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Seismic hazard evaluation using strain energy release in Egypt

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summery

According to the legal rules in Egypt, establishment of a new repository for the final disposal of radioactive wastes is only permitted in natural geological formations with suitable seismic and tectonic parameters. The strain energy release technique is used in this work to evaluate the seismic hazard for seven regions of Egypt. The representative parameters applied for this evaluation are related to the physical release process of the strain energy. Seismic data are collected from International Seismological Center (ISC, 1910-1993), Helwan Catalogs (1900-2002), and earthquake data reports of U.S department of International Geological Survey (USCGS, 1900-1994). Some earthquake source zones are well defined on the basis of both tectonics and average seismicity rate.

The parameters of magnitude, M2, M3 and DT has been calculated, where M2 equivalent to the mean annual total strain energy release and the magnitude. M3 is analogous to the maximum strain energy which accumulated and released in a region. Empirical relation between M3 and M2 is obtained and the result shows that it has a worldwide validity. The quantity DT, showing the time difference per year between the upper bound line (in the energy diagram) and the time since the last seismic activity (strain energy accumulation) is suggested here. The approximate time of the next earthquake occurrence with magnitude less or equal the maximum strain energy is calculated. Finally, a table shows the regions in Egypt ranked to the M2 parameter, and the safe region suitable for a waste disposal site.

Key Words: Egypt, Strain Energy Release, Historical Earthquakes, M2,M3, Dt

Introduction

The methods of disposal of nuclear waste are becoming increasingly important, both politically and practically. The choice of sites has been a major problem for Egypt. Site selection and characterization is a process to assess the ability of a site to contribute to the isolation of the waste and limited radionuclide releases to levels consistent with impact on human and the environment within the relevant standard. In determining the site characteristics that are important to the assessment of the design and safety, the following shall be considered as minimum: geology, hydrogeology, geochemistry, tectonic and seismicity, surface process, meteorology, climate and impact of human activity (IAEA, 1995).

The site should be located in an area of low tectonic and seismic activity such that the isolation capability of the disposal system will not be endangered. Areas of low tectonic and seismic activity should be selected in the regional analysis. Preference should be given to areas or sites where potential for adverse tectonic, volcanic or seismic events is sufficiently low that it would not affect the ability of the disposal system to meet safety requirements. (IAEA, 1995).

The primary features of active plate tectonics in the vicinity of Egypt (Fig1) are discussed in details by m Mckenzie (1970). Three major plate boundaries namely the African-Eurasian plate margin, the Levant transform fault, and the Red sea plate margin separate the African, Eurasian and Arabian plates. Apiece of the African plate, called the Sinai block or subplate, is partially separated from the African plate by the spread-apart or rifting along the Gulf of Suez[3] (Woodward, 1985). In addition to these plate boundaries, there are two megashear zones running from southern Turkey to Egypt.

