW direction and are clear at G. Hela, G. Kharin, G. Maghara, G. Yellg, etc....., where the delineated folds of NE - SW axes are very conspiceous feature in north Sinai. The folding northern to the basement rocks, especially, at Um Bogma has an axis trending NE, NW, and E - W while the third folding system south of Wadi Sidri near the Gulf of Suez with an axis trending NW - SW.

Sinai peninsula is greatly dissected by various fracturing and faulting systems which have been throughly delineated by elongated zones whith steep gradients and closures of the observed fields (Dobrin, 1976). A group of faults trending ENE - WSW can be shown for the first time in the extreme northern part of Sinai while another two groups of NNW - SSE and NW - SE bound the Gulf of Suez and extend further eastwards into Sinai. The Gulf of Aqaba trend faults which are mainly NNE -SSW are well developed in southern Sinai near the Gulf of Aqaba and extending further northwards and westwards.

These fault systems intersect each other in various parts in particular in the basement rocks in southern Sinai.

Also, the study of the Bouguer anomaly map of the area shows that the southern part is characterized by the presence of batholiths give rise negative gravity anomalies. It is known that the granitic batholiths give rise negative gravity anomalies because of the relatively low denisty of granite in relation to the intruded country rocks (Bott, 1956).

Quantitave analysis :

Interpretation of the main anomalies recorded on the gravity and magnetic maps are carried out along more than 100 profiles, fig 5, distributed allover the study area. All the investigated anomalies are, nearly, expressed by assymetrical curves with varying shape, width and maximum and minimum amplitudes.

There are several methods for the quantitive interpretation to determine the basement surface by estimating the widths and depths of the causative bodies. In this study. the most suitable methods used were :

1 - Nabighan method (1972) :

This method is used to determine the depths of the magnetic bodies. The horizontal derivatives are computed for more than 40 profiles, and transformed to the vertical gradient by Hibert transform in which a simple transformation in the frequnence domain yeild an analytical function. The amplitude function is drown and the half-maximum width is equals to the depth of the two dimensional causative body. Some results of this method is summarized in table (1).

2 - Koulomzine and lamontagne's method (1970) :

This method is applied along more than 35 profiles. The results of two of these profiles are shown in figure (6 a, b).

3 - Green and Stantly (1975) :

In this method, the depth to the contact can be obtained from the width of the symmetrical peak of the amplitude function [A(x)] of the analytical signal. The width of the function is equal to the depth (h) of the contact where the height of [A(x)] is 0.707 of the pek height, [A(o)]. This method is applied to more than 36 profiles and the results of some of this method shown in table (2).

4 - Spectral analysis techniques :

The spectral analysis techniques were applied to the gravity and magnetic anomalies along more than 75 profiles.

According to Treitel *et al.*, 1971 and Cassano *et al.*, 1975, the depths to the basement rocks were calculated. Figure (7 a, b) illustrated the log modified amplitude spectrum along 2 profiles.

5 - Powell's techniques (1967) :

This technique is applied along 15 magnetic profiles. Figure 8 (a, b), shows the calculation along profiles 25 and 27 m.

6 - Milos pick *et al.* method (1973) :

According to this technique a number of trials for estimating the depth to the basement compex had been carried out, based upon selecting a profile through two well reaching the basement rocks and third point where the basement rock crops out. Three equations are established from which three coefficient c0, c1and c2 are determined. Applying the equation :

$$H(X)n = \sum_{n=o}^{n=m} Cn \ (\Sigma g)n$$

g -----> The gravity values at N ponts.)

The value of the basement depth (H) can be determined any where. The results of some points of calculation shown in table (3), Fig. 9.

7 - Peter's method :

This method was used here for a rough estimation of the depth to the basement compex along 56 profiles. The results of four of these profiles are shown in figure (10 a, b).

8 - The density contrast between the basement compex and the sedimentary section was calculated using the linear correlationbetween the gravity values at more than 20 well and their depths to the basement surface.

9 - The residual components of the Bouguer anomaly values using the above determined density contrast was determined. The resulting component is considered to be arising from the basement surface. The residual components of the area has been transformed into basement depths along more than 30 profiles.

The results of the above mentioned depth determination techniques are used together with the basement depths of the drill holes to plot the basement relief map of Sinai Peninsula; Fig. 11.

RESULTS AND CONCLUSIONS

1 - The qualtitative analysis of gravity and magnetic anomalies of the area reveals that Siani Peninsula can be divided into four areas. The first is that in the extreme north Sinai which is called the Mediterranean foreshore area where the gravity and magnetic fields show a pattern having relative maximum and minimum anomalies characterized by gentle gradient comparing to other portions. These anomaly features are trends NE - SE. The second is that bordering the Gulf of Suez, known as the Gulf of Suez rift area, Fig. 12, where the polarity is negative forming several anomaly features trending NW - SE and characterized by steep gradients. The third area is that located in Sinai Peninsula south of the first area. The fields show a complicated pattern compared to its other portions. The anomalies trending NE - SE , NW - SW and E - W. The fourth area is that occupied by the basement rocks in the southern part of Sinai.

