



Analysis and interpretation of geophysical data to delineate the geologic structures of Abu Dabbab area, South Eastern Desert, Egypt

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ABSTRACT

The present study aims to identify the geologic structure of the Abu Dabbab area. The previous work state that the study area contains different ore minerals such as Tantalum, Niobium, Cassiterite, Gold, and sulphides. Processing, analysis, and interpretation of aeromagnetic and recorded seismic events data of the study area were to define the seismic activity zones and the main trend in the study area and its relation with ore deposits distribution. The area is controlled by different structural elements of trends NE-SW, NNW-SSE, and E-W. The results indicated that most of ore deposits are located at an active fault zone which is characterised by high seismic activity. There are high deformation zone trends NE-SW. There is a high value zone located approximately at the centre of the northern portion of the study area. This high energy zone is oriented towards NE and extends to the Red Sea. The energy map shows that the energy released from the study area is considered as a part of the energy release of the Red Sea area suggesting a tectonic connection between this region and the Red Sea.

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1. Introduction

The study area is located to the south of the Eastern Desert, Egypt, 30 km north of Marsa Alam city, and lies between Latitudes 25° 10' & 25° 29' N and Longitudes 34° 25' & 34° 45' E [Figure \(1\)](#). Abu Dabbab area is drained by some main wadis; Wadi Abu-Dabbab, Wadi Dabr, Wadi El-Nabi, Wadi Mubarak, and Wadi El-Nuweibi. The Precambrian basement rocks of Egypt represent about 100,000 km² (about 10 % of the total area of Egypt). These rocks crop out in the Eastern Desert, Sinai and as small exposures in the south Western Desert, especially at El-Oweinat area. Some researchers use geophysical data for mineral exploration and subsurface structures such as Sultan et al. (2009), (Salem et al. 2013 ; Mekki et al. 2021). Ibrahim and Yokoyama (1994) studied the micro earthquake swarm which occurred in the Abu-Dabbab area and they concluded that the micro earthquake swarms there are not deeper than 16 km and are due to igneous intrusions. Badawy et al. (2008) studied the micro-earthquakes and neotectonics of Abu Dabbab, Eastern Desert of Egypt, and stated that; the seismogenesis at the Abu Dabbab area is controlled by both tectonic forces and a magmatic intrusion. Emad K. Mohamed et al. (2015) investigated the source mechanism of earthquakes using the digital wave-form data recorded by the Egyptian National

Seismic Network (ENSN) during the period from 2004 to 2008. He approved that the results of the stress tensor using focal mechanisms of recent earthquakes show a prevailed tension stress field in N52°E, N41°E, and N52°E for the northern Red Sea, Gulf of Suez, and Gulf of Aqaba zone respectively. One of the most useful geological applications of magnetic surveys is to map structural trends by following lineations in magnetic contours Affleck (1963). Afflek (1963) suggested that the magnetic trends are indeed related to tectonic trends and structural lineaments. Shaaban (1973) used gravity, magnetic and electrical methods to determine the favourite sites for the occurrence of ore bodies (Lead, Zinc, and sulphides) at the area between El-Quseir and Marsa Alam and delineate of the structural-lithological conditions controlling their localisation of the ore bodies. This study aims to delineate the structural controlled configuration of mineral deposits at the Abu Dabbab area and its vicinities.

2. Geology of the study area

The geology of the study area according to the modified geological map of the Abu Dabbab EGSM (1992) [Figure \(2\)](#) comprises a wide variation of igneous, metamorphic, and sedimentary rocks. [Table \(1\)](#) explain the Precambrian rocks exposed in the study area are

