SEISMICITY AND SEISMOTECTONICS OF IDFU AREA, NORTHERN ASWAN, EGYPT

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Abstract: *Before the occurrence of the November 14, 1981 earthquake (M 5.3), south of Aswan city, the area and its surroundings were known as aseismic areas, occurrence of that event encouraged many seismic studies to be curried out around the northern part of Aswan reservoir. The study area is located about 100 km to the north of Aswan city in the Western Desert (24.7° – 25.3° N and 32° – 33.3° E). On December 13, 2006 an earthquake (M 4.0) occurred in the west of Idfu city, it was felt in the area and its surroundings. Because of the importance of the area for tourism and being a main road to the Red Sea coast, also for the High Dam safety, this study was carried out. The spatial distribution of the located events shows two seismic zones; in the first zone the activity is distributed roughly N-S around the main fault in the Nile which delimits Gulf of Suez–Red Sea fault trend (N35° W) while in the second zone it is distributed approximately parallel to the main trend of Gabal el-Barqa fault in the Western Desert. Focal mechanism solution of the Dec. 13, 2006 earthquake indicates strike slip faulting with normal component, the nodal plane strikes 325° and dips 48° is selected as preferred rupture plane because it agrees with the general trends of the tectonic lines in the area that delimits Gulf of Suez-Red Sea fault trend (N35° W). The frequency magnitude relation of the data gave a fairly good fit to a line with the form: Log N = (1.87 ± 0.085) – (0.43 ± 0.043) M. The seismic activity in the area may be related to the long segments of the Nile Valley as well as to Gabal el-Barqa fault that is one of the Western Desert fault systems. The results of this study may be used for seismic hazard analysis.*

Key words: *Idfu, seismic activity, seismotectonics, b-value and focal mechanism*

Introduction

The study area is located about 100 km to the north of Aswan city in the Western Desert between latitude 24.7° - 25.3° N and longitude 32° - 33.3° E (Fig. 1). Aswan region was known as aseismic before 1981 where no events were reported in the international catalogue (ISC) since its inception in 1920. After the occurrence of the Nov. 14, 1981 Kalabsha earthquake (M 5.3) that occurred about 60 km south of Aswan in the northern part of Aswan reservoir (Kebeasy et al., 1987), a temporary network of MEQ-800 seismographs has been distributed around the northern part of the reservoir from Dec., 1981 to July 1982 by the Egyptian Geological Survey and Mining Authority (EGSMA) to monitor the aftershocks (Toppozada et. al., 1988). That temporary network was replaced by a permanent telemetered seismic network to monitor the activity in the area.

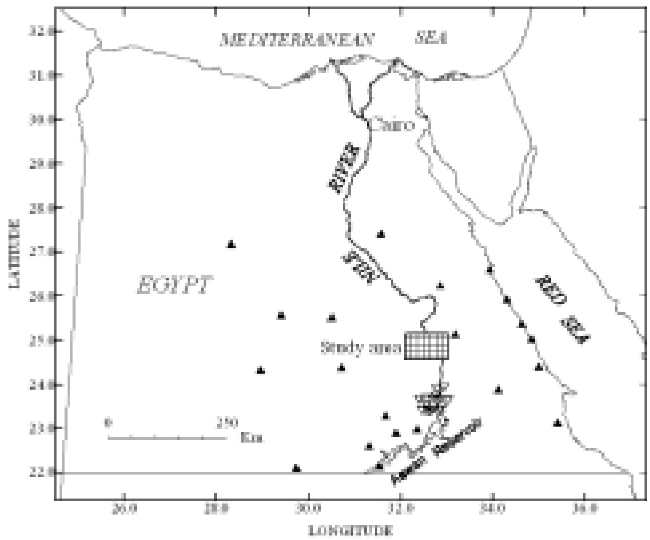

Fig. 1 Location map of the study area, Aswan local seismic network stations (∇) and the Egyptian national seismic network stations (▲).

In addition to the events that recorded around the reservoir area, some events were located to the north of Aswan city, in the study area; these events were recommended to be studied in details and taken into consideration as a seismic source in the future.

On October 12, 1992 an earthquake occurred in Dahshour area, 25 km to the southwest of Cairo with magnitude M 5.8. It was the largest in the recent history. This earthquake was felt from Alexandria to Aswan (Hussein and Farouk, 2000). This shock had a great interest from all the Egyptian authorities, so the Egyptian national seismic network (ENSN) was installed all over Egypt which increased the capability of monitoring and locating the seismic activity.

