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6.4 The MASI-1999 field experiment

Introduction

In northern Norway, the seismicity is relatively low (e.g. Bungum et al. (1991)). However, the Stuoragurra fault near Masi in Finnmark came in focus, after Olesen (1988) discovered that this fault shows a vertical offset of at least 8 m since the glaciation of the last ice age. Some of the open questions in connection with this fault are: How active is this fault today? Can the recent seismicity be connected to the observed faultgauge and are observed source mechanisms compatible with the orientation of the fault? How deeply can this fault be traced into the crust?

To investigate these questions, NORSAR was interested in installing a temporary network of seismic stations in Finnmark. NORSAR got the information that the University of Potsdam, Germany, owns a set of 13 mobile seismic stations, which were available for such an experiment during the summer of 1999. Therefore, NORSAR planned the field experiment MASI-1999 as a cooperative effort between the two institutions.

Because the ARCES array is also located in Finnmark, all investigations of the structure of this area are in also part of the needed calibration of this primary station of the IMS network. Study the wave field from local and regional events using many stations distributed over the whole area, will give a better understanding of the observations of local and regional phases at the ARCES array.

Some time ago, Frank Krüger from the Institute of Geoscience at the University in Potsdam, Germany, was involved in a study about possible source locations of microseisms. He found in the data of the Gräfenberg array in southern Germany indications that one source of microseisms is most likely located north of Scandinavia in the Norwegian and / or Barents Sea (Krüger, 1998). To get a better location for the source region where these microseisms are generated, it is interesting to observe the microseisms in the vicinity of the assumed source region.

So, different interests for installing a temporary seismic network in Finnmark came together, and the project MASI-1999 was carried out.

The field experiment and the data base

In the time period 18 - 27 May 1999, 13 Lennartz MARSlite data loggers equipped with three-component LE-3D/5s seismometers were installed. These instruments have an eigenperiod of 5 seconds. The coordinates of the seismometer sites are given in Table 6.4.1 and Fig. 6.4.1 shows a corresponding map of the Finnmark area. The poles and zeroes of the transfer function are given in Table 6.4.2. During the installation phase, one station was running in parallel at the ARCES array site ARA0 to check the compatibility of data from the mobile stations and the ARCES array. At all sites, continuous data were recorded and written on hard disks. With the chosen sampling rate of 125 samples per second, these hard disks were filled up after about 2 months. Therefore, two disk-change and maintenance trips were necessary during the deployment time of the mobile stations. In the middle of August, during the last disk-change trip, the station MA05 was moved to the ARCES array site ARA0, to have a continuous data stream available also during the ARCES refurbishment and upgrading in September 1999. The field experiment was finished during the last days of September, when all stations were dismantled and sent back to Germany. The last available data records from the mobile stations were from 1

October 1999. The performance of the 13 stations was quite good, only 3 stations had outages (see Table 6.4.1) due to technical problems.

All data from the mobile stations were stored continuously on recordable CDs together with all available data from the permanent stations in and around Finnmark: ARCES, KEV, KTK, and TRO (see Fig. 6.4.1). The data from the Kevo station (KEV) are, except for some minor outages, continuously available. We included in our data base the output of the broad-band 80 Hz sampled Guralp CMG-3T instrument at KEV. The short period data from the stations Kautokeino (KTK) and Tromsø (TRO) are unfortunately triggered data, so that these stations contribute little to the data base. All data from the ARCES array (i.e. all short period array channels and the channels from the ARCES broad-band site ARE0) were copied into the data base. However, due to the ARCES upgrading work, the ARCES array was out of operation for about 3 weeks. The data from both the mobile MASRlite stations and the other stations were reformatted into a common GSE2.0 format (double differences, 6 bit compression).