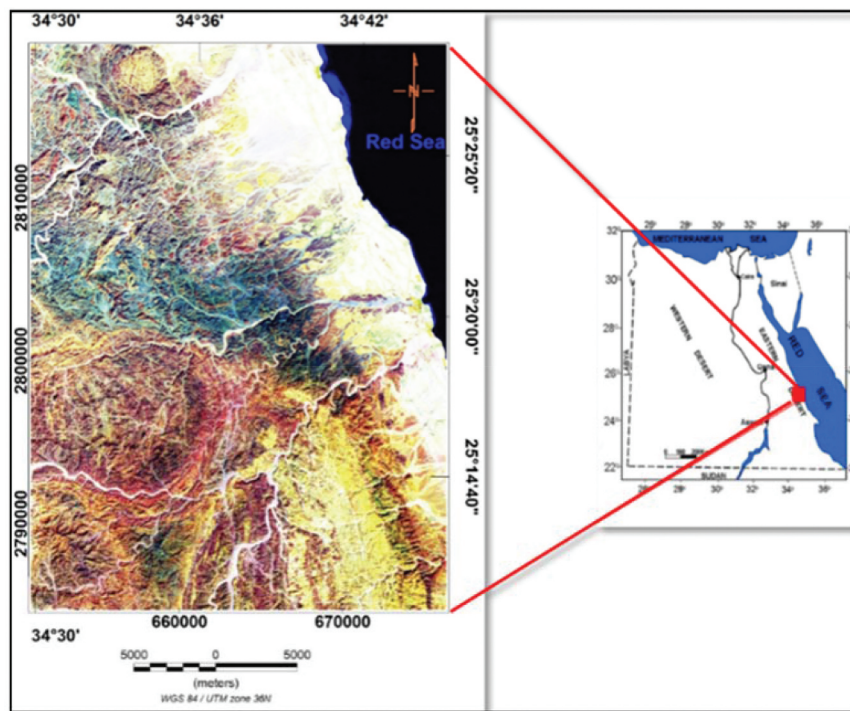


Figure 1. Location map of Abu Dabbab area.

subdivided into three tectonic assemblages with sixteen tectono-stratigraphic units. These units are arranged from base to top, as shown in Table 1:

3. Methods

3.1. Magnetic method

Magnetic characteristics of rocks depend largely on the content of magnetic minerals (such as magnetite), which are normally in the form of fine grains dispersed throughout the rock matrix Sharma (1997). Airborne surveys are probably the most common for large areas. The low-sensitivity airborne magnetometer used during the survey was a Varian IIV.85 proton free-precession magnetometer, with a sensitivity of 0.1 nT. The magnetometer was placed in a fibreglass tail stinger in the aircraft. The base station magnetometer was a Varian VIW 2321 G4, single-cell Caesium Vapour (Aero-Service 1984). The important advantage of the proton magnetometer is that it measures the absolute magnetic field of the Earth as its sensitivity is higher than any of the instruments considered in this survey.

The intensity of magnetisation, I , is related to the strength of the inducing magnetic field, H , through a constant of proportionality, k , known as the magnetic susceptibility (Burger 1992).

$$I = KH$$

Data Correction of the Airborne Magnetic Survey: The aeromagnetic data were processed by (Aero-Service 1984), and the International Geomagnetic Reference Field (IGRF) was calculated and removed from the station readings (Aero-Service 1984).

3.2. Recorded micro earthquakes

Extensive micro-earthquake studies were carried out during the period from 25 November 2001 to 2 June 2015, moreover previous seismicity studies for the area under investigation were considered in this study.

The first motion arrivals of p-wave and available S-wave from the three components stations were measured. The phases are weighted according to their clarity. The location of the seismic events is determined using the program Hypo 71 Pc (Lee and Valdes 1985).

3.2.1. Magnitude calculations

The limits of the epicentral distances and periods of the seismic waves are used as control parameters for the validity of calculating magnitude. The magnitudes (M) were calculated according to the following formula:

$$M = 2\log T - 0.87 + 0.0035D$$

Where:

M = magnitude.

T = signal duration in seconds.

D = epi central distance in kilometers.

Since 1997, Egypt's National Research Institute of Astronomy and Geophysics (NRIAG) has been running a program to construct a national seismic network (ENSN). The field stations transmit their

