京都大学防災研究所年報 第 52 号 B 平成 21 年 6 月
Annuals of Disas. Prev. Res. Inst., Kyoto Univ., No. 52 B, 2009

Identification of Local Seismicity Observed South of Aswan City, Egypt

Sayed A. DAHY*, Gaber H. HASSIB* and Jim MORI

*National Research Institute of Astronomy and Geophysics, Helwan, Cairo, Egypt

Synopsis

The Aswan Seismic Network detected and observed a number of events near Aswan city. The magnitude of these events ranged from 0.9 to 2.6. These events were considered very important events because they were located not far from the Aswan High Dam. The main purpose of this work is to investigate and identify these events using different seismic methods. Small earthquakes and explosions have the same flat displacement spectrum for short- period P waves and discrimination of small events depends on detection and location. The final results indicate that the sources of these events are natural earthquakes.

Keywords: Aswan High Dam, Seismicity, Explosions

1. Introduction

Like earthquakes, the force of an underground explosion creates seismic waves that travel through the Earth. A seismic monitoring network must be able to detect and identify both types of seismic signals. Detection consists of recognizing the seismic event, and locating the source of the seismic signals. Identification involves determining whether the source was an underground explosion or natural earthquake. The identification problem in seismic monitoring is called the discrimination problem. It is to distinguish underground explosions from other seismic sources (Office of Technical Assessment, 1988).

Accurate event location is essential for identification, including the reliable separation of onshore and offshore events and the determination of source depth. When location alone is insufficient to identify the source, secondary waveform attributes must be relied on. For small events, experience has shown that a number of methods, often different in different regions, can be used to distinguish explosions (e. g., mine blasting) from earthquakes.

Physical differences between earthquakes and explosions cause their seismic signals to differ, and these differences can be used to identify the events. Once a seismic signals has been detected, the next task is to determine whether it was created by an underground explosion.

Seismic signals are generated not only by underground nuclear explosions, but also by natural earthquakes, rockbursts in mines and chemical explosions conducted for mining, quarry blasting and construction. Every day there are many earthquakes around the globe whose seismic signals are the same size as those of potential underground explosions.

Ericsson(1970) and Basham (1971) indicated that, one of the most useful diagnostic aids to distinguish between earthquakes and explosions is using the relative amplitude of surface- wave that are generated for a given short- period P- wave signal. Douglas et al. (1972) analyzed seismograms for various sources and showed that, for many orientations of the fault plane, earthquakes generate smaller P- waves than explosions for the same

Rayleigh- wave amplitude. Pulli and Dysart (1987) and Bennett et al (1989) reported that the discriminant is less effective in separating earthquakes and explosions in Scandinavia and in the eastern European shield, respectively. Again, as pointed out by Bennett et al (1989), propagation path differences for the explosion and earthquake populations may have an effect on the performance of this discriminant. Douglas et al (1990), found that the Pn wave is stronger relative to Sn and Lg, nad these ratios increase with frequency. This result is due to larger high frequency Pn amplitudes relative to the Lg amplitudes.

2. Seismological Observations and Data

On November 14, 1981, a magnitude 5.3 earthquake occurred in the Kalabsha area along the Kalabsha fault near Gebal Marawa, 70 Km southwest of the city of Aswan. The earthquake is considered a very important event because it is located not far from the Aswan High Dam. In late June 1982, a telemetered network of eight seismograph stations was installed around the northern part of Aswan reservoir by the National Research Institute of Astronomy and Geophysics, Helwan, Egypt and Lamont- Doherty Geological Observatory. A ninth station was added in December 1982 and the network was expanded to 13 stations in 1985 (Kebeasy et al., (1987). The main purpose of the network is to monitor induced seismic activity along the Kalabsha fault and around High Dam Lake.

