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Seismicity of Norway

1990 - 2000

by

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March 2002

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Introduction

The seismic network in Norway has been developed from one station in 1905 to 24 stations and 4 seismic arrays at the end of 2000, which cover an area of 2500 km by 1500 km including the Svalbard Archipelago in the north and the Jan Mayen Island to the west (Figure 1).

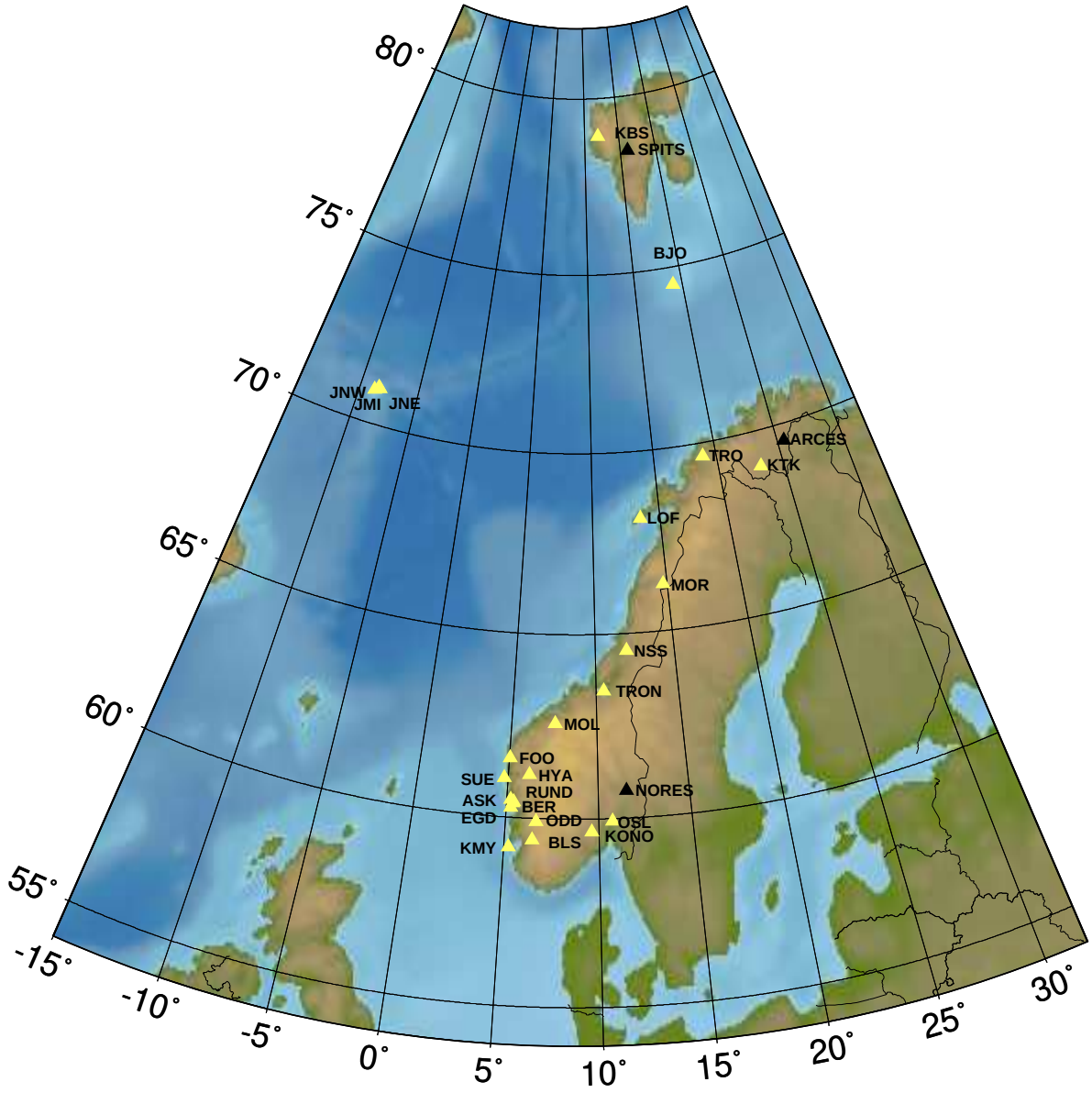
Although the earthquake activity in Scandinavia is considered moderate, there is a significant amount of seismicity, especially in the offshore areas west of Norway (Figure 2). In historical times, this moderate seismicity has produced earthquakes of magnitude as large as 5.8, as was the case with the 1819 Lurøy earthquake in Rana, northern Norway. Another significant earthquake, which caused minor damage, was the 1904 Oslofjord earthquake,which had a magnitude of 5.4.

During the time period 1990-2000 the Norwegian National Seismic Network (NNSN) developed from several networks and stations into a permanent unified network. The purpose of this report is to describe the network development and recorded seismicity during this time period.

Seismic network and processing

Seismic network before 1990

In order to monitor the seismicity of Norway and the adjacent offshore areas, a network of digital seismic stations have been operating on mainland Norway since the beginning of the 1980's. Prior to this, a number of single-stations and regional networks were installed in different parts of Norway and seismicity has also been monitored with the NORSAR arrays (Norwegian Seismic Array) (Bungum, 1999). The Institute of Solid Earth Physics (the former Seismological Observatory 'Jordskjelvstasjonen') at the University of Bergen (UiB) has been operating seismic stations since 1905 when the first seismic station in Norway was installed in Bergen. Later in the 1960's and 1970's several stations were operative. Due to the oil and gas exploration in early 1980's, a better understanding of the seismic hazard offshore Norway was needed and the Institute of Solid Earth Physics, in co-operation with the Norwegian petroleum industry and NORSAR, expanded and modernised the seismic networks. The Western Norway and the Northern Norway networks started operation in 1984 and 1988, respectively (Havskov et al, 1992). The financial support from the petroleum industry was an essential part of this development.



△ *NNSN stations* ▲ *NORSAR arrays*

Figure 1. Location of stations in the Norwegian National Seismic Network (NNSN) at end of 2000. The NORSAR arrays are operated as part of the International Monitoring System (IMS), and are not part of NNSN, but data are included with the data from NNSN.

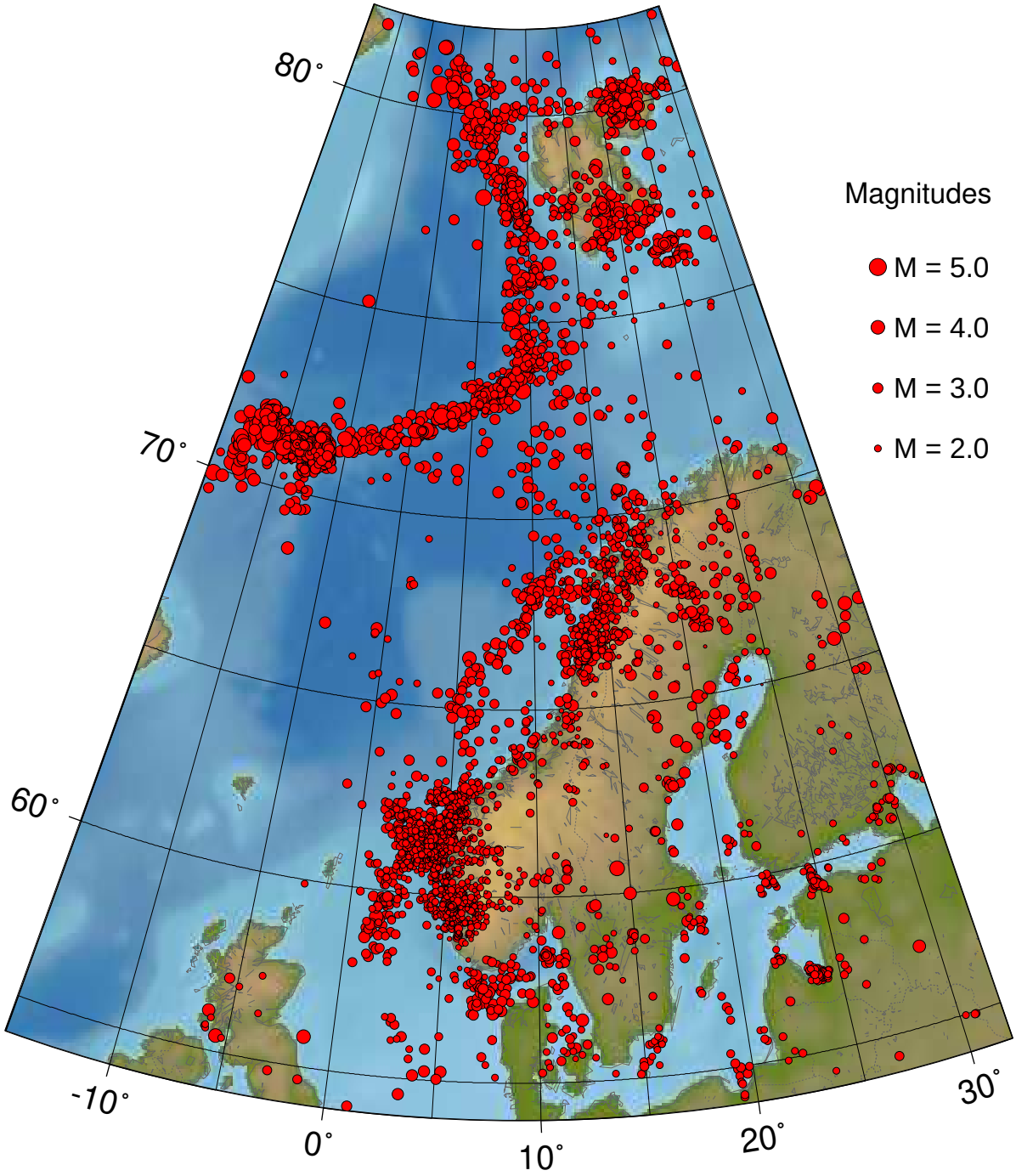


Figure 2. Seismicity of Norway and the adjacent offshore areas in the period 1990-2000. Known and probable explosions are not included.

Seismic network, 1990 to 2000

In 1990 a total of 26 seismic stations (including 3 arrays) were in operation in Norway (see Table 1). The operation was mainly organized in two projects, the Western Norway Network (WNN) and the Northern Norway Network (SEISNOR), both supported by the oil industry. NORSAR was financing the operation of the seismic arrays and UiB was financing the remaining stations.

In 1992 the SEISNOR and WNN networks were integrated into a new project called the Norwegian National Seismic Network (NNSN) supported by Oljeindustriens Landsforening (OLF). At the same time the stations were modernized with new digitisers and communication facilities. Under this new agreement the UiB took over the responsibility for the operation of all the single stations in Norway, while NORSAR operated the arrays and had a contract with UiB to supply data to NNSN. During this integration the network was expanded with a small regional array, SVAES (now SPITS), at Jansonhaugen near Longyearbyen at Svalbard and with a three-component broadband seismometer at Bjørnøya (BJO). The situation in January 1993 was then:

Stations supported by:	Station code:
OLF/UiB (9):	KMY, ODD, SUE, MOL, NSS, MOR, LOF, TRO, BJO.
OLF/NORSAR (1):	SVAES
Norsk Hydro (1):	OSG
UiB-USGS (2):	KONO, KBS
UiB (12):	BLS, BER, EGD, ASK, HYA, FOO, KTK, JMI, JNE, JNW, RGS, FRO
NORSAR arrays (3):	NORSAR, NORES, ARCES
Total: 24 stations and 4 arrays	

During the nineties, the OLF project gradually gave support to more UiB stations, SVAES/SPITS was operated by NORSAR alone, 3 stations (OSG, FRO and RGS) stopped operating and 3 new stations were added (RUND, TRON and OSL). The situation at the end of 2000 was as follows:

Stations supported by:	Station code:
OLF/UiB (13):	KMY, ODD, BLS, SUE, HYA, FOO, MOL, NSS, MOR, LOF, TRO, KTK, BJO
UiB (9):	BER, EGD, ASK, JMI, JNE, JNW, RUND, TRON, OSL
UiB/USGS (2):	KONO, KBS
NORSAR (4):	NORSAR, NORES, ARCES, SVAES
Total: 24 stations and 4 arrays	

The oil industry has financed nearly 100 % of the expansion and direct operational cost of the stations installed between 1984 and 2000 while the UiB has financed the operation of the remaining stations and all personnel costs.

Seismic network after 2000.

Starting with the year 2001, the Faculty of Mathematics and Natural Sciences, University of Bergen (UiB), and OLF has entered a long-term agreement of sharing the operational costs, whereby UiB gradually increases its financial contribution. This means that all single stations in Norway are now part of the NNSN, while before 2001, the term NNSN formally only covered the OLF sponsored stations. Therefore, at the end of year 2000, Norway had one unified seismic network, NNSN, and a corresponding database including data from all seismic stations and arrays in Norway.

Summary of technical status of NNSN at the end of 2000

The network consists of single stations recording locally and two small networks recording centrally (Bergen and Jan Mayen). All recording (except for KONO and KBS) is done with a SEISLOG (PC/QNX based) digital data acquisition system (Utheim et al, 2001), which record the detected events as well as continuous data in a 3-week ringbuffer files. The digital resolution of the digitisers used is 24 bit for all stations except JNE, JNW, BER, ASK and EGD, which are 12 bits due to limitation of the local transmission lines.

Most stations use 3 component short period sensors, however the stations, RUND, KONO, KBS, BJO and JMI have broadband sensors. At stations LOF, MOL, SUE, three-component force-balanced accelerometers are installed in addition to the short-period seismometers.

The stations KONO and KBS are part of the global IRIS (Incorporated Research Institutions for Seismology) network and therefore all equipment are sponsored by the US Geological Survey.

All stations, except BJO are connected to internet via ISDN or permanent lines. BJO has a slow modem connection. This means that all stations are accessible instantly for data download, however, the BJO station only allows for limited data transfer and the bulk of the data is sent to UiB by tape.

Table 1. Seismic stations and arrays in Norway in the period 1990-2000. Abbreviations: Analog: start of analog recording, Digital: start of digital recording, SP: short period seismograph, LP: long period seismograph, BB: broad band seismograph, ACC: accelerometer, 3C: three component, 1Z: one component vertical.

Name	Code	Latitude	Longitude	Alt.(m)	Analog	Digital	Closed	SP	LP	BB	ACC
Askøy[1]	ASK	60.483N	5.195E	50	1982	1984		3C			
Bergen	BER	60.384N	5.334E	50	1905	1982		1Z	3C		
Bjørnøya	BJO	74.506N	19.188E	18		1992				3C	
Blåsjø[2]	BLS	59.423N	6.456E	540		1982		3C			
Espegrend	EDG	60.188N	5.226E	20		1991		1Z			
Florø	FOO	61.598N	5.044E	15	1983	1990		3C			
Frøya	FRO	61.757N	4.882E	20	1983	1990	1993	1Z			
Høyanger	HYA	61.166N	6.187E	30		1985		3C			
Jan Mayen	JMI	70.928N	8.731W	211	1961	1982		3C		3C	
Jan Mayen	JNW	70.990N	8.297W	57	1972	1982		1Z			
Jan Mayen	JNE	71.029N	8.428W	95	1972	1982		1Z			
Karmøy	KMY	59.212N	5.247E	58		1984		3C			
Kautokeino[1]	KTK	69.116N	23.237E	340		1987		3C			
Kongsberg	KONO	59.649N	9.598E	216	1962	1978				3C	3C
Lofoten	LOF	68.126N	13.538E	80		1986		3C			3C
Mo i Rana[1]	MOR	66.286N	14.735E	445		1987				3C	
Molde	MOL	62.569N	7.542E	98		1986				3C	3C
Namsos	NSS	64.525N	11.967E	102		1986		3C			
Ny Ålesund	KBS	78.919N	11.924E	46	1967	1985				3C	
Odda	ODD	59.912N	6.628E	684		1984		3C			
Oseberg	OSG	60.497N	2.876E	150		1988	1996	3C			3C
Oslo	OSL	59.937N	10.723E	70		2000		1Z			
Rognes	RGS	63.021N	10.435E	410	1985	1989	1993	1Z			
Rundemannen	RUND	60.414N	5.367E	525	1997	1997				3C	
Sulen	SUE	61.057N	4.761E	10		1984		3C			3C
Tromsø	TRO	69.633N	18.928E	15	1960	1986		3C			
Trondheim	TRON	63.454N	10.436E	34	1997	1997		3C			
NORSAR arrays											
ARCES	ARA0	69.535N	25.506E	353		1987		33[3]		3C[4]	
NORES	NRA0	60.735N	11.541E	300		1984		33[3]		3C[4]	
NORSAR	NAO	60.824N	10.832E	379		1970		132	22x3C		
	NAO	61.040N	11.215E	717		1976		42	7x3C[5]		
SPITS	SPA0	78.178N	16.370E	323		1992		9[6]		3C	

(1) Up to 1992, operated as a small array instead of a 3-component station. (2) Up to 1992 operated as 3 nearby stations in cooperation with NORSAR. (3) 21 vertical sensors and 4 three component; (4) Combined LP+IP up to 1999, BB since then. (5) BB since 1995. (6) Extended SP.

Data collection

All stations are contacted automatically several times a day through the software SEISNET (Ottemöller and Havskov, 1999) and detected events are transferred to the central database. In addition, complete 24 hour continuous digital data is transferred daily from stations JMI and RUND. Stations JNW, BER, EGD, ASK and KONO are also recorded continuously on paper in order to have an independent backup.

The collected data is placed in a database ready for processing and important events are located automatically. All data collected is immediately available for the public (see page 12). Due to the cost limitation of primarily using ISDN lines, data is collected every 6 hours, however if a large event occur (detected by the network around Bergen) a data collection is initiated immediately and the complete data set will be available within 10-20 minutes. If necessary, collection of data can also be made manually. Outside working hours collection and processing of data can be made from the homes of the seismological staff at the Institute. This to secure easy and fast response to public inquiry.

Station Downtime

The operational stability for each station in operation in the NNSN is shown in Table 2. All stations have downtimes less than 5% on the average except the station at Bjørnøya. There are many reasons for a station to be down e.g. weather conditions, computer hardware/software problems, communication problems, unavailability of technicians, lack of sufficient spare parts and access problems to some of the remote stations.

A new downtime logging system was implemented in 1998. As a consequence the station downtime is followed more closely and also short time periods when the stations or communication is malfunctioning are logged.

Table 2. Down time in % for each station during the time period 1993 – 2000. Statistical info only available for those stations included in the Norwegian National Seismic Network.

	BJO	BLS	FOO	HYA	KMY	KTK	LOF	MOL	MOR	NSS	ODD	SUE	TRO
Jan-June 1993	39				12		25	2	28	0	11	4	0
July-Dec 1993	5				0		0	11	1	0	0	3	1
Jan-June 1994	3				1		0	12	0	0	0	0	1
July-Dec 1994	16.8			0	0		0	0	0	0	0	7.6	0
Jan-June 1995	62		0	0	1.6		0	0	0	0	0	0	0.3
July-Dec 1995	69		0	16.8	0		0	0	13	0	0	0	0
Jan-June 1996	0		4	0	0		0	0	4	0	7	0	0
July-Dec 1996	12		0	0	3		0	0	0	0	0	6	1
Jan-June 1997	19		0	0	0		0	11	2	0	0	7	0
July-Dec 1997	25.5	3.8	7.1	0	11.7	0	2.2	0	0	0	0	0	0
Jan-June 1998	63	2.2	11.4	0	15.5	0	1	19	0	2.2	1.6	5.6	1
July-Dec 1998	0	0	0	0	13	8.7	4.3	3	12.1	0.3	2.5	1.2	0
Jan-June 1999	0	0	6.7	0	0	0	0	8.1	0	0	0	0	0
July-Dec 1999	0	8.7	1	0.5	2	0	1.8	1.3	0	0	0.7	0.3	1.7
Jan-June 2000	0	17	0	0	0	0	0	5	0	0	21	0	24
July-Dec 2000	0	0	24	0.5	0	0	0	0	11	0	22	3	26
Average	19.6	4.5	4.5	1.4	3.7	1.2	2.1	4.5	4.4	0.2	4.1	2.4	3.5

Data processing

The basic principle for the NNSN database is to be as complete as possible in the prime area of interest (54-82 N and 15 W-32 E, Figure 2). Due to the limitation in the NNSN station geometry, i.e. the locations of stations along the coast vs. the offshore seismic activity, data from other seismic agencies are included in the NNSN database to ensure a complete geographical coverage. The primary sources for additional data are NORSAR and the British Geological Survey (BGS) which provide seismic data from the NORSAR arrays and other array data processed by NORSAR (Apatity, Fines and Hagfors, located in Russia, Finland and Sweden respectively) and data from the North Sea. The basic principle for including data in the database is as described below:

Any seismic data recorded by NORSAR and fulfilling one of the criteria listed below, are included in the NNSN database. From the BGS only local/regional events located in the prime area are included.

i) Local and regional events recorded by NORSAR and also detected by the Bergen network.
ii) Local and regional events with local magnitude larger than 2.0 detected by NORSAR and not recorded by the Bergen network.
iii) Teleseismic events recorded by NORSAR and also detected by the Bergen network.
iv) Teleseismic events with NORSAR magnitude $M_b \geq 5.0$.

Data from other agencies are included whenever it is considered useful. For the prime area, it is estimated that the detection threshold is around 3.0 while for mainland Norway and the near coastal areas, the detection threshold is around 2.0.

The analyses for the computation of earthquake source parameters (e.g. location, magnitude) are done using the earthquake data processing software SEISAN (Havskov and Ottemöller, 1999). Based on the data in the NNSN database, monthly seismic bulletins are issued. The bulletins therefore contain data from both NNSN and other networks. The monthly bulletins are sent to national and international agencies, such as the International Seismological Centre (ISC). Further processing using SEISAN is performed regularly for various research tasks or for special interesting events and all results are stored in the NNSN database, which are available for the public.
In addition to instrumentally recorded events, the database also contains information about felt earthquakes. Macroseismic data have been collected continuously in Bergen since the 1880's, earlier data has been included from historical information but the database contains mainly earthquake information starting from year 1900.

Velocity models and magnitude relations

The velocity model used for locating all local and regional events, except for the local Jan Mayen events, is shown in Table (3) (Havskov and Bungum, 1987).

Table 3. Velocity model for locating events in Norway

P-wave velocity (km/sec)	Depth to layer interface (km)
6.2	0.0
6.6	12.0
7.1	23.0
8.05	31.0
8.25	50.0
8.5	80.0

Magnitudes are calculated from coda duration and/or amplitudes. The coda wave magnitude scale (M_C) is estimated through the relation:

$$M_C = -3.0 + 2.6 * \log10(T) + 0.001 * D.$$

where T is the coda length in seconds and D is the hypocentral distance in km.
Local magnitude M_L is calculated using the equation given by Alsaker et al. (1991):

$$M_L = 1.0 * \log(A) + 0.91 * \log(D) + 0.00087 * D - 1.67$$

where D is the hypocentral distance in km and A is the maximum ground displacement in nm.

