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Processing and re-interpretation of gravity bouguer map of a selected area in the W-NW of Iraq

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Abstract

Geophysical data interpretation is crucial in characterizing the subsurface structure. The Bouguer gravity map analysis of the W-NW region of Iraq serves as the basis for the current geophysical research. The Bouguer gravity data were processed using the Power Spectrum Analysis method. Four depth slices have been acquired after the PSA process, which are: 390 m, 1300 m, 3040 m, and 12600 m depth. The gravity anomaly depth maps show that shallow-depth anomalies are mainly related to the sedimentary cover layers and structures, while the gravity anomaly of the deeper depth slice of 12600 m is more presented to the basement rocks and mantle uplift. The 2D modeling technique was used for the quantitative interpretation of a selected Gravity profile along the study area. The model section of the gravity profile illustrated the relatively high density of subsurface basement rocks and/or upward mantle process which causes the effect of positive gravity values. Furthermore, several faults are indicated in the sedimentary sections by potential gravity methods such as several grabens, half grabens, and horst structures which are identified in Bouguer depth maps by relatively high and low gravity values, these structures were also affected by the basement rock uplift and/or Mantle upwards.

Keywords: Gravity Data, Power Spectrum Approach, 2D modeling, Positive Gravity anomaly, Gravity Depth-slices

1. Introduction

Gravity surveying detects variations in the gravitational field of the earth by variations in the density of subsurface rocks. Although it is commonly referred to as the "gravity method," but what is actually being measured is the variation in acceleration caused by gravity. The majority of oil and gas exploration has been done using gravity methods, especially in the early part of the 20th century. While these techniques are still used extensively in hydrocarbon exploration and several other uses (Reynolds, 2011). In addition to a decrease with station elevation and an increase to the pole, sets of relative gravity values also reveal geological impacts in geographical patterns. The latter are usually obscured by other elements that need to be considered in order to display the geological data. The act of cleaning is known as "reduction," and the outcomes are known as anomalies of different kinds, which are the subject of interpretation, (Jacoby and smiled, 2009).

In order to evaluate gravity results, geological model fields are typically calculated and then compared to actual data. This is computer-required and, until recently, was only sometimes carried out in the field. Even today, the quality and importance of the data being gathered can be evaluated by an observer who is momentarily cut off from his laptop by an understanding of the impacts connected with a few basic bodies. This can occasionally result in a crucial decision being made to infill with new stations at a time when this can be conducted swiftly (Milsom, 2003). Roy et al., (2005) used Bouguer gravity data analysis to find variations in crustal thickness, which supports the hypothesis that the southeast Colorado Plateau and the Rio Grande rift are underlain by a low-density upper mantle province that is associated with areas of middle to late Tertiary magmatism. Tewari, et al. (1991) conducted a comparison of the gravity anomaly across the Cambay basin with that across the Proterozoic Aravalli/Delhi trends suggesting a crustal thinning in both regions, on either side of which the Moho rapidly deepens. This study of the Cambay rift basin in the northwest Indian platform shows high Bouguer gravity anomaly values. Lineaments and faults of Basement rocks of Al-Jazira area, NW of Iraq have been studied using the Gravity and Magnetic maps (Al-Banna, 1992). The study illustrated three systems depending on the maximum horizontal gradient of potential maps. Each system consists of two perpendicular sets of lineaments related to the Hijaz and Najd orogeny. The study was detected the depth of the basement rocks which was 6.5 km depth. Al-Rahim and Abdulrahim (2021) depicted the subsurface depression of Al Ma'aniyah, southwest of Iraq, using Gravity Multi-2.5D modeling. According to the gravity data inversion, the Al-Ma'aniyah depression's basement depth was ranging from 7.5 to 10 km. Abdulrahim et al., (2022) studied the primary geological structures and features in the Bahr An-Najaf area of Southwest Iraq using the free-air gravity, magnetic, and topographic data obtained from satellite imagery. The Bahr An-Najaf Depression was located in accordance with the negative anomalies on the reduction to pole magnetic map and the free-air gravity map. The major faults in the region, particularly the Abu Jir Fault, are also delineated on both maps. The current research attempts to process and re-interpret the Bouguer gravity map of Al-Khleisia and the surrounding areas to identify the crustal thickness variation within the study area that is probably related to positive gravity anomaly/values and basement structures. Furthermore, an attempt to separate the sedimentary basin of the study area to different depth levels depending on the power spectrum analysis technique, which this analysis has not been applied to the selected area before.

2. Location of the study area

The selected survey area covers about 3000 km^2, and it is represented by Al-Khleisia and the surrounding areas, which are within the provinces of Mosel and Anbar in the Northwestern Iraq. The elevation ranges of the area are between 300 to 1910 m above the sea level (figure 1).

