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# Gravity Field Interpretation for Major Fault Depth Detection in a Region Located SW- Qa'im / Iraq

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## Abstract:

This research deals with the qualitative and quantitative interpretation of Bouguer gravity anomaly data for a region located to the SW of Qa'im City within Anbar province by using 2D- mapping methods. The gravity residual field obtained graphically by subtracting the Regional Gravity values from the values of the total Bouguer anomaly. The residual gravity field processed in order to reduce noise by applying the gradient operator and 1$^{st}$ directional derivatives filtering. This was helpful in assigning the locations of sudden variation in Gravity values. Such variations may be produced by subsurface faults, fractures, cavities or subsurface facies lateral variations limits. A major fault was predicted to extend with the direction NE-SW. This fault is mentioned by previous studies as undefined subsurface fault depth within the sedimentary cover rocks. The results of this research that were obtained by gravity quantitative interpretation find that the depth to this major fault plane center is about 2.4 Km.

**Key words:** Gravity anomaly, Fault depth, Fault Depth detection, Residual Gravity anomaly.

## Introduction:

Gravity methods have been applied for long years in detecting subsurface geological structures which were variable in depth, size and shape. The gravimetric methods were commonly used to detect near surface ores and the deep crustal blocks as well the regional variation of Bouguer gravity anomaly attributed to earth's crust thickness changes or large scale density or mass heterogeneity. The local variations of gravity anomaly refer to the shallower or near surface heterogeneity. Negative anomalies refer to low density subsurface rocks and basinal structures, while positive anomalies refer to high density or uplifted structures. Therefore, gravity anomalies give a clear vision about subsurface distribution of rock densities and subsurface structures [1].

Gravity method is applied to detect the subsurface bodies' geometry in addition to their mass distribution. The result obtained by applying such method provides comprehensive subsurface visions which are useful for environmental and engineering goals. Some examples of gravity method applications were the detection of fault locations, buried channels and cavities. One of the purposes behind gravity methods application is the estimation of (depth, amplitude coefficient, location of the body and shape factor) for gravity anomaly which produced by simple shaped subsurface structures [2, 3]. Gravity profiles as a method of detection has been commonly used to visualize the surface gravity anomaly in high precision a cross fault observations, also, to describe the density distribution of the ground rocks and to estimate structures distribution in crust and subsurface media deformations [4, 5].

The current study aims to use some processing methods to detect locations of subsurface sudden density variations related to subsurface structures, which are mainly faults. This could be maintained by applying some noise reduction 2D-filtering techniques, in order to clarify such features. Also , the quantitative interpretation of residual gravity anomaly along a profile that pass over a major expected faulting location in the region used to give more information about its subsurface features.

## Location and Geology of the Study Area

The study area is located within the stable shelf in the western part of Iraq bounded by the coordinates : (Longitudes :40°06′36″ , 40°51′30″ - Latitudes : 33°20′00″ 34°15′00″ ) , the study area was calculated according to map scale, which is about ( 4800 $Km^2$) near Syrian boarders ,Figure(1).

From the geological map of the region, Figure (1), the study area is composed of rocks that belong to Miocene era. Rocks at the northern east part of the study region are composed of calcareous limestone rocks of Ghar-Furat , Fatha and Ghar Formations. The remaining part of the region which is the central, southern and southern west parts, showed a sequence of rocks belong to the era Paleocene (sandstone), and Triassic era (clay rocks), Paleocene era (sand and clay) sediments. The northern east part of the region contains calcareous rocks that have high density as compared by the other sedimentary rocks within the study area [6].