The whole data base is copied to CDs, to have all data easily available by direct access. One CD usually contains the data for a half day. In addition, all available bulletins were copied to the CDs, i.e. the automatically produced listings of NORSAR's data processing for ARCES and Apatity (detection lists, fk-lists, the single array location bulletins, and the GBF bulletins), the preliminary Scandinavian bulletin produced at the University of Helsinki, and the pIDC-produced REBs. Because the experiment ended only a few weeks ago, the production of these CDs at NORSAR has just been completed. For backup, the contents of all CDs were copied in addition onto EXA-BYTE tapes. As soon as possible, the data base will be copied to a second set of CDs at the University in Potsdam such that both partners can work with the data in their research programs.

Data examples

Although the field experiment and the production process of the recordable CDs ended very recently, some preliminary data examples of this campaign can be shown. Because one main topic of this experiment was the detection of neotectonic movements in northern Scandinavia, a first screening of the data concentrates on local and regional events which cannot be associated to known sources of man-made seismic sources like the northern Swedish iron mines or the mines and quarries on the Kola peninsula, Russia.

Unfortunately, a felt earthquake in the north-east of the Stuoragurra fault system (30 March 1999) occurred just before the mobile stations were installed, and the largest earthquake in recent years offshore of Tromsø (17 October 1999) occurred two weeks after demobilization of the stations. Although we missed these two very interesting events, we recorded some local seismicity. Up to now, the data until the end of June 1999 have been preliminarily searched. During this time at least two smaller, non felt events could be found and located. One on the Stuoragurra fault and one at the end of the Porsanger Fjord, in addition, on 22 August 1999, a M_L 2.6 (GBF) event occurred near Masi on the Stuoragurra fault, which was large enough to be felt by local people.

Fig. 6.4.2 shows vertical-component seismograms of the small event at the end of the Porsanger Fjord on 24 May 1999. All seismograms shown were recorded in 1° to 2° epicentral distance range. This event with M_L = 1.9 (GBF) was not observable at all stations and shows a relatively low SNR. However, with the MASI-1999 stations the epicenter could be well located

(see Table 6.4.3). For estimating the depth of this event, which presumably occurred close to the Earth's surface, a better S velocity model of the region is needed.

Fig. 6.4.3 shows a map with unfiltered records at all temporary seismic stations (vertical components) of the felt event from 22 August 1999 south of Masi on the Stuoragurra fault. Fig. 6.4.4 shows the same records as single seismograms, and Fig. 6.4.5 shows the same data high-pass filtered above 40 Hz. Note the low attenuation for the high frequently energy in this region. A preliminary location of the event is listed in Table 6.4.3.

On 17 August 1999 a mining induced event occurred near Lovozero on the Kola peninsula. The event was the strongest earthquake observed during the last years in this area and was well recorded with the MASI-1999 stations. Fig. 6.4.6 shows the raw data and Fig. 6.4.7 the broad-band filtered (8 - 20 s) data, where a dominant Rayleigh wave is visible. Using these Rayleigh observations, one can get a surface wave magnitude estimate of $M_S = 4.3$. The traditional IASPEI formula was applied by measuring amplitudes at shorter dominant periods for the 2° to 5° distance range (e.g. see Willmore, 1979). The measured magnitude is consistent with Kværna et al. (1999), who used NOA and ESDC broad-band data to derive $M_S = 4.2$.

The main set of observed events is related to mining explosions in the Nikel area, Russia and to the Kiruna area of Sweden. Fig. 6.4.8 shows the bandpass filtered (6 - 10 Hz) vertical-component traces of an explosion in the Nikel area.

Further Work

The examples shown indicate that the records of the MASI-1999 experiment are usable to address different scientific issues:

- neotectonic movements on the Stuoragurra fault in Finnmark.
- fault plane solutions for the best observed events in this area.
- better travel-time tables for local/regional P- and S-phases.
- Moho depth measurements in this region with receiver function studies.
- local/regional amplitude attenuation curves by observing the same event at different distances.
- an improved S-phase understanding in northern Scandinavia by analyzing the 3C data.
- crustal structure by inversion of local/regional surface waves.
- source studies of the ocean generated microseisms.
- relative location of seismic events in the different mining areas.

