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TIME AND MAGNITUDE DISTRIBUTION OF THE JANUARY-MAY 1983 SEISMIC SEQUENCE IN THE CEPHALONIA ISLAND OF IONIAN SEA

By

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Abstract: *The magnitude and time distribution of the aftershock sequence which occurred off the southwestern coasts of the Cephalonia island between January and May 1983, is investigated. The time-distribution of the frequency of aftershocks follows the well known decay law with a value equal to 0.94 for the parameter p of this law. The magnitude-frequency relation holds also for the present case, with a b-value equal to 1.01.*

1. INTRODUCTION

On January 17, 1983 (12h 41m 31s) an earthquake of surface wave magnitude equal to 7.0 occurred in the Ionian sea, at a distance of about 40 Km off the southwestern coasts of Cephalonia island. This shock was followed by numerous aftershocks, the largest of which occurred on March 23, 1983 with a surface wave magnitude equal to 6.2. Although the largest aftershock was smaller than the main shock, it was felt in Cephalonia island with a maximum observed intensity VII, while the main shock was felt with a maximum observed intensity equal to VI.

The seismogenic volume of this main shock is part of a well defined seismic zone (Papazachos 1980). The epicenter of the main shock (37.96 N, 20.26 E) was located at a region which has been considered as a seismic gap of the second kind (Papadimitriou and Papazachos 1982).

In the present paper, the temporal and magnitude distribution of the aftershocks are studied. For this purpose, instrumental observations have been used. Such a study is of imprortance because it contributes to the solution of seismic risk and earthquake prediction problems.

2. THE DATA

The data to investigate the time and magnitude distribution of shocks of this seismic sequence were taken from the Greek network of seismological stations as well as from the seismological stations of the neighbouring countries. The records of the station of Athens (Wood-Anderson records) were the basic source of data for the investigation of the time and magnitude distribution of the aftershocks. Earthquakes with magnitudes less than 4.0 were recorded. However, wishing to include all the earthquakes of the sequence with magnitudes larger than a certain value and only these, we finally included in our catalogue and used in the present study only the earthquakes with $M_s \geq 4.5$. Thus, a catalogue of complete and homogeneous data with respect to magnitude for the period January 17-May 29, 1983, has been made. This catalogue is shown on table (I). Information is given in this table on the time of occurrence, the surface wave magnitude, the epicenter coordinates, the focal depth, the errors in the time of occurrence, RMS, the errors in the determination of the epicenters, ERZ, and of the focal depths, ERH, and the number of observations for each shock, N.O. The standard error, RMS, is given in seconds, while the ERH and ERZ are given in Kms.

3. TIME DISTRIBUTION OF AFTERSHOCKS

The time distribution of aftershocks has been studied by several investigators. Mogi (1962) showed that the time distribution of aftershocks in the early stage after the main shock in which the stress decreases with time, is expressed by the relation

$$n = n_1 t^{-p}$$

where t is the time measured from the time of occurrence of the main shock, n is the number of aftershocks which occurred in the time period t, and n_1, p, are constants.

The parameter n_1 denotes the frequency of aftershocks one time unit after the origin time of the main shock, and its value depends on the magnitude threshold and varies from sequence to sequence (Utsu 1962).

The parameter p, which measures the rate of decay of aftershock activity with time, is constant for each sequence independent of the lower limit of magnitude chosen for counting the frequency of aftershocks (Comninakis 1978).

Therefore, p can be regarded as a quantity characterizing the sequence (Utsu 1969, Papazachos 1974a).

Table I.- Information on all the earthquakes with M $\geq$ 4.5 of the sequence.

