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The Deep Faults in Kut-Hai and Surrounding Area Inferred From Gravity and Magnetic Data

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Abstract
Gravity and magnetic data are used to study the tectonic situation of Al-Kut- Al-Hai and surrounding areas in central Iraq. The study included application of many processing and interpretation programs. The window method with different spacing was used to separate the residual from regional anomalies for gravity and magnetic data. The Total Horizontal Derivative (THDR) techniques used to identify the fault trends in the basement and sedimentary cover rocks depending upon gravity and magnetic data. The identified faults in the study area show (NW-SE), (NE-SW) (N-S) and (E-W) trends. It is believed that these faults extending from the basement to the upper most layer of the sedimentary cover rocks.

Keywords: Deep faults, Kut, gravity, magnetic, THDR

الفوالق العميقةَ لمنطقة الكوت–الحي والمناطق المحيطة بها والمستنبطة من المعلومات الجذبية والمغناطيسية

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الخلاصه
استخدمت المعلومات الجذبية والمغناطيسية لدراسة منطقة الكوت –الحي و المناطق المحيطة بها في وسط العراق للتعرف على الوضع التكتوني في المنطقة . تضمنت الدراسة استخدام برامج معالجة و تفسير متعددة ،فقد استخدمت طريقة تغير النافذة (window) لفصل الشواذ الجذبية و المغناطيسية المحلية عن الاقليمية .فيما استخدمت طريقة الانحدار الافقي الكلي (THD) في معالجة المعطيات الجذبية والمغناطيسية وذلك لتحديد اماكن الفوالق ومعرفة اتجاهاتها في صخور القاعدة العميقة و في صخور الغطاء الرسوبي .تم تحديد اتجاهات الفوالق في منطقة الدراسة و تبين انها باتجاهات ((NE–SW)،(NW–SE)) واخرى باتجاه (N–S)،(E–W) يعتقد ان هذه الفوالق ممتدة من صخور القاعدة الى اعماق قريبة من سطح الارض.

Introduction

Gravity and magnetic data were used to detect and delineate the subsurface structures at a region that extend from Kut to Hai and surrounding area. The magnetic data which are related to changes in magnetic susceptibilities are used to determine the locations and the depths of the magnetic bodies. Gravity data are used to determine the location of boundaries of anomalies within the basement and sedimentary cover. Different techniques including the derivatives are developed by

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many authors to enhance the magnetic and gravity fields. These techniques used to determine the boundaries and depths of the causative sources.

Al – Banna (2000) [1], used the amplitude –matrix technique for determine the predominant trends of Bouguer, regional and residual anomalies of Anah and north Nasryia. Salem et al. (2008) [2] used the tilt derivative technique to interpretive the magnetic anomalies. Salako (2014) [3] used Source Parameter Imaging (SPI) to interpretated the magnetic data in order to determine the depth to basement surface of Borno basin, northeast Nigeria. Abu Eta et al (2013) [4] studied the basement tectonic of eastern Yemen region ,from the aeromagnetic data. They applied numerous derivatives to detect the edges and trends of the magnetic anomalies. These derivatives include the Total Horizontal derivative and Analytical signal. It is found that, the boundaries of sources are correlated with the boundaries of the positive and negative anomalies of the RTP map.

Saada (2016) [5], studied the area lies at eastern Desert – Egypt, from the aeromagnetic data. He is applied numerous derivatives for estimate the edges detection and depth of magnetic structures, these derivatives include the Total Horizontal derivative, Tilt derivative and Analytical signal. The results of the used techniques show good correlation in delineating the general structural framework of the area. Amin et al (2014) [6] studied the subsurface structures in Hur AL-Huwazah area by gravity and magnetic surveys. They detected numerous gravity and magnetic anomalies and obtain the basement depth of these structures by using Analytical Signal (AS) for RTP magnetic data.

Total Horizontal Derivative techniques (THDR) and residual potential maps have been applied to study the Kut- Hai area to locate the boundaries of the magnetic and gravity sources. It is interested to detect the edge of causative sources of magnetic and gravity and discussed the degree of similarity between them.

Location and tectonic setting of study area

The study area is situated in central part of Iraq and a few part within the Diwania Government, Figure-1. It lies largely in the Mesopotamia Plain. The coordinate of the study area is tabulated in Universal Transverse Marketer (U T M) system in Table-1.The study area covering more than ($40000km^2$).

Table1- Coordinate of the study area using the Universal Transverse Merkator(U T M) system

point	Northern	Eastern
A	**3640000**	**480000**
B	**3640000**	**680000**
C	**3520000**	**480000**
D	**3520000**	**680000**

Tectonically, the study area is part of the unstable shelf in Iraq [7]. This zone subdivided from north to south into the Tigris, Euphraties ,Zubair subzones on the Mesopotamia zone . The Mesopotamia zone is an asymmetric foredeep with regional dip to the (NE) and (E) . The Mesopotamian zone contains buried faulted structures below the Quaternary cover, separated by broad syncline. The fold structures mainly trend NW-SE in the eastern part of the zone and N-S in the southern part of Iraq,some NE – SW trending structures occur [8]. Two main longitudinal faults (Najid faults system) crossing the studied area, the first fault represented by Tikrit-Amara fault, this fault is located in the east of study area. The second fault is Ramadi-Musaib fault which crossing the central part of the studied area diagonally [8].In outside parts of study area two longitudinal faults (Najd faults system) are bounded the studied area. These faults are Makhol-Hamrin at the east and Euphrates faults at the west [8]. The transverse Kut-Dezful fault, crosses the study area trending E-W, Figure- 1.

