A Review of the Seismicity and Impact of Earthquakes on Life in Egypt

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[Abstract]

This review assesses seismicity in Egypt and the risks posed by earthquakes to the economy and to human life. Historical seismicity and tectonic data enable assessment of earthquake recurrence and severity. Hazard assessment of this sort is very important for Egypt due to the great expansion in construction and particularly the rapid increase of illegal construction, following the political unrest of 2011. Unregulated construction poses a great threat to citizens. In Egypt, even moderate earthquakes can cause economic disaster and serious loss of life, as in 1992. Egypt has a recorded earthquake history dating back to 2200 B.C. Seismic events have been documented near Alexandria in 1870 and 1955, near Fayum in 1303 and 1847, and in the Nile Valley and near Cairo in 2200 B.C. and 1111. The seismotectonic setting of Egypt suggests relatively high activity along the Gulf of Aqaba–Dead Sea transform, the Northern Red Sea and Gulf of Suez, Dahshour, near heavily populated Cairo, and in Aswan. Based on data from the National Research Institute of Astronomy and Geophysics (NRIAG), the International Seismological Centre Bulletin, published papers, and catalogs, I have constructed a list of historical and recent earthquakes in Egypt.

1 Introduction

Egypt is located in the northeastern corner of Africa, where it is affected by the subduction of the African plate beneath the Eurasian plate to the north, and the Red Sea-Gulf of Suez Rift and the Gulf of Aqaba-Dead Sea transform fault to the east. The Afro-Arabian rift system is the northern part of the east African rift system (Fig. 1), the world's largest active continental rift system, extending from Jordan Valley in the north, through the Red Sea, the Gulf of Aden, East Africa, and terminating in a large number of splaying faults in southern Africa (Girdler, 1991). Ben-Menahem et al. (1976) documented the approximately northward movement of the Arabian plate relative to the African plate, resulting in the oblique opening of the Red Sea. This relative movement is truncated to the northwest by the predominantly shearing force along the Gulf of Aqaba and a smaller component of sinistral shear along the Gulf of Suez. Determination of the opening poles points to a location near the Cyrenaica platform of Libya (Laughton, 1970; Freund et al., 1970; Girdler and Darracott, 1972; Izzeldin, 1982; Joffe and Garfunkel, 1987). The constant width of the southern Red Sea is replaced by a narrow graben (Prodehl and Mechie, 1991) and splitting in two directions occurs: the graben-like Gulf of Aden turns to the east and the Ethiopian rift system branches to the southwest into East Africa (Fig. 1).

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The Red Sea is NNW-SSE trending and bifurcates into the Gulf of Suez and the Gulf of Aqaba in the North. The Red Sea is a divergent plate boundary between the African and Arabian plates, and is considered as a major zone of separation between Africa and Arabia (Steckler et al., 1988). This zone continues northward to the Dead Sea through the Gulf of Aqaba. The Red Sea and the Gulf of Suez represent two rift systems created by extensional movement, and the Gulf of Aqaba itself resulted from strike-slip movement with several extensional components (Ben-Avraham et al., 1979; Eyal et al., 1981; Garfunkel et al., 1981). These two rifts and the Aqaba transform zone delineate three continental blocks: Africa, Arabia and Sinai. The Red Sea represents a mature stage of continental drift (Colletta et al., 1988). The closing of the Suez rift and the activation of the Aqaba transform occurred about 15-12 million years ago (MYA) (Berthelot, 1986; Courtillot et al., 1987). Rifting started in the north as well as in the south in the Oligocene, about 30 MYA (Bayer et al., 1988, 1989; Voggenreiter et al., 1988a). Major rifting of the continental lithosphere began in the Red Sea rift near the Oligocene-Miocene boundary and an organized seafloor spreading appears to have begun about 5 MYA.

Seismic activity in Egypt is due to interaction and relative motion between the Eurasia plate and the Africa plate. Several plate tectonic models have been adopted to explain the tectonic process in this region (e.g. DeMets et al., 1990, 1994; Jestin et al., 1994; McClusky et al., 2003). These models indicate that the African plate is moving northward relative to the Eurasian plate at a slip rate of ~10 mm/yr, while the Arabian plate is moving north–northwest relative to Eurasia, at a rate of about ~18-25 mm/yr. These movements cause crustal spreading along the axis of the Red Sea and left-lateral slip along the Dead Sea transform zone. The motion between Africa and Arabia (~10-15 mm/yr) is thought to be taken up partially by leftlateral motion along the Dead Sea transform Fault (McClusky et al., 2003; El-Fiky, 2000). New GPS observations indicate that Anatolia converges with Sinai at a slightly lower rate of 7-8 mm/yr (Wdowinski et al., 2006) in a somewhat more northerly direction relative to its convergence with Africa 8-9 mm/yr along the Cyprean arc.

2 Earthquake Recording in Egypt

Recording of earthquakes in Egypt started in 1903 (established by the Helwan observatory). Another set of short-period seismograms was added in 1951, and the system was replaced with a standardized set when Helwan was chosen by the U.S. Coast Geodetic survey to be equipped with the world wide standardized seismograph system in May 1962 (Maamoun et al., 1984). A Japanese Seismograph System with visual recording and frequency analyzer was added and operated commencing in December 1972. In 1975, three stations were installed at Aswan, Abu Simbel, and Marsa-Matrouh. In November 14, 1981, a seismic network was installed around Lake Nasser to monitor microseismicity. In 1982, the Aswan local seismic network (13 stations for monitoring micro-earthquakes) was installed to study the seismic hazard around the Aswan High Dam after the Kalabsha earthquake in 1981. The Kottamia Broad Band station (KEG) was installed in 1992 (part of the Mediterranean Sea Project in Italy) to study seismic activity in this region. In 1994, the Hurghada seismic network was installed in the entrance of the Gulf of Suez, the southern part of the Gulf of Aqaba and the northern part of the Red Sea (Hurukawa et al., 2001). The network consists of nine stations with a vertical-component, velocity-type seismometer and one station with a three-component, velocity-type seismometer. The Gulf of Aqaba local seismic network was installed in 1995 for monitoring seismic activity in the Gulf of Aqaba active region.

The Egyptian National Seismic Network (ENSN) began recording in 1997. It covers all active and strategic areas in Egypt, and monitors natural and induced seismicity all over the country. The ENSN includes over 69 three-component stations and STS2 broadband stations, and is operated by the National Research Institute of Astronomy and Geophysics (NRIAG) (Fig. 2).