J. Schweitzer

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Friedrich, A., F. Krüger, & K. Klinge (1998). Ocean-generated microseismic noise located with the Gräfenberg array. *J. of Seismology* **2**, 47 - 64.

Kværna, T., L. Taylor, J. Schweitzer & F. Ringdal (1999). Continious assesment of upper limit M_S. *Semiannual Technical Report 1 April - 30 September 1999.* NORSAR Sci. Report 1-1999/2000, Keller, Norway.

Olesen, O. (1988). The Stuoragurra fault, evidence of neotectonics in the Precambrian of Finnmark, northern Norway. *Norsk Geologisk Tidsskrift* **68**, 107 - 118.

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Station	lat [°]	lon [°]	elev. [m]	start time	end time	outages
MA00	69.5346	25.5056	403	18-05-1999 18:16:40	01-10-1999 14:34:59	24-05-1999 13:26:53 - 17-08-1999 10:16:34
MA01	69.3752	24.2122	315	18-05-1999 14:29:01	30-09-1999 11:00:00	-
MA02	69.1875	25.7033	160	19-05-1999 10:19:30	29-09-1999 13:40:38	01-07-1999 21:42:56 - 15-08-1999 17:54:11
MA03	70.0210	27.3962	95	19-05-1999 16:00:59	01-10-1999 09:26:09	-
MA04	69.7127	29.5059	20	19-05-1999 20:41:22	01-10-1999 06:01:02	-
MA05	69.4533	30.0391	30	20-05-1999 09:27:04	16-08-1999 13:05:41	-
MA06	70.4813	25.0610	50	21-05-1999 09:43:37	28-09-1999 12:07:39	-
MA07	69.7050	23.8203	265	21-05-1999 15:44:24	29-09-1999 07:30:27	-
MA08	70.1278	23.3736	15	22-05-1999 09:01:06	29-09-1999 09:38:23	31-07-1999 15:57:28 - 07-08-1999 10:40:41
MA09	69.4566	21.5334	90	22-05-1999 16:01:08	27-09-1999 13:00:00	-
MA10	69.5875	23.5274	375	23-05-1999 16:26:27	30-09-1999 07:00:00	-
MA11	68.6595	23.3219	390	24-05-1999 09:04:58	30-09-1999 09:09:13	-
MA12	69.8349	25.0824	75	24-05-1999 16:35:00	29-09-1999 07:45:51	19-06-1999 17:58:00 - 27-06-1999 08:01:11
MA13	70.3161	25.5156	30	25-09-1999 08:42:10	29-09-1999 05:27:19	-
GP03	69.99	24.94	20	18-05-1999 08:56:17	24-05-1999 19:00:00	-

Table 6.4.1. *Coordinates and recording times of the MASI-1999 mobile station experiment in Finnmark, Norway (the exact end times can be some minutes later). MA00 is the station which recorded at the beginning and at the end of the experiment in parallel with the ARCES array site ARA0. The equipment of the station MA12 was used at MA00 during the first week, and in August the station MA05 was dismantled and the equipment moved to MA00 until the end of the experiment. All dates and times are in the format [dd-mm-yyyy hh:mm:ss]. Station GP03 was used to test some equipment during the first week of the experiment in Lakselv. Although the data are very noisy, they were also stored on the CDs. This station was moved at the end of the installation phase to station MA13.*

	Real	Imaginary
Constant	6.419832	0.0
Poles	-0.8884425	-0.8887107
	-0.8884425	0.8887107
	-0.4272566	0.0
Zeroes	0.0	0.0
	0.0	0.0
	0.0	0.0
	0.0	0.0

Table 6.4.2. *Parameters of the transfer function (poles and zeroes in the Laplace domain) for the MASI-1999 experiment mobile station. Applying these parameters, the units of the transfer function are [counts/nm].*

DATE	TIME	LATITUDE	LONGITUDE
24 May1999	05:00:12.8	70.91	26.53
22 August 1999	02:08:47.9	69.27	23.70

