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NATIONAL SEISMIC NETWORK AND EARTHQUAKE ACTIVITIES IN EGYPT

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ABSTRACT

The continuous recording of earthquakes in Egypt started with the establishment of Helwan Observatory on 1903, while in May 1962; all systems were replaced by the World Wide Standardized Seismograph System (WWSSS). There are two radio-telemetric seismograph networks were erected in July 1982 and 1990 and installed at the northern part of Naser Lake (Aswan) to monitor the micrseismicity after the occurrence of November 14, 1981 earthquake. While the second one deployed around the southern part of Gulf of Suez and southern Sinai Peninsula to monitor the earthquake activity of this triple-junction area of complicated tectonic setting. After the occurrence of 12th October 1992 earthquake, the Egyptian government financed the construction of the Egyptian National Seismic Network (ENSN), which cover the whole Egyptian territory and can detect and record the majority of local, regional and teleseismic events. This network consists of 63 seismic stations equipped with short-period, broadband and borehole seismometers and supported by advanced and more sophisticated systems for recording, transmission, receiving and analysis of digital data. Most of the recorded data are transmitted to the main center via Satellite technology. It is concluded that, the seismicity of Egypt is of moderate level and it is mainly due to the interaction between Eurasia, Africa and Arabian plates. The national network helps in completing the earthquake catalogue for Egypt. Based on this catalogue, the seismic hazard assessment studies for Egypt can be conducted. Furthermore, the expected earthquake effects can be estimated, and then the strategic buildings can be protected.

Keywords: seismograph, earthquakes, seismicity, hazard.

1 INTRODUCTION

Earthquakes are natural hazard phenomenon; hence they have effects on the nature, human life and man-made structures. Then monitoring of these earthquakes for any area plays an important role in proposing measures to minimize their damages. Most of earthquakes are generated from the earth's crust and the upper mantle. There are some regions (belts) characterized by its high level of earthquake occurrences on the earth's surface. These belts define the boundaries of the major lithospheric plates. Egypt is located in the northeastern corner of Africa and close to one of the continental fracture system (Hellenic arc) at the convergence boundary of two major lithospheric (Eurasia and Africa) plates. Also Egypt is bounded from the eastern part by the northern extension of the east African rift system which represents one of most

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active tectonic belts and its two branches (Gulf of Suez and Gulf of Aqaba). Thus, Egypt is affected by destructive earthquakes occurred in both of northern and eastern tectonic belts. Although these damaging earthquakes are infrequently occurred, their risky consequences can not be ignored. This is due to the fact that, most of earthquakes occur near overpopulated cities and villages, coupled with the poor methods and materials of construction. Soil characteristics in different localities and their amplification impact on seismic waves are important parameters that control earthquake risk. Monitoring of earthquake activities represents the basic data for assessment of seismic hazard which is greatly needed to identify areas with different degrees of vulnerability. They will serve for further risk studies, construction codes and also for land-use planning.

2 HISTORICAL EARTHQUAKE ACTIVITIES

By reviewing early earthquakes reported occurring in Egypt, many searches in Arabic and Persian writings revealed a considerable amount of information concerning early earthquakes in Egypt and surrounding areas. The historical activity indicates that, Egypt was seismically active from as long back as 2200 BC. There are several publications comprising earthquakes that happened in and around Egypt since 2200 BC and 1903 (Sieberg, 1932; Ambraseys, 1961, 1978, 1983; Maamoun, 1979; Maamoun et al, 1984; Ambraseys et al, 1994; and El-Sayed and Wahlstrom, 1995). There are many historical earthquakes affected Egypt (Fig.1), the following is the description of the major and destructive historical events and their effects;

2.1 2200 BC: Sharkia Province earthquake

Sharp shock with a felt area of approximately 45000 km^2 was reported at Sharkia province. The estimated maximum intensity was VII near the village Tell Basta and Abu Hammad, about 16 km southeast of Zagazig. This earthquake was a severe one and caused deep fissures and soil cracks at these places.

2.2 May 26, 1111: East Cairo earthquake

A damaging earthquake in Lower Egypt affected Cairo and Fustat (Old Cairo area) around 9:00 am. It was felt over an area of approximately 25000 Km^2 and ruined a number of places. Maximum intensity VI was reported from Re-Hachope temple where slight damage was reported.