On December 13, 2006 an earthquake with magnitude M 4.0 occurred to the west of Idfu city, it was felt in and its surrounding areas. The event was recorded by Aswan and the ENSN stations. No previous study was carried out in the area, so the event stimulated this work to be done due to the importance of the area for tourism and developing point of view, also Idfu considers as one of the main roads that joins the costal cities on the Red sea with the Nile River as well as this study can be used in the seismic hazard analysis.

Structural pattern

The main structural elements of Egypt (Fig. 2) can be grouped under some major categories (Youssef, 1968); 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. Parallels 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 Desert 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 this trend.

3 - East-west fault trend: They are not numerous but most of them are major, 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-Aswa- dfu stretch and in the Western Desert parallel with that segment of the Nile.

WWCC, 1985, showed that the nature of the tectonic stress system presently acting on and within the Aswan region is indicated through two lines of evidence; earthquake focal mechanism and the pattern of late Cenozoic faulting. This evidence directly reveals the effect of the stress regime and from the causative stresses or sets of stresses may be inferred. From the structural point of view, faults and joints are the most deformational feature observed at the cliffs bordering the Nile stream (Said, 1962 & 1981). These faults have different directions. The most abundant have the NW-SE and NNW-SSE trends while others (less abundant) have the WNW-ESE, ENE-WSW and NE-SW directions.

In the Eastern Desert, the major fractures and faults observed in the area belonging to two trends; the NE-SW trending fractures and faults which are in the most cases short dissecting lines, and the NE-SE, essentially parallel to the axis of the Red Sea rift, the common occurrence of this set indicate that this area has been under the influence of the tectonic forces leading to the development of the Red Sea.

The Western Desert fault system is relayed to the active plate margin to the east as a secondary fault system. The Western Desert faults that cross the Aswan area are classified into several systems depending on their trends (Fig 3), the most important of these are the east - west system in Kalabash area, that exhibit right slip displacement and the north-south system that exhibit left slip displacement. The east-west faults dominate in the region; they are longer, have had greater degree of activity in the Quaternary, and have larger total displacements than the north - south faults.

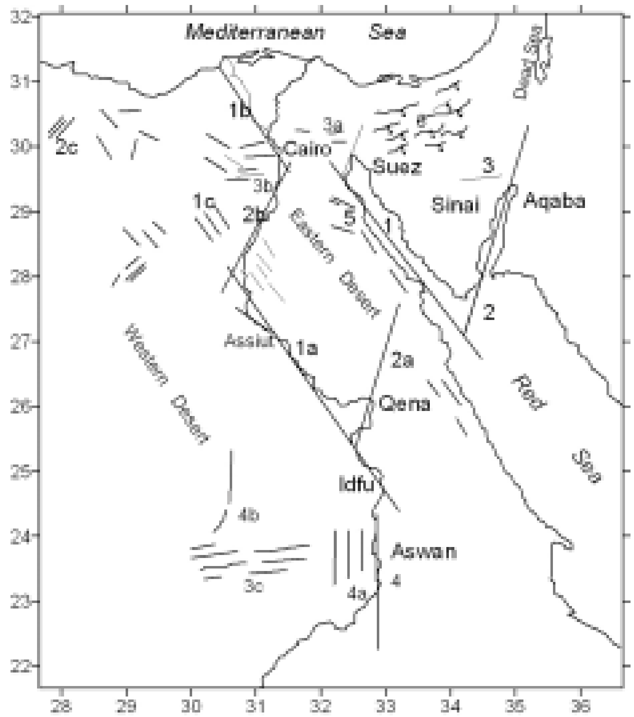

Fig. 2: 1, 1a, 1b, 1c = Gulf of Suze trend (about N35° W); 2, 2a, 2b, 2c = Gulf of Aqaba trend (about N15° E); 3 (Central Sinai fault), 3a, 3b, 3c = east west trend; 4, 4a, 4b = north south trend; 5 = N45° W. (Modified from Youssef, 1968).

a) East – West trending faults: the most important faults of this system are the Kalabsha fault which is identified as the most active fault in the area and it is the source of the 1981 main shock (Kebeasy et al., 1987), and the Seiyal fault;

b) North – South trending faults: These faults run parallel to each other; they are relatively long and well defined. Important faults among of this system are: Khor el-Ramla fault (about 45 km length), Kurkur (50 km length), Gabal el-Barqa (110 km length), Abu Dirwa (15 km length) and Gazelle fault with a total length of 35 km.

Gabal el-Barqa fault is well defined and easily traceable bedrock structure; it is interpreted to have a left slip sense displacement. Different ages of clastic dikes indicate multiple earthquake events in the region. Its degree of activity is estimated to be low (WWCC, 1985). No evidence of surface fault displacement of geologically recent wadi deposits or desert lag deposits was observed. This suggests that there has been no measurable surface faulting along the fault during the past 5000 to 10,000 years.

