Egyptian Geophysical Society
EGS Journal, vol. 2, No. 1, 17-29 (2004)

STRUCTURE AND EVOLUTION OF NORTH AFRICAN PASSIVE MARGIN CRUST: AS INFERRED FROM 2-D GRAVITY MODELING OF NILE DELTA AND ITS SURROUNDING AREAS, EGYPT

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دراسة حول تركيب ونشوء القشرة الأرضية الهامدة بشمال أفريقيا باستخدام النمذجة الثنائية الأبعاد للبيانات التثاقلية لدلتا النيل والمناطق المتاخمة.

الخلاصة: استهدفت هذه الدراسة التعرف على طبيعة القشرة الأرضية فى منطقة دلتا النيل وتخومها وكذا الحافة الهامدة لهذه القشرة فى شمال أفريقيا ولهذا الغرض تم استخدام بيانات بوجير التثاقلية والمعطيات الجيولوجية والسيزمية.

وقد أوضحت النتائج أن القشرة الأرضية بالمنطقة تتكون من طبقتين من الصخور النارية تسفلها طبقة من البازلت تمثل الوشاح العلوى من الأرض ويعلو الصخور النارية غطاء من الرسوبيات بالغ السمك ما بين ٢-١٢ كيلومتراً وتقدر كثافة الجزء العلوى منه (من عصر الميوسين إلى الحديث) بحوالى ٢,١جم/سم٣ وكثافة الجزء السفلى (من عصور ما قبل الميوسين) بـ ٢,٥ جم/سم٣ وتزداد هذه الكثافة لتصل إلى ٣,٣٣ جم/سم٣ فى نطاق الوشاح الصلب.

وقد أظهرت الدراسة أيضاً التأثيرات المختلفة للاجهادات المتعاقبة والتى تسببت فى نشوء القشرة الأرضية وتركيبها المتباين بالمنطقة ذات الاهتمام والتى تبدو ذات طبيعة قارية (جرانيتية) فى الجزء الجنوبى منها إلى متوسطة (أنديزيتية) إلى شبه محيطية من جزئها الشمالى وذلك خلال دورات النشوء المختلفة ابتداءاً من الدهر القديم إلى الوقت الحاضر.

ABSTRACT: *The aim of the present study is to investigate the crust and the upper mantle nature of the Nile Delta and its surroundings; and/or of North African passive margin, in general, using essentially Bouguer gravity data supported by geologic, seismic and other geophysical information. The selected area lies between latitude parallels 29°,31°45'N and longitude parallels 30 ,32°E. To accomplish this study, the Bouguer gravity data has been subjected to evaluation, processing, analysis, modeling and interpretation. From the resulted 2-D crustal geologic models taken along S-N direction, the crust beneath this area comprises two igneous layers: upper and lower crust underlain by the solid upper mantle basaltic layer . A huge sedimentary cover of densities 2.1 g/cc and 2.5 g/cc for the upper (Miocene to Recent) and lower (Pre-Miocene) layer formations, attains athickness that varies nearly between 2 and 12 km; thickens northward, and tops the previous igneous layers. Meanwhile, the thickness of the upper crust (including sediments); or depth to midcrustal discontinuity (Conrad), of density of 2.7 g/cc, ranges between 22 and 13km with visible thinning and stretching northerly. Also, the lower crust, of gabbroic nature, has adensity value of 2.9 3g/cc and thickness ranges, nearly, between 11 and 10 km. Moreover, the depth to the upper mantle-crust boundary (Moho); or the crustal thickness, ranges approximately between 33 and 23 km. The shape and depth of Moho discontinuity reveals clearly the ascending lithosphere material, i.e. the northward thinning and stretching of the crust. From the study, anomaly trends nearly represent all stresses impact responsible for crustal evolution, were inferred. According to the crustal thickness - composition relationship, the crust of North African margin, as depicted from the crust of Nile Delta and its surrounding regions, seemed to be of continental nature, in the southern parts. It has been changed to intermediate that was developed to semi-oceanic type beneath nearly the northern half of the Nile Delta block with more oceanisation northerly offshore. This relation with the obtained anomaly trends and crustal geologic sections reveal clearly the development of Precambrian to Cambrian crust as a result of evolution crustal cycles (crustal framework) prevailed from Early Paleozoic to Present.*

INTRODUCTION

It is known that the seismic wave velocity, obtained from artificial shooting, does not represent a unique rock unit density value unless it is proved by a comparison with gravity measurements and/or simulation. This implies that some external factors, far from the mineralogical constituent, are responsible for this discrepancy. On the other hand, the seismic surface velocity of the earthquakes gives, to some extent, a reasonable and unique rock unit and/or layer representation (Woollard, 1959). However, the earthquake activities are not distributed everywhere all-over the world and their most known occurrences are in the active oceanic ridges and continental margins and relatively rare or nearly absent in the continental shields and platforms. Therefore, comparison and simulation of seismic wave measurements with the analogous gravity observations, to clarify and adjusting these seismic results, seem to be urgent. Concerning the present study, many authors have studied the northeast African crust using either potential data (gravity and/or magnetic) or seismic ones. Gumper and Premory (1970) have declared that: the African crust, generally, is typical shield area with thickness range between 35 and 40 kilometers. Makris et al. (1979), Keller et al.(1980), Makris et al. (1988a) and El Hadidy et al. (2000) using seismic data have reached nearly to the same result with some addition about the crustal tone and behavior at the eastern and the northern African margins. Riad et al. (1983) and Tealeb et al.(1986) ,using gravity data,. concluded that the crustal thickness of Egypt and Sinai Peninsula varies from 32 to 35 km; with noticeable crustal thinning towards the Mediterranean coast, and approximately the same result for Arabia, has been interpreted by Tealeb and Riad (1986). Also, Sitto (1991) have been simulated the crust of Nile Delta by 2-dimensional (d) gravity models and concluded its thickness exhibits a visible thinning northward. Abd El-Rahman et al. (1988) and Omran (2000) have obtained approximately the same results and showed the crustal thickness of the Nile Delta and Delta Cone varies between 20 to 32 km with markedly thinning and stretching at the Mediterranean coast and extending northerly off-shore. Also, Makris et al. (1988a), through S-N trending gravity profile; starting from south of Siwa oasis and extending northerly up to the Mediterranean coast, emphasized clearly the transition (thinning and stretching) of the continental crust in the obtained 2-dimensional (d) geologic section. In contrast, with another W-E profile crossing the previous one at its end (at Mediterranean coast), the obtained geologic section showed the crust without any oceanisation nature (Fig. 4, page 355). Also, El-Hadidy et al. (2000), as mentioned above, gave a crustal model offshore (path in), from seismic data without any sign about the crustal transition.

