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DECONTAMINATION OF THE SEISMICITY CATALOGUE OF IDFU, EGYPT USING DISCRIMINATION CRITERIA

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عملية تنقيح سجل الزلازل بمنطقة ادفو (مصر) استنادا على معايير التمييز

الخلاصة: تعتبر منطقة إدفو التي تقع في الجزء الجنوبى من مصر الوسطى منطقة نشاط لمجموعة من الظواهر الاهتزازية، كما يتضح من الأحداث التي سجلت من قبل الشبكة القومية للزلازل . وتبين أن المحاجر التى تعمل بالقرب من إدفو قد سببت إفساد الكتالوج المحلي لزلازل الشبكة القومية والتي بدورها تؤدي إلى نتائج خاطئة في الدراسات الزلزالية وتفسير خاطئ لمصادر النشاط الزلزالي للمنطقة. إزالة هذا الإفساد أمر ضروري من أجل تحديد حقيقية النشاط الزلزالي للمنطقة . يهدف هذا البحث إلى التمييز بين الزلازل الطبيعية وتفجيرات المحاجر لمنطقة إدفو باستخدام عدة طرق و أساليب نوعية وكمية. وقد جرى تطبيق تقنيات التمييز, مثل التعقيد والنسبة الطيفية, لفصل الزلازل و انفجارات المحاجر. وأظهرت نتيجة الدراسة ان الكتالوج المحلى للشبكة القومية للزلازل قد أفسد بنسبة ٩٠ % بانفجارات المحاجر (والتى تعتبر من المصادر الإصطناعية) و ١٠ % فقط هى المصادر الطبيعية من الزلازل فى الكتالوج. كما وجد أن قيمة التعقيد للزلازل في منطقة إدفو أعلى منها فى تفجيرات المحاجر، بينما النسبة الطيفية للزلازل أقل من التفجيرات.

ABSTRACT: *Idfu region which is located in the central part of Egypt is considered as a cluster area of seismic events as demonstrated from the events recorded by the Egyptian National Seismic Network (ENSN). It is found that the quarries operating near Idfu contaminate the recorded seismograms. Those in turn, cause a local catalogue contamination that leads to false results in seismic studies and misinterpretation for activity of seismic sources. Decontamination is necessary in order to determine the real seismicity of the region and thus seismic hazard assessment studies.*

Discrimination techniques such as complexity and spectral ratio were applied to separate earthquakes from quarry blasts. About 380 events were recorded and compiled within the ENSN bulletin as micro-earthquakes occurred in Idfu region through the time period from 2001 to 2015. Available 100 waveform data were tested using complexity and spectral ratio to distinguish natural events from the artificial ones.

As a result of this study, 90 % of the examined seismic events were found to be quarry blasts (artificial sources) and only 10 % were earthquakes (natural sources). It is also found that the complexity of earthquakes of the horizontal component at Idfu station is higher than blasts, while the spectral ratio of earthquakes is lower than blasts.

1. INTRODUCTION

Working on seismicity of central part of Egypt, cluster of events (Fig. 1) were found in recent years near Idfu region that was considered as a non-active area in the past. The seismic activity shown in ENSN local catalogue at the northern part of Idfu was about 60 kilometers width between latitudes 25°N and 25.5°N and longitudes 33°E and 33.3°E. A recent mining quarry established in the study area causes a number of quarry blasts frequent. These blasts are recorded by ENSN seismic stations and thus causing contamination of the local earthquakes catalogue. Decontamination of any catalogue is essential for a reliable seismic hazard assessment and understanding the seismogenic processes of any seismic area (Kekovalı et al., 2012).

Discrimination or classification of recorded seismic events is one of the most important tasks for seismologists, which is the main goal of this study, in order to be able to make decontamination using different discrimination criteria to distinguish between natural and artificial seismic sources.

2. DATA

There are 379 events recorded by the Egyptian National Seismic Network (ENSN) in the Idfu region during the time period from 2001 till 2018. The magnitude ranges from 2 to 4.1 and depths between zero and 21 kilometres. Among them 227 events have depths equal to zero (Fig. 2).

All waveform data were reviewed and selected based on signal quality (that is, signal-to-noise ratio) as well as on the ability to pick a first arrival at Idfu station.

The vertical component of Idfu station which is about 31 km away from Idfu governorate was used in compiling the complexity and spectral ratio of events to discriminate between earthquakes and quarries.

