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DELINEATING THE REGIONAL STRUCTURES AND DEPTH OF BASEMENT ROCKS USING THE GRAVITY DATA ANALYSIS AT WEST ASSIUT, EGYPT

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ABSTRACT

The purpose of the gravity approach is to detect subsurface structures using disturbances in the earth's gravitational field produced at the surface. Gravity was used to outline the subsurface structures; due to the study area includes many huge national projects such as Assiut Cement, New Nasser City and Assiut International Airport, It is important to assess the subsurface geological structures in the area. Bouguer gravity data of Egyptian General Petroleum Company (EGPC 1984) was used to performed Bouguer gravity anomaly map at the study area to start the gravity interpretation by separation of the residual anomaly from regional anomaly and then the data was filtered by mathematical methods called Tilt derivative (TDR), low pass, high pass and downward continuation to apply the gravity filtering using commercial software Oasis Montaj 2015. The Bouguer, residual and regional maps depict multiple structural features (mainly normal faults) with varied tendencies, such as E-W, NE-SW, and NW-SE. The source body derived from these data had depths varying from less than 2000 m to more than 4000 m. The basement depth in the research area below sea level varies between 2160 m and more than 2900 m.

Keywords: Gravity; Subsurface structures; Depth of basement rocks; Assiut; Egypt.

1. INTRODUCTION

The study area is located at 13 kilometers southwest of Assiut, it comprises roughly 580 km^2 and is situated between longitudes 31° 00 E and 31° 15 E and latitudes 27° 00 N and 27° 12 N (Fig. 1). Gravity was used to outline the subsurface structures; due to the study area includes many huge national projects such as Assiut Cement, New Nasser City and Assiut International Airport, It is important to assess the subsurface geological structures in the area. Many filters were used to interpret the gravity data using the Oasis Montaj program [1]. The final form of the processed gravity data can be used in many types of engineering and environmental problems, including determining the thickness of the surface or near-surface soil layer, changes in water table levels, and the detection of buried tunnels, caves, sinkholes and near-surface faults [2]. Many geological studies have been carried out by many researchers and companies on different regions near the study area [3] and [4]. However, No detailed geophysical studies have been conducted on the study area.

2. GEOLOGICAL SETTING:

With heights ranging from 170 to 240 meters above sea level, the topography of the examined area exhibits few abnormalities in the surface (Fig. 2A). From base to top, the exposed Lower Eocene deposits in the Assiut area are subdivided into 3 units: (a) Zawia Formation, (b) Drunka Formation, and (c) Matmer Formation [5] (Fig. 2B).

Fig. (1). The research area's location map.

In some locations of the area, hard solid limestone is revealed on the surface. Gravel and silt make up the surface soil. The rocks found in West Assiut are sedimentary in origin and range in age from the Lower Eocene to the Quaternary (Fig. 3A). The Lower Eocene rocks are found on the plateau that runs alongside the Nile Valley. The Nile Valley's bottom is made up of Lower Eocene rocks beneath the surface. The Nile Gorge is made up of Quaternary and Pliocene sediments. Pliocene strata are made mostly of clay with sand interbeds and rest unconformably over Eocene carbonate. Quaternary deposits are made up of gravel and sand, which are usually covered by silty clay layers (Fig. 3A) [6]. Many writers have looked at the Assiut area's structural setting, including [7], [8], [9], [10], and [11]. As seen in (Fig. 3A), the main direction of surface faulting is northwest.

3. METHODOLOGY

3.1. Bouger anomaly map

The Egyptian General Petroleum Company's Bouguer gravity data (EGPC 1984), which was issued as a set of Bouguer maps of Egypt at 1:500,000 scale is utilized for this study [14]. The gravity anomaly field in the research area varies from a greatest value (-24 m.gal) in the western section to a minimum value (-43 m.gal) in the north and east (Fig. 4). Uplift of thicker basement rock is primarily responsible for the increase of gravity anomaly, whereas lower gravity readings indicate sedimentary basins

3.1.2. Gravity separation

3.1.2.1. Tilt derivative (TDR)

To identify the inclined and vertical lithological and/or structure connections, the derivative filter (TDR) approach was applied to gravity data. The TDR map obtained by applying the filter on the Bouguer anomaly map is shown in (Fig. 5). The boundary between the sedimentary basin (low values) and the basement (high values) is easily discernible. The magnitudes of tilt derivative anomalies in Bouguer map data range from -1.14 to 1.27 radians on this map. These variables are used to locate the structure's edges. A zero-contour line highlights the borders of the low gravity anomaly at the north and southern regions of the tilt derivative (TDR) map of the gravity data. The northern and southern sectors either include a thick sedimentary layer or are underlain by low-density basement rocks due to the low gravity. An uplifted basement block corresponds to the large gravity anomaly in the middle part [15].

