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A REVIEW OF THE RECENT SEISMIC ACTIVITY IN THE SOUTHERN PART OF EGYPT (UPPER EGYPT)

HAGGAG Hamed Mohamed *, GABER Hassan Hassib, SAYED Abdalah Dahy and EZZAT Mohamed El-Amin

Aswan Earthquake Research Center, P.O.Box 152, Aswan, Egypt
**Corresponding author's e-mail:* haggaghm@yahoo.com

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ABSTRACT

Analyzing the earthquake catalogue of the Upper Egypt area since 1982 revealed some characteristics of the seismic activity in the area. Construction of a seismicity map according to the seismicity level in the Upper Egypt showed 14 seismic zones and that the seismic activity is intense around the strait of the Gulf of Suez, along the Red Sea axis, Abu Dabbab and Aswan area. While the detailed study of Aswan zone showed 8 distinct sub-seismic zones and that the activity is concentrated in and around Gable Marawa area. The b-value was calculated for each seismic zone; it is found that the highest value is in Abu Dabbab area followed by Aswan area. A seismic energy released map of the Upper Egypt was constructed for the period from 1982 to 2006; the map reveals the main active zones with high energy values. The study gives new insight for a better understanding of the seismic activity in the Upper Egypt and helps in the seismic hazard assessment.

KEYWORDS: seismicity, Aswan, seismic energy, Upper Egypt

INTRODUCTION

The southern part of Egypt (Upper Egypt) was known as aseismic for a long time except for a view historical events that were documented in the annals of ancient Egyptian history and on some temples. The Upper Egypt area extends from latitude 22° to 28° N and longitude 26° to 36.5° E (Fig. 1). Some large earthquakes were located in the Red Sea in the catalogue of the International Seismic Center (ISC) and only one was located in Gilf El-Kebeir area in the southeastern part of Upper Egypt (Fig. 1). Recently, because the closest station for recording earthquakes from the Upper Egypt was at Helwan, south of Cairo (about 690 km from Aswan), low magnitude earthquakes in the Upper Egypt could not be recorded.

A felt earthquake occurred on 14 Nov. 1981 at Aswan in the south (Ms 5.3) on the Kalabsha fault beneath Gable Marawa (Kebeasy et al., 1987). After the 1981 main shock, a telemetered seismic network was established to monitor the local activity around the northern part of Aswan reservoir (Fig. 1). On October 12, 1992 a moderate size earthquake of M_w 5.8 occurred at epicentral distance of about 25 km to the south west of Cairo city, it was felt until Aswan in the south (Hussein and Farouk, 2000). The earthquake stimulated the Egyptian government for installing the Egyptian National Seismic Network (ENSN). The main purpose of the network is to cover all the Egyptian territories in order to increase the capability of monitoring the seismic activity particularly in the southern part of Egypt. Seismic stations in the southern part of Egypt are shown in Figure 1, while Figure 4 shows the earthquake epicenters from 1981 to 2006.

STRUCTURAL PATTERN

Youssef, 1968 grouped the main structural elements of Egypt under some major categories (Fig. 2), the most important are the followings:

1. Gulf of Suez – Red Sea fault trend (N35° W): Among the many fractures that strike in this trend, the most important are those that delimit the Gulf of Suez -Red Sea graben. Grabens parallel with this trend and with that of the following category are abundant in Sinai. Long segments of the Nile Valley as well as faults in the Eastern and Western Deserts parallel this trend.
2. Gulf of Aqaba fault trend (N15° E): Numerous faults in Sinai, the Gulf of Suez region, the Nile valley and other parts of Egypt parallel to this trend.
3. East-west fault trend: They are not numerous but most of them are active, among the most important are the central Sinai fault, the Cairo – Suez faults, faults west of the Nile Delta and faults in the southern Western Desert south of Kharga depression.
4. North-south fault trend: Faults trending nearly north-south are limited in number and are mostly minor. In the southern part of the country, several major north- south faults are present in the Nile valley along the Kalabsha-Aswan-Idfu stretch and in the Western Desert parallel with that segment of the Nile.