The moment magnitude M_w is calculated from the seismic moment M_0 using the relation (Kanamori, 1977)

$$M_w = 0.67 * \log(M_0) - 6.06$$

The unit of M_0 is Nm. The moment is calculated from standard spectral analysis assuming the Brune model (Brune, 1970) and using the following parameters:

Density: 3.0 g/cm^2
$Q = 440 * f^{0.7}$
P-velocity = 6.2 km/s
S velocity = 3.6 km/s

For more computational details, see Havskov and Ottemöller (2001).

For the Jan Mayen area, a local model and coda magnitude scale are used (Sørnes and Navrestad, 1975)

Table 4. Crustal model for Jan Mayen

P-wave velocity (km/sec)	Depth to layer interface (km)
3.14	0
6.33	3
8.27	18

The coda magnitude for Jan Mayen is given by Westre (1975):

$$M_C = 3.27\log(T)-3.24+0.001*D$$

where T is the coda duration and D is the hypocentral distance in km.

The regional and teleseismic events recorded by the network are located using the global velocity model IASPEI91 (Kennett and Engdahl, 1991).

Body wave magnitude is calculated using the equation by Veith and Clawson (1972):

$$M_b = \log(A/T) + Q(D,h)$$

where h is the hypocentre depth (km), A is the amplitude (microns), T is period in seconds and Q(D,h) is the correction for distance and depth.

Surface wave magnitude Ms is calculated using the equation (Karnik et al., 1962):

$$M_S = \log(A/T) + 1.66\log(D) + 3.3$$

where A is the amplitude (microns), T is period in seconds and D is the hypocentral distance in degrees.

Data availability to the public

All the data stored in the NNSN database (currently 100 Gb), are available to the public via internet, e-mail and manual request. It is possible to search interactively for specific data, display the data remotely (waveforms and hypocenters) and download the data. The various forms of access are:

Ftp server: ftp.ifjf.uib.no
Logg in to the address above, manually move to the directory containing the data of interest (directory organized in year-month) and copy the data.

AutoDrm to address
Send an e-mail with a request coded with the AutoDrm syntax (autodrm@ifjf.uib.no) and receive the data by e-mail.

Web access: Connect to http://www.ifjf.uib.no//seismo/seisweb/seisweb.html, and start the SEISWEB access system (Moreno et al, 2001). Through this system one can select data by area and magnitude and display the results. Figure 3 shows an example.

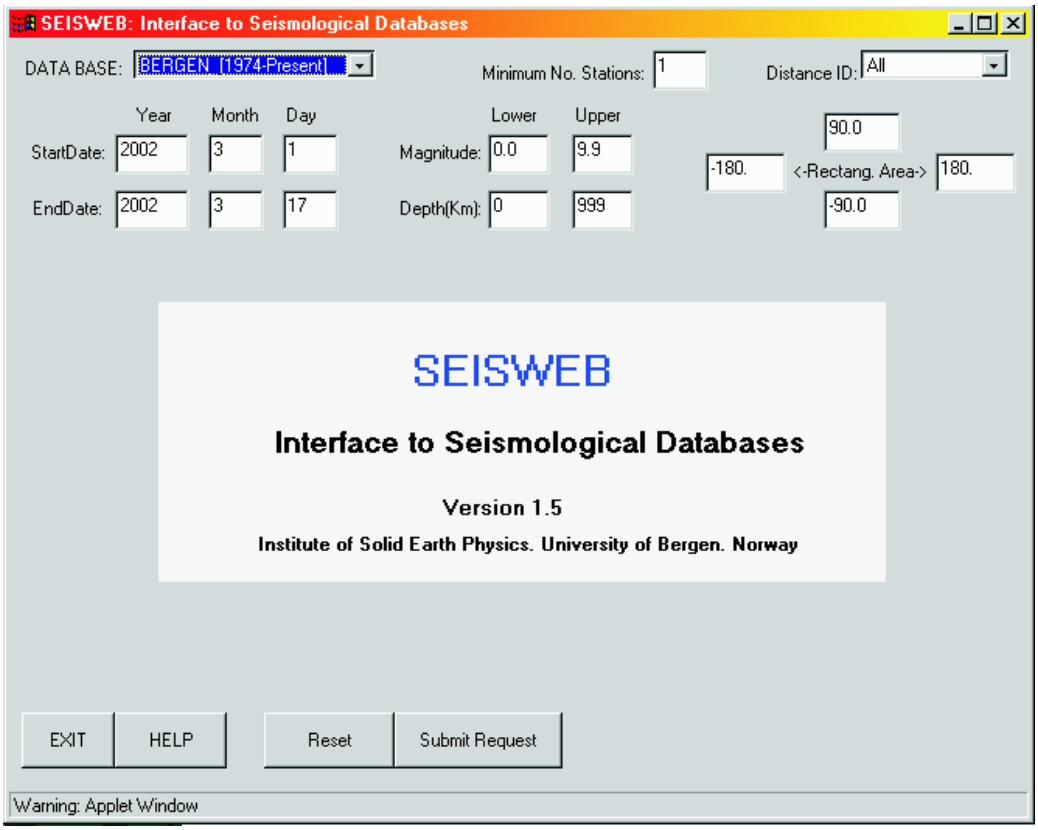


Figure 3a. Access to the database via SEISWEB. This is the user selection screen with different options for selection criteria.

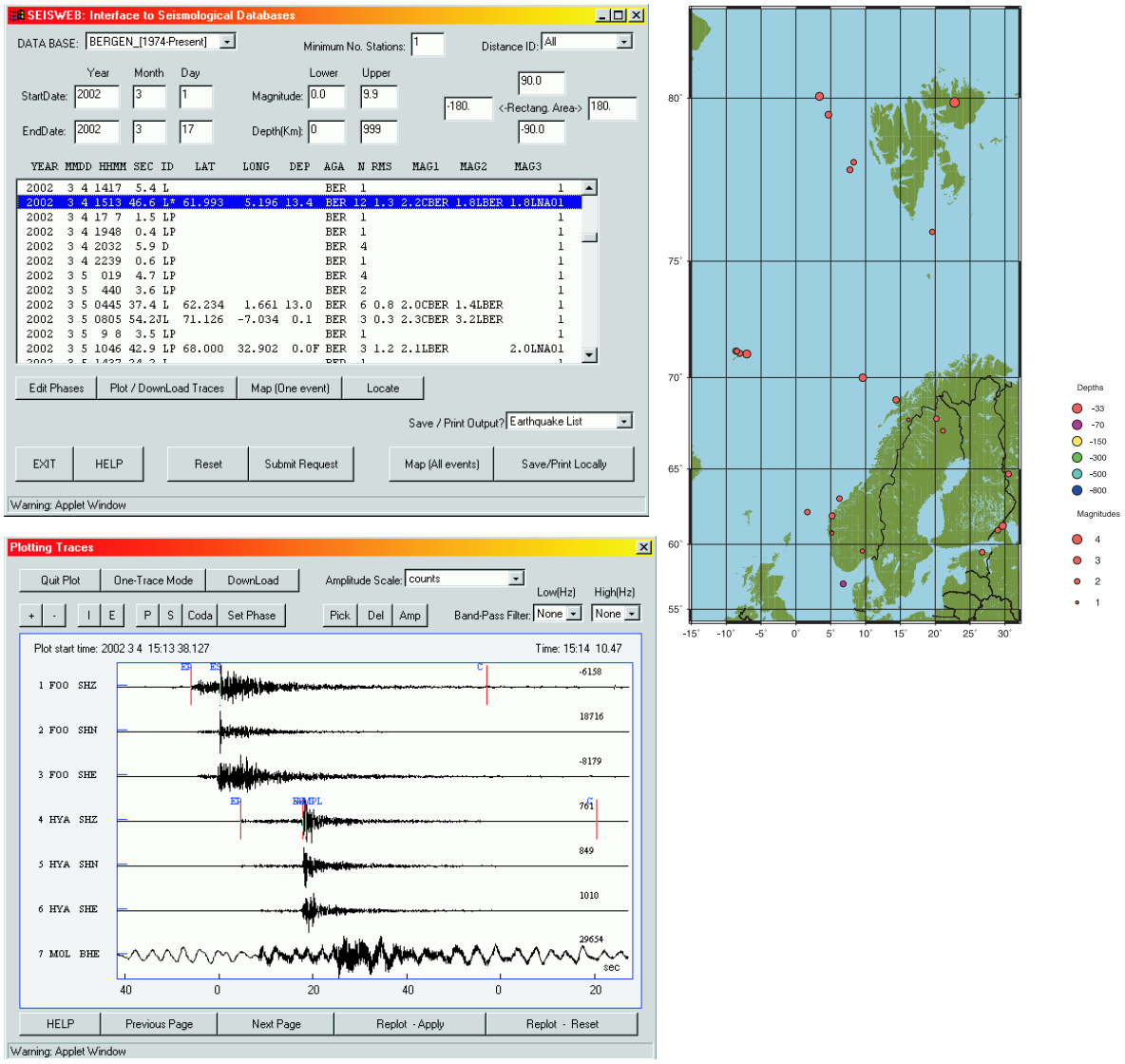


Figure 3b Access to the database via SEISWEB. Upper left: A list of events selected is displayed, and for each event there are several options like editing / viewing the detailed parameters or displaying the traces (lower left). The trace display is also interactive. Right: A map of all selected events.

Summary of data for the period 1990 through 2000

The data base

For the period from 1990 to 2000 the NNSN database contains more than 41000 events most of which have been recorded by Norwegian stations. There has been a gradual increase from about 1800 events in 1990 to 5900 in 2000 (Figure 4). The events are divided into 3 categories:

- Local - defined as an event occurring in the Norwegian prime area (54N - 82N and 15W - 32E (Figure 1)
- Distant/Teleseismic - an event more than 3.000 km from the stations and outside the prime area.
- Explosions and probable explosions, see later section for explosion definition.

The distribution of the 3 event types is given in Figure 4. The recording of located local events has been relatively constant (about 500 events per year) during the time period, with a slight increase after 1993. There is a gradual increase in the recorded distant events from about 400 to 1000 events pr. year at the end of the period. The number of explosions includes events identified both manually and automatically as explosions, and the amount increased drastically from 1995 to 1996, when the explosion identification policy was changed (also see Figure 13).

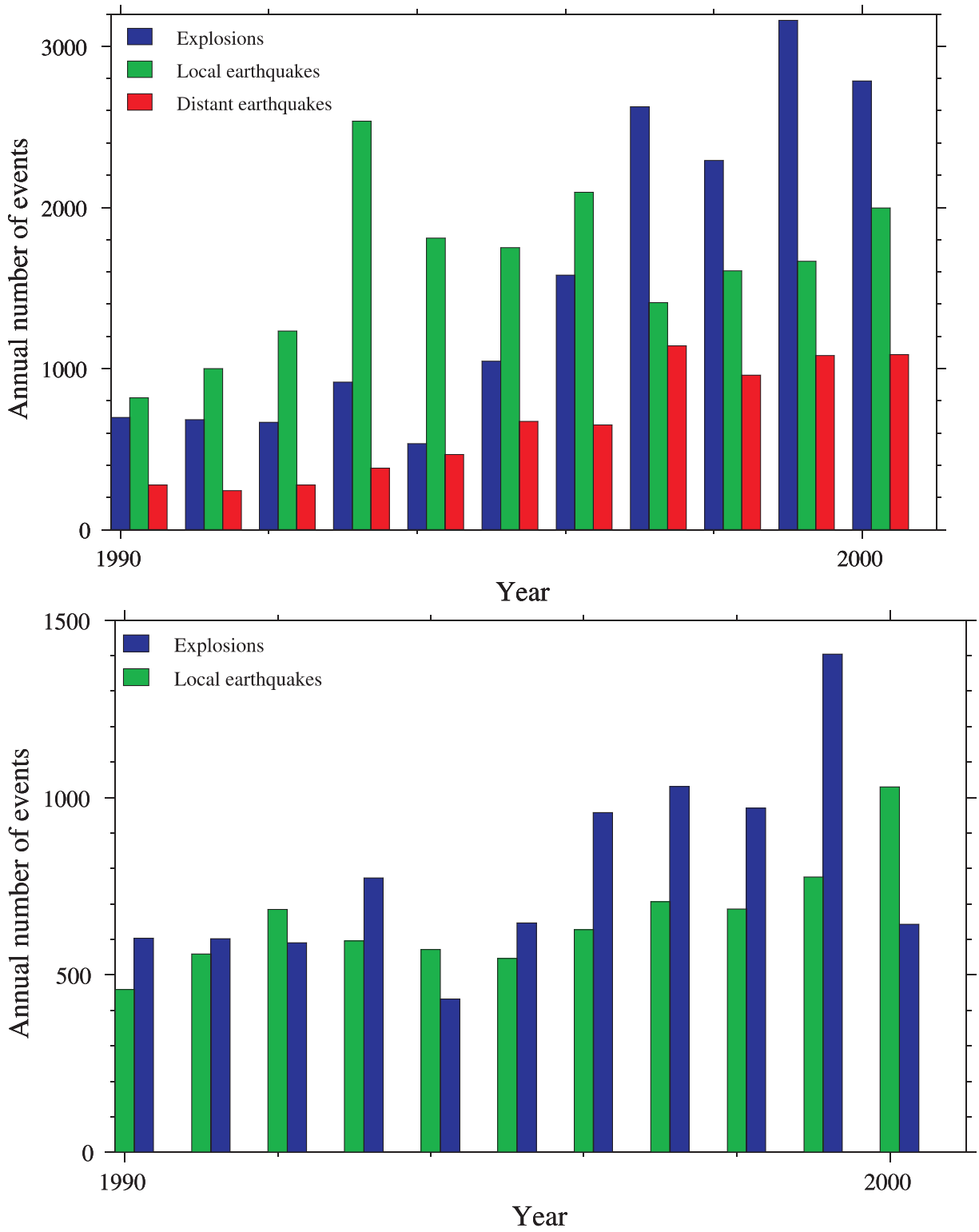


Figure 4. Statistics of local and distant earthquakes, and explosions (confirmed and probable) recorded in Norway during the period 1990-2000. The lower diagram displays only the events that have been given a location, while the upper diagram displays also the events with no location (which are treated as “local events”)

Local events

Figure 6 illustrates the magnitude distribution of earthquakes located in the Norwegian area during the period. In general, the detection becomes poor when the magnitude is less than 2.0 and there are very few events with magnitudes larger than 4.0.

Generally the spatial distribution of the seismicity follows the main tectonic elements on the region. The activity seems to be concentrated in several smaller areas. On mainland Norway, the activity is highest in southwestern Norway, whereas the southeastern parts (the Oslo Graben area) exhibits moderate seismicity. Offshore, the highest activity is associated with the northern part of the North Sea decreasing southwards along the Viking and Central Grabens. In mid- and northern Norway, the offshore areas are characterised by earthquakes occurring in two major zones; one parallel to the coast and the other associated with the large sedimentary basins. Along the continental margin there is another active zone giving rise to moderate seismicity.

Crustal stresses responsible for the seismic activity in the prime area can be grouped into three major forces with respect to their origin and lateral extent (Hicks et al., 2000; Lindholm et al., 1995; 2000). The most important of these originate from the plate-wide stresses associated with the so-called 'ridge-push' force from the Mid-Atlantic plate boundary. These plate-wide stresses are usually overprinted by regional and local stress perturbations. At the regional level, sediment loading in offshore basins combined with the topography on land constitutes the second major stress generating forces. The third group of forces is related to the postglacial uplift of the landmasses associated with the melting of the ice cover in Fennoscandia. As a result of these combined forces, stress accumulates in geological time, and are released through individual earthquakes, especially in areas where the strength of the crust is low. The geological structures such as faults act as the zones of weakness, where earthquakes repeatedly occur.

Most of the local earthquakes in Norway have a magnitude of less than 3.0, and only a few events with magnitude larger than 4.0 are located in the Norwegian area (Figure 5). During this decade, the largest events recorded near mainland Norway had a local magnitude of 4.5 (Table A2 - 2, appendix 2), while the largest events in the whole area had M_b 5.9 (located near Svalbard, 80.2ºN, 2ºE).

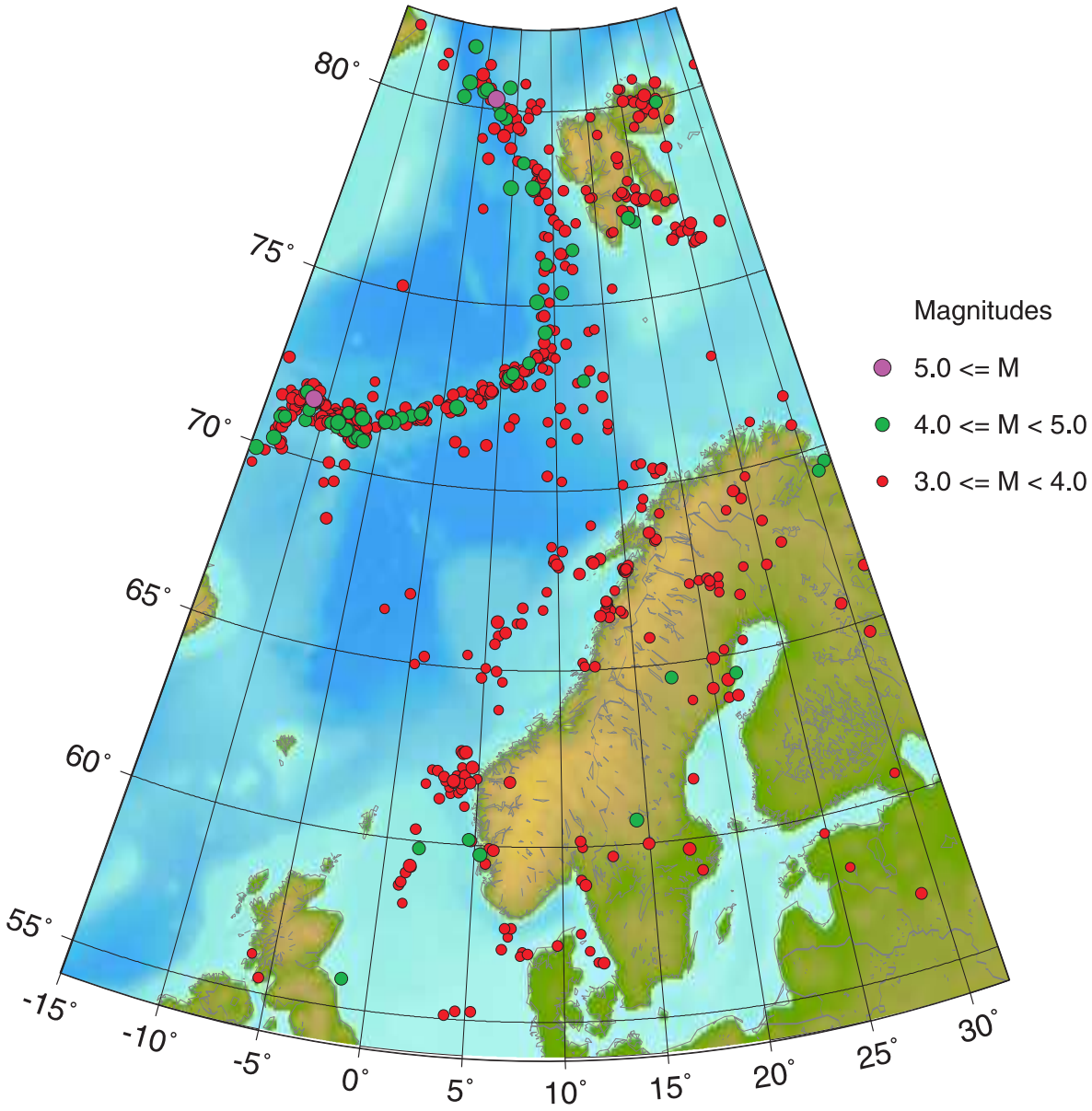


Figure 5. Large earthquakes in Norway and the surrounding areas during the period 1990 – 2000.

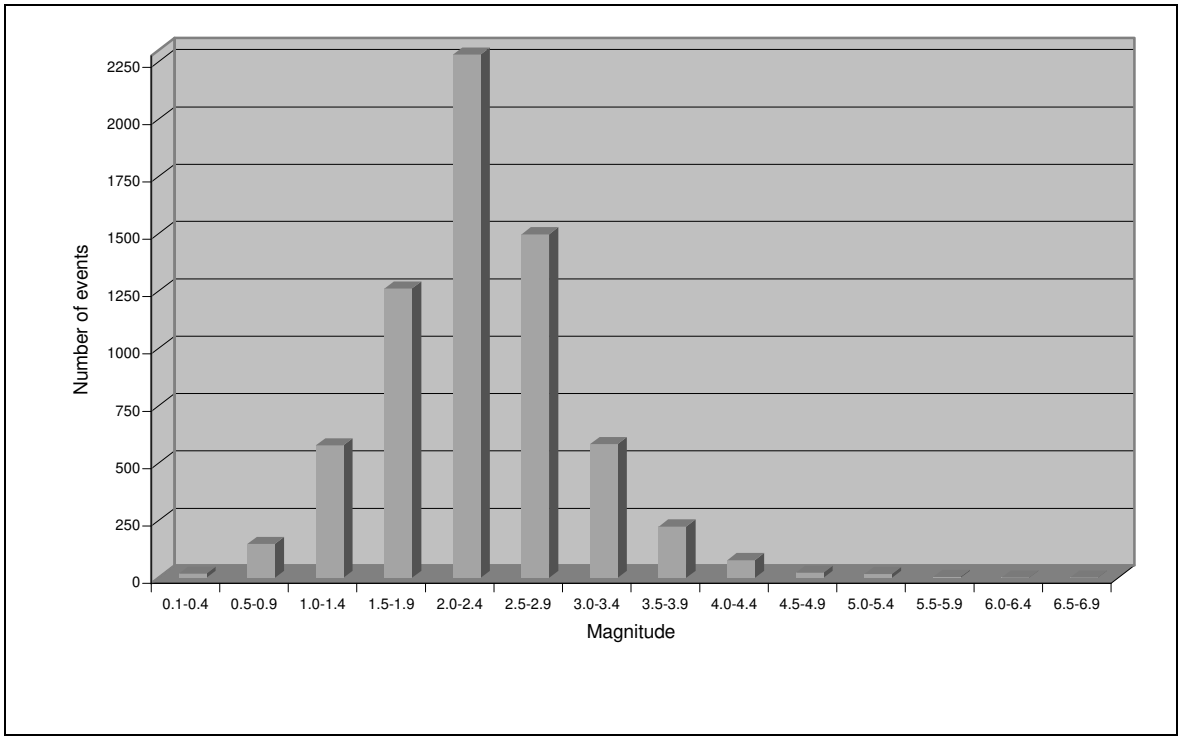


Figure 6. Magnitude distribution of earthquakes occurring in the Norwegian area during the period 1990-2000.

Distant events

The Norwegian National Seismic Network also records distant earthquakes. Between 1990 and 2000 there has been an increase in the number of recorded distant earthquakes from about 300 in the beginning to approx. 1000 in the end of the decade (Figure 4). This large increase (especially seen from 1997) is caused by a new processing routine where teleseismic earthquakes (magnitude ≥ 5.0) recorded and located by NORSAR are included and augmented with more data from the broadband stations. Figure 7 shows the location of the distant events. The majority of the events are located at plate boundaries although a few intraplate events are recorded too. When locating the teleseismic events, earthquake locations from PDE (preliminary determination of epicentres from USGS) are included in the database and selected as the prime location when a satisfactory solution cannot be obtained with the NNSN data.

