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ΠΡΟΕΔΡΙΑ ΓΕΩΡΓΙΟΥ ΜΕΡΙΚΑ

ΑΣΤΡΟΝΟΜΙΑ.— **Statistical Analysis of the large Earthquakes of the Present Century**, *by Academician John Xanthakis**.

ABSTRACT

The temporal variation of the annual number of the intermediate and dεep focus earthquakes ($M \geq 6.8$) is investiqated for the period 1901-1980.

Possible periodicities of 22 and 4 years were detected.

INTRODUCTION

In the present paper the temporal variation of the annual number of $M \geq 6{\cdot}8$ earthquakes, N, is studied. The data used for the period 1901-1981 are those listed in Table A_{II} i.e. «Large Shallow Earthquakes» (Hereafter LSE) and in Table A_{III} i.e. «Intermediate and Deep Focus Earthquakes» (Hereafter IDFE) of Abe's paper (Abe, 1981) as well as the data published by Abe and Noguchi (1983). The data for the quantity, N, for the time interval 1975-1985 have been taken from the Preliminary Determination of Epicentres (Montly Listing of the National Earthquake Information Center)

At first the 5-year sliding means of the annual number of earthquakes N (5) were computed. These N (5) values can be considered as giving the «mean variation» of the quantity N during the period under consideration. The small circles in figure 1a represent the 5-year sliding means N^{ob} (5) which correspond to the total number of N recorded during the time interval 1901-1985.

It can be seen that the quantity N^{ob} (5) shows sinusoidal fluctuations

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which can be represented by a number of periodic terms - having periods of 22 years. These periodicities are partly overlapping. The periodic terms are of the form

$$a_n \sin \frac{2\pi}{22} T_n, \text{ where } n=1, 2.... 6.$$

and are represented in fig. 1a by solid sinus curves.

In fig. 1b the small circles respesent as previously the values of the quantity N (5), and the solid line the values of this quantity computed by means of equation (1)

$$N^{com}(5) = 18.6 + \underset{1904\text{-}37}{5 \sin \frac{2\pi}{22}(T-1904)} - \underset{1926\text{-}48}{5 \sin \frac{2\pi}{22}(T-1926)} + \underset{1942\text{-}84}{10 \sin \frac{2\pi}{22} \cdot (T-1942)} + \underset{1955\text{-}72}{5 \sin \frac{2\pi}{22}(T-1955)} - \underset{1960\text{-}71}{5 \sin \frac{2\pi}{12}(T-1960)} - \underset{1972\text{-}2000}{5 \sin \frac{2\pi}{22}(T-1972)}. \quad (1)$$

Equation (1) represents satisfactorily the «mean variation» of the quantity N^{ob} (5) which gives the observational data. The standard deviation of the differences N^{ob} (5)—N^{com} (5) is equal to $\sigma = \pm 1.7$

The aim of the present work is to establish an analytical relation not only for the «mean variation» of the quantity N(t) but also for the total annual number of earthquakes, N. To this end let us study the differences

$$N^{ob} - N^{com} (5) \quad (2)$$

These differences do not seem to be random but exhibit only one periodicity with a period equal to 4 years and a confidence level above 99% as it can be seen in fig. 2.

In fig. 3a the small circles represent the values of the differences N^{ob}-N^{com} (5) while the sinusoidal curves represent the position and the width of the periodicities with period equal to 4 years. These can be represented by the relation

$$P = b_n \sin \frac{2\pi}{4} T_n \quad (3)$$

Finally in fig. 3b the small circles represent the observed annual number of earthquakes N, and the solid line the values of this quantity computed by means of the relation:

$$N^{com} = 18.6 + \Sigma a_n \sin\frac{2\pi}{22} T + \sum b_n \sin\frac{2\pi}{4} T_n \qquad (4)$$

where the values of a_n, b_n and T_n are shown in Table I. The standard deviation of the differences $N^{ob} - N^{com}$ is equal to $\sigma = \pm 1.7$ i.e. equation (4) represents the observational data (annual number of earthquakes, N with $M \geq 6.8$) with an accuracy equal to $(1 - \frac{1.7}{18.6})100\% = 90,9\%$.

Conclusions

From the above analysis it is concluded that the annual number of earthquakes with magnitude $M \geq 6.8$ included in the catalogues published by Abe and Kanamori (1979) and by Abe (1981) can be analytically expressed by means of two periodic terms with periods equal to 22 and 4 years, respectively.

It is obvious that the present analysis does not allow an extrapolation which would permit a long term prediction because the two periodic terms appear sporadically overlapping either in the same or in opposite phase forming a kind of «network» of sinusoidal functions with constant period and different amplitudes.