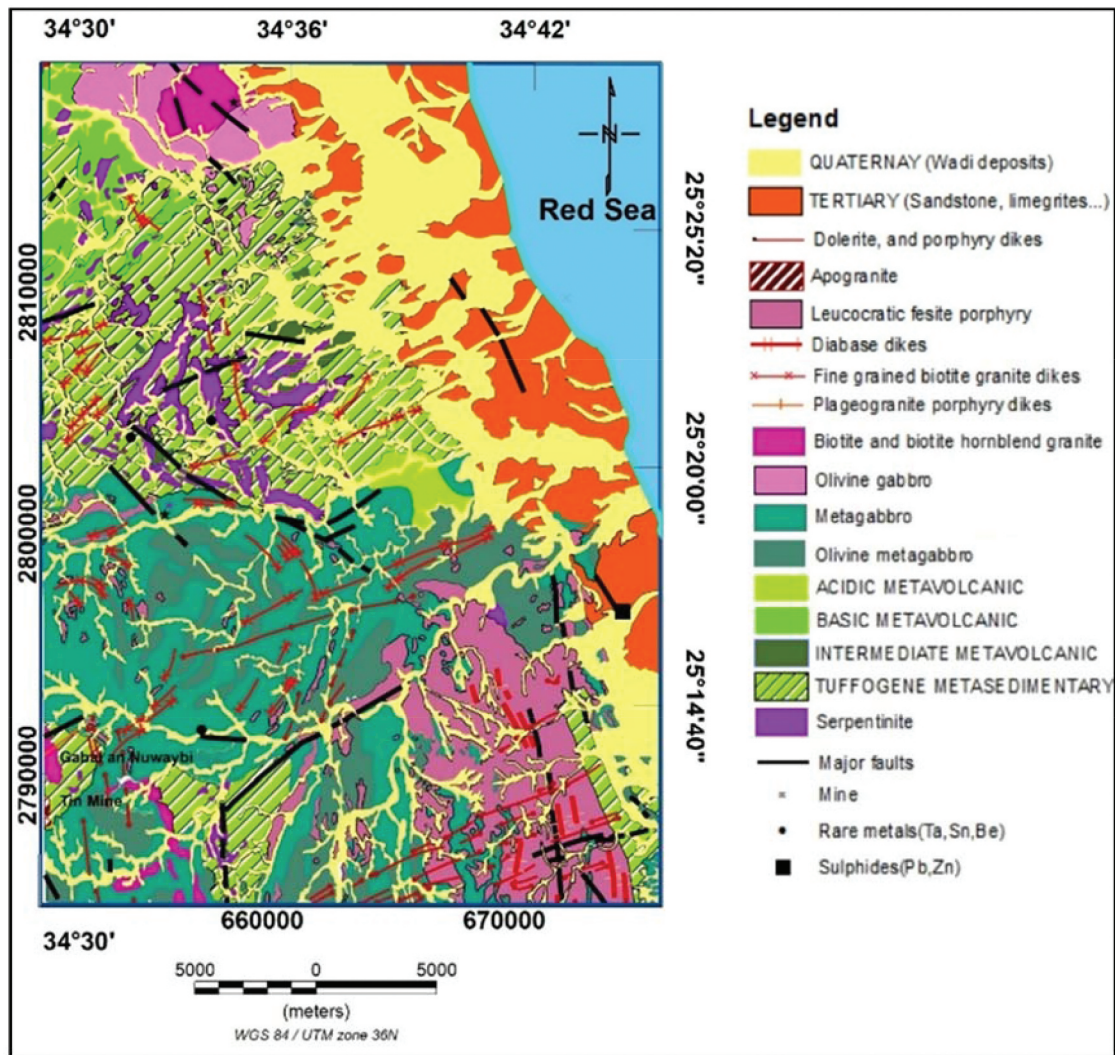


Figure 2. Geologic map of Abu Dabbab area, modified after EGSMA, 1991.

seismic signals directly to the main recording centre in Helwan, Cairo, Egypt, through radio-link, telephone, or satellite transamination technologies.

Table 1. The Precambrian basement rock units in the study area.

III: Late to post-tectonic assemblage
- Dykes
- Apogranite
- Coarse-grained biotitic granite
- Felsites
- Medium-grained biotite-hornblende granites
- Granodiorite
- Tonalite
- Olivine gabbro
II: Island arc assemblage
- Mélange matrix
- Metagabbro-diorite complex
- Acidic metavolcanics
- Basic metavolcanics
- Metavolcaniclastics
I: Ophiolitic assemblage
- Serpentinites and talc carbonates

There are additionally six additional recording units at the sub centres at Aswan, Marsa Alam, Burj Al-Arab, Hurghada, El Arish, and the El-Kharga oasis. The ENSN sensors are outfitted with a variety of seismometers for research purposes, including 11 very broadbands, 9 BB, 10 three-component short periods, and 47 single component short periods.

4. Data analysis and interpretation

4.1. Aeromagnetic data

The aeromagnetic survey is a good technique that supports geological and structural mapping. The low-sensitivity airborne magnetometer used during the survey was a Varian V-85 proton free-precession magnetometer, with a sensitivity of 0.1 nT. The magnetometer was placed in a fibreglass tail stinger in the aircraft. The base station magnetometer was a Varian VIW 2321 G4,

