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Implications of Latest Earthquakes from Geophysical Surveys in Shaikhan Area Northern Iraq

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ABSTRACT

The study area that located in the northeast Mosul was be subjected to multi-earthquakes scattered in the whole area with different magnitudes, intensities and depths. Earthquakes data recorded by the European – Mediterranean Seismological Center. A total of (83) gravity stations were measured using Lacoste–Romberg gravimeter. A large portion of area could not be covered due to unavailability of tracks. All corrections were corrected for especially the implementation of terrain correction using the recent techniques to find out the Bouguer anomaly of the study area. The epicenters zone of earthquakes and their aftershocks were identified by EMSC which are located around Shaikhan district. Simulation to the Bouguer anomaly data was applied by using Oasis montaj program and gravity models along seven profiles in W-E, SE-NW, and SW-NE directions were performed. The interpreted models illustrate that the most earthquakes are corresponding with the faults movement lines. However, on the basis of our comparative analysis of gravity data results and epicenter locations, the researchers would like to confirm that the most aftershock seismic activity occurs at a depth of 2 km (Paleogen and Cretaceous formations) that represents the brittle-ductile transition zone in the study area. The present study indicates a number of suggested faults that displayed on the DEM which may be predicted associating with other earthquakes epicenters around them in the future.

Key words: Earthquakes, Gravity, Faults, Shaikhan, Northern Iraq

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INTRODUCTION

The study area is located in the northeast Mosul, it is situated with the crossroads of Shaikhan anticline to the east (near of Shaikhan province) and Bashiqa anticline to the south. The location of the study area on the tectonic map is shown in (Fig. 1). The target area of this study, was severely damaged by frequent earthquakes. The concentration of damage is thought to have been caused by the characteristics of the earthquake ground motion affected by the local subsurface structure southern Shaikhan village. Tectonically Iraq is situated in a relatively active seismic zone at the northeastern boundaries of the Arabian Plate. The matching Zagros, Tauros Belts obvious the subduction of the Arabian plate into the Iranian and Anatolian Plates. The major and wide spread lineaments are the axes of the anticlines which have the general direction of Zagros (NW-SE) and Tauros (E-W) Folds. The trends of theses axes are nearly normal to the direction of the enforced stress. By reason of differences in the thicknesses and mechanical stratigraphy of the sedimentary rocks, the axes of anticlines are not constant but plunge in different pattern[(1)]. The area of study falls close to the foot hill zone where the basement depth is approximately varying from 6km to 9km. In such a complex regions, the seismic method has its own limitation to map the geological configuration, because energy transmission is very scanty and most part of the energies absorbed by the formations at the top subsurface in this area. To triumph over this problem it is always recommended to utilize one of passive geophysical methods to complement some value added constraints information to seismology data. Gravity data acquisition has been carried out in the geologically complex areas of southern Shaikhan anticline and its surroundings.

The surface rocks in the study area are included of the Quaternary, the Tertiary, and the Cretaceous formations. Bakhma Fn. (upper Cretaceous) is scattered in the core of Shaikhan anticline on the northern edge of the study area[(3)]. The purpose of this study was to determine the subsurface structures of the study area by the use of gravity observation records and earthquakes location.

Seismic history

The seismic history reveals yearly seismic activity of different strength[(4)]. Earthquake data from 1900-1988 was utilized for the seismicity studies. Most earthquakes are spread on the boundaries of the Zagros-Tauros subduction zones, in addition to few intraplate type occurs on the tectonically stable zone to the west. It was found that 95.5% of the earthquakes have magnitudes range of (4.0-5.5) and that 75.5% of them have a focal depth range of (0.0- 50.0) Km[(4)].

