Chapter 6

Gravity Application for Delineating Subsurface Structures at Different Localities in Egypt

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Additional information is available at the end of the chapter

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Abstract

Gravity method is important tool for delineating structural elements which dissects the area of study. The gravity tool in the present study is applied on two studied areas. The first area is located at the northeastern part of Greater Cairo, and the second area is located at the northwestern part of Sinai, Egypt. The result of interpretation for gravity data for the first area indicates that there are many directions for fault elements of NE-SW parallel to Gulf of Aqaba and NE-SE parallel to Gulf of Suez and, also, the E-W trend parallel to the trend of Mediterranean Sea. The result of interpretation of the second area indicates different fault elements of different direction such as NW-SE trend parallel to trend Gulf of Suez, NE-SW is parallel to Gulf of Aqaba and E-W trend parallel to the trend of Mediterranean Sea.

Keywords: fault, structural trends, Cairo, Sinai, Egypt

1. Introduction

Geophysical tools are applied to delineate geological structures, to investigate promising areas, and to locate ore bodies by clarifying the distributions of physical properties in the earth. The main targets for gravity survey are mainly used for delineating subsurface structures which control the configuration of oil reservoirs and groundwater aquifers. Gravity survey can be used for geotechnical investigation through determining the subsurface features such as caves, fractures and faults. Gravity methods also can be used for mineral exploration through the interpretation of gravity data that depend on the density contrast between the ore bodies and contrary rock. The gravity data interpretation can used for archeological prospecting to locate the archeological features which are buried at different historical times. Many authors used the gravity data interpretation for groundwater exploration such as [1, 2]. Araffa and Fernando [3] used gravity data to delineate structures and tectonic on northern part of Greater Cairo.

2. Gravity data acquisition

The gravity data collected in two areas by using CG3 Instrument of spacing between stations of 3–5 km according to ease of roads, wadis and tracks. The CG3 Autograv is a microprocessor-based automated gravity meter that has a measurement range of over 7000 mGals, a reading resolution of 0.005 mGals.

3. Gravity data corrections

The measured gravity data are reduced for different corrections such as tide, drift, latitude, free air, and Bouguer anomaly. Also, gravity data are corrected for topographic correction where the two study areas are rough topography and then have direct effect on the gravity measurements using Hummer template.

4. Case studies

The gravity measurements were carried out on different localities in Egypt for delineating subsurface structures which have been controlled the configuration of groundwater aquifers.

4.1. Area Northeastern part of Greater Cairo

The Greater Cairo consists of three governorates: Cairo, Giza, and Kalubia. The Greater Cairo is located in northern Egypt, known as Lower Egypt. Although the Cairo metropolis extends away from the Nile in all directions, the governorate of Cairo resides only on the eastern bank of the river in addition to two islands within it on a total area of 214 km^2 (**Figure 1**). Greater Cairo is affected by different fault elements [4–6]. Araffa [7] evaluates the structural elements in Mokattam area (east Cairo). The present study aims to detect the fault elements and their role on the distribution of the basaltic sheet, to determine the basins and uplifts, as well as to estimate groundwater and oil potentiality. The last target of this study is to evaluate the active fault elements and potential effects on the environment through population and constructions.

4.1.1. Geology of the study area1

The geological setting of the study area is investigated through the geological map which is published by [8] (**Figure 1b**). The geological map shows that the cultivated parts are occupied by the western part of the study area. Geologically, the study area contains different geological units of different ages such as Quaternary, Middle Miocene, and Oligocene deposits. Different formations that belong to Quaternary deposits are represented in the study area and mainly composed of sand sheets which are located at the eastern part of the area and sand dunes which are found at the central and southern part of the area.

