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The Bouguer Anomaly Map of Iraq According to a New Local Theoretical Gravity Equation and Its Geological Importance

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Abstract

Four hundred and seventy eight gravity base stations in Iraq were used to obtain a new local theoretical gravity equation. The obtained equation was used to construct a Bouguer anomaly map of Iraq depending on the available gravity base stations. This map was compared with the Bouguer map constructed for the same stations using the international formula (1930). Good similarity in shapes and locations of the anomaly were observed, while the gravity anomaly values in the new map were increased by about 30 mGal. The eastern zero gravity contour line of the new obtained gravity map coincides with the western boundary of the tectonic Mesopotamian zone, while the main negative gravity values coincide with the Mesopotamian area, which contains most oil fields in eastern Iraq. All negative gravity anomaly areas coincide with the deepest basement rocks (the sedimentary basins) in Iraq. The obtained results are very valuable in geological applications.

Keywords: Gravity Base Station, Theoretical Gravity, Oil Fields, Basement Rocks, Iraq.

خارطة شذوذ بوجير للعراق طبقا لمعادلة نظرية جديدة محلية واهميتها الجيولوجية

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الخلاصه

استخدمت اربعمائة وثمان وسبعون محطة قياس اساسية للجاذبية لاستنباط معادلة جديدة محلية لحساب الجاذبية النظرية في العراق . تم الاعتماد على المعادلة المستنبطة في رسم خارطة شذوذ بوجير جديدة للعراق . تم مقارنة خارطة شذوذ بوجير الجديدة مع الخارطة المعدة باستخدام المعادلة العالمية (1930) لحساب قيم الجاذبية النظرية في العراق ولوحظ وجود تماثل عام في شكل الشواذ، مع وجود انخفاض في مستوى قيم الشواذ بمقدار 30 مللي كال تقريبا . قيمة الخط الصفري في الخارطة الجديدة توافقت بشكل كبير مع الحدود الغربية لحوض ما بين النهرين التكتوني الذي يضم معظم حقول النفط في العراق . كما تطابقت مناطق قيم الجاذبية السالبة مع الاحواض الرسوبية في العراق ومنها بشكل خاص منطقة الاعماق الكبيرة نسبيا لصخور القاعدة شرق العراق . اظهرت هذه الدراسة اهمية المعادلة النظرية المحلية المستنبطة من خلال المعلومات الجيولوجية التي قدمتها .

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Introduction

Bouguer gravity anomalies are almost used to describe the lateral variation within the crust of the earth. The computation of Bouguer anomaly values is usually obtained by the subtraction of theoretical gravity from the corrected observed values [1, 2]. The theoretical gravity is calculated according to certain equations known as theoretical equations, such as the 1930's equation and 1967's equation. The theoretical equation describes the distribution of the gravity from the equator to the poles, which is known as the normal ellipsoid of the Earth [3].

The general expression of the theoretical gravity equation is :

$$g(\Theta)=g_e\,(1+A\sin^2\Theta - B\sin^2 2\Theta) \qquad \text{…………..} (1)$$

where:

$g(\Theta)$ = *The theoretical gravity value.*

g_e = *The absolute gravity value at the equator.*

Θ = *The latitude in degree.*

A and B are constants which are determined to show the best fit and related to the actual geometry of the earth [4]. Many theoretical gravity equations were prepared since 1906. These equations were obtained in many cases depending on the absolute gravity values [3, 2]. This paper attempts to obtain a local theoretical gravity equation depending on the available absolute gravity values of Iraq.

The Gravity Base Stations Network of Iraq

Four hundred and seventy-eight gravity base stations were achieved in Iraq for the period 1963-1985 (Figure-1). These stations were connected to the main six gravity base station, which were fixed by Woollard [1963] through the program of Wisconsin University [5, 6]. The gravity survey of these base stations was achieved by the Iraqi geological survey company. These stations are characterized by the properties that the time difference between any two adjacent stations does not exceed two hours and the gravity difference does not exceed 17 mGal. Also, the difference in surface topography level depends on the elevation of the considered gravity base stations (Figure-2). The gravimeters used in the survey are Lacoste and Romberg Models G271 and G532, respectively [6]. The mean square error of the gravity base stations in Iraq was found to be equal to ±0.0229 mGal [6]. The error within the close polygons of the gravity base stations of Iraq was adjusted by using a computer program based on the least square method [6].

