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The Jurassic and Deep Structures Inferred from Gravity Data Depending on Stripping Technique for The Uppermost Layers in Central and Southern Iraq

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Abstract
The gravity anomalies of the Jurassic and deep structures were obtained by stripping the gravity effect of Cretaceous and Tertiary formations from the available Bouguer gravity map in central and south Iraq. The gravity effect of the stripped layers was determined depending on the density log or the density obtained from the sonic log. The density relation with the seismic velocity of Gardner et al (1974) was used to obtain density from sonic logs in case of a lack of density log. The average density of the Cretaceous and Tertiary formation were determined then the density contrast of these formations was obtained. The density contrast and thickness of all stratigraphic formations in the area between the sea level to the top of Jurassic formations were used to determine the gravity effect of these layers. The gravity anomaly map of the stripped formation was determined. The gravity anomaly map of the stripped formation was subtracted from the Bouguer gravity map, and the gravity anomaly map of deep structures was obtained. The regional and residual maps (3rd order polynomial) were determined for the gravity anomaly maps before and after stripping. The regional gravity map before stripping shows one positive anomaly located at the western part of the study area and west Abu-Jir and Euphrates faults. The regional gravity map after stripping shows a positive anomaly located along an axis extended from Kut toward Najaf. This positive anomaly map divided the sedimentary basin into two sub-basins. The positive gravity residual anomaly of the Bouguer map before stripping shows regionally three structural axes trending NW-SE. These axes are Baghdad-Kut axis, northwest Karbala axis and west Samawa- Nasiriyah axis. The positive residual anomaly map after stripping shows two important anomaly areas. The first area is located between Kut and Karbala-Najaf . and the second is located northwest Karbala by about 100-120 km. These two areas may be prospective areas for hydrocarbon. The stripping method application in the study area shows good result; therefore, it can be used to enhance the gravity data to investigate deep structures in other areas.
Keywords: Key words: Stripping technique, Gravity anomaly, Density, Jurassic and Cretaceous, Central and Southern Iraq,

التراكيب الجوراسية والعميقة المستنبطة من البيانات الجاذبية بالاعتماد على مبدأ التقشير للطبقات العليا في وسط وجنوب العراق

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تم استخلاص تراكيب الجوراسي والتراكيب العميقة من خلال دراسة خارطة بوجير للجاذبية. حيث تم حساب تأثير الجاذبية للطبقات العليا من سطح البحر الى السطح العلوي للجوراسي في وسط وجنوب العراق والتي تم قشطها من خلال حساب التأثير الجذبي للطبقات العليا بالاعتماد على مجس الكثافة او من المجسات الصوتية و بالاعتماد على معادلة 1974Gardner et al لتحويل السرع الزلزالية إلى الكثافة. استخدمت معطيات فرق الكثافة والسمك للطبقات الصخرية الممتدة من مستوى سطح البحر إلى عمق أعلى الجوراسي لحساب التأثير الجذبي. أعدت خارطة للشواذ الجاذبية للطبقات العليا ومن ثم طرحت من خارطة بوجير للجاذبية لمنطقة الدراسة ومنها استخلصت خارطة الشذوذ الجذبي والتي تمثل تأثير الطبقات السفلى من سطح الجوراسي والمصادر الأعمق . ان الشواذ الجاذبية الموجبة للخرائط قبل التقشير أظهرت وجود ثلاث شواذ موجبة تمتد بشكل محاور هي محور بغداد-الكوت ومحور شمال غرب كربلاء ومحور غرب السماوة والناصرية. أما خريطة شواذ الجاذبية الموجبة بعد التقشير فأظهرت منطقتين تميزت بشواذ الجاذبية الموجبة، المنطقة الاولى محصورة بين الكوت ومحور كربلاء-النجف والمنطقة الثانية تقع شمال غرب كربلاء بمسافة تتراوح من 100-120 كيلومتر. هاتان المنطقتان تعدان من المناطق المهمة لاحتمال تواجد التجمعات الهيدروكربونية فيها. اعطى تطبيق طريقة التقشير في منطقة الدراسة نتائج جيدة ومفيدة حيث اسهمت في تحسين الصورة التركيبية للتراكيب العميقة

Introduction

The gravity method of geophysical exploration is based on the measurement of variations in the gravity field caused by horizontal density variations within the subsurface [1]. It is an important technique for many problems involving subsurface mapping, and it is the principal method in several specific types of geological studies[2]. The investigation of deep structures is an important aim of gravity interpretation. Stripping the upper subsurface layer is considered a tool to enhance the anomaly of the deep subsurface gravity sources[3]. The gravity anomaly of the upper layers can be determined depending on the thickness and density of layers obtained from well logs or core samples. introduced the stripping technique, which depends on determining the gravity effect of the upper subsurface layer and subtracting from the Bouguer gravity anomaly to enhance the gravity of the deep sources[3]. [4] applied the gravity stripping technique to enhance the figure of deep structure in the southern part of the western desert of Iraq. He concluded that the deep structures, including the basement and the crust gravity effect, represent 60-70% of the Bouguer gravity map in the Western Desert [4]. [5] applied the stripping technique in Eastern Alps and surrounding areas. They derived the density model from samples and density obtained from sonic logs. They enhance the gravity anomaly of the deeper gravity sources. The obtained information was used to build a gravity model constrained by seismic information for Moho [5]. [6] uses the stripping technique in gravity interpretation of Eastern Mediterranean. The Cenozoic and Mesozoic rocks' gravity effects were stripped, and the gravity map of the deeper gravity sources was obtained [6]. [7] determined the gravity effect of the Miocene rocks and stripped this effect from the Bouguer gravity map to investigate the deep complex structures. They delineate two main troughs separated by a structural ridge[7]. This study attempts to use the stripping technique to eliminate the gravity effect of shallow sources in order to investigate the deep structures in central and southern Iraq.