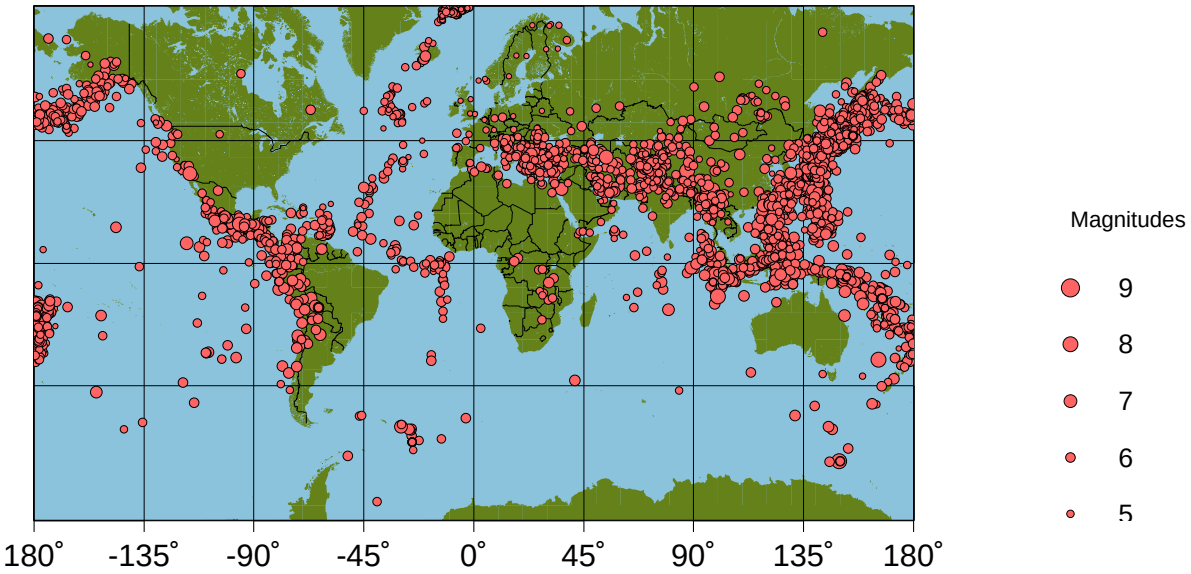


Figure 7. Events with magnitude ≥ 4 registered by the Norwegian seismic stations in the period 1990-2000.

Felt events

On average, eight earthquakes per year are felt by people in Norway (Figure 8 and 9). If the event is large enough to be felt by a sufficient number of people, a macroseismic investigation is performed i.e. questionnaires are sent to the public asking for information. Details of such information, provided that it is compiled systematically, can be used to assess the macroseismic intensities of an earthquake. The macroseismic intensity is usually a complex function of the earthquake source, attenuation of seismic waves along the propagation path, the effect of local site conditions, the effect of the built environment and the human perception of an earthquake. The most common scale used for macroseismic intensities is the Modified Mercalli's Intensity Scale (MMI), which was used for the NNSN data (Table A2 - 1, Appendix 2.). The macroseismic intensity is not equivalent to the magnitude of an earthquake. Table A2 - 2, appendix 2 gives a list of the felt earthquakes in Norway during the period from 1990 to 2000. The strongest earthquake had an intensity of V (highlighted in grey in Table A2 - 2), i.e. the quake was strong and felt by most people indoors. Figure 10 shows intensity map of the largest earthquake in the period 1990 – 2000, the M_l 4.5 earthquake, August 8, 2000 (intensity V). See also Appendix 2 for more intensity maps.

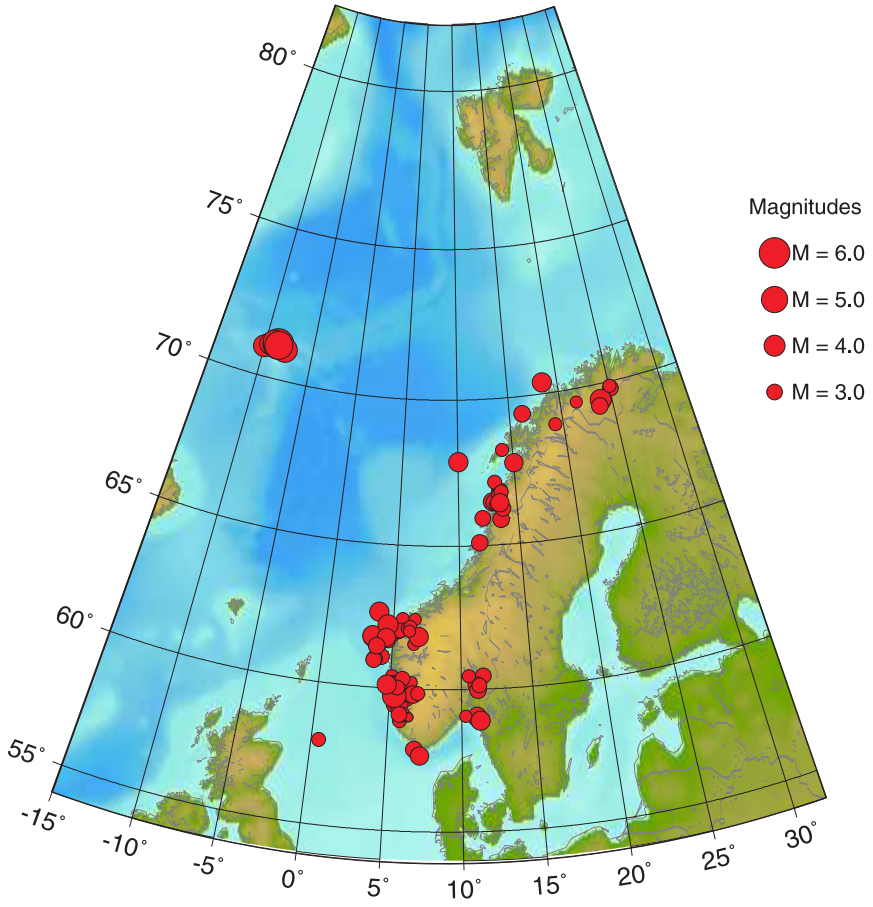


Figure 8. Earthquakes felt in Norway during the period 1990-2000.

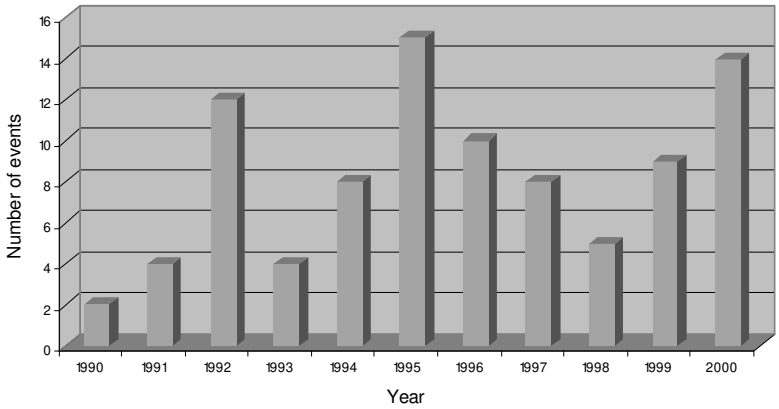


Figure 9. Felt earthquakes in Norway during the period 1990-2000.

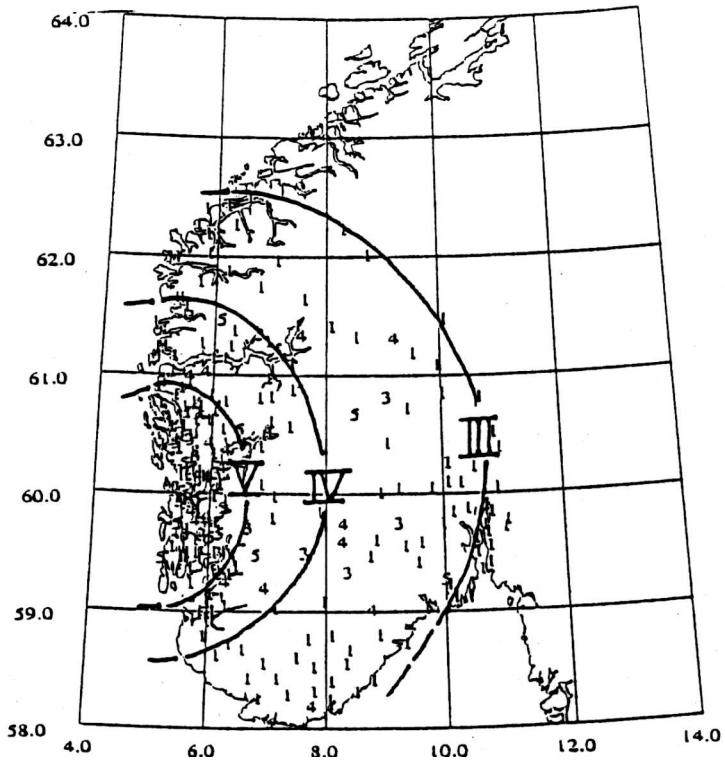


Figure 10. Example of a macroseismic map for the magnitude 4.5 event on August 8, 2000. Note that the event was felt all over Southern Norway. This is the largest earthquake near or at mainland Norway for the reporting period.

Events with focal mechanism

If it is possible to read enough polarities, a fault plane solution is determined. During the period 1990-2000, 52 fault plane solutions were calculated. As seen in Figure 11 and Table 5, most of these events are located in western Norway. Figure 12 shows a close-up of this area.

Two distinct areas, where a majority of the events with focal mechanisms are concentrated, can be identified. The first of these is the northern termination of the Viking Graben corresponding to the offshore areas between Nordfjord and Sognefjord. A variety of mechanisms are observed ranging from pure strike-slip to pure dip-slip mainly reverse. The second area corresponds to Sunnhordland, where different mechanisms also are observed. Except the Stord/Bømlo event and a few others with reverse mechanisms, the majority of the focal mechanisms are dominated by oblique-normal solutions. These observations are compatible with the previous interpretations of the principal stress axes orientations based on focal mechanism inversions and other data (e.g. Hicks et al., 2000; Lindholm et al., 1995; Lindholm et al., 2000).

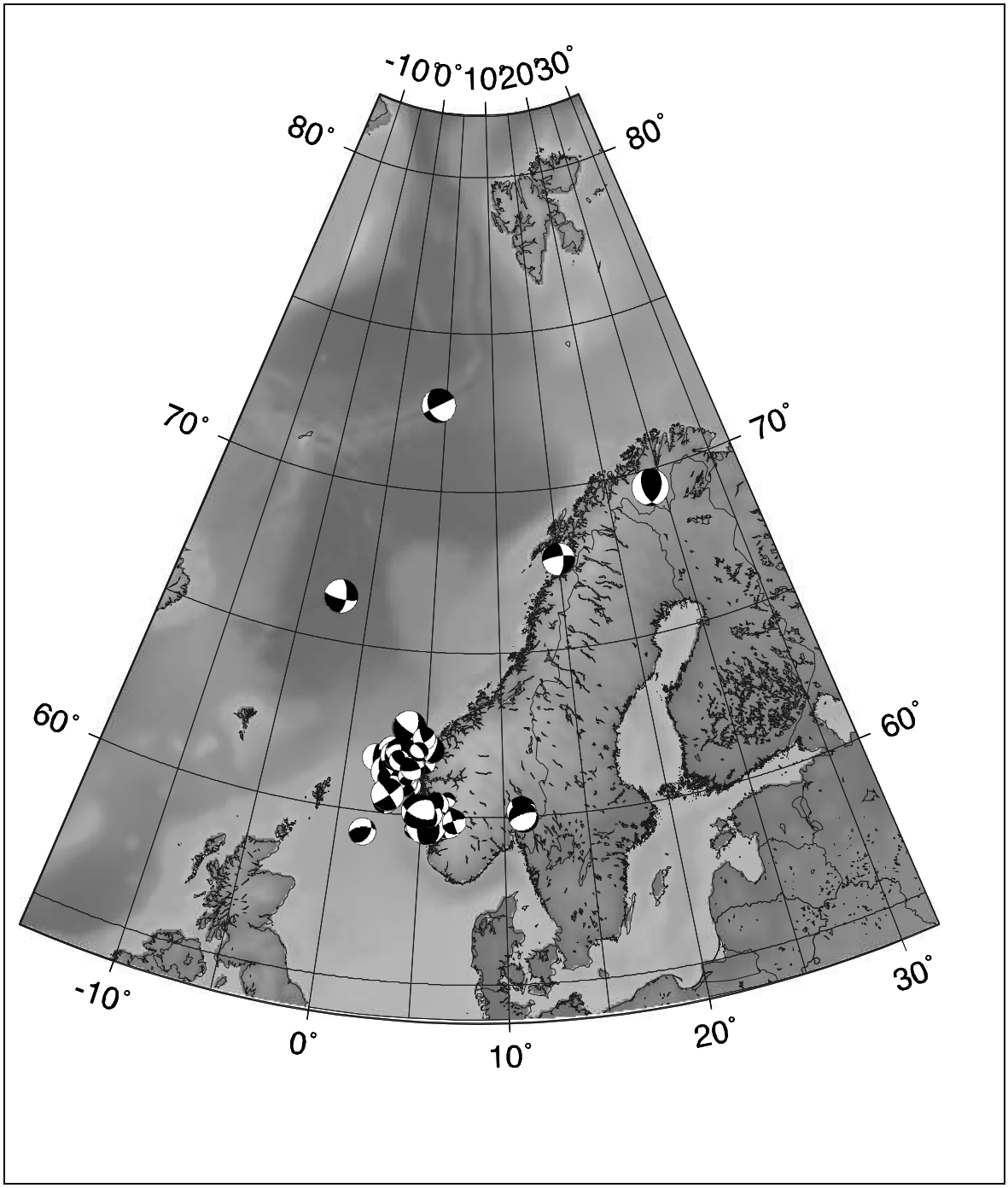


Figure 11. Fault plane solutions for events in the period 1990-2000. The size of the fault plane solution indicates the magnitude, which is within the range 1.6 (smallest symbol) and 4.5 (largest symbol) (See also figure 12 for details).

Table 5 List of events with fault plane solutions. Abbreviations: no: number corresponding to the number in Figure 12; HRMM: Hour and minute in UTC; Depth: focal depth in km; AGA: Agency locating the earthquake; NST: Number of stations used for location; M: Magnitude type (c=coda, l=local, w=moment) and magnitude reporting agency (BER=Bergen, NAO=NORSAR).

no	Year	Date	HRMM	Sec	Latitud	Longitud	Depth	NST	Mc	Ml	Mw	STRIKE	DIP	RAKE
1	1990	4 4	1253	18.7	61.645	1.881	9.1	7	3.0			20	20	110
2	1992	1 1	0803	57.6	67.789	15.022	11.0	8	3.6	3.1	3.1	267	76	-26
3	1992	11 8	1912	34.7	61.890	2.941	28.3	15	3.4	3.4		90	0	90
4	1993	1 2	2204	47.7	61.604	4.990	17.0	8	2.5			315	90	55
5	1993	1227	0520	44.2	61.274	2.736	10.0	57	3.3	3.3	3.7	152	48	31
6	1994	727	0942	42.2	62.641	3.866	13.0	16	3.7	3.7	3.2	19	54	-19
7	1994	1119	0907	31.2	60.159	11.056	15.0	17	3.3	3.3	2.9	246	66	-147
8	1995	317	2343	59.7	61.815	4.228	22.9	15	2.8	3.1		169	62	67
9	1995	620	2122	14.8	61.736	3.993	15.0	29	3.2	3.5	3.1	112	84	40
10	1995	822	0141	6.6	60.354	2.738	23.0	13	2.7	2.3	2.3	360	84	-7
11	1995	1113	0122	3.4	59.975	11.172	14.0	19	3.3	3.0	3.0	254	70	-78
12	1995	1113	0809	21.8	61.565	4.049	15.0	20	3.2	3.3	3.0	150	70	90
13	1995	1120	0401	59.4	60.064	5.400	5.0	12	2.3	2.0	2.1	116	36	31
14	1995	12 8	0741	17.4	72.686	4.200	10.0	18	3.8	3.7		150	40	0
15	1995	1223	0555	18.8	60.900	4.211	11.0	10	2.3	2.0	2.0	150	10	90
16	1996	111	0100	34.8	60.066	4.967	14.0	10	2.1	1.7		350	20	0
17	1996	121	0216	33.3	69.449	23.926	10.0	22	4.1	3.6		174	54	64
18	1996	2 8	0441	45.2	61.051	2.897	24.0	16	2.7	2.6		86	36	31
19	1996	317	0328	20.4	60.227	5.176	7.1	13	2.3	2.4		328	74	-43
20	1996	330	1414	56.8	60.277	5.006	5.0	10	1.8	1.6		123	28	-42
21	1996	416	1027	4.0	62.006	5.393	13.0	19	2.7	2.8		24	70	-78
22	1996	6 7	1325	29.1	59.841	5.126	12.0	12	2.2	1.9		8	41	75
23	1996	625	0337	29.4	61.763	3.040	17.0	35	3.0	3.2		327	62	-10
24	1996	815	2341	13.2	59.881	5.744	6.0	12	2.1	1.6		327	62	-10
25	1996	1030	0346	10.0	61.090	4.067	10.0	13	2.0	2.2		300	60	0
26	1996	1031	1252	11.5	61.790	3.533	20.0	37	3.4	3.7		313	66	-32
27	1996	1031	1257	44.0	61.749	3.541	20.0	35	3.3	3.8		312	61	-27
28	1996	1031	2347	39.5	61.799	3.531	20.0	32	3.7	3.9		286	64	-55
29	1996	1216	0409	4.8	61.015	3.794	20.0	26	3.0	2.8		297	52	-50
30	1997	1 1	1151	45.9	62.348	4.866	5.0	12	2.6	2.1	2.1	153	76	27
31	1997	114	1013	14.0	60.160	4.547	0.0	8	1.6	1.8		127	71	-68
32	1997	318	0553	52.8	66.380	-2.224	10.0	37	3.7	3.2	2.8	356	64	-15
33	1997	513	2207	9.8	60.961	3.720	19.0	26	3.1	2.9	3.0	296	71	-23
34	1997	812	0814	24.0	59.816	6.645	12.0	14	2.7	2.8	2.7	184	64	16
35	1997	915	1558	48.4	60.188	5.145	9.0	14	2.6	2.7	2.5	318	80	-28
36	1998	124	1652	18.5	59.590	4.634	10.0	7	2.2	1.4	1.7	260	30	-89
37	1998	310	0223	12.1	60.512	6.536	3.0	9	1.7	1.3	1.5	141	36	-53
38	1998	516	2354	56.0	53.002	2.414	15.0	30	3.8	3.1		256	71	36
39	1998	1128	0908	8.7	60.347	5.867	10.0	17	2.4	2.8	2.7	134	64	56
40	1999	124	1927	22.1	61.730	3.283	8.0	17	2.9	2.7	2.7	6	77	-37
41	1999	2 2	1730	56.8	61.622	3.387	12.0	12	2.3	1.8	2.0	124	64	56
42	1999	315	0228	6.4	61.165	3.967	7.0	12	2.1	1.5	1.7	340	44	22
43	1999	4 5	0313	31.7	59.368	1.589	15.0	27	3.0	2.6	2.7	25	45	45
44	1999	411	1811	11.1	61.429	4.254	6.5	17	2.6	2.7	2.5	75	70	52
45	1999	615	0112	57.3	61.926	4.585	15.0	15	2.1	2.0		321	62	-66
46	1999	1226	1359	31.0	59.903	6.228	5.0	13	1.5	1.8	1.8	334	70	-78
47	2000	5 5	0452	17.6	60.566	2.836	10.0	27	2.7	2.8	3.6	320	84	-7
48	2000	812	1427	26.2	59.748	5.329	18.0	55	3.8	4.5	4.0	333	40	58
49	2000	1126	0017	16.0	60.038	5.478	11.0	16	2.7	2.6	2.5	116	36	31
50	2000	1129	0222	16.1	59.850	6.981	15.0	16	2.7	2.6	2.5	160	87	-8
51	2000	1129	0959	27.7	60.045	5.512	7.0	14	2.7	2.4	2.5	340	44	22
52	2000	12 8	0048	5.6	60.131	4.788	4.0	33	3.3	3.8	3.6	112	62	-49

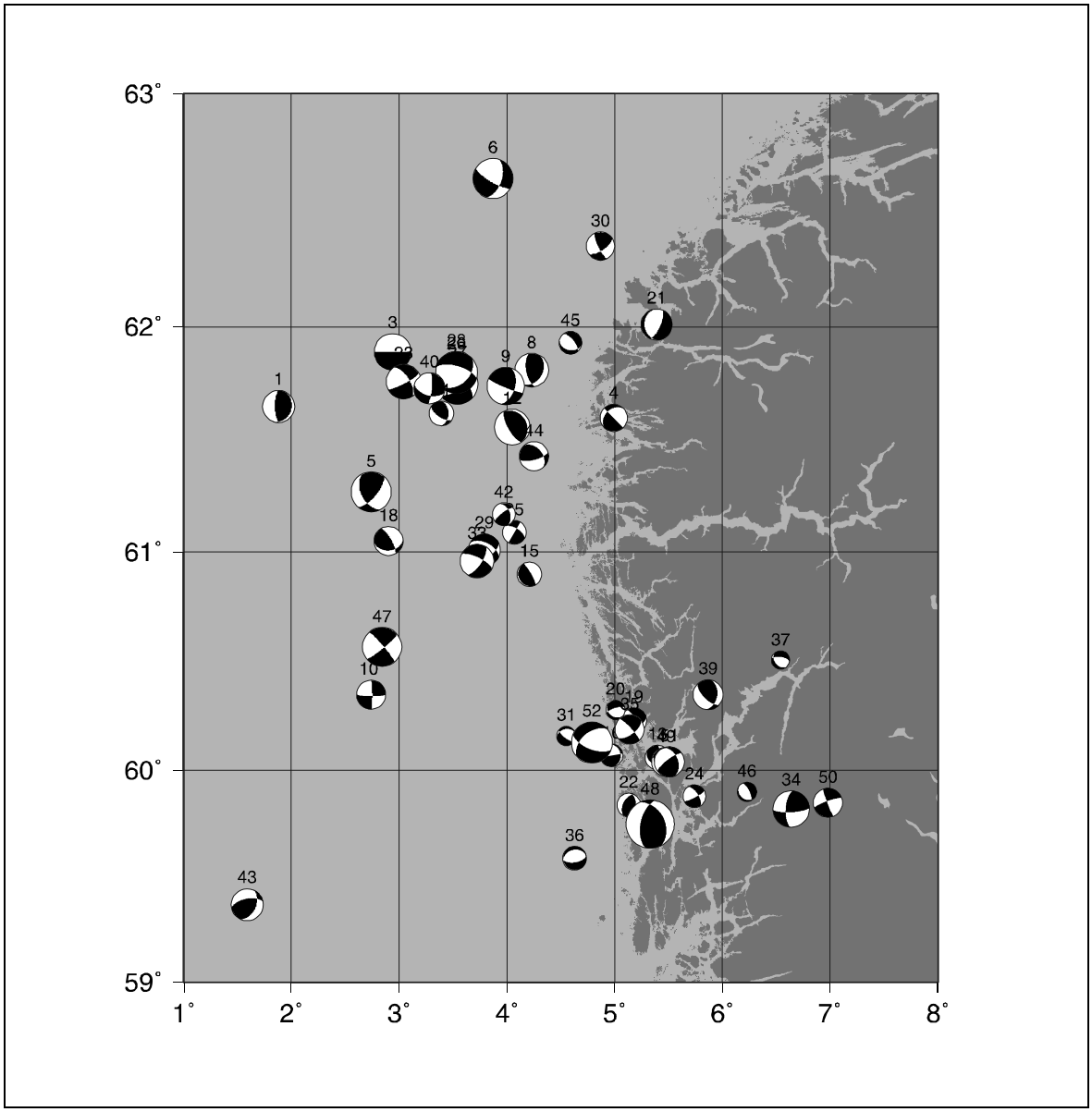


Figure 12. Close up of the fault plane solutions for events in the period 1990-2000. The number on top of each mechanism is referring to the list in Table 5. The size of the fault plane solution indicates the magnitude, which is within the range 1.6 (smallest symbol) and 4.5 (largest symbol).

