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Comparison Among Subsurface Linear Features of Residual Gravity Fields at The Eastern and Western Parts of Central Iraq by Applying the THD Filtering Technique.

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ABSTRACT

In this study, upward continuation technique is considered as a clean filter because it produces no side effect like other filter used in processing to acquire residual gravity data in the western and eastern regions of the central part of Iraq. The residual anomalies maps achieved to 2km, 12km, 16km, and 22km upward elevation levels The approximate equivalent depth of detection for the four upward continuation elevation levels generally ranges (0.6-1) in relation to the upward continuation elevation. The Total Horizontal Derivative (THD) technique is applied to the residual anomaly maps to identify the lineaments (faults or source boundaries) of the two studied parts. The THD measures the lateral rate of change of the measured gravity field. It is useful to detect the edges and delineate the boundaries (Faults), where the peak values occur over the edge of block. The most lineament trends in western part area is NW-SE trend, and the less trend is NE-SW. The N55W, N45W, and N35W trends percentage is 51% of all lineaments in the western part. The percentage of the three mentioned trends for the four considered levels range is 48-60%, where the percentage value increase with the deeper lineaments, this may indicate the faults in the sedimentary cover affected by the basement rocks. The group of lineaments N35E, N45E, and N25E trends percentage in western part faults about 24%. Applying the idea of conjugate faults for the western part indicates that According to the idea of conjugate faults to the inferred trends in the western part of the study area, it is concluded that the main stress direction is N-S. This stress direction may be related to the collision of the Arabian plate with the northern plates in certain geological history. The predominant lineaments trends in the eastern bank of the Euphrates River are N45W, N35W and the N55W, respectively. These three trends represent 72% percentage of lineaments in this part for all upward elevation levels. The general trends of lineaments in eastern part are NW-SE. The NW-SE lineament trends are noticed in the both parts of the study region corresponds to the Najd fault system, while N-S fault trends are associated with the Nabitah system.

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مقارنة بين المظاهر الخطية تحت السطحية لحقول الجاذبية المتبقية في الأجزاء الشرقية والغربية من وسط العراق من خلال اعتماد حسابات المشتقة الافقية الكلية

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الملخص

تم في هذه الدراسة استخدام تقنية الاستمرارية التصاعدية للحصول على بيانات الجاذبية المتبقية في المناطق الغربية والشرقية من الجزء الأوسط من العراق. تم تحقيق خرائط الشذوذ المتبقية على مستويات ارتفاع تصاعدية تبلغ 2 كم و12 كم و16 كم و22 كيلومترا على التوالي. يتراوح عمق الكشف المكافئ التقريبي لمستويات الارتفاع المستمر الأربعة بشكل عام (0.6–1) بالنسبة إلى الارتفاع المستمر الصاعد.تم تطبيق تقنية Total Horizonte Derivative (THD) على خرائط الشذوذ المتبقية لتحديد المظاهر الفوالق تحت السطحية لجزئي منطقة الدراسة. يقيس THD معدل التغير الجانبي في مجال الجاذبية المقاس. من المفيد اكتشاف الحواف وتحديد الحدود (الفوالق)، حيث تحدث قيم الذروة على حافة الكتلة .أكثر اتجاهات الخطوط في منطقة الجزء الغربي هي اتجاه NW-SE ، والاتجاه الأقل هو NE-SW. تبلغ نسبة اتجاهات N55W وN45W و N35W 51% من من بين النسب الاخرى في الجزء الغربي. وتتراوح نسبة الاتجاهات الثلاثة السابقة الذكر عند تطبيق الارتفاعات الاربع للاستمرارية التصاعدية المدروسة بين 48–60%، وتزداد قيمة النسبة مع زيادة ارتفاع الاستمرارية التصاعدية (اي مع زيادة عمق التحري وقد يدل ذلك على وجود عيوب في الغطاء الرسوبي متأثرة بصخور الطابق السفلي (. حيث بلغت نسبة اتجاهات مجاميع النسب للاتجاهات N35E وN45E وN25E في الجزء الغربي حوالي 24%. إن استخدام فكرة الصدوع المترافقة للجزء الغربي يشير إلى أن ان استخدام فكرة الفوالق المتوافقة على الخطيات المستنبطة في الجزء الغربي من العراق يشير الى ان اتجاه الاجهاد الرئيسي هو N-S وهذا يعني احتمال حصول تغيرات في اتجاهات الاجهادات المؤثرة على الوضع التكتوني عبر التاريخ الجيولوجي. اتجاهات الخطوط السائدة في منطقة شرق نهر الفرات هي N45W، N35W وN55W، على التوالي. وتمثل هذه الاتجاهات الثلاثة نسبة 72% من النسب الاخرى ضمن هذا الاتجاه في هذا الجزء و لكل مستويات الاستمرارية التصاعدية المستخدمة. ان اعلى نسب اتجاهية عند الجزء الشرقي للمنطقة تمثل في الجزء الشرقي هو شمال غرب–جنوب شرق. إن اتجاهات الخطوط الخطية شمال غرب – جنوب شرق هي منطقة الجزأين التي تتوافق مع منظومة صدوع نجد، في حين تتوافق اتجاهات الصدوع بالاتجاه شمال–جنوب مع اتجاهات الفوالق لمنظومة نبيتا.

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Introduction

The geophysical methods are applied to geological structures and also, to assess assess the potential for mineral and hydrocarbon resources (Dobrin and Savit, 1988). Geophysical methods measure the subsurface physical properties in order to detect the anomalies, those are related to subsurface geological features like: fold and faults, (Roy, 2008).

The gravity method involves the measurement of variations in the gravity field of the earth produced by local differences in density of subsurface rocks. (McDowell et al., 2002; Kearey et al., 2002). The upward continuation is a mathematical technique used to separate the anomalies of deep sources from shallow sources (Jacobsen, 1987). The gravity anomalies which depict the variations in density of subsurface geological layers make them particularly well-suited for the exploration of significant sedimentary basins. This suitability arises from the substantial density contrast that typically exists between the less dense sedimentary deposits and the denser underlying rock formations (Reynolds, 1997; Blacky, 1995).

The Arabian Plate shows a complex array of tectonic features (Buday and Jassim, 1984 and 1987). Iraq is a part of the Arabian Plate, so the geologists in Iraq achieved a lot of geological studies and have extensively documented the tectonic events, (Jassim and Goff, 2006 and Numan, 1997). The significant regional events such as the Chaldean, Hercynian, and Alpine movements have affected the tectonic features of Iraq. These events have produced many geological features like: folding faulting, volcanic activity, tectonic collisions, continental rifting, subsidence, and periods of progression and regressions.

Lineaments in geology are known as extended, natural geological features, such as folds or faults that are detected through geophysical measurements. These methods are employed to identify the faults and to ascertain their orientations within the earth subsurface (Hung et al., 2005). Regional studies have been conducted across western, central, and eastern Iraq to identify geological lineaments and faults. These studies have employed diverse information sources and techniques. Gravity, aerial photographs, and satellite images data are used to identify a group of lineaments extending from the Paleocene to the lower Eocene (Al-Mashhadani, 1984).

