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GEOLOGICAL INTERPRETATION OF GRAVITY DATA ON A PART AT THE WESTERN REGION OF THE HIGH DAM LAKE, SOUTH EGYPT

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التفسيرات الجيولوجية المستنبطة من البيانات التثاقلية على جزء من منطقة غرب بحيرة ناصر ، جنوب مصر

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قسم الجيولوجيا - كلية العلوم - جامعة أسيوط - أسيوط ٧١٥١٦ - مصـر

تهدف هذه الدراسة إلى تحديد عمق وهيئة سطح الركيزة المعقدة (Basment Complex) وكذلك تقييم التراكيب الجيولوجية التحت سطحية في جزء من منطقة غرب بحيرة ناصر بناءاً على تفسير شواذ البوجير التثاقلية (Bouguer Gravity Anomalies) ، لذلك فقد استخدمت طريقة التدرج الأفقي (Horizontal Gradient) للمجال التثاقلي حيث تم إجراء تحليل أحصائي لإتجاهات القيم العظمى لها للتعرف على الأتجاهات التكتونية الأساسية التي أثرت على هذه المنطقة المدروسة كجزء من المنطقة الجنوبية لمصر حيث نوقشت الأجهادات المحتملة في نشأتها .

أمكن فصل المجال التثاقلي باستخدام طريقة المربعات الصغرى إلى مركبتين : المركبة الأقليمية (Regional Component) وهي الناتجة من التراكيب العميقة ممثلة بكثيرة حدود من الدرجة الأولى (First Order Polynomial)، والمركبة المحلية (Local Component) وهي الناتجة من سطح صخور الركيزة المعقدة وما يعلوها من تراكيب رسوبية وكذلك تم استخدام طريقة التحليل الطيفي (Spectral Analysis) في تحديد عمق صخور الركيزة المعقدة حيث وجد أن متوسط عمق هذه الصخور يتراوح من ١٥٠ - ٦٠٠ متر تقريباً .

وأمكن أيضا تصميم نماذج تثاقلية (2 1/2 D-Gravity Moddels) على طول ثلاثة بروفيلات في اتجاهات مختلفة حيث أفادت نتائجهم في معرفة شكل سطح صخور الركيزة المعقدة بمنطقة الدراسة ومعرفة التراكيب التحت سطحيةالسائدة ، مما ساعد في التعرف أيضاً على توزيع الكتل الهابطة والصاعدة (Subsided and Uplifted Blocks) وقد أشارت نتائج هذه الدراسة ألى إحتمال تأثير هذه التراكيب على وجود خزانات للمياه الجوفية (Water-Bearing Zones) بالمنطقة التي قد تتسرب من مياه بحيرة ناصر خلال الكسور التي تأخذ إتجاهات مختلفة .

Key Words : Gravity- High Dam - South Egypt.

ABSTRACT

The structural setting of the area was determined using the horizontal gradient of the gravitational field and the statistical analysis of its maximum trends. The gravitational field was resolved into its two components; residual and regional using the available software programs. The calculated residual field was used to determine the interfaces of shallow depths. The spectral analysis technique was also carried out to estimate depths to the buried causative discontinuities. 2.5 gravity modeling programs were made along some selected profiles to portray the configuration of the basement surface. The structural picture of the area, as revealed from the current study mainly shows a complicated pattern of many fault systems influenced the basement as well as the overlying thin sedimentary section. The regional field of the area was represented by a first-order trend surface. Based on the spectral, analysis interpretation, the depths to the top of basement rocks between 150 to 600m. These results contirnct the calculated models. The distribution of top of the basement rocks rasge range between 150 to 600 m. These results are cpnfirnd from the calculated models. The distribution of local uplifted and downfaulted basement blocks in the area may assist in accumulation of groundwater migrated from the High Dam lake throughtout an infensie. Also an intensive fractune pattern daminated in the sfudy area .

INTRODUCTION

The objectives of the present study are to reveal and evaluate the subsurface structure and the basement configuration at an area localed west of the High Dam Lake south Egypt (Fig. 1). The study is based on the analysis and interpretation of the Bouguer gravity field and also on the available surface and subsurfac geological information.

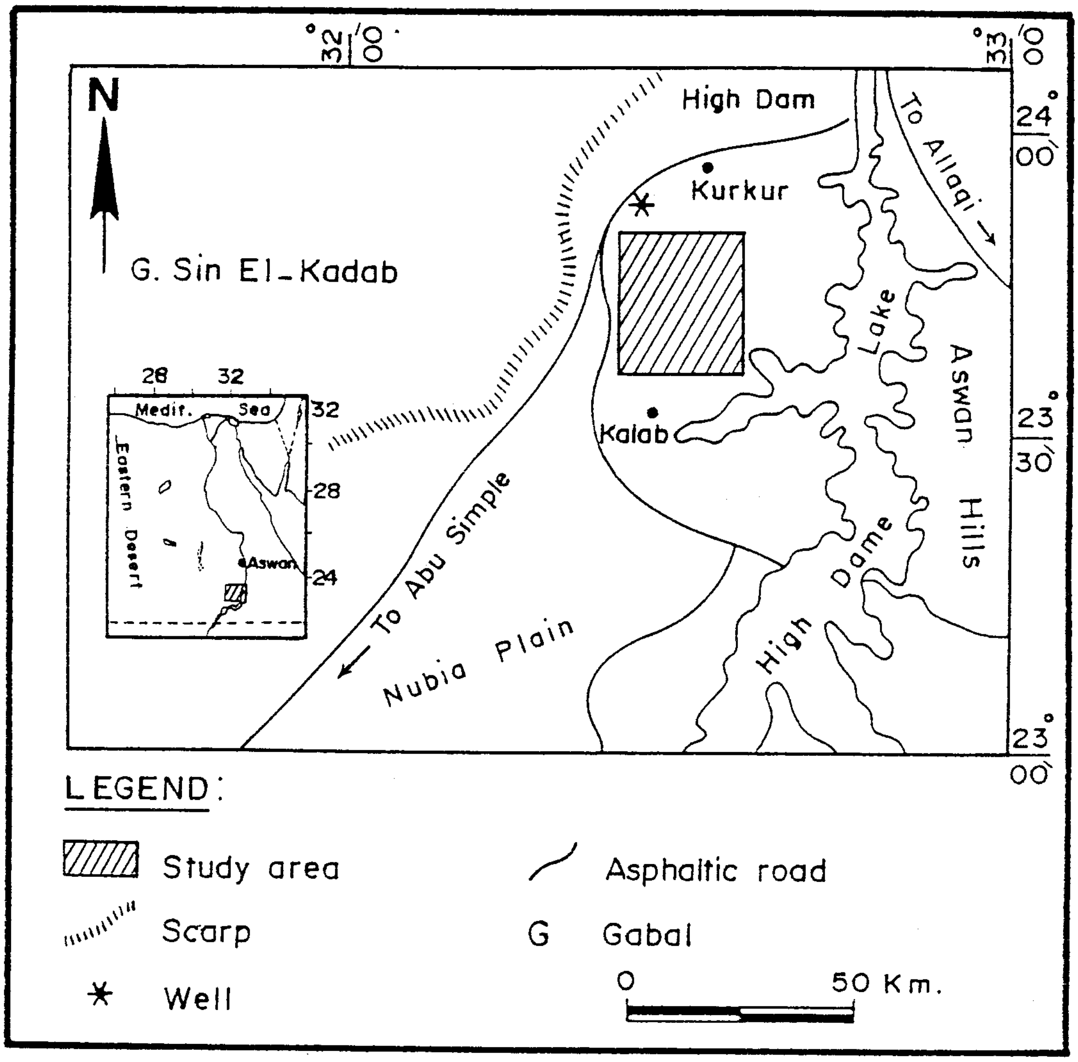

Fig. 1: Location map of the studied area.