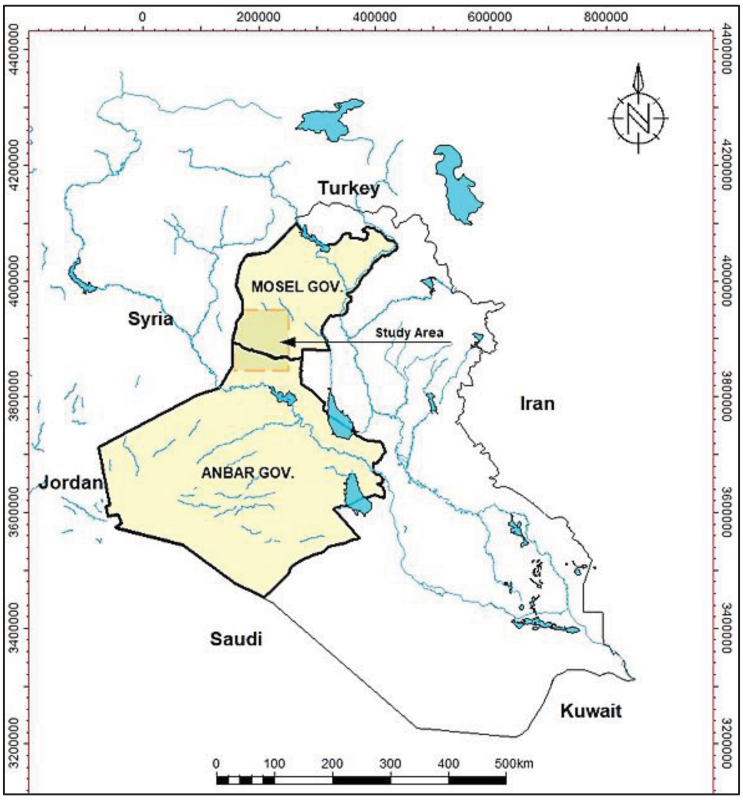

Figure 1. A location map of the study area (in red square) within the map of Iraq.

3. Geological and Tectonic setting of study area

Tectonically, the region is split into two sections (figure 2): The northern part of the Western Desert Subzone contains the Inner Platform, which extends to the area west and south of the Euphrates River. There is no evidence of Alpine compressional deformation, and Permo-Triassic rifting has a little impact (Sissakian and Fouad, 2015). The Zagros foreland basin on land that juts southeastward into the Arabian Gulf, its marine counterpart, is known as the Mesopotamia Foredeep. Because it is located between the Inner Platform and the Low Folded Zone, it is thought to be level terrain. (Fouad, 2015). The study area's Ad Dawadimi Terrane is identified by the presence of thick phyllites and low to medium gravity and magnetic data values. Additionally, it has strongly magnetic ophiolites bordering it on the east. The general N-S longitudinal tendency of the terrane is linked to the Amar (Idsas) collision belt. The strong magnetic field, high gravity, and magnetic anomalies observed on Ar-Rayan Terrane may be explained by an ophiolitic suture. It is expected that the terrane contains rocks from the Amar Group, which are volcanic-sedimentary rocks with the syn-tectonic gabbro and post-tectonic granites (Jassim and Goff, 2006).