From the concurrent review, it is quite clear that, the northeast African passive margin (Said, 1962; Said, 1981 and others) needs more additional crustal studies to give a reasonable and justifiable model, to clarify the postulated models and, at least, to add a new geological and geophysical data. These reasons with others related to the argument about the crustal transition are considered the main objectives of the present study which are encouraging in the implementation of this work. To do so, 2-dimensional (2-D) gravity simulation technique served by seismic and geologic constraints was postulated to emphasize these targets. The Nile Delta and its surroundings, occupy the north central part of the north African rim, including both the onshore (hinterland unstable shelf areas) and the Delta Nile Cone (Miogeosyncline sediments, Schlumberger, 1984) areas, consider more appropriate sites to do such study. The selected area, Fig.(l) lies precisely between parallels 29°, 31°45' N and 30°, 32 ° E . This area starts from South of El Fayoum in the west and El Galala El Baharyia in the east and extends northerly up to Mediterranean coast and offshore covered a surface area of about 125000 km^2. The proceeding of the present work has been achieved through three main tracks. Firstly, the main geologic setting of the selected area according to the previous geological and geophysical results was discussed and its relation to the global stresses is emphasized. Secondly, the gravity data, in the form of contour map of scale 1: 8000000, supported from the compiled Egyptian Bouguer gravity map of Egypt (1984) was subjected to evaluation, digitization, processing, analysis, crustal geologic simulation. Finally, the obtained results were exhibited in the form

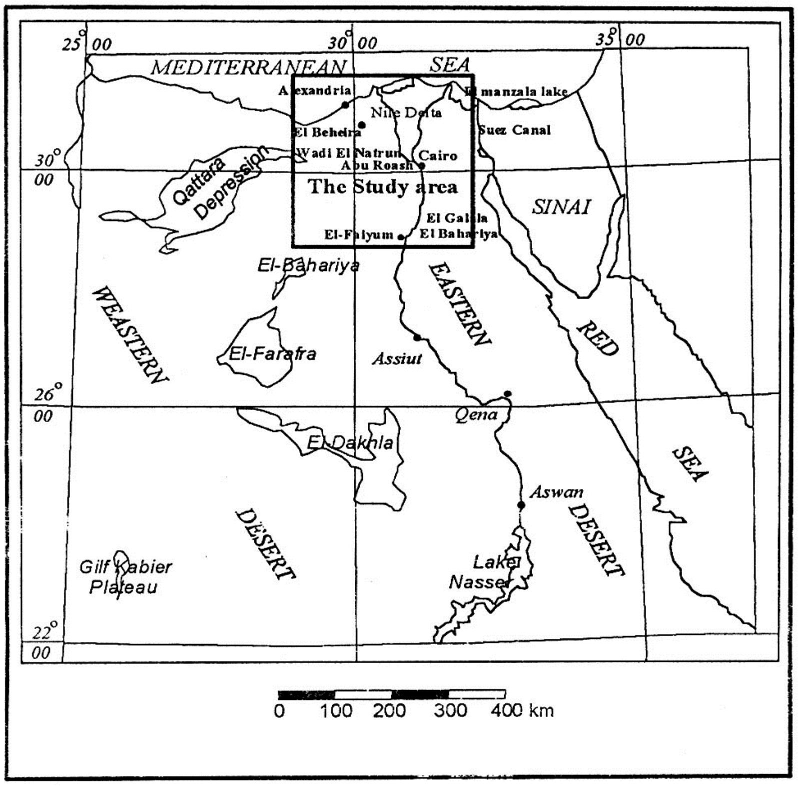

Fig. (1): Location map of the area of study

of 2-d geologic crustal sections and contour maps and subjected to further discussion as inferred hereafter.

Geologic and Structural Setting

The northern Egypt represents the Northeast African passive continental margin of African craton. This craton comprises four geologic provinces The unstable shelf is the northern one and has been constructed from Paleozoic to Recent sediments overlying the basement rocks. This province has been signed by most of the orogenic effects which prevailed from Precambrian age up to present. The studied area occupies the northern central part of this geologic province. It includes the northern Nile Delta and the surrounding areas. The surface geology of this area consists of Mesozoic to Tertiary sediments, in the southern parts and Miocene - Pleistocene sediments in the northern parts with sand dunes, mud, silt and sabkha covering these regions up to the Mediterranean coast.

From structural point of view, the northern Egypt has suffered from all stresses effect prevailing from Pre-Cambrian up to Recent where the sedimentary cover has been signed by most of the resulted deformational tectonics from Paleozoic up to Recent. The structure grains according to many workers (Said, 1962; Morgan,1990, and Meshref,1990) comprises: faulting, uplifting, folding, subsidence and other tectonic features which have been printed by different stresses effect. These trends are as Late Precambrian (NE- SW to ENE-WSW and NW-SE) Northeast African (N-S trend), Hercynian (NW-SE to NNW-SSE trends of Late Carboniferous to Jurassic), Pangea assembly (Late Paleozoic) and Afro-Arabian - Eurasian separation (E-W and other trends of Triassic age), Alpian (ENE-WSW to NE-SW trends of Late Cretaceous -Early Tertiary age), particularly Laramide phase (Syrian Arc system), Red Sea - Gulf of Suez rifting (NNW-SSE to SSW-SE trend of late Oligocene), Miocene Subsidence (E-W trend of Late Miocene age) and Gulf of Aqaba (NNE - SSW to NW-SE Pliocene age). However, the Nile Delta and the surrounding areas have been affected by most of the previous tectonic stresses. The paramount Alpine major tectonic Trans-compression (Said, 1981;Youssef, 1968 and Meshref, 1982) is signed by folded belto and/or arcuate faults trending E-W to ENE-WSW (Syrian Arc trend) extending from north eastern desert to Sinai. Uplifting, normal and transform faulting associated with Red Sea rifting, as well as uplifting of northern Nile Delta associated with Gulf of Suez events (Middle Miocene age; Horms and Wary, 1990) have been investigated. Miocene subsidence and Aqaba fault systems (Late Miocene to Paleocene) are also inferred. Then, the hinterland and offshore Nile Delta cone is greatly affected by stresses associated with the subduction zone; between North African and south Eurasian plate margins, situated far north offshore Mediterranean coast. Litho-stratigraphically all these previous sediments, approximately represented the product of all environmental depositional conditions prevailed from Paleozoic up to Recent. The unstable shelf is characterized by a relatively thick sedimentary cover in the south of about 3 km (south of Hinge Zone), thickens due to north, particularly in the central Nile Delta. (Said ,1981; Abd Elrahman,1988 ; Omeran,2000 and others), to reach to about 10 km and decreases gently northward off-shore the coast. According to generalized litho-stratigraphic column section of Schlumberger (1984) for the Nile Delta, which depending mostly on the geologic sections correlation, the thickness of the Pre-Miocene formations ranges approximately from 2 to 3 km whilst the formations thickness of Miocene to Recent varies between 3 to 6 km. Hence, the total sedimentary cover occupying the Nile Delta and Nile Cone speculatively varies between 5 to 9 km except at Abu Roash area, situated south of Nile Delta block, where the Mesozoic sediments are cropping out. The depth to the basement is about 1.9 km (Said, 1962).