Location of the study area

The study area lies in the central and southern part of Iraq and has a trend NW-SE (Figure 1)[8]. The study area includes many cities such as Karbala, Najaf and Nasiriya. This area includes five oil fields: West Kifl, Diwan, Kifl, Samawa, and Nasiriya

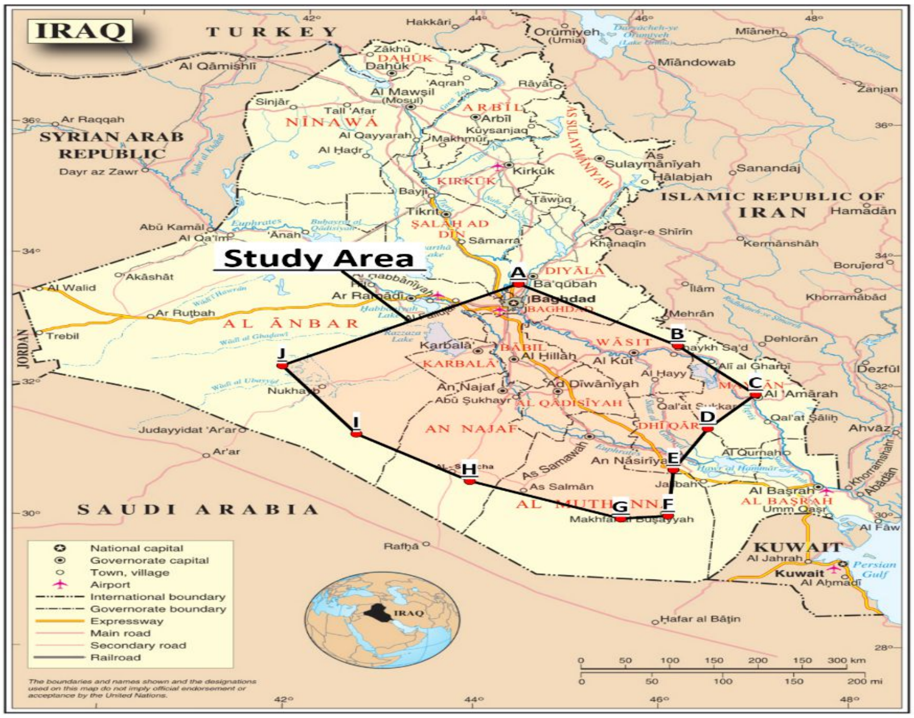


Figure 1- The location of the study area [8].

Subsurface geology of the study area:

The geology of study area is identified from the data obtained from the six wells drilled within Diwan, West Kifl, Samawa, East Baghdad, Nasiriyah, and Kifl oil fields. The geological information of the study area is represented by the Kf-1 well from the Kifl oil field, which was drilled in the years (1954-1960) within Najaf Governorate, near the platform flank of Mesopotamian Foredeep. Figure 2. The drilling penetrated this well to the Kurra Chine Formation (Triassic) at a total depth of about 4330 m [9].

Tectonics and structure of the study area The studied area is located between the stable platform (Al-Salman sub-zone) and the unstable platform (Mesopotamian sub-zone) Figure 3[10]. The unstable shelf or the outer platform represents the eastern part of the study area, While the western part represents by transition zone [11]. The thickness of the sedimentary cover is relatively thin in the western part of the study area, and it increases toward the east[12]. The zone was probably uplifted during the Hercynian deformation, but it subsided from late Permian time onwards. It is a monocline dipping to the NE with short anticlines 10 km structural noses[13]. Some longer NW-SE oriented anticlines 20-30 km long lie near and parallel with the Euphrates Boundary Fault, especially between Samawa and Nasiriya. They are related to horsts and Grabens developed along the fault zone[14].

