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Linda B. Loughran (Ed.)

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VII.6 Teleseismic detection at high frequencies using NORSAR data

This paper summarizes initial results from NORSAR noise and signal studies aimed at identifying possibilities to improve the detection capability of the NORSAR array. Particular emphasis is given to high-frequency signals (2-5 Hz), which are typical for NORSAR recordings of many Eurasian events.

Noise characteristics. Bungum and Mykkeltveit (1984) have summarized the main features of seismic noise spectra observed at NORSAR. These spectra are characterized by a very strong microseismic peak at 0.2-0.3 Hz, especially during North Sea storm activity. The spectral slope is very steep (50 dB/decade) up to at least 40 Hz, and the NORSAR noise at high frequencies is among the lowest observed. Above 2 Hz, there is little difference between "high noise" and "low noise" conditions, except that cultural activities cause increases in high frequency noise during day time. Because of the limited resolution and gain ranging applied at NORSAR, the spectra actually observed at NORSAR instruments are biased high above 3 Hz as discussed by Bungum (1983).

Signal characteristics. Main features, discussed by Ringdal and Husebye (1982) are a) large and region-dependent variation in signal levels across NORSAR, often spanning an order of magnitude across the array, b) significant deviations from a plane wavefront model, making steering delay corrections necessary in the beamforming process, and c) significant energy at high frequencies (> 2 Hz) from Eurasia, especially for underground explosions.

Detection algorithms. Current Detection Processor (DP) procedure at NORSAR (Ringdal, 1981) is to form conventional array beams with a filter of 1.2-3.2 Hz and envelope beams with a filter of 1.6-3.2 Hz. These beams are then subjected to a linear STA/LTA detector and passed through a grouping algorithm to delete side lobe detections. In the present study, we have analyzed SNR of a number of presumed explosions from Eurasia by applying 8 predetermined bandpass filters to:

(a) An array beam using current DP steering delays (0.1 sec accuracy)
(b) An array beam using recomputed delays (0.05 sec accuracy)
(c) An optimum weighted array beam, with steering delays as in (b) and each channel weighted by S/N^2 (S = signal amplitude, N = noise amplitude)
(d) The best subarray beam for the particular event.

Examples of results are shown for two events in Figs. VII.6.1 and VII.6.2. These results, which are largely confirmed (with few exceptions) by the other events analyzed, give that:

(a) Significant gains are possible by applying more high-frequent filters than currently done.
(b) The weighted array beam is generally best, while the best subarray beam SNR is quite close (within 2-3 dB average).
(c) Gains compared to current processing can reach 10-20 dB for high-frequent signals, and somewhat less for signals of low dominant frequency.

Detection performance for presumed explosions. By comparing the SNR of the best beam to the event magnitude, it is possible to estimate approximately the optimum NORSAR thresholds, i.e., thresholds that could be achieved if processing as indicated above were implemented. We have found that (cf. Figs. VII.6.3 and VII.6.4) these "instantaneous" detection thresholds are:

- West of Ural Mountains: m_b 2.0-2.5 (possibly better)
- Caspian Area m_b 2.0-2.5
- Semipalatinsk m_b 2.5-3.0
- Siberia m_b 2.5-3.5

It is noteworthy that there is a large range in thresholds across Eurasia, and this can be interpreted as being due to "source focusing" effects similar to the "receiver focusing" effects routinely observed at NORSAR.

Detection in the coda of an earthquake. An example of the importance of high-frequency detection in this connection is given in Fig. VII.6.5, where NORSAR 06C06 signals from an m_b 5.8 earthquake near Kamchatka are followed one minute later by signals from a presumed explosion (m_b 3.8) at Semipalatinsk. With the standard 1.2-3.2 Hz filter, the latter signal is completely masked by the coda, whereas a filter of 3.2-5.2 Hz shows the explosion signal dominating that of the earthquake. This figure is based on a single instrument, and further improvements are of course possible by multichannel processing.

