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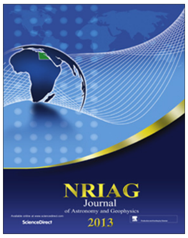

Preliminary crustal deformation model deduced from GPS and earthquakes' data at Abu-Dabbab area, Eastern Desert, Egypt

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KEYWORDS

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Abstract A local geodetic network consisting of eleven benchmarks has been established to study the recent crustal deformation in the Abu-Dabbab area. Seven campaigns of GPS measurements have been collected started from October 2008 and ended in March 2012. The collected data were processed using Bernese version 5.0, and the result values were adjusted to get the more accurate positions of the GPS stations. The magnitudes of horizontal displacements are variable from one epoch to another and in the range of 1–3 (±0.2) mm/yr. Due to the differences in rates of the horizontal displacement; the area is divided into two main blocks. The first one, moves to the east direction of about 3 mm/yr, while the second block, moves to the SW direction of about 6 mm/yr. According to the strain fields that were calculated for the different epochs of measurement, the main force is compression force and is taken the NW–SE to NWW–SEE direction. This force could be because of local and regional tectonic processes affecting on the study area. The maximum values of compression stress are found in the southern central and western part of study area. Estimated accumulation of this strain energy may be considered as an indicator of the possibility of earthquake occurrence.

From the seismic tomography study, the 3D Vp and Vp/Vs crustal models indicate high Vp/Vs values forms an elongated anomaly, in the central part of the study area, that extends from a depth of 12 km to about 1–2 km of depth is obtained. By using this crustal model in relocations all seismicity informed that most of the seismicity strongly tend to occur in a cluster manner exactly

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above the southern part of the study area. Based on the conducted source mechanism study, it is noticed that shallow earthquakes are associated by a high CLVD ratio (up to 40%). Furthermore, initiation of a high level seismic activity, without a large seismic main shock is observed in the Abu-Dabbab area. The distribution of micro-earthquakes tends to align in an ENE–WSW direction marking a zone of activity verse the Red Sea. The nucleation of the seismic activity beneath the southern part of the Abu-Dabbab crust is more consistent with the obtained crustal deformation result by increasing the crustal movement in the south part than the northern part. Then, based on the obtained results of the above mentioned studies; seismic tomography; source mechanisms, and crustal deformation we conclude that these seismic activities that are associated by crustal deformation are owing to some magma activity beneath the crust of the Abu-Dabbab area.

1. Introduction

Abu-Dabbab area (34.35° to 34.65°E, 25.15° to 25.35°N) is located in the south-east of Egypt on the Red Sea coast and in the north of the city of Marsa Alam at about 30 km. This area has begun to increase its strategic importance because it contains many minerals such as phosphate, feldspar and quartz in addition to the discovery of some gold mines in the area. Also, this area is characterized by a mild climate and clean environment, making it an attractive environment for tourism and various investments. The area is a part of the Red Sea mountain range, which consists essentially of backbone of high and rugged mountains parallel to the Red Sea coast, the greater part of which is covered by Late Proterozoic basement rocks of the Nubian Shield (Said, 1962). Its mountains were pen planed and its sediments were highly deformed and metamorphosed. Three main wadies, Wadi Abu-Dabbab, Wadi Mubarak, and Wadi Dabr and their tributaries are drain Abu-Dabbab areas.

Abu-Dabbab area is characterized by high seismicity and complex tectonic setting. The area had been hit by two recent events (12 November 1955 and 2 July 1984) with magnitudes 5.5 and 5.1, respectively. And thus from that time seemed to interest scientists of the National Research Institute of Astronomy and Geophysics (NRIAG) studying the seismic activity of the area hoping to find out the cause of this activity. And manifestations of this study of the recent crustal movements in the area and their relationship to seismic activity are tested.

Recently, many conducted studies in different countries of the world have shown the relationship among the recent crustal movements and the recent seismic activity. Therefore, monitoring of the recent crustal movements can give an early indication of the rate of gathering of energy stress on the faults and thus the probability of occurrence of earthquakes. Given the importance of the Abu-Dabbab, the study of recent crustal movements and seismic activity study are of great importance to reduce the risk of this activity.

2. Geological settings

The Arabo Nubian massif occupies the eastern part of the Eastern Desert of Egypt and extends to the southern part of Sinai Peninsula. It is a surviving aggregate of a mobile belt that developed in the early part of geologic history before the differentiation of preservable faunas. They include widespread acidic igneous intrusions. Large-scale of ultra basic to basic intrusions such as flow, dykes, masses and other shapes were introduced in the sediments before their metamorphism. The derivatives of ultra basic intrusions are represented in the area by the serpentine rocks. Some of these serpentine bodies are relatively massif, of significant size, and form many of the peaks in the area.

According to Youssef (1982), the main tectonic structures developed in the Eastern Desert can be summarized in the following:

1. A set of fault systems is trending nearly in the east–west direction.
2. A set of normal faults trending northwest-southeast, nearly parallel to the Gulf of Suez-Red Sea trend.
3. A set of fault systems trending nearly northeast–southeast, nearly parallel to the Gulf of Aqaba trend. The last two trends of faulting are assumed to be two complementary sets of shear fractures that have been produced by a compressive stress oriented N10°W–S10°E, (Said, 1962).

