DELINEATION OF THE MAIN STRUCTURAL AND TECTONIC TRENDS IN SOUTH IRAQ, USING DIRECTIONAL FAN FILTERING TECHNIQUES

Fitian R. Al-Rawi [*], Ameen I. Al-Yasi [*] and Ali M. Al-Rahim [*]

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ABSTRACT

The concealed geology and structures of southern part of Iraq has been investigated by analyzing the gravity fields. The main structural and tectonic trends are clearly defined in the N – S and NW – SE directions through using Fan Filtering technique. Deep regional geological trends represent basement features, while shallow structural trends are confined to structures in the sedimentary rocks.

The deep trends act as zones of weakness that affected the sedimentary cover through the different phases of the Alpine Orogeny and led to create different types of N – S and NW – SE folded shallow structures. The obtained structural trends indicate the possibility of N – S and NW – SE distribution, of the geological features all over the central and southern part of Iraq and they add new information concerning deep geologic structures.

تحديد الاتجاهات التركيبية والتكتونية الرئيسية في جنوب العراق، باستخدام أسلوب ترشيح المروحة الاتجاهي

فتيان رشيد الراوي، أمين ابرهيم الياسي و علي مكي حسين الرحيم

المستخلص

تم التحري عن جيولوجية وتراكيب جنوب العراق عن طريق تحليل المجال ألجذبي. لقد حددت بوضوح الاتجاهات التركيبية والتكتونية الرئيسية باتجاه شمال – جنوب وشمال غرب – جنوب شرق من خلال استخدام أسلوب ترشيح المروحة. تمثل الاتجاهات الجيولوجية الإقليمية العميقة ظواهر في صخور القاعدة، بينما تكون الاتجاهات التركيبية الضحلة محصورة في تراكيب الصخور الرسوبية.

لقد عملت الاتجاهات العميقة كأنطقة ضعف والتي أثرت على الغطاء الرسوبي خلال المراحل المختلفة لحركات بناء الجبال الالبية وأدت الى إنشاء الأنواع المختلفة من تراكيب الطيات الضحلة باتجاه شمال – جنوب وشمال غرب – جنوب شرق. تشير الاتجاهات التركيبية التي حددت الى احتمال توزيع الظواهر الجيولوجية باتجاه شمال – جنوب وشمال غرب – جنوب شرق فوق جميع أجزاء وسط وجنوب العراق وهذه تضيف معلومات جديدة الى الدراسات التي تهتم بالتراكيب الجيولوجية العميقة.

[*] Department of Geology, College of Science, University of Baghdad, Iraq

INTRODUCTION

One of the most important properties of the Fourier transform is that features with a certain direction in the space domain are transformed into a feature with only one direction in the frequency domain (Thorarinsson *et al.*, 1988 and 1989). The directional analysis may either be performed directly on the power spectrum or an energy rosette can be calculated by integrating the power spectrum from the center out to some chosen frequency values.

Feature location is accomplished by applying a Fan Filter technique to the complex data in the frequency domain and then takes the inverse Fourier transforming to the result. The procedure is a zero-phase filtering, which does not distort the location of spatial amplitude peak. It is an all pass filter in an overlapped band direction (overlapping wedge-arc filters). Band pass filter can be applied to the overlapped band direction to reject some of the undesired directed frequencies (Mobil, 1980 and Mesko, 1984).

Fan Filter techniques were first used in the analysis of seismic data. The term velocity filter was used firstly by Embree *et al*. (1963). Wiggins (1966) called these 2D operators as "*w-k* filters"; Terital *et al*. (1967) translated it as "Fan Filter".

The identification of trends is as important as they are often related to linear geologic and tectonic features, such as fault groups and fold axes (Mobil, 1980). This procedure is approaching to anomaly separation that reduced the ambiguity inherent in the interpretation of potential field. It is applicable to the analysis of lineation in all kinds of maps. It should be noted that linear features in the power spectrum are perpendicular to the linear space domain features, which they are related (Clement, 1973).

LOCATION AND GENERAL GEOLOGY OF THE STUDY AREA

The study area is located in southeastern part of Iraq with an area of (220 x 220) square kilometers (Fig.1). It lies largely in the Mesopotamian Plain, only the south and southwestern parts of the area lie within the Southern Desert of Iraq.