In conclusion, the demonstrated gains from high-frequency processing of teleseismic explosions clearly warrant a modification in the present NORSAR detection algorithms. The practical implementation of these changes is now the subject of further study.

F. Ringdal

References

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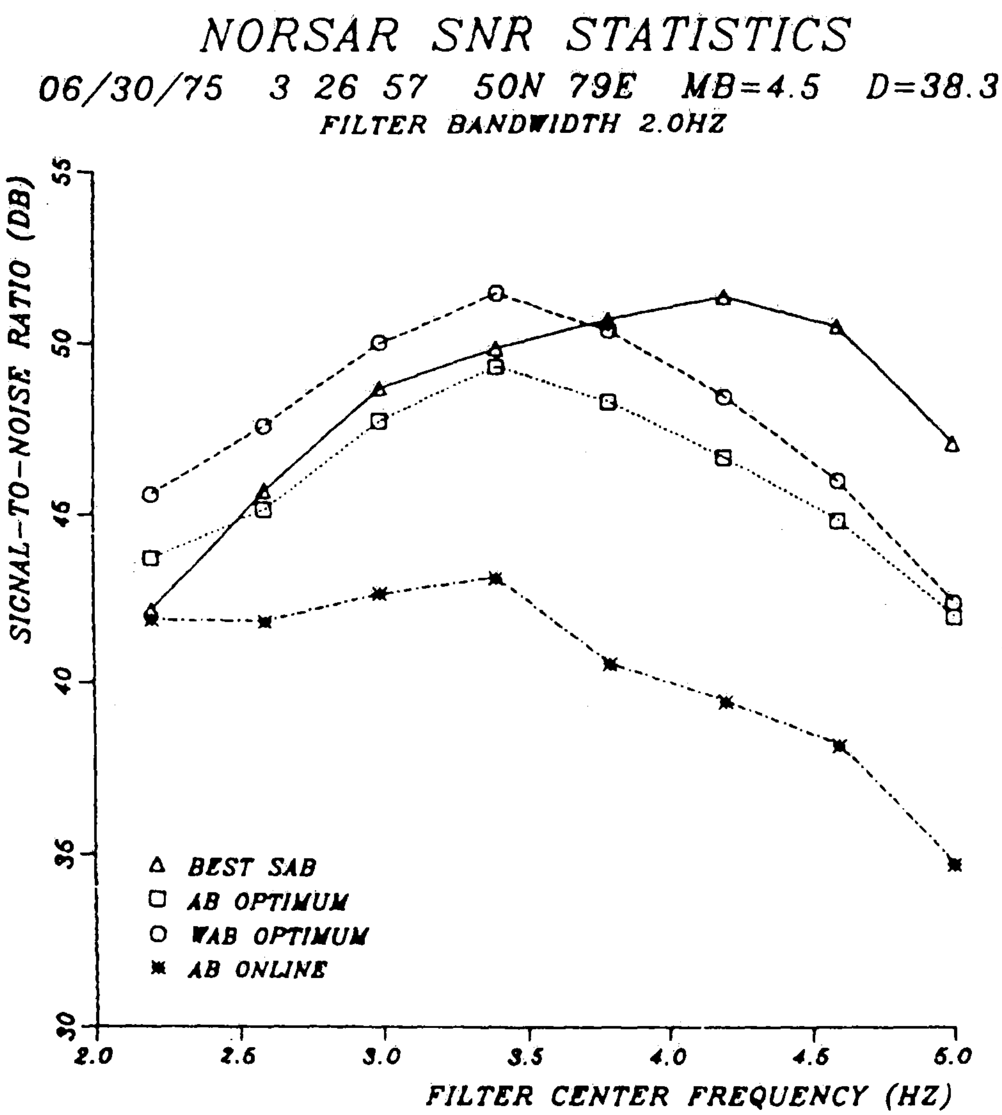

Fig. VII.6.1 Observed SNR at NORSAR for different filters and beamforming methods, as explained in the text. The case shown is an m_b 4.5 Semipalatinsk presumed explosion.