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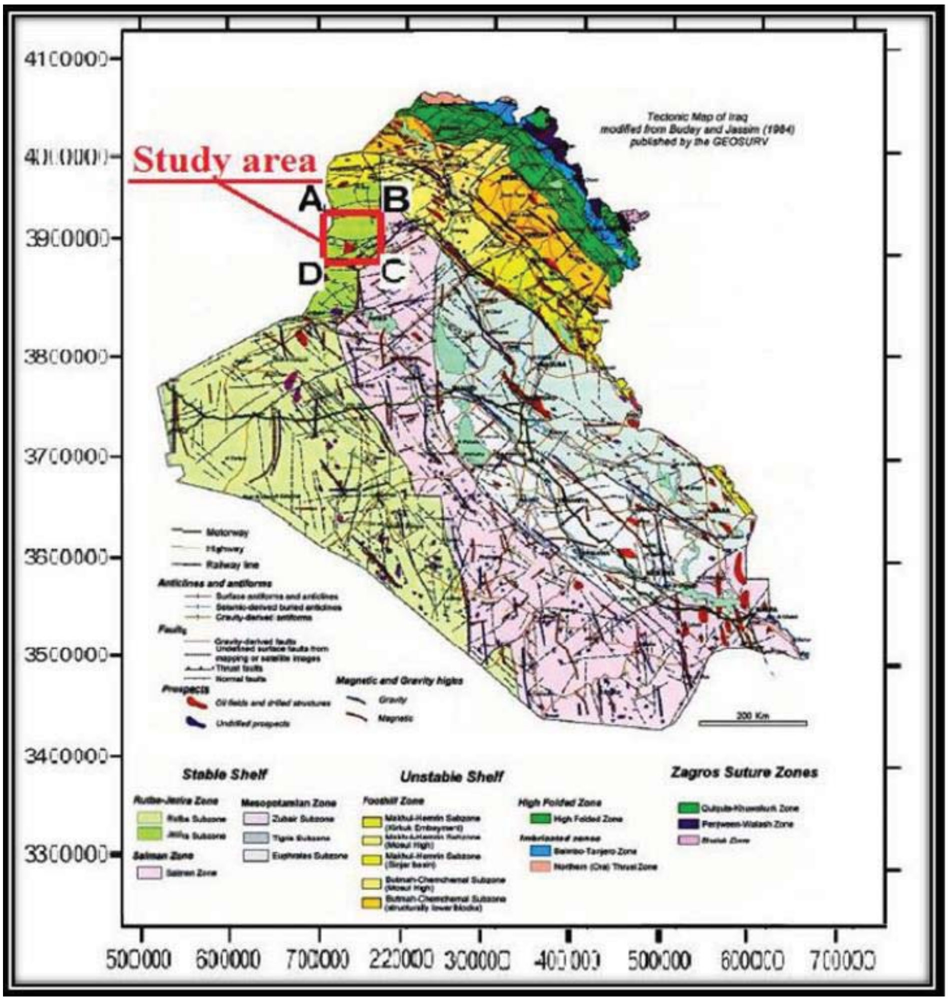

Figure 2. Tectonic map of the studied area within the Tectonic map of Iraq (Jassim and Goff, 2006).

Related to the geology, the Zahra, Mukdadiya, Injana, and Fatha are the main geologic outcropped Formations in the research region (figure 3). The oldest subsurface Geologic Formation was Khabour Fn., while the youngest was Fatha Fn. A variety of significant anticlines, such as the Maqlob, Kand, Ain Sifini, Shaykhan, Chia Gara, and Maten are present in and near the research area due to its location within the foot hill and high folded zones of the tectonic system (Jassim and Goff, 2006).

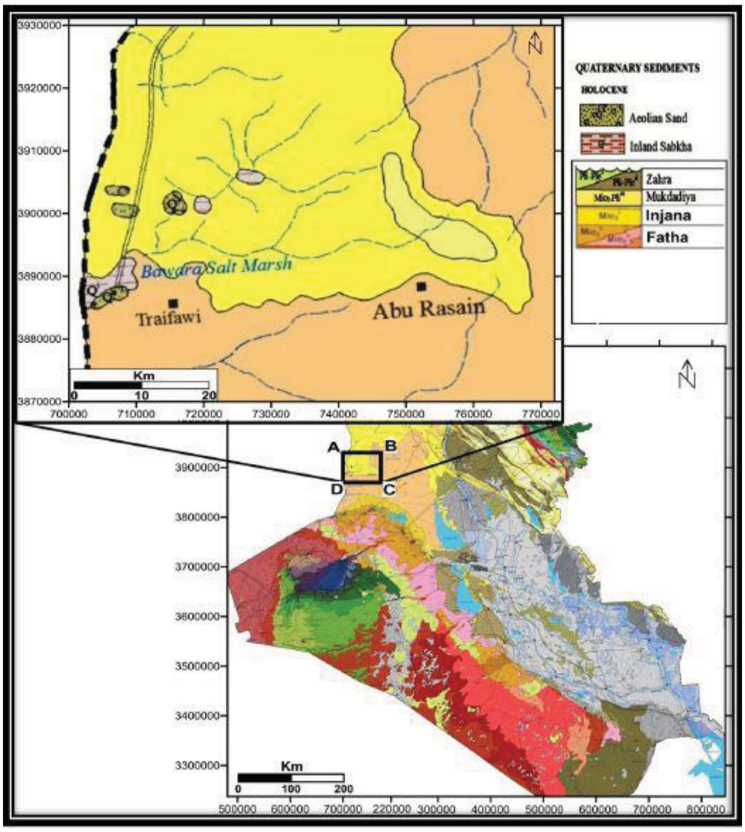

Figure 3. Surface Geology of the study area (Sissakian and Fouad, 2015).

The stratigraphic column is described as beginning in the upper Miocene (Injana Fn.), exhibiting the absence of most of the Cretaceous, Jurassic, and Permian ages, and ending at the Ordovician (Khabour Formation). This is demonstrated by the exploration oil well Khlesia-1 (1959), which was drilled within the study area and has a total depth of 3791 m (figure 4).