3 Historical Seismicity

Egypt has a historical record of earthquake activity spanning 4,800 years. Taher (1979) examined Arabic documents (about 170 texts with 40 manuscripts) from libraries in Cairo with documents from other countries to study seismicity of eastern and Middle Eastern countries. Information on historical earthquakes cannot be regarded as a complete data set because some old Arabian literature has been lost. Moreover, dating of the earthquakes is a matter of debate among different authors (Poirier and Taher, 1980). Intensity was estimated from detailed information about the effects and damage after the earthquake, which can be directly translated into Modified Mercalli intensity. Historical earthquakes were selected from different publications (e.g. Maamoun, 1976; Maamoun et al., 1984 (Catalog I); Ben-Menahem et al., 1976; Poirier and Taher, 1980; Badawy and Horvath, 1998; and Ambraseys et al., 1994).

Date	Probable Lat	Probable Long	Approximate Intensity, Magnitude	Felt at
2200 B.C.	30.50N	31.70E	VII, 5.4	Tell Basta
1210 B.C.	23.60N	32.60E	VII, 5.4	Abu- Simbel
320 A.D.	32.00N	30.00E	VII, 6.0	Alexandria
742	30.00N	32.50E	VI	Suez
796	30.00N	29.55E	VIII, 6.0?	Alexandria
857 Mar.	30.03N	31.15E	VII	Cairo
885 Nov.	30.03N	31.15E	IX-X	Cairo
950 Jul. 26	30.03N	31.15 E	VIII-IX	Cairo
951 Sep. 15	31.13N	29.55E	VIII-IX, 5.3	Alexandria
956 Jan. 01	31.13N	29.55E	VIII, 6.0	Alexandria
967	25.00N	34.50E	VIII, 5.4	Red Sea
1111 May.26	30.30N	31.50E	VIII, 5.4	Cairo
1212 May.02	29.30N	34.57E	VIII, 5.4	Aqaba
1262	30.03N	31.15E	VIII-IX	Cairo
1303 Jul. 30	30.03N	31.15E	IX	Cairo
1303 Aug.08	31.13N	29.55E	VII	Alexandria
1326	32.00N	30.00E	VI,5.3	Alexandria
1341 May.	31.13N	29.55E	VIII	Alexandria
1347 Dec.	30.03N	31.15E	VIII- IX	Cairo

1373 Oct.	30.03N	31.15E	VI	Cairo
1375	30.13N	29.55E	VIII	Alexandria
1385 Sep.20	30.03N	31.13E	V	Cairo
1437 Nov.7	30.03 N	31.15E	VI	Cairo
1438 Feb.	30.03 N	31.15E	VI	Cairo
1481 Jul.	30.03 N	31.15E	VII	Cairo
1512 Apr. 7	30.03N	31.55E	V- VI	Cairo
1523 Apr. 5	30.03N	31.55E	V	Cairo
1525 Apr. 9	30.03N	31.55E	V	Cairo
1526 Jul. 14	30.03N	31.55E	V	Cairo
1529 Nov.12	30.03N	31.55E	VII	Cairo
1532 Jul. 10	30.03N	31.55E	V	Cairo
1573 Feb. 04	30.03N	31.55E	VII	Cairo
1576 Apr.21	30.03N	31.55E	VII	Cairo
1588 Jan. 30	30.03N	31.55E	VII- VIII	Cairo
1588 Jan. 14	30.03N	31.55E	VIII	Cairo
1588 Apr. 09	30.03N	31.55E	IX	Cairo
1698	32.00N	30.00E	VI, 5.3	Alexandria
1778	27.50N	34.00E	VII, 5.4	Naga-Hamdi
1847 Aug.07	29.50N	30.50E	VII, 5.4	Fayum
1854	23.54N	32.57E	VII?, 5.4?	Aswan
1870 Jun. 24	32.00N	30.00E	VII	Alexandria
1879 Jul. 11	32.00N	30.00E	VI, 5.3	Alexandria
1886 Dec.07	30.50N	31.70E	V	Delta
1900 Jan. 18	29.00N	33.00E	V, 4.4	Mediterranean
1900 Mar.06	29.37N	34.60E	VII, 5.4	Gulf of Suez

Table 1 Historical seismicity in Egypt from 2200 B.C. to 1900

A total of 58 Egyptian earthquakes have been reported from 2200 to 1900 B.C. Some of these have poor information and some have locations outside Egypt. Altogether, 22 earthquakes have reliable information concerning location, and 11 of these caused destruction (Table 1). Some events were felt in Cairo and Alexandria (probably from the Mediterranean Sea) and others were felt in the Gulf of Suez, the Gulf of Aqaba, and the southern part of Egypt (Fig. 3). The epicenter of the 2200 B.C. event may have been near that of the event that occurred on April 29, 1974 (Maamoun et al., 1984). The event of 1210 B.C. caused some damage in Abu Simbel, Numerous houses were damaged in Alexandria and many people were injured in the 320 A.D. event. On April 796, a severe seismic event caused destruction in many locations in Upper Egypt; damage to the walls of the Karnak temple. The largest known earthquake in the Nile Valley struck on August 7, 1847. It was felt throughout all of Egypt. Heavy damage was reported in the Nile Valley, in which 85 people were killed and 3,000 houses and many mosques were destroyed in Fayum. In Cairo, 100 people were killed and thousands of houses were destroyed; however, thousands of people were injured and many houses were destroyed in the whole country (Maamoun et., al 1984).

4 Recent Earthquake Activity in Egypt (from 1900 to the Present)

This list was taken from (Maamoun et al., 1984 (Catalog II); the International Seismological Center (ISC); and the National Research Institute of Astronomy and Geophysics (NRIAG)). The magnitude of selected earthquakes is ≥ 4.5 (Fig. 4). The most significant events occurred in Shadwan, (1969 and 1972), in the Nile Delta (1974), in Aswan (1981), in Cairo (1992), and in the Gulf of Aqaba (1995) (Table 2).

Date	Origin time	Lat.	Lon.	Magnitude
1906 Dec. 26	11:43	27.50N	34.00E	5.0
1906 Dec. 26	17:45	27.50N	34.00E	5.5
1909 Feb. 23	20:51	27.80N	33.50E	5.0
1920 Oct.01	02:10	29.40N	31.00E	4.6
1927 May.02	06:20	32.50N	31.00E	4.5
1951 Jan. 30	23:07	23.07N	32.01E	5.7
1951 May. 28	14:16	31.80N	27.00E	5.0
1952 Mar. 22	04:52	27.20N	34.50E	5.0
1955 Sep. 12	06:09	32.02N	29.60E	6.0
1969 Mar. 24	11:54	27.47N	33.87E	4.9
1969 Mar. 24	12:50	27.49 N	33.78 E	4.8
1969 Mar. 27	06:15	27.49 N	33.75E	4.7
1969 Mar. 31	07:15	27.60N	33.90E	6.1
1969 Mar. 31	09:01	27.50N	34.14E	4.8
1969 Mar. 31	11:30	27.77N	34.06E	4.6
1969 Mar. 31	21:44	27.46N	33.89E	4.8
1969 Mar. 31	22:40	27.49N	33.73E	4.7
1969 Apr. 03	06:15	27.44N	33.80E	4.6
1969 Apr. 04	06:42	27.70N	32.90E	4.5
1969 Apr. 04	12:18	27.65N	33.83E	4.6
1969 Apr. 05	17:51	27.53N	33.99E	4.5
1969 Apr. 08	10:31	27.48N	33.76 E	5.0
1969 Apr. 13	16:15	27.81N	33.79 E	4.8
1969 Apr. 14	13:43	27.31 N	33.50 E	4.8
1969 Apr. 16	08:12	27.37 N	33.94 E	4.9
1969 Apr. 17	08:01	27.55 N	33.87 E	4.7
1969 Apr. 23	13:37	27.57 N	33.71 E	4.8
1969 May. 10	09:27	27.50 N	34.11 E	4.7
1969 May. 24	05:59	27.51 N	33.79 E	4.7