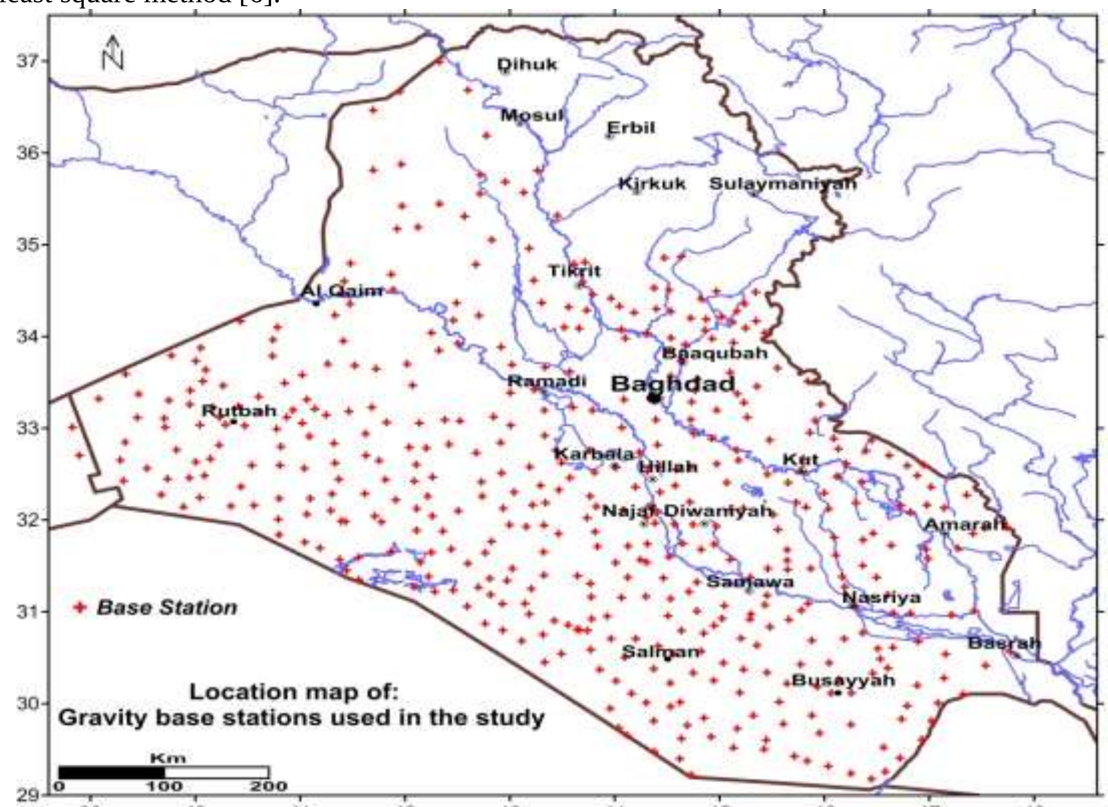

Figure 1- Location map of gravity base stations used in the study (this map was constructed by the researchers depending on the location data of gravity base stations [6]).