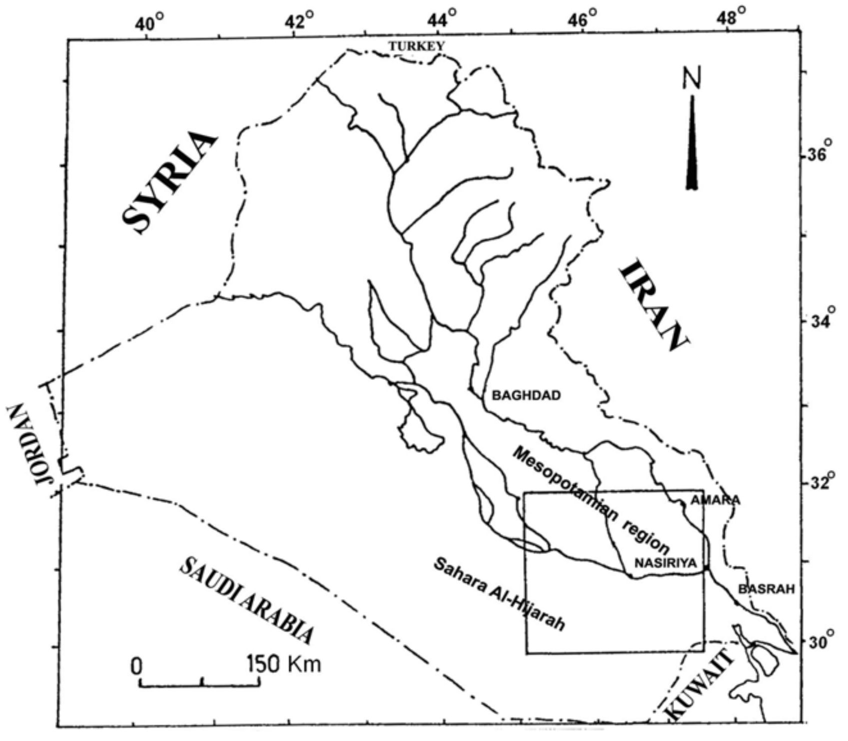

Fig.1: Location map of the study area

The southwestern part of the study area lies in the Stable Shelf (Salman Zone). Its central and northern parts lie in the Unstable Shelf (Mesopotamian Zone), which is subdivided into three subzones. The northeastern part lies in Tigris Subzone (which is the deepest and more affected by the Alpine movements), the central part lies in the Euphrates Subzone (which is the shallower and least affected one), and the southeastern part lies in the Zubair Subzone (Buday and Jassim, 1987) (Fig.2).

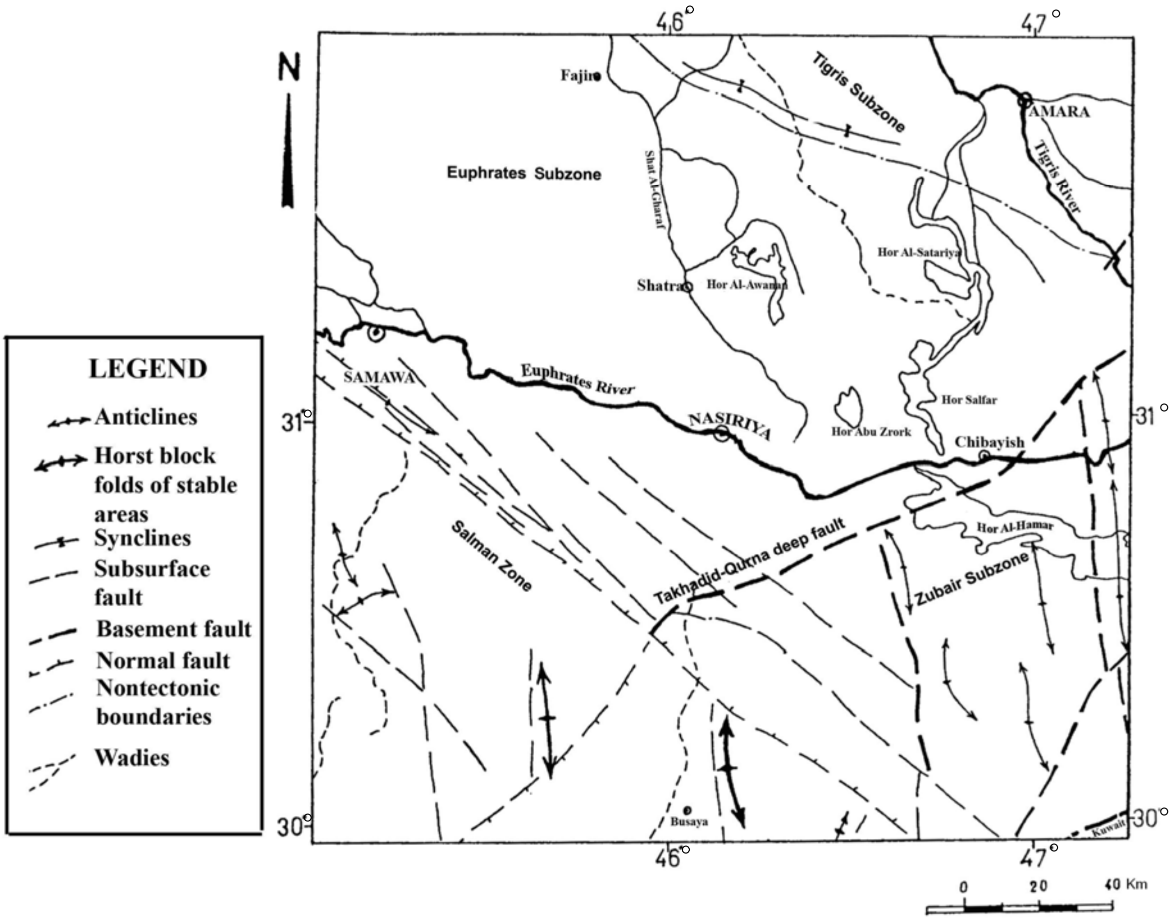

Fig.2: Main tectonic and structural features of the study area
(after Buday and Jassim, 1987)

Takhadid – Qurna deep seated fault defines the boundary between Mesopotamian and Basrah Blocks (Fig.2). This fault forms the northwestern boundary of Zubair Subzone, which extremely differs from the rest of the Mesopotamian Zone by its conspicuous N – S trending structures extending more than hundreds of kilometers toward the Kuwaiti and Saudi Arabian territories. These features are related to basement trends (Iraqi – Soviet Team, 1979), while Buday and Jassim (1987) stress as the influence of the troughs with saliferous Hourmuz deposits. Japan National Oil Corporation (1983) claimed that the N – S trend, in southern Iraq, is to be basement horst blocks over which younger sediments are draped.