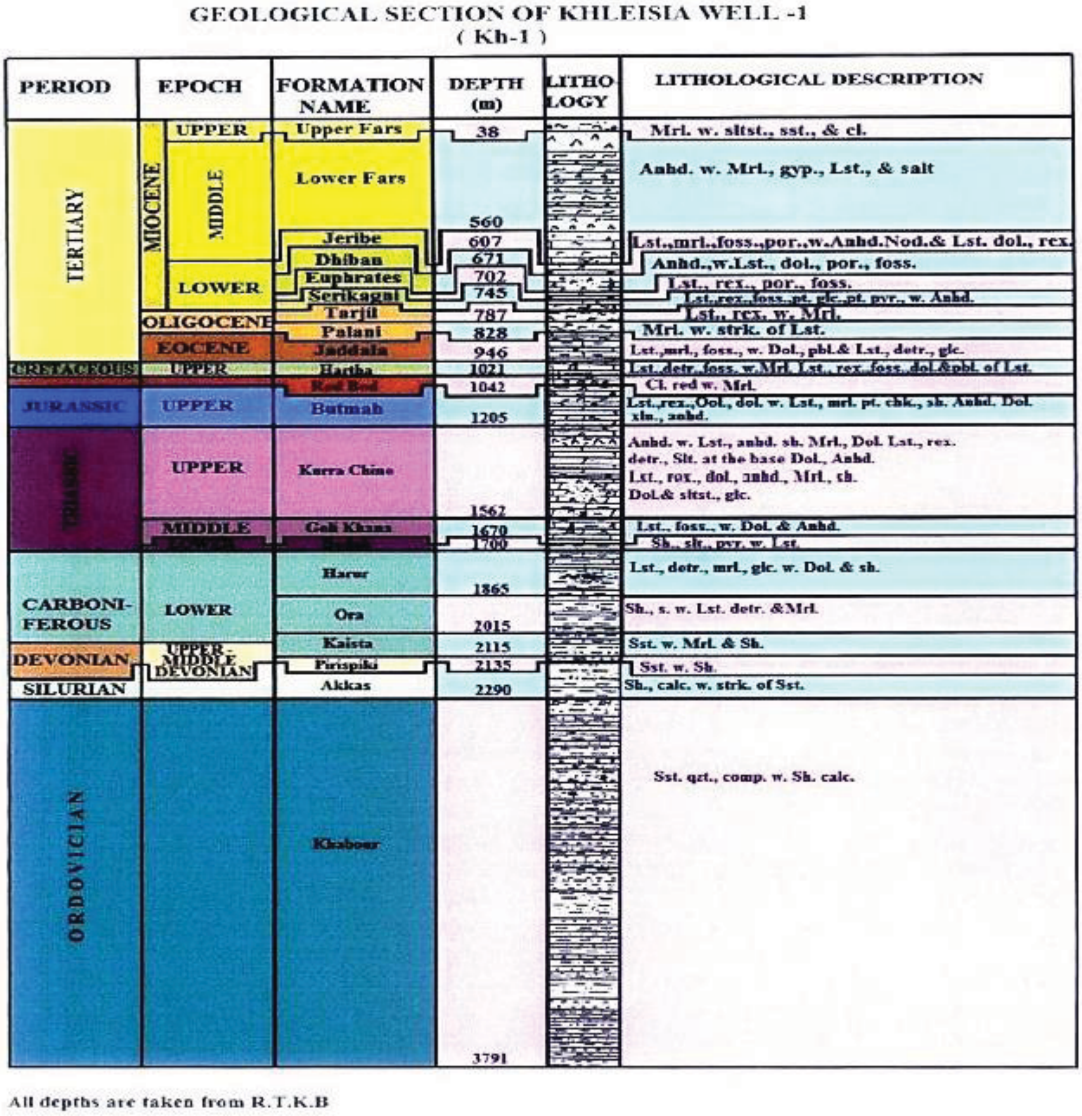

Figure 4. Subsurface Geology of the study area from Khleisia well-1 (OEC, 2016).

