Local magnitude, duration magnitude and seismic moment of Dahshour 1992 earthquakes

Mohamed M. Dessokey ([1]), Hesham M. Hussein ([1]), El-Sayed M. Abdelrahman ([2]) and Mohamed F. Abdelwahed ([1])

([1]) *National Research Institute of Astronomy and Geophysics (NRIAG), Seismology Department, Helwan, Cairo, Egypt*

([2]) *Cairo University, Faculty of Sciences, Geophysics Department, Cairo, Egypt*

Abstract

Local magnitudes M_L have been calculated for 56 earthquakes of the Dahshour 1992 sequence using simulated records of the KEG broadband station and the estimated calibration function of the Dahshour area. These were compared with their corresponding values of duration magnitudes obtained from the analog short period seismograms of the HLW station. The local magnitudes M_L and the duration magnitudes M_D for this region imply a linear relation as follows: $M_L = 1.2988\ (\pm 0.04)\ M_D - 0.9032\ (\pm 0.14)$. Seismic moment has also been estimated for these events using simple measurements from the time domain records. These measurements based on the simulated Wood Anderson seismograms are used for the local magnitude (M_L) estimation. The derived relationship between seismic moment (M_0) and magnitude (M_L) is: $\log(M_0) = 0.954(\pm 0.019)\ M_L + 17.258(\pm 0.075)$.

Key words *Dahshour 1992 earthquake – local magnitude – moment*

1. Introduction

On October 12th 1992 at 15:10 (GMT), an earthquake of 5.3 duration magnitude (M_D(HLW)) hit the region of Dahshour 25 km southwest of Cairo city. Figure 1 shows the location of this event. This event was strongly felt all over Egypt from Alexandria to Aswan producing a lot of damage especially in the Cairo area. A review of the historical seismicity catalogue indicates that a strong event hit the same area in August 1847. A large number of aftershocks (fig. 2) for Dahshour earthquake were recorded by the nearest VBB station of the MEDNET network (KEG station). The KEG station (fig. 1) has been fully operative since 1989. The main purpose of this study is to derive appropriate empirical relations between local magnitude, duration magnitude and seismic moment for earthquakes which occurred in this region using 56 waveform data recorded by the VBB station of Kottamiya (KEG) of the MEDNET network.

Mailing address: Dr. Mohamed M. Dessokey, National Research Institute of Astronomy and Geophysics (NRIAG), Seismology Department, P.O. Box 70, Helwan 11421, Cairo, Egypt.

2. Analysis

In this study, local magnitudes and moments were calculated for 56 Dahshour 1992 earthquakes in the period from 12th to 30th of October 1992 using Kottamiya (KEG) very broadband station records. These parameters were

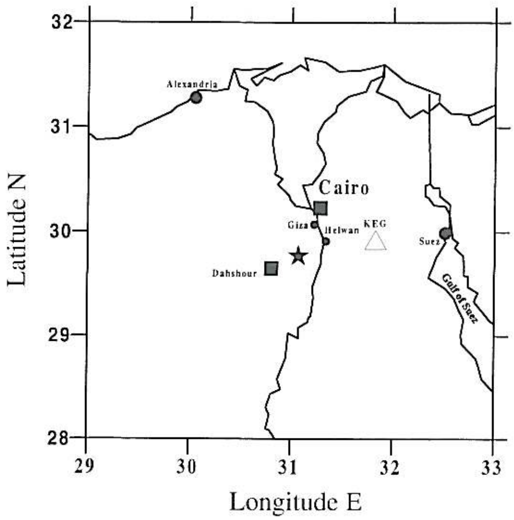

Fig. 1. Location map of Dahshour mainshock (star). Triangle represents KEG seismic station.

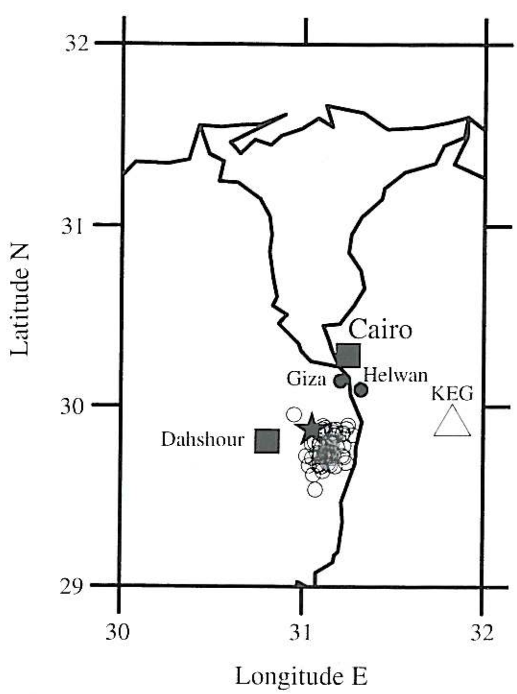

Fig. 2. Epicentral map of selected Dahshour earthquakes 1992 (circles). Star represents the main shock.

