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SEISMICITY OF FENNOSCANDIA IN RELATION TO COSMIC CONDITIONS

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This paper deals with the distribution of earthquakes in Fennoscandia in connection with cosmic conditions. Considerad here are earthquakes of a magnitude $M \gg 3$ from 1900—1950 (data from Markus Båth, 1956). Within these 50 years 269 earthquakes were registered (Fig. 1). Comparatively strong earthquakes (magnitude $M \gg 4$) during this period are shown in Table 1. The strongest earthquake in Fennoscandia on 23rd October 1904 had a magnitude of $M = 6.5$ and the quantity of energy released was 3.5×10^{21} erg. All the other earthquakes taken together released only 5.4×10^{20} erg, which is almost 6.5 times less. In order not to obscure the picture of the distribution of seismic energy of all the earthquakes in Fennoscandia, this strongest earthquake ($M = 6.5$) is excluded from the following statistical account. As seen in Table 2 the 74 earthquakes with a magnitude of $M \gg 4$ released slightly more than 95 % of the energy of all the earthquakes recorded in Fennoscandia (1900—1950). The remaining 195 earthquakes with a magnitude of $M = 3.0$—3.9 released less than 5 % of the total seismic energy in Fennoscandia. The energy released by earthquakes of lesser magnitude ($M < 3$) is insignificant. On the whole, 74 strong earthquakes form the seismic picture of the region.

In order to analyse the seismic material, it has been necessary in the following to use some conventional terms, such as the synodic and reduced anomalistic age of the earthquakes as well as the reduced lunar days.

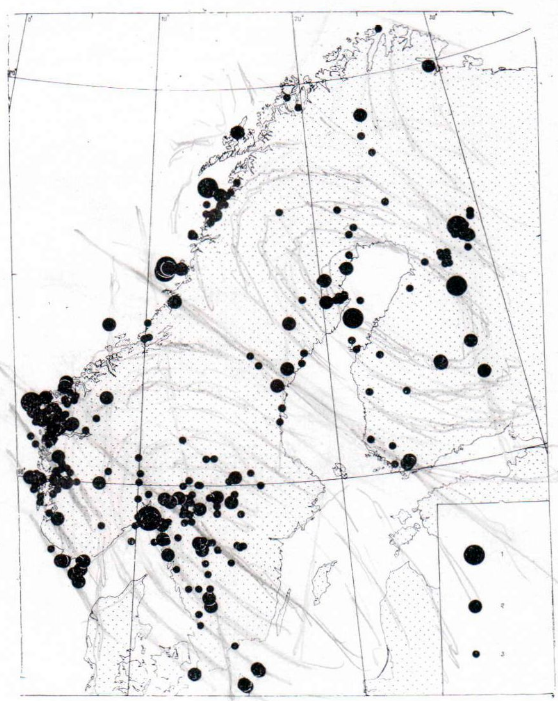

Fig. 1. Earthquakes in Fennoscandia (1900—1950). Earthquake magnitude (M): 1) 5.0—5.4 or more: 2) 4.0—4.9: 3) 3.0—3.9.

TABLE 1

The strong earthquakes (with magnitude M ≫ 4) in Fennoscandia for the period 1900—1950, their synodic and reduced anomalistic ages and reduced lunar time

