Delta J. Sci. 12 (2)1988 520 - 538

THICKNESS OF THE EARTH'S CRUST IN NORTH EGYPT ESTIMATED FROM THE GRAVITY AND MAGNETIC DATA

BY

M.Sharaf*

*Geology Dept. Faculty of Science,Banha Univ, Eygpt.

Received : 4. 4. 1988

ABSTRACT

The thickness of the earth's crust (depth to the Moho surface) in North Egypt was calculated using the regional components of gravity and magnetic data . The regional gavity component was separated from the Bouguer anomaly map along two sets of profiles, one passing by points at equal depth to the basement and the other parallel along sets of profiles oriented N-S and E-W directions.

Correlation study of different emperical formulae relating gravity component with the thickness of the crust was carried out. Known values of crustal thickness along deep seismic profiles in North Egypt were used. A new emprical relationship between crustal thickness and gravity anomalies in the area under study was deduced.

Using the vertical magnetic data the thickness of the earth's crust was also calculated.

Accordingly a map for the Moho Surface was constructed. The thickness of the crust was found to range from more than 31 km in the southern part; to less than 31 km in the northern direction. This change is probably due to the transition from continental crust in the North Africa into intermediate crust in the Mediterraneansea.

Moreover, the depth to the lithosphere-asthenoshpere boundary was calculated and a tentative lithosphere thickness map was constructed.

INTRODUCTION

The Moho surface forms the fundamental background of the gravity field of the earth [5, 6, 8, 13] . Several emperical formulae representing the relationship between the gravity anomalies and the crust structure, deduced from deep serismic sounding, were calculated for different areas in the world [5 - 5 - 13 ,18]
In Egypt many authers had continued inthis field and different formulae were established for different areas in Northern Egypt [4, 9 , 15, 20].

In the present work the study area located between Latitude 28° 00 N to Mediterranean sea and Longitudes 25° ooE to 31° 30E (Fig. 1) . Assuming the regional gravity field changes linearly, it is possible to get this change along profiles passing by points of equal depth to basement. From such profiles it is possible to calculate the regional field which must be due to very smooth change in the thickness of the earth's crust.

Asimilar study has been applied by using a vertical magnetic field [1, 2, 5,].

METHODS AND TECHNIQUES

1) Gravity Methods:-

The gravity data used in the present study includes the Bouguer anomaly map, provided by the General petroleum Company 1984 (a scale 1 : 500,000 and contour interval 2 milligal), Due to the technical difficulties, this map was replotted ina scale 1: 2000, 000 with contour intervals of 10 milligal (Fig 2). Drill hole information, deep seismic refraction profiles and published material were also used. Sixteen main profiles passing by wells reaching the basement were constructed. Using Abu Roash well as a bas, the regional gravity values were calculated along these profiles. Secondary profiles oriented in N-S and in E-W directions were also used ; and the regional component at the points of their intersection with the main profiles had been calculated and used for constructing the regional anomaly map of the area (Fig. 3).

Eight emperical relationship are given in table (1). Each of them was used for calculating the crustal thickness (H) corresponding to each value of regional component (Δ g).

The correlation between the gravity anomaly and the depth to the Moho boundary (from seismic refraction profiles) in the area under study, was carried out using the regression analysis (Spiegel , 1972), assuming a linear model of the subsurface medium.

Table I. Emperical Relations Between Crustal Thickness (H) And Regional Gravity Anomalies (G)

FORMULA	REGION	REFERENCE
$H = 35(1 - \tanh 0.0037\Delta g)$	Whole earth	Dementiskaya , 1958
$H = 32 - 0.08\Delta g$	Whole earth	Woolard ,1959
$H = 40.5 - 32.5 \tanh (\Delta g + 75) / 275$	Whole earth	Woolard and Strange,1962
$H = 35 + 0.073\Delta g$	Whole earth	Sazhina and Grushinsky,1971
$H = 29.97 - 0.075\Delta g$	NE. Egypt	Riad. 1969
$H = 32.93 - 0.11\Delta g$	Quattara area	Darwish , 1979
$H = 32.93 - 0.11\Delta g$	Quattara area	Darwish , 1979
$H = 32.88 - 0.067\Delta g$	Bahariy area	Sharaf.et.al.1988
$H = 31.003 - 0.053\Delta g$	Egypt	Ghaleb, 1984