The data used in the present investigation were collected from the records of the Aswan Seismic Network (Fig.1) and also from the records of the Egyptian National Seismic Network (ENSN). The data set for this study consists of 27 unknown events (Table 1) observed close to south of Aswan city and recorded during the period from 1999 to 2003. Also we used about 15 quarry explosions near the Old Aswan Dam and 15 natural earthquakes that occurred in different regions along the Seiyal and Khor El Ramla faults, south- west of Aswan zone.

All of these events (earthquakes and quarry explosions) having local magnitude ranging from 0.9 to 2.8 and were recorded at the same stations with the same type of equipment. The locations are shown in Figure (1).

In this study, local magnitudes (M_L) for these events have been calculated using the magnitude-duration relationship (Lee et al., 1972)

$$M_L = 2.0 \log D - 0.87 \qquad (1)$$

Where D is the signal duration from the P- wave onset to the end of the discernable signal.

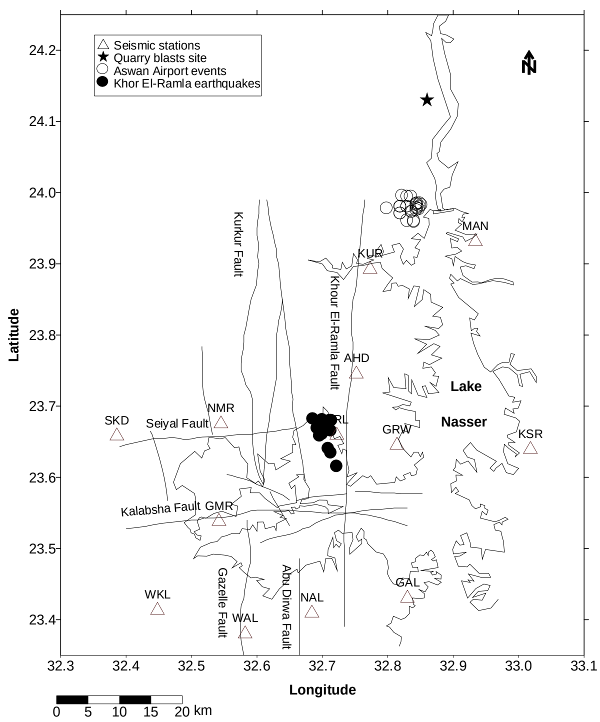

Fig. 1. Geological structure and location of the investigated seismic events

3. Local Geological Setting and Active Faults

The geology of the Aswan area is controlled primarily by regional basement rock uplift and regional faulting. The River Nile divides the Aswan area into eastern and western areas. In the eastern aswan area two broad groups of folds have been traced. The older group is found only in the basement rocks, while the younger group can be traced in the basement and overlying sediments. The fold axes of the older group trend NE- SW and NNW- SSE. In the western Aswan area the dominant fold system trends ENE- WSW parallel to the younger fold trend in the eastern Aswan area. The area is traversed by two major fault systems trending and NNW- SSE. Geology of the western Aswan area is dominated by a sedimentary successions varying from Cretaceous to Quaternary.

The area west of Aswan is characterized by a great number of faults, and the largest faults are the Kalabsha and Seiyal faults (Fig. 1). Seven faults were identified as active faults. The nearest faults for this study are,

1) Seiyal fault: The Seiyal fault, about 100 km long, is located approximately 12 km to the north of Kalabsha fault at the eastern edge of the Sinn El-Kaddab plateau. It is approximately parallel to the Kalabsha fault. It is also a right- lateral strike- slip fault as indicated by right- stepping en echelon folds. From studying the seismicity, it is less active than the Kalabsha fault.

2) Kurkur fault: This fault is a N- S trending fault, about 44 km long. It runs about 28 km to the west of the High Dam. It is interpreted to be a left-lateral strike- slip fault indicated by the small left-stepping en echelon folds common along the fault trace (Issawi, 1968; 1978). Seismic activity of the Kurkur fault is estimated to be very low.

3) Khor El Ramla fault: This fault is a N - S trending fault with total length of about 36 km, and it is approximately 17 km southwest of the High Dam at its closest approach. A cluster of microearthquakes that trends approximately N- S has been recorded around the southern end of the fault. The fault plane solution of these events indicates left lateral faulting. The degree of activity of the Khor El Ramla fault was estimated to be very low.