Seismicity

The area under study was considered aseismic for a long time. After the occurrence of the Nov. 14, 1981 earthquake (M 5.3) that occurred in Kalabsha area (about 60 km to the south of Aswan) in the northern part of Aswan reservoir (Kebeasy at. el., 1987) an immediate temporary network of portable seismic stations was distributed by the EGSMA to monitor the aftershocks. On July 1982, the temporary network was replaced by a telemetered seismic network around the northern part of the reservoir. In 1992, a number of seismic stations were installed in the southern part of Egypt as a part of the ENSN. During the operation of these networks, a few numbers of earthquakes were recorded and located north of Aswan city, in Idfu area (Table 1).

Table 1: Parameters of the used earthquakes in this study:

No.	Date			O.T		Location		M
	y	m	d	h	m	Lat	Long	
1	1982	04	04	08	56	24.76	33.27	3.8
2	1993	02	18	12	12	25.08	33 09	2.9
3	1999	06	22	16	38	25.10	32.99	2.4
4	1999	09	28	03	57	24.92	32.86	2.5
5	1999	09	16	23	21	25.03	32.86	2.3
6	2003	03	22	12	38	24.69	32.45	2.9
7	2004	09	17	03	04	25.11	32.68	1.9
8	2005	02	24	08	46	24.93	32.57	3.3
9	2006	12	13	12	22	25.03	32.72	4.0

Figure three shows the spatial distribution of the located earthquakes from 1982 - 2006. The figure indicates that the activity can be divided into two seismic zones; in the first zone, the activity is distributed roughly N-S around the main fault in the Nile which delimits Gulf of Suez–Red Sea fault trend (N35° W) while in the second zone it is distributed approximately parallel to the main trend of Gabal el-Barqa fault (Fig. 3).

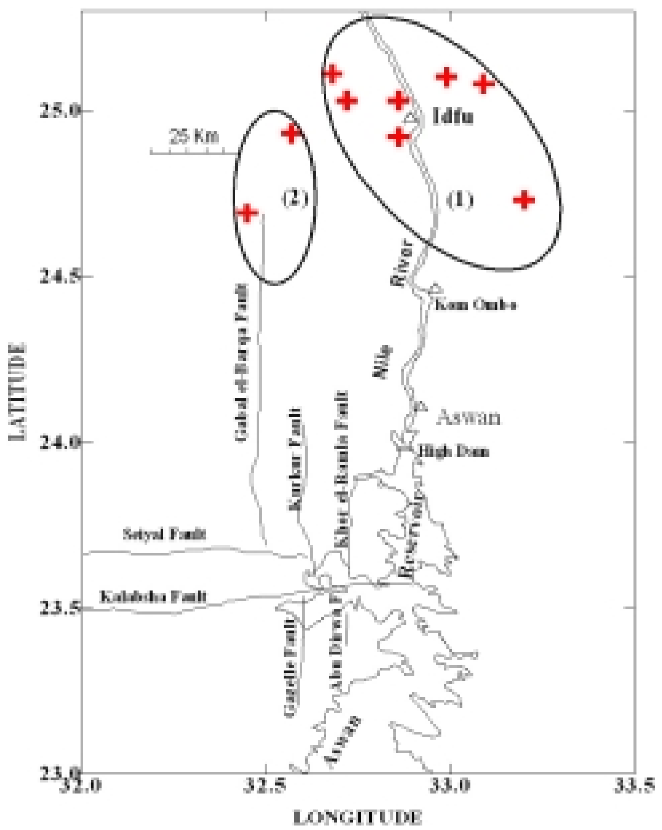

Fig 3 The main significant faults in Aswan region (After WWCC, 1985), and the epicenteral distribution of the seismic activity in the study area during the period 1982 – 2006.

Events recorded after 1982 were located using Rou software program developed by Baumbach, 1990, while the magnitude is calculated using the Aswan formula developed by Fat-Helbary, 1989 as follows: $M = 2.17 \log D - 1.3 + 0.00075\Delta$ Where, D is signal duration and Δ is the epicentral distance.

Focal Mechanism

Focal mechanism solution of the December 13, 2006 earthquake that occurred west of Idfu area and recorded by the Aswan and the ENSN stations is estimated. The fault plain solution shows strike slip faulting with a normal component (Fig. 4). The first nodal plane strikes 325° and dips 48° while for the second plane the strike and the dip are 59° and 88° respectively. The first nodal plane with a left lateral displacement and strikes 325° is selected as preferred rupture plane because it agrees with the general trends of the tectonic lines in the area, where it is parallel to the long segment in the Nile that delimit the Gulf of Suez-Red sea (N35° W) main structural element as well as to the north - south trend of Gabal el-Barqa fault.