The gravity and magnetic maps show that Sina is affected by the tectonics of the Gulf of Suez. Gulf of Aqaba as well as Syrian arc and the Mediterranean trends, where the directions of the major structural features elements in the area trending NW, NNE, NE and E - W respectively.

2 - The quantitative interpretation of the gravity and magnetic maps indicated that :-

a. The density contrast between the basement rock and the sedimentary section was found to have an average value of 0.25 mg / cm^3.

b. The basement rocks lie at depths ranging between 1.5 km in some parts to more than 7.5 kms in some other. The southern Sinai is greatly domenated by surface basement rocks, through which distrubuted several important high mountains peaks including G. Katherine (1636 m), G. Thabt (2438 m), G. Musa (2285 m), G. Gunna (1265 m), G. Serbal (2078 m) .... etc.

c. The basement rocks of the area are affected by several archings and saggings in the form of anticlinal and synclinal folds as well as zones of dislocation having different trend patterns, relief and areal extensions.

3 - In the light of the Bougner, residual and the aeromagnetic anomaly maps, and the results of the different techniques, the basement map of Sinai Peninsula, the drill hole informations of the area and structural lineation map constructed from Erts - 1 satellite images by El-Shazly *et al.*, 1974 ; a tentative map showing the main structural features of the basement complex of the area, is outlined, Fig. (13). From this map four major systems of faulting trending ENE - WSW, NNW-SSE, NE-SW and E-W, ten major basins in the form of Grabens (G), and ten major uplifts in the form of Horsts (h) are emphasized.

4 - The sits of faulting in various parts of Sinai particularly in the basement rocks in southern Sinai are sits of importance for locating mineral deposits, especialy those of hydrothermal origin.

5 - The priority of regarding the petroleum and natural gas resources are the Gulf of Suez rift area ; the Mediterranean foreshore area in the extreme north of Sinai and the area south of it respectively where the presence of adequate source rocks reservoir rocks and oil traps.

6 - The ground water in Sinai Peninsula can be pointed to the occurence of suitable conditions for water and soil conservations, where the occurrence of a number of subiclosed hydrographic basins, especially in the northeastern part of Sinai. Fig. 12.

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Table 1 : Depth determination from some magnetic profiles of the area using Nabighan method

No. of profile	Depth to the basement surface kms.
M 5	1.87
M 12	1.75
M 14	4.2
M 35	3.6
M 42	2.85

Table 2 : Depth determination using Hilbert Transform method (Green, R., and Stanley, J. M., 1975)

No. of profile From gravity map	Basement Depth in km.	No. of profile From Magnetic map	Basement Depth in km.
G 1	4.0	M 15	4.75
G 3	2.5	M 16	4.75
G 12	3.5	M 17	2.25
G 14	1.5	M 18	2.75
G 24	6.5	M 20	2.6
G 28	3.5	M 21	3.7
G 30	5.5	M 22	5.3
G 35	4.5	M 23	6.26
G 39	6.75	M 24	3.82
G 43	3.5	M 25	6.2
G 47	2.75	M 26	7.85
G 50	4.5	M 27	6.8
G 52	4.17	M 28	6.5
G 54	4.8	M 29	7.2
G 55	3.5	M 31	6.7

Table 3: Depth determination of the Basement surface using Milos pick and et. al. Method (1973)

No. of profile	Basement depth in km.	No. of profile	Basement depth in km.
1	2.096	11	4.904
2	3.94	12	4.06
3	2.1	13	2.96
4	2.1	14	7.3
5	3.94	15	8.04
6	3.128	16	4.52
7	5.89	17	4.63
8	3.28	18	8.04
9	2.758	19	2.069
10	3.128	20	4.317