4. Seismicity of the Aswan Region

The seismicity of Aswan region has been studied by many seismologists (e. g., Simpson et al., 1985, Kebeasy et al., 1987, El - Khashab et al., 1991). Simpson et al., (1986) indicated that the seismicity of the Aswan area is concentrated in two distinct clusters on and near the Kalabsha fault. The 1981 event and its aftershocks are at depths of 12 to 25 km. East of the Kalabsha fault, there are two shorter segments of activity at depths of 0 to 10 km. The highest level of activity is at depths of 15 to 30 km beneath Gebel Marawa. The seismicity elsewhere is less than 15 km deep.

Woodward- Clyde Consultants, (1985) concluded from studying the historical and recent seismic activity that the area is characterized by a low level of seismic activity. The majority of local earthquakes recorded by a temporary network from 13 December 1981 to 6 July 1982 were concentrated along the Kalabsha fault. The map in figure (2) shows the seismicity for the period from 1982 to the end of 2003. Most of the seismicity is concentrated at Gebel Marawa along the Kalabsha fault and its extension towards east. Other activity is located in the Khor El Ramla area west of the Khor El Ramla fault. Some of these events are located along the Abu Direwa fault at a focus depths of 0 to 6 km. Few events are observed in the northern part of High Dam Lake close to the Aswan International Airport.

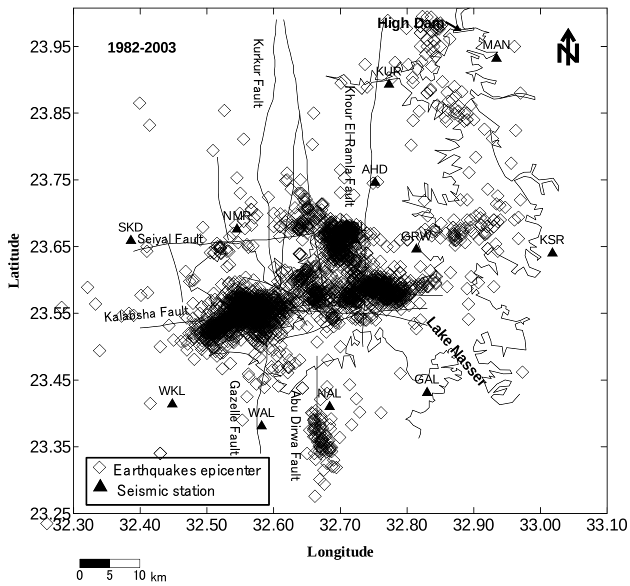

Fig. 2: Seismicity map of Kalabsha area from January 1982 to December 2003. The lake outline refers to the water level of 180m.

In Fig. 3, the number of earthquakes are shown for 22 years for the time period from January 1982 to December 2003. The main level of seismicity decreases with several peaks in the shallow and deep seismic activity that occurred within a few

