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ELOCS

INSTRUMENTALLY ANALYZED SEISMICITY OF THE NORWEGIAN CONTINENTAL SHELF

by Hilmar Bungum

ELOCS Report 2-2
December 1987

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SUMMARY

The seismicity of the Norwegian Continental Shelf has been covered instrumentally for more than 80 years. Useful data can be found as far back as to the mid-1920s, with significant improvements in coverage in the mid-1960s (the WWSSN network), at the end of the 1970s (regional networks), and again in 1986/87 (Northern Norway).

An extensive analysis of data from all of this time period, aimed at integration of results, has given us a pattern of seismicity which correlates quite well with regional as well as local geological features. Earthquakes have been found to occur along the entire continental shelf, and with about the same level of activity to the north as compared to the southern areas.

A more detailed description of the seismicity can be given as follows (from north to south):

- To the north, the earthquakes are confined to the eastern part of the Lofoten Basin, and limited by the Senja Fracture Zone in the sense that large parts of the Barents Sea exhibit no earthquake activity above detection thresholds.

- The seismicity then follows the Northern Norway coastal areas along the Rana Fault Complex as well as more offshore along the Kristiansund-Bodø Fault Complex.

- Further west, a concentrated zone of earthquakes has been found close to the intersection between the Vøring Plateau Escarpment and the eastern part of the Jan Mayen Fracture Zone.

- Further south, the earthquake activity is weaker again until one reaches the Møre Basin's southern part, with concentrated seismicity zones on both sides as well as due south in the northernmost part of the Viking Graben.

- The earthquake activity then divides into two distinct zones separated by the Horda Platform, and the easternmost of these follows the Øygarden Fault Zone quite closely, with an extension inland immediately south of 60°N.

- On the western side, the seismicity follows the western flank of the Viking Graben and then continues, with a lower activity rate, into the Central Graben.

- A concentrated zone of earthquakes is also present west of Jutland and north of the Ringkøping-Fyn High, possibly tied to the western part of the Tornquist Zone.

- For completeness, we note also that the seismicity on the continental side has a zone following the Oslo Graben, a more active one around lake Vänern in Sweden, from there a more linear extension along the Swedish side of the Bothnian Bay, and finally a northwesterly trending zone along the Swedish-Finnish border as well as a more dispersed activity in northern Finland.

These results are based on a combined interpretation of earthquake catalogues based on different magnitude scales, M_S for the historical (felt) earthquakes, m_b for some of the more recent instrumental data, and M_L for the most recent microearthquake data. In this study, relationships between these magnitudes have now been established as follows:

$$M_S = 0.85\ M_L + 0.60 \qquad\qquad M_S = 1.04\ m_b - 0.53$$

Of these, the M_S/M_L relationship is quite reliable, while the M_S/m_b is only tentative because of the instabilities of m_b estimates for earthquakes on the Norwegian Continental Shelf.

The last part of this study involves determinations of focal mechanisms for a number of North Sea earthquakes. Normal faulting with EW extensional movements seems to be fairly common for some of the offshore areas (such as the Viking Graben), but strike-slip mechanisms have also been found for some smaller earthquakes in the northern North Sea. On the continental side, one event investigated shows thrust faulting with NW-SE compressional movements, consistent with the dominating stress orientation also for other parts of Fennoscandia.

1. INTRODUCTION

The Norwegian Continental Shelf covers very large areas, from the Central Graben in the south to the Svalbard platform in the north. Even though these areas are quite different geologically and tectonically, they are all characterized by a low-to-moderate seismicity that essentially follows the graben structures in the south and the continental margins further north.

Within the context of local, regional as well as global tectonics, earthquakes have played an important role in that they are manifestations and realizations of the release of stresses in the crust and upper mantle. This interaction between seismological and other geophysical and geological problems has been very important also in an earthquake hazard context because it has made it possible to use the geological record as a primary source of information about earthquakes older than a few hundred years in some areas (such as southern Norway and the North Sea) and a few tenths of years in other areas (such as the Barents Sea and the Norwegian-Greenland Sea).