However, if we consider the mean variation N(5) (see figure 1b) we reach the conclusion that we should probably expect an increased seismic activity during the 11 years following 1989.

TABLE 1

an	T_n
+5	1902-1936, 1955-1977
—5	1926-1948, 1960-1971, 1978-2000
+10	1942-1964
bn	T
—5	1902-1906, 1914-1920, 1929-1937, 1935-1939, 1957-1965 1972-1978, 1973-1979, 1983-1987
+5	1906-1914, 1917-1921, 1930-1936, 1945-1953, 1977-1981, 1946-1950
+7.5	1905-1915
—7.5	1913-1917
+10	1908-1912, 1944-1962
—10	1931-1935, 1963-1967, 1965-1969
+15	1942-1946, 1956-1958

TABLE 2

Year	$N^{com}(5)$	P	N^{com}	N^{ob}	Year	$N^{com}(5)$	P	N^{com}	N^{ob}
1901	18.6	0	19	20	38	20.0	+ 5	25	25
02	18.6	0	19	21	39	21.3	0	21	21
03	18.6	− 5	14	15	1940	22.5	0	23	23
04	18.6	0	19	20	41	23.2	0	23	25
05	20.0	+ 5	25	27	42	23.6	0	24	27
06	21.3	+ 7.5	29	31	43	26.4	+15	41	41
07	22.5	+ 5	28	28	44	28.6	0	29	31
08	23.2	− 7.5	16	17	45	30.1	− 5	25	26
09	23.5	+ 5	28	27	46	30.5	+ 5	35	35
1910	23.6	+ 7.5	31	30	47	29.9	− 5	25	25
11	23.2	− 5	18	19	48	28.5	− 5	24	27
12	22.4	− 7.5	15	16	1949	27.7	+ 5	33	31
13	21.5	− 5	17	18	1950	26.5	+ 5	32	34
14	20.0	0	20	19	51	24.0	−10	14	14
15	18.6	− 5	14	14	52	21.4	− 5	16	14
16	17.2	+ 5	22	22	53	18.6	0	19	17
17	15.8	0	16	16	54	15.8	0	16	14
18	14.8	+ 5	20	21	55	13.2	0	13	12
19	14.0	0	14	15	56	12.5	0	13	13
1920	13.5	− 5	8	8	57	12.2	+15	27	27
21	13.6	− 5	9	11	58	12.5	− 5	8	8
22	14.0	0	14	16	59	13.3	0	13	15
23	14.8	+ 5	20	23	1960	14.5	+ 5	19	19
24	16.9	0	16	17	61	14.5	0	15	17
1925	17.2	0	17	19	62	14.4	0	14	12
26	18.6	0	19	19	63	15.8	0	16	15
27	18.6	0	19	22	64	15.7	0	16	13
28	18.6	0	19	19	65	15.0	0	15	17
29	18.6	0	19	19	66	13.0	0	13	12
1930	18.6	− 5	14	13	67	12.6	− 5	8	10
31	18.6	+ 5	24	16	68	13.1	+10	22	22
32	18.6	− 6	14	13	69	13.1	− 5	7	8
33	18.6	− 5	14	14	1970	12.6	0	13	14
34	18.6	+ 5	24	22	71	13.5	0	13	11
35	18.6	+ 5	24	23	72	13.5	0	13	10
36	18.6	0	19	21	73	14.0	− 5	9	9
37	18.6	0	19	22	74	14.8	− 5	10	11

(Συνέχεια) TABLE 2

75	15.9	0	16	15	81	14.8	0	15	16
76	17.2	+ 5	22	22	82	14.0	— 5	9	10
77	18.6	— 5	14	14	83	13.5	0	13	12
78	18.6	0	19	10	84	13.5	— 5	8	9
79	17.2	0	17	16	85	14.0	0	14	16
1980	15.9	— 5	11	10					

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ΠΕΡΙΛΗΨΗ

Στατιστική ἀνάλυση τῶν μεγάλων σεισμῶν κατὰ τὸν παρόντα αἰώνα

Εἰς τὴν ἐργασία αὐτὴ μελετᾶται τὸ πλῆθος τῶν σεισμῶν μεγέθους M≥6·8 Richter πού ἀναφέρονται στούς καταλόγους τῶν Abe καὶ Noguchi.