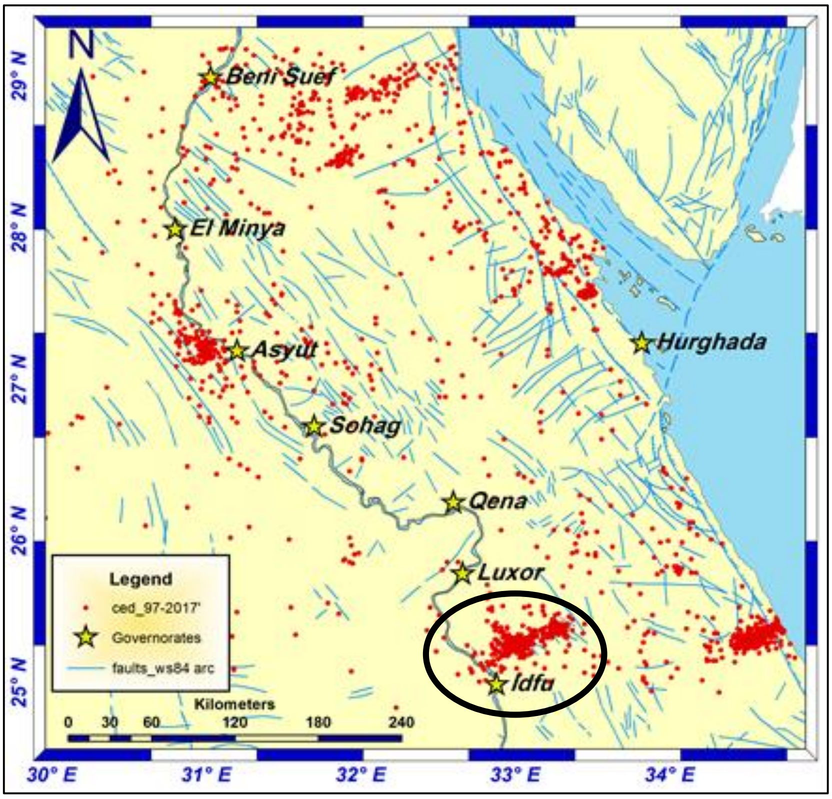

Fig. (1): Seismic activities in central Egypt data (ced) recorded by ENSN.

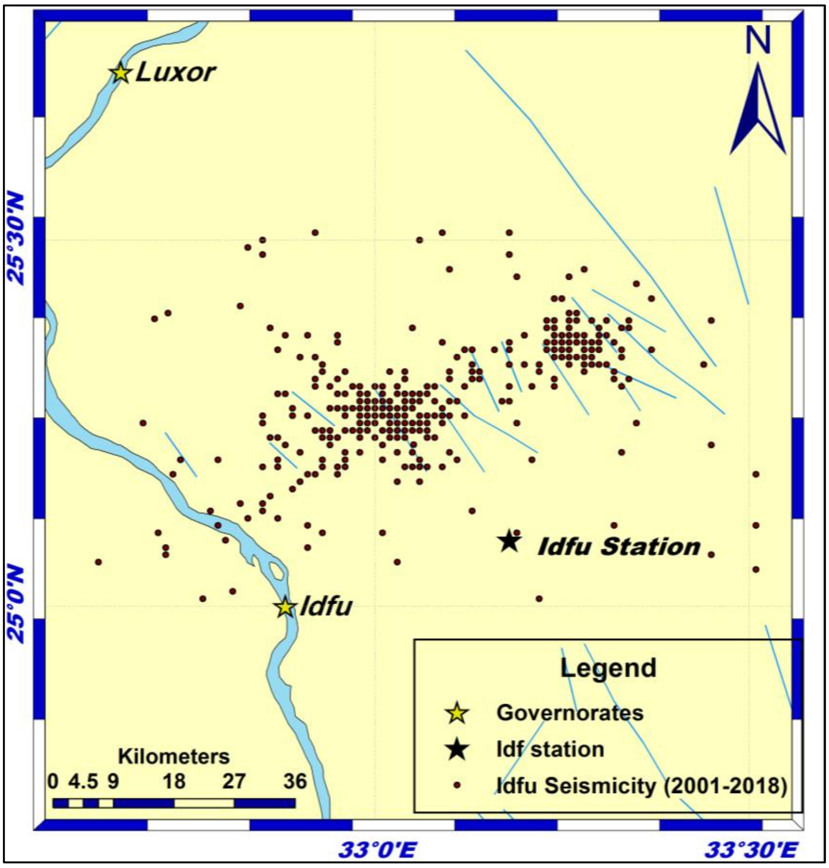

Fig. (2): Geographical distribution of events and location of Idfu station and Idfu governorate.

3. METHODOLOGY AND RESULTS

A variety of waveform-based discrimination methods have been developed and investigated over the last five decades. Through this study, several methods were used that can help in resolving possible biases in the identification of the blasts. Initial discrimination criteria's were applied to decontaminate the local catalogue, such as daytime and nighttime, focal depth ranges, local magnitude range using the ZMAP software of Wiemer (2001), for data analysis. Also, the shape of waveform and its frequencies band were used. All these methods were applied by Horasan, et al. (2009), Kekovalı et al. (2012), Yılmaz et al. (2012).

Qualitative Analysis Results

a) Daytime and Nighttime as an Initial Discrimination Criterion

Daytime and nighttime are simple criteria used to separate earthquakes from quarries. Since the quarry blasts commonly occur during the daytime especially at working hours (8 a.m. to 3 p.m.), while earthquakes could occur any time during the day (Yilmaz et al., 2012), then by a simple histogram relation (Fig. 3) to insure that there are artificial seismic sources in any study area. It is very clear that the number of events has been rising during the daytime between 08 a.m. and 01 p.m. Among 381 events recorded at northeast of Idfu region, 109 events were recorded in only one hour between 10 a.m. - 11 a. m. Time-of-day is not the sole criterion for discrimination, though it can be utilized in conjunction with satellite imagery and waveform analysis in time-frequency domain to further provide constraints on anomalously timed events (Kekovalı et al., 2012).

b) Focal Depth

Focal depth is an important criterion distinguishing between earthquake and quarry blasts. In the study area, 227 events (blue dots) were found to have zero focal depths documenting that they are blasts, while few others (red dots) have depths greater than zero reaching 21 km as shown in the following 3D hypocenter depth variation (Fig.4).