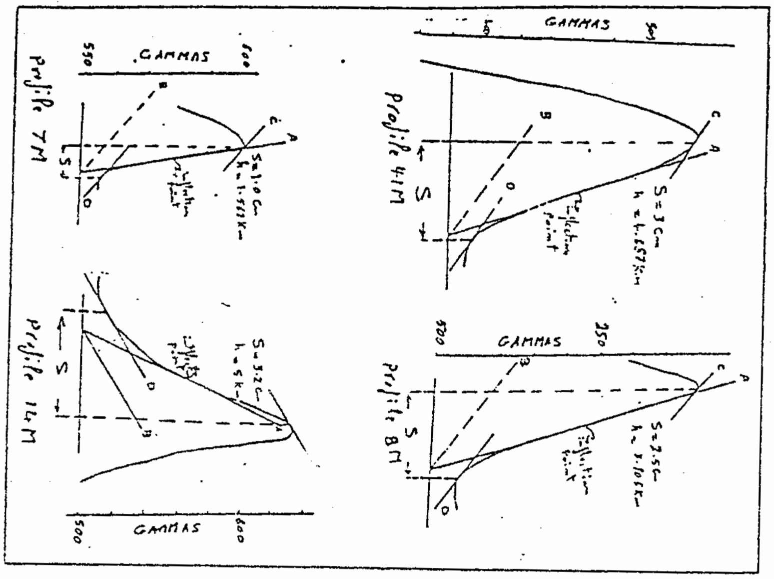

Fig. (10) Calculated depths using peter's method along profiles 7,8,14 and 41M

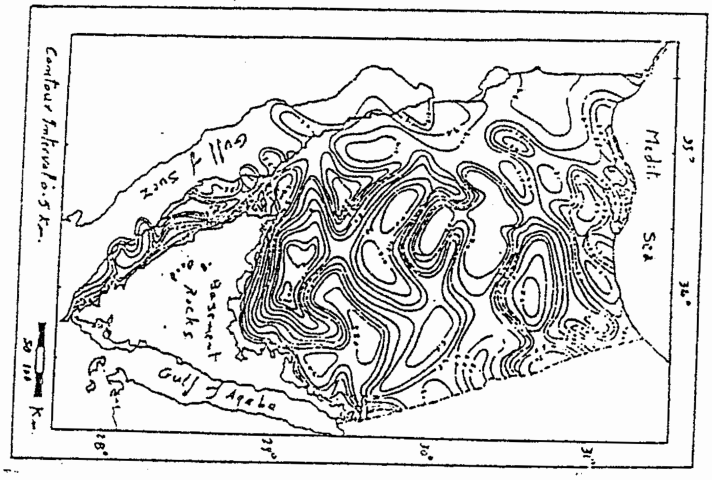