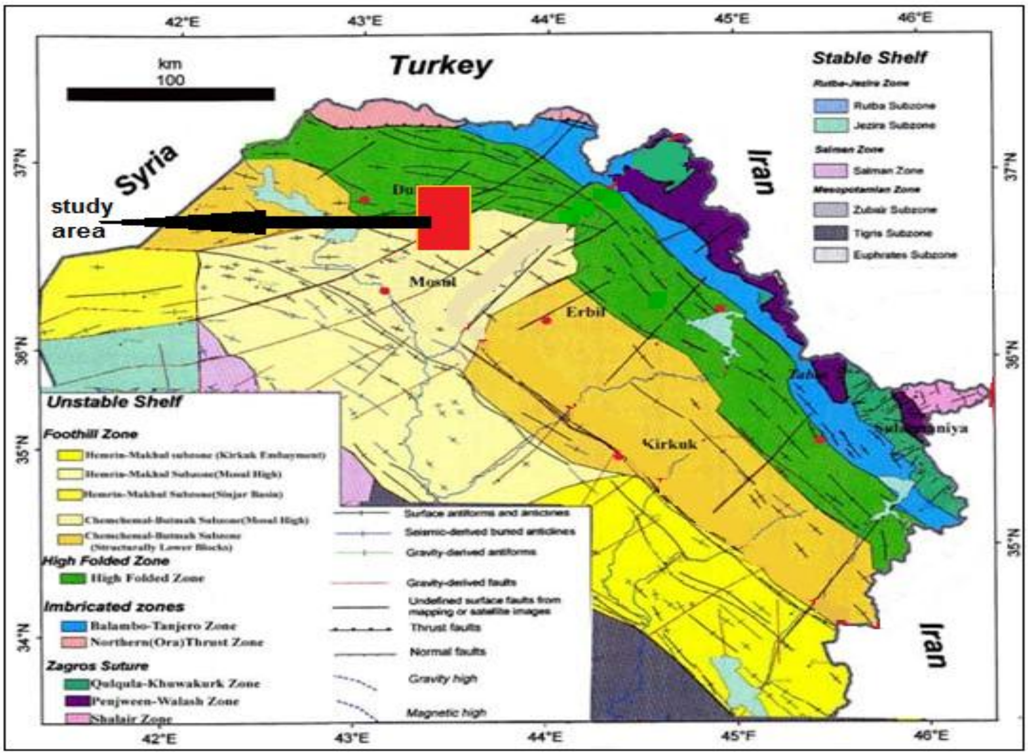

Fig. 1: Location of the study area on the Tectonic map [(2)].

In general, the magnitude of seismic activity in Nineveh government is intermediate, in the range of (2.6-5.9) degrees in Richter scale for the last ninety years, and the focal depth is shallow. There are no major earthquakes noticed in the south of folded zone .Scattered activity is found somewhere else, and have shown a general association of epicentral locations with major geological structure. These data were utilized to draw a seismotectonic map of the Nineveh governorate and surrounding area, (Fig.2) showing the relationship between earthquake and epicenters and main geological features. This map has been used to provide locations of earthquake risk throughout the region [(5)].

MATERIAL AND METHOD

Seismicity of the study area

The study area is seismically active with recent major and minor earthquakes ranged of (2.1-5.0)magnitude in Richter scale with epicenters between(36,58°N - 43,27°E and 36,90°N - 43,55°E) and focal depth range of (2-10)km. The preliminary earthquakes information has been summarized in the (Table 1). Earthquake data recorded by the European – Mediterranean Seismological Center and collected from the web site **www.emcs.csem.org**[(6)]. (Fig.3) shows The distribution of earthquakes on the Digital Elevation Model (DEM) of the study area .

Gravity data

Benefit of potential field data in siesmotectonic studies has been accentuated from time to time and to great extent assisted in distinguishing the weak zones, viz. faults, fractures and crustal heterogeneities that are closely related to seismicity and are widely used in supplying insights on the geologic construction of any seismogenic district[(7)] .

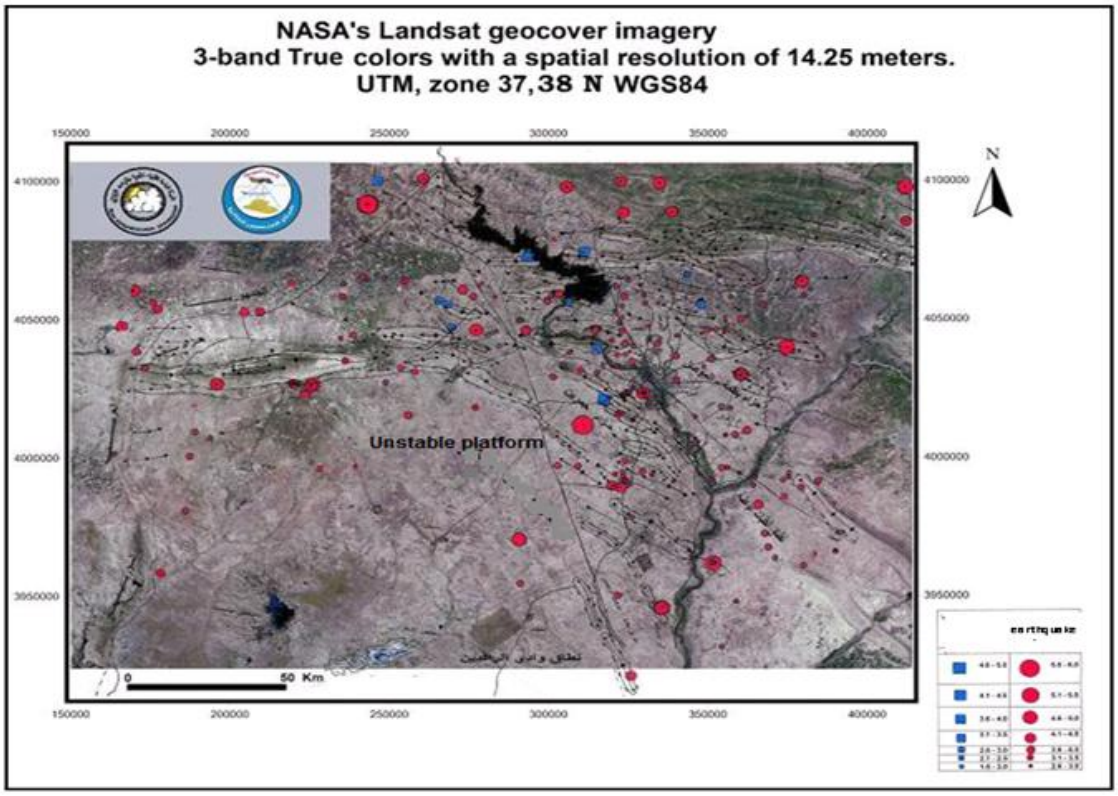

Fig. 2: Seismotectonic Map of North Western Iraq with Earthquake epicenters(5)

Table 1: The earthquakes information collected from web site www.emcs.csem.org[6]. (F= Focus).