1969 Aug.03	23:51	27.80 N	33.76 E	4.6
1969 Aug. 09	13:28	27.50 N	34.00 E	4.5
1969 Sep. 26	02:14	27.56 N	33.80 E	5.0
1969 Dec. 30	05:10	27.46 N	33.93 E	4.8
1970 Jan. 09	06:14	30.20 N	34.00 E	4.7
1970 Apr. 28	03:20	27.61 N	33.60 E	4.8
1970 Oct. 08	02:45	31.70 N	35.30 E	4.9
1970 Dec. 19	12:15	27.44 N	33.88 E	4.8
1970 Dec. 19	22:44	27.55 N	33.86 E	4.5
1971 Jul. 08	23:40	27.54 N	33.81 E	4.8
1972 Jan. 12	08:15	27.54 N	33.81 E	5.1
1972 Jun. 28	09:49	27.70N	33.60E	5.6
1973 Mar. 05	23:59	27.74N	33.41E	4.6
1974 Apr. 29	20:04	30.60N	31.70E	4.9
1978 Dec. 09	07:12	23.99 N	26.39 E	5.2
1979 Apr. 23	13:01	31.16 N	35.50 E	5.0
1981 Nov. 14	09:05	23.77 N	32.63 E	5.6
1981 Nov. 14	15:49	23.77 N	32.66 E	4.9
1981 Nov. 16	00:42	23.77 N	32.65 E	4.5
1981 Nov. 19	04:23	23.75 N	32.55E	4.5
1982 Mar. 23	10:48	27.90 N	34.28 E	4.7
1982 Aug. 20	12:57	23.60 N	32.63 E	4.7
1982 Oct. 14	13:40	26.76 N	34.82 E	4.8
1982 Oct. 30	04:36	27.63 N	33.82 E	4.6
1983 Jan. 21	13:17	29.20 N	34.73 E	4.8
1983 Jan. 25	15:59	28.96 N	35.01 E	4.7
1983 Jan. 31	17:36	29.82 N	33.89 E	4.5
1983 Feb. 03	13:46	29.18 N	34.76 E	4.9
1983 Feb. 10	17:29	28.92N N	35.61E	4.9
1983 Jan. 31	17:36	29.82N	33.89E	4.5
1983 Feb. 03	13:45	28.91N	34.75E	4.5
1983 Feb. 03	17:32	29.25 N	34.88 E	4.6
1983 Feb. 03	19:11	29.17 N	34.60 E	4.5
1983 Feb. 03	23:30	29.26 N	34.77 E	4.8
1983 Jun. 12	12:00	28.55N	33.12E	5.0
1983 Jun. 12	16:29	28.53 N	33.39 E	4.7
1984 Mar. 29	21:36	30.20 N	32.18 E	4.8
1984 Apr. 20	14:21	35.97 N	28.07 E	4.6
1984 Jul. 02	01:46	25.25 N	34.25 E	5.1
1984 Sep. 30	04:40	25.98 N	35.01 E	4.7
1985 Jan. 25	06:08	31.90N	35.51E	4.6

1985 Feb. 28	16:55	27.71 N	33.71 E	4.5
1985 Dec. 31	19:42	29.13N	34.90E	4.8
1987 Jan. 02	10:14	30.46 N	32.22 E	5.0
1987 Sep. 06	09:05	27.08N	35.07 E	4.9
1987 Oct.18	01:05	29.50N	35.05E	4.4
1987 Dec. 14	21:50	30.68N	31.69E	4.8
1988 Jun. 05	18:26	27.97N	33.73E	4.8
1989 Dec. 18	21:48	28.41N	33.33E	4.6
1992 May. 22	23:10	30.17 N	32.01	4.5
1992 Oct. 12	13:09	29.75 N	31.13E	5.8
1992 Nov. 11	18:41	29.69 N	30.97 E	4.6
1992 Nov. 05	19:16	29.65 N	30.98 E	4.5
1993 Mar. 10	19:26	29.99 N	31.65 E	4.5
1993 Jul. 30	23:34	28.71 N	34.73 E	4.7
1993 Aug. 03	12:31	28.81 N	34.69 E	4.5
1993 Aug. 03	12:43	28.78 N	34.57 E	5.8
1993 Aug. 03	12:54	28.67 N	34.76 E	4.9
1993 Aug. 03	13:12	28.52 N	34.68 E	4.9
1993 Aug. 03	13:29	28.81 N	34.45 E	4.5
1993 Aug. 03	13:33	28.19 N	34.66 E	4.9
1993 Aug. 03	13:45	28.61 N	34.56 E	4.9
1993 Aug. 03	15:38	28.54 N	34.81 E	4.5
1993 Aug. 03	16:33	28.78 N	34.59 E	5.4
1993 Aug. 03	17:50	28.61 N	34.81 E	4.5
1993 Aug. 03	18:02	28.93 N	34.51 E	4.5
1993 Aug. 03	20:53	28.77 N	34.63 E	4.7
1993 Aug. 09	06:05	28.78 N	34.62 E	4.6
1993 Aug. 13	00:31	28.54 N	34.65 E	4.6
1993 Oct. 18	20:51	28.74 N	34.62 E	4.6
1993 Nov. 03	18:39	28.70 N	34.56 E	4.8
1993 Nov. 08	01:06	28.68 N	34.64 E	4.8
1994 Apr. 06	21:18	28.75 N	34.62 E	4.5
1995 Nov. 22	04:11	28.80 N	34.79 E	6.2
1995 Nov. 22	07:55	29.02 N	34.69 E	4.8
1995 Nov. 22	12:47	28.52 N	34.90 E	5.1
1995 Nov. 22	12:53	28.91 N	34.82 E	4.6
1995 Nov. 22	22:16	28.78 N	34.80 E	4.6
1995 Nov. 23	18:07	29.20 N	34.74 E	5.2
1995 Nov. 24	09:24	28.38 N	34.78 E	4.5
1995 Nov. 24	16:43	28.96 N	34.73 E	4.9
1995 Nov. 25	11:41	29.15 N	34.81 E	4.8