Gravity data were employed to study the western desert of Iraq and section from eastern part of Syria area. The predominate lineament trends detected are N35W, N35E, and N65E (Abbas, 1985). Geological lineaments in various parts of Iraq have been delineated through a combination of geological field surveys and satellite imagery analysis. Many researches have discussed the geological lineaments in Iraq, (Dunnington, 1958; Bellen et al., 1959; Al-Amiri, 1984; Al-Jubouri, 1988; Al-Sulaiman, 1989; Nadir, 1990; Al-Banna A.S. 1992 and Ziegler, 2001). A series of geophysical studies deals with the predominate lineament trends which belong to the geological features in Iraq (Mousa and Al-Rahim, 2016; Al-Banna and Daham, 2019; Al-Banna and Al-Kishef, 2019; Mousa et al., 2020; Al-Hadithi and Al-Banna 2022; Al-Banna and Al-Saffar, 2022 and Al-jizani et al., 2023). This study aims to compare the predominate lineament trends of the geological features at four levels for the eastern and western parts of central Iraq using gravity data.

Date and methods

Description of site

The study area is located in central Iraq within latitude 30.69° to 34.5° N and longitude 38.79° to 46.7° E. It represents a strip like area crossing Iraq transversely towards NE-SW direction. The study area is divided into two parts by Euphrates River. The western part extends from Iraq- Jordan and Saudi Arabia borders to Euphrates River (A part). While the eastern part start from Euphrates River passing through the Mesopotamian zone towards the east and ending at Khanaqin area near the Iraq-Iran border (B part) (Fig. 1).

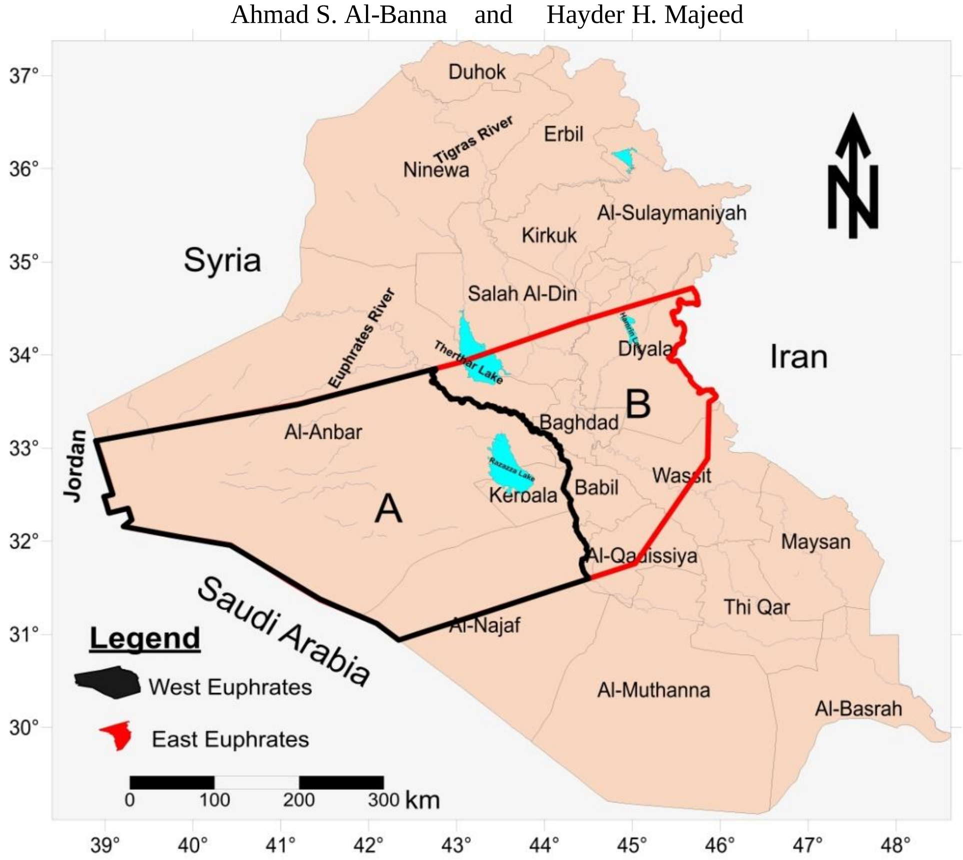

Fig. 1. Location map of the both studied areas (A) Western Euphrates River (B) East Euphrates Rivers.

Geology and tectonic setting of the study area

The geological map of the study area exhibits significant variation, including transition from Mesozoic formations at west to Quaternary formations at east (Jassim and Goff, 2006). Regarding regional geology, the study area is characterized by strata that dip towards the northeast, corresponding to the surface land slope. Conversely, sedimentary layers originating from Rutba town dip in a westerly direction (Buday, 1980; Konert et al., 2001; Jassim and Goff, 2006; Aqrawi et al., 2010; Sissakian and Fouad, 2012, 2015).

The Al-Ma'aniyah depression area is situated above the Nukhaib Graben on the stable shelf in southwestern Iraq, within the Al-Najaf province. According to gravity and magnetic interpretation, the basement rocks in western part consist of many types, some of them are acidic and the others may be ultra-basic rocks (Al-Banna, 1999). According to other studies the basement rocks depth (5-6) in western part includes granodiorite, granite, phyllite, gabbro and schist rocks, while the eastern part (8-14 km) include gabbro, granodiorite, and granite rocks, (Jassim and Goff, 2006; Al-Banna and Daham, 2019: Al-Banna and Majeed, 2023).

The near surface geology of the western part (west Euphrates) is characterized by outcropped rock formations which belong to Palaeozoic to Mesozoic ages, (Jassim and Goff, 2006). The lithology of these formations is mostly limestone, dolomite and some formations are composed of sandstone, siltstone, shale, marl and rarely conglomerate, (Sissakain and Mohammed, 2007) (Fig. 2).

On the other hand, the eastern part of the study area (Eastern Euphrates River) is characterized by alluvial fan deposits, and floodplain formations dating back to the Quaternary era. The Bakhtiari Formations consist of sandstones, conglomerates, shales, and marls, while the Muqdadiya Formation includes sandstones, siltstones, shales, and conglomerates (Buday, 1980).

The western part coincides with stable tectonic shelf (inner platform) including Rutba extremely to the western side and Salman (Transition) zones at the eastern side (Buday and Jassim, 1984 and 1987; Al-Banna, A. S., 1998; Fouad, 2015; Al-Banna and Ali, 2018). The eastern part (B) of the study area is located at unstable shelf (Mesopotamia basin) or the outer platform, (Al-Kadhimi et al., 1996; Al-Banna et al., 2013; Fouad, 2015; Al-Banna and Ali, 2018; AL-Banna and Al-Assady, 2021).

