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Stations Correction and Earthquakes Relocation in the Kalabsha Area, Aswan, Egypt

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Abstract: A total number of 343 earthquakes recorded by more than 7 stations from the Aswan seismic network in the Kalabsha area was relocated and the seismic stations correction for P-wave are estimated using joint hypocenter determination method. Seven stations AHD, SKD, NMR, GMR, KSR,GRW and KRL have minus signs instation P-wave travel time corrections and their values-0.009,-0.178,-0.070,-0.027,-0.344,-0.123, and-0.067, respectively. It is possible to assume that the underground structure in this area has a particular characteristic of high velocity structure and other stations WKL, WAL, GAL, KUR, MAN and NAL have positive sign and their values 0.038, 0.158, 0.065, 0.219, 0.197 and 0.057, respectively. It is possible to assume that underground structure in this area has particular characteristic of low velocity structure. The hypocenter location determined by the joint hypocenter determination method is more precise than those determined by other routine work program. This method simultaneously solves for earthquake location and station corrections. The station corrections reflect not only different crustal condition in the vicinity of the stations, but also the difference between actual and model seismic velocities along each of the earthquake-station ray paths. The stations correction obtained correlate with the major surface geological features in the study area. As a result of the relocation, the majority of the hypocenters are closer to the faults than those before relocation.

Key words: Kalabsha area · Hypocenter location · Kalabsha fault · Nasser Lake

INTRODUCTION

Precise earthquake location has been one of the primary research objectives in seismology since seismic data were available because it provides initial insight into observed seismicity and faults or subsurface structures responsible for the observations. The quality of the locations is affected by limitations imposed by the quality of the data (available phases, signal-to-noise ratio, clock accuracy, the accuracy of arrival times, etc.), station distribution, prior information of the velocity structure in the area, techniques for location and others. These limitations have been reduced by denser and wider seismic station coverage providing higher quality data and improved earth velocity models. Despite these improvements, there is still room for better earthquake location. In addition, the assessment of the result quality is not easy since precise source parameters and velocity structures of the selected study areas are usually not available [1].

The joint hypocenter determination method (JHD) in general, used initial P-wave arrival times and it has been known and developed since 1967 by Douglas [2], Freedman [3], Hurukawa *et al.* [4] and Pujol. J. [5]. The main idea for this method to earthquake implication is that; it should reveal any regional bias in travel times from the same region and then from it is bias characteristic, the nature of velocity in that area could more understood. JHD is one of the powerful methods to determine hypocenter location but it is more clearly understand and imagine.

Kalabsha area is located south Aswan city by about 60 Km. This area was investigated by many seismologists since Aswan earthquake in Nov. 14, 1981 It occurred near the western edge of Nasser Lake with magnitude 5.3 and followed by many aftershocks. Kalabsha area is also of interest because it is located near the Aswan High Dam and Toshka Project. Wadi Kalabsha covers an area of 3500 km^2 and surrounds Gabel Marawa, which represents a relict of the retreated Sin El-Kaddab scarp [6,7]. The summit of the Gabel Marawa rises 251 m above sea level. The floor width of this Wadi Kalabsha varies from place to place. It is of 3 km in some locations. Its depth ranges from 175 to 225 meters.

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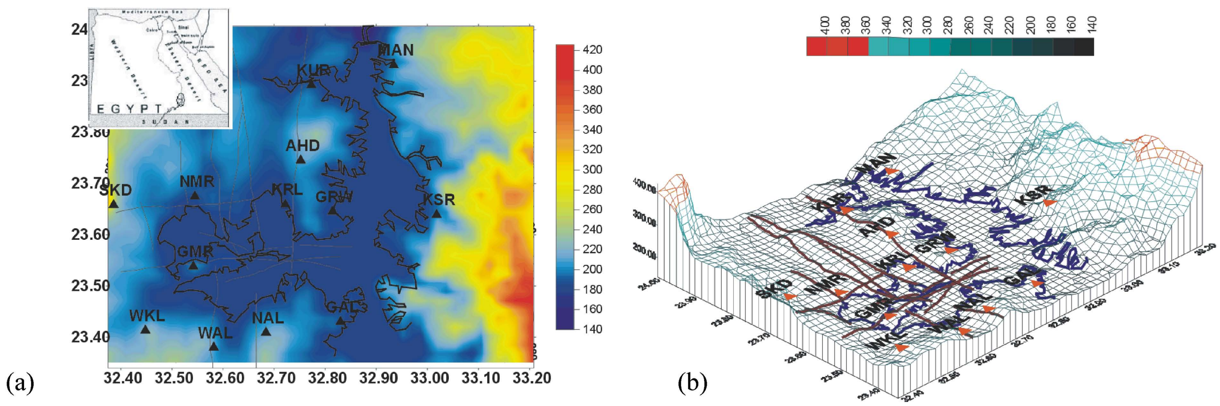