estimated using the trace amplitudes of the simulated Wood-Anderson seismograms. The details will be discussed as follows.

2.1. *Local magnitude*

Finding a precise magnitude scale for local earthquakes is considered one of the most important problems facing seismologists. Richter (1935) developed the first magnitude scale, which is considered one of the most important contributions to characterize an earthquake according to its radiated seismic wave energy. He calibrated this magnitude scale by measuring the maximum amplitude of shear waves of Wood Anderson seismograms for earthquakes in the Southern California region. The local magnitude M_L is the base 10 logarithm of the average maximum amplitude (A) in millimeters measured from the two horizontal components of the Wood Anderson at a given epicentral distance plus a correction factor $\log(A_0)$ for distance from source to receivers. Therefore, the general local magnitude formula is

$$M_L = \log(A) - \log(A_0). \qquad (2.1)$$

The calibration function $\log(A_0)$ was estimated by plotting the maximum recorded amplitude against epicentral distance for a number of stations. Richter (1935) calculated this factor for the South California region where M_L is to be estimated. Local magnitudes were calculated for the 56 events by transforming the S wave displacement spectrum from a horizontal component seismogram by convoluting it with the theoretical response of a Wood Anderson seismometer. This Wood Anderson spectrum will be transformed back to the time domain. The record in this way represents a Wood Anderson seismogram. M_L was obtained by measuring the maximum trace amplitude on these simulated Wood Anderson seismographs plus the amplitude distance correction ($-\log(A_0)$).

Determination of a new calibration function ($-\log(A_0)$) in our case by direct measurement of the maximum recorded amplitudes of the Wood Anderson records at different stations having different epicentral distances was not possible due to the lack of stations in this region. Therefore, an indirect method must be used for the estimation of this function.

M_L scale is defined such that a magnitude zero earthquake ($M_L = 0$) which is recorded on a Wood Anderson seismometer with a trace amplitude 1 μm and at a distance of 100 km. This means that the value of $\log(A_0)$ will be given as follows:

$$\log(A_0) = \log(A_r) - \log(A_{100}) \qquad (2.2)$$

where, A_{100} is the maximum trace amplitude at distance 100 km from the source and A_r is the amplitude at a certain distance (r).

Following Nuttli (1973), the amplitude A of the Lg phase changes with epicentral distance r by the following relation:

$$A \alpha r^{-5/6} e^{-\gamma r} \qquad (2.3)$$

where γ is the anelastic attenuation coefficient.

Taking the attenuation relation into consideration and using the same procedure as Kiratzi and Papazachos (1984) we obtained the following relation:

$$-\log(A_0) = \frac{5}{6}\log\left(\frac{r}{100}\right) + \qquad (2.4)$$
$$+\gamma(r-100)\log(e).$$

The anelastic attenuation coefficient (γ) was estimated by regression analysis of intensity relative to distance using the formula obtained by Howell and Schultz (1975) as

$$\ln(I) = \ln(I_0) + a - b\ln(\Delta) - c\Delta \qquad (2.5)$$

where, I_0 is the intensity at the source, Δ is the epicentral distance, a is a term related to the boundary condition of the source, b is a coefficient defines the rate of the geometrical spreading of energy and c is a coefficient defines the rate of exponential absorption.