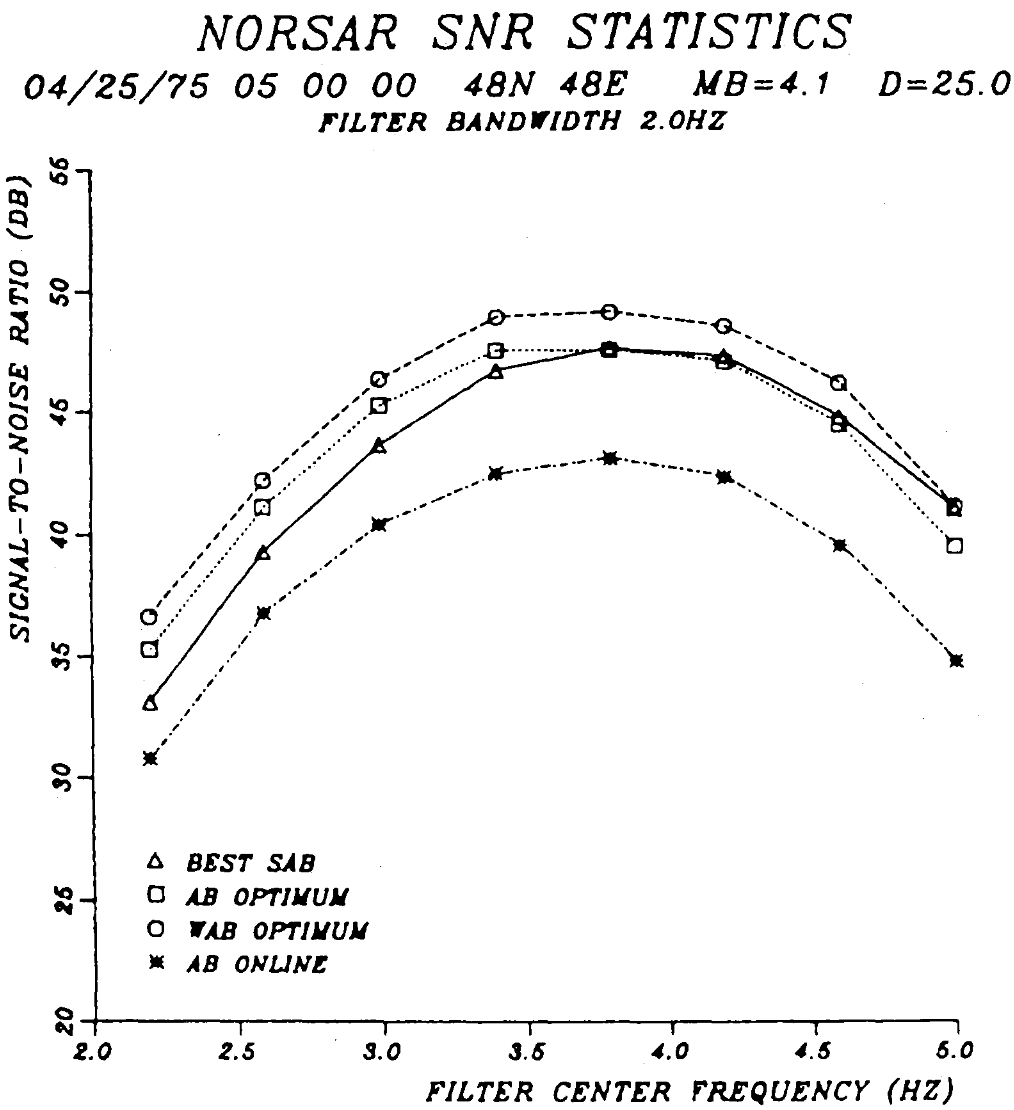

Fig.VII.6.2 Same as Fig. VII.6.1, but for a presumed explosion from the Azgir area.

