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REGIONAL DISTRIBUTION OF RELEASED EARTHQUAKE ENERGY IN NORTHERN EGYPT ALONG WITH INSHASS AREA

by

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ABSTRACT

A review of the seismicity and seismic history of Egypt indicates some areas of high activity concentrated along Oligocene-Miocene faults. These areas support the idea of recent activation of the Oligocene-Miocene stress cycle. There are similarities in the special distribution of recent and historical epicenters. From the tectonic map of Egypt, distribution of Intensity and magnitude show strong activity along Nile Delta. This due to the presence of a thick layers of recent alluvial sediments. The released energy of the earthquakes are effective on the structures. The present study deals with the computed released energies of the reported earthquakes in Egypt and around Inshass area. Its effect on the urban and nuclear facilities inside Inshass site is considered. Special consideration will be given to old and new waste repository sites. The application of the determined released energy reveals that Inshass site is affected by seismic activity from five seismo-tectonic source zones, namely the Red Sea, Nile Delta, El-Faiyum, the Mediterranean Sea and the Gulf of Aqaba seismo-tectonic zones. El-Faiyum seismo-tectonic source zone has the maximum effect on the site and gave a high released energy reaching to 5.4E+21 erg.

Key words: Inshass, Earthquakes distribution, Seismic energy.

INTRODUCTION

Egypt is situated in the north-eastern corner of the African plate, interacting with the Arabian and Eurasian plates through divergent and convergent plate boundaries, respectively (Sofratom, 1984 and Ben-Avraham, et al. 1987). Low and intermediate level nuclear wastes have been treated, packaged and stored temporary insitu until final desposal. A design of shallow ground desposal is under investigation. Site selection is one of the important aspects which taken into consideration for the final decision. One of the important factors is the evaluation of the regional and local seismological sitting. Inshass area is a part of the Eastern Nile Delta. It is featureless plain bounded by Damietta branch to the west and to the north by El-Ismailia Canal. It is located between latitudes 30° 10′ N and 30 ° 25′ N and between longitudes 31 ° 20′ E and 31o 40′ E. The main target of the present study is reviewing the seismicity of Egypt, and determination of the released seismic energy emancipated from the reported earthquakes affecting the investigated area.

In order to achieve this target, the seismicity of Egypt should be reviewed. A released energy map for the studied area should be also constructed. The seismic energies emanated from the faults related to Inshass as a part of Nile Delta included in the present investigations.

According to the regulations of International Atomic Energy Agency (IAEA), specific geologic conditins as structure, stratigraphy, tectonics and seismic activities have to be studied in the considered area. Therefore, carrying out site evaluation for constructing the second nuclear reactor and repository for low and intermediate levels of radioactive wastes at Inshass area is important objective.

HISTORICAL SEISMICITY

A search in some of the recently published compilations of historical earthquakes of the Middle East was made to colect the desired events in and around the studied area, with special interest in many works (Maamoun and Ibrahim, 1978; Ambraseys, 1978 and 1980; and Porier and Taher, 1980) . It was found that, for Egypt, a total of 60 earthquakes were felt, with intensities of V-IX, during the period from 2200BC to 1900. Some of these earthquakes are reported with poor information regarding their epicenters, while some have locations outside the Egyptian border (Alam et al, 1979). Altogether, 22 of the earthquakes have reliable information concerning the location. Eleven of these caused destruction (Table 1). The assigned intensities, based on the historically reported damage, may not be homogeneous, neither in time nor in space. Therefore, only general conclusions can be made regarding the characteristics of the historical seismicity as follows: .

- Destructive earthquakes that have occurred in Egypt which report major and regional destruction are available.

- A general concentration of the historical activity is quite clear around the Nile Valley and Nile Delta. These areas are densely inhabited, but the presence of thick sediments is likely to be the main cause of high intensities.

- The historical and recent epicenters are distributed in similar ways, indicating the same areas have been active for many centuries.

- There are similarities in the intensity distribution of some historical earthquakes and recent earthquakes in the respective areas. As an example, the events in 1210 BC, which was located close to the event of 14 November 1981 near Abu-Simbel, as well as the events in 600 BC, of 12 November 1955 and Of 31 March 1969 near luxor. These similarities give some help in the argument about the location of the historical epicenters. The event in 1303 was placed south of Cairo near El-Faiyum. Maamoun et al (1984) considered the location erroneous and placed it near Crete. The event of 12 October 1992 near Cairo is similar to the 1303 events according to the distribution of reported damage and intensities, which yields strong support for the location of the 1303 earthquake.

- The events in 1210 BC and 1854 are close to Aswan as well as tectonic studies concluded. Water and sediment loads could have been triggering factors. The recent microseismicity is likely, to a large extent, induced by the water reservoir.

- The epicenters of historical earthquakes seem to correlate well with general tectonics of the region. The 600 BC and 1778 events have epicenters close of the Red Sea. The rest of the earthquakes are located in other three major tectonic zones .