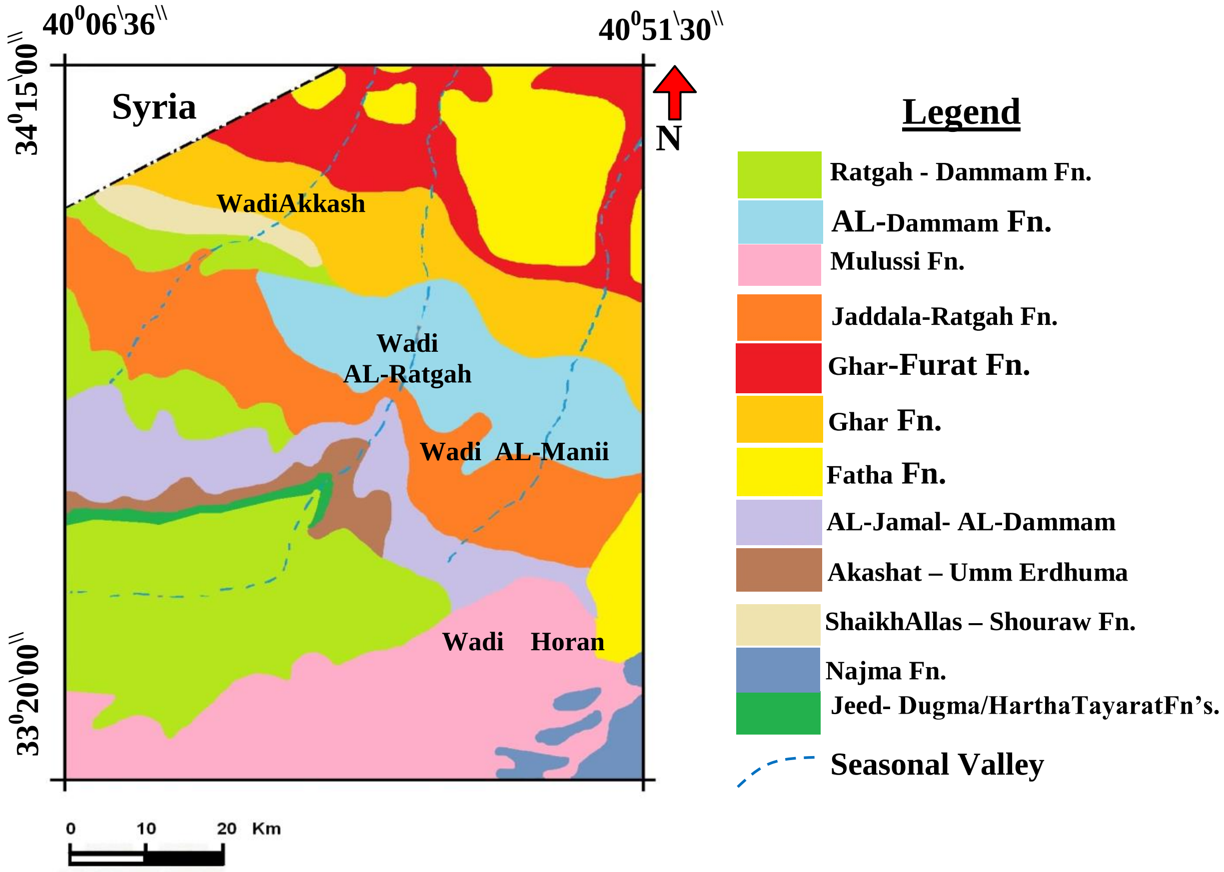


**Fig. (1): A geological map for the study area, reference [6] modified**.

Concerning the basement rocks of the study area, the largest middle part and eastern part of the study area consist of igneous basement rocks (Granite, Granodiorite), and the western part of the region consists of Umm Erdhuma sandstone Formation and post tectonic Gabbros and Diorite which appear as tongues at the northern-east part which are high density rocks. Fault directions at the study area are: NW-SE, NE-SW, and N-S according to reference [7]. Major faults zone correspond to the NW-SE Najd Fault System and the NE-SW Transversal System. The three major fault systems are the N-S Nabitah (Idsas) System, the NW-SE Najd system and the NE-SW or E-W Transversal System [8].

Previous studies of Iraqi geological survey and mining referred in reference [9], the main structural features in the tectonic map of Iraq. Figure (2) shows the only concern to study the region structural features. From Figure (2), the most northern part of the region belongs to the basic massives or the regional depression zone, while the middle part of the region belongs to Akashat-Kubaisa zone, and the southern part belongs to Rutba subzone. The map shows some undefined faults within the sedimentary cover and basement rocks in addition to subsurface anticlines within the sedimentary cover rocks.

