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Evaluation of the Tectonic Boundaries in Tikrit-Kirkuk Area Using Potential Data, North - Central Iraq

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Abstract
The gravity and magnetic data of Tikrit-Kirkuk area in central Iraq were considered to study the tectonic situation. The residual anomalies were separated from regional using space windows method with space of about 24, 12 and 10km to delineate the source level of the residual anomalies. The Total Horizontal Derivative (THD) is used to identify the fault trends in the basement and sedimentary rocks depending upon gravity and magnetic data. The identified faults in the study area show NW-SE, less common NE-SW and rare N-S trends. Some of these faults extending from the basement to the upper most layer of the sedimentary rocks. It was found that the depth of some gravity and magnetic source ranges between 12-13Km, which confirm the basement depth that obtained by C.G.G. 1974. While the depth of shallow gravity source equals about 4Km, this depth may be lay with sedimentary cover in Triassic age. A comparison of the residual gravity and magnetic anomalies of the relatively shallow depths showed a general coincidence. The obtained tectonic boundaries divided the study area to many blocks. In general the tectonic boundaries control the river running in the area, at the same time the longitudinal faults control the main oil fields in the study area.

Keywords: THD technique, tectonics blocks, Tikrit-Kirkuk, faults detection, central Iraq

تقييم الحدود التكتونية باستخدام البيانات الجهدية في منطقة تكريت – كركوك شمال – وسط العراق

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الخلاصة
استخدمت المعطيات الجهدية لغرض تحليل الوضع التكتوني لمنطقة تكريت–كركوك. اجريت عملية فصل الشذوذ المتبقي عن الاقليمي باستخدام طريقة سعة النافذة (Space Windows Method) ولنوافذ ذات مسافات مختلفة (Spacing) هي 24، 12 و10 كيلومتر للكشف عن مستويات متعددة للمصادر المسببة للشواذ من الاعمق الى الاقرب.استخدمت طريقة الانحدار الافقي الكلي (THD) في معالجة المعطيات الجذبية والمغناطيسية وذلك لتحديد اماكن الفوالق ومعرفة اتجاهاتها في صخور القاعدة العميقة وفي الصخور الرسوبية، وتبين ان اتجاهات هذه الفوالق هي شمال غرب–جنوب شرق، وبقدر اقل باتجاه شمال شرق–جنوب غرب وفوالق قليلة جدا باتجاه شمال–جنوب بعض هذه الفوالق ممتدة من صخور القاعدة الى اعماق قريبة من سطح الارض. وقد وجد أن عمق بعض المصادر المسببة للشواذ الجذبية والمغناطيسية يتراوح 12–13كم ، مما يؤكد عمق صخور الفاعدة الذي حصلت عليه C.G.G. 1974. في حين أن عمق مصدر الشواذ الجذبية الضحلة حوالي 4 كم ، وإن عمق هذا المصدر الضحل قد يكون ضمن الغطاء الرسوبي في العصر الترياسي. اظهرت مقارنة الشواذ الجذبية والمغناطيسية المتبقية للاعماق الضحلة نسبيا توافقا بشكل عام. وفقا لتوزيع الفوالق

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قسمت منطقة الدراسة بشكل عام الى عدة كتل. ظهر من خلال الدراسة ان الحدود التكتونية يشكل عام تسيطر على مجرى الانهار في المنطقة. فيما تتحكم الفوالق الطولية في توزيع الحقول النفطية في منطقة الدراسة.

Introduction

Potential field methods, especially gravity and magnetic, are important reconnaissance tools for delineating sedimentary basin geometry during the early stage of exploration [1].. Understanding the tectonic framework of a region is the first step in the search for petroleum in a sedimentary basin, through detailed analysis of the basin framework and reconstructing of crustal geometry [2]. Gravity and magnetic data are normally used for qualitative interpretation of regional geology and structural features in a region, this area is characterized by many surface and subsurface anticlines and faults.

AL-Banna (1998) [3], prepared a tectonic evaluation of Hamrin- Samarra-Tikrit area using gravity data regional and residual anomalies to obtain the deep and shallow structures. Mutib and Ahmed (2005) [4], study the data of the area northwest of Kirkuk oil field. His study shows the sharpness of the height of the gravity and the continuation of the stratigraphic sequences bend to the rocks of the Cretaceous. AL-Esho (2017) [5], interpreted of the available geophysical data for west Tikrit area. He concludes that there is no clear closures in the gravity Bouguer map unlike the magnetic scope map which shows high closures in the eastern central part of the study area.