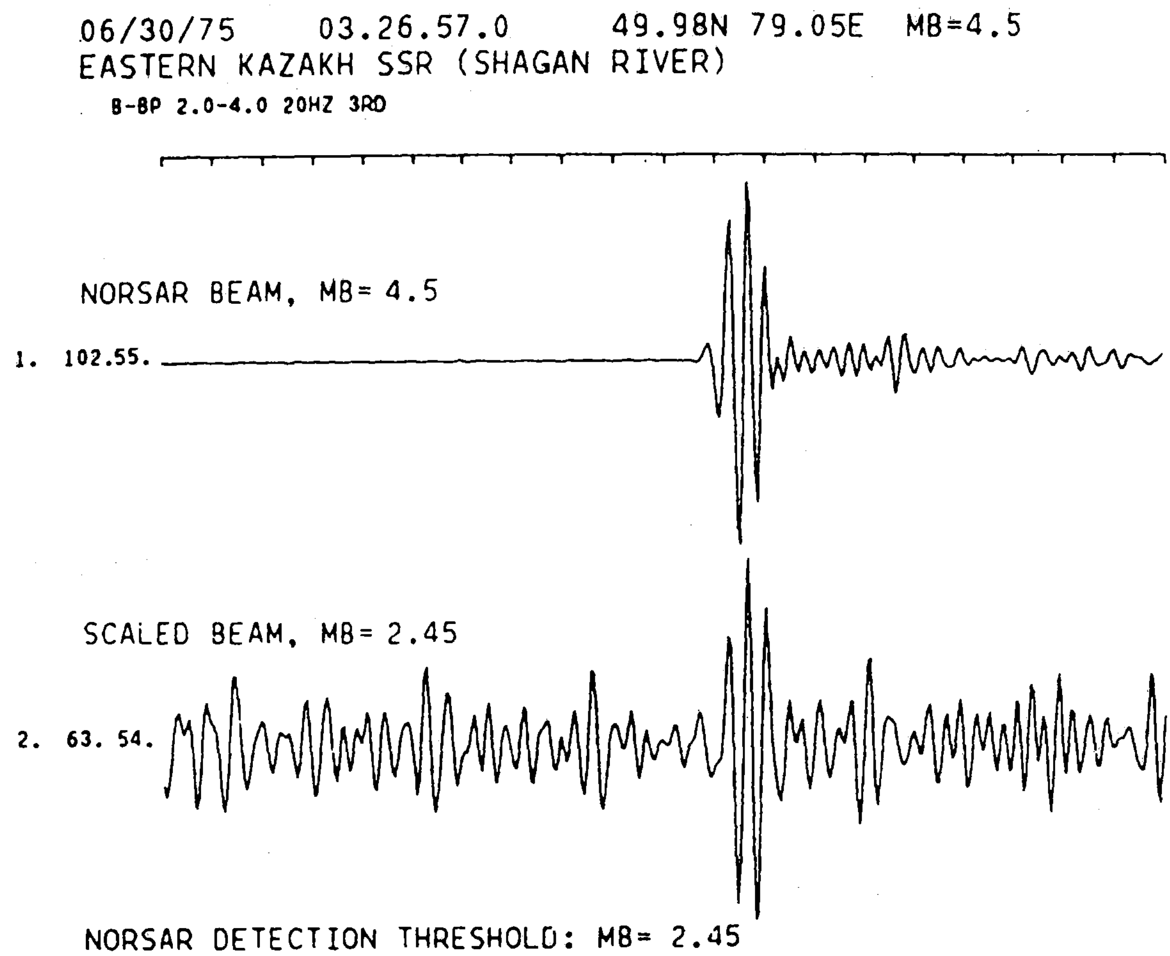

Fig. VII.6.3 NORSAR array beam (top) and a scaled beam added to preceding noise, and indicating the "optimum" instantaneous dectection threshold. This figure corresponds to the event of Fig. VII.6.1. Note that this is a "best case" event, and that typical scaled thresholds for other Semipalatinsk events range from m_b 2.5 to 3.0.

