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GEOLOGICAL HAZARD AT RAS EL-BAHAR AREA AS DEDUCED FROM POTENTIAL FILED DATA AND EARTHQUAKES DISTRIBUTION

H.T. EL-Badrawy,*M.R. Soliman, and T. Heba**

* *Biological and Geological Dept., Faculty of Education at Kafr El-Sheikh, Tanta University.*
** *Department of Geology, Faculty of Science, Tanta University, Egyp.*

المخاطر الجيولوجية فى منطقة رأس البحار باستخدام بيانات الجهد التثاقلى وتوزيع البؤر الزلزالية.

الخلاصة: تتناول هذه الدراسة تفسيرات تشوهات القص وتأثيراتها التكتونيكية فى منطقة راس البحار ومن خلال قيم شذوذ بوجير وخرائط المغناطيسية أمكن تحديد نطاقين رئيسين للقص يمثلان صدوعاً مضربية فى الناحية الغربية للمنطقة، كما تم تحديد ثمانى مجموعات بارزة من الصدوع العادية وازاحات جانبية أثرت على الصخور القاعدية بالمنطقة وذات اتجاهات إلى الشمال الغربى (اتجاه خليج السويس) والشمال الشمال الشرقى (اتجاه خليج العقبة).

وقد أوضحت الدراسة أيضاً أن العمق إلى صخور القاعدة بناءً على شذوذ بوجير يتراوح ما بين نصف كيلومتر و٣,٥ كيلومتر، بينما تشير نتائج المغناطيسية إلى وجود هذا العمق ما بين ٠,٤ كيلومتر و٧,٨ كيلومتر، كما أن الصدوع ونطاقات القص التى تم تحديدها هى من النوع النشيط زلزالياً وهى المسئولة عن الأضرار السيزمية بالمنطقة والتى سببتها الزلازل التى ضربت المنطقة حديثاً وبلغت قوتها ما بين ١-٣,٩ بمقياس ريختر.

هذا وقد حددت الدراسة كذلك ثلاثة أحزمة بارزة من الصخور القاعدية ترتبط بطية راس البحار المحدبة وطيتى شرق وغرب خليج الزيت والتى تعتبر جميعها ذات إمكانيات بترولية جيدة.

ABSTRACT: *The present study aims to interpret the shearing deformations and their tectonic implications at Ras El-Bahar area. From the Bouguer anomaly and RTF magnetic maps, two major sets wrench (shear) zones mostly of strike-slip faults were delineated in the western side. Eight major sets of normal and left and right lateral horizontal displacements have affected the basement rocks in the study area -with NW system (Suez trend) and NNE system (Aqaba trend).*

The approximate depth estimated using the absolute value of the 3-D analytic signal technique ranges between 0.5 to 3.5 km. The average depth levels of the causative sources deduced by using Power spectrum technique on the Bouguer anomaly and RTP maps, range also between 0.5 to 3.5 km. The depth to faults using Euler solution for the Bouguer anomaly map ranges from 0.5 to 2.5 km, while for the magnetic data the depth ranges from 0.4 to 7.8 km.

The interpreted faults and shear zones in the study area are seismically active and responsible for the seismic hazard in this area, where the recent earthquakes of magnitude 1 to 3.9 are spatially scattered and associated with both sides of these zones. Three major uplifted belts of the basement in this area, associated with Ras El Bahar anticline and East and West Zeit Bay anticlines are considered to be good potential areas for oil prospecting.

INTRODUCTION

The Gulf of Suez region represents one of the most prolific and prospective oil and gas provinces in Egypt. It cannot be considered stable during a long span of time, at least since the late Cretaceous to Oligocene due to deformations and volcanic eruptions which prove the high seismisity of this area during these times. The seismic activity in the Gulf of Suez is intense high at the southern entrance of the Gulf. Almost all earthquakes occurred at the center of the Gulf of Suez, the northern end of the Red Sea and the Gulf of Aqaba where old and new plate boundaries between the African and Arabian plates exist (Hurukawa et al., 2000).

The principal target of the present study is to analyze the Bouguer anomaly and areomagnetic maps, as well as the seismic activity in the southwestern comer of the Gulf of Suez located between latitudes 27°32'-28°00'N and longitudes 33° 25'-32° 35' E (Fig. 1). This analysis is used to evaluate the regional tectonic framework of this area and to detect the relation between the subsurface structures and the seismic activity in the study area.

Geological Background

The stratigraphy of the studied area is based on information obtained from seven wells drilled by the General Petroleum Company (GPC). The study area is made entirely of sedimentary rocks of Eocene, Oligocene, Miocene, Pliocene and Recent ages and consists of a thin section of calcareous material intercalated with sandstone. Generally, the Miocene rocks in the studied area can be subdivided into two major units: The Evaporite unit of Middle Miocene age, and the Gharandal clastic unit of Lower Miocene age. The evaporite unit underlies the Pliocene-Recent clastic sediments and comprises the following formations from top to base:

a- Zeit Formation: is composed of intruded beds of anhydrite and shales with a few salt beds in the lower part of the section.

b- South Gharib Formation: is composed mainly of salt and anhydrite intercalated with thin beds of shale or sandstone.

c- Belayim Formation: is composed of rock salt with streaks of anhydrite in its upper part, while the lower part is mainly anhydrite with shale intercalation.

d- Gharandal Group is subdivided into three formations from top to base: Kareem Formation, Rudeis Formation and Nukhul Formation.

The Eocene and Pliocene rocks are encountered in Ras El Bahar Well no. 2 only and is composed of a thin section of limestone,

PROCESSING OF POTENTIAL FIELD DATA

The Bouguer anomaly map of the study area is used as the main source of the gravity information which is compiled by General Petroleum Company (1985) at scale 1:500,000 (Fig.2). This map shows a major regional minimum of large amplitude trending NW-SE. The large minimum (-28 mgal), is associated with the synclinal structural along the part of the coastal plain of the Red Sea lying within the studied area. Two major gradients bounded this large minimum are evident on both sides. They are ascribed to be due to two large basement faults or fault zones bounding the synclinal structure. The direction of slope of the gravity gradients is shown in the grid vector map.

The reduced to the magnetic pole (RTP) map of the study area was compiled by the Aero Service Division Western Geophysical Company of America (1982) at scale 1:500,000 with contour interval of 25 nT, (Fig. 3). This map is characterized by very strong magnetic anomalies with different amplitudes at the northern, northeastern and southwestern parts. These anomalies may be attributed to the occurrence of subsurface basic intrusion of high magnetic content with high susceptibility, or coincide with the minor volcanic exposure.

Both the Bouguer anomaly and the RTP maps of the study area are separated into residual and regional using both Butterworth residual filter (as shown in Fig. 4) and least squares fiber technique (Abdel Rahman et al., 1985), as shown in Fig. (5).

The apparent susceptibility distribution is calculated from RTP data at different depths (Fig. 6). These maps exhibits distinct locations of high magnetic susceptibilities associated with positive anomalies of high amplitudes and steep gradient located in the northeastern and southwestern parts of the maps. The high susceptibility values suggest that the rock type may be related to granites or gabbros, which are rich in magnetic minerals or magnetic ore deposits.

Depth Estimation

Faulting pictures at different levels of the gravity and magnetic data are carried out using Euler Deconvolution technique (using Geosoft, V.4.00.03), with different structural indices (SI) according to Reid et al. (1990). The solution of the Bouguer anomaly map with SI == 0 for probable faults at depths from 0.5 to 2.5 km is represented in Figure (7).

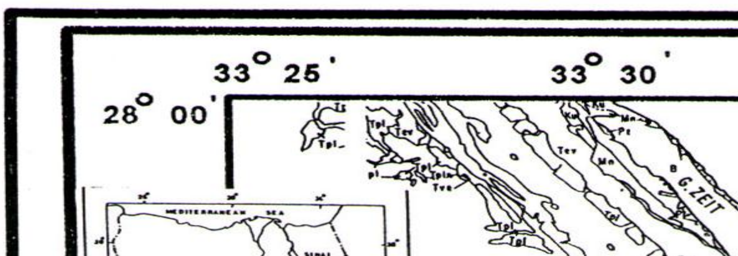
For the magnetic data, Euler solutions at different depths are represented in Figure (8). The plot of the first solution shows the faults picture at depths ranging between 0.4 and 1.0 km. The second shows the faults picture at depths from 1.0 to 2.0 km. the third represents the pictures at depths from 2.0 to 3.0km. The fourth shows the pictures at depths from 3.0 to 4.0 km, while the last one represents the pictures at depths from 4.0 to 7.8 km.