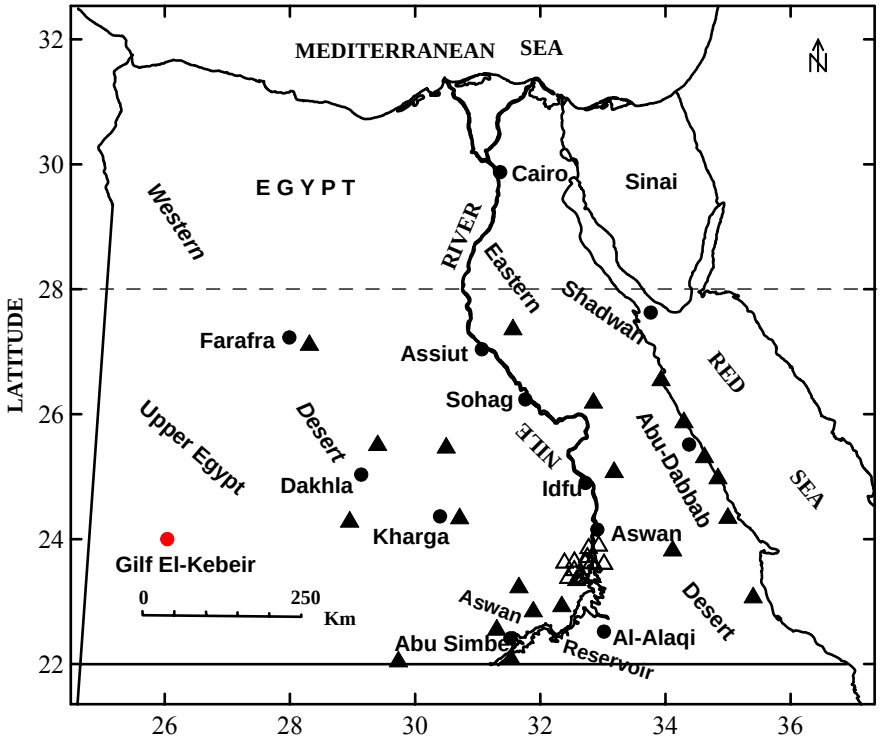

Fig. 1 Location map of the Upper Egypt area, Aswan seismic network (Δ), the Egyptian national seismic network, ENSN, (▲) and Gilf El-Keber earthquake.

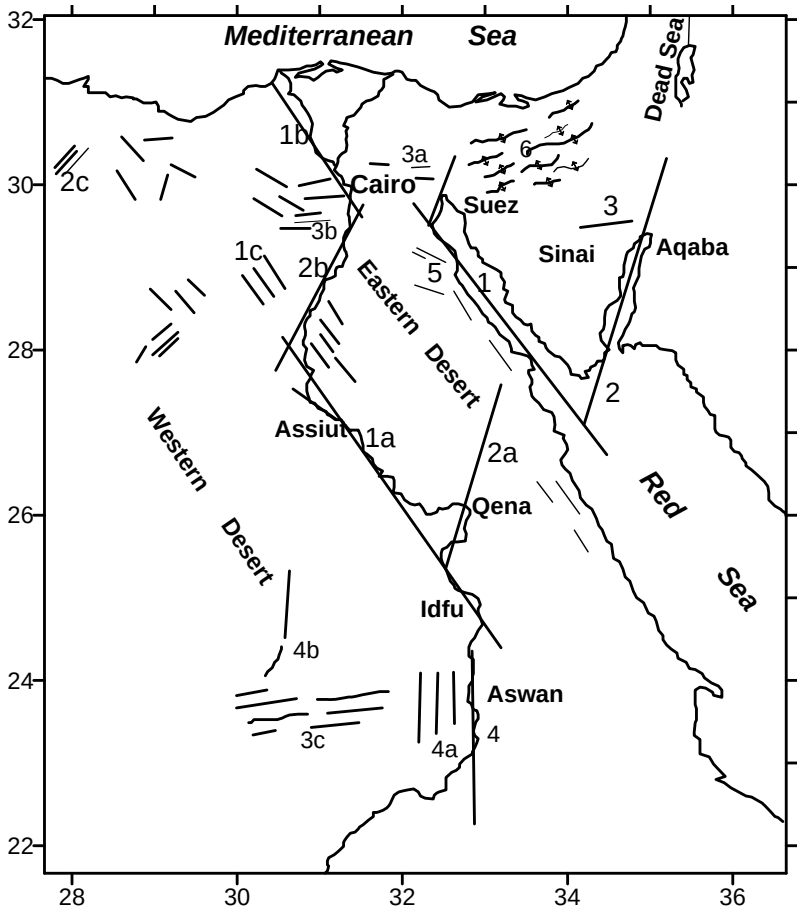

Fig. 2 1, 1a, 1b, 1c = Gulf of Suez trend (about N35° W); 2, 2a, 2b, 2c = Gulf of Aqaba trend (about N15° E); 3 (Central Sinai fault), 3a, 3b, 3c = east west trend; 4, 4a, 4b = north south trend; 5 = N45° W. (After Youssef, 1968).