4. Materials and Method

The Bouguer map of Iraq (figure. 5) in general shows various positive and negative gravity anomalies which mainly reflect and related to the density-variation of subsurface structures. The area of interest Bouguer map illustrates some positive gravity anomalies which ranged from 5-14 mGal, particularly in the middle part of the selected study area, as shown in figure 6. The Bouguer gravity data of the selected area has been analyzed utilizing the Geosoft Oasis montaj ED, which is a software package that capable geoscientists to visualize, analyze, and integrate all types of geoscience data, such as geophysics, geology, and geochemistry

In order to evaluate gravity results, geological model fields are typically calculated and then compared to actual data. This is computer-required and, until recently, was only sometimes carried out in the field. Even today, the quality and importance of the data being gathered can be evaluated by an observer who is momentarily cut off from his laptop by an understanding of the impacts connected with a few basic bodies. This can occasionally result in a crucial decision being made to infill with new stations at a time when this can be conducted swiftly (Milsom, 2003). Roy et al., (2005) used Bouguer gravity data analysis to find variations in crustal thickness, which supports the hypothesis that the southeast Colorado Plateau and the Rio Grande rift are underlain by a low-density upper mantle province that is associated with areas of middle to late Tertiary magmatism. Tewari, et al. (1991) conducted a comparison of the gravity anomaly across the Cambay basin with that across the Proterozoic Aravalli/Delhi trends suggesting a crustal thinning in both regions, on either side of which the Moho rapidly deepens. This study of the Cambay rift basin in the northwest Indian platform shows high Bouguer gravity anomaly values. Lineaments and faults of Basement rocks of Al-Jazira area, NW of Iraq have been studied using the Gravity and Magnetic maps (Al-Banna, 1992). The study illustrated three systems depending on the maximum horizontal gradient of potential maps. Each system consists of two perpendicular sets of lineaments related to the Hijaz and Najd orogeny. The study was detected the depth of the basement rocks which was 6.5 km depth. Al-Rahim and Abdulrahim (2021) depicted the subsurface depression of Al Ma'aniyah, southwest of Iraq, using Gravity Multi-2.5D modeling. According to the gravity data inversion, the Al-Ma'aniyah depression's basement depth was ranging from 7.5 to 10 km. Abdulrahim et al., (2022) studied the primary geological structures and features in the Bahr An-Najaf area of Southwest Iraq using the free-air gravity, magnetic, and topographic data obtained from satellite imagery. The Bahr An-Najaf Depression was located in accordance with the negative anomalies on the reduction to pole magnetic map and the free-air gravity map. The major faults in the region, particularly the Abu Jir Fault, are also delineated on both maps. The current research attempts to process and re-interpret the Bouguer gravity map of Al-Khleisia and the surrounding areas to identify the crustal thickness variation within the study area that is probably related to positive gravity anomaly/values and basement structures. Furthermore, an attempt to separate the sedimentary basin of the study area to different depth levels depending on the power spectrum analysis technique, which this analysis has not been applied to the selected area before.

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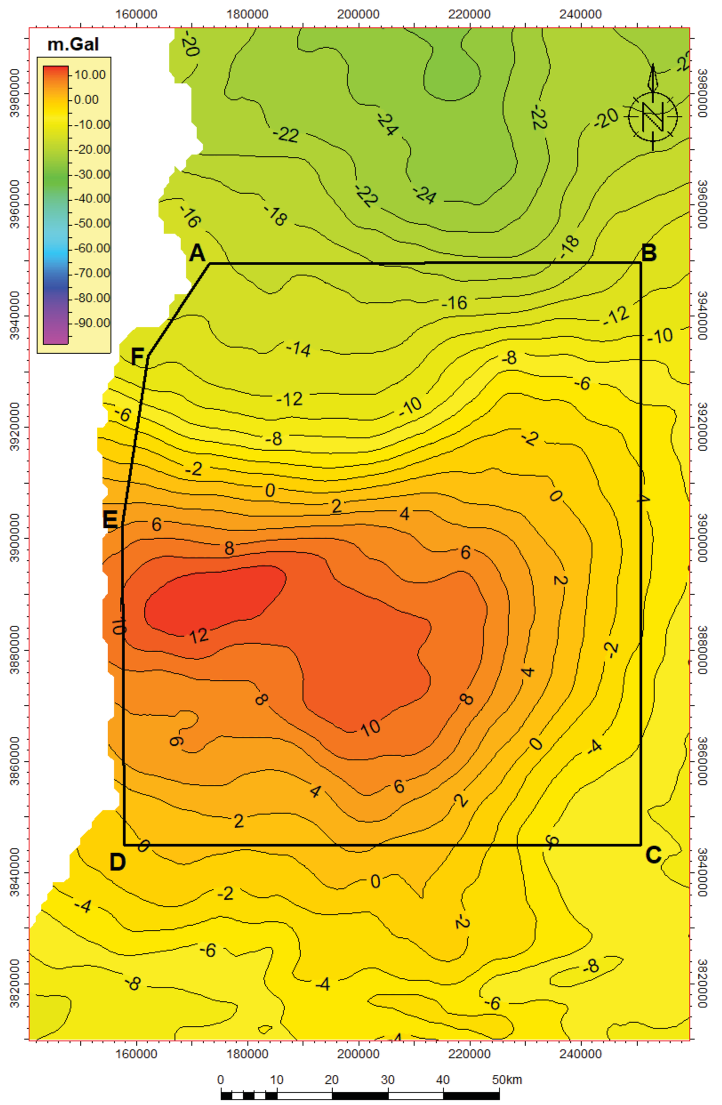

Figure 6. Bouguer Gravitational map of the study area (black rectangle) showing the variation in gravity values, positive values mainly shown in the middle of the selected area.