Table 6.4.3. *Epicentral parameters of two local events, which were observed with the MASI-1999 stations and for which data are shown in Fig. 6.4.2 - 6.4.5.*

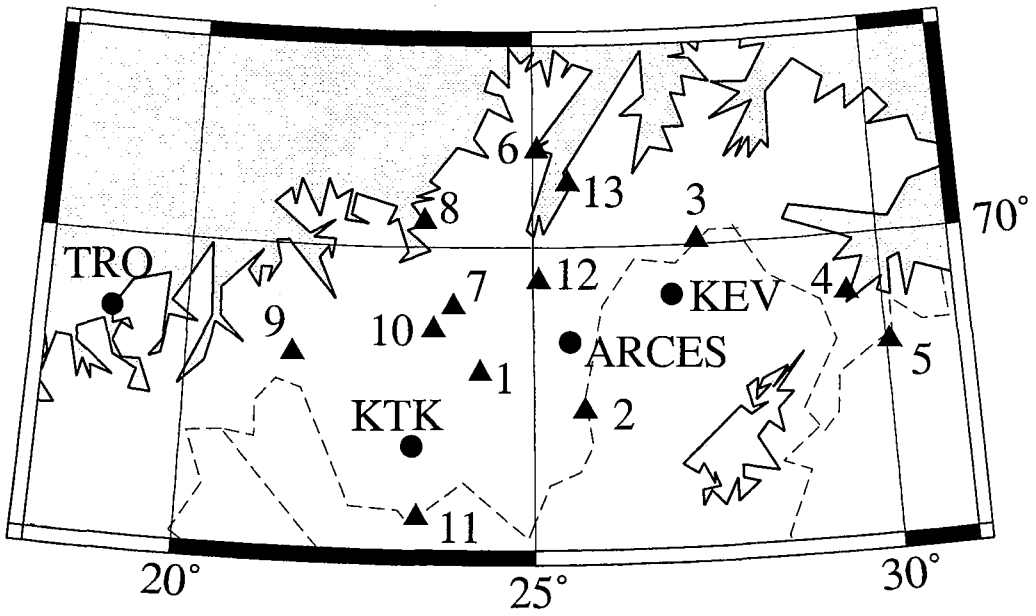

Fig. 6.4.1. *Map of all 13 MASI-1999 stations in Finnmark (triangles). The dots show the positions of the permanent stations ARCES, KEV, KTK, and TRO in the same area. The station MA00 was located at ARCES.*