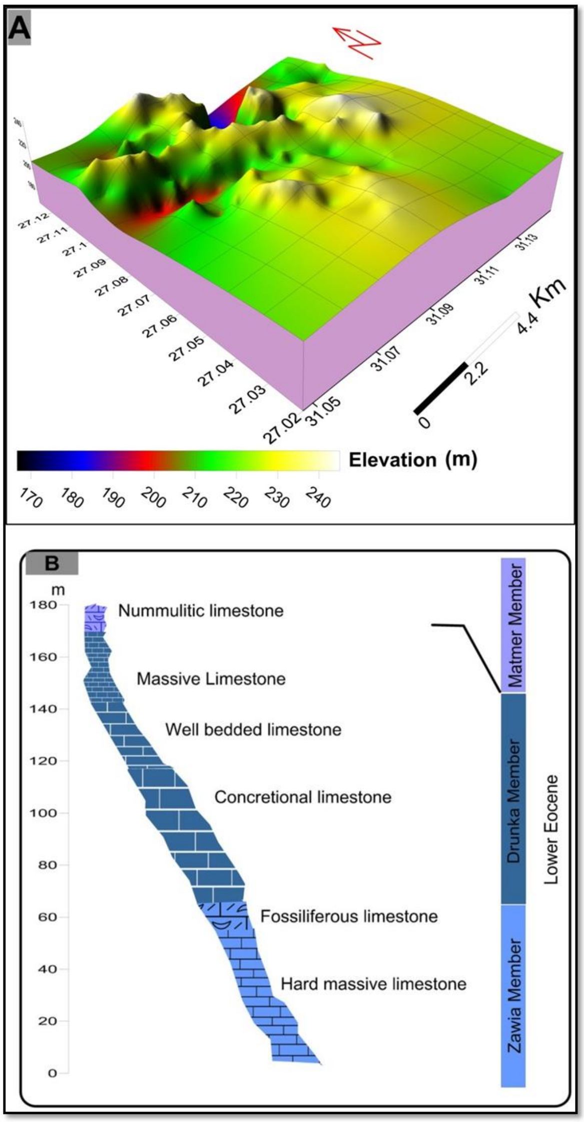

Fig. (2). (A) the research area's elevation map. (B) Stratigraphic cross section of Drunka village's western scarp modified after [3].

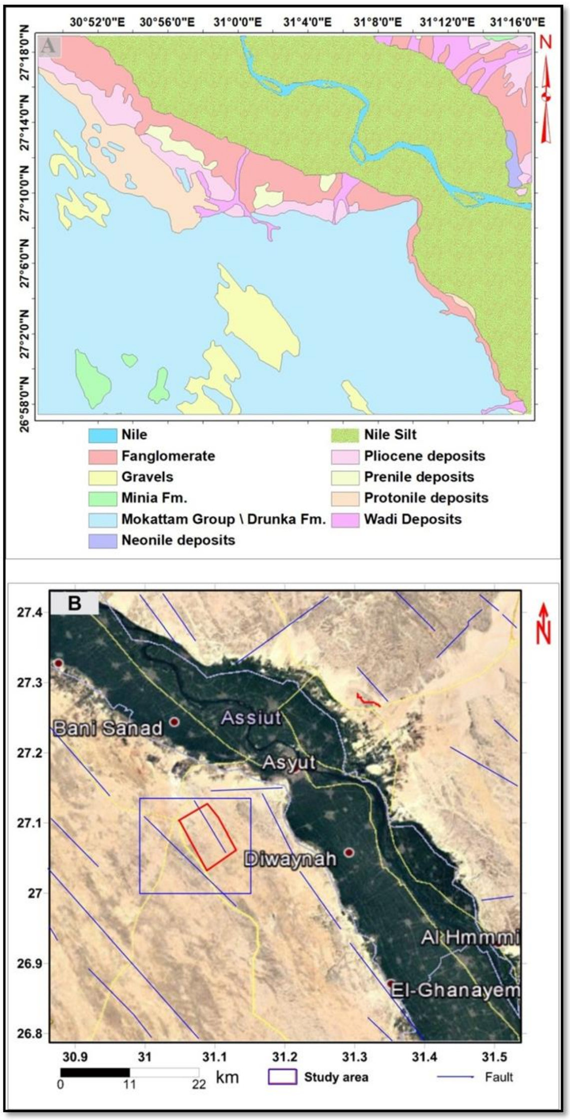

Fig. (3). (A) Geological map of the research region and its surroundings (modified after [12]. (B) A structural map displaying faulting modified after [13].