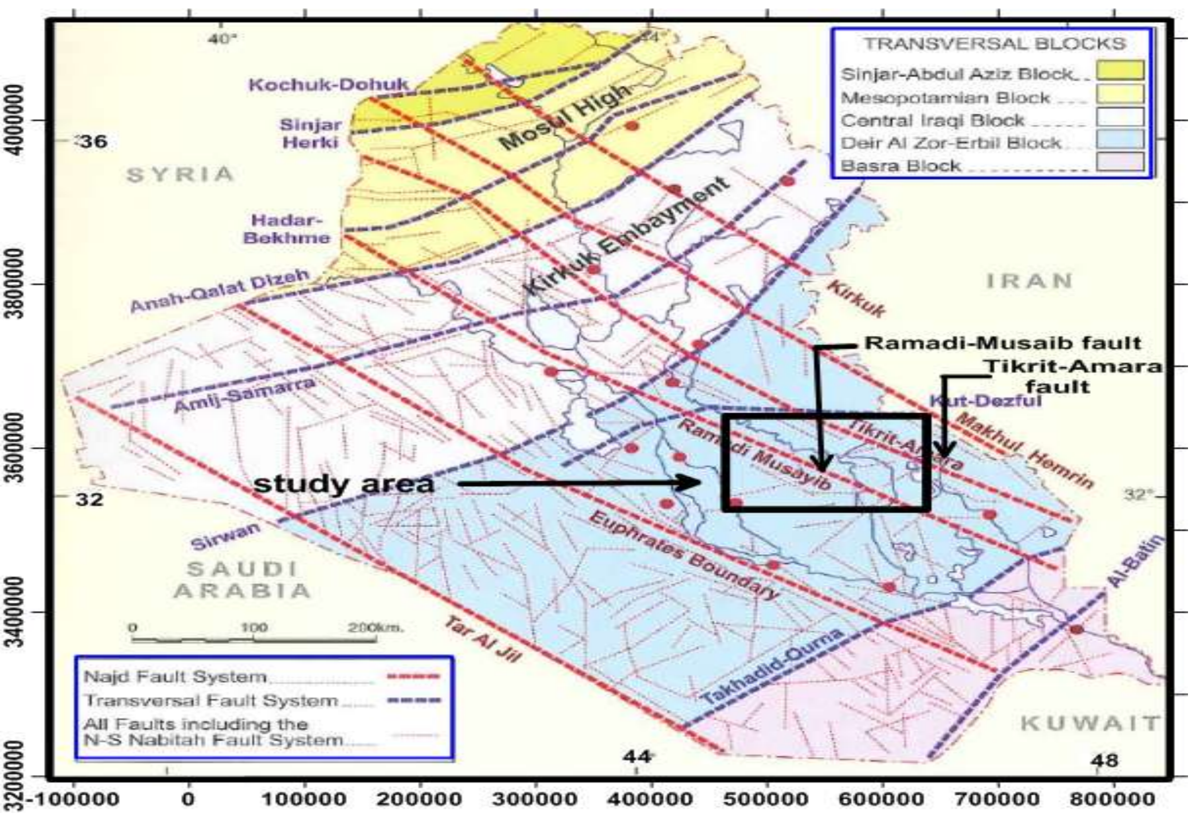

Figure 1- Tectonic map of Iraq showing location of study area [8].

Available data and Processing

The Bouguer anomaly map of the study area is a part of a map compiled at a scale of 1:1000000 with 1 mgl contour interva**l**. This map is published by GEOSURV and Iraq Petroleum Company (IPC). The data were acquired between 1960 and 1990. These maps were digitized at grid (2 * 2) km. The Bouguer anomaly is calculated with the reduction density of 2.175 g/cc [9], the accuracy of field measurements ranging between 0.02-0.03mgl.

The Aeromagnetic map total intensity map of the study area is part of the Aeromagnetic Total Field Intensity map of Iraq. It is constructed by the [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 Pole (RTP) map Figure- 2 in order to symmetrically position the anomalies above the causative bodies. This process is achieved by GET GRID program that is available at the Oil Exploration Company (OEC) in Ministry of Oil.

A set of gravity and magnetic data were digitized and derivatives designed to highlight subsurface borderlines and structural directions have been calculated and provided as Geotiff images in the Surfer project. Figures- 2 and 3 show the RTP magnetic and gravity anomalies maps.

In this study the gravity and RTP magnetic maps are analyzed and interpreted using many enhancement methods including Total Horizontal Derivative (THDR), residual gravity and magnetic maps with diffrenent windows. The results of enhanced maps are used to evaluate the tectonic situation of the study area.

Description of magnetic map

The reduction to pole magnetic map simplifies the process of analysis and interpretation of the magnetic anomalies [11]. The RTP map shows the values with contour interval of 2 nT. Two low magnetic anomalies separated by large high were observed, the first low magnetic is very large represented by anomaly (B), the value of this low is (4900 nt) and divides into two low anomalies has different trends. First trend is (NW-SE) represented by anomaly (B1) with nearly (E-W) trend and the second trend is (N-S) represented by anomaly (B) .The other magnetic anomaly (D), which is smaller than anomaly (B) and has circular shape with value at (4930 nt), is agree in location with positive gravity anomaly (P) . Between B and D anomalies the high magnetic anomaly Q is observed. This large high magnetic has value is (5150 nt) and trend (NW-SE). The high (Q) anomaly is divided into five minor anomaly with different trends. The gradient between anomaly (Q) with the surrounding anomalies (B,D) relatively sharp gradient ,these indicate and help in defining the boundaries of regional faults that pass through the study area. Finally in the (SE) of study area a high magnetic anomaly is observed (L). This anomaly is circular in shape with magnetic value of (4980 nt).