Table (1) :Destructive earthquakes in Egypt [modified after Alam et al, 1979]

Date Y	Date M	Date D	Latitude in Degrees (North)	Longitude In Degrees (East)	I	m_b	Remarks
2300BC			30.5	31.7	VII	5.4	I=VII (Lower Egypt)
1210BC			23.6	32.6	VII	5.4	I=V (Abu Simbel)
600 BC			27.6	33.9	VIII	6.1	I=V (Thebes)
28 BC			27.6	33.9	VIII	6.1	I=VI (Thebes)
320 AD			32.0	30.3	VII	6.0	I=VI (Alexandria)
956	01	01	32.0	30.0	VII	6.0	I=VI (Alexandria) I=VI (Cairo)
976			25.5	64.5	VII	5.4	I=VI (Luxor) I=V (Aswan)
1111	05	26	30.0	32.0	VII	5.4	I=V (Cairo)
1303	08	08	29.9	31.0	VIII	5.4	I=VII(Alex. & El-Fayium)
1754	09	10	30.0	32.0	VII	5.4	2/3 of Cairo destroyed
1847	08	07	29.5	30.5	VII	5.4	I=VI-VII (Cairo)
1955	09	12	32.2	29.6	VII	6.0	I=VII-VIII (Alexandria)
1969	03	31	27.6	32.9	IX	6.1	I=VI (Nile Valley and Nile Delta)
1981	11	14	23.6	32.6	VII	5.6	I=VII (Aswan)
1992	10	12	29.9	31.0	VIII	5.4	I=VII (Cairo) ; strongly felt in large parts of Egypt.

Note: **Y** *means Year.* **M** *means Month.* **D** *means Day.* **I** *means Intensity.* m_b *means body wave magnitude.* **BC** *means Before Christ.* **AC** *means After Christ.*

INSTRUMENTAL SEISMICITY

Data related to earthquakes which occurred around Egypt in period 1900-1997, have been collected and evaluated. Epicenter distribution pattern suggests four seismic active trends, mostly in good agreement with the distribution of major tectonic features.

Recent activities of earthquake recording in Egypt started since 1899 with Helwan station. Its instruments have been upgraded several times. Late 1975 three other stations were added at Aswan , Abu-simbel and Mersa Matrouh. As from July 1982 a radio-telemetry network of thirteen vertical short period stations was operated for monitoring microearthquake activity around the northern part of Lake Nasser.

Collected seismic data (Ismail, 1978) showed that a number of microearthquakes were located around Cairo in the period from 1903 to 1950. Moreover, Gergawi and El-Khashab, 1968) have located a large number of microearthquakes around Cairo, the Gulf of Suez and the Nile Delta region, and defined an active trend that runs along the Gulf of Suez and passes through the Nile delta to the Mediterranean Sea. Kebeasy et al 1994 using Helwan observations found a microearthquakes active trend that starts from Cairo and runs to the north along the west side of the Nile Delta. They attribute this activity to a probably active fault along this trend as shown in Fig (1).

SEIASMIC ENERGY DETERMINATION

The total energy released from an earthquake is the best physical parameter characterizing the size of the earthquakes. The total energy (E_T) can be estimated in the following way (Kasahara, 1981) :

$$\begin{aligned} E_t &\cong A * \Delta\sigma * \mu \\ &= u^2 A \ \mu / H \\ &= u^2 L \ \mu \end{aligned} \qquad (1)$$

where:

$\Delta\sigma$ is stress drop, i.e., the difference between the stress immediately before and after the occurrence of an earthquake, $\Delta\sigma$ for shallow earthquakes ranges usually between 0.1 and 100 bars and does not depend on the M_S>6. M_S is the surface wave magnitude,
μ is the average shear strength of the faulted rock over the fault plane surface,
H is the depth of the fault,
L is the length of the fault,
u is displacement.

The total energy could be divided into mechanical energy spent to cruch rocks by the fault which dissipated due to friction, and into seismic energy (E_s) associated with the seismic wave propagation according to the following relation (King and Knopoff, 1958):

$$E_s = E_e \qquad (2)$$

where E_s is the seismic energy and E_e is the elastic energy. The released elastic energy is calculated applying the next relation (Bath, 1956 and Bath, 1982):

$$\text{Log } E_s = 4.78 + 2.57 \, m_b \qquad (3)$$

Where

E_s is the released energy from a single earthquake,
m_b is the corresponding body wave magnitude.

The moving block unit in the present study has a size of 1° latitude times 1° longitude and is shifted by steps of 0.5° in both latitude and longitude. These values are chosen to get reasonable smoothing.

The released energy was calculated for earthquakes of $m_b \geq 3$ in the period 1900 -1997. The indicated data completed for that events of these magnitudes. It should be noted that the threshold magnitude varies for different areas. The resulting pattern of released energy, as shown in Fig. (2) describes the following:

1. Agreement with the distribution of earthquake epicenters. However, the released energy map is more easy to interpret in terms of tectonics (Compare Fig. (2) with the map of the tectonics as displayed in Fig. (1) after Kebeasy, 1990).

2. High energy released in northern Red Sea is possibly caused due to tectonic activity connected with northern Egypt.

3. Contour lines running NNE-SSW as shown in Fig. (2) are well agreeing with the Gulf of Aqaba-Levant and northern Red Sea and Suez-Cairo-Alexandria fault systems, respectively. These contour lines matched with boundaries of the Sinai Peninsula plate

4. High anomalies of the released energy agree properly with major fault in the area. As shown in Fig. (2). These anomalies extend from Egypt NNE to Turkey and NW to Crete.

5. A single large earthquake in southwestern Egypt (24^{O}N, 26.5^{O} E) gives high released energy anomaly and suggests a possible continuation of the Eastern Mediterranean -Cairo – El-Fayium zone to the southwest.