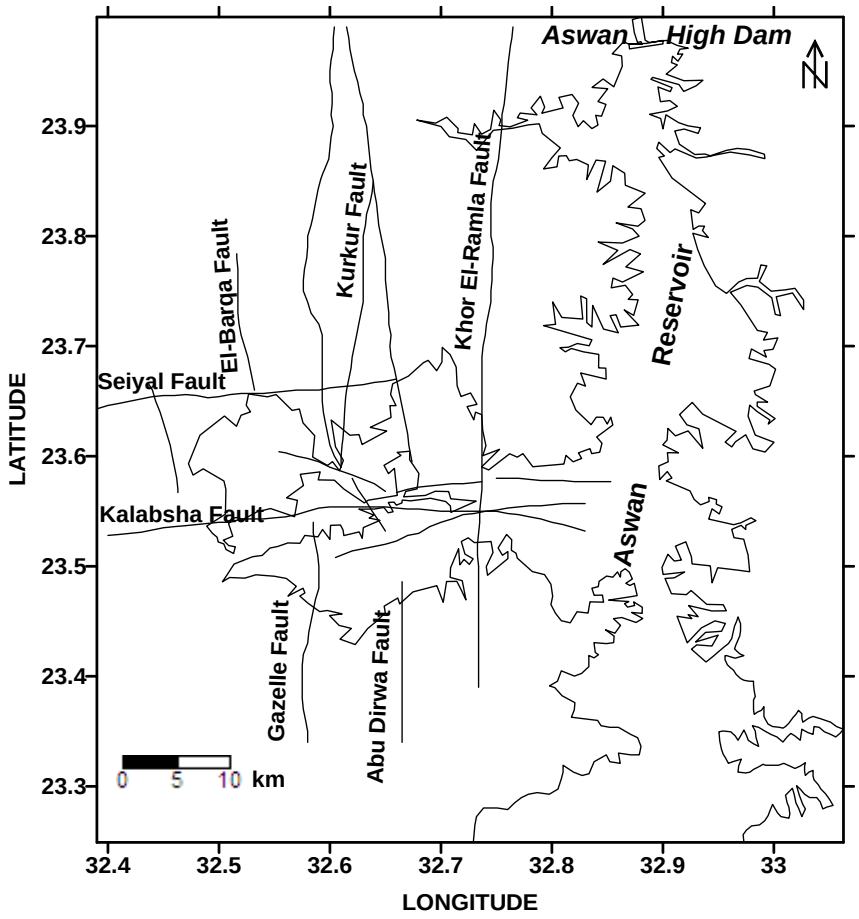

Fig. 3 Main faults in Aswan area (after WCC, 1985).

From the structural point of view, faults and joints are the most deformational feature observed at the cliffs bordering the Nile stream (Said, 1962 and 1981). These faults have different directions. The most abundant have the NW-SE and NNW-SSE trends while others have the WNW-ESE, ENE-WSW and NE-SW directions.

The Western Desert faults that dissected Aswan area were classified into several systems according to their directions (Fig. 3), the most important of these are:

a) East –west trending fault system: includes the Seiyal fault and the most active Kalabsha fault in the area, which was identified as the source of the 1981 main shock (Kebeasy et al., 1987).

b) North-south trending faults: Important faults among of this system are; Khor El-Ramla fault, Kurkur, Gable El-Barqa, Abu Dirwa and Gazelle fault.

SEISMICITY AND SEISMIC ZONING

The general distribution of the earthquake epicenters in Egypt falls along three major trends. The first trend extends along the Gulf of Suez through Cairo and Alexandria. The activity along this trend is attributed to the Red Sea rifting. The second trend extends from the NE (East Mediterranean) to the SW (Cairo-El Faiyum) along which small to moderate historical earthquakes were observed. It is speculated that this seismic zone extends into the Gilf El-Kebeir area. The seismic activity, largely due to shallow small-size earthquakes along the third trend (Levant-Aqaba trend) is related to the active sinistral movement along the Levent fault system and the Gulf of Aqaba (Said, 1990).

Many authors, e.g. Seiberg (1932); Karnik (1969); Ibrahim (1979); Maamoun (1979); Maamoun et al. (1984) and Ambraseys et al. (1994) reported a few number of historical earthquakes that occurred in and around Egypt. Among them, the following earthquakes were reported in the Upper Egypt: Circa 1210 B.C. at the entrance of Abu Simble temple; 600 B.C. in the Thebes (Luxor) region; 27 B.C. at the temples of Luxor and Karnak; 977 A.D, at Qus; June 22, 1778 at Nag Hammadi and Tahta; and 1850 October 27 that felt north Assiut.

Seismicity remarkably increased in Egypt just because there are new seismic stations operating now unlike a decade ago or more. Information about the instrumental earthquakes that occurred in Upper

Egypt before the Aswan 1981 earthquake were collected from Maamoun et al. (1984); the international bulletins (e.g. ISC, NEIC) and Helwan station bulletin. Among these significant events are:

- 12 November 1955, Abu Dabbab earthquake (M 6.0): on the Red Sea coast.
- 31 March 1969, Shadwan island earthquake (M 6.3): In Shadwan island.
- 9 December 1978, Gilf El-Kebeir earthquake (M 5.3): in the southwestern part of the Upper Egypt.
- 14 November 1981, Kalabsha earthquake (M 5.6): about 80 km south of Aswan.

Figure (4) is a location map of the earthquake foci that located in the Upper Egypt during the period from 1981-2006. The figure shows that the seismic activity was concentrated in different seismic zones from the east to the west. It shows also higher distribution of the activity from the Red Sea towards the Nile River and Aswan area, while it is fewer in the west and rare in the far west due to the lack of the seismic stations that can monitor the low magnitude events. This seismic activity can be grouped according to the seismicity level and the spatial distribution into the following seismic zones, as shown in Figure 4:

- ***Seismic zone (1)***

This zone contains the seismic activity occurred in an area where the main faults of the Gulf of Aqaba and the Gulf of Suez intersect, also it comprises the activity that occurred in Shadwan island. This island lies at the mouth of the Gulf of Suez in the northern end of the Red Sea. On March 31, 1969 a strong earthquake with magnitude 6.3 has been occurred in the island. Focal mechanism solution of June 28, 1972 earthquake (M 5.5) that occurred in Shadwan island showed a normal faulting with small strike slip component (El-Amin, 2004). Several authors dealt with this region, e.g. (Ben-Menahem et al., 1976 and Hassib, 1990).

- ***Seismic zone (2)***

This zone lies to the south of zone (1). It can be considered as an active zone; the activity was distributed around the central part of the axial rift of the Red Sea. The earthquakes magnitude ranged up to 4.6.

- ***Seismic zone (3)***

It is an active zone lies in the southern part of the Red Sea, it is clear that the activity is distributed almost north-north west parallel to the main axial rift of this part of the Red Sea.