No	DATE	ORIGIN TIME	M	φ_N^o	λ_E^o	h	RMS	ERH	ERZ	NO
MS	Jan. 17,1983	12:41:30.8	7.0	37.96	20.26	5	0.37	2	2	36
1.	" " "	12:54:15.8	4.8	38.24	20.49	1	0.27	5	4	14
2.	" " "	12:56:39.9	4.7	38.27	20.61	3	0.55	-	8	11
3.	" " "	14:18:57.8	4.6	38.21	20.47	1	0.70	6	5	23
4.	" " "	15:14:09.8	4.5	38.46	20.17	3	1.01	-	14	6
5.	" " "	15:53:56.9	5.4	38.13	20.49	11	0.34	3	1	33
6.	" " "	16:22:29.4	4.8	38.22	20.40	1	0.63	8	4	20
7.	" " "	16:53:30.2	5.4	38.08	20.38	9	0.40	2	1	41
8.	" " "	17:08:31.1	4.5	38.02	20.26	14	0.73	5	3	22
9.	" " "	17:13:36.4	4.5	38.05	20.34	1	0.75	5	5	22
10.	" " "	17:54:02.2	4.9	38.21	20.15	0	0.74	16	-	17
11.	" " "	18:34:09.8	4.5	38.16	20.46	5	0.66	7	5	15
12.	" " "	18:51:12.3	4.8	38.16	20.59	7	0.62	6	3	15
13.	" " "	23:19:17.8	4.5	38.15	20.55	9	0.52	6	2	15
14.	Jan. 18,1983	01:31:57.3	4.5	38.18	20.52	11	0.54	6	2	16
15.	" " "	06:09:39.9	4.5	38.18	20.53	3	0.64	9	4	13
16.	" " "	07:52:43.7	4.7	38.21	20.45	4	0.28	3	2	23
17.	" " "	09:31:09.6	4.6	38.08	20.45	10	0.50	4	2	18
18.	" " "	14:13:19.7	4.7	37.83	20.09	11	0.43	4	2	18
19.	" " "	18:19:17.7	4.7	38.15	20.51	7	0.60	6	2	21
20.	" " "	19:14:08.9	4.9	37.82	20.19	9	0.29	3	1	20
21.	" " "	21:38:52.3	4.5	38.02	20.44	14	0.49	10	4	8
22.	" " "	22:34:42.7	5.0	38.03	20.38	8	0.44	4	2	26
23.	Jan. 19,1983	00:02:15.1	6.0	38.06	20.39	6	0.45	4	2	29
24.	" " "	00:18:22.4	4.9	38.10	20.40	9	0.29	3	2	25
25.	" " "	05:41:51.0	5.6	37.82	20.04	9	0.31	2	1	27
26.	" " "	08:08:38.6	4.8	38.08	20.42	2	0.50	4	3	16
27.	" " "	08:25:32.9	4.8	38.10	20.52	6	0.38	4	2	17
28.	" " "	13:24:56.5	4.7	38.07	20.30	2	0.52	4	4	23
29.	Jan. 20,1983	06:18:46.1	4.6	38.08	20.35	8	0.28	2	1	26
30.	" " "	07:35:09.6	4.8	38.12	20.38	6	0.58	8	4	19