Magnetic Methods

consideringa two-dimensional body, infinite along the y-axis, them $\frac{\partial^2 u}{\partial x \partial y} = 0$, $\frac{\partial^2 u}{\partial y^2} = 0$ and its curvature would be defined as

$$R = \left[\left(\frac{\partial^2 u}{\partial y^2} - \frac{\partial^2 u}{\partial x^2} \right)^2 + \left(2 \frac{\partial^2 u}{\partial x \partial y} \right)^2 \right]^{\frac{1}{2}} \qquad \therefore R = \frac{\partial^2 u}{\partial x^2}$$

According to Laplace's general equation , $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} +$

$$+ \frac{\partial^2 u}{\partial Z^2} = 0$$

thus, for the two- dimensional case, $\frac{\partial^2 u}{\partial y^2} = 0$, and

$$\frac{\partial^2 u}{\partial x^2} = - \frac{\partial^2 u}{\partial Z^2} \text{ and So } R = \frac{\partial^2 u}{\partial Z^2} \quad \ldots\ldots \quad (1)$$

where U is the gravitational potential due to the mass of a body with a uniform density .

If the same body is magnetically polarized vertically, then according to poisson,

$Z = \frac{I}{\gamma \sigma} \left(\frac{\partial^2 u}{\partial Z^2} \right)$ where γ is the gravitational constant

$$\therefore \quad Z = \frac{I}{\gamma \sigma} R \quad (2)$$

Thus, the vertical magnetic effect of a vertically polarized two - dimensional body is of the same form as its curvature, and by using the proper constant one may be converted to the other. With certain a pproximations, the curvature in this case is expressed according to Netteltor (1940) as follows:-

$$R = \frac{\delta^2 u}{\delta x^2} = \frac{2\gamma\sigma t\, x}{x^2 + z^2}$$ where (t) is the depth

substituting this in equation (2), we get :

$$Z = \frac{2\, I\, t\, x}{x^2 + z^2} = \frac{2\, I\, t}{z} = \frac{x/z}{(x/z)^2+1} \qquad \ldots\ldots\ldots (3)$$

Also, according to Nettelton, $Z = \left(\frac{2It}{z}\right) F''_k \left(\frac{x}{z}\right) \ldots\ldots (4)$

where $F''_k \left(\frac{x}{z}\right) = \Pi$ in the two dimensional case

Therefore, expression (4) would be in the form of $\Delta z = \frac{2\pi I \Delta t}{z}$ (5) where (Δ z) is the difference of the vertical magnetic field values between two arbitrary points in gamma,(Δ t) is the difference in the depth at these two points in kilometers; (Z) is a given depth to the Moho- surface and (I) is the mean intensity of magnetization of the crust ; where $I = Z/2\Pi$.

If we consider the depth of the Moho at Abu Roash is equal to 32.5 km After Riad [15], Tealeb, [4] and Sharaf [19] and taken as a reference point; the depths to Moho at other places were calculated from the vertical magnetic map (Fig 4) using the previously equation (5).

CRUSTAL THICKNESS

The regional anomalies and the corresponding values of the crustal thickness, along the deep seismic refraction profiles and for each point previously calculated, were plotted (Fig. 5) and used for calculating the regression equation. Using the least square method the best fit line was found to satisfy the following relation :-

$$H_c = 32.78 - 0.069 \quad g \quad \ldots\ldots \; (6)$$

S.D. =1.09   C.C= -0.93

The standard deviation (S.D) and correlation coefficients (c.c) show that the equation (6) is more reliable formapping the crustal thickness (Hc) in North Egypt.

All data deduced from the gravity and magnetic values used for mapping the crustal thickness (Fig.6).

TENTATIVE LITHOSPHERE THICKNESS

The lithosphere-asthenosphere boundary (Lithosphere thickness) is supposed to reflect their behaviour on the character of the regional gravity. Tentative lithosphere thickness map for the area under study was compiled using the emperical formulal-

$$H_L = 123 \pm 0.476 \quad g \quad (1^\circ)$$

Which was previously calculated for Egypt and Africa

[16], [9] and [17] on the basis of a model for standard African crust and lithosphere [3].

Averaging anomalies to the wavelength ($\simeq$ 250 kms) of the Bouguer field over a 1° grid; Fig 7; were considered to reflect the behaviour of the lithosphere-asthenosphere boundary. Tentative lithosphere thickness map was constructed (Fig 8).