Structurally, Abu-Dabbab area is confined to a big dome like structure (Zaghloul and Ghobrial, 1983). The rock masses in the area have an elongated stock as bodies with rough dissected surface. The contacts among the masses are usually accompanied by eruptive and tectonic breccias. Fig. 1 shows the lineaments of the study area located on a satellite image. The lineaments are modified after the geologic map of Egypt by Conoco Co. (1987). The local trends of major, minor faults and lineation are predominated by two directions, the minor trend has a NNW–SSE direction with azimuth 155° parallel to the Red Sea coastal line and the major trend is ENE–WSW with azimuth 60° perpendicular to the former. This azimuth frequency diagram is calculated using the surface lineaments of Fig. 1. The area is characterized by a rugged topography and its sediments have been highly deformed and metamorphosed.

3. Seismicity of the Abu-Dabbab area

Since the beginning of the 20th century, earthquake swarms have been detected at Abu-Dabbab in the Eastern Desert of Egypt have been known. After 1970, the swarms were instrumentally recorded and studied by several authors. As reported by Morgan et al. (1981), the past seismicity at Abu-Dabbab was accompanied by a sound of distinct rumbling similar to the sound of a distant quarry blast. The tradition passed down over the centuries reports that this peculiar sound has been heard by Bedouins for several generations. The name itself is

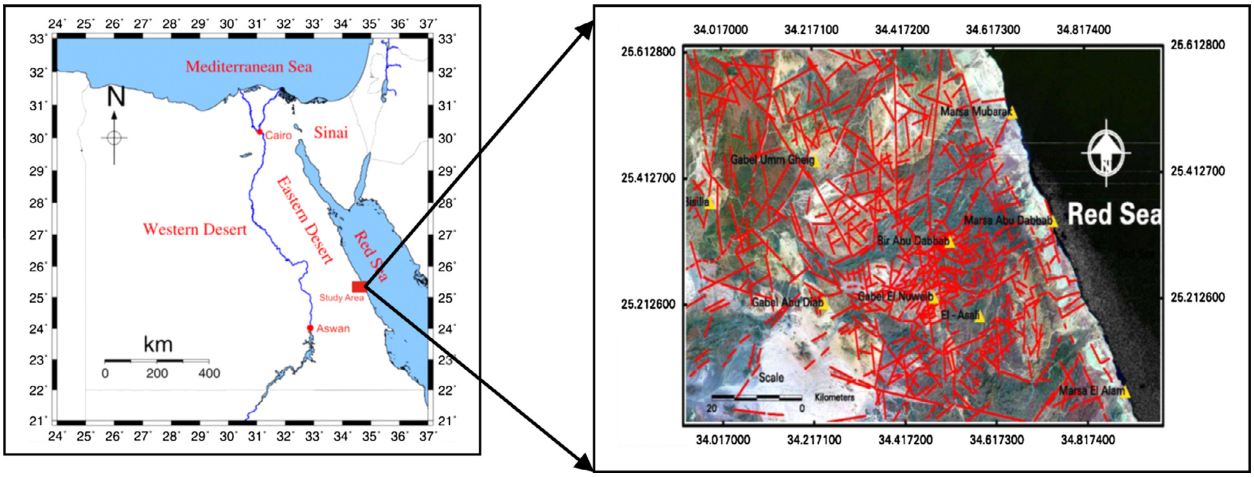

Fig. 1 Lineament map of the study area located on satellite image. Lineaments are modified after geologic map of Egypt (after Conoco Co., 1987).

meaningful since "Abu-Dabbab" means "earthquake sounds" (from Abu = father and Dabbab = knocking).

Fairhead and Girdler (1970) analyzed the seismicity of the Red Sea for the period 1953–1968 using the data of the World-wide Standardized Seismograph Network (WWSSN), and observed an event of magnitude (mb = 6) on November 12, 1955. The epicenter of this event was located in the Precambrian rocks of the Egyptian Red Sea Hills that are near Abu-Dabbab area. On July 2, 1984 an earthquake of magnitude 5.1 occurred in the Abu-Dabbab area. The extremely tight clustering of the Abu-Dabbab hypocentres and the relatively high level of seismic activity maintained for long periods suggest that seismicity in this area is not directly related well only to regional tectonics, but it is controlled by a plutonic intrusion into the Precambrian crust (Daggett et al., 1986).

Many earthquake swarms (1976, 1984, and 1993) were instrumentally observed and discussed by several authors (Hamada, 1968; Fairhead and Girdler, 1970; Daggett et al., 1980, 1986; Hassoup, 1987; Kebeasy, 1990; El-Hady, 1993; Ibrahim and Yokoyama, 1994; Badawy et al., 2008; Hosny et al., 2009, 2012; Azza et al., 2012). At the beginning of 1992, the National Research Institute of Astronomy and Geophysics (NRIAG) started to deploy the Egyptian National Seismic Network (ENSN). A catalog for the period from 1997 to 2012 collected from the ENSN was used. The space distribution of the earthquakes shows that the earthquakes of Abu-Dabbab take a perpendicular trend to the Red Sea trend nearly NE–SW direction. The recorded seismic activity by ENSN ranges from 10 to 15 events/day to more than 60 events/day, and sometimes reached 100 events/day during the swarm. In addition to the above-mentioned swarm activity, from January 2003 to December 2007, four microearthquake swarms (January 2003, April 2003, October 2003, and August 2004) were identified. Therefore, the Abu-Dabbab area is considered an active seismic area in Egypt.