Fig. 1: a) Location and topographic map. b) Topographic map in 3d view.

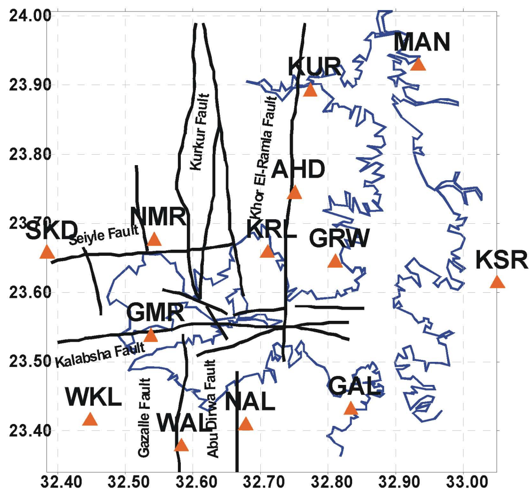

Fig. 2: Structure map

Two main fault systems are noted in the area. One is composed of approximately north-trending faults; the other of approximately west-trending ones. Supplementary north-east and north-west faults are also noted.

Figure 1 shows the location and topographic map also identifying the main faults. Topographic digital data obtained after Smith and Sandwell [8].

The north-trending faults system predominates in the Nubia plain, whereas the faults affect the sandstone beds of the Nubia Formation on the plain. This system includes the Gebel El Barqa, Kurkur, Khor El-Ramla, Gazal and Dirwa faults. The west-trending fault system predominates in the western part of the region where the faults cross the Sinn El-Kaddab scarp and plateau and locally extend into the Nubia plain. Two of these faults are Kalabsha fault and Seiyle fault [9]. Figure 2 shows the structure map also identifying the main faults.

Aswan Seismic Network consists of 13 remote stations distributed around the northern part of the Aswan High Dam Lake, 11 of them are distributed around the active faults in the area. They are located at the western side of the lake while the rest of them are located at the eastern side. They are mainly used to control the extension of the E-W Kalabsha active fault [10,11].

Table 1: coordinates of Aswan Seismic Network stations

STN.	LAT.	LON.	ELV.
1 AHD	23.746	32.750	0.222
2 SKD	23.659	32.384	0.270
3 NMR	23.678	32.542	0.200
4 GMR	23.539	32.537	0.274
5 WKL	23.417	32.447	0.203
6 WAL	23.380	32.582	0.187
7 GAL	23.433	32.833	0.278
8 KUR	23.894	32.773	0.190
9 KSR	23.616	32.050	0.260
10 GRW	23.646	32.810	0.260
11 MAN	23.931	32.933	0.195
12 KRL	23.660	32.710	0.185
13 NAL	23.410	32.678	0.200