The general geology of the southern part in the Western Desert of Egypt was studied by many workers amony them are: El-Shazly et al. (1976), Issawy (1978), Said (1981) Kebeasy et al. (1987), Radwan (1990) and Vyskocil et al. (1990). There are no detailed and enough subsurface information about this area .

Most of the southwestern part of Aswan region is covered with forel and sediments ranging in age from Cretaceous to Quaternary, with some exposures of igneous and metamorphic rocks (Fig. 2). The sedimentary section in the studied area is thin and consists of successions which unconformably overlies the basement rocks (Fig. 3).

The studied area belongs to the stable shelf (Said 1962). In other amodified classification, it is included in the Archican Nubian shelf Smith, 1984) (Fig. 4).

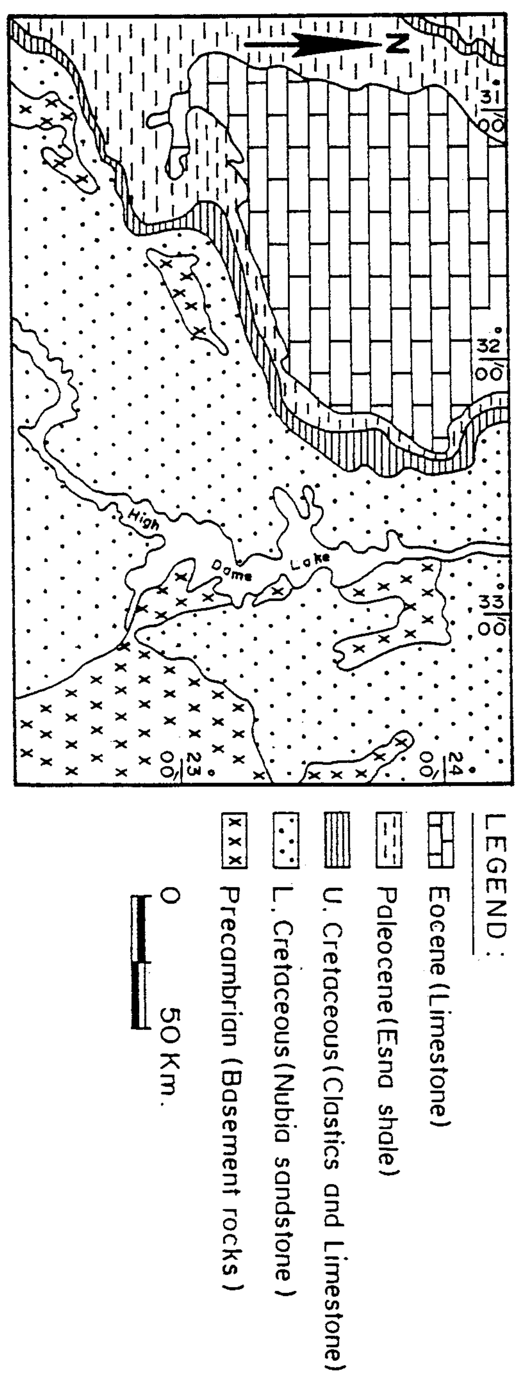

Fig. 2: Simplified geological map of the examined area and the surrounding parts (compiled after the Geological Survey of Egypt, 1981).

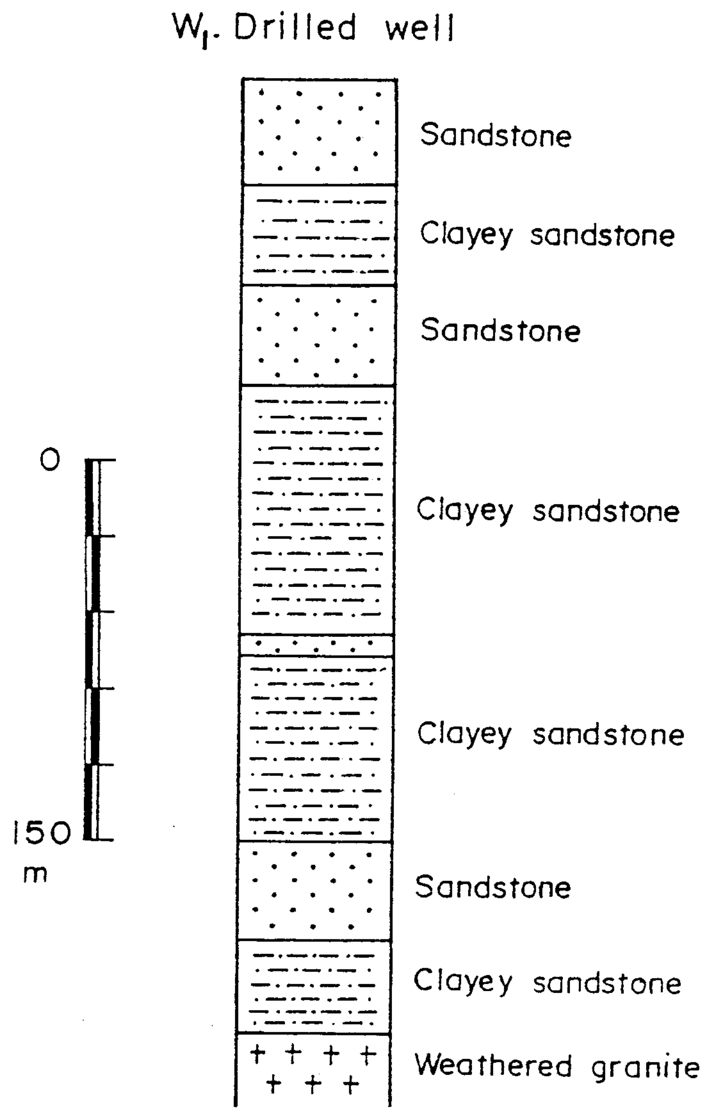

Fig. 3: Subsurface lithologic log of W_1 drilled well.