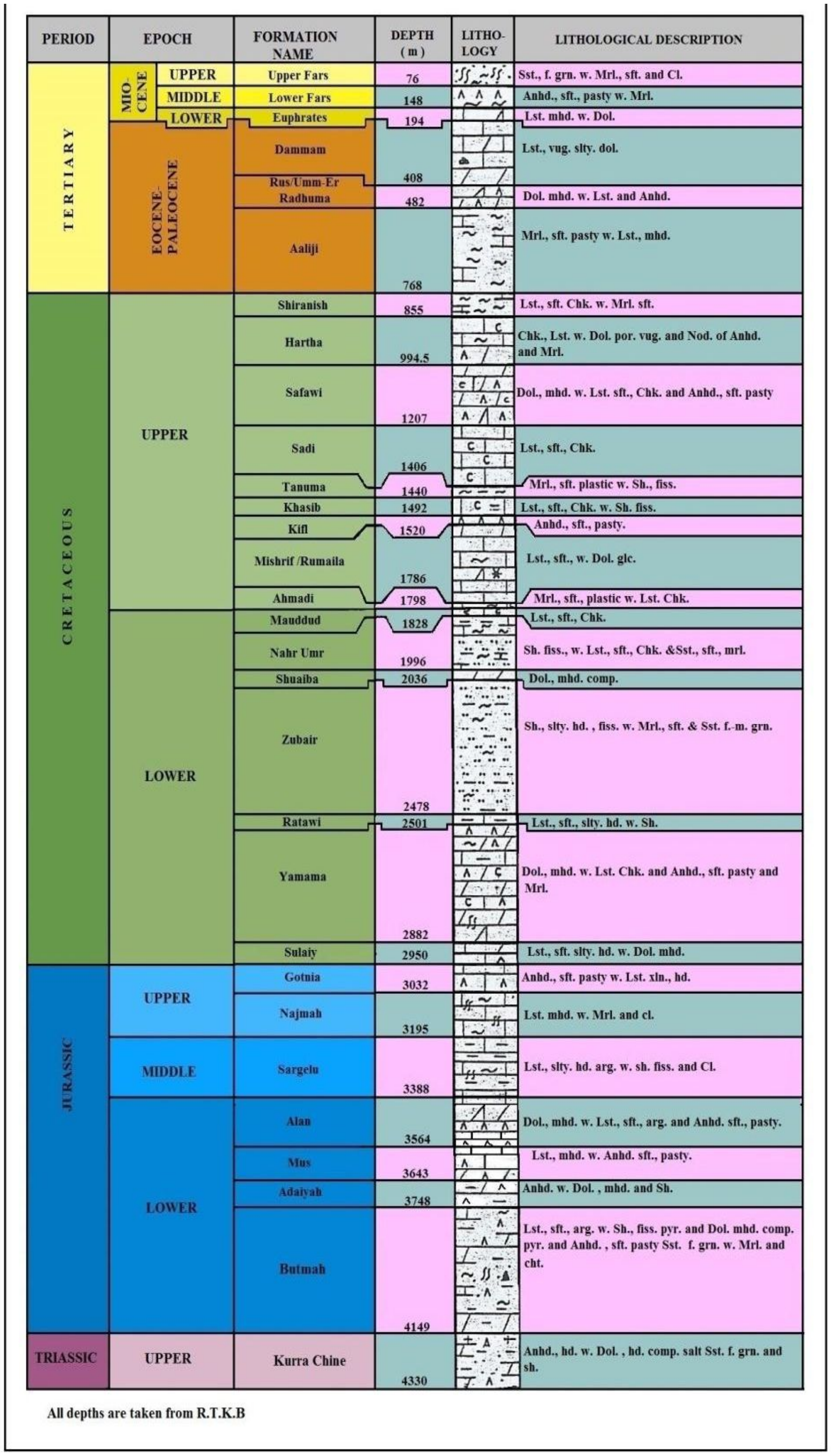


Figure 2- The stratigraphic column of (Kf-1) well in Kifl Oil Field. (OEC, 2000) [9].

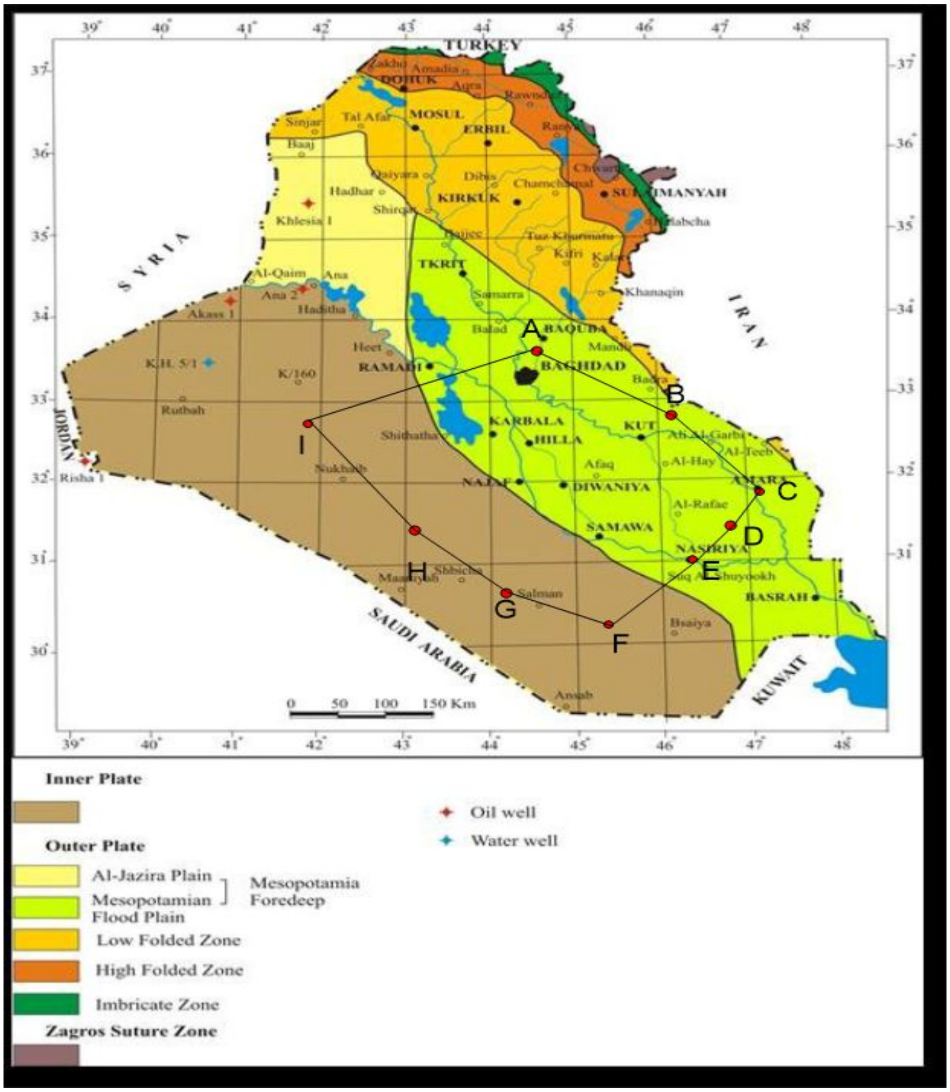


Figure 3- Location of the study area on the tectonic map of Iraq [10]