The spatial distribution of microearthquakes tends to align in the ENE–WSW direction marking a zone of activity verse the Red Sea (Fig. 2). The characteristics of the seismic activity at Abu-Dabbab, an extremely tight clustering within a very small area at the southern part of the study area that could be regarded to the mechanical and frictional behavior of Serpentinite rocks exist in this area. The most of these earthquakes have magnitudes less than 4.0 ML (microearthquakes). Fig. 3A shows the number of events versus years during the period from 2003 to 2011, it can be seen that maximum number of events was in years 2003 and 2004 and after that the number decreased till 2008 and from 2009 the seismicity started to increase again. Number of events versus magnitude, during the period from 2003 to 2011, is shown in Fig. 3B, it is appear that most of the earthquakes that occurred in this area are micro-earthquakes; more than 75% of the events are less than 2.0 M_L. The seismicity at Abu-Dabbab is concentrated at focal depth from 2 to 16 km (Fig. 3C). Fewer number of these events is recorded at depths 17 km and no events of deeper depths are recorded, which means that ductile rocks beneath this depth could be found.

Focal mechanism solutions show different fault styles, normal faulting with a strike slip component is dominant before and after the investigated swarm as background seismicity. Reverse faulting with a strike slip component is characteristic in all events during the seven-day swarm. The maximum compressive stress ($\sigma1$) is perturbed from the regional NW–SE direction to E–W and ENE–WSW orientation. This stress perturbation can be explained only by the intrusion of magma beneath the resurgent dome. Thus, the direction of fault slip seems to be controlled by local tectonic processes rather than by regional processes. This implies that the magmatic intrusion governs the present-day deformation and seismic activity at Abu-Dabbab area. The magmatic intrusions are consequently accompanied by high heat flow. At Abu-Dabbab area, the heat flow is measured at 92 mW/m^2, relatively, as one of the highest values in the Eastern Egyptian Desert (Boulos, 1990).

4. Three dimensional tomography results

From the tomographic results Hosny et al. (2009), we noted that the distributions of Vp and Vp/Vs are characterized by marked lateral and depth variations, suggesting the presence of significant structural heterogeneities (Fig. 4). If these velocity contrasts and variations are the expression of horizontal and vertical discontinuities, an attempt to delineate the fault geometry at depth is natural (Eberhart-Philips and Michael, 1993).

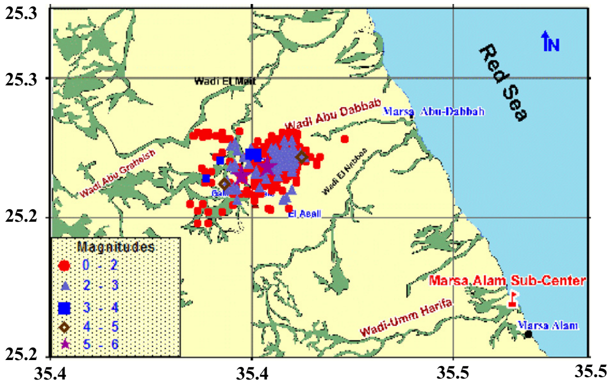

Fig. 2 Seismicity map of the Abu-Dabbab area in the period from 1900 up to 2012. The data are recorded by ENSN from, August 1997 up to the 2012 year. Other older data from international data centers (ISC, IRIS and NEIS). This base map after Conoco and General-Petroleum Corporation, 1987, Geologic map of Egypt, scale 1:500,000.

The overall *Vp* and *Vp*/*Vs* pattern reflects the complex geologic features of the study area. The mean value of *Vp*/*Vs* is a most important parameter to infer some rheological features and to understand the spatial distributions of earthquakes. The low *Vp*/*Vs* areas may indicate higher rigidity crustal rocks with brittle behavior, while the increase of *Vp*/*Vs* ratio may identify areas of relatively more soft crustal rocks with ductile behavior (Seiduzova et al., 1985). Low P-wave velocity anomalies can be seen through different depths and they could be related to the intersection among the faults cutting the area. The high P-wave velocity anomalies (brittle rocks) are bounded by low velocity anomalies that correspond to more ductile rocks. In fact the low *Vp* and high *Vp*/*Vs* anomalies could be due to some magma intrusions present at depth. These high *Vp*/*Vs* anomalies could suggest the occurrence of small size volumes of hot intrusive igneous rocks initiated at different depths. The origin of these intrusive igneous rocks or magma could be explained by the presence of fractional heating at depth that could arise from the reactivation of old shear zones during the formation of active Red Sea rift.

Boulos (1990) and Morgan et al. (1985) studied the Red Sea coastal thermal anomaly in Egypt and they perceived for the Abu-Dabbab area a high heat flow value of about 92 mW/m^2 ± 10,which is more than twice the average value of Egyptian Eastern desert (47 mW/m^2). El-Hady (1993), reported, from the distribution of earthquake focal depths and rheological studies, that the brittle-ductile transition zone in the Abu-Dabbab area occurs at a relatively shallow depth range (9–10 km) which is consistent with the measured heat flow value of the Abu-Dabbab area.

After seismicity relocations, using the new 3-D model, most of the seismic events occur as clusters (Fig. 5). The majority of these clusters are located in the depth ranges, from 5 to 8 km and from 8 to 12 km and below the southern part of the Abu-Dabbab area. The earthquake swarms recorded during the past century and the currently located seismicity have focal depths not greater than 15 km. This may be taken as an indication that ductile material, at high pressure and temperature, or fluid, is present below the high rigidity material in the upper crust, supporting the presence of intrusive igneous rocks or magma through the south part of the upper crust of the Abu-Dabbab area.

