EARTHQUAKES AND COSMIC CONDITIONS IN THE SOUTHERN PART OF SCANDINAVIA

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The occurrence of earthquakes in southern Scandinavia including Denmark 1900–1950 is considered in relation to period within the synodic month and the lunar day. It is concluded that the release of the earthquakes is related to variations in the tide-generating forces.

In this paper the expression the southern part of Scandinavia means the far southern part of the Scandinavian peninsula situated to the south of approximately 60° N and to the west of 17° E (fig. 1). Information on earthquakes with a magnitude M $\geqslant$ 3 from 1900 to 1950 is gathered from Båth (1956) and Lehmann (1956). Within these 50 years more than a hundred earthquakes were registered (see also table 1).

Southern Scandinavia is a region of predominant uplifts mainly of Precambrian folded basement and partly (in the north-west) of Caledonian folded basement. A small region of predominant subsidence of Precambrian or Caledonian folded basement is located only in the extreme south (fig. 1). Within the limits of southern Scandinavia a considerable region near the lake of Vänern is located where in Cenozoic time intensive differential block movements have occurred on the site of the predominant uplifts of Precambrian basement.

On the whole there are three regions: the western, the central (Lake Vänern), and the eastern.

The Scandinavian peninsula

The distribution of earthquakes in southern Scandinavia (with magnitude M $\geqslant$ 3) and of their energy according to the day of the synodic month is shown in fig. 2. (The synodic age of an earthquake is the time in days between the dates of the earthquake and the passed new Moon; it is read off regarding the average duration of the synodic month as 29.6 days). As is seen from the diagram, the earthquakes and especially their energy are distributed unevenly within the synodic month.

In the western region most of the seismic energy (95 %) was released in the interval between the 11th and 21st (63 %) and between the 26th and 2nd (32%) day of the synodic month. For the other half of the synodic month (2–11th and 21–26th day) the release of energy was 17

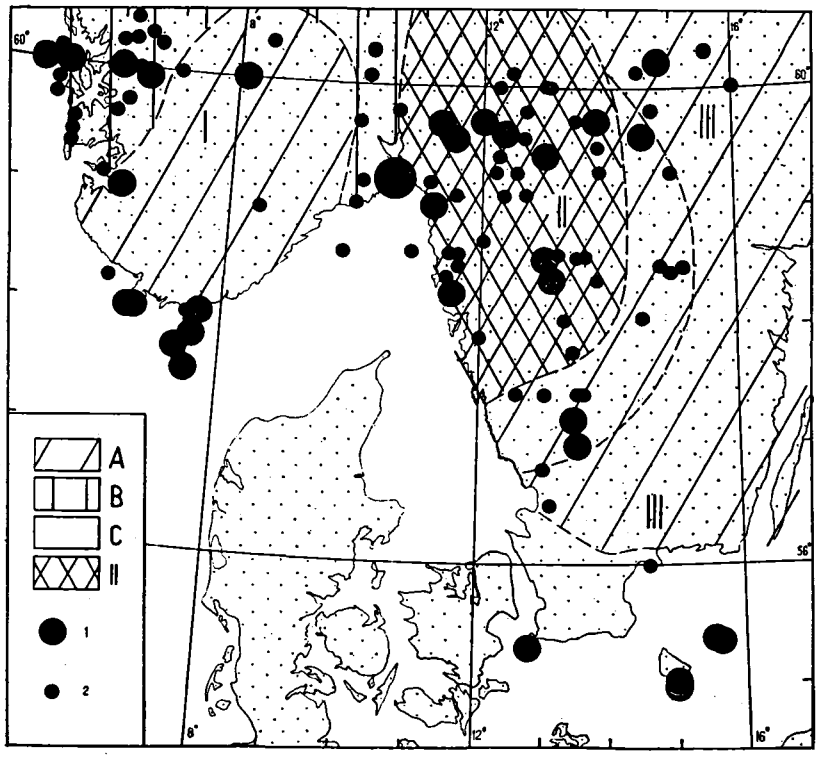

Fig. 1. Earthquakes 1900–1950 in southern Scandinavia. Regions of predominant uplift of Precambrian *(A)* or Caledonian *(B)* folded basement. The Vänern region *(II)* has been subjected to intensive block movements of the Precambrian basement in Cenozoic time. Regions of predominant subsidence of Precambrian or Caledonian folded basement *(C)*. *I:* Western region. *II:* Central (Vänern) region. *III:* Eastern region. Magnitudes *(M)* of earthquakes: *1:* 4–5 or more. *2:* 3–3.9.

times less than that within the aforementioned half of the synodic month. This is a remarkable fact, indicating the extremely important role played by lunar phases in the distribution of seismic energy in the Norwegian region during the lunar month.