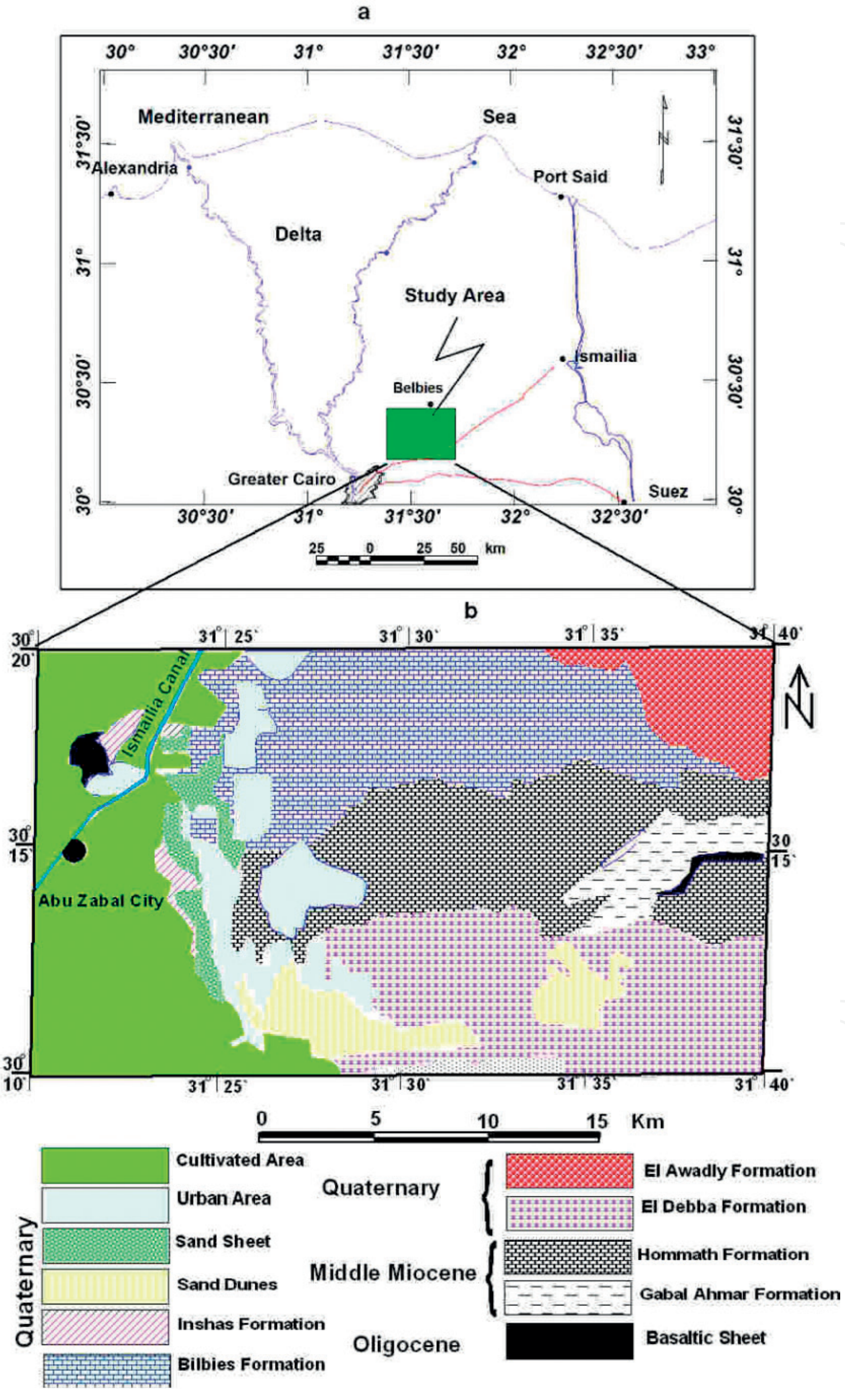

Figure 1. (a) Location map of the area1 and (b) geologic map of the study area1 (Araffa et al, 2014).

While Inshas Formation is composed of sand, intercalated with Nile mud and silt, occupies the eastern part of the study area, the next formation of Quaternary deposits is the Bilbies Formation which consists of sand and carbonate pockets located at the northern part of the area. El Awadly Formation is located at the northeastern part and composed of cross bedded gritty sands. The last formation of Quaternary deposits in the study area is represented by El Debba Formation which covers the southeastern part of the area and is composed of sand intercalated with flint. The Middle Miocene deposits are represented by Hommath Formation, which are composed of sandy limestone, sandstone, and sandy marl, occupying the central part of the survey area. The Oligocene deposits are represented by two formations: the first one is Gabal Ahmar Formation located at the eastern part of the Greater Cairo and consists of fine sand and sandstone, while the second formation is represented by basaltic sheet which is located at the western part of Greater Cairo and lies at the north of Abu Zabal city.

4.1.2. Gravity data and interpretation

Two thousand two hundred and fifty stations are carried out to cover the study area using CG-3 Autograv (**Figure 2a**). The gravity anomalies observed in the Bouguer field are caused by lateral density contrasts within the sedimentary section, crust, and subcrust of the earth. The corrected gravity data is then used to construct a Bouguer anomaly map (**Figure 2b**) using [9].

4.1.3. Regional/residual separation of gravity data at area1

The regional-residual separation technique is carried out to filter the regional component, which originates due to deep-seated sources from the residual component, which is related to local, shallow structures. Least squares technique is used to perform the gravity field's separation [10]. Calculations for different orders up to the fifth order were used to estimate the best order of separation. The results of the regional-residual separation for different orders were mapped by [9]. **Figure 3a–e** represents the regional component for the first, second, third, fourth, and fifth orders, respectively.

Figure 4a–e represents the residual component for the first, second, third, fourth, and fifth orders, respectively. A correlation factor r(x,y) has been calculated to select the best order of residual for gravity interpretation. **Table 1** shows that the best order for gravity separation is the third order. The residual gravity map of the third order was used for gravity interpretation to delineate the structural elements that dissect study area. The fault map (**Figure 5**) reveals different structural trends such as NW-SE, NE-SW, and the E-W trends parallel to the Gulf of Suez, Gulf of Aqaba, and Mediterranean Sea, respectively.

4.1.4. Conclusion of area1

From the quantitative interpretation of the gravity data, we can conclude that:

The fault elements dissecting the area are active and have characteristic trends of NW-SE, NE-SW, and E-W.

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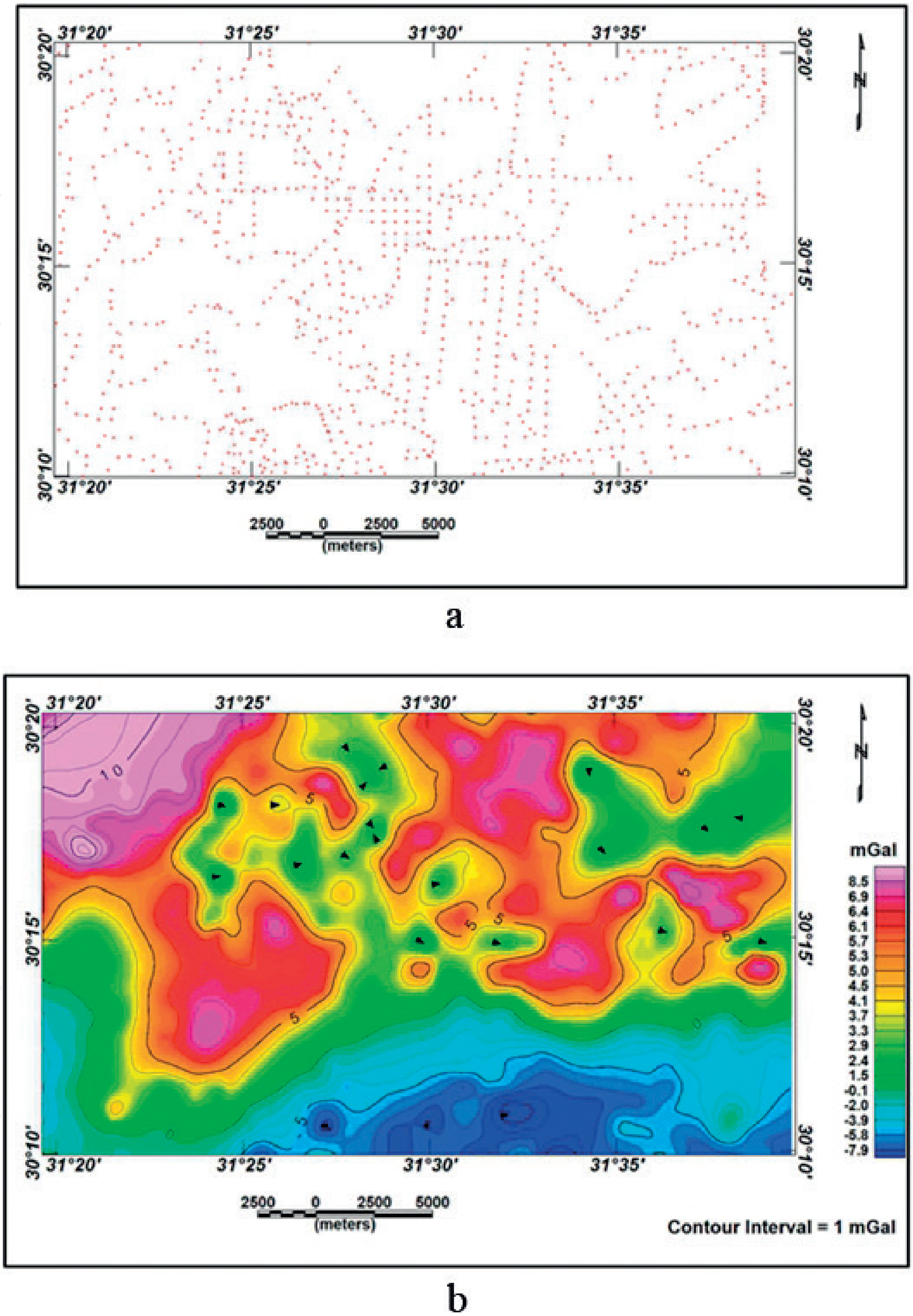