1995 Nov. 29	08:10	29.38 N	34.74 E	4.5
1995 Dec. 11	01:32	28.91 N	34.75 E	4.9
1995 Dec. 26	06:19	29.23 N	25.29 E	4.5
1996 Jan. 03	10:05	28.70 N	34.90 E	4.8
1996 Feb. 26	07:17	28.66 N	34.75 E	4.9
1997 Mar. 08	15:21	27.48 N	34.23 E	4.5
1997 May 26	23:01	28.28 N	34.61 E	4.5
1997 May 25	18:33	31.44 N	27.64 E	5.5
1999 Oct. 11	20:39	28.95 N	31.50 E	4.5
1999 Dec. 21	14:36	29.22 N	34.78 E	4.5
1999 Dec. 28	12:17	30.21 N	31.87 E	4.6
2000 Mar. 08	14:22	28.82 N	34.69 E	4.5
2006 Jul. 30	01:54	26.27 N	35.57 E	4.7
2007 Nov. 20	09:18	31.64 N	35.59 E	4.5
2012 Jan. 30	17:04	27.74 N	34.03 E	4.5
2013 Jan. 31	08:01	29.85 N	31.95 E	5.5
2013 Feb. 06	01:42	31.59 N	34.06 E	4.9
2013 May. 11	02:10	25.36 N	34.00 E	6.1
2013 Jun. 01	11:49	28.41 N	33.22 E	4.7
2010 Dec. 23	18:45	22.72 N	29.73 E	4.7
2015 Jun. 27	15:34	29.01 N	34.77 E	5.0
2015 Jul. 24	06:51	29.31 N	28.75 E	5.0

Table 2 Seismicity in Egypt from 1900~present m>4.5

4.1 Shadwan Earthquake, March 31, 1969

The Gulf of Suez is one of the most attractive regions in Egypt due to the presence of earthquake swarms. Several earthquake swarms have been identified (Ben-Menahem and Aboodi, 1971; Maamoun et al., 1984; Daggett et al., 1986; Hurukawa et al., 2001). One of these occurred in Shadwan Island in the Northern part of the Red Sea, on March 31, 1969. Many cracks and fissures were observed in buildings South of Shadwan, where walls and houses were damaged. The effects extended to Wadi-Qena (200 km), where columns fell; it was felt in Fayum and extended to Cairo and the Nile Delta (Maamoun and El-Khashab, 1978). Another event occurred in Shadwan in June 28, 1972, and it was felt in the Northern Red Sea area and in the southern part of the Sinai Peninsula. More than 408 micro-earthquakes were recorded in an earthquake swarm at the entrance of the Gulf of Suez in August 2001 (Badawy and Abdel-Fattah, 2006).

4.2 Aswan Event, November 14, 1981

The Aswan area, located in southern Egypt, is considered one of the most strategic areas due to the presence of ancient Egyptian monuments and the Aswan High Dam. The Dam was built in 1960 and is a rock-filled dam, fed by the Nile River. It is 111 m high, with a crest length of 3,830 m and a volume of 44,300,000 m^3. The dam forms Lake Nasser, a vast reservoir in southern Egypt (about 350 km) and northern Sudan (about 150 km). It has a gross capacity of 169 billion m^3 and is one of the largest man-made lakes in the world (Latif, 1984). The Kalabsha Valley spreads from Nasser Lake and represents 10% of the total lake area. Seismic activity is concentrated in Kalabsha area, where the 14 November 1981 earthquake (M 5.3) occurred. This event damaged a few buildings in Aswan (Kebeasy et al., 1987). Simpson et al. (1989) suggested that seismicity in this area might be reservoir-triggered, while Telesca et al. (2012) thought that seismic activity in Aswan might be related to both tectonic activities along the Kalabsh fault and/or reservoir-induced seismicity due to Lake Nasser.

4.3 Cairo Earthquake, October 12, 1992

Cairo is the largest city in Egypt, with a population of 9,278,441 in January, 2015, according to the Central Agency for Public Mobilization and Statistics. It is the most populous city in the Middle East and Africa and was named "the city of 1,000 minarets." Tourists from all over the world visit Cairo to see the monuments and artifacts of ancient Egypt. On October 12, 1992 a significant earthquake occurred in Egypt, with a magnitude 5.8, an epicenter about 10 km southwest of Cairo and located at an estimated depth of 23 km. Although this earthquake was classified as a moderate event, it caused serious damage, loss of many lives, and great economic damage. According to reports from the National Center for Environmental Information (NOAA), USGS report 1993, Japanese Expert Tem 1993, and published papers (e.g Abou Elenean et al., 2000; Badawy and Peter, 1995; Badawi and Mourad, 1994; Fergany and Sawada, 2009). About 561 people were killed, 12,192 injuries were reported, 20,000 families lost their homes, and 8,300 buildings were damaged. Destruction of buildings appeared to have resulted mainly due to low construction standards. In Heliopolis, a 14 story building collapsed. Many Egyptians panicked, especially in schools, because of the lack of public training about natural disaster. Many casualties in Cairo were victims of this panic as people rushed out of buildings. An estimated $4 billion in damage resulted. Liquefaction was observed along the Nile floodplain and in agricultural fields. The earthquake caused different degrees of damage to some Islamic monuments. The upper part of the minaret of Al-Azhar mosque collapsed, and many mosques in old Cairo were badly cracked. Six churches, including the Hanging Church, and the Coptic Museum were damaged.

4.4 The Gulf of Aqaba event, November 22, 1995

The Gulf of Aqaba earthquake occurred on November 22, 1995, magnitude 7.2 (Hamouda, 2011), and was felt in Egypt, Jordan, and Saudi Arabia, followed by a very large number of aftershocks (more than 1,200), including several strong earthquakes with magnitudes as large as 5.6. The Gulf of Aqaba region has repeatedly been struck by earthquake swarms, the most significant of which was the 1993 swarm. The 1993 swarm with a magnitude of 5.6 and the 1995 swarm were the largest. The 1995 sequence was more active and energetic and destroyed many buildings in Nuweiba.

5 Discussion

Egypt has a long historical and instrumental record of small and moderate earthquake activity. This is due to activities and boundaries of the African, Arabian, and Eurasian plates, the Red Sea rifting system, and the Gulf of Aqaba-Dead Sea transform fault, in addition to local tectonics and the fault system in Dahshour, the Gulf of Suez, and Aswan. The most significant earthquakes that have occurred in Egypt are the off shore earthquake of Alexandria on September 12, 1955, the Shadwan Island earthquake in March 1969, the Aswan earthquake on 14 November 1981, the Dahshour earthquake on October 12, 1992, and the Aqaba earthquake on November 22, 1995 (Fig. 2). These earthquakes have caused loss of life, damage to property and buildings, and economic loss. There are similarities and correlations between some historical and recent earthquakes, for example the 1210 B.C. and the November 14, 1981 quakes in southern Egypt, the event of 796 and the event of 1955, the event of 1303 and the event of October 12, 1992; and several historical events in the Mediterranean Sea and Gulf of Aqaba.