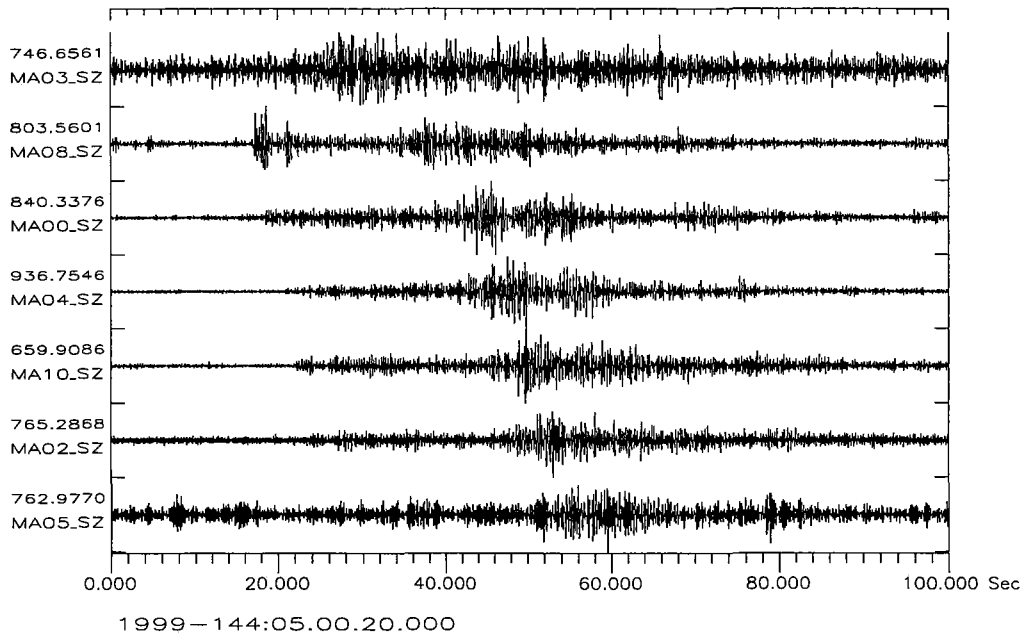

Fig. 6.4.2. *Vertical- component seismograms of the M_L 1.9 event on 24 May 1999 (see Table 6.4.3). The seismograms were band-pass filtered between 3 and 9 Hz, the epicentral distances to the stations are between 1° and 2°.*