Data acquisition and processing

The average density of the upper subsurface formation (layers) was determined depending on the density obtained from the sonic log after loading the well coordinates and logs, and check shot of (Dn-1, Sa-1, Wk-1, EB-4, NS-1 AND Kf-1) wells.

The relationship between the density and seismic velocity were used to-convert the sonic log to density log [15].

All the calculations within this study were achieved using the Petrel and Excel programs. The following equation were applied [15] :

$Density = 309.42\,V^{-0.25}$ [15]

Where

$$density\ (kg\backslash m^3)$$

V=velocity (m\second)

The average density of the layers from the sea level to the top of Jurassic formations was determined for the six well considered in the study. Then, the density map of the study was plotted, (Figure 4). This map indicates that the high average density is located in the western side of the study area with a value of about 2.6 gm/cm^3, while the low average density on the eastern side shows a value of about 2.16 gm/cm^3.

The density contrast of the upper formations (Cretaceous and Tertiary) were determined over all the area by subtracting the host rock density from the average density values. The host rock density value considered in this study is (2.67 gm/cm^3) which is equal to the average density of the continental crust. The density (2.67 gm/cm^3), also used in many gravity studies in Iraq, represent the average density of basement. The density contrast obtained by subtracting host rock density from the average density of cretaceous and Tertiary formations was plotted as a map shown in Figure 5. This map is characterized by low negative density contrast in the southwestern part of study area, about -0.1 gm/cm^3, and high negative density contrast at the north eastern part of the study area, about -0.5 gm/cm^3.

The thickness of the Cretaceous and Tertiary formations were plotted depending on the available information (Figure 6). This map is characterised by low thickness (1200 m) in the southwestern part, while the thickness increase and reach about 4800 meters at the east of the study area (Figure 6).

The gravity effects of the Cretaceous and Tertiary formation were determined using horizontal slab equation.

$\Delta g = 2\pi G \Delta \rho h$

Where

Δg = gravity effect (gal G= Gravitational constant (6,67 x 10^{-8})

$\Delta \rho$ = Density contrast (gm/cm^3)

h = Thickness of layers (cm)

This equation can be written by simple form :

Δg (mgal) = 0.0419 x Density contrast (gm/cm^3) x Thickness (meters)

The obtained gravity effect of the formations from the sea level to the Jurassic formations was plotted as a map, Figure 7. Generally, This map is characterized by gravity anomaly values range -4 mgl to -12 mgal at the western part. The gravity anomaly values decrease toward the east part of the study area, reaching -96 mgal.

The Bouguer anomaly map of the study area of the scale of 1: 1000 000 and 1 mgal contour interval compiled by Iraqi Petroleum Company (IPC) and reconstructed by GETECH were used. . This map was plotted in a contour interval of 4 mgal. (Figure 8).

The gravity anomaly map of the Cretaceous and Tertiary formations (Figure 7) was subtracted from the Bouguer gravity map of the study area (Figure 8) , to obtain the Bouguer gravity anomaly map for the deep structures (after stripping), including Jurassic and deeper ages sources (Figure 9). This map is characterized by a relatively high positive gravity anomaly between Kumait and Kut area trending northwest-southeast and extending smoothly toward Baghdad. This anomaly extended as a tongue toward the Najaf area in the west. Another relatively small positive anomaly is shown at the northwest Karbala trending north direction. About five negative anomalies were noticed. The first one is in west of Baghdad. The second and third two negative anomalies are located west of Karbala at the western border of the study area. The fourth and south of Samawa. The fifth negative anomaly at Nasiriya trending to the north-south.

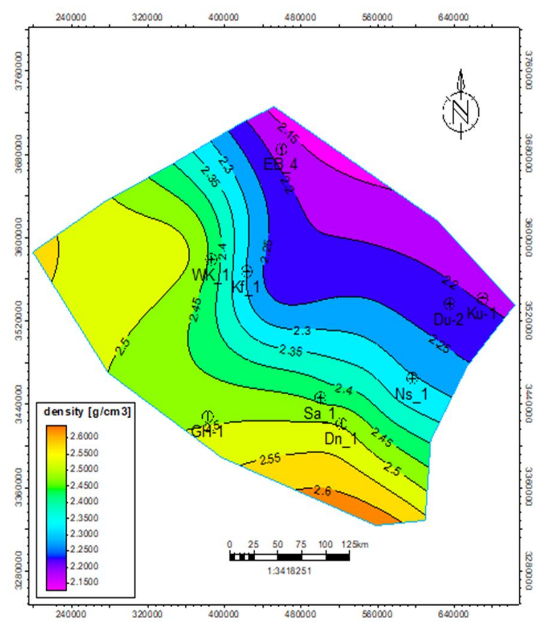


Figure 4-The average density map of Cretaceous and Tertiary formations in the study area.