- ***Seismic zone (4)***

It contains the activity in Baranes area on the Red Sea coast, about 200 km to the east of Aswan.

- ***Seismic zone (5),*** Abu-Dabbab area

It is the most active zone in the Eastern Desert; many famous earthquakes were occurred in it. It contains the activity in Abu-Dabbab area that lies on the Red Sea coast. The activity is distributed parallel to the Red Sea coastal line NNW-SSE. Two strong earthquakes of magnitude 6.0 and 5.2 were occurred on November 12, 1955, and July 2, 1984 respectively. Prior to the 1955 earthquake, no events have been reported in Abu Dabbab area in the ISC catalogue.

- ***Seismic zone (6)***

Contains the activity located in the northern part of the Eastern Desert of the Upper Egypt, it can be considered as an active area where many earthquakes were recorded by Aswan and the ENSN seismic stations with magnitude ranging up to 4.2. The general trend of the seismicity runs almost N-S.

- ***Seismic zone (7)***

It is located in the southern end of the Eastern Desert; the seismicity almost distributed N-S and E-W.

- ***Seismic zone (8)***

Contains the seismicity located in Wadi Al-Alaqi area in the south of the Eastern Desert. The seismicity almost has the NW-SE direction where the main fractures and faults are in the direction NW-SE parallel to the Red Sea trough. A few number of events were recently recorded with magnitude up to 3.8 in the area.

- ***Seismic zone (9)***

This area (Abu Simbel) lies about 270 km to the southwest of Aswan; the surface geology showed some faults in the area with different direction, N-S; E-W; NE-SW and NW-SE (El-Shazly et al., 1977). The seismic activity in this zone was distributed in different directions with magnitude ranged up to 4.2.

- ***Seismic zone (10)***

It contains the activity in Tushka area north of Abu-Simbel zone. It can be considered as an extension of Abu-Simbel zone events. Most of the events were located recently and characterized by magnitude ranging up to 2.8. This zone has a great importance from the developing point of view where the national Tushka project is constructed.

- ***Seismic zone (11), Aswan zone***

This is the closest active seismic zone to the High Dam, the main project of Egypt that controls the electricity and irrigation. Because of the presence of the first local seismic network around the area, some detailed studies were carried out concerning the seismic activity in the area, for the safety purpose of the High Dam, e.g. Mohamed (1997 and 2001).

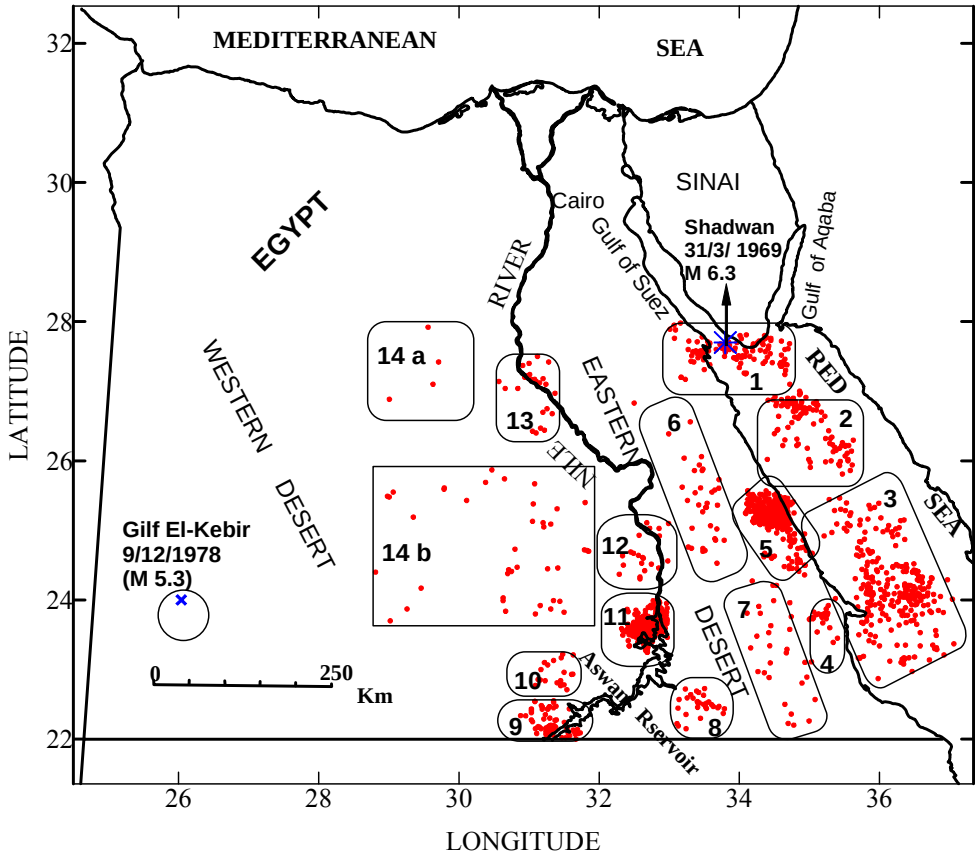

Fig. 4 Seismicity map of the Upper Egypt during the period from 1981 to 2006 and the recent seismic zones.