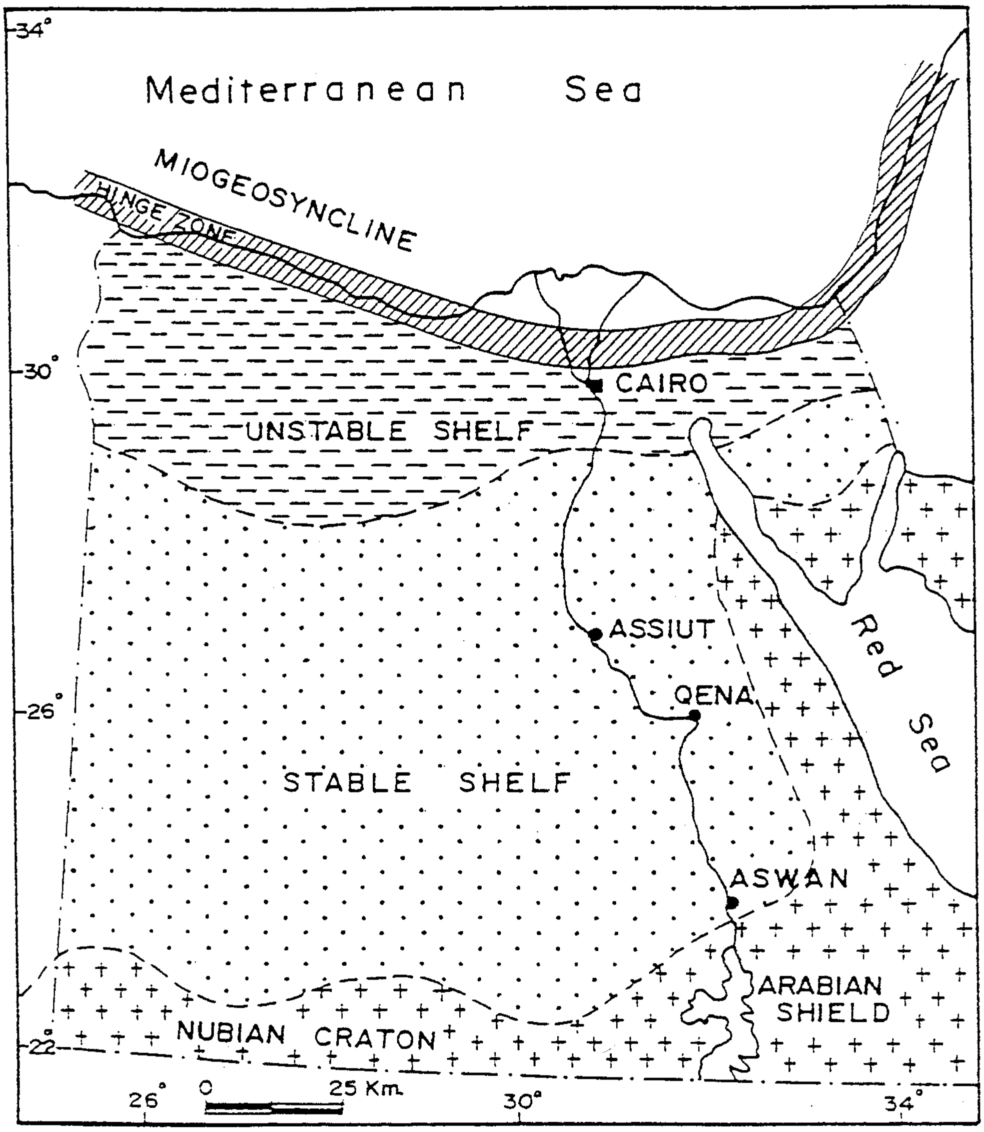

Fig. 4: Sketch of the major structural elements of Egypt (complied after Meshrif, 1990).

ANALYSIS OF THE BOUGUER GRAVITY MAP?

The Bouguer gravity map of the studied area (Fig. 5) was in 1989 by the National Research Institute of Astronomy and Geophysics (NRIAG) inserted in Cairo-Helwan, uning a Bouguer density of 2.3 g/m/cm3.

The achievement of our objectives was mad through different methods and techniques:

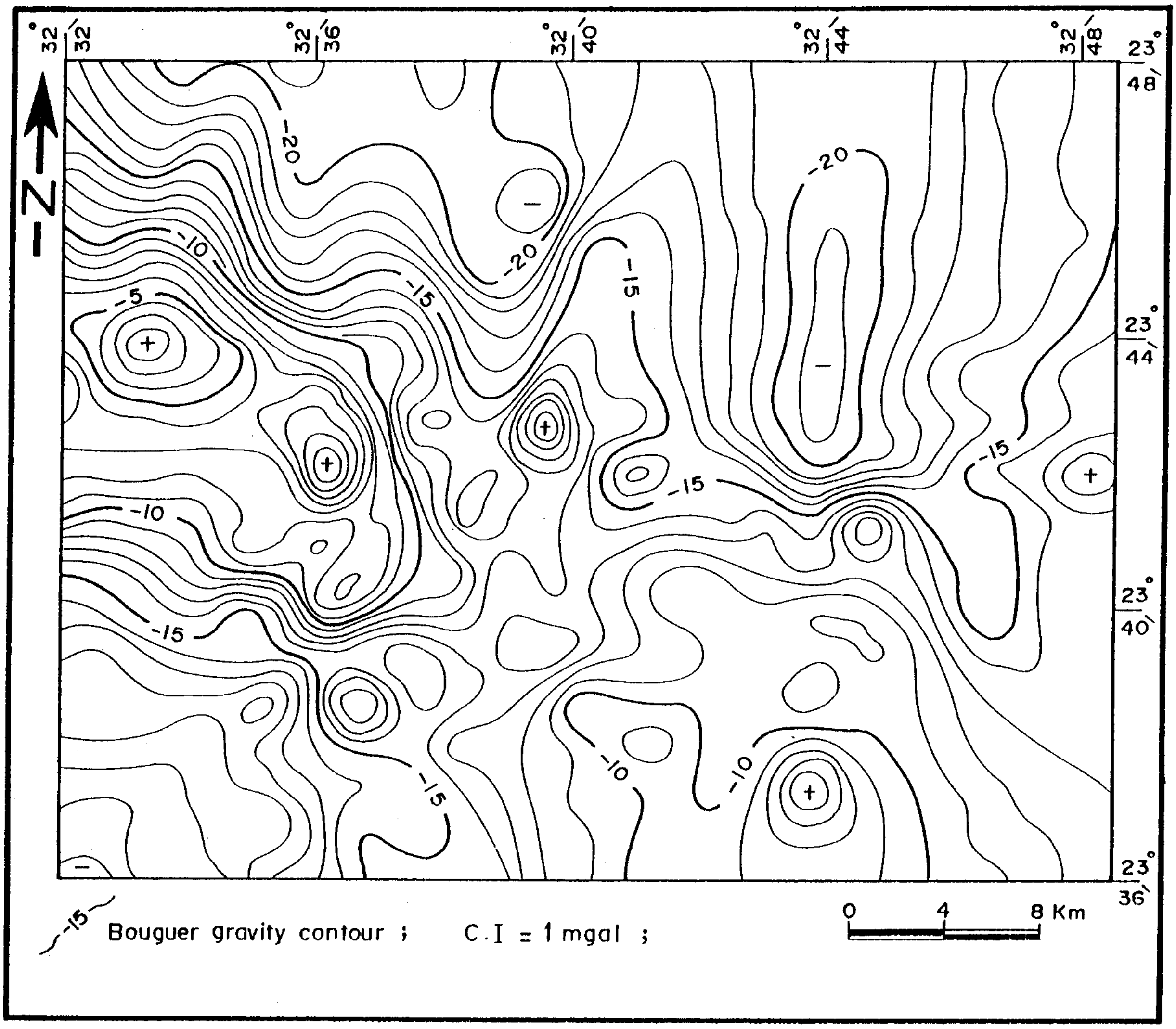

Fig. 5: Bouguer gravity anomaly map of the examined area, western region of the the High Dame Lake.