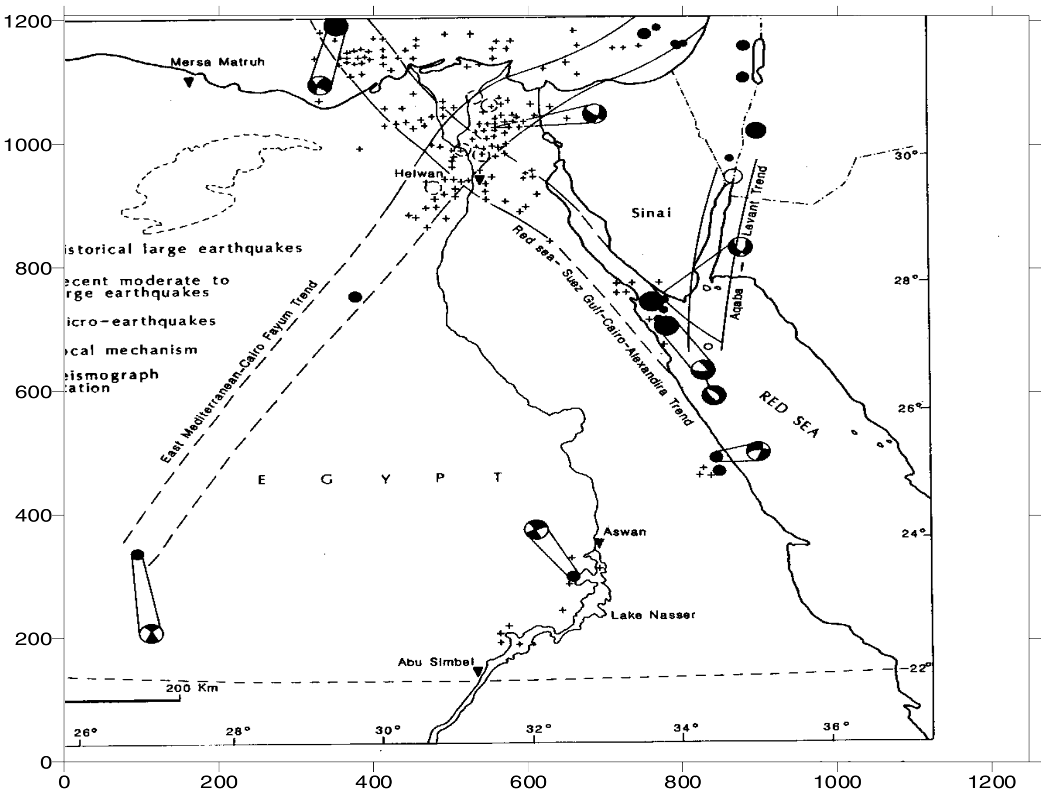


Fig.(1) seismotectonic map of Egypt and epicenters of earthquakes (after Kebeasy, 1990) and modified 2002 by adding new earthquakes.

Several statistical models have been applied to evaluate the seismic risk and seismic hazard in Egypt .(El-hemamy 1990,1994). The most popular of them is known as the magnitude-frequency law (Gutenberg and Richter 1944). This is based on the knowledge of all earthquakes (whole process), which occurred during a given time, at a given region with magnitudes greater or equal to M and described by:

$$\text{Log } N = a - b M , \qquad (1)$$

where a and b are parameters and N is the number of the earthquakes.

The theory of the extreme values Gumbel (1958) is a well-known and commonly used method to assess the seismic hazard and has the advantage that it requires for analysis only the extreme value magnitudes (part process). Yegulap and Kuo (1974) have incorporated the latter into the assessment of limiting earthquake magnitudes on a global basis. Karnik and Hubnerova (1968) give the estimation of the probability of the occurrence of the largest earthquakes using the Gumbel first asymptotic distribution. Later, Schenkova and Karnik (1970) modified the above method to obtain the limiting earthquake at an infinite return period. Seismic hazard have been studied at Egypt by many authors El-Hemamy (1990,1995) and El-Sayed et al (1996).

The objective of our work is to assess the seismic hazard for some regions of Egypt using parameters obtained from the strain energy release.

Data and applied method

Historical earthquakes

Egypt has a historical record of earthquake activity extending over the past 4,800 years. In addition to the magnitude 5.9 Dahshour earthquake of 12 October 1992, which damaged over 1,000 schools and killed or injured over 7,000 people, the three most significant earthquakes of this century include: 1) the magnitude 6.7 earthquake offshore of Alexandria on 12 September 1955, which destroyed over 300 buildings, 2) the magnitude 6.8 Shadwan Island earthquake on 31 March 1969, and 3) the magnitude 5.2 Aswan earthquake of 14 November 1981, which called attention to the importance of earthquake monitoring in the High Dam area and of hazard and risk studies in the country. More recent is the Aqaba earthquake of 22 November 1995, magnitude 7.2 which killed at least 8 people and injured 30 in the epicentral area. Damage occurred in many parts of northeastern Egypt as far away as Cairo. Few injuries and some damage were reported in Saudi Arabia. Substantial damage with power outages and liquefaction occurred at Eilat, Israel. Some damage also occurred at Jerusalem and Aqaba. It was felt from Sudan to Lebanon.

