NORSAR ROYAL NORWEGIAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

Scientific Report No. 2-78/79

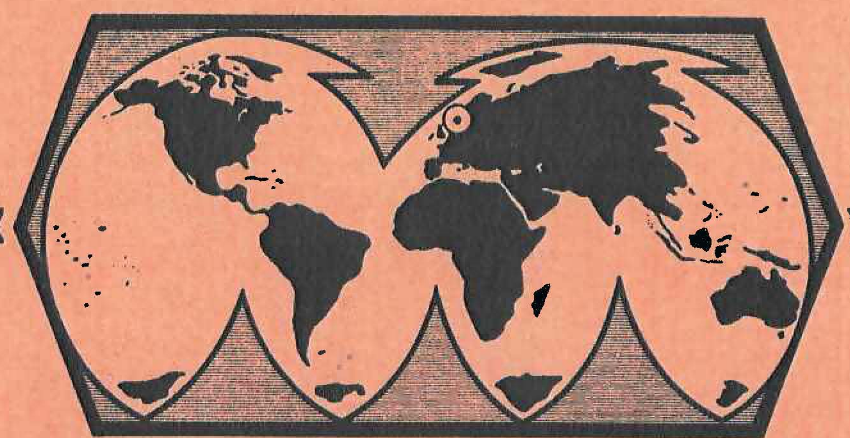
SEMIANNUAL TECHNICAL SUMMARY

1 October 1978—31 March 1979

By
H. Gjøystdal (Ed.)

Kjeller, 30 April 1979

Sponsored by
Advanced Research Projects Agency
ARPA Order No. 2551



VI.2 An Earthquake Sequence in Meløy, Northern Norway - A Unique Intraplate Phenomenon

A unique earthquake sequence began in Meløy, Northern Norway, in mid-November 1978, and 10 weeks later about 10,000 shocks had been recorded from a volume not larger than 10x8x6 km^3. So far, the largest earthquake had an estimated ML magnitude of 3.2 units and a maximum MM intensity of 6. The strike of the estimated faulting plane is $N25^oE$ with a dip of 63^oE (Bungum et al, 1979; Bungum and Husebye, 1979).

This paper summarizes our studies on the spatial and temporal patterns of the Meløy earthquake sequence, and also gives a discussion of possible source mechanisms. In our continuing studies, we will use these well-recorded events in an evaluation of various event detection and discrimination techniques at near distances.

The first positively recorded earthquake in the Meløy sequence occurred on 3 November 1978 and was measured at ML=2.4, using data from the NORSAR array which has an epicentral distance of about 700 km. The first reports out of Meløy itself came a few days later, and during the week 12-19 November ground shakings were widely felt many times. The first local seismographs were installed by NTNF/NORSAR 19 November, altogether 7 different sites were used (see Fig. VI.2.1), and at any one time a maximum of five stations were in operation. The earthquake sequence time history between 11 November 1978 and 18 February 1979 for station Neverdal is presented in Fig. VI.2.2. The main concentration of larger shocks was in the time period 11-18 November, and we also notice the interesting predominance of night-time shocks during this interval. After 5 December, the activity decreased having a minimum around 20 December, whereafter new outbursts of microtremors occurred on 27-28 December, 3-4, 8-10 and 18-20 January. A characteristic feature of the sequence is that of 'major' earthquakes followed by aftershocks lasting sometimes a few hours, sometimes a few days. The largest number of events recorded in one single day occurred on 2 December with 820 at ENG, 750 at NEV and 270 at ORN. We have computed hypocenters for 255 events evenly distributed in time throughout the recording period and on the basis of Pg-Sg time difference and also absolute Pg travel times when such were available.