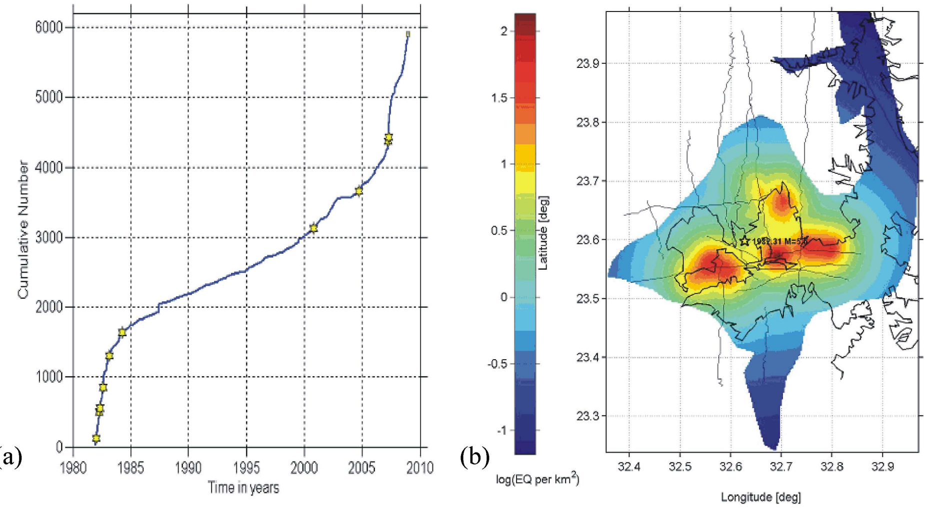

Fig. 3: a) Smoothed graph of cumulative number versus time b) Density of the earthquake distributions in the area.

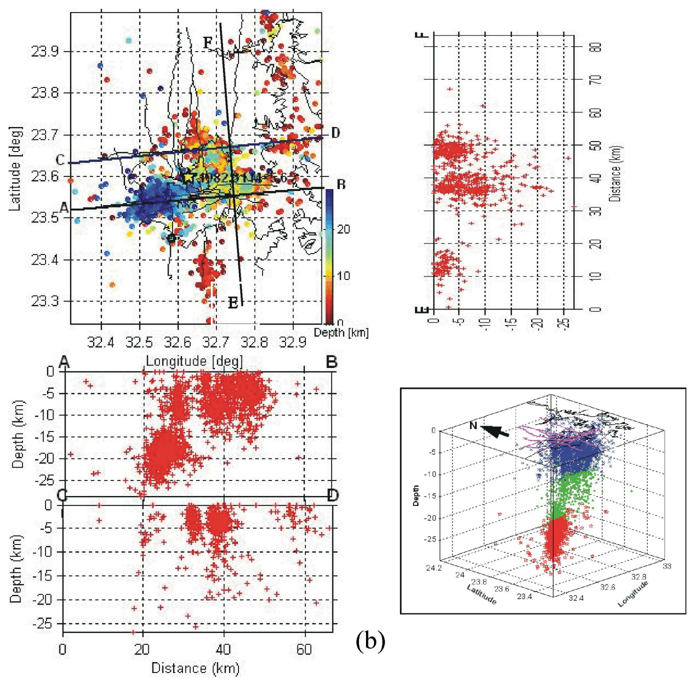

Fig. 4: a) Cross section along Kalabsha fault (a-b), Seiyal fault (c-d) and Kukur fault (e-f), b) Seismicity map in 3d view.

Data acquisition and analysis were carried out in the center located at Aswan Seismological data Center, (Figure 2 and Table 1). The arrival times were measured as a part of routine processing of Aswan Seismological data Center.

Seismicity of Aswan Area: The seismicity at Aswan has been confined mainly to the Wadi Kalabsha area, a larger embayment west of the reservoir which started to fill only after the water level of the reservoir exceeded 165 meters in 1974. The topography of embayment is controlled by the Kalabsha fault. Kalabsha fault is a major E-W right lateral strik-slip fault that intersects the reservoir at about 60 km south of Aswan High Dam. Figure 3a shows a smoothed graph of cumulative number versus time and figure 3b illustrates the density of the earthquake distributions in the area. The most of hypocenters is concentrated in the eastern part, middle part and western part of Kalabsha fault and in the eastern part of the Seiyal fault. Figure 4 shows the cross section along Kalabsha fault, Seiyal fault and Kukur fault.

East Kalabsha Fault Seismic Zone: This zone lies to the Eastern side of the Kalabsha fault. It represents the activity aligned along the Kalabsha fault trend. The zone is composed of separated clusters nearly of an east west trend. This activity is characterized by a hypocenter depths less than 9 Km.