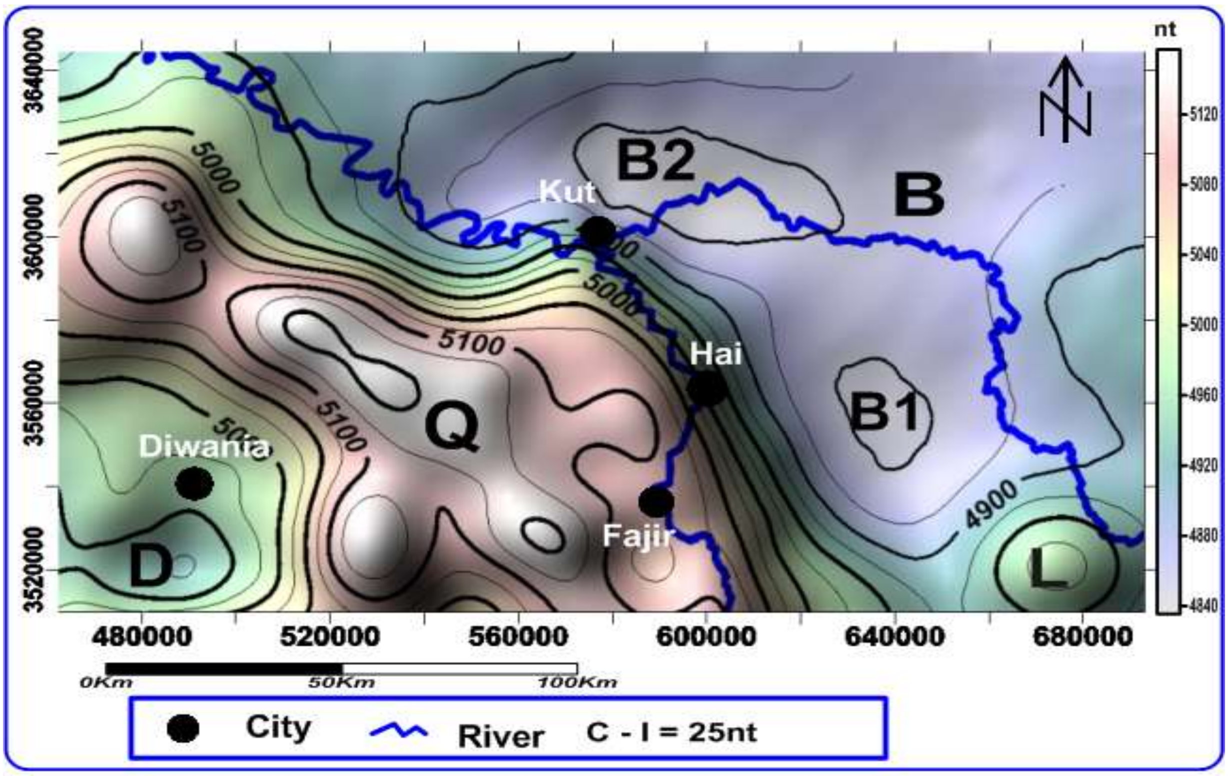

Figure 2-Reduction to Pole (RTP) magnetic map of the study area.

Description of Bouguer gravity map

Most of the Bouguer anomaly map of the study area reveals considerable regional gravity gradient towards the east and northeast of study area, which is associated with the deepest region of the Mesopotamia Basin. The regional gravity field decreases with an average value of 0.25mgl/km towards the east. The gradient of gravity value equals to (-90mgl) is located at the Iraqi – Iranian border, as (R) anomaly, Figure-3.Generally the gravity map shows a large negative anomaly in the lower middle part of the area with a circular shape. The value of this anomaly is -63mgl, which is represented by anomaly (V). Also there are two major gravity high anomalies in southwestern and southeastern of study area. These are located at both side of study area. One of these Bouguer gravity high is the anomaly (P) , which located at the south west of study area , and the value of this anomaly is -40mgl with trend NE-SW. The other highest gravity anomaly that located at east of anomaly (V) exactly between the Tigris and Gharaf rivers, is named (A) anomaly. The value of this anomaly is about -54mgl and trend is NW-SE. The boundaries between the (V) anomaly with the surrounding anomalies has gradient change of very sharp especially between anomalies (A) and (P), these indicated and helpful to defining the boundaries of tectonic zones and subzones in this region.

In the other side in the (NW) and (W) of the study area two small highest gravity anomalies are observed. These anomalies are characterized by short wavelength with trend (NW-SE), these are (M) and (K) anomalies. The values of these anomalies ranging between -42mgl to -45mgl and bounded (V) anomaly by sharp gradient. Beside these anomalies these is (S) anomaly with -45mgl.

Finally in the northern part of the study area the regional anomaly (C) is observed with E – W trend. The boundary between (C) anomaly and other anomalies shows very sharp gradient especially towards the NE and E trends.