2.1. Horzontal gradient and trend analysis of gravity anomalies:

The Bouguer gravity map of the studied area was used to investigate the structural and tectonic feature by the analysis and iterpreatation of the determined horizontal gradient values of the Bouguer gravity anomalies. For this purpose, the studied area was digitized with grid separation (S) of 0.5 Km. The gradient magnitude and the direction of the gravitational field isolines were determined from four (4) points which lie in the corners of the square grid on a circle of a radius equals to $s\sqrt{2}$ around the calculating point (p) (Fig. 6). The gradient magnitude Vxz (p) was determined by applying the formula given by vàlek in 1972:

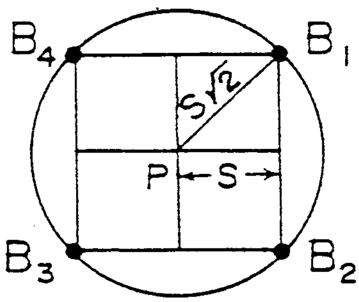

Fig. 6: Scheme used for calculating the horizontal gradients of the gravitational field (after Válek, 1972) in the studied area.

$$V_{xz(p)} = (0.707 / 2S) . \sqrt{R_1^2+R_2^2} \qquad (1)$$

where,

$R_1 = g(B_1) - g(B_3)$ and $R_2 = g(B_2) - g(B_4)$ are the differences of the gravity anomalies in points; B_1, B_2, B_3 and B_4 (Fig. 6).

The direction of the isolines (α) in radians is approximately estimated using the vàlek's Formula:

$$\alpha = \theta + \pi/2, \qquad (2)$$

where,

$$\theta = \arctan [(R_1 + R_2) /(R_1-R_2)]$$

The linear isolines of the maximum horizontal gradient and different trends (possible fault zones) were detected and statistically analysed in terms of their azimuth direction every 10° around the north. A map showing the distribution of the different determined interpreted maximum horizontal gradient (Fault) trends is illustrated in Figure 7. Also, these maximum gradients (possible faults) are represented in the form of a frequency curve of number (Fig. 8).

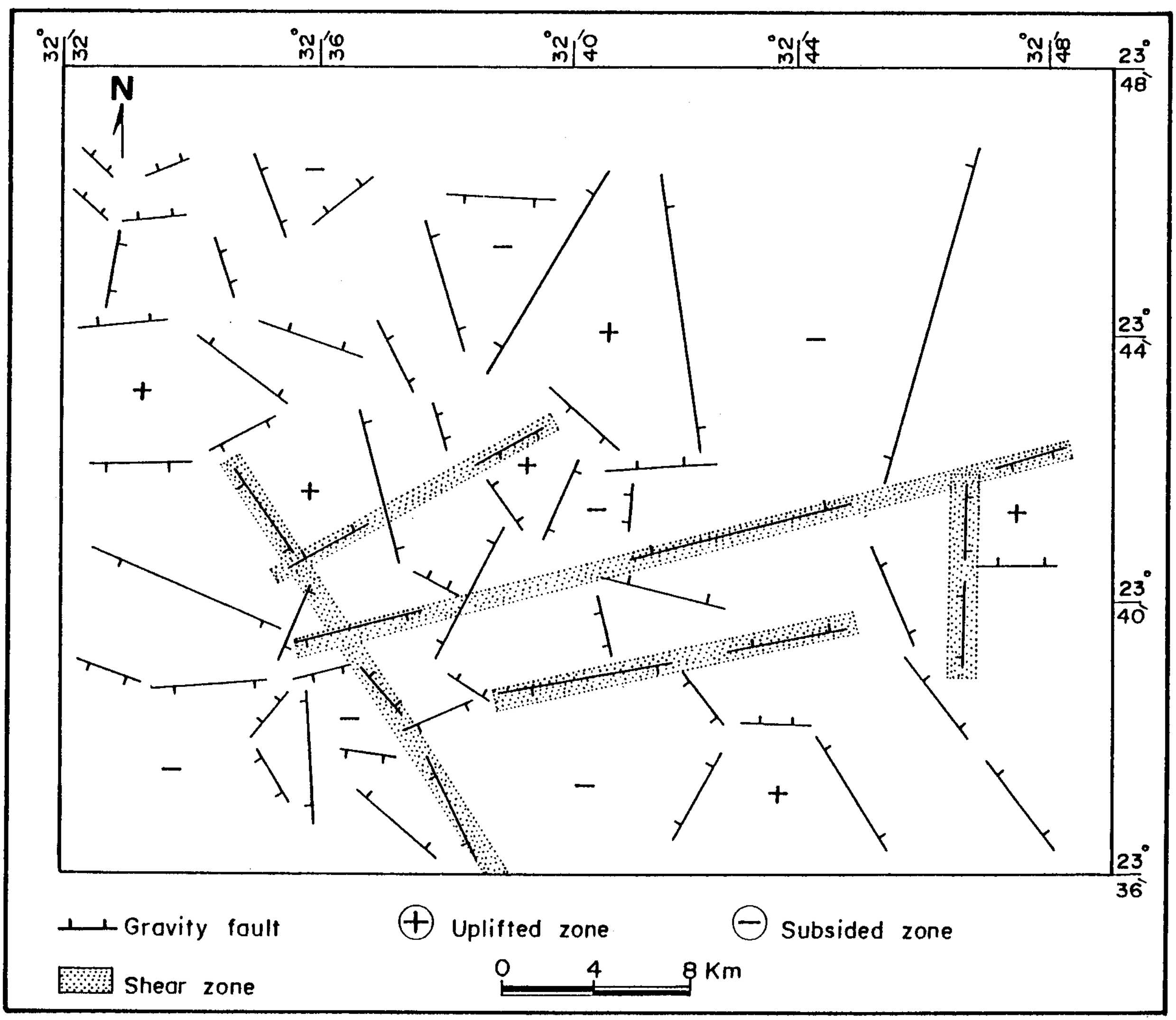

Fig. 7: A map showing the distribution of different interpreted gravity faults in the studied area.