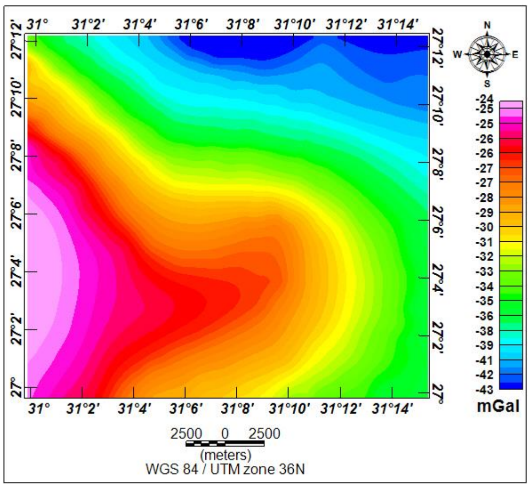

Fig. (4). TDR map of the study area.

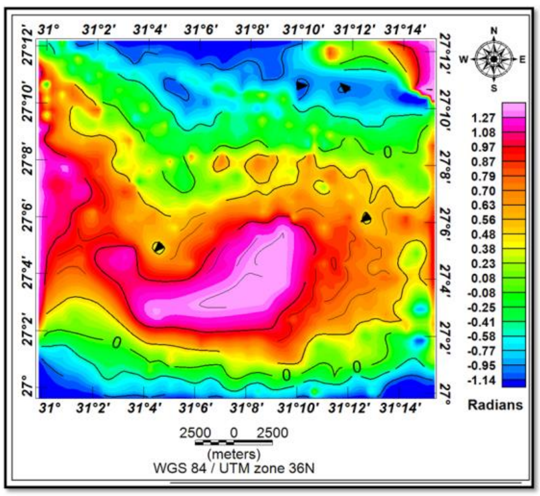

Fig. (5). Bouguer anomaly map of the study area.

3.1.2.2. High and low pass filter

On the Bouguer anomaly map, the residual and regional maps were generated using a low and high pass filter technique with a cut wave number of 0.035 cycle/unit (Fig. 6 A and B). The gravity anomaly field runs from a maximum value (6 mGal) in the central and western sections to a lowest value (-6 mGal) in the north and south parts of the study area, according to the high-pass filter map. Uplift of denser basement rock causes the high gravity anomaly, whereas lower gravity readings suggest sedimentary basins.

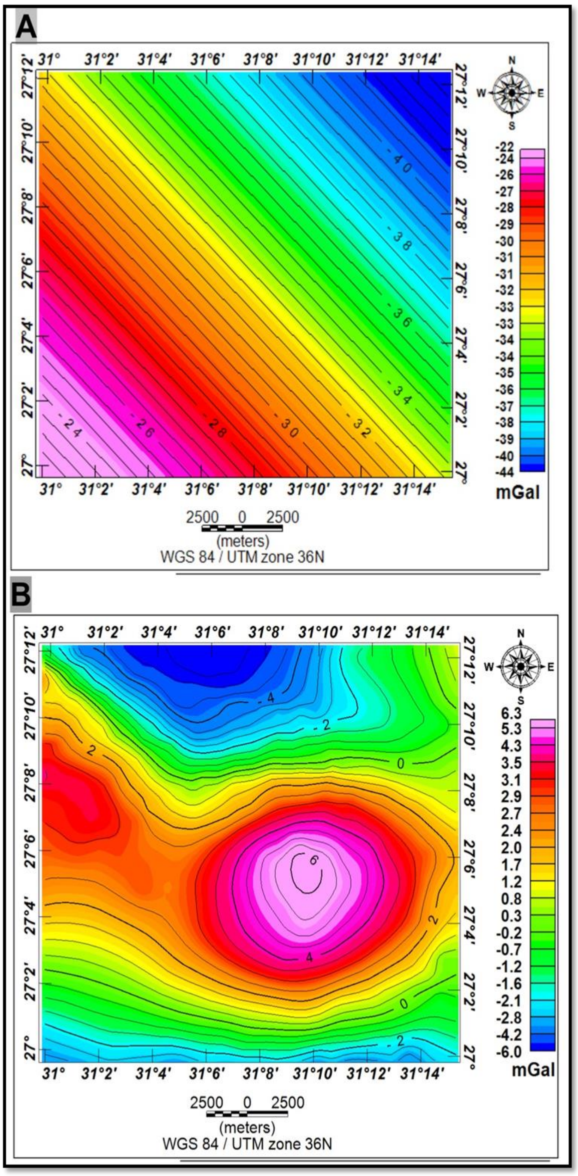

Fig. (6). (A) Regional anomaly map and (B) residual anomaly map using a low- and high-pass filter with a cut wave number of 0.035 cycle/ unit.