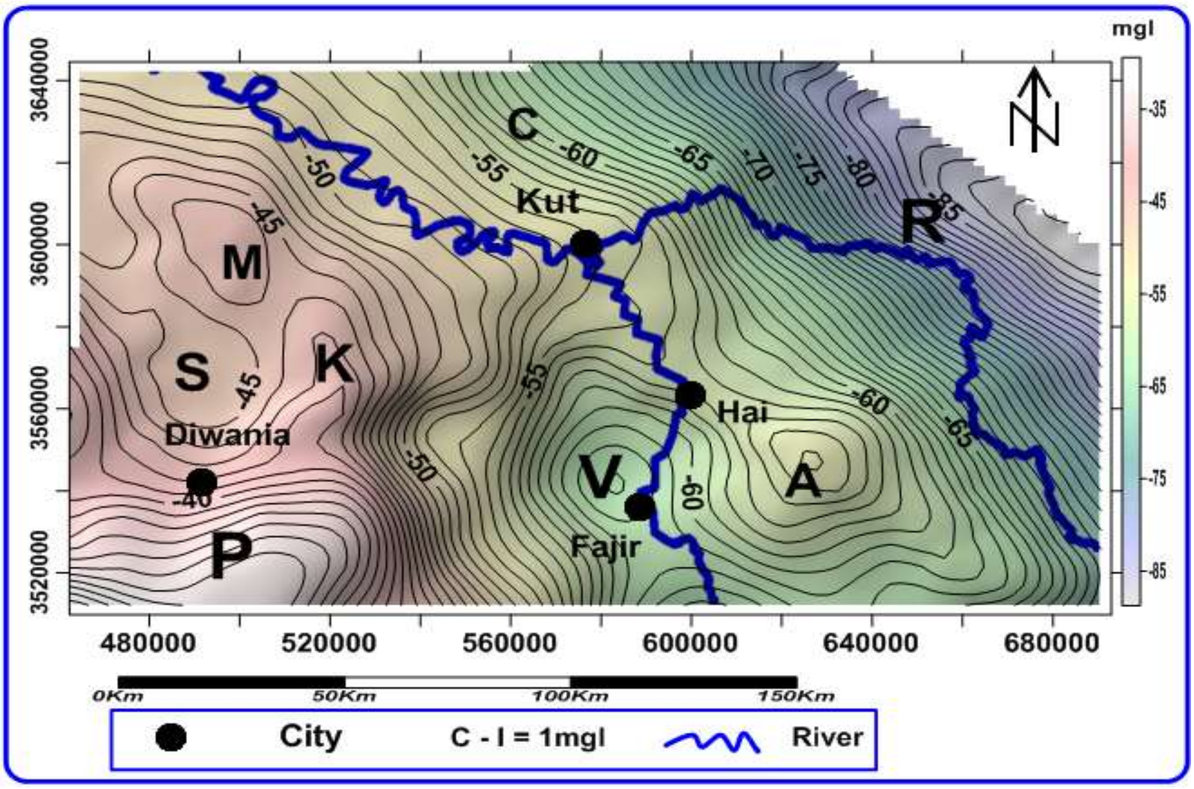

Figure 3- Bouguer gravity anomalies map of the study area.

Total Horizontal Derivative (THDR) of magnetic and gravity data

Horizontal Gradient is change in gravity and magnetic average with horizontal distance. This method is used to limited maximum gradient in the study area, and this method gives information about fault location, boundaries of the body, discontinuances and basin edge. However, the Horizontal Gradient method gives indication about tectonic setting through limitation location of geological feature in subsurface [2]. This derivative technique is designed to look at fault and contact features. The maxim values in the enhanced map indicate the boundaries of causative sources.

The Total horizontal derivative represents the resultant of two horizontal derivative, these are the horizontal derivative in X direction and second is horizontal derivative in Y direction. The total horizontal derivative results from these two types by equation:

1^{st}order=dt/dx ----1

1^{st}order= dt/dy ----2

THDR=$\sqrt{((dt/dx)^2+(dt/dy)^2}$ ----3[5].

Where, the dt/dx and dt/dy are the first horizontal derivative of the gravity or magnetic data. The total horizontal derivative technique is designed to detect contact or fault locations. The THDR usually produce a more exact location for faults than the Tilt Derivative (TDR), Analytical Signal (AS) and vertical derivative.

THDR of RTP magnetic data:

Application of THDR technique for magnetic data aims to detect the faults or contact within basement rocks. The results of the applied theTHDR to RTP data were shown in, Figure- 4. Many faults with different trends are detected. These include two systems of faults; the first system is the major faults. These include two faults; one of these faults is running along Gharaf River. It is best mapped from THD magnetic map comprise with (NNW-SSE) trend and extend along the border between the east and west of Gharaf River. This fault may divide the study area in two parts. It is believed that the Gharaf fault is the extension of Ramadi –Musaib fault in the study area.

The second important fault marked 12. It is parallel to Gharaf fault and comprise with NW-SE trend, the Gharaf fault and fault 12 agrees with the residual RTP map. East of Gharaf faults another fault trending NNW-SSE may be exist.

The second system of faults is minor faults system. This system agrees with the residual RTP maps. It comprises the (NE-SW) parallel to the transversal faults trends, and (NNE-SSW) trends, the longer fault in this system represented by fault 11 northeast the study area. There is another type of faults which trend N-S, but this trends of faults is less common than NW-SE and (NE-SW) trends. Finally, at the southeast corner of the study area numerous faults surround anomaly L) are observed.