The aim of this study is using Total Horizontal Derivative techniques (THD) of gravity and magnetic data residual to locate the faults or boundaries of the magnetic and gravity sources.

Location of the study area

The study area is located in central and northern Iraq, with Longitude 42^{o}38'42" _ 45^{o}07'48" and Latitude 33^{o}59'24"_35^{o}30'36" (Figure-1). The area dimensions in North-South (169) Km and in East-West (226) Km and covering an area of about (38194) Km^2.

Table 1- Coordinates of study area boundaries (WGS-84 UTM Zone- 38)

Point	East (m)	North (m)
A	**284804**	**3930707**
B	**511589**	**3930707**
C	**511589**	**3760085**
D	**284804**	**3760085**

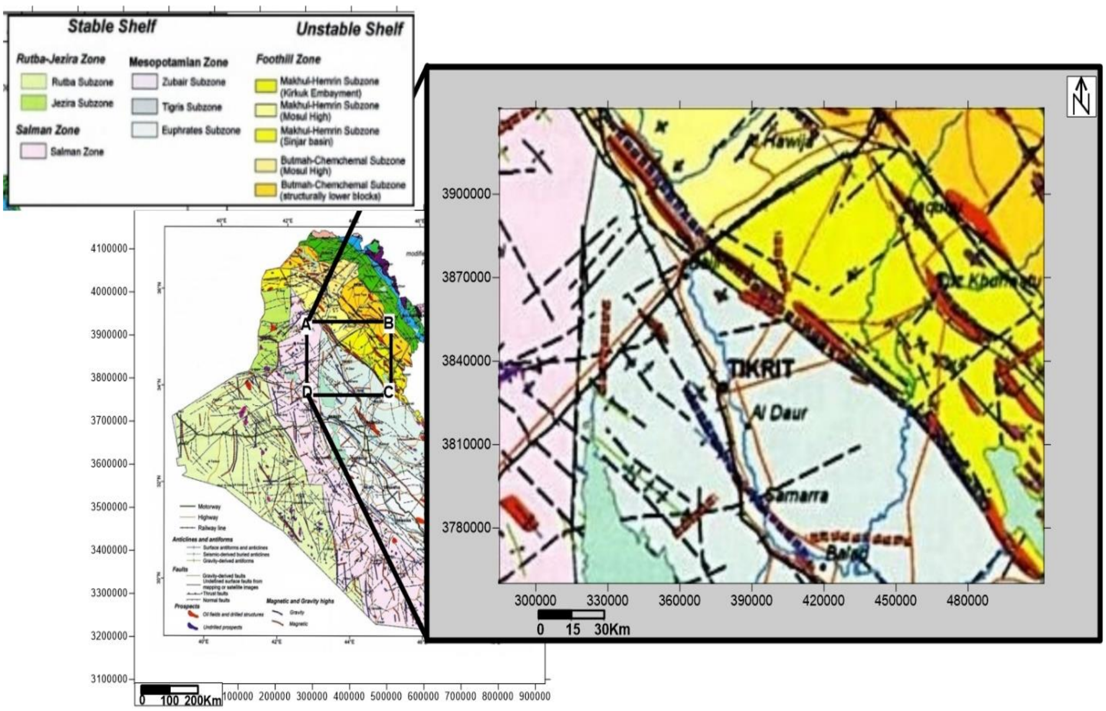

Figure 1- Location and Tectonic map of study area [6].

Geology and Tectonics setting of the study area

The study area from the tectonic side belongs to the Outer platform (of the Arabian platform of the Arabian plate), which is separated from the Inner platform by transition zone [7]. Precisely within the Mesopotamia Foredeep and Western Zagros Fold-Thrust Belt (Low Folded Zone) [8]. The Mesopotamia Foredeep consists of flat, broad plains of Tigris and Euphrates rivers, it is basically flat terrain, covered by Miocene to Holocene restricted marine and continental (molasse) deposits [9]. The zone was probably uplifted during the Hercynian deformation but it subsided from Late Permian time onwards. It is a relatively flat terrain with a gradient of less than 10 cm per kilometer extending from Baiji in the NW to the Arabian Gulf in the SE [6]. The foredeep contains many buried structures including neotectonically active ones. The Low Folded Zone forms the first topographic and morphological front of the Western Zagros Fold-Thrust Belt. The boundary between the Mesopotamia Foredeep and this zone is taken along the slopes of Hamrin – Makhul mountain range and its continuation northwestwards. The zone consists of a series of widely spaced, low amplitude gentle folds. These folds trend NW – SE but change gradually to E – W as they extend northwestwards [8]. The geological formation outcrops at the study area ranging from middle Miocene to Pleistocene, such as Fatha, Injana, Mukdadiya and Bai Hassan Formations. The Quaternary deposits cover large areas of the study area ranging from Pleistocene to Holocene.

