TOWARDS AN EGYPTIAN EARTHQUAKE PREDICTION PROGRAM

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ABSTRACT

It is well known that earthquakes inflict enormous losses in both human and economical levels. At present, economic losses from earthquakes comprises several billions dollars per year,and hence an equal amount is spent each year strengthening installations which are erected in seismically active zones. Naturally, the increase in population density and development of the economy and civilization rapidly increase losses if an earthquake occurs. For instance, a single earthquake in a densely populated region may claim up to a loss of million lives, and incur an economic loss up to 100 billion dollars. In fact, many developing countries losses from earthquakes consume a considerable portion of the national income. On the other hand, earthquake prediction holds great potential for saving lives, reducing property damage, enhancing the safety of critical facilities, and helping make possible more-rapid restoration of normal living after an earthquake. Therefore, a national earthquake prediction program, for any country, represents one of the major tasks facing the respective scientific communities. The main objective of such a program is to provide the necessary information concerning the location and the time of the expected coming earthquake event. At present, the location of earthquake events is based on historical records, knowledge of active faults, the results of surveys, seismicity gaps where earthquakes have not occurred and so forth. Once it is known where earthquakes are likely to occur, various kinds of networks can be established to observe the precursory phenomena that make it is ossible to predict an earthquake before it happens. In order to effectively participate in the protection of the Egyptian communities against earthquake hazards, a proposal for Egyptian earthquake prediction program will be introduced here. This has been done in the lights and guidelines of the acquired experience from Aswan Project and by other countries suffering from earthquake disasters.

Keywords: Earthquake, Precursory, A Proposal for Egyptian Earthquake Predication Program, Aswan, Egypt.

1. INTRODUCTION

Egypt is considered one of the few regions of the world where evidence of historical earthquake activity has been documented during the past 4800 years [Kebeasy et al.,1988]. A critical review of the earthquakes history of Egypt and its Surrounding vicinity could throw some light on the seismicity and seismotectonics of Egypt, and hence, enable us to determine accurately the corresponding seismic regions in Egypt. Microearthquake activity has been observed in various regions of Egypt. The Helwan station observations point out to such activity around Cairo, the Nile Delta and around the Gulf of Suez. Using these observations, a number of microearthquake has been found to be located around these regions which can be defined an active trend that runs along the Gulf of Suez and passes through the Nile Delta to the mediterranean Sea. Another microearthquake active trend was found to start from Cairo and Runs to the north along the west side of the Nile Delta which can be attributed to a probable active fault along this trend [Kebeay et al, 1988].

On November 14, 1981, an moderate earthquake of magnitude 5.5 occurred in the area along Kalabsha fault 70 km southwest of Aswan city. This earthquake was considered as a very important event since its location is near Aswan High Dam and its possible association may be related to the impoundment of water in the high Dam Lake and tectonic activities in its region [Toppozada et al., 1984]. Such earthquake triggered an urgent alarm for studying seismic and associated crustal deformations activities in this region based upon actual field data. Therefore several programs were initiated for studying seismicity, underground water behavior, the structural response to seismic effects and crustal movements in Aswan region since 1982 [Vyscocil and tealeb, 1985]. Moreover, on October 12, 1992, a moderate earthquake of magnitude 5.9 occurred in Cairo at a distance 12 km south Sakarra. This earthquake was a remarkable event where it was felt over the whole area of Egypt an neighboring countries. Heaven damage was reported in Cairo, in which approximately 300 people were killed, 1200 were injured and 450 of houses were destroyed. Moreover, thousands of people were injured and thousands of houses were damaged in different parts of the country. The damage is estimated preliminarily to be over 1500 million U.S. dollars. Such a great event can be considered as a basic motivation which necessitates that all efforts should be oriented toward the establishment of an Egyptian earthquake prediction program.

The obtained results of Aswan programs are not enough to predict earthquake but they may be to help in proposing a national earthquake prediction program for over actively seismic regions of our country. Such a program is feasible and has its potential in order to overcome or at least minimize the hazards associated of unexpected events. This will be done in the lights and guidelines of the acquired experience from Aswan Project and by other countries suffering from earthquake disasters. Before digging into that it is necessary to review the geology, tectonics and seismicity of Egyptian territory.

2. OVERVIEW ABOUT GEOLOGY AND TECTONICS OF EGYPT

The information contained in this section has been extracted mainly from Kebeasy et al., 1988 and Said, 1990. Egypt is a part of the north Africa craton which during its geological history underwent periodic transgressions from the ancient Tethys situated to the north and northeast of the country.