4.1. Power spectral Data analysis

The subsurface density variation can be analyzed using the Power spectrum data analysis approach for the Bouguer gravity data of the study area. The PSA approach is used to convert the Bouguer data to the frequency domain depending on the Fast Fourier Transform method, in order to highlight the spatial variation of the gravity data corresponding to the rock-density contrast of subsurface structures (Maus and Dimiri, 1996). The SPA approach tries to separate the data/signal into a series of frequencies of the same relative magnitudes, which in turn reflects the interface's mean depth of the specific geologic layer (Chamoli and Dimri, 2010). This will assist to a large extent in separating the subsurface structures depending on the density contrast-frequency transform relationship. The data of the study area is separated into four series of depth slices depending on spatial high and low frequency division of Bouguer gravity data (Barbour and Parker, 2015), which are: 390 m, 1300 m, 3040 m, and 12600 m, as shown in figure 7.

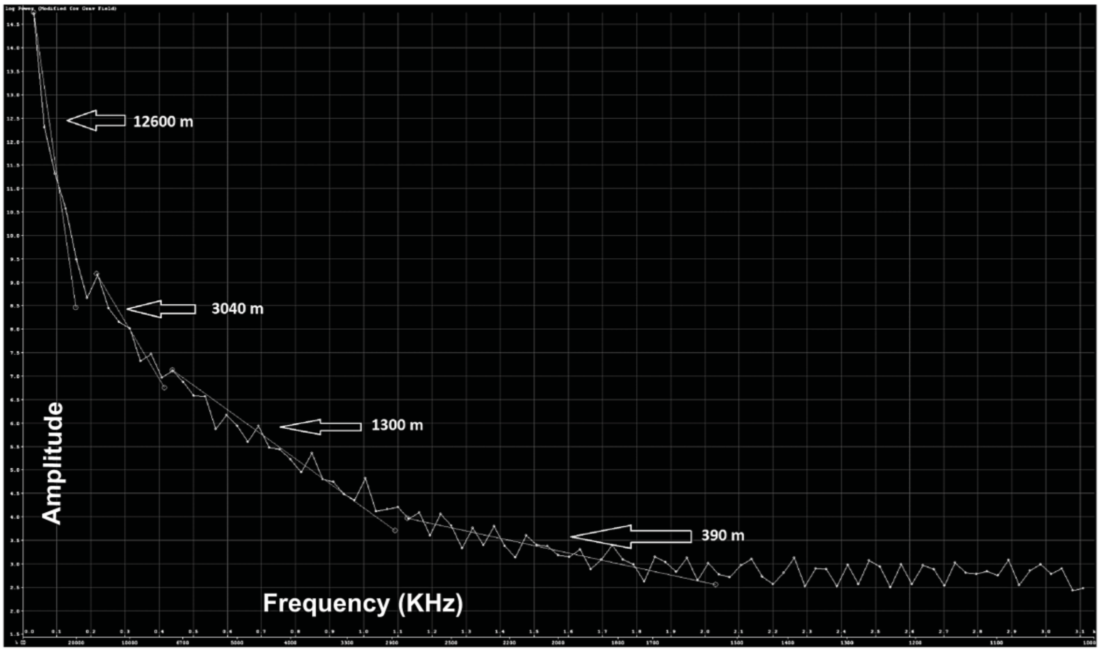

Figure 7. The Power Spectrum approach of the Bouguer Gravity that separates data to four depth slices according to high and low Frequency.

5. Data Modeling and Results

Four depth slices of gravitational variation have been constructed according to the Power Spectrum analysis as mentioned before. The four depth maps of Gravity anomaly illustrate the effect of density contrast due to the subsurface rocks/structures, as shown in figure 8.