3.1.2.3. Downward continuation

Using grid spacing of 100, 500, 800, and 1200 m (Fig. 7 A, B, C, and D), four downward continuation maps were created in this study. The anomalies begin to separate at a depth of 500 m, which could show that the top of the main bodies is near this level. The splitting of anomalies increases as you go closer to level 1200 m, which could indicate that the source body's base is near this level.

4. RESULTS AND DISCUSSION

4.1. Delineating of Structure Elements:

The position and trends of the faults that cut through the study region were discovered using a bouguer, residual and regional gravity anomaly maps (Fig. 8). East-west, northwest-southeast and northeast-southwest are the three directions in which these faults run.

4.2. Basement depth estimation:

4.2.1. Radially average power spectrum

Power spectrum assessment was used as a quantitative method for measuring the depth of the source body using the formula [16].

$$H = -S/4\pi \qquad (1)$$

The depth is represented by H, while the slope of the logarithmic (energy) spectral is represented by S; such technique was applied for gravity data by using (Oasis Montaj software 2015) (Fig. 9). For deeper sources, the approximate annual depth of gravity source bodies is 4000 m and 2000 m for the basement intrusions sources respectively.

4.2.2. Euler deconvolution

Euler deconvolution, sometimes known as Euler depth deconvolution, is a technique for interpreting potential fields. This method was used to calculate the depth of the anomaly source. At each solution, the Euler deconvolution procedure was used. The best Euler depth convolution findings are concentrated in a few areas of the research region and are not evenly distributed. The structural index (SI) is a measure of the field's decay rate as distance from the source increases. (Table.1) shows an appropriate model for structural index value.