The lithosphere thickness in the north-west corner of the area reachs about 100 km and increases southwards. To the southeast and southwest, the lithosphere thickness increases gradually, to more than 140 km in both corners.

CONCLUSION

From the analysis and interpretation of the gravity and magnetic data in the Northern Western Desert, the following are concluded:-

1- The regional Bougue anomaly values are closely related to the crustal structure. The bestfit equation relating the crustal thickness to the regional values was found ($H_c = 32.78 - 0.069\ g$) and used for mapping the crustal thickness.

2- Also, the magnetic values were used, confirm the gravity data , for calculating the crustal thikness using equation $\Delta z = \frac{2\pi 1 \ \Delta t}{Z}$

3- The thickness of the earth's crust changes regularly in NW direction which reaches the minimum value (less than 31 km) at the northern part and the maximum value (more than 36 km) at the southern part of the area.

4- The Bouguer anomalies averaged over 1° grids (long wavelength) were used for mapping the depth to the lithosphere-asthe-nosphere Boundary. Tentative lithosphere thickness map was constructed . Thinning of the lithosphere was obtained, along a NW-SE trend, in the Northern Egypt.

5- The change in the thickness of the crust is probably due to the transition from continental crust in North Africa into intermediate crust in the Mediterranean Sea.

6- The shape of the reliefs of the Moho and lithosphere-as-themosphere boundaries in North Egypt showed that it is structurally and tectonically related to syrian Arc and the Mediterranean region systems.

REFERENCES

1- Ahmed, F.M., Deebes, H. and Fahim, M. 1978:- The Geomagnetic vertical Component in Egypt Reduced to Epoch 1975.0 " H.I.A.G." Bull. No. 165

2- Ahmed, F.M., Deebes, H., Fahim,M., Gouda , H.A, and

Hassaneen, A. 1974: The Absolute Geomagnetic components of the Western Desert Region, Egypt Reduced to the Epoch 1977-0 "H.I.A.G" Bull-No.235.

3- Brown,c. and Girdler, R.W.(1980) Interpretation of African Gravity and Its Implication for the Break up of the Continents. Jour. of Geoph. Res., v.85, No. B11, 6443 - 6455.

4- Darwish, Y.A.M., 1979:- Geological Interpretation of Gravity anomalies on the Quattara Depression area, Western Desert, Egypt. Ph.D. Thesis, Assuit, Univ. Geol. Dept.

5- Deebes,H., Gouda, H.A., Fahim, M. and Ahmed, F.M.,1980:- the Absolute Geomagnetic Field components of the Nile Delta Region Reduced to the Epoch 1977.0 "H.I.A.G. "Bull-No 236

6- Demenitskaya, R.M., 1958:- Planetary structures and their reflection in Bouguer anomalies. Sov. Geol., 8.

7- Demenitskya, R.M., 1967 :- Crustand Mantle of the Earth. Nedra, Moscow, 280 pp

8- Demenitskaya,R.M., and Belyaevsky, N.A., 1969 :- the relation between the earth,s crust surface relief and gravity field in the USSR, In: The Earth's crust and upper Mantle. Am. Geophys. Union Geophys., 13: 312 - 319 .

9- Ghaleb, M., A. 1985 :- Geophysical studies In Egypt And the Eastern Mediterranean- PH.D.Thesis , Cairo Univ.

10- Grabowska, T.Maloszewski, S. and Ney, R. (1979):- Interpretation of Gravimetric and Magnetic Anomalies along VII th international profiles in Poland. Publ. Inst. Geophys. Pol. Acad. Sc., A-2(101), 25-23.

11- Grabowska, T.; Malozewski, S; Ney R_1 and Raczynska, M.(1980) statistical Investigations of the Relation Between the Gravity Anomalies and the Earth's Crust thickness along DSS profile VII, M-7,LT-2.
publ. Inst. Geophys. pol. Acad. Sc. A-8(130), 17-32.

12- Grabowska, T.(1980):- Interpretations of the Gravimetric and Magnetic Anomalies with the Earth's crust structure with the Lublin Region Including the Results of Deep scismic sounding (Profiles V111, Lt-3,c) publ. Inst. Geophys. pol.Acd Sc., A-8 (130), 157 - 168

13- Pick, M., Picha, J, and vyskocil,V. (1973):- Theory of the Earth's Gravity Field. Acad., publ. House of the CS Acadamy of sciences. progue.

14- Nettelton, L.L.1940:- Geophysical prospecting for oil. Mc Graw-Hill Book company, INC.