To estimate the average depth levels of the causative sources in the study area,3-D analytic signal according to Roest et al., (1992) and Macleod et al., (1993) and energy spectra techniques (using Geosoft, V.4.00.03) are carried out on both the Bouguer anomaly and R.T.P. maps. The estimated depths using the absolute value of the 3-D analytic signal technique are shown in Figure (9). The average depth levels of the causative sources deduced using the power spectrum technique from the Bouguer anomaly and RTP maps are shown in Figure (10).

Two and one half dimensional modeling along a number of selected profiles were carried out using GeoModel program developed by Cooper (1998). The to gain more information about the geometry, parameters, susceptibilities and depths of the causative sources. In order to improve the fitness of the calculated and observed curves and to modify the shape and other attributes of the models, the theoretical anomaly was calculated over 2 *Vz* -D bodies to establish the structural set-up of the basement configuration. The results (Fig. 11) revealed that the basement rocks in the study area show a very wide range in their composition as reflected by their susceptibilities, which range between 150 and 850 X 10^{-6} c.g.s. units. These values have been readjusted during the modeling. The results of the gravity profile (GB2) and the magnetic profile (Bl) are presented as illustrating examples.

The results obtained from the application of the different techniques are integrated and supplemented by geological information were used to construct and illustrate the configuration of the subsurface basement rocks (Fig.12).

For integrating between the seismic activity and the interpreted subsurface structures in this area, the data of recent seismicity were utilized as derived from earthquakes catalogues, published papers as Riad and Meyers(1985);Ambraseys, (1991); Ambraseys et al., (1994); Shater and El-Amin (2000); Riad et al. (2000) and Ismail, et al., (2000), as shown in Figure.(l3). These recent seismicities were correlated (linked) with the interpreted subsurface tectonic elements in the study area, Fig. (14). In this study, the given evaluation is based mainly on the generally accepted concepts of the earthquake epicenter distribution.



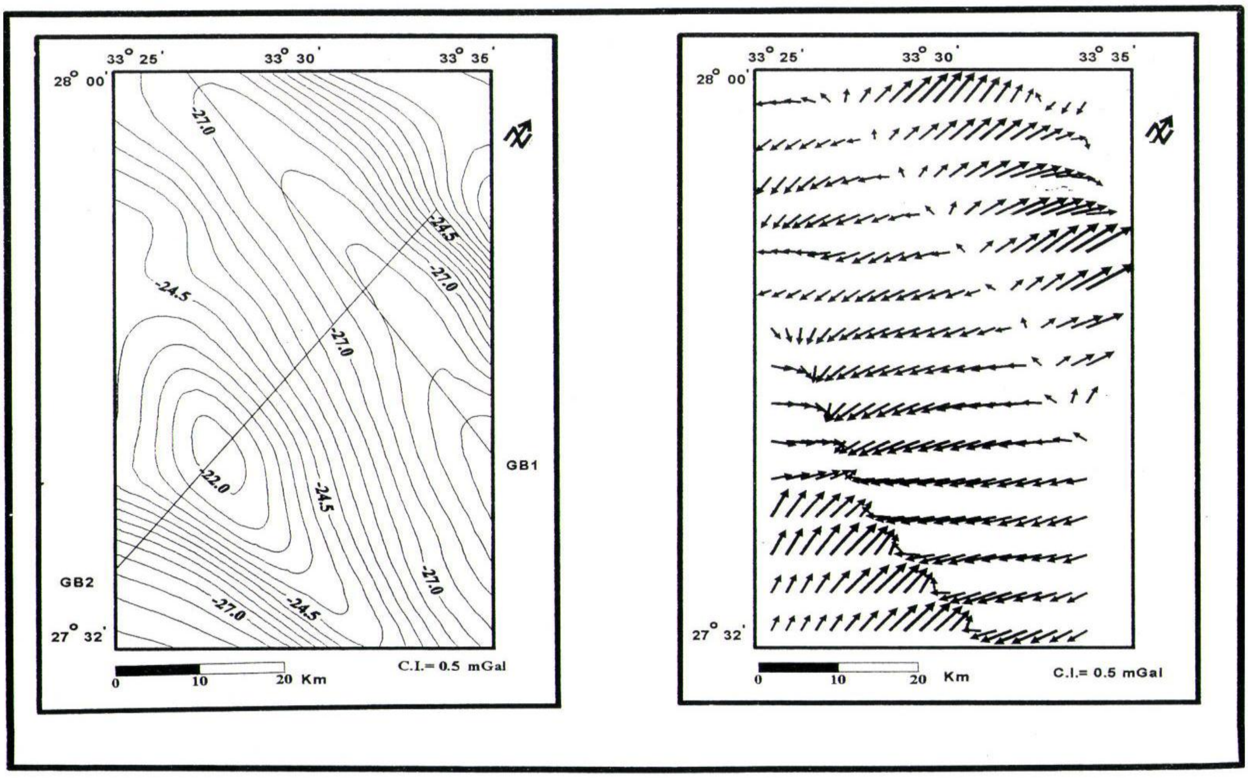


Fig. (2): Bouguer anomaly and its grid vector maps of the study area (after GPC, 1986)

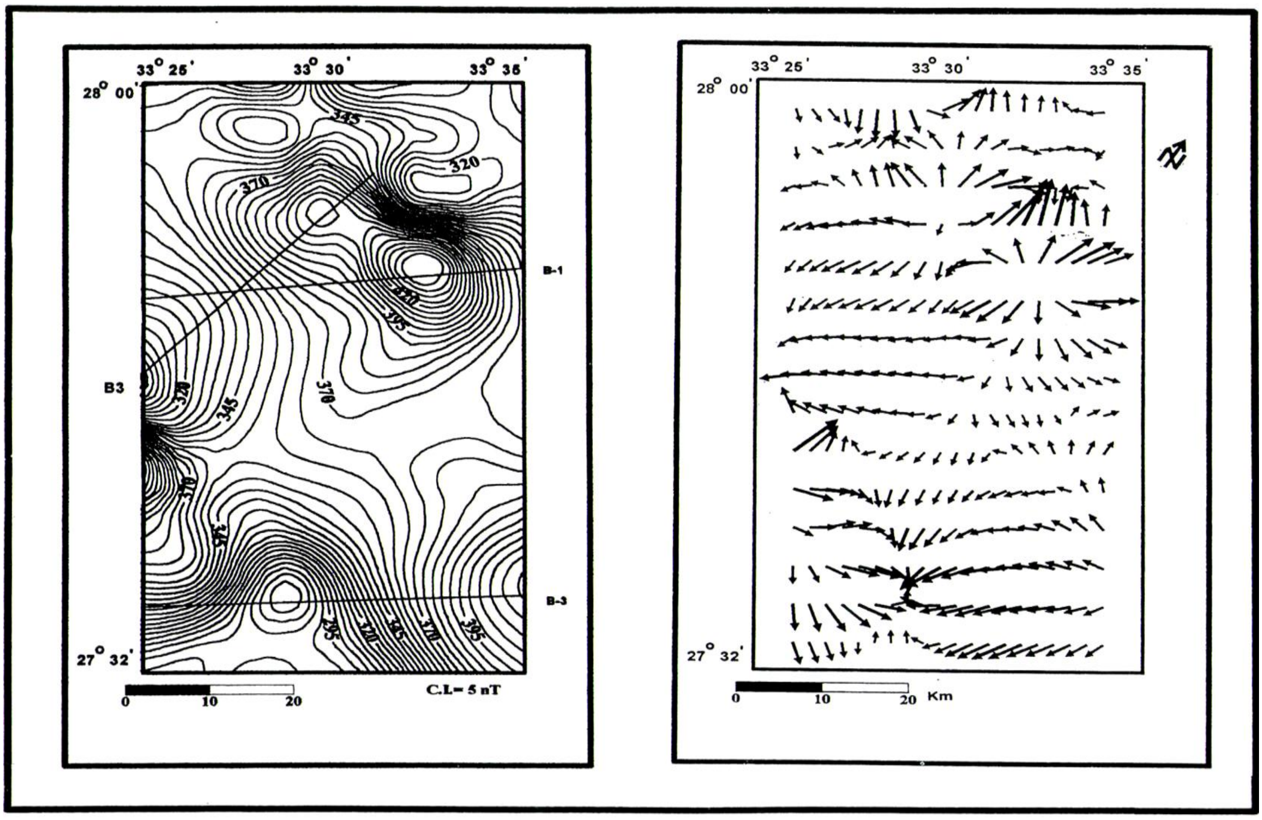


Fig. (3): R.T.P. and its grid vector maps of the study area (after Aeroservice, 1984)