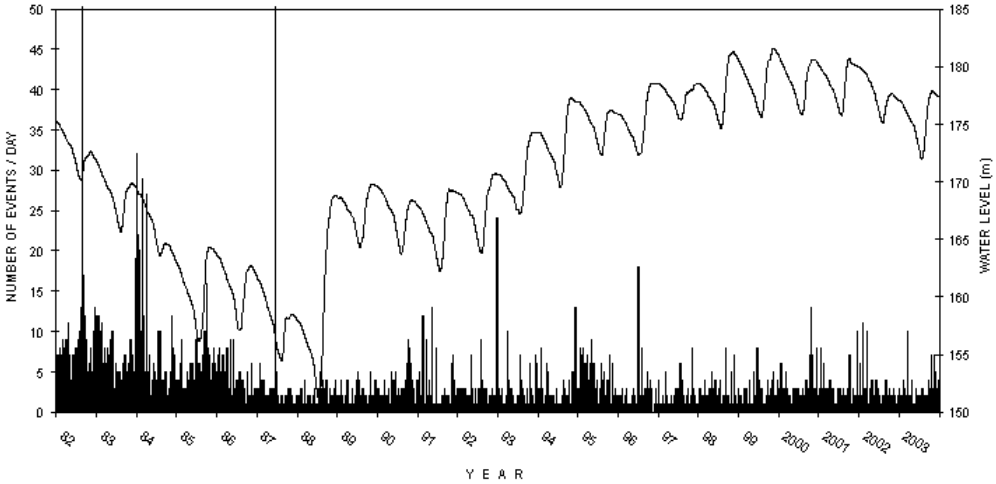

Fig. 3. Examples of quarry explosion and two natural earthquakes

Table 1: List of unknown events observed near Aswan Airport

	Mon	Day	hr	min	sec	Lat. N	Lon. E	Depth	Mag.
1999	11	6	11	10	46.2	23.98	32.82	3.3	1.7
1999	12	4	13	40	0.3	23.98	32.82	4.3	1.7
1999	12	5	6	35	23.7	23.98	32.82	3.5	1.1
1999	12	22	7	39	21.39	23.975	32.844	0.71	2. 6
1999	12	22	14	24	52.5	23.97	32.82	5.7	1.1
2000	1	8	0	31	43.9	23.96	32.83	2.6	1.6
2000	1	8	20	17	35.35	23.98	32.83	1.13	0.9
2000	1	9	3	39	18.91	23.97	32.82	1.76	1.4
2000	1	13	5	37	0.35	23.98	32.83	1.6	1.4
2000	1	13	6	16	22.82	23.98	32.82	1.13	1.1
2000	3	17	19	58	44.9	23.995	32.823	1.39	1.8
2000	8	31	2	12	27.66	23.96	32.84	0.13	2.2
2002	1	13	3	49	19.4	23.994	32.83	24	1.9
2002	5	11	8	52	27.2	23.985	32.85	2.93	2.0
2002	9	3	0	2	24	23.984	32.846	1.23	2.3
2002	9	3	0	9	28.4	23.982	32.852	4.87	1.8
2002	9	3	6	48	40.5	23.972	32.838	0.98	1.7
2002	9	3	8	3	40.4	23.976	32.848	2.37	1.2
2002	9	4	5	7	54.1	23.977	32.846	0.47	1.4
2002	9	7	7	48	57.7	23.98	32.85	0.97	1.9
2002	9	9	17	57	48.7	23.983	32.844	1.16	1.6
2002	9	12	4	24	18.6	23.978	32.844	0.92	1.1
2002	10	13	15	23	8.6	23.958	32.841	0.27	1.7
2003	5	26	0	21	44.6	23.982	32.845	0.14	2.2
2003	6	6	7	44	41.6	23.994	32.836	0.04	1.8
2003	6	19	19	45	2.81	23.977	32.799	3.69	0.9
2003	7	12	6	13	22.75	23.973	32.837	0.49	1.3

weeks after the annual seasonal water level maxima. Few events detected and observed near Aswan Airport are associated with the increasing the lake water level to 180 meter.

5. Event Identification

The aim of this study is to evaluate the effectiveness of some discriminants by investigating amplitude spectra and dynamic characteristics of the waves generated by different types of sources in a certain region of Aswan. The source properties of quarry explosions, the dynamic characteristics of their waves (amplitude, periods and waveform) and comparison with the characteristics of natural earthquakes have been mainly studied for quarry explosions.

Each seismic source can be described by its space-time parameters (volume, location, depth of the source, origin time) and its dynamic parameters (energy, magnitude, spectrum). For seismic events that cannot be distinguished by depth and location, other methods of discrimination are used and these methods are based on physical differences between earthquakes and explosions. Some of the applied methods after modification can be used for identification of local seismicity that occurred near Aswan International Airport.