15- Riad, S., 1969:- Using Gravity Survey for studying Deep Structures of North African Platform Within the Northeastern part of U.A.R.: PH.D. thesis, Moscow state Univ. Moscow.

16- Riad, S. ; Fouad,A. Refai, E. and Ghaleb, M.(1983) preliminary Interpretation of Regional Gravity Anomalies of Egypt. paper presented at the XV111 General Assem. of the IUGG, Hamburg.

17- Riad,S. and EL-Etr, H.A. (1985):- Bouguer Anomalies and Lithosphere-Crustal thickness in uganda, Jour. of Geodynamics,3,169-186.

18- Sazhina,N., Grushinsky, 1966:- Gravity prospecting.Mir pub. USSR. Moscow.

19- Sharaf, M. 1984:- Interpretation of Bouguer Anomalies of EL-Faiyum Area In Terms of Subsurface Geological structures pH.D. Thesis, Assuit Univ.

20- Sharaf.M.,El-Awady M., Zahra.H., 1988:- Analysis of Gravity anomalies in El-Bahariya Area, Western Desert-Egypt and their tectonic significances (in press).

21- Sharma,P.V.,1976. Geophysical Methods in Geology. Methods in Geochemistry and Geophysics 12. Elsevier, Amsterdam, 428 PP.

22- Spiegel, M.R. (1972) Theory and Problems of Statitics, SI (metric) ed., Shaum's outline Series, Mc Graw. Hill Book company, New york.

23- Stokes , W.L., Judson, S.and Picard, M.D., 1978. Introduction Geology, Physical and Historical, 2nd edition. Prentice-Hall, U.S.A., 656 PP.

24- Tealeb, A.A., 1973:- Gravity investigation of West Cairo area. M.Sc. Thesis, Cairo Univ.

25- Vyskocil, V., 1972:- Correlation between Cravity Anomalies and the crust-Mantle Boundary in central Europe Studia-geoph.et. geod., V.16 329 - 338

26- Woolard, G.P.1959 Crustal structure from gravity and seismic measurements. J. Geophys. Res., 64(10): 1521 - 1544.

27- Woolard, G.P., 1969 a standardization of gravity measurements in the earth's crust and upper mantle. Am. Geophys. Union Geophys. Monoger., 13: 283-293.

28- Woolard, G.P., 1969 b Regional variations in gravity in the earth's crust and upper mantle. Am. Geophys. Monogr., 13: 320 - 341.

29- Woolard, G.P. and Strange, W.E., 1962. Gravity anomalies and crust of the earth in the PAcific Basin In: The crust of the pacific Basin. Am. Geophys. Monogr., 6: 60 - 80.

30- Young, K., 1975. Geology, the Paradox of Earth and Man. Houghton Mifflin, Boston, Mass., 566pp.