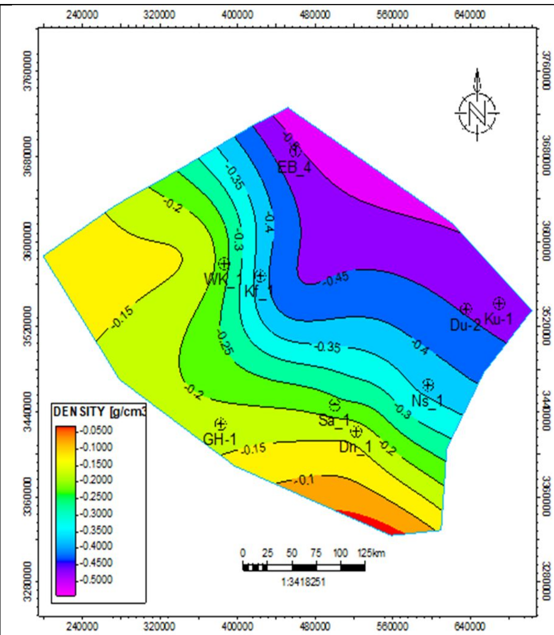


Figure 5-The density contrast map of Cretaceous and Tertiary formations in the study area.

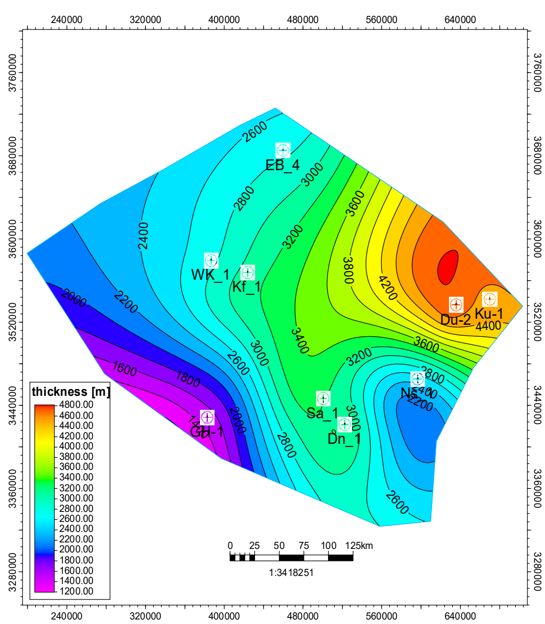


Figure 6-The thickness map of Cretaceous and Tertiary formations in the study area.

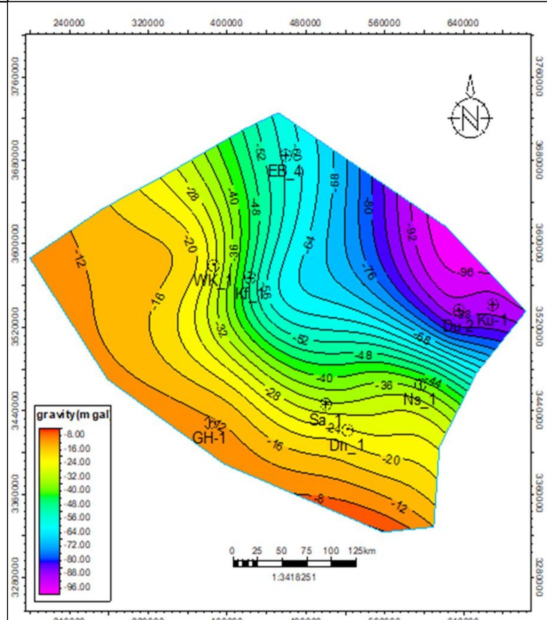


Figure 7-The gravity effect map of Cretaceous and Tertiary formations in the study area.

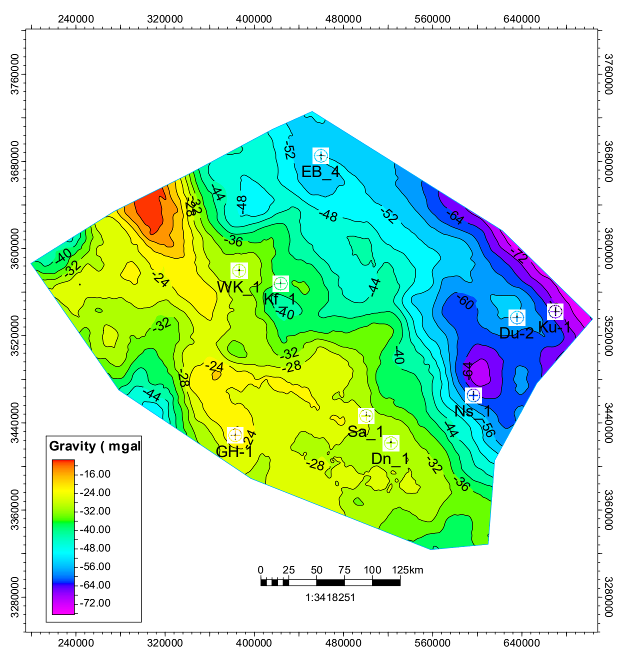


Figure 8-The Bouguer gravity anomaly map of the study area.