Explosions

Mining activities and other man-made explosions cause much of the seismic activity seen on land. Before August 1995 the Institute of Solid Earth Physics identified probable explosions in the Seismological Bulletins by normalizing the time of day distribution of seismic event occurrence as a function of area. The filter worked on the following principle: Areas where explosions occur were defined. If an event was located in one of these areas, with a magnitude below a given maximum magnitude, a depth below a given maximum depth, within a given time of day interval and within a given year interval, it was identified and marked as a probable explosion. In August 1995 new filter parameters were applied. These are more detailed and cover all of Scandinavia whereas the old filter parameters only covered some explosion sites. Furthermore, in the new filter, the areas defined can be polygons of any shape, while the old filter areas were defined by latitude and longitude limits only. For each filter area used, an analysis was made to define the time of day distribution and the estimated maximum magnitude of explosions. For this report, all explosion filtering has been made with the new filter and consequently, the number of probable explosions in this report will not coincide with older reports.

Despite the use of the explosion filter, the amount of work related to explosion processing seems to increase. Most explosions come from the same areas at similar time of the day. The operator therefore recognizes most explosions easily. In 1996, a new practice was initiated whereby operator recognized explosions were identified manually, and only explosions recorded by several stations were processed. However all explosions are registered into the database. The statistics in Figure 13e clearly shows this shift in practice. Before 1996, there were very few operator-identified explosions while after 1996, this is the dominant way of identifying explosions. Figure 13 only shows the located probably explosions with a determined magnitude.

Figure 13 b shows the confirmed explosions. The institute has an agreement with some mines to notify time of explosions. Another major source is the navy, which on request confirms suspected events as explosions. From time to time there are also other random sources of information. In most cases, the explosion locations are known to within a couple of km or better, however the epicentres shown of Figure 13c are the location calculated based on the network.

Figure 13c shows the automatically identified explosions. Due to the limitation of the areas covered with the explosion filter, some of these events are probably earthquakes, like some of the earthquakes in Figures 2 and 5 might be explosions.

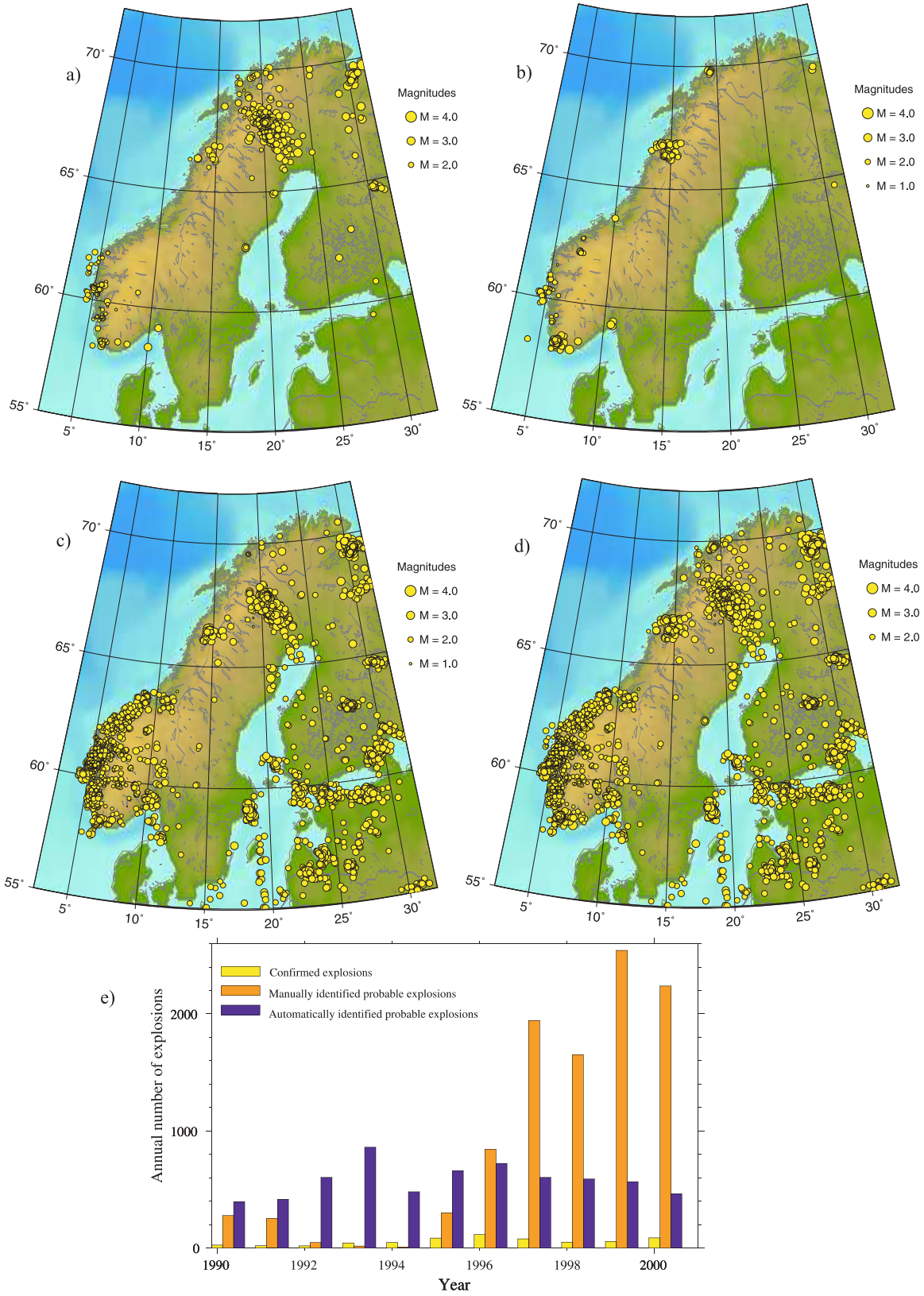


Figure 13. Explosions recorded by the Norwegian Seismic Network during the period 1990-2000. a) Events manually marked as “probable explosion”. b) Events marked as confirmed explosions. c) Events automatically marked as “probable explosion”. d) All confirmed and probable explosions. e) Statistics showing the annual amount of the different event types.

Important seismicity in the period 1900-2000

This period did not experience large earthquakes at or near mainland Norway. In total there were only 3 earthquakes with magnitudes larger or equal to 4 (Table 6). However, there was observed cases of unusual earthquake activity, which merits further description. The locations of these sites are presented in Table 6 and Figure 15.

Table 6. Earthquakes with magnitude larger than or equal to 4 and other important events. Abbreviations are: year and date: YYYY MMDD; HRMM: Hour and minute in UTC; Sec: Seconds; Latitud: Latitude; Longitud: Longitude; Depth: focal depth in km; NST: Number of stations used for location; RMS: Root mean square localisation uncertainty; M: Magnitude type (c=coda, l=local, w=moment).

#	Year	Date	HRMM	Sec	Latitud	Longitud	Depth	NST	RMS	Mc	Ml	Mw	
1	1992	1 1	0803	57.6	67.789	15.022	11.0	8	1.7	3.6	3.1	3.0	Steigen swarm
2	1996	121	0216	33.3	69.449	23.926	10.0	22	0.9	4.1	3.6	3.4	Finnmark
3	1997	512	2245	53.1	59.020	6.362	1.0	5	0.5	1.9	1.3		Kvernafjellet/Flørlia
4	2000	7 4	1956	51.1	71.125	-12.174		5		3.2			Kolbeinsey ridge
5	2000	812	1427	26.2	59.748	5.329	18.0	55	0.6	3.8	4.5	4.0	Stord
6	2000	12 8	0554	1.4	59.792	1.878	8.0	25	1.3	3.9	4.0	4.0	North sea

Steigen swarm, January 1992

On January 1st, unusual activity started in Steigen, northern Norway, (Atakan et al, 1994). By the end of 1992, 207 earthquakes had been recorded at this locality and many of these were larger than magnitude 3.0 and also felt by people. All earthquakes are concentrated in a small area (10 km in diameter) and due to the magnitude distribution, the sequence have character of a seismic swarm (no clear main/aftershock). The fault plane solution shows an oblique slip fault NE with a normal component dipping NW, which correlate with a local fault zone (Table 5). This area is 120 km north of the area where the 1819 Lurøy earthquake occurred.

Finnmark event, January 1996

The M_L3.7 earthquake of January 21st, 1996 at 02:16 was felt in the Finnmark area with a maximum intensity of V (Figure A - 1, Appendix 2). It was the largest earthquake in this area since April 3rd 1930 when a similar earthquake occurred and was felt. From the most recent earthquake, there were 10 damage reports from Masi, Kautokeino, Alta, and Kvænangen.

Figure 14 shows seismograms from this event recorded by Norwegian stations. The earthquake occurred along a fault zone, stretching from Kautokeino through Masi to Lakselv. The fault plan solution of the earthquake indicates a reverse (oblique) fault (Figure 11). Related to the fault the maximum horizontal compressional axis is in WNW-ESE direction, which is in accordance with the regional stress orientations related to the mid-ocean ridge in the Norwegian Sea.

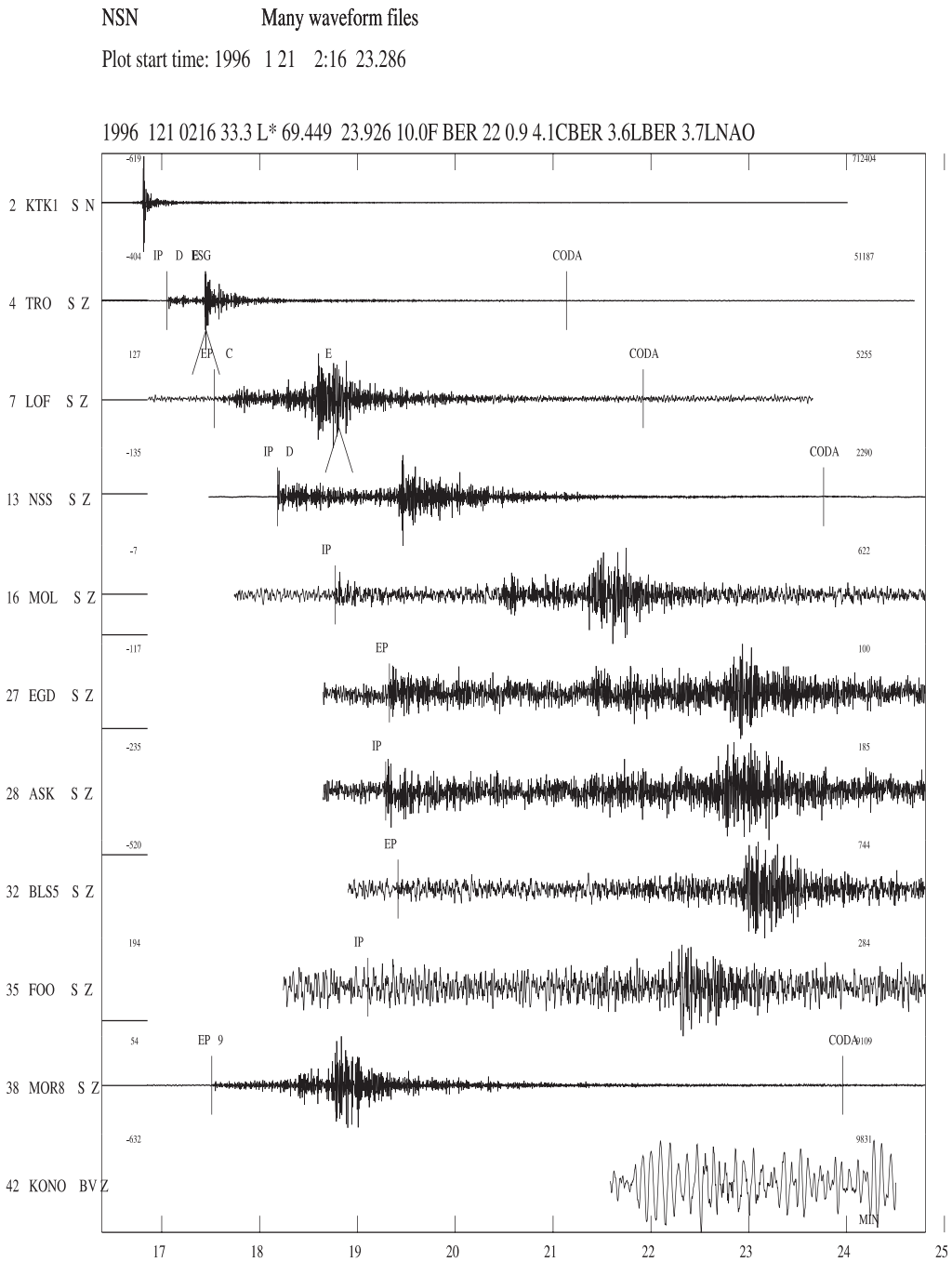


Figure 14. Seismogram from the M_L3.7 earthquake, January 21st 1996.

Kvernafjellet/Flørlia event, May 1997.

In the area Kvernafjellet/ Flørlia, the hydro power company Lyse Kraft, was constructing a tunnel in connection with a power station. May12th at 22:45 (UTC) a small earthquake was felt by the workers at the construction site. The event was recorded by NNSN stations and it was estimated to M_L=1.5. It was reported that there have been observed damage on the tunnel sidewalls due to rock deformation. During the time period January 1st 1990 to June

30th 1997, 8 events are located in an area around Kvernafjellet. It is interesting to note that the construction period in Flørlia/Kvernafjellet started in May 1996 with the building of roads, and that the time of the first event in this series of similar events started in August 1996. These events are probably the first case of known and documented induced earthquakes in Norway.

Kolbeinsey ridge swarm, July 2000

An earthquake swarm sequence was identified west of Jan Mayen, from June to September 2000. The largest earthquake recorded was of magnitude M_b4.5. The seismograms from several earthquakes had an unusual wedge-shaped form, with no clear onset of P- and S-phases (Tvedt, 2001). It is observed from other studies (Havskov and Atakan, 1991) that this waveform type may have its origin from the earthquake source, or its immediate vicinity, and that it may be caused by hot fluid in or near the source so the activity probably took place on the spreading ridge.

Stord event, August 2000

August 12th, at 16:27 the largest event in mainland Norway during the reporting period occurred near Stord and was felt in a radius of 300 km (Figure 10 and Figure A2 - 1) (Hicks and Ottemöller, 2001). With a depth of 18 km and a reverse focal mechanism (Table 5 and Figure 12), the earthquake is quite similar to the 1984, M_L=4.4 event, and this area regularly has magnitude 4.0 and larger events. The 2000 Stord earthquake had 35 locatable aftershocks within 72 hours of the main shock, which seems to be typical for large events in this area.

Near the Heimdal and Frigg Platforms in the North Sea, December 2000

On December 8, at 05:54, a magnitude 4.0 earthquake occurred in the northern North Sea. This earthquake was followed by a total of 21 earthquakes (probably aftershocks) located to the same area but with lower magnitudes. The largest earthquake was expected to be felt at the Heimdal or Frigg platforms, but no report of any influence from these earthquakes on the platforms or to the reservoir was reported/confirmed by the oil companies/platform personnel.

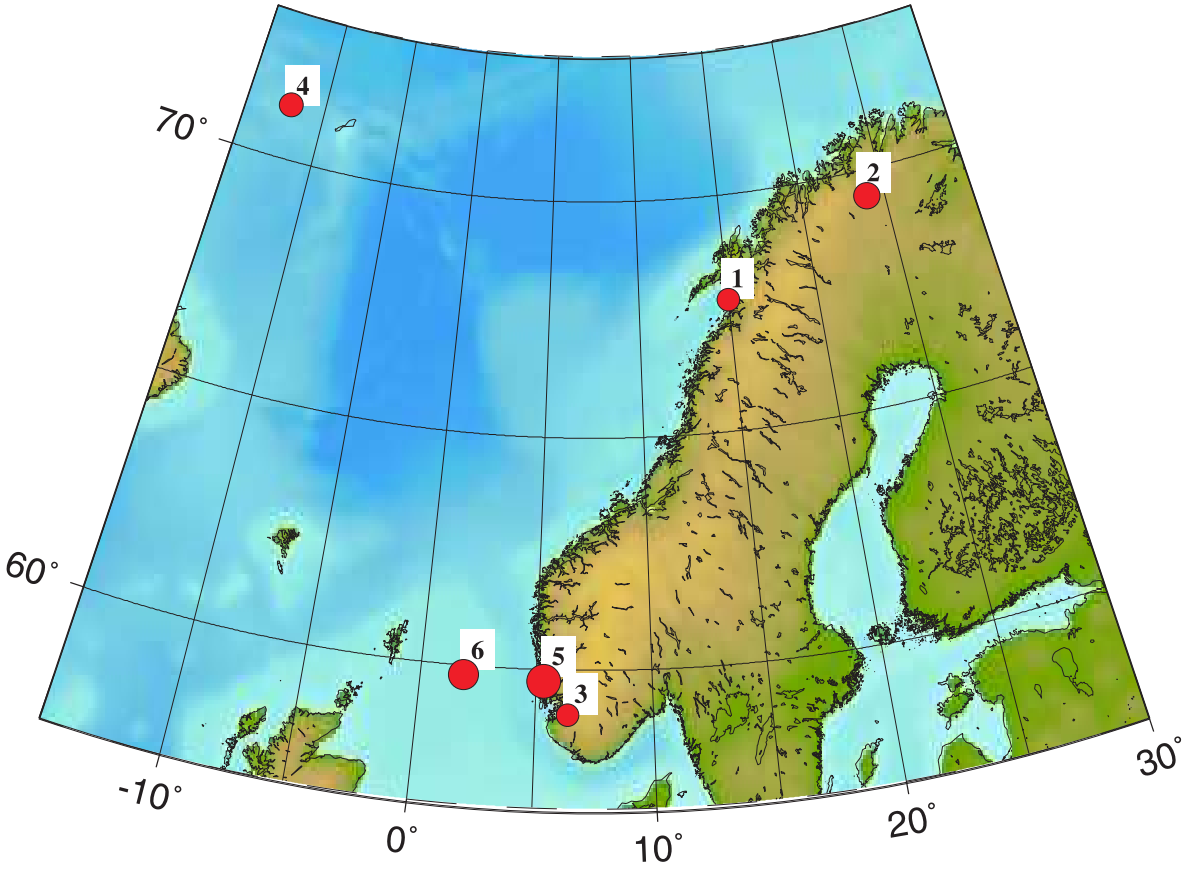


Figure 15. The map shows the locations of cases of unusual earthquake activity listed in Table 6.

Final remarks

The Norwegian National Seismic Network is now well established with a stable technical and financial position. The associated NNSN database has increased in both quantity and quality during the period 1990-2000 and the database has been extensively used for research in the fields of seismic hazard and risk, studies of the crust, seismotectonics and earthquake engineering.

Due to the technical development of the network, there has also been a strong development in software for seismic data acquisition, communication and processing and at present the public domain software developed in the group (SEISLOG, SEISNET, and SEISAN) is used worldwide, at universities, research institutions and commercial companies in more than 30 countries. The list of papers and talks, using data from the network, give an indication of this activity (Appendix 3).

The network is still slowly being upgraded and probably more of the stations will in the future get broadband sensors. It is also expected that the communication to the stations

will improve in capacity and technical ability, while at the same time being more economical to operate. The last remaining station (BJO) without internet will probably have a permanent connection within the near future.

The processing methods and capabilities have also gradually improved during this period and much more analysis is done with the data in 2000 than routinely done in 1990 (like calculating fault plane solution and additional magnitude types Getting more high quality data will also be emphasized in the future.

Acknowledgments.

The authors are grateful to professor E. Sundvor and employees at NORSAR for giving comments on the manuscript.

References

Alsaker A., L.B. Kvamme, R.A. Hansen, A. Dahle and H. Bungum, 1991. The ML scale in Norway. *Bull. Seism. Soc. Am.*, Vol. 81, No. 2, pp.379-398.

Atakan, K, C. D. Lindholm and J. Havskov, 1994. Earthquake swarm in Steigen, northern Norway: An unusual example of intraplate seismicity. Terra Nova, Vol 6, pp. 180-194.

Brune, J.N., 1970: Tectonic stress and spectra of seismic shear waves. *Jour. Geophys. Res.,* 75 pp4997-5009.

Bungum H., 1999. National Centennial Report for Norway. IASPEI Handbook of Earthquake and Engineering Seismology.

Grünthal, G., (ed), 1998. '*European Macroseismic Scale 1998'*, Cahiers du Centre Européen de Géodynamique et de Séismologie Volume 15, Luxembourg.

Havskov J., and K. Atakan, 1991. Seismicity and Volcanism of Jan Mayen Island, Norway. *Terra Nova* 3, pp 517-526.

Havskov J., and H. Bungum, 1987. Source parameters for earthquakes in the northern North Sea, *Norsk Geologisk Tidskrift*, Vol.67, pp 51-58.

Havskov, J. and L. B. Kvamme, R. A Hansen, H. Bungum and C. D. Lindholm (1992). The northern Norway seismic network: Design, operation, and results, Bull. Seism. Soc. Am. 82, 481-496.

Havskov, J. and L. Ottemöller, 1999. SEISAN earthquake analysis software, Seism. Res. Letters, Vol. 70, pp. 532-534.

Havskov, J. and L. Ottemöller, 2001. SEISAN: The earthquake analysis software, version 7.2, manual, Univeristy of Bergen, pp. 255.

Hicks E. and L. Ottemøller 2001. The ML 4.5 Stord/Bømlo, southwestern Norway, earthquake of August 12, 2000. *Norsk Geol Tidsskrift* no.4, Vol.81, pp. 293-303.

Hicks, E.C., Bungum, H., and Lindholm, C.D. 2000. Stress inversion of earthquake focal mechanism solutions from onshore and offshore Norway. *Norsk geologisk Tidsskrift* 80, 235-250.

Kanamori, H. 1977: The energy release in great earthquakes. *Journal of Geophysical Research.* 82; 20, pp2981-2987.