According to Said (1990) as in Figure (1), three major geological provinces are distinguished. These are the well defined Nubian Arabian Shield of massif and the surrounding shelf areas of which their structural unit boundaries can not be traced with great precision. The shelf areas are subdivided, regarding to its salient feature into the stable shelf, the unstable shelf. Beside that are, the Gulf of Suez graben, the basement complex areas in the Eastern Desert, Southern Sinai Peninsula,the exposed parts of the Arabo-Nubian Massif which includes also the Oweinat area in the extreme southern part of the western Desert of Egypt. The Arabo-Nubian craton exposed part consists mainly of The precambrian rocks. El-Shazly (1981) distinguished several stages within these metamorphic sequences of geosynclinal archean formations with frequent intrusion of platonic and volcanic rocks.

The relatively stable shelf of Egypt embraces the areas north and west of the Nubian-Arabian Shield. It exhibits a gentle deformation and its sedimentary cover is mainly represented by continental and epicontinental deposits such as the Mesozoic Nubian sandstone. The sedimentary sequence on the Stable Shelf is relatively thin with some 400 m of sediments near the Nubian-Arabian shield area and increasing to as much as 2500 m near the transition zone into the unstable shelf in the north. It is composed of sands and shales in its lower locations and of shallow water carbonates in its upper part.

The Unstable Shelf is situated north of the Stable Shelf with the transition between the two structural depositional units following a line approximately set from The Siwa Oasis through Farafra Oasis and Suez into central Sinai. The sedimentary sequence of Unstable Shelf is relatively thick with a lower part of the section composed mainly of clastic sediments followed unsection by a middle calcareous series and tapped by a blanket of biogenic carbonates. The formations are gently folded and show signs of lateral stress. This structural deformation is related to the Laramide phases of the Alpine orogeny. The trend of these fold bundless is highly arcuate to the northeast and referred to as the Syrian Arc.

The Gulf of Suez-Red Sea graben is an area of subsidence within the Stable Shelf and the northern part of the Arabian-Nubian Shield. The Gulf of Suez was formed originally during early Paleozoic time as a narrow embayment of the Tethys and intensively rejuvinated during the rifting phase of the great East African Rift system in the lower to middle Tertiary time.

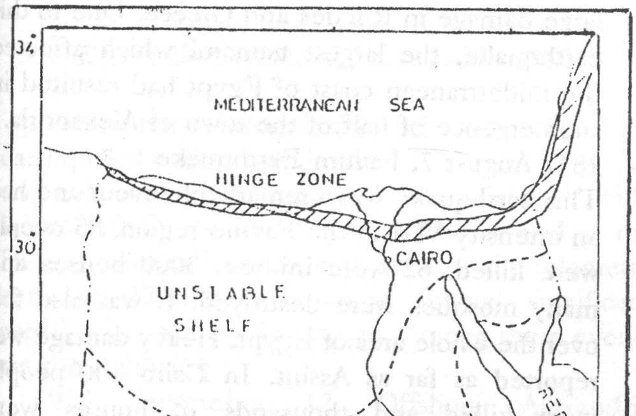

Figure 1. Tectonic map of Egypt. (After Said, 1990).

Great accumulations of sediments from this last subsiding depression interrupted times by a general and regional uplift with subsequent erosion. Its connection with the Mediterranean Sea to the north and with the Red Sea to the south is established during early Miocene and with the distribution of mediterranean fauna from north as from south as the southern Red Sea.

The Red Sea originated during Oligocene time after the arching and crustal thining in the general area of the Nubian Shield and subsequent collapse in the context of the East African rifting. Spreading of the Red sea floor was and still related to the relative motion of the various plates and zones present in the northeastern africa and the near East.

The presence of three plates is postulated for the northeastern most area of Africa. They are referred to as the Nubian plate, the Arabian plate and the Sinai plate. The relative motion of these plates has led to the opening of the Red sea, the Gulf of Aqaba and in part and in part to the Gulf of Suez.

The spreading of the Red Sea is without doubt due to the northeast ward drift of the Arabian plate along Dead Sea transform fault. Left lateral movement of the Arabian plate along the Gulf of Aqaba has also been established. The lateral displacement amounts to about 110 km along the Dead Sea near the Aqaba gulf and the Gulf of Suez junction is far larger than the lateral displacement along the Aqaba Gulf. The width of the Red Sea in its northern part is about 190 km. the difference may have been absorbed by plate movement between the Sinai peninsula and the arabian plate. Although plates are consider rigid units, the Sinai plate may have undergone deformation to some degree with fore-shortening that led to the partial opening of the Gulf of Suez.

A clockwise movement of the Nubian plate away from the Arabian and Sinai plate could also be taken into consideration.

It is interesting to note, however, that the Gulf of Suez took part in the spreading only to a certain extent, and that it represents the absorbed arm of the triple junction of the Red Sea and Gulf of Aqaba. Delta course with their tributaries are not older than 6 million years ago [Kebeasy et al., 1988].