Waveform Characteristics One of the most important problems in seismic monitoring is to distinguish underground explosion from other seismic sources. If a seismic event is small the problem of discrimination is not straightforward. Explosions release their energy in a very small volume and produce primarily P waves. In contrast, earthquakes represent the motion of blocks along a fault; the source dimensions are much larger for a given size than for an explosion, and earthquakes produce large S waves.

Below is a figure (4) comparing two recent natural earthquakes with a quarry explosion of approximately the same size. Both events were recorded by the Egyptian National Seismic Network with the same type of equipment and the distance between the explosion and recording station is approximately the same as the distance between the earthquake and recording station. The explosion waveform is dominated by the P wave (first arrival), while the earthquake has much large S waves (and surface waves).

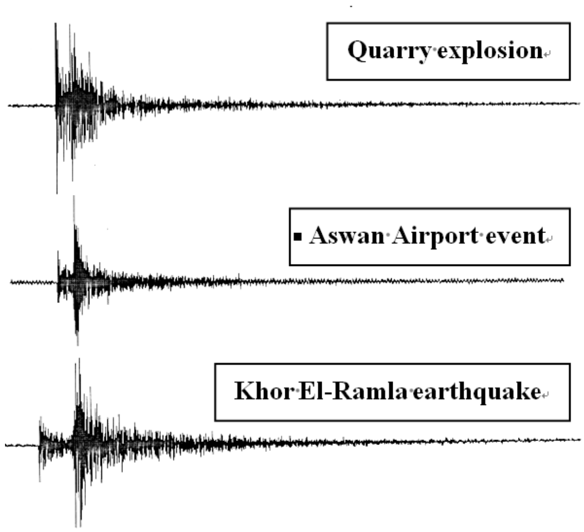

Fig. 4. Examples of quarry explosion and two natural earthquakes.

On the other hand, the duration of explosion source processes is shorter and the oscillations have an impulse character. This characteristic and the increasing high frequency component absorption cause the more rapid attenuation of the explosion-generated oscillations with distance. The explosions are spherically symmetric centers of energy, so the explosion generated P-wave are recorded at all seismic stations as waves of compression. For the natural earthquakes in the region under investigation, the first motion can be either a compression phase or dilatation phase, which is due to the specific mechanism of the earthquake source.

Body to Surface Wave Amplitudes The ratio between body-wave to surface-wave amplitude (Ap: As) is used when investigating the natural earthquakes and presumed quarry explosions.

Underground explosions like industrial explosions in quarries generate signals, which tend to have surface or S-wave amplitude (As) and body wave amplitude (Ap) that differ from those of natural earthquake signals. This is basically a result of explosions emitting more energy in the form of body waves (high-frequency seismic radiation), and earthquakes emitting more energy in the form of surface waves (low-frequency seismic radiation). To use this identification method, both Ap and As

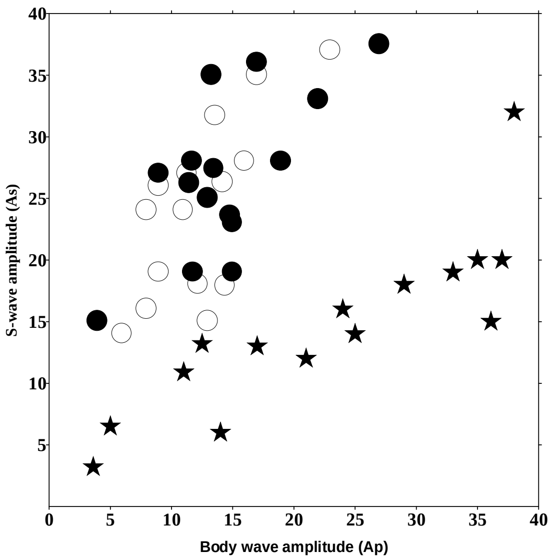

Fig. 5. Relation between body wave and S-wave amplitude (Ap: As). Khor El Ramla earthquakes (close circle), Airport events (open circle) and quarry explosions (star).