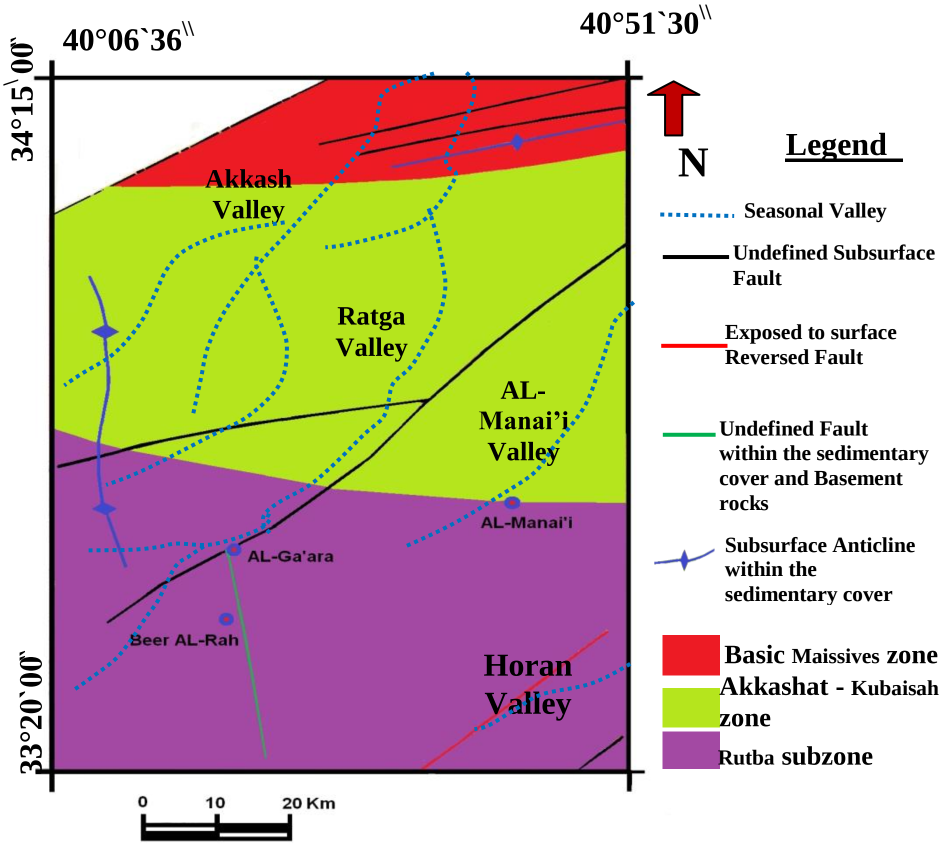


**Fig.(3):Structural map of the region showing the undefined faults within sedimentary cover and basement rocks (reference [9], modified).**

The current study aims to interpret the gravity field for the study area in order to detect locations of subsurface rocks density sudden variations. Furthermore, the detection of subsurface faulting and fracturing locations, their extension and direction, then compare it with the geological information available from previous studies. Such information is important for any future oil, gas or groundwater exploration studies or for Infrastructures Engineering projects.

## Method

In gravity method, the regional anomaly whose wavelength is long, refers to the deep subsurface features, while a local anomaly whose wavelength is small refers to shallow or near surface features. Separating regional and local gravity anomaly could be maintained by applying several analytical methods like the 2D surface filtering methods [10]. Bouguer gravity anomaly data of 336 data nodes picked manually for the concerned study region only. The original GEOSURV map of reference [11], contour density increased by reducing its contour interval. Only the concerned part of the studied region was processed.

The qualitative interpretation have been achieved by the following procedures:

1- Increasing the original Bouguer anomaly contour map density from C.I.=2.25mGal to C.I.=0.5mGal , figure(4).
2- Establishing the regional gravity anomaly map by applying the 2$^{nd}$ order polynomial regression as it is shown in map of Figure (5).
3- Obtaining the residual anomaly map , Figure (6), by subtracting the regional anomaly data node values of Figure(5), from the

total Bouguer anomaly data nodes of Figure (4).

4- Gradient operator filtering for the residual gravity anomaly, Figure (7).

5- The first derivative with the direction NW-SE applied on the residual gravity anomaly, Figure (8).

The gradient operator map, Figure (7), gives preliminary visions about the location of sudden variations in gravity or subsurface density contrasts from high to low and vice versa. This provided a preliminary assignment for the locations of faults in the region.

The 1st directional derivative, Figure (8), was more precise in delineating the limits of high density contrast within the residual anomaly and mostly agrees with the gradient map of Figure (7).

Qualitative interpretation is helpful in recognizing the anomalous subsurface bodies, limits of sedimentary bodies, cross-cutting features, structural styles and faults [12].

The total, regional and residual Bouguer anomaly maps were drew by adopting the Kriging interpolation method as it is recommended by reference [13]. Gravity processed maps of this study drew by using Surfer V.11 and Magpick computer software's [14, 15].