3. OVERVIEW ABOUT SEISMICITY OF EGYPT

Egypt is considered one of the few regions of the world where evidence of historical earthquake activity has been documented during the past 4800 years [Poirer and Taher, 1980]. But this information of historical earthquake can not be regarded as complete as much of the old Egyptian literature which was lost creating gaps in the earthquake record. In order to review critically the information of historical principal earthquakes in Egypt and to investigate the space and time distribution of earthquake activity, earthquake dating have been the subject of differences among different authors. The location of the most of these historical earthquakes centers almost exclusively along the Nile valley.

3.1. Review of Historical Earthquake Activity (2800 B.C to 1900 A.D)

Information on historical earthquakes is documented in the annals of ancient Egyptian history and Arabic literature.According to Poirer and Taher (1980) about 83 events were reported within the above historical period to have occurred in and around Egypt and have caused damage of variable degrees in different localities. Earthquake intensities were assigned through the syuding of reported earthquake damage to determine the epicenteral historical earthquakes. In the following paragraphes the description of a few major historical earthquake will be given [Kebeasy et al.,1988] :

- 2800 B.C. Sharquia Province Earthquake :
  This unknown location earthquake was a severe one and caused deep fissures and soil cracks in Tell Basta, Sharquia province. The estimated maximum intensity is VI in a confined area near this village.
- 1210 B.C. Near Abu Simpel Event:
  This event caused cracks in the temple of Ramsis II in Abu- simpel, upper Egypt with estimated intensity VI. It is not certain that the cracks are due to an earthquake.
- 221 B.C. Earthquake :
  This earthquake had an intensity VII at Siwa Oasis. However, it also caused destruction in about 100 localities in Libya. It is possible that this earthquake is the large one which took place in central Italy which intensity X and caused landfalls and diversion of rivers there.
- 27 B.C. Thebes, upper Egypt, Earthquake:
  This earthquake was a severe one and caused great damage leaving only four villages undestroyed in Thhbes, Upper Egypt.
- 1068 March 18, Aqaba Earthquake:
  This is the first historical earthquake known to have strongly affected the Gulf of Suez area. It was located near Aqaba at the north end of the Gulf of Aqaba. This event was felt strongly in Cairo where a mosque was damaged.
- 1303 August 8, Offshore Mediterrenean Earthquake :
  This earthquake was placed south of Cairo because of the severe damage to many mosques and churches among which is the famous Amr-Ibn-El Aas mosque. Damage was also considerable in the Nile valley up to Qus in the south and Alexandria in the north where most of the town walls and 120 m high beacon collapsed. It was also reported that this earthquake caused large damage in Rhodes and Greece. Due to this earthquake, the largest tsunami which affected the midetrranean coast of Egypt had resulted in submergence of half of the town of Alexandria.
- 1847 August 7, Fayum Earthquake :
  This earthquake was a remarkable event and had an intensity VIII in the Fayum region. 85 people were killed, 62 were injured, 3000 houses and many mosques were destroyed. It was also felt over the whole area of Egypt. Heavy damage was reported as far as Assiut. In Cairo 100 people were killed and thousands of houses were destroyed. Moreover, thousands of people were injured and thousands of houses were damaged in different parts of the country. Intensity distribution of this earthquake is given in Figure (2).
- 1870 June, Offshore Earthquake :
  This earthquake was widely felt in Egypt and in different localities in Greece, southern Turkey and Palestine. This event had an intensity VIII in Alexandria and VII in large part of the Nile Delta and Cairo.

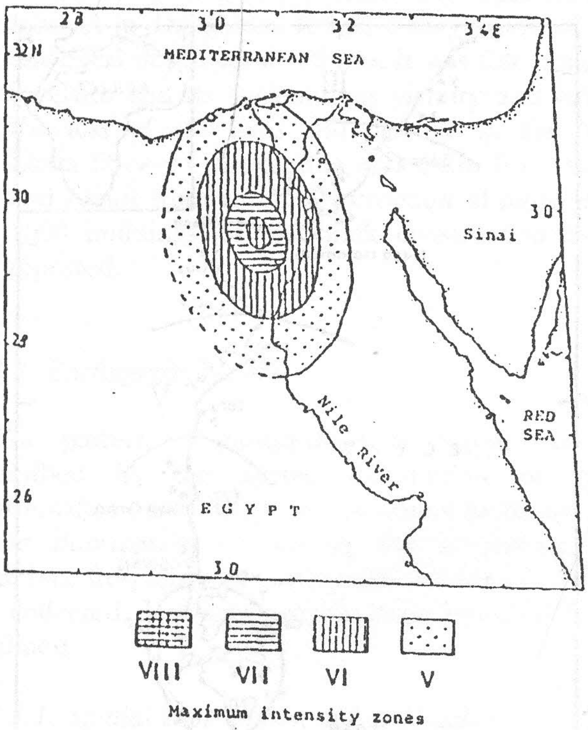

Figure 2. Intensity map for earthquake of 7 August, 1847.