Construction of a new seismicity map of Aswan area during the period 1981–2006 shows the following eight seismic clusters (Fig. 5), these zones were grouped according to spatial distribution and the level of the seismicity:

A - West High Dam zone

B - Northern old stream channel zone

C - Southern old stream channel zone

D - Gable Marawa zone (GMR)

E - East Gable Marawa

F - East - East Gable Marawa

G - Khor El-Ramla zone

H - Abu Dirwa zone

It is found that Gable Marawa zone is the most active zone in Aswan region. It is located around the site of the Nov. 14, 1981 earthquake. Seismicity at this zone characterized by a focal depth between 15-25 km.

- ***Seismic zone (12), Idfu - Kom Ombo area***

It lies about 100 km north of Aswan in. Most of the activity is distributed around the north-south, El-Barqa, fault (Fat-Helbary and Haggag, 2004). In 2006, an earthquake (M 4.0) was located west of Idfu city. Focal mechanism solution of that event showed strike slip faulting with a normal component.

- ***Seismic zone (13), Sohag – Assiut area***

A few number of earthquakes were recorded in and around this area during the period 1982-2006. The most famous one is that occurred west of Sohag city in 1998 with magnitude 4.5.

- ***Seismic zone (14), Western desert zone***

Many faults in the southern part of the Western Desert almost have the E-W direction. A few regional faults trend N-S and others different faults trending NE and NW are present (Riad and Hassan, 1992). The area characterized by a low level of seismicity where no earthquakes were recorded before 1981 except Gilf El-Kebir earthquake that occurred in southwestern part of Egypt in 1978 with magnitude 5.3.

Maamoun et al. (1980) and Hassib (1990) determined the focal mechanism of that earthquake and concluded a reverse fault with a strike slip component.

Seismicity of the Western Desert is distributed in different directions and can be grouped according to the spatial distribution into the following sub-zones:

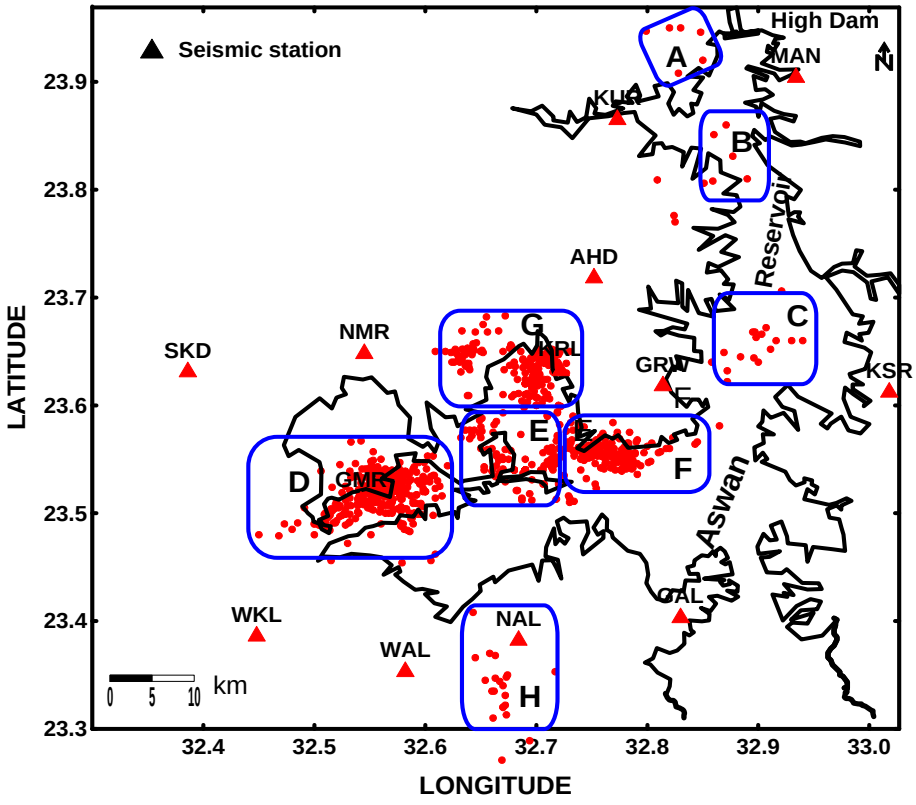

Fig. 5 Seismicity and the seismic zones in Aswan area from 1981 to 2006.

- ***Seismic zone (14 - a)***

This zone lies to the west of Sohag – Assiut zone. It includes the northern activity of the Western Desert around Farafra Oasis. Four earthquakes were recorded in the area during the period 1997-2006 with magnitude ranged from 3.7- 4.6.

- ***Seismic zone (14 – b)***

It includes the seismic activity in the southern part of the Western Desert, where some earthquakes were distributed around Dakhla and Kharga oasises.

SEISMIC ENERGY RELEASED

The energy released by an earthquake is the strain energy accumulated by tectonic stresses. A small part of the energy released by natural or artificial events is converted to elastic energy and transmitted to distant parts of the earth as seismic waves. The famous formula of Gutenberg and Richter (1956) is used to calculate the energy released in the study area:

$$\text{Log } E = 11.8 + 1.5\ M \quad ,$$

where M is the magnitude and E is seismic energy in ergs.

In the present work, the catalogue of the Upper Egypt earthquakes during the period 1982-2006 was analyzed in order to calculate the energy released in the area and to compare its values with the seismicity in the area.