The earthquake in the southern part of Scandinavia (October 23rd, 1904) had a magnitude of M = 6.5. This is considered as a strong earthquake and its share is 98 % of the whole seismic energy of southern Scandinavia during 1900–1950. All the other earthquakes taken together produced only 2 % of the released energy. In order not to mask the features of the distribution of seismic energy of all the earthquakes of the southern Scandinavia, that particular earthquake is excluded from the statistical accounts.

Table 1. Earthquakes in southern Scandinavia 1900–1950.

Date (day, month, year)	Greenwich Mean Time (hours, minutes)	Co-ordinates Lati-tude N	Co-ordinates Longi-tude E	Magni-tude M	Synodic age of the earth-quakes (days, hours)	Reduced local lunar time (hours)
5 XI 1901	22 58	59.7	13.8	4.7	24 18	15.8
29 IV 1902	13 15	57.2	13.4	4.0	21 14	8.6
23 X 1904	10 27	59.2	10.5	6.5	13 18	12.1
18 XI 1904	2 30	59.6	11.5	4.7	10 23	6.3
13 XII 1904	21 51	58.7	11.3	4.2	7 06	4.7
3 VI 1906	3 24	58.0	6.5	4.3	11 07	6.7
10 XII 1906	16 11	58.0	6.5	4.2	24 23	8.4
10 I 1907	0 32	59.6	12.3	4.9	25 20	16.4
5 IV 1907	1 25	58.4	13.1	4.0	22 07	20.2
29 VI 1907	20 00	60.0	8.1	4.5	19 06	16.9
8 I 1908	22 30	58.3	11.5	4.4	5 13	6.8
15 III 1909	7 58	59.0	11.2	4.1	23 14	1.5
24 VIII 1911	21 48	60.0	5.2	4.9	1 06	9.1
18 IX 1912	20 48	60.2	14.8	4.0	8 04	3.3
23 VIII 1921	22 00	55.0	15.0	4.0	20 19	18.1
23 VIII 1921	23 45	55.0	15.0	4.0	20 21	19.8
11 VI 1922	12 44	59.6	14.5	4.3	16 07	12.5
27 X 1922	5 10	59.7	12.0	4.2	7 04	12.1
19 X 1926	17 17	57.8	7.5	4.2	12 18	19.5
23 V 1929	18 36	57.5	7.4	4.9	14 14	19.2
29 V 1929	23 31	57.7	7.3	4.7	20 19	19.2
26 X 1929	13 44	57.0	13.5	4.2	23 14	7.5
31 X 1930	23 17	55.3	12.8	4.5	10 01	4.1
3 IX 1932	19 06	58.6	13.0	4.2	2 23	5.5
5 VIII 1933	23 58	59.4	13.0	4.5	14 08	1.2
9 X 1939	10 09	58.0	7.6	4.6	26 03	1.3
4 I 1942	22 39	60.0	6.0	4.0	17 13	20.8
26 XI 1942	3 09	59.9	6.4	4.8	17 13	1.3
29 VIII 1943	5 35	59.0	6.2	4.1	27 22	19.2
20 XI 1944	1 36	60.0	4.8	4.0	4 03	10.6
24 IV 1946	17 45	55.4	15.6	4.3	22 16	12.7
22 VII 1948	19 15	55.4	15.6	4.0	16 01	19.3

In the central region (Vänern) most seismic energy (84.8 %) was released in the interval between the 5th and 12th (31.4 %) and the 22nd and 27th (53.4 %) day of the synodic month. For the remaining days of the synodic month (12–22nd and 27–5th day) the daily energy release was 8 times less than that within the aforementioned days. This is another remarkable fact indicating the extremely important role played by lunar phases in the distribution of seismic energy of the Swedish region during the lunar month.