Another way to determine seismic energies could be applied using the relationship between the earthquake magnitude and common logarithm of the released energy in the form of seismic waves. This relationship is represented by an empirical linear equation determined by treating 10 earthquakes in California and Nevada by the method of least squares, which is given by Bath (1979), as follows:

$$\text{Log } E_s = 12.24 + 1.44 \text{ M} \qquad (4)$$

where:

E_s is the energy in ergs, and
M is the calculated magnitude of earthquake.

Applying this technique, the seismic released energies through the implied system of faulting around Inshass during the successive phases of tectonic activities can be defined utilizing the computed earthquake magnitudes. By studying the fault parameters, the fault downthrow was selected to compute, the comparable earthquake magnitudes. The relation between the magnitudes and the fault downthrow was used. The applied relationship (Moustafa, 1995) is :

$$M_l = 3.71 + 0.8 \log D \qquad \text{for } 3.6 \leq M_L \leq 5.3 \qquad (5)$$

Where:

M_l is the local magnitude,
D is the displacement (fault downthrow) in cm.

RELEASED SEISMIC ENERGIES DISTRIBUTION

Subsurface structural features of the studied area, in terms of fault elements, have delineated on the basis of seismic, gravity and well depth data, which carried out by El-Hemamy (1994) as shown in Fig. (3 a,b,c,d). The determined released energies of a certain rock unit represent the total sum of energies emanated through the considered fault during the growth of its throw by the increment increased during the deposition of the total thickness of the considered rock unit. Accordingly, the seismic energies of the various rock units at Inshass and its surrounding area were calculated at different depths (0.5 km, 1.0 km, 1.5 km, and 2 km). After El-Hemamy, (1994), these depths represent the Miocene and Pleistonce-Recent Epochs, Oligocene, Eocene, Upper Cretaceous, respectively. Every type of these rocks will be discussed in terms of energy maps.

MIOCENE AND PLEISTOCENE - RECENT ROCKS:

It exhibits high released energies in the west southern part in the map. The energies decrease in the NE direction. Seismic released energies ranged from 2.5E+20 ergs in the north east part of the map to 9.5E+20 ergs in the south west part in the area, as displayed in Fig.(4). More or less the energies reflect the fualt positions as shown in Fig. (3a).

OLIGOCENE ROCKS:

At the surface of Oligocene rocks as displayed in Fig. (5), all the released seismic energies associated with the definite number of faults are moderate as compared by the underlying rock units. The maximum value of the released energy is 8.5E+20 ergs. The minimum value if the seismic released energy is 5.2E+20 ergs.

EOCENE ROCKS:

The constructed seismic released energy map on the top of Eocene rocks reveals four high energy anomalies in the area as shown in Fig. (6). All the energy values released through the initation of these faults as shown in Fig. (3c) are very low. The released energies ranged between 1.0E+19 and 6.1E+20 ergs.

TOP UPPER CRETACEOUS ROCKS:

The energy map on the Upper Cretaceous rocks (Fig.7) reveals only one very high released energy anomaly located to the southwest of the Fig.(7). The maximum determined released energy value for this anomaly reaches 5.4E+21ergs. In general, this map reflects that, the intensive tectonic activity during the formation of Upper Cretaceous rocks are restricted to the major longitudinal faults of Egypt. As displayed in Fig. (3d), the most effective faults located in El-Faiyum area.

DISCUSSION OF RESULTS

The tectonic setting of Egypt is complex. According to the authors (El-Gamili, 1982; and Bayoumi, 1983), four different stress cycle have played a big role in the geological history. The most important stress cycle is that of the Oligocene -Miocene period. The Nile Rift Valley and many other main structures in Egypt were developed during this cycle (Said, 1981).

El-Gamili (1982) and El-Hemamy (1994) studied the gravity anomalies around the Nile Delta and concluded that the Nile area is a major graben (ranged from 2 km to 20 km in depth) filled by loose alluvial and river sediments. They also concluded that the tectonic movements all around the block of the Nile Delta gave this region some tectonic independence.

The presence of loose sediments in a narrow band (Nile graben) in the hard rock could act as a good conductor and amplifier of the seismic waves. The distribution of the intensities for the earthquake of 12 October 1992 shows a clear NNW-SSE extended pattern (Ibrahim, 1994).

The empirical relationships between the fault parameters and earthquake energies emanated from these faults of the consecutive time intervals of the accompanying lithostratigraphic units represented a new constructed released energy map for the four rock stratigraphic units.

There is a good agreement between the distribution of the released energy and seismotectonic provinces given by Kebeasy (1990). The high released energy observed at the entrance of the Gulf of Suez from the Red Sea , is considered as the most active zone in Egypt. There is further a good agreement with the NNE-SSW oriented Gulf of Aqaba transverse fault. In general, the released energies are in spatial compatibility with fault systems.

High anomalies of the released energy are associated with the suggests a possible continuation of the eastern Mediterranean Cairo- El-Faiyum zone to the southwest.

Finally, it could be concluded that, the application of determined released energy reveals that the concerned Inshass site is affected by seismic activity from five seismo- tectonic source zone, namely the Red sea, Nile Delta, El-Faiyum, the Mediterranean sea and the Gulf of Aqaba seismo-tectonic source zones. The present investigations showed that, El-Faiyum seismotectonic source zone has the maximum effect on the Inshass site and give high released seismic energy anomalies reaching 5.4E+21 ergs.