Karnik, V., Kondorskaya, N.V., Yu, V. Riznichenko, Ye, F. Savarensky, S.L. Solovev, N.V. Shebalin, J. Vanek, and A. Zatopek, 1962. Standardisation of the earhquake magnitude scales. *Studia Geophys. et Geod*., Vol. 6, pp. 41-48.

Kennett, B.L.N. and E.R. Engdahl, 1991. Traveltimes for global earthquake location and phase identification, *Geophys. J. Int*., Vol. 105, pp. 429-465.

Lindholm, C.D., Bungum, H., Bratli, R.K., Aadnøy, B.S., Dahl, N., Tørudbakken, B. and Atakan, K. 1995. Crustal stress in the northern North Sea as inferred from borehole break-outs and earthquake focal mechanisms. *Terra Nova* 7, 51-59.

Lindholm, C.D., Bungum, H., Hicks, E.C. and Villagran, M. 2000. Crustal stress and tectonics in Norwegian regions determined from earthquake focal mechanisms. *In Nøttvedt, A. Et al. (eds): Dynamics of the Norwegian Margin. Geological Society, London, Special Publications* 167, 429-439.

Ottemöller,L. and J. Havskov, 1999. SEISNET: A general purpose seismic network, Seism. Res Letters, Vol. 70, pp. 522-528.

Moreno, B, L. Ottemöller, J. Havskov and K.A. Olesen, 2002: Seisweb: A Client-Server-Architecture-Based Interactive Processing Tool for Earthquake Analysis. *Seism. Res. Letters.* Vol.73, No.1

Sørnes A. and T. Navrestad, 1975. Seismic survey of Jan Mayen. *Norsk Polarinstitutt*, Årbok 37-52.

Tvedt, E., 2001: Earthquake swarms. *Cand. Scient. Thesis, University of Bergen.*

Utheim,T., J. Havskov and Ø. Natvik, 2001: SEISLOG data acquisition system. *Seis. Res. Letters Vol.72, No.1,* pp77-79.

Veith K.F., and G.E. Clawson, 1972. Magnitude from short-period P-wave data. *Bull. Seism. Soc. Am*., Vol. 62, pp.435-452.

Westre S., 1975. Richter's lokale magnitude og total signal varighet for lokale jordskjelv på Jan Mayen. *Cand. real thesis*., Seismological Observatory, University of gen, Norway.

Appendix 1 - Yearly seismicity maps

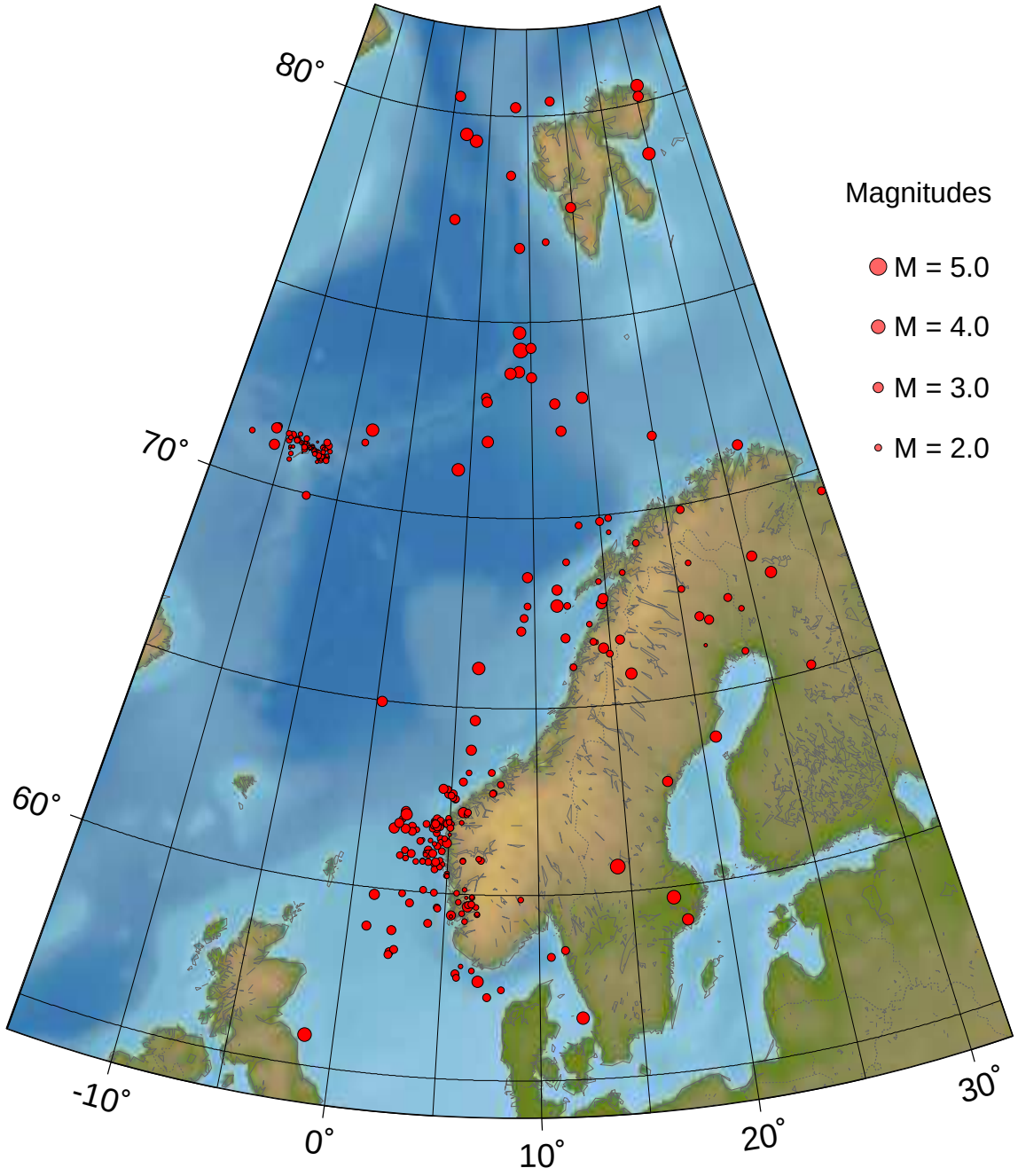


Figure A1 - 1. Events taking place in 1990 .

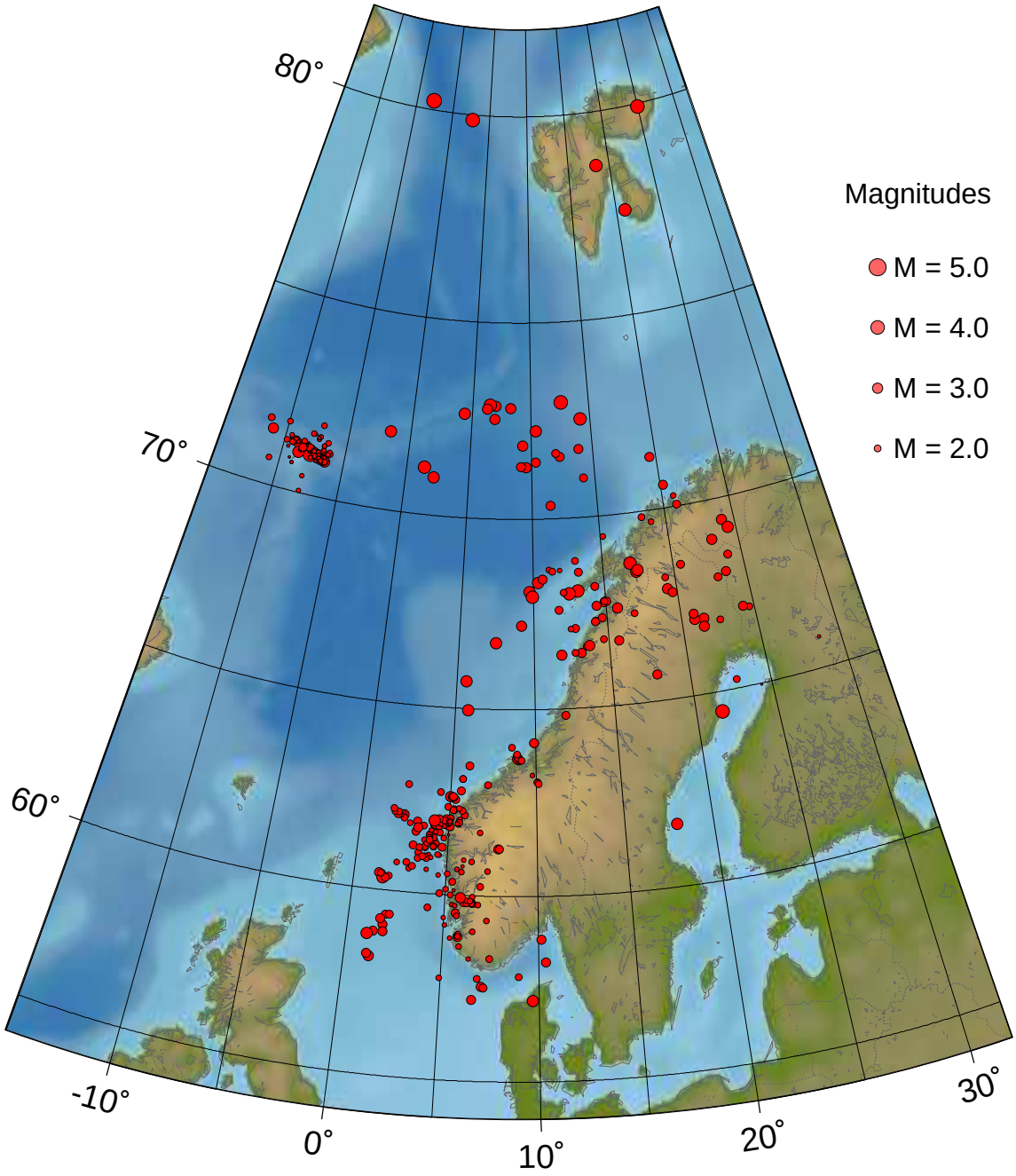


Figure A1 - 2. Events taking place in 1991.

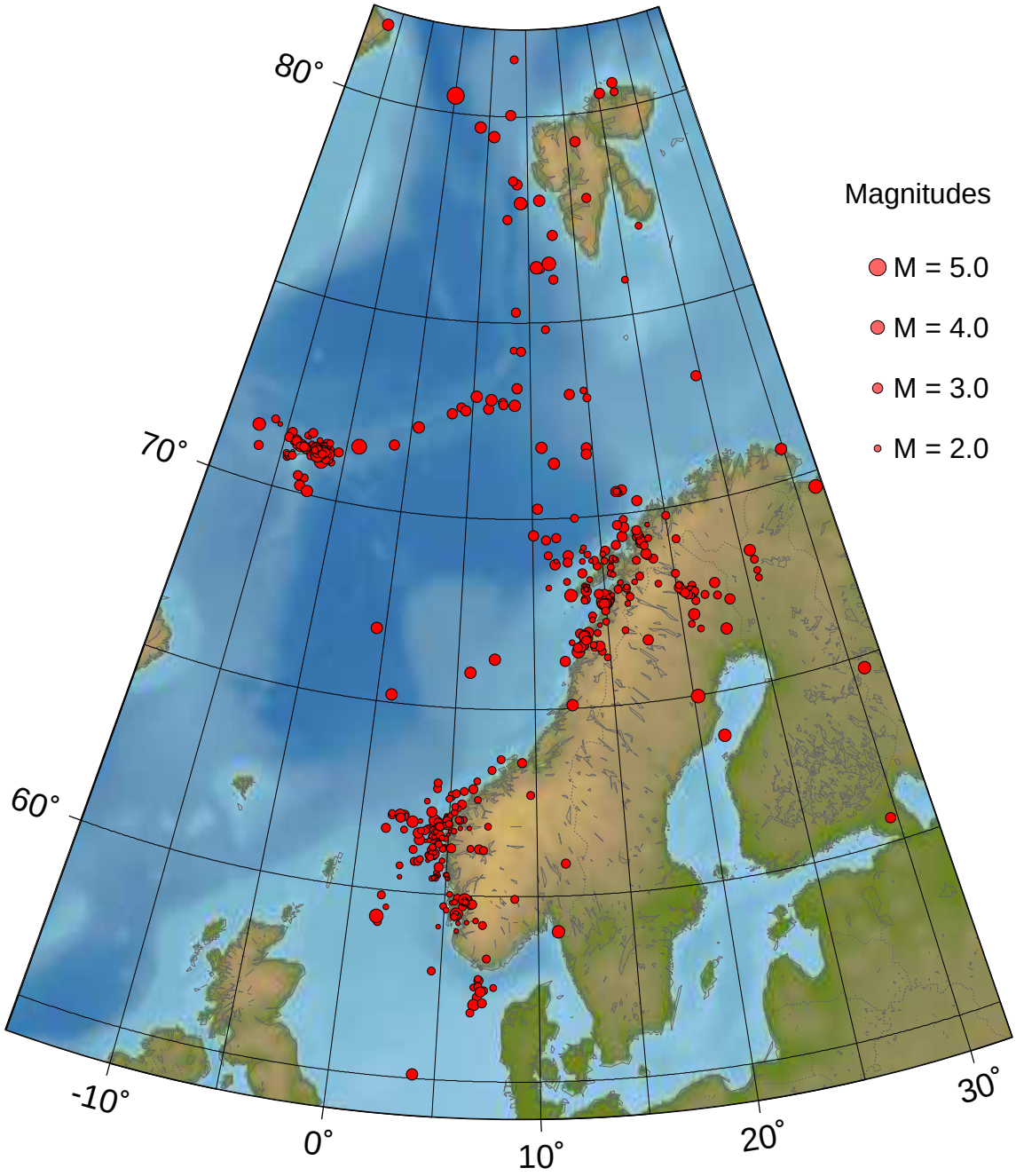


Figure A1 - 3. Events taking place in 1992.

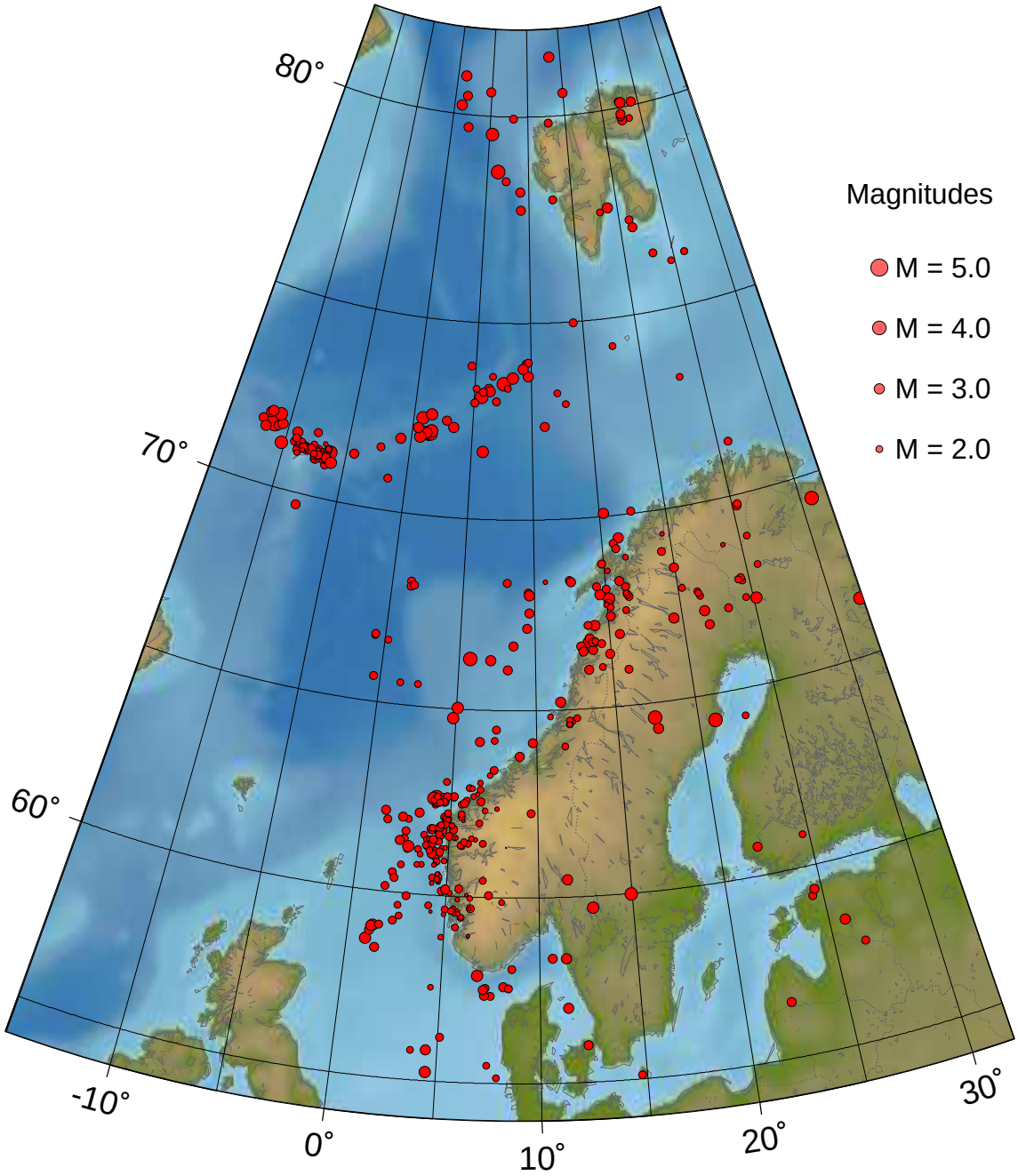


Figure A1 - 4. Events taking place in 1993.

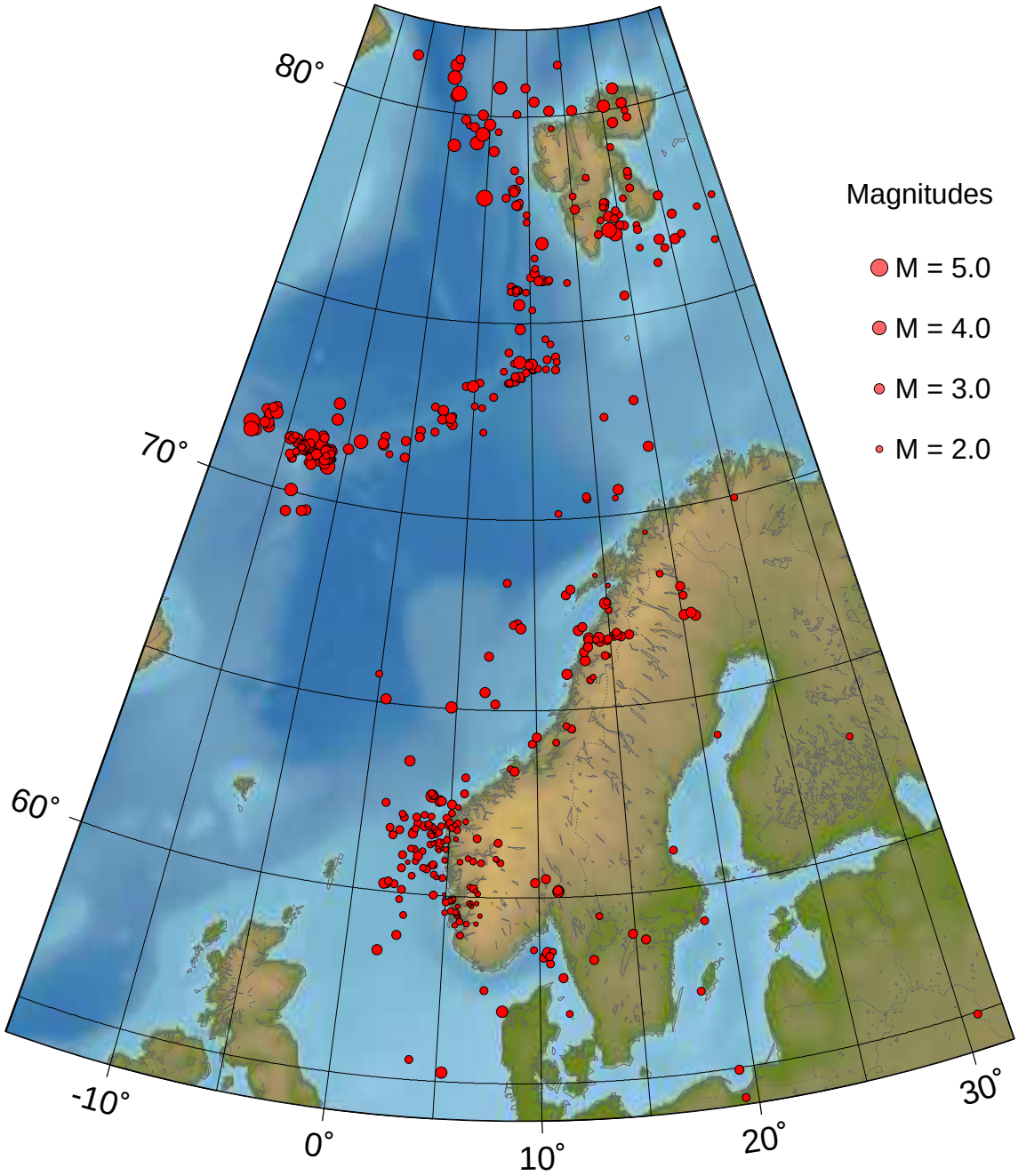


Figure A1 - 5. Events taking place in 1994.