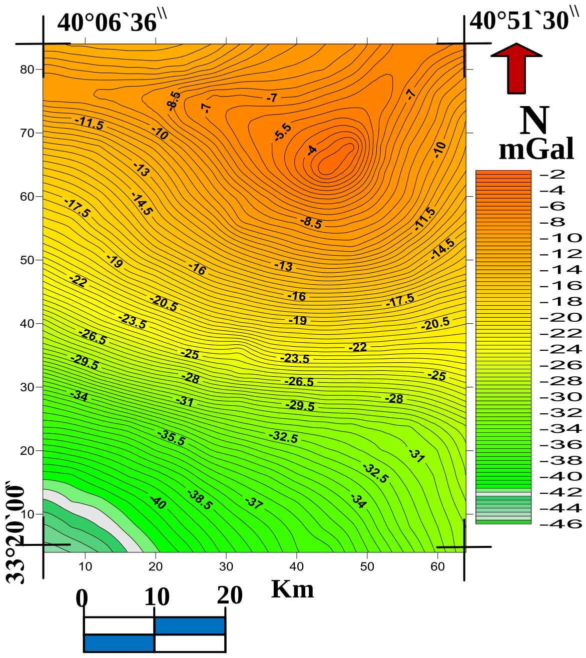


**Fig. (4): The high density contour Bouguer Anomaly map, C.I.=0.5 mGal.**

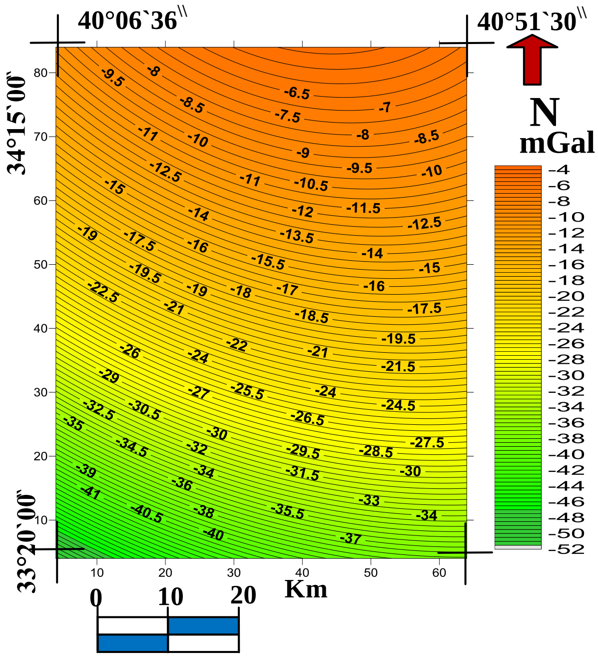


**Fig. (5): The regional Bouguer Anomaly map obtained by applying the 2nd order polynomial regression, C.I.=0.5 mGal.**

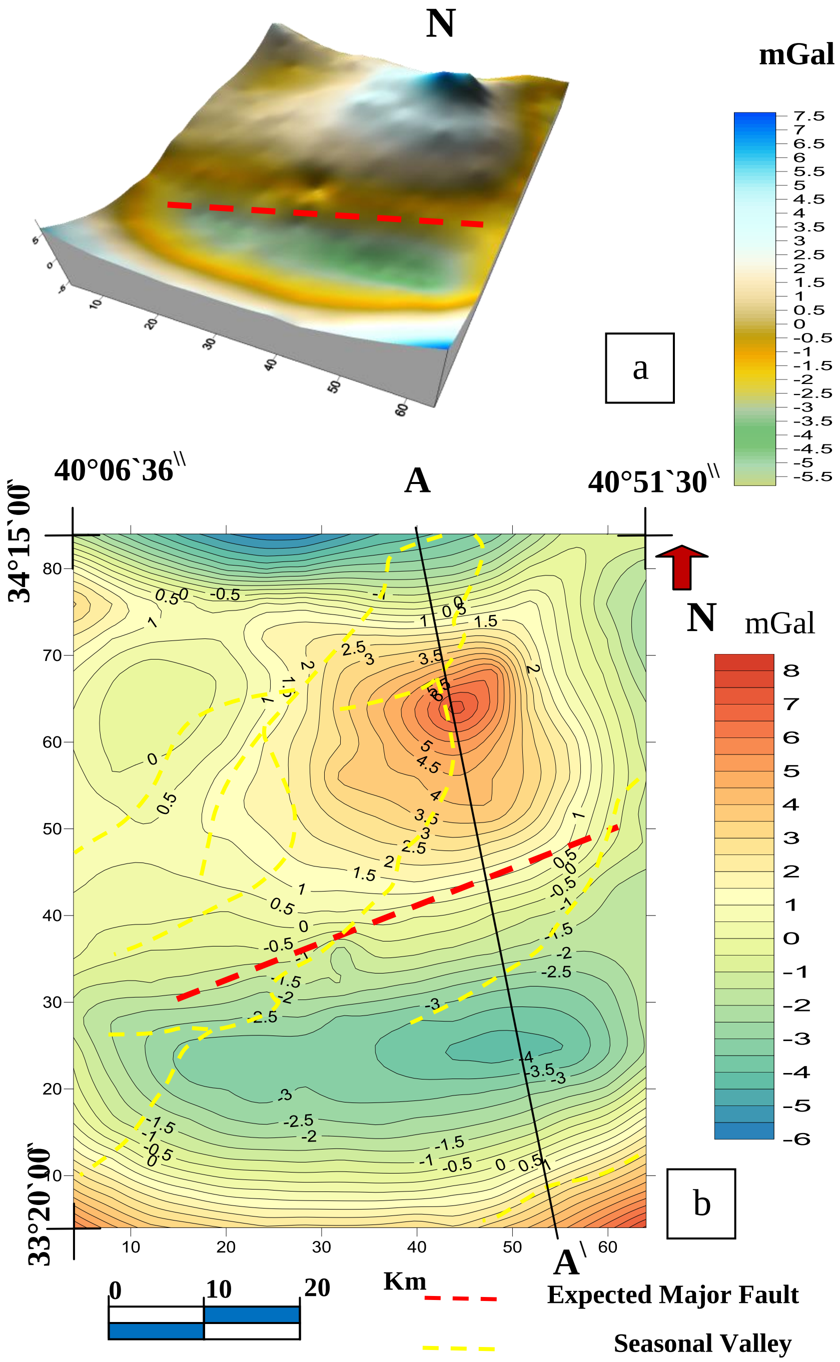


**Fig. (6): The Residual gravity anomaly: a) as a 3D- surface; b) as a contour map, C.I. =0.5 mGal .**

A residual gravity along the profile A-A\ drew, as shown in Figure (9), and the maps of Figures (6,7,8). Gradient operator and 1st directional derivative curves displayed at the same graph, Figure(9), to assign the locations of subsurface high density contrast which some of them refer to the proposed major and minor fault locations.