Seismology is a young science, dating back not much longer than about a hundred years. At that time, there was, internationally as well as in Scandinavia, a surge of interest in macroseismic (felt) information from earthquakes (Muir Wood et al, 1985), at the same time as the first seismographs came into operation. In northwestern Europe, the first seismological stations were installed around 1900, then experienced a decline before and after the second world war, and a build-up again during the 1960s. The most important development here was the establishment of the World-Wide Seismological Station Network (WWSSN) in the beginning of the 1960s, an event which played a very important role in the development of the concept of global tectonics.

Following the success of the global seismological networks (which regularly now are being updated with new and more modern instrumentation), a similar development took place on the regional and local level about a decade later through the establishment of a large number of microearthquake networks. These local networks provide possibilities for a much more detailed delineation of seismicity patterns, focal mechanisms, etc. (Lee and Stewart, 1981), which in turn can be correlated with similarly detailed information on the geologic side.

In the context of seismic hazard and loading, the historical earthquake information is very important because it gives a more long-term assessment of seismicity and because it provides information about the strongest earthquake motions in a particular area. The historical seismicity is covered in the present ELOCS project by a separate report (ELOCS Report 2-1), and the data compiled there are shown in Fig. 1.1, with the magnitude distribution shown in Fig. 1.2. The tectonic information (faults) in Fig. 1.1 is also compiled under the present project (ELOCS Report 1-3), as shown in more detail in Fig. 1.3.

The purpose of the present report is to compile and analyze instrumental recordings of earthquakes in and around the Norwegian Continental Shelf. This limits the time period of analysis to the last 80 years or so for the very largest earthquakes and to the last 30 years when a better coverage is required (Bungum et al, 1986a; Muir Wood et al, 1986). Further significant improvements have taken place within the last 10 years (Bungum et al, 1986b).

The present report is organized as follows: In Section 2, we analyze available earthquake locations for a longest possible time period. In Section 3 we cover the time period from 1980 to 1984 and in Section 4