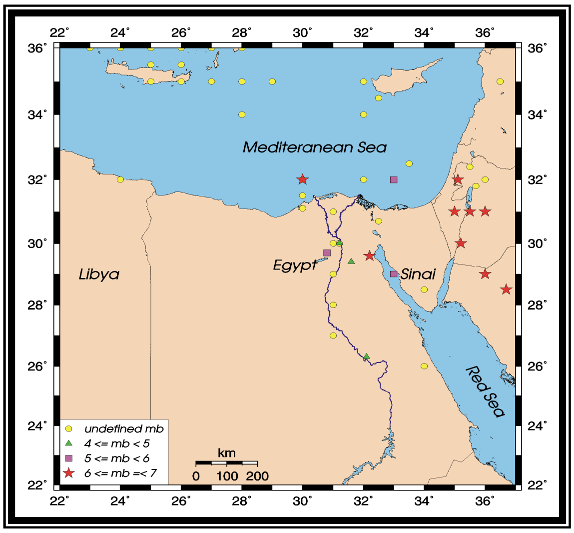

Fig. (1) Distribution of the historical earthquakes.

2.3 August 8, 1303: Mediterranean Earthquake

Many researchers (Ambraseys, 1961; Maamoun et al., (1984) and Ambraseys et al., (1994) stated that, a violent earthquake affected Syria and Egypt, particularly in Alexandria, where many houses were ruined and much of the city walls were destroyed and killing a number of people. This event occurred in the Mediterranean Sea off shore of Egypt and triggered a seismic sea waves (tsunami) that submerged half of the city of Alexandria. The lighthouse at Alexandria was shattered and its top collapsed. The maximum intensity was IX at Alexandria. In the Nile Delta there was a widespread damage. Two villages in Sharkia province were destroyed. Great number of houses, mosques and streets were collapsed within Delta area. Heavy damage was observed in Fayoum, Cairo, Beni-Suef, slight damages were reported as far as Assiut in the south of Nile River. This shock was felt also in Greece and especially in Rhodes area. Several sequences were reported through three weeks.

2.4 October 2, 1698: Rosetta earthquake

This earthquake was felt over an area bordering Bihira, Alexandria, Kafr-Elsheikh and Gharbia provinces. Maximum intensity VI was observed in Rossetta, where no serious damage was reported.

2.5 September 1754: Tanta area (Nile Delta) earthquake

A locally and destructive earthquake was felt over an area of approximately 150,000 km^2. Maximum intensity VIII was estimated in Gharbia province and VII in the Nile Delta and Cairo**.** Kebeasy et al., (1981) located the epicenter of this earthquake at Tanta in the middle of Nile Delta, where the maximum damage was reported. Two thirties of old houses were heavy damaged and consequently thousands of people were killed and injured.

2.6 August 7, 1847: Fayoum earthquake

This earthquake is the largest in the Nile Valley where it was felt over nearly the whole area of Egypt. Maximum intensity VIII was assigned in Fayoum and its neighboring area. The heavy damages were reported in the Nile Valley till Assiut. In Fayoum 85 people were killed, 62 were injured, 3000 houses and many mosques were destroyed. In middle Egypt, 27 people were killed. In Cairo, 100 people were killed and thousands of houses were destroyed. Moreover, thousands of people were injured and thousands of houses were differently damaged in the whole country. Another shock strongly felt in Cairo and Alexandria in the morning of 10 August, which caused damage and injuries in Alexandria.

3 INSTRUMENTAL EARTHQUAKE ACTIVITIES

The continuous recording of earthquakes in Egypt started with the establishment of Helwan Observatory on 1903. Helwan Seismological Station (HLW) is located at 29^{o} $51^{'}$ N, 31^{o} $20^{'}$ E, and its elevation is 115 meters above S.L. on limestone bedrock (Fig. 2). An E-W component of Milne-Show seismograph was the only instrument used at that time. Another N-S component of Milne-Show and a vertical component of Galitzin-Willip seismographs were respectively initiated in 1922 and 1938. There are different episodes of modernization for Helwan Station; the first one was started by adding another set of short-period Sprengnether Seismographs in 1951. All systems were replaced by the standardized set of Benioff- S.P and Sprengnether- L.P seismographs when Helwan was chosen by the U.S. Coast and Geodetic Survey to be equipped with the World Wide Standardized Seismograph System since May 1962. A Japanese S.P. Seismograph system with visual recording and frequency analyzer was added and operated since December 1972.