Gravity and Magnetic Data

The Bouguer anomaly map of the study area is a part of Bouguer anomaly map of Iraq compiled at a scale of 1:1000000 with 1 mgl contour interval. This map is published by GEOSURV and Iraq Petroleum Company (IPC) (Figure-2). The Aeromagnetic map of the study area is part of the Aeromagnetic Total Field Intensity map of Iraq. It is constructed by the C.C.G [10]. The grid lines of the survey were done with space interval of 2 km in Iraq. The Total Magnetic Intensity (TMI) data was processed to obtain the Reduction To the Pole (RTP) map (Figure-3) in order to symmetrically position the anomalies above the causative bodies. This process is achieved by Geosoft (Oasis Montaj) program that is available at the Oil Exploration Company (OEC) in Ministry of Oil.

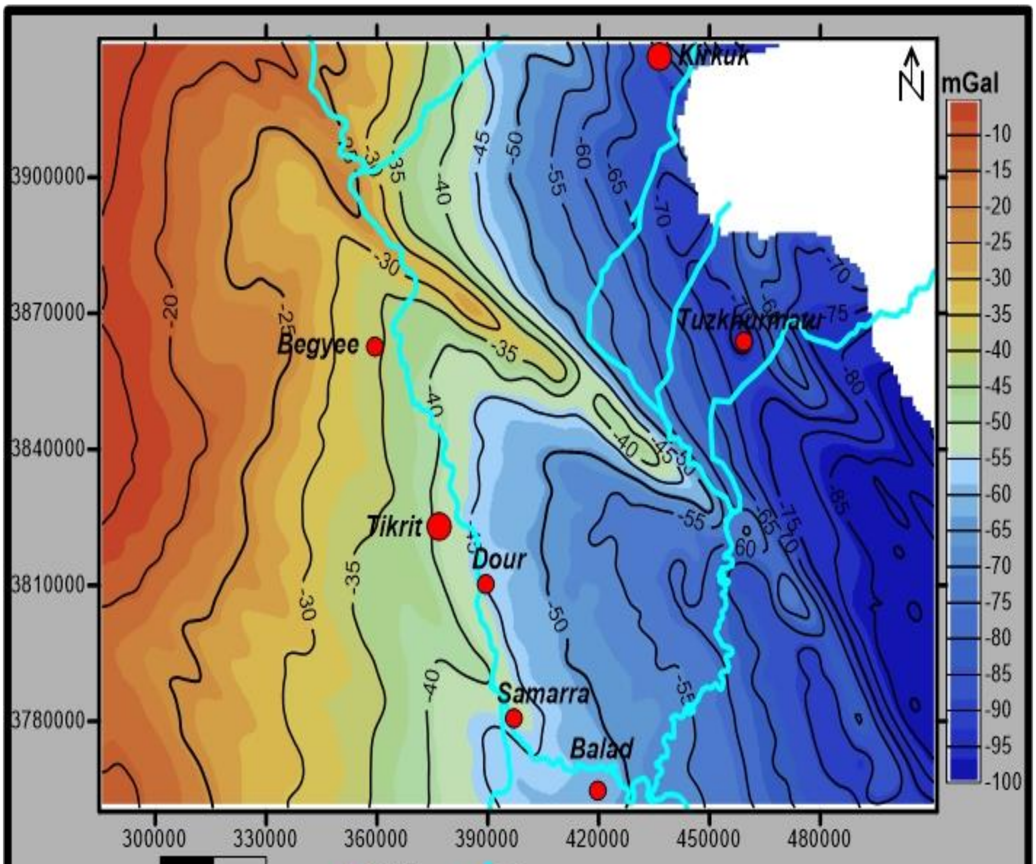

Figure 2- Gravity Bouguer map of the study area.