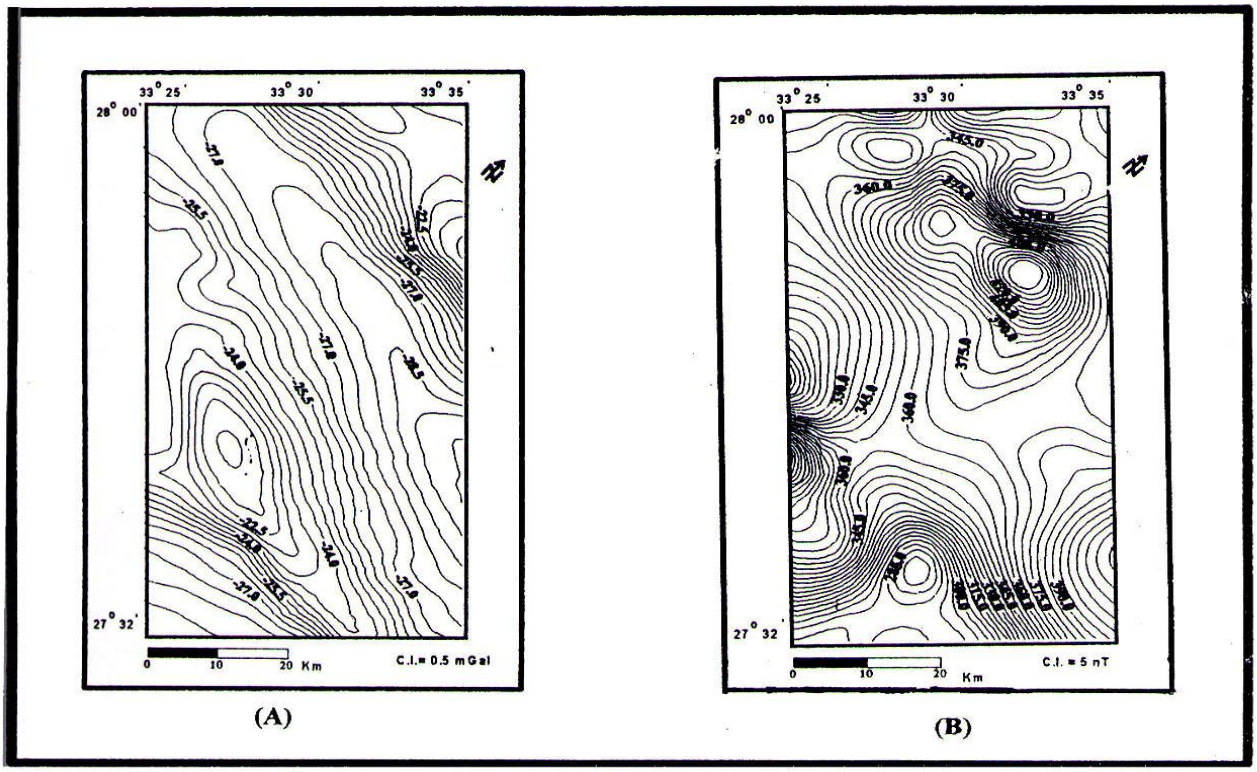


Fig. (4): Butterworth residual filter of the gravity (A) and the R.T.P. data (B)

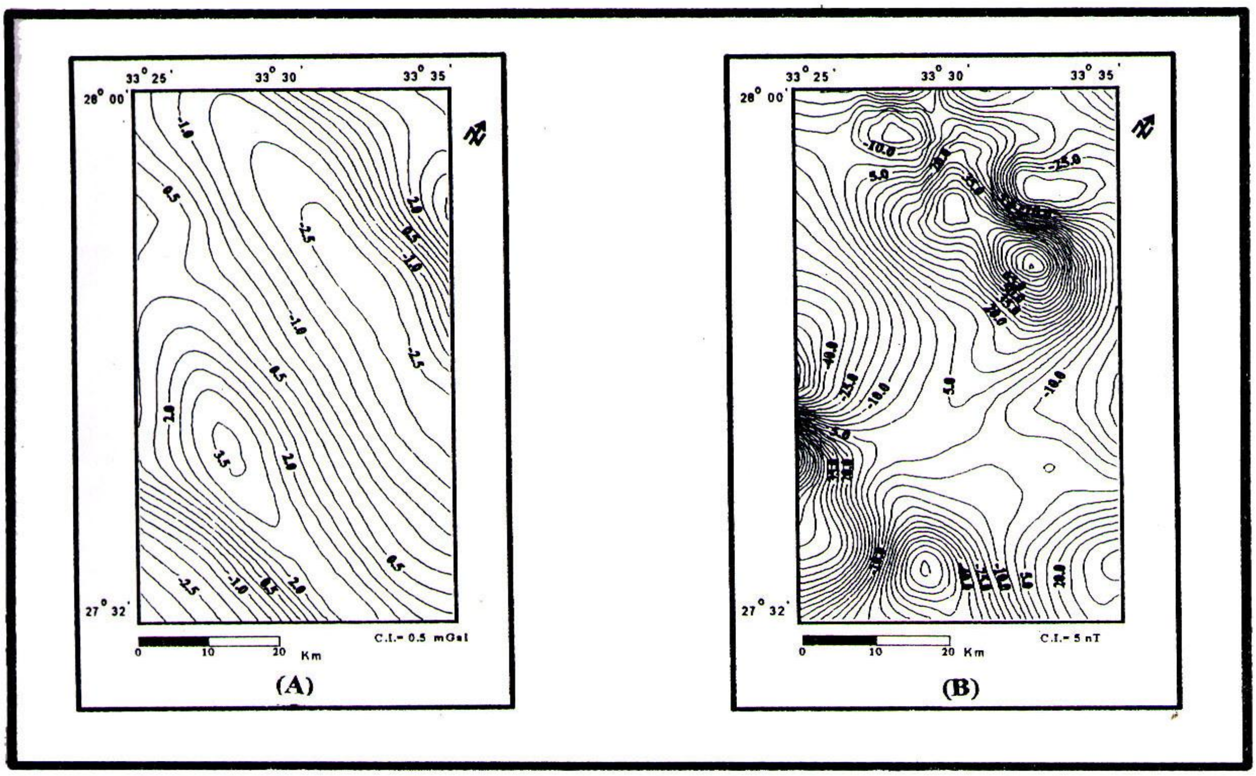


Fig. (5): Least-square (2nd order) residual of the gravity (A) and the R.T.P. data