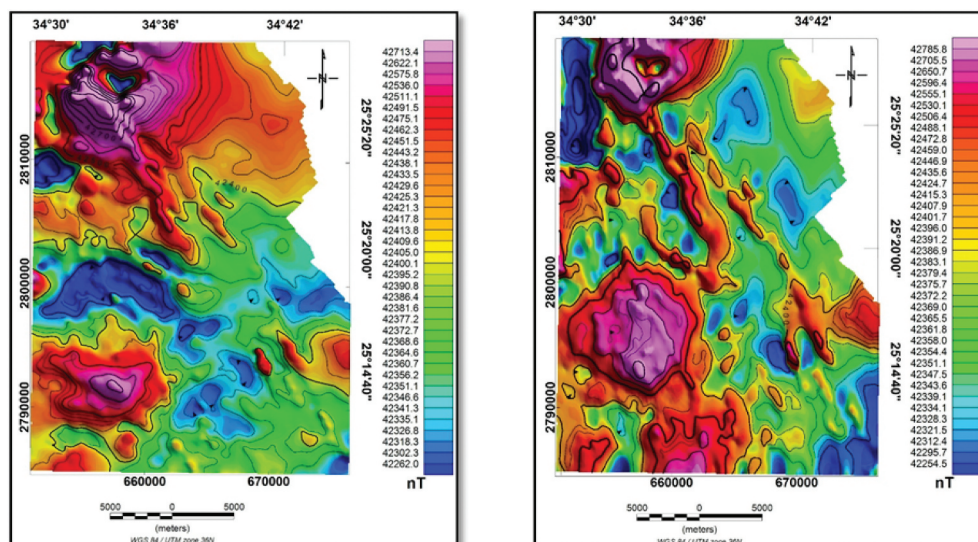


Figure 3. (a) Aeromagnetic intensity contour map of Abu Dabbab area in nT. (b) Reduced to the pole (RTP) aeromagnetic intensity contour map of Abu Dabbab area in nT.

single-cell Caesium Vapour (Aero-Service 1984). The total magnetic intensity contour map Figure (3a) has been subjected to the various methods of analysis to attain the aim of the present study. These include the following:

4.1.1. Reduction to the north magnetic pole (RTP)

The RTP map Figure (3b) could be subdivided into three zones. 1- High magnetic anomaly at southwestern part and represented geologically by metagabbro and metadiorite association, at northern part refer to olivine gabbro and gabbro norite. 2- Medium magnetic anomaly along the red sea shoreline and represented geologically by sedimentary rocks. 3- Low magnetic anomaly at southeastern and northwestern parts, it is granite porphyry and medium-grained biotite.

4.1.2. Power spectrum

The power spectrum curve Figure (4a) explains shallow magnetic components between 0.3 and 1.25 cycles/grid unit, while the deep component ranges from 0.01 to 0.3 cycles/grid unit. The slope of the line fitted to the low-frequency part of the spectrum was used to calculate the median depth of the deep sources, which is assessment as 1.6 km depth, while the slope of the second line fitted to the high-frequency part of the spectrum was used to calculate the median depth of the shallow sources, which is assessed as 0.85 km depth.

4.1.3. Upward continuation

In this study, a set of upward continuation filters were used on the RTP map. Six upward maps (at 100 m, 500 m, 1000 m, 2000, 3000, and 4000 m) were selected. Inspection of the upward continuation map to 100 Figure (4b) shows the most features of the RTP map, while the upward

continuation maps Figure (4c) or upward 1000 m reduce these shallow source anomalies and declare the deeper ones. Inspection of the upward continued maps at 4000 m Figure (4d) shows the high magnetic amplitudes of varying deep roots at northwestern, southwestern parts of the area.

4.2. Recorded micro earthquakes

El-Hady (1993) studied the seismic events in the Red Sea margin and Abu-Dabbab in corresponding to geothermal evaluation. He proved that the brittle-ductile transition depth in the study area was considered 9–10 km, based on focal depths of seismic activity. Data related to earthquakes that occurred within the study area during the period Nov. 25th, 2001 to 2 June 2015 have been recorded and evaluated. These data are used to study seismicity at the investigated area and determine the seismo-active trend as well as its relation with the subsurface faults deduced from other geophysical data interpretation.

4.2.1. Yearly recorded earthquakes

Altogether two thousand, eight hundred sixty-eight (2868) recent earthquakes were recorded during the period between the years 2001 to 2015. The interval number of earthquakes in 15-years “between” Nov. 25th, 2001 to 2 June 2015 is shown in (Figure 5a, and 5b).

All the events were recorded and interpreted. Their distribution according to magnitude is shown in Table (2). The strongest event was of magnitude 3.9 and occurred on 13 January 2006 (03^h 28^m 46^s origin time) and focal depth was 15.5 Km. the ranges of focal depths for the interpreted events are varied from 0.03 km to 35 Km (shallow earthquake events).