5. Moment tensor results

Hosny et al. (2012) studied the source mechanisms and the stress pattern of the study area by obtaining the moment tensors for some earthquakes occurred during an earthquake swarm in August 2004 (Fig. 6). He concluded that the resulting focal mechanisms of the selected events represent different styles of faulting (normal and reverse with strike slip faulting mechanisms). The normal faulting events are characterized by focal depths larger than 7 km and the reverse ones are shallower with focal depths less than 6 km. A non-double-couple component, compensated linear-vector dipole (CLVD) ratio up to 35% is obtained for some events. The presence of some events with a high CLVD ratio, besides the initiation of a high level seismic activity, in the Abu-Dabbab area, without a large seismic main shock, leads us to suggest that the seismic activity of the Abu-Dabbab area might be due to some magma intrusion, increasing of fluid pressure and gases being consistent with the relatively high heat flow of the area.

6. GPS observations

In August 2008, a GPS network consisting of eleven stations was established in the area of Abu-Dabbab. Seven GPS campaigns were carried out from October 2008 to March 2012. The first campaign was in 2008 from 7 to 11 October; the second campaign was in 31 December 2008 to 4 January 2009; the third one was from 6 June to 10 June 2009; the fourth campaign was in 2009, from 6 to 10 October and the fifth was in 2010, from 4 to 8 April.; and six campaign was in 2011, from 15 to 20 June finally and last one was in 2012, from 29 March to 2 April.

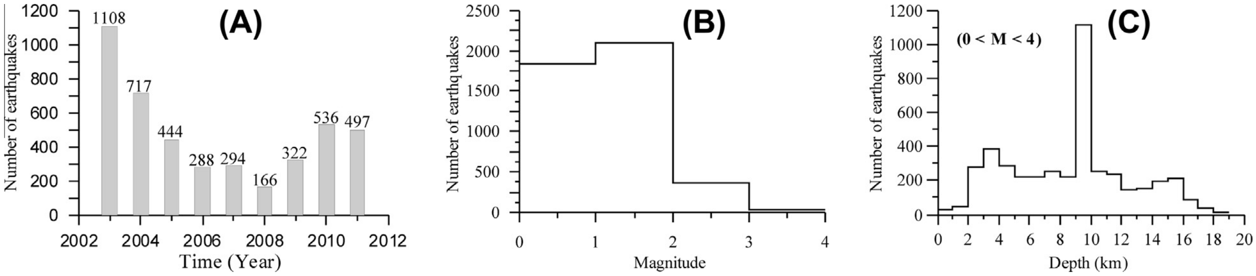

Fig. 3 Frequency of earthquakes with time, magnitude and focal depths at Abu-Dabbab area during the period 2003–2011.