In 1975 three stations were initiated at Aswan (south Egypt), Abu-Simbel (south Egypt) and Matrouh (northwest Egypt) as a part of the national network. These stations which were equipped with Russian standard S.P. Seismometers. National program of updating these stations and also adding new seismological stations at selected sites has been started since April, 1984. Aswan station was provided by 3 S.P- and 3 L.P seismometers and visual/digital recording system (Table 1). The Nasser (Aswan) Lake event occurred in November 14, 1981. In July 1982, a radio-telemetered seismograh network was installed around the northern part of the Lake (reservoir) to monitor the microseismicity (Simpson et al., 1984).

Table (1) Parameters of seismological stations from 1899 to 1984.

Station Code	**Location**	**Instrument type**	**Comp.**	**T_o**	**T_g**	**Record speed**	**Magnific.**	**Period of operation**
HLW	Helwan	Milne-Show	E-W	12	11.1	10 & 15	250	1899 to 1962
HLW	Helwan	Milne-Show	N-S	12	-	10 & 15	250	1922 to 1962
HLW	Helwan	Galitzin-Willip	V	11.2	11.1	15	1000	1938-1962
HLW	Helwan	Sprengnether	3-comp.	1.5	1.05	60	3000	1951-1962
HLW	Helwan	Benioff	3-comp.	1.0	0.74	60	30000	1962 to 2000
HLW	Helwan	Sprengnether	3-comp.	15	100	30	3000	1962 to 1995
HLW	Helwan	Japanese	3-comp.	S.P.	-	120	30000	1972- 2003
MTH	Matrouh	SKM-3	3-comp.	S.P.	-	60	10000	1975-1990
ASW	Aswan	SKM-3	3-comp.	S.P.	-	60	10000	1975-1996
ASW	Aswan	SKM-3	3-comp.	L.P.	-	30	2000	1972-1996
ABS	A.Simbel	SKM-3	3-comp.	S.P.	-	60	20000	1975-1991
Aswan telemeter Network	Northern Nasser Reservoir		13 V 2 E-W 2 N-S	1.0	-	Analog & Digital	30000 to 100000	1982 to present

Using Helwan seismograms, Ismail (1960) had reported all recorded earthquakes which have epicentral distance within 10 degrees from Helwan, in the period between 1903 and 1950. The majority of these events were originating from the known active zones of the eastern Mediterranean basin. Some of these were reported felt at Cairo. The epicenters of the other earthquakes were found in some surrounding Helwan station and Cairo (Fig. 3). The low sensitivity and the slow recording speed (low time resolution) of the seismograph system could not help in determining the location of these events. Ismail's work was extended by Gergawi and El-Khashab (1968) for the time period between 1950 and 1962 to local and nearby earthquakes within distance 4.5 degree from Helwan. In spite of the short time interval, the sensitivity of the seismograph system had enabled them to investigate some local seismic activity. The instrumental Helwan magnitude scale (Maamoun, 1978) was brought into the study of seismicity of Egypt (Maamoun et al., 1981).

Maamoun et al., (1984) collected available information on earthquakes occurring in the period between 2200 B. C. and 1981 A. D. in the region between 22.0^o – 33.5^o N and 25.0^o – 34.5^o E. They investigated the data to construct a homogeneous catalog to be used on the basis of qualitative and quantitative studies. They distinguished the data in relation to time into two main periods; from 2200 B. C. to 1903 (historical observations) and from 1900 to 1981 (instrumental earthquakes) that located depending upon the number of the recording stations, their distribution around the epicenter, and the size of the event. Kebeasy (1990) showed that the seismic activities are concentrated in four narrow belts and these belts are: 1) Levant-Aqaba trend, 2) Northern Red Sea-Gulf of Suez-Cairo-Alexandria trend; 3) Eastern Mediterranean-Cairo-Fayum trend, and 4) Mediterranean Coastal Dislocation trend.

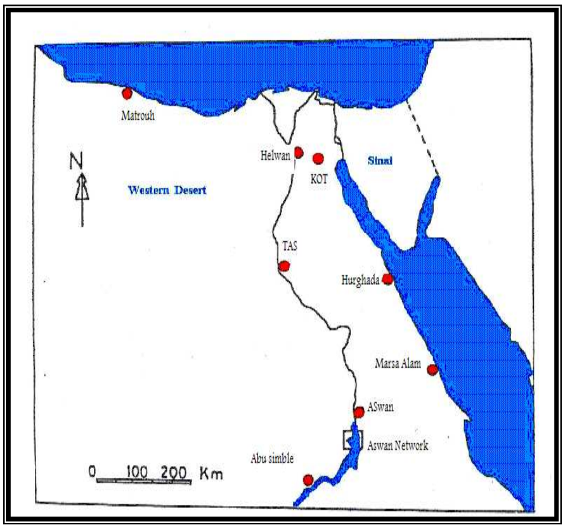

Fig. (2) Geographical distribution of seismic station before 1997.