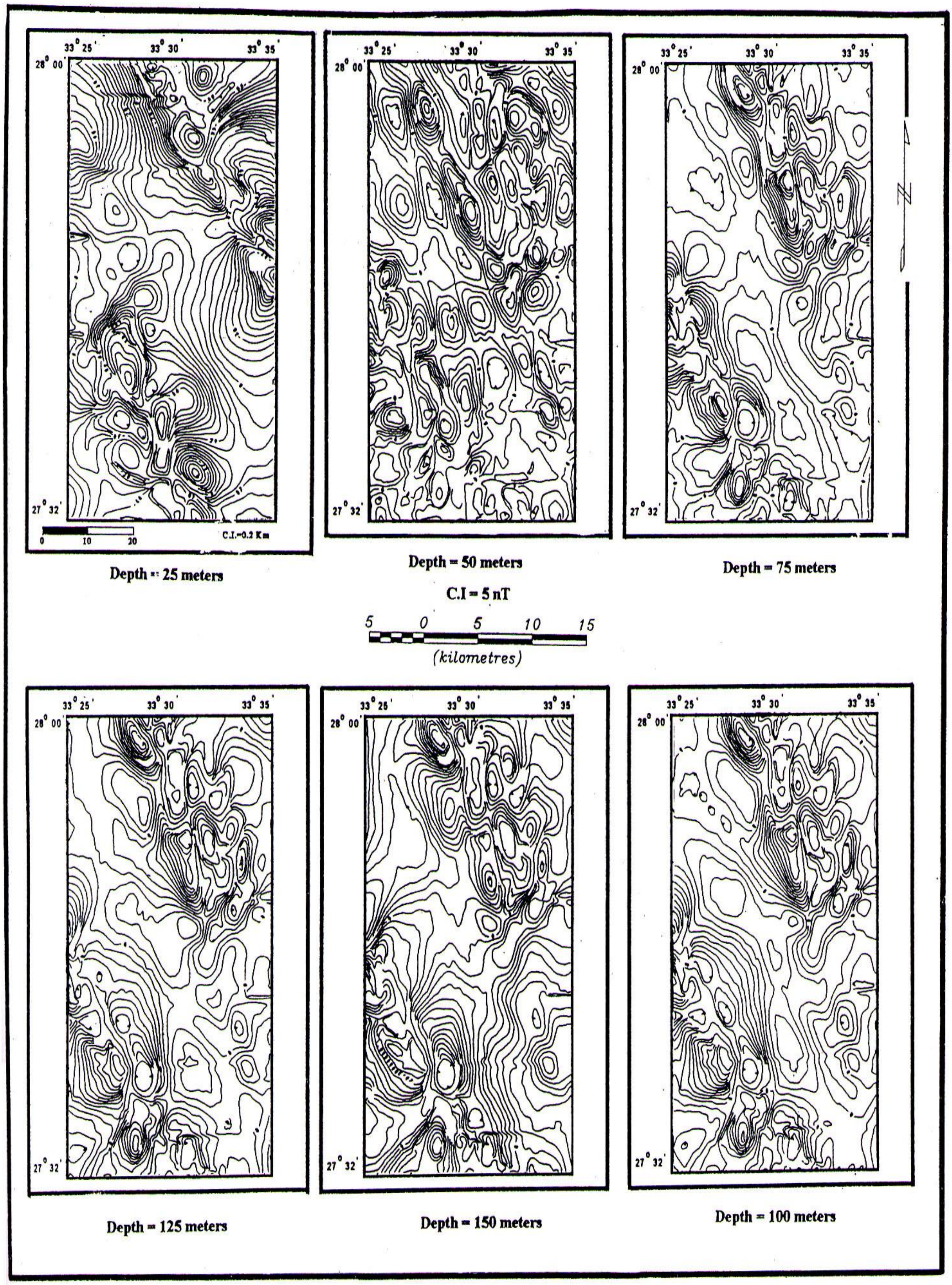


Fig. (6): Apparent susceptibility measured at different depths

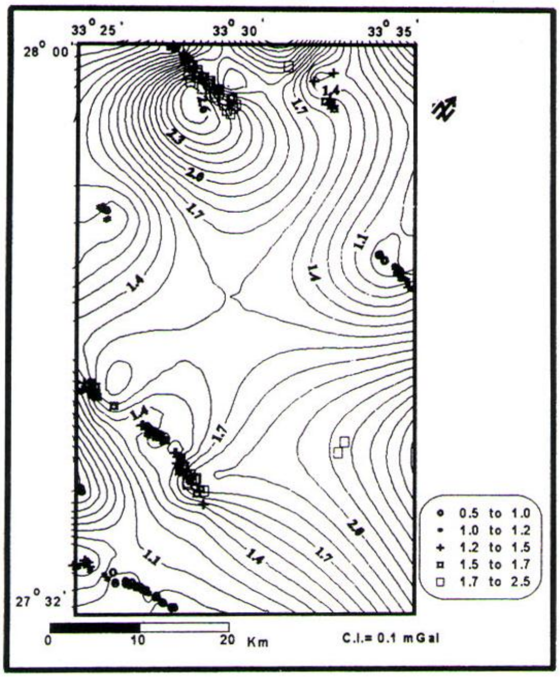


Fig. (7): Euler deconvolution of Bouguer anomaly map (S.I. = 0)

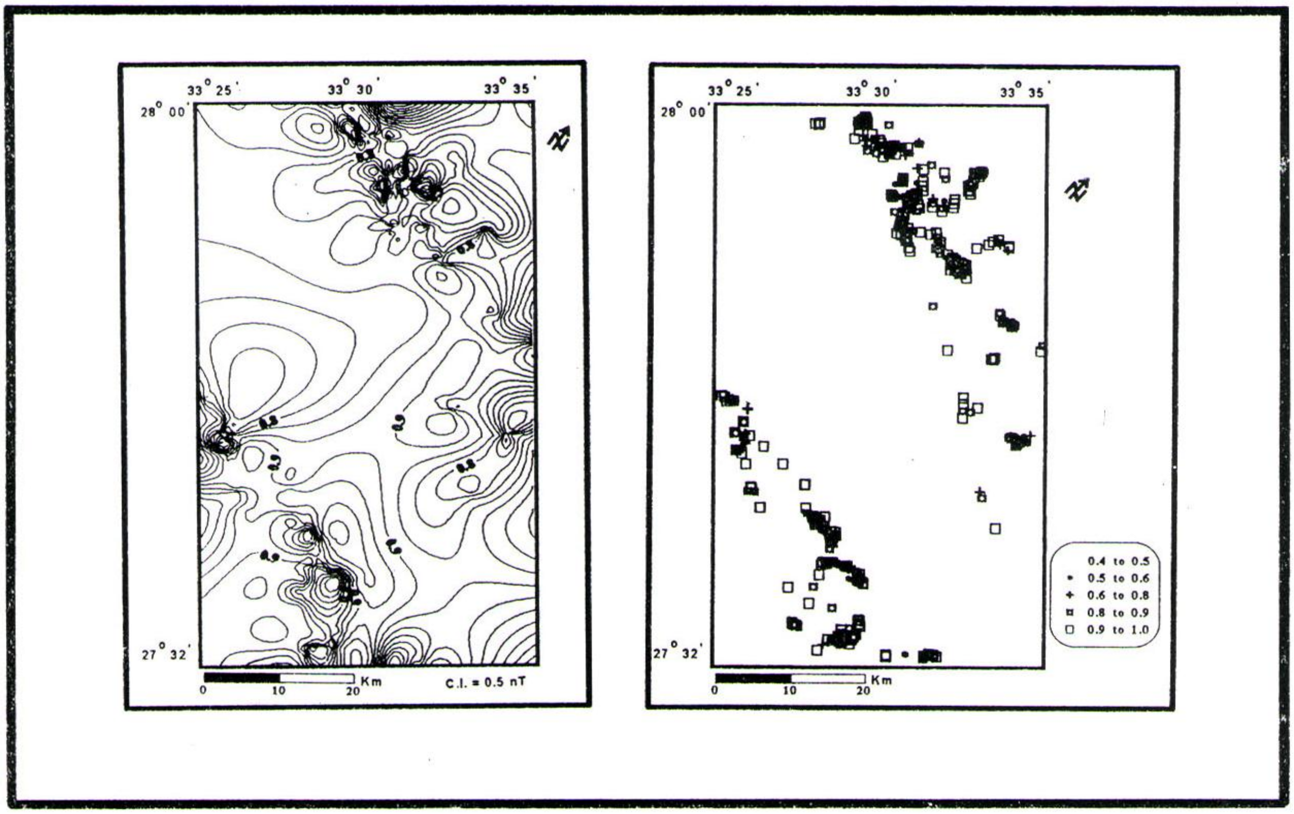


Fig. (8): Euler deconvolution of R.T.P. map at different depths (S.I. = 0.5)