Ἡ Σχετικὴ διερεύνηση δεικνύει ὅτι τὸ πλῆθος τοῦτο τῶν σεισμῶν ὑφίσταται πιθανότατα περιοδικὲς μεταβολὲς μὲ περιόδους 22 ἔτη καὶ 4 ἔτη. Οἱ τελευταῖες περιοδικότητες τῶν 4 ἐτῶν ἐμφανίζονται ὑπὸ μορφὴ πλέγματος καὶ ἐπικάθηνται ἔτσι ἐν μέρει ἢ ἐν ὅλω ἢ μία ἐπὶ τῆς ἄλλης.

Τὸ γεγονὸς τοῦτο δὲν μᾶς ἐπιτρέπει τὴν ἐπέκταση τῶν ἐξεταζομένων γιὰ τὴν ἐπίτευξη προγνώσεως σεισμοῦ πολὺ χρόνο πρὶν ἀπὸ τὴν ἐκδήλωσή του.

Note by Academician **Angelos Galanopoulos**

The shorthness of the sample period makes difficult the acceptance of 22-year periodicity of large earthquake events ($M \geq 6.8$) found by the author of the present paper. However, if this result is not fortuitous, one might hazard the theory that the derived periodicity is due to a similar periodicity of the external geomagnetic field. A change of the geomagnetic activity may affect the assumed weak magnetic coupling between the outer liquid core and the lower mantle of the earth and consequently the rate of rotation of the mantle and the related global stress field.

It might be added that constructive and/or destructive interference of the said periodicity with others, shorter and/or longer, obscures their self-consistency. Therefore, eventual periodicities or «repeat-possibilities» can not be used for earthquake prediction, let alone for earthquake forecasting.

Moreover, each earthquake changes the related focal volume —sometimes slightly, sometimes drastically— and the altered focus is either stronger or weaker than it was in its former state. Therefore, any long-term prediction, let alone probabilistic forecasting, based on statistical averages or previous earthquake behaviour, no matter how sophisticated the applied probabilistic approach gets, may ultimately not be valid. As the stresses and strains and deformation of the focal volume build towards previous critical levels, the breakdown strength leading to another earthquake or earthquake clustering may have changed, and that will be evident only in hindsight.