3.2. Recent Earthquake Activity (1900 - 1992)

Instrumental information of the Egyptian earthquake events within the above recent period was collected from Gutenberg and Richter (1954), Ismail (1960), Kebeasy et al. (1984) as well as the Helwan station Bulletin and Aswan radio-telemetry network. During this period several significant earthquakes occurred in Egypt. Among these events are the following :

- 1955 September 12, Offshore Alexandria Earthquake :
  This earthquake had a magnitude 6.1 and was felt in the entire east mediterranean basin and in Palastine, Cyprus,and as far as Athens. In Egypt, it was felt strongly and led to the loss of 22 lives and damage in the Nile Delta between Alexandria and Cairo. Destruction of more than 300 buildings of old brick construction were reported in Rashid, Idku, Damanhour, Mohamodya, and Abu-Hommes. A maximum intensity of VII was assigned to a limited area in Bihira province where 5 persons were killed and 41 more were injured. Also an intensity V to VI was reported in 15 or more localities, Figure (3). The epicenters of this event is located along the northern prolongation of the Red Sea-Gulf of Suez tectonic trend.

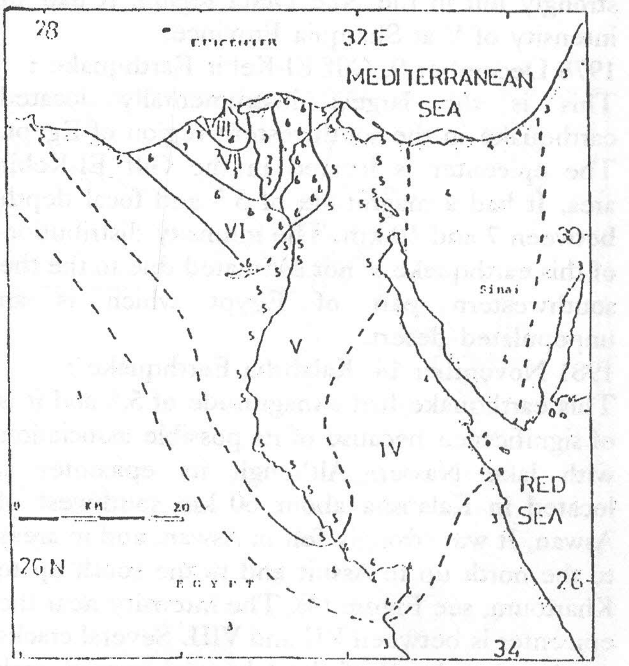

Figure 3. Intensity map for earthquake 0f 12 September, 1955.

- 1955 November 12 Abu-Dabbab Earthquake :
  This earthquake had a magnitude of 5.5 and was felt in Upper Egypt at Aswan and Qena and as far as Cairo but no damage was reported.
- 1969 March 31 Shadwan Island (Red Sea) Earthquake :
  The magnitude of this earthquakes 6.3, a maximum intensity of IX is assigned to a small area in Shadwan island. On Shadwan island landslides, earth slumps and rock falls were common. Fissures and cracks in soil were found with main direction parallel to the Red Sea-Gulf of Suez direction. At a distance less than 10 km west of the fractured area,in the sea, one of the submarine coral reefs was raised by a few meters above the sea level since this event. Rumbling sound similar to thunder and noise caused by sound of falling rocks on the land or the sea was accompanied by something similar to big

explosion and were associated with sea wave disturbances. This earthquake was proceeded by 35 large foreshocks during the last half of the year.

- 1974 April 29, Abu-Hammad Earthquake :
This earthquake had a magnitude of 4.9 and was strongly felt in the Nile Delta region. It had an intensity of V at Sharquia Province.
- 1978 December 9, Gilf El-Kebir Earthquake :
This is the largest instrumentally located earthquake in the southwestern region of Egypt. The epicenter is located in the Gilf El-Kebir area. It had a magnitude of 5.5 and focal depth between 7 and 10 km. The intensity distribution of this earthquake is not estimated due to the the southwestern part of Egypt which is an unpopulated desert.
- 1981 November 14, Kalabsha Earthquake :
This earthquake had a magnitude of 5.5 and it is of significance because of its possible association with lake Nasser. Although its epicenter is located in Kalabsha about 60 km southwest of Aswan, It was strongly felt in Aswan, and in areas to the north up to Assuit and to the south up to Khartoum, see Figure (4). The intensity near the epicenter is between VII and VIII. Several cracks on the west bank of the lake and several rock falls and minor cracks on the east bank were reported. The largest of these cracks is about one meter in width and 20 km in length [Kebeasy et al., 1982]. This earthquake was preceeded by three main foreshocks and followed by a large number of aftershocks. The focal depth of this earthquake seems to be very shallow (0-10 km).
- 1983 February 03, Aqaba Earthquake:
This earthquake occurred in Aqaba to the northern end of the Gulf Of Aqaba and had a magnitude of 4.9 . It was felt strongly around the epicentral area and was followed by about 5.6 aftershocks of magnitudes between 1.7 and 4.8 in the following three weeks.
- 1984 March 29, Wadi Hagul Earthquake :
This earthquake occurred in Wadi Hagul southwest of Suez its magnitude is 4.7 and was felt strongly in Suez,Ismalia and Cairo. Large number of aftershocks were recorded by nearby temporary stations. The focal depth is estimated to be 10 km.