A cross section (A-A′) was made along the intensity lines of the main shock of October 12, 1992 sequence passing through the KEG station and the epicenter (fig. 3). Figure 4 shows the intensity-distance graph presentation and its corresponding mathematical fitting. This yields the following equation:

$$\ln(I) = 2.263 - 0.167\ln(\Delta) - 0.0003\Delta. \qquad (2.6a)$$

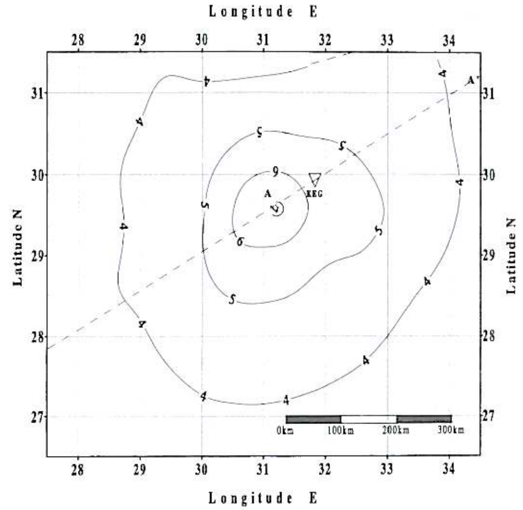

Fig. 3. Isoseismal map of Dahshour earthquake (Megahed, 1995), showing the profile A-A′ passing through the KEG station.

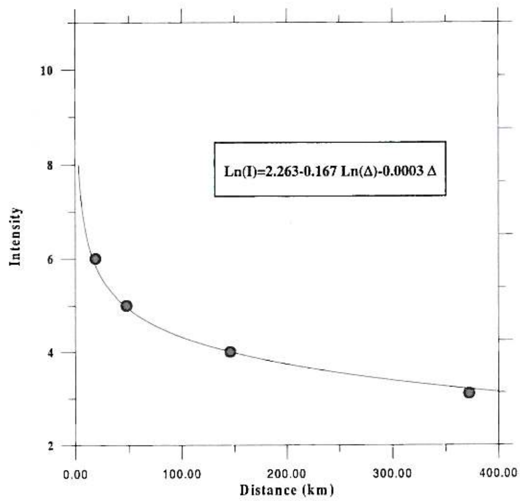

Fig. 4. Mathematical fitting of intensity values along the profile A-A′. Solid circles represents the actual intensity values.

From eqs. (2.5) and (2.6a), the values a, b and c can be evaluated as

$$(\ln(I_0)+a) = 2.263$$

$$b = -0.167$$

$$c = 0.0003.$$

Substituting b and c values in the next equation of Howell and Schultz (1975) we obtained the value of γ as follows:

$$\gamma = \frac{5}{6}\cdot\frac{c}{b} = 0.001497 \text{ km}^{-1} \qquad (2.6b)$$

Therefore, the final formula for local magnitude estimation becomes

$$M_L = \log(A) + \frac{5}{6}\log\left(\frac{r}{100}\right) + \qquad (2.7)$$
$$+0.0015(r-100)\log(e)+3.$$

The number 3 is in this equation because the trace amplitude is always in millimeters but the trace amplitude in the definition of local magnitude requires the trace amplitude in microns. Using the last equation and the simulated digital records of the KEG station, 56 local magnitude values of Dahshour earthquake sequence were obtained. Table I shows the results of the local magnitude estimation.

2.2. *Duration magnitude*

Duration magnitude of some events of this sequence obtained from the analog short period records of the HLW station is plotted relative to M_L (fig. 5). The duration magnitude is estimated from the relation (Lee *et al.*, 1972)

$$M_D(\text{HLW}) = 2.0\log(D) + 0.0035\Delta - 0.87. \quad (2.8)$$

Due to the interference of earthquakes in the first few days of this sequence it is very difficult to obtain the duration magnitude for some events. M_L is related to M_D(HLW) by the following relation:

$$M_L = 1.282\ (\pm\ 0.04)\ M_D(\text{HLW}) - 0.804\ (\pm\ 0.12). \quad (2.9)$$

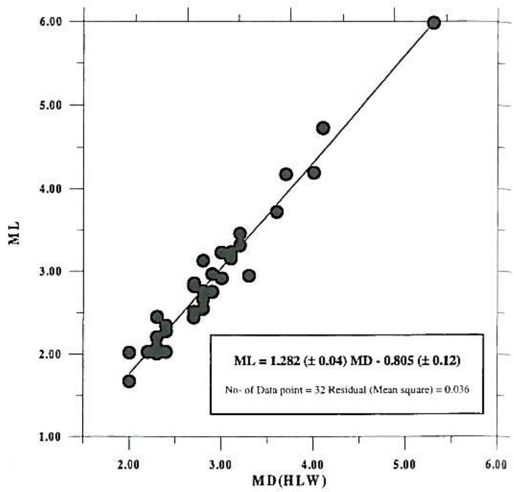

Fig. 5. M_L *versus* M_D for Dahshour earthquake sequence. The above equation represents the linear regression fit of the data.