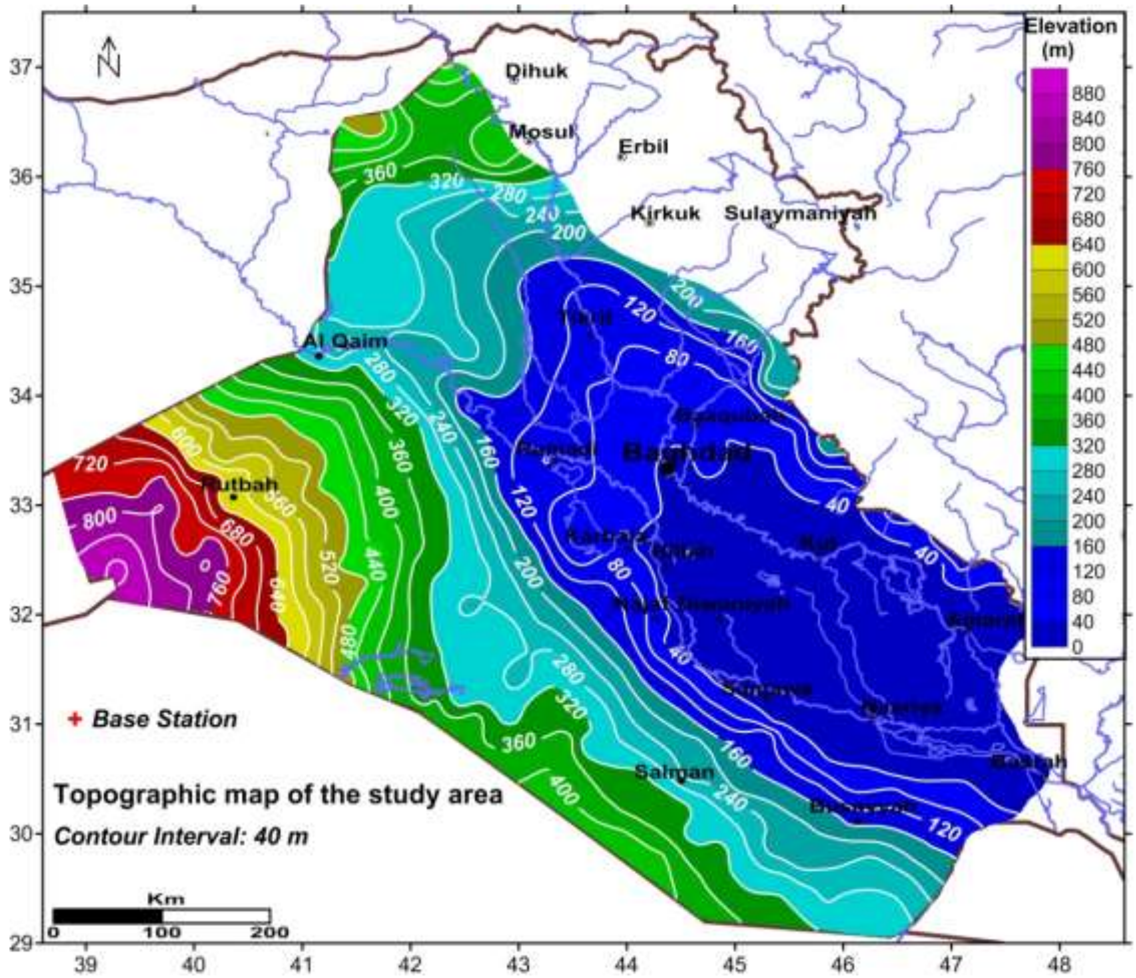

Figure 2- Topographic map of the study area (constructed by the researchers depending on the elevation data of gravity base stations [6]).

The Theoretical Background

In 1737, Clairaute [3,7] provided an expression for calculating the theoretical gravity value depending on gravity base station measurements on the earth surface. The expression is as follow:

$$g(\theta)= g_e[1+((5C/2)-f)) \sin^2\theta] \quad \text{…………. (2)}$$

where:

$g(\theta)$= The theoretical gravity value.

g_e = Gravity absolute gravity value at the equator.

θ=The geographic latitude.

C= The ratio of centrifugal force/gravity value.

f = The flattening of the earth.

Stokes and Helmer extended Clairaute's theorem by taking f =1/297 [7]. These expressions actually represent the normal distribution of the gravity difference between the equator and poles of the earth which is equal 5300 mGal. The most famous formula of the theoretical gravity is the international equation (Cassinis formula, 1930) [3]:

$$g(\theta)(mGal)= [978049(1+0.0052884 \sin^2\theta- 0.0000059 \sin^2 2\theta)] \quad \text{… (3)}$$

The Geodetic Reference System (GRS 1967) accepted the following equation for computing the normal gravity at the sea level according to the geographic latitude [8- 15].

$$g(\theta)(mGal)=[978031.8(1+0.0053024 \sin^2\theta-0.0000059 \sin^2 2\theta)] \quad \text{… (4)}$$

The first value of the equation represents the absolute gravity value at a point at the equator which represents relatively the lowest absolute gravity value according to the geographic latitude. The second part in the brackets represents the normal distribution of gravity difference between the absolute gravity value at the equator (lowest value) and the pole (highest value). Thus, this second part of the equation is related to the flattening of the earth. The third part in the brackets represents a correction for the flattening to achieve the best fit for the relatively low and high geographic latitudes.