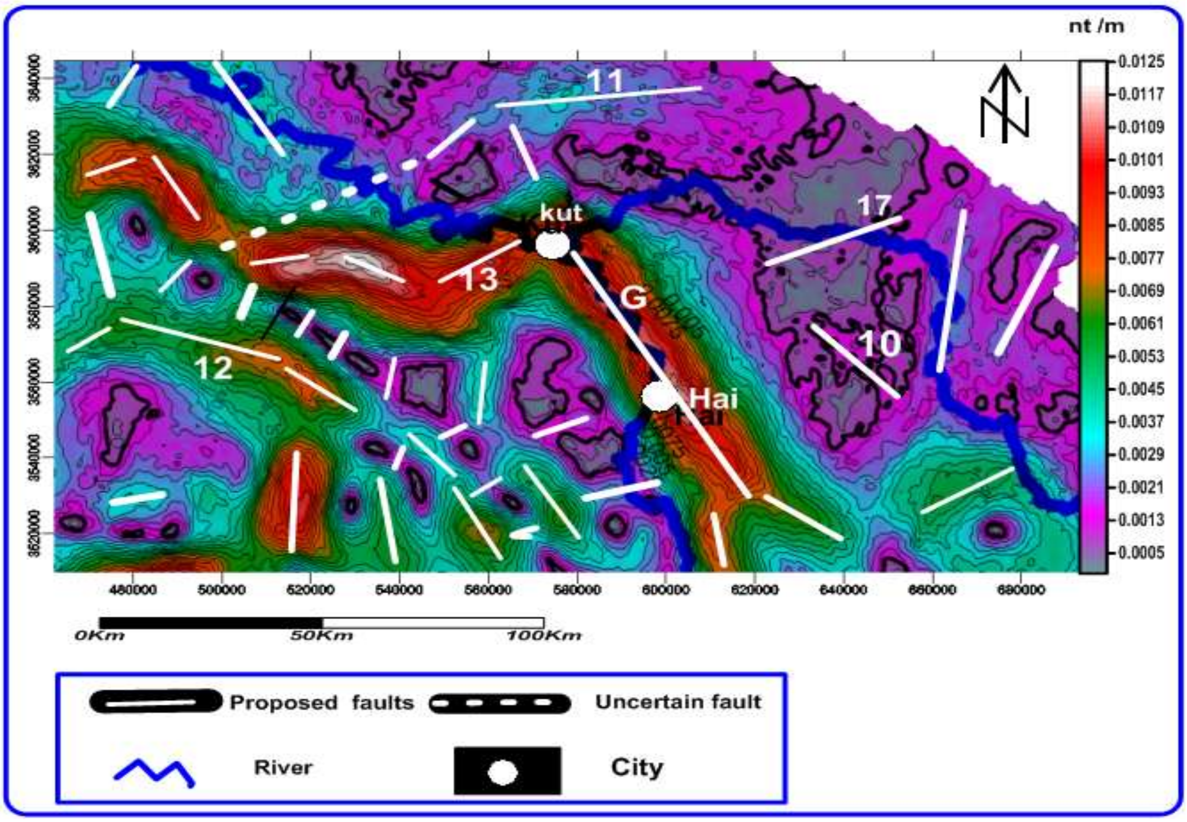

Figure 4-Total Horizontal Derivative (THDR) magnetic map showing faults systems of magnetic structures.

THDR of gravity map

The THDR of gravity map found to be the most useful parameter for determining faults trends, that effect on sedimentary cover. The distribution of faults is shown in Figure- 5.

These systems of faults include major fault zones correspond to the (NW-SE) parallel to Najid faults system. These consist of four faults. The first fault may be the extension of Ramadi-Musaib fault. This fault intersects Gharaf fault that is located on THDR of RTP magnetic map and Gharaf River. This fault which extends NW trend seems to be parallel with the Tigris river south Kut City. Two other fault are parallel to the first fault. These fault are located on both sides of gravity residual anomaly A, between Tigris and Gharaf Rivers. At the northeast corner fault 8 is observed, it is believed that this fault is the extension of Tikrit –Amara fault, but it was deformed by strike slip faults. The minor fault zones correspond to E-W and N-S trends systems, the E-W trending faults system is prominent at the east part of study area. It is represented by numerous faults. The N-S trend is less common in study area.

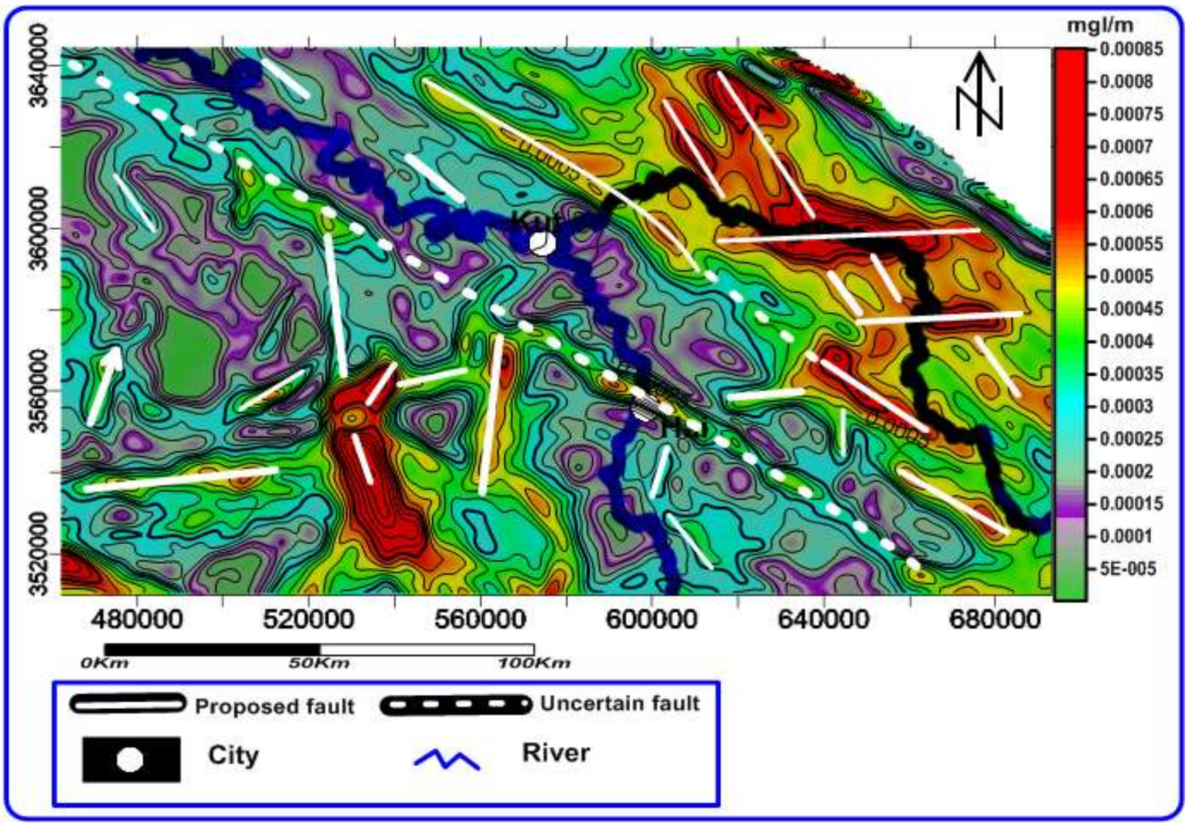

Figure 5- Total Horizontal Derivative (THDR) of gravity map showing fault systems of gravity structures.

Isolation of gravity and magnetic anomalies

Some of isolation filters were applied to enhance the gravity and magnetic pictures, In order to evaluate the study area tectonically. The separation carried out using different windows spacing analysis method. This method of analysis was applied to the both of gravity and RTP magnetic data. The residual gravity and RTP magnetic maps of the study area were obtained by Surfer program using 48 Km and 24 Km window spacing. The gravity and magnetic anomalies in the study area reflect mainly the effect of the basement, but several local gravity anomalies are also detected. These local anomalies may be related to the features within sedimentary cover. The faults or contacts obtained from THDR technique superimposed on the residual RTP magnetic maps and the residual gravity maps as shown in Figures- (6), (7), (8) and (9).