Salman Subzone is characterized by a maze of differently trending short antiforms. The amplitude of these structures are not exceeding more than tens of meters. The area is also characterized by a relatively denser net of faults. Remarkable is the high number of N – S trending faults. The area is also dissected by NW – SE trending faults corresponding to basement blocks.

The general picture of the structural pattern in the Mesopotamian Zone is characterized by broad syncline or monocline interrupted by mostly narrow antiform accompanied by faults. The folded structures and fault trends have prevalent NW – SE trend. The main structure has an axis that runs in southeast direction (Iraqi – Soviet Team, 1979).

The Euphrates Subzone is characterized by a monocline dipping generally northeast with scattered local structures. This subzone represents a transitional area between the Stable and Unstable Shelves. The border between the two units is formed by step faults of relatively small throws. These are relatively young structures, probably of Miocene age (Buday and Jassim, 1987). The main sign of Zubair Subzone is the presence of several relatively long and narrow antiforms separated by less expressive synforms, all of them trending sub meridianaly.

THE GRAVITY MAP

The Bouguer anomaly map of the study area (Fig.3) was compiled at a scale of 1: 1000 000, published by the Iraqi Petroleum Company (IPC, 1960), with 1 mgal contour interval. The dominant feature of the Bouguer anomaly map of the area is the considerable regional gradient toward the east and to northeast, which is associated with the deepest part of the Mesopotamian trough. The gravity field decreases with an average value of 0.22 mgal/ Km. The boundary between Stable and Unstable Shelves is supposed to be located between contours –35 to –55 mgal (Al-Sayyab and Valek, 1968) as indicated by the considerable gradient striking NW – SE and changes to N – S, in the southern part of the map.

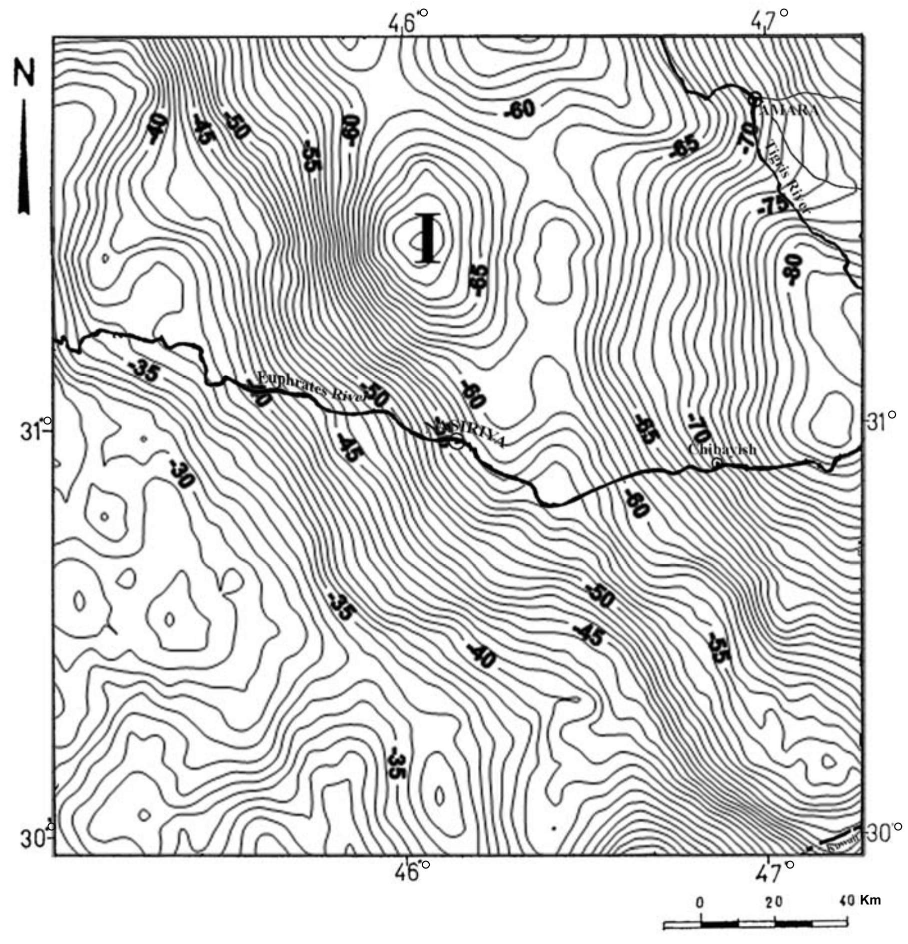

Fig.3: Bouguer anomaly map of the study area
(after IPC, 1960) (C.I. = 1 mgal)

The southwestern part of the map is characterized by short wavelength and low amplitude anomalies. While in the northeast, the width and amplitude of the anomalies are gradually increased, leading to the suggestion of the dominance of the large and deep structures. Several local anomalies with different trends and areal distribution can be deduced from contour undulations. A large negative anomaly with a circular shape and amplitude of –10 mgal (anomaly I) suggests the location of an important geologic structure, which may be composed of low density rocks or it may be a trough.

DIRECTIONAL INTERPRETATION

Two-dimensional power spectra and directional filters analyses are applied to gravity data to differentiate and separate linear signals of tectonic importance from background potential field data. Such reliable anomaly separation greatly facilitates the interpretation of lineation in a map. Reasonable care should be taken in such a way in order to avoid creation or over interpreted false anomalies. A strike-filtered anomaly should therefore meet several criteria to prove its authenticity. The lineation must be a significant feature in the power spectrum, the anomaly should be geologically reasonable and the lineament should be perceptible on the unfiltered map (Thorarinsson *et al*., 1988 and 1989).