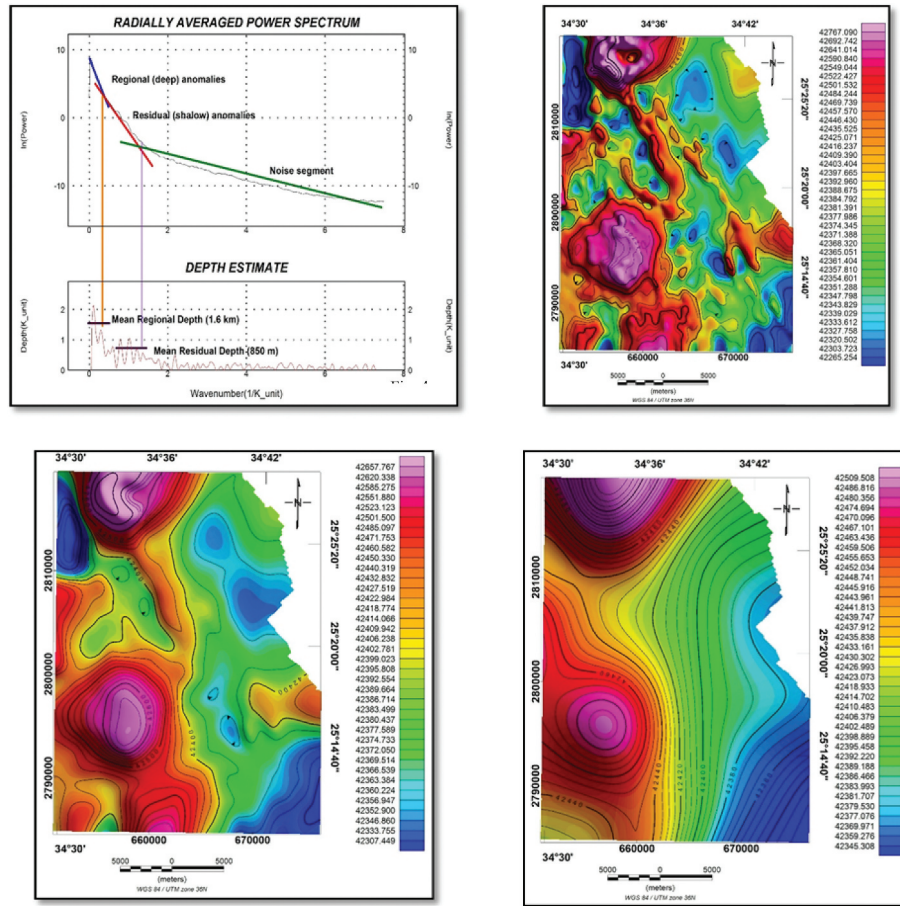


Figure 4. (a) Power spectrum of aeromagnetic map with RTP in nT/km². (b) Upward continuation contour map to 100 m of the study area. (c) Upward continuation contour map to 1000 m of the study area. (d) Upward continuation contour map to 4000 m of the study area.

The distribution of epicentres of all recorded earthquake events is shown in Figure (5c) where earthquake locations with $M > 1$, $1 < M < 2$, and $M < 2$, are plotted. The figure illustrates the seismo-active trends in the study area.

The distribution patterns of the earthquake foci can indicate the shape and size of the structures beneath the ground surface that is the source of the earthquakes. The seismological mapping of the deeper rock structures is an extension of the normal field methods used by geologists to map surface features. The local variation in focal depths in the Abu Dabbab area may be related to crustal structure in addition to the local heat flow of the study area. Figure (6a) shows the epicentres and focal mechanisms of earthquakes in the Abu Dabbab region during the period from 1955 to 2017. Normal faulting solutions (in blue) and thrusting solutions (in green).

The depth of seismic events in the Abu Dabbab area during the period between 25 November 2001 to 2 June 2015 explain in Figure (6b). Two vertical

cross sections Figure (6c) are drawn to determine the disruption patterns of micro-earthquake foci depths along these sections. The two lines A_A1 and B_B1 are cross sections along and cross the epicentral trend. Cross sections were generated using the epicentres within 2 km of the cross section lines. The results obtained from the sections are shown in Figure (7a) and (7b).

To study the pattern of seismic energy release in the study area, the seismic energy map for the study area was constructed. The following equation (Bath, 1979) was used to calculate the seismic wave energy E (in ergs) for every single earthquake, $\log E = 4.78 + 2.57 M$. Where M = magnitude of the event. The recorded earthquake events during the period 25 November 2001 to 2 June 2015, were used for this processing. The visual inspection of the energy contour map Figure (8) shows that the pattern of seismic energy release has the following characteristics: 1-There is a high-value zone located approximately at the centre of the northern portion of the study area.