No.	Date	Greenwich Mean Time (hours, minutes)	Latitude N	Longitude E	Magnitude M	Synodic age of the earthquake (days, hours)	Reduced anomalistic age of the earthquake (days)	Reduced local lunar time (hours)
1	2	3	4	5	6	7	8	9
1	November 5, ... 1901	22 58	59.7	13.8	4.7	24 18	9.0	15.8
2	April 10, ... 1902	19 30	64.3	27.6	5.2	2 17	0.7	7.1
3	April 29, ... 1902	13 15	57.2	13.4	4.0	21 14	19.0	8.7
4	September 4, ... 1902	9 00	65.5	11.0	4.5	2 15	7.0	19.7
5	October 23, ... 1904	10 27	59.2	10.5	6.5	13 18	15.2	12.1
6	November 18, ... 1904	2 30	59.6	11.5	4.7	10 23	13.0	6.3
7	December 13, ... 1904	21 51	58.7	11.3	4.2	7 06	12.4	4.7
8	February 6, ... 1905	17 10	62.0	5.0	4.7	2 17	14.1	3.2
9	June 3, ... 1906	3 24	58.0	6.5	4.3	11 07	25.0	6.7
10	December 10, ... 1906	16 11	58.0	6.5	4.2	24 23	23.2	8.4
11	January 10, ... 1907	0 32	59.6	12.3	4.9	25 20	25.0	16.4
12	January 14, ... 1907	13 03	65.5	11.0	5.2	0 18	1.9	1.2
13	January 27, ... 1907	4 58	65.5	11.0	5.4	13 11	14.2	6.8
14	April 5, ... 1907	1 25	58.4	13.1	4.0	22 07	2.3	20.2
15	May 26, ... 1907	10 32	64.4	20.3	4.4	14 14	25.7	12.1
16	June 29, ... 1907	20 00	60.0	8.1	4.5	19 06	4.1	16.9
17	January 8, ... 1908	22 30	58.3	11.5	4.4	5 13	4.7	6.8
18	June 30, ... 1908	4 53	67.3	14.3	4.8	1 23	13.3	16.3
19	March 9, ... 1909	0 18	64.0	21.6	5.0	17 02	16.0	23.9
20	March 15, ... 1909	7 58	59.0	11.2	4.1	23 14	22.0	1.5
21	February 24, ... 1911	18 13	64.6	11.5	4.2	25 19	16.8	10.1
22	August 24, ... 1911	21 48	60.0	5.2	4.9	1 06	3.3	9.1
23	December 26, ... 1911	8 55	62.9	27.6	4.3	6 04	19.2	17.7
24	September 18, ... 1912	20 48	60.2	14.8	4.0	8 04	9.4	3.3
25	July 19, ... 1913	15 50	64.0	8.0	4.9	16 01	12.9	15.4
26	August 4, ... 1913	7 38	61.4	5.8	5.2	2 06	0.8	18.2
27	September 11, ... 1913	2 34	67.5	13.5	5.0	10 19	9.9	6.7
28	July 8, ... 1917	14 41	68.9	15.6	4.0	19 13	2.5	11.9
29	April 10, ... 1918	0 26	61.4	6.5	4.9	28 21	0.1	13.4
30	August 22, ... 1918	20 22	60.6	6.0	4.0	16 11	1.1	19.8
31	September 6, ... 1920	4 46	66.9	14.0	4.5	23 17	25.3	22.3
32	August 23, ... 1921	22 00	55.0	15.0	4.0	20 19	19.9	18.1
33	August 23, ... 1921	23 45	55.0	15.0	4.0	20 21	20.0	19.8
34	June 11, ... 1922	12 44	59.6	14.5	4.3	16 07	8.9	12.5
35	July 13, ... 1922	18 58	61.6	5.7	4.2	19 06	15.2	15.7
36	October 27, ... 1922	5 10	59.7	12.0	4.2	7 04	7.8	12.1
37	March 23, ... 1923	1 10	61.3	5.6	4.2	6 00	18.5	8.6
38	May 5, ... 1923	3 09	62.4	6.0	4.2	19 07	5.2	0.0
39	May 5, ... 1924	6 20	61.8	5.4	4.0	1 19	14.5	18.3
40	January 4, ... 1926	8 30	69.9	29.4	4.0	19 17	17.2	6.4

TABLE 1 (continued)