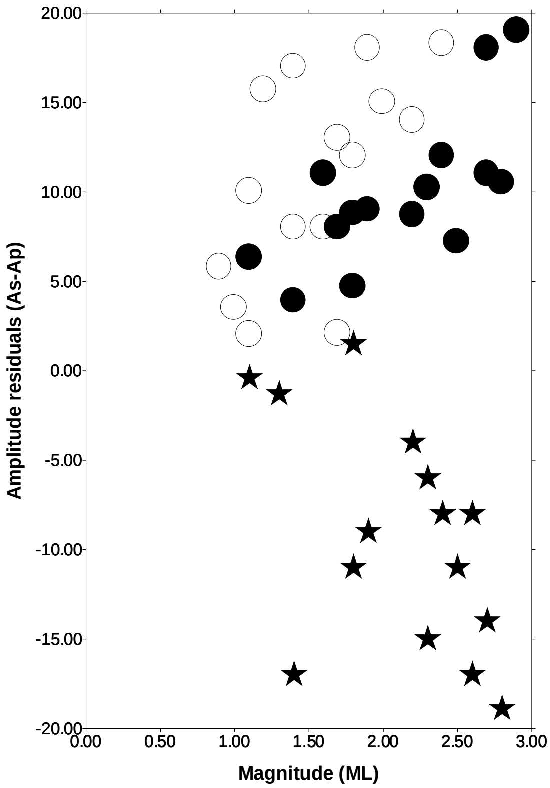

Fig. 6. Relation between local magnitude (M_L) and amplitude residual (As-Ap)

values (maximum trace amplitude of P and S-waves in mm) are required. The relationship between the maximum trace amplitude on the seismogram of P-wave (Ap) and S-wave (As) for events which occurred in or near the Aswan International Airport and Khor El Ramla earthquakes with quarry explosions fired near the Old Aswan Dam are shown in Fig. 5.

It can be seen that quarry explosions are clearly distinguished from the Airport events and Khor El Ramla earthquakes, especially in the large amplitude range and the separation can be mainly attributed to the difference in the source nature.

Generally it is observed that, P-wave amplitude for explosions are greater than those of earthquakes. Also S-wave amplitude for explosions are less than those of earthquakes. This can be explained that, in case of explosions most of the released energy is confined in the range of high frequency waves. On the contrary, for earthquakes the released energy is distributed in a large range of frequencies. In addition, quarry explosions do not, generally generate large S-waves as they are fired near the earth's surface.

Amplitude Residuals of Local Magnitude. The relation between M_L and deviations of maximum trace amplitude on the seismogram namely is shown in Fig. 6. For quarry explosions, the deviations are mostly minus when the maximum trace amplitude of P-wave is greater than the maximum trace amplitude of S-wave. Earthquakes in both regions show values for amplitudes of S-wave are greater than those of P-waves.

These significant deviations are probably due to the response of the short-period seismograph and the spectra of underground explosions, which have a strong peak at a higher frequency and a relatively simple pattern, as is easily seen from the analogue records. It is also significant that, the spectra of quarry explosions near the old Aswan Dam appear very similar. On the other hand, for earthquakes, the spectra are more complicated and appear very different from those of explosions.

6. Conclusions

These investigations are related to the problem of identification of quarry explosions and small earthquakes. The results of the present study show that: waveform characteristics of seismic waves generated by local earthquakes and quarry explosions can be used as a diagnostic aid in distinguishing between the two types of events.

Separation between natural earthquakes and underground quarry explosions is observed clearly in the relation between P wave and S wave amplitudes (Ap: As), as calculated from the records of the Aswan short- period seismic stations.

Using the relation between local magnitude and amplitude residuals (As- Ap) for different local events which occur in different regions with known quarry explosions, it was possible to distinguish underground quarry explosions from natural earthquakes. The capability of this described method to differentiate between natural and artificial events is tested and shows good results.