The percentage of number of events-depth histogram established by Z-map is shown in Fig. (5) illustrating that the majority of events were concentrated around zero depth level representing quarry blasts. About 80% of recorded events were found to have zero depth.

c) Magnitude Range

Originally earthquake magnitudes were based on the amplitude of ground motion displacement as measured by a standard seismograph. The ENSN used two main types of magnitudes; Local magnitude (Which is applied to data with hypocenters of the earthquake less than 600 km) and Duration magnitude (That depending on the duration of event).This qualitative analysis used local magnitudes in order to show that the local magnitude of events in our study area is ranging between 2 and 3. And that, only nine seismic events with $M \geq 3.0$ have been recorded in ENSN in the period from 2001 - 2018 ranging between 3.2 and 4.1 which occurred in 7^{th} December 2015 shown in Fig. (6).

d) Shape of Waveform

It is easy to distinguish earthquakes from quarries by the shape of waveform. The following figures show two seismograms of the same station (Idfu station), with the same magnitude (M=2.1) for 28^{th} Jun 2014 earthquake which is characterized on seismogram by very clear P and S waveforms (Fig. 7a) and the waveform of 08^{th} May 2010 quarry that is characterized by head and tail shape with very sharp P-wave onset (Fig. 7b). It is clear that in case of the quarry blast (Fig. 7b), most of the energy is concentrated in P-wave while in case of earthquake (Fig. 7a), the energy is distributed across P and S-waves.

e) Frequency Bands

MATLAB program code used Fourier analysis to convert a signal from the time domain (Fig. 7a and 7b) to frequency domain (FFT) in order to calculate and observe spectral modulation on the seismograms of earthquake (Fig. 8) and quarry blast (Fig. 9). The quarry blasts often consist of several delayed blasts for economic and safety reasons. This is called ripple firing or delayed shooting (Horasan, et al, 2009). The multiple explosions modulate the spectrum of the signal. Hedlin et al. (1989 and 1990) used this property to discriminate between ripple-fired quarry blasts and earthquakes. As a result of using this method about 85% of all events have been discriminated as quarries. Fig. (8) shows lower-frequency bands for an earthquake, while Fig. (9) exhibits higher-frequency content of quarry blasts.

Quantitative Analysis Results

f) Complexity (C):

A complexity (C) (statistical) method is usually used to discriminate natural seismic source (earthquakes) from artificial ones (quarries). The seismic events could be classified through their degree of spectral complexity and richness of different types of waves and amplitudes. Complexity is defined as [the ratio of the seismogram's integrated powers S^2 (t) in the selected time windows (t_1–t_2 and t_0–t_1)].C can be written according to Arai and Yosida (2004) as follows:

$$C = \int_{t1}^{t2} S^2(t)dt \,/ \int_{t0}^{t1} S^2(t)dt \qquad (Eq. 1)$$

g) In the time domain the symbols of t_0 is the first onset of the event, t_1 is the end of P-wave and $t_2$the end of event (the coda). Depending on the distance to the epicenter from the IDF seismic station, the time window selected t_1- t_2 was (2-8) seconds.