Derivation of the Local Theoretical Gravity Equation of Iraq

The geographic latitude of Iraq has an approximate range of 29˚-37˚, which is situated within the middle part of the Earth. Therefore, we believe that it is possible to eliminate the third part of the international equation. Also, due to the availability of the actual absolute gravity value which is corrected to the sea level, it is possible to determine a local theoretical gravity equation for Iraq. Four hundred and seventy-eight absolute gravity base stations were used to obtain the theoretical equation of Iraq. The elevation correction (free air and Bouguer correction) using a density of 2.175 gm/cc for the surface layer were applied to the absolute gravity values [6]. The corrected gravity values were plotted against the sine square of the geographic latitude in decimal degree (Figure -3). The first order of the least square fitting of the relation produced the following equation:

$$Y=(978019.0+5129.099\ \sin^2 \theta) \qquad \text{…………(5)}$$

By putting the constant 978019.0 out of the bracket, we have

$$Y= 978019.0\ (1 + 0.005244376\ \sin^2 \theta) \qquad \text{………..(6)}$$

Y can be replaced by g (ɵ), then the equation can be written as follows:

$$g(\theta)(\text{ mGal})=[\ 978019.0\ (1+0.005244376 \sin^2 \theta]) \qquad \text{………….(7)}$$

where :

g(ɵ)= theoretical gravity value

ɵ= geographic latitude (for the range 29˚- 37˚) in Iraq.

The obtained equation can be considered for Iraq only.

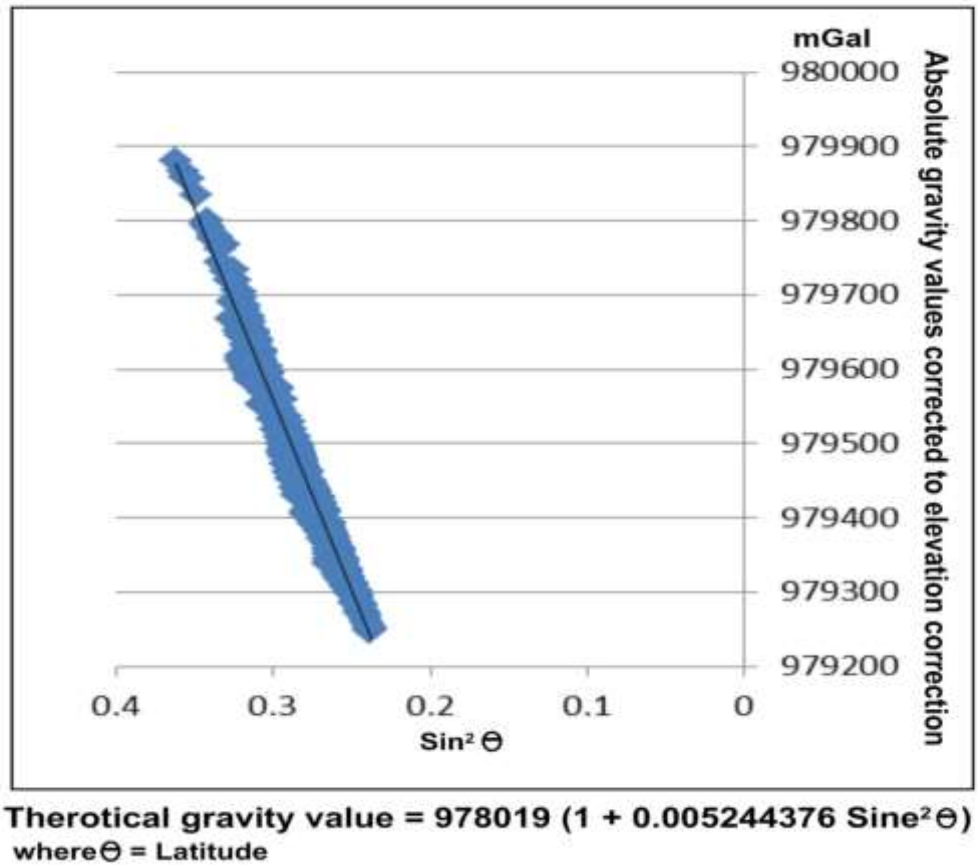

Figure 3- The relation of absolute gravity values (corrected to elevation correction) to $\sin^2\theta$ (latitude in degree) to obtain the theoretical gravity equation of Iraq.

The Bouguer Gravity Map of Iraq

The latitude corrections were applied to the absolute gravity values of the considered base stations, which were corrected to the sea level, to obtain two Bouguer anomaly maps of Iraq. The first map was plotted depending on the theoretical gravity equation (1930) (Figure -4). The second map was constructed using the new obtained local theoretical gravity equation (Figure -5).