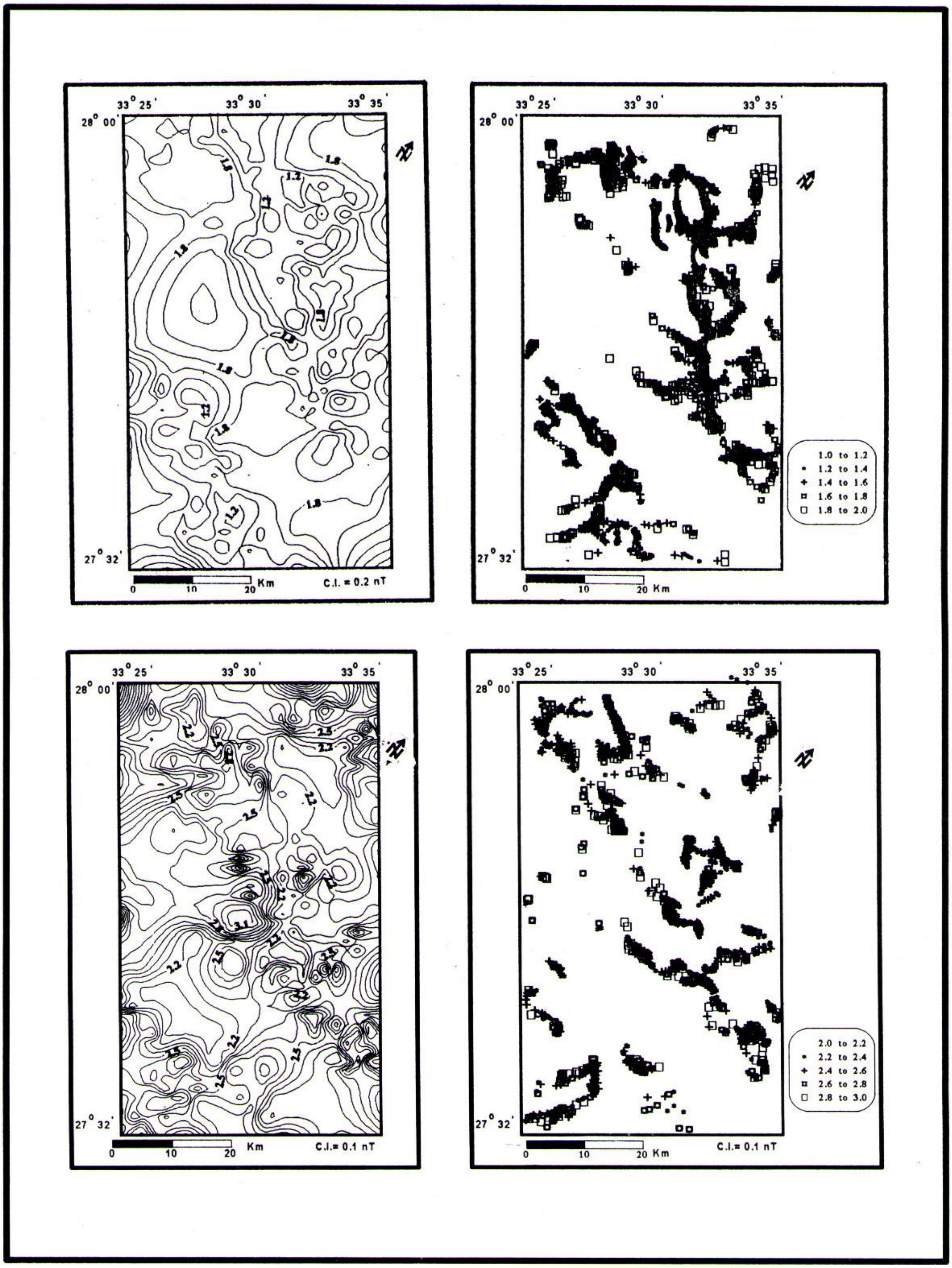


Fig. (8): "Continued"

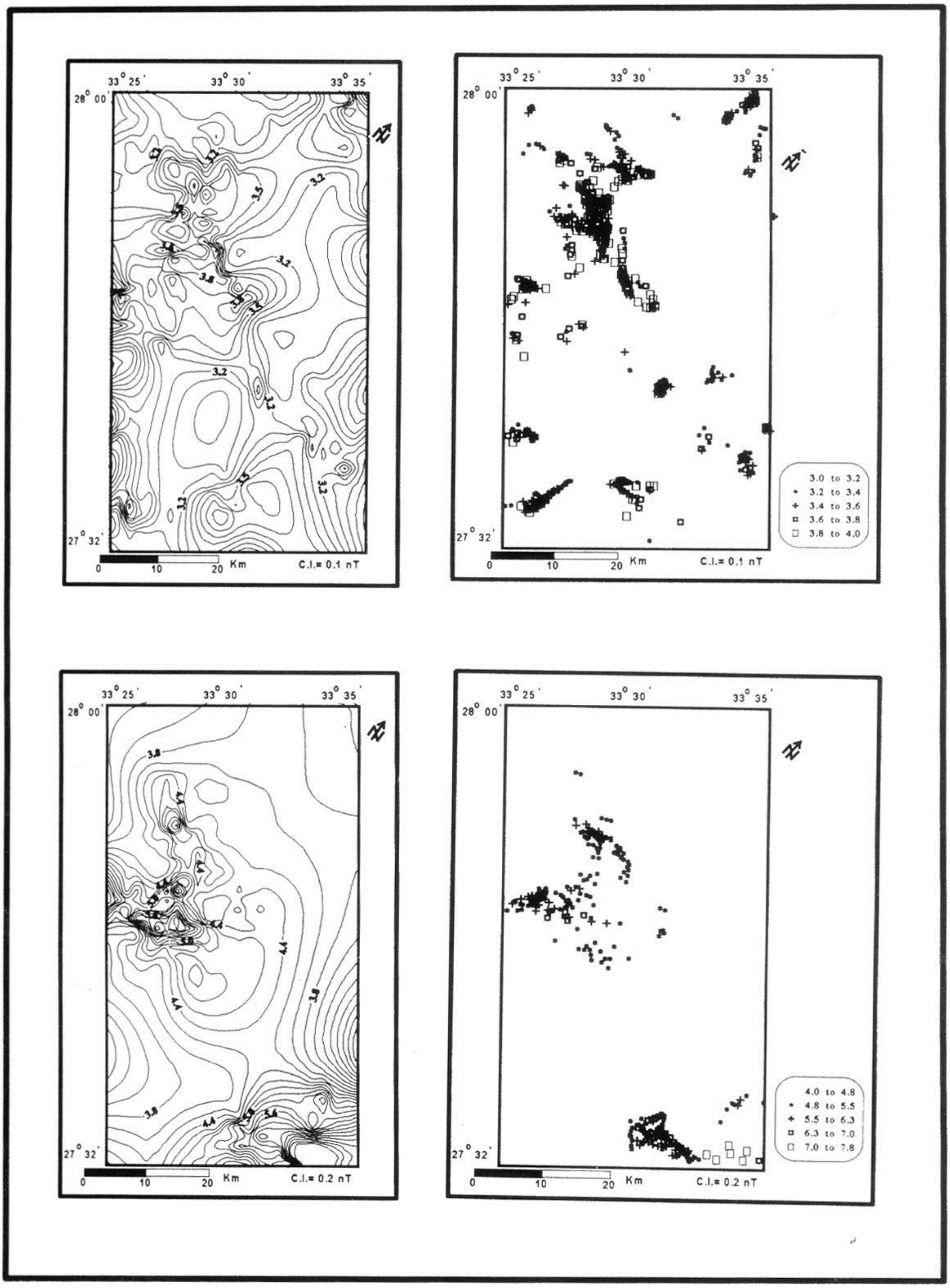


Fig. (8): "Continued"