In the eastern region of southern Scandinavia a narrow zone located immediately to the south-east of the central region may be marked out. In this narrow zone the distribution of seismic energy during the synodic month is almost analogous to the distribution of seismic energy in the synodic month in the central (Vänern) region. This underlines not only the territorial closeness of these regions, but also their similar readiness to react to the influence of cosmic effects. In the remaining part of the

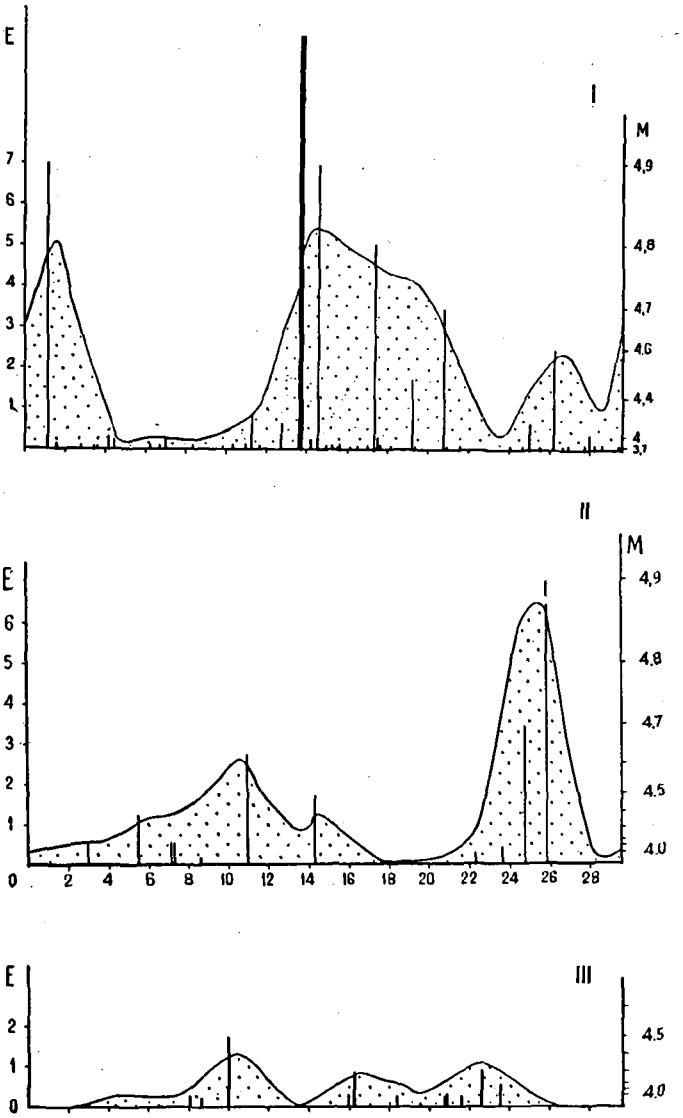

Fig. 2. Distribution of the earthquakes 1900–1950 and their energy depending upon the average synodic age. Days of the average synodic month are marked on the horizontal line. Vertical lines are the magnitudes (*M*) of single earthquakes. Curved lines and dotted areas show the smoothed change of seismic energy ($E \times 10^{18}$ *erg.*). Thick line: The earthquake of the magnitude $M = 6.5$. *I:* Western region. *II:* Central (Vänern) region. *III:* Eastern region.

eastern region the largest quantity of seismic energy has been released within the interval between the 4th and 11th day of the synodic month.

From the above the following may be said. Firstly, the seismic energy is distributed within the synodic month highly selectively for each region. Secondly, each of the three regions in the southern part of Scandinavia has released seismic energy during 1900–1950 in strictly definite time intervals within a synodic month. Thirdly, the inverse distribution of seismic energy during the synodic month in the western and central regions is connected with a considerable rate of differential movements in the central regions, and with a low rate of differential movements in other regions which belong to another tectonic regime.

It is also to be noted that within the whole of Fennoscandia (including Norway, Sweden and Finland) only within the Vänern region has the Precambrian folded basement been intensively subjected to differential block movements during the Cenozoic and almost exclusively within this region has the seismic activity been considerable between the last quarter of lunar phase and the new Moon. Other parts of Fennoscandia where the seismic activity is intensified prior to the new Moon are those regions in which the differential block movements of Caledonian folded basement have been intensified during Cenozoic time.

