Egyptian Geophysical Society
EGS Journal, vol. 3, No. 1, 57-64 (2005)

SEISMIC HAZARD EVALUATION USING STRAIN ENERGY RELEASE TO DELINEATE A NEW RADIOACTIVE WASTE DISPOSAL IN EGYPT

Soheir Tawfik El-Hemamy

Siting and Environmental Department, National Center for Nuclear Safety and Radiation Control, Atomic Energy Authority, Cairo-Egypt

تقيم المخاطر السيزميه باستخدام الطاقه المنطلقه لاختيار موقع جديد لدفن النفايات المشعه فى مصر

الخلاصـة: يختص هذا البحث بدراسة الخواص الهندسية لإنشاء مدفن جديد للمواد المشعة في مصر، ومن شروط المدفن أن يكون آمنا من الناحية الزلزالية. ومن خلال حساب معاملات الطاقة المنطلقة تم حساب M3, M2 وهى تعادل المتوسط السنوي للطاقة المنطلقة و أعلى طاقة منطلقة متجمع على التوالي. وتم أيضا حساب Dt وهى توضح الفارق السنوي بين الطاقة المتجمعة والطاقة المنطلقة. وقد أمكن التنبؤ بالوقت التقريبي لحدوث الزلزال وكذلك كمية الطاقة المنطلقة.وبذلك أتضح أن أنسب الأماكن من الناحية الزلزالية لبناء مدفن هو الجزء الجنوبى للصحراء الغربية.

ABSTRACT: *This work deals with the establishment of a new guideline for a new disposal for low and intermediate radioactive waste in Egypt. It is only permitted in natural geological formations with acceptable seismic and tectonic parameters. The representative parameters applied for this evaluation are related to the release process of the strain energy. The examined parameters are magnitude M2, equivalent to the mean annual total strain energy release, and magnitude M3, analogous to the maximum strain energy which may be 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. An effort is made to forecast the approximate time of the next earthquake occurrence with magnitude less or equal to the maximum strain energy release. Finally, it clears that the Western Desert is a suitable region for establishing the site of radioactive waste repository.*

INTRODUCTION:

The methods of disposal of low- and intermediate-waste are becoming increasingly important, both politically and practically. In Egypt, big amounts of radioactive waste are already disposed at Inshass site. Further, radioactive wastes are production solid and liquid wastes and are disposed near the surface. Therefore, the waste disposal site must be carefully selected to ensure that man and other living species will not receive unacceptable detriments at present or in future. The selection of an appropriate repository design will depend primarily on geological, hydrologic, topographic, tectonics, seismicity and climatic conditions (IAEA, 1995).

The site should be located in an area of low tectonic and seismic activity. 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 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. A piece 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 (Woodward, 1985). In addition to these plate bounders, there are two megashear zones running from southern Turkey to Egypt Several statistical models have been applied to evaluate the seismic risk and seismic hazard in Egypt (El-Hemamy 1990; 1995). The most popular of them is the magnitude-frequency law (Gutenberg and Richter 1944). This is based on the knowledge of all earthquakes with magnitudes greater or equal to M, which occurred during a given time and the following formula is used at a given region:

$$\log N = a - bM \tag{1}$$

The parameter (a) is the activity and defines the intercept of the recurrence relationship at M = 0. The higher seismicity of the region is the greater value of (a). The b-value is sometimes thought of as a measure of the brittleness of the crust; it defines the relative proportion of the small and large earthquakes, and N is the number of the earthquakes.

The theory of the extreme values (Gumbel 1958) is well-known and occasionally used method to assess the seismic hazard and has the advantage that it requires for analysis only the extreme value magnitudes.