In Fig. VI.2.1, 66 events with at least 5 readings (phases), and RMS values less than 0.15 s are plotted. The epicenters are confined within an area of roughly 10 km N/S, 8 km E/W, with a concentration around 66.81^{o}N, 13.63^{o}E. The computed hypocenter depths are in the range 3-9 km, and the corresponding uncertainty is of the same order as for the epicentral coordinates, which is usually within $\pm$ 1 km. The hypocentral 'time development' indicates that essentially all of the 10 x 8 x 6 km^3 volume has been activated all of the time. However, some migrations in the earthquake activity are apparent, predominantly in the N-S direction. A composite focal mechanism solution for the Meløy earthquakes are presented in Fig. VI.2.1. The solution indicates predominantly normal faulting, where the plane striking N25^{o}E and dipping 60^{o}E is the one which gives the best fit to hypocentral solutions, therefore also being the probable faulting plane. Most of the events above ML=2.0 were felt, and the maximum intensity on the Modified Mercalli scale was 6. Very many earthquakes were heard, and the reported sounds can be classified in three groups: (i) sounds without any felt tremor, (ii) sounds associated with earthquakes felt, and (iii) sounds generated in the epicentral area. The latter sounds (described as when a load of snow rushes off roofs) were quite different from group (ii). The above information was partly derived from newspaper ads.

The Meløy earthquake sequence is in our opinion an outstanding example of <u>intraplate</u> seismic activity. The main problem is to fit this phenomenon into the tectonic framework of the area, which briefly can be described as follows: From the inserted seismicity map for Fennoscandia in Fig. VI.2.1 it is seen that Meløy is located in the middle of a distinct seismicity zone along the coastal area between 65^{o}-70^{o}N. One of the largest events in Fennoscandia so far took place here in 1819, the so-called Lurøy earthquake, with a presumed location of about 50 km SW of Meløy and an estimated magnitude of the order of 6.0-6.5 on the Richter scale. Further to the west of the Meløy area there is another seismicity zone which coincides with the passive continental margin. The seas between these two seismicity zones are part of an epicontinental basin with maximum sedimentary thicknesses of the order of 8-9 km, and with clear evidence of block faulting. The early Eocene uplift of western Fennoscandia, contemporaneous with the Norwegian Sea opening, amounted to a maximum of

2 km. A striking neo-tectonic feature is found some 200 km to the northwest in Swedish Lappland, namely, the so-called post-glacial Pärve fault, with a length of approximately 150 km and a maximum height of around 30 m. The on-going presumed glacial rebound of Fennoscandia is also rated a spectacular neo-tectonic feature.

It is interesting to note that the indicated strike direction of N(20-30^{o})E of the Meløy earthquakes is coincident with the Caledonian folding axis, the sedimentary basin axes and also that of the Pärve fault. The normal faulting with an eastward dipping angle of 60^{o} appears to rule out a causal connection both to the on-going glacial rebound and the Eocene uplift having positive gradients for onshore areas. A direct relationship to the off-coast sedimentary basin block tectonics appears somewhat doubtful as here the fault walls nearest to the coast face westward. However, a more subtle relationship to the off-coast sedimentary basins is possible, through the following hypothesis: After an initial rifting/graben formation process the sedimentary depository potential of the area in question is maintained due to continuous subsidence of the area as part of an isostatic compensation mechanism on a lithosphere whose loading response is either elastic or visco-elastic. Such a process could be associated with an 'overshoot' effect on the flanks, and in our particular case normal faulting facing eastwards. A detailed discussion of the Meløy sequence in a geological context is presented by Gabrielsen and Ramberg (1979).

Usually an earthquake activity as reported here will intuitively be suspected as being precursory for a significantly larger event. The exceptional nature of this intraplate earthquake sequence makes it difficult, however, to argue convincingly either in favor of or against such a hypothesis. From the magnitude-frequency relationship, which shows a near perfect linearity up to about ML=3.0 (with a non-anomalous slope of 1.1), we may argue that the release of energy seems 'complete', an assumption supported by the gradual decrease in activity for the last 2 of the 3 months displayed in Fig. VI.2.2. However, a downward bend in the high-magnitude end of the recurrence curve (above ML=3.0) might indicate the 'lack' of a few somewhat larger earthquakes (ML~3.4-3.6). Therefore, even if we know from historical records that the general Meløy area has the potential of large earthquakes, we have no firm evidence whether or not the on-going microearthquake activity is precursory to somewhat larger earthquake(s) in the near future. The large Lurøy earthquake of 1819 is not considered conclusive in this context as the lack of foreshocks there may simply reflect poor reporting practices.