The main faults in the study area were delineated by Jassim and Buday, as mentioned in Jassim and Goff (2006). Various data and information are used to delineate the faults including satellite images, gravity and magnetic gradients, and, to a lesser extent, seismic reflection sections. The Total Horizontal Derivative (THD) of gravity is found to be the most valuable parameter for fault detection. The main longitudinal faults in the study area include Tar Al Jil fault, Euphrates boundary fault, Ramadi-Musaiyib fault, the Tikrit-Amara fault, Makhul-Hemrin fault and Euphrates boundary fault (Abu-Jir fault). The NE-SW or E-W transversal system, includes Amij-Samarra, Sirwan, and Kut-Dezful, faults, (Fig. 3). These fault systems were originated during the Late Precambrian Nabitah orogeny and have experienced multiple reactivations throughout the Phanerozoic era (Jassim and Goff, 2006).

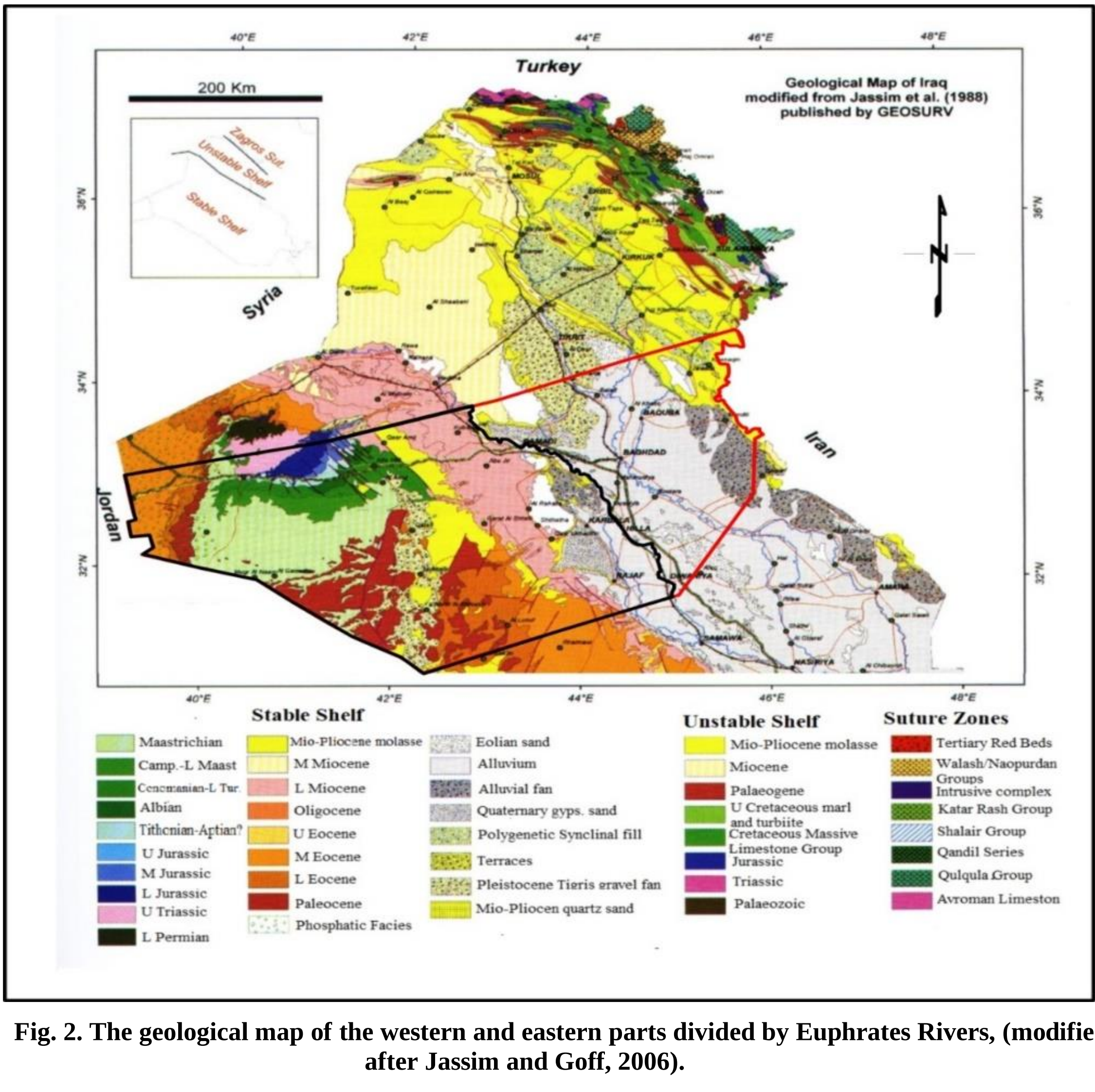

Fig. 2. The geological map of the western and eastern parts divided by Euphrates Rivers, (modified after Jassim and Goff, 2006).