By applying these methods to Aswan Airport events, we conclude that, these events are not artificial events but all events are natural earthquakes. The most generally accepted explanation for the cause of the earthquake occurrence in such cases is that rocks near the Aswan reservoir are already strained from the local and regional tectonic forces to a point where nearby faults are almost ready to slip. Water in the High Dam Lake adds a pressure perturbation that triggers the fault rupture. The pressure effect, perhaps, is enhanced by the fact that the rocks along the fault have lower strength due to increased water- pore pressure.

References

Basham, P. W. and Whitham, K. (1971): Seismological detection of underground nuclear explosions, publications of the Earth Physics Branch, Department of Energy, Mines and Resources, Ottawa, Vol. 41, pp. 145-182.

Bennett, T. J., Barker, B.W., Mclaughlin, K.L. and Murphy, J.R. (1989): Regional discrimination of Quarry blasts, earthquakes and underground nuclear explosions, Final Report, GL-TR - 89-0114, S- Cubed, La Jolla, California.

Douglas, A., Hudson, J.A., and Blamey, C. (1972): Quantitative evaluation of seismic signals at teleseismic distances. III. Computed P and Rayleigh wave seismograms, Geophys. J. Int., Vol. 28, pp 385-410.

Douglas, A., Richardson, L. and Hutchins, M. (1990): Surface reflections and S to P conversions on P seismograms, Geophys. J. Int. Vol. 100, pp. 303- 314.

El-Khashab, H. M. A., Hassib, G.H., Ibrahim, E.M. and Dessoky, M .M. (1991): Seismicity and composite focal mechanism for microearthquakes in Kalabsha area west of Aswan Lake and their tectonic implication, J. of Geodynamics, Vol. 14, pp. 87-104.

Ericsson, U. A. (1970): Event identification for test ban control. Bull., Seismol. Soc. Am. Vol. 60, No. 5, pp. 1521- 1546.

Issawi, B. (1968): The geology of Kurkur Dungul area, General Egyptian Organization for Geological Research and Mining; Egyp. Geological Survey paper No. 46, Cairo, 102 p.

Issawi B., (1978): Geology of Nubia West area, Western Desert, Egypt, Ann. Geol. Survey Egypt, Vol. 3, pp. 237- 253.

Kebeasy, R. M., Simpson, D. W. and Gharib, A., (1987): Induced seismicity around Aswan Lake, 29th General Assembly of IUGG (IASPEI), August 1987, Vancouver.

Lee, W. H. K., Bennett, R. E. E. and Meagher, K. L (1972): A method of estimating magnitude of Local Earthquakes from signal duration, U. S. Geological Survey Open- File Report, 28 p.

Office of Technical Assessment, (1988). Seismic verification of nuclear tests treaties. U. S. Congress, Office of Technology Assessment.

Pulli, J. J. and Dysart, P.S, (1987): Spectral study of regional earthquakes and chemical explosions recorded at the NORESS array, Technical Report, C 87- 03, center for seismic studies, Arlington, Virginia.

Simpson, D., Kebeasy, R., Maamoun, M., Ibrahim, E., and Megahed, A., (1985): Induced seismicity around Aswan Lake, Tectonophysics, Vol. 118, pp.281.

Woodward- Clyde Consultants, (1985). Earthquake activity and stability evaluation for the Aswan High Dam, Report, High and Aswan Dam Authority, Ministry of Irrigation, Egypt.

エジプトアスワン市南部で観測された地震活動の検出

Sayed A. DAHY*・Gaber H. HASSIB*・Jim MORI

* National Research Institute of Astronomy and Geophysics, Helwan, Cairo, Egypt

要　旨

アスワン地震観測網により，アスワン市周辺で多くの地震が観測された。これらの地震のマグニチュードは0.9から2.6であった。　アスワンハイダムからそれほど遠くないところを震源とすることから重要なイベントである。この研究の目的は，異なる地震学的手法を用いてこれらの地震を調べることである。小地震と発破は短周期のP波では同じ平坦な変位スペクトルをもち，震源位置によって小地震を識別する必要がある。これらの地震は，自然地震であると結論づけることができる。

キーワード：アスワン・ハイ・ダム，地震活動，爆破