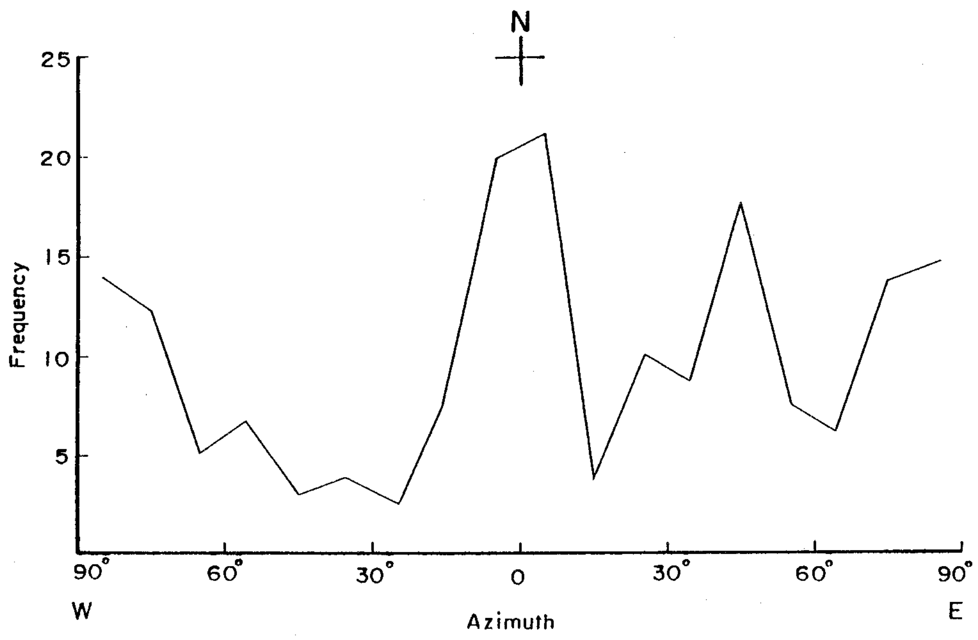

Fig. 8: Azimuth frequency curve of maximum horizontal gradient trends of gravity anomalies in the investigated area.

2. Least-square residuals:

For geological interpretation, both local and vgional effects are separated from and each other Therefore, the Bouguer gravity field of the studied area was subjected to a separation technique using the least-squares method. In the least-squares method, the objective function is the sum of the squared differences between each observation and the value of the fitting functional at that observation point. The decision-making criterion is the minimization of the objective function. Generaly , the robust(M) estimator [11] can be obtained by minimizing the objective function:

$$Q(c) = \sum_{i=1}^{n} \mu(r_i/s),$$

where μ is the functional defining the particular robust method and r_i is the residual at the ith observation fiven by

$$r_i = g_i^{(o)} - f(x_i, y_i, z_i, c),$$

where g_i is the ith . observation, $f(x_i, y_i, z_i)$, (c) is the fitting function evaluated at ith observation point (x_i, y_i, z_i) c is a set of parameters uniquely defining the function f, and s is a scale factor. The least squares method can be viewed as an(M) estimator with

$$\mu(v) = v^2$$

Regional-residual separation by polynomial fitting assumes that the regional may be fitted by a completen-order polynomial in both x and y directions, that is,

$$f(x, y, z, c) = P_n(x, y, z, c) \quad (5)$$

where c is the set of polynomial coefficients.

Of necessity, the polynomial is fitted to the total field and not to the (unknown) regional by the least-squares method [12] and [13] abdelraham. According to [13] the optimum order of the regional potential surface can be determined. Cons.equently, the least-distorted residual component of the field can be calculated using the correlation coefficient (Rnm) between residual maps of successive orders (n and m). The residual map of the lower order in the well-correlated doublet is leing considered as the most plausible for gravity interpretation. The correlation coefficients between the successive residual maps were computed. Then, the regional field in the examined area can be represented by a first-order surface. The least-squares first-order regional and residual maps of the area are shown in Figure (9) and (10) respectively.

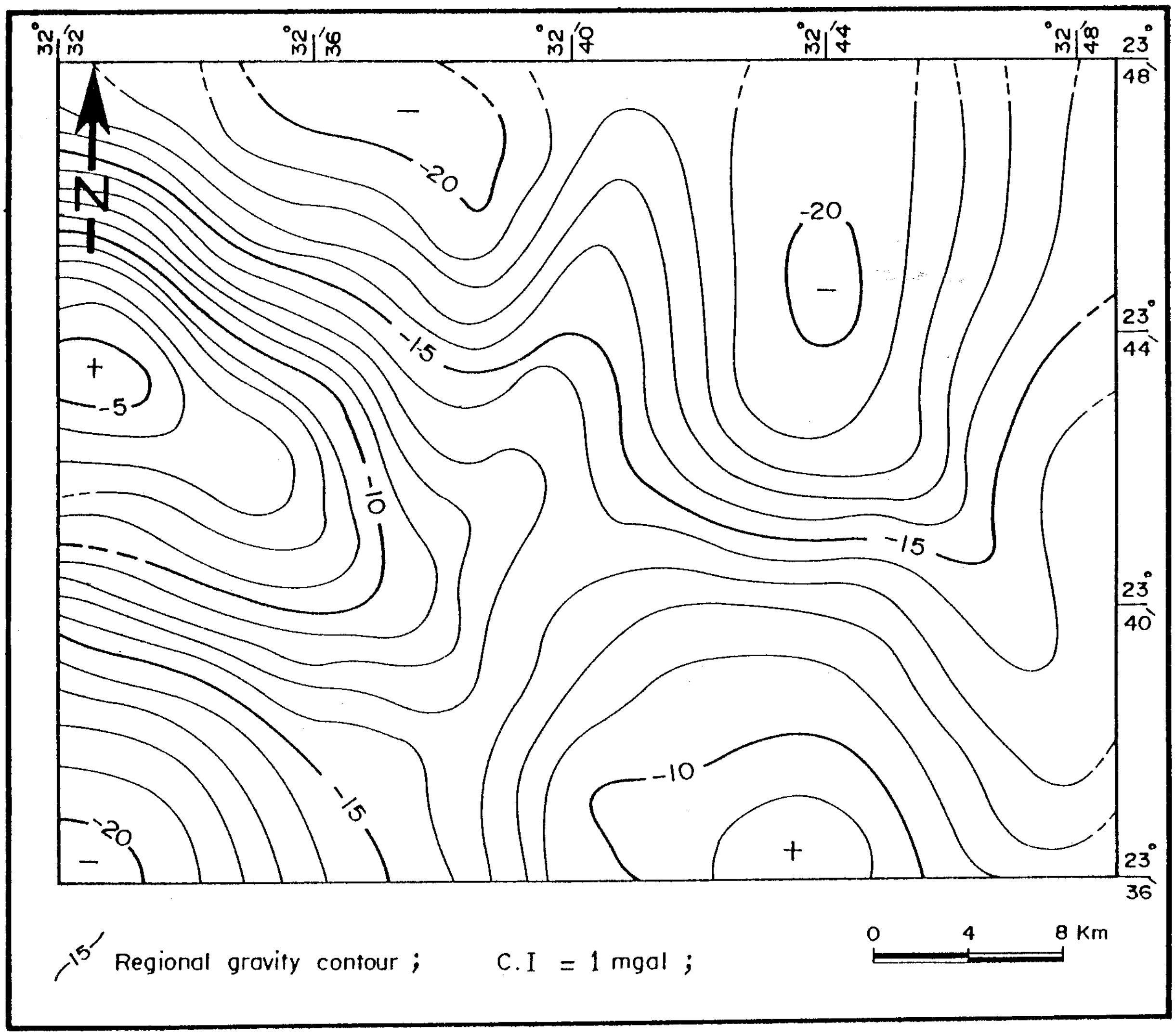

Fig. 9: Regional gravity trend (first order) map of the studied area.