El-Fayium seismo- tectonic source zone acts as an efficient fault, added to the scarcity of seismological data, especially the microearthquakes. Anyhow, the repository system should be erected taking into account to that it must resist damage affect of an earthquake generated with high energy at the site.

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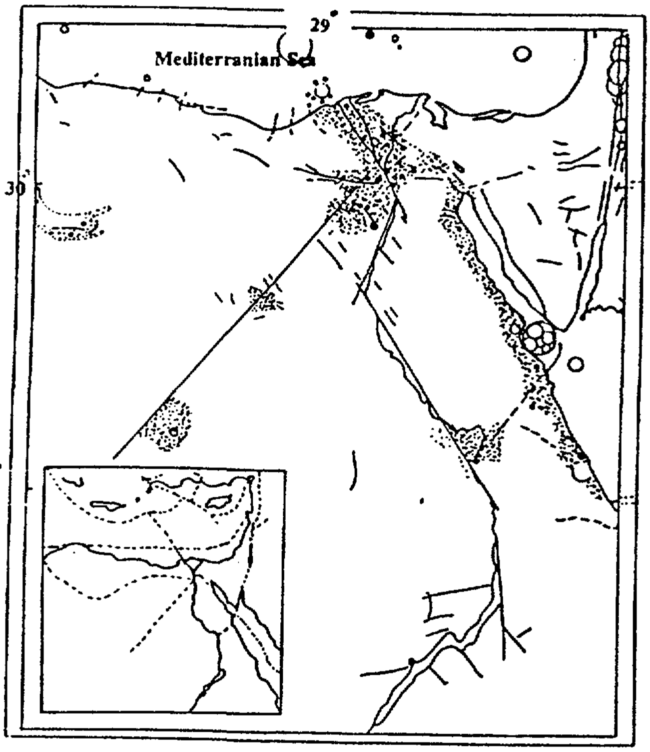

Fig (1) Epicentral distribution of all earthquakes, focal Mechanism of princible earthquakes and active seismic trends.

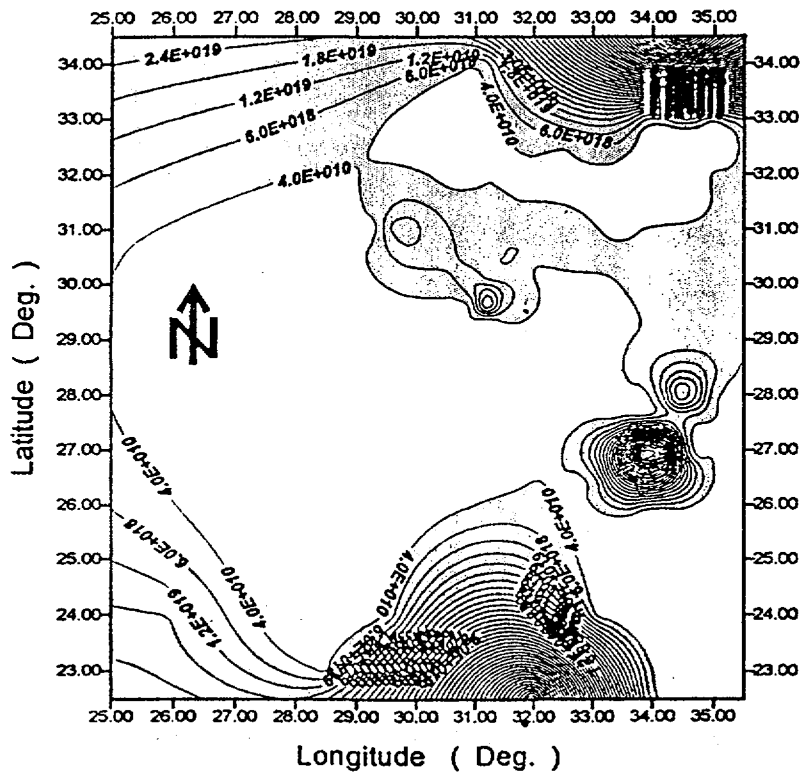

Fig (2): Distribution of released seismic energy in Egypt.