No.	Date	Time	Latitude	Longitude	Depth	Magnitude	Region
1 F	11-03-2013	14:57:09.0	36.64 N	43.55 E	10	5.0	Iraq
2	11-03-2013	15:05:01.0	36.69 N	43.42 E	2	3.2	Iraq
3	11-03-2013	15:14:36.0	36.69 N	43.50 E	2	3.3	Iraq
4	11-03-2013	15:17:30.0	36.67 N	43.34 E	2	2.2	Iraq
5	11-03-2013	15:30:54.3	36.71 N	43.39 E	5	2.5	Iraq
6	11-03-2013	16:15:58.0	36.66 N	43.45 E	2	3.0	Iraq
7	11-03-2013	16:57:48.0	36.74 N	43.29 E	2	2.5	Iraq
8	11-03-2013	17:02:42.0	36.90 N	43.42 E	2	3.0	Iraq
9	11-03-2013	17:12:29.0	36.77 N	43.27 E	2	2.4	Iraq
10	11-03-2013	17:47:38.0	36.71 N	43.45 E	2	2.9	Iraq
11	11-03-2013	18:01:40.0	36.63 N	43.50 E	2	2.5	Iraq
12	11-03-2013	18:25:32.4	36.65 N	43.40 E	5	2.6	Iraq
13	11-03-2013	19:03:19.0	36.70 N	43.44 E	2	2.2	Iraq
14	11-03-2013	19:17:03.0	36.84 N	43.28 E	2	2.8	Iraq
15	12-03-2013	00:50:23.0	36.77 N	43.28 E	2	2.1	Iraq
16	12-03-2013	06:31:58.0	36.69 N	43.42 E	2	3.6	Iraq
17	13-03-2013	00:05:19.2	36.83 N	43.38 E	5	2.7	Iraq
18 F	13-03-2013	06:23:03.0	36.66 N	43.38 E	10	4.3	Iraq
19	14-03--2013	02:38:17.0	36.70 N	43.29 E	2	2.4	Iraq
20	14-03-2013	04:19:13.0	36.72 N	43.34 E	2	2.8	Iraq
21	09-05-2013	03:13:28.0	36.63 N	43.44 E	2	3.3	Iraq
22 F	02-08-2013	01:31:10.0	36.68 N	43.27 E	2	4.2	Iraq
23	02-08-2013	02:12:57.0	36.58 N	43.38 E	4	3.3	Iraq

The gravity data are acquired using Lacoste–Romberg gravimeter model G-271 with an accuracy of 0.01 mGal. Gravity data acquisition at(83) stations in the study area were completed. The station interval varies from 0.5 to 5.0 km. GPS-GARMN was used to acquire elevation data of higher accuracy (±4m). The gravity data is processed using IGSN, 1971 for a standard density of 2175 kg/m3 for the Bouguer slab. The overall accuracy of Bouguer anomaly map prepared from this data is about ± 1.297 mGal and is good enough for the present study. Terrain gravity anomaly. A large portion of area could not be covered due to its inaccessibility; however the area of this study could be covered due to availability of tracks.. The distribution of the measurements is shown in Fig. 4.