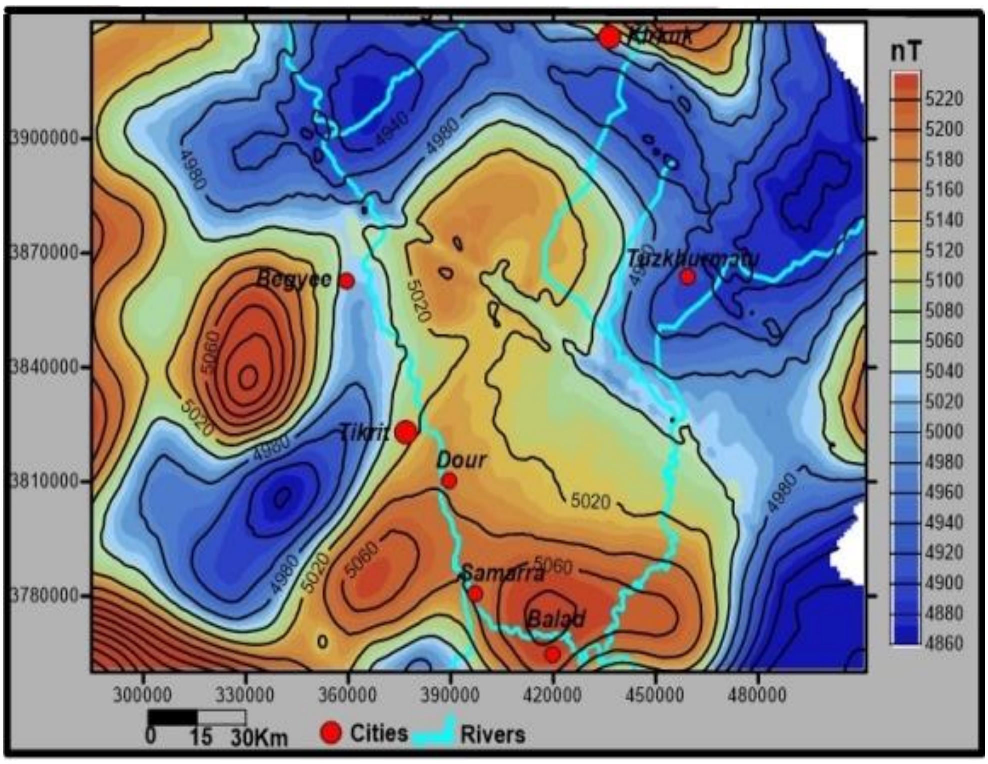

Figure 3- The Reduction to the pole (RTP) map of the study area.

Separation and Description of Gravity and Magnetic Anomalies

The process of separating Gravity and Magnetic anomalies is necessary to evaluate the study area. So the anomalies are separated using space windows method with different spacing which are 24, 12 and 10 Km to detect multiple levels of rock thickness that cause the anomalies from the deepest to the shallower source. The residual anomalies are obtained by subtracting the regional anomalies from gravity and RTP magnetic data. The gravity and magnetic anomalies of the sources from the earth surface to the depth of about 11Km can be obtained from the residual gravity and magnetic map of space window 24km.

The relatively shallow source within the sedimentary cover may be obtained using the residual gravity and magnetic maps using spacing window 12km and 10km. These two space windows investigate a source of depth of 5.6Km and 4.7Km respectively. The general trend of gravity anomalies is NW-SE. The depth of these anomalies depending on $X_{1/2}$ method is found to be range from 4Km to 12.5Km, the length between 20Km-75Km and the width about 12.5Km-17.5Km. The amplitude of positive residual gravity anomalies are ranging from (1) to (18) mGal, with an almost elongate shape.The RTP magnetic anomaly map of space window 24Km show many positive and negative magnetic anomalies seems to be nearly circular in shape with small elongation in N-S, NE-SW and E-W trends. This map shows an elongated negative magnetic anomaly lying with Makhul and Hemrin folds. This anomaly becomes clearer in residual magnetic maps of space windows 12Km and 10Km. The amplitude of the positive anomalies is ranging from 2-70 nT. The depth of these anomalies is determined depending on ($X_{1/2}$ Law) method and it is found to be about 13Km. The length of these anomalies is ranging from 42Km-112Km, with width of 15Km-60Km. A comparison of the residual gravity and magnetic anomalies of the relatively shallow depths showed a general coincidence between positive gravity anomalies and negative magnetic anomalies (Figure-4).