Fig. (11) Basement relief map of Sinai peninsula

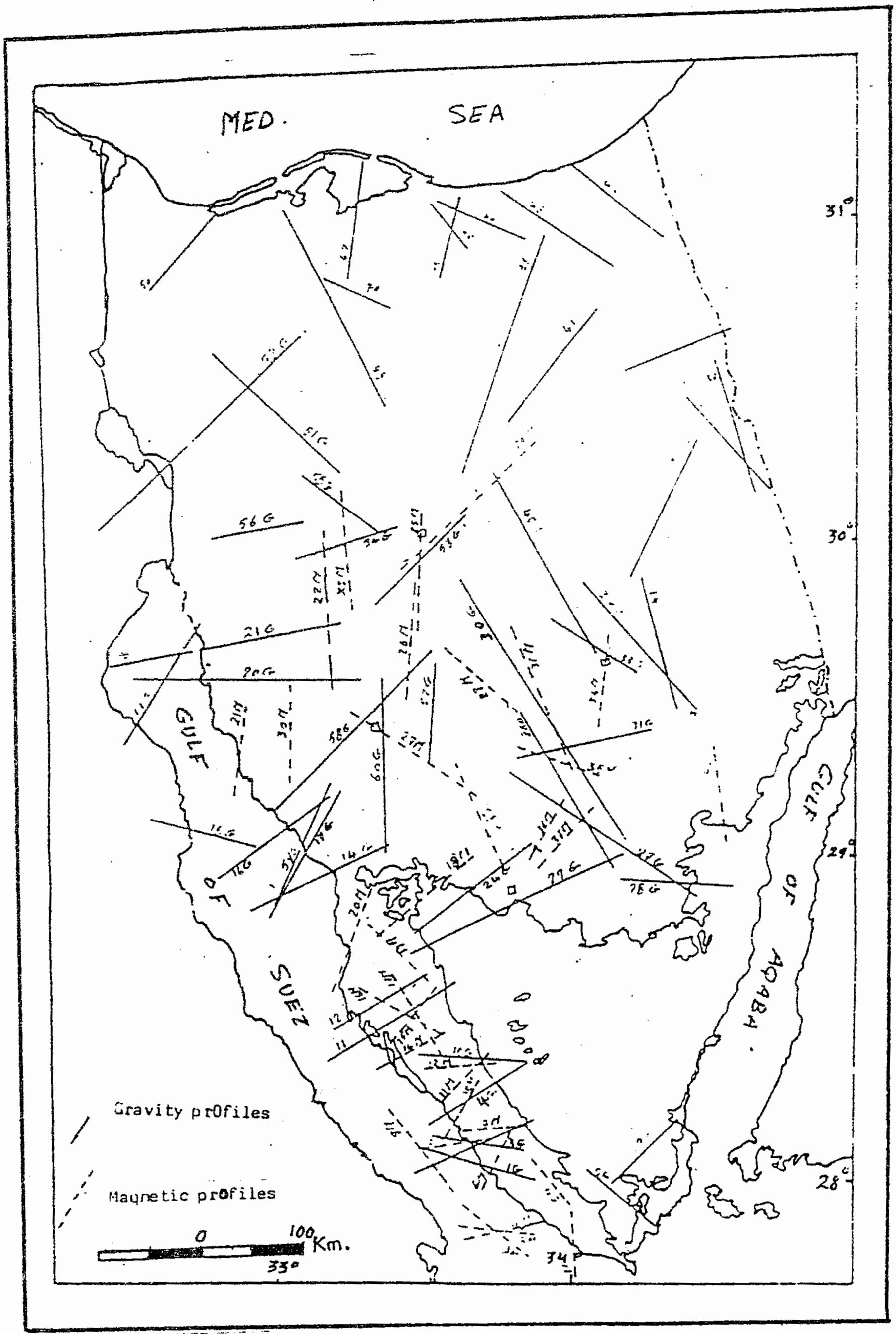

Fig. (5) Location map of the studied profiles over the gravity and magnetic maps