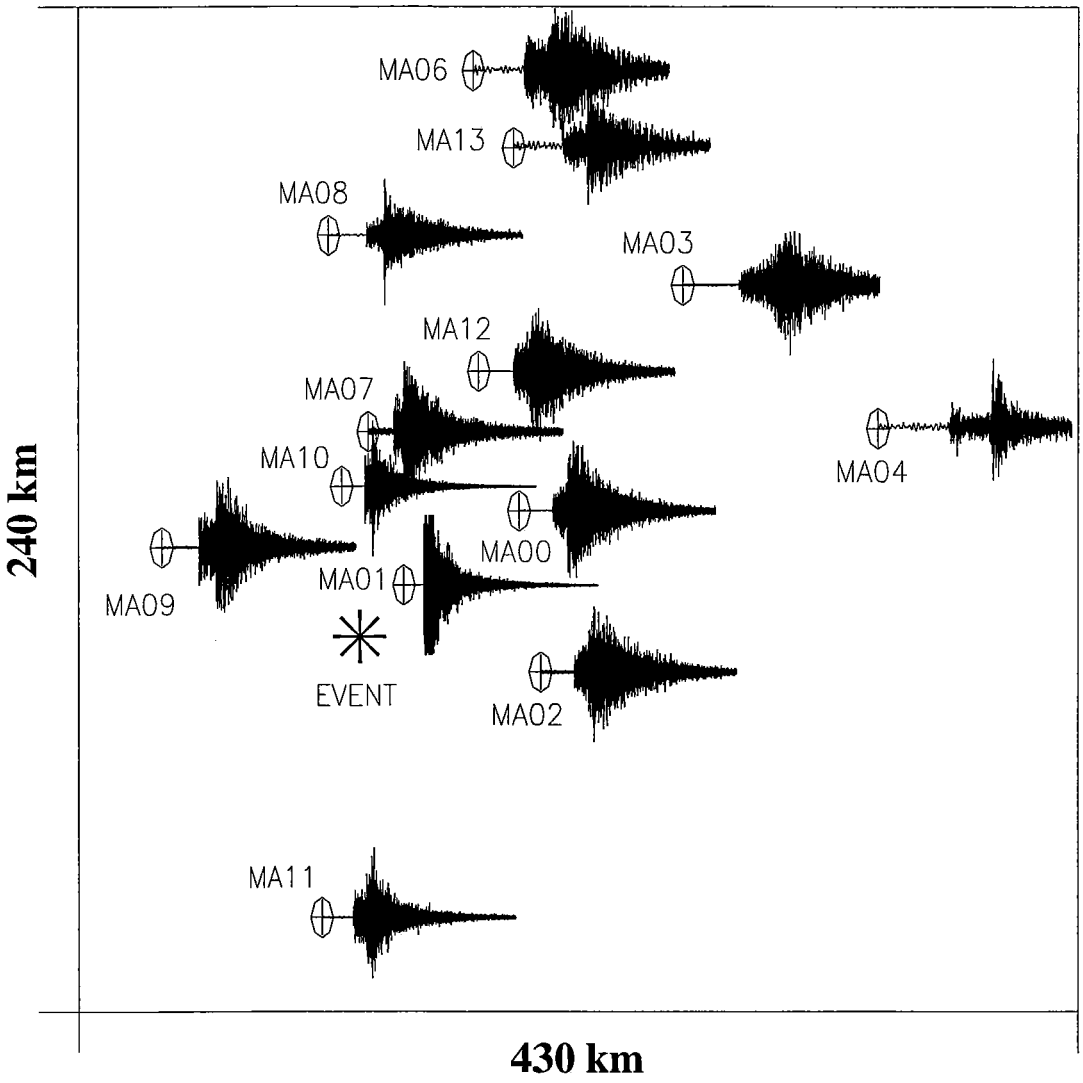

Fig. 6.4.3. *Geographical distribution of observed seismograms with respect to the felt event of 22 August 1999. Shown are unfiltered vertical-component traces. Note that the seismogram at station MA01 is clipped, and the different amplitude ratio between P and S onsets.*

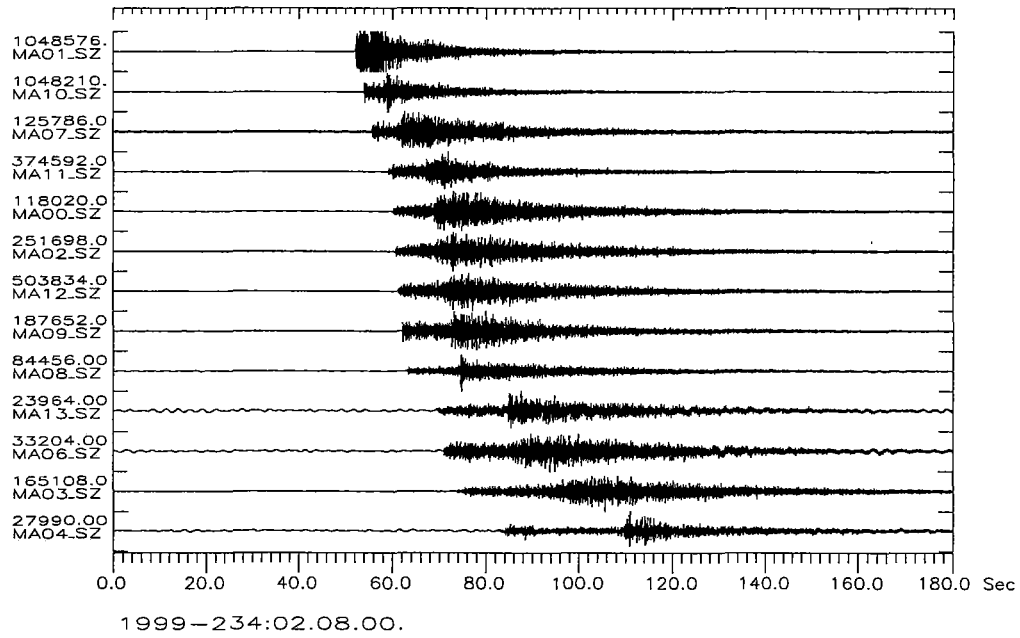

Fig. 6.4.4. *The unfiltered vertical-component records at all MASI-1999 stations of the 22 August 1999 M_L 2.6 event at the Stuoragurra fault. The stations observed the event in epicentral distances between 0.2° and 2°. The closest station MA01 was clipped.*