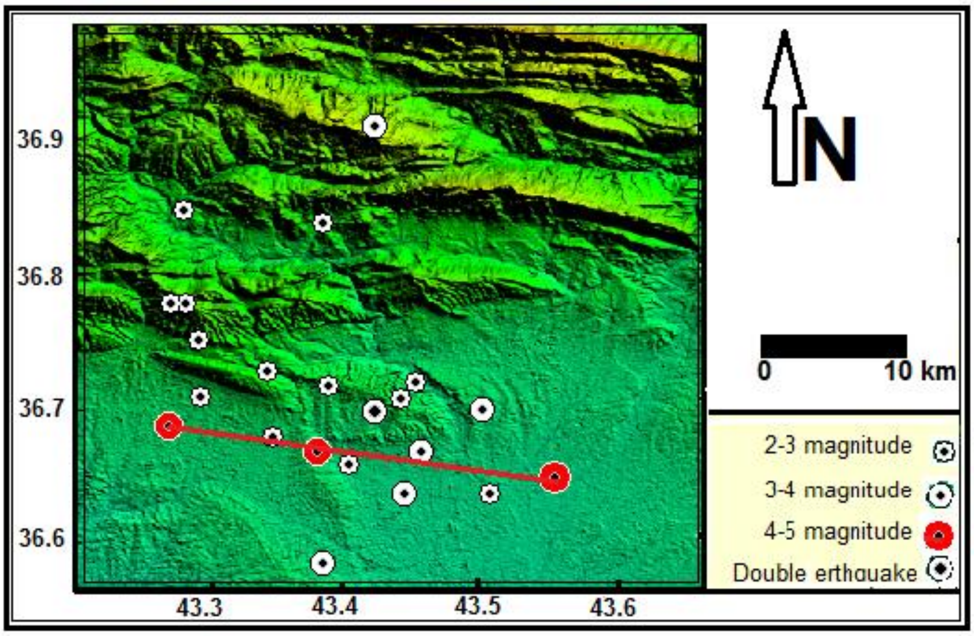

Fig. 3: The digital elevation model (DEM) and 23 earthquake epicenters (dot size is proportional to magnitude) in the study area

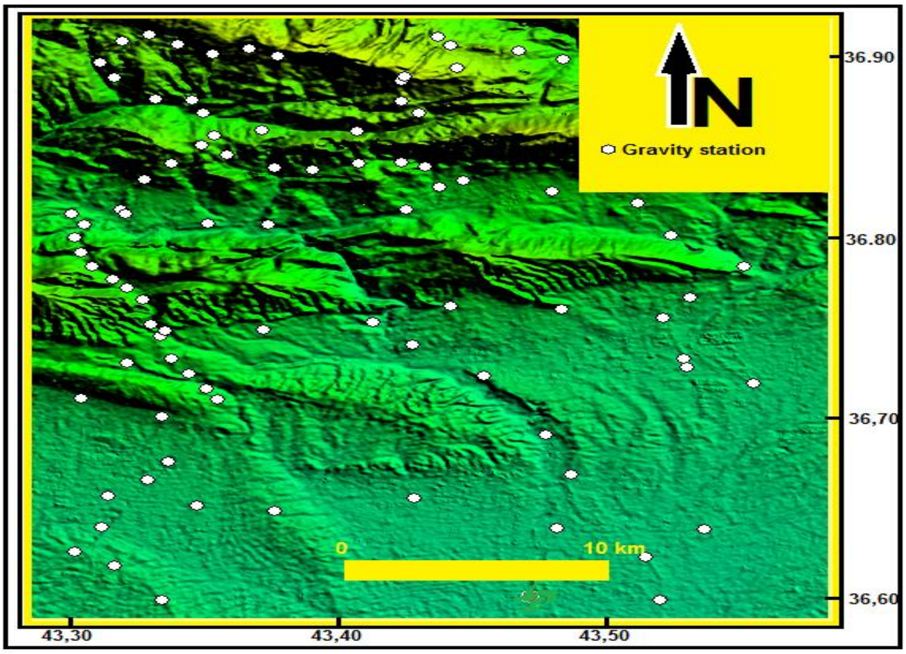

Fig. 4: The distribution of gravity data in the study area

Analysis of gravity data

The gravity data were used to determine the basin geometry in locations where other geophysical and subsurface data were not available. The analysis of the gravity data involves estimating the gravitational effects of deep crustal and upper mantle compensatory features and subtracting these effects from the data to enhance the shallower features. These residual gravity data were then used to produce the residual gravity map for the study area (Fig.5).

The gravity results indicate that the study area is characterized by a Bouguer anomaly having an amplitude of ~ -40 mGals approximately centered along longitude 43.4E (Fig. 5). This map is characterized by the presence of several two-dimensional positive and negative anomalies. The majority of them are trending in NW-SE and E-W directions, which is the main trend of the structures in this area. Most of positive and negative anomalies are in harmony with the surface structures. Major gravity gradients are in the direction of northeast and southwest across the main trend of the Zagros Fold-Thrust Belt. Earthquake locations correlate with distinct residual Bouguer anomalies indicating that the intraplate seismicity is associated with an ancient, buried rift that is currently being reactivated by the contemporarygenerated stresses. Gravity data of the study area and surrounding regions have delineated major E-W and NW-SE oriented lineaments and faults. The epicenters zone of earthquakes and their aftershocks is located southern Shaikhan anticline that appeared as semi flat area .The all focuses of earthquakes are aligned towards E-W direction (Fig.5). The locations of earthquake activity assists to outline The buried rifts those acted as a "zone of weakness" in the stable continental crust . On the other hand, most of earthquakes are purely due to tectonic activities such as faulting and re-activation of existing faults.