By using Fan Filter technique with an interval angle of 20° and with an overlap of 10°, seventeen trending maps are obtained. These represent the distribution of the energy magnitude of the gravity field within a selected direction, respectively. The intensity of contours in the filtered data will reflect the strength of aligned data and in turn is a function of the number of grid points defining the trend on the original map (Mobil, 1980).

Rose diagram could be drawn to reflect the intensity or amplitude values, which describe the length of the features in a given direction. Then, the intensity of the contours is transformed into percent value and subtracted from the threshold value to increase the recognition of the rose. Also, absolute horizontal derivative was prepared for the rose that determines the increasing intensity of the amplitude.

A plane surface is removed from the gravity data (Fig.4) and then power spectrum for the data are calculated (Fig.5). After applying the Fan Filter (Fig.6), seventeen trending gravity maps are obtained, as shown in Fig. (7). The percent magnitude of these contours (after subtracting threshold value) was rosettes with its absolute horizontal derivative are shown in Fig. (8). It appears from these maps that the main distribution of contours intensity are in a N – S direction (trending map 80° – 100°, Fig.9) and in a NW – SE direction (trending map 40° – 60°, Fig.10) in addition to minor trend in NE – SW direction (Fig.11).

A similar result can be shown on rosette and absolute horizontal derivative diagrams (Fig.8) where the total energy of the gravity field is distributed on two main trends, towards the north and a secondary one trending N50°W. Also, there are less significant trend in directions N20°W and N50°E.

The N – S direction is shown in two locations, 1 and 2 (Fig.9, trending map 80° – 100°) with a third minor N – S trend (3). In location 1, anomaly trend is consistent with the N – S structural trends of Zubair Subzone, as indicated on tectonic map (Fig.2), while in location 2, anomaly trend added a new information about the possible existence of such structures to the north of Euphrates River (Tigris Subzone), where no such structures with this trend are indicated in previous studies. The location 3 is consistent with the geologic structures, trending N – S, in Salman Zone.

The NW – SE trends occupy two locations in map 40° – 60° (Fig.10), the first one is probably related to Baghdad Depression (Baghdad – Tigris Subzone) where it occupies a large area that extends and coincides with monocline structures of the Mesopotamian Zone. The second location reflects the general trend of NW – SE faults direction in Salman Zone.

The various trends over the whole area reflect the different stresses that acted on the region. The north and northwest trends are consistent with prevailing trends of old deep faults and represent the extension of Precambrian structures from Saudi Arabia into Iraq. The N – S and NW – SE trends are basement faults and they are typical for the Hajaz and Najid Orogenies, respectively. Both trends are rejuvenated due to the Alpine Orogeny, where they are consistent with Zagros tectonic province.