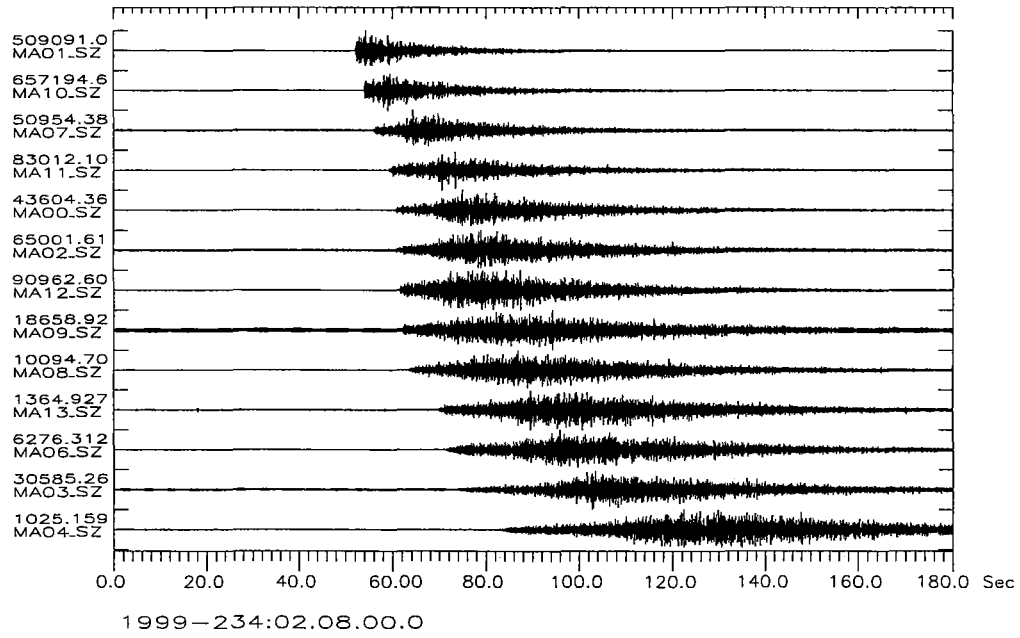

Fig. 6.4.5. *The same data as in Fig. 6.4.4., now filtered with a Butterworth high-pass at 40 Hz. Note the high-frequency scattered energy, which is an indication for a relative high Q structure in the Finnmark area.*

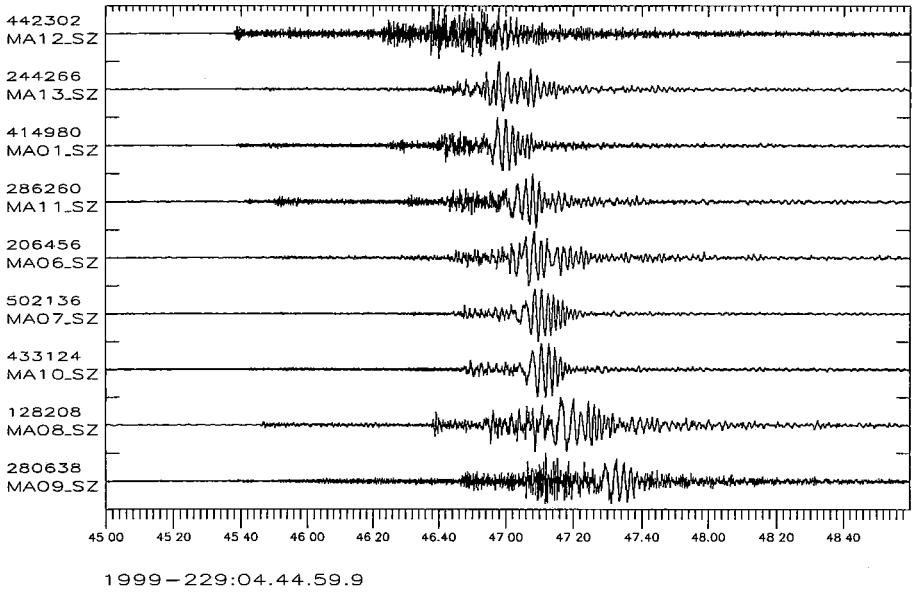

Fig. 6.4.6. *The raw seismograms of the Lovozero event 17 August 1999 as observed at some of the MASI-1999 stations.*