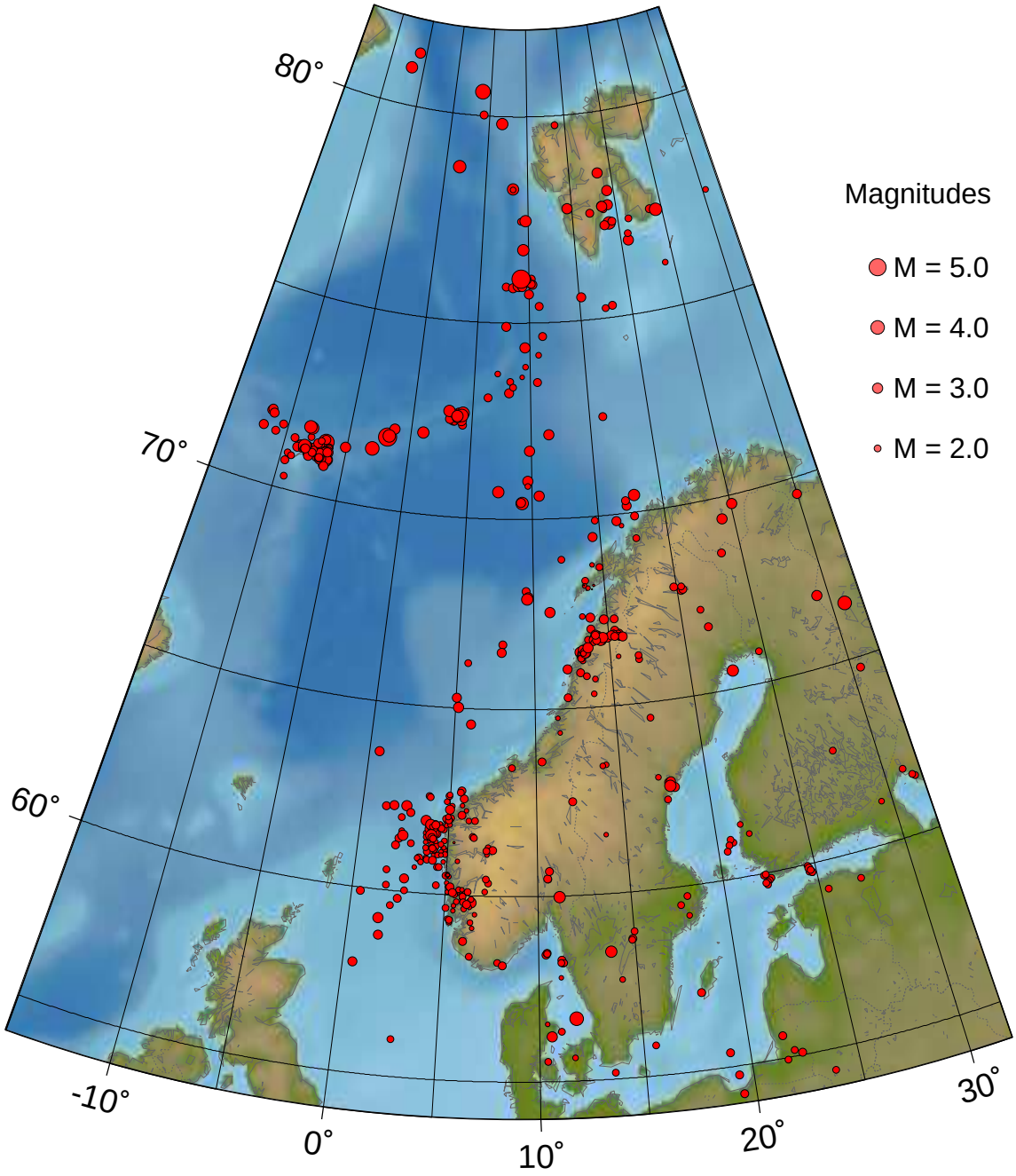


Figure A1 - 6. Events taking place in 1995.

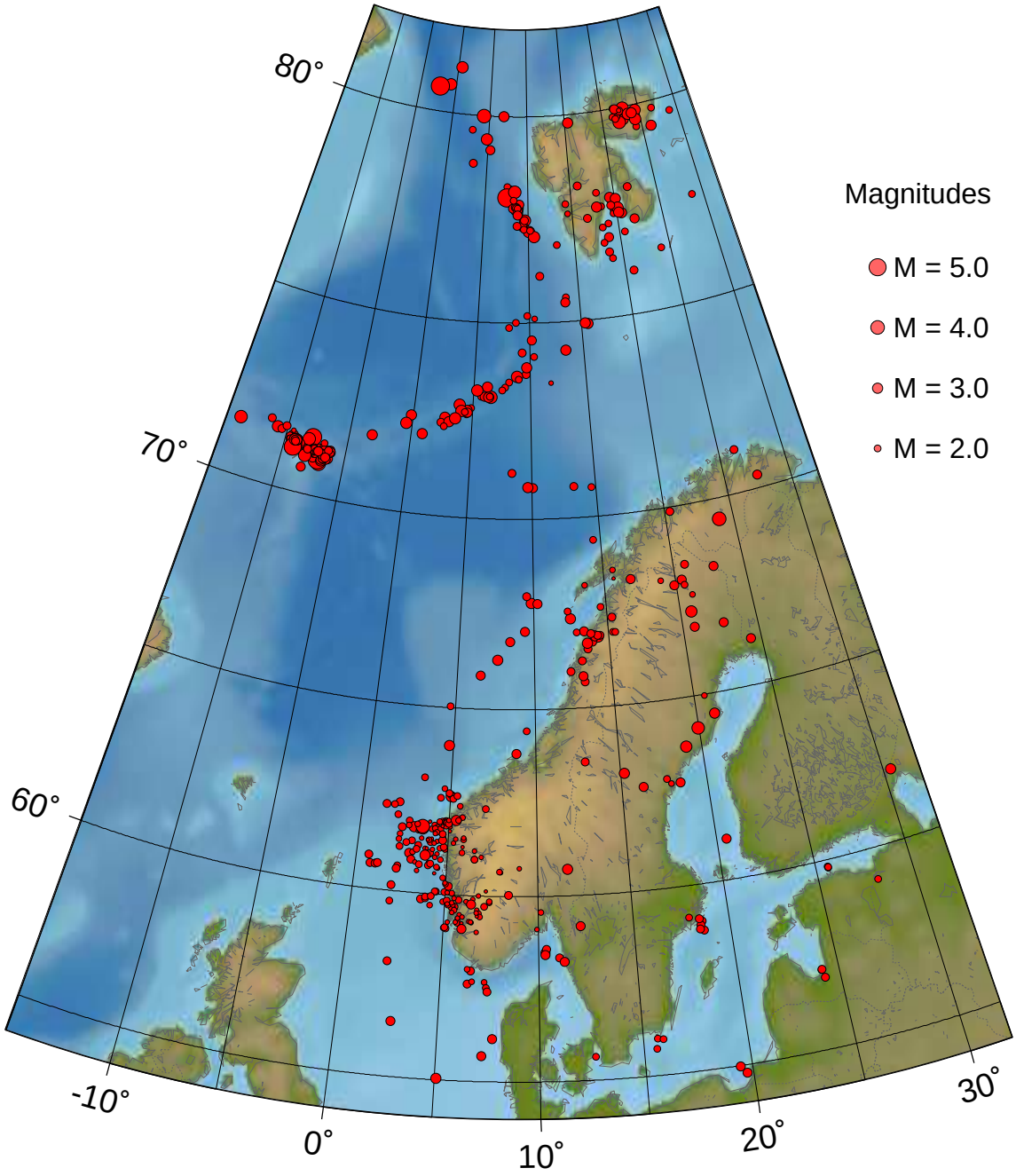


Figure A1 - 7. Events taking place in 1996.

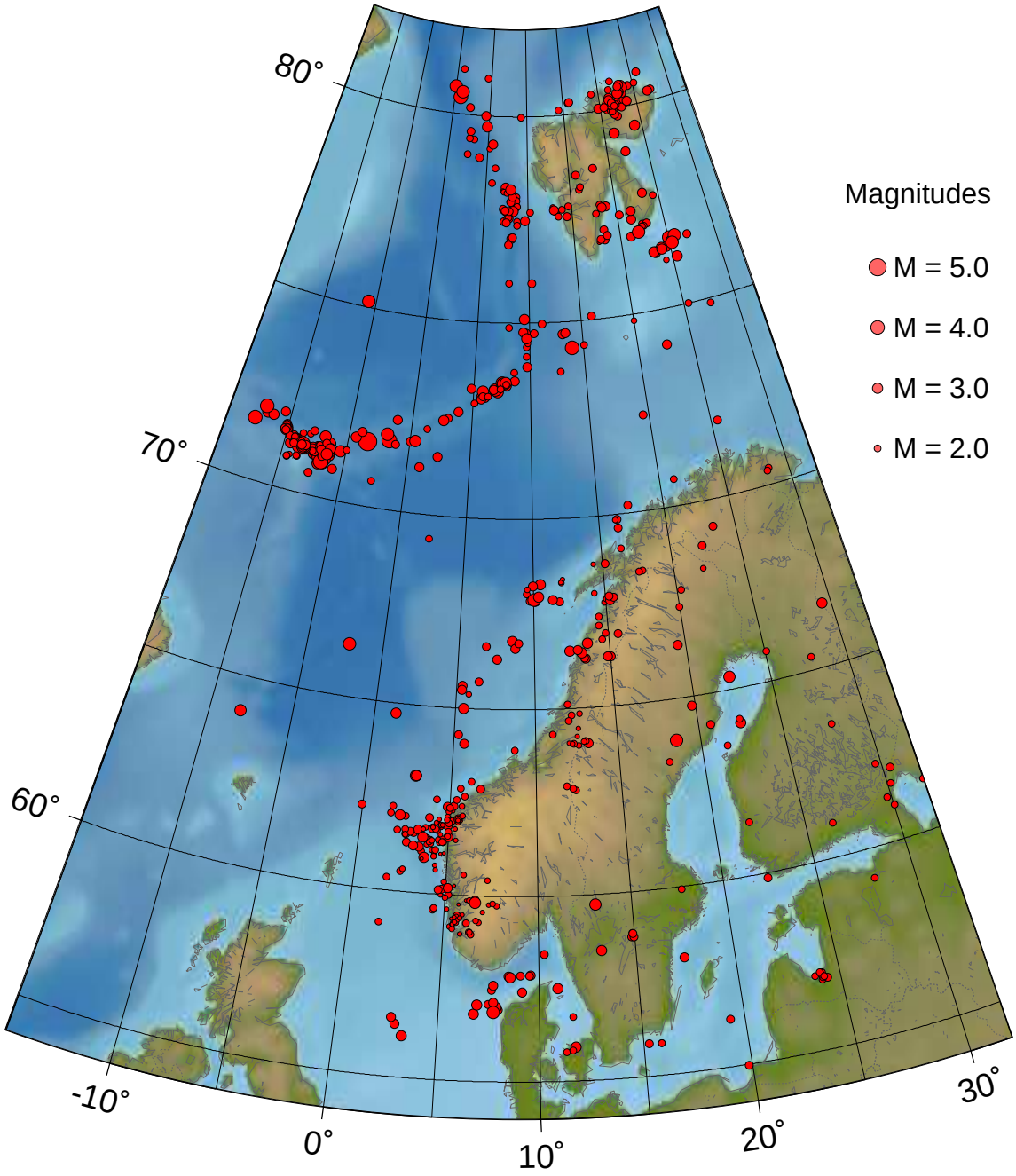


Figure A1 - 8. Events taking place in 1997.

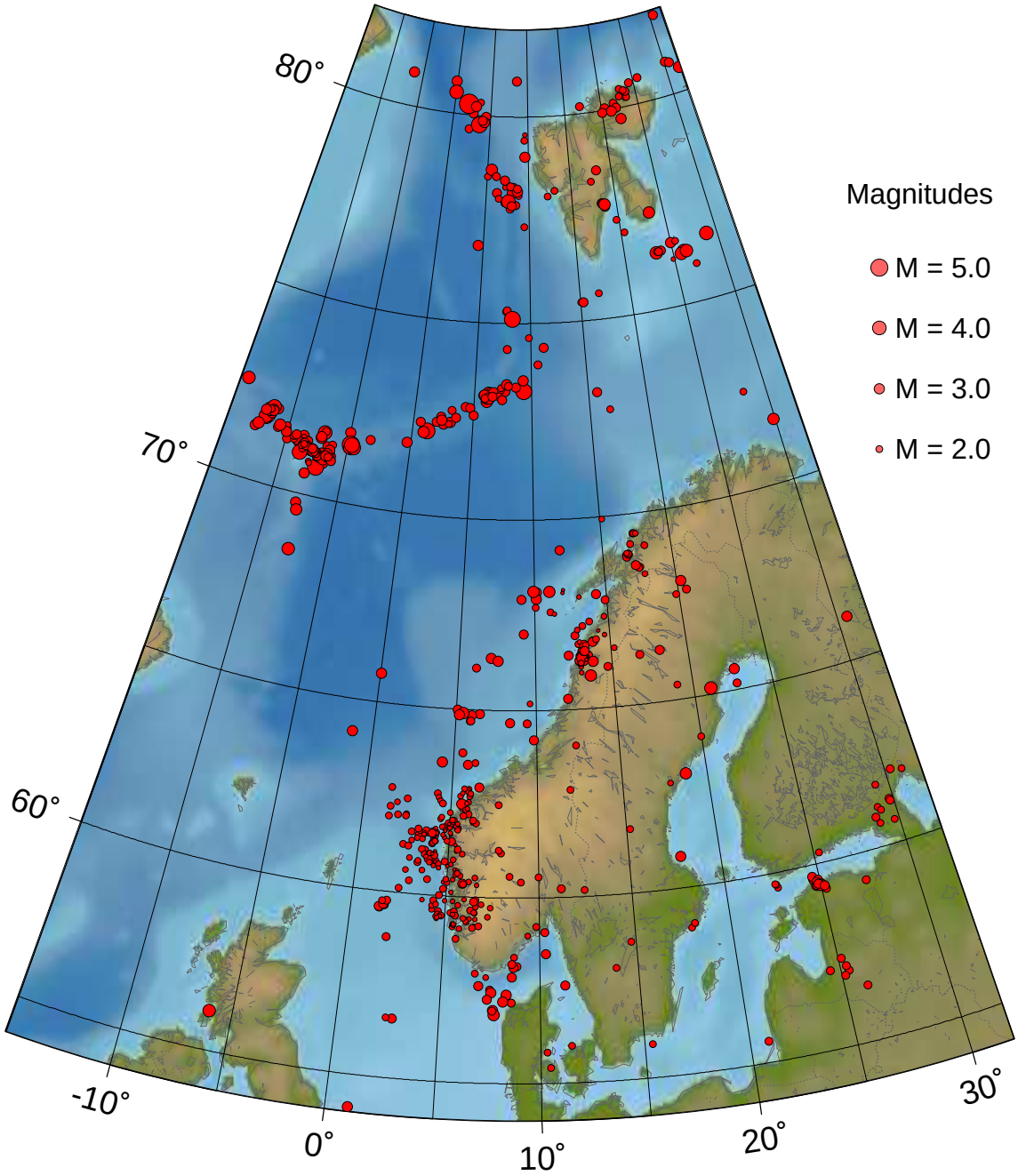


Figure A1 - 9. Events taking place in 1998.

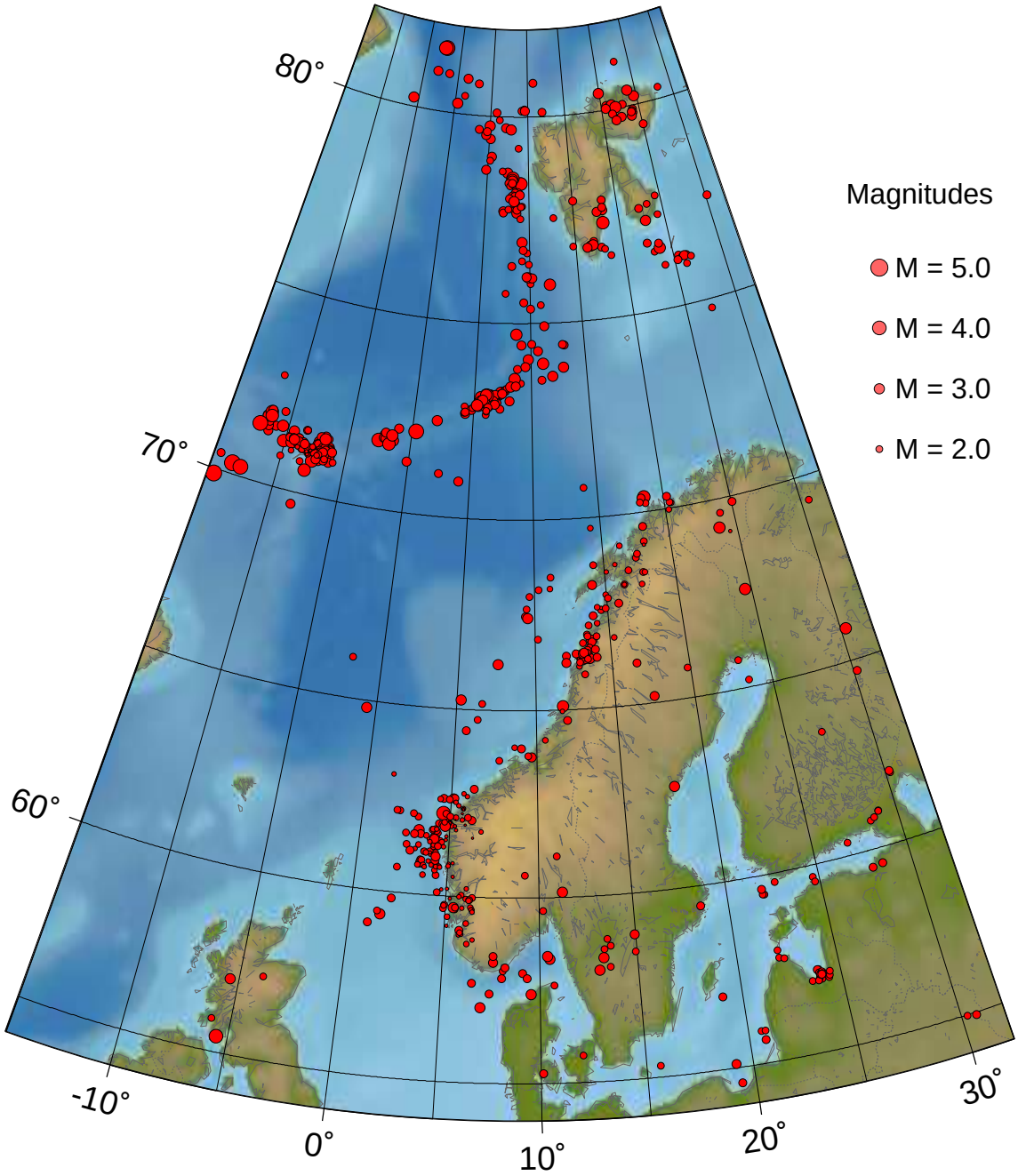


Figure A1 - 10. Events taking place in 1999.

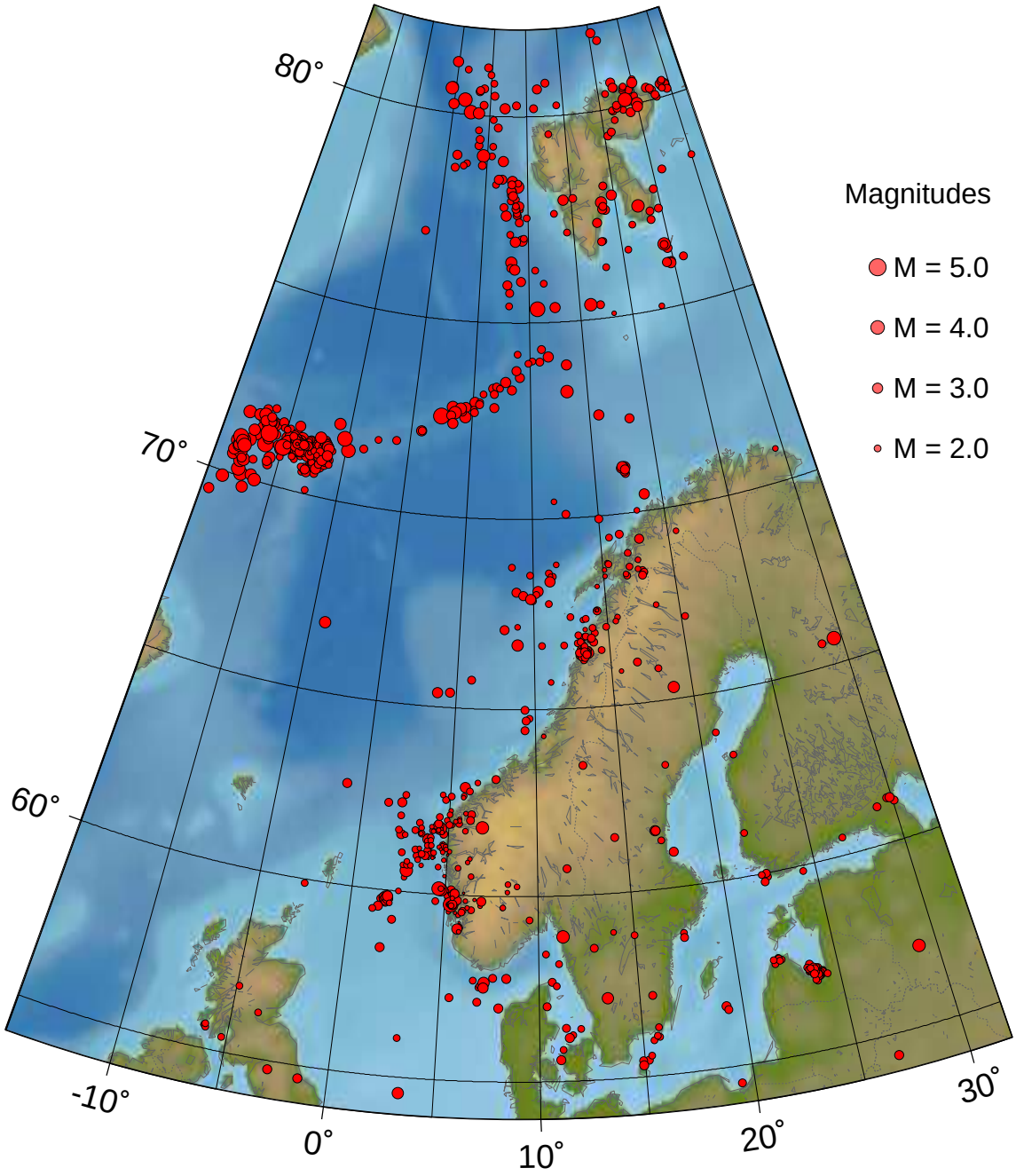


Figure A1 - 11. Events taking place in 2000.

Appendix 2 - Felt earthquakes

This Appendix give detailed information of all felt earthquakes. The felt events have been evaluated using the Modified Mercalli intensity scale (Table A2 - 1). The list of all felt earthquakes are given in table A2 - 2, and Figure A2 - 1 gives the intensity maps for events for which it was possible to make an intensity map.

Table A2 - 1. The Modified Mercalli Intensity Scale. (From Grünthal, 1998[*])

Intensity	Decription
I	Not felt
II	Felt indoors by few
III	Felt indoors by several
IV	Felt indoors by many, outdoors by few
V	Felt indoors by practically all, outdoors by many
VI	Felt by all, indoors and outdoors
VII	Frightened all - general alarm
VIII	Fright general - alarm approaches panic
IX	Panic general
X	Cracked ground
XI	Disturbances in ground many and widespread
XII	Damage total

[*] Grünthal, G., (ed), 1998. '*European Macroseismic Scale 1998*', Cahiers du Centre Européen de Géodynamique et de Séismologie Volume 15, Luxembourg.

Table A2 - 2. Earthquakes felt in Norway during the time period 1990-2000. Excluding events on Jan Mayen. Events with intensity V are highlighted. Events with no intensity marked were felt by too few to make a macroseismic investigation. Abbreviations: M_C; Coda magnitude, M_C; Local magnitude and M_C; Moment magnitude.