Figure (6) shows an energy contour map of the total seismic energy released in the Upper Egypt during the period from 1982 to 2006. The map reveals the main seismic zones with high-energy released values where the activity is concentrated. Distribution of the released energy shows that the role of the faults in the seismic activity is distinct where most of the activity is concentrated around the main faults especially in Aswan area.

Mohamed (2003) analyzed the catalogue of the local Aswan earthquakes in detail and concluded that a dense concentration of energy is shown at the area, where the faults intersect, particularly at GMR zone where the Kalabsha fault intersects with the N-S faults, this is also clear in figure 6 where a dense concentration of energy contour lines are shown in the area.

FREQUENCY MAGNITUDE RELATION

The frequency of occurrence of earthquakes as a function of magnitude is commonly expressed as:

$$\log N_c = a - b\,M$$

which is a slightly modified form of the Gutenberg –

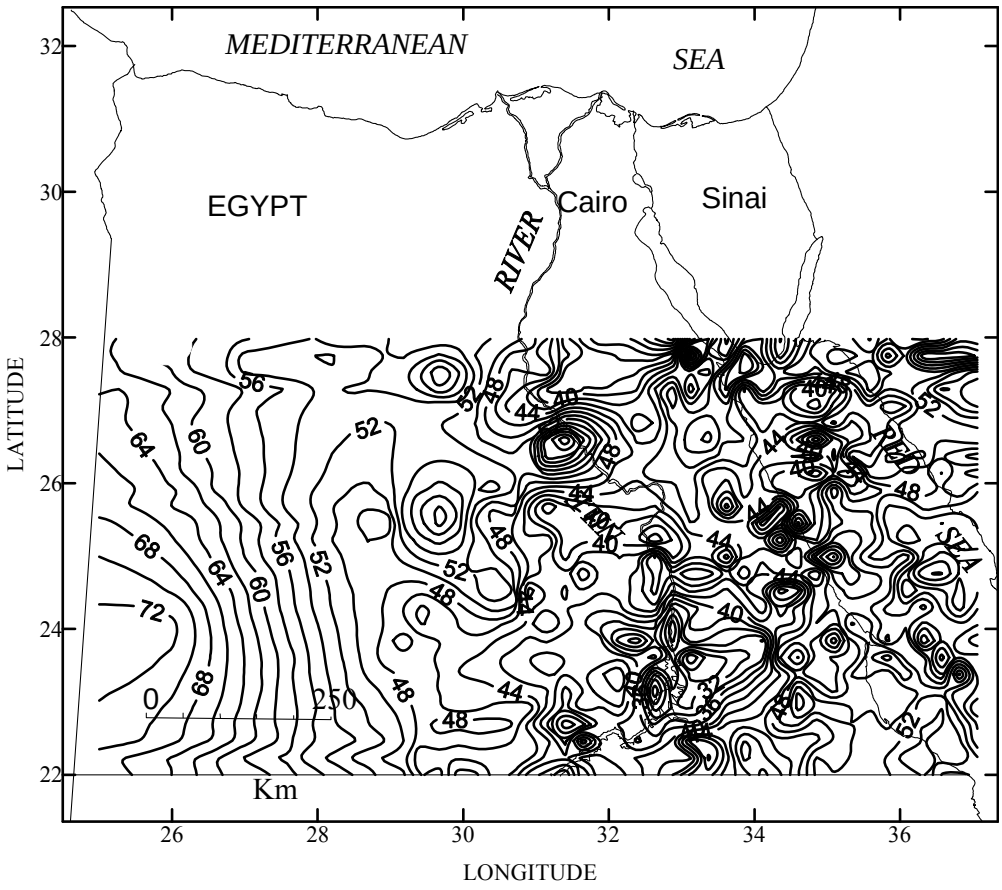

Fig. 6 Energy contour map of the Upper Egypt during the period from 1982- 2006.

Richter relation (Gutenberg and Richter, 1954), where N_c is the cumulative number of earthquakes of magnitude greater than or equal to M and a and b are constants. The constant a depends on the sample size and it is found to vary from region to region (Gupta and Rastogi, 1976) whereas the parameter b, commonly called the b-value, is a measure of the relative number of large and small events in the sample. This relation is considered important criteria for comparing the seismicity of different studied areas.

Mogi (1962b) and Scholz (1968) indicated that a very fundamental physical property of the fracture process would be discovered if the Gutenberg-Richter relation could be explained completely and the physical meaning is understood.

For the proposed seismic zones, a linear regression analysis was carried out to estimate the coefficients of the Gutenberg-Richter relation between the magnitude and their log N_c as shown in Figure 7. In each zone a magnitude range was selected that gives the best fit to a line in the linear frequency magnitude relation (Table 1).

Variation in the values of the b-value for the different zones can be attributed to the differences in number of the used data (available) and the magnitude range.

CONCLUSIONS

The continuous monitoring of the seismic activity through the Aswan telemetered seismic network and the ENSN has given some new insights for a better understanding of the seismicity in the Upper Egypt. The seismic activity in the area is concentrated in different clusters, Construction of a new seismicity map for the Upper Egypt showed 14 active seismic zones, and that the activity is concentrated around the entrance of the Gulf of Suez, on the Red Sea axis, Abu Dabbab and Aswan area with some scattered earthquakes in some other zones. The detailed study of Aswan area showed 8 seismic zones and the activity is concentrated in and around Gable Marawa area.

