

SVERIGES GEOLOGISKA UNDERSÖKNING

SER. C.

Avhandlingar och uppsatser.

N:o 364

ÅRSBOK (1930) N:o 1.

A SEISMOLOGICAL MAP  
OF NORTHERN EUROPE

BY

K. E. SAHLSTRÖM

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WITH ONE PLATE

*Pris 0.50 kr.*

STOCKHOLM 1930

KUNGL. BOKTRYCKERIET. P. A. NORSTEDT & SÖNER

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In his valuable memoir «Sveriges jordskalv» (Earthquakes in Sweden) (5), Rudolf Kjellén in 1910 gave a survey of the seismic conditions in Sweden. He publishes a list of all earthquakes that have been observed and recorded in the country, compiled from a great number of different sources. The catalogue, which goes from the year 1375 to 1906, contains 421 earthquakes. On the basis of this material, Kjellén has constructed a seismic map of Sweden, using the following method. According to its size, each earthquake is given a certain figure value (in «earthquake units») from  $\frac{1}{2}$  to 5, while information that earthquakes are of frequent occurrence is rated as 10. Taking into consideration the distribution of the more important shocks, the country is then divided into a number of zones, and the degree of seismicity within these zones is expressed in the number of square kilometers for each «earthquake unit» within the time considered. The map shows strongly seismic regions around Lake Vänern, along the Bothnian Gulf, in Halland, and in southeastern Skåne. As aseismic regions the whole of interior Norrland appears, and also the eastern coast from Blekinge in the south all the way up to Gästrikland. The cause of the earthquakes is, in Kjellén's opinion, the still continuing elevation of the land.

A cartographic presentation of the seismicity in Norway and Sweden during the period 1887—1911 has been given by C. F. Kolderup (6, p. 111), 1887 being the year when a systematic recording of earthquakes was started in Norway. Vestlandet, Nordlandet, and the Oslo region stand out as those parts of Norway where earthquakes are most frequently experienced.

In a memoir «Über kartographische Darstellung der Seismicität» (10), Henrik Renqvist has recently described a new principle for seismic maps: «Nachdem die Schüttergebiete aller Beben der zu untersuchenden Periode in Spezialkarten eingetragen worden sind, macht man sich von dem ganzen Lande eine mit regelmässigem Punktnetz versehene Pause im selben Massstabe. Man legt nun diese Pause auf die Spezialkarten und notiert, wievielmals jeder Punkt in ein Schüttergebiet fällt. Die somit erhaltenen Summenzahlen der Fälle von Erdbeben werden in eine neue Punktkarte eingetragen und dienen zur Unterlage bei Eintragung von Linien gleicher Erdbebenhäufigkeit.»

Using this method, Renqvist has constructed a seismic map of Finland. The distance chosen between the points was 30 kilometers. This map shows the highest degree of seismicity within a zone across the country from the Bothnian Gulf in an eastnortheastern direction to the Russian frontier. Both northwards and southwards from this zone, the seismicity decreases rather

regularly. The common view that the earthquakes in Finland are occasioned by the Fennoscandian land elevation is corroborated by the evidence presented by this map.

As this method introduced by Renqvist has seemed to me decidedly better than those previously employed, and makes possible a more reliable and, at the same time, more detailed picture of the seismic conditions, I have constructed maps according to the same principle for Sweden, Norway, and Denmark which, together with Renqvist's Finland map, have been combined to the map of Northern Europe as here presented. For Sweden I have followed R. Kjellén's catalogue cited above, and for the period 1907—1925 the reports worked out by myself (11). The total number of earthquakes is 523, 160 of which took place before the year 1800. For Norway I have followed C. F. Kolderup's list of 1912 and for the years 1912—1925 the later annual reports by the same author (6 and 7). The number of earthquakes is 718, 40 of which occurred before 1800. For Denmark my sources have been F. Johnstrup's catalogue of 1870 (4) and later papers by V. Hintze (2).

Those few earthquakes in Sweden and Denmark that have been reported before 1600 have been omitted, as their extension is too imperfectly known, and only those from 1600—1925 included.

With regard to the frequently occurring fore-shocks and after-shocks I have found it best to follow the same principle as Kjellén in his catalogue: to refer all shocks that occur with short intervals in one and the same district to one number, until one month has passed without any shocks. For Norway this principle gives a somewhat lower total number than the sum in Kolderup's catalogue.