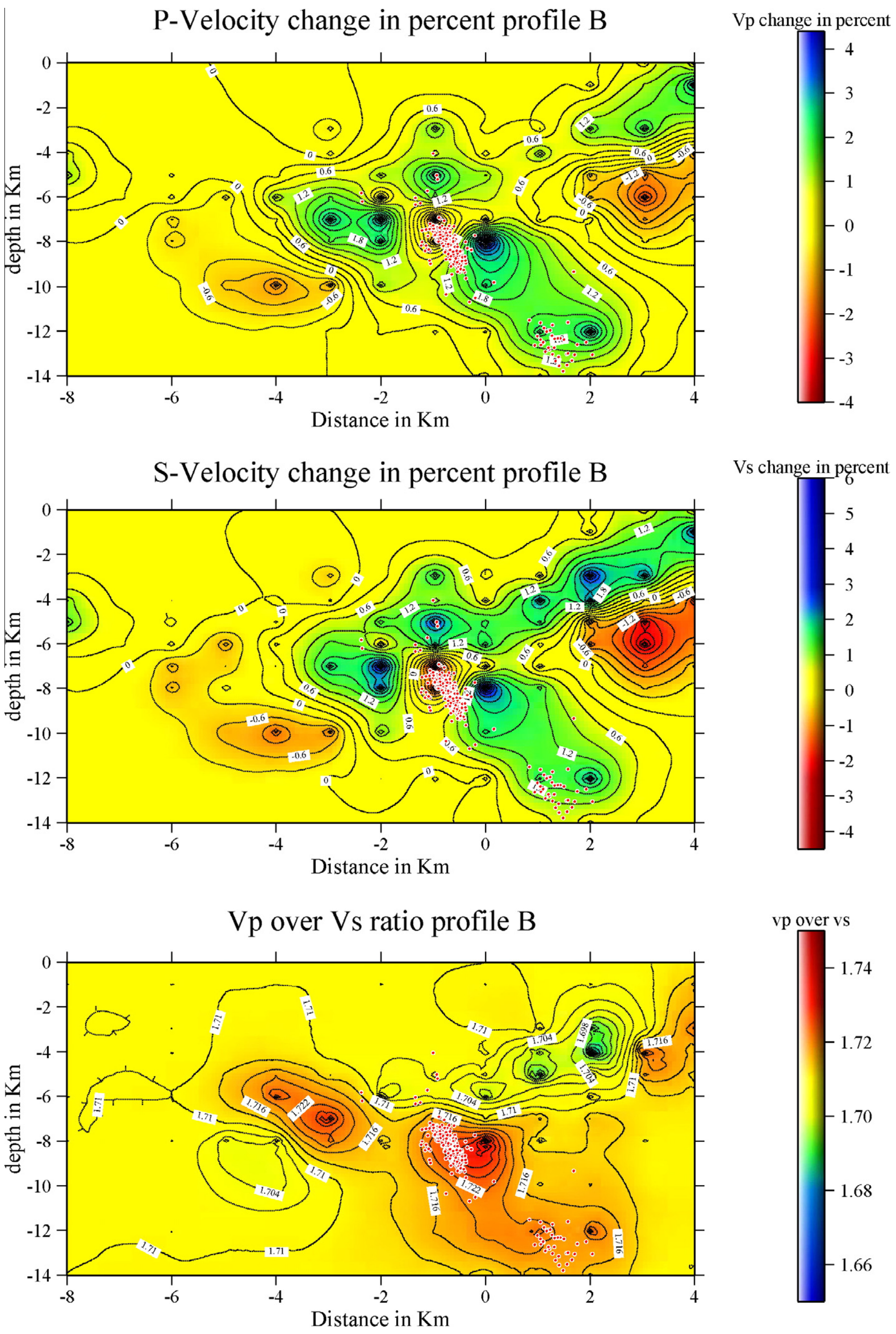

Fig. 4 Profile B, vertical cross-section, of *Vp*, *Vs* and *Vp*/*Vs* variations and relocated hypocenters. Red and blue colors denote low and high *Vp* and *Vs* velocities, respectively; while blue and red colors denote low and high *Vp*/*Vs* ratio. Small open circles show the relocated earthquakes which occurred within a 3-km wide band around each profile. The percent velocity perturbation scale is shown at the right of each cross section.

7. GPS data processing

The collected data were processed using the Bernese software version 5.0 (Dach et al., 2007). Precise orbits from the IGS were used throughout the processing and all the network solutions are constrained solution with respect to station AD03 (station inside the network). An absolute antenna PCV correction tables for satellite and receivers are applied to correct the all phase observations, the elevation cutoff angle is set to 15° and sampling rate in the pre-processing is 30 s while the sampling rate in calculation the network solution is reduced to 180 s. A SIGMA strategy was used as a strategy for ambiguity resolution, which was done through two steps; the first is fixing widelane ambiguities with widelane phase observations, and the second is fixing narrowlane ambiguities by using ionosphere free phases and fixing widelane ambiguities.

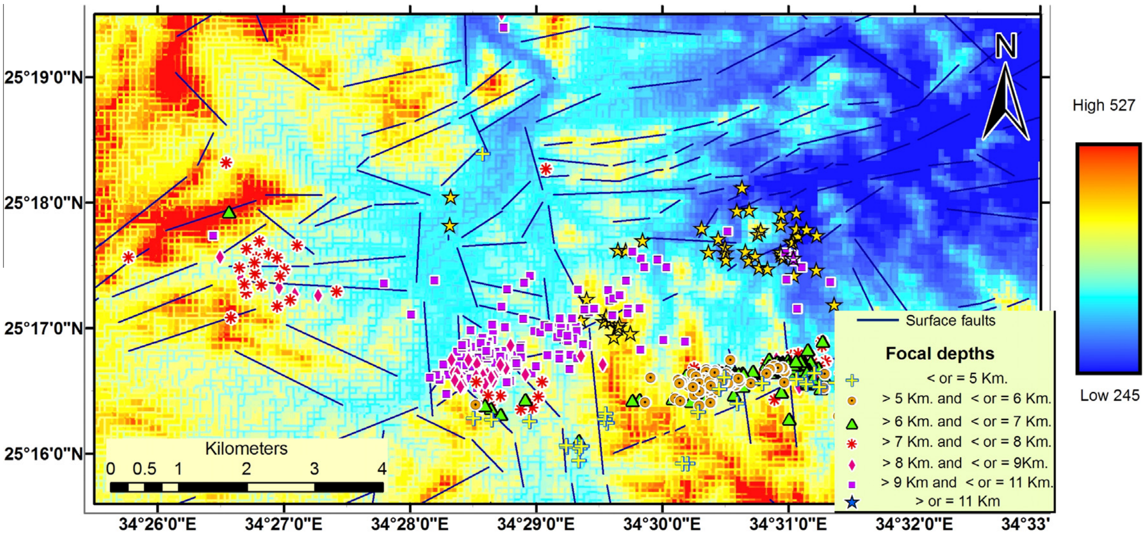

Fig. 5 Topographic map with the relocations of the earthquake activities by using the 3-D tomographic velocity models. Solid lines indicate the possible faults. Different focal depths are indicated with different symbols.

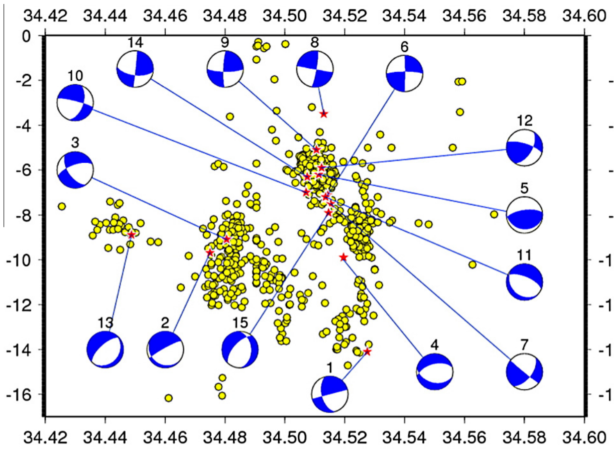

Fig. 6 The selected fault plane solutions by using moment tensor technique of the fifteen studied earthquakes are plotted. The results are plotted on vertical cross section of hypocentral distribution of 2004 swarm microearthquakes' activity. The vertical axis is focal depth in km, while horizontal axis is the distance in degrees.