Generally, the two Bouguer maps appear to be similar in shape and location of anomalies. The first map shows negative Bouguer values in most areas of Iraq, except for a small area at northwestern Iraq (Al-Jazira area). The second map shows a major longitudinal positive Bouguer gravity values lying at the western part of Iraq, extending from the north to the south. Many negative Bouguer gravity values appear on the second map. A comparison between the two obtained maps were traced along three profiles trending NE-SW. These profiles are C-C′, B-B′, and A-A′, crossing the study area perpendicular to the main structural trends in Iraq (Figure -6). It is clear that the newly obtained local equation roughly increased the regional gravity values by about 30 magl .The major negative gravity anomaly which is located at the eastern part of Iraq coincides with the Mesopotamian tectonic zone which contains most oil fields in central and southern Iraq (Figure -7) [16, 17]. The negative anomalies were found to coincide with the deepest parts of the basement rocks, on which the raw map depends in determining the volume of the petroleum geology of Iraq [17], which was digitized and converted to the grid format in this research (Figure -8). The negative gravity anomaly boundaries show good matching with the anomalies previously delineated in the isostatic map and the crustal map of Iraq, prepared previously [18, 19]. The western boundary of the major negative anomaly coincides with the tectonic boundary between the stable and unstable shelves in Iraq, which was traced depending on the gravity to elevation ratio [20].