Table II shows the duration and local magnitude for the events of this sequence.

2.3. *Seismic moment*

In this study, the seismic moment was estimated directly from the records of the simulated Wood Anderson seismograms using Bolt and Herriaz (1983) method. The following relation was used:

$$\log(M_0(\varphi)) = a + b\log(\varphi), \qquad (2.10)$$

where,

$$\varphi = C.D.\Delta^P$$

where, C is the maximum peak to peak amplitude in millimeters, D is the duration between S arrival in seconds and the onset of the amplitude $C/3$, Δ is the epicenter distance in kilometers and a, b, P are constants. The appropriate values of P was found to be 1. Figure 6 shows the parameters C, $C/3$, D for Dahshour mainshock.

The value of φ estimated in this way for the 56 records were plotted against the seismic moment calculated independently by the spec-

Table I. M_L values of the selected Dahshour earthquakes and their required parameters obtained from the simulated W.A. records as the result of the present study.

No.	Δ (km)	A_N (mm)	A_E (mm)	Log A	$-\text{Log } A_0+3$	M_L
1	82.00	1241.200	983.850	3.05	2.934	5.90
2	60.30	0.580	0.490	−0.27	2.848	2.60
3	69.30	0.200	0.380	−0.54	2.899	2.40
4	84.50	0.750	0.780	−0.12	2.948	2.80
5	56.90	0.130	0.106	−0.93	2.822	1.90
6	69.20	0.340	0.290	−0.50	2.885	2.40
7	69.30	65.200	78.500	1.86	2.872	4.70
8	64.60	0.260	0.290	−0.56	2.858	2.30
9	63.10	0.430	0.300	−0.44	2.862	2.40
10	65.90	0.290	0.230	−0.59	2.869	2.30
11	59.10	0.240	0.270	−0.59	2.842	2.30
12	78.50	18.690	17.200	1.25	2.920	4.20
13	63.10	0.510	0.380	−0.35	2.862	2.50
14	55.90	0.840	0.860	−0.07	2.824	2.80
15	66.70	0.200	0.200	−0.70	2.880	2.20
16	62.70	8.980	5.700	0.87	2.853	3.70
17	59.60	1.760	3.060	0.38	2.844	3.20
18	68.40	0.240	0.240	−0.62	2.881	2.30
19	64.80	0.810	0.970	−0.05	2.864	2.80
20	71.80	0.900	0.690	−0.10	2.902	2.80
21	81.30	16.770	19.200	1.25	2.936	4.20
22	69.30	0.120	0.130	−0.90	2.891	2.00
23	74.10	1.260	1.120	0.08	2.903	3.00
24	64.10	2.520	2.620	0.41	2.860	3.30
25	62.90	0.480	0.300	−0.41	2.861	2.50
26	72.50	1.120	1.180	0.06	2.900	3.00
27	65.50	0.250	0.340	−0.53	2.858	2.30
28	67.00	0.140	0.130	−0.87	2.875	2.00
29	72.40	0.160	0.110	−0.87	2.896	2.00
30	76.60	1.210	0.900	0.02	2.917	2.90
31	72.80	1.900	1.390	0.22	2.906	3.10
32	68.50	0.370	0.350	−0.44	2.888	2.40
33	69.70	0.145	0.160	−0.82	2.893	2.10
34	70.40	1.110	0.950	0.01	2.896	2.90
35	62.60	0.600	0.670	−0.20	2.853	2.70
36	69.00	0.225	0.260	−0.62	2.890	2.30
37	75.70	1.190	1.360	0.11	2.918	3.00
38	68.00	1.870	2.480	0.34	2.886	3.20
39	85.00	0.054	0.050	−1.28	2.950	1.70
40	71.10	0.159	0.108	−0.87	2.899	2.00
41	71.70	2.150	1.377	0.25	2.902	3.20
42	64.10	0.160	0.130	−0.84	2.855	2.00
43	81.70	3.750	2.740	0.51	2.941	3.50
44	76.20	54.850	45.820	1.70	2.916	4.60
45	74.40	0.207	0.188	−0.70	2.908	2.20
46	75.20	2.700	2.470	0.41	2.916	3.30
47	71.10	0.080	0.060	−1.15	2.894	1.70
48	69.20	0.880	0.940	−0.04	2.891	2.90
49	76.30	0.698	0.656	−0.17	2.916	2.80
50	76.40	0.330	0.200	−0.58	2.921	2.30
51	71.80	2.120	1.880	0.30	2.897	3.20
52	69.90	2.530	2.800	0.43	2.884	3.30
53	76.20	0.337	0.337	−0.47	2.920	2.50
54	81.70	0.440	0.360	−0.40	2.941	2.50
55	54.30	0.600	0.410	−0.30	2.806	2.50
56	77.10	0.820	0.600	−0.15	2.913	2.80

Table II. The duration magnitude values of Dahshour earthquakes recorded by HLW station and their corresponding local magnitude values.