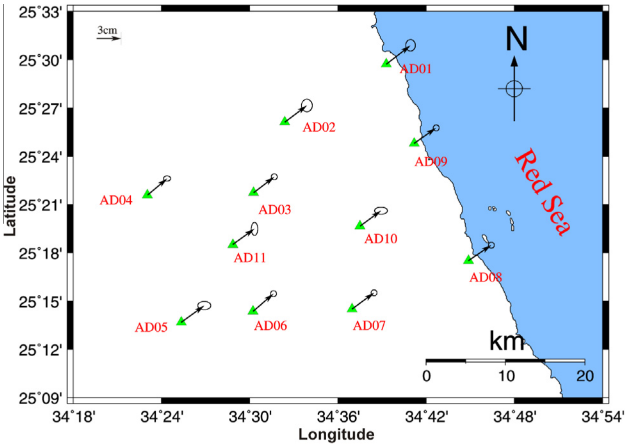

Fig. 7 The computed annual horizontal velocity of Abu-Dabbab network including the African plate motion.

8. Velocity estimation

The annual velocity of Abu-Dabbab geodetic network was calculated among the first epoch to the last one. These values of velocities include also the African plate motion, it can be noticed that the whole stations of this network are moved to the northeast direction and it is typically the direction of the African plate motion. The annual horizontal velocity of this region including the annual horizontal velocity of the African plate was calculated (Fig. 7). From the measured velocity values including also the African plate motion, it can be noticed that the whole stations of this network are moved to the northeast direction which typically is the direction of the African plate motion. By considering the annual horizontal velocity of the African plate, the residual annual horizontal velocity of Abu-Dabbab geodetic network can be calculated, as shown in Table 1 and Fig. 8. In this figure, some stations of the network indicate significant changes while other stations indicate no significant changes through the period of observations. The magnitudes of the movements are distributed inhomogeneous over the area and it is ranging from 1 to 3 mm/yr.

9. Strain parameters' estimation

The horizontal components of the displacement vectors are used to estimate the strain tensor parameters: dilatations, maximum shear strains and principal axes of strain are estimated within the observation periods. The area under study was divided into five blocks, and the strain parameters for each block were calculated. Fig. 9 shows the all divided blocks, block I, block II, block III, block IV, and block V.

The horizontal components of the velocity vectors are used to estimate the strain parameters of the Abu-Dabbab area. The strain analysis is calculated among the periods from the first

Table 1 The geodetic stations and computed residual annual horizontal velocity of Abu-Dabbab network.

Station	Longitude	Latitude	October 2008 to March 2012			
			de (mm)	*δe* (mm)	d*n* (mm)	*δn* (mm)
AD01	34°39′18.31346″E	25°29′44.03445″N	2.8	0.6	2.9	0.6
AD02	34°32′24.05659″E	25°26′07.36945″N	0.3	0.1	0.3	0.1
AD03	34°30′16.23343″E	25°21′44.94770″N	−1.3	−0.3	−0.7	−0.2
AD04	34°23′03.03074″E	25°21′35.87021″N	−2.6	−.3	0.2	0.1
AD05	34°25′21.43234″E	25°13′41.75134″N	1.5	0.3	0.3	0.1
AD06	34°30′14.24080″E	25°14′22.81498″N	−1.6	0.3	1.3	0.3
AD07	34°36′57.83915″E	25°14′31.11900″N	0.4	0.1	−0.4	0.1
AD08	34°44′53.15905″E	25°17′30.68689″N	1.4	0.3	−1.0	−0.2
AD09	34°41′11.77808″E	25°24′47.88270″N	0.3	0.1	−1.0	−0.2
AD10	34°37′30.92781″E	25°19′39.82606″N	−1.0	0.2	−1.1	−0.1
AD11	34°28′51.78089″E	25°18′31.01445″N	−0.1	0.1	−0.8	−0.2

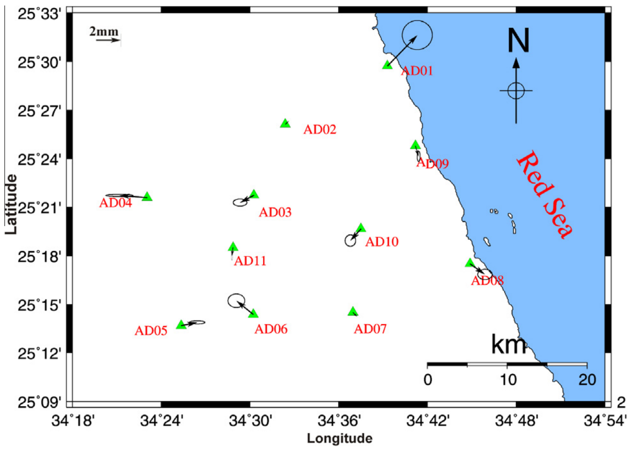

Fig. 8 The computed residual annual horizontal velocity of Abu-Dabbab network.

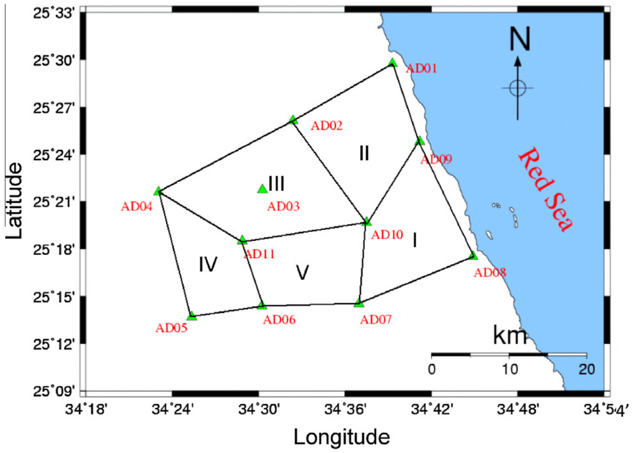

Fig. 9 Five blocks of Abu-Dabbab geodetic network.