Figure 2. (a) Location map of measured gravity stations and (b) Bouguer anomaly map at area1.

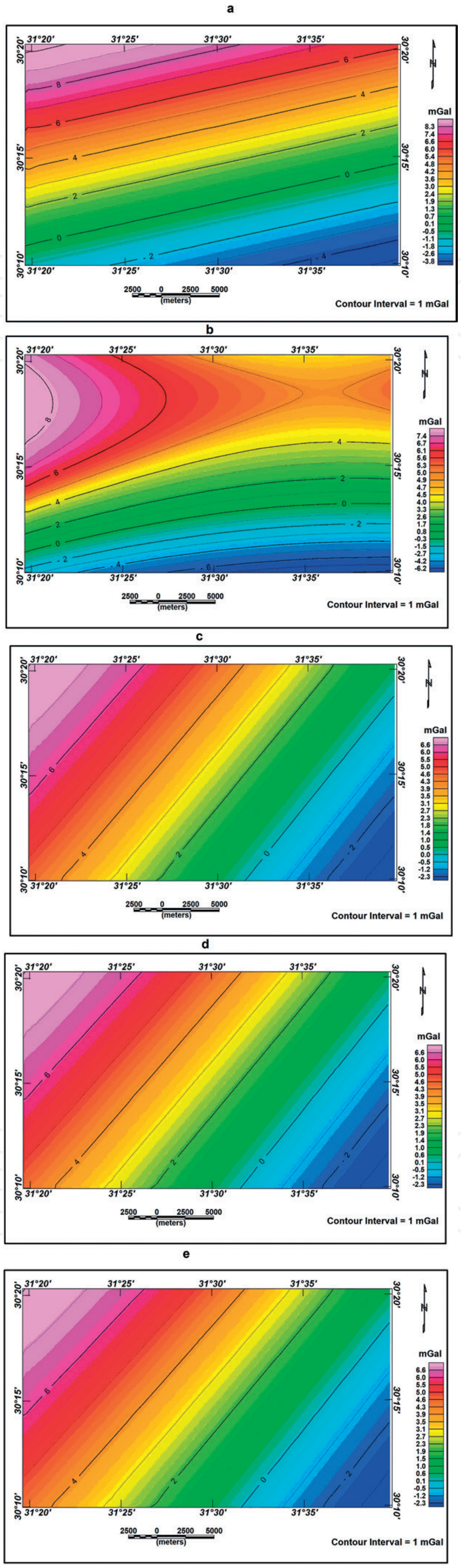

Figure 3. Regional maps for the (a) first order, (b) second order, (c) third order, (d) fourth order, and (e) fifth order.

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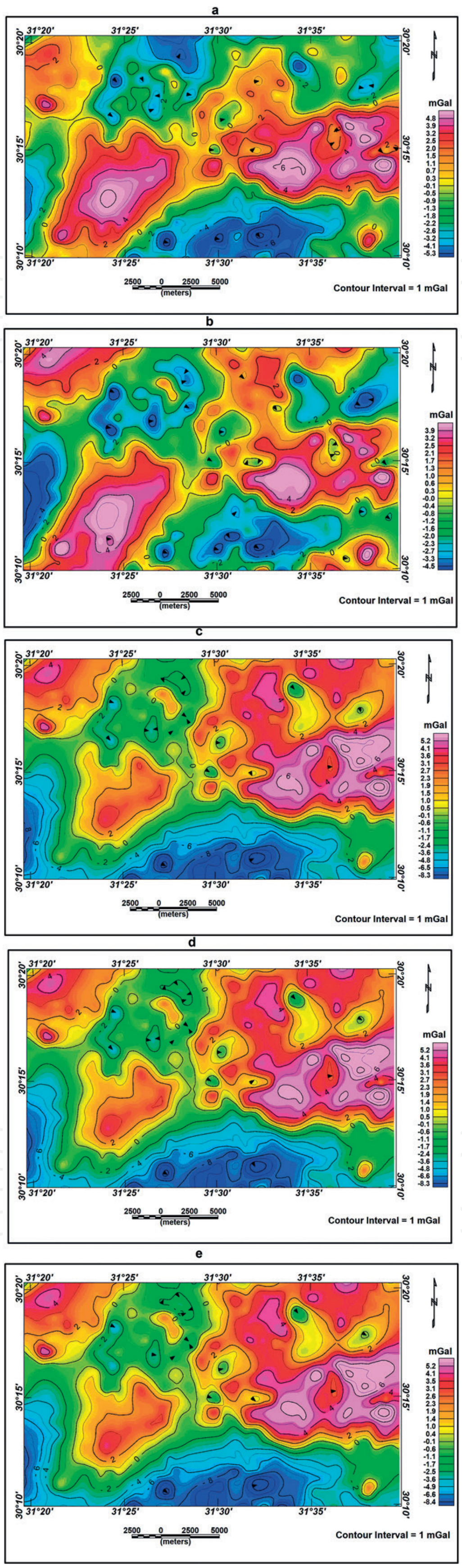

Figure 4. Residual maps for (a) first order, (b) second order, (c) third order, (d) fourth order, and (e) fifth order at area1.