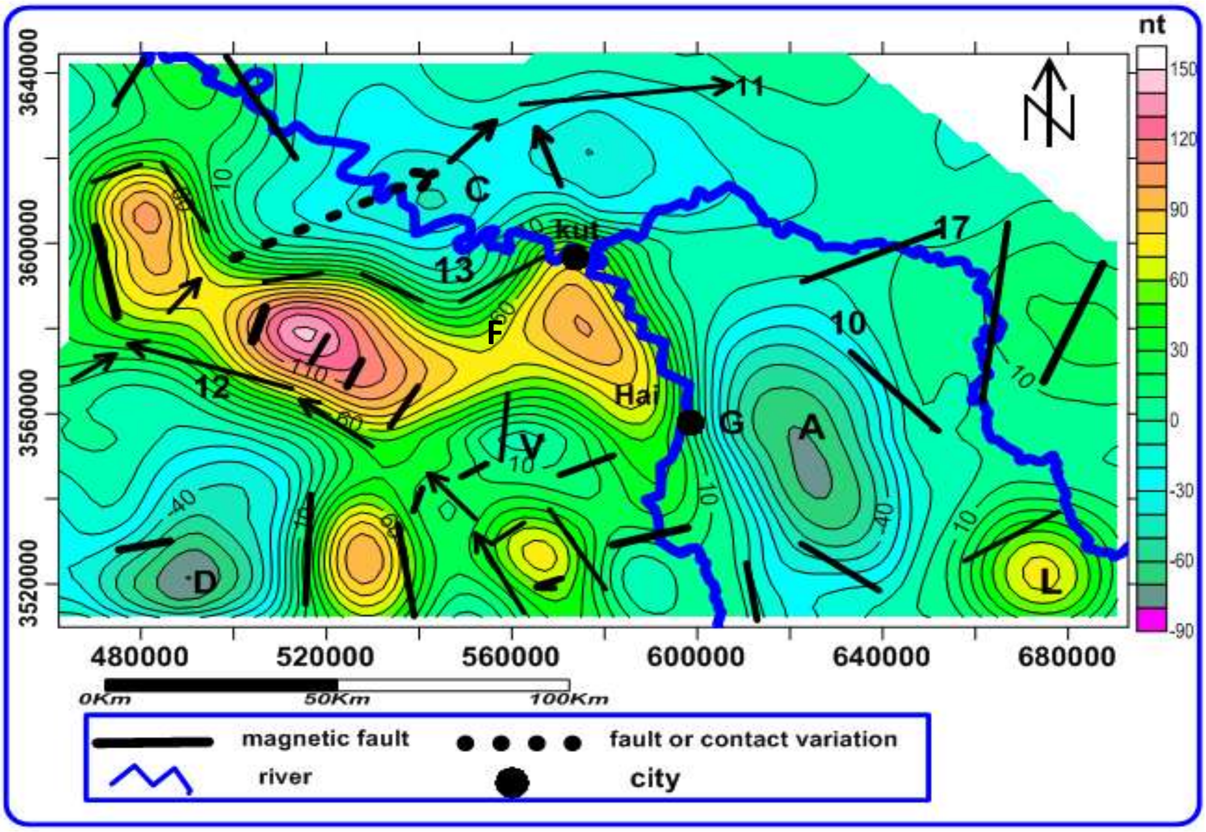

Figure 6- Residual magnetic map (window 48km) showing possible faults inferred from magnetic data.