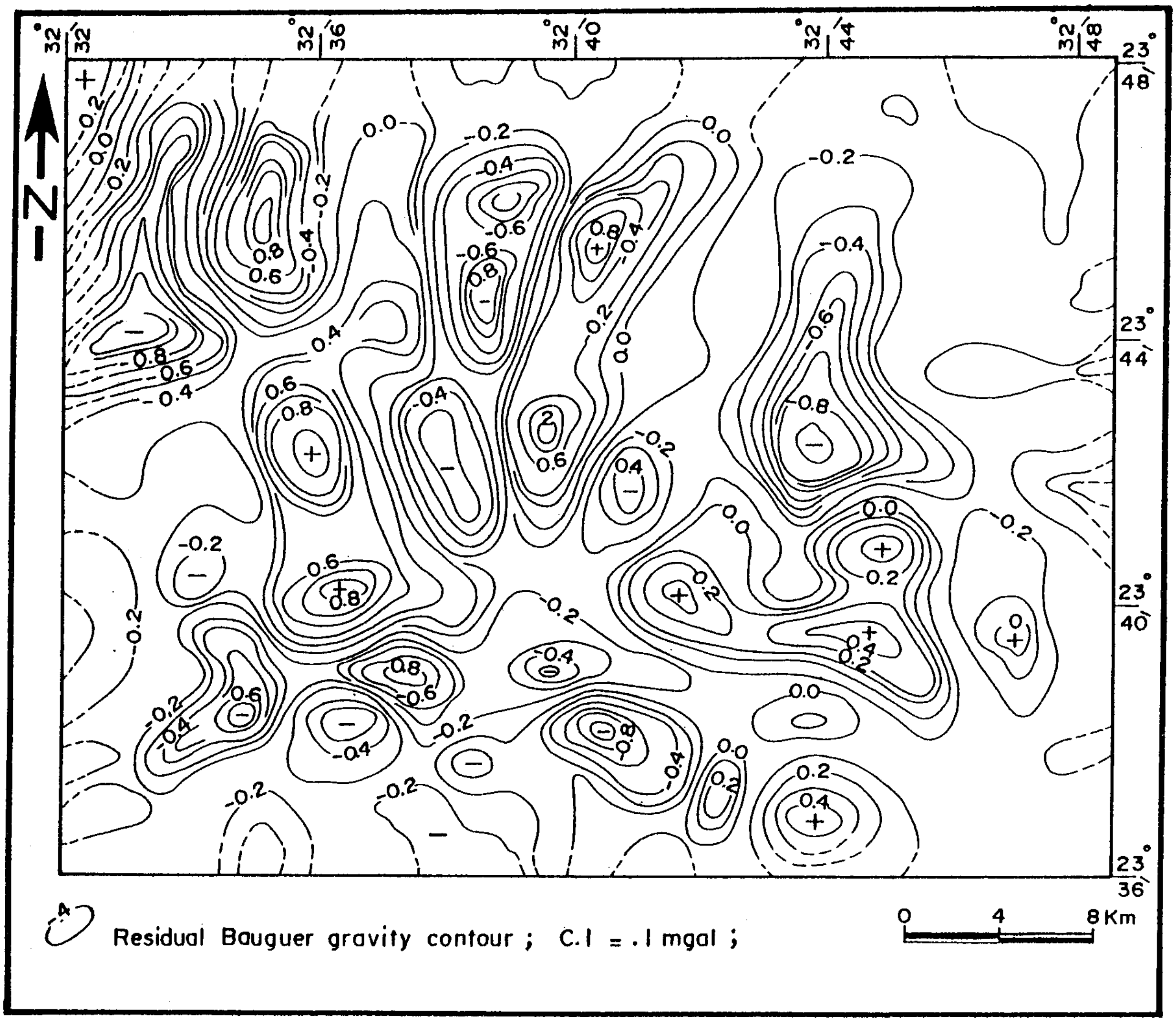

Fig. 10:Residual gravity anomaly map (first order) of the area.

2.3. Spectral analysis:

Spectral analysis techniques were suggested by many authors (e.g. [14] ; [15] ; [16], for the analysis and interpretation of the geopotential field data. These techniques represent an impotant tool because the power spectra can be used to determine the average depth values for the different buried causative bodies, specially the subsurface of the basement . The field anomalies which were measured in space domain, are trans formed into frequency domain via Fourier transform, and the parameters of the different anomaly sources are determined from the characteristics of the energy amplitude spectra.

Fourier's spectral analysis was applied in this study on the observed gravitational anomalies of the examined area along different porfiles, using the fast Fourier transform-method [15] and [16]. The average depth (h) to the top of the basement discontinuity (the shallower density contrasts within the earth's crust) was calculated from the slope of the straight line interpolating the diagram of the natural logarithm of the energy spectrum versus the spatial frequency, especially in the high frequency contents of the spectra. The measured depths are interpreted on the base of the low frequency contents of the spectra, related to deep sources (e.g. Moho discontinuities),which were not considered in this study. Some examples of the measured spectral analysis values along the studied profiles are given in Figure 11. Generally, the depth values varies from about 150 to 600 m.

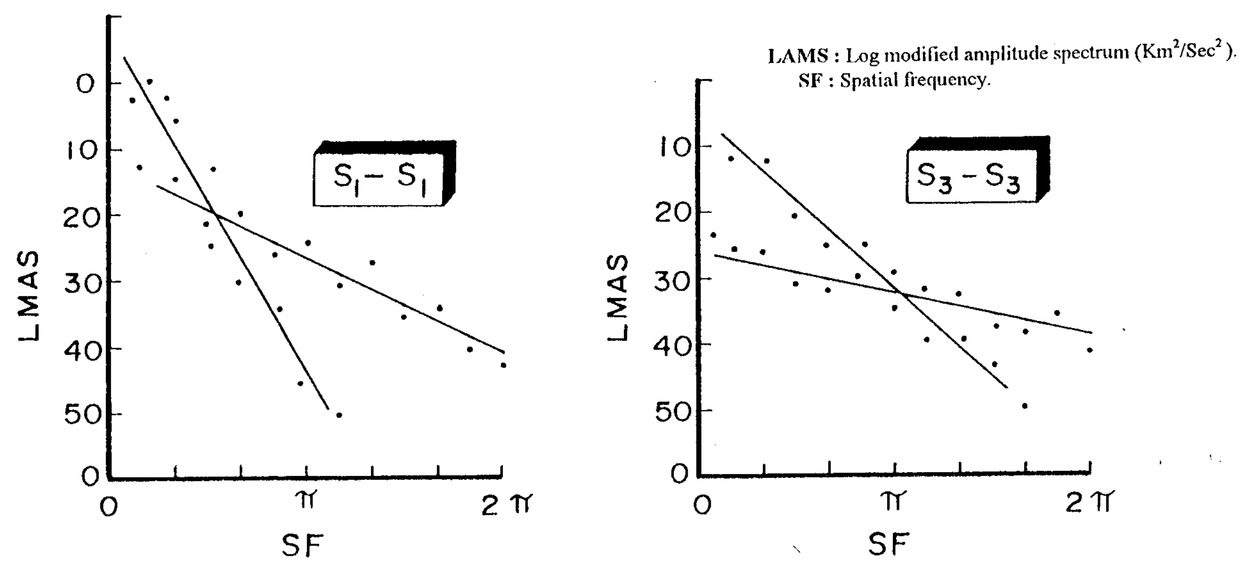

Fig. 11: Examples of the determined spectral analysis values along some studied profiles.