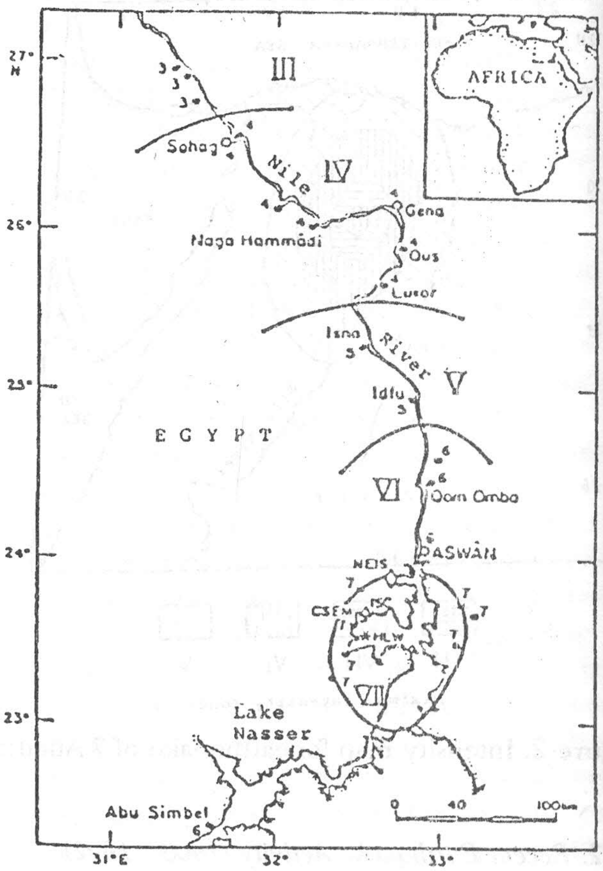

Figure 4. Intensity map for earthquake Of 14 November, 1981. (Afer Kebeasy et al., 1984).

- 1984 July 2, Abu-Dabbab earthquake :
This earthquake had a magnitude of 5.1 and was felt strongly in Aswan, Qena and Qusseir. Large number of foreshocks and tremendous sequence of aftershocks are recorded. The focal depth of the whole sequence is less than 12 km.
- 1987 January 2, Ismalia earthquake
This earthquake had a magnitude 4.3 occurred at Ismalia Province.
- 1992 May 24, Wadi Hagul Earthquake :
This earthquake occurred in Wadi Hagul southwest of Suez its magnitude is 4.3 and was felt in Suez, Ismalia and some parts of Cairo.
- 1992 October 12, Cairo earthquake. This earthquake is a markedly event in the modern history of Egypt. This is the largest instrumentally located earthquake in the

southwestern region of Cairo. The epicenter is located in Dahshour. It had a magnitude of 5.8 and focal depth about 10 km. It was felt strongly in Cairo and its surrounding vicinity and led to the loss of 450 lives and damage in the Nile Delta between Alexandria and Cairo from north and Assuit from south. Destruction of more than 1000 buildings of old brick construction were reported.

3.3. Earthquake Pattern

The pattern of earthquakes in Egypt can be described by the spatial distribution of such earthquakes particularly the epicenters locations and some information concerning the magnitude. In addition, frequency of earthquake occurrence based on collected data in a specific time period will be outlined.

3.3.1. Spatial Distribution of Earthquakes

Distribution of epicenters of both historical and instrumentally earthquakes is given in Figure (5). Figure (6) shows the epicenters of all of these earthquakes as well as microearthquakes together with the focal mechanism of some principal earthquakes and the location of the seismographic stations. The distribution of earthquake epicenters suggests that the activity tends to occur along three main seismic active trends as follows :

a. Northern Red Sea - Gulf of Suez - Cairo - Alexandria trend:

This trend is the major active trend in Egypt. It is Characterized by the occurrences of shallow, micro, small, moderate and large earthquakes. Activity along this trend has increased in recent years and is attributed to the Red sea rifting as well as several active faults. All earthquake foci are limited within the crust.

b. East mediterranean - Cairo - Fayoum trend:

This trend extends from East Mediterranean to East of the Nile Delta to Cairo and Fayum region. Along this trend small to moderate historical and recent earthquakes are observed. All earthquake foci are limited within the crust. A seismic gap exists in the Gulf of Suez where no earthquakes have been detected. Another gap is found between Cairo and Alexandria where only microearthquakes are observed frequently.