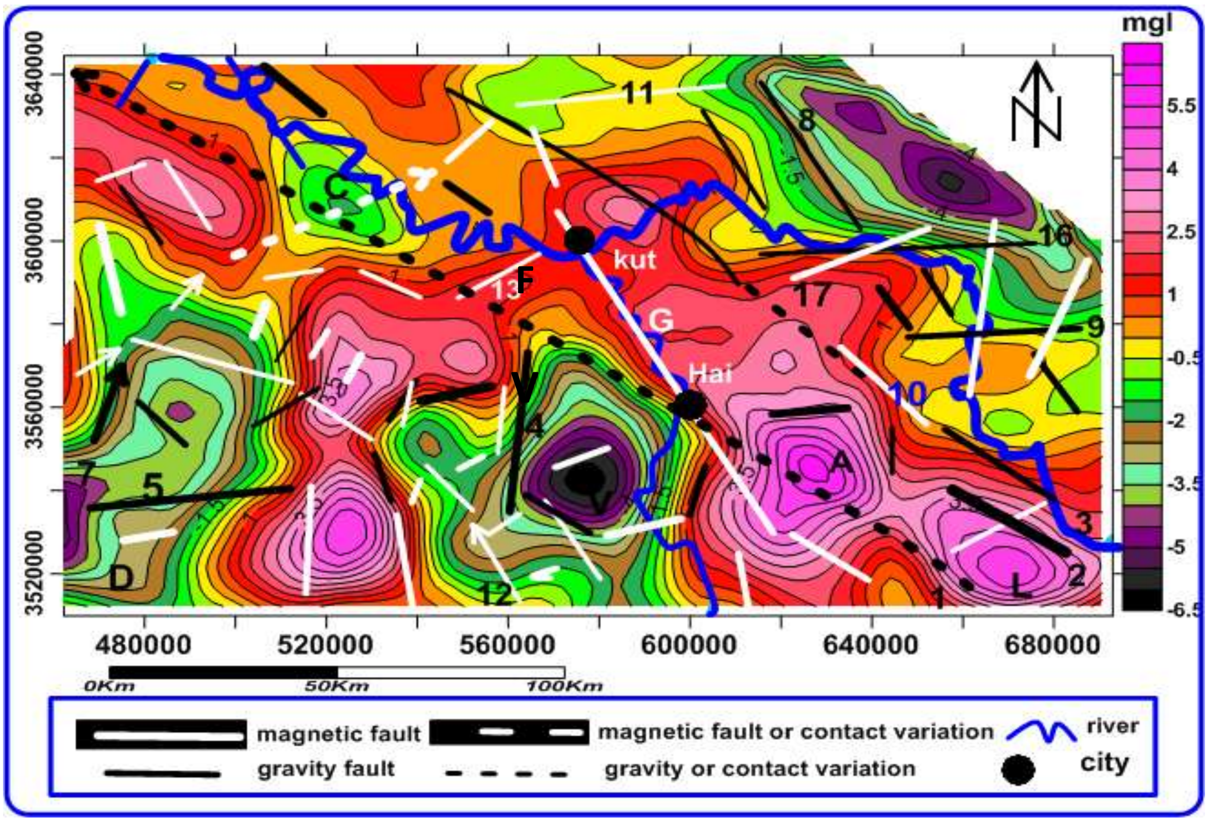

Figure 7- Residual gravity map (window 48km) showing possible faults inferred from gravity and magnetic data.

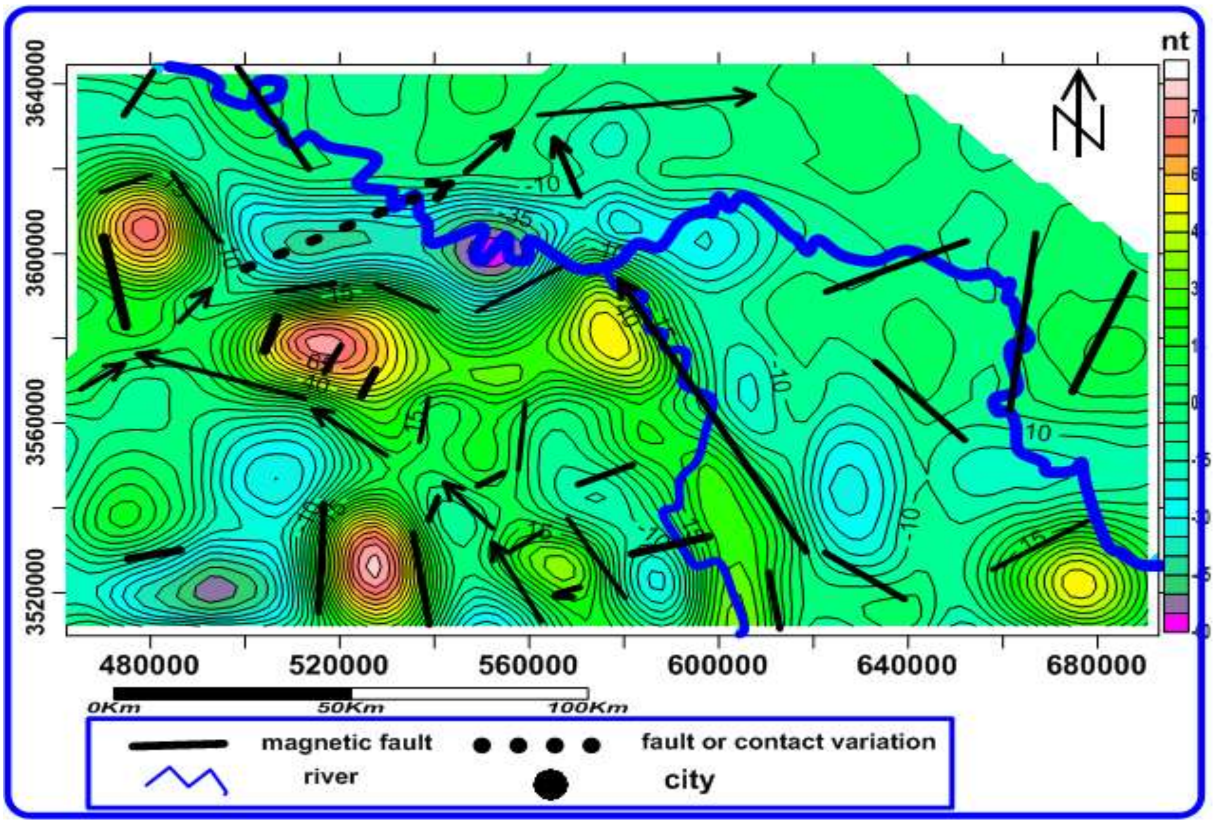

Figure 8-Residual gravity map (window 24km) showing possible faults inferred from magnetic data