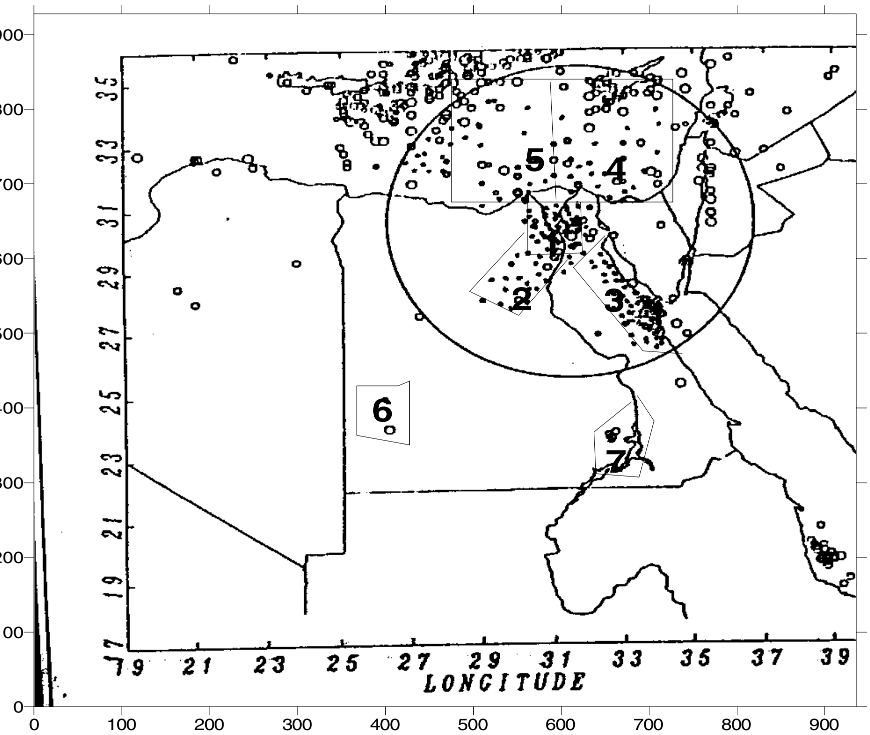
Search in some of the recently published compilations of historical earthquakes of the Middle East was made, with special interest in the works of Ambraseys (1961 and 1978), Poirier and Taher (1980), Ambraseys (1994) and Maamoun et al. (1984). It was found that, for Egypt, a total of 58 earthquakes are reported felt, with intensities of V-IX, during the period 2200 B.C. - 1900 A.D. Some of these earthquakes are reported with poor information regarding the epicentral area; some have locations outside the Egyptian border. Altogether, 22 of the earthquakes have reliable information concerning the location. 11 of these caused destruction (Table I). The assigned intensities, based on the historically reported damage, may not be homogeneous, neither in time nor in space. Therefore, only general conclusions can be made regarding the characteristics of the historical seismicity:

1. Destructive earthquakes have occurred in Egypt. Reports of major and regional destruction are available
2. A general concentration of the historical activity is quite clear around the Nile Valley and Nile Delta. These areas are densely inhabited, but the presence of thick sediments is likely the main cause of the high intensities
3. There are similarities in the intensity distribution of some historical earthquakes and recent earthquakes in the respective areas. Examples are the events in 1210 B.C., which was located close to the event of November 14, 1981 near Abu-Simbel, and the events in 600 B.C., of November 12, 1955 and of March 31, 1969 near Luxor. These similarities give some help in the argument about the location of the historical epicenters. The event in 1303 was placed by Sieberg (1932) south of Cairo near El-Faiyum. Maamoun et al. (1984) considered the location erroneous and placed it near Crete. The event of October 12, 1992 near Cairo is similar to the 1303 event as to the distribution of reported damage and intensities, which yields strong support for the location given by Sieberg (1932) for the 1303 earthquake

4. The events in 1210 B.C. and 1854 close to Aswan as well as tectonic studies for the Aswan High Dam area support that significant seismic activity of tectonic origin has occurred. Water and sediment loads could have been triggering factors. The recent microseismicity is likely to a large part induced by the reservoir.
5. The epicenters of historical earthquakes seem to correlate with the general tectonics of the region (compare Figures 1 and 2). The 600 B.C., 28 B.C. and 1778 events have epicenters

Seismic hazard assessment requires Knowledge of the spatial and temporal distribution of earthquakes sources. Both historical and instrumental are collected. Riad and Meyers (1985)[10] produced a map which shows the special distribution of reported shocks in the middle east region. They reported the earthquakes in manual per geographic areas. The earthquakes data used in this study are derived from different catalogue around Egypt[(11-13)] (Ambrasys et al 1989, International Seismological Center 1910-1993, Helwan Cataloges 1900-2002, USCGS,1900-1994) In this compilation, data prepared during pervious studies in the region were used as primary data. A special emphasis was given to contribution to data from the region. The data compiled from number of sources covers the period 627-1994. All magnitudes were homogenized to Ms and dependent events (foreshocks, aftershocks, and induced events). Catalogue completeness was carefully studied and the period 1900-2003 was found completed for magnitude larger than 3.