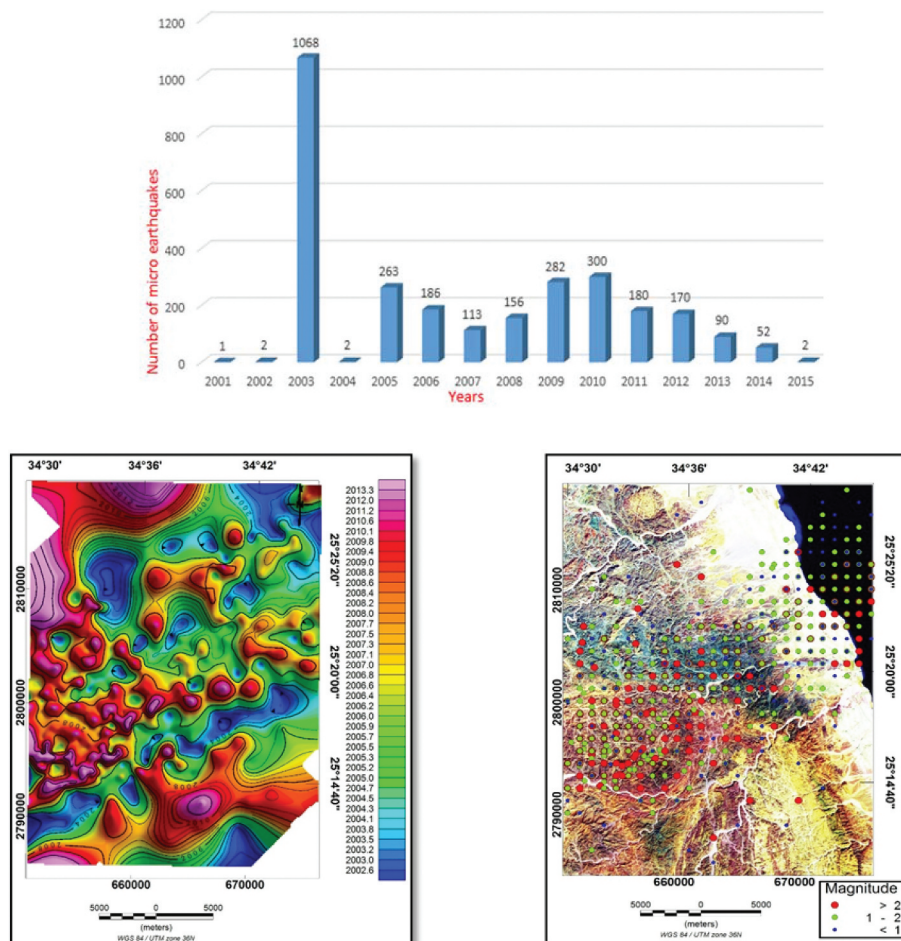


Figure 5. (a) Number of seismic events “between” 25 November 2001 to 2 June 2015. (b) Time colour map of seismic events of the study area. (c) Distribution of recorded seismicity on Landsat™ image of Abu-Dabbab area “between” 25 November 2001 to 2 June 2015.

Table 2. Distribution of magnitude.

Magnitude	Number of events
less than 1	896
From 1 to 2	1607
greater than 2	365

This high-energy zone is oriented towards NE and extends to the Red Sea. 2-The energy release from the study area is considered as a part of the energy release of the Red Sea area suggesting a tectonic connection between this region and the Red sea.

5. Results

There are two main average levels (interfaces) at depths of 0.85 km residual (shallow) sources and 1.6 km (deep) regional sources below the measuring level.

Upward continuation of the study area from 100 m to 4000 m depth indicated that there are two large magnetic bodies extended from the surface to a depth

of 4000 m its locations are in Um Rus gold deposits and the other is located at the western part of the study area at metagabbro-diorite complex.

Abu Dabbab region showed a heterogeneous stress regime in the past and it was not so obvious as to identify the active stress regime that has undergone several deformation episodes.

Seismic energy map has high value zone located approximately at the centre of the northern portion of the study area. This high energy zone is oriented towards NE and extends to the Red Sea, The map shows that the energy released from the study area is considered as a part of the energy release of the Red Sea area suggesting a tectonic connection between this region and the red sea.

The study area is affected by more different fault trends NE-SW major fault, and minor fault such as NNW-SSE, and E-W trends.

There is a high-value zone located approximately at the centre of the study area at metagabbro rocks. This high-energy zone is oriented towards NE and extends to