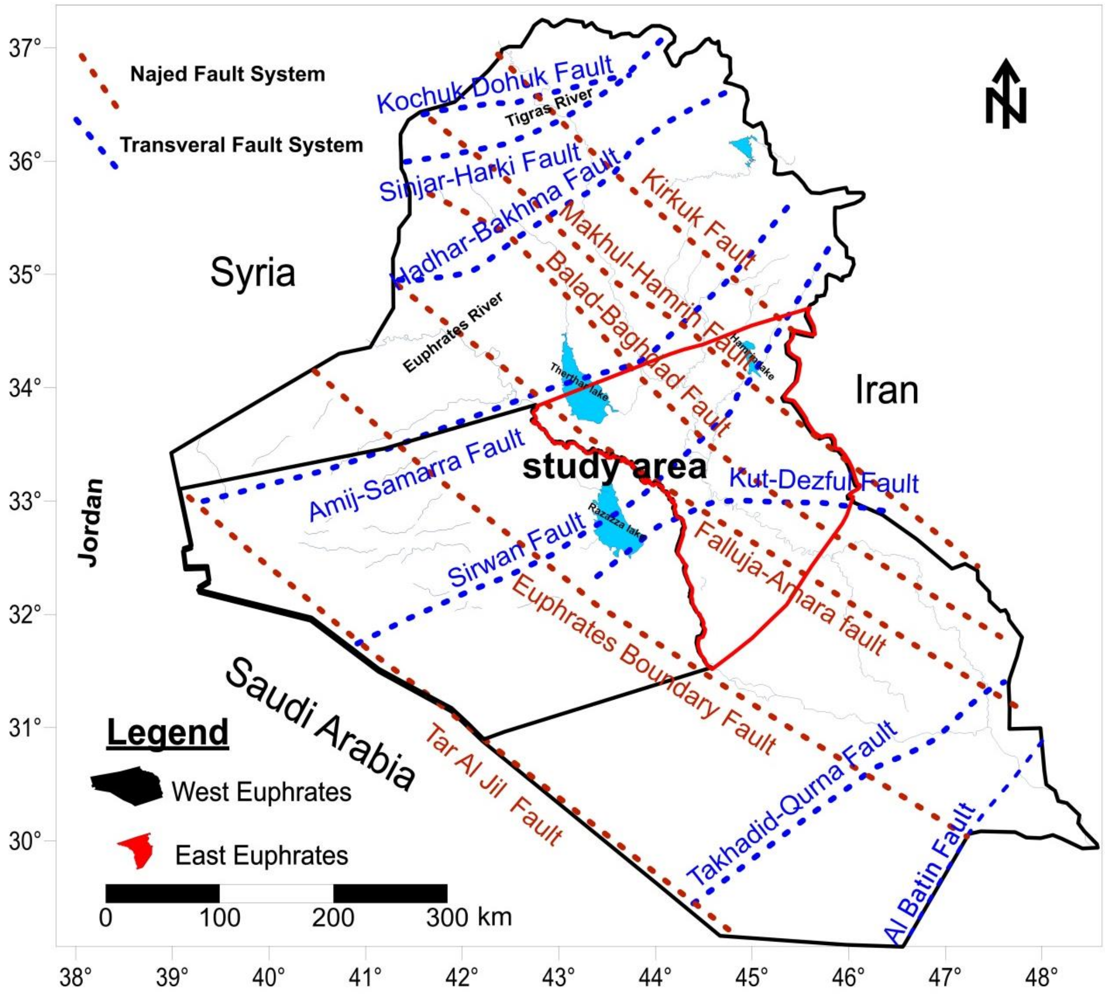

Fig. 3. The Tectonic map of the study area (modified after Jassim and Goff, 2006).

Materials and method

Data acquisition

The gravity surveys in Iraq, including the study area, were carried out for the period 1959 and 1979. The gravity data of many gravity surveys were unified by the Iraqi geological survey company, (Abbas et al., 1985). These data were reprocessed by Getech Group/ British in 2010. The regional view of the gravity map gives an idea of presence of sedimentary basin in eastern Iraq (Oil Exploration Company, 2005) and the bouguer gravity calculate by new local theoretical gravity equation (Al-Banna et al., 2020). The Bouguer gravity anomaly map of Iraq is plotted with a grid spacing 1 X 1 kilometer. The gravity anomaly map of the study area indicates that the gravity values range from -9 to -97 mgal, (Fig. 4).

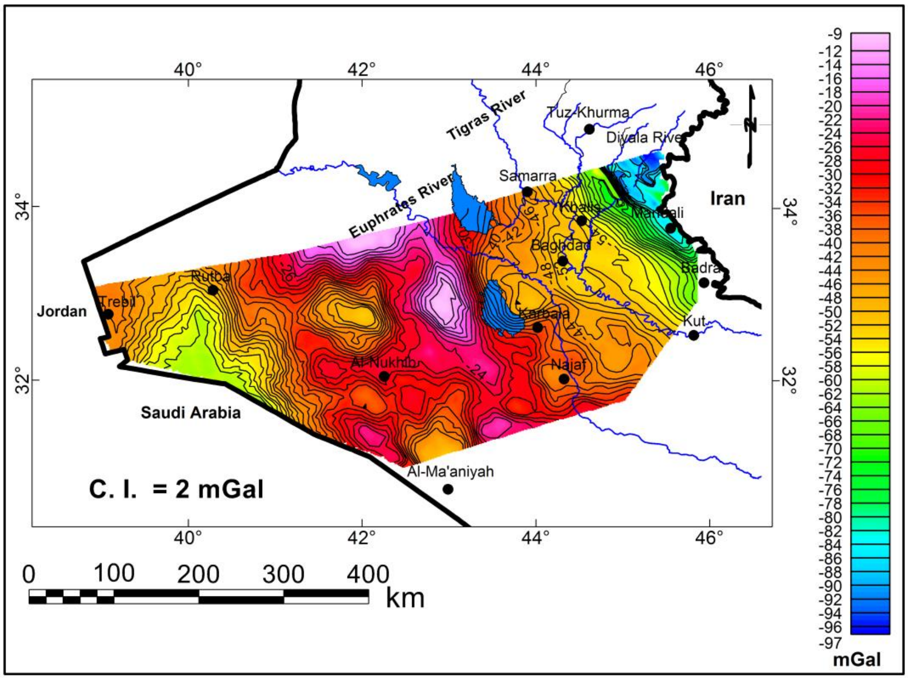

Fig. 4. The Bouguer gravity anomaly map of the study area (Getech, 2010).

Residual Anomalies of Gravity data

An upward continuation technique is applied to obtain the regional and residual anomalies maps of the gravity data for four elevations 2, 12, 16, and 22 km for both western and eastern sides of the Euphrates River. Generally, the main residual gravity anomalies maps show the same location of positive and negative anomalies, which indicate that the anomalies mostly almost reflect the effect of deep sources, (Figs. 5 and 6). Constant positive and negative anomalies in both parts of the study area, indicate that these anomalies may be related to the deep source (Figs.5 and 8).

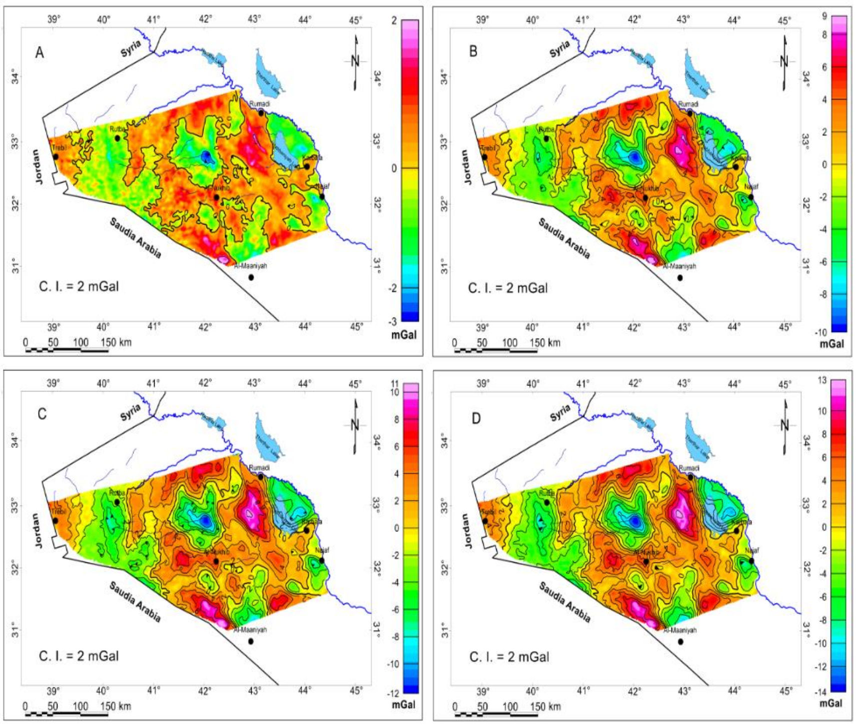

Fig. 5. The residual gravity anomaly maps of western part area, derived by using upward continuation for the elevation levels: (A) 2 km; (B) 12km; (C) 16 km and (D) 22km.