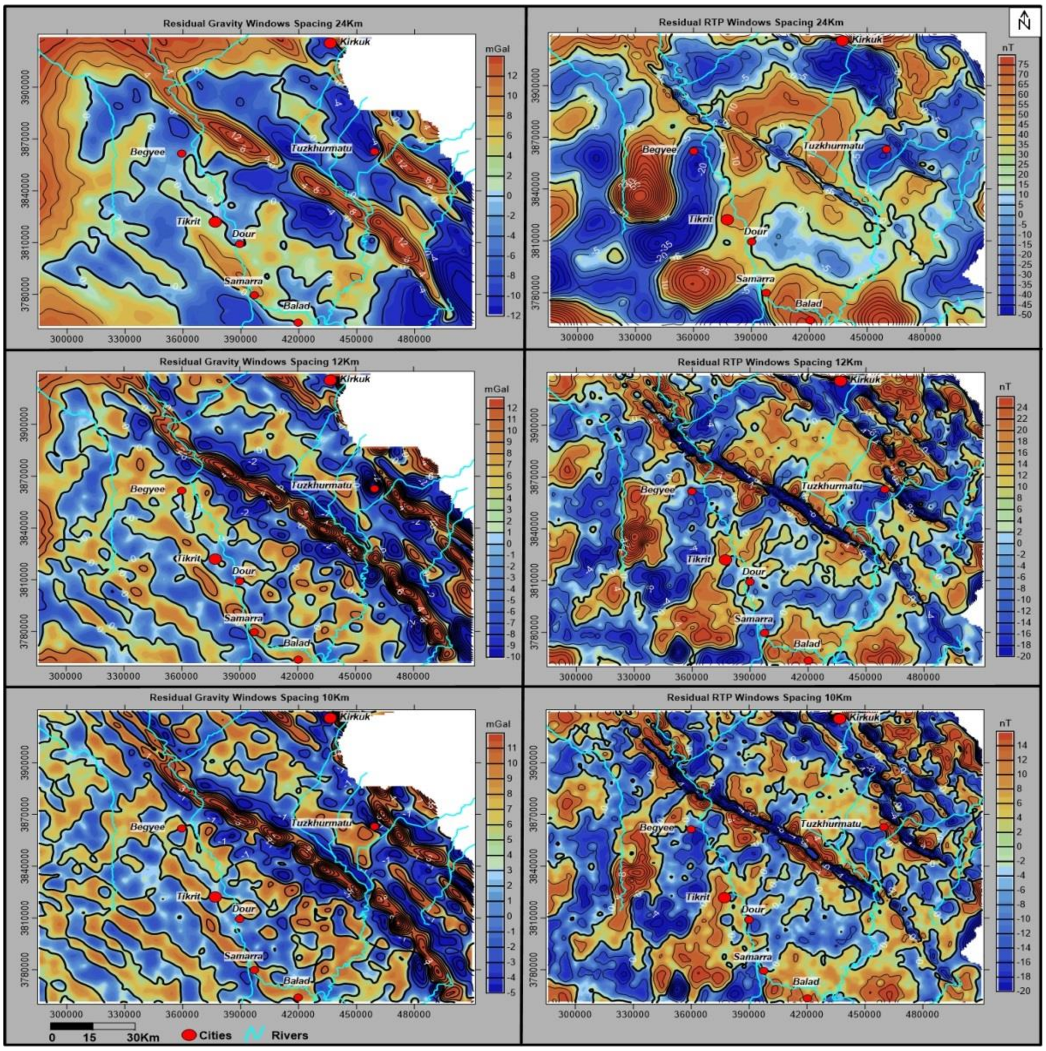

Figure 4- Residual gravity and magnetic maps of space windows 24, 12 and 10Km.

Total Horizontal Derivative (THD) of magnetic and gravity data

The 1st horizontal derivatives are: (dt/dx) and (dt/dy) where t is the anomaly can be used in delineating magnetic contacts. It is severely affected by the inclination of the inducing geomagnetic field and is therefore not a good indicator of the true location of a contact until the magnetic data have been reduced to the pole. The horizontal derivative can be simply calculated in the space domain. By itself this is not a useful derivative since in profile form it is directional (i.e. depending on the direction of (+ x) the gradient could be either negative or positive). Total Horizontal Derivative (THDR) as the name suggests it measures the full horizontal gradient [11].

$$THDR = \sqrt{(\frac{dt}{dx})^2 + (\frac{dt}{dy})^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

This technique is used to detect the location of the faults or edge of the sources in the subsurface the edge or faults indicated by the maximum of the Total Horizontal Derivative (THD) values, **m**agnetic and gravity derivatives can be likened together in that they can help define/estimate the physical properties of the source structure causing the anomaly [12].