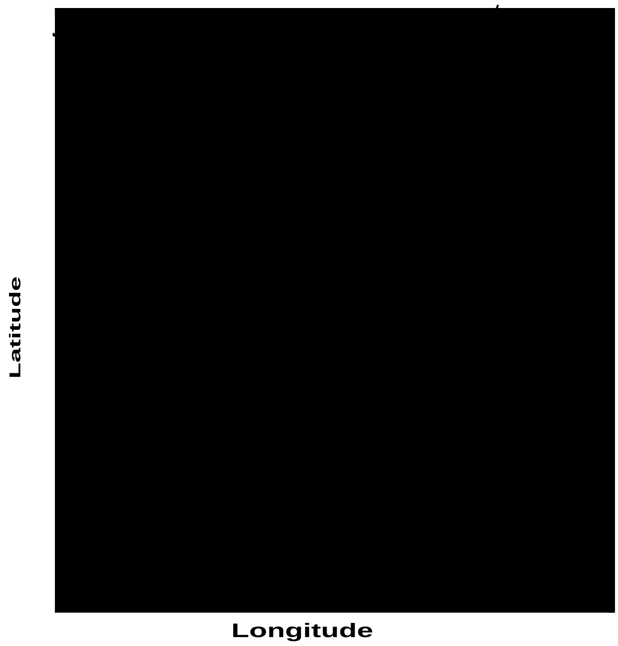

Fig. (1): Seismotectonic map of Egypt and epicenters of earthquakes (after Kebeasy, 1990) and modified (2002), by adding new earthquakes.

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, Karnik and Schenkova (1970) modified the above method to obtain the limiting earthquake at an infinite return period.

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

DATA AND APPLIED METHODS

1. Historical Earthquakes

Egypt is situated in the northern-eastern corner of the African plate, interacting with the Arabian and Eurasian plates through divergent and convergent plate boundaries, respectively. Also, Egypt is affected by opening of the Red Sea (Mid Oceanic System) and its two branches (the Gulf of Suez and the Gulf of Aquba-Dead Sea transform system). The relative motion along these plates creates areas of high seismicity. During the last century, Egypt has been shaken by some severe earthquakes (Ms=5.8 -7.3). These earthquakes caused considerable damage.

Seismic hazard assessment requires knowledge of the spatial and temporal distribution of earthquakes sources. The earthquakes data used in this study are derived from different catalogue around Egypt (Ambraseys and Barazangi 1989, Gergawi and El-Khashab 1968, Maamoun et al. 1984, Ibrahim 1982). The data compiled from a number of sources covers the period 627-2002. The catalogue completeness was carefully studied and the period 1900-2003 was found complete for magnitudes larger than three.

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 and Barazangi (1989), Poirier and Taher (1980) 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. to those-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 earthquakes have reliable information concerning the location. Eleven of these caused destruction. The intensities assigned, 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 were located close to the event of November 14, 1981, near Abu-Simbel, and the events in 600 B.C., of November 12, 1955, and March 31, 1969, near Luxor. These similarities give some help in locating the historical epicenters. The event in 1303 was placed by Sieberg (1932) near El-Faiyum, south Cairo. 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 the 1303 earthquake given by Sieberg (1932).
4. The events in 1210 B.C. and 1854 close to Aswan as well as tectonic studies for the Aswan High Dam area support the conclusion that significant seismic activity of tectonic origin has occurred there. Water and sediment loads could have been triggering factors.
5. The epicenters of historical earthquakes seem to correlate with the general tectonics of the region.

Individual cells of 2^0 latitude x 2^0 longitude are distributed in the examined area as shown in Fig.2, with starting point at 23^o - 37^o N and 28^0 - 35^0 E. For each zone, the parameters (a) and (b) of equation (1) are calculated using the least squares method as well as the annual maximum magnitude are determined. It is therefore, easy to compute the parameters M2 (the mean annual rate of energy release), M3 (the maximum strain energy) and the waiting time Tr of the strain energy release. The time period from 627 B.C to 2003 is considered.

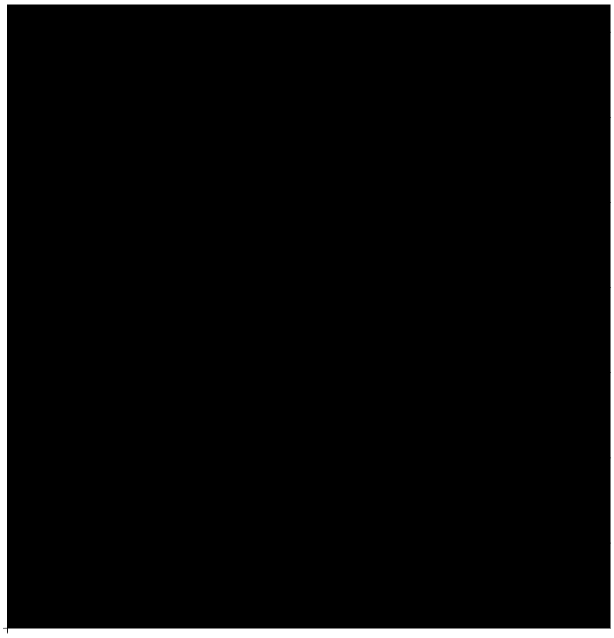

Fig. (2): Seismogenic zones based on the major tectonic elements that is reported in the studied area