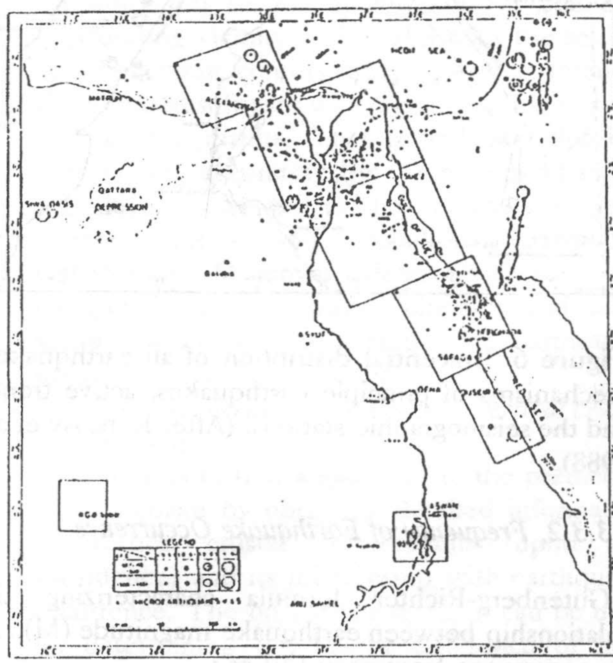

Figure 5. Distribtion of earthquake occurred in Egypt (2200-BC-1990 AD) showing the seven most active seismographic stations. (After Kebeasy, et al., 1986).

c. The levant-Aqaba trend:

This trend is a continuation of the levant active fault and extends along the Gulf of Aqaba and southwest in the red sea and bisects the northern trend at about 27° N and 34.6° E. earthquake occurrences are found mainly in both ends of the Gulf of Aqaba. Only shallow small size earthquake are observed along the trend.

In addition to those trends there are several areas known to be active such as south west of Aswan, Abu-Dabbab, Gilf El-Kebir and Wadi Hagul of the Gulf of Suez.

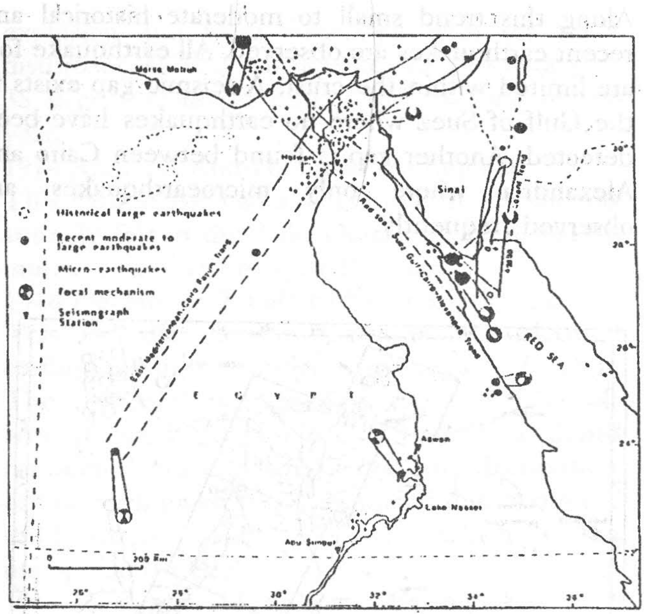

Figure 6. Epicentral distribtion of all earthquakes, mechanisms of principle earthquakes, active trends and the seismographic stations. (After Kebeasy et al., 1988).

3.3.2. Frequency of Earthquake Occurrence

Gutenberg-Richter formula characterizing the relationship between earthquake magnitude (M) and its occurrence frequency (N) as :

$$LOG\ N = a - bM \quad (1)$$

Where : a and b are constants. Kebeasy and Maamoun (1981) investigated the frequency of earthquake occurrences within 200 km around Alexandria and determined a and b as 2.85 and 0.45 respectively and estimated that the largest event expected to occur in the region should have a magnitude between 6.3 and 6.7 with recurrence of eight times every one thousand years. Kebeasy and Maamoun (1981) studied the seismic activity within an area of 200 km around Cairo and estimated a and b values as 2.31 and 0.37 respectively. Also they estimated that the largest expected event should have a magnitude between 6.0 and 6.5 with a recurrence of three times every 100 years. Both results were obtained on the basis of 25 years period of collected data (1935 -1978). Data used during this time period is considered to be homogeneous. In addition, Kebeasy et al. (1988), Savage (1984) investigated the activity around Aswan area during the interval from 27 B.C. to 1984 and estimated the recurrence of earthquake of magnitude 5.5 or more to be once in approximately 300 years.