The faults of the study area are delineated depending on the applying of (THD) to the residual gravity and magnetic data of space window 24Km. Three main trends of lineaments are predominate in the study area Figures-(5, 6 and 7), the first trend is in NW-SE, which has values (N15W, N30W, N43W, N49W, N60W, N74W and N80W). This trend is best mapped from gravity gradient interpretation and more common in THD of gravity residual than THD of the magnetic residual. The lineaments which being in this direction may correspond to the NW-SE Najd Fault System that developed during Late Precambrian Nabitah orogeny. The other trend is in NE-SW, more common in THD of residual magnetic maps they were detected with values (N12E, N17E, N30E, N44E and

N80E), this trend might correspond to the Transversal Fault System. The third one which is less common of lineaments is in the N-S direction.

The gradient of gravity determined the longitudinal faults, while the gradient of magnetic determined some basic longitudinal faults and better defined the transversal faults. This can explain that the transversal faults are older and deeper and that the basic longitudinal faults below Makhul and Hamrin are deep and old. The longitudinal faults that appear in gravity only may be shallow faults.

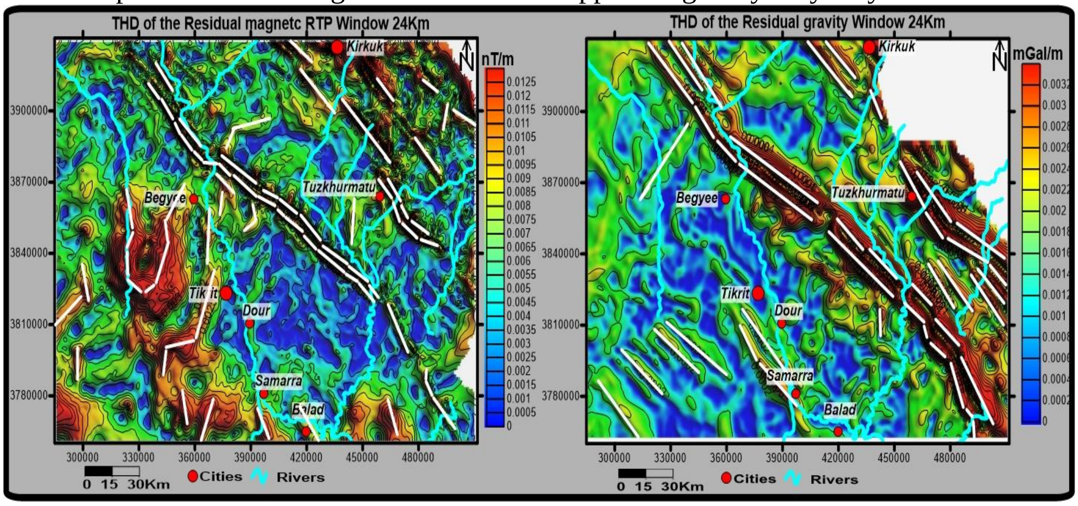

Figure 5- The total horizontal derivative (THD) of residual space windows 24Km of the gravity and magnetic data shows lineaments features.

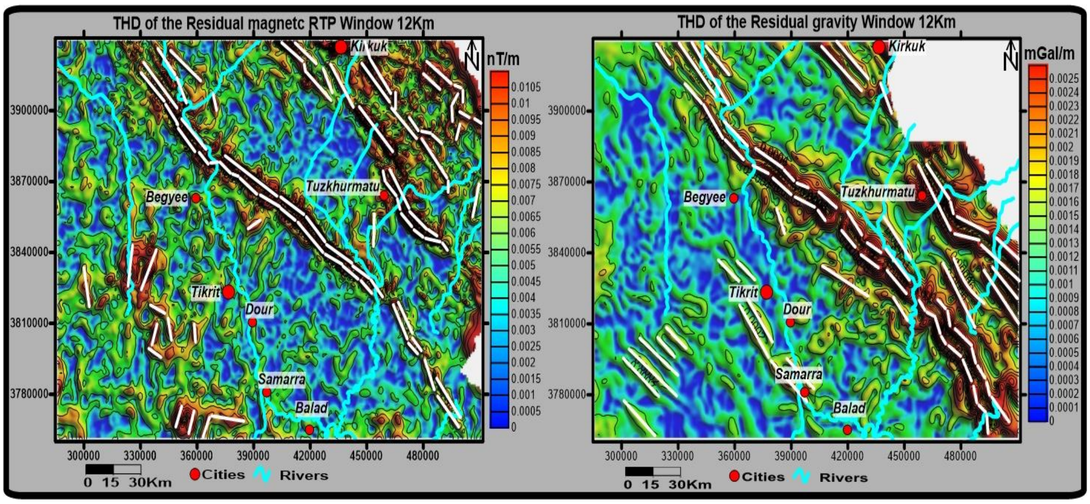

Figure 6- The total horizontal derivative (THD) of residual space windows 12Km of the gravity and magnetic data shows lineaments features.