Individual seven zones as show in Fig (2). are crossing the examined area with starting point at 20^o N and 25^o E. For each zone the parameters and b of equation (1) and the annual maximum magnitude, M1, are calculated using the least squares method. It is easily therefore, to compute the parameters M2, M3 and the waiting time Tr of the strain energy release. The time period is considered from 627 B.C to 2003.



Fig(2) Seismogenic zones based on the major tectonic elements that are reported in the studied area

Strain Energy Release

Earthquake magnitude and strain energy release, e in erg, can be related through Bath's (1958) equation:

$$Log\ E = 12.24 + 1.44\ M \qquad (2)$$

It is important to investigate the variations of the strain energy, from the mean annual rate and related this to earthquake magnitudes, which are there by characteristic to the seismic hazard. The analytical method described by Macropoulos and Burton(1983)[14]. They expressed this earthquake magnitude, as M2 through an empirical relationship and they note that the average properties of this fluctuating process are known with great accuracy. Therefor M2 is the magnitude that corresponds to the mean annual rate of energy release. The total energy released from an earthquake is an upper limit to maximum strain energy and mathematically is expressed by the following equation Makropoulos and Burton 1983)[14] through the analytical methods:

$$M3 = 1/B\text{-}b\ (BM2\text{-}bM1\text{-}log\ (b/B\text{-}b) \qquad (3)$$

Where B, b is a constant from equation (1)

Values of M2 and M3 through commutative strain energy release diagrams, described by[15] (Bath 1973). These diagrams present the plotting of the cumulative energy release as a function f time. Those diagrams are widely used by many authors[(14,16-20)] (Galanopoulos 1972, Makropoulos 1978, Makropoulos and Burton 1983, Voidomatis 1984, Tsapanos 1998) to estimate the annual and maximum possible strain energy which is being accumulated and released in different parts of the Egypt.

Result and Discussion

The area of the study is classified into regions according to the tectonic map as show in fig (2). We calculate the strain energy release against time for every region. The gradient of the middle line joining the origin to the total strain energy release can be related to the equivalent earthquake magnitude M2. Variations in the rate of the strain energy release are enveloped by two outer lines, which are parallel to the middle line. The vertical separation of the enveloping lines may be regarded a measure of the maximum strain energy release, which may accumulated and released in a region. This interpreted as the large magnitude earthquakes M3 that can be evaluated through equation (3). The horizontal projection of the enveloping lines represents the maximum time Tr, required to accumulate the energy equivalent to M3 if no smaller earthquakes occur during the period. This time is called waiting time. Dt is the estimated probable time of the next earthquake occurrence with magnitude less or equal to M3 , and it is the time difference between the upper bound line (in energy-time diagram) and the time since the end of the last seismic activity.

The first zone indicate to the delta area as show in (Fig1), The origin of the Nile valley has been of controversy[21] Sandford (1934) advocated that the Nile valley is of erosional origin. On the other hand, many authors[(22-24)] (e.g. Said, 1981; El Gamili 1982; and Kebeasy,1990) consider it of tectonic origin. The tectonic origin of the Nile valley is supported by the fault scraps bordering the cliffs of the Nile valley, by the numerous faults recognized on its side[(25,27)] (El-Gamili, 1982 and said 1981,1990) and by the focal mechanisms of the most recent earthquakes[25] (NRIAG, 2001). Moreover, recent studies indicate that the Nile valley of Egypt occupied the marginal part of two tectonic zones (the Eastern Desert and inner part of Neogen-Quaternary platform) and is considered as a barrier that prevent the extension of the activity of the East African origin belong to the west[26] (said, 1990). The most instance seismic activities reported for the Nile valley are related to the tectonic activity of the red sea axial zone[22] (Said, 1981). We can see from fig (3).a high seismic activity at the end of 1992 i.e the new energy accumulated starts at 1992. The quantity DT has a value 37 years, which means that in the next 20 years the region will experienced an earthquake which equivalent to strain energy of the order of 10^{21}erg. Which equivalent to magnitude and the calculated year is 2040