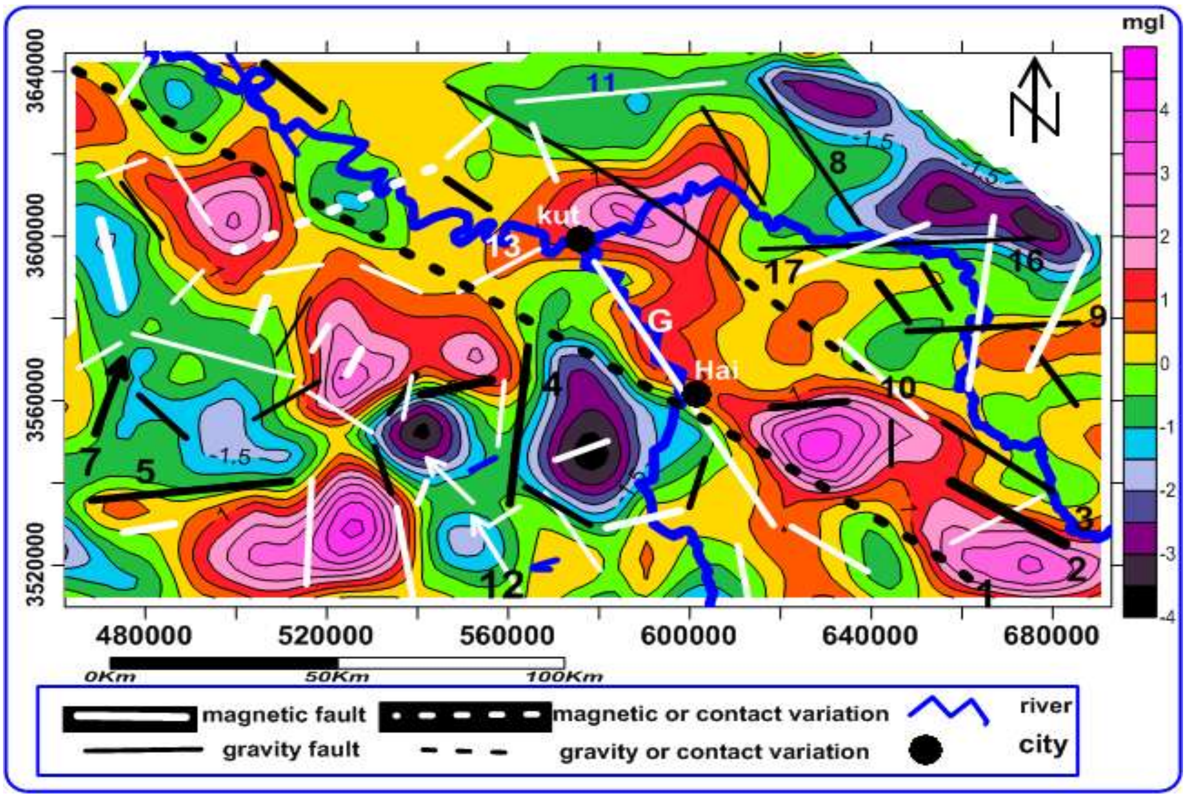

Figure 9- Residual gravity map (window 24km) showing possible faults inferred from gravity and magnetic data.

Discussion of the results

The interpretation of study area depends on the gravity and magnetic data. These data were processed with THDR technique to detect the faults or contacts, and with window spacing method to separate the relatively residual anomalies from the regional anomalies. Many faults and anomalies were detected Figures- (6, 7, 8, and 9). It seems that most faults are deep and old crossing the basement and the sedimentary cover. Some faults in the sedimentary rocks are inherited from old faults in the basement rock. It is believed that some contacts may be due to lateral changes in the basement composition and lateral changes in physical properties within the sedimentary rocks. Four faults trends are detected within basement and sedimentary rocks; these are NW-SE, NNW-SSE, NE-SW, NNE-SSW, and some faults with trends E-W and N-S. Some faults may be show continuous activity from Paleozoic to Quaternary periods. These faults may be related to different tectonic events, starting from the opening of paleo – Tethys during the late Precambrian to Cambrian age, and continue during opening of the Neo – Tethys during the Early Mesozoic time [8]. The Neo-Tethys closed during late Cretaceous, and the Zagrous Mountains uplifted during Paleocene to Eocene, due to the collision of Iranian and Anatolian plates with the Arabian plate.

The NW-SE to NNW-SSE trend is mainly interpreted from the integration between the THDR of RTP magnetic and gravity maps with the residual magnetic and gravity maps of 48km and24km spacing window. The important fault is Gharaf fault, which is found to be the longer regional fault and best mapped from magnetic interpretation. This fault extendes along the Gharaf River. This fault divides the study area into two parts, the first part in the NW of Gharaf River and second part located in the SE of Gharaf River. The southeastern part seems to be deeper than other part. It is believed that this fault is older than other faults in study area.One of the main faults of the (NW-SE) trend in the study area is the Ramadi- Musaib fault. This fault is clear in residual gravity maps and in THDR map inferred from gravity data. This fault may be the same fault that detected from magnetic data with variation in trend due to the variation in physical properties; or may be other faults that intersect with the first one north Hai City. The Variation between the trends of the two faults may be due to the difference in direction of stresses effecting the creation of them. Other fault NW-SE trend is fault 8 (Tikrit-Amara fault), this fault has NNW-SSE. It is very clear in gravity map. Tikrit-Amara fault zone extends from the Al-Jazira region in NW of Iraq through Tikrit and Balad to Baghdad and Nahrawan. It is continues along SE trending of the Tigris river between the Kut and Amara, [8]. The gravity data indicate that, this fault represent the western side of major graben located at the eastern part of the study area.The NE-SW faults appear in area west of Gharaf fault; these faults may be younger from the previous faults. These faults are parallel or semi-parallel to the transversal faults system in Iraq. One of these faults is faulting 13 which running along the SW to NE. This fault cross Gharaf fault in the middle of study area and deformed the Gharaf River channel trend. This fault may be an active fault, due to occurring earthquakes along it. Fault 11 another fault trending NE-SW. This fault located at the north part of the study area and crossing fault 17 that trend NW-SE.

The fourth system of faults is E-W trends. This trend is best mapped from gravity data and represented mainly by two strike slip faults, such as faults 16 and 9. They are located at the eastern part of study area. These faults cross Tikrit – Amara fault and deform Tigris River channel. The other faults that trending E-W is fault 5 which is located at the southwest of the study area.

Conclusions

Through interpretation and analyses of available data the following conclusions are observed

1. Structural interpretation and analysis of the study area reveal four main structural trends, they are represented by (NW-SE) to (NNW-SSE) , (NE-SW) to (NNE-SSW) , (E-W) and less common (N-S) trends.
2. Most of these structural trends in sedimentary cover may be inherited from weak areas in basement rocks.

   Most of regional structures trend have agreed with the trend of structures in tectonic map of Iraq, such as Ramadi-Musaib fault and Tikrit – Amara fault.
3. The main deep structures of the NNW-SSE trend is the Gharaf fault (G), which clearly presented by the magnetic data. This fault extends along the Gharaf River dividing the basement rocks of study area into two parts. It is believed that the eastern part is deeper than the western side.
4. The positive gravity anomaly A is located between Tigris and Gharaf Rivers with NW-SE trend. It coincides with the relatively negative magnetic anomaly in location and trend. It may represent

uplift in the sedimentary cover corresponding to uplifts in the basement rocks or to the folding processes that resulted due to the collision of Arabian and Iranian plates. This anomaly is bounded from east and west by regional fault (1) and fault (3) respectively.

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