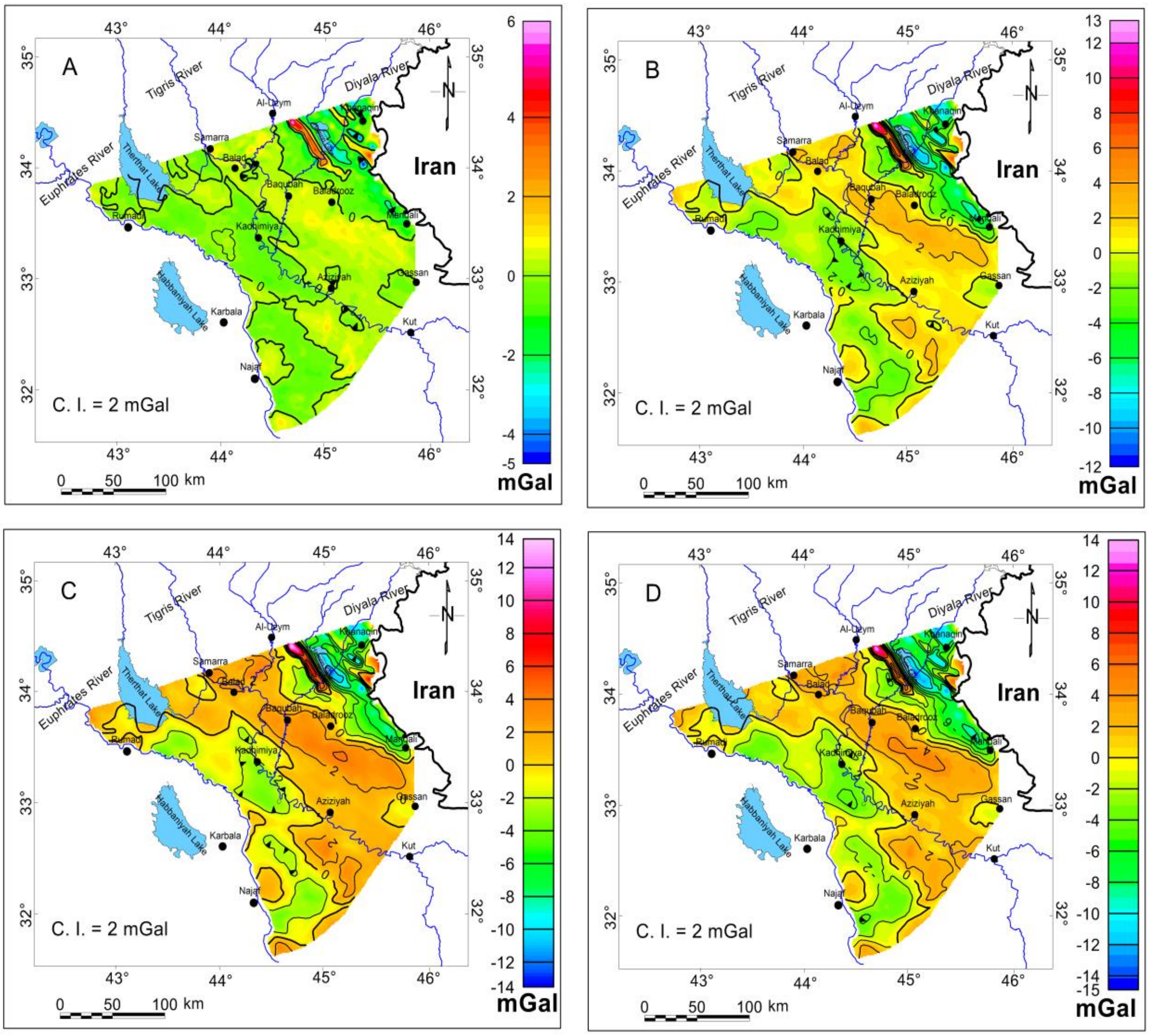

Fig. 6. The residual gravity anomaly maps of eastern part area derived by using upward continuation for the elevation levels: (A) 2 km; (B) 12km; (C) 16 km and (D) 22km.

Processing and results

The Total Horizontal Derivative (THD) technique is a valuable tool for identifying subsurface fault structures or the edges of geological bodies. This technique operates by indicating areas of maximum THD values, which often correspond to lineaments associated with body boundaries or faults. This approach is in accordance with the principles outlined by Cordell and Gauch (1985). The Total Horizontal Derivative (THD) can be calculated using two horizontal derivatives, the first-order horizontal derivatives represented as $(\frac{бT}{бX})$, $(\frac{бT}{бy})$ and the second-order horizontal derivatives represented as $(\frac{б^2T}{б^2X})$ and $(\frac{б^2T}{б^2y})$, along with (dT/dx). It is commonly employed in the delineation of magnetic and gravity contacts. The THD is determined by the equation below.

$$THD = \sqrt{(\frac{бT}{бX})^{\,2} + (\frac{бT}{бy})^2} \quad \text{------ (1)} \qquad \text{(Blakely, 1995)}$$

Were,

$бT$: is the gravity anomaly value variation in mGal, $бX$: horizontal distance variation towards X- direction in Km, $бy$: horizontal distance variation towards y-direction in Km.

Horizontal derivatives have been computed from residual gravity anomaly maps represent the intresed level.While the regional includes the effect of sources at many depth levels. The process of producing Total Horizontal Derivative (THD) maps and then using them to determine lineaments and draw a rose diagram was done using the following programs (Oasis Montaj 2015, Arc Map 10.7, and RockWorks16), respectively. The THD maps are employed to delineate lineaments at four upward elevation levels, 2 km, 12 km, 16 km, and 22 km, for both the western and eastern parts of the area (Figs. 7 and 8). The upward elevation levels used in this study are relatively define the source at depths 1.6, 10, 13, and 18 km, respectively. The number of faults depends on the types of rocks in the sedimentary basin after precipitation and lithification process and the tectonic activities. It is noted that from comparing the increase in the percentage of linearities, both the eastern and western regions that show in (Figures 7 B, C and 8 B, C) respectively, at intermediate depths of (10-13 km), more faults appear, and this may be related to the basement rocks and the lower part of the sedimentary stratigraphic column.

The rose diagrams are plotted to illustrate the main trends of the lineaments in both western and eastern areas, (Figs. 9 and 10). The lineament trends identified through the analysis of gravity and magnetic data summarized in Tables (1 and 2). This comprehensive approach aids in characterizing subsurface geological features and structures.