Evaluation of Gravity Contour Map

Generally, the gravity survey and any geophysical survey pattern depend on the objectives of the survey as well as other economic reasons. The Egyptian General Petroleum Company (EGPC) compiled the gravity surveys ,made along most parts of Egypt during 1980, in the aim of evaluation of sedimentary basins that are promising for oil potentialities. The provided Bouguer contour map (Fig.2), unlikely, lacks the location of the gravity stations was constructed using a single contour interval of 5 mGal implying a unique station distribution pattern which is appropriate in the present area where the basement rocks were topped by a thick sedimentary cover of less than 300 m elevation in the south and dives under Mediterranean waters northerly. Also, the scale of 1:50000 of the Bouguer map reveals that a relatively regional survey pattern has been employed and the regional studies seem to be reasonable.

Data Processing and Analysis

To implement the crustal simulation, it is better to remove the effect of shallow seated causative bodies producing anomalies from regional ones in order to show whether the derived long wavelength anomaly map or the original Bouguer one is more reasonable for rational modeling procedures. The supported Bouguer contour map has been digitized and transformed to Fourier domain (frequency domain) in order to calculate the power spectrum and carry out further filtration operations. The inspection of the resulted radially averaged log power spectrum shows that: firstly a high frequency band lies between 0.06 and 0.02 cycle/km representing the near surface contribution to the relatively near surface bodies. Also, an intermediate frequency band between 0.02 to 0.006 cycle/km reflecting the intermediate causative bodies and/or layer contribution. Moreover, a low frequency one (regional-component) of less than 0.006 cycle/km reflecting the deep-seated bodies and/or layer contribution. It is worth mentioning that, the obtained frequency band, starts at

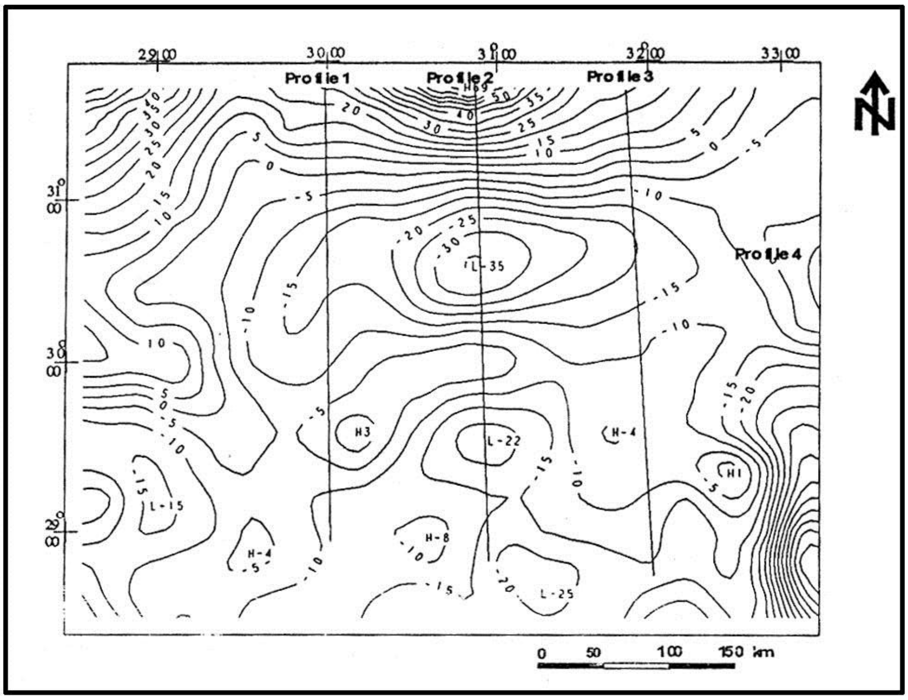

Fig. (2): Bouguer gravity contour map of the area of study; C.L=5mGal

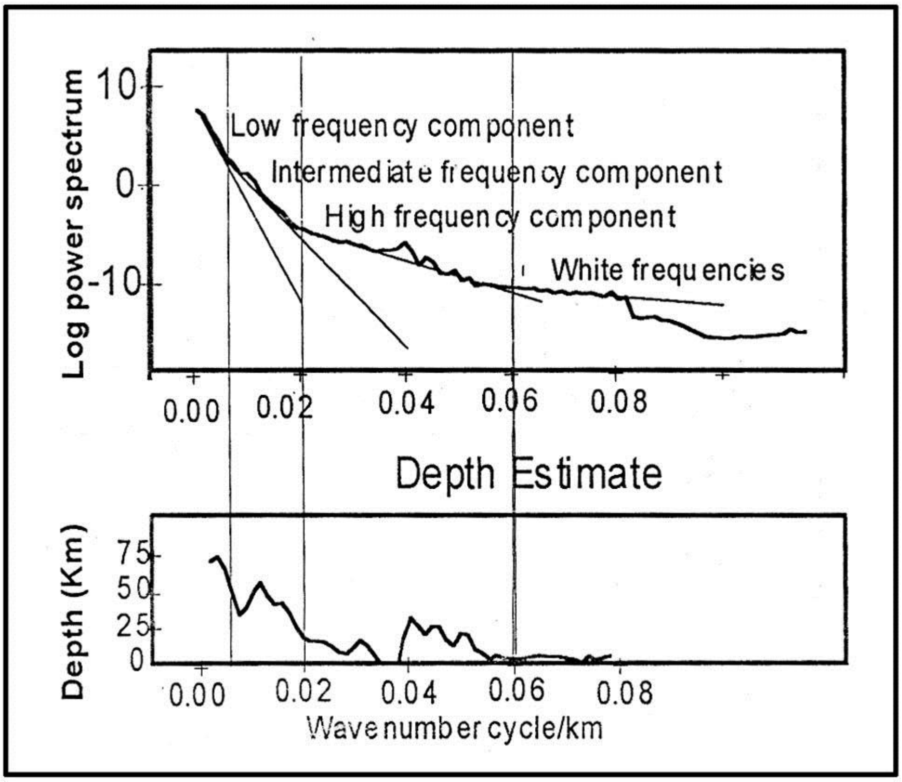

Fig. (3): Radially averaged log power spectrum

0.006 cycle/km; represents a wavelength of 125 km. This value is the same as that selected by Riad et al. (1983) and Tealeb and Riad (1986) for estimating crustal thickness (Moho depth) in Egypt and Siani.

In light of the obtained spectrum (Fig.3), the data being transformed have been filtered out based on the previously mentioned three cut-off frequency bands. Meanwhile, the filter operator (coefficients) as well as the filtration operation have been processed in the frequency domain and the filtered transformed data was inversely Fourier transformed (IFFT) to space domain form, and contoured in the form of Band-pass filtered Bouguer contour maps as shown Figs.(4, 5 ,and 6) .

From the inspection of the low pass band filtered Bouguer contour map, Fig.(6), it is obvious that, the filtration operation failed to remove the expected sedimentary cover and/or basement relief impact to give only deep seated causative bodies and /or layer contribution. Hence, the modeling operation for such low frequency data will go far from reality because this broad negative anomaly will affect the crustal thickness during the modeling procedures. Therefore, the modeling approach has been achieved along profiles taken directly from the original Bouguer gravity contour map, Fig (2).