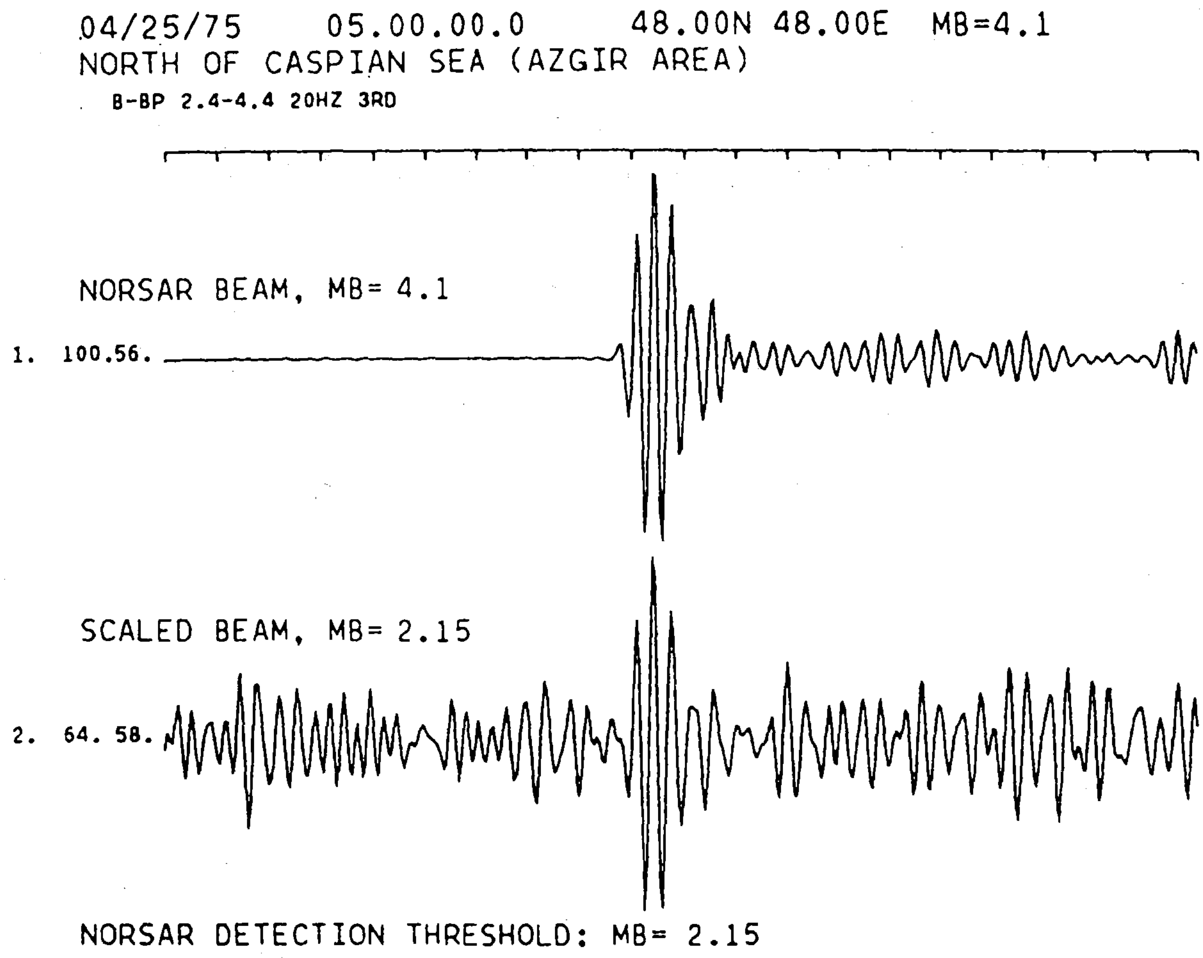

Fig. VII.6.4 Same as Fig. VII.6.3, but corresponding to the event of Fig. VII.6.2. Other events studied from this area have given scaled thresholds from m_b 2.2 to 2.5.