2. Strain Energy Release

Earthquake magnitude (M) and strain energy release E (in erg) can be related through Bath's (1979) equation:

$$\log E=12.24+1.44M \quad (2)$$

It is important to investigate the variations of the strain energy from the mean annual rate, and relate them to earthquake magnitudes. The analytical methods described by Macropoulos and Burton (1983) express the earthquake magnitudes M2 through an empirical relationship and they note that the average properties of this fluctuating process are known with great accuracy. Therefore, M2 is the magnitude that corresponds to the mean annual rate of energy release. The total energy released from an earthquake is defined in the above work as an upper limit of maximum magnitude earthquakes and is expressed as M3. So M3 will be equivalent to the maximum strain energy and mathematically is expressed by the following equation (Makropoulos and Burton, 1983)

$$M3=\frac{1}{E-b}(EM2-BM1)-\log(\frac{b}{E-b}) \quad (3)$$

Where E is a constant from equation (2), b is a constant from equation (1) .The values of M2 and M3 can be obtained through commutative strain energy release diagrams, described by Bath, 1979. These diagrams present the cumulative energy release as a function of time. They have been widely used by many authors (Galanopoulos 1978, Makropoulos 1978, Makropoulos and Burton 1983, Voidomatis 1984, Tsapanos 1988, Tsapanos and Theodoros 1998) to estimate the annual and maximum possible strain energy which is being accumulated and released in different parts of Egypt.

DATA ACQUISITION AND ANALYSIS

Figure 3 depicts the plotting of the strain energy release against time (in years) in the first cell. The gradient of the middle line joining 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 as a measure of the maximum strain energy release which might have been accumulated and released in a region. This is interpreted as the large magnitude earthquakes M3 that can be evaluated through equation (3). The horizontal projection of the lower 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. From the previous observations we can consider that, as the energy release decreases [gets closer to the lower parallel line], the possibility of a large earthquake occurrence appears to be greater and vice versa. Thus, the lower parallel line is the boundary of the highest seismic hazard for the region, because this is the line of maximum storage of energy that may be released. The close relation between the parameters M3 and M2 is of great importance because it has proved very useful in regional seismic hazard assessments and for the examined regions. Figures 3 through 9 shows the strain energy release versus time for seven regions studied (2^0 side cells). The quick look on Fig.3, (cell 1) none of seismic activity periods go over the line AA\.

So we can consider that this line as a bound over which no strain energy will be accumulated. If we extend this line to the future and connect the end of the last seismic period with it, we can estimate the probable occurrence time of the next earthquake with magnitude less or equal to M3. This is called Dt, and it is the time difference (in years) between the upper bound line (in the energy-time diagram) and the time since the end of the last seismic activity.

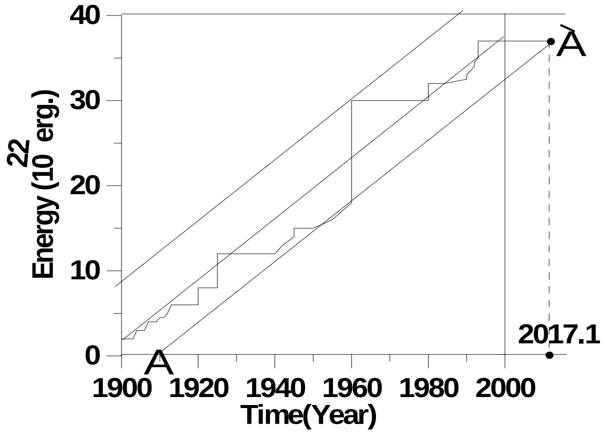

Fig. (3): Cumulative strain energy release as a function of time for Delta area.

SEISMIC ZONES IN EGYPT

In the present study the source zones will be defined by polygons within which it is assumed that the seismicity is uniform in terms of the type and distribution of earthquakes. It is assumed that a single earthquake generating process (mechanism) can therefore characterize the seismic activity of the source and it is also assumed that earthquakes have an equal probability of occurring at any point within the seismic source zone.