Order	Value
r12	0.919825
r23	0.666593
r34	0.999966
r45	0.999966

Table 1. Correlation factor for different orders.

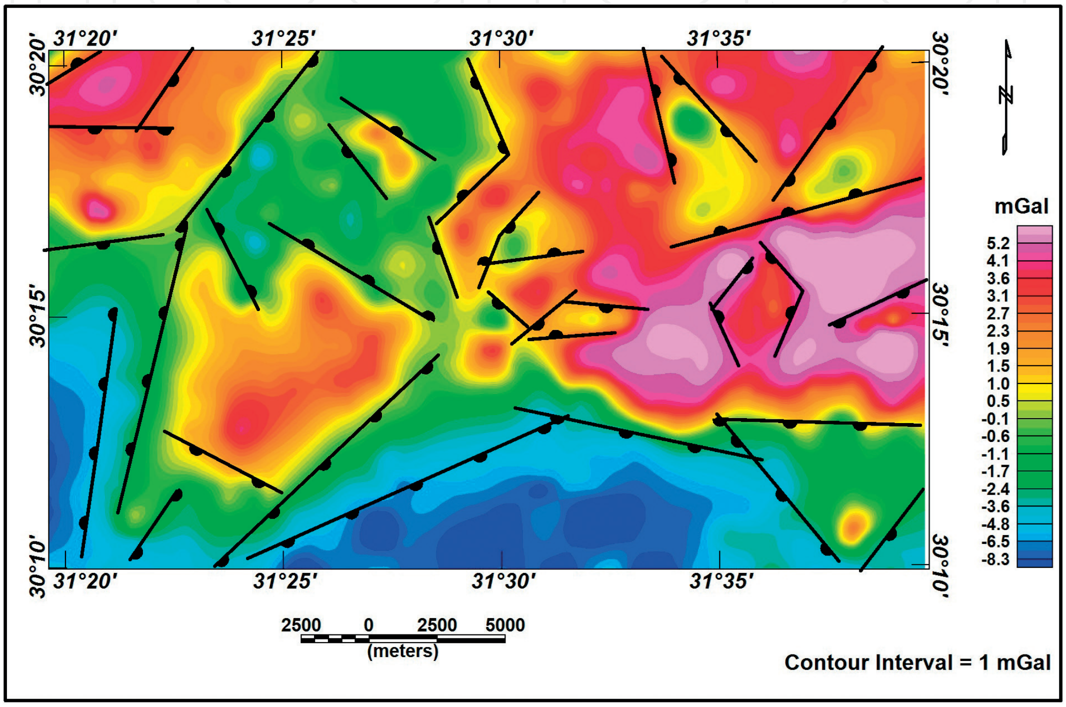

Figure 5. Location of possible faults as inferred from the gravity map of the study area1.

4.2. Area2: Northwestern Sinai, Egypt

Area2 is located at the eastern bank of the Suez Canal of northwestern part of Sinai around Al Qantara East and lies at latitudes 30° 29′ 35″ and 30° 56′ 43″ N and longitudes 32° 22′ 34″ and 32° 43′ 06″ E and represents an area of 1648 km^2 (**Figure 6**).

4.2.1. Geology of the area2

The surface geology of area2 is a part of geological map of Sinai which is constructed by [11]; the study area contains different geological units of different geological ages such as deposits of Quaternary age which include two sub-ages such as Holocene and Pleistocene. The deposits of Pleistocene contain two formations; the first one is Sabakha, which outcrops at the western part of the area2 beside the bank of Suez Canal and at the northwestern part of the area2. The second formation is the sand sheet and sand dunes which cover most the study area2. The deposits of Pleistocene in the study area include two formations (Al Qantara and