The initial density model in the present study was postulated utilizing density models of Makris et al. (1988a), El Hadidy et al.(2000) and Omran et al.(2000).

Also the thickness of the sediments as detected from spectrum Fig. (3) will be utilized in the modeling procedures. The sedimentary model thickness will be constrained by litho-stratigraphic generalized column section Schlumberger (1984) as mentioned above. In addition, the crustal thickness (upper and lower crust) detected from the log power spectrum will be considered in the modeling process of initial density model.

According to Woolard (1959), the inspection of this suggested density model depicts that, the density of the upper mantle layer as 3.33 g/cc accords with the known upper mantle density (3.32 g/cc) of continental plateaus. Concurrently, the lower crust density in this model as 2.93 close to fall in the known range of 2.86-2.88g/cc. Moreover, the density contrast between the lower crust and upper mantle as 0.4 g/cc is in agreement with the known range of 0.4-0.45 g/cc for this sharp discontinuity to continuous surface and nearly universe marker reflectance of the upper mantle (Moho). Finally, the upper crust - lower crust density contrast as 0.23 g/cc is more appropriate for such relatively faint discontinuity (Conrad) second order surface and/or zone. Hence, these outlines manifest that the suggested density model seem to be justifiable.

Data Modeling

Computer devices and the optimization algorithms facilitate working on the inverse problem solution. According to Paterson and Reeves (1985), Reeves and Macleod (1983) and others, modeling technique comprises two routines Forward and Inverse Modeling approaches which are based mainly on Talwani et al.(1959), Taiwan! et al.(1954), and others. Least squares algorithms (Powell ,1965; Abdelrahman, 2001 and others). The difference between the inverse and forward modeling is, an initial guess for simple model type and employing linear or nonlinear inversion (density, susceptibility, location, shape and depth inversion) of the observed data into body parameters in the case of inverse modeling. While in the forward or iterative modeling, the data linear or nonlinear inversion is substituted by building and rough estimation of the initial model (2-D or 3-D of any shape) and matching the observed and calculated data to attain best fit with reasonable geologic parameters.

In the present study, the modeling process has been employed using 2-D forward modeling and optimization algorithms programs served by seismic and geologic constraints. Three gravity profiles have been selected; for modeling approach, trending in S-N direction in order to study the nature of the crust and the behavior of the mobile crustal passive margin northerly. Each profile has been simulated by 2-D density new model served by geologic and seismic constraints. Therefore, Three 2-D crustal geologic sections, along the selected gravity profiles, were obtained from the modeling procedures after numerous iterations, these sections were inferred in Figs. (7,8 and 9).

Results and Discussion

The visual inspection of the Bouguer gravity contour map (Fig.2) shows that, the area is characterized by a low anomaly of broad extension; with negative value reaching about-35 mGal at its center. This anomaly is situated above the central part terminated by a high one of strongest amplitude, reaching about 60 mGal in the northernmost part, with faint amplitude anomalies (negative or positive) in the eastern, western and southern parts. The low negative anomaly may be attributed to the huge sedimentary cover as mentioned above. Also, the faint and high ones may reflect the basement relief irregularities as well as the shape and composition of the crustal layers, respectively, because of the relatively regional nature of the contours which extend, at least, more than 200 km in the area. The trends of the anomaly contours are mostly in NE -SW, E-W, NW-SW and ENE - WSW to NE-SW directions reflecting, Afro-Arabian -Eurasian Separation, Mediterranean, Red sea -Gulf of Suez, Syrian arc and Gulf of Aqaba deformation trends. It is worthmentioning that, the abnormal high amplitude value of the northern part is mostly attributed to the structure of the crustal layers. In other words, an isostatic overcompensation, for mass deficiency of the thick sediments, reflects that the northern African margin is still active.

1-High frequency band- pass filtered Bouguer contour maps. This map (Fig.4) reflects the shallow seated causative bodies producing anomalies trending mostly in ENE - WSW to E-. NNW-SSE, NNE-SSW to NW- SE and NE-SW to ENE-WSW directions. Most of these anomalies have semicircular, elongated and open shapes with values between-4 and 3 mGal,with long aerial extension and, may reflect the undulation of basement relief and supra - basement bodies as well as the sedimentary cover attitude.

2-Intermediate frequency band-pass filtered Bouguer contour maps. This map (Fig.5) depicts the intermediate causative bodies producing anomalies. These anomalies have amplitude values between -10 and 10 mGal and trending approximately in the same previously mentioned directions emphasizing obviously the ancient NE and NW, N-S as well as the E-W trends and signifying the intermediate-seated bodies and/or layers producing anomalies.

3- Low frequency band-pass filtered Bouguer contour maps. The appearance of the anomaly contours of this map, (Fig.6), shows close agreement with the original Bouguer gravity contour map, (Fig. 2), except some smoothing for the contour lines. This depicts that, the deep seated causative bodies and/or layers producing anomalies are paramount and responsible for the general shape of the contour map. The visible occurrence of the ancient Pelusium Mega-shear (NE-SW), cutting the southern Nile Delta, in this long wave length anomaly map confirmed the idea of Afro-Arabian - Eurasian rifting along this right - lateral fault (Neev and Fredman,1978 and others). In addition, the sedimentary impact is still obvious; where the central anomaly attains negative value of about-30 mGal and has the same attitude since its great areal extension that reaches more than 300 km, in the area. Therefore, the sedimentary cover contribution, in the spectrum, lacks a strong expression in the short wavelength component. Accordingly, the spectrum of the sedimentary cover impact has a remarkable overlap with that of the deep -seated.

Detailed analysis, interpretation and discussion of all these derived filtered contour maps is beyond the scope of this study and may be considered in a future work. In the same time, the sedimentary impact still exists and will affect the crustal thickness and hence it will be appropriate to do simulation procedures along profiles taken directly from the original Bouguer data as achieved hereafter. From the radially averaged log power spectrum (Fig.3), the following can be emphasized:

1-The first high frequency segment reflects the analogous Basement relief depth and/or sedimentary cover thickness and equal to about 13 km. These bodies producing anomalies exhibit in the high frequency band Bouguer contour map Fig. (4).

2-The intermediate igneous bodes and/or layer are situated at an average depth of about 20 km. The gravity contribution of these intermediate causative bodies are inferred in Fig. (5).