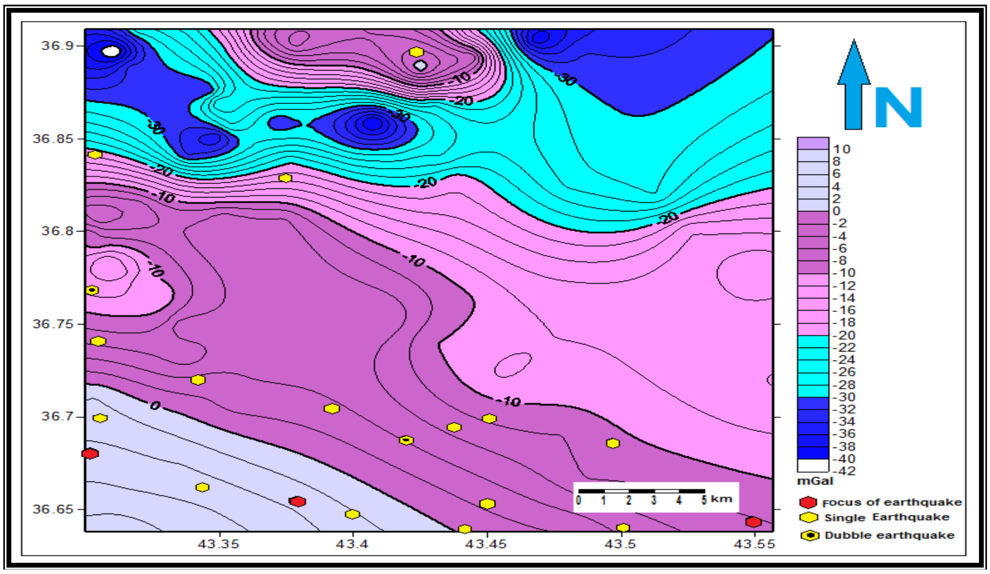

Fig. 5: The correlation between the Bouguer anomaly map of the study area and the locations of earthquake epicenters.

RESULT

Quantitative Interpretations

The modeling procedure implies the use of appropriate residual gravity anomaly and density contrast between the body of interest and adjacent rocks. The points were carefully taken into account in constructing the final shapes of the geological models in the study area depending upon the formula of Talwani *et. al* [8]. We finally applied 2D modeling to our Bouguer anomaly data by using Oasis montaj program[9]. Gravity models along seven profiles in W-E, SE-NW, and SW-NE directions were performed. (Fig.6) shows the location of these profiles on the DEM of the study area.

Geophysical and geological models for profiles (Tr1-Tr7)in (Fig.6) are given in (Figures 7 to 13). In our geophysical approach we have assumed that there is no lateral variation of the lithologies in the formations and hence the densities used (showed in the (Figs. 7 to 13) are generally applicable throughout the area.

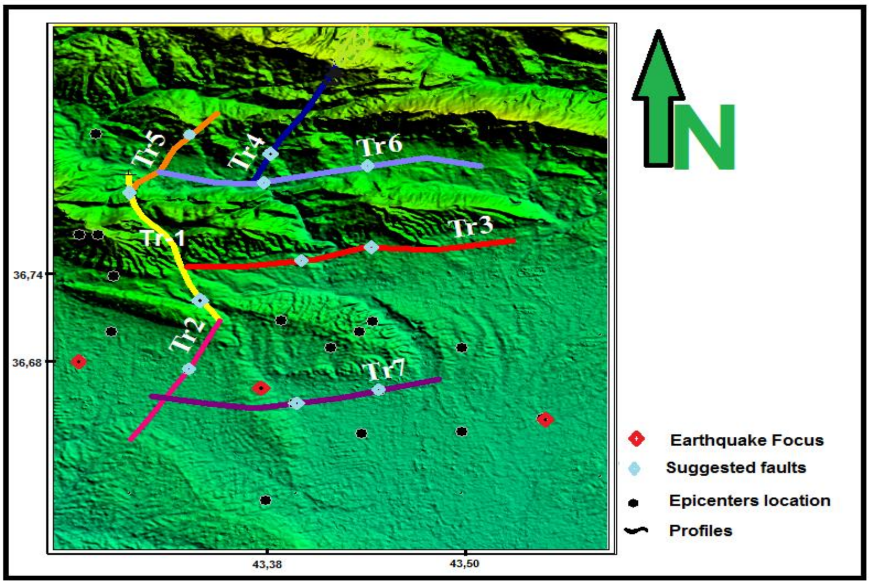

Fig. 6: Earthquakes Epicenters, Focuses, and the profiles that appeared in the DEM of the study area