A seismic energy released map of the Upper Egypt was constructed for the period from 1982 to 2006. From the distribution of the energy released in the Upper Egypt during this period, it is clear that the areas of dense amounts of energy released reveal the areas of high seismicity.

The b-value was calculated for the proposed seismic zones; it is found that the highest value was determined in Abu Dabbab area where it reached about 1.1. High values were also found in Aswan zones. These high values indicate a low apparent

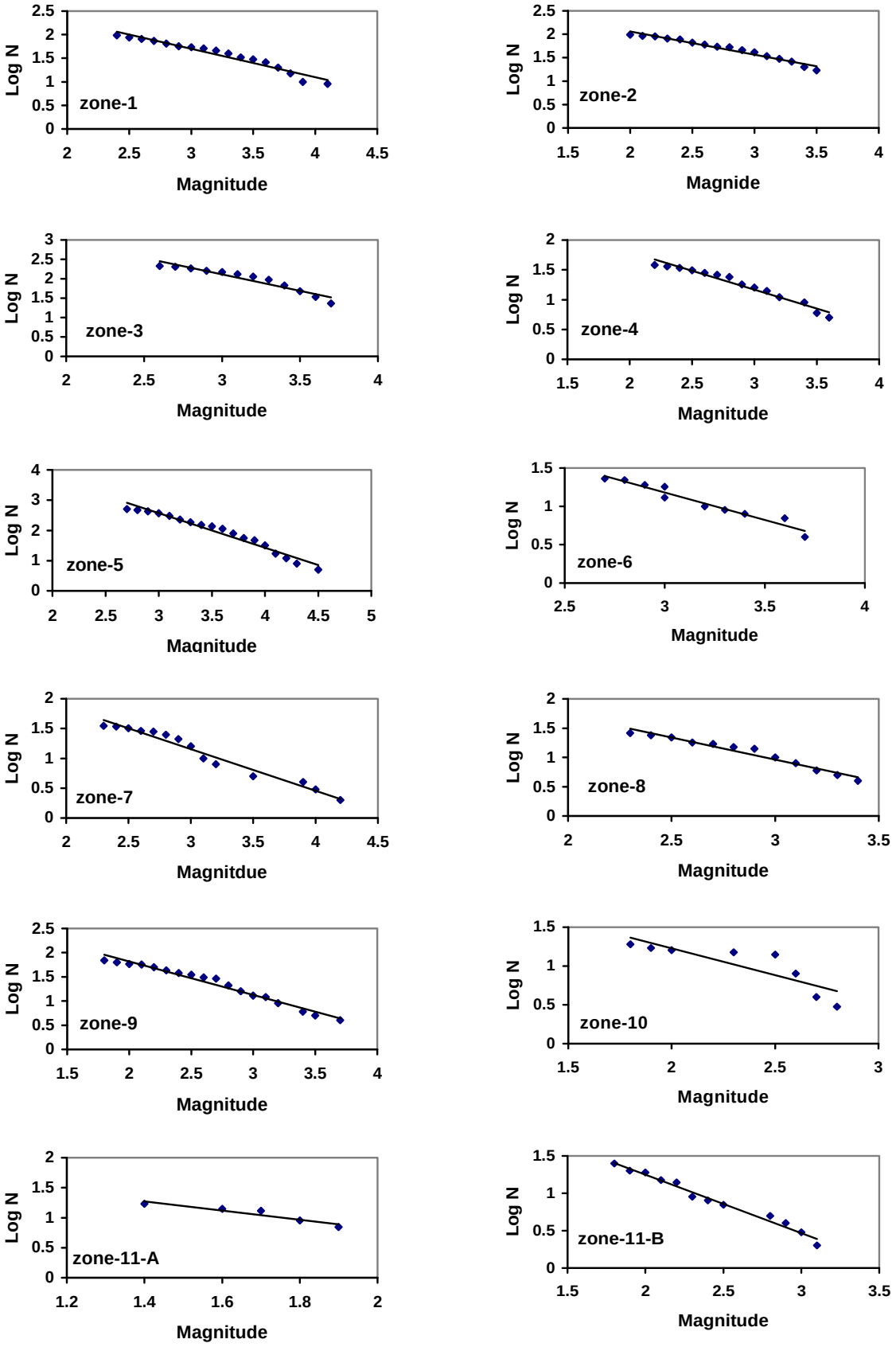

Fig. 7 Cumulative frequency magnitude relation for the seismic zones, 1 to 11B in the Upper Egypt (to be continued).