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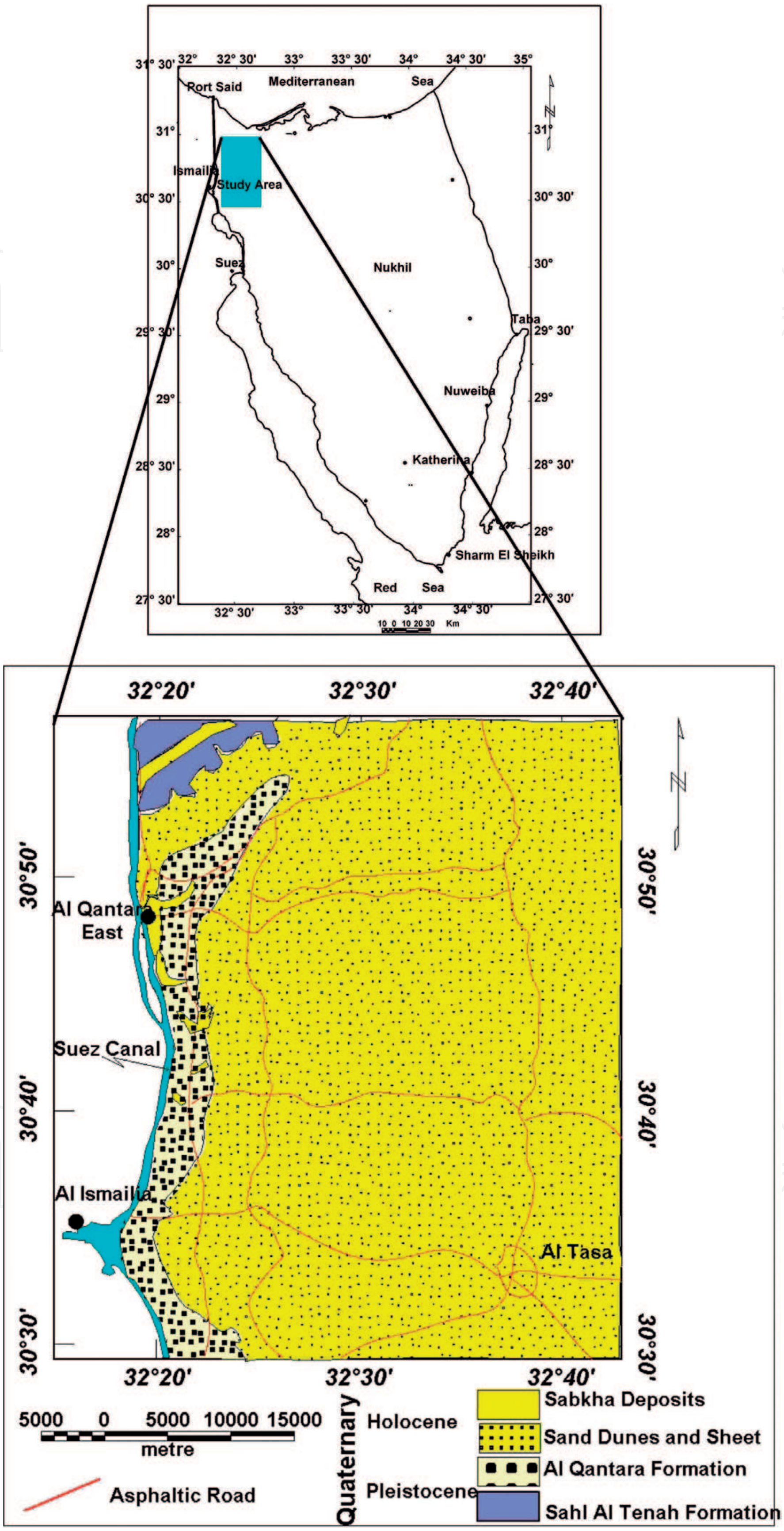

Figure 6. Location of geologic map of area2 (modified after UNESCO Cairo Office [11]).

Sehl Al Tinah). Al Qantara Formation consists silty sand with clay intercalation. Sehl Al Tinah Formation is composed of sand and silt (**Figure 6**).

The subsurface stratigraphy of the study area2 was denoted from the borehole drilled at distance of 60 km south the study area and located by latitude 29° 50′ 31″ and longitude 32° 39′ 36″ of depth 500 m. The description of lithostratigraphy for the borehole is shown as the following, Alluvium of Quaternary deposits up to depth of 30, Middle Miocene of depth from three formations 0 to 80 m (Ayun Musa Formation), which consists of sand intercalated with clay. The Lower-Middle Miocene deposits include two formations (Abu Rudeis and Nukhul). The Abu Rudeis Formation is located at depth from 80 to 230 m and represented by mud and clay. The Nukhul Formation is formed by clay and sandstone. The Lower Cretaceous is represented by Malaha Formation which consists of sandstone intercalated with clay. The Malaha Formation is represented by deep Nubian sandstone aquifer in the area2 (**Figure 7**).

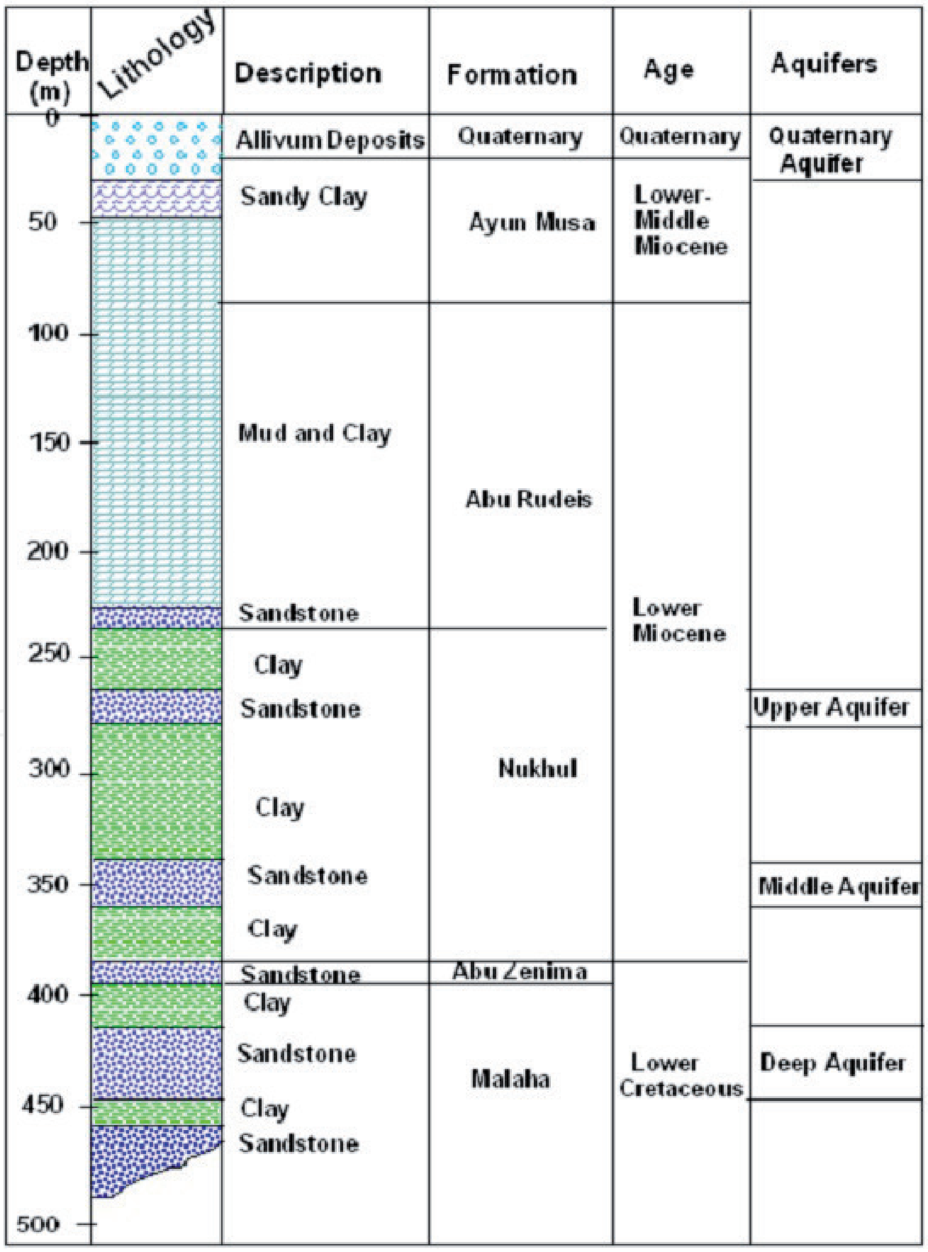

Figure 7. Al Qantarah borehole drilled at Al Qantarah Coast Village.