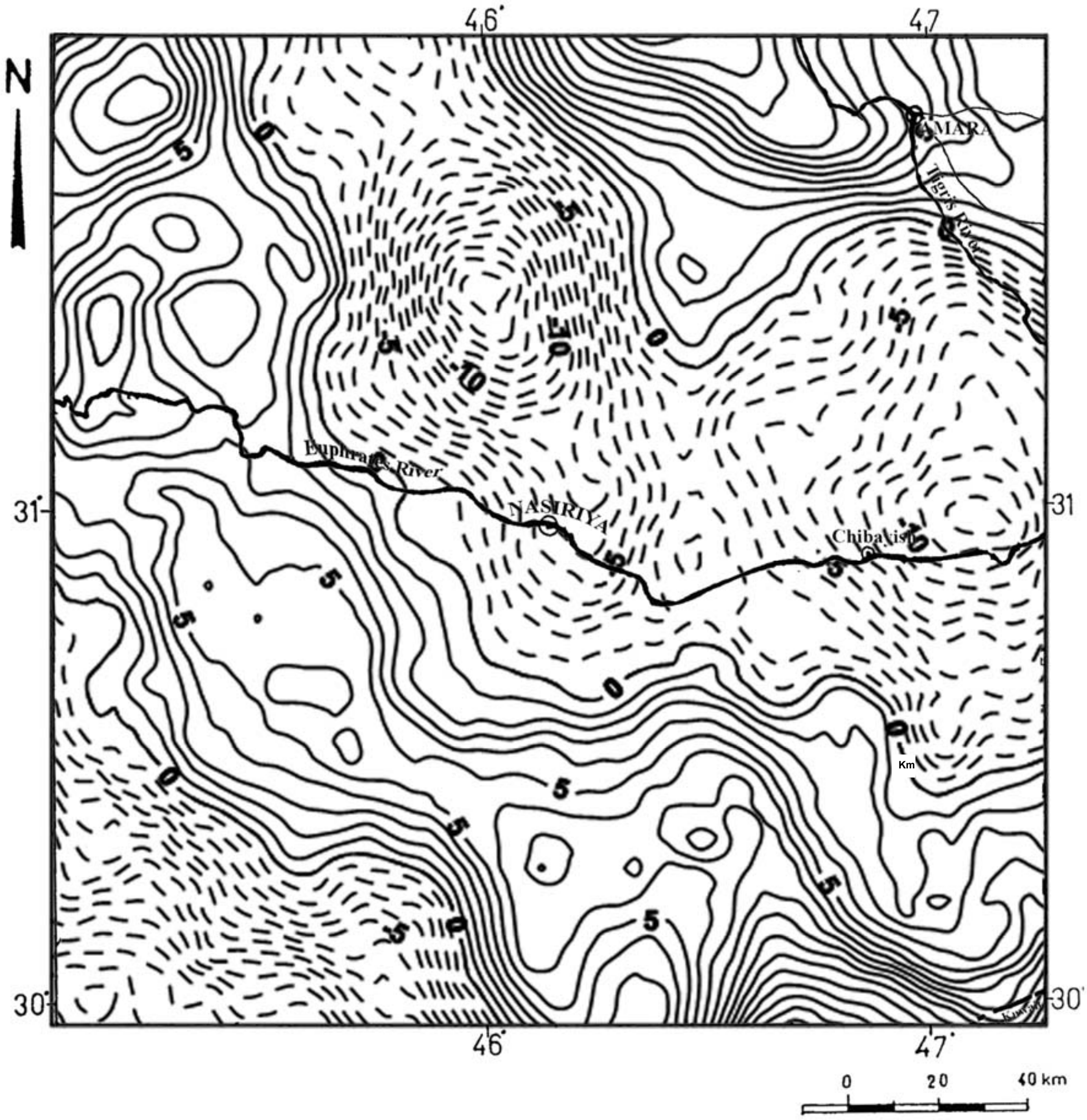

Fig.4: The gravity map after removing a plain surface
(C.I. = 1 mgal)