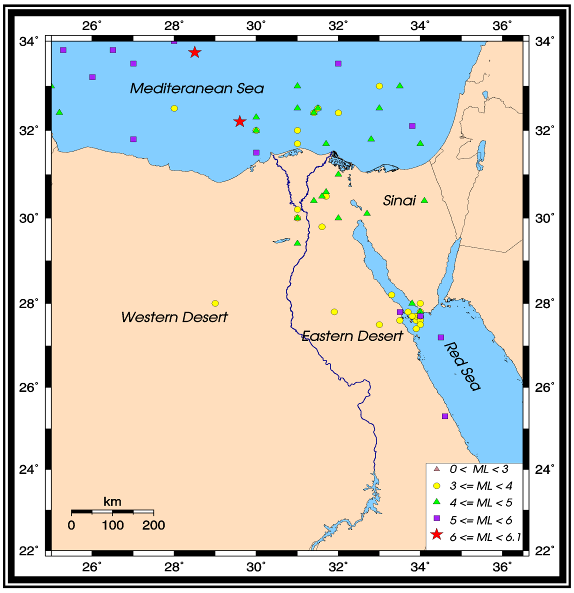

Fig. (3) Seismicity of Egypt from 1900 – 1962

All the available data for earthquakes that occurred in an area between 22^{o} – 34^{o} N and 25^{o} – 37^{o} E in the period of time from 1900 to July 1997 have been collected in this study (Fig.4). There are major and destructive instrumental earthquakes have been occurred and cause panic damage and they are;

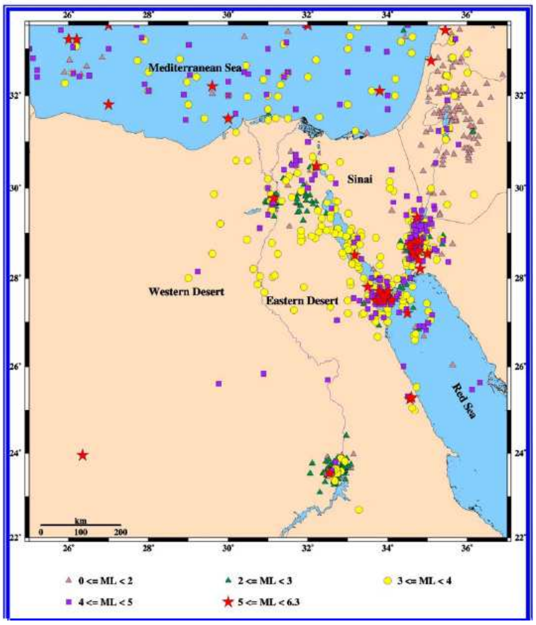

Fig. (4) Distribution of earthquakes from 1900 – July 1997.

3.1 September 12, 1955: Alexandria earthquake

This earthquake caused catastrophic damage in many localities of Egypt; 20 killed, 106 injured and hundreds of buildings destroyed. The epicenter of this earthquake located at 32.2^o N and29.6^o E with normal focal depth. Rothe (1969) assigned 6.7 as a surface wave magnitude. The main shock was widely felt in an area represented by a circle with radius more than 300 km. in Egypt and neighboring area. A maximum intensity of VIII was estimated in a limit area in Bihira province, where 5 persons were killed and 41 or more injured. In Rashid and Idku, the water pipes were damaged, furthermore destruction of more than 300 buildings of older brick constructions were reported in Rashid, Idku, Damanhur, Mahmodia and Abu Hommos. The Damanhur police office and two schools of Abu Hommos were also suffered further damage. A maximum intensity VII occurred at different localities of Bihira, Kafr-El Sheikh, Tanta, Monofia and Alexandria provinces where 3 persons were killed and 26 or more injured. Many of poor buildings suffer heavy damage. The police offices of Kafr-El Dawar, Kom Hamada and Quesna are slightly damaged. The high electric power cables of Dessouk were fallen.

3.2 March 31, 1969: Shadwan earthquake

The epicenter of this earthquake is located to the northwest of Shadwan Island (27.6o N and 32.9^o E). A maximum intensity of IX was assigned in Shadwan Islands, Tawila and Jubal, and a body-wave magnitude of 6.3 (Maamoun and El-Khashab, 1978). On the Shadwan Island itself, landslides, earthslumps and rock falls were common. Fissures and cracks in soil extend parallel to the Red Sea –Gulf of Suez direction. Ten Kilometers west of the fractured area in the sea a submerged coral reef was raised above sea level. Heavy damage was reported in south Sinai and Hurghada and extends to the middle and southern Egypt (Qus, Luxor and Esna).