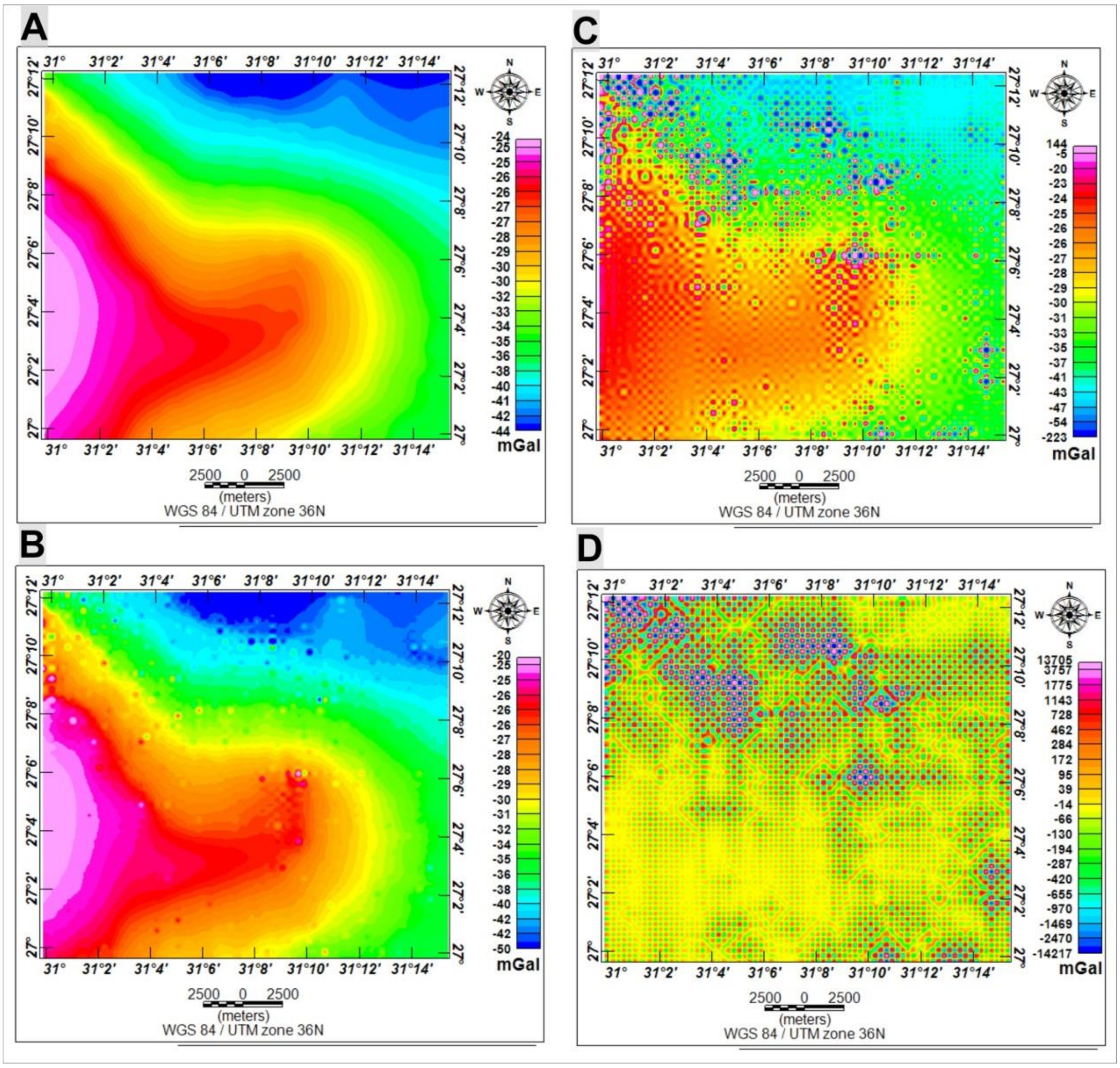

Fig. (7). The downward continuation of Bouguer anomaly map at depths 100, 500, 800 and 1200 m respectively.

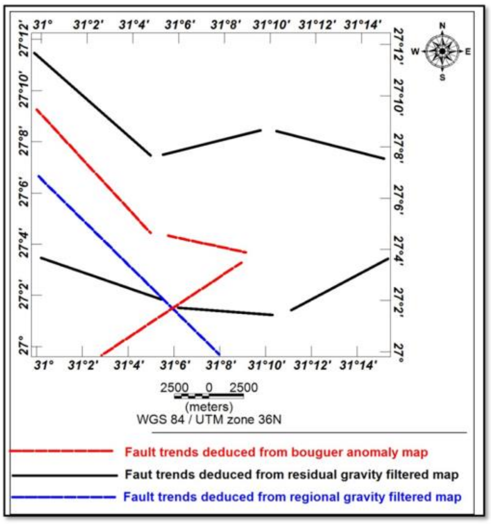

Fig. (8). A map showing the fault trends deduced from Bouguer anomaly map, residual and regional

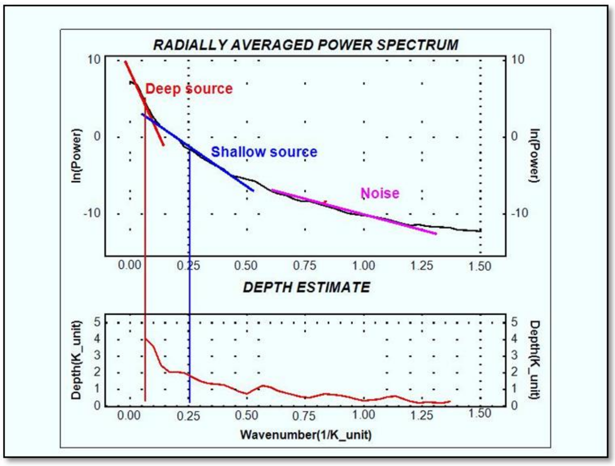

Fig. (9). Radially averaged power spectrum for the gravity data.