The second zone is the El-Fayom area, the quantity of D.T is 22.5 years and we can see in Fig.(4) there is a continuous accumulation of the strain energy, since 2003 in the area, do we can assume that the active seismic period should be expected the year 2025 with energy of 10^{22} erg. (About magnitude 6.3).

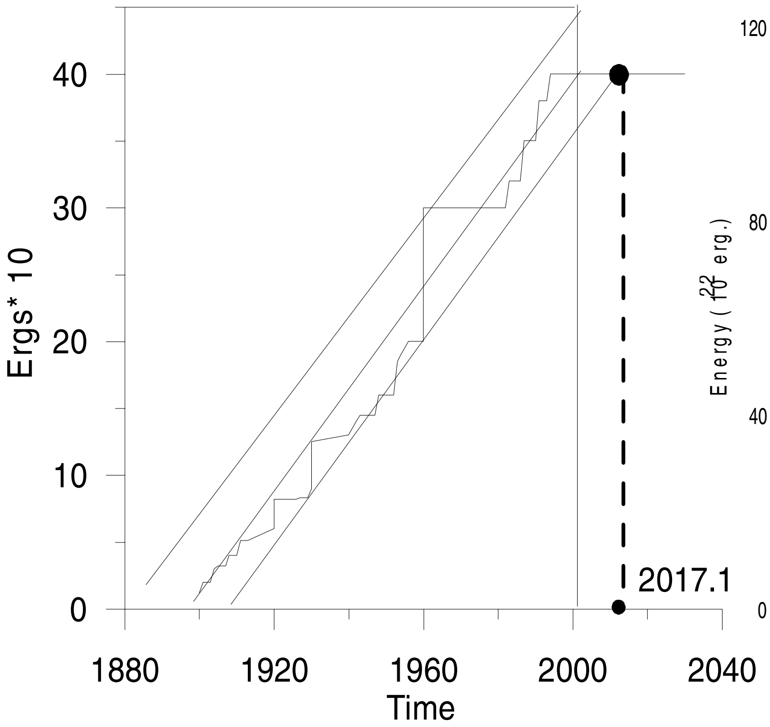


Fig. (3) Cumulative strain energy release as a function of time for the Delta area