3.3 October 12, 1992: Cairo earthquake

A relatively moderate-magnitude earthquake (M_s 5.9) with epicenter about 40 Km south of Cairo centre, in Dahshour (Fig. 5), caused a disproportional amount of damage (estimated at more than LE 500 million) and the loss of many lives. The area mostly affected was Cairo, in particular the old section of Cairo, Bulaq and the region to the south, along the west bank of the Nile to Gerza and El-Rouda. The shock was also strongly felt and caused damage and life loss in the southern Delta, around Zagazig. Damage extended throughout Fayoum and as far as south as Beni-Suef and Minia. In all, 350 buildings collapsed completely and 9000 were irreparably damaged, killing 561 persons and injuring 9832. Many of the causalities in Cairo were victims of panic-stricken stampedes of pupils rushing out of schools. About 350 school and 216 mosques were ruined and 50000people were made homeless. The maximum assigned intensity was VIII at the epicentral area (Fig. 6).

3.4 November 22, 1995: Gulf of Aqaba earthquake

A strong earthquake with magnitude 7.2 with epicenter located in the southern part of the Gulf of Aqaba, 450 km. southeast of Cairo. Most of reported damage was concentrated in Sinai where a number of hotels were totally collapsed leading to the loss of three lives and the injury of ten people in Nuweiba city. Almost all the buildings in Nuweiba city were damaged on the Gulf of Aqaba. Damage was also reported to the platforms of the port facilities in Nuweiba city. This damage recorded at cities along eastern side of the Gulf of Aqaba in Jordan and Saudi Arabia as well as Elat Port. The maximum intensity was IX for this earthquake.

4 EGYPTIAN NATIONAL SEISMIC NETWORK (ENSN)

As a result of this damage, the Egyptian government supports the National Research Institute of Astronomy and Geophysics (NRIAG) to install the Egyptian National Seismic Network (ENSN) and the strong motion network (Figs. 9 and 10). ENSN consist of main center at Helwan and five sub-centers at Hurghada, Burg El-Arab, Marsa Alam, Aswan and Kharga. The main center receives the seismic data from the near distance stations through a telemetry communication and from the remote stations and the sub-centers via the telephone lines and the satellite communications. The received data is analyzed for determining the earthquake parameters. The sub-centers collect the data from some close distance stations and send it to Helwan via Satellite communications. The distribution of the seismic stations and the strong motion units are chosen to cover the known seismic sources as well as possible. Also, this distribution includes the regions of historical earthquakes.

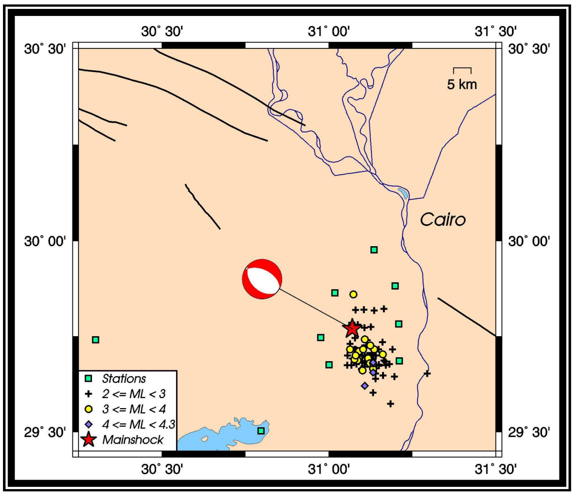

Fig. (5) Location of 12th Oct. 1992 earthquake.

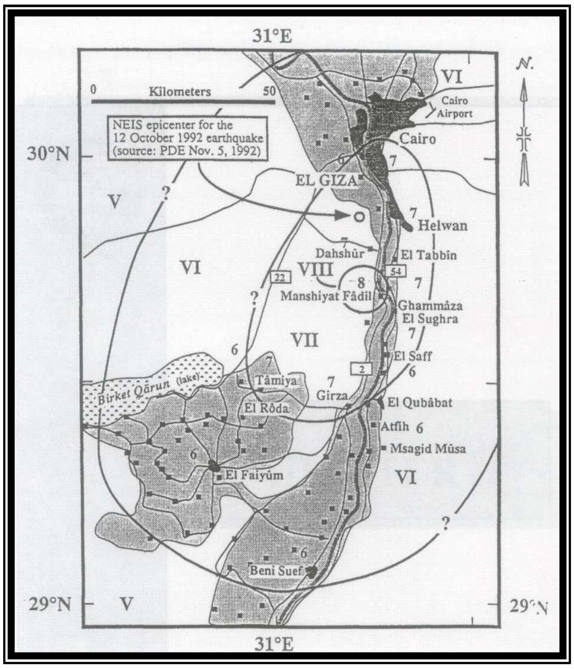

Fig. (6) Intensity map for Oct. 12, 1992 earthquake.