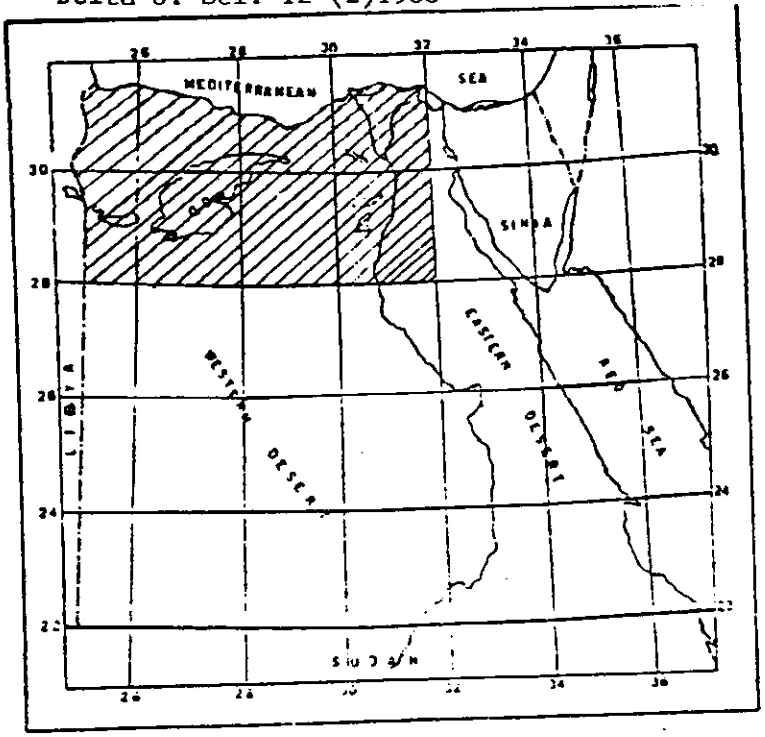


Fig 1 Location Map of the study Area

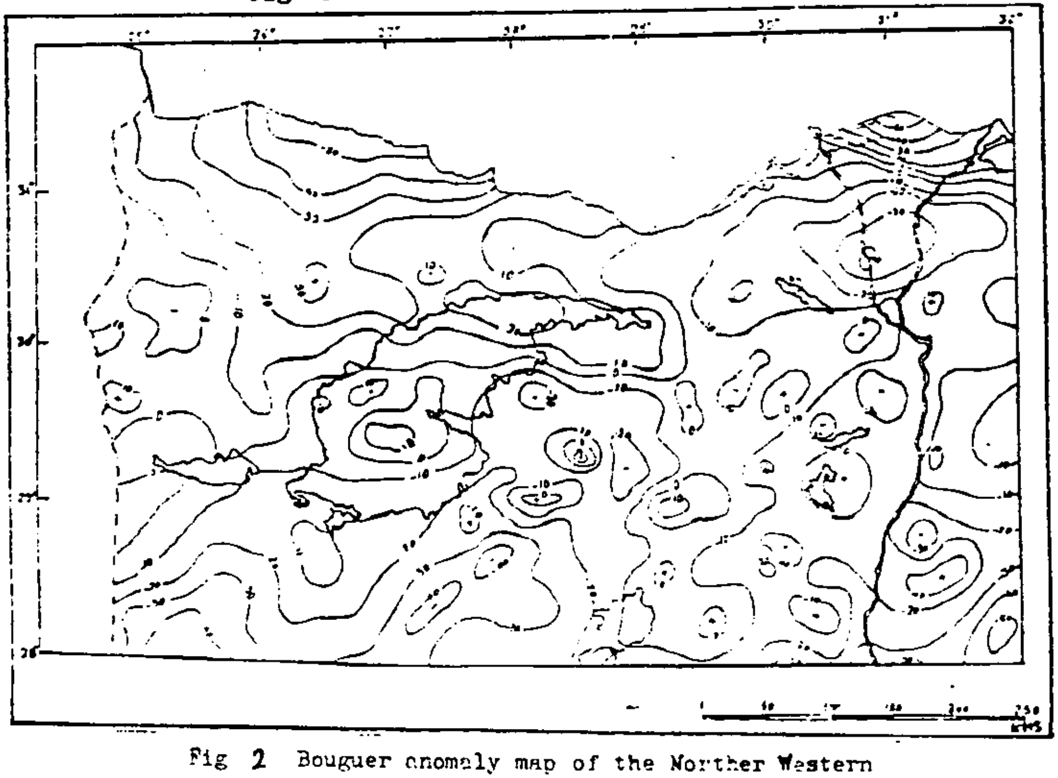


Fig 2 Bouguer anomaly map of the Norther Western Desert, Egypt (After C.P.C. 1985)