2.4. Gravity modeling:

In the gravitational field analysis, the process of delineating the subsurface structural features is of a prime concern. The gravity modeling of the form $2^1/_2$-D is considered as an effective and important step in such approach. The software based on the $2^1/_2$-D body approximation given by Enmark [17] (1981) which is only slightly changed from the well-known 2-D fromual given by Talwani et al. [18] (1959), i. e. A body of polygonal cross-section with tails in the strike direction cut off, was used in this study and applied along four profiles covering most of the examined area. An optimization procedure (generalized matrix inversion) that computes the best model in the least-squares sense was applied. In the present work the residual anomalies were used in the modeling process to avoid the effect of deep and/or laterally extensive density variation [19].

The density values used in the studied models were deduced from the W_1 drilled well (near the examined area) that reached the basement at a depth of about 0.5 km (Fig. 4). The desity of the sediments is attributed to vary from 2.25 to 2.55 gm/cm^3 while the density of the basement (acidicrocks) in the studied area is about 2.7 gm/cm^3. Satisfactory models of final shapes were obtained after many trials for each studied model. In this study the minimum and maximum density contrasts used in the modeling process were -0.15 and -0.45 gm/cm^3 respectively. Figure 12 illustrates location of the studied examples.

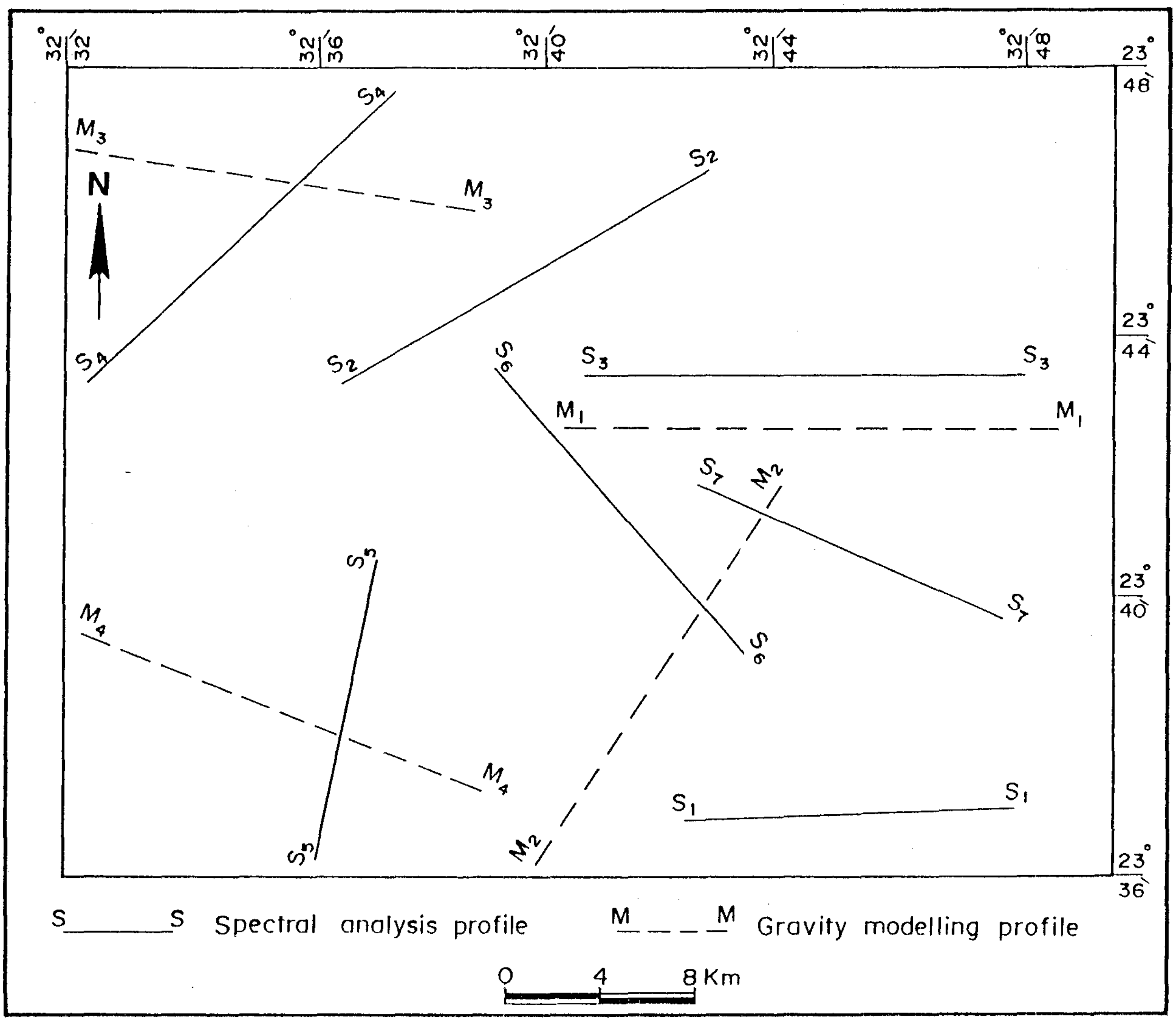

Fig. 12: Location map of the studied gravity profiels.