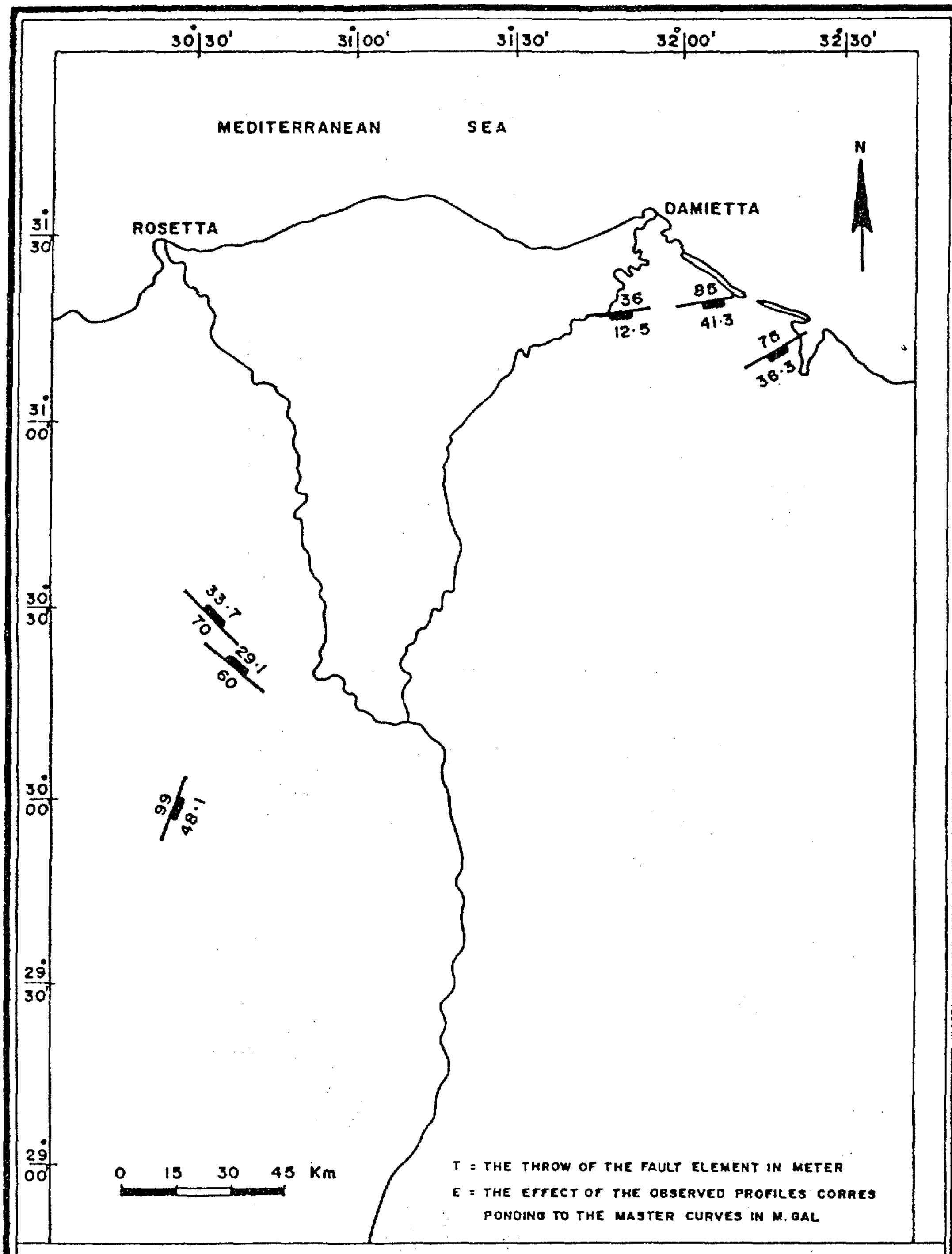

Fig (3a) A map showing the fault elements dissecting the depth range of 0.5 km (after El-Hemamy)