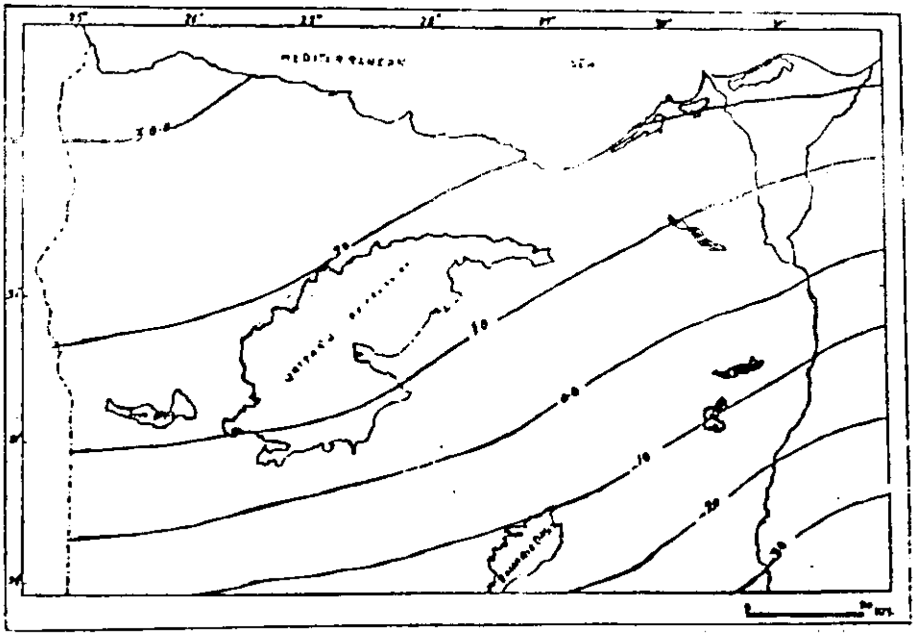


Fig (3) Regional Component of the Bouguer Anomaly Field in the North of Egypt.

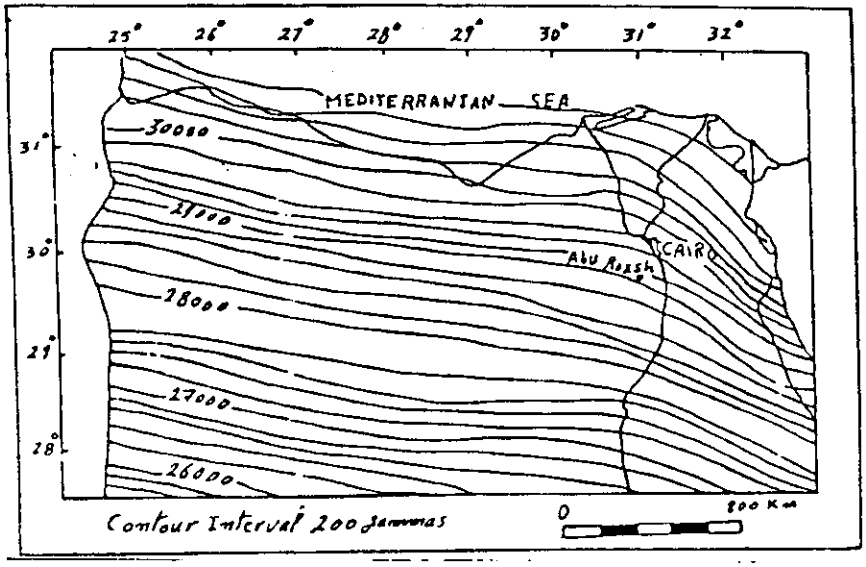
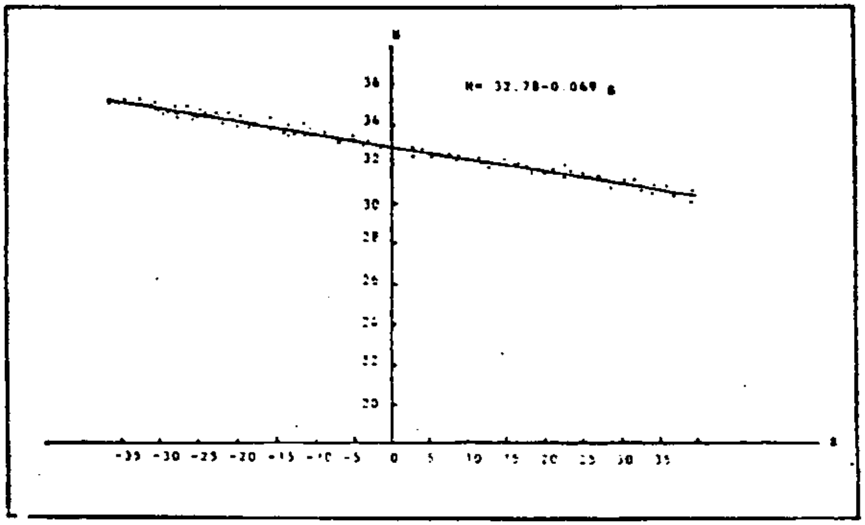


Fig. (4) Isomagnetic Lines of vertical component Reduced to 1977(After Ahmed, F. et.al (1980)



Fig(5) Relation Between the Average Crustal Thickness (H) and The Regional Anomaly (Δg) in the North of Egypt