1	2	3	4	5	6	7	8	9
41	August 18, ... 1926	13 58	65.8	28.5	5.1	9 23	22.4	19.8
42	October 19, ... 1926	17 17	57.8	7.5	4.2	12 18	0.1	19.5
43	February 25, ... 1927	20 00	65.5	29.0	4.2	23 14	21.2	14.8
44	June 15, ... 1927	6 16	61.7	4.4	4.3	15 11	18.2	6.2
45	April 13, ... 1929	8 05	65.3	21.6	4.1	3 12	0.5	18.6
46	May 23, ... 1929	18 36	57.5	7.4	4.9	14 14	12.6	19.2
47	May 29, ... 1929	23 31	57.7	7.3	4.7	20 19	18.6	19.2
48	October 26, ... 1929	13 44	57.0	13.5	4.2	23 14	3.6	7.5
49	March 10, ... 1930	22 36	62.9	17.7	4.0	10 08	25.6	3.4
50	April 3, ... 1930	17 47	69.0	24.0	4.2	4 12	21.9	3.7
51	June 10, ... 1930	0 15	61.0	5.4	4.1	12 21	9.6	2.2
52	October 31, ... 1930	23 17	55.3	12.8	4.5	10 01	12.4	4.1
53	November 16, ... 1931	3 21	62.5	25.8	4.9	6 05	7.3	12.0
54	November 16, ... 1931	19 30	62.5	25.8	4.3	6 21	8.0	3.6
55	September 3, ... 1932	19 06	58.6	13.0	4.2	2 23	0.0	5.5
56	August 5, ... 1933	23 58	59.4	13.0	4.5	14 08	2.3	1.2
57	November 2, ... 1934	16 40	62.1	28.0	4.0	25 01	16.6	10.2
58	December 12, ... 1934	20 10	60.2	23.2	4.4	6 06	13.4	4.6
59	January 7, ... 1935	17 32	65.0	20.2	4.0	2 12	1.2	4.9
60	January 11, ... 1935	22 17	60.2	23.2	4.2	6 17	5.2	6.5
61	January 28, ... 1935	15 12	65.6	11.9	4.0	23 12	22.4	8.9
62	October 10, ... 1935	5 52	62.5	17.1	4.0	2 20	26.6	16.7
63	April 5, ... 1936	21 22	64.0	18.0	4.1	13 19	13.1	23.4
64	March 11, ... 1938	16 08	61.9	4.2	5.2	9 10	0.3	20.8
65	June 22, ... 1939	14 11	61.4	5.0	4.0	5 01	2.7	22.3
66	October 9, ... 1939	10 09	58.0	7.6	4.6	26 03	26.0	1.5
67	January 27, ... 1941	1 21	61.2	5.8	4.4	27 03	8.0	15.7
68	January 4, ... 1942	22 39	60.0	6.0	4.0	17 13	17.8	20.8
69	November 26, ... 1942	3 09	59.9	6.4	4.8	17 13	15.0	1.3
70	August 29, ... 1943	5 35	59.0	6.2	4.1	27 22	13.5	19.2
71	April 24, ... 1946	17 45	55.4	15.6	4.3	22 16	20.3	12.7
72	February 8, ... 1947	20 45	62.2	8.2	4.0	17 09	4.9	18.9
73	July 22, ... 1948	19 15	55.4	15.6	4.0	16 01	13.9	19.3
74	July 23, ... 1948	8 31	62.5	6.0	4.0	16 14	14.5	7.5

TABLE 2

Distribution of earthquakes and their energy in Fennoscandia from 1900—1950

Magnitude	Number of earthquakes	Summary energy, in %%	Quantity of energy which on an average accounts for one conventional earthquake, in %%
5.0—5.4	8	56.7	7.1
4.5—4.9	18	28.7	1.6
4.0—4.4	48	10.0	0.2
3.5—3.9	84	3.6	0.04
3.0—3.4	111	1.0	0.01