Population centers and archaeological sites are located around the Nile Valley, which occupies only a very small portion of Egypt. Soft soil and unconsolidated deposits can significantly amplify ground motion and increase the damage in Cairo and the Nile Delta. The subsurface formations in Cairo are composed of three layers; the top layer is soft sediment ranging from 3-40 m in thickness. The second layer is composed of shale, ranging from 0.5-3 m, while the third layer is basaltic, ranging from 6-60 m (Said, 1989). Ground accelerations can cause severe damage and huge socioeconomic losses, Abd El-Aal (2010) estimated the generated ground acceleration in Cairo within a circle of 100 km up to (29-69 gal), while distant earthquakes, in the Gulf of Aqaba, Cyprus, and Crete (200~800 km), can generate ground accelerations up to 20 gal around Cairo.

Following political unrest on January 25, 2011, building activity increased rapidly. A report published by the Ministry of Planning stated that the real-estate sector has deteriorated since the revolution. The number of illegal buildings has tripled since then, and buildings collapse regularly due to building code violations and poor maintenance. It is an alarming situation. The city of Alexandria has seen a number of major building collapses in recent years. Several buildings have collapsed in 2015 alone, including an 8-story apartment building that left 25 dead. Similar violations have occurred across much of the country. Pointing to the magnitude of the problem, the Housing Ministry reported that 318,000 illegal buildings were constructed in 23 of 27 Egyptian provinces between 2009 and 2012. There are many non-governmental reports that suggest a number far greater than that in official documents.

Egyptian earthquakes are classified as small or of moderate size; however, buildings are not designed to resist earthquakes, and relatively moderate earthquakes can cause huge disasters, because of illegal construction, unconsolidated soils, and a lack of disaster response training.

The government needs to take quick action to prevent illegal construction. A disaster preparedness program should be implemented in all sectors to educate the population about natural disaster hazards and appropriate procedures following earthquakes.

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References

Abd El-Aal, A. E. K., 2010; Ground Motion Prediction from Nearest Seismogenic Zones in and around Greater Cairo Area. Egypt Nat. Hazards Earth Syst. Sci., 10: 1495-1511.

Abou Elenean, K. M., Hussein, H. M., Abu El-Ata, A. S,, and Ibrahim, E. M., 2000; Seismological Aspects of the Cairo Earthquake, 12th October 1992. Ann. Di Geofisica, 43 (3), 485-504.

Abou Elenean, K., Arvidsson, R., and Kulhanek, O., 2004; Focal Mechanism of Smaller Earthquakes Close to VBB Kottamia Station, Egypt. Ann. Geol. Surv. Egypt XXVII, 357-368.

Ambraseys, N. N., Melville, C. P., and Adams, R. D., 1994; The Seismicity of Egypt, Arabia and the Red Sea. Cambridge University Press, Cambridge, 181 p.

Badawi, H. S., and Mourad, S. A., 1994; Observations from the 12 October 1992 Dahshour Earthquake in Egypt. *Natural Hazards* **10**, 261-274.

Badawy, A., and Horvath, F., 1998; Seismicity of the Sinai Subplate Region: Kinematic Implications, Geodynamics, 27, 451-468.

Badawy, A., and Abdel-Fattah, A. K, 2006; 2001 August Earthquake Swarm at Shadwan Island, Gulf of Suez, Egypt. Geophys. J. Int. 167, 288-296.

Bayer, H.-J., Z. El-Isa, H. Hotzl, J. Mechie, C. Prodehl, and G. Saffarini, 1989; Large Tectonic and Lithospheric Structure of the Red Sea Region. *J. Afr. Earth Sci.,* **8**, 565-587.

Bayer, H.-J., Hotzl, H., Jado, A. R., Roscher, B., and Voggenreiter, W., 1988; Sedimentary and Strucrural Evolution of the Northwest Arabian Red Sea Margin. *Tectonophys.,* 153, 137-151.

Ben-Avraham, Z., G. Almagor, and Z. Garfunkel, 1979; Sediments and Structure of the Gulf of Aqaba-Northern Red Sea, Sediment. *Geol.,* 23, 239-267.

Ben-Menahem A., and Aboodi, E., 1971; Tectonic Patterns in the Northern Red Sea Region. J. Geophys. Res. 76, 2674-2689.

Ben-Menahem, A., 1979; Earthquake Catalogue for the Middle East (92 BC - 1980 AD), Bollettinodi Geofisica Teoricaed Applicata, 21, No. 84, 245-310.

Ben-Menahem, A., Nur, A., and Vered, M., 1976; Tectonics, Seismicity and Structure of the Afro-Eurasian Junction: The Breaking of an Incoherent Plate, *Phys. Earth Planet. Inter.,* 12, 1-50.

Berthelot, F., 1986; Etude Thermique du Golfe de Suez dans son Contexte Geodynamique (in France). Thesis, Universite de Paris VI, 190 pp.

Bosworth, W., and Streckler M. R., 1987; Stress Field Changes in the Afro-Arabian Rift System during the Miocene to Recent Period. *Tectonophys.,* 278, 47-62.

Colletta, B., Le Quellec, P., Letouzey, J., and Moretti, I., 1988; Longitudinal Evolution of the Suez Rift Structure (Egypt). *Tectonophys.,* 153, 221-233.

Courtillot, V., Armijo, R., and Tapponnier, P., 1987; The Sinai Triple Junction Revisited. *Tectonophys.,* 141, 181-190.

Daggett, P. H., Morgan, P., Boulos, F. K., Hennin, S. F., El-Sherif, A. A., El- Sayed, A. A., Basta, N. Z., Melek, Y. S., 1986; Seismicity and Active Tectonics of the Egyptian Red Sea Margin and the Northern Red Sea. Tectonophysics 125, 313-324.

DeMets, C., Gordon, R. G., Argus, D. F., Stein, S., 1990; Effect of Recent Revisions to the Geomagnetic Reversal Time Scale on Estimates of Current Plate Motions. Geophys. Res. Lett. 21 (20), 2191-2194.

DeMets, C., Gordon, R. G., Argus, D. F., Stein, S., 1994; Effect of Recent Revisions to the Geomagnetic Reversal Time Scale on Estimates of Current Plate Motions. Geophys. Res. Lett. 21, 2191-2194.

El-Fiky, G. S., 2000; Crustal Strains in the Eastern Mediterranean and Middle East as Derived from GPS Observations. Bull. Earthq. Res. Inst. Univ. Tokyo, 75, 105-125.

Eyal, M., Eyal, Y., Bartov, Y., and Steinitz, G., 1981; The Tectonic Development of the Western Margin of the Gulf of Aqaba Rift. *Tectonophys.,* 80, 39-66.