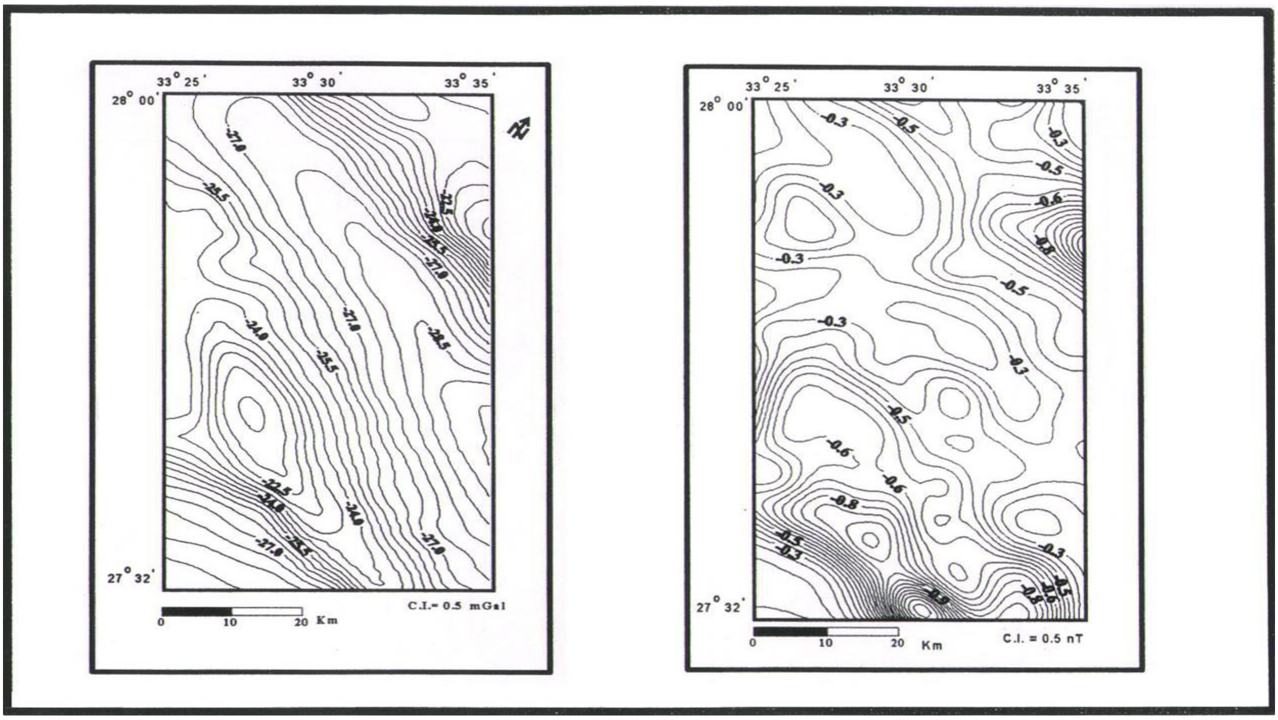


Fig. (9): 3-D analytic signal of the residual gravity (A) and the R.T.P. (B) data

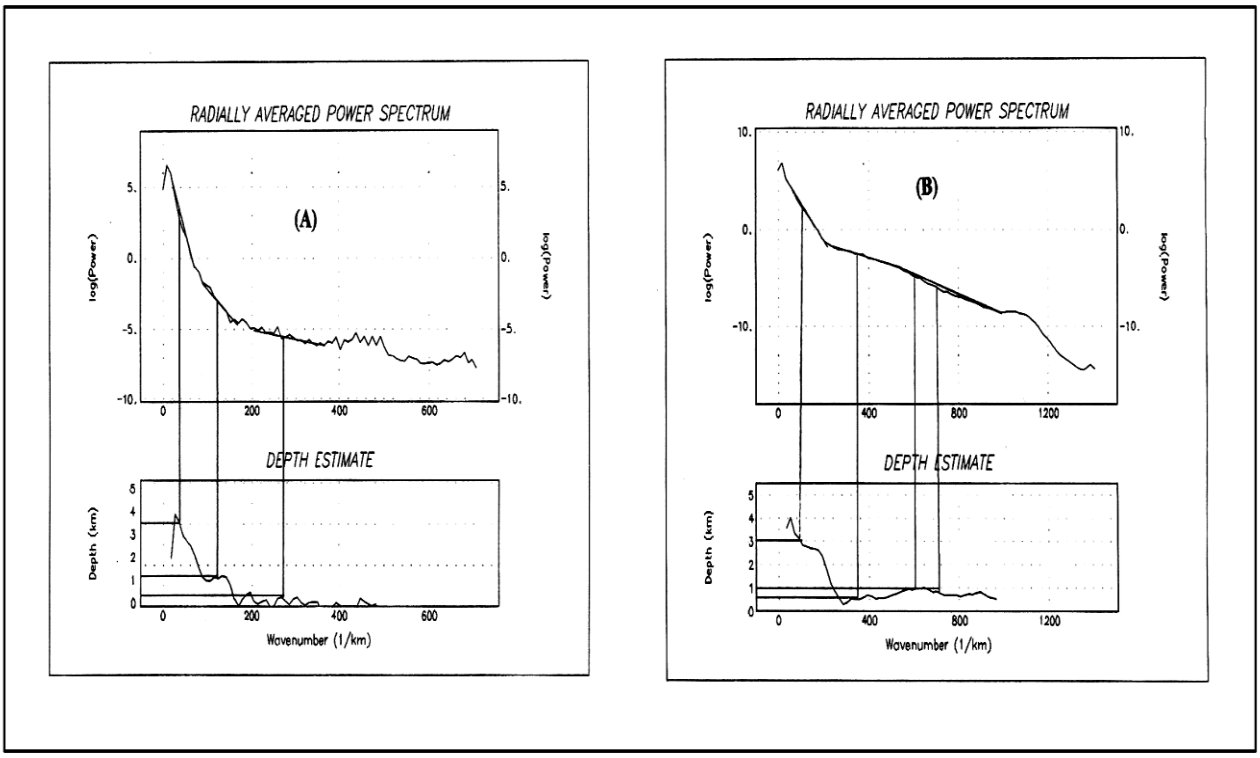


Fig. (10): Energy spectra of the gravity (A) and the R.T.P. data (B)

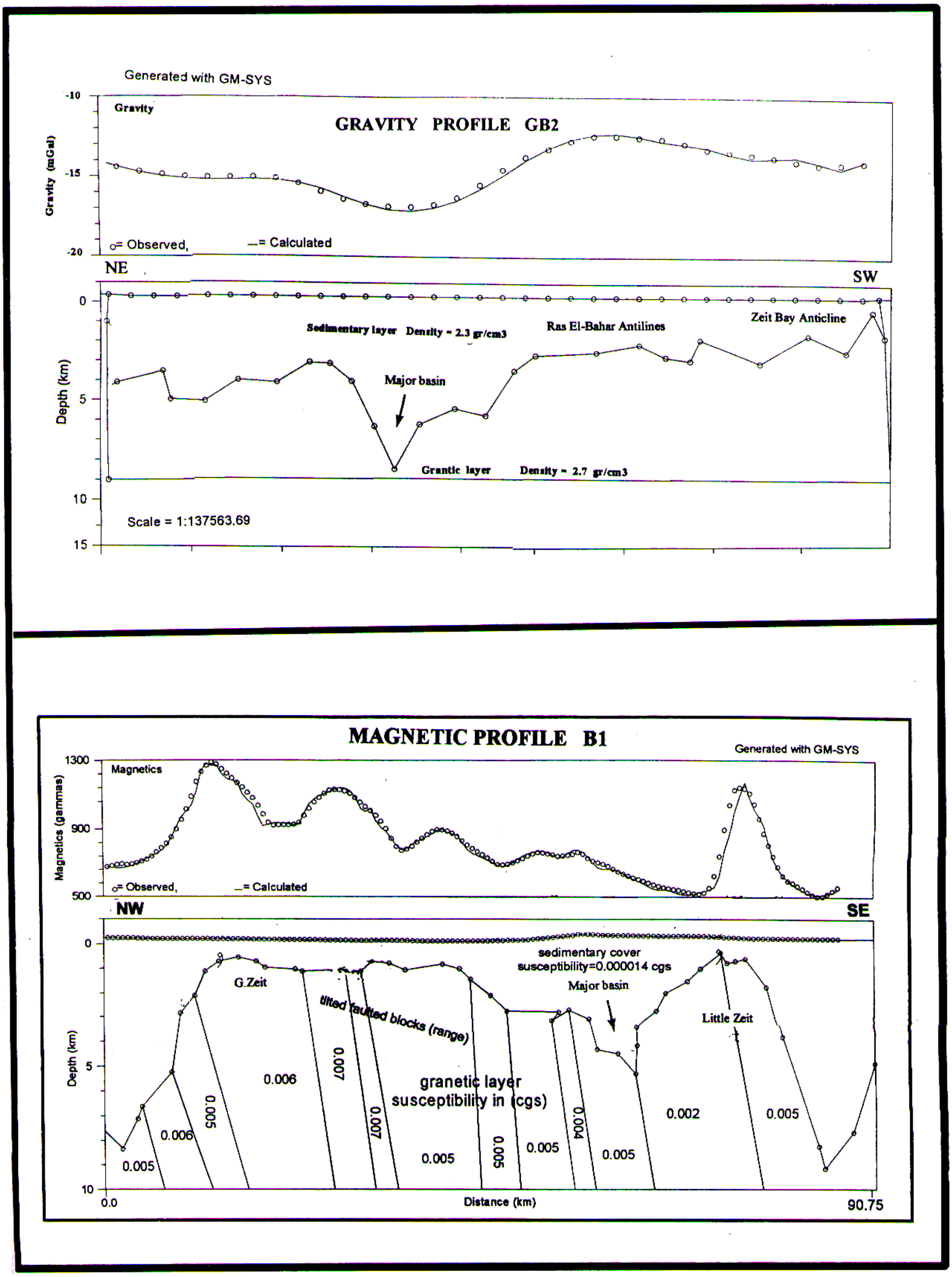


Fig. (11): Crustal models along gravity profile (GB2) and magnetic profile (B1)