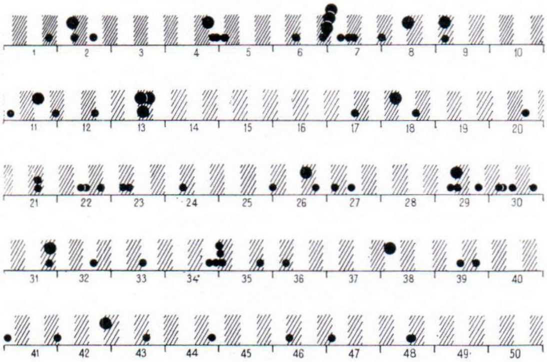

Fig. 2. Strong earthquakes in Fennoscandia (1900—1950). Years of the XX century are on the horizontal line. The lunar orbit perigee is: in the syzygy zones (shading): beyond the syzygy zones (left unshaded). Earthquake magnitudes (M): 4.8—5.4 or more (large circles): 4.0—4.7 (small circles).

The average synodic age of an earthquake is the time interval (in days) between the date of the earthquake and the last new moon; it is determined by taking the average duration of the synodic month as 29.6 days. In this paper, the difference in the time interval between two real subsequent new moons and the duration of the average synodic month is corrected.

The reduced anomalistic age of the earthquake is the time interval (in days) between the date of the earthquake and the previous moon's passage through its perigee. The duration of the reduced anomalistic age is determined by taking the average duration of an anomalistic month as 27.6 days. For the conversion of the current anomalistic age into the reduced anomalistic age a correction is introduced (sometimes up to some dozens of hours).

For the purpose of uniformity, it is convenient to use the reduced lunar days conjugated by duration with the solar days instead of the lunar days with a duration of 24 hours 50 minutes.

The whole time interval between 1900 and 1950 is divided into two groups of intervals which are equal in total duration (each amounting to 25 years). One of them, *i.e.* the first group of intervals, corresponds to the conditions under which the new moon or full moon was near the perigee of the lunar orbit. The second group of time intervals corresponds to the conditions under which the new moon or full moon was far from the perigee (Fig. 2).

13 strong earthquakes (M = 4.8—5.4) have been recorded within the first group of time intervals, while only 3 strong earthquakes fall within the second group of intervals. On the whole, the amount of seismic energy released by strong earthquakes in the first group of intervals was twice as high as that in the second group of intervals. Thus, with the increase in the tidal efforts (the proximity of the perigee part of the lunar orbit to the syzygy phases) the seismic activity in Fennoscandia is increasing.

The greatest amount of seismic energy (416×10^{18} ergs or 77 %) was released in the regions situated north of the 60° parallel (the greater part of Norway and Sweden and the whole of Finland).

In Fennoscandia as a whole the main quantity of seismic energy (81.2 %) was released in the interval between the 28—3 (32.9 %) and 9—18 (48.3 %) days of the synodic month. Within the other part of the synodic month (3—9 and 18—28 days) the frequency of the seismic energy released was 5 times less.

This is a remarkable fact indicating the extremely important role played by the lunar phases (with the mutual location of the Earth, the Moon and the Sun) in the distribution of the seismic energy of this region during the lunar month.

It may be mentioned in passing that the strongest earthquake with a magnitude of M = 6.5 (it occured on the 13.7th day of the synodic month) falls within the interval of the 9—18 days of the synodic month (main maximal released seismic energy in Fennoscandia).