epoch to the last one. The rate of the accumulated strains in the area under investigation is small and lies in the lowest class. The average rate of the areal dilatational strain accumulation, the estimated total amount of the maximum shear strains and the magnitudes and orientations of the principle axes of the strain rates are shown in Figs. 10–12 respectively. Referring to the average rate of the areal dilatational strain accumulation (Fig. 10), the area can be divided into two areas. (1) Extension strain area is covering the southeastern part. (2) Compression strain area is covering the north and northwestern part. The occurrence of the southern part lies under the influence of the forces of tension and the occurrence of the northern part under the influence of strong pressure not to mention some of the central parts in which it occurs by the contrast among the forces of pressure and tension. And clear from these analyzes in general, the seismic activity in the area occurs in parts of discrepancy observed among the forces of pressure and tension. The medial part in the present period has been confirmed by seismic data. The contrast zone may be related to any co-seismic and/or post-seismic movements.

The total amount of maximum shear strain at Abu-Dabbab area and the earthquake activities for the considered period are shown in Fig. 11. Earthquakes with magnitudes more than 0.1 M_L were selected and plotted to study the relation between the seismic activity and maximum shear strain. The study area is divided into two zones, which are separated by microearthquakes aligned in the NS–SW direction marking a zone of activity verse the Red Sea. The northern zone is characterized by low maximum shear strain, while the southern one associated by high shear strain value. This means that, the value of maximum shear strain decreases toward the north and increases to the south of the study area. Fig. 12 shows the annual extensive, compressive, and strike slip strain for Abu-Dabbab area. According to the stress and strain field estimations of the different epochs, the Abu-Dabbab area has suffered from compression and tension. The first principal strains of all epochs are compression force in the NE–SW direction and the second principal strains are extension in the SE–NW direction. The direction of the compression force is from NE to SW. This force is owing to the opening of the Red Sea where the direction of this force is parallel to the main axis of the earthquakes trend recorded.

10. Discussion and conclusions

Abu-Dabbab area is characterized by small population. So, no historical earthquakes have been reported at Abu-Dabbab area. However, two recent events (12 November 1955 and 2 July 1984) were widely felt in Upper Egypt. The data used in this study consist of the catalog of earthquake hypocenters

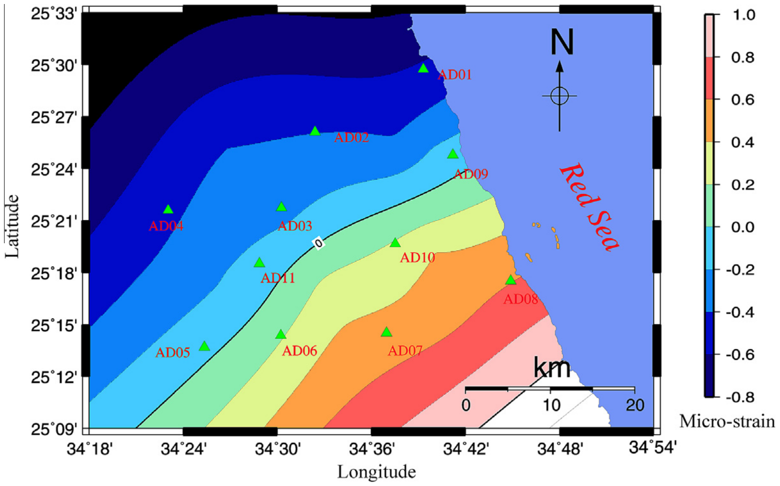

Fig. 10 Distribution of the dilatation strain rates at Abu-Dabbab geodetic network area.

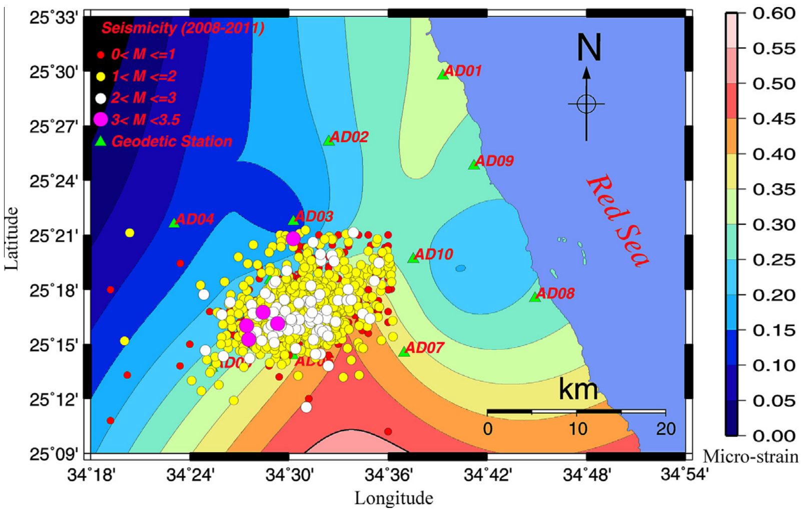

Fig. 11 Distribution of the maximum shear strain rates at Abu-Dabbab geodetic network area.