No.	Date Y M D	Origin time H M S	Distance (km)	Duration (s)	M_D (HLW)	M_L
1	921012	13 9 55.87	38.6	1040	5.3	5.90
2	921012	1350 9.65				2.60
3	921012	1411 8.64				2.40
4	921012	1415 7.43				2.80
5	921012	1458 14.73	9.8			1.90
6	921012	15 7 42.05	22.4			2.40
7	921012	1525 24.65	22.1	279	4.1	4.70
8	921012	1552 50.77	17			2.30
9	921012	1655 9.79	15.4			2.40
10	921012	1831 42.36	18.5			2.30
11	921012	1955 59.20	11.5			2.30
12	921012	2131 34.22	32	169	3.7	4.20
13	921012	2146 16.02	18	57	2.7	2.50
14	921012	2334 22.50	9.6	65	2.8	2.80
15	921012	2346 24.42	20.9			2.20
16	921013	18 9 8.14	15.4	161	3.6	3.70
17	921013	1834 54.26	11.9	92	3.1	3.20
18	921013	2327 56.39	21.3	37	2.36	2.30
19	921014	244 23.14	17.5	56	2.7	2.80
20	921014	350 14.53	24.4			2.80
21	921014	940 27.04	34.3	237	4	4.20
22	921014	1041 57.34	22			2.00
23	921014	12 9 15.72	27.8	34	2.3	3.00
24	921014	1346 39.47	16.4			3.30
25	921014	1423 44.67	21.4			2.50
26	921014	1431 27.90	26.4	69	2.9	3.00
27	921014	2016 11.05	17.8	45	2.5	2.30
28	921015	1213 41.41	19.4	35	2.3	2.00
29	921016	328 51.46			2.4	2.00
30	921016	556 11.84	29.6	108	3.3	2.90
31	921016	957 46.87	25.3	62	2.8	3.10
32	921016	18 7 53.12			2.7	2.40
33	921017	135 28.51	23	35	2.3	2.10
34	921018	812 16.12	24.6	78	3	2.90
35	921018	13 4 28.44	18.9	63	2.8	2.70
36	921019	1046 30.95	24	39	2.4	2.30
37	921019	1230 16.44	31.2	85	3.1	3.00
38	921019	1459 50.43	21.7	79	3	3.20
39	921020	6 0 30.77	44			1.70
40	921020	1728 28.44	27.4	30	2.2	2.00
41	921020	2314 47.46	25.9	87	3.1	3.20
42	921021	18 9 27.53	17.5			2.00
43	921022	828 58.70	36	94	3.2	3.50
44	921022	1738 57.30	31.2			4.60
45	921023	240 5.43	27.7	34	2.3	2.20
46	921023	1512 10.08	28.3			3.30
47	921023	16 2 4.12	24.5			1.70
48	921025	9 5 4.64	26.3	55	2.7	2.90
49	921025	1226 15.06	31.7	68	2.9	2.80
50	921025	1621 5.28	32.9	38	2.4	2.30
51	921025	1945 34.56	27.4			3.20
52	921026	645 23.96	22.6	99	3.2	3.30
53	921026	843 52.01	31.2	34	2.3	2.50
54	921028	620 54.90	37.8	59	2.8	2.50
55	921028	1825 56.28	6.6	50	2.55	2.50
56	921030	14 8 11.19	31.9			2.80