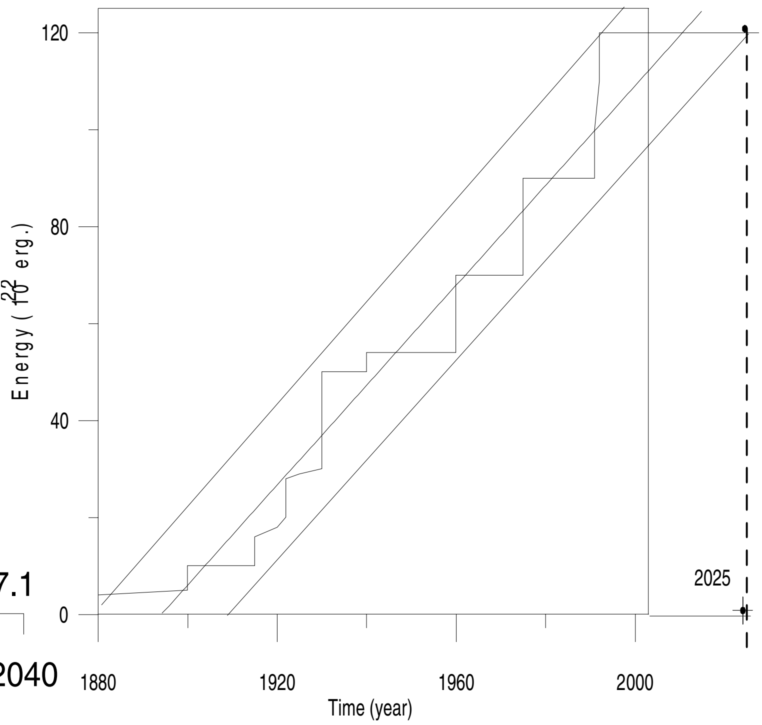


Fig (4) Cumulative strain energy release as a function of time for El Fayom area

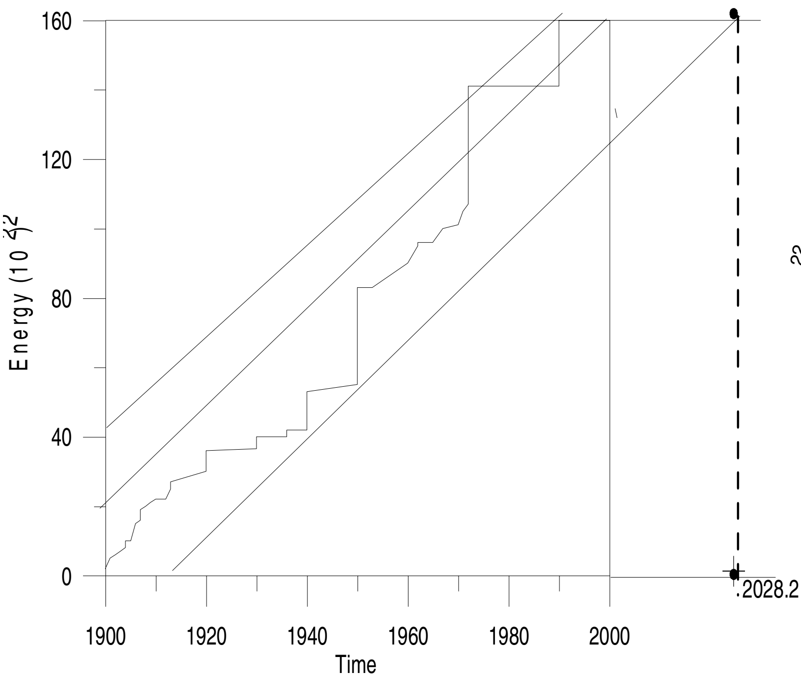


Fig. (5) Cumulative strain energy release as a function of time for the Red Sea area

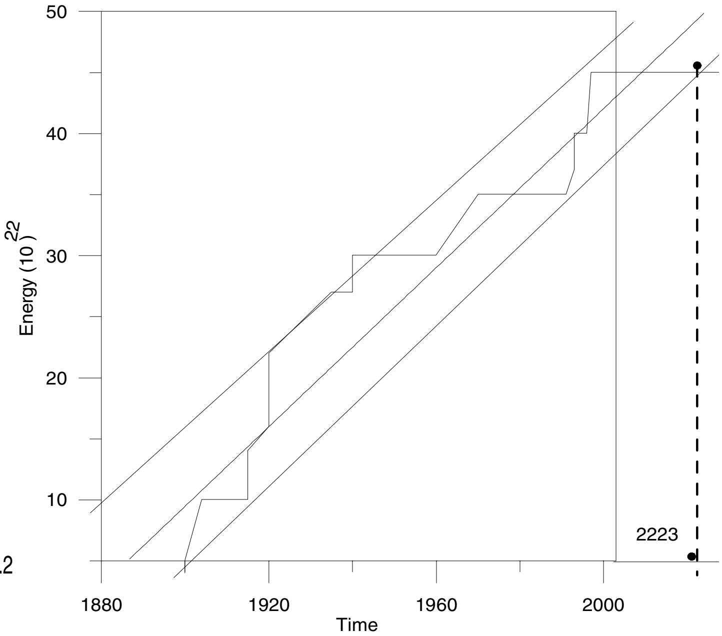


Fig. (6) Cumulative strain energy release as a function of time for Mediterranean sea area

The third cell indicates to the Red Sea area, The Red Sea region is one of the areas around the world, which is well investigated geophysically. It has positive Bouguer anomalies indicating the presence of intrusive rocks beneath the deep water[27] (Adel A.A. Othman) Over the center, there are a large magnetic anomalies; There are probably associated with material with seismic velocities of 4.1~0.4 km/s overlying material with velocity 7.1Km/s[28] (Heirtzler and Le Pichon, 1965). Near the margins seismic velocities of about 6 Km/s are found suggesting the presence of down faulted basement[29] (Girlder, 1969). The quantity of D.T is 25.2 years and we can see in Fig(5) there is a continuous accumulation of the strain energy, since 2003 in the area, do we can assume that the active seismic period should be expected the year 2028 with energy of 10^{22} erg. (About magnitude 6.5).