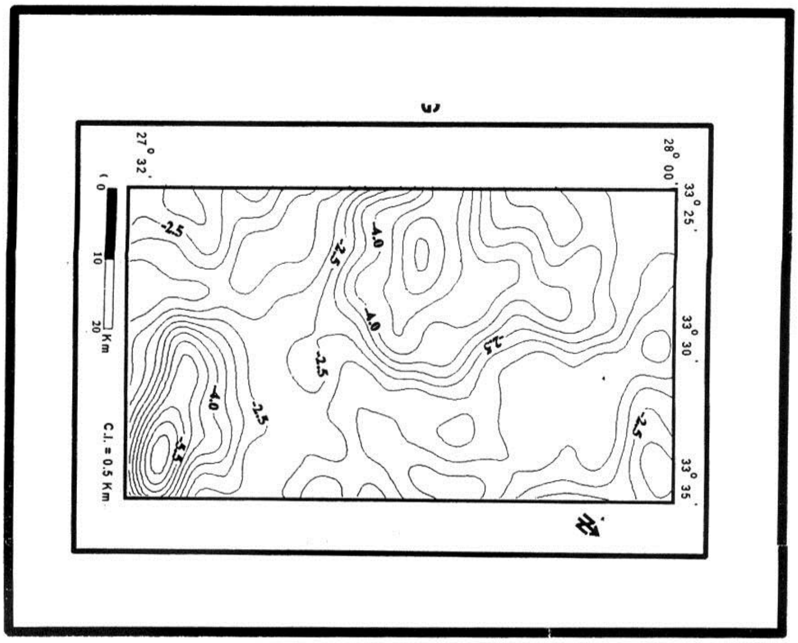


Fig. (12): Basement relief map of the study area

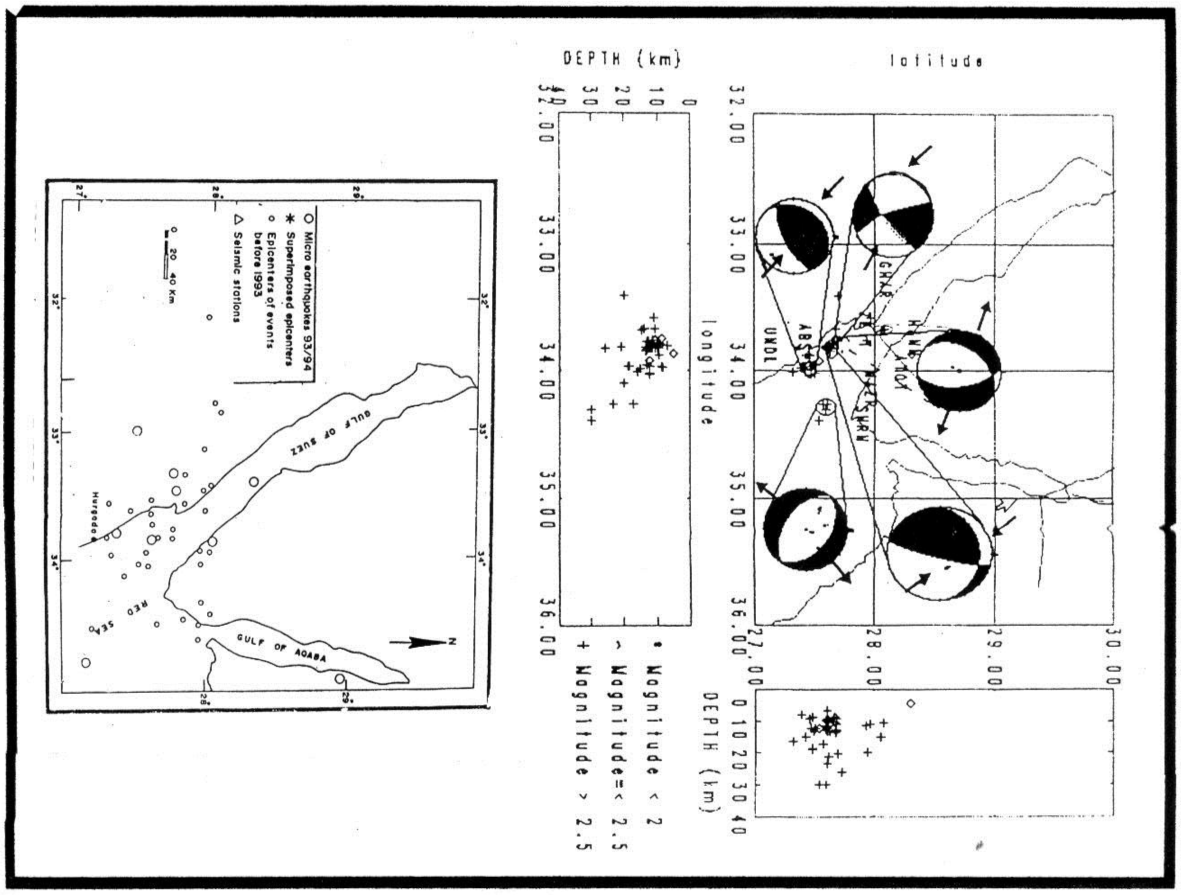


Fig. (13): Earthquakes distribution and focal mechanisms in the study area (modified after El-Shater & El-Amin, 2000 and Ismail et al., 2000