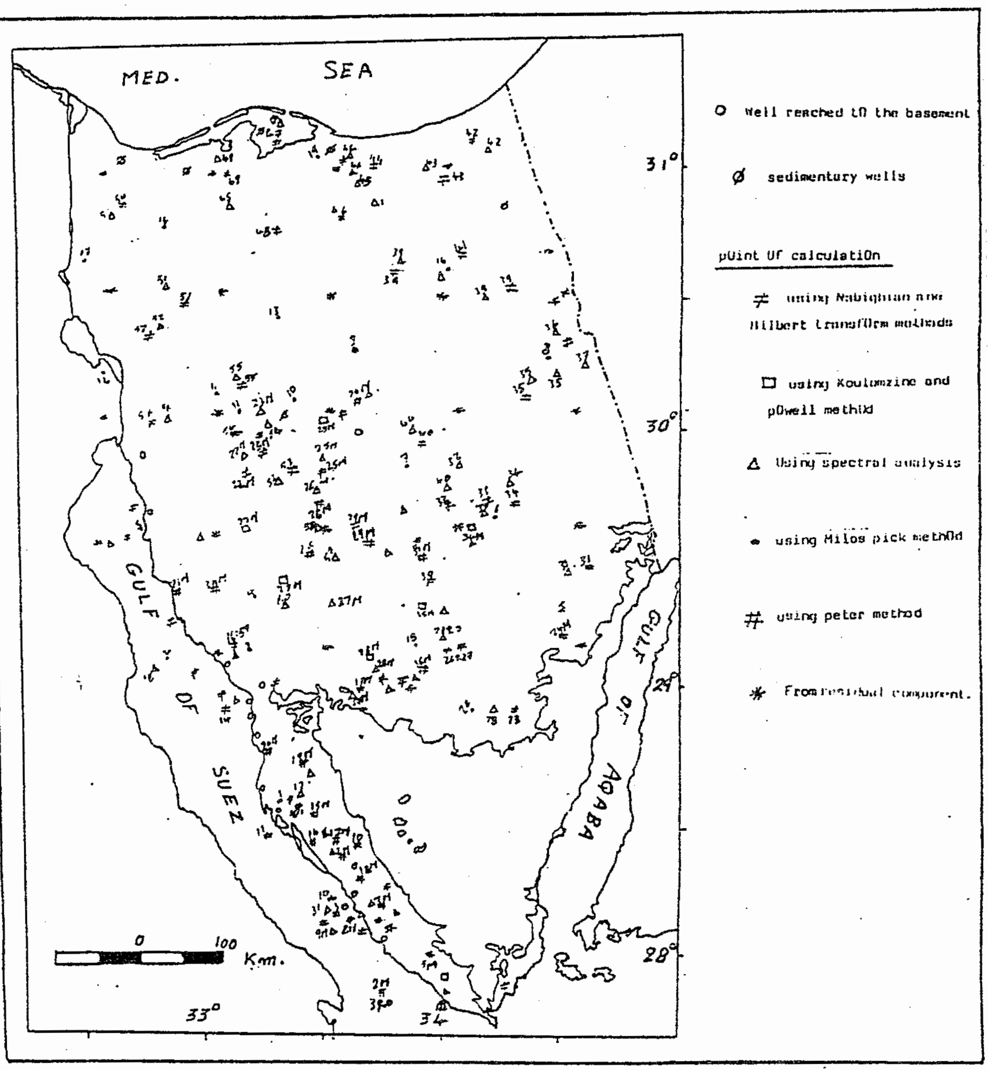

Fig. (9) Location map of the calculated points

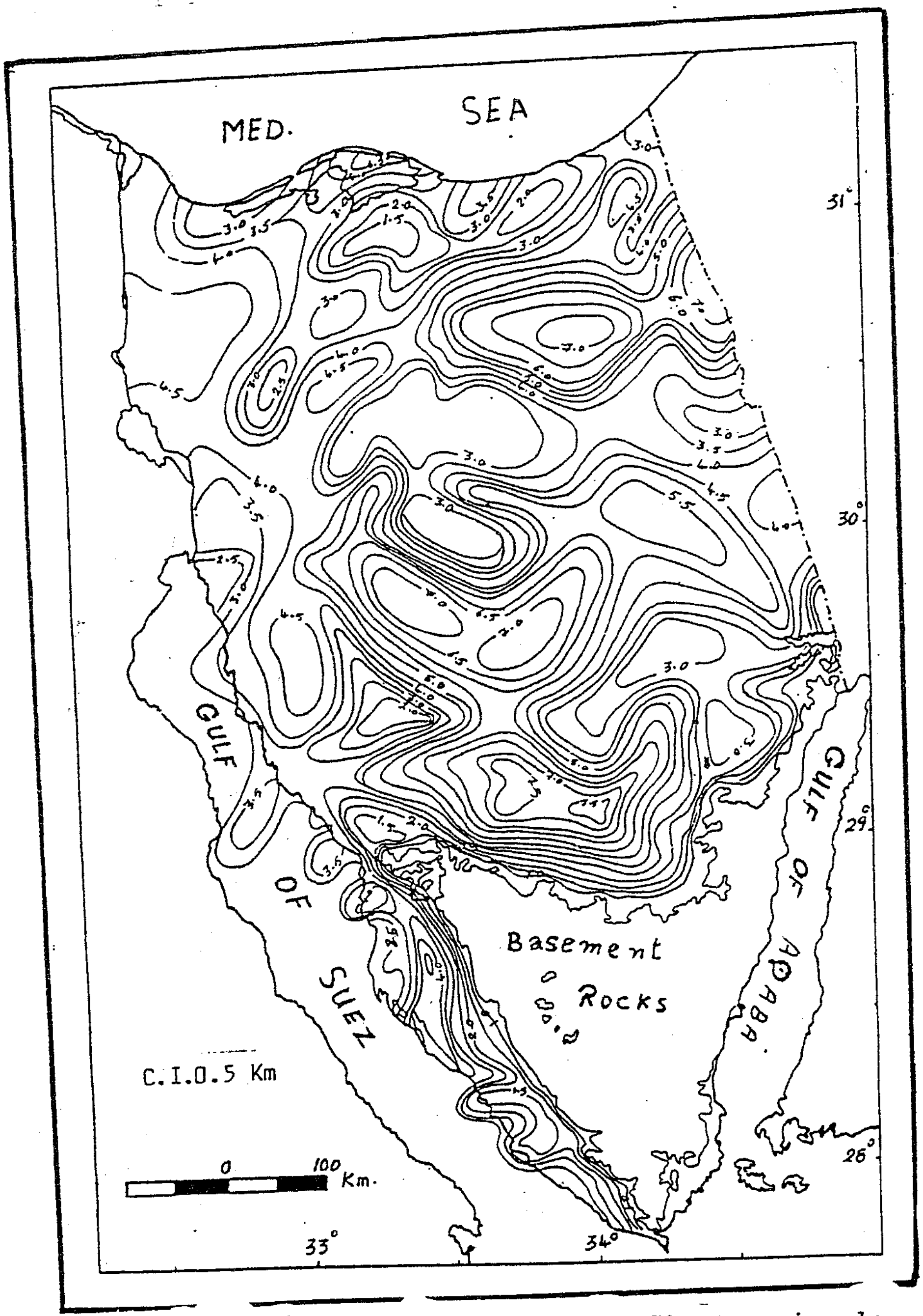

Fig. (11) Basement relief map of Sinai peninsula