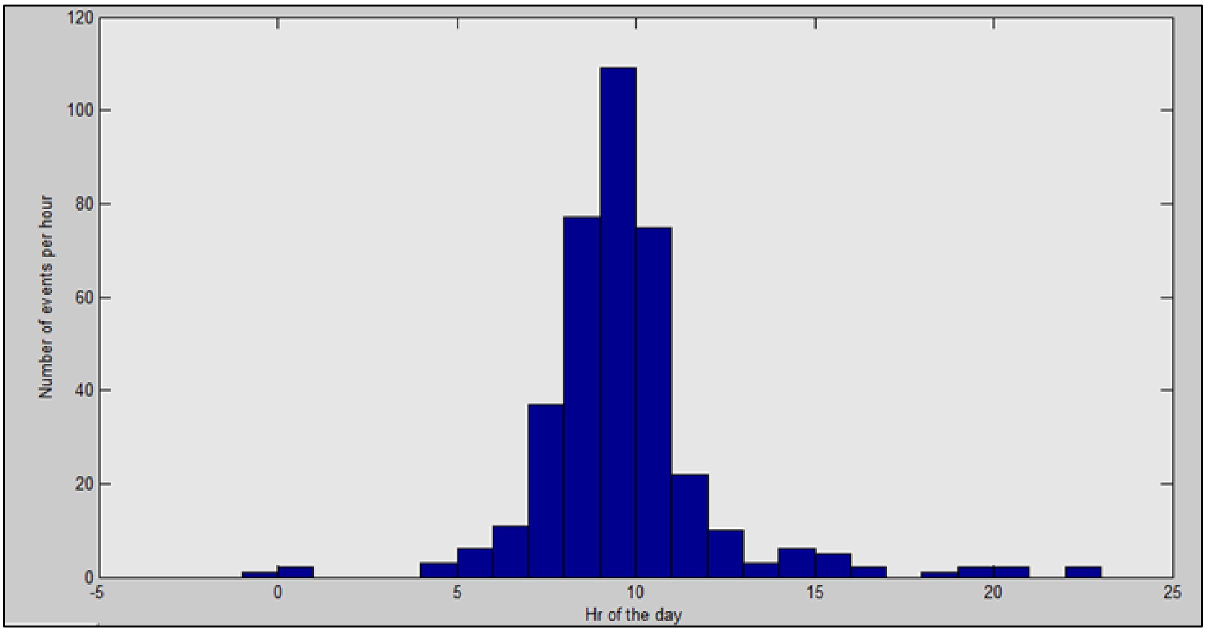

Fig. (3): Number of events per day hours in Idfu region.

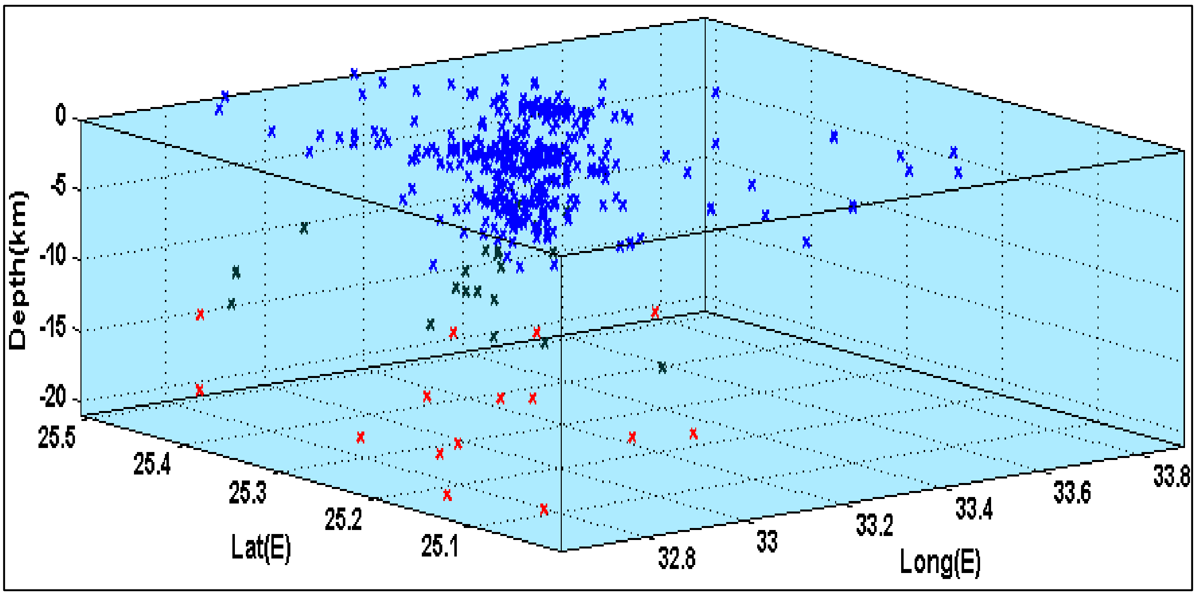

Fig. (4): 3D hypocenter distribution of events listed in the local catalogue of ENSN at Idfu region.