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4.2.2. Gravity measurements and interpretation of area2

Sixty-five gravity stations have been done using gravimeter of model CG3 Autograv. The collected gravity data were corrected to different gravity corrections such as drift, tide, free air, Bouguer, latitude, and topographic corrections using specialized software [9]. The corrected gravity values were resented by Bouguer anomaly map using [9]. The gravity anomaly map (**Figure 8**) reflects different high and low anomalies according to density variations of subsurface rocks. The gravity anomaly map separated into two components (regional and residual which are related to deep and shallow sources). The least squares technique was applied for gravity separation. **Table 2** indicates that the calculations of least squares technique are carried out up to the fifth order and reflect that the best order for gravity separation is the fourth order. **Figures 9–13** represented the regional and residual for the orders from the first to fifth. The fourth order residual gravity map

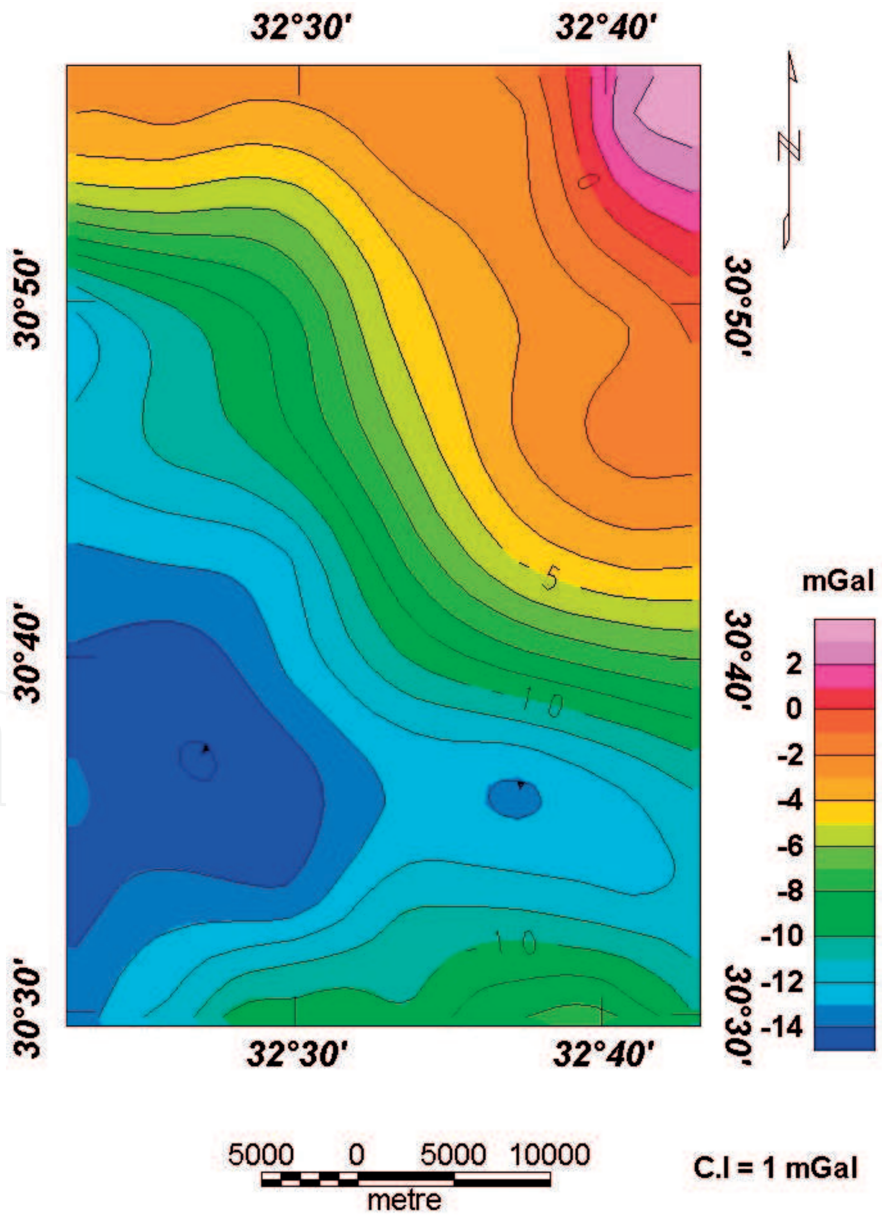

Figure 8. Bouguer anomaly map of area2.

Order	Value
r12	0.7584
r23	0.4728
r34	0.25965
R45	0.9999

Table 2. Correlation factor for different orders.