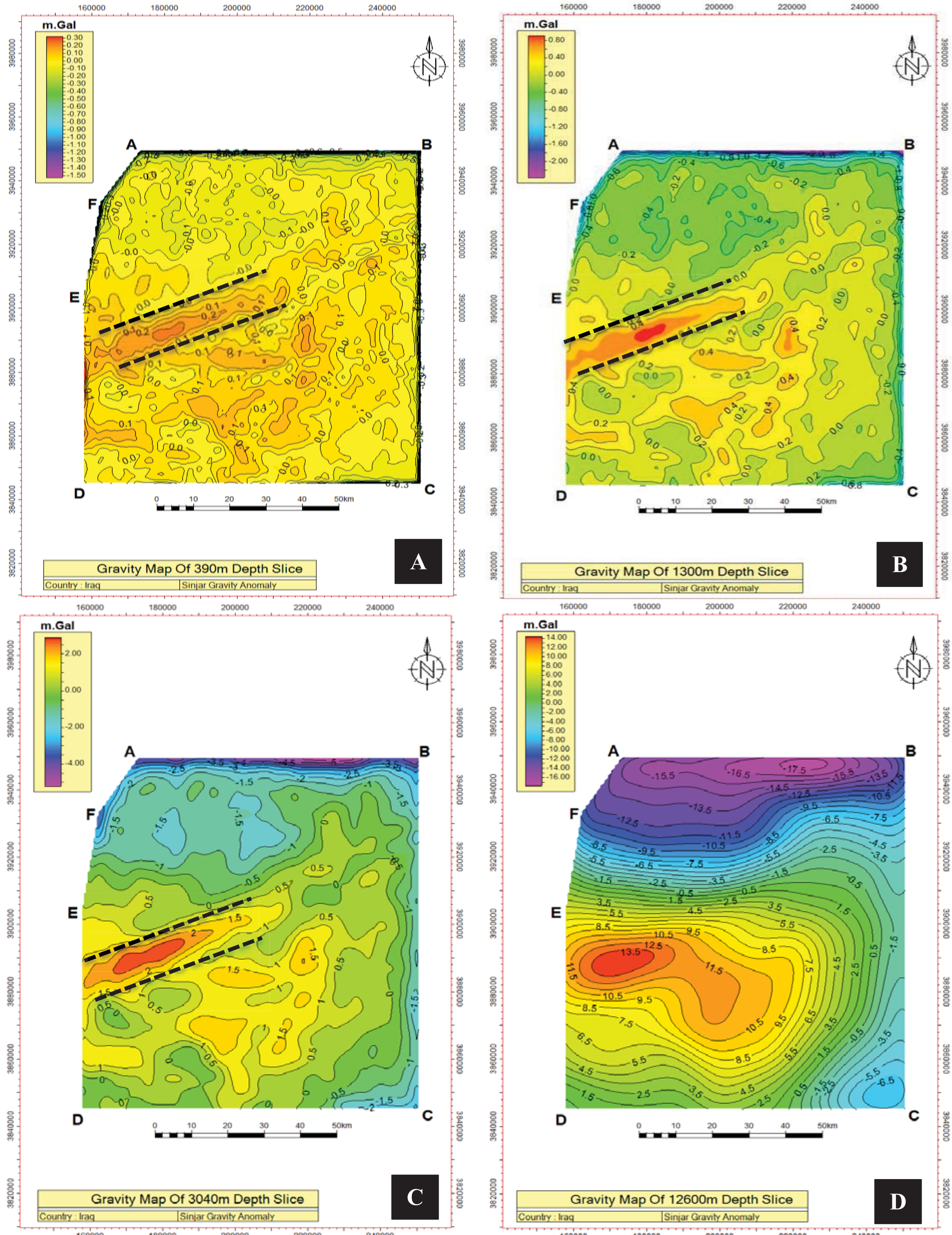

Figure 8. A, B, C and D are Four depth slices illustrate the gravity variation with related depth of subsurface structures, the dashed black arrow highlights the main observed structures within the study area.

The four gravity depth slices/maps illustrate that the gravitational effect differs from the shallow to the deeper investigation depth of the subsurface structures, whereas the high separation of gravity effect (positive and negative anomaly) can be noticed in the deeper depth slice of 12600 m of the study area (figure 8D) in comparison to other three depth-slices (figures 8A, B & C). It can be notice from these depth maps that the relatively shallow-depth gravity maps (figures 8A B & C), the gravity anomaly obviously related to the sedimentary layers and tectonic structures within the study area. However, the gravity anomaly of the deeper depth slice (figure 8D) is more presented to the basement rocks and structures. The latter gravity effect probably response on the dominant positive gravity anomaly that clearly shown in the main Bouguer gravity map of Iraq (see figures 5 and 6).