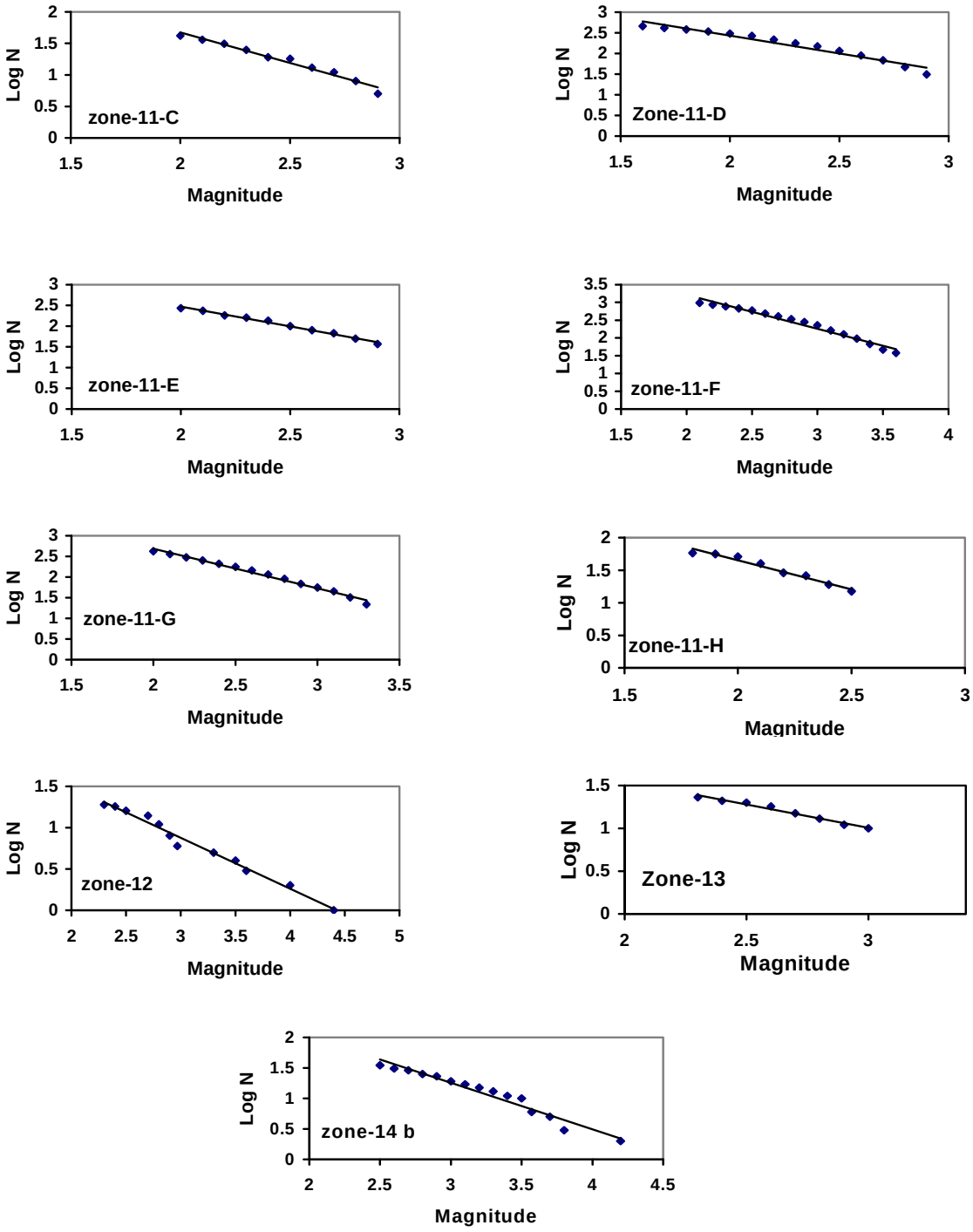

Fig. 7 (Continued) Cumulative frequency magnitude relationship for the seismic zones 11c to 14b in the Upper Egypt.

Table 1 b-values of the identified seismic zones.

Zone Number	Magnitude interval	b-value
1- Shadwan Island zone	2.2 - 4.2	0.596 ± 0.034
2- Central part of the Red Sea zone	2.0 - 3.5	0.490 ± 0.024
3-Souther part of the Red Sea zone	2.6 - 3.7	0.848 ± 0.079
4- Baranes zone	2.2 - 3.6	0.632 ± 0.036
5- Abu Dabbab zone	2.7 - 4.5	1.145 ± 0.054
6- Northern Eastern Desert zone	2.7 - 3.7	0.716 ± 0.059
7- South of Eastern Desert zone	2.3 - 4.2	0.695 ± 0.036
8- Al-Alaqi zone	2.3 - 3.4	0.751 ± 0.047
9- Abu Simble zone	1.8 - 3.7	0.692 ± 0.029
10- Tushka zone	1.8 - 2.8	0.689 ± 0.167
11-Aswan area:-		
A-West High Dam zone	1.4 – 1.9	0.766 ± 0.147
B-Northern old stream channel zone	1.8 – 3.1	0.781 ± 0.034
C-Southern old stream channel zone	2.0 – 2.9	0.970 ± 0.056
D-Gable Marawa zone	2.1 – 3.6	0.950 ± 0.040
E-East Gable Marawa zone	2.0 – 2.9	0.950 ± 0.030
F-East-East Gable Marawa zone	1.6 – 2.9	0.860 ± 0.055
G-Khor El-Ramla zone	2.0 – 3.2	0.920 ± 0.024
H-Abu Dirwa zone	1.8 – 2.5	0.880 ± 0.067
12- Kom Ombo - Idfu zone	2.3 - 4.4	0.610 ± 0.024
13- Sohag zone	2.3 – 3.0	0.55 ± 0.03
14 a- Northern Western Desert zone	Insufficient data	-------
14 b- Southern Western Desert zone	2.5 - 4.2	0.762 ± 0.045

stresses in these areas and that most of the events are located on or near the major faults.

The study gives new insights for a better understanding of the seismic activity in the Upper Egypt through the new seismic zones, and the determined values of the b-value in the Gutenberg-Richter relation helps in the seismic hazard assessment.

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