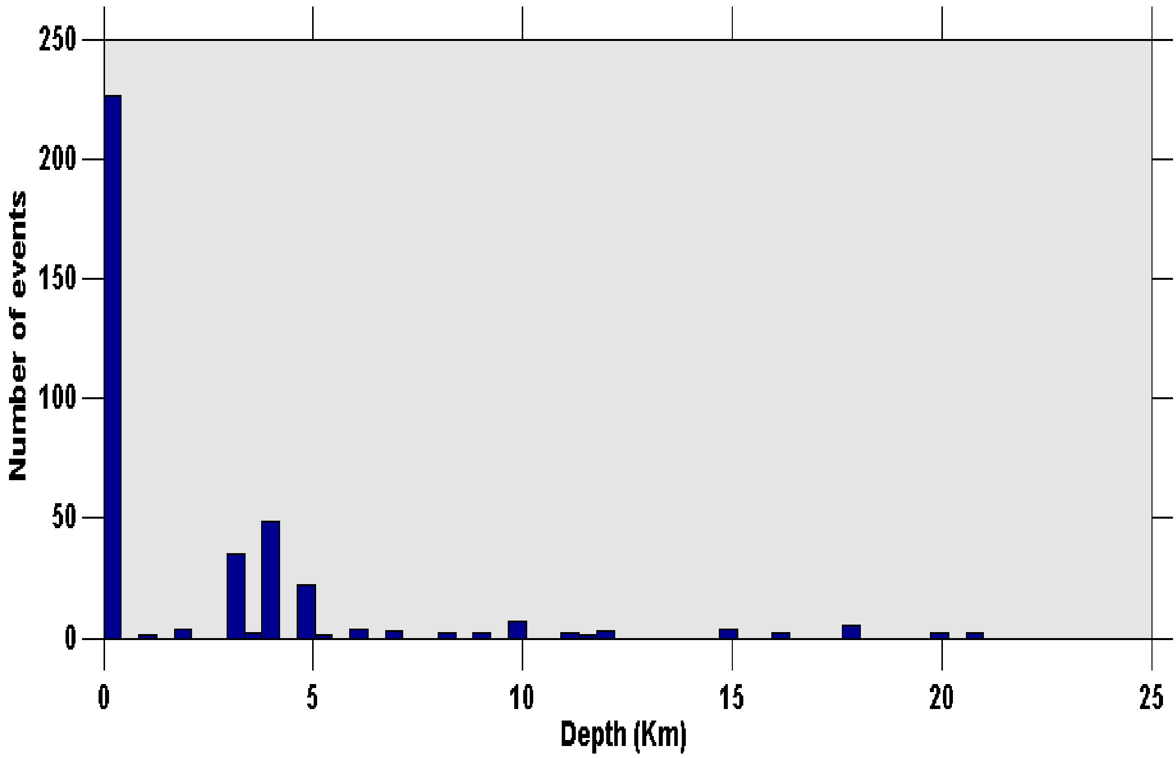

Fig. (5): Number of events-depth histogram at Idfu.

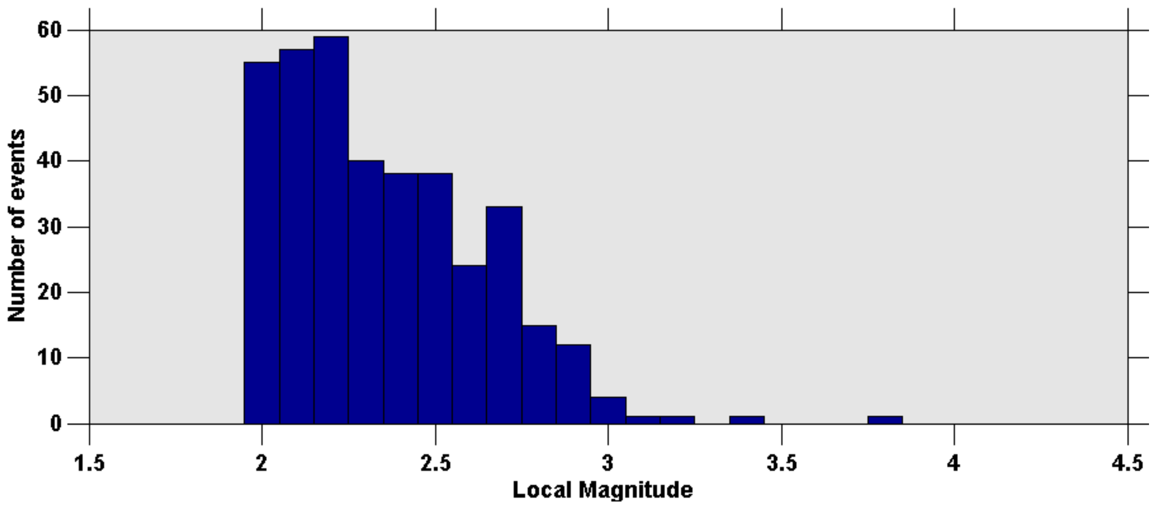

Fig. (6): Number of events - Local magnitude histogram in the study area.

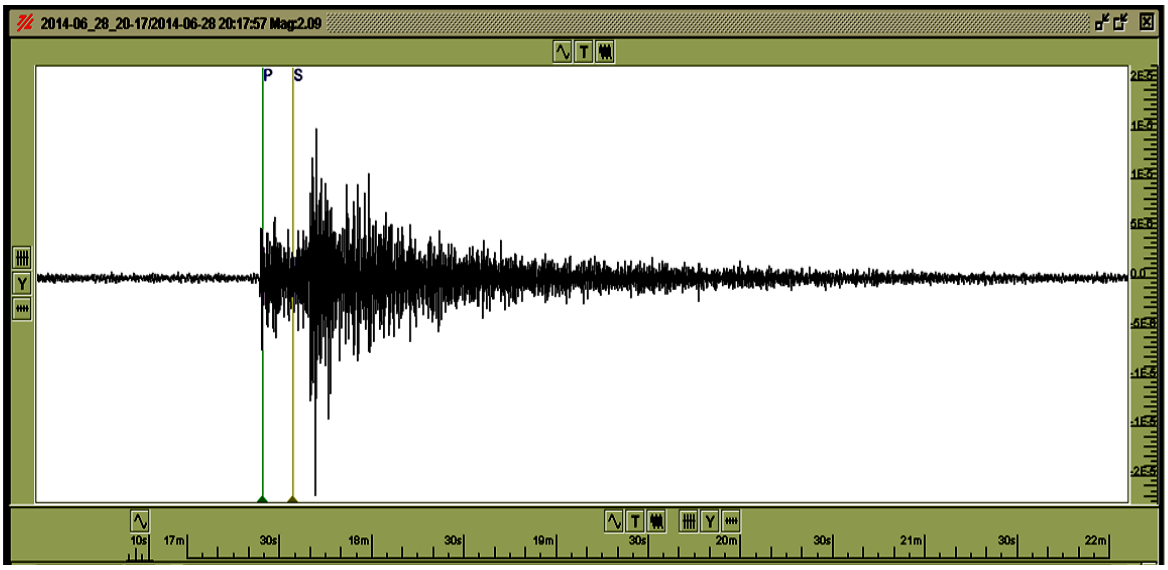

Fig. (7a): Vertical component of Idfu station for 28th Jun 2014 earthquake (M_L=2.09).