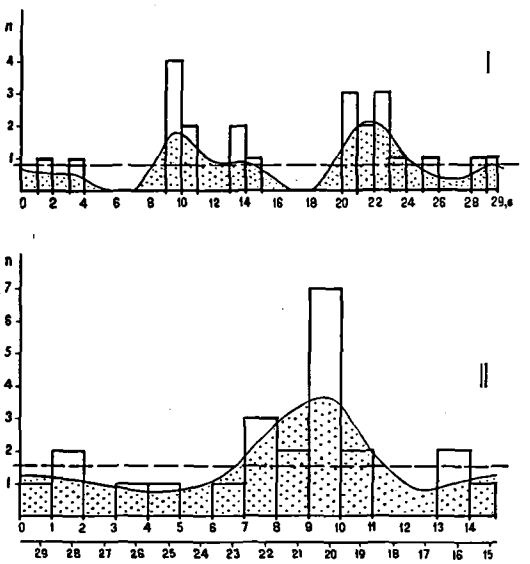

Fig. 3. Distribution of earthquakes in Denmark 1875–1954 according to the days of the synodic month. *I:* Relative to all the days of the synodic month. *II:* Relative to the syzygy line; earthquakes occurred on both sides of the syzygy line are combined. Curved line show the smoothed change of number of earthquakes. Horizontal dotted line show the averaged number of earthquakes. *n:* Number of earthquakes.

Denmark

Earthquakes in Denmark are mainly concentrated in the north-western part of Jutland and in Zealand, and sometimes they have been registered also on the island of Bornholm. According to Lehmann (1956) 14 earthquakes in north-western Jutland (including one earthquake in the western Jutland), 6 earthquakes in Zealand and 3 earthquakes within the island of Bornholm were registered during 1875–1954.

The distribution of Danish earthquakes according to the days of the synodic month is shown in fig. 3. As it is seen from the upper part of fig. 3 the earthquakes are distributed unevenly. The greatest number of earthquakes is located in the interval between the 9th and 11th and between the 20th and 23rd day of the synodic month. The pattern of distribution of the number of earthquakes in the days of synodic month is especially clearly seen on the lower diagram of fig. 3 where both halves of lunar orbit counted from the new Moon to full Moon (and further on from full Moon up to the new Moon) are combined. A distinct maximum which falls between the 7–11th and the 19–22nd day of synodic month is marked; the number of earthquakes occurring is greater than the intradiurnal number only within the limits of this maximum, whereas during all the remaining days it is less.

Earthquakes and cosmic conditions

It follows that the reciprocal location of the three interacting bodies (the Earth, the Moon, the Sun) is found to be of some importance for the origination of earthquakes.

The distribution of earthquake energy in the central region according to reduced lunar time (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), reveals a distinct and sharp intradiurnal maximum at the time most remote from the moment of upper and lower culmination of the Moon (fig. 4). The large minimum of seismic energy is timed with the moment of the Moon's passage through local meridian. Close to the time of the Moon's passage through local meridian, within 0 ± 2 hours and 12 ± 2 hours, only 14.3 % of the seismic energy was released whereas at the Moon's greatest moving off from culmination (within 6 ± 2 hours and 18 ± 2 hours) 66.4 % of the seismic energy of the region was released.

The Moon's effect resulted in the intradiurnal distribution of seismic activity also for the western and eastern regions, but to a smaller extent (fig. 4).

The maximum number of earthquakes in Denmark occurred between 3 and 5 o'clock in the lunar day and during the time interval divisible by these hours (7–9, 15–17, 19–21 o'clock). During the remaining two-thirds of the day on the average 2–3 times fewer earthquakes were registered (fig. 5).

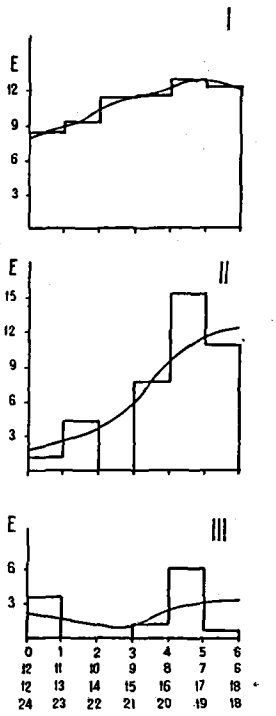

Fig. 4. Distribution of energy-strong earthquakes ($M \geqslant 4$) 1900–1950 during the lunar day. *E:* Energy of earthquakes in 10^{18} *ergs.* The curved line shows the change in energy averaged over a cumulative three-hours period. The time is reckoned from the moment of the Moon's upper culmination over the given locality. *I:* Western region. *II:* Central (Vänern) region. *III:* Eastern region.