3- The deep-seated causative bodies have an average depth value of about 30 km beneath the surface. It is worth to note that, the depth of the deep-seated . bodies reflected by the low frequency spectrum segment ranges between 30 and 75 km. The greatest depth values may represent variation in the upper solid mantle and/ or lithosphere-asthenosphere irregularities in this region. However, from the obtained 2-D geologic sections; as shown in Figures (7,8 and 9), the following can be highlighted:

(A) Profile 1:

As previously mentioned, this profile (Fig.7) has been taken along S-N direction starting nearly from west of El Faiyum town, up to north of Alexandria city and extending northerly off- shore the Mediterranean coast. From the obtained crustal geologic section, the thickness of sedimentary cover varies between about 3 and 4 km at the first 100 km, increases to reach about 12 *at* nearly 325 km from the starting end and then decreases gently northward to reach about 11 km at the end of the profile. Also, the thickness of the upper sedimentary layer varies between about one kilometer; in the southernmost part, and reaches to7.5 km at the end of profile. In addition, the upper crustal thickness (including sediments) ranges from 22 to 21.5 km in the first 230 km, decreases from 21.5 to 20 km between 230 and 250 km and then decreases rapidly northward to reach about 13.5 km. Meanwhile, the lower crust is characterized by a nearly consistent thickness that ranges from 11 to 9.5 km. Moreover, the crustal thickness and/or the depth of Mohorovicic discontinuity, in general, varies between 33 and 23 km revealing visibly crustal stretching and thinning northerly.

(B) Profile 2:

This profile was taken to represent the central part of the area and starts from El Faiyum the crossing the Nile Delta block , passing nearly in midway between Damieatta and Rosetta Nile branches , up to Mediterranean coast and extends northerly offshore passing a distance of 353 km. The inspection of this model emphasizes the thickness of sediments varies between 2 and 3 km at the first 150 km in southern part, increases up to ll.5 km at the central sedimentary basin (situated nearly at long.31° E and latitude 31° N). Finally, it decreases to about 10.5 km at the northernmost part of the profile; at Mediterranean Sea coast and off-shore. Meanwhile, the thickness of the crust ranges between 33.5 km, in the southern part and decreases to reach about 22 km in the extreme northern rim. The mid-crustal discontinuity surface (Conrad Surface) depth varies nearly between 22 and 13 whilst the Mohorovicic (Moho) surface depth varies between 33 to about 22 km as inferred from Fig.(8).

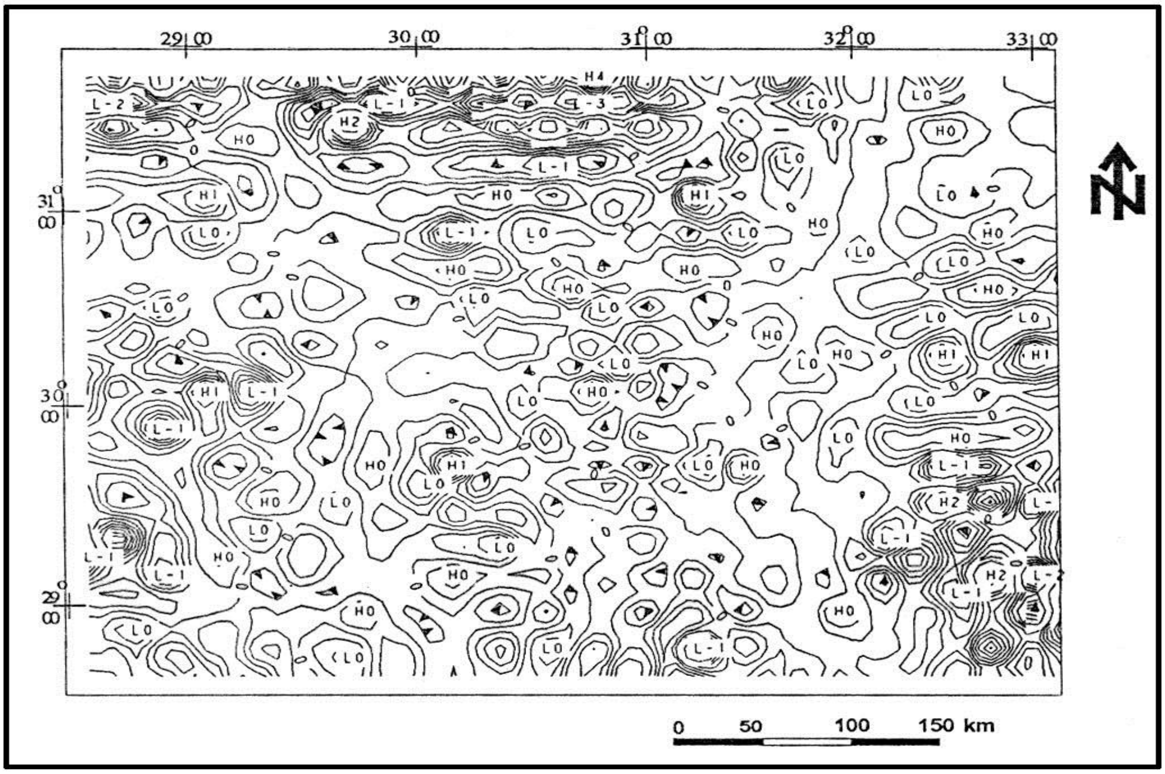

Fig.(4): Short wavelength (band – pass filtered) Bouguer contour map; C.I. = 0.25 , 1mGal, frequency b and from 0.06 to 0.02 cycle/km.