No	DATE	ORIGIN TIME	M	φ^o_N	λ^o_E	h	RMS	ERH	ERZ	NO
31.	Jan. 20,1983	09:51:09.6	4.5	38.20	20.38	12	0.44	15	6	7
32.	" " "	15:54:00.9	4.5	38.08	20.14	13	1.20	-	15	7
33.	Jan. 21,1983	21:11:30.5	4.8	38.27	20.30	1	0.40	6	3	16
34.	Jan. 22,1983	12:54:07.0	5.0	37.92	20.35	7	0.36	3	2	25
35.	" " "	16:01:41.5	4.7	38.02	20.32	9	0.33	2	1	29
36.	Jan. 24,1983	00:56:43.4	4.6	38.00	20.32	10	0.60	5	2	22
37.	Jan. 28,1983	09:12:29.0	4.7	38.14	20.27	4	0.56	5	5	26
38.	Jan. 30,1983	11:46:08.0	4.5	38.13	20.30	1	0.33	4	3	20
39.	Jan. 31,1983	01:06:21.6	4.5	38.19	20.37	0	0.53	4	3	27
40.	" " "	15:27:01.7	5.8	38.12	20.49	4	0.51	4	3	35
41.	Feb. 1,1983	13:07:32.8	4.5	38.12	20.29	1	0.40	5	4	13
42.	Feb. 2,1983	06:16:40.1	4.6	38.12	20.48	12	0.45	6	2	14
43.	" " "	12:43:15.3	4.7	38.13	20.38	5	0.48	4	3	19
44.	Feb. 3,1983	13:25:37.1	4.6	38.06	20.40	1	0.66	6	4	20
45.	Feb. 4,1983	00:34:18.8	4.6	38.00	20.33	12	0.34	2	1	25
46.	Feb. 11,1983	09:59:56.9	4.6	38.15	20.45	9	0.58	6	3	18
47.	Feb. 16,1983	16:50:49.4	4.8	37.99	20.44	10	0.37	6	2	17
48.	Feb. 21,1983	00:13:09.7	5.6	37.84	20.29	12	0.50	6	3	23
49.	" " "	00:36:41.3	4.5	37.76	20.37	9	0.37	5	3	9
50.	Feb. 22,1983	10:52:32.9	4.5	37.92	20.13	7	0.41	4	3	24
51.	Feb. 23,1983	06:12:37.9	4.6	38.14	20.43	9	0.56	5	2	22
52.	" " "	19:11:09.5	4.5	38.05	20.42	2	0.46	9	6	10
53.	Mar. 18,1983	00:45:41.7	4.7	38.27	20.44	0	0.61	9	8	15
54.	Mar. 22,1983	05:12:56.0	4.7	38.18	20.46	3	0.48	5	3	21
55.	Mar. 23,1983	23:51:07.8	6.2	38.22	20.41	3	0.28	3	2	32
56.	Mar. 24,1983	02:36:03.5	4.9	38.20	20.33	13	0.80	9	15	19
57.	" " "	02:56:40.3	4.5	38.23	20.53	1	0.28	10	-	8
58.	" " "	04:17:33.6	5.6	38.10	20.49	12	0.45	4	2	35
59.	" " "	12:50:58.4	5.3	38.08	20.35	0	0.54	3	2	36
60.	" " "	14:07:07.2	4.7	38.43	20.43	3	0.66	15	15	12

No	DATE	ORIGIN TIME	M	φ^o_N	λ^o_E	h	RMS	ERH	ERZ	MO
61.	Mar. 24,1983	14:19:32.9	4.5	38.36	20.33	5	0.71	-	-	12
62.	" " "	18:45:08.3	4.5	38.39	20.39	1	0.48	14	-	9
63.	" " "	19:35:57.2	5.1	38.23	20.41	2	0.45	3	2	34
64.	" " "	22:03:20.6	4.5	38.20	20.51	2	0.26	5	4	18
65.	Feb. 25,1983	11:00:07.7	4.7	38.31	20.41	8	0.34	7	9	14
66.	" " "	18:56:39.1	5.3	38.15	20.30	0	0.59	4	3	30
67.	" " "	20:20:47.0	4.8	38.21	20.41	4	0.53	5	3	24
68.	" " "	20:43:14.0	4.7	38.11	20.41	10	0.52	10	2	14
69.	" " "	21:00:51.2	4.9	38.14	20.35	2	0.53	4	3	29
70.	Feb. 26,1983	17:17:25.4	4.9	38.14	20.25	1	0.80	5	5	27
71.	Feb. 31,1983	07:20:03.5	4.7	38.22	20.44	1	0.70	8	5	16
72.	May, 13,1983	07:48:42.0	4.5	38.01	20.17	8	0.69	3	2	33
73.	May, 29,1983	05:09:17.8	4.8	38.12	20.32	0	0.48	2	3	28