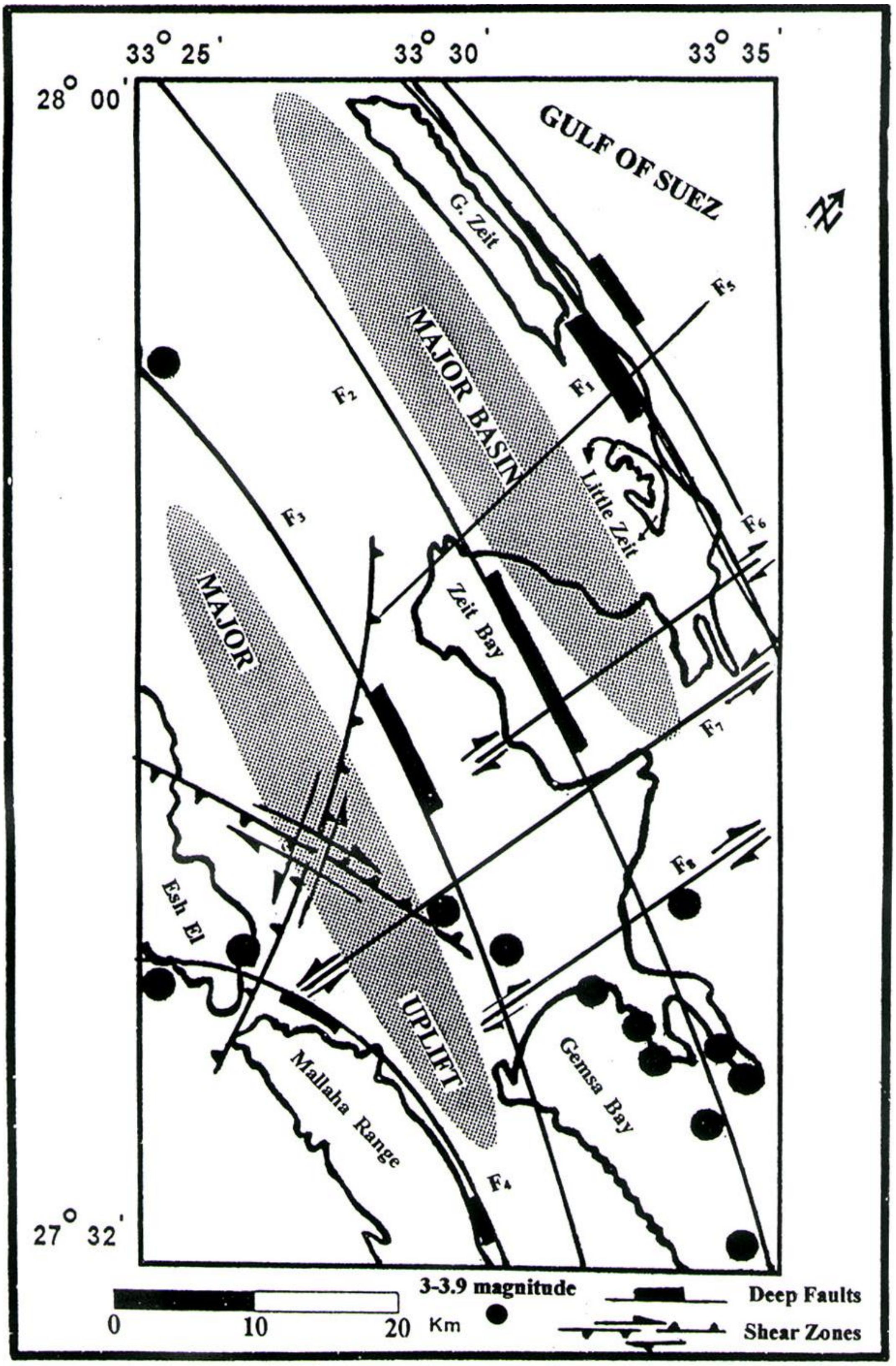


Fig. (14): Interpreted tectonic Basement map of the study area

RESULTS AND DISCUSSION

The interpreted subsurface deep structures deduced from the Bouguer and RTF maps are shown in Fig. (14). This elucidates that:-

1- Close examination of the interpreted maps shows alternating sets of positive and negative anomalies of NW trend, which may be correlated with structural highs and lows in the Basement. Also, two series of positive anomalies are extending along the eastern and western sides of Zeit Bay.

2- The Zeit Bay owes its present shape to structurally faulted Basement blocks and is associated with a group of negative gravity anomalies. These anomalies were interpreted as due to structural uplifted blocks bounding Zeit Bay from both sides (the Eastern Zeit Bay and the Western Zeit Bay anticlines respectively).

3- Eight major sets of faults that affected the Basement rocks in the study area denoted F1-F8 are interpreted. F1-F4 are normal faults of NW system (Suez trend), while F5-F8 seems to be associated with a left and right lateral horizontal displacement along its extension of NNE system (Aqaba trend). These faults are closely related to that deduced by Meshref et al., (1976) and Abdel Baki et al.,(1977).

4- Two major sets of wrench (shear) zones mostly of strike-slip faults were delineated in the western part of the study area, most of these structures were probably originated before the Miocene time and may be rejuvenated in post-Miocene.

5- The interpreted subsurface deep structures have extension on the surface. This is clearly shown from the correlation between the structures shown in Fig. (14) with that obtained from the field investigation as shown in the geologic map (Fig.l).

6- There are close relations between the spatial distribution of recent earthquakes of magnitude 1 to 3.9 affected this area, and the interpreted faults and shear zones in the study area. The earthquake activities are spatially scattered and associated with both sides of these zones. So, it could be concluded that these zones are seismically active and responsible for the seismic hazard in this area. The seismic risk is considerably high, so, this area is geologically active and unstable.

7- Close examination of the two and half dimensional modeling along the selected gravity profile (GB2) and magnetic profile (Bl), shows an excellent fit between the observed and computed ones. The gravity and magnetic anomalies are associated with east Zeit Bay, west Zeit Bay and Ras El Bahar anticlines. Meanwhile, these anomalies are believed to be associated with Ras El Bahar and Zeit Bay anticlines. A deep anomaly at the central part of the profile may be due to deep basin located between G.Zeit, Little Zeit and Zeit Bay highs. The detected faults bounded uplifted tilted basement blocks are separated by grabens or half grabens that show deeper basement ranging in depth between 4.0 to 5.0 km. Also, the modeled basement blocks show wide magnetic range of magnetic susceptibilities suggesting that the relatively acidic basement rocks of low susceptibilities values were intruded by very basic intrusions probably of mantle composition at different depths

8- The three major uplifted belts of the Basement in this area are associated with Ras El Bahar anticline. East and west Zeit Bay anticlines are considered to be good potential areas for oil, since it is well known fact that oil migrates upwards towards the axes of anticlines or structural uplifts.

REFERENCES

Abdelrahman, E. M., Riad, S., Refai, E., Amin,Y., (1985): On the least-square residual anomaly determination.. Geophysics, 50. No. 3,473-480.

Abdel Baki, S. H., Mesherf, W.M. and EL-Gindy, N.S., (1978): Regional structural interpretation of gravity data of Ras El-Bahar, North Eastern Desert, Egypt. Egyptian Journal of Geology, V.I 9, 179-192 p.

Aero Service Division Western Geophysical Company of America. (1984): On integration of airborne gamma-ray spectrometer and magnetometer survey of the Eastern Desert of Egypt. Houston, Texas, USA. 127 p.

Ambraseys, N.N. (1991): Seismicity of Egypt, In Cosgrove, J. and Johnes, M. (eds), Neotectonics and Resources, pp. 48-157. London and New York.

Ambraseys, N.N., Melville, C.P. and Adams, R.D. (1994): The Seismicity of Egypt, Arabia and the Red Sea, a historical review. Cambridge Univer. Press, Cambridge, 173 p.

Cooper, G.R.J. (1998): Geomodel, 2.5 D interactive magnetic and gravity modelling and inversion. Geophys. Dept. Univ. Witwatersrand, Johannesburg, 17 p.

Geosoft Inc. (1992): Areosoft potential field mapping and processing system (MAGMAP), Toronto, Canada, 27 p.

General Petroleum Company. (1985): Gravity Map of Egypt, the Egyptian Academy of Scientific Research and Technology, Hurukawa, H., Seto, N., Inoue, H., Nishigami, K., Marzouk, I., Megahed, A.M., Ihrahim, E. Desoky, M., Murakami, H.,

Hussein, H., Megahed, S., Mohammed, H. and Abdel-Fattah, R. (2000): Seismological observation at the Gulf of Suez, Egypt. 5th International Conference on the Geology of the Arab World, Cairo University, p.987-998.

Ismail, A. M., Basta, N. Z. and El-Hakim, B. (2000): Seismic activity at Qena-Safaga region. Annals Geol. Surv. Egypt, VXXIII, pp.707-712

Macleod, I., Jones, J. and Dai, T. (1993): 3-D analytic signals in the interpretation of total magnetic field data at low magnitude latitudes. Exploration Geophysics, 679-688 p.

Mesherf, W. M., Refai, E. M. and Abdel Baki, S. H. (1976): Structural interpretation of the Gulf of Suez and its oil potentialities. Fifth Exploration Seminar, EGPC.

Reid, A. B, Allsop, J. M, Ganger, H., Millett, A. J., and Somerton, I. W. (1990): Magnetic interpretation in three dimensions using Euler deconvolution. Geophysics, Vol. 55, pp. 80-91.

Riad, S. and Meyers, H. (1985): Earthquakes catalog for the Middle East Countries, p. 1900-1983. World Data Center.

Riad, S., Ghalib, M., El-Difrawy, M.A., Gamal, M. (2000): Probablistic seismic hazard assessment in Egypt. Annal Geol.Surv.Egypt, V.XXIII, pp.851-881.

Roest, W., Verhoef, J. and Plikington, M. (1992): Magnetic interpretation using the 3-D analytic signal. Geophysics, 57, pp. 116-125.

Shater, A.A. and EL-Amin, M., (2000): Mement tensor component of the Gulf of Suez earthquakes. 5 Inter. Conf.on Geology of the Arab World, Cairo Univ. 1021-1028 p.

Schlumberger, (1984): Well Evaluation Conference, Egypt. Schlumberger, France, pp. 1-60.