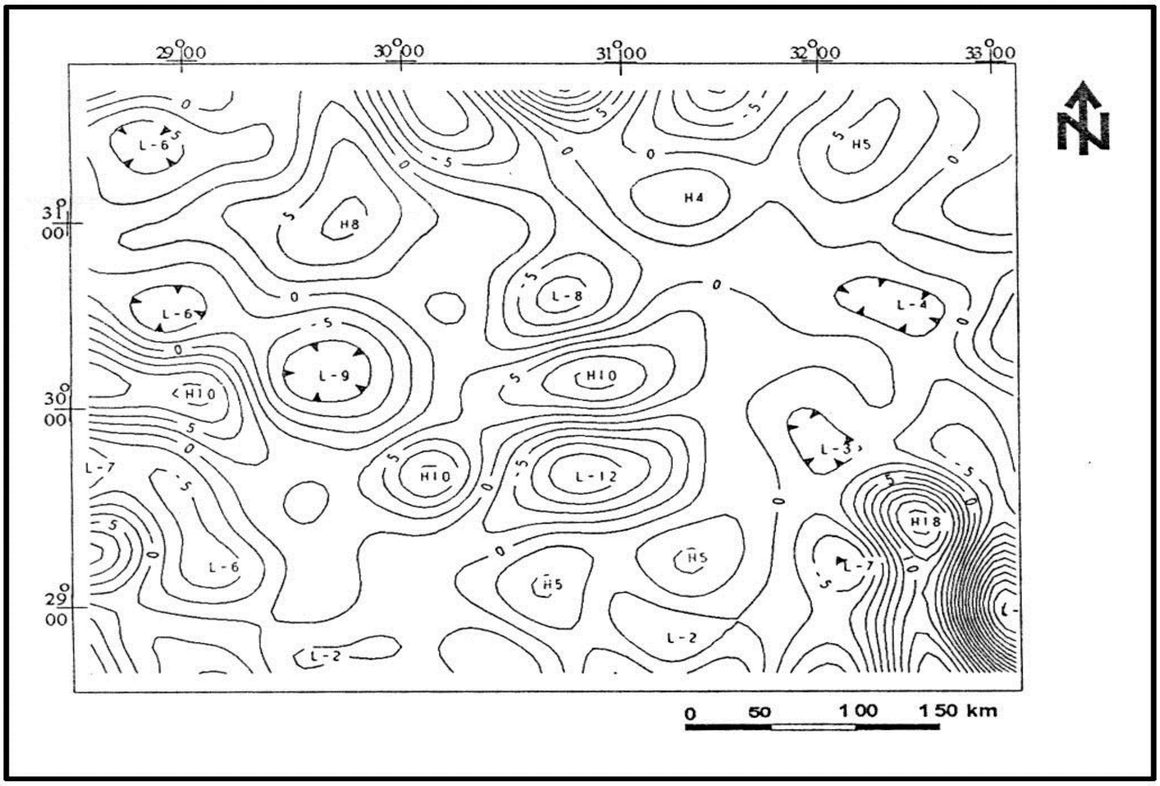

Fig.(5): Intermediate wavelength (band – pass filtered) Bouguer contour map; C.I. =2.5 , 5mGal.

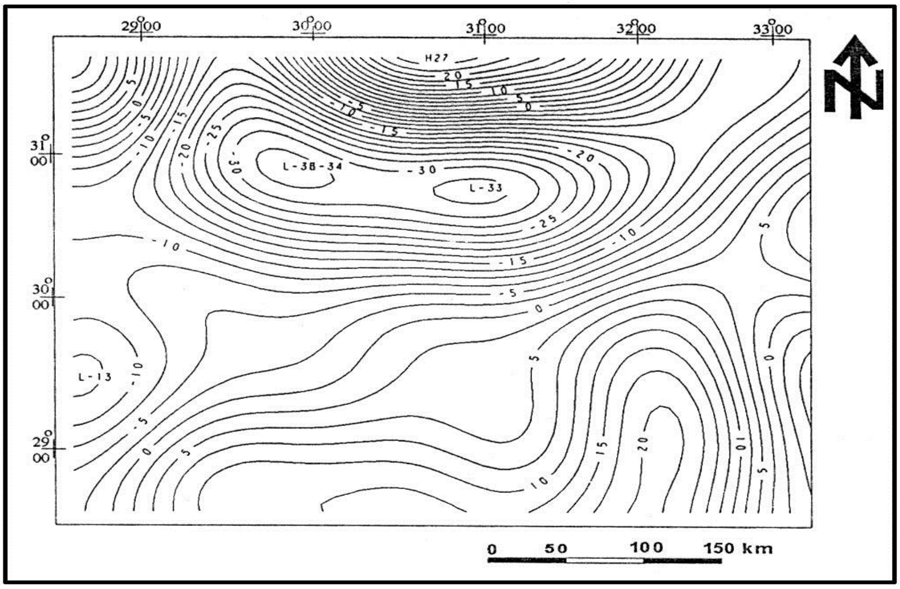

Fig. (6): Band – pass filtered Bouguer contour map; C.I.=5mGal, frequency band < 0.00 c/km

(C) Profile 3:

The profile has been taken also along S-N direction passing a distance of 365 km. It starts from El Galala El Bahariya in the south, extending northwards up to the Mediterranean Sea coast and offshore as manifested from Fig. (9). From this section the thickness of the sedimentary cover varies from 5 and 3.5km in the first 150 km, increases to reach to about 12 km at 340 km, then decreases to about 11 km at the end of the section. Also, the thickness of the upper crustal layer (depth to Conrad discontinuity) ranges between 22 and 13.5 km. In the same time, the thickness of the lower crust ranges between 11.5 and 9.5 km. Moreover, the thickness of the crust (depth to the Moho surface) ranges between 33.5 and 23 km.

From the previous sections the thickness of the sedimentary cover, in general, varies nearly between 2 and 12 km and this in close agreement with Abd El-Rahman et al.(1988), Ghazala et al.(1992), Omran(2000) results. Also, the thickness of the crustal layers ranges from 33 to 22 km also in agreemant with Ginzburg et al.(1981) and Tealeb and Riad (1986). Except the upper crust, the composition of the upper mantle and the lower crust ,in density term, is of basaltic nature (density =3.33g/cc), is in close agreement to Omran (2000) and Sitto (1991) results. The upper crustal layer has been simulated by wide range of densities. Makris (1988a), through deep seismic shooting, has implied that it is close to "gabbroic" (2.85) characteristics of density 2.82 g/cc. Abd El Rahman , 1988 (in Omran 2000) and Omran (2000) have been shown that it attains density values of 2.68 and 2.67 g/cc respectively, and has nearly "granitic tone". El Hadidy et al.(2000) have inferred that this layer has a density value of 2.74 g/cc implying an andesitic nature. The abnormal high and low density values derived from seismic velocity ones for crustal layers may be attributed either to the density - depth (age) direct proportional relation or to the prevailing physical state (confining pressure, water content and temperature) or both.

Therefore, the higher seismic velocity value (6.0 km/s), of Makris et al.(1988a), may be affected by the higher confining pressure (inherent in elastic modulus) for such upper crustal layer situated under sedimentary succession of more than 10 km and hence a derived high density value of 2.82g/cc has been obtained. Although, this layer is assumed to be of "granitic nature" as their analogous of continental plateau regions the new obtained density of 2.7 g/cc for the postulated new model classifies it as intermediate or of andesitic nature. This can be proved if the successive deposition and erosion cycle, uplifting and the associated raised lithosphere magmatic material have been considered. From the obtained geologic sections, the plastic behavior of both Conrad and Moho discontinuities (ascending upward) emphasizes clearly, thinning, stretching of the crust, uplifting and raising up of lithosphere and magmatic material, after of course erosion operation cycles, to seek for the isostatic compensation. Ascending of the lithosphere and magmatic material gives rise to these upwelling magma to inject and/or to intrude in the upper crust as well as extrude at the surface as volcanics. The occurrences of different age volcanic rocks, Meneisy,(1990), in Nile Delta and its surroundings are well geologically and geophysically documented (Said, 1962; Said, 1981; Bayoumi and Ahmad 1969; and Bayoumi and Ahmad 1970; Meshref et al. 1982; Neev et al., 1978 and others)