H. Bungum, B.Kr. Hokland,
E.S. Husebye, F. Ringdal

References

Bungum, H., B.Kr. Hokland, E.S. Husebye and F. Ringdal, 1979: An exceptional earthquake sequence in Meløy, northern Norway. Nature, in press.

Bungum, H., and E.S. Husebye, 1979: The Meløy, N. Norway, earthquake sequence - a unique intraplate phenomenon. Nor. Geol. Tidsskr., in press.

Gabrielsen, R.H., and I.B. Ramberg, 1979: Tectonic analysis of the Meløy earthquake area based on Landsat, lineaments and mappings. Nor. Geol. Tidsskr. in press.

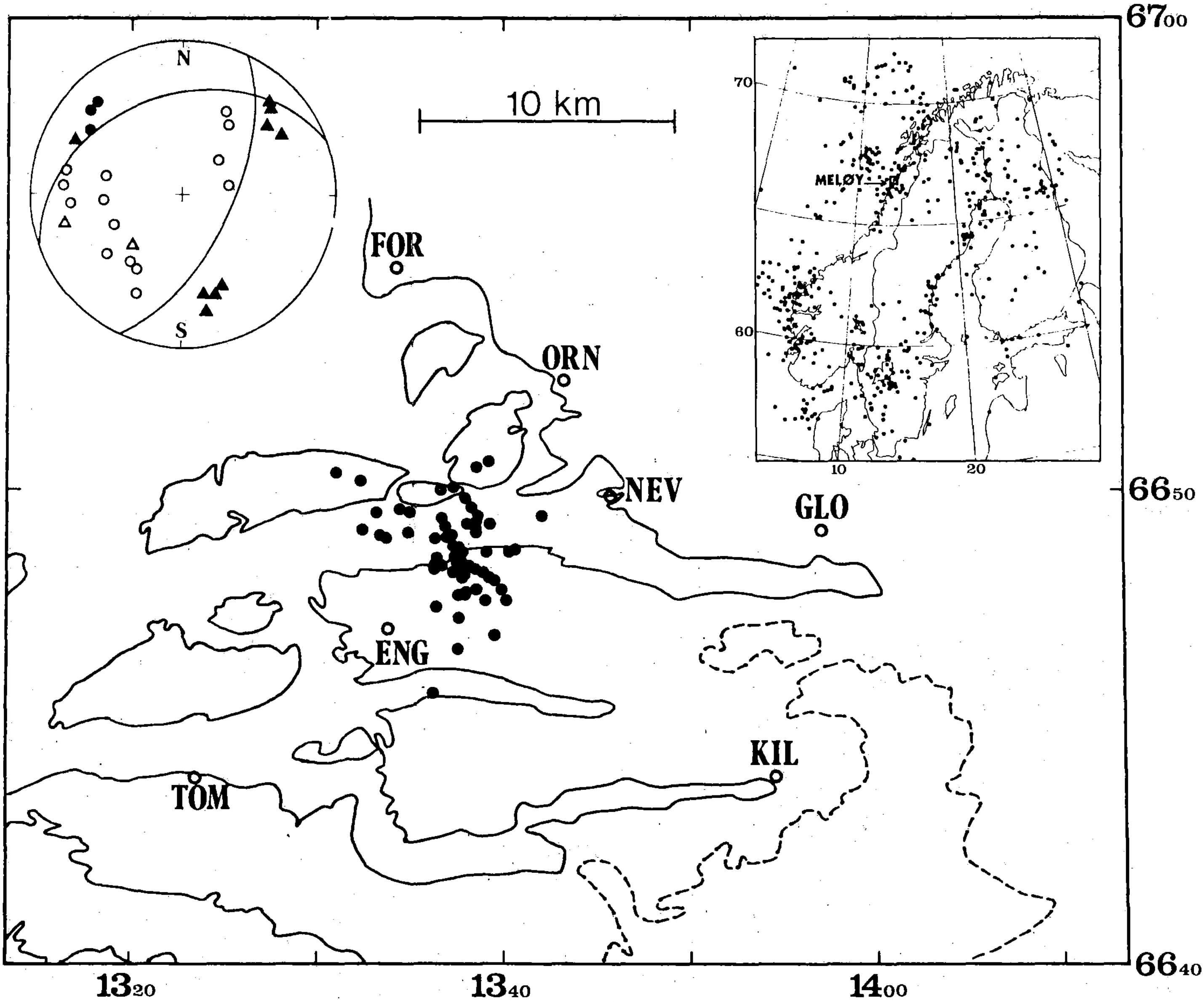