Frequency of shallow earthquakes occurrences in the Gulf of Suez region during the period of 29 years (1953-1981) was studied by Kebeasy et al. (1984). The corresponding values of a and b of equation (1) are 2.46 and 0.39 respectively. Based on the above results, as presented in this section, Kebeasy et al. (1988) distinguished seven seismic regions of particularly high seismic activity in Egypt Figure (5). These regions are Cairo, Alexandria, Gulf of Suez, Hurghada, Quseir, Aswan and Gilf Kebir. The first six regions represent economic and strategic centers for Egypt. The probability of strong earthquake recurrence within these seismic regions exists.

4. PROPOSED NATIONAL PROGRAM FOR EARTHQUAKE PREDICTION STUDIES IN EGYPT

In order to effectively participate in the protection of the Egyptian communities against earthquake hazards, a proposal for Egyptian earthquake prediction program will be introduced. This has been done in the lights and guidelines of what has been studied in the previous chapters and the positive results we have obtained in Aswan region, as a pilot project, from the investigation of the different geophysical earthquake precursory and the application of the statistical geophysical models on the available geodetic and seismic data. Moreover, the acquired experience by other countries suffering from earthquake disasters has been taken into considerations. The main objective of such a program is to provide the necessary information concerning the location and the time of the expected coming earthquake event. At present, the location of earthquake events is based on historical records, knowledge of active faults, the results of surveys, seismicity gaps where earthquakes have not occurred and so forth. Once it is known where earthquakes are likely to occur, various kinds of networks can be established to observe the precursory phenomena that make it possible to predict an earthquake before it happens.

In this context, our guiding principle of earthquake prediction proposed program has been as follows: An earthquake is a rupture that take place in the rocks within the earth's surface layer, by detecting precursory phenomena preceding the main rupture, it is possible to predict the probable location, size and time of earthquake. Precursory phenomena, especially in the case of large earthquakes, have been categorized as long-term (with a lead time of years) and short-term (with a lead time of days or hours). Hence, we can follow the precursory phenomena through nation wide basic observation, specific observations, intensified observations, concentrated observations (realization of prediction). In order to satisfy this objective, the following stipulations are necessary to establish the foundations of earthquake prediction national program for the entire Egyptian territory as a natural extension guided by what has been achieved for Aswan region until now.

1- *Making the efforts towards the collection of the historical earthquakes records information to extend the recent earthquake catalogue which is necessary part in earthquake prediction analysis.*
As it is known, great earthquakes tend to recur in the same spots at intervals between 100 and 1000 years. Since modern seismology dates back only 100 years and reliable data have been collected for only 50 years, the importance of studying ancient earthquakes for the purposes of long-range prediction and disaster countermeasures goes without saying. Moreover, the speculations that are unsupported by historical evidence can lead to erroneous conclusions.

2- *Geomorophological studies for geologic landforms (faults, foldings, ..., etc) and strata materials.*
Whereas the "past" must be extended and more information must be mined from it, the ancient documents are one way to do this, landforms and strata materials, that precede human history, contain some imprints of the past. Finding and decoding these imprints will be helpful in providing the information needed for earthquake prediction such as predicting earthquake recurrence intervals and estimating the sizes of the past earthquakes, i.e. they give a preliminary picture about the recurrence of earthquakes on the areas under consideration.

3- *Detailed survey of active faults.*
That is will helpful in determining the areas which may be hit by great earthquakes in the future. As it is known, the faults which have been active repeatedly in the recent geological past are considered likely to repeat their activity in the future and when a part of an extensive fault system becomes active, it sometimes seems to trigger other sections of the fault system.

4- *Observation of seismic activity.*
Covering the whole country by seismic network for monitoring seismic activities in Egypt and its surrounding vicinity and establishing the seismic data collection centers and supporting them by the required software which granty sound analysis and reliable results. That is will be helpful in determining accurately the boundaries of highly seismic zones as well as the discovery of latent active faults from detailed earthquakes distribution. Moreover, determination of the changes in seismic wave velocities and other seismic precursory associated with earthquake occurrences can be obtained.