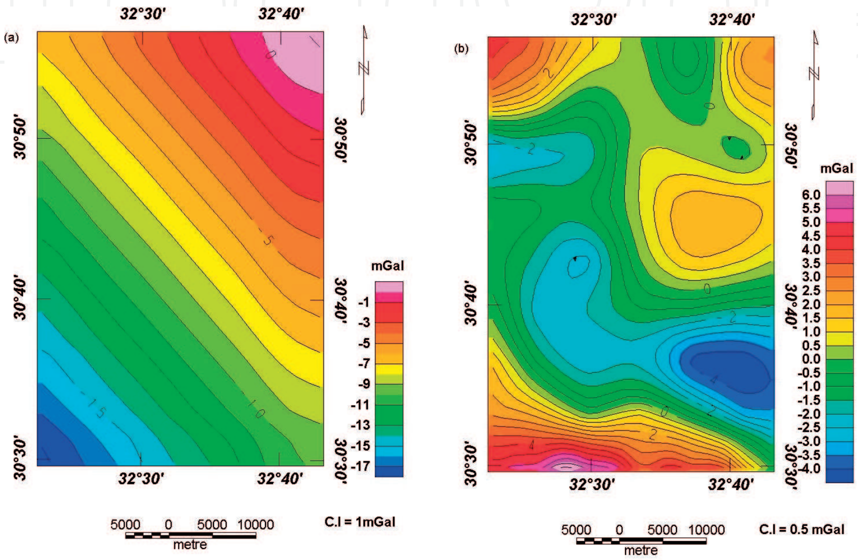

Figure 9. (a) First-order regional Bouguer anomaly map and (b) first-order residual Bouguer anomaly map.

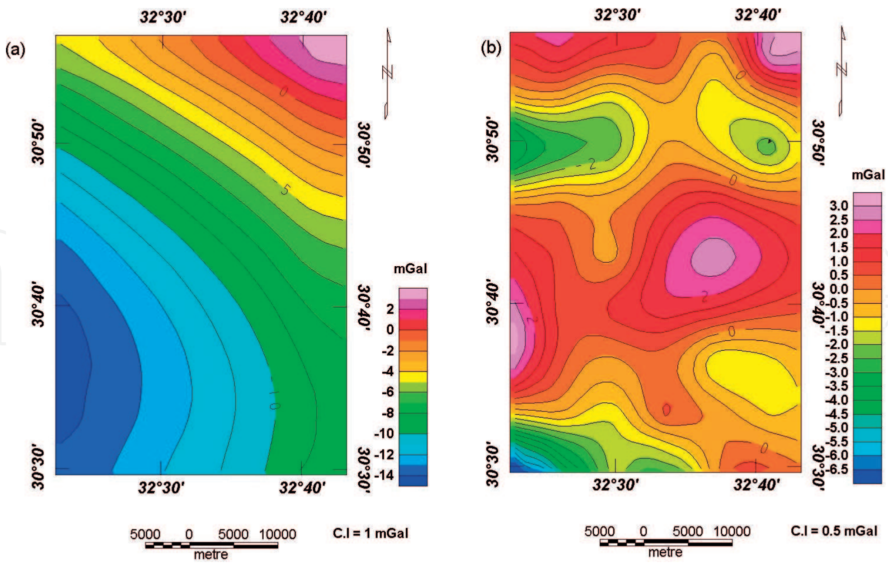

Figure 10. (a) Second-order regional Bouguer anomaly map and (b) second-order residual Bouguer anomaly map.

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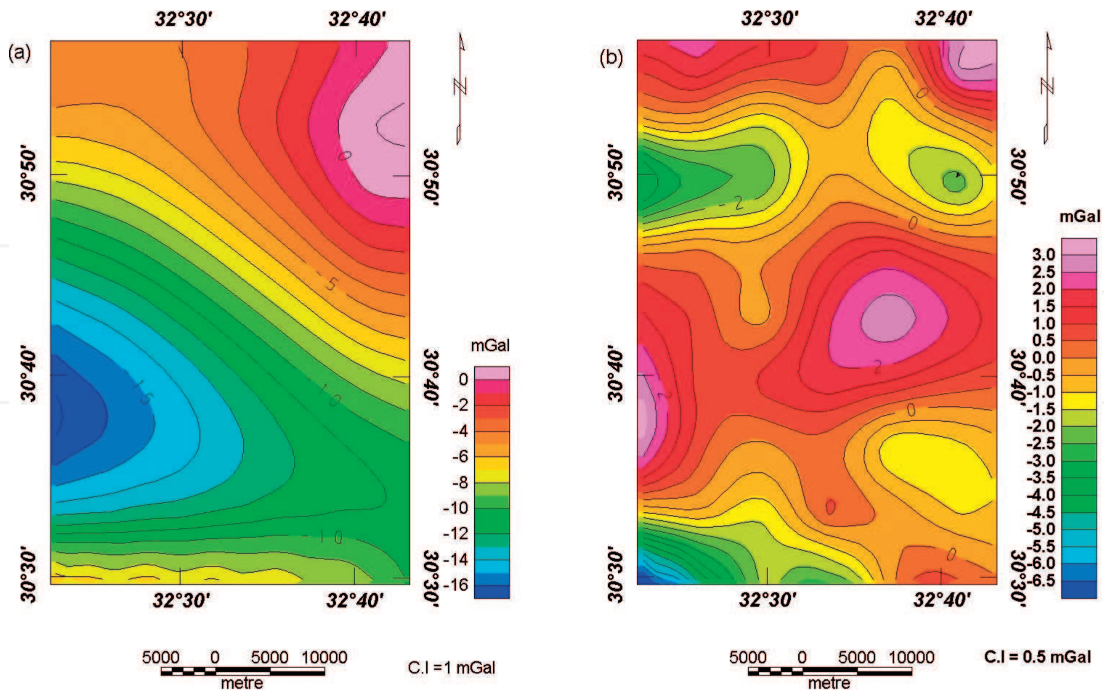

Figure 11. (a) Third-order regional Bouguer anomaly map and (b) third-order residual Bouguer anomaly map.