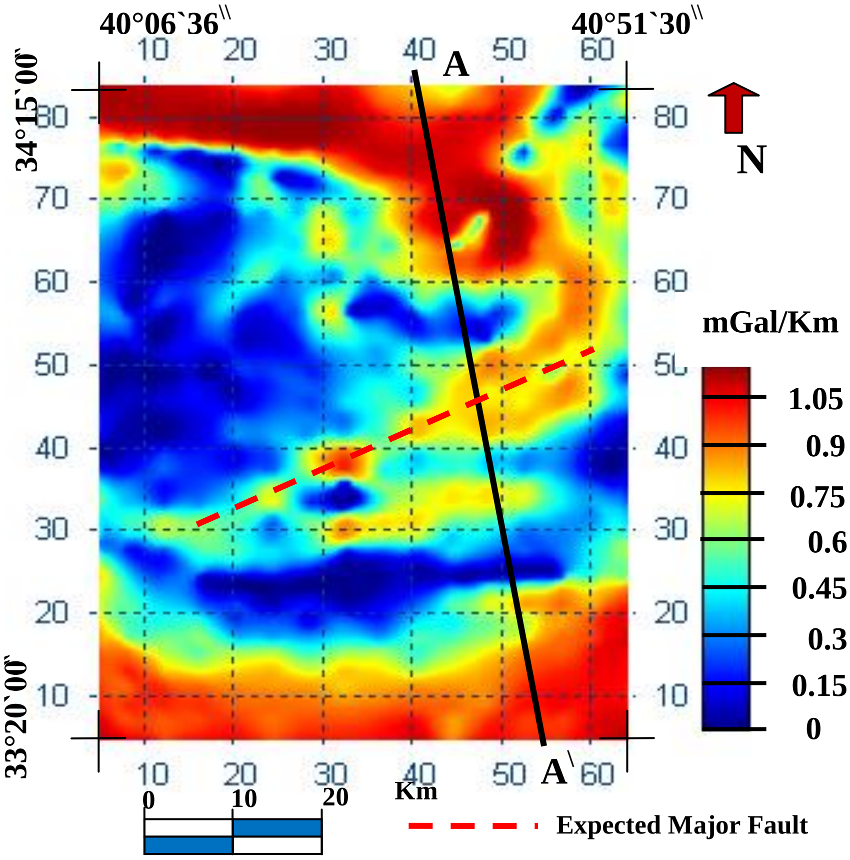


**Fig. (7): Gradient operator map for the residual gravity anomaly.**

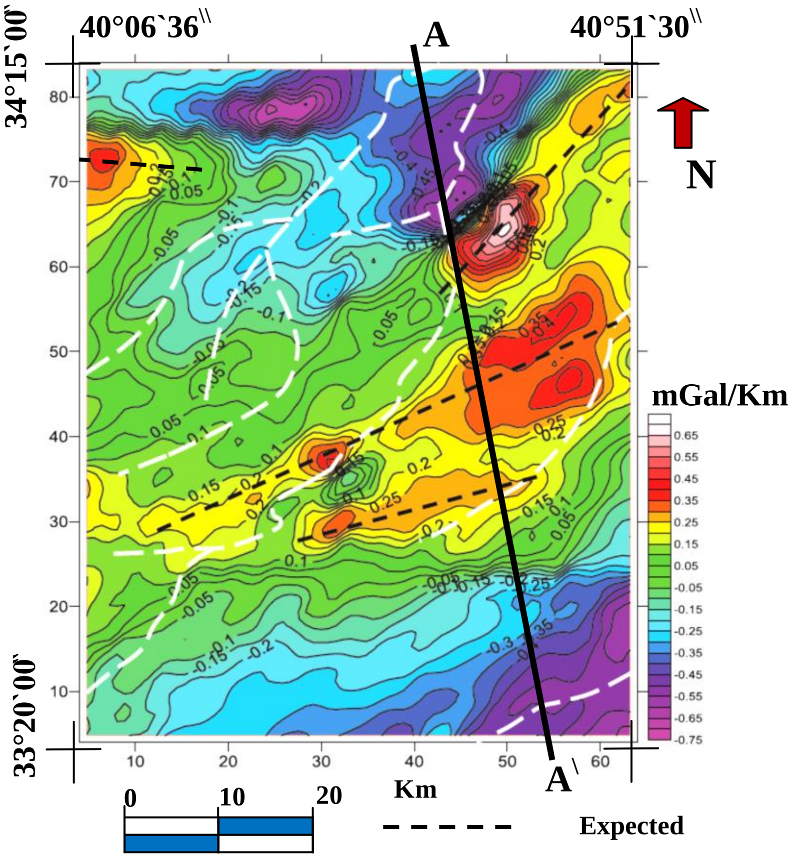


**Fig. (8): 1st directional derivative in the direction NW-SE for the residual gravity anomaly.