The main criteria for determining the boundaries of the seismic zones include the distribution of instrumental and historical seismicity, the tectonic setting and the location of the active faults. It is almost impossible to prescribe a standard procedure for the definition of the seismic source zones, since the process involves a high degree of judgment .There are five geographic areas of earthquake hazard in Egypt.

1. The Delta region and Mediterranean fringe,
2. Areas surrounding the Red Sea, Gulf of Suez and Gulf of Aqaba Junction,
3. Area surrounding Lake Nasser in the South of Egypt,
4. South-West Cairo (Dahshour area),
5. Gulf of Aqaba, Dead Sea Rift, and
6. Western Desert.

1. Tectonic Setting and Seismicity of the Delta Region and Mediterranean fringe

This part of Egypt has experienced significant historical earthquake damage and is vulnerable to earthquakes originating both locally and offshore in the eastern Mediterranean basin. The maximum expected intensity ranges from VI to VIII. The highest intensities are associated with those parts of the Delta where the subsoil is of poorest quality and provides a very insecure foundation (unconsolidated and water-saturated). Maamoun and Ibrahim (1978) attributed the activity of this trend to the continental shelf and the probable deep faults parallel to the coast. This trend begins from Cyrenacia (Libya) in the west to Alexandria and then northeastward to Beirut Bay. This trend is almost parallel to the continental margin, which could be considered as a weakness zone having experienced thinning during the Triassic period (Ben Avraham *et al.*, 1987).

2. Tectonic Setting and Seismicity of the Red Sea, Gulf of Suez and Gulf of Aqaba.

The northern limit of the Red Sea lies at the tectonic triple junction between the rifts of the Red Sea, Gulf of Suez and the Gulf of Aqaba. This zone has been associated with considerable seismic activity (Shadwan earthquake). The highest intensities are expected to be in those areas where unconsolidated coastal or fluvial sediments occur.

3. Tectonic Setting and Seismicity of the Areas around Nasser Lake, Southern Egypt.

The recent apparent increase in the seismicity of Nasser Lake is probably due to the re-activation of the Klabsha fault rather than man-induced seismicity and the creation of the reservoir. The hazard is shown to be most severe around the northern part of the Lake Nasser, where the reservoir is particularly wide and the Kalabsha fault is delineated

4. Tectonic Setting and Seismicity of the South West Cairo (Dahshour Area).

Abou Elenean (1997) and Deif (1998) defined the area of the epicenter of Dahshour earthquake, 1992, south-west Cairo, and its surroundings as a separate seismic zone**.** This zone experienced some historical earthquakes and also the most catastrophic one, in Egypt on 12 October 1992.

Faults of the area are trending east west, parallel to the Mediterranean trend, or northwest southwest, parallel to the Gulf of Suez trend. The focal mechanisms of Abou Elenean (1997) for this region provide pure normal faulting or normal faulting with large strike-slip components Figures (1-7). The first nodal plane of the fault plane solution of the large event in 1992 is trending nearly E-W, showing coincidence with the surface lineaments, as appeared directly after the occurrence of this event. Thus, this plane is recommended to be the most probable fault plane. The auxiliary plane is trending mainly NW-SE parallel to the Gulf of Suez.

5. Tectonic Setting and Seismicity of the Gulf of Aqaba-Dead Sea Rift .

The Gulf of Aqaba-Dead Sea rift is a seismically active transform boundary, extending from the Red Sea spreading center in the south to the Taurus-Zagros collision zone in the north. This 1100-km long sinisterly slips system marks the boundary separating the Sinai subplate from the Arabian plate and hence, it is one of the rare places on the Earth where the boundary is actually exposed on the continent and not buried beneath the ocean.

Ben-Avraham (1985) found that the mid-oceanic ridge of the Red Sea-Gulf of Aqaba system changes to transform fault and runs into the continent. Being left lateral, 1100 km continental transform, the Dead Sea fault accommodates the relative motion between Sinai and Arabia (Joffe and Garfunkel, 1987) and therefore, is the main seismic source along the eastern side of the Sinai subplate.

6. Tectonic Setting and Seismicity of the Western Desert.

The East Mediterranean-Cairo-Fayum Pelusiac trend extends from the east of the Nile Delta and Fayum to the Western Desert region, Fig.1. Along this trend, small to moderate historical and recent earthquakes are observed and earthquake foci are confined within the crust and do not define any seismic plane. The moderate and first instrumentally recorded event of Gilf El-Kebir area in 1978 may be the extension of this trend into the southwestern part of the Western Desert.