Middle Kalabsha Fault Seismic Zone: This zone lies in middle part of Kalabsha fault. This activity is characterized by a hypocenter depths less than 10 km.

West Kalabsha Fault Seismic Zone: Seismicity of this zone is concentrated in and around the Gabal Marawa (GMR) telemetered station on the most active Kalabsha fault. It is characterized by the highest seismic activity. The seismicity is clustered along NE-SW lineament.The seismicity at this zone is almost concentrated at depth between 15 and 30 km.

East Seiyal Fault Seismic Zone: The forth zone is located east of the Seiyal fault and south of Kurkur fault, where the two faults sets intersected. The seismicity at this zone is almost concentrated at depth between 1 and 10 km.

Data: Earthquake data routinely determined by Aswan seismic network in the period from January 1982 to December 1999 are used in the analysis. Using the initial P-wave reading observed at seven or more stations among 13 stations. The total number of earthquakes was 343 earthquakes. The distribution of earthquakes in this study has been shown in Figure 6.

The initial velocity model is the laterally homogeneous model used by Aswan Seismic Network, for routine hypocentral locations is that 5.14, 6.0, 6.8, 7.3 and 8.1 Km/s and its thickness are 1, 4, 10.5 and 16.5 Km. respectively.. The results of routine work processing were used as initial hypocenteral coordinates and origin times.

Joint Hypocenter Determination (JHD) Method: Generally the calculation of the travel times by JHD for local earthquakes. are based on an assumed crustal structure consisting of flat lying constant velocity. It is notice that the ray path of first arriving P-wave from a hypocenter can follow one of two possible types of paths, either refract or direct. Furthermore different ray paths for any given distance and depth are possible. Thus, all possible travel paths would be exhaustively checked to obtain the minimum path for an arbitrary velocity thickness.

Consequently, if the rough epicenter location, depth, origin times of seismic events are known, the equation of condition for calculating the corrections to these approximates values are [12].

$$dTij = To - Tc = \frac{\partial \text{ Tij}}{\partial \text{ xi}} dxi + \frac{\partial \text{ Tij}}{\partial \text{ yi}} dyi + \frac{\partial \text{ Tij}}{\partial \text{ zi}} dzi + dti + dsj \quad (1)$$

I= 1........q, j= 1......p

whereas

dTij = To-Tc = The travel time residual for the i-th event at j-th station

$\frac{\partial \text{ Tij}}{\partial \text{ xi}}, \frac{\partial \text{ Tij}}{\partial \text{ yi}}, \frac{\partial \text{ Tij}}{\partial \text{ zi}}$ = Coefficients obtained from travel time table

dx,dy,dz = Corrections to the hypocenter in Cartesian coordinate x, y, z.

dt_i = The correction to the initial origin time for the i-th event

ds_i = The correction to the station travel time correction at j-th station

This equation can be written in a compact matrix as follows:

$$\Delta T = A\ \Delta X \quad (2)$$

ΔT = the vector of observed-calculated (o-c) residuals based on approximate solution

A = coefficient matrix

ΔX = the solution vector containing the aggregate of hypocenters and station time correction.

All the solution of the equations in this study are obtained by means of the iteration of the least square method.

Station Corrections Estimated Using JHD: The P-wave station corrections determined from the JHD inversion show a consistent and clear pattern of positive and negative values associated with the SW and NE part of the study area (Figures 5). For the SW and NE part stations, all corrections are positive. On the contrary, the E and W part stations have negative corrections.