**

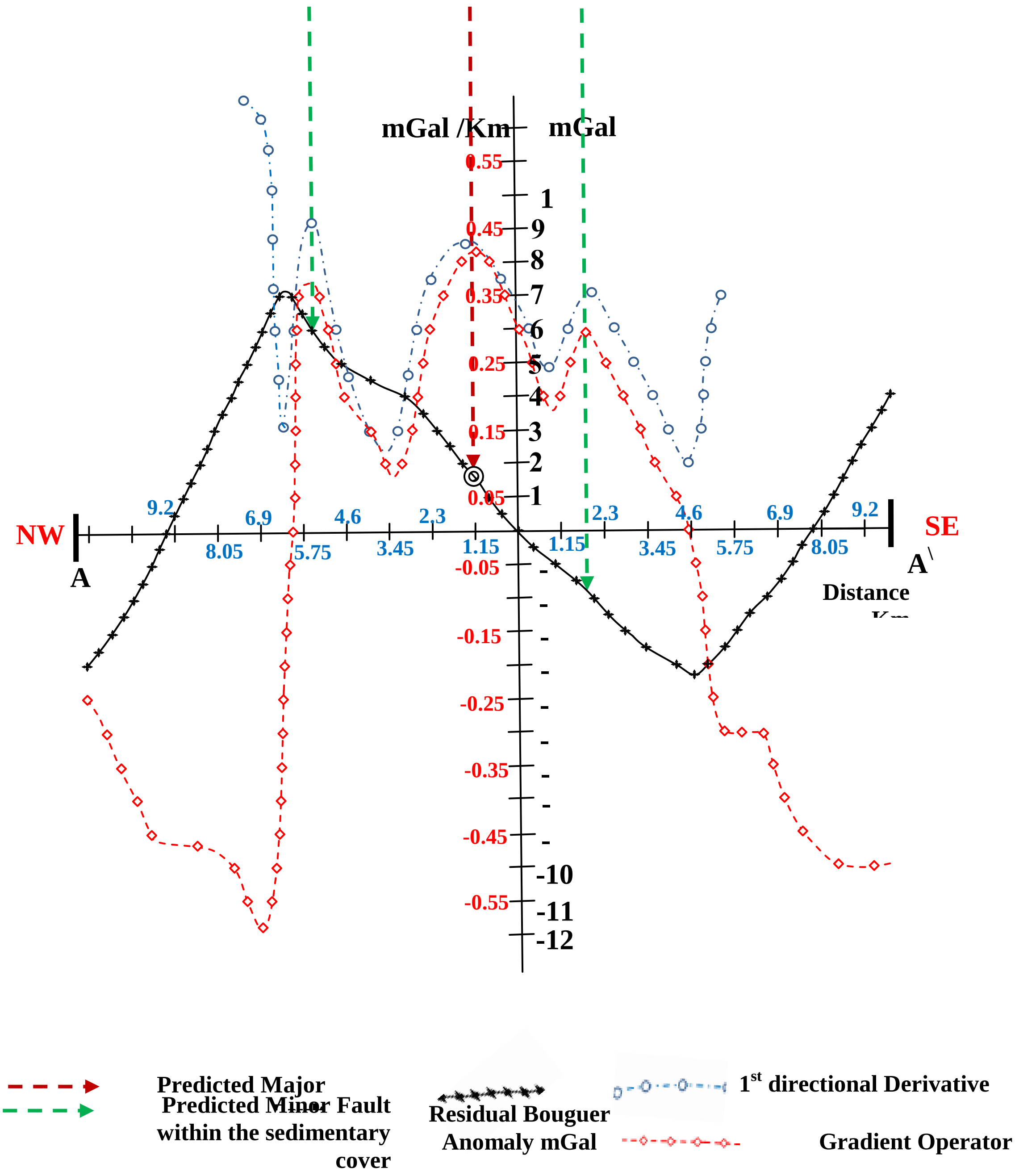


**Fig. (9): a comparison among the gravity residual field, 1st derivative and horizontal gradient along the profile A-A\ , showing the expected location of the major fault.**