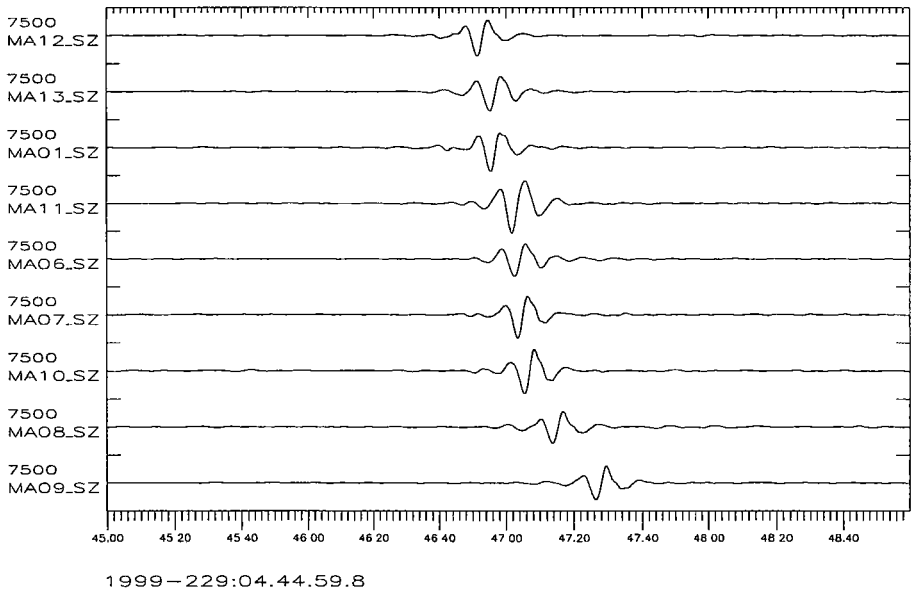

Fig. 6.4.7. *Seismograms of the Lovozero event 17 August 1999 now filtered with a Butterworth band-pass filter between 8 and 20 seconds. The amplitude scale was normalized to the maximum amplitude. From these data the a M_S value 4.3 was determined.*

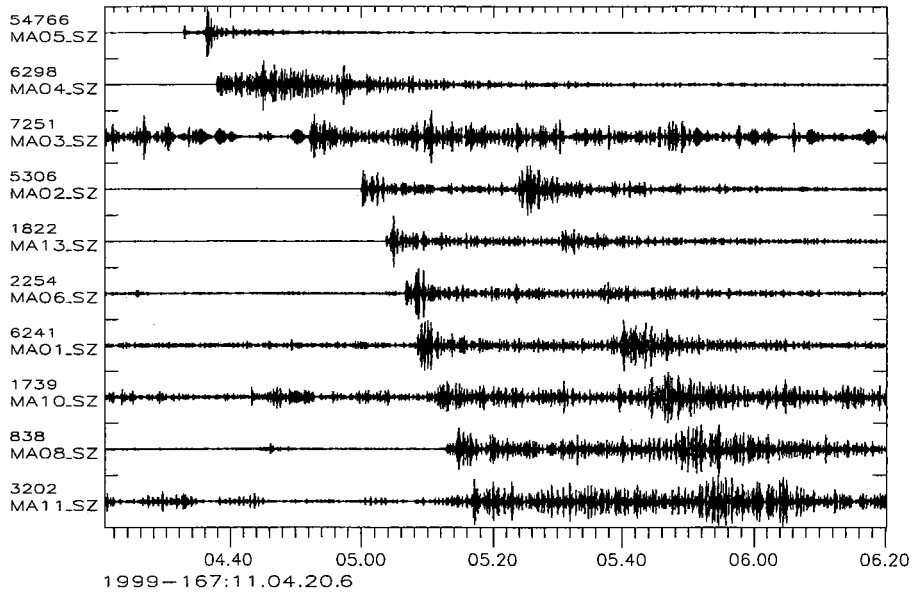

Fig. 6.4.8. *Seismograms of an explosion on 16 June 1999 in the Nikel area (Russia), close to the MASI-1999 station MA01. The seismograms were band-pass filtered between 6 and 10 Hz.*