RESULT AND DISCUSSION

The first zone is related to the Delta area as shown in Fig.2. The origin of the Nile Valley has long been subject of controversy. Sandford (1934) advocated that the Nile Valley is of erosional origin. On the other hand, many authors (e.g. Said, 1981; El Gamili 1982; and Kebeasy, 1990) consider it to be 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 (El-Gamili, 1982 and Said 1981,1990) and by the focal mechanisms of the most recent earthquakes (Abou Elenean, 2000). 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 prevents the extension of the activity of the East African origin belonging to the west (Said, 1990). The seismic activities reported for the Nile Valley are related to the tectonic activity of the Red Sea axial zone (Said, 1981). We can see from Fig.3 a high seismic activity at the end of 1992, i.e., the new energy starts to accumulate since 1992. The quantity Dt has a value of 37 years, which means that in the next 20 years the region would experience an earthquake equivalent to strain energy of the order of 10^{22}erg, which is equivalent to magnitude 5.6

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

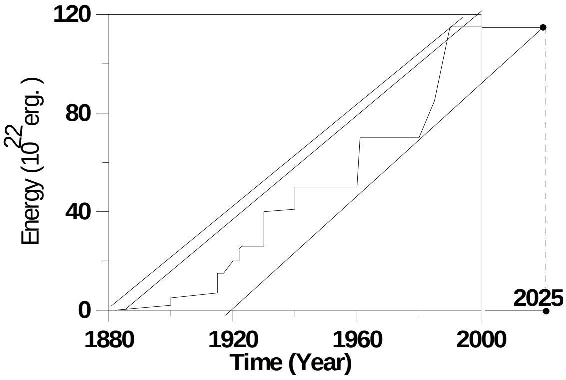

Fig. (4): Cumulative strain energy release as a function of time for the Fayoum area.

The third cell is related to the Red Sea area. The Red Sea region is one of the areas around the world which are well investigated geophysically. It has positive Bouguer anomalies indicating the presence of intrusive rocks beneath the deep water (Othman 1990, 1993) over the center and there are large magnetic anomalies. They are probably associated with the material with seismic velocities of 4.1~0.4 km/s overlying the material with a velocity of 7.1km/s (Heirtzler and Le Pichon, 1965). Near the margins, seismic velocities of about 6 km/s are found suggesting the presence of down faulted basement (Girlder, 1969). The quantity of Dt is 25.2 years and we can see in Fig.5 that there is a continuous accumulation of the strain energy since 2003, so we can assume that the active seismic period should be expected the year 2028.2 with energy of 10^{22} erg. (magnitude of about 6.5).

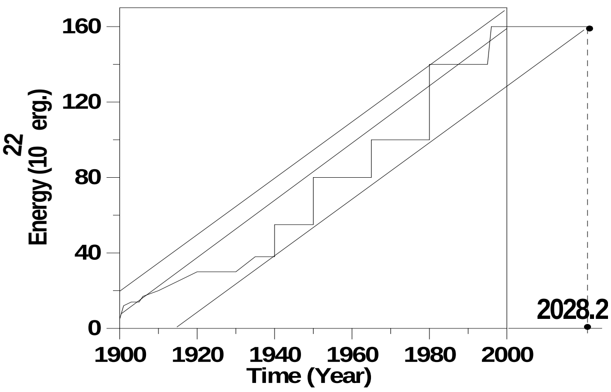

Fig. (5): Cumulative strain energy release as a function of time for the Red Sea area.

According to the distribution of earthquakes and the seismic zones map, Fig.1, the fourth and fifth cells are considered as two zones. They are characterized by high seismic energy release, Figures 6&7. Here Dt is 23.2 years (with energy accumulating since 2000). We can assume that the active seismic period should be expected the 2023 and 2005 years respectively with energy 10^{22} erg.

Aswan area is the sixth cell. The high seismicity energy release (Fig. 8) of the region is close to Kalbshea fault. The quantity Dt is 20.1 and the energy has accumulated since 2000, which means the largest earthquake in the cell will occur in 2013 with M= of 5.7 .