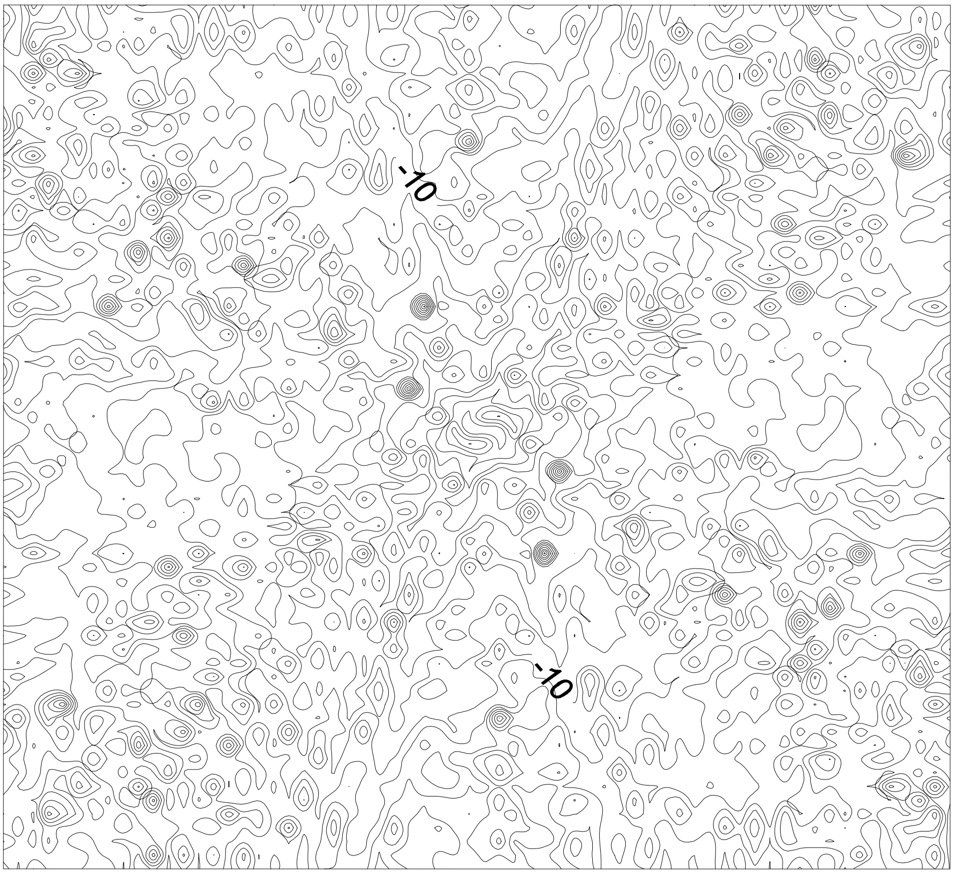

Fig.5: 2D power spectrum of the gravity data

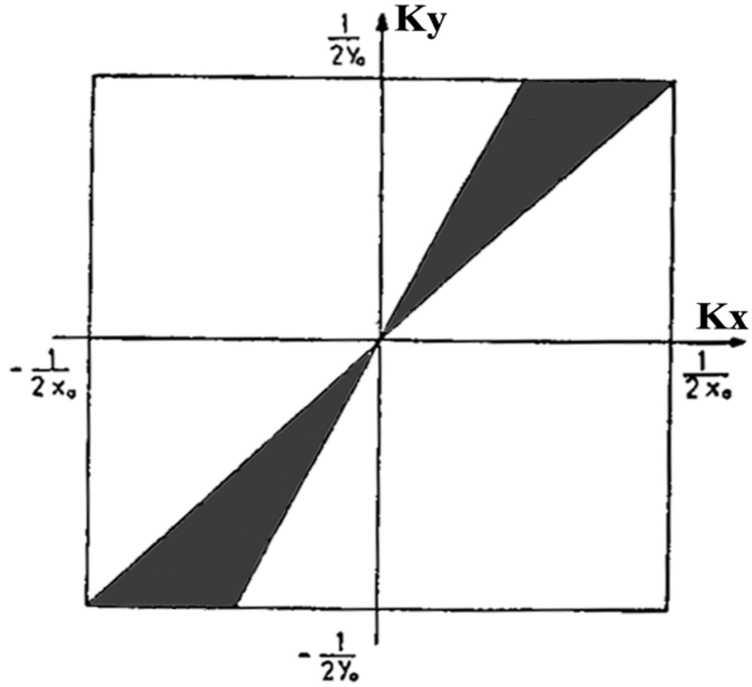

Fig.6: Fan filter design in wave number domain

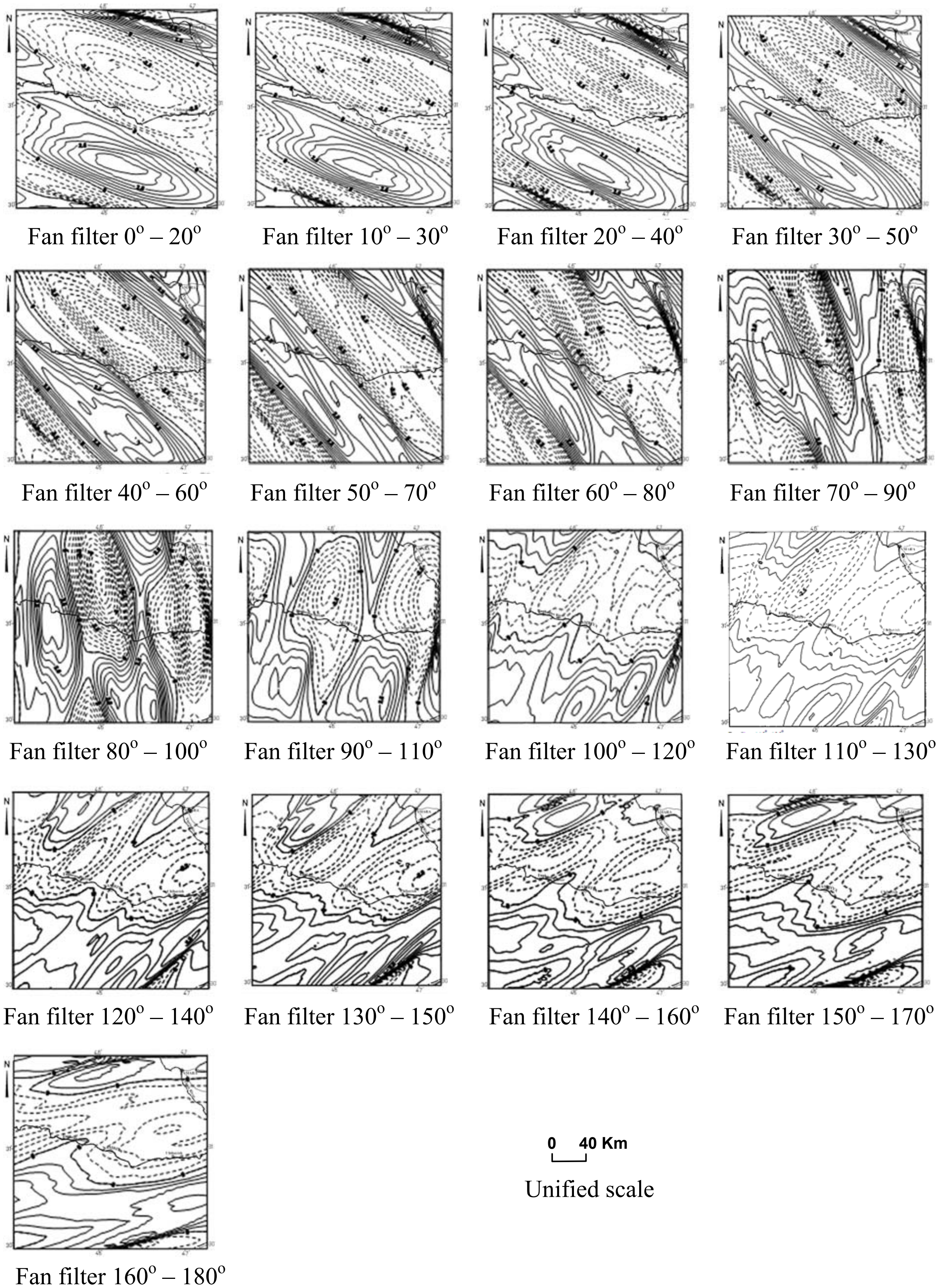

Fig.7: Seventeen trending gravity maps are obtained by using Fan Filter technique, with an angle of 20° and with an overlap of 10° (C.I = 0.5 mgal)

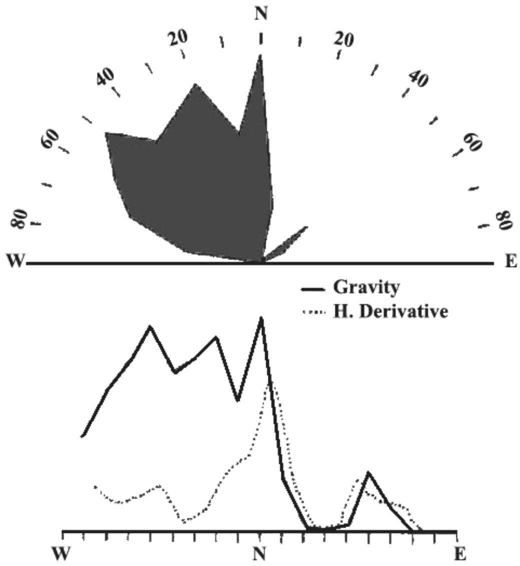

Fig.8: Rose diagram and the absolute horizontal derivative of the 17 trending gravity maps