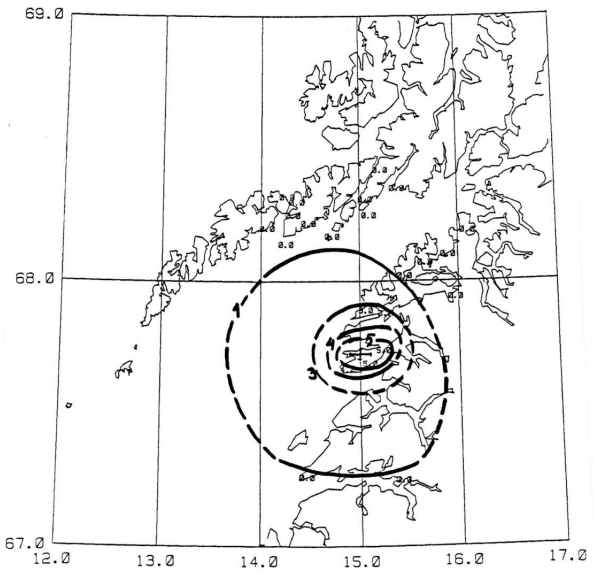
Date	Time (UTC)	Max. Intensity (on MMI scale)	Magnitude ( )	Instrumental Epicenter Location
19.01.90	23:41	IV	3.4 (M_C)	61.82N / 4.37E western Norway
25.02.90	10:00	IV	3.0 (M_C), 2.5 (M_L)	59.67N / 6.20E western Norway
23.09.90	00:35	IV	2.8 (M_C), 2.5 (M_L)	59.42N / 5.34E Karmøy, western Norway
20.01.91	19:27	III	2.5 (M_C), 1.8 (M_L)	59.53N / 5.0E western Norway
23.01.91	15:45	IV	3.1 (M_C), 2.9 (M_L)	61.91N / 4.51E western Norway
23.08.91	04:07	III	2.7 (M_C)	58.89N / 5.78E Stavanger, southern Norway
28.10.91	13:14	IV	3.0 (M_C)	59.94N / 5.85E Rosendal, western Norway
01.01.92	08:03	V	3.6 (M_C), 3.1 (M_L)	67.79N / 15.02E Steigen, northern Norway
19.02.92	06:39	IV	3.8 (M_C)	59.05N / 11.04E Oslo Fjord, southern Norway
11.03.92	22:05	IV	2.6 (M_C), 2.6 (M_L)	62.44N / 5.70E Ålesund, western Norway
11.04:92	15:05	III	2.5 (M_C)	59.93N / 5.67E Hadangerfjord, western Norway
14.04.92	13.10	V	3.7 (M_C), 3.5 (M_L)	59.49N / 5.66E Stord, western Norway
22.05.92	08.40		3.1 (M_C)	61.08N / 4.27E Nord Hordaland, western Norway
24.05.92	14.48	III	2.4 (M_C)	69.55N / 21.56E Kvænangen, northern Norway
28.06.92	12:23	IV	2.8 (M_C), 3.0 (M_L)	61.89N / 4.94E Nordfjord, western Norway
28.06.92	20:56	IV	2.4 (M_C)	62.44N / 6.61E Sunn Møre, western Norway
03.08.92	11:16		3.6 (M_C), 2.7 (M_L)	66.49N / 12.90E Lurøy, western Norway
06.08.92	07:32	V	3.3 (M_C), 3.7 (M_L)	59.89N / 6.09E Rosendal, western Norway
09.11.92	17:52	IV	2.5 (M_C), 2.3 (M_L)	60.43N / 5.10E Sotra, western Norway
07.02.93	22:17	III	3.2 (M_C), 2.6 (M_L)	69.42N / 16.24E Andenes, northern Norway
06.03.93	01:26		3.3 (M_C), 2.6 (M_L)	57.89N / 6.81E Lindesnes
27.11.93	18:57	IV	3.1 (M_C)	60.61N / 11.64E Kongsvinger, southeastern Norway
27.11.93	23:11		2.5 (M_C)	68.92N / 19.25E Northern Norway
21.01.94	01:26		3.1 (M_C), 2.2(M_L)	65.94N / 12.02E Eastern Norway

26.01.94	17:27	III	3.0 (M_C), 2.4 (M_L)	66.86N / 13.56E Meløy, northern Norway
22.02.94	05:55	III	2.7 (M_C), 2.2 (M_L)	66.80N / 13.63E Meløy, northern Norway
27.07.94	09:42	III	3.4 (M_C), 3.9 (M_L)	62.88N / 3.95E Offshore Ålesund, western Norway
10.08.94	21:02		2.4 (M_C), 2.0 (M_L)	60.23N / 6.49E
09.09.94	01:02	II	2.3 (M_C), 2.0 (M_L)	61.58N / 6.57E Sogn, western Norway
22.09.94	05:25	III	2.7 (M_C), 2.8 (M_L)	67.16N / 13.18E Meløy, northern Norway
19.11.94	09:07	V	3.3 (M_C), 3.5 (M_L)	60.16N / 11.05E Kløfta, eastern Norway
06.02.95	17:00	IV	2.5 (M_C), 3.0 (M_L)	59.80N / 6.41E Hordaland, western Norway
14.03.95	15:29	II	2.0 (M_C)	61.96N / 5.54E Sogn, western Norway
17.03.95	23:43	III	2.8 (M_C), 3.2 (M_L)	61.96N / 5.54E Florø, western Norway
29.03.95	22:26	II	3.0 (M_C), 2.7 (M_L)	66.47N / 13.10E Mo i Rana, northern Norway
29.03.95	22:37	II	2.3 (M_C)	66.55N / 13.40E Mo i Rana, northern Norway
10.05.95	23:42		3.0 (M_C), 2.5 (M_L)	66.48N / 13.02E Northern Norway
21.05.95	21:52		2.5 (M_C), 1.8 (M_L)	60.46N / 10.55E Eastern Norway
20.06.95	21:22	V	3.2 (M_C), 3.8 (M_L)	61.74N / 3.99E Offshore Florø, northern Norway
03.07.95	12:49	II	3.1 (M_C), 3.3 (M_L)	69.79N / 25.11E Finnmark, northern Norway
14.10.95	04:32	II	2.5 (M_C), 2.6 (M_L)	60.23N / 5.24E Sotra, western Norway
23.10.95	01:08	II	3.5 (M_C), 3.1 (M_L)	69.44N / 24.10E Finnmark, northern Norway
13.11.95	01:22	IV	3.3 (M_C), 3.2 (M_L)	59.96N / 11.17E Oslo area, eastern Norway
13.11.95	08:09	IV	3.3 (M_C), 3.5 (M_L)	61.52N / 4.03E Offshore Florø, western Norway
20.11.95	04:01	II	2.3 (M_C), 2.2 (M_L)	60.06N / 5.40E Fitjar, Stord, western Norway
21.01.96	02:16	V	3.7 (M_L)	69.45N / 23.93E, Masi, Finnmark, northern Norway
17.03.96	03:28	IV	2.4 (M_L)	60.23N 5.18E, Sotra, western Norway
16.04.96	10:27	V	2.8 (M_L)	61.94N 5.51E, Nordfjord, western Norway
31.10.96	12:52	IV	3.4 (M_C), 3.7 (M_L)	61.78N / 3.61E Offshore Florø, Western Norway
31.10.96	12:57	IV	3.3 (M_C), 3.8 (M_L)	61.74N / 3.67E Offshore Florø, Western Norway
31.10.96	23:47	IV	3.7 (M_C), 3.9 (M_L)	61.76N / 3.60E Offshore Florø, Western Norway
11.11.96	16:41	II	2.5 (M_C), 2.7 (M_L)	59.76N / 6.40E Sauda, Southwestern Norway
10.12.96	10:42	II	2.4 (M_C), 2.8 (M_L)	59.16N / 5.97E Rennesøy, Southwestern Norway

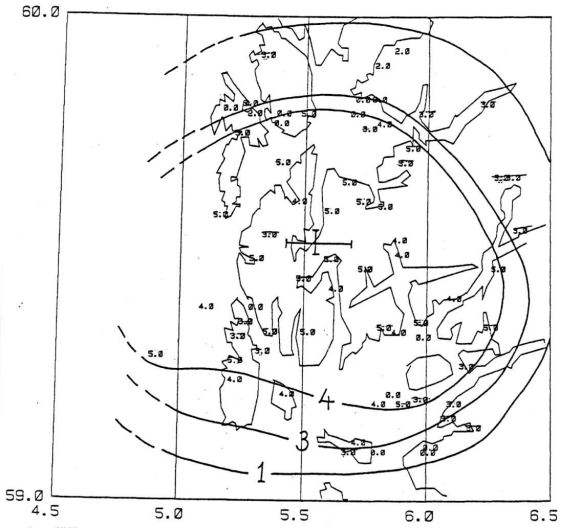
16.12.96	04:09	II	3.0 (M_C), 2.8 (M_L)	61.01N / 3.90E Offshore Sula, Western Norway
31.12.96	16:11	II	3.1 (M_C), 3.0 (M_L)	66.70N / 13.59E Meløy, Northern Norway
28.04.97	03:23	III	2.8 (M_C), 2.3 (M_L)	61.99N / 5.60E Eidså, Møre og Romsdal
12.05.97	22:45	II	2.0 (M_C), 1.5 (M_L)	59.00N / 6.36E Kvernafjellet, Rogaland
13.05.97	22:07	III	3.0 (M_C), 3.2 (M_L)	60.96N / 3.73E Offshore, close to Troll
30.06.97	11:25	II	1.7 (M_C), 1.3 (M_L)	59.02N / 6.41E Kvernafjellet, Rogaland
12.08.97	08:14	II	2,7(M_C), 3.0(M_L)	59.80N / 6,52E Sauda, Hordaland
15.09.97	15:58	IV	2.6(M_C), 2.5(M_L)	60.18N / 5.19E Offshore, gen
13.12.97	07:02	IV	4.5(M_L), 4.7(M_B)	71.04N / 9.66W Jan Mayen
20.12.97	21:40	II	3.8(M_C), 3.4(M_L)	67.89N / 10.12E West of Lofoten
01.01.98	21:00	IV	2.4 (M_C), 2.1 (M_L)	59.05N / 10.29E Sandefjord, Vestfold
09.03.98	14:19	III	3.5 (M_C), 2.7 (M_L)	65.57N / 14.98E
13.10.98	22:21	II	3.0 (M_C), 2.2 (M_L)	66.24N / 13.77E
26.10.98	23:06	II	2.1 (M_C), 1.4 (M_L)	66.47N / 12.97E
28.11.98	09:08	V	2.4 (M_C), 2.8 (M_L)	60.35N / 5.86E
07.01.99	14:04	III	2.7 (M_C), 1.9 (M_L) 2.1 (M_w)	66.83N / 13.73E
17.01.99	20:13	III	2.6 (M_C), 2.5 (M_L) 2.3 (M_w)	68.24N / 14.06E
30.03.99	0921	II	2.5 (M_C), 2.5 (M_L) 2.3 (M_w)	69.86N / 25.05E
10.04.99	15:04	V	2.9 (M_C), 2.7 (M_L) 2.5 (M_w)	60.14N / 11.27E
29.05.99	00:31	V	3.2 (M_C), 3.9 (M_L) 3.6 (M_w)	62.20N / 4.59E
22.08.99	02:08	III	3.3 (M_C), 2.4 (M_L) 2.3 (M_w)	69.26N / 23.72E
23.08.99	14:11	III	3.3 (M_C), 3.1 (M_L)	65.10N / 11.68E
13.10.99	22:37	III	2.1 (M_C), 1.8 (M_L) 1.9 (M_w)	62.13N / 6.00E
17.10.99	12:07	III	3.6 (M_C), 3.6 (M_L) 3.4 (M_w)	70.39N / 18.53E
01.02.00	12:42	III	2.1 (M_C), 2.3 (M_L) 2.3 (M_w)	61.61N / 4.72E
10.02.00	06:17	IV	3.4 (M_C), 3.6 (M_L) 3.3 (M_w)	61.77N / 4.52E
13.03.00	05:20	III	2.1 (M_C), 2.2 (M_L) 2.4 (M_w)	62.17N / 6.25 E
07.04.00	03:38	III	3.4 (M_C), 3.4 (M_L) 2.9 (M_w)	66.45N / 13.47E
27.04.00	21:44	III	2.9 (M_C), 3.2 (M_L) 3.0 (M_w)	61.44N / 3.88E

01.06.00	17:08	V	3.6 (M_C), 3.7 (M_L) 3.5 (M_w)	61.84N / 6.89E
05.07.00	17:58	III	2.3 (M_C), 2.2 (M_L) 2.1 (M_w)	62.01N / 6.21E
12.08.00	14:27	V	3.6 (M_C), 4.5 (M_L) 4.1 (M_w)	59.76N / 5.34 E
01.09.00	11:48	III	2.8 (M_C), 2.6 (M_L)	59.10N / 5.74E
19.10.00	10:27	IV	3.5 (M_C), 3.3 (M_L) 3.1 (M_w)	57.67N / 7.2E
26.11.00	00:17	III	2.7 (M_C), 2.6 (M_L) 2.5 (M_w)	60.04N / 5.48E
29.11.00	02:22	III	2.7 (M_C), 2.7 (M_L) 2.5 (M_w)	59.85N / 6.98E
29.11.00	09:59	IV	2.7 (M_C), 2.4 (M_L) 2.5 (M_w)	60.05N / 5.51E
29.11.00	22:07	V	3.8 (M_C), 3.8 (M_L) 3.4 (M_s)	58.89N / 11.29E
08.12.00	00:48	V	3.3 (M_C), 3.8 (M_L) 3.6 (M_s)	60.13N / 4.79E

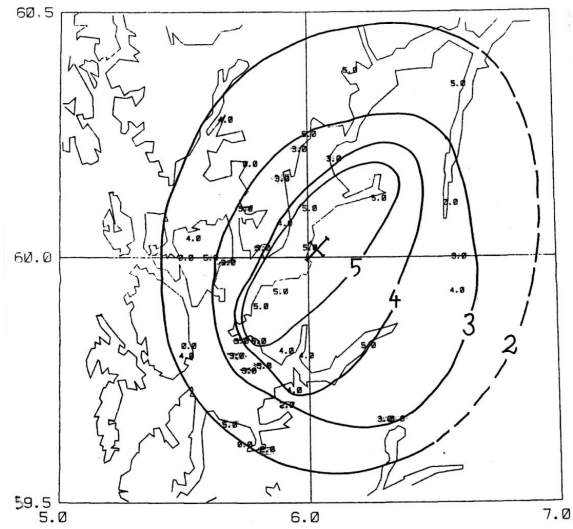
Figure A2 - 1. Intensity maps for the events marked with grey in table A2 - 2.



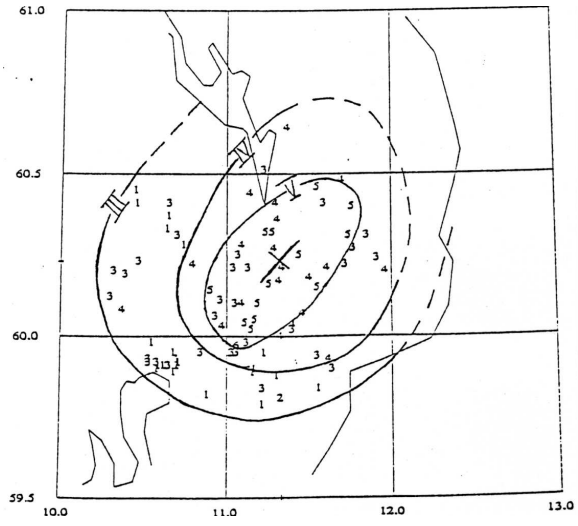
01.01.1992 Mc3.6



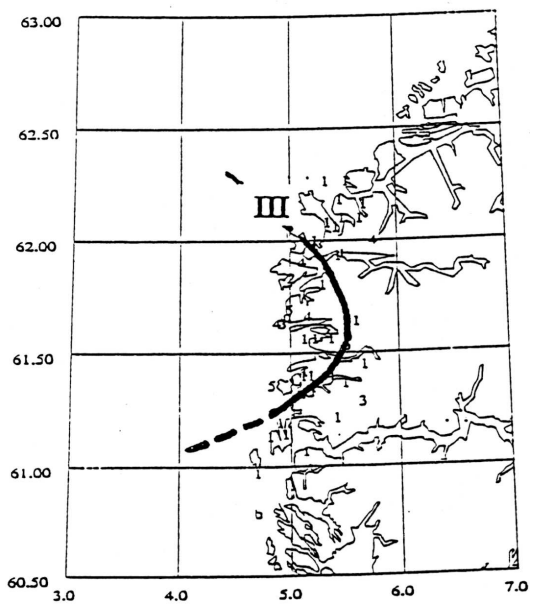
14.04.1992 Mc3.7



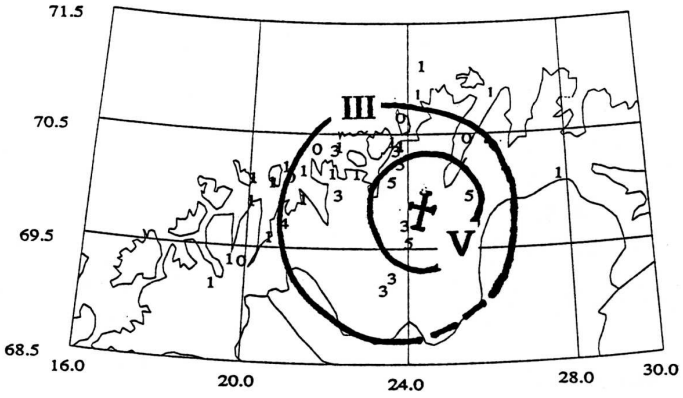
06.08.1992 Mc3.3



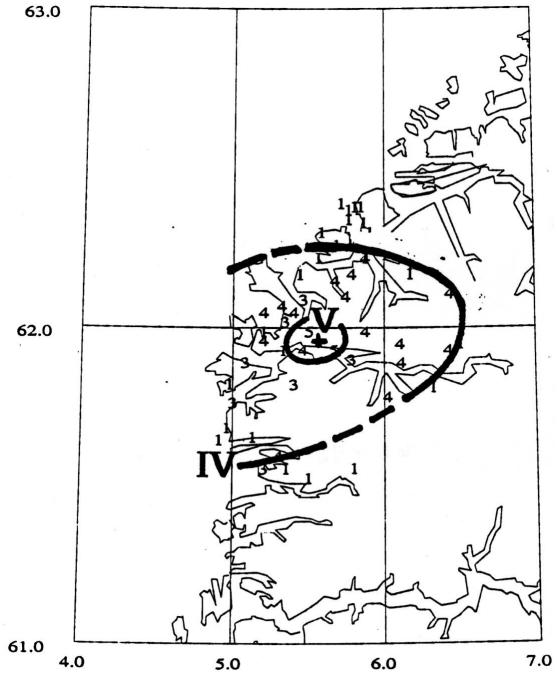
19.11.1994 Mc3.3



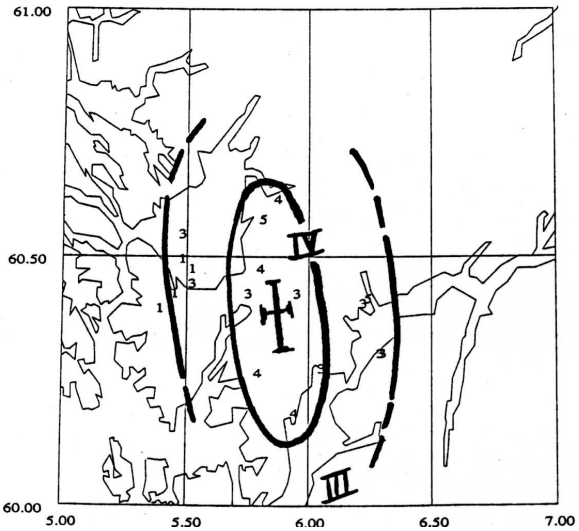
20.06.1995 Mc3.2



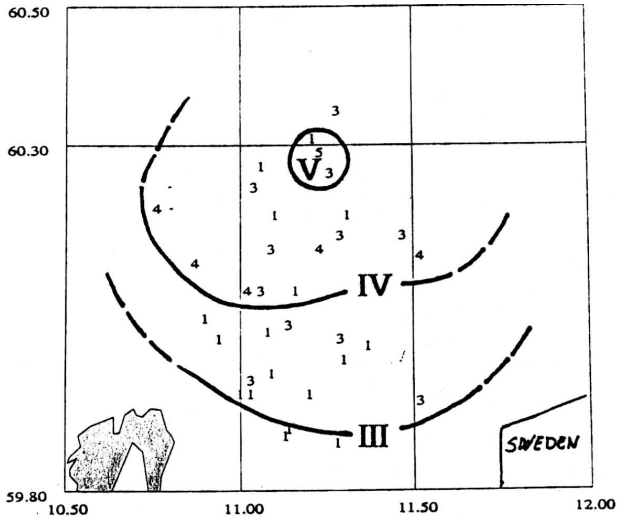
21.01.1996 Ml3.7



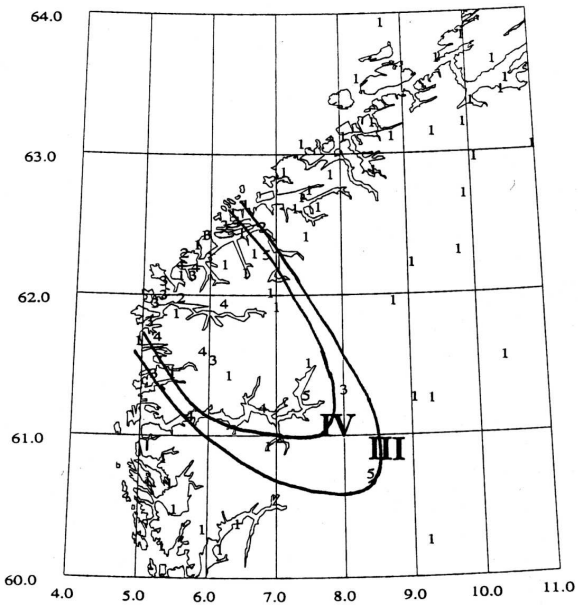
16.04.1996 Ml2.8



28.11.1998 Mc2.4



10.04.1999 Ml2.7



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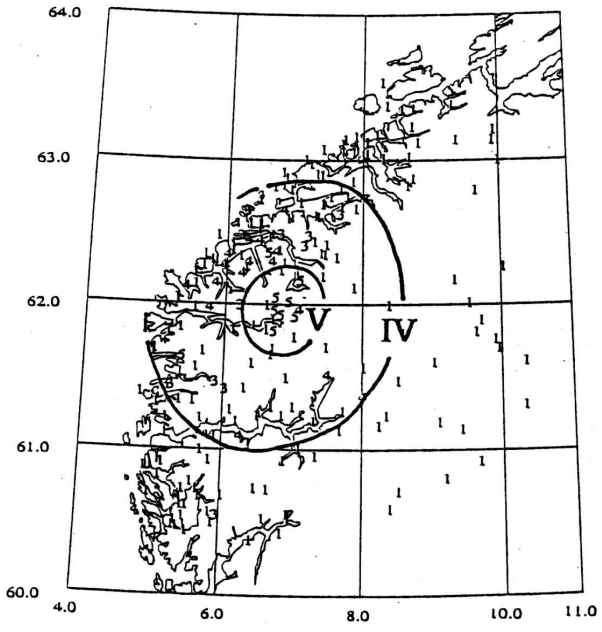

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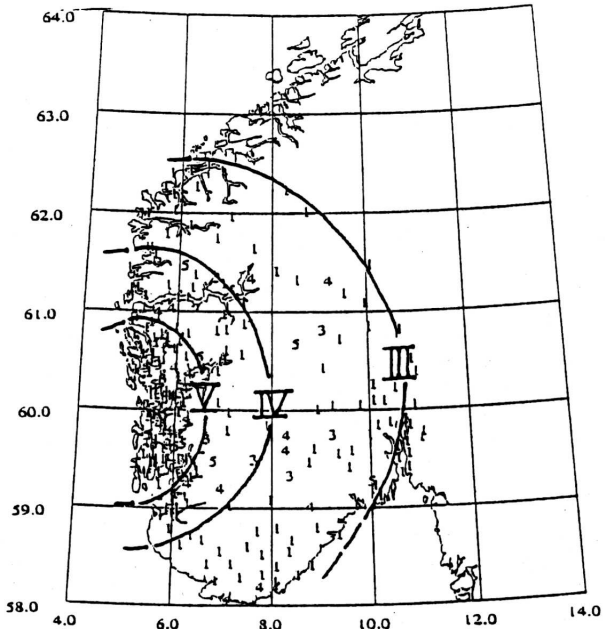

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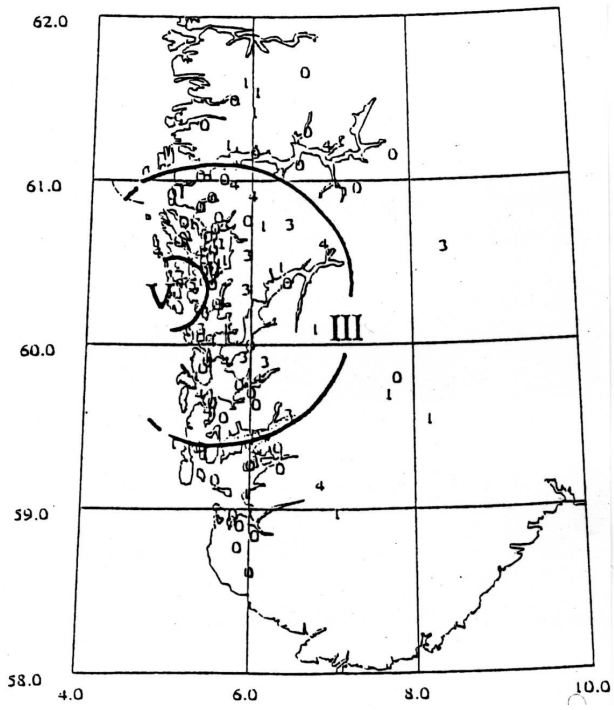

08.12.2000 Mc3.3

Appendix 3 - References

Publications and Reports (1996 – 2000)

Atakan,K. and Havskov,J. 1996. Local site effects in the northern North Sea based on the single station spectral ratios of the OBS data. *Terra Nova* 8, 22-33.