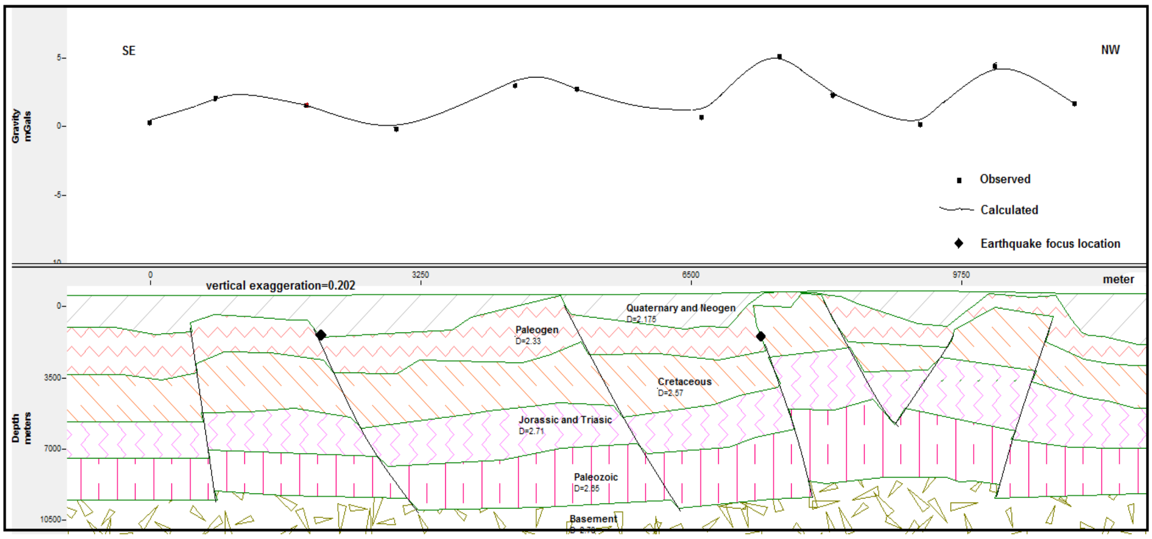

Fig. 7: Epicenters on the SE-NW gravity model along profile 1. The values indicate densities of subsurface rocks in g/cc.

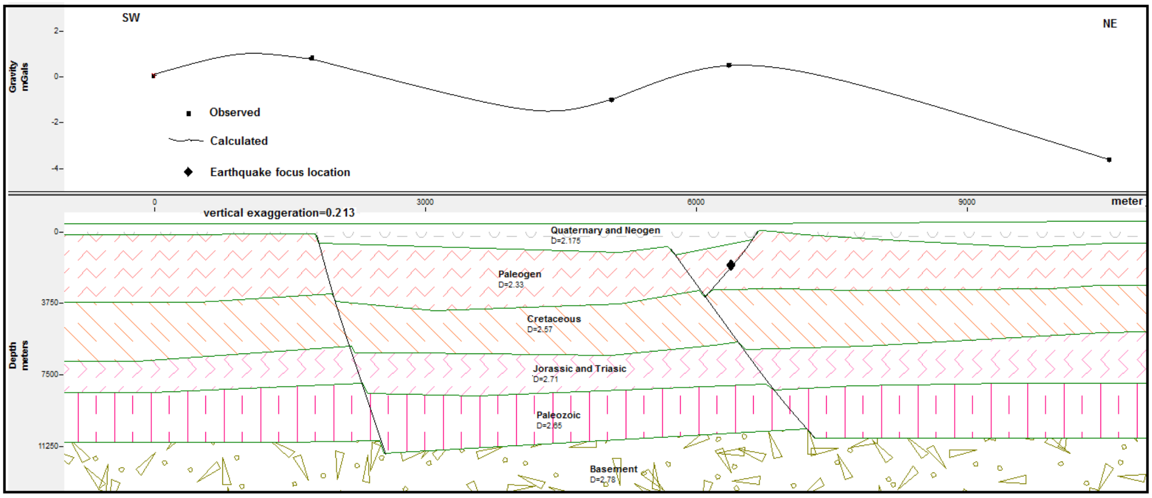

Fig. 8: Epicenters on the SW-NE gravity model along profile 2. The values indicate densities of subsurface rocks in g/cc.

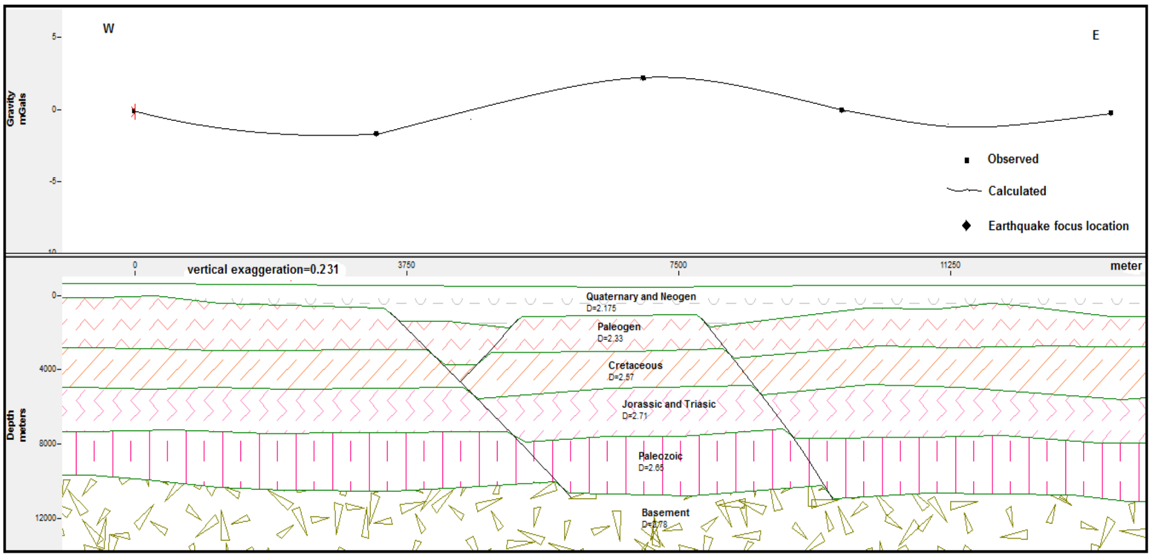

Fig. 9: W-E gravity model along profile 3. The values indicate densities of subsurface rocks in g/cc.