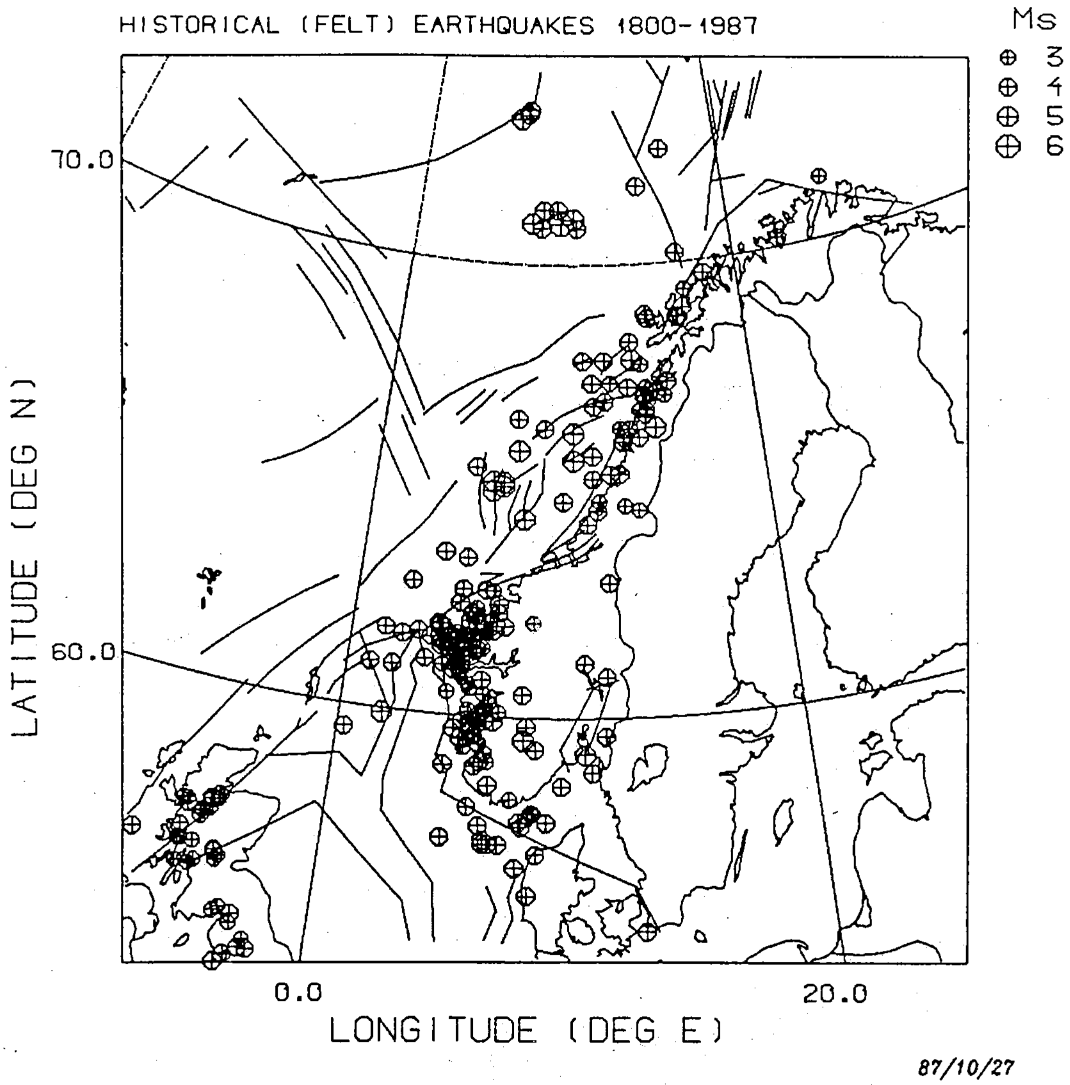

Fig. 1.1 Epicentral distribution of felt earthquakes, 1800-1987, as reported in the new historical data based completed under the present project (Elocs Report 2-1).

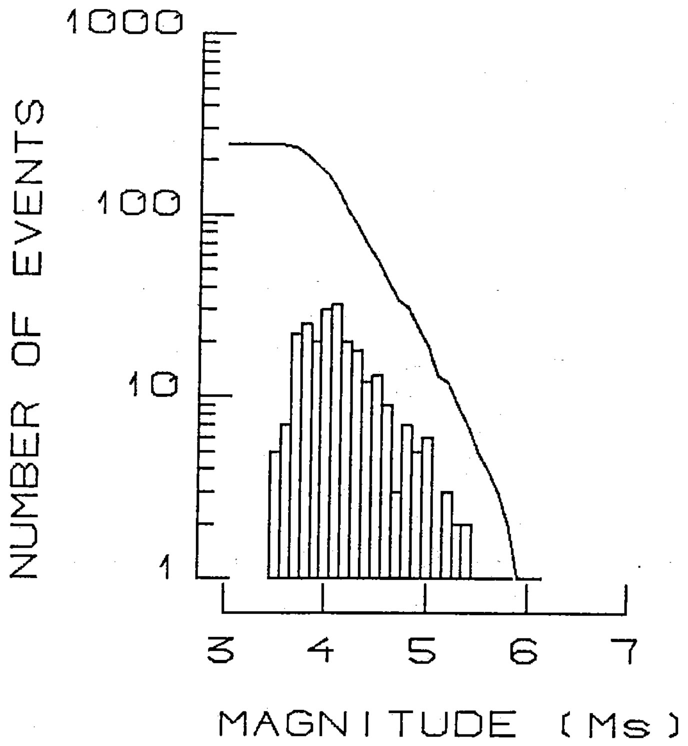

Fig. 1.2 Magnitude (M_s) distribution for the felt earthquakes plotted in Fig. 1.1.