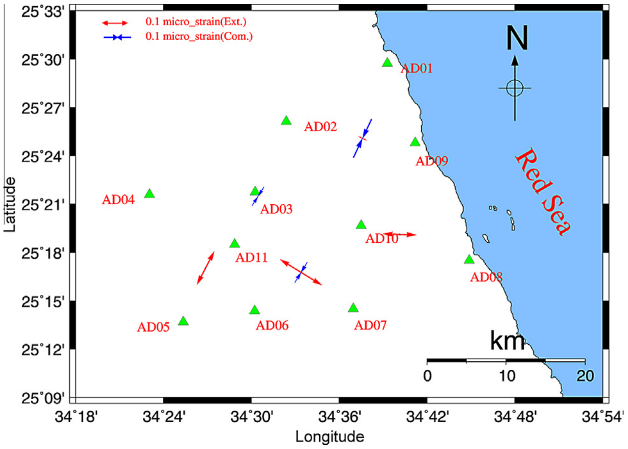

Fig. 12 Annual strain tensor of Abu-Dabbab geodetic network.

determined by the Egyptian National Seismic Network (ENSN) from 2002 to 2011.

Based on, the design and selection of points of the Abu-Dabbab local geodesic network; methods of analysis; repeated measurements on the basis of geological studies of the area and seismic studies (seismicity locations, seismic tomography, and the moment tensor conducted studies) the following could be extracted:

1. From the seismic tomography the low Vp and high Vp/Vs anomalies could be due to some magma intrusions present at depth. These high Vp/Vs anomalies may suggest the occurrence of small size volumes of hot intrusive igneous rocks initiated at different depths. The origin of these intrusive igneous rocks or magma could be explained by the presence of fractional heating at depth that could arise from the reactivation of old shear zones during the formation of active Red Sea rift.
2. After seismicity relocations, using the new 3-D tomographic model, most of the seismic events occur as clusters. The majority of these clusters are located in the depth

ranges, from 5 to 8 km and from 8 to 12 km and below the southern part of the Abu-Dabbab area. The earthquake swarms recorded during the past century and the currently located seismicity have focal depths not greater than 12 km. This may be taken as an indication that ductile material, at high pressure and temperature, or fluid, is present below the high rigidly material in the upper crust, supporting the presence of intrusive igneous rocks or magma through the south part of the upper crust of the Abu-Dabbab area.

3. From the source moment tensor results, the presence of some events with high CLVD ratio, besides the initiation of a high level seismic activity, in the Abu-Dabbab area, without a large seismic main shock, leads us to suggest that the seismic activity of the Abu-Dabbab area might be owing to some magma intrusion, increasing of fluid pressure and gases being consistent with the relatively high heat flow of the area.

According to the space distribution of the earthquakes in the study area, it is noticed that the earthquakes at Abu-Dabbab occur at a perpendicular trend to the Red Sea trend. The maximum number of events during the period from 2002 to 2010 was found in the year 2003 and after that the number decreased till the year 2008 and from 2009 started to increase again. More than 75% of the earthquakes occurred in the area are micro-earthquakes and less than 2.0 M_L. The spatial distribution of microearthquakes tends to align in the ENE–WSW direction marking a zone of activity verse the Red Sea.

The final results of the horizontal movements at some stations of the network indicate significant changes while other stations indicate no significant changes through the period of observations. The magnitudes of the movements are distributed inhomogeneous over the area. Estimated displacement vectors were used to reconstruct the strain parameters. According to the strain field estimations, the compressional force is dominant all over the study area. The value of compression is varied from place to another throughout the area under study. The value of compression force decreases toward the northern and northwestern parts of the area, while it increases toward the southern and southeastern parts. The total amount of maximum shear strain accumulation during the present interval is relatively small. The maximum shear strains increases toward the south direction and decreases toward the north direction. The maximum values of shear strain are found generally in the southern part. On the other hand, the minimum values of shear strain are found generally in the northern part of the study area. The earthquake epicenters are concentrated at the contrast zone between the forces of pressure and tension which reflects an energy release in the deformation process. As known, the crustal deformation processes could occur during the accumulation of the energy within the Earth's crust and during the different phases of energy released. This means that the southern part of the network suffers from the seismic deformation during the interval period. Moreover, dramatic increases in general earthquake activity can be expected in this area. Magnitudes and orientation of principal axes of the strain rates across the five blocks of the network are calculated and plotted. The area has suffered from variable compression and tension through the time of observations. The compression is prevailing in the most blocks in the area and is taken northwest–southeast to the NWW–SEE direction. The maximum values of compression strains are found close the Red Sea coast and decrease the farther from the shore. The values of the extension strain are found in the some blocks of the network. There are some balance between compression and extension in the others.

From the estimated magnitudes and directions of the deformation fields and the characteristics of the seismic activity at Abu-Dabbab (extremely tight clustering within a very small area and different style of source mechanisms), the area has been affected by local and regional stress pattern. The dominated stresses are result from either the extension related to the intrusion of a pluton into the Precambrian crust or the shortening (compressional) due to the opening of the Red Sea. The results of these analyses represent the framework of the dynamic model for the deformation, which occurred at Abu-Dabbab area during the different epochs of the measurements.

Finally, we can conclude that, based on the combined present studies of seismic tomography; moment tensor; earthquake relocations and crustal deformation, the seismic activity of the Abu-Dabbab area is not only owing to the regional stresses of the Red Sea but also more influenced by the local stress pattern due to some magmatic activities beneath the crust of the Abu-Dabbab area. This magmatic intrusion can be interpreted as some magmatic spread through the faults that cut the lower crust of the study area, which make collection of ductile rocks at the lower crust and consequently we never found any earthquakes occur at lower depths than 15 km. These earthquakes occur at the boundary between the brittle and ductile rocks or at the transition zone (brittle ductile zone).

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