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

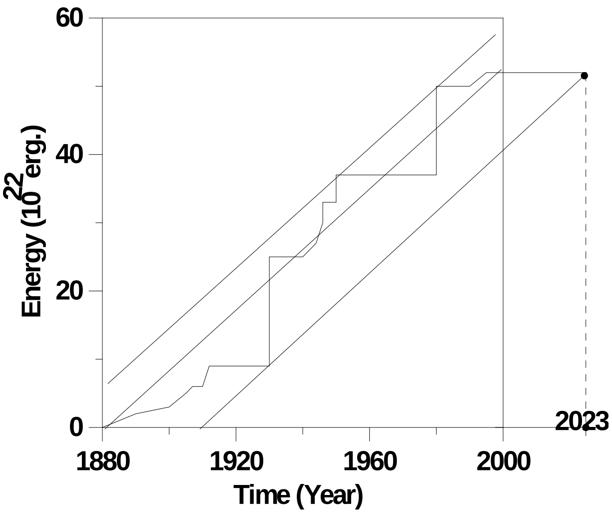

Fig. (6): Cumulative strain energy release as a function of time for the Mediterranean Sea area (Zone 4).

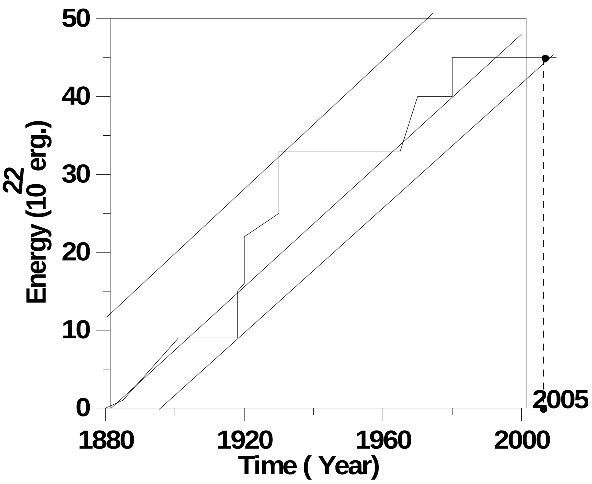

Fig. (7): Cumulative Strain energy release as a function of time for the Mediterranean Sea area (Zone 5).

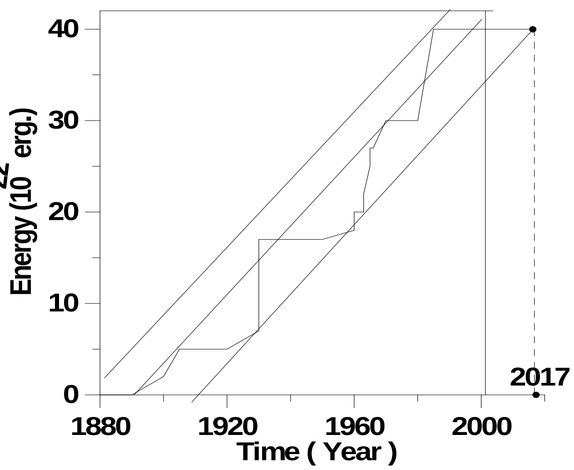

Fig. (8): Cumulative strain energy release as a function of time for the Aswan area.

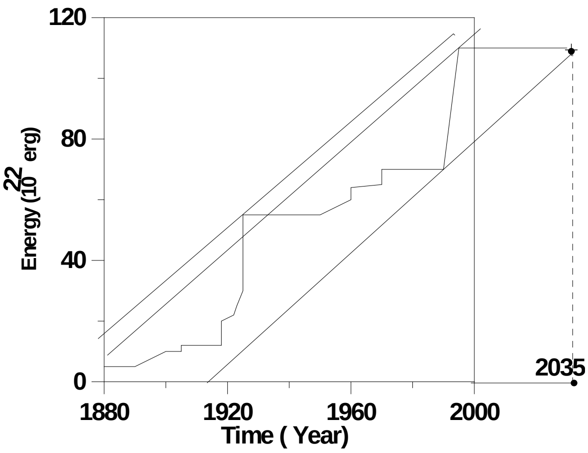

Fig. (9): Cumulative strain energy release as a function of time for the south-west Western Desert.

The numerical values of a, b, m, as well as of average strain energy releases per annum, M2, the maximum strain energy release,M3, as well as T_r (in years) are listed in Table 1.