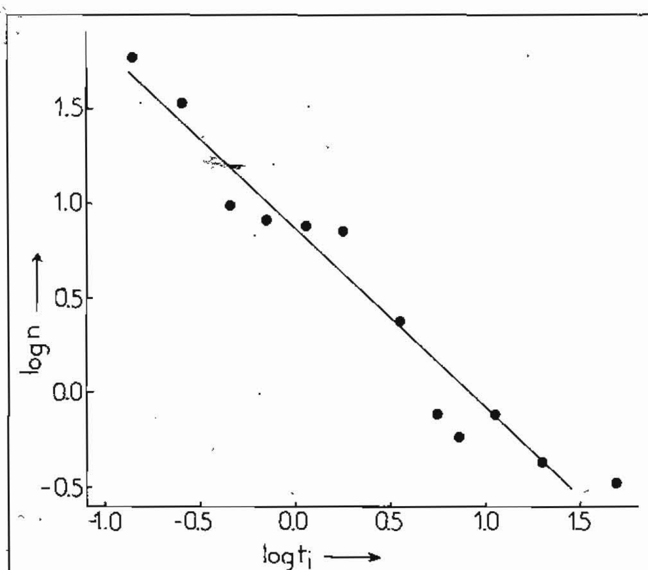

Fig. 1.- The time distribution of the aftershocks of the January 1983 main shock.

Taking the common logarithms of the relation (1), we get

$$\log n = \log n_1 - p \log t \tag{2}$$

In order to determine the parameters n_1 and p for the sequence which is studied in the present paper, the data have been grouped according to a procedure suggested by Utsu (1962), as it is shown in figure (1). By application of the least squares' method, the relation (1) takes the form

$$n = 7.2 \cdot t^{-0.94} \tag{3}$$

4. MAGNITUDE DISTRIBUTION OF AFTERSHOCKS

One of the most important statistical laws in Seismology is the Gutenberg-Richter's magnitude-frequency relation of earthquakes (1944), which gives the number of earthquakes, n(M) with magnitude between M and M + dM, within a certain time interval. This relation has the form

$$\log n(M) = a' - bM \tag{4}$$

Today, most seismologists calculate the cumulative distribution N(M). The cumulative frequency curve is not affected very much by differences in the magnitude class and gives a smoother curve than the ordinary one. Intergrating equation (4) we get

$$\log N(M) = a - bM \tag{5}$$

where a,b, are parameters. The parameter b shows the proportion of large to small shocks in a given group of earthquakes. When b is large, small shocks predominate, and conversely (Comninakis 1978).

Figure (2) shows the cumulative distribution of the magnitudes of the shocks which are listed in table (I). The data are fitted, in the least squares' sense, by the relation