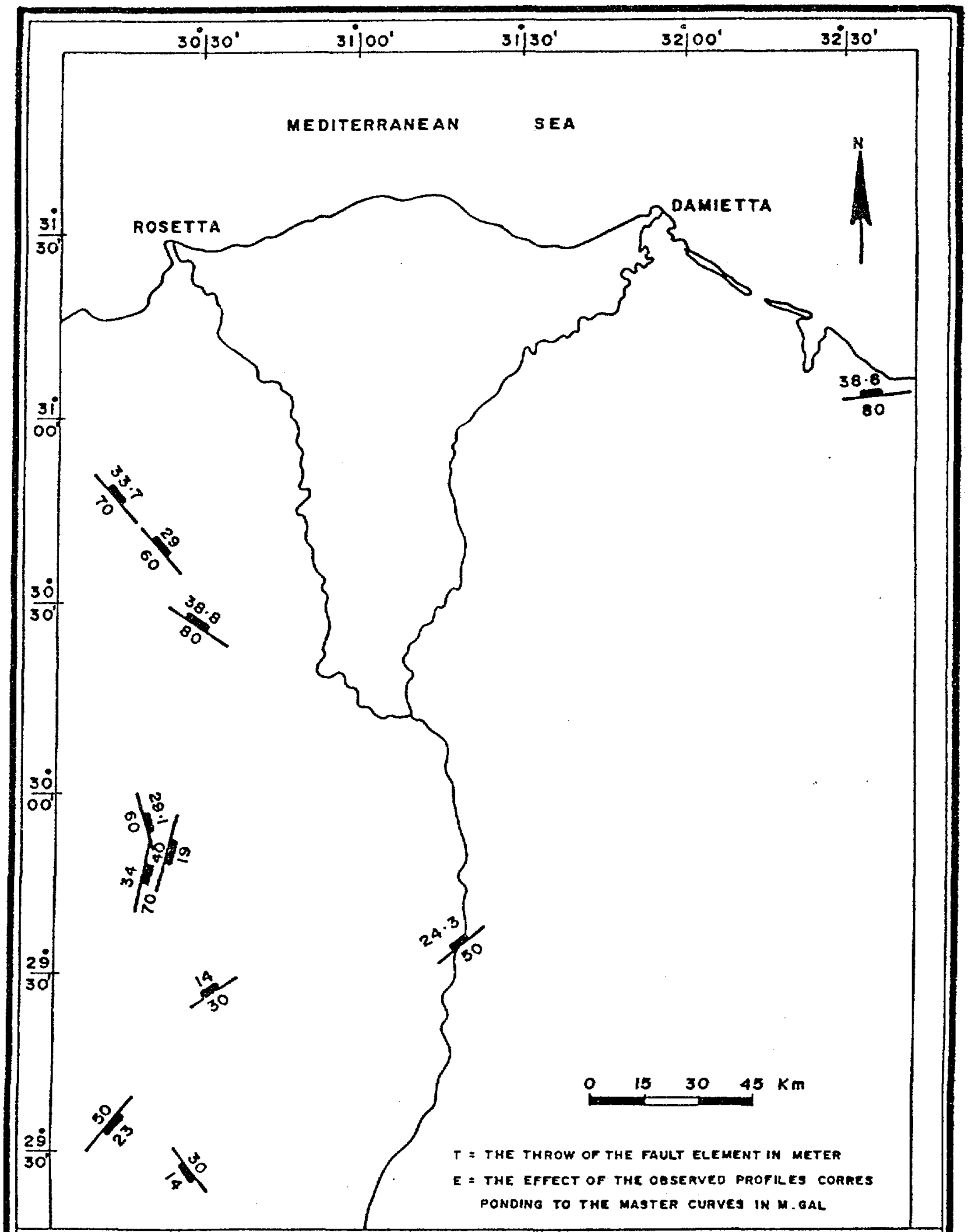

Fig (3b) A map showing the fault elements dissecting the depth range of 1.0 km (after El-Hemamy)

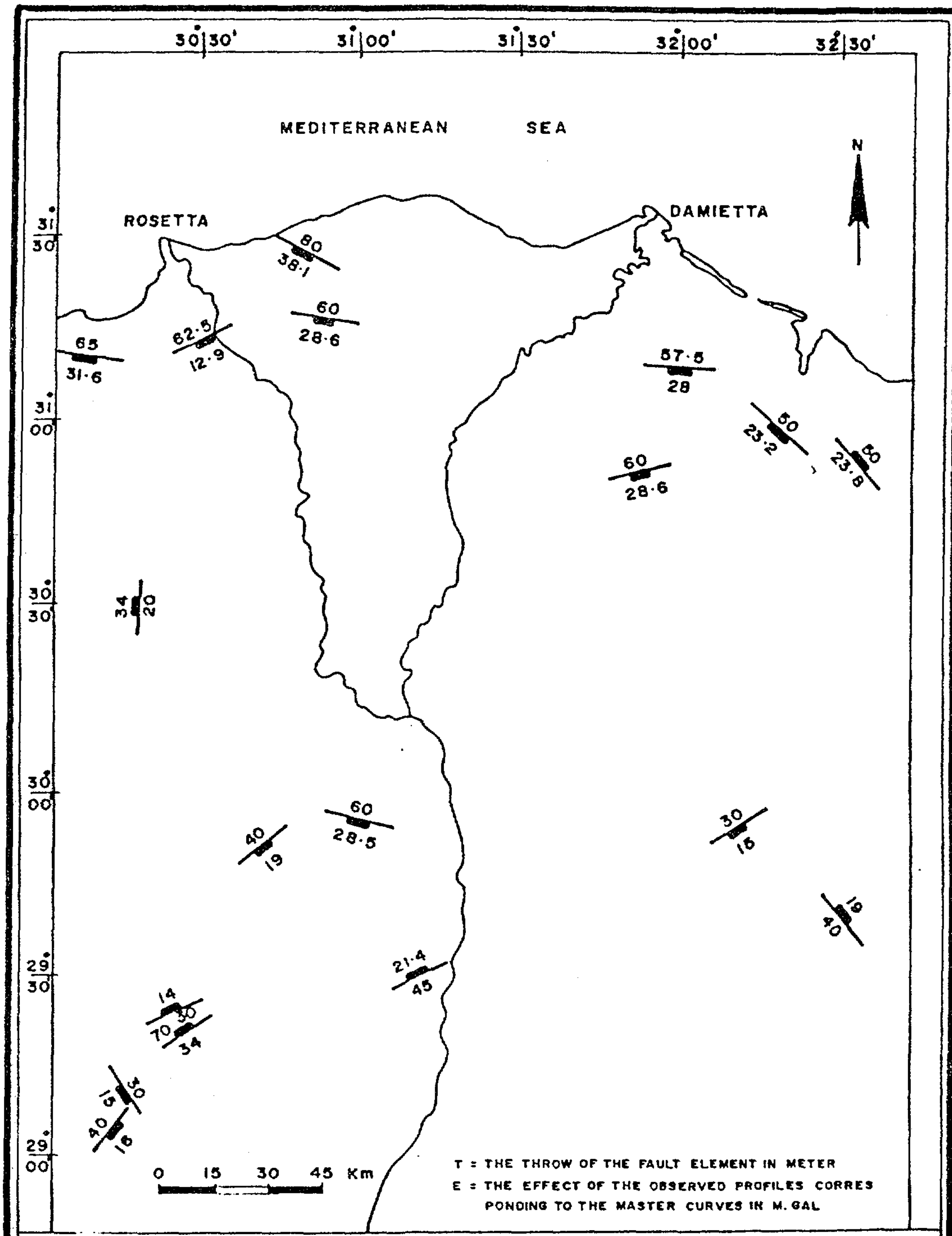

Fig (3c) A map showing the fault elements dissecting the depth range of 1.5 km (after El-Hemamy)