Frequency Magnitude Relation

An important criterion for comparing seismicity of different areas is to consider the b-value for the number of earthquakes relation to the magnitude curve. This curve is determined from the equation of Gutenberg and Richter (1958) as follows:

$$\log N = a - bM$$

where, N is the number of earthquakes greater than or equal to magnitude M, while a and b are constants. The parameter a is a measure of the level of seismicity and depends on the period of observation, it is found to vary from region to region (Gupta 1976), whereas, the parameter b describes the relative number of small and large events in a given interval of time.

The Gutenberg and Richter relation can be hold for all magnitude ranges, in all locations and all times (Runddle, 1989). The frequency-magnitude plot for the data located in the study area (Fig. 5) gave a good fit to a line with the form:

$$\log N = (1.87 \pm 0.085) - (0.43 \pm 0.043)\, M$$

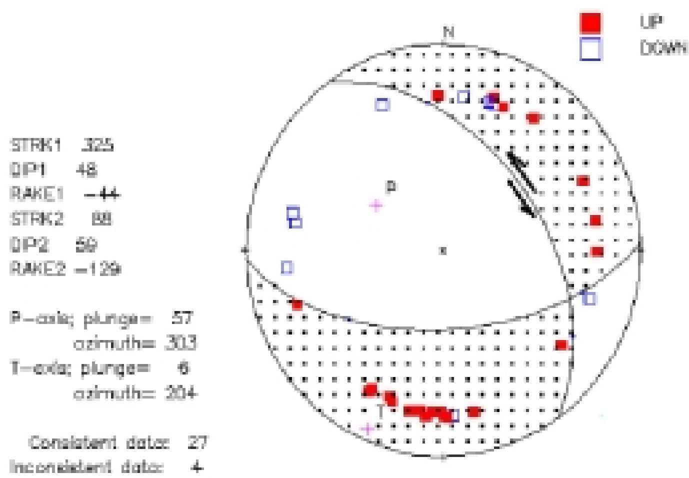

Fig. 4 Focal mechanism solution of the Dec. 13, 2006 earthquake.

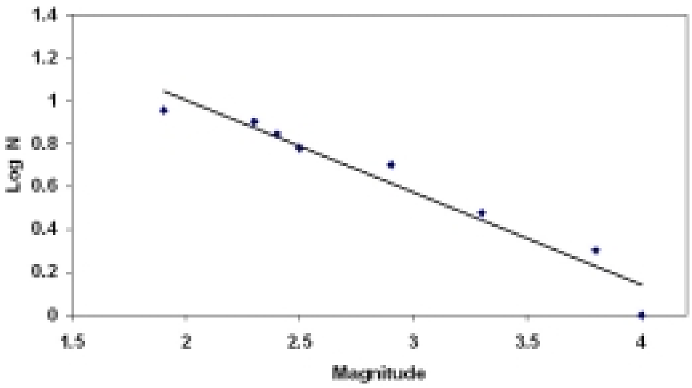

Fig. 5 Magnitude frequency relation for the study area

Summary and Conclusions

For a long time Idfu area, about 100 km to the north of Aswan city, was considered aseismic. After the main shock of 1981, a number of earthquakes were recorded and located in Idfu area during the period from 1982 to 2006.

The spatial distribution of the located events shows two seismic zones; in the first zone the activity is distributed roughly N-S around the long segment in the Nile which delimits Gulf of Suez–Red Sea fault trend (N35° W) while in the second zone it is distributed approximately parallel to the main trend of Gabal el-Barqa fault.

The frequency magnitude plot for the study data gave a fairly good fit to a line with the form: $\text{Log } N = (1.87 \pm 0.085) - (0.43 \pm 0.043)\, M$

Fault plane solution of the Dec. 13, 2006 shows strike slip faulting with normal component. The fault plane strikes 325° and dips 48° is taken as preferred rupture plane because it agrees with the general trends of the tectonic lines in the area, where it is parallel to the long segment in the Nile that delimit the Gulf of Suez-Red sea (N35° W) main structural element as well as the N-S trend of Gabal el-Barqa fault.

So, it can be concluded that the seismic activity in the area can be divided into two seismic zones and it is related to the long segment in the Nile as well as to Gabal el-Barqa fault which is one of the Western Desert fault system. The Western Desert fault system is related to the active plate margin to the east; therefore, the activity in the area may be related to the active plate margin in the east.

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