$$\log N = 6.32 - 1.01\,M \tag{6}$$

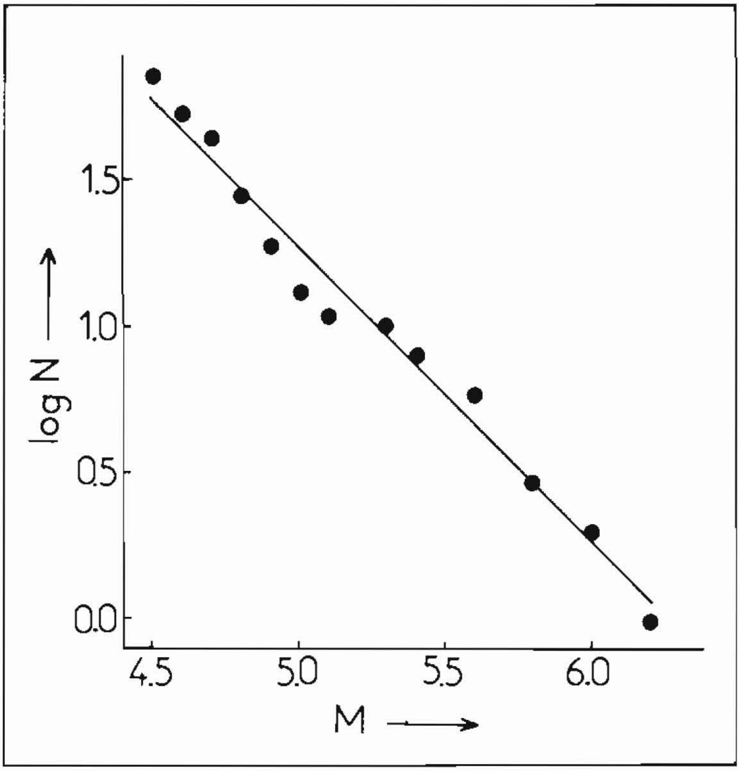

Fig.2.- The cumulative magnitude distribution of the aftershock sequence of the January 17, 1983, main shock.

5. DISCUSSION AND CONCLUSIONS

Recent studies concerning the parameter b of the magnitude-frequency relation lead to the conclusion that there is a clear physical meaning for this parameter.

According to Papazachos and his colleagues (1967) and Mogi (1967), the value of the foreshock b is smaller than the value of the aftershock b.

Experiments on rock samples which have been performed in the laboratory by Scholz (1968), showed that the value of the parameter b decreases when stress increases. Its final value depends rather on the state of stress than on the heterogeneity of the material.

Wyss (1972) observed that there is a time-variation of the b in an area, and that its value decreases when stress increases.

Swarm studies performed by Pasquale (1977), led to the conclusion that the value of the parameter b decreases before the largest afteshock. After its occurrence, b-value increases till the end of the sequence.

Karakaisis (1984) determined more accurate values for the b parameter of the aftershock sequences. The mean value of this parameter for Greece and surrounding area is b = 1.08, while the value of the same parameter of the Cephalonia seismic sequence is equal to 1.01.

Evidence has been presented by Mogi (1962) that the parameter p of the decay law depends on some physical conditions in the focal region. He has observed a consisted geogrpahical distribution of the values of this parameter in the area of Greece. The same author (Mogi 1967) suggested that the parameter p seems to be correlated with areas of recent volcanism, supporting the assumption made by Papazachos (1974a) that p parameter is presumably related with material properties in the seismogenic volume (viscosity etc). Papazachos (1974b) has found a representative p value for the area of Greece equal to 1.13 while Karakaisis (1984) determined a mean value, almost equal to 1.0. The value of this parameter of the present sequence is equal to 0.94.

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ΠΕΡΙΛΗΨΗ

ΧΡΟΝΙΚΗ ΚΑΙ ΚΑΤΑ ΜΕΓΕΘΟΣ ΚΑΤΑΝΟΜΗ ΤΗΣ ΣΕΙΣΜΙΚΗΣ ΑΚΟΛΟΥΘΙΑΣ ΙΑΝΟΥΑΡΙΟΥ-ΜΑΪΟΥ 1983 ΣΤΟ ΝΗΣΙ ΚΕΦΑΛΟΝΙΑ, ΙΟΝΙΟ ΠΕΛΑΓΟΣ

Υπό
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Η χρονική και κατά μέγεθος κατανομή της μετασεισμικής ακολουθίας που έγινε μεταξύ Ιανουαρίου και Μαΐου 1983 κοντά στις νοτιοδυτικές ακτές της Κεφαλονιάς, εξετάζεται στην εργασία αυτή. Η χρονική κατανομή της συχνότητας των μετασεισμών ακολουθεί τη γνωστή σχέση της ελάττωσης με τιμή της παραμέτρου p της σχέσης αυτής ίση με 0,94. Η σχέση των Gutenberg-Richter μεταξύ του μεγέθους των σεισμών και της συχνότητας αυτών ισχύει επίσης για την ακολουθία που εξετάζεται, με τιμή της παραμέτρου b ίση με 1,01.

Τα χειρόγραφα κατατέθηκαν στις 4.2.86