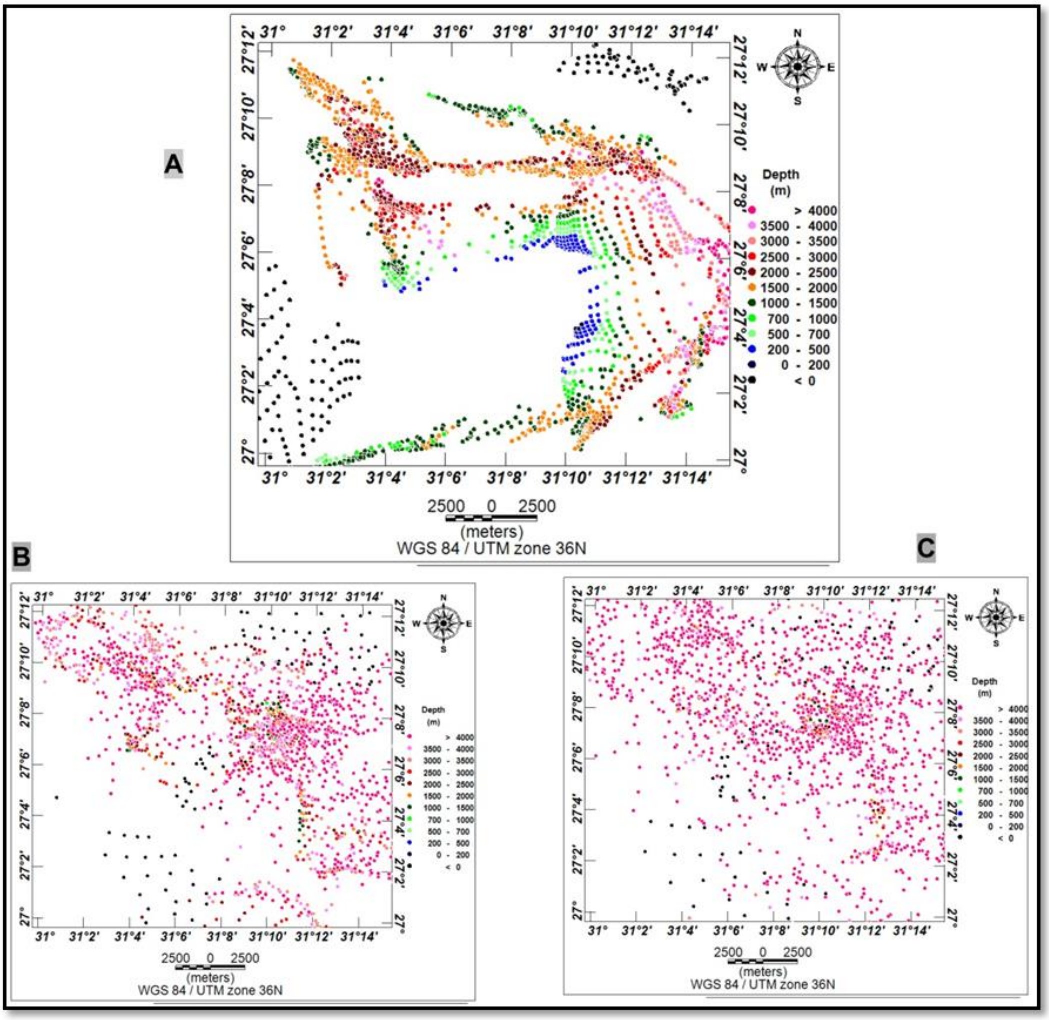

Fig. (10). (A) Bouguer anomaly map Euler solutions with structural index = 0. (B) Structural index = 1 Euler solutions. (C) Structural index = 2 Euler solutions.

The structural indexes used in this study were 0, 1, and 2 to determine the optimal solution for structural index, with SI = 0 displaying the best result (Fig. 10A, B and C).

(Table.1)

SI	Gravity Field
0	Dyke / Sill / Step / Ribbon
1	Pipe / Cylinder
2	Sphere
3	N /A

4.2.3. 3-D gravity model

The GM-SYS 3D program was applied to the observed gravity data to carry out 3-D gravity modeling which is useful in the determination of the depth to the top of the basement surface. It is assumed that all the grids must have the same cell size, dimensions, distance units and projection which indicated by the index grid. The numbers of the cells used in X - direction were 180 and in Y – direction was 168 cells with grid cell size 1000. The model assumed also that, the subsurface is divided into two main layers; the first was for the sediments with density 1.9 g cm-3 and the second layer was for the basement with density 2.7 g cm-3. It is important to note that, the 3-D gravity modeling depends on the fact that, there are two types of the data; the first is the fixed observed grid data which represented by the Bouguer anomaly data as shown in (Fig. 11A) and the second is the variable calculated data as shown in (Fig. 11B). The model gave good agreement between observed and calculated maps with a very small percentage of error map (Fig. 11C). The result of 3D modeling is abasement relief map (Fig. 12A) and 3-D view map (Fig. 12B) which show the basement depth of the study area. The basement depth varies between 2160 m to more than 2900 m in the study area. The basement depth in the northern and eastern parts of the study area is deep, more than 2900 m indicating thick sedimentary cover; in the south, southwestern and central parts of the study area the basement is shallow, around 2160 m. The general dip of basement in the study area (from shallow to deep) is from south-west toward north-east.