The distribution of the earthquakes as a function of the synodic and reduced anomalistic age is shown in Fig. 3. As can be seen the plots of the strongest earthquakes (with a magnitude of $M \geqslant 4.0$) in Fennoscandia fall within narrow zones elongated in a direction extending from

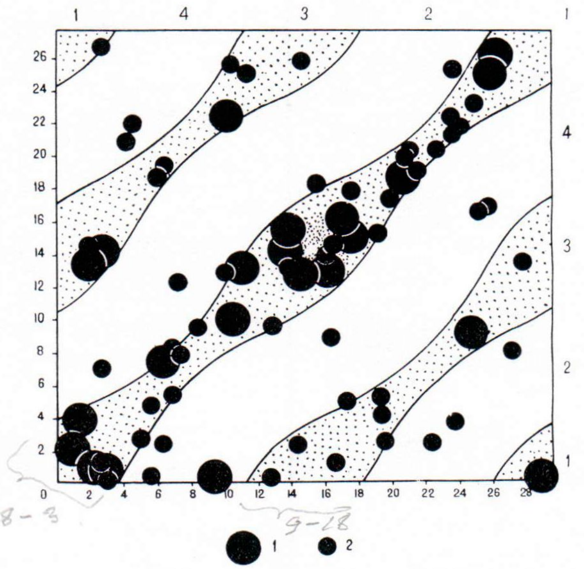

Fig. 3. Distribution of strong earthquakes (with M ≫ 4.0) in Fennoscandia from 1900—1950 as a function of the average synodic and reduced anomalistic age. Days of the average synodic month are on the abscissa. Days of the reduced anomalistic month are on the ordinate. Circles designate earthquakes. Earthquake magnitudies: 1) 4.6—5.4 or more: 2) 4.0—4.5. By dots is shown the time during which cosmic conditions favor the earthquakes.

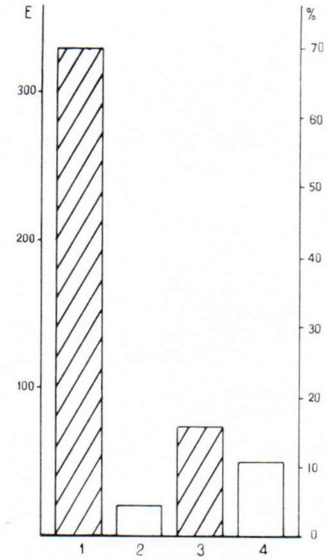

Fig. 4. Distribution of energy of all earthquakes in Fennoscandia according to seismically active zones (shading) and seismically passive belts (is left unshaded). 1 and 3 — seismically active zones: 2 and 4 — seismically passive belts. E — energy, in 10^{18} ergs (on the right — is energy in percent).

the lower left corner to the upper corner of the diagram.

56 earthquakes (with a magnitude of M ≫ 4) occured in the seismically active zones, whereas only 19 earthquakes occured in the seismically passive belts. If the number of earthquakes in the seismically passive belts (numbers 2 and 4) is recalculated to one hundred percent, then the seismically active zones (numbers 1 and 3) show an increase of 295 % (Table 3).

Especially interesting is the distribution of earthquake energy (Table 3). In seismically active zones the release of seismic energy increased 6 times (641 %) as much as it did in seismically passive belts. This is especially obvious for the first seismically active zone, where the energy of the earthquakes exceeded that of the earthquakes in the seismically passive zone 7—18 times (Fig. 4).

TABLE 3

Distribution of strong earthquakes (M ≫ 4.0) in Fennoscandia (1900—1950) and their energy in seismically passive betls and seismically active zones

Belt, zone	Seismically passive belt		Seismically active zone		Seismically passive belts	Seismically active zones	In the active zones as compared to the passive belts, %%
Numbers (belt, zone)	2	4	1	3	2 + 4	1 + 3	
Number of earthquakes ...	10	9	39	17	19	56	295
Energy of earthquakes × 10^{18} ergs, ...	20.3	49.3	373.5	72.6	69.6	446.1	641
%%	3.9	9.7	72.4	14.0	13.6	86.4	