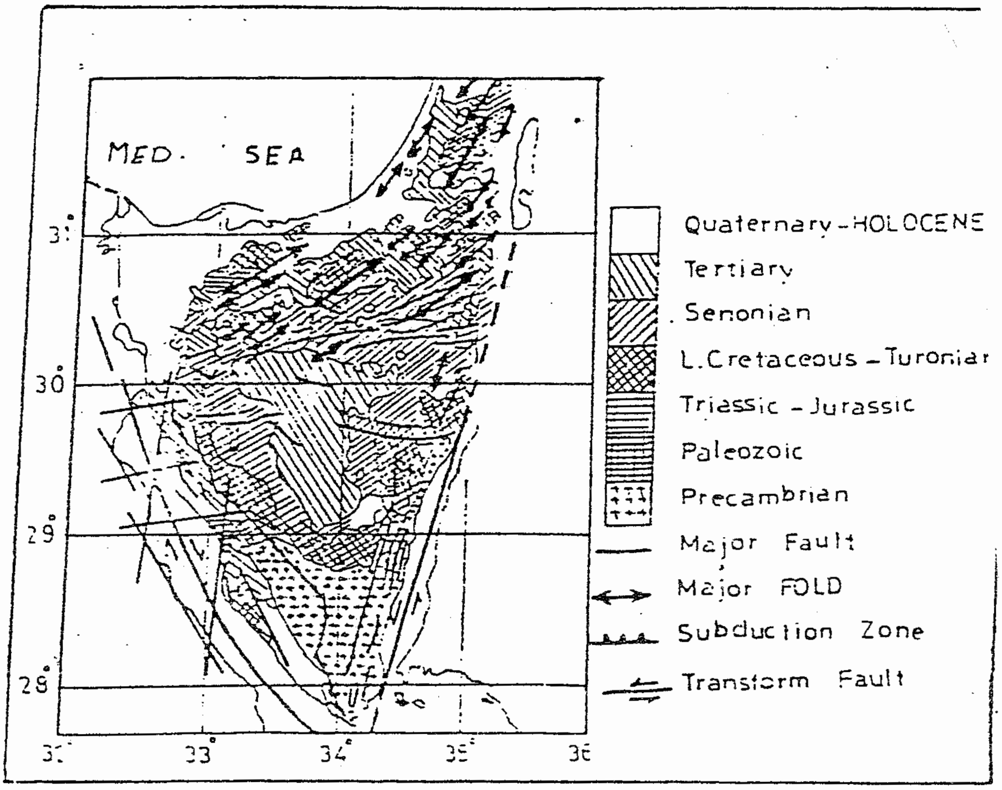

Fig. (4) Geologic and Tectonic map of the area

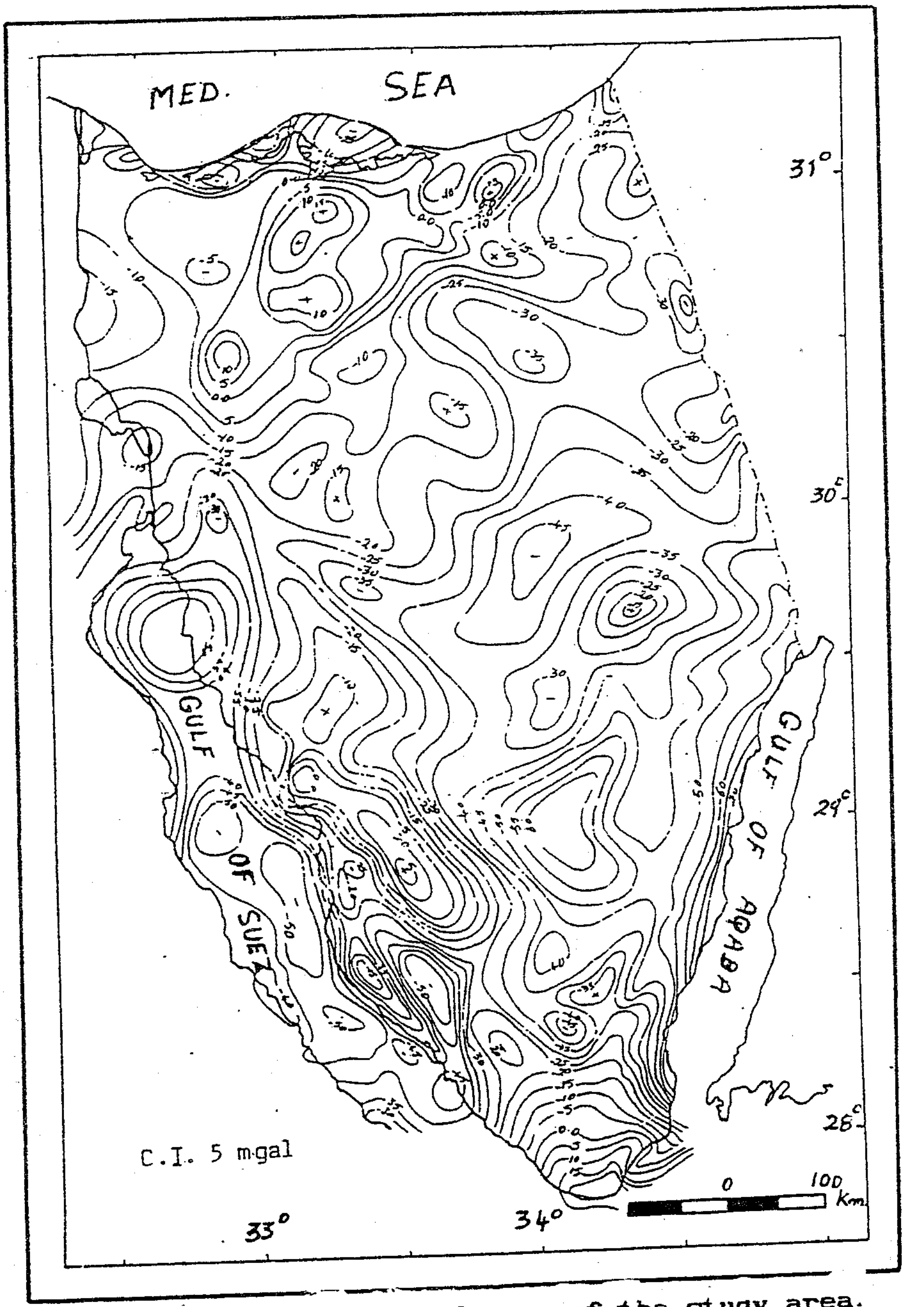