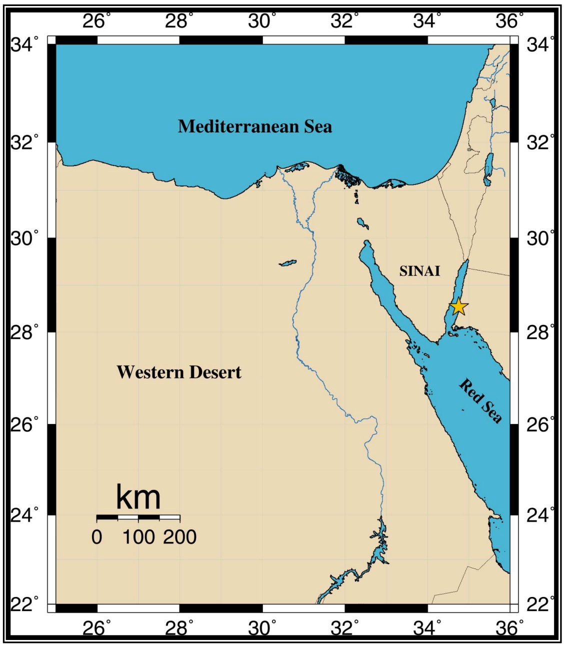

Fig. (7) Location of 25th Nov. 1995 earthquake

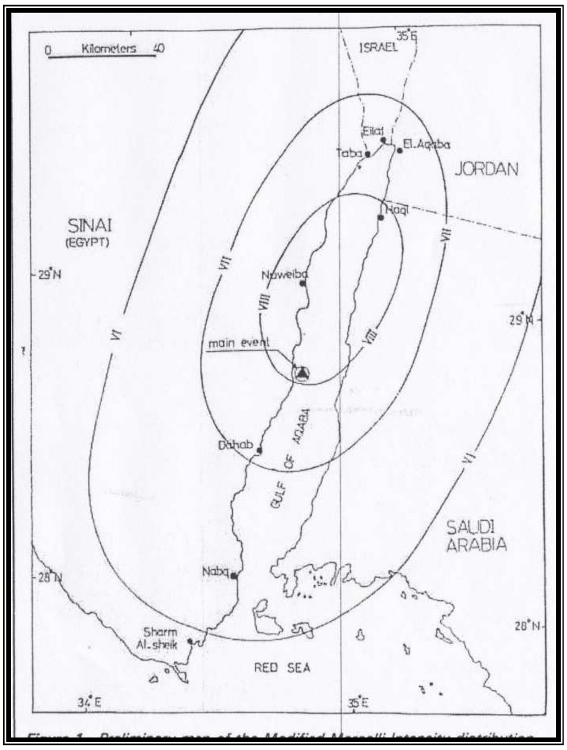

Fig. (8) Intensity map for Nov. 25, 1995 earthquake.

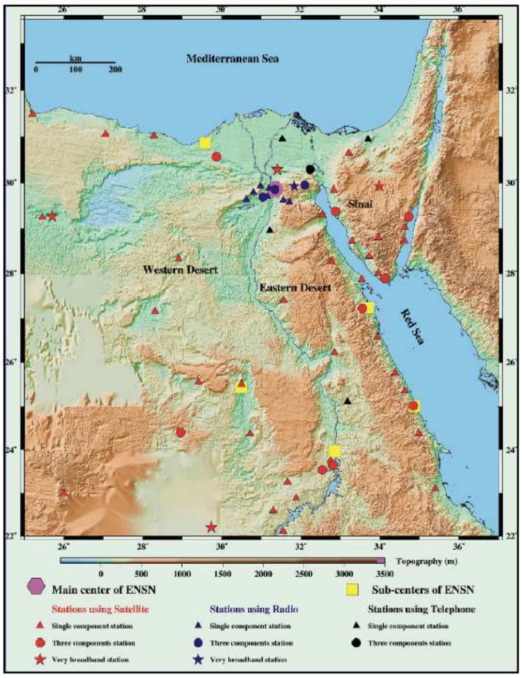

Fig. (9) Geographical distribution of ENSN stations.