It is obvious that this material is very incomplete, especially in the case of older times, with regard both to the number of earthquakes that have occurred and to the true extension of the recorded shocks. Therefore, too much importance must not be attributed to the course of one particular frequency curve. Yet the material appears to be, at the same time, so rich that the picture presented by the map must be true in its main features. In many cases, this has been directly corroborated through comparison with the earthquakes that have taken place during the last few decades, and the extensions of which have been recorded with a greater accuracy.

On the map, the following four regions stand out as strongly seismic:

1) *The Bothnian Region*, around the Bothnian Gulf, in a belt from Hälsingland to Österbotten, and comprising the coast region of Norrland and the larger part of Österbotten.

2) *The Oslo—Väner Region*, embracing the country around Oslo and eastwards to Lake Vänern.

3) *Vestlandet* (westernmost Norway).

4) *Nordlandet*, comprising the middle portion of the Nordland «fylke».

Further there is an isolated area in Finmarken in Norway, around Karasjokk.

As aseismic regions there stand out southern Finland, Finnish Lapland

Finmarken in Norway, the interior portions of the Scandinavian peninsula, the east coast of Sweden from Gästrikland southwards to Blekinge, and finally the larger part of Denmark.

All more important earthquakes, the extension of which has been satisfactorily recorded, also are found to belong to one of the seismic regions defined above.

In Pl. 1 are also shown the limits for the 19 most important earthquakes during the period 1800—1925. Among them, 4 belong to Nordlandet, 5 to the Bothnian Region, 6 to Vestlandet, and 4 to the Oslo—Väner Region. To judge from their extension these earthquakes thus have had their origin within one of the seismic zones that are indicated by the frequency curves. On the other hand, not one earthquake of a similar magnitude has originated in those tracts that are indicated by the frequency map as aseismic areas.

The two maxima of the Bothnian Gulf Region, one around Löfvånger in Västerbotten and the other near Härnösand, appear in a sufficiently well-marked way to be regarded as representing two particular sensitive areas within this region. A bridge of more stable country unites the aseismic region of interior Scandinavia with that of eastern Sweden. Also the Oslo—Väner Region culminates with two highly seismic areas, viz. the surroundings of Oslo and central Värmland. The decreasing seismicity towards Lake Vänern is also recognizable in the fading in this direction that has been proved in several comparatively recent earthquakes, the extensions of which have been recorded in detail. The same holds true of the decrease towards the West Coast, and the delimitation in the north.

The more stable area of the Väner basin cuts off the seismic tract in Västergötland, which thus receives an independent position, apparent also from a number of smaller earthquakes with their epicentres within this tract (the Västgöta plain and Falbygden).

From this tract, a belt of marked seismicity goes southwards into western Småland. Here are found the places of origin of a number of small or, for Sweden, moderately great earthquakes, which generally do not show their effects as far out as to the Halland coast. There are facts known distinctly indicating that at least the middle part of the Halland coast is more stable than western Småland. On R. Kjellén's map, a too high degree of seismicity appears to have been attributed to Halland, through the imperfect method employed in the plotting. In Skåne, the southeastern part of the province shows the highest seismicity, while in Denmark northeastern Sjælland and the northwesternmost part of Jylland appear to be most strongly seismic.

Separated from the Oslo—Väner Region by a stretch of somewhat more stable country lies the seismic area at the northern end of Lake Vättern, where was located the epicentre of the 1879 earthquake which comprised 35,000 square kilometers.

In Norway, the Vestlandet Region forms a narrow belt with the seismicity culminating in the north, in Sogn—Møre. This coast region represents the area most rich in earthquakes within the countries here considered.

Also the fourth region, Nordlandet, is a narrow coastal belt, with the highest seismicity in the island fringe.

Entirely isolated is the Karasjokk Region in Finmarken. Of the earthquakes reported from there, however, 14 are designed as local ones, and all these date from the period 1889—1900. But it seems, from the information on earthquakes in Finmarken compiled by Kolderup (6, p. 74), that Karasjokk suffers earthquake shocks more often than the rest of Finmarken. Furthermore, Renqvist's map of Finland shows an increased seismicity in the northernmost point of the country. It seems, therefore, that there exists in the interior of Finmarken an area with a higher seismicity than the surrounding region.