Fig. (1) Bouguer anomly map of the study area.
(After G.P.C. 1984).

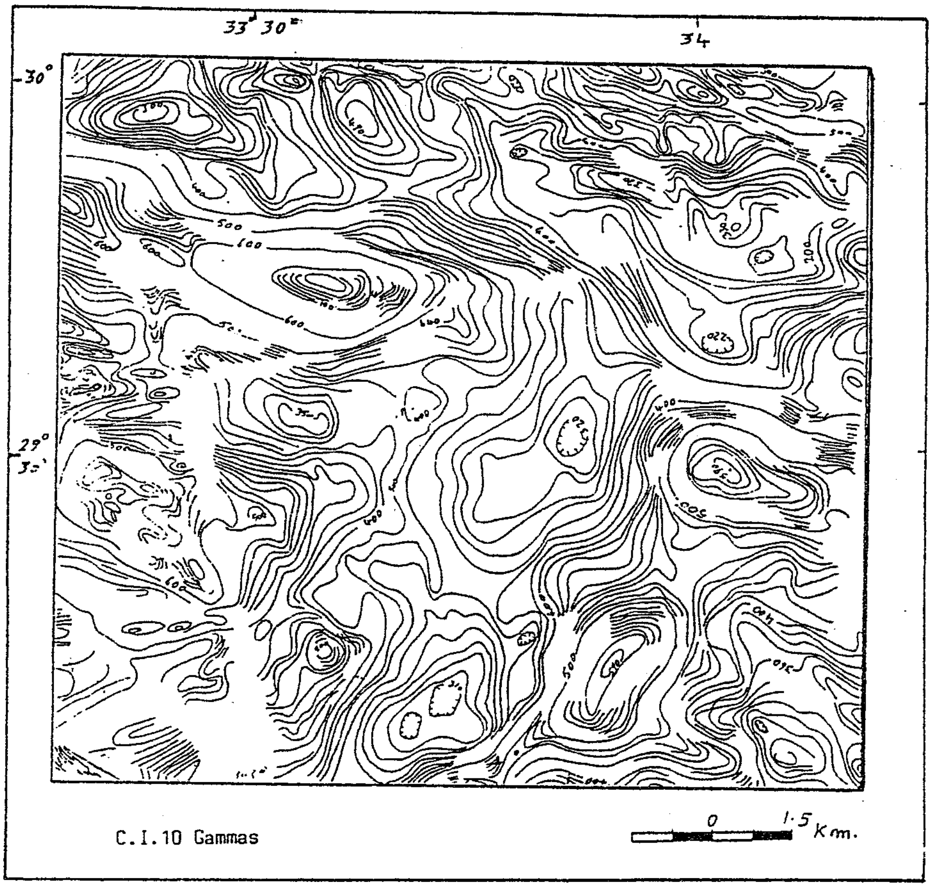

Fig. (2) Aeromagnetic map of the study area (After G.P.C. 1984).