Fig. VI.2.1 Map of the Meløy area with the 7 locations used as sites for the portable seismographs. The black dots are computed epicenters for 66 earthquakes for which the depth range is 3-9 km. In the upper right corner a map shows Scandinavia with instrumentally located earthquakes for the time period 1951-1978, and in the upper left corner is inserted a composite focal mechanism solution for the Meløy earthquakes.

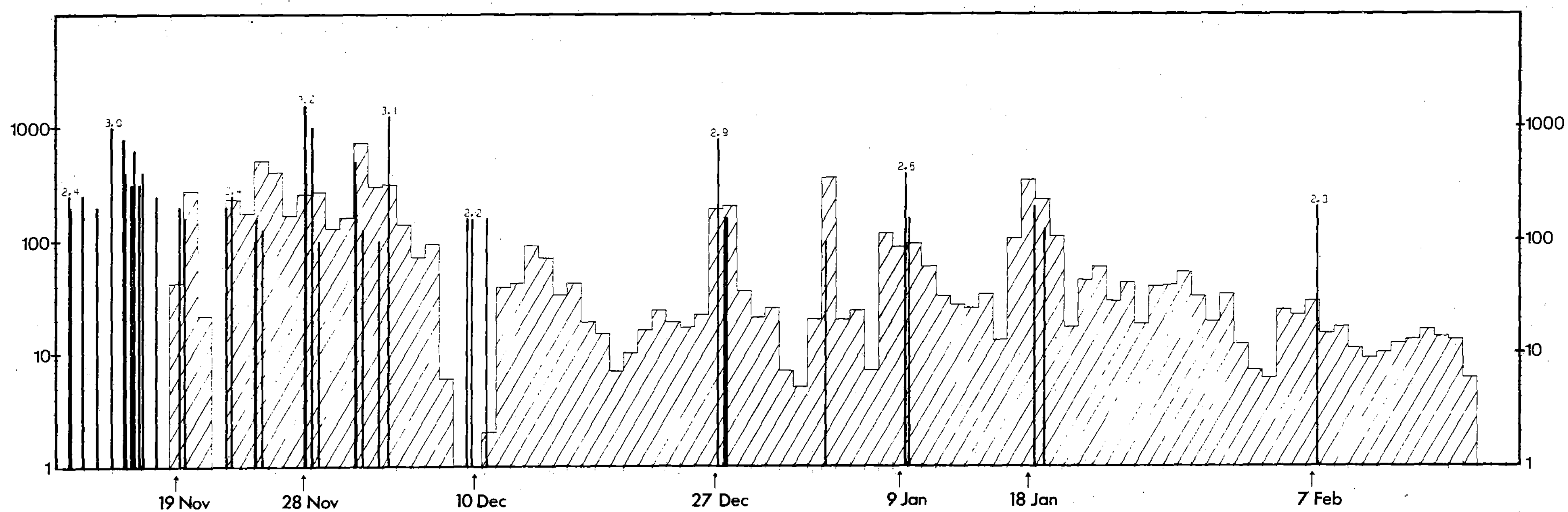


Fig. VI.2.2 Time development of the Meløy earthquake sequence as recorded at the Neverdal station. The histogram shows number of events on a daily basis, and all events with an ML magnitude at 2.0 or above are plotted separately as vertical lines with height proportional to magnitude.