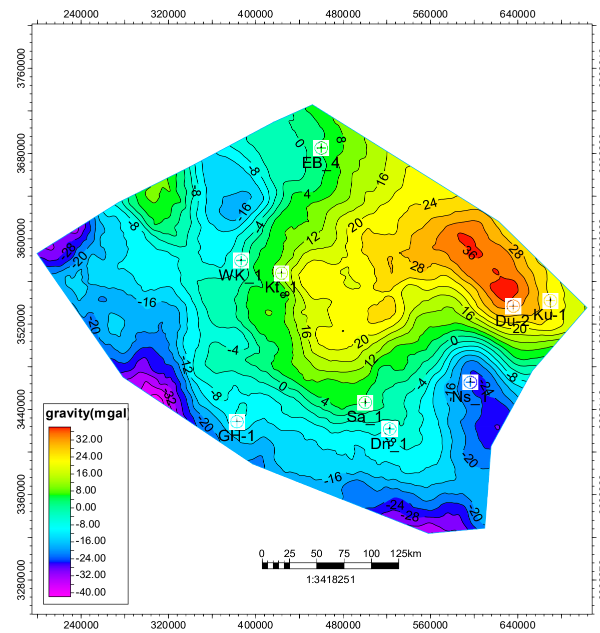


Figure 9-The obtained gravity anomaly map of Jurassic and deeper sources.

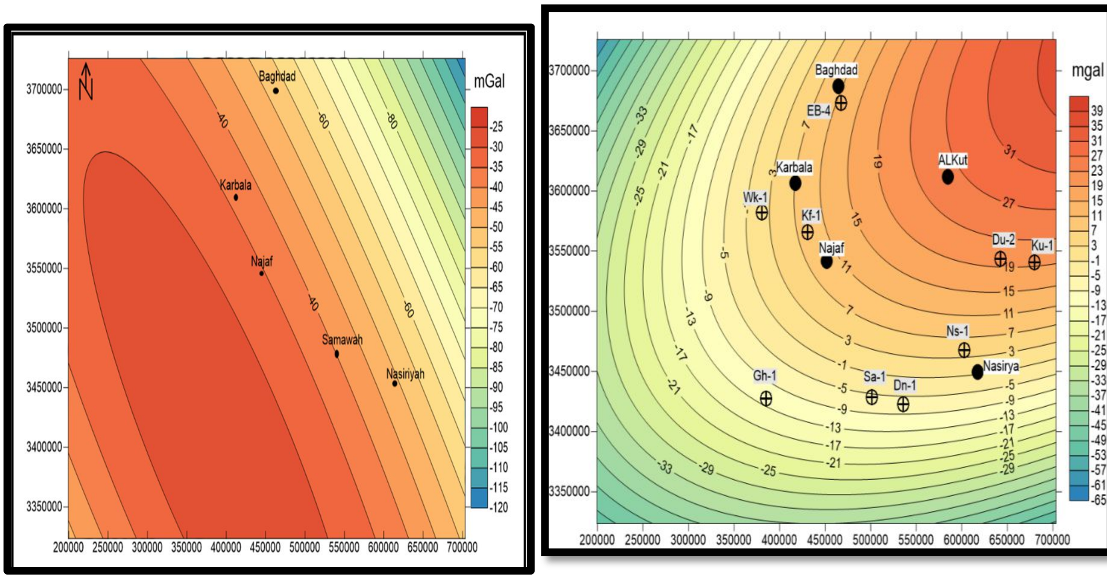
Separation of gravity anomalies:

The process of separating Gravity anomalies is necessary in order to evaluate the study area. It is necessary to clarify the effect of the sources with different depth levels on sedimentary cover rocks, so anomalies have been separated by using the polynomial method. The regional gravity maps of the study area, which is obtained using the 3rd order polynomial method, before and after stripping were obtained (Figure 10- A and B) respectively. The regional gravity map before stripping shows a main positive anomaly trending Northwest-Southeast, and locating west of the Abu-Jir Fault, (Figure 10-A). This trend coincides with the previously conclusions indicated by Al-Banna and Karadaghi (2018) [16]. The regional gravity map of the study area after stripping shows a main positive gravity anomaly trending Northeast-Southwest passing through Kut –Najaf axis, (Figure 10-B). This axis may indicate that the sedimentological basin may be divided into southern and northern sub-basins.

Residual gravity anomaly map

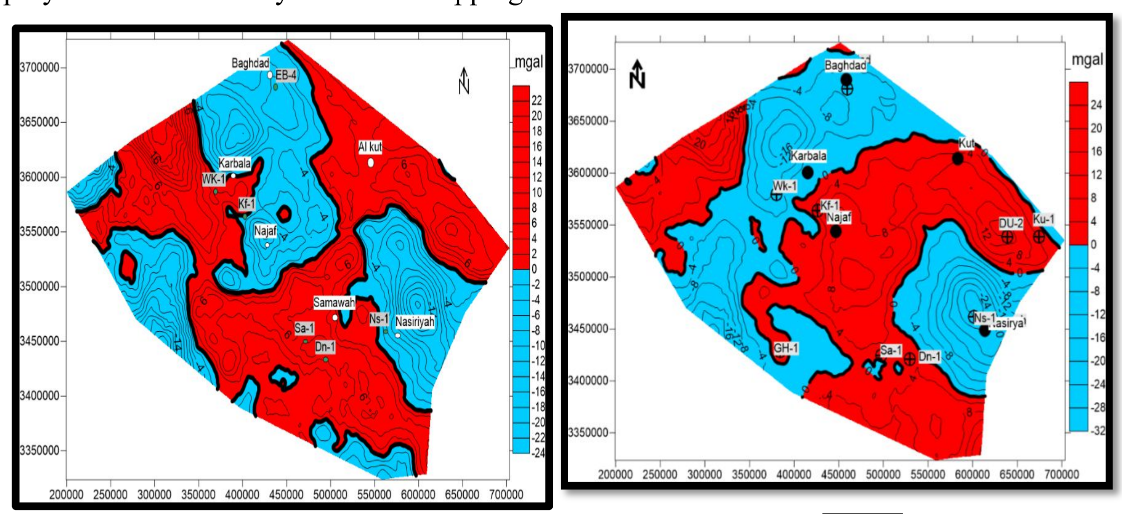
The residual gravity map before stripping can be obtained by subtracting the regional gravity map of third-order polynomials before stripping from the Bouguer gravity map, (Figure 11-A). This map shows mainly three groups of positive anomalies: East Baghdad –Kut axis, Northwest Karbala axis and west Samawah- Nasiriyah axis. All these anomalies axis trending Northwest –Southeast. Three main negative anomalies were found in east Karbala, east Nasiriyah and the western part of the study area.