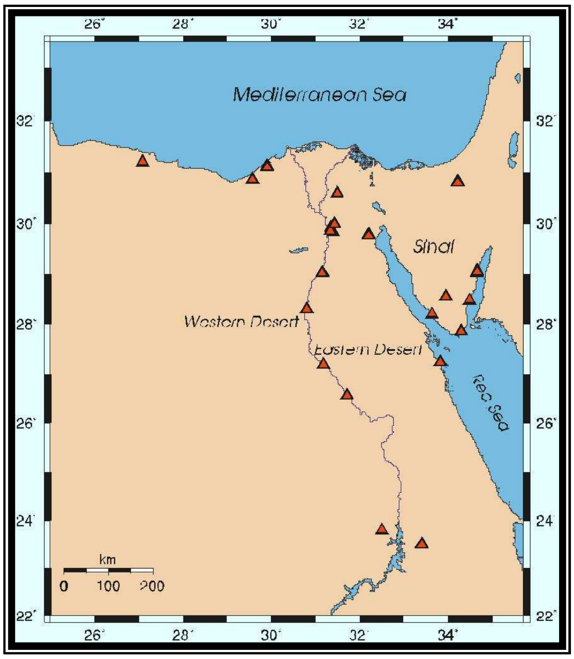

Fig. (10) Geographical strong motion stations.

4.1 Data Processing

The seismic Data Analysis software (DAN ver.2.56) provided by Nanometerics Inc. (Canada) extracts the digital data of remote site online from the ring buffer. The arrival times of P- and S-waves from the available stations are picked. The location program assign a numeric factor to qualitative quality factors assigned to phase reading during picking. The location of seismic events could be done by two implemented programs, Hypo71 PC) and LOC (Geological Survey of Canada). LOC program is preferable to locate regional events, while it is preferable to use Hypo71 when well azimuth coverage of stations is available.

Two magnitude scales are used to calculate the relative size of each earthquake (M_n and M_l). The response is the value read from the response file for given frequency and phase. Amplitude is the zero to peak counts and period as measured between the peaks of the peak to peak measurements. DAN firstly converts the amplitude to counts into actual ground motion in nm/sec suing the system response file. The program then converts this ground motion to ground displacement and then to ground motion that would be recorded on Wood-Anderson Seismograph. Finally, the maximum amplitude is selected and Richter empirical formula for southern California is used to calculate the Ml value (Eq. 1).

$$\mathbf{Ml = Log_{10} A + 2.56 \log_{10}\Delta - 1.67} \qquad (1)$$

Where A; is the ground motion in µm; Δ in km $10 < \Delta < 600$ km. While, M_n is calculated using Nuttli (1973) for distance $\Delta > 4$ degrees (Eq. 2).

$$\mathbf{M_n = -0.10 + 1.66 \log_{10} (\Delta\ km) + \log_{10} (amp/magnification) - 1.0 * \log_{10} (period)} \qquad (2)$$

4.2 Seismic activity

The local seismic activities (Fig.11) recorded by ENSN from Aug. 1997 (starting time of ENSN recording) to May 2007 are located at specific seismic zones that reflect their tectonic activity. These zones are; Cairo-Suez District; Beni Suef zone; Southwest Cairo zone; Central Gulf of Suez; Northern Red Sea; Gulf of Aqba; Northern Naser's Lake zone; Abu Dabbab zone; El-Minya-Sohag zone and Mediterranean Sea Zone.

Cairo – Suez shear zone extends from the northern Gulf of Suez toward Cairo city and is characterized by moderate activity. The northern part of eastern Desert which reflects a tendency of ENE –WSW active faults (these faults transverse the Gulf of Suez main faults). One of these faults is shown by a cluster of seismic activity from the Gulf of Suez to Beni-Suef city. Southwest Cairo zone (Dahshour area) is characterized by moderate seismic activity. A cluster of seismic activity comes clearly from the central part of Gulf of Suez, which indicates that the entire Gulf is active. A cluster of earthquakes is shown at the northern part of Red Sea at the triple junction area. The activity tends to lie at the Aqaba fault extension to the south. There are high seismic activity is also related to the Gulf of Aqaba and its extension towards the north.