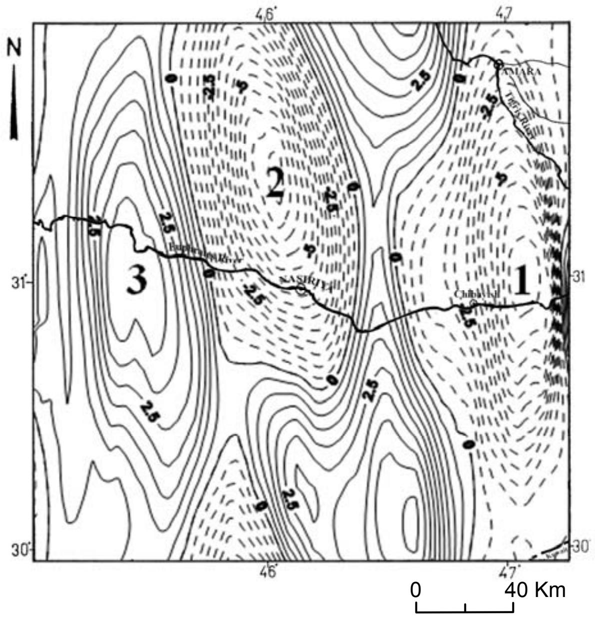

Fig.9: Fan filter 80° – 100° (C.I = 0.5 mgal)

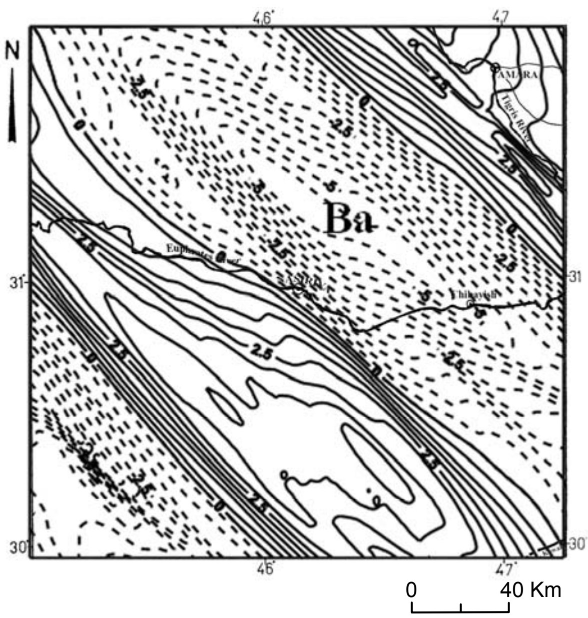

Fig.10: Fan filter 40° – 60° (C.I = 0.5 mgal)

The NE – SW trend (Fig.11) is consistent with the NE – SW compressive stress that produced Zagros suturing. The defined N – S and NW – SE trends on the contour intensity maps are not restricted to certain part of the study area, as shown by previous workers. They cover the whole area, which indicates the possibility of the existence of the N – S structural trend to the north of Takhadid – Qurna deep seated fault, where no surface features exist and at the same time most of the previous studies are depending upon gravity and magnetic data interpretation.

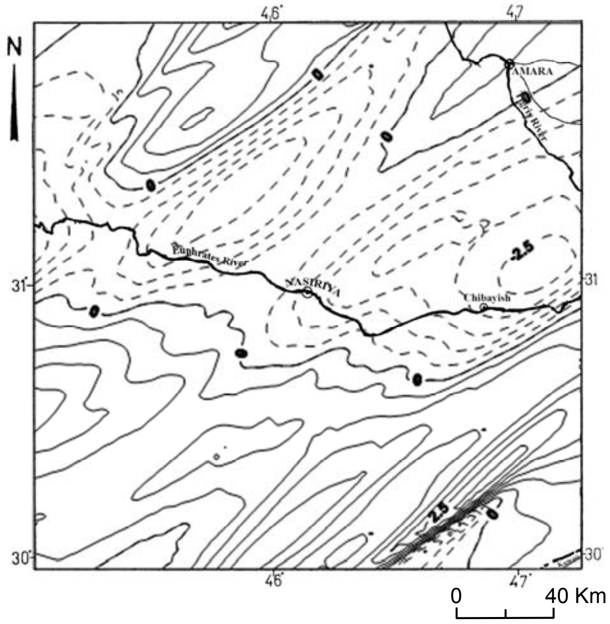

Fig.11: Fan filter 140° – 160° (C.I = 0.5 mgal)

Another attempt has been made to analyze the degree of contribution of residual field on the total field and to show the effect of the regional trend field on shallow structures. The procedure includes separating the gravity field into their components (regional and residual) in a specific direction. The rose diagram (Fig.8) illustrates the distribution of the total energy of the gravity field in different directions. The total energy can be divided into residual and regional in a specific direction. So using a Fan Filtering for residual field, the resulting rose diagram shows the distribution of the residual field on different directions. Subtracting residual rose from the total one will offer the distribution energy of the regional field.

Thus, a Fan Filter technique has been applied to high pass filtered map of the gravity data with wavelength of 100 Km (Fig.12, for the residual field and Fig.13, for the regional field using low pass filter and high pass filter with 100 Km wavelength, respectively). The result is a rose diagram plotted at the same scale for the energy distribution of the gravity field without subtracting threshold value (Fig.14a). This rose diagram shows a prevailing N – S trend and with a secondary NE – SW one. By subtracting the residual rose from the total one; gives the regional energy rose plotted with the same scale (Fig.14b). The regional rose diagram shows prevailing of NW – SE trend, which describes the main direction of the boundary between the Stable and Unstable Shelves. From these two roses, it can be concluded that the area is affected directly by prevailing old deep faults. These deep faults trend N – S, NW – SE and NE – SW are strongly influenced the shallower structures. The N – S deep faults most probably represent the recurrent basement faults that have been reactivated through time. The N – S shallow structures are likely to have nucleated along such pre-existing north trending basement faults. The NE – SW trends of shallow structures are consistent with the effect of compressive stress related to Zagros suturing on the transverse deep faults.