5- *Geodetic measurements for detecting vertical crustal deformations.*
This item is to find a gate way to the prediction of earthquake by obtaining detailed information on vertical crustal deformations (uplift and subsidence) and its relationship with earthquake occurrence. The only method which can be used for determining the height difference of high precision needed for detecting vertical crustal movements is the spirit leveling, using precise levels and invar rods and respecting the up to date of specifications of first (or zero) order accuracy. There are different techniques of using precise leveling for this purpose depending on circumstances which are releveling on single points, releveling considering pairs of points crossing the fault in the highly seismic area and releveling several points (leveling network). The last case is preferred, that is based on fitting a *velocity surface for vertical crustal movements over the entire area of interest.*

6- *Geodetic measurements for horizontal crustal deformations.*
A detailed information about horizontal crustal deformation and its relationship with earthquake occurrences can be obtained by repeated geodetic measurements of an existing network of points covering the area of high seismicity. This network is optimally designed such that satisfying the

preanalysis conditions (the internal consistencies, the anticipated earth movements, seismical and geological data) in addition to the configuration of this network. The observations of this network (angles and distances) [i.e. hybrid network] are measured by using modern geodetic theodolites (1 second or less) and multiple wavelength distance-measuring equipments (0.1 p.p.m or better), and using the appropriate corresponding specifications of first (or zero) order accuracy.

7- *Geodetic measurements of regional crustal movements.*
To study the crustal deformation in a regional scale and its relationship with the local activities and earthquake occurrences. The local geodetic networks have to be connected together with appropriate regional geodetic network. Then the regional geodetic networks are connected together in a national zero order network covering the whole country for studying the regional crustal movements and tectonics of Egypt and its surrounding vicinity. These networks can be observed periodically (or continuously) by the high precision extraterrestrial techniques like GPS. Also, the design of these network must be satisfied all the needs of preanalysis and optimal conditions of monitoring regional crustal movements networks.

8- *A densely distributed telemetric network of embedded volume strainmeter is situated in and around the highly seismic zones for obtaining continuous observations of crustal deformation.*
Since geodetic measurements are intermitten, thus the continuous observations of crustal movements aims at : To fill in the gaps in geodetic surveys with continuous observations of crustal movements and to study the earthquake mechanism through observations of the release of strain that accompanies the principal rupture.

9- *A telemetric deep wells stations should be established in and around the highly seismic areas.*
Due to accumulation of strain within the crustal bedrock of the area of the focus coming earthquake and its surroundings, there is an interaction between the rocks and underground in the affected area. The output of this interaction is changes in the underground water characteristics like water level, temperature, pressure,geochemical composition, etc. which can be monitored as earthquake precursors.

10- *Measurements of gravity acceleration, geomagnitism and geoelectricity.*
Repeated measurements of gravity acceleration, geomagnitism and geoelectricity taken at several well distributed fixed monuments (which could be the geodetic network stations themselves) covering the highly seismic zones and using modern precise instruments. This will be done to investigate the relationship between the changes of these geophysical parameters and earthquake occurrences.

11- *Establishing central laboratories needed for detailed survey of crustal constitutions and earthquake prediction simulation experiments in several parts of Egypt.*
The presence of these laboratories can be divided as : One in upper Egypt to cover the different needs of the highly seismic zones in Aswan and the Red Sea Coast, one in Cairo and its surrounding vicinity and another in the north coast. These laboratories is a basic work supporting the earthquake prediction program in the Egyptian territory because they are necessary for understanding of earthquake mechanism which is not only useful for elucidation of the precursory phenomena but also lead to new findings in the observation or research.

12- *Directing the attention towards the unusual animals behavior studies that occurred immediately before great earthquakes which are considered as extremely short range earthquake precursors complementary to the geophysical ones.*

13- *Establishment of the data bank and the data processing centers and supporting them by tele-communication networks for the different types of observations (for quick data processing and on-line results). Construction of an integrated system of data collection, analysis and diagnostic judgment should be promoted for the area under investigation.*

14- *Developing a more generalized geophysical statistical model which can exploit all the output data of the used various disciplines and satisfying all the Egyptian territory circumstances for obtaining a more meaningful and reliable results.*

15- *Making contacts, acquiring expertise and exchanging experience and knowledge with scientists and scientific organizations from other countries working in the subject matter, for the* *purpose of refining the proposed program and performing the acquired modernization of all its aspects depending on the related future discoveries.*

5. RECOMMENDATION

It is not difficult to visualize that the above proposed national program for earthquake prediction studies in Egypt can not be completed into its sought frame work without the full co-operation between interested geophysicists, geodists, zoologists, etc. from governmental agencies, private industry, research institutes, and respective departments of the Egyptian universities. Therefore, the following recommendations are proposed:

Coordinating the roles and responsibilities of respective governmental bodies, research institutes and corresponding departments of the Egyptian universities working in fields related to earthquake prediction studies for a full cooperation program that unifies their efforts towards a common goal in the lights and guidelines of proposal national program for earthquake prediction studies in Egypt. In this context, sotme of the important objectives will be:

Establishing a data bank for earthquake prediction related information;

Acquiring the most recent appropriate instrumentation, technology, expertise;

Developing more reliable prediction models;

Making contacts and exchanging experiences with the respective organizations in other countries having long activities in this field; ...... etc.

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