Atakan,K., Karpuz,M.R., and Dahl,S.O. 1996. Importance of geological data in probabilistic seismic hazard assessments: A case study from Etne, Western Norway. IN: V.Schenk (Ed.), *Earthquake Hazard and Risk*, 169-198. Advances in Natural and Technological Hazards Research, Kluwer Academic Publishers, Netherlands.

Atakan, K., 1997. A recent submarine mass-movement in Grunnevika (Duesund), Masfjorden, western Norway. *Technical report* no. 7. Institute of Solid Earth Physics, University of gen, Norway.

Atakan,K. and Langeland,C. 1997. Seismicity and heat-flow, Paleoheatflow project. Progress Report 97-01. Institute of Solid Earth Physics, University of gen.

Atakan,K. 1998. Comments on the possible effects of seismicity on slope instabilities in the Norwegian continental margin, with special emphasis on the Storegga submarine slide. *Technical Report 98-04, prepared for the ENAM project, Geological Institute, University of gen, Norway, 21p.*

Bungum H. and C. D. Lindholm 1997. Seismo- and neotectonics in Finnmark, Kola, and in the southern Barents Sea, Part 2: Seismological analysis and seismotectonics. *Tectonophysics*, Vol. 270, pp. 15-28.

Byrkjeland U., H. Bungum and O. Eldholm (2000): Seismotectonics of the Norwegian continental margin. *J. Geophysical Res*., 105, pp. 6221-6236

Bungum, H., C. Lindholm, A. Dahle, G. Woo, F. Nadim, J.K. Holme, O.T. Gudmestad, T.S. Hag g and K. Karthigeyan (2000): New seismic zoning maps for Norway, the north Sea and UK. *Seism. Res. Lett*., 71, pp. 687-697.

Dehls J. and O. Olesen (eds.) (2000): Neotectonics in *Norway. Annual Technical report 1999. NGU Report 2000.001.*

Dehls J. and O. Olesen (eds.) (2000): Neotectonics in Norway. Final report 2000. *NGU Report 2000.02.*

Federenko, Yu.V., Husebye, E.S., Heincke, B., and Ruud, B.O., 1998. Recognizing explosion sites without seismogram readings: neural network analysis of envelope-transformed multistation SP recordings 3-6 Hz*, Geophys. J. Int.,* 133, F1-F6

Fejerskov, M. & C. Lindholm (1997): Crustal stress in and around Norway; An evaluation of stress-generating mechanisms. *J. Geol. Soc. London* Vol.167

Fjeldskaar W., C. Lindholm, J. Dehls and I. Fjeldskaar (2000): Postglacial uplift, neotectonics and seismicity in Fennoscandia. *Quaternary Science Reviews*, 19, pp. 1413-1422.

Havskov, J and L Ottemøller. SEISAN earthquake analysis software. Seismological Research letters, 70, 532-534.

Hicks, E., 1996. Crustal stresses in Norway and surrounding areas, derived from earthquake focal mechanism solutions and in-situ data, *Cand. scient. thesis, University of Oslo*, 167 pp.

Hicks, E. (1998): Accurate location of seismic events in northern Norway using local network, and implications for regional calibration of IMS stations. *Semiannual Tech. Summ., 1 Octo 1997 - 31 March 1998, NORSAR Sci. Rep. 2-97/98*, Kjeller, Norway, May.

Hicks, E. & H. Bungum (1998): Jordskjelvaktiviteten rundt Bleikvassli gru . *Report. for Gjensidige Forsikring, Oslo,* 11 pp.

Hicks, E., H. Bungum & C. Lindholm (1998): Seismicity in the Ranafjord area. Neotectonics in Norway. *Annual Tech. Rep*., NGU Rep. 98.016. 14 pp

Hicks E., H. Bungum and C. Lindholm (2000): Seismic activity, inferred crustal stresses and seismotectonics in the Rana region, Northern Norway. *Quaternary Science Reviews*, 19, pp. 1423-1436

Hicks E., H. Bungum and C. Lindholm (2000): Stress inversion of earthquake focal mechanism solutions from onshore and offshore Norway. *Norsk Geol. Tidsskrift*. 80, pp. 235-250.

Hicks E. and L. Ottemøller (2000): The ML 4.5 Stord/Bømlo, southwestern Norway, earthquake of August 12, 2000. *Norsk Geol Tidsskrift.*

Husebye, E.S., Ruud, B.O. and Dainty, A.M., 1997. Robust and Reliable Epicenter Determinations; Envelope Processing of Local Network Data, *Bull. Seism. Soc. Am*., 88, 284-290.

Husebye, E.S. and Ruud. B.O., 1997. Seismic wave propagation in the crust - event location in a semiautomatic manner. *Proceedings of the 19th Annual Seismic Research Symposium on Monitoring a Comprehensive Test Ban Treaty, Orlando, FL, 23-25 Sept. 1997*, 242-251.

Husebye, E.S., Ruud B.O. and Federenko, Yu.V., 1998 Automated Explosion Site Recognition Using 3-Component Covariance Time Traces in 12 Frequency Bands for Analysis. *In proceedings of the 20th Annual Seismic Research Symposium on Monitoring a Comprehensive Test Ban Treaty (CTBT), Santa Fe, NM, USA.*

Institute of Solid Earth Physics, UiB and Norsar 2000. A preliminary report on the 12 August 2000, Stord earthquake. *Norwegian National Seismological Network, Technical Report No.9. Institute of Solid Earth Physics, University of gen, Norway,* 5p.

Lindholm, C., H. Bungum, E. Hicks & M. Villagran (1997): Crustal stress and tectonics in Norwegian regions determined from earthquake focal mechanisms. *In* Nøttvedt, A. et al. (eds): Dynamics of the Norwegian Margin. *Geol. Soc., London, Special Publications* 167, pp.429-439.

Lindholm C. and H. Bungum (2000): Probabilistic Seismic Hazard; A review of the seismological frame of reference with examples from Norway. *Soil Dyn. and Earthq. Eng*. 20, pp. 27-38.

Mendi, C.D., Ruud, B.O. and Husebye, E.S., 1997. The North Sea Lg-blockage puzzle, *Geophys. J. Int*., 130, 669-680.

Midzi, V., Singh, D. D., Atakan, K. and Havskov, J. 1999. Transitional continental-oceanic structure beneath the Norwegian Sea from inversion of surface wave group velocity data. *Geophysical Journal International*, 139, 433-466.

NORSAR (1998): Halsnøysambandet. Vurdering av jordskjelvrisiko. *Report prepared for Statens vegvesen, Hordaland Vegkontor, Novem .*

NORSAR (1998): NORZINK A.S., Odda. Earthquake Hazard Analysis for Residue Depository Site Phase 1: *Report for Grøner a.s.*

NORSAR & IKU (1998): Earthquake hazard update and slope stability evaluation Ñ Active faulting and earthquake loading. *Report SP-29-NS-01R-00000-98 prepared for Norsk Hydro Produksjon a.s., Decem .*

NORSAR & NGI (1998): Development of a seismic zonation for Norway. *Report prepared for the Norwegian Council for Building Standardization (on behalf of a consortium of industrial partners)*, NORSAR, 185 pp

NORSAR (1999): NORZINK A.S., Odda. Earthquake Hazard Analysis for Residue Depository Site. Phase 2: Detailed analysis. *Report for Grøner a.s.*

Ottemøller, L and J. Havskov. SEISNET: A general purpose virtual seismic network, *Seismological Research Letters*, 70, 522-528

Pacesa, Andrius. Near surface attenuation in Norway, *MSc thesis, University of gen.*

Sellevoll, A, H. Bungum and J. Havskov. Fra spørreskjema til storpolitikk, *GEO*, Februar 1999, 12-16.

Oral and poster presentations (1996 – 2000)

Atakan,K. 1996. Jordskjelv: Opprinnelse og Konsekvenser. Faglig Pedagogiskdag. Universitetet i gen, Norway, Feb.2.

Atakan,K., Anundsen,K. and Helle,S.K. 1996. Seismotectonics in Southwestern Norway: correlation with local fault zones and geodetic measurements. 25th General Assembly of the European Seismological Commission, Reykjavik, Sep. 9-14.

Atakan,K. 1996. Jordskjelv: Opprinnelse og konsekvenser. Populærvitenskapelig foredrag, Åpen dag for Realfag, Universitetet i gen, 50 års jubileum. gen, Okt. 5.

Atakan,K. 1996. Seismicity and heat-flow in the Vøring margin. Paleoheat-flow Project Meeting (Vøring margin), Norsk Hydro a.s., gen Research Centre, Octo 28.

Atakan,K. 1996. Jordskjelvrisiko i Norge: har vi råd til å neglisjere den? Den Norske ASTIN-gruppe (NAG), undergruppe av Den Norske Aktuarforening, Samvirke Forsikring a.s., Oslo, Novem 15.

Atakan,K., Anundsen,K. and Helle,S.K. 1997. Seismotectonics at Yrkje, Southwestern Norway: Correlation with local fault zones and geodetic measurements. Norsk Geologisk Forening XV Landsmøte (NGF-97), University of gen, gen, Norway, Jan.9-11, 1997.

Atakan,K. 1997. Jordskjelvsrisiko i Norge: Ren statistikk eller virkelighet? Norsk Statistisk Forening, gen, Norway, 15 May 1997.

Atakan,K. and Dahle,A. 1997. Recent felt earthquakes in Norway. 28th Nordic Seminar on 'Detection Seismology', Helsinki, Finland, 16-18 June 1997.

Atakan,K. Anundsen,K. and Helle,S.K. 1998. Active tectonics in intraplate areas: A case study from Southwestern Norway. Abstract in the 'ESC XXVI General Assembly', 23-28 Aug.1998, Tel Aviv, Israel.

Atakan, K. The role of Caledinoan structures in present day seismicity of Norway and the adjacent areas. *Geonytt* No.1, 2000, 33

Bungum, H. (1998): Seismotectonics on- and offshore in Mid Norway, with emphasis on the correlation between mapped earthquakes and mapped faults. 29th Nordic Seminar on Detection Seismology, Karasjok, Norway, August.

Bungum, H. (1998): A new seismic zonation for Norway. 29th Nordic Seminar on Detection Seismology, Karasjok, Norway, August.

Bungum, H., Hicks, E., Lindholm, C., Olesen, O., Dehls, J., Olsen, L., Bockmann, L. & Riis, F. 1999: Neotectonics in Norway - NEONOR. Abstract. International Association of Seismology and Physics of the Earth's Interior, International Union of Geodesy and Geophysics, Birmingham 19-30 July 1999. A.170. Poster

Bungum H., O.T. Gudmestad, T.S Hag g, J.K. Holme, K. Karthegian, C. Lindholm, F. Nadim and G. Woo (1999): New seismic zonations in cooperation between Norway and UK. Abstract. Ninth Int. Conf. on Soil Dynamics and Earthquake Engineering, SDEE `99, gen, August 9-12, 1999.

Bungum, H. and U. Byrkjeland. 1996. Seismotectonics of the mid-Norwegian margin, 25th General Assembly of the European Seismological Commission, Reykjavik, Sep 9-14.

Bungum, H., C.D. Lindholm & A. Dahle. 1996. European historical seismograms as a basis for long period ground motion prediction models. 25th General Assembly of the Europe an Seismological Commission, Reykjavik, Sep. 9-14

Bungum, H., A. Dahle & C.D. Lindholm. 1996. Methodologies, models and uncertainties relating to seismic hazard analyses in Norway. 25th General Assembly of the European Seismological Commission, Reykjavik, Sep. 9-14.

Bungum, H., M. Roth and R.A.W. Haddon: Full waveform modelling of the August 17, 1999, Kola Peninsula earthquake. 31st Nordic Seminar on Detection Seismology, Korsør, Denmark, 27-29 Septem 2000.

Bungum, H.: Neotectonics, earthquakes and seismodynamics in Norway: Results and implications. Industrial Liaison Annual Meeting, Department of Geology, University of Oslo, 13 Octo 2000.

Bungum, H.: Ground motions from large European earthquakes: Data base and prediction models. 29th General Assembly of IASPEI, Thessaloniki, Greece, 18-28 August 1997.

Baadshaug, U. & S. Mykkeltveit: NOR_NDC; Norwegian Data Center. 28th Nordic Seminar on Detection Seismology, Helsinki, Finland, 16-17 June 1996.

Dehls, J., O. Olesen, H. Bungum & C. Lindholm: NEONOR: Neotectonics in Norway. ES-SSA 97 Abstract. Seismological Society of America, Eastern Section, Ottawa, 6-9 Octo .

Fedorenko, Y., Husebye, E.S. and Ruud. B.O. Epicenter locations tied to ANN multidimentional envelope waveform recognition. 29th General Assembly of the IASPEI, Thessaloniki, Greece, 18-28 Aug. 1997.

Federenko, Yu.V., Husebye, E.S., Ruud, B.O. and V. Pinsky: Explosion Site Recognition; Neural Net Discriminator Using Single 3-Component Stations. XXVI General Assembly of the European Seismological Commision (ESC), Tel Aviv, Israel, August 23-28, 1998.

Havskov, J. 1996. Coda Q from different tectonic provinces,. 25th General Assembly of the European Seismological Commission, Reykjavik, Sep. 9-14.

Havskov, J., Computer communication and seismic networks. 29th General Assembly of the IASPEI, Thessaloniki, Greece, 18-28 August 1997.

Havskov, J., Sismologia en Noruega. Instituto Nacional de Sismologia, Santiago de Cuba, Cuba, April.

Hicks, E.C., Bungum, H. & Lindholm, C.D. 1999: Concentrated earthquake zones on the Norwegian continental margin. Abstract. International Association of Seismology and Physics of the Earth's Interior, International Union of Geodesy and Geophysics, Birmingham 19-30 July 1999. A.166.

Hicks, E., H. Bungum, C. Lindholm & O. Olesen (1998): New seismicity and focal mechanism stress data from Ranafjord, northern Norway. European Geophysical Society Annual Meeting, Nice, April.

Hicks, E., H. Bungum & F. Ringdal (1998): Results from a new local seismic network in Ranafjord, northern Norway, and comparison of epicenter locations to NORSAR GBF locations. 29th Nordic Seminar on Detection Seismology, Karasjok, Norway, August.

Hicks, E., H. Bungum & C. Lindholm (1998): Crustal stresses in onshore and offshore Norway. Preliminary results from the inversion of earthquake focal mechanism solutions. 29th Nordic Seminar on Detection Seismology, Karasjok, Norway, August.

Hicks, E., H. Bungum, C. Lindholm & J. Dehls (1998): The NEONOR project: Neotectonics in Norway. 29th Nordic Seminar on Detection Seismology, Karasjok, Norway, August.

Hicks, E.: Stress inversion of earthquake focal mechanism solutions in Norway. 28th Nordic Seminar on Detection Seismology, Helsinki, Finland, 16-17 June 1997.

Hogden S. 1996. A regional overview of the seismotectonic and crustal conditions in the Svalbard region. Seminar for Applied Goephysics, Tomte, Univ. of Oslo, 14-15 nov.

Husebye, E.S. and Ruud. B.O. Fast, Robust and Reliable Epicenter Determinations - Envelope Processing of Local Network Data. 29th General Assembly of the IASPEI, Thessaloniki, Greece, 18-28 Aug. 1997.

Husebye, E.S. and Ruud. B.O. Seismic wave propagation in the crust - event location in a semiautomatic manner. 19th Annual Seismic Research Symposium on Monitoring a Comprehensive Test Ban Treaty, Orlando, FL, 23-25 Sept. 1997.

Husebye, E.S. Ruud B.O. and Federenko, Yu.V. 1998.: Automated Explosion Site Recognition Using 3-Component Covariance Time Traces in 12 Frequency Bands for

Analysis. 20th Annual Seismic Research Symposium on Monitoring a Comprehensive Test Ban Treaty (CTBT), Santa Fe, TX, USA, Septem 21-23.

Höhne, E. Hicks and H. Bungum (2000): MASI-Project 1999; A Seismic Survey to Study Neotectonic Phenomena in the Finnmark Area. Nordic Detection seminar, Korsør 27-29 Septem , 2000

Kremenetskaya, E., V.E. Asming & F. Ringdal: Study of travel-time models for the Barents region. 28th Nordic Seminar on Detection Seismology, Helsinki, Finland, 16-17 June 1997.

Kværna, T. & F. Ringdal: Event magnitude, capability maps and magnitude thresholds. 28th Nordic Seminar on Detection Seismology, Helsinki, Finland, 16-17 June 1997.

Kværna, T. & F. Ringdal: Event magnitudes, capability maps and magnitude thresholds. Proc. 19th Annual Seismic Research Symposium on Monitoring a Comprehensive Test BanTreaty, 23-25 Septem .

Lindholm, C., H. Bungum, A. Dahle, K. Atakan, R. Wahlström, S. Gregersen, P. Manyniemi, M. Uski & G. Grünthal: Seismic zonation of Scandinavia (a GSHAP subproject). 29th General Assembly of IASPEI, Thessaloniki, Greece, 18-28 August 1997.

Lindholm C.D., M. Fejerskov, H. Bungum and E. Hicks. 1996. Crustal stress in Norwegian regions; Observations and stress generating mechanisms. 25th General Assembly of the European Seismological Commission, Reykjavik, Sep. 9-14.

Lindholm C.D., H. Bungum, A. Dahle and O. Olesen. 1996. Stuoragurra, a seismically active post-glacial fault in Norway; Implications for Hazard modeling. 25th General Assembly of the European Seismological Commission, Reykjavik, Sep. 9-14.

Lindholm C., J. Schweitzer, F. Krüger, F. Scherbaum, G. Richter, J. Höhne, E. Hicks and H. Bungum: MASI-project 1999, a seismic survey to study neotectonic phenomena in the Finnmark area. Poster presentation. XXVII General Assembly of the European Seimological Commission (ESC), Lisbon, Sept. 10 -15, 2000.

Lindholm C., S. Molina and H. Bungum (2000): Probabilistic Seismic Hazard Analysis: Zoning Free versus zoning methodology. Nordic Detection seminar, Korsør 27-29 Septem , 2000. Lindholm C., J. Schweitzer, F. Krüger, F. Scherbaum, G. Richter, J.

Lindholm C., J. Schweitzer, F. Krüger, F. Scherbaum, G. Richter (2000): MASI-project 1999, a seismic survey to study neotectonic phenomena in the Finnmark area. Poster session. European Seismological Commission (ESC), Lisbon, 10-15 Septem .

Lindholm, C., H. Bungum, A. Dahle, J. Schweitzer, F. Nadim & J. Holme (1998): A new seismic zonation for Norway. 29th Nordic Seminar on Detection Seismology, Karasjok, Norway, August.

Lindholm, C., H. Bungum, A. Dahle, J. Schweitzer, F. Nadim & J. Holme (1998): A new seismic zonation for Norway. XXVI General Assembly, ESC, Tel Aviv, Israel, August.

Lindholm C. D., H. Bungum, A. Dahle, F. Nadim, J. Holme and G. Woo (1999): Seismic zonation for Norway. Abstract. International Association of Seismology and Physics of the Earth's Interior, International Union of Geodesy and Geophysics, Birmingham 19-30 July 1999.

Lindholm C. and H. Bungum (1999): Earthquake hazard in Norway: The seismological frame of reference. Ninth Int. Conf. on Soil Dynamics and Earthquake Engineering, SDEE `99, gen, August 9-12, 1999.

Mendi, C.D., Ruud, B.O. and Husebye, E.S. The North Sea Lg-blockage puzzle. 29th General Assembly of the IASPEI, Thessaloniki, Greece, 18-28 Aug. 1997.

Midzi,V., Singh,D.D., Atakan,K. and Havskov,J. 1998. Quasi-continental oceanic structure beneath theNorwegian Sea from inversion of surface wave group velocity data. Abstract in the 'ESC XXVI General Assembly', 23-28 Aug.1998, Tel Aviv, Israel.

Molina S., C. D. Lindholm and H. Bungum (2000): Zone Free versus Zoning Methodology in Seismic Hazard. Poster session. European Seismological Commission (ESC), Lisbon, 10-15 Septem .

Ottemøller, L. and J. Havskov. Automatic data collection in the Norwegian national seismic network. XXVI General Aseembly of the European Seismological Commission, Israel, August.

Ottemöller, L. 1997. Determination of velocity models for Norway by inverting travel times of local earthquakes and explosions. 29th General Assembly of the IASPEI, Thessaloniki, Greece, 18-28 Aug. 1997.

Ringdal, F., C. Lindholm, H. Bungum & A. Dahle: Earthquake hazard zonation in NW Europe. 28th Nordic Seminar on Detection Seismology, Helsinki, Finland, 16-17 June 1997.

Wolf, E., C. Lindholm, H. Bungum, K. Atakan, S. Gregersen, K. Arhe & J. Malaska: Seismogeographical regionalization of Scandinavia. 29th General Assembly of IASPEI, Thessaloniki, Greece, 18-28 August 1997.