The regional gravity map after stripping was subtracted from the gravity anomaly map after stripping and the residual gravity anomaly map after stripping was obtained Figure(11-B). The residual map after stripping shows mainly positive areas and two main negative areas. The most important positive residual anomaly trending NW-SE and located eastern Kut City. The other positive anomaly located east Najaf City. On other side the first negative area extended from Baghdad to the north Karbala and continued to the west borders of Iraq, trending in a NE-SW direction. The second negative anomaly is located at Nasiriyah and the surroundings area with an elliptical shape trending with its longitudinal axis in the N-S direction.



A B

Figure 10-A:Map shows regional gravity anomalies of 3^rd^ order polynomial Bouguer gravity map of the study area before stripping. **B**- The regional map of gravity anomalies of 3^rd^ polynomial of the study area after stripping.



A B

Figure 11-(A): Map shows the residual gravity anomalies of 3rd order polynomial of the Bouguer gravity map of the study area before stripping.

(B) Map shows the residual gravity anomalies of 3rd order polynomial of the Bouguer gravity map of the study area after stripping.

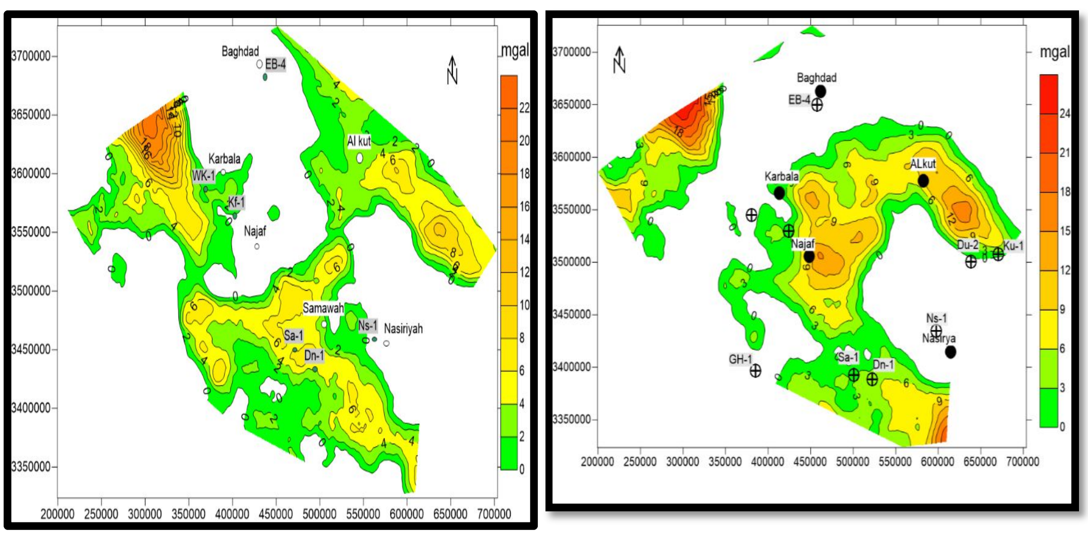
Comparison between the positive residual gravity anomaly map before and after stripping :

The positive residual gravity anomaly of the total gravity effect (before stripping) (Figure 12-A), and the positive residual gravity anomaly of deep structures (after stripping)(Figure 12-B) were compared. The residual gravity anomalies map before stripping shows four main groups of positive anomalies. These anomalies are Baghdad –Kut, northwest Karbala, Glisan, and west Samawa- Nasriyiah (Figure 12-A).

The positive residual anomalies of the gravity anomaly map after stripping, which may be related to the Jurassic and deep structures (gravity sources) , were shown in Figure (12-B). This map shows three main positive anomalies, These are the East Kut anomaly which is trending NW-SE, east Karbala-Najaf, trending nearly N-S, northwest Karbala, and south Nasiriyah anomalies.

The comparison shows that most shallow structures are effected by the deeper structures. The location and trends of the anomalies were changed in some areas. For example, the anomaly east Kut City extended to Baghdad in Figure 12-A, while it ends in its northern side around Kut City. The most important anomalies which is appeared east of Karbala and Najaf cities. This anomaly seems to be relatively negative anomaly before stripping ,while it is showing a positive anomaly of more than 8 mgal in the same location after stripping as shown in Figure 12-B. The authors believe that the area between Kut and Karbala-Najaf axis in the map of the deep structures may be an interest as a prospective area for petroleum presence. The southern part of the anomaly northwest Karbala, which is extended to the west Karbala (Figure 12A), found to end at the location about 100 km northwest of Karbala in Figure 12-B, This may be indicate the importance of the area northwest Karbala, which extended to Fallujah City, (Figure 12-B). This area may need additional detailed geophysical studies.