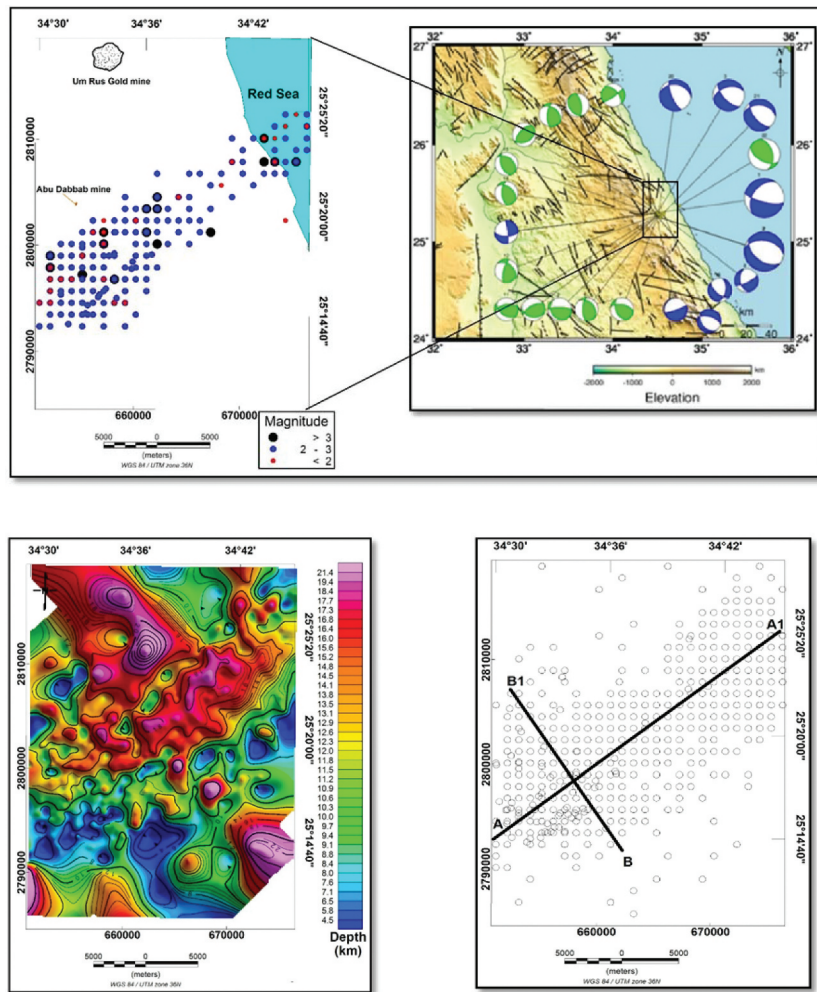


Figure 6. (a) Epicentres and focal mechanisms of earthquakes in Abu Dabbab region during the period from 1955 to 2017. Normal faulting solutions (in blue) and thrusting solutions (in green). (After Sherif m. Ali1 and Hazem Badreldin 2019). (b) Depth of micro earthquakes during the period between 2001 to 2015. (c) Epicentre distribution map in the period 25 November 2001 to 2 June 2015, A-A1 and B-B1 are lines of cross sections shown in Figures 6 and 7.

the Red Sea. The energy map shows that the energy released from the study area is considered as a part of the energy release of the Red Sea area suggesting a tectonic connection between this region and the Red Sea.

6. Conclusion

Analysis and interpretation of aeromagnetic and earthquake seismic activity data explained that the study area is the seismically active zone, a large metamorphosed area and highly deformation contains mineral deposits as following:

- (1) xTantalum, Niobium, and Cassiterite at Abu Dabbab mine in Apogranite rocks, The Apogranite of Abu Dabbab has been emplaced along an NW trending shear zone. Figure (9a).
- (2) Gold deposits at Um Rus old gold mine, Quartz veins are common over most of the Um Rus intrusion zone.

The study area is affected by different faults as follows:

- (1) NE-SW major fault: this fault extends to a depth of more than 5 Km and is perpendicular to the Red Sea rift valley. The region along this fault is also active seismically and has a large deformation zone. It contains deposits of Tantalum, niobium, tin, sulphides, and gold, especially at its intersection with the NW-SE fault that is parallel to the Red Sea rift valley. It is Abu Dabbab Shear zone, NNW-SSE fault. Figure (9b).
- (2) E-W fault: It intersects the study area at Marsa Abu Dabbab in the eastern part and passes through Abu Dabbab deposits so it making this area more deformed and have different economic deposits.

There is a high-value zone located approximately at the center of the northern portion of the study area. This high-energy zone is oriented towards NE and extends to the Red Sea. The energy released from the study area is considered as