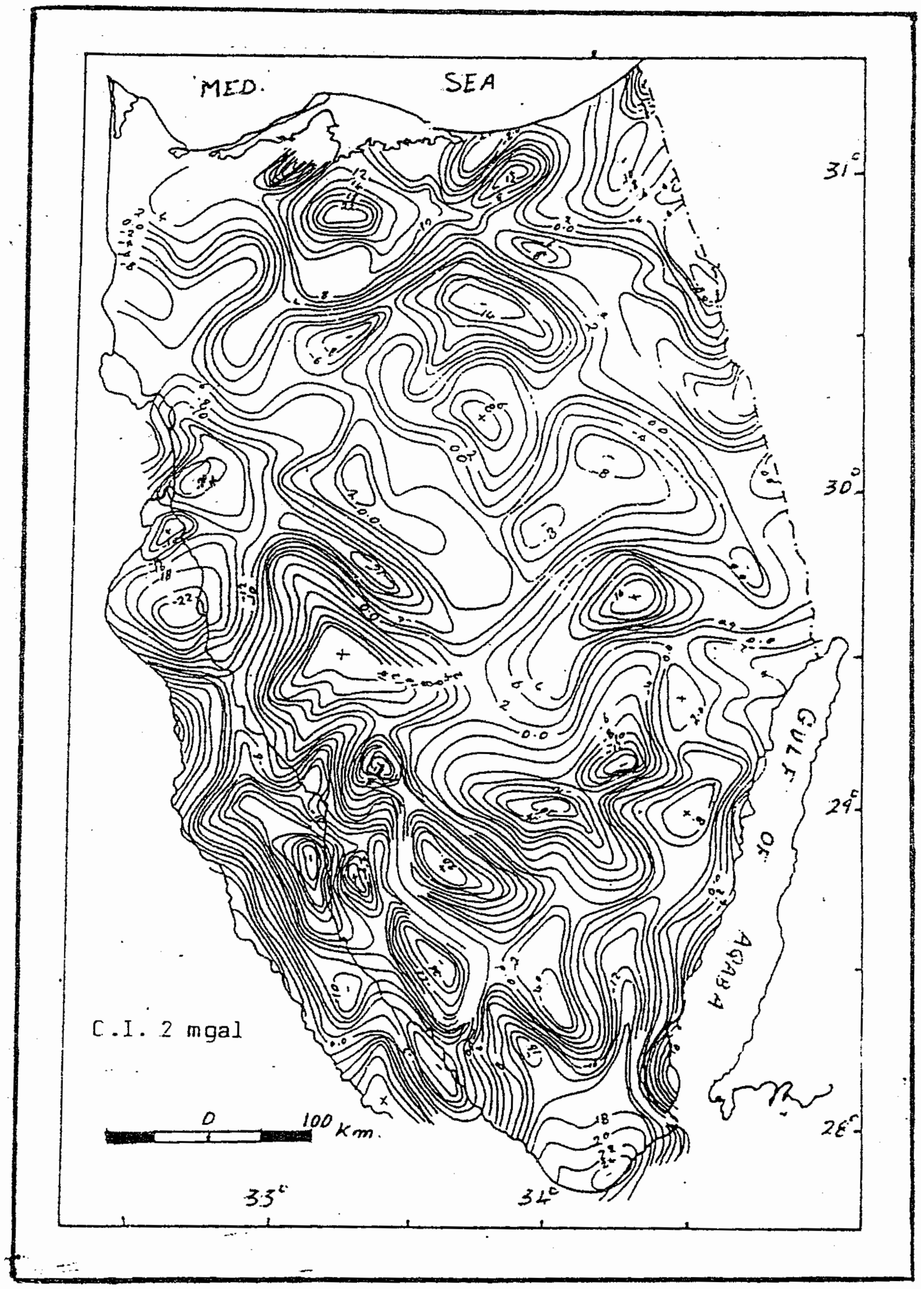

Fig. (3) Residual anomaly map

تكتونية صخور الركيزة المعقدة واحواض الترسيب فى شبه جزيرة سيناء - مصر

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تضمنت هذه الدراسة بشبه جزيرة سيناء تحليل نوعى وكمى لغرائب البوجير وشدة المغناطيسية الكلية للتعرف على شكل سطح القاعدة والتعرف على تراكيبها باستخدام عدة طرق لتأويل البيانات المغناطيسية والجاذبية وقد وجد أن عمق الركيزة المعقدة فى منطقة البحث متفق مع نتائج الحفر ووجد أن متوسط هذا العمق يتراوح مابين ٥ر٢ و٥ر٧ كيلو متر حيث تم اعداد خريطة توضيحية متكامله لتضاريس سطح الركيزة وأن هذا السطح مقعدا نظرا لوجود عديد من المرتفعات والاحواض . هناك شواهد على تعرض هذة المنطقة لقوى تكتونية مرتبطة بتكوين خليج السويس وخليج العقبه وsyrian arc وبالاضافة الى ذلك وجد أن الجزء العادى من القشرة الارضية قد تأثر بهذة القوى فى شكل فوالق وطيات لها نفس هذة الاتجاهات كذلك أمكن التعرف من وجهة النظر التركيبية على المناطق التى يحتمل أن يتراجد بها مياه جوفية وبترول وتركيزات معدنية .