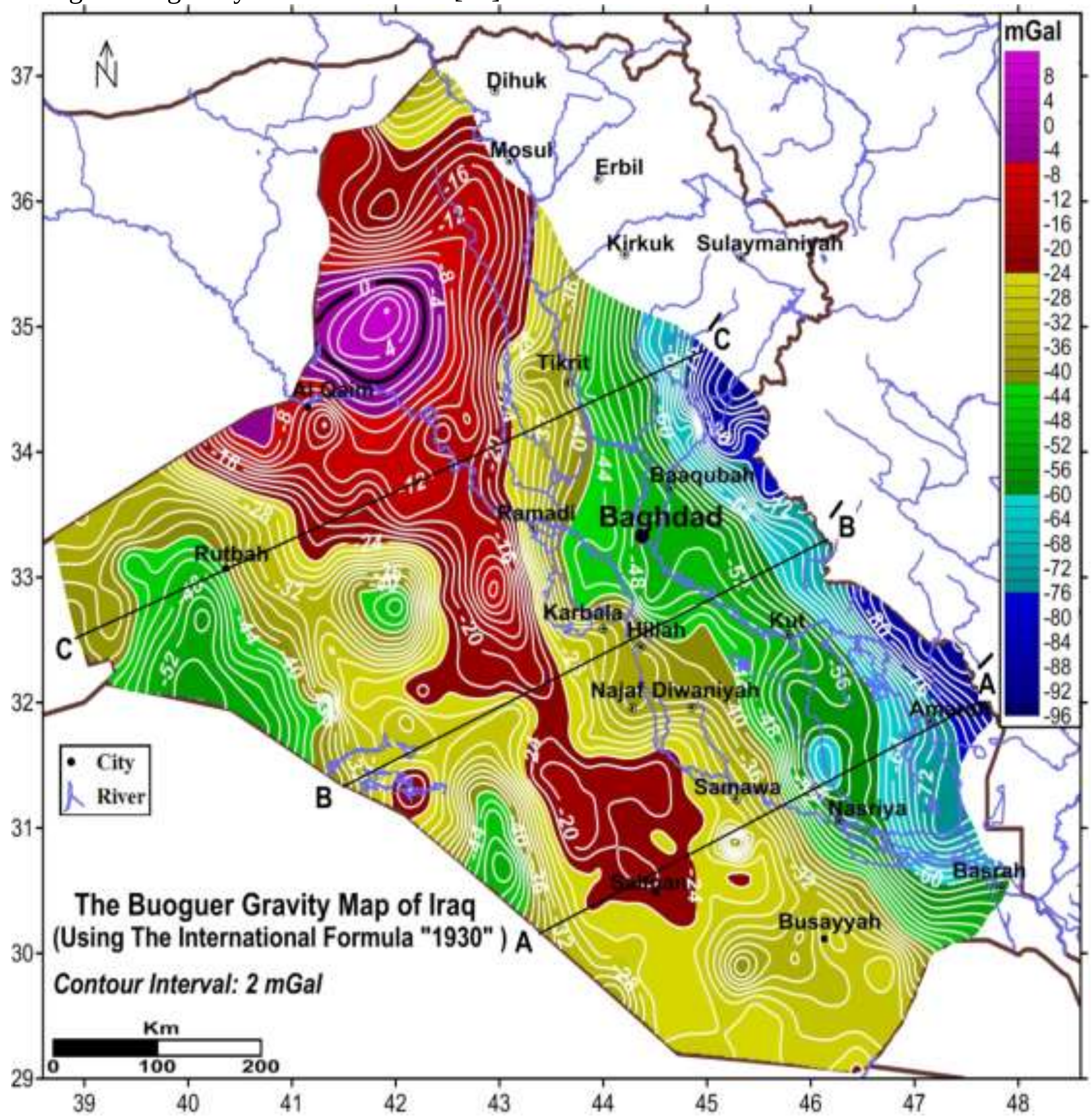

Figure 4- The Bouguer gravity map of the study area (Most areas of Iraq) using the international formula (1930).

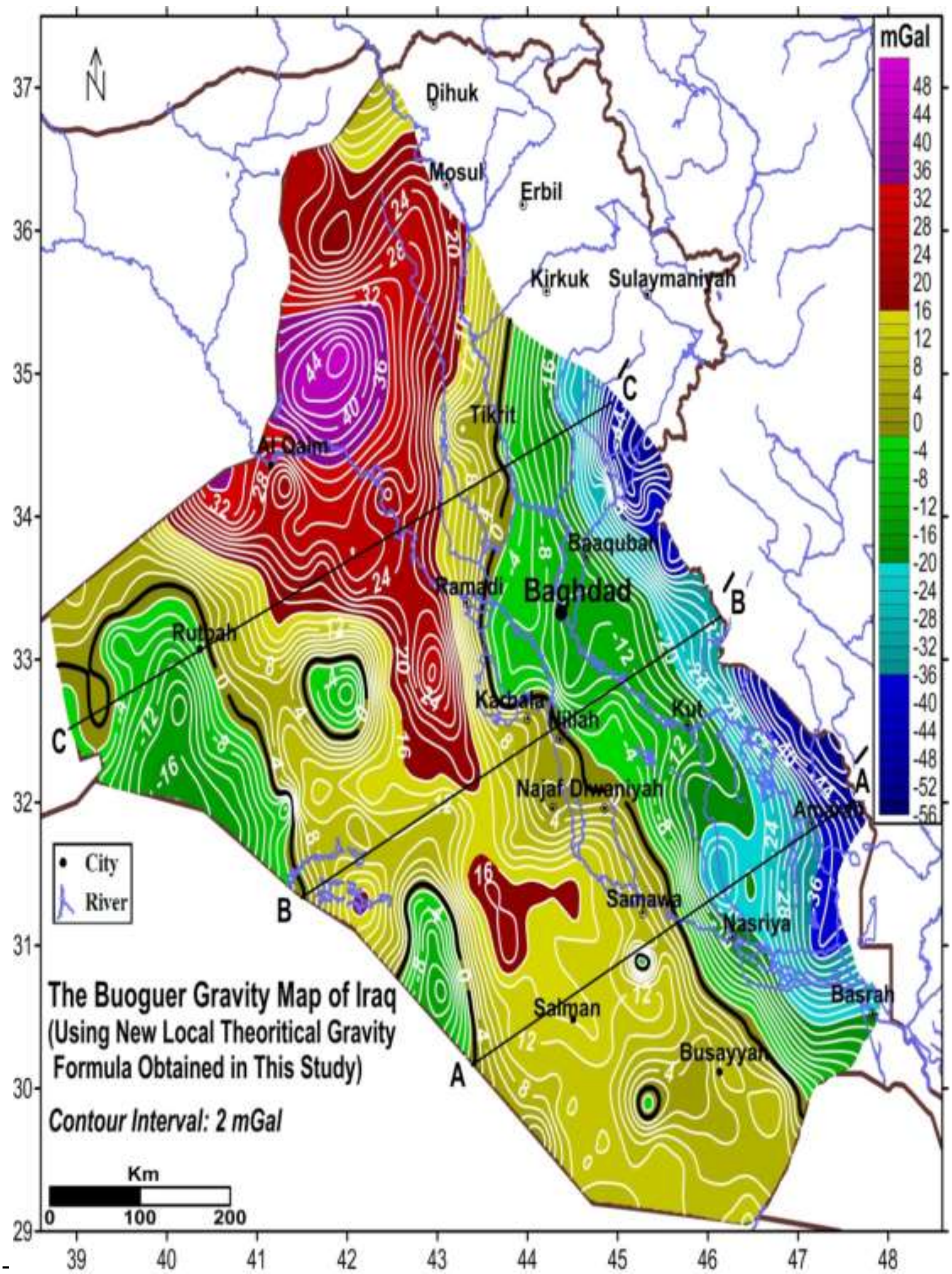

Figure 5- The Bouguer gravity map of the study area (Most areas of Iraq) using the new local theoretical gravity formula obtained in this study.