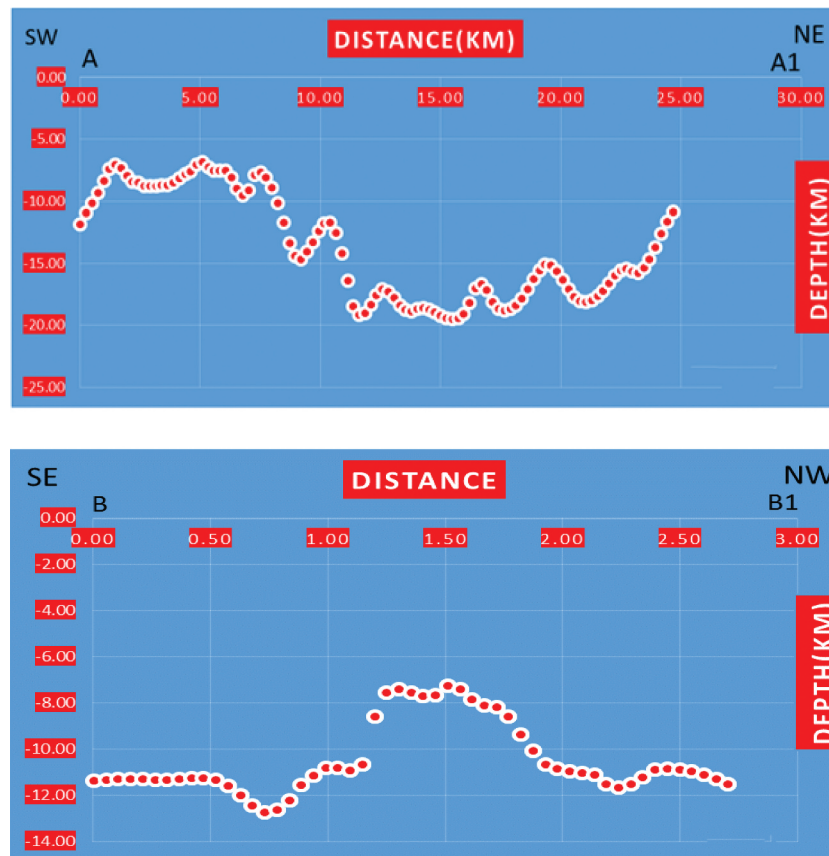


Figure 7. (a) Cross section along line A-A1 in .Figure 4. (b) Cross section along line B-B1 in Figure 4.

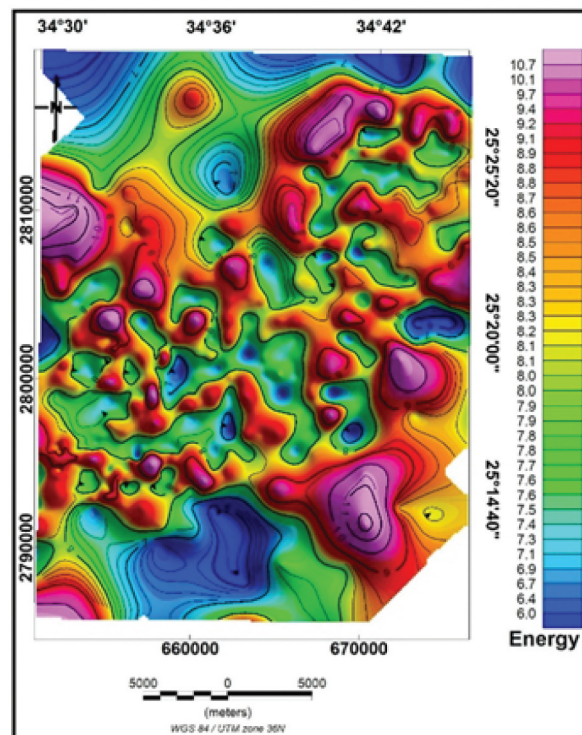


Figure 8. Seismic energy map for the period 25 November 2001 to 2 June 2015.

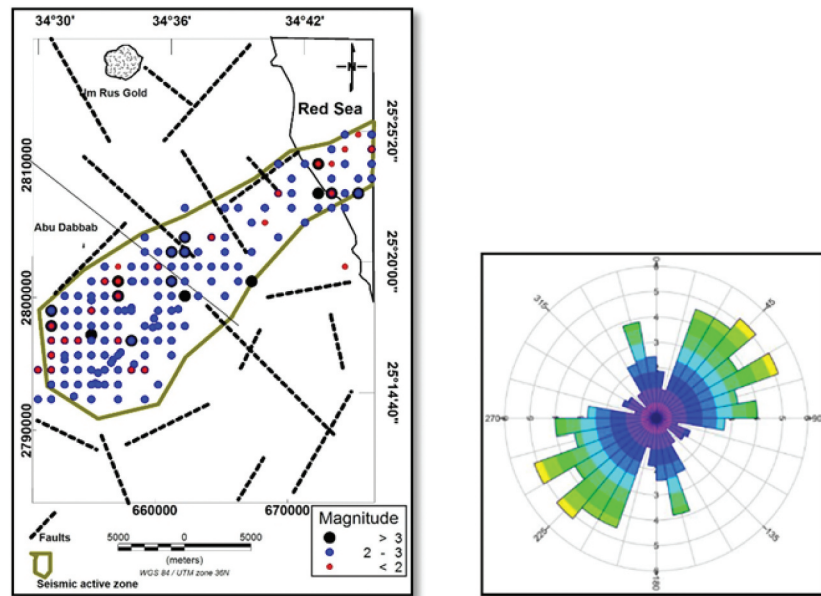


Figure 9. (a) Abu Dabbab Shear zone trends NE-SW. (b) Rose diagram of the study area.

a part of the energy release of the Red Sea area suggesting a tectonic connection between this region and the Red Sea.

7. Recommendation

- (1) Conduct a detailed gravity survey to detect the depth of the magma and confirm the depth of the main fault.
- (2) Electromagnetic survey at Um Rus area and Abu Dabbab deposits to identify the depth of the deposits.
- (3) Continuous follow-up of the movement occurring before and after the daily explosions in the Sukari Gold mine (south Abu Dabbab mine) to study the stability of the rocks in the neighbouring areas.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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