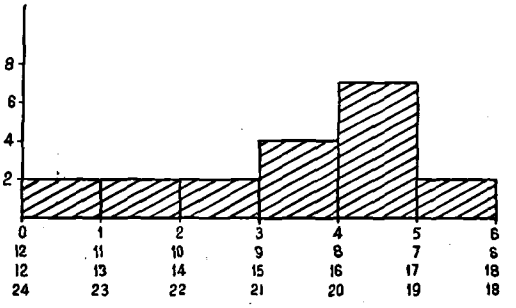

Fig. 5. Distribution of earthquakes in Denmark 1875–1954 according to local reduced lunar time by hours calculated from the moment of passage of the Moon through local meridian (upper or lower culmination).

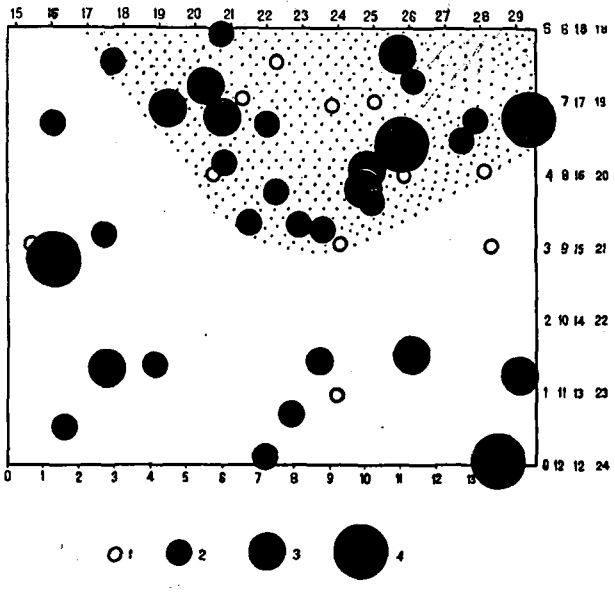

Fig. 6. Distribution of earthquakes 1900–1950 in southern Scandinavia according to their synodic age and hours of the reduced lunar days, calculated from the moment of the upper culmination of the Moon. *1:* Earthquakes in Jutland and Zealand. *2–4:* Earthquakes in southern Scandinavia. The magnitudes are: *2:* 4–4.3. *3:* 4.4–4.7. *4:* ≥ 4.8–4.9.

On the whole the earthquakes in the southern part of Scandinavia and in Denmark are essentially dependent on local lunar time decreasing at the Moon's passage through local meridian and sharply increasing far from this meridian.

Distribution of earthquakes according to local lunar time and simultaneously according to their synodic age is shown in fig. 6. There is a striking growth in the number of earthquakes in the upper part of this diagram. A distinct maximum of earthquakes in certain sections of this figure indicates the role of cosmic influence on the period of intense seismic activity in the southern part of Scandinavia and in Denmark.

The southern Scandinavian earthquakes in the period 1900–1950 were distributed in time in strict conformity with the cosmic conditions of the Earth as a whole; this largely concerns the distribution of earthquakes during the synodic month and during the lunar day. An earthquake is the result of continuous development within the planet's interior. The stimuli of earthquakes, however, are different. The results obtained are based on the complicated comparison of uncoordinated data. The earthquakes under study are distributed not unsystematically but very selectively, in conformity with variations of cosmic conditions, *e.g.* with variations of tide-

generating forces (see Tamrazyan, 1965). From this point of view the seismic activity in the southern part of Scandinavia and Denmark is of a certain interest.

Dansk sammendrag

Jordskælv i det sydlige Skandinavien inclusive Danmark i årene 1900–1950 analyseres med henblik på en eventuel sammenhæng med den kosmiske situation i samme tidsrum. Jordskælvene er resultatet af en stadig udvikling i tektonisk ustabile områder præget af hævninger og sænkninger (se fig. 1). En sammenstilling af jordskælvsenergi og tidspunktet for jordskælvene regnet inden for den synodiske måned og månedagene (fig. 2–6) synes ifølge forfatteren at vise, at udløsningen af jordskælvene overvejende indtræder i overensstemmelse med de tidevandsfremkaldende kræfter, det vil sige er afhængig af den indbyrdes stilling af Jord, Sol og Måne.

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