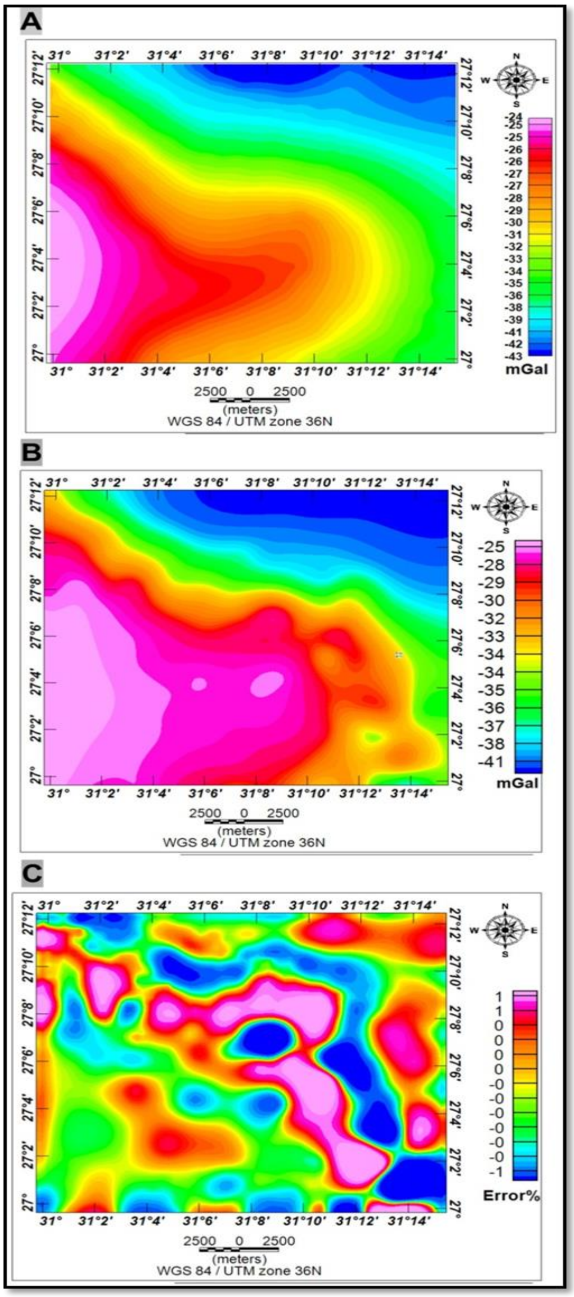

Fig. (11). (A) the observed gravity anomaly map of the gravity data. (**B)** the calculated gravity anomaly map of the studied area. **(C)** error percentage of the gravity data

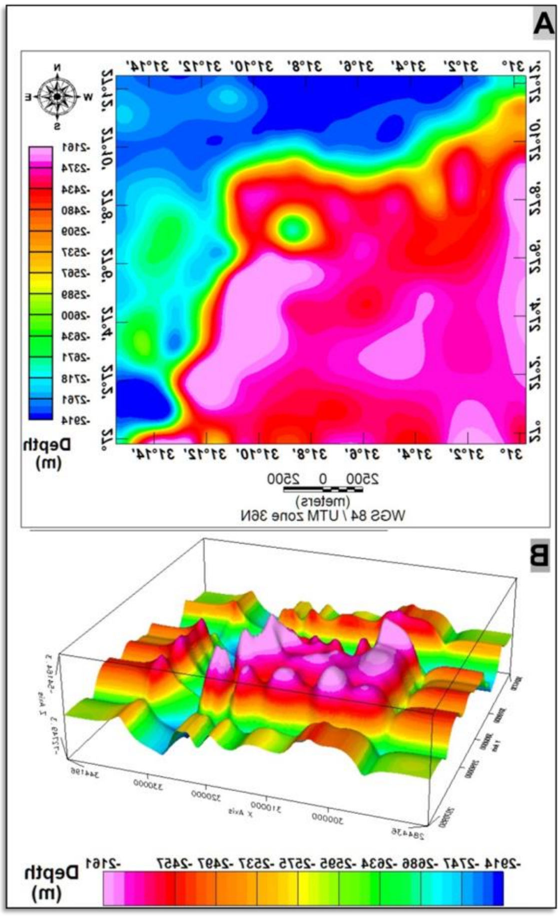

Fig. (12). (A) Basement relief map. (**B**) 3-D view of basement map.

5. CONCLUSION

The Egyptian General Petroleum Company's Bouguer gravity data (EGPC 1984), which was issued as a set of Bouguer maps of Egypt at 1:500,000 scale is utilized for this study. A Bouguer gravity anomaly map was used to separate the residual anomaly from the regional anomaly, and then the data was filtered using mathematical methods such as Tilt derivative (TDR), low pass, high pass, and downward continuation to apply gravity separation using commercial software Oasis Montaj 2015. The principal fault trends in the research area run in the following directions: E-W, NE-SW, and NW-SE., The spectral analysis revealed a depth of 2000–4000 m for shallow and deep sources. The basement depth in the research area below sea level varies between 2160 m and more than 2900 m using the GM-SYS 3D application.

Acknowledgment(s)

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Conflict of interest

The authors declare that they have no competing Interests

REFERENCES

[1] Oasis Montaj Programs. Geosoft mapping and processing system: version 8.3.2 (HJ), Inc Suit 500, Richmond St. West Toronto, ON Canada 2015, N5SIV6.