Fergany, E. A., Sawada, S., 2009; Estimation of Ground Motion at Damaged Area during 1992 Cairo Earthquake Using Empirical Green's Functions. Seismological Research Letters, v. 80, pp. 81-88.

Freund, R., Garfunkel, Z., Zak, I., Goldberg, M., Wesissbrod, T., and Derin, B., 1970; The Shear along the Dead Sea Rift. *Philos. Trans. R. Soc. London,* 267, 107-130.

Garfunkel, Z., Zak, I., and Freund, R., 1981; Active Faulting in the Dead Sea Rift. *Tectonophys.,* 80, 1-26.

Girdler. R. W., 1991; The Afro-Arabian Rift System: An Overview, *Tectonophys.,* 197, 139-153.

Girdler, R. W., and Darracott, B. W., 1972; African Poles of Rotation: Comments, *Earth Sci, Geophys.,* 2, 131-138.

Hamouda, A. Z., 2011; Recent Evaluation of the Assessment Seismic Hazards for Nuweiba, Gulf of Aqaba, Arab J. Geosci., 4, 775-783.

Hurukawa, N., Seto, N., Inoue, H., Nishigami, K., Marzouk, I., Megahed, A., Ibrahim, E. M., Murakami, H., Nakamura, M., Haneda, T., Sugiyama, S., Ohkura, T., Fujii, Y., Hussein, H. M., Megahed, A. S., Mohammed, H. F., Abdel-Fattah, R., Mizoue, M., Hashimoto, S., Kobayasi, M., Suetsugu, D., 2001; Seismological Observations in and around the Southern Part of the Gulf of Suez, Egypt. Bull. Seismol. Soc. Am. 91, 708-717.

Izzeldin, A. Y., 1982; On the Structure and Evolution of the Red Sea: Based on Geophysical Data from the Central and Northern Parts. Thesis, Strasbourg Univ.

Japanese Expert Team, 1993; Report of Japan Disaster Relief Team on the Earthquake in Arab Republic of Egypt of October 12, 1992.

Jestin, F., Huchon, P., Gaulier, J., 1994; The Somalia Plate and East African Rift System: Present-day Kinematics. Geophys. J. Int. 116, 637-654.

Joffe, S. and Garfunkel, Z., 1987; Plate Kinematics of the Circum Red Sea: A Re-evaluation, *Tectonophys.,* 141, 5-22.

Kebeasy, R. M., Maamoun, M., Ibrahim, E., Megahed, A., Simpson, D. W., and Leith, W. S., 1987; Earthquake Studies at Aswan Reservoir. J. Geodynamics, 7, 173-193.

Latif, A. F. A.,1984; Lake Nasser: The New Man-made Lake in Egypt (with Reference to Lake Nubia), in: Ecosystems of the World 32, Lakes and Reservoirs, edited by F. B. T. El-Serveir, 385-416, Elsevier Publishing Co., Amsterdam.

Laughton, A. S., 1970; A New Bathymetric Chart of the Red Sea. *Phil. Trans. R. Soc. London. A.* 267, 21-22.

Maamoun, M., and El-Khashab, H., 1978; Seismic Studies of Shadwan (Red Sea) Earthquake. Bull. of Helwan Inst. of Astr. and Geophys. 170.

Maamoun, M., 1976; La Seismicite du Moyen et du Proche- Orient dans le Cadre de la Seismotectonique Mondiale. These-Doct. Es Science, univ. Louis Pasteur de Strasbourg, France.

Maamoun, M., Megahed, A., and Allam, A., 1984; Seismicity of Egypt. Helwan Inst. Astron. Geophys. Bull. Ser. B 4, 109-162.

McClusky, S., Reilinger, R., Mahmoud, S., Ben Sari, D., and Tealeb, A., 2003; GPS Constraints on Africa (Nubia) and Arabia Plate Motions. Geophys. J. Int. 155, 126-138.

Poirier, J. P., and Taher, M. A., 1980; Historical Seismicity in the Near and Middle East, North Africa, and Spain from Arabic Documents (VIIth–XVIIIth Century). Bull. Seismol. Soc. Am., 70, 2185-2201.

Prodehl, C., and Mechie, J., 1991; Crustal Thinning in Relation to the Evolution of the Afro-Arabian Rift System: A Review of Seismic-refraction Data. *Tectonophys.,* 198, 311-327.

Richter, C. F., 1958; *Elementary Seismology,* W. H. Freeman, San Francisco, 768 pp.

Said, R., 1990; The Geology of Egypt; A. A. Balkema, Rotterdam, Netherland.

Simpson, D. W., Gharib, A. A., and Kebeasy, R. M., 1989; Induced Seismicity and Changes in Water Level at Aswan Reservoir, Egypt. Gerlands Beitr. Geophys. Leipzig, 99, 191-204.

Steckler, M. S., Berthelot, F., Lyberis, N., and Le Pichon, X., 1988; Subsidence in the Gulf of Suez: Implications for Rifting and Plate Kinematics. In: Le Pichon and J. R. Cochran (Editors), the Gulf of Suez and Red Sea Rifting, *Tectonophysics,* 153, 249-270.

Telesca, L., Mohamed, A. E. E, ElGabry, M., El-hady, S., and Abou Elenean, K. M., 2012; Time Dynamics in the Point Process Modeling of Seismicity of Aswan Area (Egypt), Chaos, Solitons and Fractals, 45, 47-55.

U. S. G. S., 1992; *Reconnaissance Report on the 12 October 1992 Dahshur, Egypt, Earthquake,* U. S. Geological Survey.

Voggenreiter, W., Hotzl, H., and Jado, A. R., 1988a; Red Sea Related History of Extension and Magmatism in the Jizan Area (Southwest Saudi Arabia): Indication for Simple-shear during Early Red Sea Rifting. *Geol. Rundsch.,* 77: 257-274.

Wdowinski, S., Ben-Avraham, Z., Arvidsson, R., and Ekstrom, G., 2006; Seismotectonics of the Cyprian Arc. J. Geophys. Int. 164, 176-181.

NGDC page on the "Cairo earthquake," Retrieved 9 June 2010.

NGDC page on the "885 earthquake," National Geophysical Data Center. Retrieved 22 February 2015.