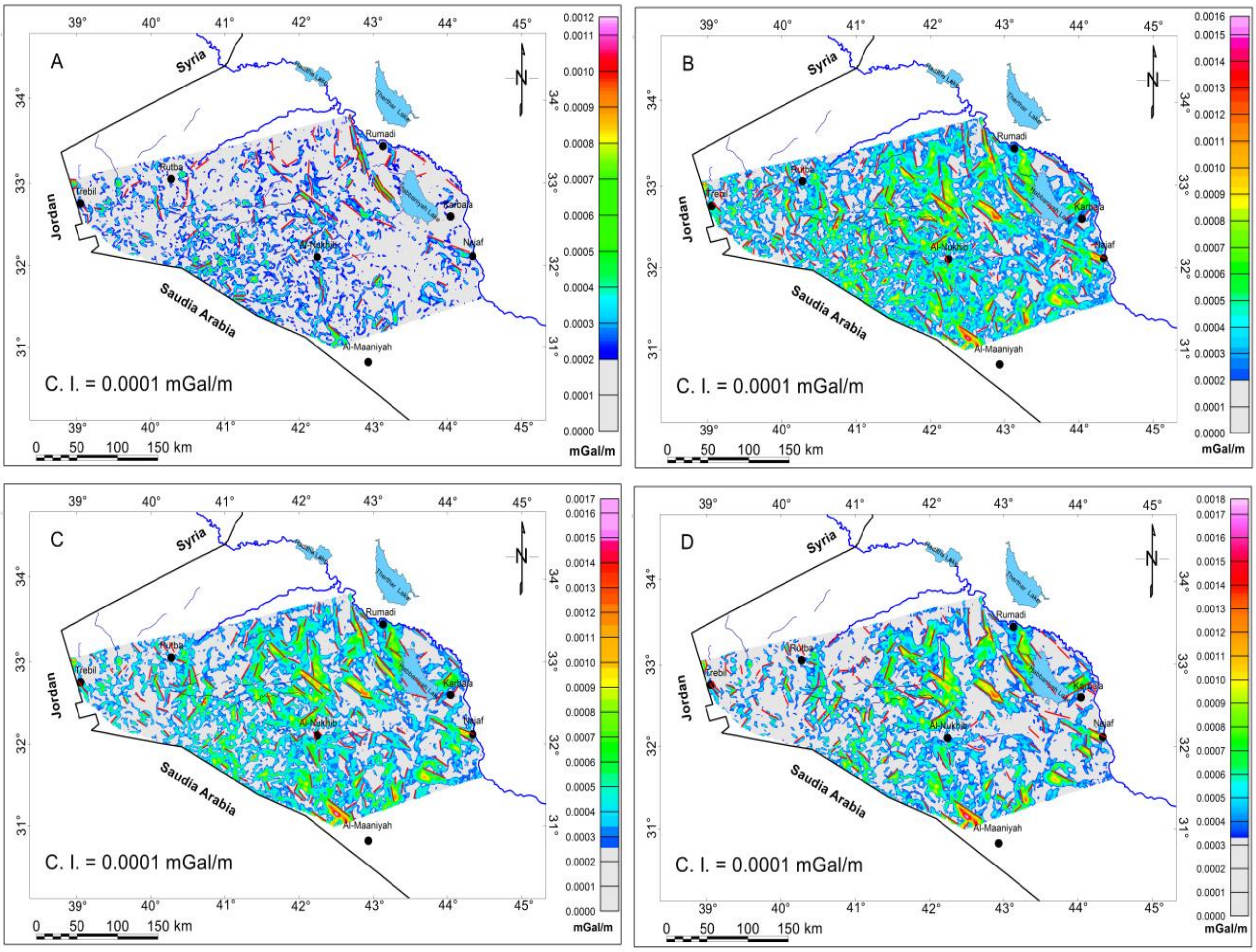

Fig.7. The main the main subsurface linear features detected by applying the THD filtering on the residual gravity field detected on Total Horizontal Derivative (THD) of residual gravity data of the western part area, obtained from upward continuation forth upward continuation elevation levels, (A) 2 km; (B) 12km; (C) 16 km; (D) 22km.

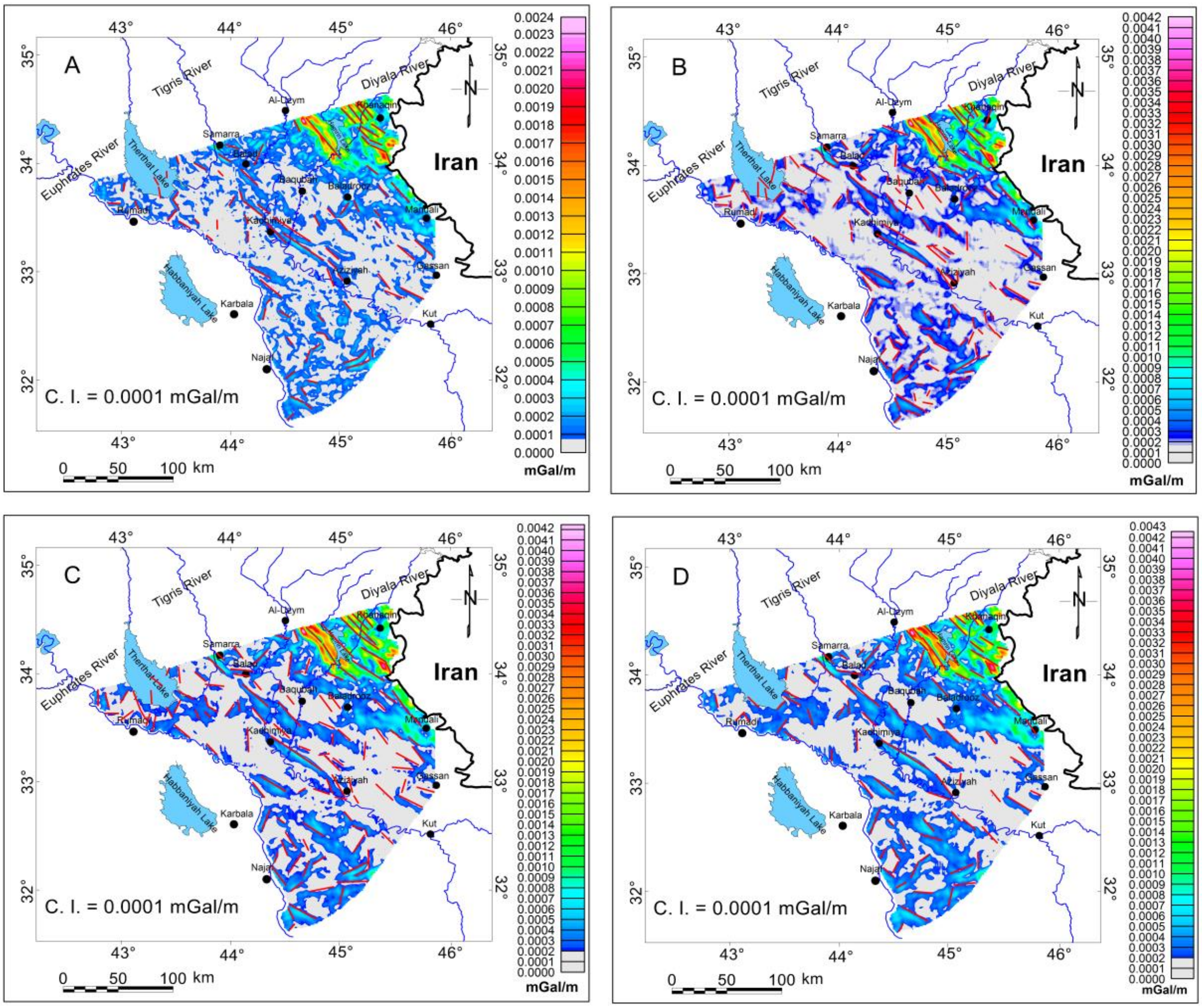

Fig. 8. The main the main subsurface linear features detected by applying the THD filtering on the residual gravity field lineaments detected on Total Horizontal Derivative (THD) of residual gravity data of the eastern part area obtained from upward continuation for the elevation levels, (A) 2 km; (B) 12km; (C) 16 km; (D) 22km.