The Bothnian Region coincides so closely with the area of the maximum post-Glacial land elevation that a connection between earthquake frequency and land elevation seems an inevitable conclusion<sup>1</sup>. Apparently the earthquakes in this region are caused by slips and movements in the rock crust at the very top of the dome-shaped uplift.

With regard to the Oslo—Väner Region, L. von Post has shown that the post-Glacial land elevation around Lake Vänern and in Värmland has had a very irregular course, and has clearly been influenced by the fact that the rock crust is cut up by fissures and faults into a system of blocks (8, 9). In this region the curves illustrating the amount of the upheaval (isobases) and the curves of the earthquake frequency are so strikingly in conformity with each other that it seems necessary to postulate an intimate relation between the raise of land and the earthquakes.

Also C. F. Kolderup is inclined to see a genetic relation between the Norwegian earthquakes and the land elevation, but the course of the latter is not sufficiently well known to allow any detailed comparisons. Both the Vestlandet and the Nordlandet regions probably form zones of weakness at the northwestern border of Fennoscandia, but within the continental shelf. The deep basin of the bordering sea (the »Scandic») undeniably approaches the northern end of the Vestlandet seismic zone with a bay, but the deep-sea slope all the same lies too far off to make it probable that the earthquakes have originated from there. Also a compilation by E. Tams (12) of earthquake epicentres in the Scandic and its surroundings in 1904—1915 shows that they all group themselves within a belt from the Reykjanes threshold across Iceland to the sound between Spitzbergen and Greenland, while no seismic activity has been recorded from the Fennoscandian border during the same period.

That the origin of the earthquakes in the Nordlandet Region cannot be sought too far out from the coast is also shown by the fact that the Lofoten Islands show a comparatively low seismicity.

A relation between the earthquakes and geologically proved fissure and fault lines is highly probable in Värmland, as already mentioned. Probably also some other cases of fissures not yet healed could be pointed out. Thus

<sup>1</sup> In the case of the coast of middle Norrland, this has been pointed out by A. G. Högbom (3).

several earthquakes are localized around the supposed boundary faults of the Silurian area of southern Falbygden (in Västergötland).

For the rest, however, it is quite striking how independently of all fault lines the earthquakes occur. The well-marked Närke faults show no reaction for the Värmland earthquakes, which instead fade out eastwards without any relation to the old fault lines. Eastern Sweden, with a rock crust cut by closely spaced fissures (1 a), belongs to the aseismic areas, with extremely few cases of primary seismic activity. It seems that the faults have been so completely healed that they do not react for waves from other quarters. Neither does the neighbourhood of the Lake Vättern depression display any particular seismic activity. A number of earthquakes have proved that the Hökensås massif (S. W. from Vättern) is connected with the aseismic region of southeastern Sweden. The frequency curves run across the Vättern depression. The strong secondary reaction that took place here at the great earthquake of 1904 is an isolated occurrence in the seismic records. For Norway, C. F. Kolderup has arrived at similar results when trying to refer earthquakes with a well known extension to known fault lines. The old fissures in the rock crust of Norway appear to be so completely healed that they do not break up any more (6, p. 111).

At several occasions one has been inclined to refer the centre of an earthquake in the neighbourhood of the Skagerack to the Norwegian Deep Channel. However, the low seismicity in Jylland, the decreasing seismicity of the Oslo—Väner Region in the direction towards the Skagerack, and the fact that the Norwegian coast inside the Deep Channel has fewer earthquakes than both Vesterlandet and the Oslo district all speak against the possibility that the Norwegian Deep Channel, at least in its eastern part, should be particularly sensitive in a seismic sense. And apart from the great earthquake of Oct. 23, 1904, the place of origin of which fell within a belt from the Oslo Fiord to southern Väner (1), there is no example that an earthquake has been felt both in southern Norway, Bohuslän, and northern Jylland, although this ought to be the case if the Deep Channel were a pronounced earthquake centre. On the other hand, there are at least two cases of shocks that have been felt simultaneously on the southernmost point of Norway and in north-western Jylland, viz. those of Apr. 3, 1841, and Dec. 16, 1895. Both of these have by Hintze (2) been supposed to have originated from slips along deeply situated faults, striking from Norway across Jylland in a N. W.—S. E. direction. In any case, the extension of these two shocks points at an epicentre in the western part of the Skagerack.

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