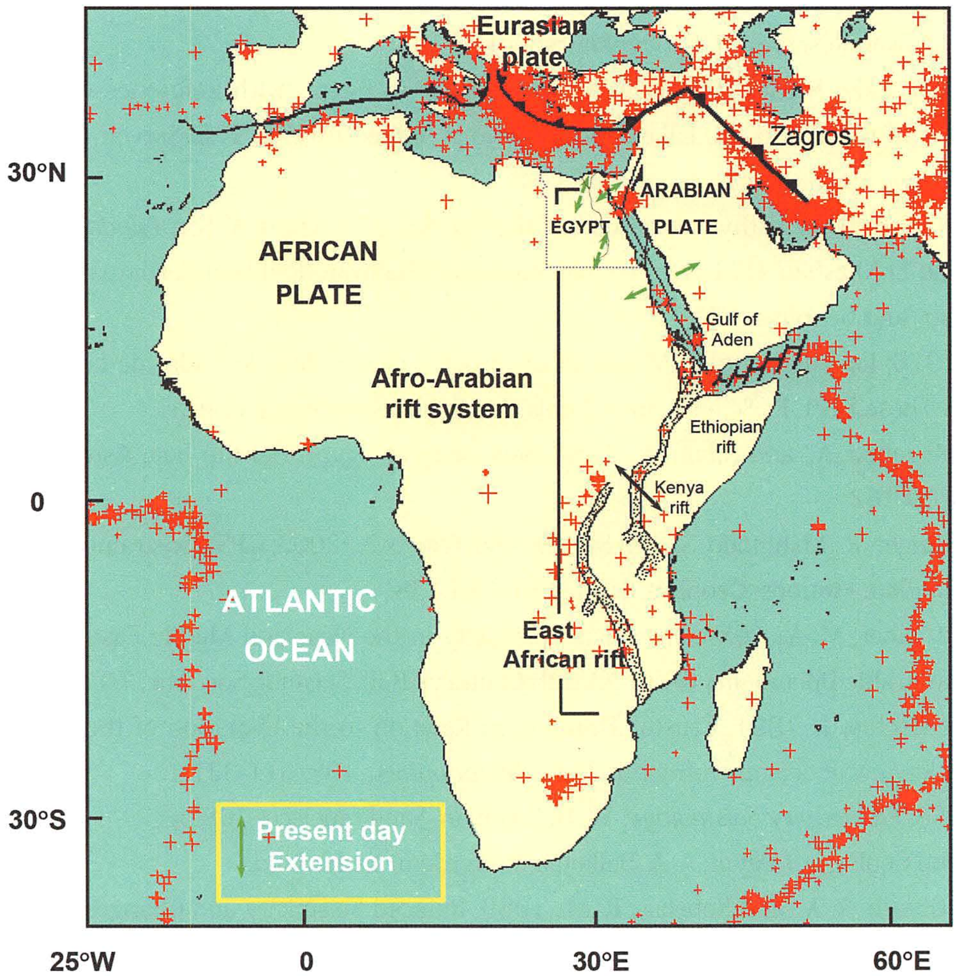

Fig. 1 Local tectonic setting in Egypt in a relation to the Regional tectonic setting. The Afro-Arabian Rift system (modified after Bosworth and Steckler, 1987), and the recent tectonic setting in Egypt (after Abou Elenean, 2004). Data are taken from the International Seismological Center (ISC). Only earthquakes located by the ISC are plotted.

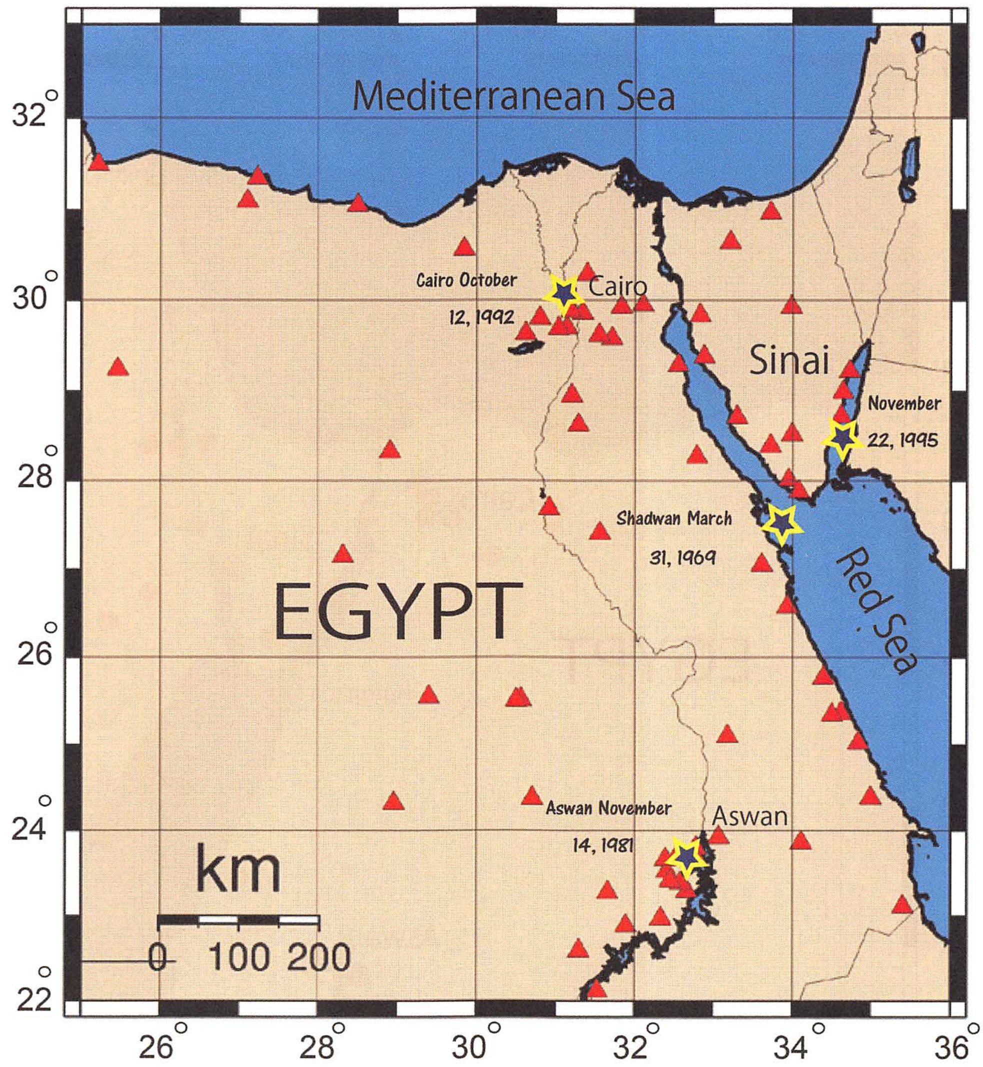

Fig. 2 Distribution of the seismic stations (red triangles), the most significant events (blue stars) felt in Egypt