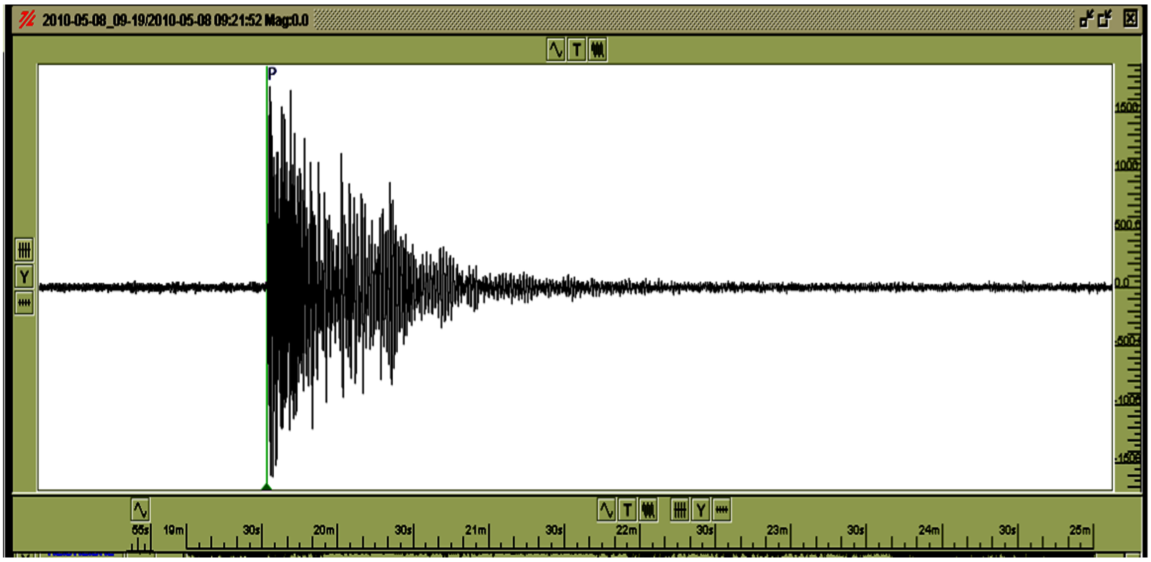

Fig. (7b): Vertical component of the Idfu station for 08th May 2010 quarry blast (M_L=2.14).

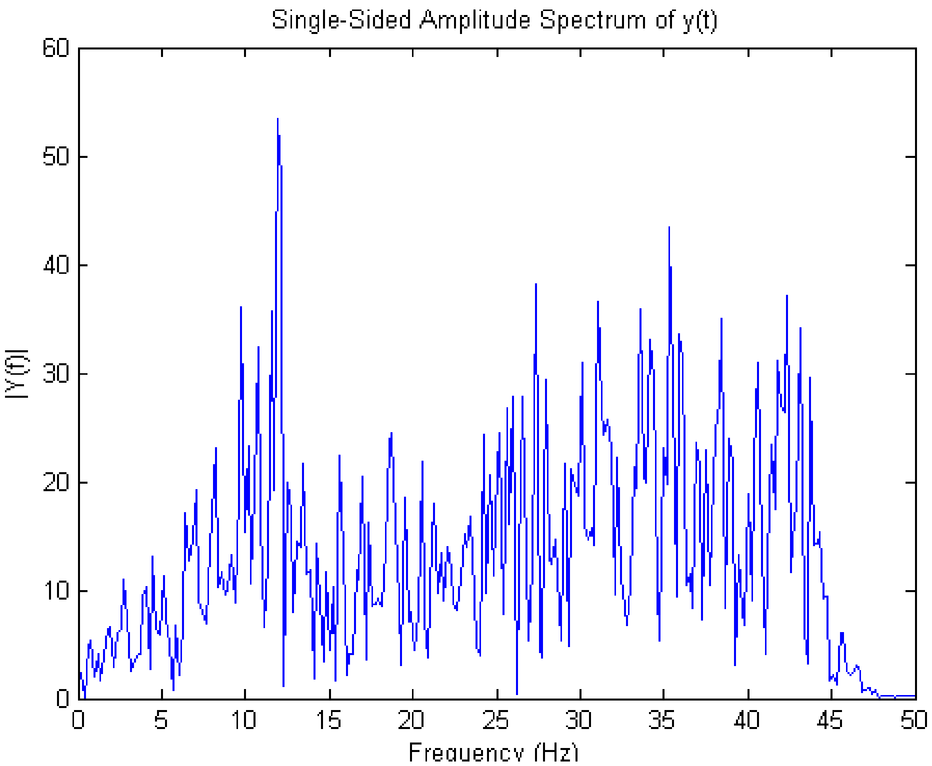

Fig. (8): FFT for 28th Jun 2014 event at IDF station showing the frequency bands of earthquake spectral modulation.