The fourth and fifth cells include the Mediterranean Sea, It is characterized by a high seismic energy release (Fig.6,7). Here DT is 23.2 years (with energy accumulated science 2000). We can observe the stored energy should be expected the year 2023 and 2011years respectively.

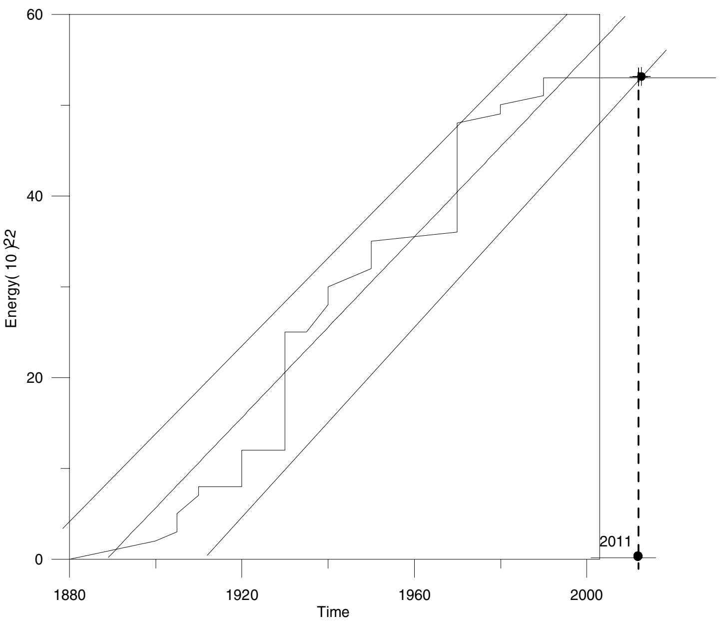


Fig. (7) Cumulative Strain energy release as a function of time For the Mediterranean sea area