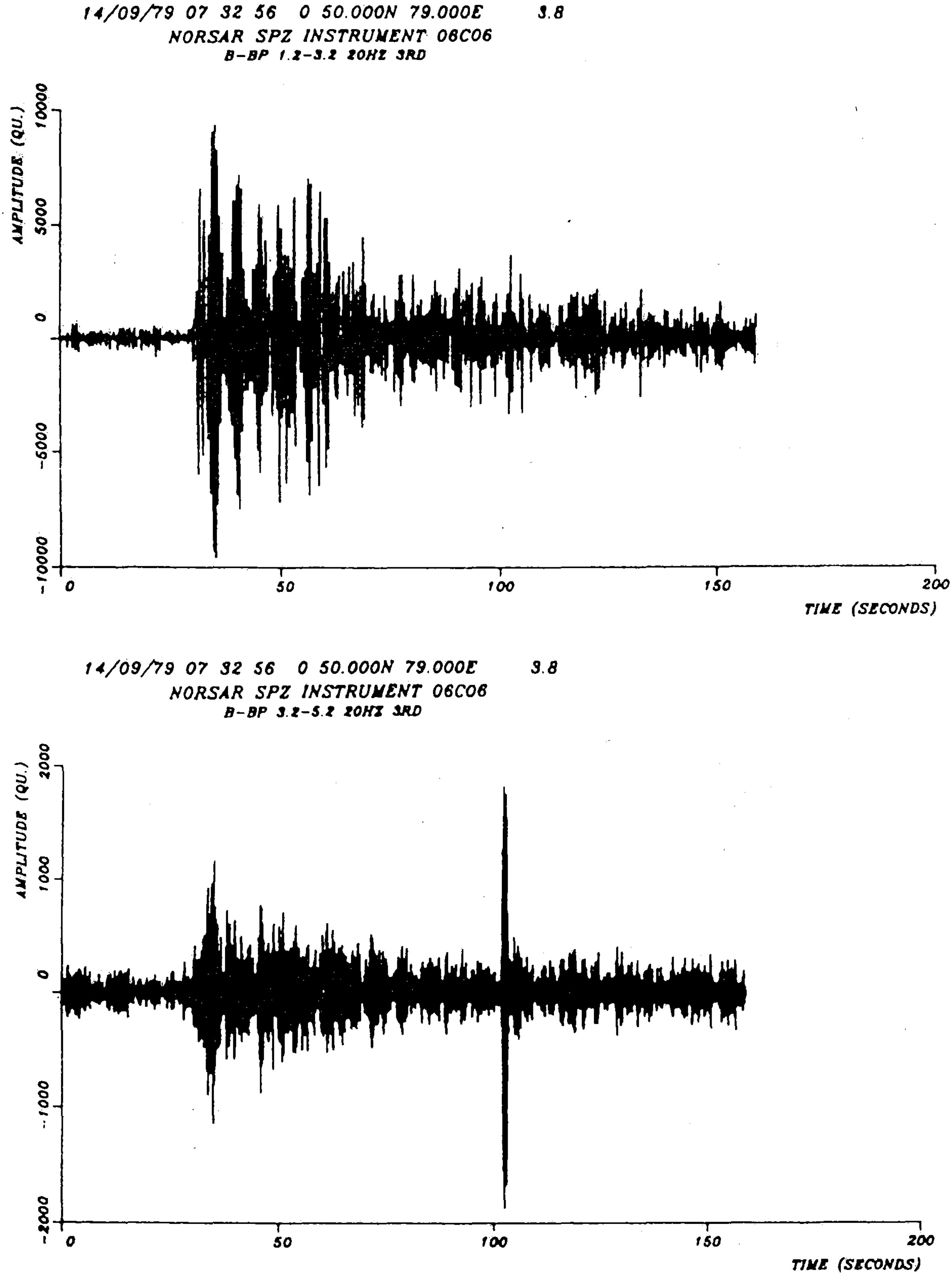

Fig. VII.6.5 Example of NORSAR recordings instrument 06C06 from a small presumed explosion with signal arrival one minute later than that of a preceding large earthquake. Note that the explosion signal is not visible on the top trace (1.2-3.2 Hz filter), but can be clearly seen on the bottom trace (3.2-5.2 Hz filter).