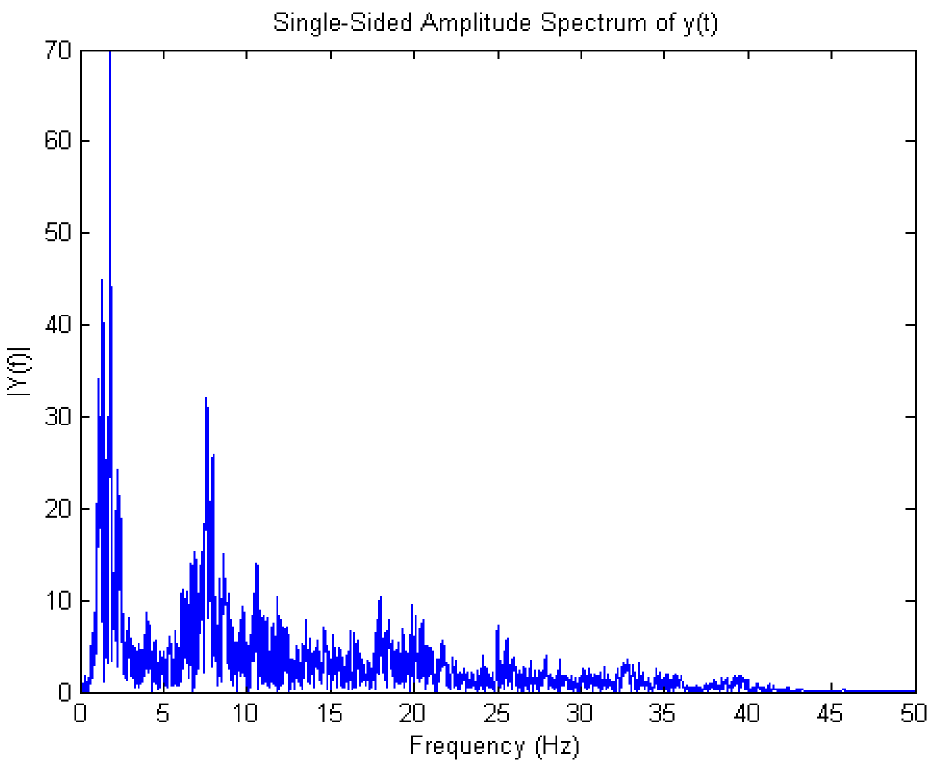

Fig. (9): FFT for the 08th May. 2010 quarry event at IDF station showing the frequency bands of blast spectral modulation.

g) Spectral Ratio (Sr):

(Sr) parameter is[the ratio of the seismogram's integrated spectral amplitudes a(f) in the selected frequency bands (high-frequency band, $h_1 - h_2$, and low-frequency band, $l_1 - l_2$]which is visually selected from the spectrum of the earthquake and explosion for the same station. Sr can be written according to Gitterman and Shapira (1993) as follow:

$$\mathbf{Sr} = \int_{h1}^{h2} a(f)dt \,/\, \int_{l1}^{l2} a(f)df \qquad \textit{(Eq. 2)}$$

In the frequency domain, calculating spectral amplitude ratio (Sr), the limits of the integrals (h_1, h_2) higher frequencies band and (l_1, l_2), the lower frequencies band, were determined by comparing the spectra of quarry blasts with those of earthquakes (Horasan et al. 2009).

The following table shows brief differences between earthquake and blasts according to equations (1) and (2):

116 events have been chosen in order to apply the statistical method of discrimination (Complexity and spectral ratio) based on important limitations:

1) Having a magnitude range from 2 to 3.8 on Richter scale.
2) Choosing vertical component (ELZ) or (BHZ) of the nearest station in the study area (IDF station).
3) Depth range is less than 15 kilometers.
4) Root mean square of the time residuals (RMS) less than 0.5 sec.

It is employed by comparing the energy content of the P-wave of the events plotting complexity (C) versus the spectral ratio of the seismogram (Sr) (Fig. 10).

In general, C becomes larger for earthquakes than for probable mining blasts, since the P- wave amplitude on the seismogram is larger than the S - wave amplitude for mining blasts. Similar results were obtained by Horasan et al. (2009), Öğütcü et al. (2011) and Kekovalı et al. (2012).

Table (1): Simple differences between earthquakes and quarries.