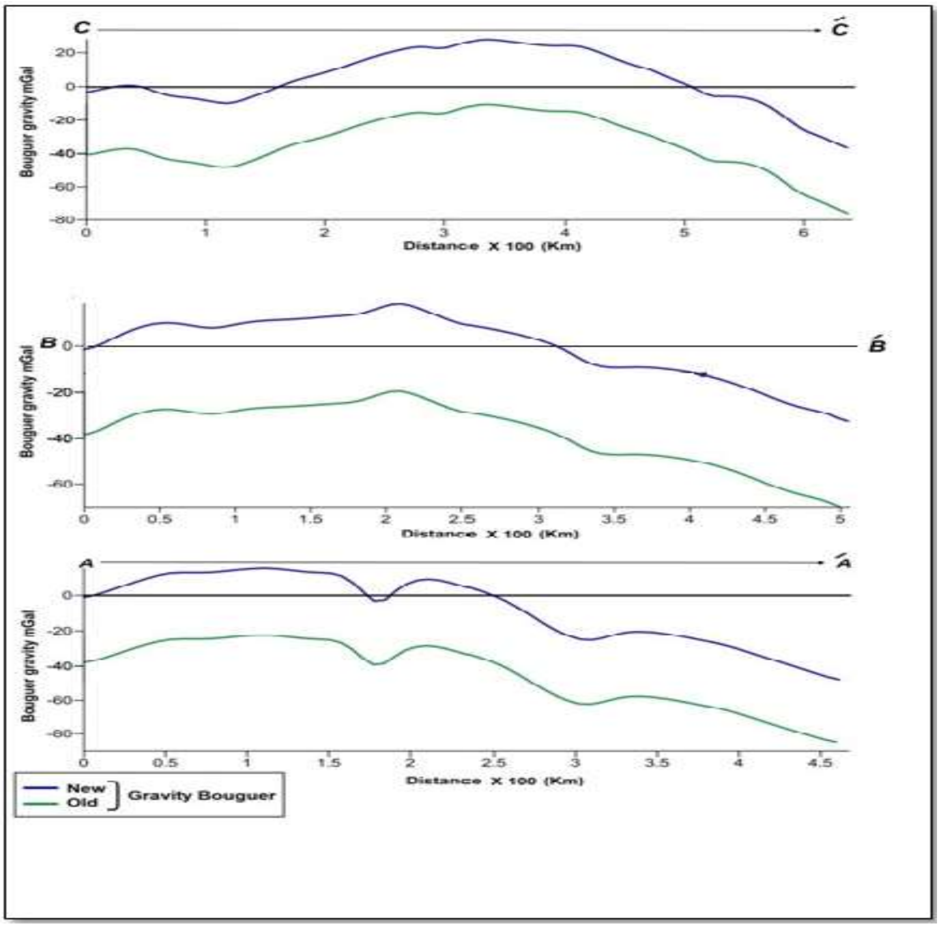

Figure 6- Comparison between the Bouguer gravity values obtained from using the international gravity equation (1930) (green color), and the new local theoretical equation obtained in the present study (blue color), along three profiles trending in the NE-SW direction, perpendicular to the main structural trends in Iraq.