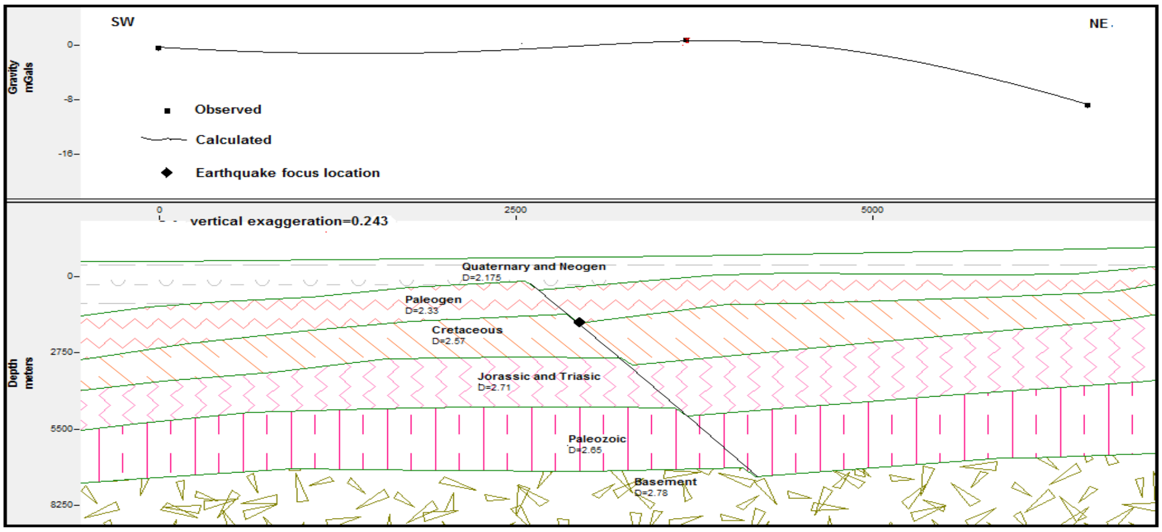

Fig. 10: Epicenters on the SW-NE gravity model along profile 4. The values indicate densities of subsurface rocks in g/cc.

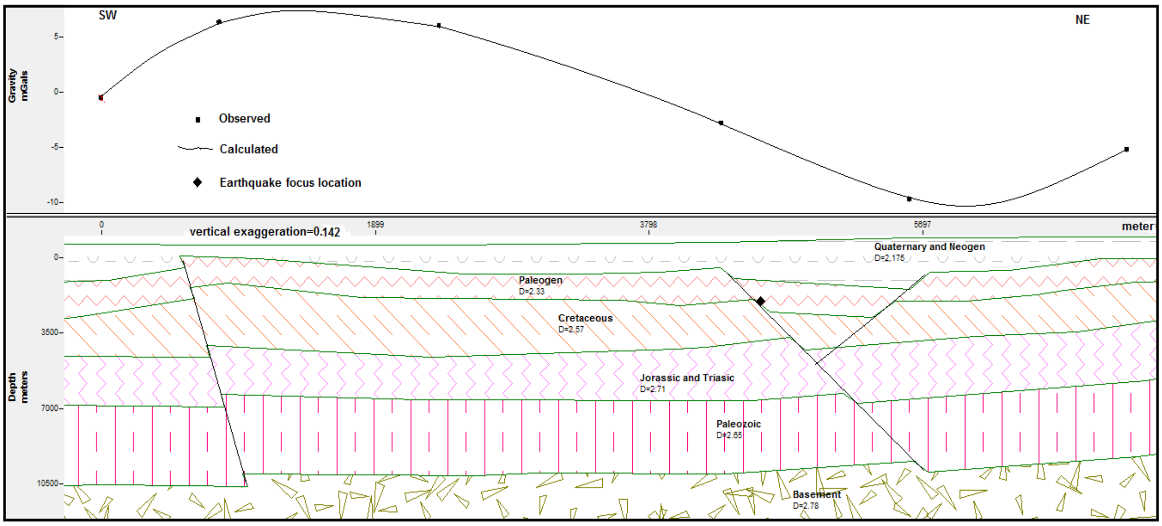

Fig. 11: Epicenters on the SW-NE gravity model along profile 5. The values indicate densities of subsurface rocks in g/cc.