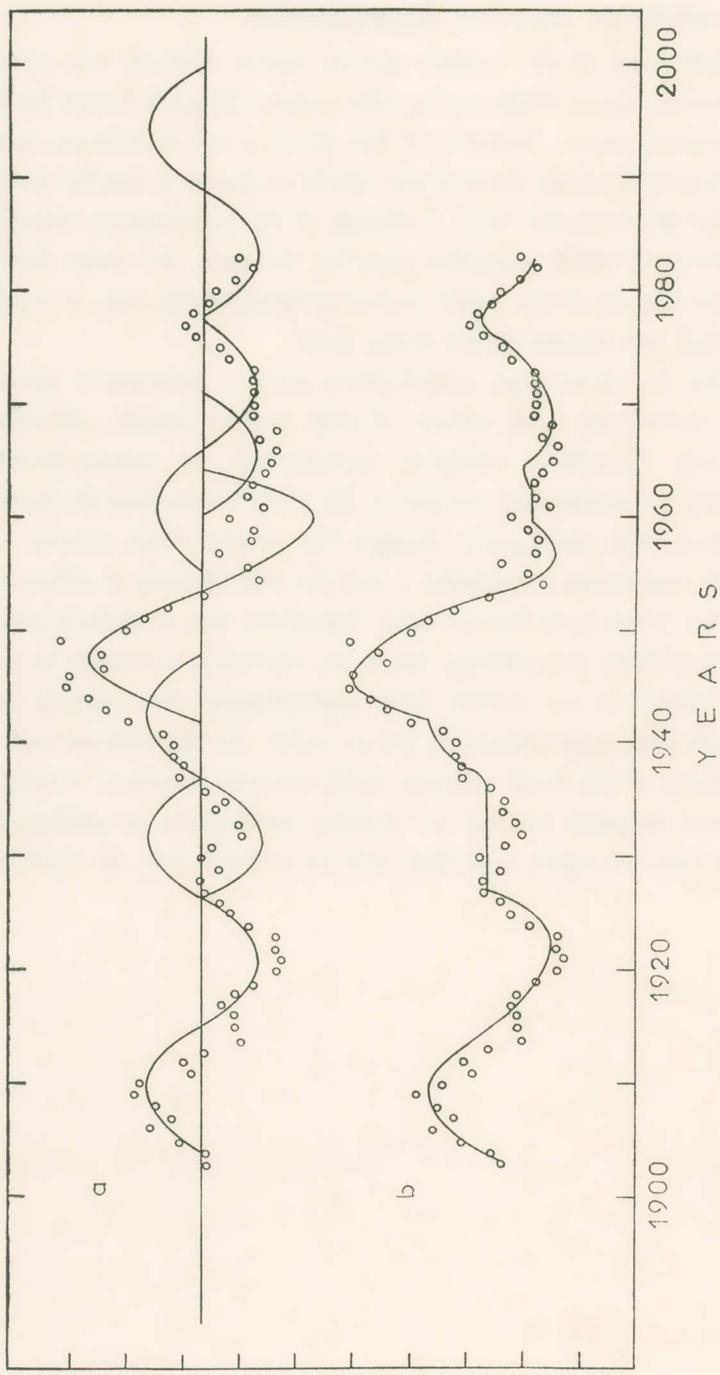

Fig. 1a. The small circles represent the values of the quantity N(5) and the solid sinus curves represent the 22-year periodicity. 1b: The small circles represent as previously the values of N(5) and the solid line the values of this quantity computed by means of equation (1).

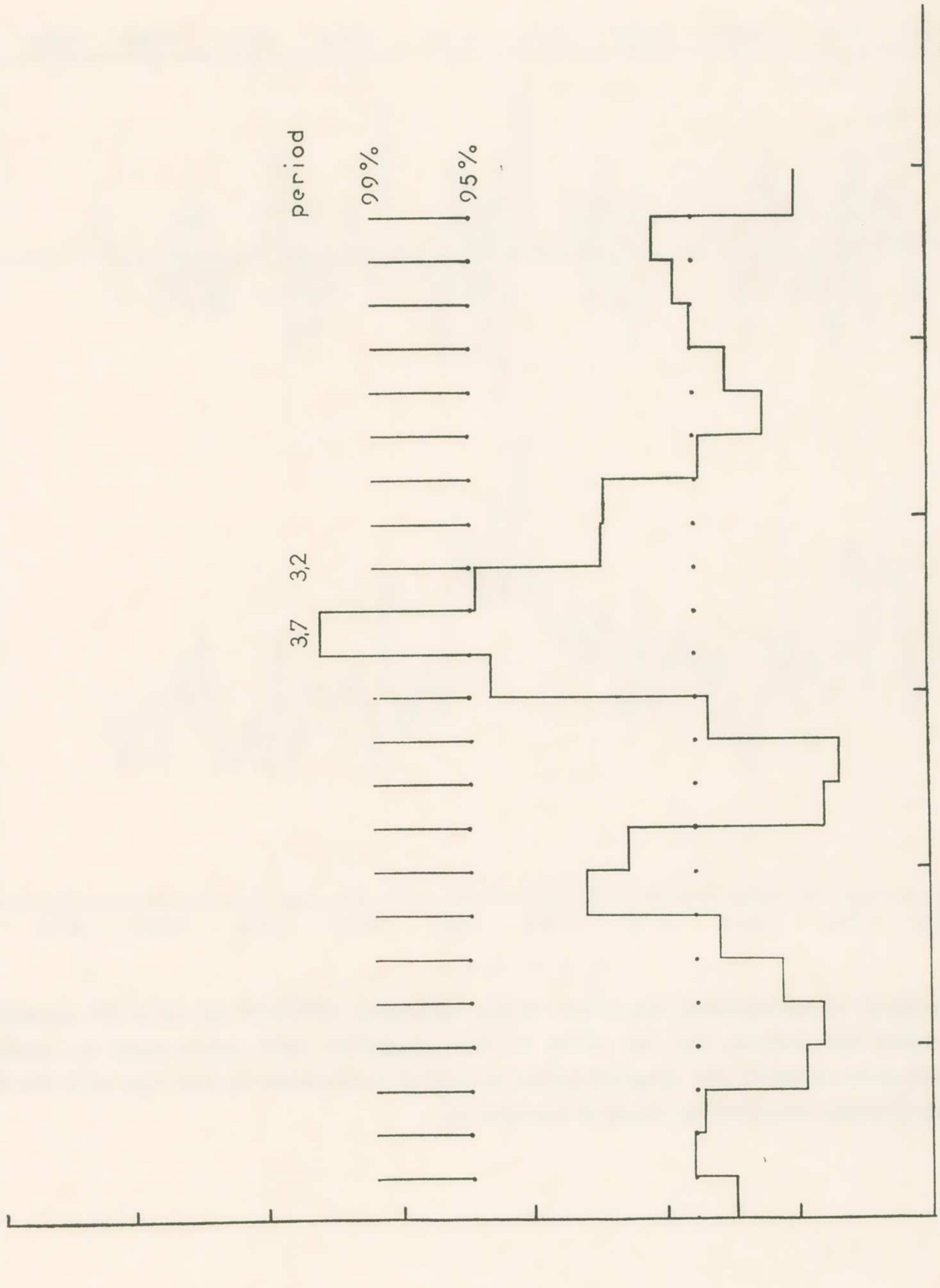

Fig. 2. Spectrum analysis of the differences $N^{ob} - N^{com}$ (5) which shows a 4-year periodicity with a confidence level above 99%.