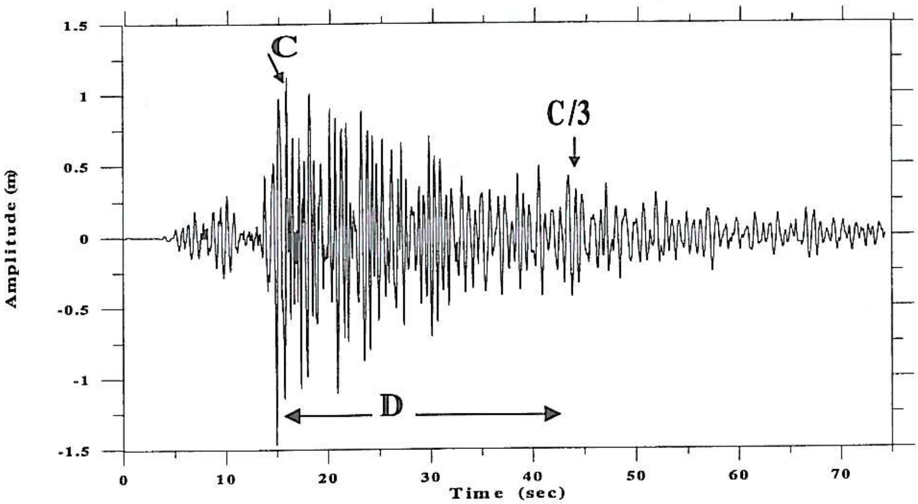

Fig. 6. Simulated W.A. record of Dahshour mainshock with illustration of measured parameters (C, $C/3$, D).

tral analysis technique (Abdelwahed, 1998). The least square fitting between φ and the values of seismic moment for the 56 events are shown in fig. 7 and yielded the following relation:

$$\log(M_0(\varphi)) = 0.928\ (\pm 0.03)\ \log(\varphi) + 17.992\ (\pm 0.067). \quad (2.11)$$

The values of $M_0(\varphi)$ with their corresponding φ parameters are shown in table III. The relation between $\log(M_0(\varphi))$ and M_L (fig. 8) was also determined. The results of the best fit with their standard errors are given as follows:

$$\log(M_0(\varphi)) = 0.954\ (\pm 0.026)\ M_L + 17.258\ (\pm 0.075) \quad (2.12)$$

$$1.7 \le M_L \le 5.9.$$

The moment magnitude relation is very close to the following equation obtained by Kim *et al.* (1989) for earthquakes in the Baltic shield:

$$\text{Log}(M_0) = 1.01(\pm 0.03)\ M_L + 16.99\ (\pm 0.09) \quad (2.13)$$

$$2 \le M_L \le 5.2.$$

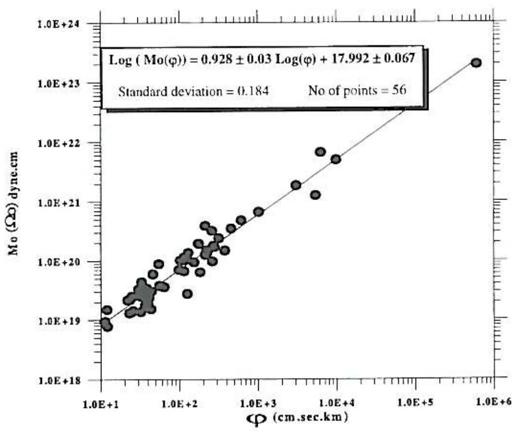

Fig. 7. Seismic moment $M_0(\Omega_0)$ *versus* φ. The above equation represents a linear regression fit to the data. $M_0(\Omega_0)$ is the moment calculated using the spectral analysis technique.

3. Conclusions

The final result of this study concerning the local magnitude calculations M_L and moment M_0 using the simulated Wood Anderson seismogram for the records of Dahshour region (NW

Table III. Resulting $M_0(\varphi)$ with their required φ parameters and corresponding $M_0(\Omega_0)$.