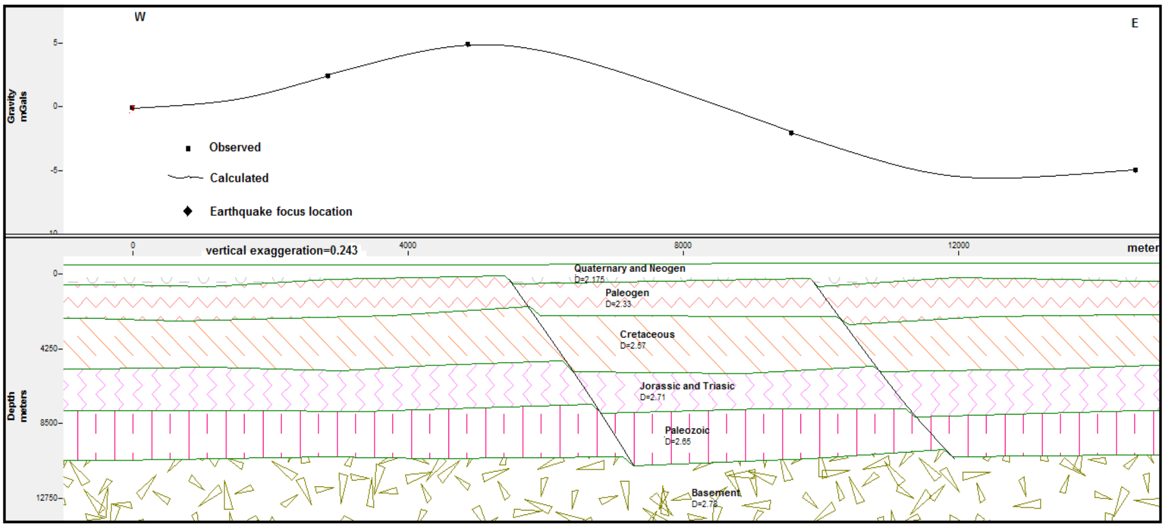

Fig. 12: W-E gravity model along profile 6. The values indicate densities of subsurface rocks in g/cc.

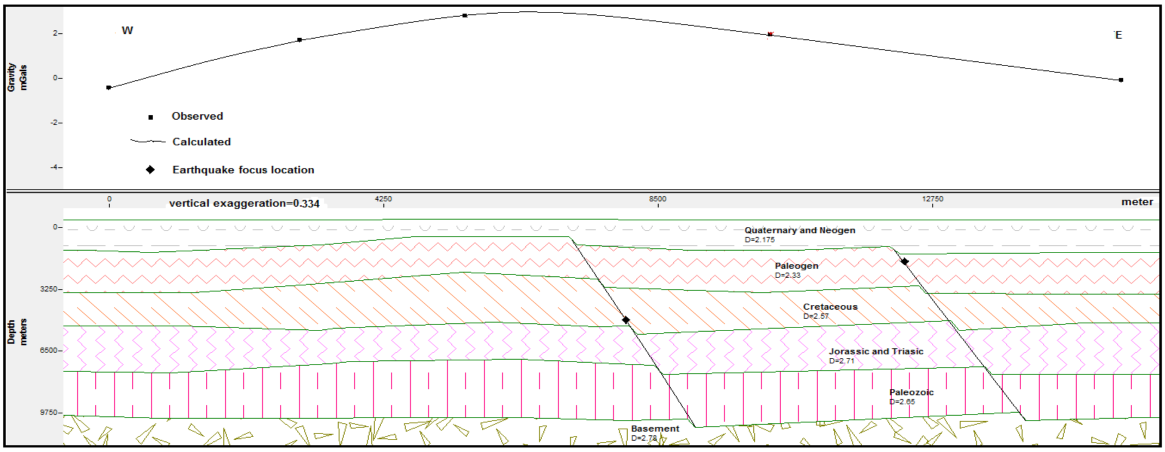

Fig. 13: Epicenters on the W-E gravity model along profile 7. The values indicate densities of subsurface rocks in g/cc

DISCUSSION

Potential field data are primarily used in the detection and delineation of geologic structures and crustal heterogeneities that are mostly associated with the earthquake processes. Gravity profiles have been generated across the epicenter and the aftershocks regions (Figs. 7to13).

The models illustrate that the most earthquakes are corresponding with the faults movement lines. Based on numerous gravity profiles through the main epicentral zone fault zones were found out, which were interpreted as different structures. However, on the basis of our comparative analysis of gravity data and epicenter locations results in the present study, we would like to point out that the most aftershock seismic activity occurs at a depth of 2 km. In this study therefore conclude that 2 km (Paleogen and Cretaceous formations) represents the brittle-ductile transition zone in the study area.

CONCLUSION

The present study contributes a new knowledge about the relationship between a gravity survey and the earthquakes information detected from the seismology observatories. It is concluded that the seven gravity traverses which were collected during this study matching with the locations of earthquakes epicenters and faults movement. So that, a prediction about the fault locations and movement depths may be found due to this study. Accordingly, the earthquake epicenters which had previously happened reflect a number of certain faults. The researchers suggest applying more detailed gravity and magnetic surveys on and around the studied area to confirm the locations and extents of faults and consequently the prediction of the future earthquakes.

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