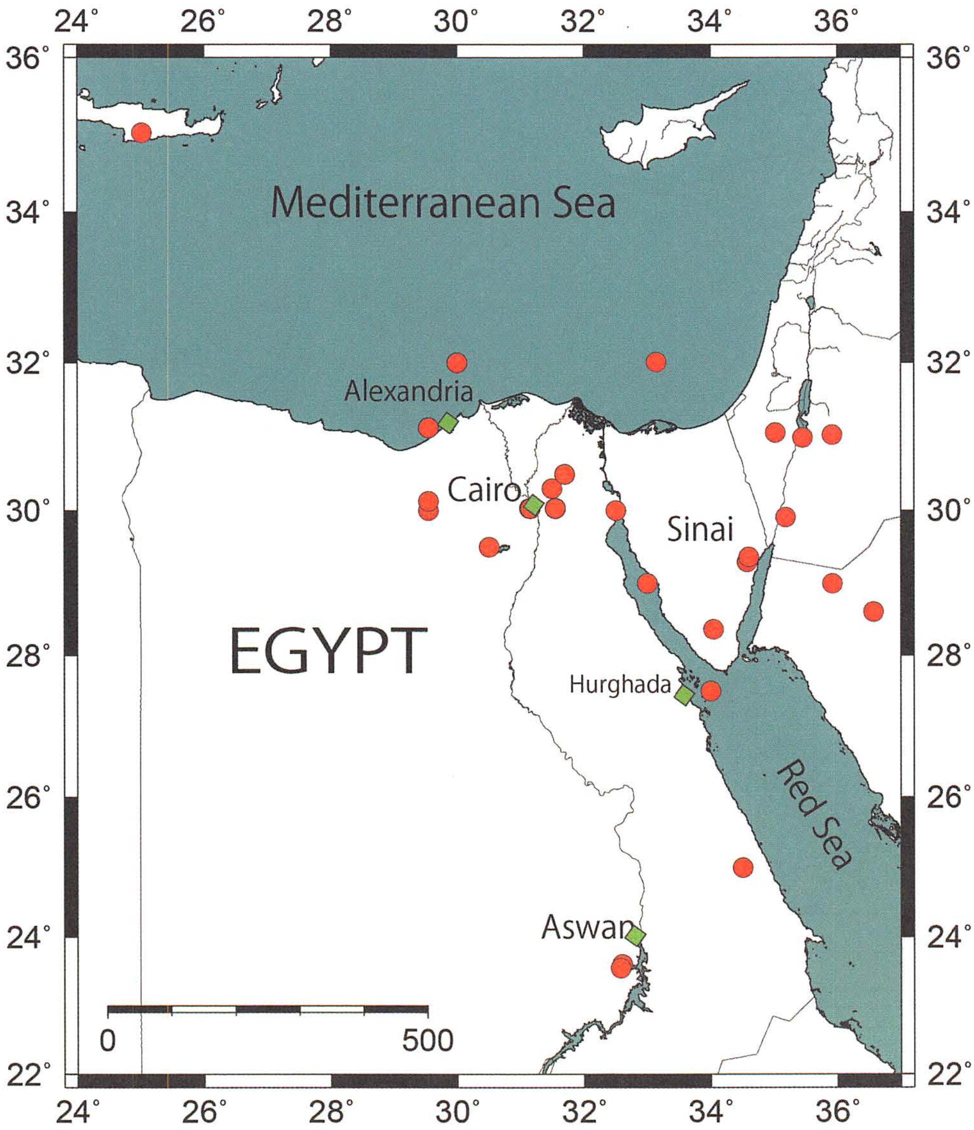

Fig. 3 Historical seismicity in Egypt (red circles) from 2200 B.C. - 1900

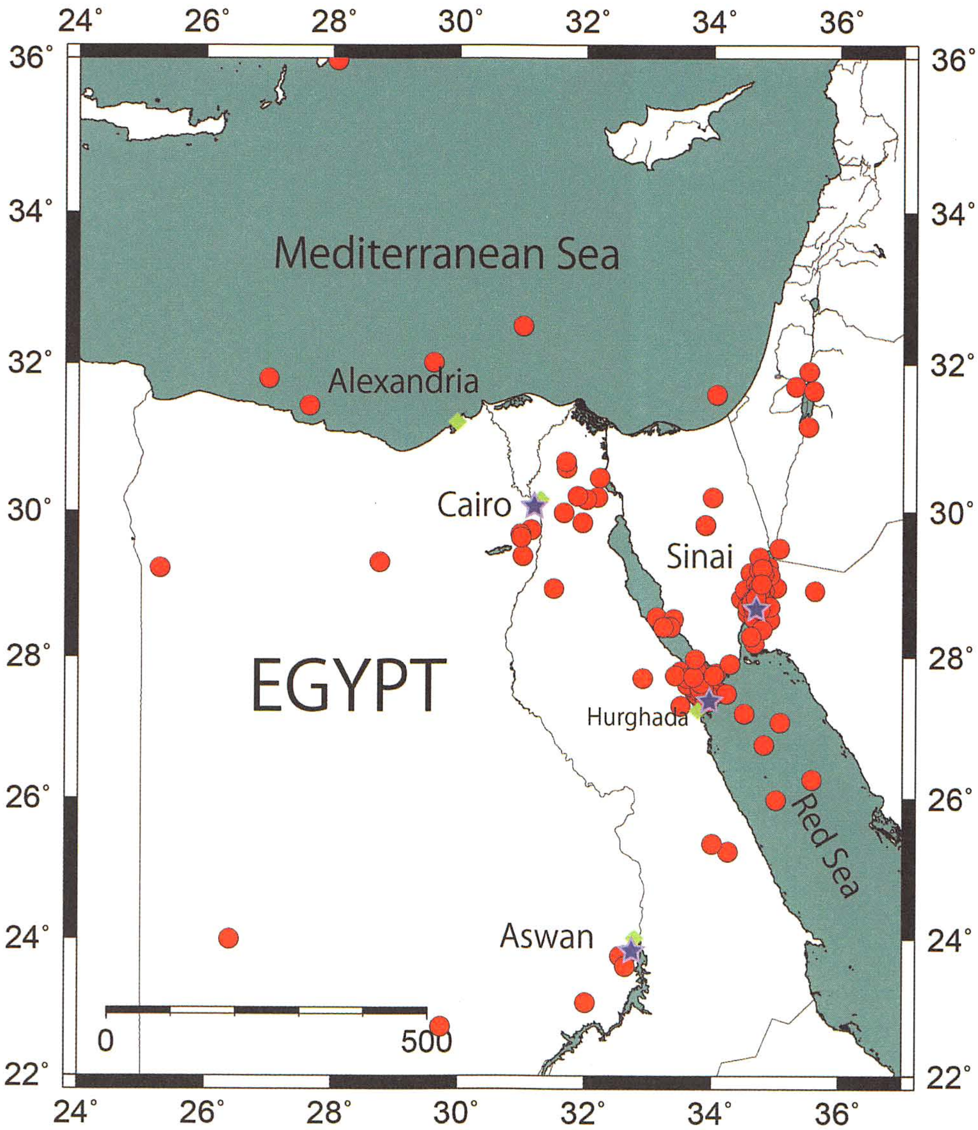

Fig. 4 Recent earthquake activity in Egypt (red circles) the most significant events (blue stars) from 1900 to the present