The b-values were calculated using maximum likelihood method and least squares method. We notice from this table that b-values range from 0.4 to 1.6, i.e., the variability for the relatively small area as Egypt is large. They reflect the non-homogeneity of the structure of Egypt. High b-values at the Red Sea area are due to the structure at the area. Low b-values at the Nile Delta, Western Desert are due to the low seismicity of the area.

Cell	a	b	MI	TE*/ year	M2	M3	TE/ 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	1.06	5.6	0.689	5.8	7.0	23.3
6	5.23	0.89	5.4	0.548	5.7	7	26.1

CONCLUSIONS

The tectonic setting of Egypt is very complicated. Active zones have developed from active plate margins activity and imply that the seismic hazard is high in some parts of Egypt. The method applied the magnitude-frequency law with the energy-magnitude relation to estimate the seismic hazard in Egypt. Also, the results of Makropoulos and Burton (1983) have been applied in this study. The empirical relationship between M3 and M2 has been derived. The quantity Dt was introduced here to forecast the time of at which the next earthquake. High-energy release agrees with the major fault in Egypt. Finally, it can be concluded that the Western Desert of Egypt outside the studied active zones, despite its remoteness and being unaffected, the neighboring active zones have low seismic release and low b-values, and for these reasons, this area is considered the best for establishing the site of radioactive waste.

ACKNOWLEDGEMENTS

The author wishes to express their her deep gratitude to Prof. Dr. Kadry M. Fouad , Emeritus Prof. of Geophysics in Nuclear Material Authority and Prof. Dr. Alessandro Michetti, Professor of Geology, "universita degli Studi dell'insubria" university, Italy, for reviewing the paper

REFERENCES

Abou Elenean, **K., 1997**, A study on the seismotectonics of Egypt in relation to the Mediterranean and Red Seas tectonics, Ph.D. thesis, Ain Shams Univ., Cairo, Egypt.

Ambraseys, N.N, 1961, On the seismicity of southwest Asia (from a XV Century Arabic manuscript). Rev. pour L'Etude des Calamites (Geneva)

Abou Elenean, **K., 2000,** Historical seismicity map of Egypt, personal communication **Ambraseys, N.N. and Barazangi, M. 1989,** Earthquake in the Bekaa Valley: Implications for Earthquake Hazard Assessment in the Eastern Mediterranean region, Geophys. 94, 4007-4013.

Bath, M., 1958, The Energies of Seismic Body Waves and Surface Waves, London: Pergamon, 1-16

Bath, M., 1979, Introduction to Seismology, Birkhauser Verlag,Basel, 335pp,

Ben Avraham, **Z., 1985,** Structural framework of the Gulf of Aqaba, northern Red Sea, J. Geophys. Res., 90, 703-726

Ben Avraham Z., Nur,A., and Cello, G. 1987, Active transcurrent fault system along the north African passive margin. Tectonophysics, Vol. 41, 260-294.

Deif, A., 1998, Seismic Hazard Assessment in and around Egypt in relation to plate tectonics, Ph.D. thesis, Ain Shams Univ., Cairo, Egypt.

El-Gamili, M. 1982, Seismic hazard evalution in Egypt , in J. Geol. Special Vol. Part 2, 71-85.

El-Hemamy, S.T., 1990, Seismic risk analysis in relation to nuclear power plant in Egypt; M.Sc. Thesis in geophysics: Fac. of science, Ain Shams University.

El-Hemamy, S.T., 1995, A study of the Neo and Paleo-Seismicity of Inshas Nuclear Reactor area in relation to the implicated Seismic Risk and Causative tectonic. Ph.D.Thesis in geophys. Fac. of Science, Ain Shams University.

Galanopoolos, A.G., 1978, Annual and Maximum Possible Strain Accumulation in the Major Area of Greece, Ann, Geol.D. Pays Hellen, 24, 467-480,

Gergawi, A. and El-Khashab H., 1968, Seismicity of U.A.R ,. Helwan Obs. Bull. 76, 27 pp.

Girdler, R.W., 1969, Geophysical background, In Hot Brines and Recent Heavy Deposits in the Red Sea. E.D. Degens and D.A. Ross (eds.) Springer-Verlag. N.Y., Inc.PP.38-58.

Gumbel, B., 1958, Statistics of Extremes, New York,: Columbia Univ. Press, 374pp

Gutenberg, B. and Richter, C.F., 1944, Frequency of Earthquakes in California, Bull. Seismol. Soc. Am., 34, 158-188.