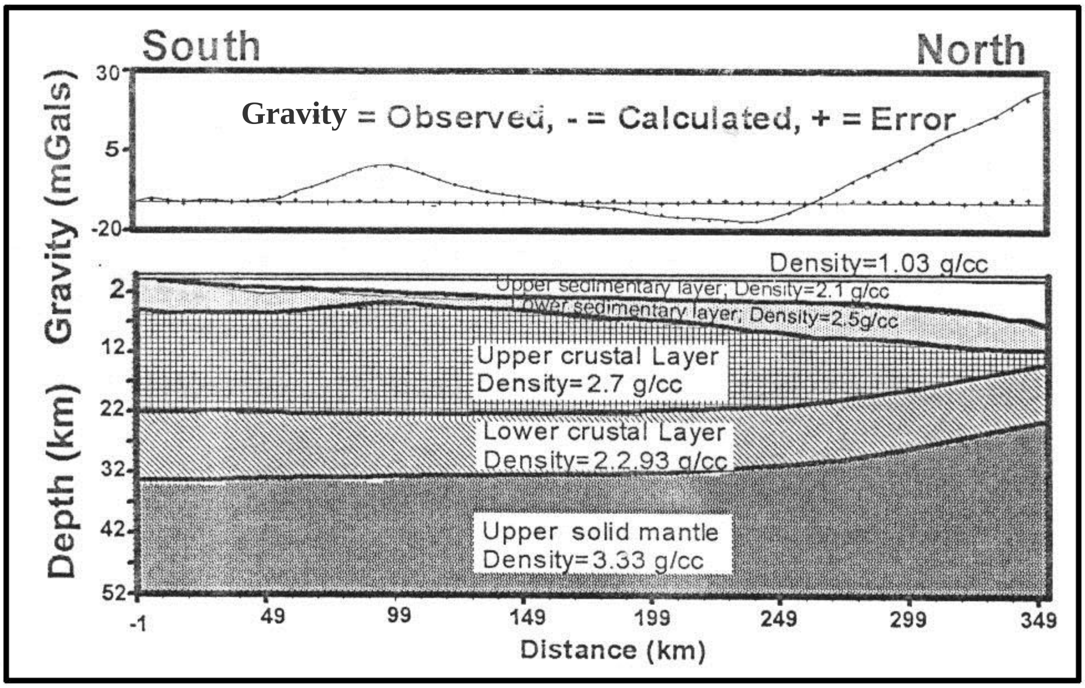

Fig. (7): 2-D Geologic crustal section along profile 1, as obtained from 2-D gravity modeling.

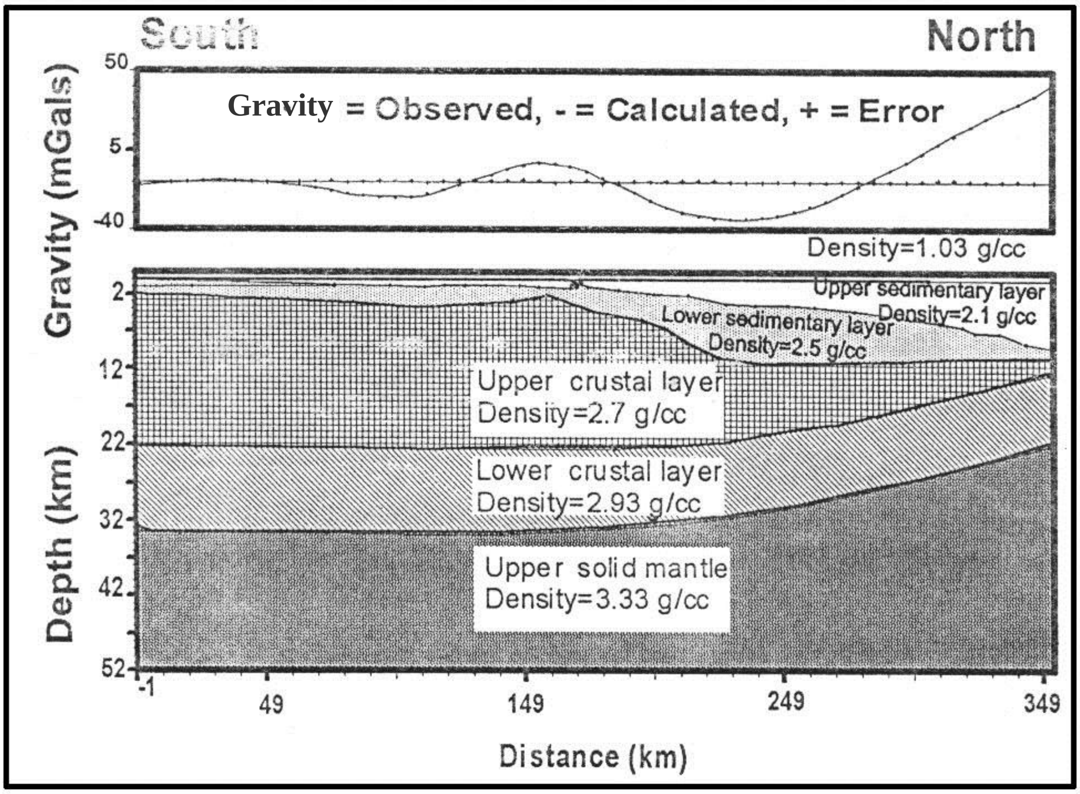

Fig. (8): 2-D Geologic crustal section along profile 2, as obtained from 2-D gravity modeling.

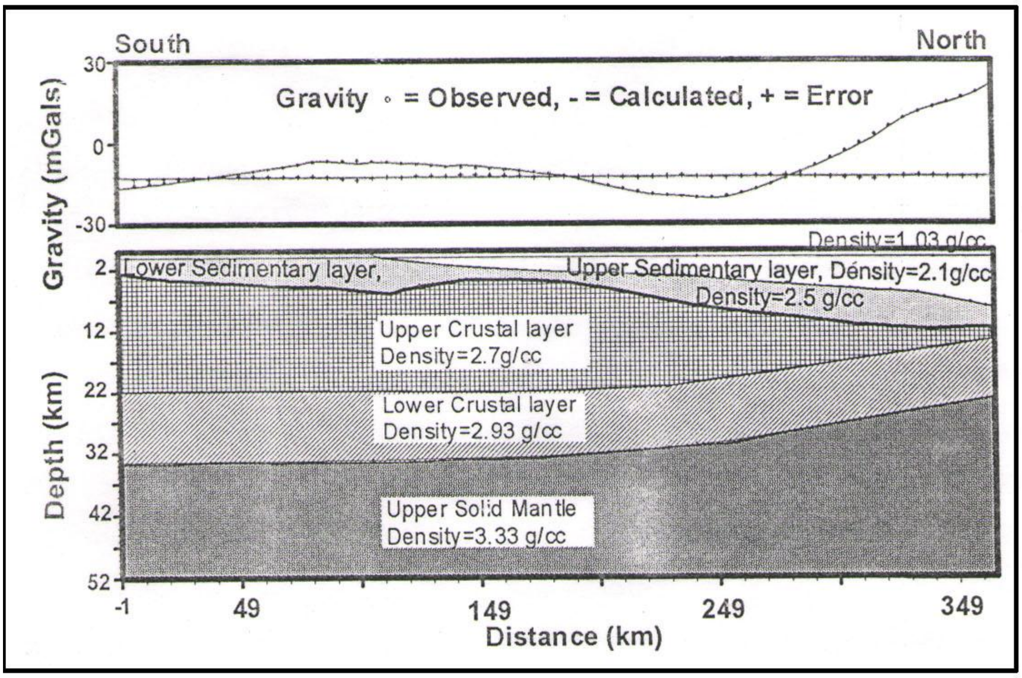

Fig. (9): 2-D Geologic crustal section along profile 3, as obtained from 2-D gravity modeling.