A cluster of earthquakes is clearly shown along the central part of the Red Sea after the operation of ENSN stations that located along the western Red Sea Coast. This activity is related to the active rifting of the northern Red Sea. Moderate seismic activity is occurred along the northern part of Naser's Lake to the southwest of Aswan High Dam. A new cluster of seismic activity is recorded along the southern part of Naser's Lake. This cluster tends to constitute in E-W direction in agreement with the major fault trends in this area. Another seismic zone is identified with increasing the delectability of ENSN by installation of some stations in the central part of Egypt. This zone extends from Abu Dabbab area along the Red Sea coast to the western direction until the Nile River. ENSN recorded a scattered activity from the western Desert to the west of El-Minya and Sohag cities. Scattered events lie along the Mediterranean coast. The regional seismic activity (Fig.12) is located at the southern part of Hellenic and Cyprean arcs. The regional events lie as far as to the northern part of Turkey and Greece. Few numbers of earthquakes are located along southern Jordan, southern Red Sea and northern Sudan.

CONCLUSIONS

Egypt is affected by many destructive and damaging earthquakes through its long history and many people were killed, injured and a lot of structures were destroyed. The recording of earthquakes started with one station since 1898. Then there are consequences of modernization have been carried out to the earthquake monitoring stations by installing additional stations in different sites. Besides the local networks that deployed around the northern part of Naser's Lake in Aswan and around the southern part of Gulf of Suez. In July 1997 the National Egyptian Seismic Network (ENSN) started to monitor the seismic activity that distributed allover Egypt. This network is designed to cover the active areas. This network consists of 63 seismic stations and transmitted their data via satellite technology of communications.

By installing the ENSN, the seismicity map of Egypt is completely changed where; the local seismic activities reflect the incredible large number of smaller earthquakes. This large number of events is related to the increasing of the detectability of the network. New earthquake source zones are discovered and some of these zones characterized by its moderate to high earthquake activity. These zones should be taken into consideration in the hazard assessment studies for Egypt. The continuous upgrading of ENSN is highly recommended because this will increase the efficiency of the ENSN for the detection of very small earthquakes.

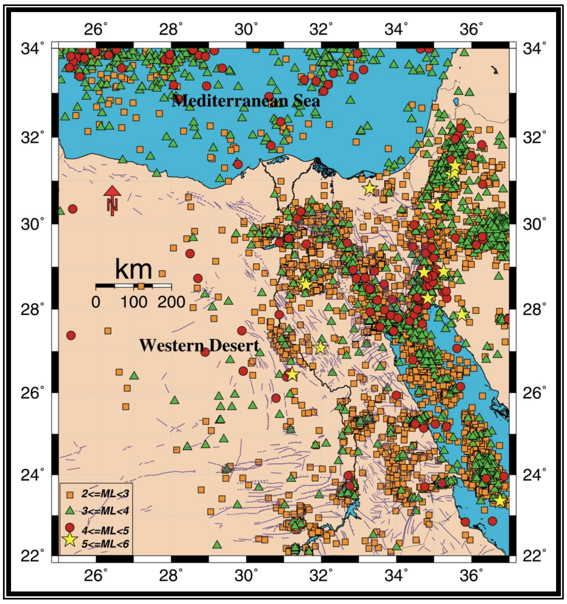

Fig. (11) Local earthquakes recorded by ENSN from Aug. 1997–May 2007.

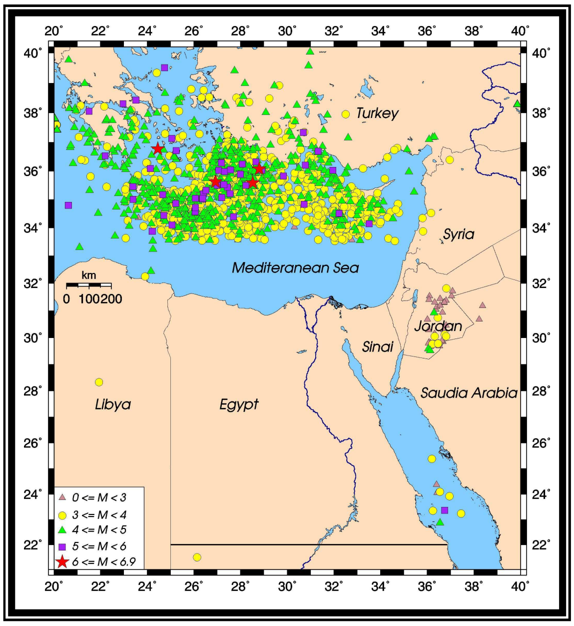

Fig. (12) Regional earthquakes recorded by ENSN from Aug. 1997–May 2007.

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