The major fault which extends NE-SW was detected in the middle of the profile A-A\, Figure (9),its location assigned as dashed red arrow. The major fault is located between two proposed minor faults which are within the sedimentary cover and not expected to extend to basement rocks depth. Minor faults assigned as green dashed arrows as shown in Figure (9). Positive peaks of gradient and 1st derivative curves referred to the locations of subsurface high density contrast from high to low or vice versa. Such locations proposed as faulting locations and they are assigned as dashed lines as shown in the maps of Figures (6,7 and 8).

The residual gravity anomaly along the profile line A-A\ interpreted quantitatively in order to find the depth to the center of the major fault plane, Figure (10).

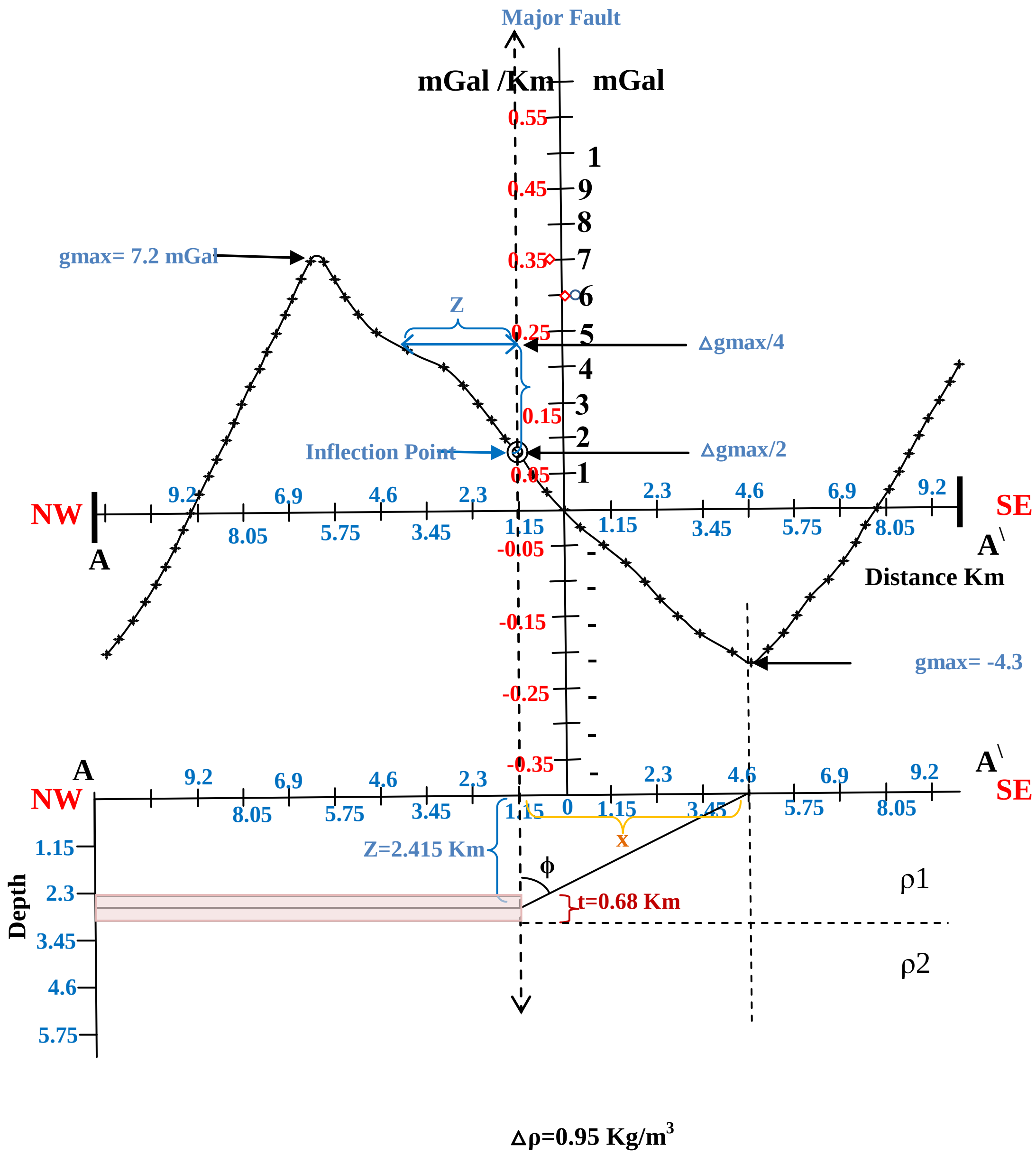


**Fig. (10): The geometrical model for the residual gravity anomaly along the profile (A-A/) showing the quantitative interpretation of the proposed major fault.**

The residual anomaly has a positive maximum of about 7.2 mGal toward NW, and negative minima of about -4.3 mGal toward SE. The location in the middle between anomaly maxima and minima represents the actual location of the fault [2].