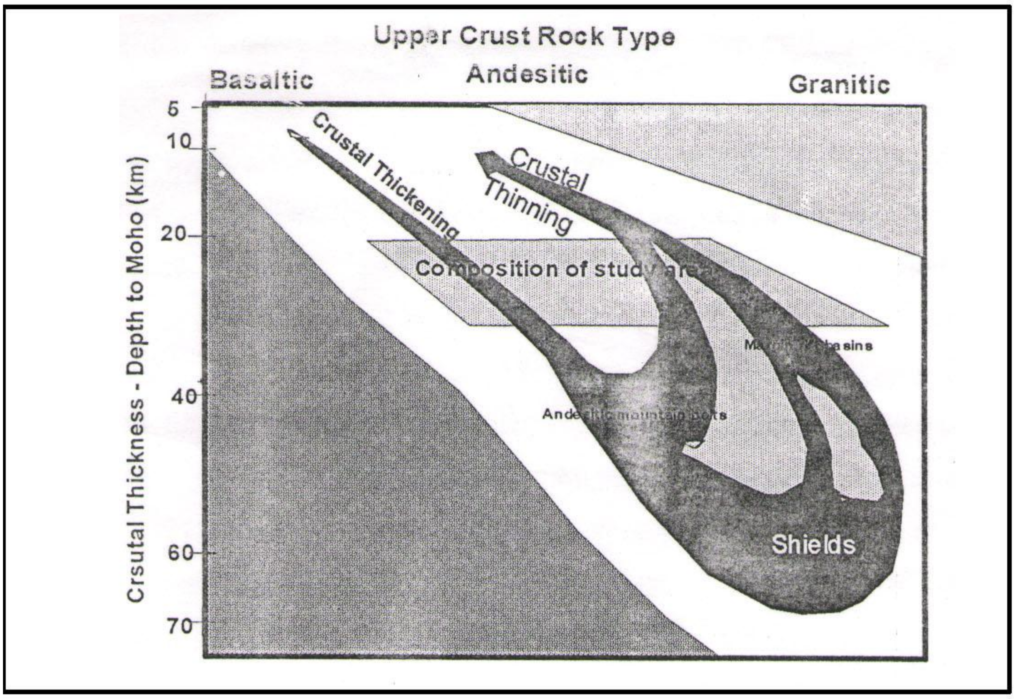

Fig. (10): Crustal type (composition) of the area of study according to crustal thickness-composition relation.

but these basalts according to Bayoumi and Sabri (1970) are of limited thickness (about 65m) and situated at shallower depths (about 100m), and cannot be detected by such coarse gravity survey as previously mentioned. Hercynian compressional, Afro-Arabian - Eurasian separation tensional , Alpine orogeny of tensional and/or compressional, Oligocene - Early Miocene tensional and late Miocene -early Pliocene subsudence bending stresses have the main role in the development of the North African crust and constructing the marginal basins. The former trends have been revealed in the previously Bouguer gravity contour map and band pass filtered Bouguer contour maps as previously discussed . However, from the crustal thickness - composition relation, Fig.(10), established by Cumming and Shiller (1971), the evolution of crust from continental, passing through intermediate to semioceanic type is clearly visible. Consequently, the North African passive margin as depicted from the crust of the Nile Delta and Delta Cone of thickness ranging between 33 to 23 km, evolved from continental in the southern parts (33 km) passing through intermediate (andesitic) to semi-oceanic type with more oceanisation nature offshore. This relation reveals clearly the transition of Precambrian to Cambrian crust; from Continental (granitic) to semioceanic or oceanic type, in the far north offshore, as a result of evolution crustal cycles generated from the interaction between stresses (including eustatic sea level changes) and stratigraphy existing from Early Paleozoic to Present.

Summary and Conclusions

From the previous analysis, results and discussion, the following can be summarized and concluded:

1- The Bouguer and the derived band pass high frequency contour maps manifest clearly the orientation of the causative bodies producing anomalies represent the most stresses response prevailed from Precambrian up to Recent. The most pronounced trends are those associated with Alpine, late Miocene subsidence, Red Sea and Aqaba rifting (ENE, E-W, NW and NE directions).

2- An overcompensation is clearly visible in the northernmost part of the area and offshore reflecting the ascending lithosphere material; after deposition and erosion cycles followed by thermal subsidence. It indicates that the plate margin beneath Nile Delta region is still active.

3- From the obtained log power spectrum, it is noticeable that the anomalous contribution is distributed through three frequency bands. The first is the short wavelength (<50km) spectrum band that represents the near surface causative bodies. Secondly, the intermediate wavelength band (125-50km); reflects contribution of the lower crust to mantle material. Finally, the long wavelength band (>125 km) represents crust - mantle surface and upper mantle material. The derived low pass band Bouguer contour map(of wavelength > 125 km) accords with the analogous original source tool Bouguer contour map and sediments and/or basement relief impact still exists and will affect the crustal thickness determination. Hence the modeled gravity profile has been taken directly from the original Bouguer gravity contour map.

4- The analysis depicted that, the initial simple (two crustal layer overlying the upper mantle) postulated model as 2-D density model of density layers of 2.1 g/cc and 2.5g/cc for the upper and lower sedimentary layers, 2.7g/cc for the upper crustal layer(basement), 2.93g/cc for the lower crustal layer (basaltic layer) and 3.33g/cc for the upper layer, is justifiable.

5- Three geologic sections taken along S-N direction have been obtained from gravity modeling and fitting iterations. From these geologic sections, the following can be marked:

I- The thickness of sediments (of density 2.1 g/cc for upper layer and 2.5 g/cc lower layer) varies in - between 2 and 12 km in the S-N directed profiles and nearly 3-11 km along W-E directed profile. Also. the thickness of the upper crustal layer (density = 2.7 g/cc) varies from about 22 to 13 km whilst the thickness of the lower crust (density =2.93g/cc) varies between 11 and 10 km. Moreover, the thickness of the crust ranges from 33 to 23 km.

II- The shape and the depth of mid-crustal and crust-mantle surfaces reflect clearly the thinning, stretching of crust and depicting the lithosphere ascending material.

III- According to crustal thickness - composition relation (Fig.l0), the crust of Nile Delta and its surrounding regions, or the crust of North African margin in general, seem to be of continental nature in the southern part (south of latit. 31 N), intermediate (andesetic) to semioceanic type beneath nearly the northern half of Delta block with more oceanisation (close to basaltic composition)northerly offshore.

IV- The transition of Precambrian to Cambrian crust from continental (granitic) to intermedite (andesitic) and from intermedite to semioceanic types reveals the evolution crustal cycles, resulted from the interaction between stresses(including eustatic sea level changes) and stratigraphy prevailling from Early Paleozoic to Present.

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