The result of this study shows the importance of stripping techniques to enhance the deeper gravity sources and improve results for deep geological models.



A **B**

Figure 12 -(A) The positive residual gravity map of the study area before stripping , (B)The positive residual gravity map study area , after stripping.

Conclusions

The stripping techniques were used for the study area in central and south of Iraq to enhance the gravity data to investigate the deep structures. Many conclusions were obtained from this study:

1-It is found that the average density of the Cretaceous and Tertiary formations in the western region of Iraq is greater than the average density in the eastern part, while the density contrast of these formations is low negative value at the western part and high negative in the eastern part,

2- The western part side of the study area coincides with the inner platform, while the eastern part coincides with the outer platform. It is found that the maximum gradient in average density and density contrast of the Cretaceous and Tertiary formations seems to coincide with the location of Abu –Jir and Euphrates faults.

3-The regional gravity anomaly map of third-order polynomials (before stripping) shows a positive gravity anomaly extended from western Karbala, Najaf and Nasiriyah and located western the Abu-Jir Fault. The regional gravity anomaly map of third-order polynomials (after stripping) shows an axis of positive anomaly trending nearly Northeast-southwest. This deep positive anomaly may divide the sedimentary basin into two sub-basins.

4-The comparison between the residual gravity anomaly maps of the original Bouguer anomaly map (before stripping) with the residual gravity anomaly obtained from the gravity map (after stripping) shows a similar location with some important exceptions.

5-The residual gravity anomalies before stripping show three main structural axes, Baghdad-Kut axis and northwestern Karbala-Najaf axis, and the west of Samawah-Nasiriyah axis.

6-The positive gravity anomaly of the deeper structures (after stripping) shows two important areas, the first area is between Kut and Karbala-Najaf, and the second is located north-west Karbala by about 100- 120 km. These areas can be considered as a prospective areas for petroleum presence.

Application the stripping method for gravity data gives good result and enhances the study area's deep structure.

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References

[1] Parasnis, D. S., "*Principles of Applied Geophysics" .London: Chapman and Hall*, 92- 97 p, 199.

[2] Milsom, J. ,"Field Geophysics". The Atrium, Southern Gate, Chichester, West Sussex PO19 8 Sq, England, 179 p. 2003.

[3] Hammer, S., "Deep gravity interpretation by stripping: *Geophysics*, vol. 28, no.3, pp.369–378, 1963.

[4] Al-Mufarjy, M. A."Deep geological structures for the southern part of the western desert using geophysical analysis" . PhD thesis, University of Mosul, 2000 (In Arabic).

[5] Simeoni O. Bruckl, E. , "The Effect of Gravity Stripping on the Resolution of Deep Crustal Structures in the Eastern Alps and Surrounding Regions". *Australian Journal of Earth Science* , vol.102, no. 2, pp. 157- 169 , 2009.

[6] Bielik, M., Rybakov,M. and Lazar M., "The gravity stripping process as applied to gravity interpretation in the eastern Mediterranean" .*The leading Ege*, vol. 32, no. 4, pp.410-416, 2013. (Tutorial).

[7] Azab A. Soliman Sh., " Source structures at Pre-Miocene level as deduced by gravity stripping" .*Egyptian Petroleum Research Institute* , vol. 10, no.1, pp. 76–92, 2021.

[8] United Nations, Iraq administered map, Department of field support, Cartographic section, Map No. 3835 Rev. 6, 2014.

[9] O.E.C (37 / D / 3 ," Kifl 3D survey, pre-planning report, Geophysical study depth," O.E.C. document, 88 p, 1991.

[10] Fouad, S. F. ,**"**Tectonic map of Iraq, scale 1: 1000 000, 2012. Iraqi Bulletin of Geology and Mining" ., vol, 11**,** no.1, pp. 1-7, 2015.

[11] AL-Banna,A. S. and Ali, K. K. "The Transition Tectonic Zone Between the two parts of the Platform in Iraq: A review study" . *Iraqi Journal of Science*, Vol. 59, no. 2C, pp. 1086-1092, 2018.

[12] Jassim, S.Z. and Goff, J.C. , "Geology of Iraq". 1st ed. Publisers Dolin, Prague and Moravian Museum, Czech Republic. 341p, (2006).

[13] Al- Kadhimi, J. A. M., Sissakian, V. K., Fattah A., S., and Deikran, D. B. "Tectonic map of Iraq 1:1,000,000 scale series", Publication of GEOSURV, Baghdad, sheet No. 2, (1996) .

[14] Buday, T. and Jassim, S.Z. ,The Regional Geology of Iraq. Vol.2: Tectonism, Magmatism, and Metamorphism. S.E. Geol. Surv. Mine. Inves., Baghdad, p.: 352, (1987).

[15] Gardner, G. H. F., Gardner, L. W., and Gregory, A. R**. "**Formation velocity and density—The diagnostic basics for stratigraphic traps". *Geophysics*. Vol. 39, no. 6, pp. 770-780, 1974.

[16] Al-Banna, A. S. and Al-Karadaghi S. S. , "Integration study of new gravity and seismic survey along NE-SW profile in Al-Najaf Desert". *Iraqi J. Sci*., vol. 56, no. 1B, pp. 314-328, 2018.