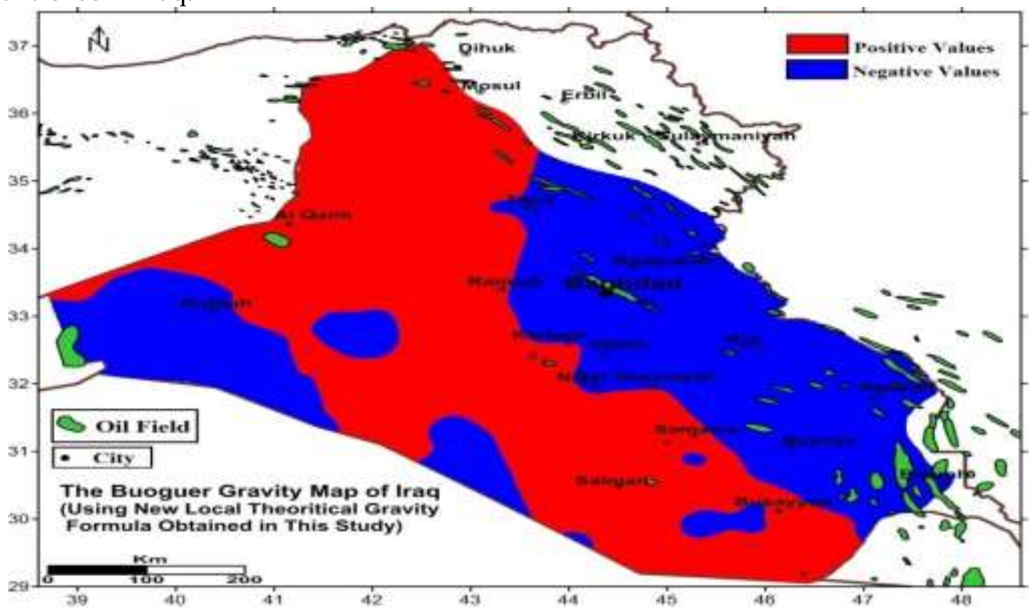

Figure 7- The Bouguer gravity map using the new local theoretical gravity formula, showing the major negative gravity anomalies located at the eastern part of Iraq, coinciding most oil fields in central and southern Iraq.

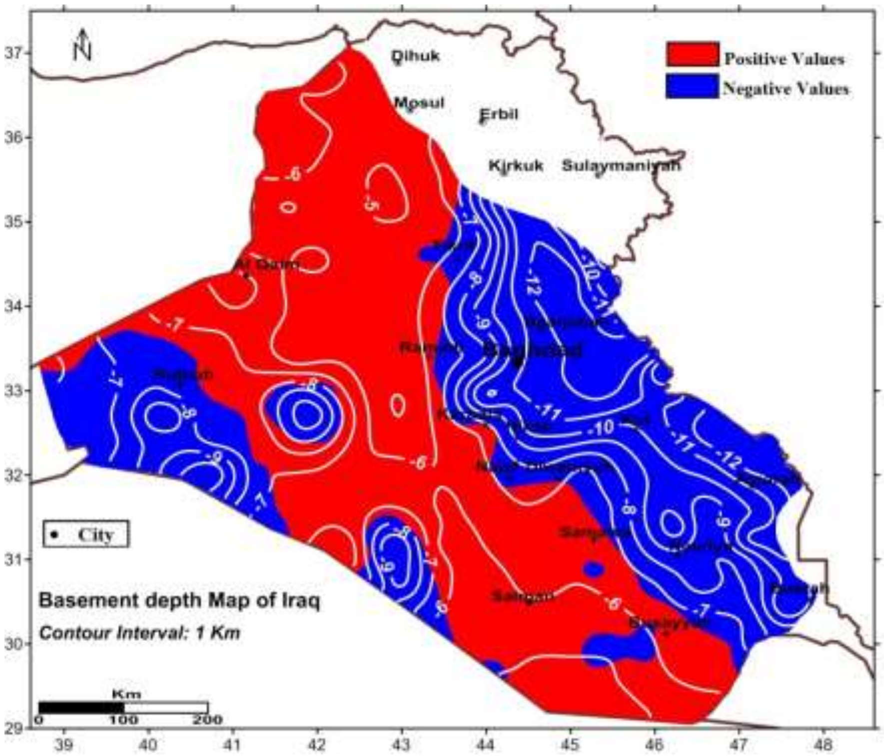

Figure 8- The new Bouguer gravity map (using the new local theoretical gravity formula) showing the negative anomalies found to coincide with the deepest parts of the basement rocks.

Conclusions

The gravity base stations of Iraq were used to obtain a new local theoretical gravity equation. This equation was used to construct a new Bouguer anomaly map of Iraq. The new theoretical local map generally increased the regional level of gravity values by about 30 mgal. The most important conclusion of the study is the coincidence of the negative gravity anomalies in the new gravity map with the deep basement rocks in Iraq. Moreover, the major negative anomaly at the east coincides with the Mesopotamian tectonic zone which contains most oil fields in Iraq.

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