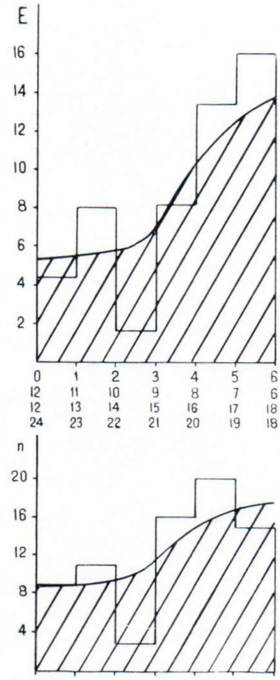

Fig. 5. Distribution during the lunar day of strong earthquakes (with M ⩾ 4) and their energy in Fennoscandia (1900—1950). n — number of earthquakes: E — energy of earthquakes, in 10^{18} ergs: curve shows the change in seismic energy (E $\times$ 10^{18} ergs) by twice-sliding three-hour periods.

The increase of several hundred percent (500—1 000 % or more) in the energy released by earthquakes as related to the variation of values of the tide-generating forces is a visual and undisputable demonstration of the genetic connection between seismic activity and tide-forming forces (Tamrazyan, 1968).

The distribution of earthquakes in Fennoscandia as related to local reduced lunar time is shown in Fig. 5.

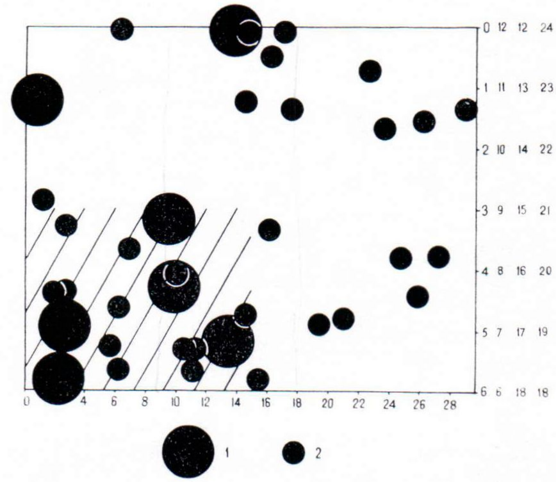

Fig. 6. Distribution of strong earthquakes in Fennoscandia by hours of the reduced lunar days (counted from the moment of the upper culmination of the Moon) and simultaneously in connection with their synodic age (1900—1950).
Eearthquake magnitude (M): 1) 5.1—5.4 or more: 2) 4.3—5.0.

The distribution of strong earthquakes as related to local lunar time and their synodic age is shown in Fig. 6. The increase in the number of strong earthquakes and especially in their energy, depicted in the lower left part of Fig. 6, is striking. Here, in comparison with the rest of the figure, the frequency of the earthquakes is twice as high and their energy is 5 times greater.

The almost distinct maximum of the strong earthquakes in certain sections of this figure indicates the role of cosmic influences on the period of intense seismic activity in Fennoscandia. The above correlations testify to the influence of cosmic conditions in triggering off the energy released at earthquake foci.

REFERENCES

BÅTH, M. (1956) An earthquake Catalogue for Fennoscandia for the years 1891—1950, Stockholm.

TAMRAZYAN, G. P. (1966) Time of origination of earthquakes in the Kuril-Adjoint-to-Kamchatka Region and the local Time (Lunar, Solar). Journal of Physics of the Earth, Vol. 14, No. 2, 41—48, Japan.

— (1968) Principal regularities in the distribution of major earthquakes relative to solar and lunar tides and other cosmic forces. Icarus (International Journal of the Solar system), Vol. 9, No. 3, 574—592. USA.

— (1968) Seismicity in Finland against a background of the cosmic conditions. Bull. Geol. Soc. Finland, 40, 113—116, Finland.

— (1969) Seismicity of Norway in relation to cosmic conditions. Norsk Geologisk Tidsskrift. Vol. 49, No. 1, 81—86, Norway.

— (1969) Seismic anomalies and the dynamic evolution of the Earth's Crust and Upper Mantle. Icarus (International Journal of the Solar System), Vol. 10, No. 1, 164—168. USA-Great Britain

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