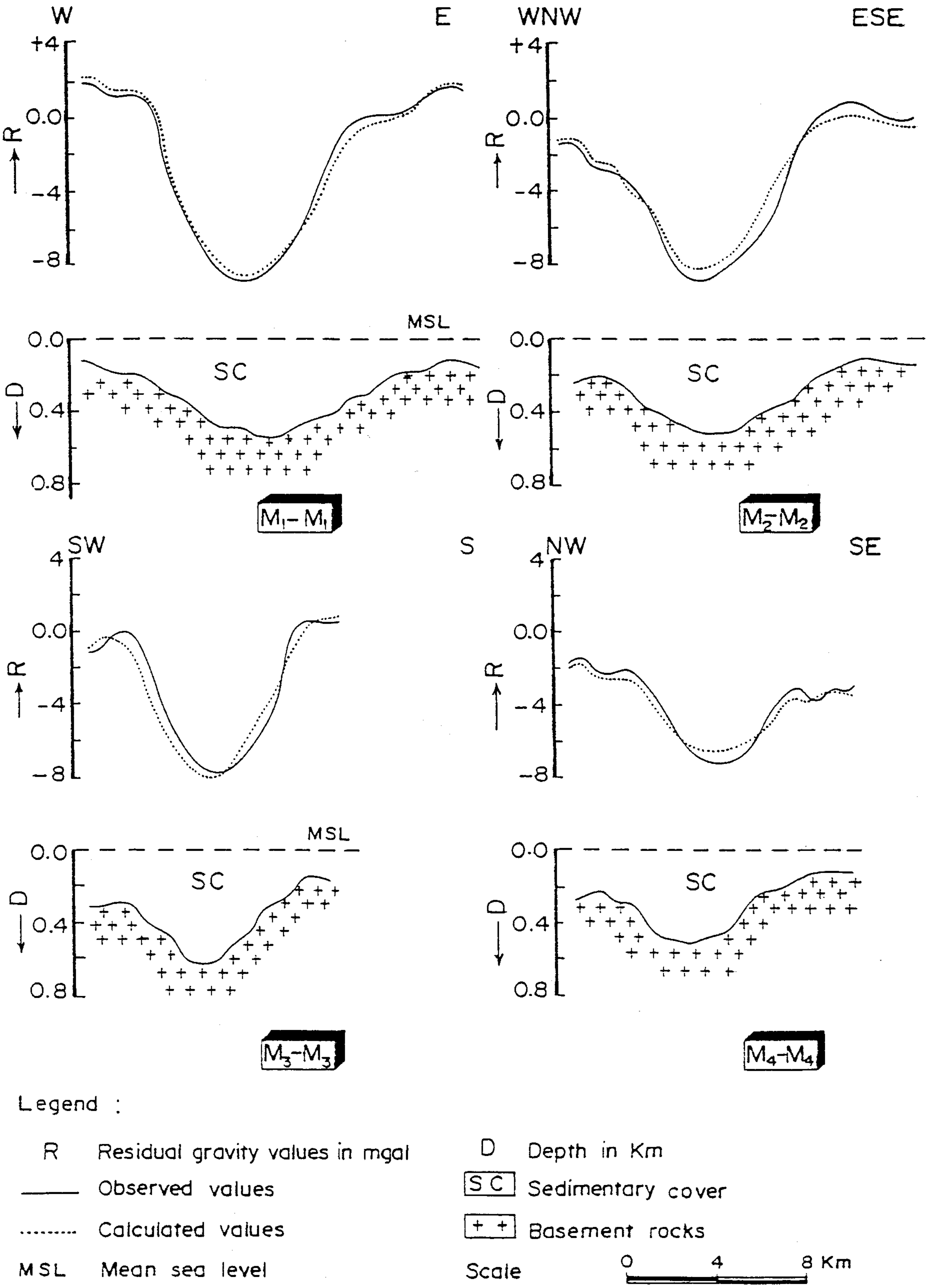

Fig. 13: Optimized gravity modelling along the studied profiles.

The basement depths obtained along each profile were useful to recognize the configuration of the basement topography along these profiles.

3. Discussion and conclusion:

The Bouguer gravity map of the studied area (Fig. 5) is characterized by negative values ranging in magnitude between -2 to -22 mgal. The main distinctive anomalies are: the generally elongated-shaped low anomaly, trending nearly N-S and is lying at the northeastern part of the area; and the elongated gravity belts of NW-SE orientation occupying the western part. Both anomalies are bordered by steep gradient isolines. These major anomalies are also clearly observed, with several smaller high and low ones, on the residual anomaly map (Fig. 10). The low anomalies may be attributed to relatively thick sedimentary sequences of significantly lower density values than the underlying basement rocks. The steep gradients bordering the low anomalies may be resulted from normal faults. However, the high anomaly belts observed on both Bouguer (Fig. 5) and regional (Fig. 9) gravity maps may be due to uplifting of the basement rocks along their locations. The regional gravity anomalies having their trends mainly in the NW-SE, NE-SW, E-W and N-S directions.

The general abundance of gravity fault trends, as interpreted from the gravitational field can be summarized according to their decreasing order in the following:1) N-S, 2) ENS-WSW, 3) E-W, 4) NNE-SSW, gravity faults and shear zones suggested that the area, as a part in the southwestern region of Egypt, has been subjected regionally to two field stresses (Fig. 14). The first (the oldest) one is the Meridinal stress which was acting in an alost N-S direction [9] that probably started in late Paleozoic and is related to the relative motion of the African and Europian plates [21]. The most pronounced activity of this stress field took place during the Alpine orogeny (Fig. 14). The other stress field is the Red Sea rifting field whose principal axis is believed to have N 55° E direction [20].

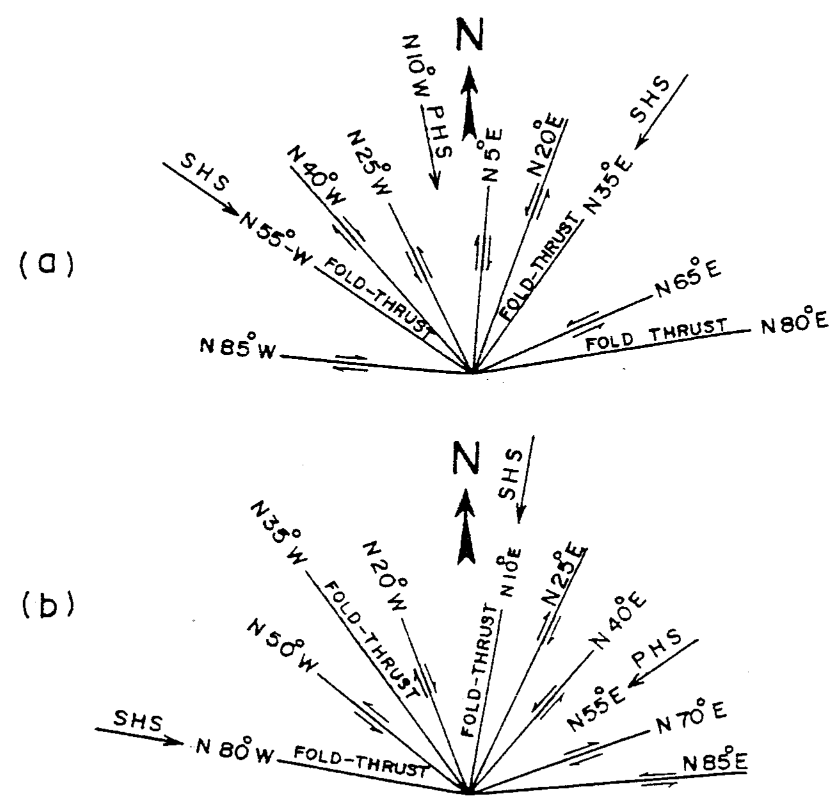

Fig. 14: (a) Meridinal wrench fault tectonic system (after Moody, 1973) and (b) Modified equatorial wrench fault tectonic system (after Riad *et al.*, 1978).

The current results of this study could be briefed in the following:

1. The trend of the profiles defines the dimensions of the modeled bodies . Because lake of density in formation from suitable number of wells different density values have been assumed. The maximum and minimum contrast values that gave the best fit are -0.51 and -0.45 gm/cm^3, respectively for all studied profiles.
2. An increase in basement depth is observed generally to the north and west followed by a decrease to the east and southwest, in contrast to the simple geological findings.
3. The depth to the top of the basement surface in the area, as deduced from the spectral analysis interpretation, ranges between about 150 m at the eastern and southwestern parts to about 600 m at the northern and western parts. The presence of highs and lows on the basement in the studied area may have important indications to encourage the exploration of many natural resources, e. g. groundwater, in such arid area of upper Egypt, which migrafed (dischargel) from the High Dam Lake through the different fractures.
4. The area, as a part in the southwestern portion of Egypt, is dissected by many fault trends which having different directions. In spite of a complex tectonic history and several events of deformation, the latest stress (possibly Cenozoic) was acting with maximum compression acting perpendicular to the spreading axis of the Red Sea.

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