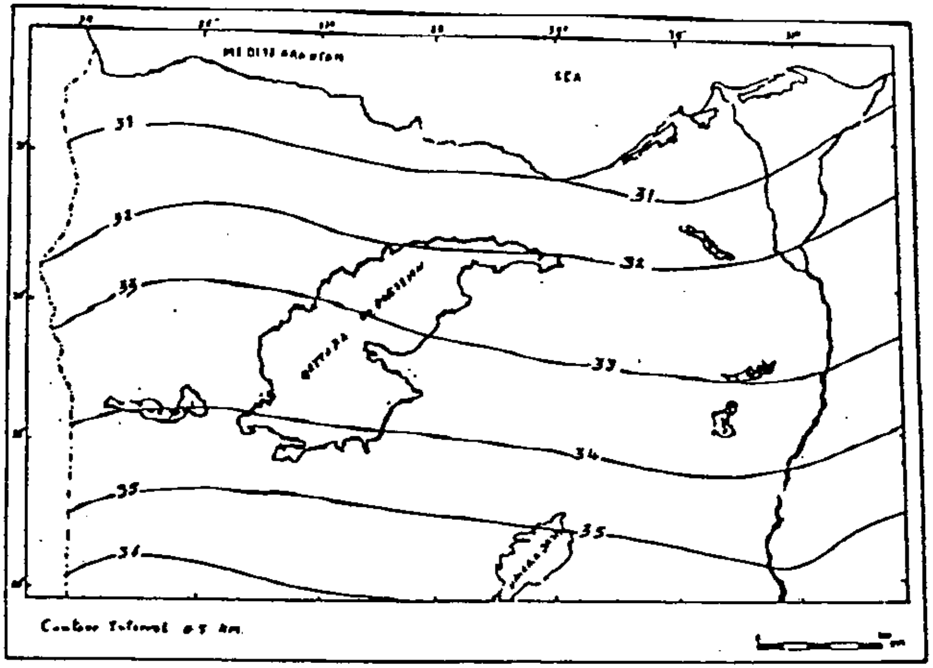


Fig 6 Crustal thickness map in the north of Egypt.

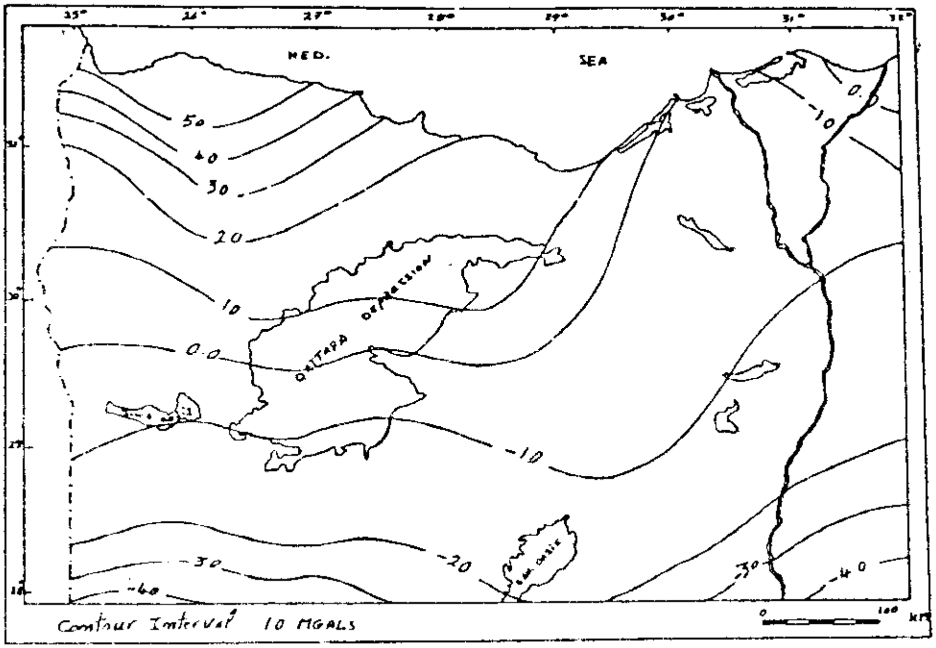


Fig.(7) Bouguer Anomaly Map of Northern Western Desert (After Anomaly values Averaged over 1° Grids