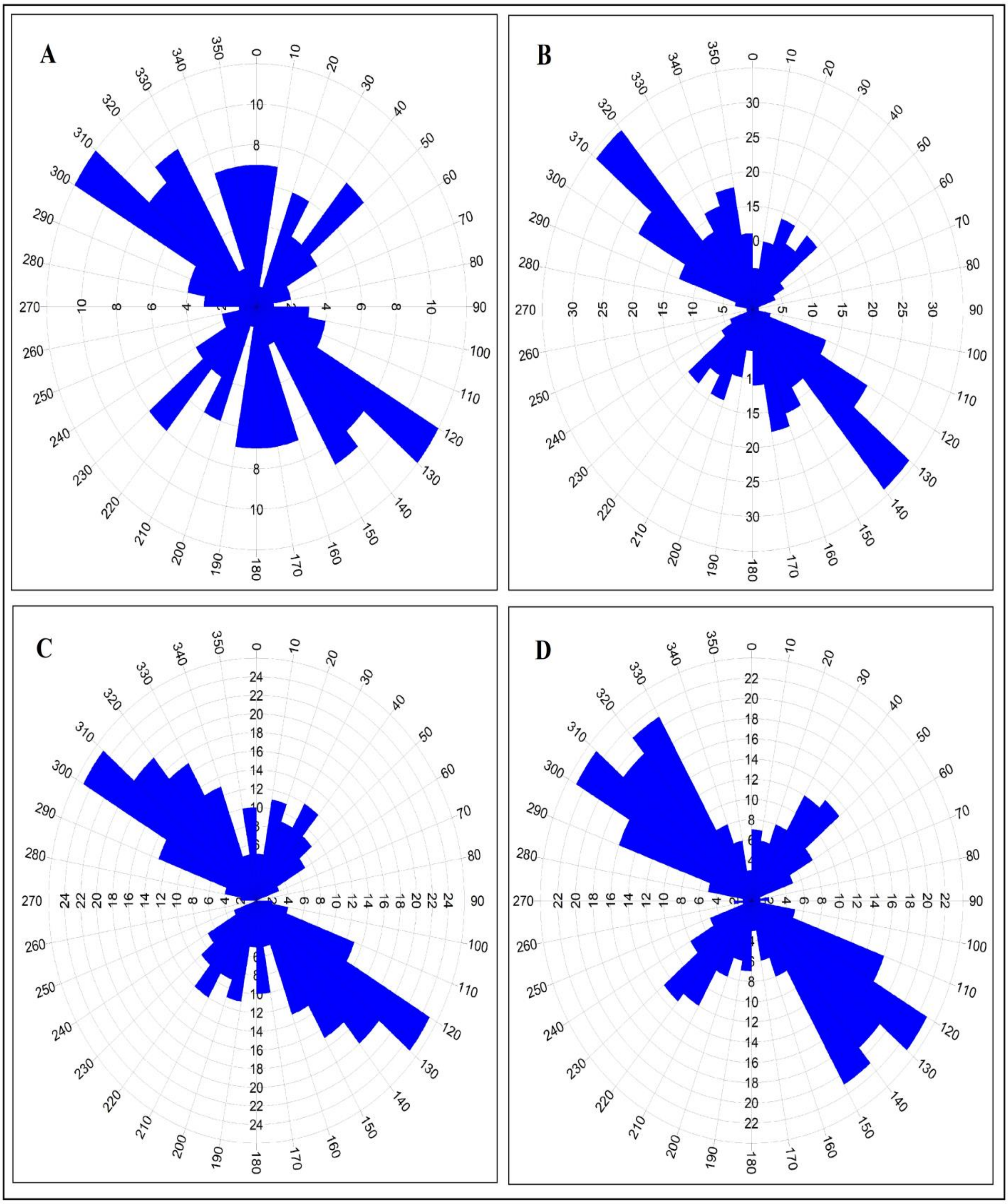

Fig. 9. Rose diagram showing Linear feature directions for the maximum THD of residual gravity anomalies at western part area, those obtained using upward continuation with elevation levels, (A) 2 km; (B) 12km; (C) 16 km and (D) 22km.