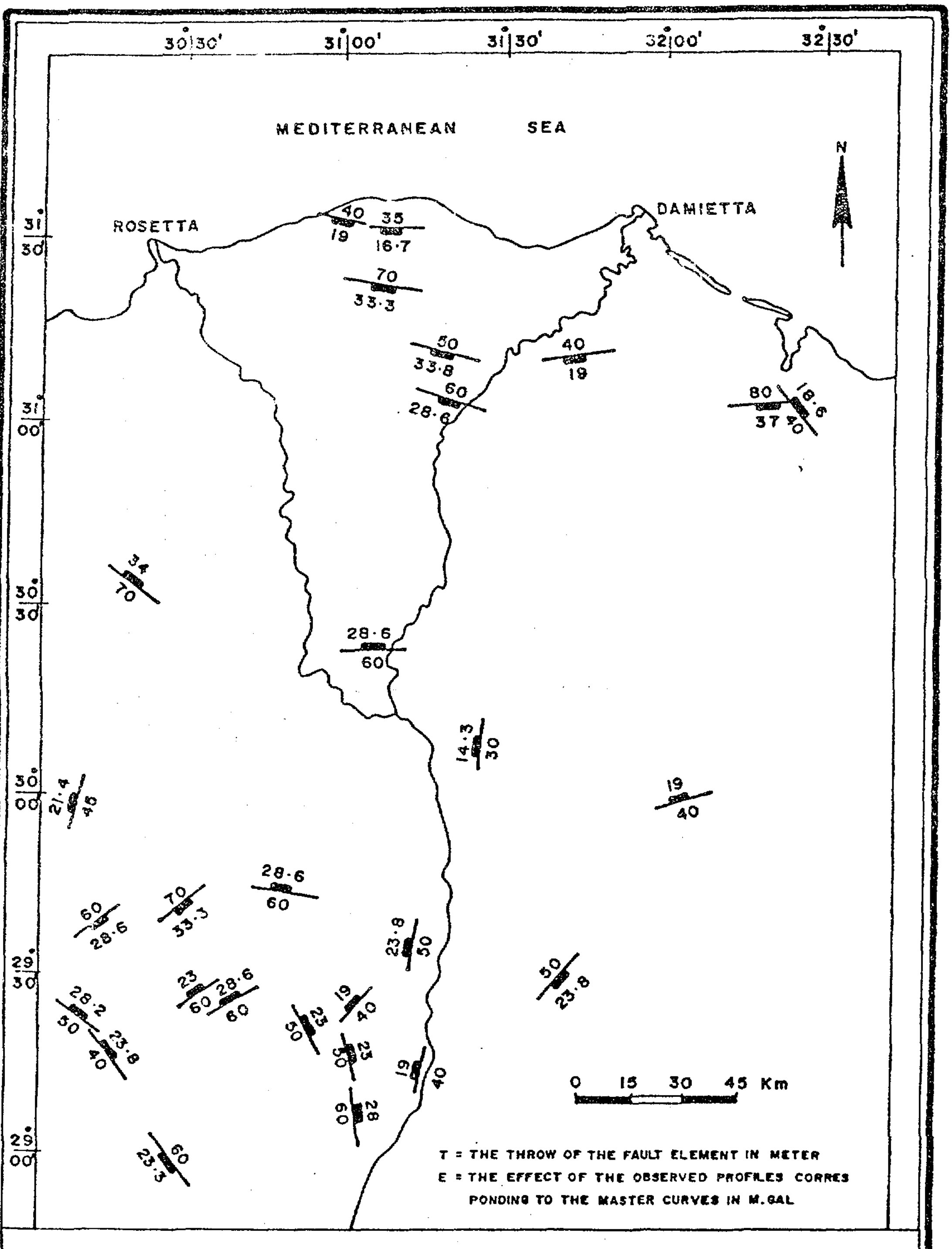

Fig (3d) A map showing the fault elements dissecting the depth range of 2.0 km (after El-Hemamy)

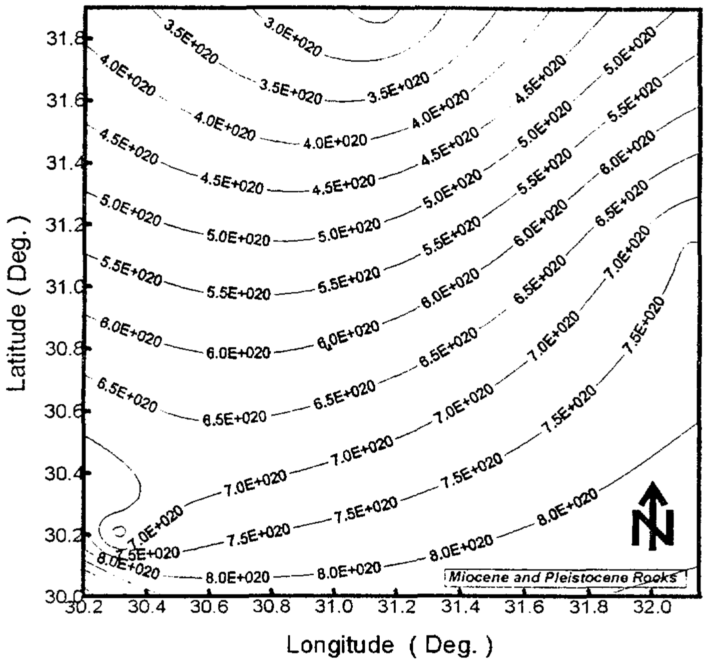

Fig. (4): Seismic released energy map due to Miocene and Pleistocene - Recent rocks.