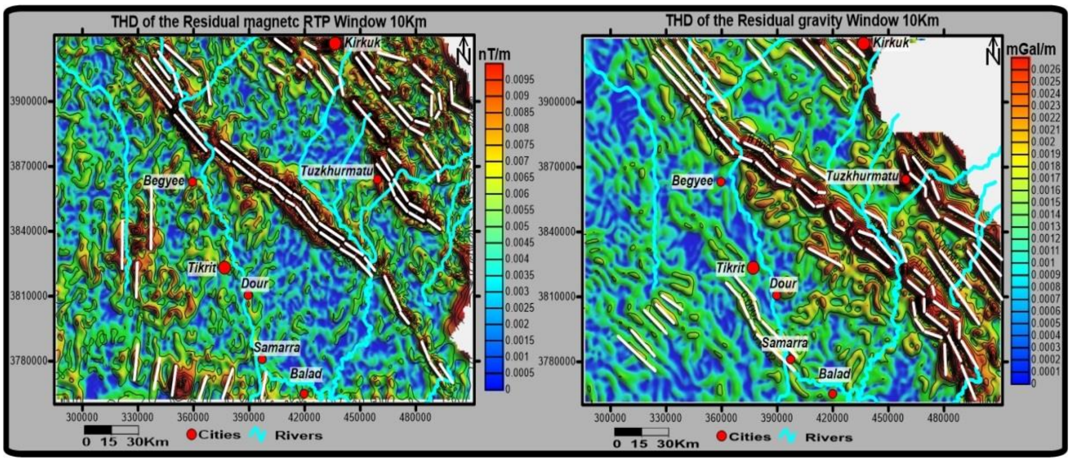

Figure 7- The total horizontal derivative (THD) of residual space windows 10Km of the gravity and magnetic data shows lineaments features.

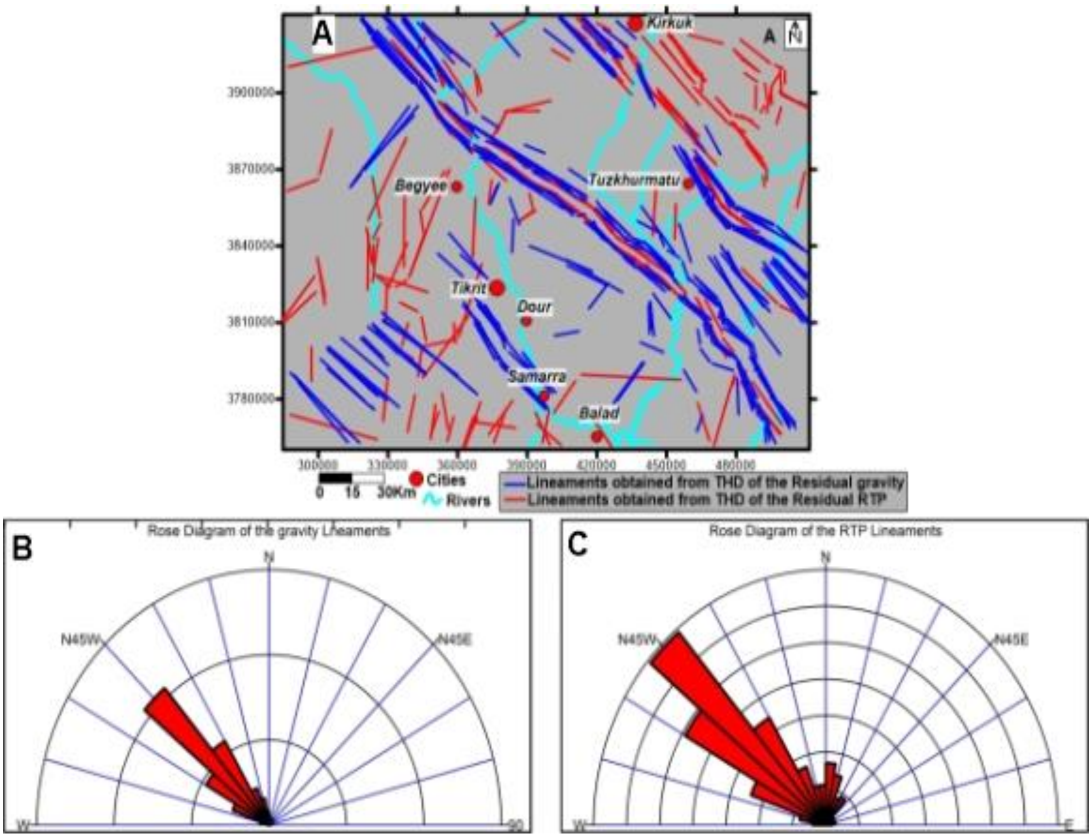

Figure 8- A- The lineaments features map for gravity and magnetic. B- Rose diagram for lineaments features from residual gravity data. C- Rose diagram for lineaments features from residual RTP magnetic data.