Parameters to discriminate	**(t_2)**	**C (complexity)**	**Dominant P-wave**	**Dominant S-wave**	**S_r (spectral ratio)**
Earthquake	Higher	Higher	Lower	Higher	Lower
Explosion	Lower	Lower	Higher	Lower-or disappear	Higher

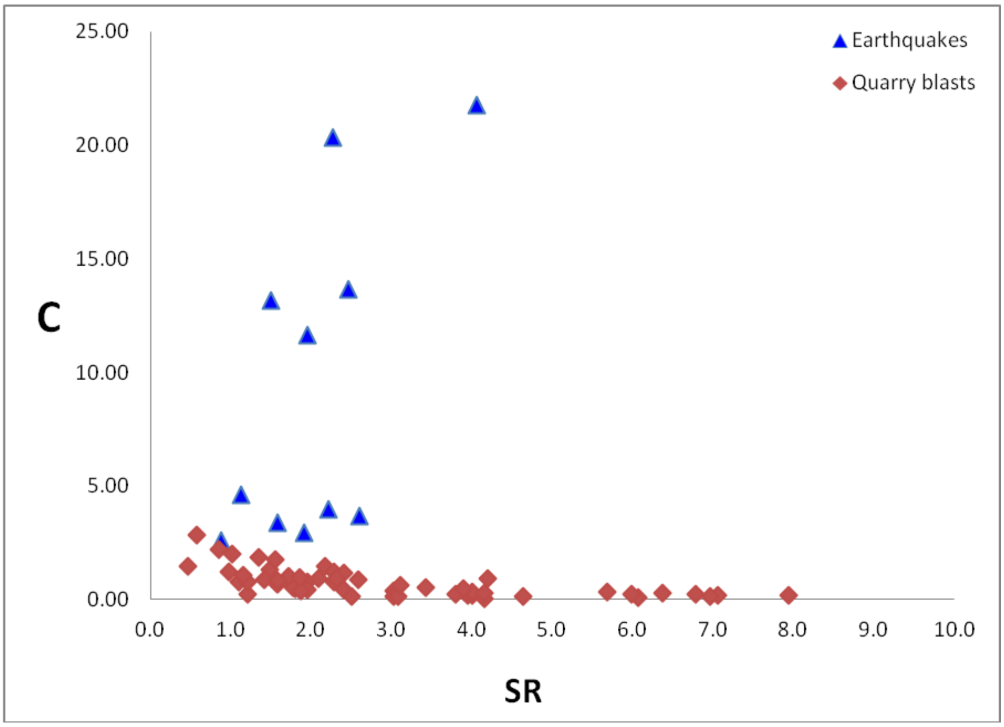

Fig. (10): Complexity (C) versus spectral ratio (SR) for all blasts and earthquakes.

Finally, we concluded that the spectral ratio is larger for blasts than for earthquakes. We also concluded that the frequency domain analyses provided more reliable separation than the amplitude discriminant in the study region.

4- CONCLUSIONS

Daytime and nighttime are simple criteria used to separate earthquakes from quarries. Therefore, datasets were used with different methodologies for the discriminant analysis of quarry blasts from natural seismicity such as frequencies bands, depths range and correlation between the complexity (C) and spectral ratio (Sr) of both mining blasts and earthquakes in Idfu region where we were able to show that the time-frequency discriminate separated 90% of a certain type of mining blasts from only 10% of the earthquake.

The natural activity in this area seems to be recent ones and it could be induced from the artificial explosions in that area.

According to the results of this research, it is evident that we were able to identify mining blasts and remove them from the ENSN local seismic catalogue. This is essential for evaluating earthquake potential and seismic hazard of Idfu region, central Egypt.

Acknowledgments

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REFERENCES

Arai, N. and Yosida, Y. (2004): Discrimination by short-period seismograms. International Institute of Seismology and Earthquake Engineering, Building Research Institute (IISEE), Lecture Note, Global Course, Tsukuba.

Gitterman, Y. and Shapira, A. (1993): Spectral discrimination of underwater explosions. Isr. J. Earth Sci. 42:37-44.

Hedlin, M.A., Minster, J.B. and Orcutt, J.A., (1989): The time-frequency characteristics of quarry blasts and calibration explosions recorded in Kazakhstan. USSR Geophysical Journal 99, 109–121.

Hedlin, M., Minster, J.B. and Orcutt, J.A., (1990): An automatic means to discriminate between earthquakes and quarry blasts, Bulletin Seismological Society of America 80, 2143–2160.

Horasan, G. et al. (2009): Contamination of seismicity catalogues by quarry blasts: An example from_Istanbul and its vicinity, northwestern Turkey.Journal of Asian Earth Sciences 34 (2009) 90–99.

Kekovalı, K., Kalafat, D. and Deniz, P. (2012): Spectral discrimination between mining blasts and natural earthquakes: Application to the vicinity of Tunçbilek mining area, Western Turkey. International Journal of the Physical Sciences Vol. 7(35), pp. 5339-5352.

Öğütçü, Z., Horasan, G. and Kalafat, D. (2011): Investigation of micro-seismic activity sources in Konya and its vicinity, central Turkey. Natl. Hazards 58:497-509.

Ş. Yılmaz, Y. Bayrak and H. Çınar (2012): Discrimination of earthquakes and quarry blasts in the eastern Black Sea region of Turkey. J Seismol DOI 10.1007/s10950-012-9348

Wiemer, S. (2001): A software package to analyze seismicity: ZMAP, Seim. Res. Lett. 27, 373-382.