No.	Δ (km)	M_L	C (cm)	c (cm)	C/c	Duration (s)	φ (cm s km)	$M_0(\varphi)\cdot 10^{20}$ (dyne·cm)	$M_0(\Omega_0)\cdot 10^{20}$ (dyne·cm)
1	82.0	5.90	261	91	2.87	28.30	605676.6	2175.70	1690.00
2	60.3	2.60	0.103	0.0368	2.80	14.50	183.6135	1.11	0.57
3	69.3	2.40	0.078	0.03	2.60	11.80	63.78371	0.41	0.32
4	84.5	2.80	0.15	0.0466	3.22	8.15	103.3012	0.65	0.87
5	56.9	1.90	0.02	0.008	2.52	10.50	11.949	0.09	0.14
6	69.2	2.40	0.0626	0.0195	3.21	5.70	24.69194	0.17	0.22
7	69.3	4.70	13	4.5	2.89	10.95	9864.854	46.27	43.90
8	64.6	2.30	0.0445	0.0115	3.87	13.35	38.37725	0.26	0.31
9	63.1	2.40	0.0792	0.0231	3.43	6.70	33.48338	0.23	0.29
10	65.9	2.30	0.0519	0.0154	3.37	12.00	41.04252	0.27	0.21
11	59.1	2.30	0.0427	0.0143	2.99	9.30	23.4692	0.16	0.20
12	78.5	4.20	3.54	1.07	3.31	11.00	3056.79	15.47	16.20
13	63.1	2.50	0.0983	0.033	2.98	5.35	33.1846	0.23	0.39
14	55.9	2.80	0.154	0.0498	3.09	6.40	55.09504	0.36	0.80
15	66.7	2.20	0.0385	0.0133	2.89	11.80	30.30181	0.21	0.30
16	62.7	3.70	1.64	0.576	2.85	9.95	1023.139	5.56	5.96
17	59.6	3.20	0.317	0.108	2.94	14.40	272.0621	1.61	1.60
18	68.4	2.30	0.045	0.0146	3.08	10.50	32.319	0.22	0.23
19	64.8	2.80	0.148	0.0512	2.89	12.15	116.5234	0.73	0.92
20	71.8	2.80	0.17	0.0518	3.28	9.45	115.3467	0.72	1.01
21	81.3	4.20	3.09	1.07	2.89	21.40	5376.044	26.23	10.90
22	69.3	2.00	0.0231	0.0072	3.19	16.15	25.85341	0.18	0.13
23	74.1	3.00	0.233	0.0687	3.39	8.85	152.7979	0.94	0.82
24	64.1	3.30	0.463	0.203	2.28	8.75	259.6851	1.54	2.84
25	62.9	2.50	0.0959	0.0294	3.26	9.30	56.09863	0.37	0.34
26	72.5	3.00	0.205	0.0682	3.01	17.75	263.8094	1.56	0.85
27	65.5	2.30	0.0436	0.0163	2.67	15.50	44.2649	0.29	0.27
28	67	2.00	0.0254	0.0079	3.21	12.90	21.95322	0.15	0.19
29	72.4	2.00	0.0296	0.0123	2.41	10.80	23.14483	0.16	0.12
30	76.6	2.90	0.224	0.0696	3.22	13.20	226.4909	1.36	1.20
31	72.8	3.10	0.347	0.11	3.15	11.10	280.4038	1.66	1.50
32	68.5	2.40	0.0726	0.0247	2.94	12.40	61.66644	0.40	0.33
33	69.7	2.10	0.0305	0.0119	2.56	11.70	24.87244	0.17	0.12
34	70.4	2.90	0.218	0.0659	3.31	13.90	213.3261	1.28	1.11
35	62.6	2.70	0.11	0.0357	3.08	16.60	114.3076	0.72	0.60
36	69	2.30	0.0398	0.0134	2.97	12.00	32.9544	0.22	0.22
37	75.7	3.00	0.235	0.0668	3.52	12.45	221.4792	1.33	1.32
38	68	3.20	0.344	0.114	3.02	7.50	175.44	1.07	1.72
39	85	1.70	0.0108	0.004	2.73	13.15	12.0717	0.09	0.07
40	71.1	2.00	0.0288	0.0091	3.16	21.35	43.71797	0.29	0.14
41	71.7	3.20	0.436	0.104	4.19	12.15	379.8236	2.20	1.31
42	64.1	2.00	0.0311	0.0095	3.27	16.20	32.29486	0.22	0.12
43	81.7	3.50	0.678	0.255	2.66	11.15	617.6274	3.47	4.14
44	76.2	4.60	9.66	2.68	3.60	8.50	6256.782	13.30	57.90
45	74.4	2.20	0.0369	0.0118	3.13	13.40	36.78782	0.25	0.15
46	75.2	3.30	0.486	0.161	3.02	5.85	213.8011	1.29	3.39
47	71.1	1.70	0.0189	0.0065	2.91	8.35	11.22065	0.08	0.08
48	69.2	2.90	0.164	0.059	2.78	11.45	129.9438	0.81	1.20
49	76.3	2.80	0.146	0.0448	3.26	11.20	124.7658	0.78	1.07
50	76.4	2.30	0.0388	0.0136	2.85	13.50	40.01832	0.27	0.16
51	71.8	3.20	0.401	0.112	3.58	11.05	318.1494	1.86	2.10
52	69.9	3.30	0.527	0.172	3.06	12.50	460.4663	2.63	3.10
53	76.2	2.50	0.0602	0.02	3.01	8.20	37.61537	0.25	0.24
54	81.7	2.50	0.0756	0.0264	2.86	7.50	46.3239	0.31	0.52
55	54.3	2.50	0.109	0.0307	3.55	21.30	126.0683	0.78	0.25
56	77.1	2.80	0.151	0.046	3.28	8.55	99.53995	0.63	0.61