By observing the anomaly model, Figure (10), the location over the fault trace is expressed by the inflection point. The inflection point is the fault plain point which divides the anomaly into two symmetrical parts [16].

Over the fault trace $\Delta$gmax represents the total variation in gravity and located at the half anomaly value. The horizontal distance when the anomaly vary from 1/2$\Delta$gmax to 1/4 $\Delta$gmax , is expressed as (Z) which is the depth to the mid thickness of an infinite dense slab has a thickness (t) and produces the positive part of the anomaly [1].

If its considered that t<z the resulted gravity will be [1,17] : $(G \vartriangle \rho t)\phi$…………….(1)

where: G= gravity constant, $\Delta\rho$= density contrast Kg/m$^3$,t=slab thickness, $\phi$=solid angle subtends the slab at the observation point, figure(11).

If the slab is considered as a semi – infinite sheet, then ,the solid angle will be 2$\phi$, and the gravity effect,(figures10and11) could be expressed by [1,17]: $\vartriangle g = 2Gt \vartriangle \rho\phi = 2Gt \vartriangle \rho(\frac{\pi}{2} - tan^{-1}\frac{x}{z})$ …….(2)

It was proposed that the dense rocks which produces the anomaly maxima are composed of dense and compact limestone have a density of (2.75 kg/m$^3$),while the low density rocks are composed of evaporates , perforated limestone and sandstone have an average density of (1.8 kg/m$^3$) according to references, [18,19] Tables, which describes the different types of rock densities . Therefore $\Delta\rho$ calculated to be about (0.95 Kg/m$^{3)}$. Later, equation (2), used to obtain (t), according to the model of Figure (10), where:

$\Delta$g=5.65 mGal, $\Delta\rho$=0.95 kg/m$^3$, x=5.75Km,z=2.415Km

Then: $\Phi=67^0.34$ ; t=0.68 Km

## Conclusions:

The qualitative interpretation for the residual gravity field yielded the preliminary locations for the proposed faults and density contrast limits of the subsurface structures. Gradient operator and 1$^{st}$ directional derivative filtering techniques applied to provide the exact proposed major and minor faults within the studied region. A major fault predicted in the region to extend with the direction NE-SW and expected to penetrate to basement rocks depth. In addition, minor faults within the sedimentary cover detected and two of them are located on both sides of the major fault location. Quantitative interpretation applied by establishing a geometrical model along the profile line A-A$^\backslash$ , to find the undefined depth of the major fault plane center. This depth (z) , calculated to be about 2.415Km. The dense slab which produced the positive anomaly part is considered as infinite sheet with a thickness (t) of about 0.68 Km.

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# تفسير المجال الجذبي للكشف عن عمق فالق رئيسي في منطقة تقع جنوب غربالقائم / العراق

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**الخلاصة :**

يتناول البحث تفسيرات نوعية و كمية لبيانات شذوذ بوجير الجذبية لمنطقة تقع جنوب غرب القائم ضمن محافظة الانبار باستخدام الخرائط الثنائية البعد. تم الحصول على خارطة الشذوذ الجذبي المتبقي من خلال طرح قيم الشذوذ الاقليمي من قيم شذوذ بوجير الكلي للمنطقة. تم معالجة خارطة الشذوذ الجذبي المتبقي للمنطقة بشكل يقلل من الضوضاء المصاحب للبيانات عن طريق تطبيق مرشحات رقمية تمثلت بعامل التدرج و المشتقة الاتجاهية الاولى و كان الهدف من ذلك هو تعيين مواقع التغاير الفجائي في القيم الجذبية. ان تلك التغايرات قد تشير الى وجود فوالق، كسور، تكهفات او تغايرات سحنية جانبية او حدود للتراكيب.تم تخمين وجود فالق رئيسي في المنطقة يمتد بالاتجاه شمال شرق-جنوب غرب، وقد اشارت دراسات سابقة بان هذا الفالق غير معلوم العمق ضمن صخور الغطاء الرسوبي في المنطقة. من خلال التفسير الكمي للبيانات الجذبية في هذا البحث تم حساب العمق الى مركز مستوى الفالق و وجد بانه يبلغ حوالي 2.4 كم عن سطح الارض.

**الكلمات المفتاحية:** الشذوذ الجذبي، عمق الفالق، كشف عمق فالق، الشذوذ الجذبي المتبقي