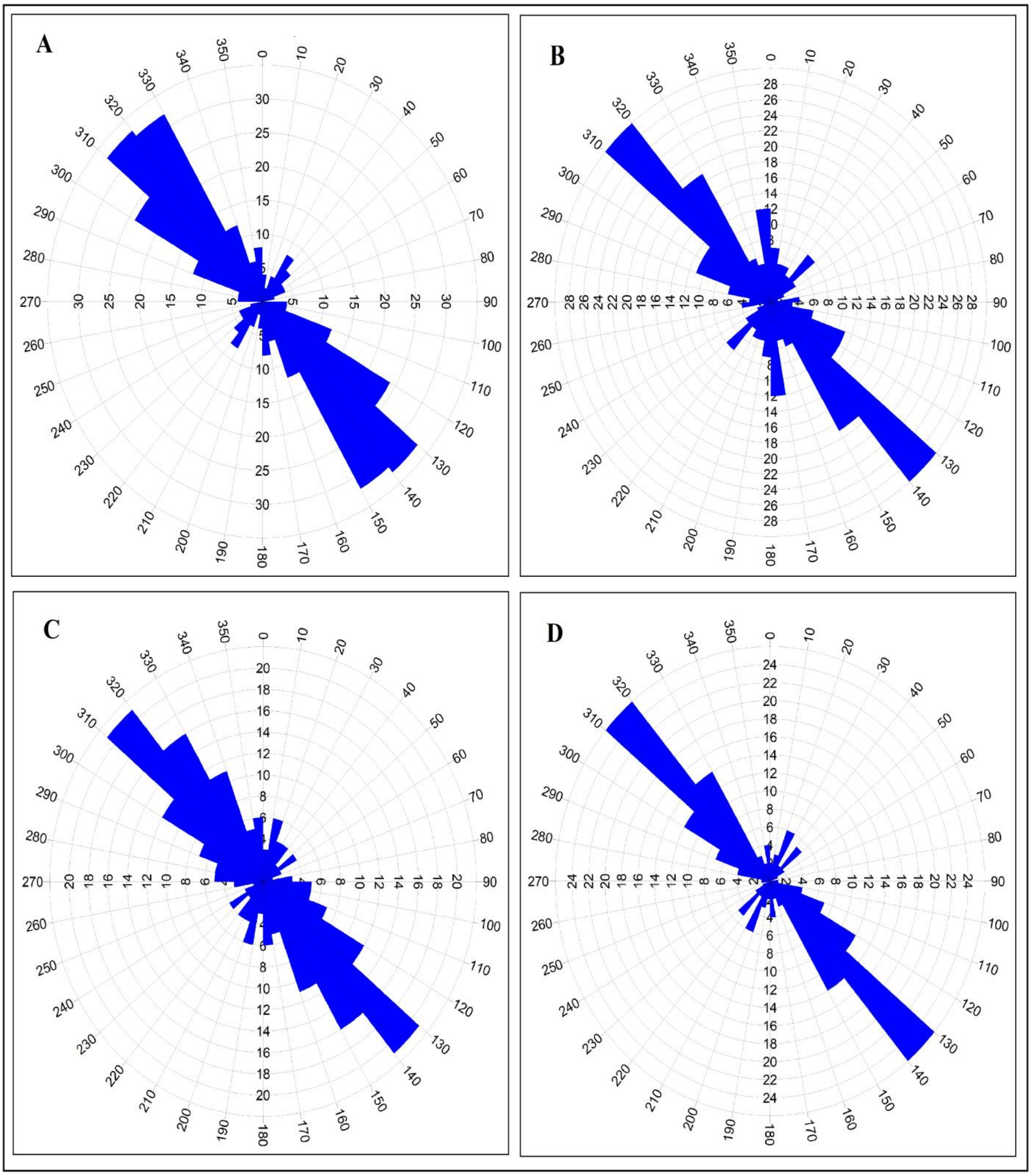

Fig. 10. Rose diagram showing the linear feature for the maximum THD values of residual gravity anomalies at eastern part area, those obtained using the upward continuation with elevation levels, (A) 2 km; (B) 12km; (C) 16 km and (D) 22km.

Table 1: The main linear feature trends at the western part of the region, obtained by applying the THD filtering on the residual gravimetric fields of 2,12,16 and 22Km upward continuation levels.

Lineament direction / Upward elevation	N65 W	N55 W	N45 W	N35 W	N25W	N15W	N05W	N05E	N15E	N25E	N35E	N45E	Pred. lineaments in each level
2km	4	12	8	9	-	7	7	7	-	6	4	8	N55W
12km	13	22	34	12	16	18	10	-	-	14	10	14	N45W
16km	13	25	20	17	13	-	10	-	11	9	12	9	N55W
22km	16	23	19	21	8	4	-	5	5	8	12	13	N55W
∑	46	82	81	59	37	29	27	12	16	37	38	44	N55W
Order	4th	1st	2nd	3rd	7th	9th	10th			8th	6th	5th	

Table 2: Linear feature trends at the eastren part of the region obtained by applying the THD filtering on the residual gravimetric fields of 2, 12, 16 and 22Km upward continuation levels.

Lineament direction / Upward elevation	N65W	N55W	N45W	N35W	N25W	N15W	N05W	Trend lineaments in each level
2 km	12	24	33	32	12	5	7	N45W
12 km	11	11	30	19	6	4	12	N45W
16 km	7	12	21	16	11	5	6	N45W
22 km	7	12	26	14	-	2	4	N45W
∑	37	59	110	81	29	16	29	
Trends Order	4th	3rd	1st	2nd	5th	7th	6th	

Discussion

The upward continuation technique is applied to gravity data for the eastern and western parts of central Iraq at elevations of 2, 12, 16, and 22 km; four regional maps of the region are obtained, which are subtracted from the maps of the Bouguer anomalies to obtain the residual maps, (Figs. 5 and 6). The Total Horizontal Derivative (THD) was applied to the residual gravity data for two distinct regions. This process is carried out to compute the Total Horizontal Derivative (THD), which plays an important role in discerning the boundaries of subsurface anomalies, which coincide with the faults in most cases (Figs. 7 and 8).

Rose diagrams are constructed to further elucidate the directional aspects of the subsurface linear features, and to compare between the eastern and western parts of the study region. Nine predominant trend directions were distinguished at the western part, for the four upward continuation elevation levels which are detected in the current study. These lineaments are arranged in descending order as follow: N55W, N45W, N35W, N65W, N25W, N15W, N35E, N45E, and N25E (Fig. 9 and Table 1). It is found approximately that the percentage of lineaments which are trending NW-SE, is 62%. The western studied part area is characterized by three conjugate fault systems; these are N55W-N35E, N45W-N45E and N05W-N65W. The angles between the first two conjugate faults are 90 degrees, and the angle for the third conjugate fault system is 60 degrees. According to the conjugate systems the direction of the maximum stress seems to be N-S and N35W. The N-S maximum stress direction has been affected the deep or basement structures, while the N35W the sedimentary structure. The main tectonic stress direction at the basement and deeper structure level is the western part the N-S direction, while at the relatively shallow structure; the stress direction is NE-SW. For the eastern part, the main stress direction for all levels is NE-SW.

The predominant trends of linear subsurface features at the eastern part are six. These trends are arranged in descending order as follow N45W, N35W, N55W, N05W, N65W, and N25W. It is found that the percentage of NW-SE trends of linear features at the eastern part is about 92%.

The conjugate fault systems in this part may be N65W-N05W and N45W-N05W. The maximum stress directions for these two systems are N35W and N25W (Fig.10, Table-2).

Conclusions

The upward continuation filtering is used to deduce four residual gravity fields which reflects different depths of investigation. Later, the subsurface linear features are visualized by applying the THD filtering technique of gravity data were used to compare the western and eastern parts of central Iraq. The comparison is achieved a comparison was made among the THD filtered residual fields for the four upward continuation levels.

Within the western part, linear features show many trend directions, the largest number of these trends is the NW-SE direction, while the lesser trends are in the NE-SW direction. The N55W, N45W, and N35W trends percentage is 51% of all lineaments in the western part. The percentage of these trends for the four deduced residual fields range between 48-60%. The groups of lineaments N35E, N45E, and N25E trends at the western part are about 24%. Using the idea of conjugate faults for the western part indicates that the main stress direction is N-S.

The eastern part region characterized by the predominant **lineament's** trends N45W, N35W and the N55W, respectively. These trends represent 72% percentage of lineaments in this part for all upward elevation levels. The general trends of lineaments in eastern part are NW-SE.

Generally, in the NW-SE trend coincide with the Najd fault system. The NE-SW lineaments trends considered as a conjugate fault associated with the NW-SE faults. The stress effect the area seems to be N-S direction.

Many trace faults in this study are compatible with the longitudinal faults that appear in the tectonic map of Iraq.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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