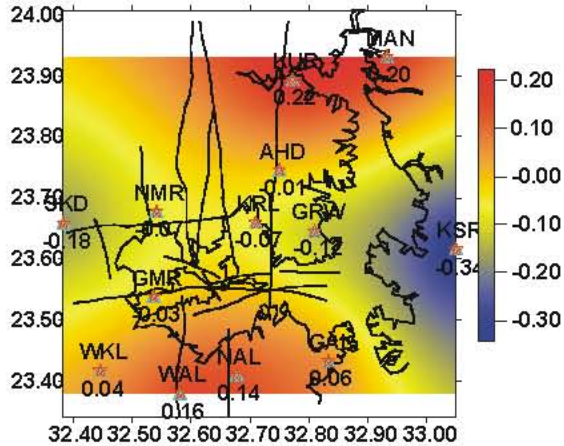

Fig. 5: Stations correction values for P-wave

Table 2: P-wave travel time and distance corrections

STN	PSC	DSC	MEAN	STD	STD²	N
1 AHD	-0.009	0.035	0.140	0.273	0.547	293
2 SKD	-0.178	0.055	-0.084	0.298	0.596	188
3 NMR	-0.070	0.057	0.060	0.348	0.696	258
4 GMR	-0.027	0.047	0.040	0.349	0.697	121
5 WKL	0.038	0.031	0.167	0.304	0.609	253
6 WAL	0.158	0.036	0.340	0.303	0.605	236
7 GAL	0.065	0.064	0.184	0.410	0.821	189
8 KUR	0.219	0.044	0.398	0.322	0.643	215
9 KSR	-0.344	0.047	-0.370	0.092	0.184	173
10 GRW	-0.123	0.043	0.008	0.411	0.822	165
11 MAN	0.197	0.043	0.323	0.366	0.731	116
12 KRL	-0.067	0.050	0.085	0.199	0.399	259
13 NAL	0.140	0.050	0.312	0.190	0.380	230
SUM= 0.000						NEQ= 343

Whereas

stn = Station name

psc = P-wave travel time station correction

dsc = distance station correction

std = slandered deviation

N = number of earthquake recorded by station

NEQ = total number of earthquake.

The station corrections vary from 0.219 to-0.344 sec for the P-waves. A positive (negative) station correction indicates that the observed travel time is larger (smaller) than that calculated from a given velocity model, suggesting that the actual velocity structure is lower (higher) than given velocity model used in earthquake location. Therefore, patterns of station corrections suggest that the SW and NE parts of the study area are characterized by low velocity, while relatively higher velocities characterize the E and W parts of the study area.

RESULTS AND DISCUSSION

The 14 November 1981 Aswan earthquake ($M = 5.7$) occurred along the east-west Kalabsha fault, which is a major trend in the northern part of the Lake Aswan in Egypt. Its hypocenter was located at 20 km depth [8].

Hassoup *et al.* [13] analyzed the characteristics of seismicity observed from 1982 to 2004 along the Kalabsha and Rawraw faults and the correlation between the temporal variation of seismicity and the water level changes in the Lake Aswan are. His results indicate that the earthquakes in the deep seismic zone along the Kalabsha fault are characterized by a relatively low *b*-values and show greater degree of clustering than the shallow events.

The earthquake location method known as the Joint Hypocenter Determination (JHD) technique has been applied to many data sets from different tectonic settings including, but not limited to, the Aegean Sea, Greece, Dimitriadis *et al.* [14], Loma Prieta California mainshock-aftershock sequence, Pujol [15] and the Subducting oceanic crusts of the Philippine Sea and Pacific plates in the Kanto district, Japan, Hurukawa and Imoto [11].

Most previous studies of earthquake relocation using the JHD technique have produced significantly improved relative and even absolute earthquake locations. The JHD technique produces two important outcomes: improved earthquake parameters (hypocenters and origin times) and station corrections.

The results obtained from joint hypocenter determination method are shown in table 2 and figure 5. Seven stations AHD, SKD, NMR, GMR, KSR,GRW and KRL have minus signs in station P-wave travel time corrections and their values-0.009,-0.178,-0.070,-0.027,-0.344,-0.123, and-0.067, respectively. This means that seismic signal from hypocenter takes a bit short time to reach the station then to make correction in travel time, we should add this value before computation; it is possible to assume that the underground structure in the study area has a particular characteristic of high velocity structure and structure and other stations WKL, WAL, GAL, KUR, MAN and NAL have positive sign and their values 0.038, 0.158, 0.065, 0.219, 0.197 and 0.057, respectively. This means that seismic signal from hypocenter takes a bit more time to reach the station then to make correction in travel time, we should subtract these values before computation; it is possible to assume that underground structure in this area has particular characteristic of low velocity structure. As shown in the figure 5.