5.1. 2D Modeling of Gravity Section

The 2D modeling technique was used for the quantitative interpretation of the observed gravity anomaly. The 2D model of selected gravity profile A-B (figure 5) which extends along this study area used FastGrav software; the model shows the relatively high density of basement rocks and an upward mantle that probably causes the effect of positive value (figure 9). Several faults are indicated in the sedimentary sections (particularly in the shallow-depth parts) by potential geophysical methods. Furthermore, several grabens, half grabens, and horst structures, surrounded by normal and reverse faults are displayed in the sedimentary cover (Fouad and Nasir, 2009), which can be noticed through the Bouguer gravity depth maps via “lows” and “high” anomaly features (figure 8a, b, and c).

6. Discussion of Results

In the relatively shallow-depth layers (300 m to ≈ 3000 m), the main structure trends have been identified which also effected by the basement rock uplift. The results of the current study were partly consistent with the previous geological and geophysical studies (e.g., Al-Banna, 1992; Fouad and Nasir, 2009), particularly in relation to the prominent NE-SW direction structure within the studied area, which represents the Al-Khleisia Graben structure.

The shallow-depth anomalies of the area are mainly related to the sedimentary cover layers and tectonically effected structures. The positive gravity is relevant to another structure and is normally related to the relatively high density of subsurface basement rocks, and the negative anomaly is related to the relatively low-density layers/structures.

7. Conclusions

The study area represents a special questionable case due to the positive value of gravity anomaly within the Bouguer map of Iraq, which can be quantitatively interpreted by the 2D model of the selected gravity profile as a high-density basement rock or Mantle upward. The power spectrum analysis of the Bouguer gravitational map illustrated that the prominent positive anomaly is mainly related to the mantle structure rather than the relatively shallow depth structures. The potential Mantle upwards may be related to the geothermal heat flow or the isostasy effect.

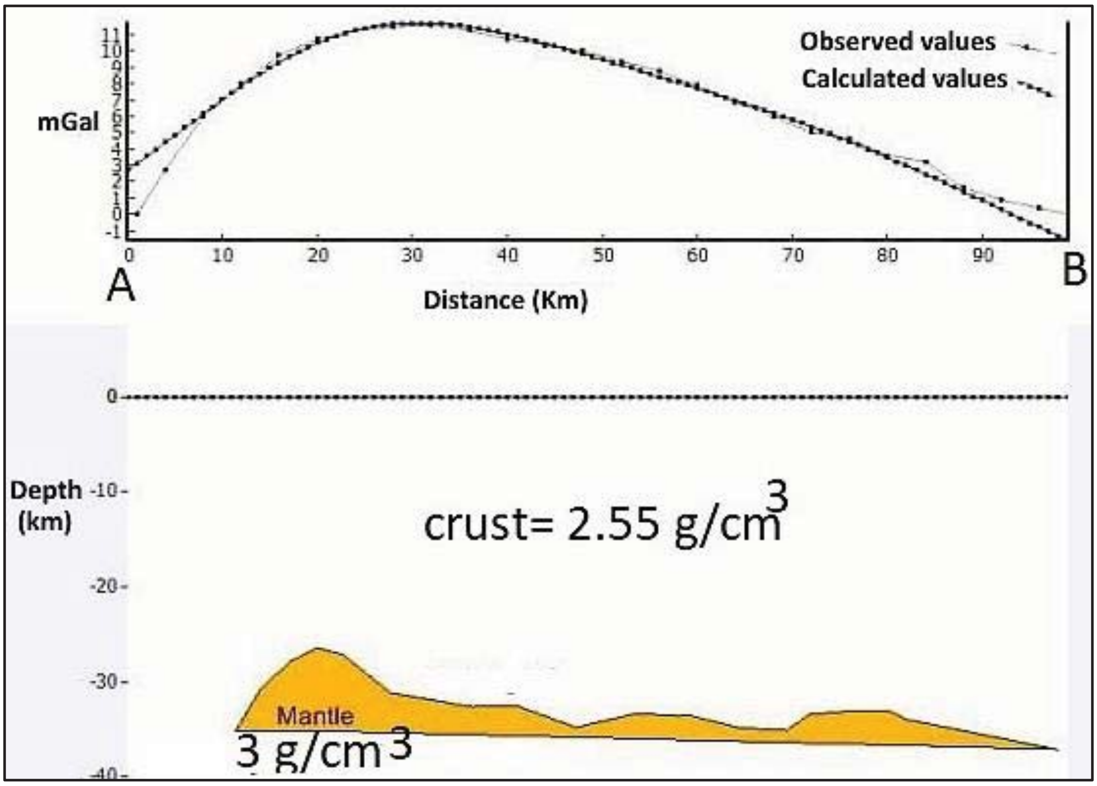

Figure 9. 2D model of a selected gravity profile (A---B) in Figure 5 extended along the study area, basement rock density or Mantle upward probably responsible of the positive gravity anomaly.

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