According to the main trends of faults in Figure-8 the area is divided into many zones by the transversal and longitudinal blocks (Figure-9). These tectonic boundaries (faults) control the rivers running in the area. The oil fields in the study area are accompanied with the major longitudinal faults (Figure. 9).

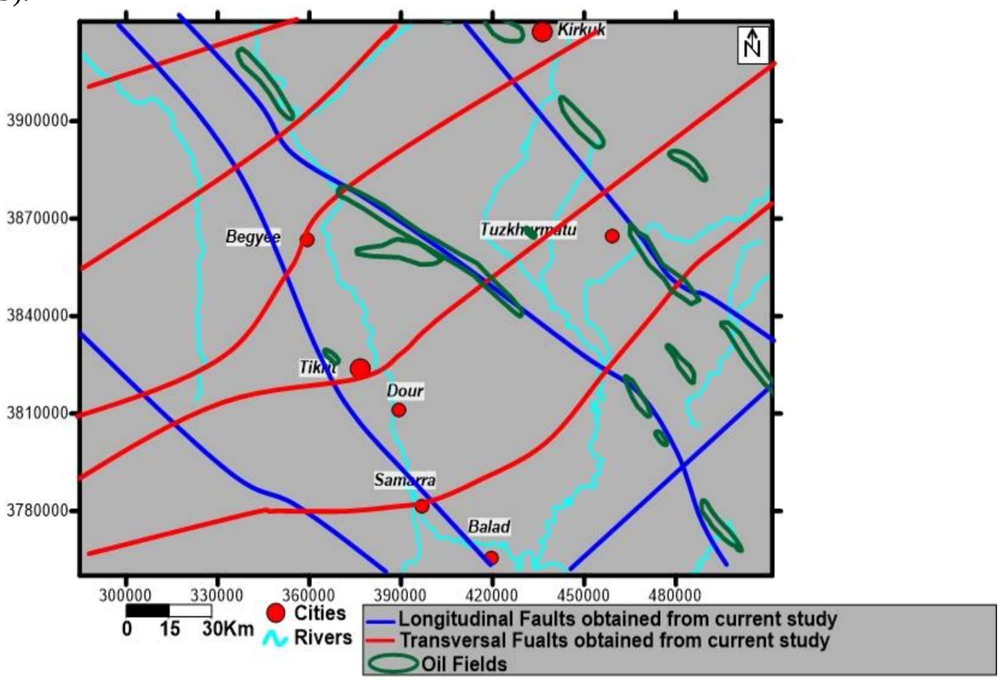

Figure 9- Basic tectonic boundaries lines estimated from gravity and magnetic lineaments.

Conclusions

The main residual gravity anomalies of the space windows 24, 12, and 10Km, indicate presence of groups of anomalies trending NW-SE and locate at the Southeastern part of the study area. The magnetic residual of the same space windows indicate presence of anomalies of NW-SE trend at the Northeast part, NE-SW trend at the Western part and E-W trend at the South part of the study area. The residual magnetic map of space window 24Km showing an elongated negative magnetic anomaly lying with Makhul and Hemrin folds. This anomaly become clearer in residual magnetic maps of space windows 12Km and 10Km. The residual gravity and magnetic anomalies of the relatively shallow depths shows a general coincidence between positive gravity anomalies and negative magnetic anomalies. The lineaments obtained from Total Horizontal Derivative (THD) of gravity and magnetic showing a predominate trend NW-SE, NE-SW and low presence N-S trend. The NW-NE best mapped from gravity gradient interpretation and more common in THD of gravity residual than THD of the magnetic residual. The NE-NW is more common in THD of magnetic residual in the study area.

The study area is divided into many tectonics blocks according to the faults obtained from (THD) and tectonics boundaries. The tectonic boundaries mostly control the rivers running in the study area. Some longitudinal faults control the distribution of the oil fields in the study area. The estimation of some gravity and magnetic source shows that some of the deep source 12-13Km, which coincide with basement depth prepared by C.G.G. 1974. The shallow gravity source of about 4Km may be with the sedimentary cover of Triassic age.

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