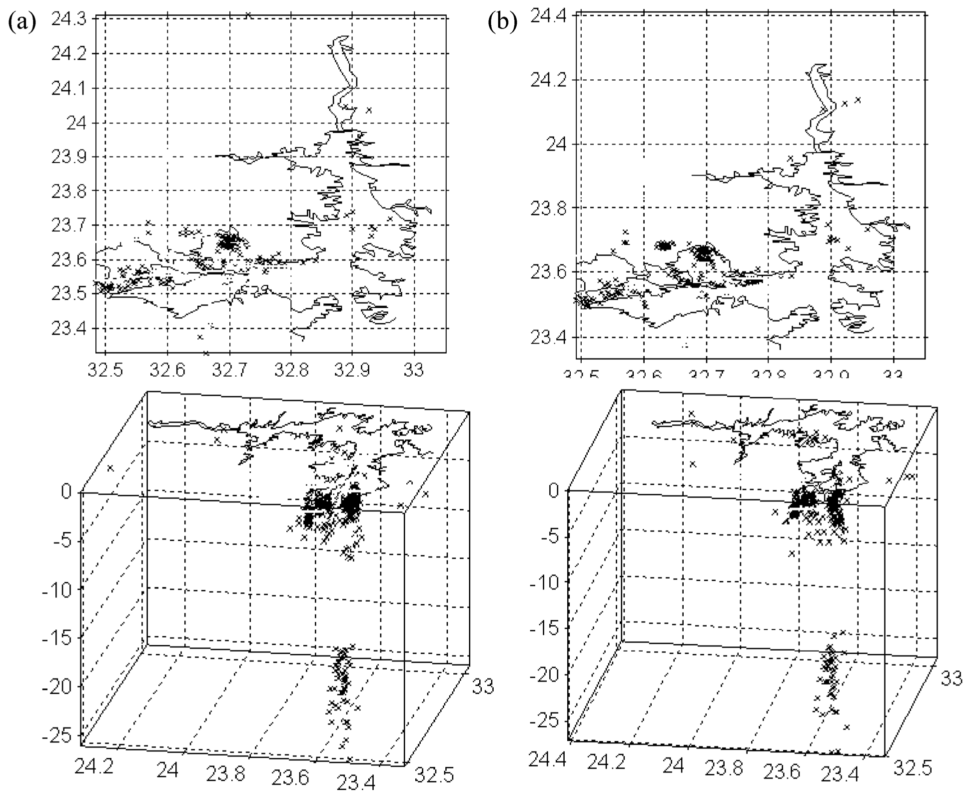

Fig. 6: a) Earthquake Hypocenters b) Relocated hypocenters (map view and 3-D view)

The station corrections obtained correlate with the major surface geological features in the study area.

Figure 6 illustrates the comparison between earthquake hypocenters location before (a) and after (b) using the joint hypocenter determination method in plane view and three dimensional views

CONCLUSION

The present paper aimed to relocate Earthquake hypocenters in the Kalabsha area by joint hypocenter determination method and to estimate the seismic Stations Correction of the Aswan seismic network which is consisted of 13 seismic stations distributed around the northern part of the Aswan High dam lake. Seven stations AHD, SKD, NMR, GMR, KSR, GRW and KRL have minus signs in station P-wave travel time corrections and their values-0.009,-0.178,-0.070,-0.027,-0.344,-0.123,and-0.067, respectively. It is possible to assume that the underground structure in this area has a particular characteristic of high velocity structure and structure and other stations WKL, WAL, GAL, KUR, MAN and NAL have positive sign and their values 0.038, 0.158, 0.065, 0.219, 0.197 and 0.057 respectively.. It is possible to assume that underground structure in this area has particular characteristic of low velocity structure. The hypocenter location determined by the joint hypocenter determination method is more precise than those determined by HYPO71PC program. The method simultaneously solves for earthquake location and station corrections. The station corrections reflect not only different crustal condition in the vicinity of the stations, but also the difference between actual and model seismic velocities along each of the earthquake-station ray paths

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