[2] Hare J, Ferguson J, Aiken C, Brady J. The 4-D microgravity method for waterflood surveillance: A model study for the Prudhoe Bay reservoir, Alaska. GEOPHYSICS. 1999; 64(1):78-87.

[3] Mohamed A, Ella E. Magnetic Applications to Subsurface and Groundwater Investigations: A Case Study from Wadi El Assiuti, Egypt. International Journal of Geosciences. 2021; 12(02):77-101.

[4] Atya M, Meneisy A, Bedair S. Integration of electrical resistivity and time-domain electromagnetic to investigate the subsurface stratigraphic conditions at Assiut Power Plant, Assiut, Egypt. NRIAG Journal of Astronomy and Geophysics. 2020; 9(1):471-482.

[5] Omara S, El-Tahlawi MR, Hafez H. The geology of the environs of Assiut. Bull. Soc. Geograph. Egypt. 1970; 43.

[6] Arfa M, Elshafei F. Soil surface seismic hazard maps for the proposed site of Nasser New City, West Assiut, Egypt. Arabian Journal of Geosciences. 2021; 14(12).

[7] Said R. The Geology of Egypt. Elsevier Pub. Amesterdam, New York, 1962, 377.

[8] Youssef MM, Riad S, Mansour HH. Surface and subsurface structural study of the area around Assiut, Egypt. Bulletin, Faculty of Science, Assiut University. 1977; 6(2):293-306.

[9] Said R. The geological evaluation of the River Nile. Springer Verlage 1981; 138.

[10] Nakhla A, Kenneth NM, Glen TP. Aeromagnetic evidence for a deep sedimentary basin near Assiut, Egypt. Egyptian General Petroleum Corporation. 1986:244-59.

[11] Rizkalla IR. Interpretation of Aero-Magnetic Data around Assiut Area, Eastern Desert, Egypt. In Egyptian Geological Society Proceeding of the 7th Annual Meeting, Cairo 1989 Mar (pp. 65-76).

[12] CONOCO. Geological map of Egypt, scale 1:500, 000, Cairo, Egypt 1987.

[13] Egyptian Geological Survey and Mining Authority (EGSMA). Geological Map of Egypt 1981. [14] EGPC (Egyptian General Petroleum Corporation). Aeromagnetic survey of north Eastern Desert and Gulf of Suez, Western Geophysical Company of America. 1983

[15] Alrefaee H, Soliman M, Merghelani T. Interpretation of the subsurface tectonic setting of the Natrun Basin, north Western Desert, Egypt using Satellite Bouguer gravity and magnetic data. Journal of African Earth Sciences. 2022; 187:104450.

[16] Spector A, Grant F. STATISTICAL MODELS FOR INTERPRETING AEROMAGNETIC DATA. GEOPHYSICS. 1970; 35(2):293-302.

تحديد التراكيب الإقليمية وعمق صخور القاعدة باستخدام تحليل بيانات الجاذبية في غرب أسيوط , مصر.

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الملخص

الغرض من نهج الجاذبية هو تحديد التراكيب الجوفية باستخدام الاضطرابات في مجال جاذبية الأرض الناتج على السطح. تم استخدام الجاذبية لتحديد التراكيب تحت السطحية ؛ نظرًا لاحتواء منطقة الدراسة على العديد من المشاريع القومية الضخمة مثل أسمنت أسيوط ومدينة ناصر الجديدة ومطار أسيوط الدولي ، فمن المهم تقييم التراكيب الجيولوجية تحت السطحية في المنطقة. تم استخدام بيانات جاذبية Bouguer للشركة المصرية العامة للبترول (EGPC 1984] لإجراء خريطة شذوذ الجاذبية Bouguer في منطقة الدراسة لبدء تفسير الجاذبية عن طريق فصل الشذوذ المحلى عن الشذوذ الإقليمي ثم تمت تصفية البيانات بالطرق الرياضية والتي تسمى مشتق الميل (TDR) ، low pass, high pass and downward continuation لتطبيق ترشيح الجاذبية باستخدام البرنامج التجاري Oasis Montaj 2015. تصور خريطة شذوذ Bouguer وخريطة الشذوذ المحلى والاقليمى المتبقية عديد من الفوالق (فوالق عادية بشكل أساسي) مع اتجاهات متنوعة ، مثل E-W ، NE-SW و NW-SE. تراوحت أعماق اجسام المصادر من هذه البيانات من أقل من 2000 م إلى أكثر من 4000 م. يتراوح عمق صخور القاعدة في منطقة البحث تحت مستوى سطح البحر بين 2160 م وأكثر من 2900 م.