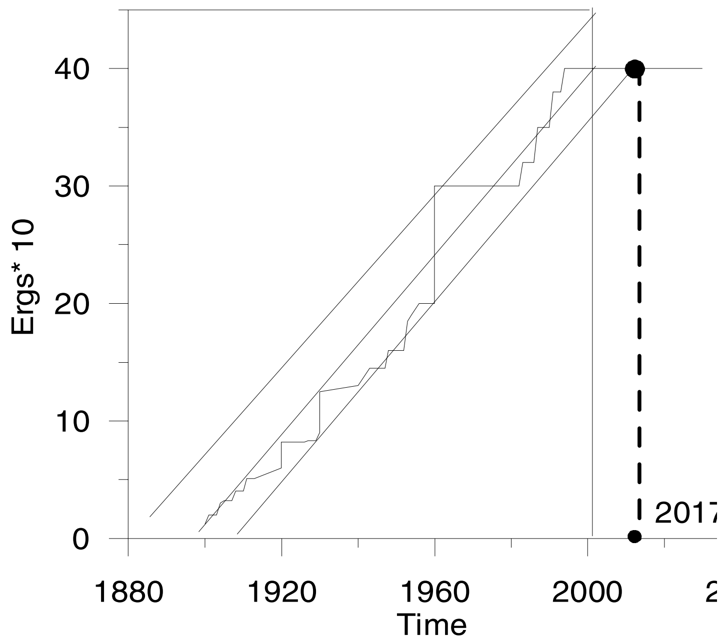


Fig.(8) Cumulative strain energy release as a function of time for Aswan area

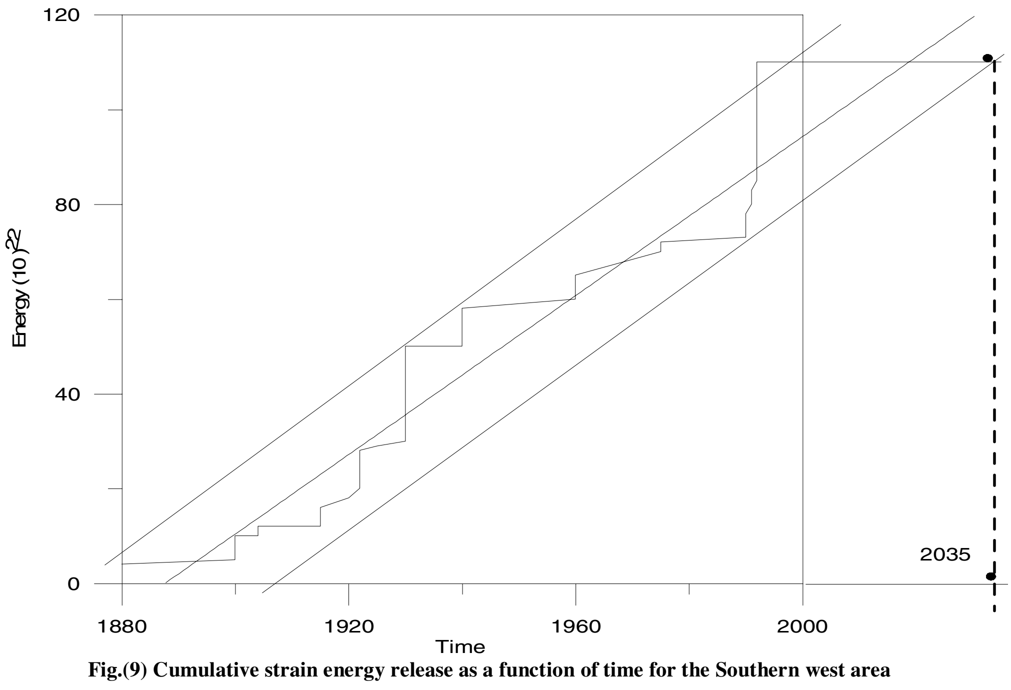


Fig.(9) Cumulative strain energy release as a function of time for the Southern west area

Aswan area is the six cell. The high seismicity energy release (Fig.8) of the region is in close to Kalbshea fault. The quantity DT= 17.2 and the energy accumulating science 2000, which mean the largest earthquake in the cell occurred in 2017 with M=5.3.

The area in the Southern west is the seventh cell. The quantity of D.T is 11.7 years and we can see in Fig(9) there is a continuous accumulation of the strain energy, since 1997 in the area, do we can assume that the active seismic period should be expected the year 2035 with energy of 10^{22} erg. (About magnitude 5.2).

Numerical all values of a, b, m, as well as of average strain energy release annum Mn and the maximum strain energy release M3. As well as T_r (in years) are in table (1).

Table (1) Strain energy release parameters

Cell	a	B	MI	TE*/year	M2	M3	T.(year)
1	6.08	0.91	5.6	0.352	6.0	7.3	40.2
2	6.35	0.94	5.8	0.365	6.1	7.1	30.5
3	5.16	0.89	6.3	1.774	6.2	7.3	35.2
4	4.99	0.79	6.3	2.987	6.1	7.2	64.1
5	6.01	0.93	5.6	0.689	5.8	7.0	23.3
6	5.23	0.89	5.4	0.548	5.7	7	26.1

b-values calculated using maximum likelihood method and list square method.. We notice from this table that, b-values ranges from 0.4 to 1.6 i.e large varieties for the relatively small area as Egypt. The reflect the non-homogeneity of the structure of Egypt High b- values at the Red sea area due to the structure at the area. Low b-values at the Nile Delta, Western Desert, due to the low seismicity of the area

Conclusions

The tectonic setting of Egypt is very complicated. Active zones have developed from plate margin actively and imply that the seismic hazard is high parts of Egypt. High b-value in general to the uplift of basement This method applied the magnitude-frequency law with the energy-magnitude relation, and is applied in this work to estimate the seismic hazard in Egypt, also it is based on Makropoulos and Burton 1983)[14]. Empirical relationship between M3 andM2 has been derived. The quantity Dt introduced her to forecast the time of the next earthquake may occurred. High-energy release agrees with the major fault in Egypt. Finally the Western Desert of Egypt has low seismic release and low b-values, for this reasons this area is the best area form the seismicity established a new repository for final disposal site.

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