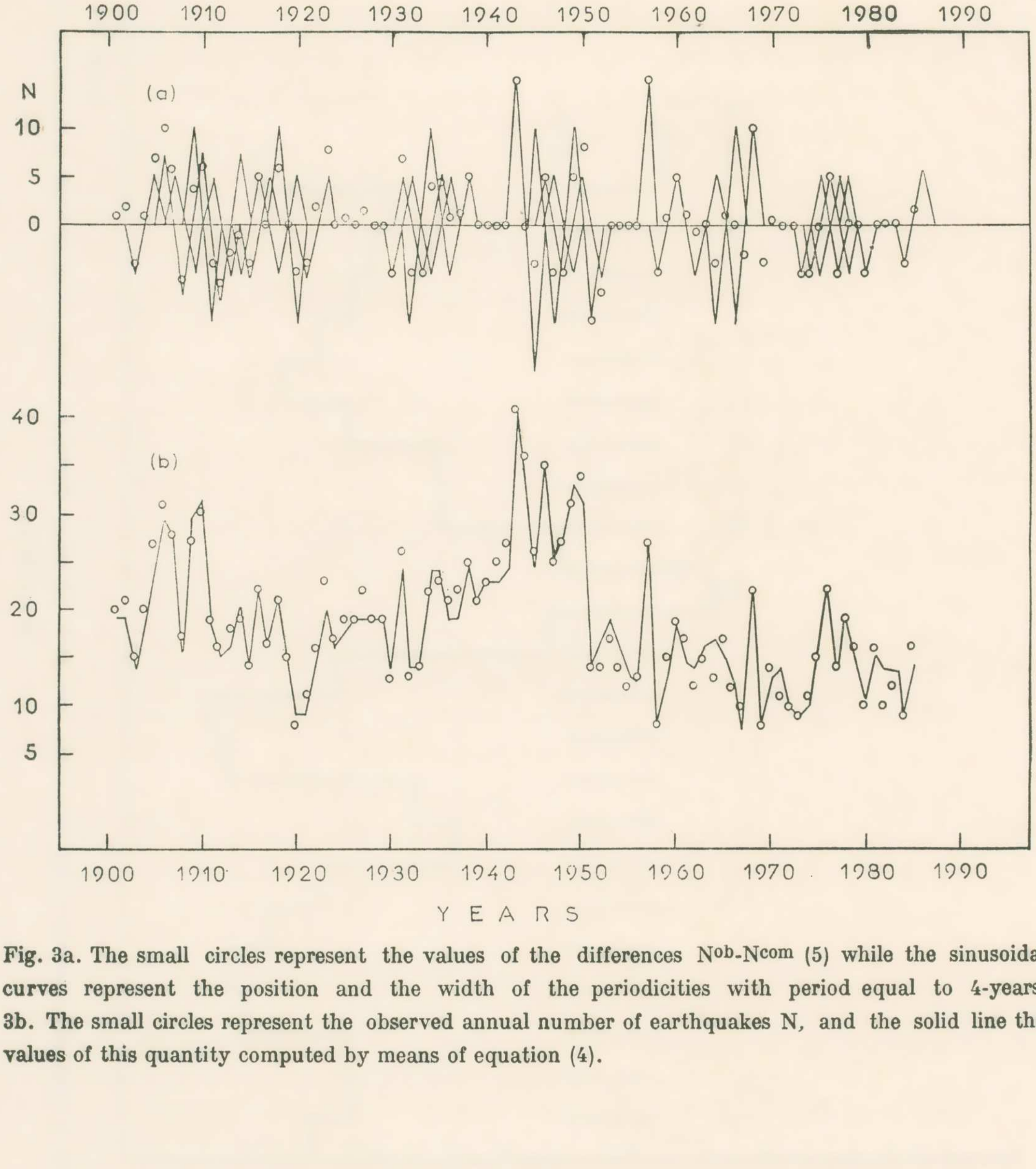

Fig. 3a. The small circles represent the values of the differences N^{ob}-N^{com} (5) while the sinusoidal curves represent the position and the width of the periodicities with period equal to 4-years. **3b.** The small circles represent the observed annual number of earthquakes N, and the solid line the values of this quantity computed by means of equation (4).