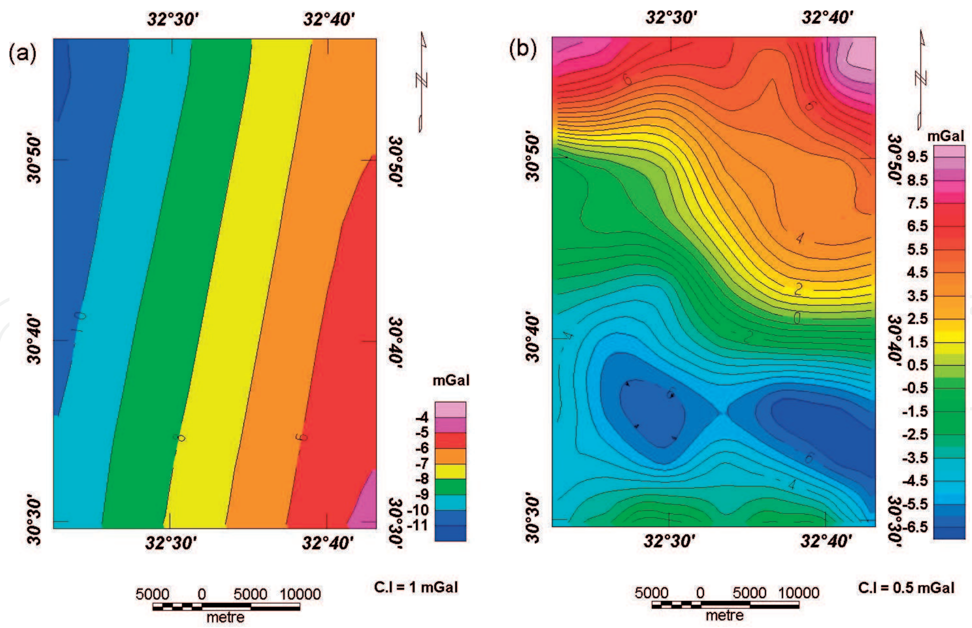

Figure 12. (a) Fourth-order regional Bouguer anomaly map and (b) fourth-order residual Bouguer anomaly map.

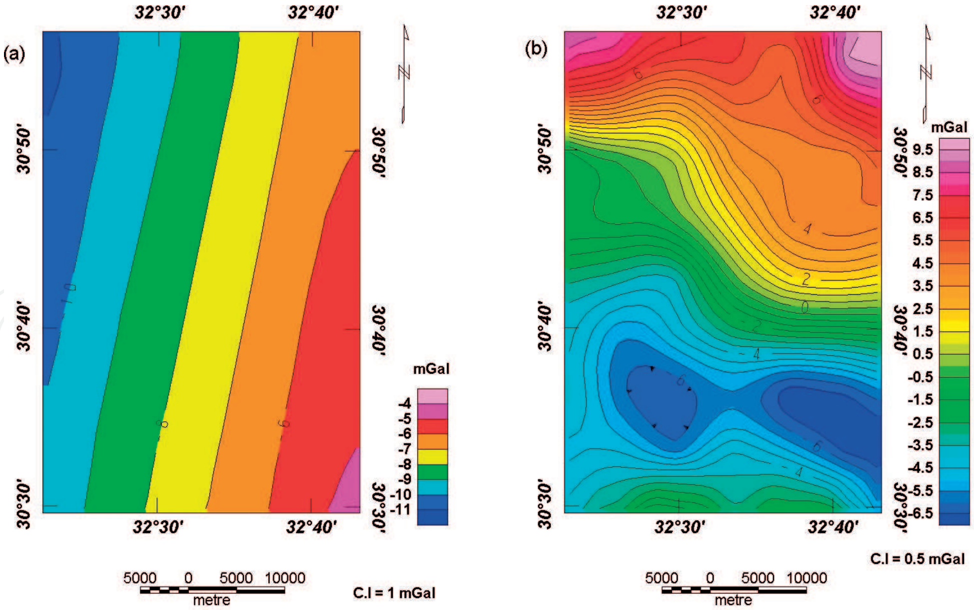

Figure 13. (a) Fifth-order regional Bouguer anomaly map and (b) fifth-order residual Bouguer anomaly map.

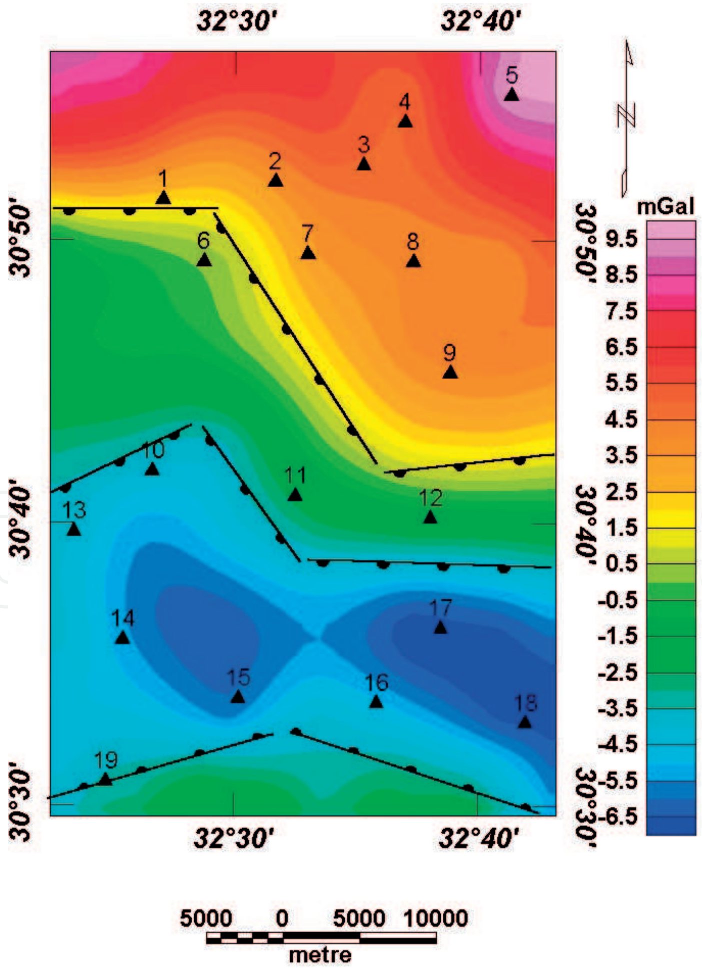

Figure 14. Fault elements dissecting study area from gravity interpretation.

was used for gravity interpretation to delineate the fault elements that dissect study area and controlled the geometry of the groundwater aquifers. **Figure 14** represents the fault map in the study area which shows different fault elements of different directions such as NW-SE trend parallel to trend Gulf of Suez; NE-SW is parallel to Gulf of Aqaba and E-W trend parallel to the trend of Mediterranean Sea. The result of gravity interpretation indicated that the study area is dissected by different fault elements of trends NE-SW, NW-SE, and E-W.

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