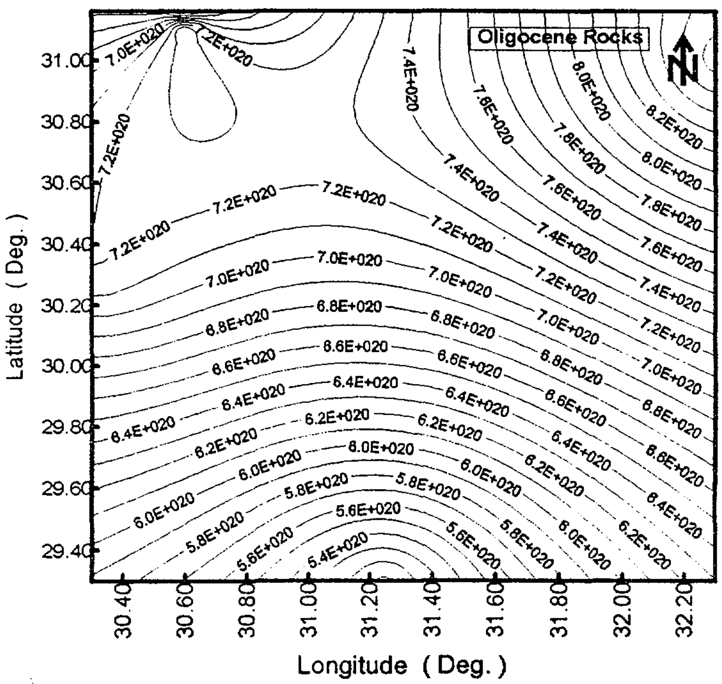

Fig. (5): Released seismic energy map due to Oliogocene rocks.

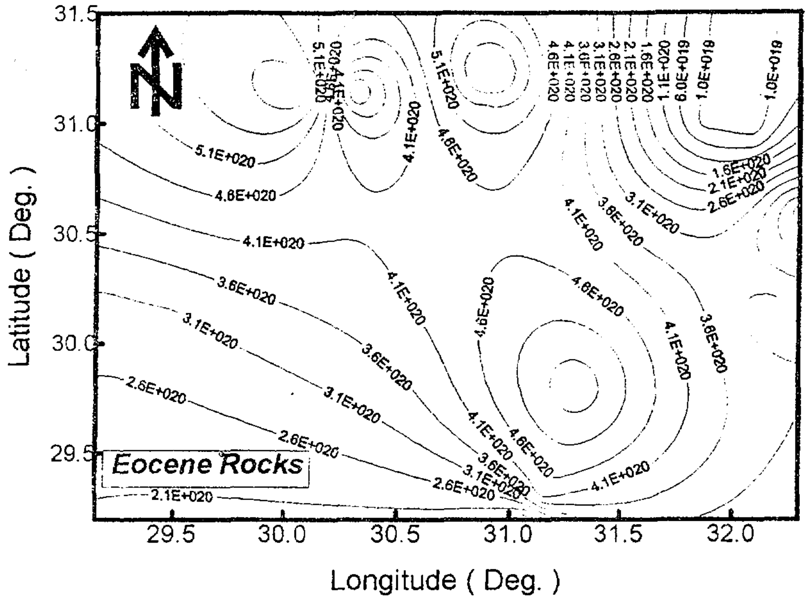

Fig. (6): Released seismic energy map due to Eocene rocks.

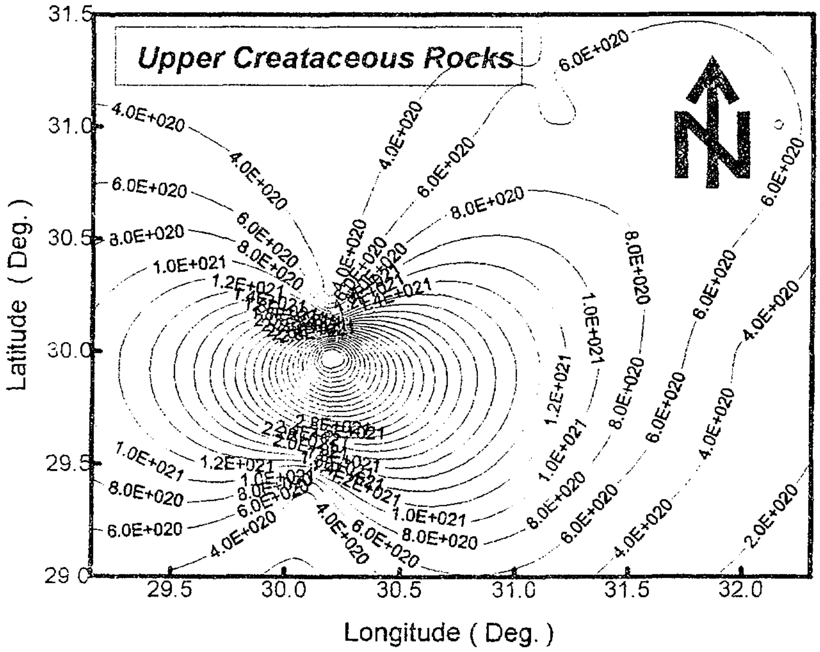

Fig. (7): Released seismic energy map due to Upper Cretaceous rocks.

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