Heirtzler J. R. and Le Pichon X., 1965, Magnetic Anomalies over the Mid-Atlantic Ridge, J.Geophys. Res., 70:4013.

Ibrahim, **E. M., and Hattori, S., 1982,** Seismic risk maps for Egypt and its vicinity, Helwan Institute of Astronomy and Geophysics Bulletin, Vol. 2, 183-207.

Ismail A., 1960, Near and Local Earthquakes of Helwan (1903-1950), Helwan, Bull., pp 49, 32

International Atomic Energy Agency, 1995, Near Surface Disposal of Radioactive Waste, Safety Series No WS-R-1, IAEA, Vienna.

Joffe, **S., and Garfunkel, Z., 1987,** Plate kinematics of the circum Red Sea - A re-evaluation, Tectonophysics, Vol. 141, 5-22

Karnik, V. and Hubnerova, Z., 1968, The probability of occurrence of largest earthquakes in the European area, Eng. Journal , Vol.70, pp.61-73.

Karnik, V and Schenkova, Z. 1970, The probability of Occurrence of Largest Earthquakes in the European area - Applied Geophysics Journal , part II, 80, 152-161.

Kebeasy, R., 1990, Seismicity of Egypt.,Said, R. (Editor), Geology of Egypt, A.A. Bakema, Rotterdam, Netherland.

Maamoun, **M., and Ibrahim, E., 1978,** Tectonic activity in Egypt as indicated by earthquakes, Bull., HIAG, No. 170.

Maamoun, M., Megahed, A. and Allam A., 1984, Seismicity of Egypt, Bulletin of the Helwan Institute of Astronomy and Geophysics. IV. pp 109-162

Makropoulos, K.C. and Burton, P.W., 1983, Seismic risk of circum-Pacific earthquakes, I. Strain energy release, Pageoph, 121, 247-267.

Makropoulos, K.C., 1978, The statistics of large Earthquake Magnitude and an Evaluation of Greek Seismicity, Ph. D. Thesis, Univ. of Edinburgh, 193 pp.

McKenzie, D.P., 1970, Plate tectonics of Mediterranean region. Geoph.J.Roy.Astro. Soc.30:109-185

Othman, A.A., 1990, Seismic Risk Evaluation based on maximum likelihood technique Applied for the Red Sea region, Qatar Univ. Sci. Journal, 13, 21 pp**.**

Othman. A.A., 1993, Seismic Risk evaluation based on maximum likelihood technique applied for the Red Sea region, Qatar Univ. Sci. Journal, 27, 33 pp.

Poirier, J. P. & M.A. Taher, 1980, Historical seismicity in the Near and Middle East, north Africa and Spain from Arabic document (7^{th}-8^{th} centuries). Bull. Seism. Soc. Am. 70; 2185-2210

Said, R. 1981, The geological evaluation of the River Nile, Elsevier Sci. Publ. Comp., Amesterdam **Said, R., 1990**, The Geology of Egypt; Elsevier Sci. Publ. Comp., Amesterdam**.**

Sandford, K.S., 1934, Paleolithic man and the Nile Valley in upper and middle Egypt. Chicago Univ. press, Oriental Inst. publ, pp3-131.

Sieberg, A., 1932, Erdbebengeographie. Handbuch der, Geophysik, BdIV, Berlin.

Tsapanos, T.M., 1988, The Seismicity of Greece in Comparison with the Seismicity of other Seismoginic Countries of the World, Proc. of the first Symp. on the Recent Trends in Seismology and applied Geophysics in Greece, Thessaloniki, 1-3 July, 186-193.

Tsapanos M. and Theodoros, 1998, Seismic Hazard for Some Regions of the World Examined Using Strain Energy Release, Journal of the Balkan Geophysical Soci, 19-26.

Voidomatis, Ph., 1984, Seismicity of the Northern Greece and Surrounding Area, Ph. D. Thesis (in Greek), University of Thessaloniki, 201 pp.

Yegulalp, T.M. and Kuo, J.T. **1974**, Statistical prediction of the occurrence of maximum magnitude earthquakes, Bull. Seismol. Soc. Am., 64, 393-414.

Woodward, C., Consultance, 1985, Earthquake Activity and Dam Stability for the Aswan High Dam, Egypt, Ministry of Irrigation, Cairo, 2.