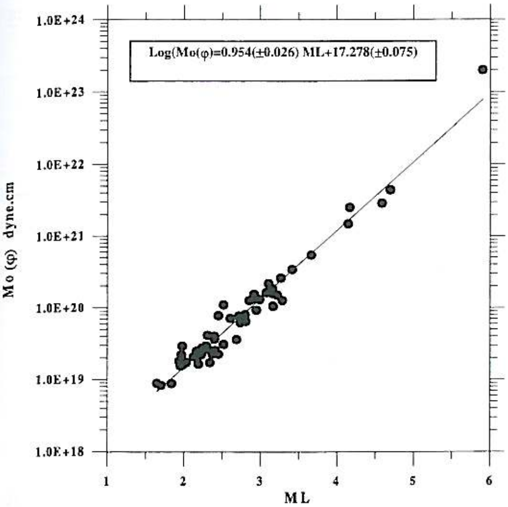

Fig. 8. $M_0(\varphi)$ *versus* M_L. The above equation represents the linear regression fit of the data.

Cairo) can be summarized as follows:

– M_L values were calculated from the Richter (1935) formula after the development of attenuation function ($-\log(A_0)$) suitable for this region using empirical calculation. We obtained the following relation:

$$-\log(A_0) = \frac{5}{6}\log\left(\frac{r}{100}\right) +$$

$$+0.0015(r-100)\log(e).$$

To determine the local magnitude we apply the following relation

$$M_L = \log(A) - \log(A_0) + 3$$

(A) is taken as the maximum trace amplitude in millimeters given from the simulated Wood Anderson seismometer. The '3' in the last equation was added to let the A value be measured in millimeters whereas, it has to be given in microns.

The duration magnitude was estimated for the respective earthquakes and its mathematical relation with M_L was found to be as follows:

$$M_L = 1.282(\pm 0.04)\, M_D(\text{HLW}) - 0.804(\pm 0.12).$$

The seismic moment (M_0) of Dahshour earthquakes was also estimated from the simulated Wood Anderson seismograms in the time domain using the method of Bolt and Herriaz (1983). Seismic moment of Dahshour earthquakes and M_L imply the following relation:

$$\log(M_0(\varphi)) = 0.954(\pm 0.026)$$

$$M_L + 17.258(\pm 0.075).$$

REFERENCES

ABDELWAHED, M.F. (1998): Seismological study of Dahshour earthquake source region using digital data analysis technique, *Thesis M.Sci.*, Fac. Sci., Cairo Univ., pp. 134.

BOLT, B.A. and M. HERRAIZ (1983): Simplified estimation of seismic moment from seismograms, *Bull. Seismol. Soc. Am.*, **73**, 735-748.

HOWELL, B.F. JR. and T.R. SCHULTZ (1975): Attenuation of modified Mercalli intensity with distance from the epicenter, *Bull. Seismol. Soc. Am.*, **65**, 651-665.

KIM, W.Y., R. WAHLSTROM and M. USKI (1989). Regional spectral scaling relations of source parameters for earthquakes in the Baltic shield, *Tectonophysics*, **166**, 151-161.

KIRATZI, A.A. and B.C. PAPAZACHOS (1984): Magnitude scales for earthquakes in Greece, *Bull. Seismol. Soc. Am.*, **74**, 969-985.

LEE, W.H., R.E. BENNETT and K.L. MEAGHER (1972): A method of estimating magnitude of local earthquakes from signal duration, *U.S. Geol. Surv.*, *Open-File Rep.*, pp. 28.

MEGAHED, M. ABD EL SAMED (1992): Preliminary studies on Dahshour earthquake (personal communication).

NUTTLI, O.W. (1973): Seismic wave attenuation and magnitude relation for Eastern North America, *J. Geophys. Res.*, **78**, 876-855.

RICHTER, C.F. (1935): An instrumental earthquake magnitude scale, *Bull. Seismol. Soc. Am.*, **25**, 1-32.

(received January 4, 1999;
accepted July 19, 1999)