The direct effect of the Alpine Orogeny is not so clear on the shallow structures. Its effect is considerable and increasing in the northeastern part of the area under consideration towards the Iraqi – Iranian international borders. The prevailing NW – SW regional trend determines the remarkable old deep faults that may be related to the Najid Orogenic Cycle. The structural evolution on that direction depends on the mobility of such deep faults and their reaction on the different phases of the Alpine Orogeny, taking in consideration the boundaries between the Stable Shelf and the Mesopotamian Zone.

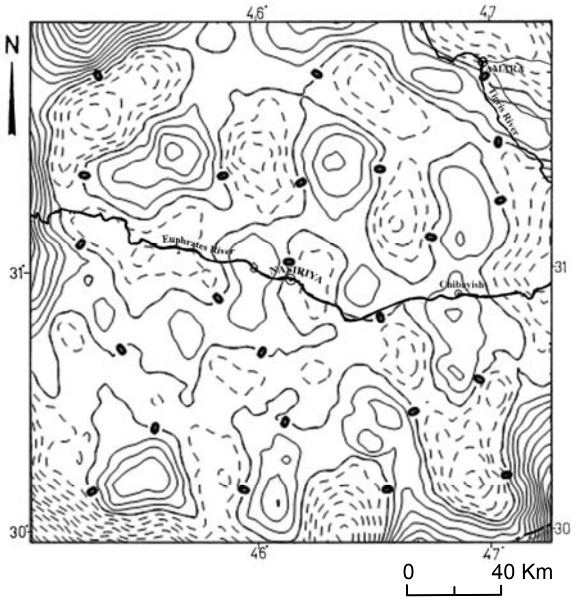

Fig.12: High pass filtered map of the gravity data with wavelength of 100 Km

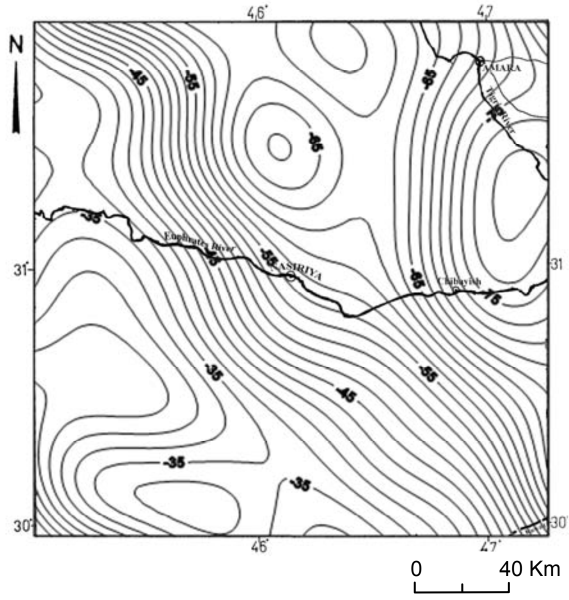

Fig.13: Low pass filtered map of the gravity data with wavelength of 100 Km

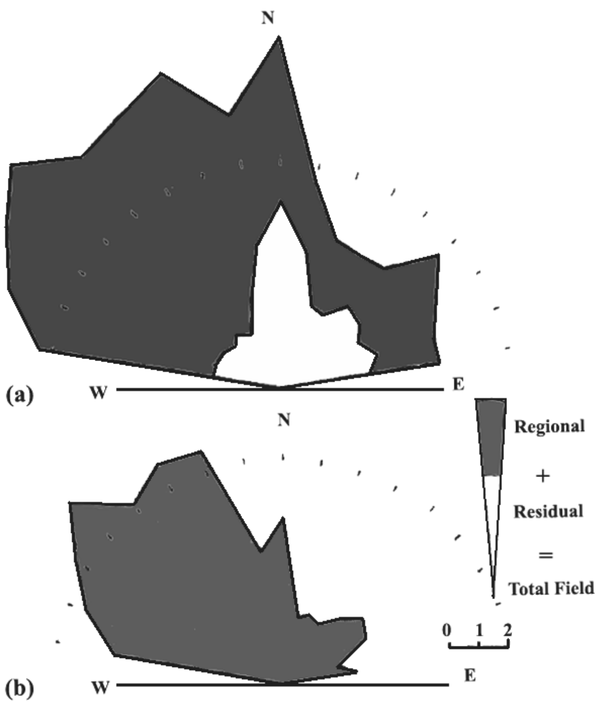

Fig.14: **a-** Rose diagram of the total energy distribution of the gravity data and its residual field
b- Rose diagram of the energy distribution of the regional field

CONCLUSIONS

- Two main trends; namely N – S and NW – SE with a secondary NE – SW trend have been defined from the directional analysis and Fan Filtering technique applied to gravity data. The residual gravity map shows two main trends in N – S and NE – SW directions. The NW – SE regional trend is of deep character. Both N – S and NW – SE trends determine the remarkable old deep faults. The shallow structures evolution will depend on the mobility of such deep faults and then their reaction took place at different phases of the Alpine Orogeny.
- The Fan Filter technique is a procedure that represents a successful method in separating potential field components into their values and directions. This greatly helps in understanding the tectonic evolution of structures in the study area. Also, it increases the possibility of envisage one set of structural trend that was developed in response to a certain field of stresses during any geological period from different trends that are formed at some later stages of crustal development. Therefore, this technique is recommended for the delineation of the prime deep structures and also for shallow features. This technique is dependable and useful in delineating the linear features in a specific direction.

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