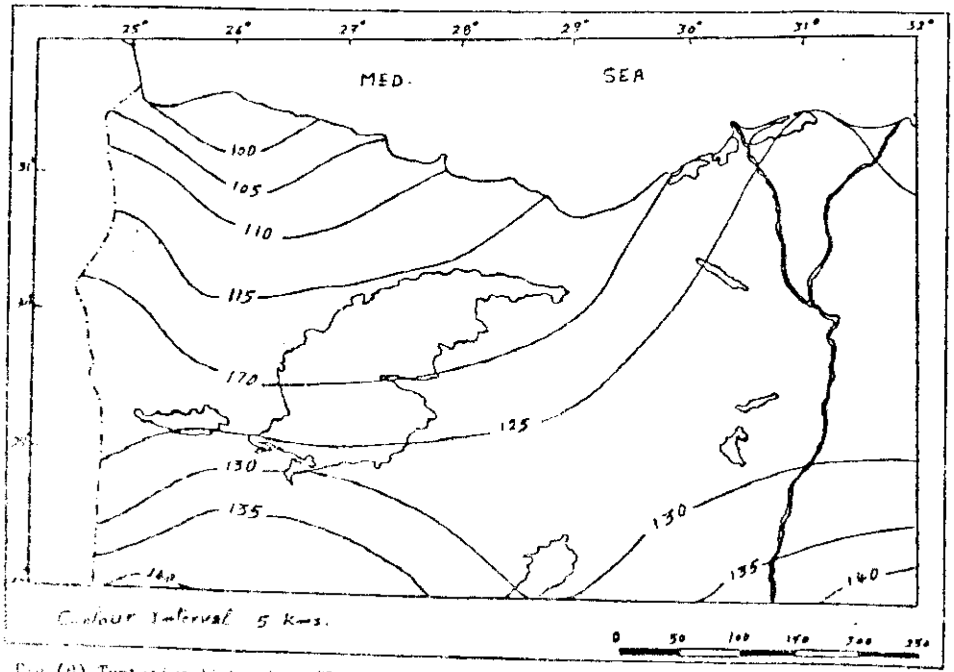


Fig.(8) Tentative lithosphere Thickness Map For Northern Desert (After Anomaly

سمك القشرة الارضيه فى شمال مصر محسوبه من بيانات الجانبيه والمغناطيسيه

محمد شرف الدين حافظ نعيم
قسم الجيولوجيا ـ كلية العلوم (بنها) جامعة الزقازيق ـ مصر

تقع منطقه البحث فى الجزء الشمالى من الصحراء الغربية ووادى النيل شمال خط عرض ٢٨ شمالا • بيستهدف الباحث من هذه الدراسة تفسير قياسات الجاذبية والمغناطيسية للتعرف على السلوك العام للقشره الارضيه لما له من فائده عظيمه فى التعرف على الوضع التركيبى التحت سطحى للمنطقة •

ومن خلال التحليل الكمى لشذوذ البوجر امكن فصل مجال الجاذبيه الى مركبتين على بروفيلات تصل احدهما بين الابار التى تصل اعماقها الى صخور الركيزه المعقده والاخرى بروفيلات طوليه وعرضيه حيث تعزى احدى هاتين المركبتين الى التراكيب التحت سطحيه العميقه ذات الامتداد الاقليمى (المركبه الاقليميه Regional component) • حيث وجد أن قيمه المركبه الاقليميه تزداد كلما اتجهنا نحو الجزء الشمالى الغربى من المنطقه ومن قيم سمك القشره على بروفيلات سيزميه فى منطقه البحث وقيم المركبه الاقليميه المناظره على هذه البروفيلات وايضا باستخدام المعادلات الخاصه بايجاد سمك القشرة الارضية امكن استنتاج القيم المتوسطه لها فى هذه المنطقة • وبدراسة العلاقة بين هذه القيم ومجال الجاذبيه الاقليميه باستخدام طريقة أقل المربعات Least square methods وجد أن هناك علاقة خطيه بينهما على الصوره $H_c = 32.78 - 0.069\, \overset{2}{g}$ ومن هذه المعادله واستخدام ايضا المجال العمودى للمغناطيسيه الارضيه أمكن حساب سمك القشره الارضيه ووجد أن قيمته تتراوح بين ٣١ كم فى أقصى الشمال و ٣٦كم فى أقصى الجنوب • ويعزى هذا التغير فى قيمه السمك الى الانتقال من الوضع القارى لشرق افريقيا الى

الوضع المائى للبحر المتوسط • وكذلك قام الباحث بتعيين سمك الغلاف الصخرى Lithosphere باستخدام مجال الجاذبيه الاقليمى المحسوب بطريقة المتوسطات على شبكه منتظمه (كل درجه أ) من خريطة البوجير •