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SEMIANNUAL TECHNICAL SUMMARY

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L. B. Loughran (Ed.)

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VII. SUMMARY OF TECHNICAL REPORTS/PAPERS PREPARED

VII.1 Real time event detection using the small-aperture NORESS Array

Since January 1985 data from the new small-aperture array NORESS in Norway have been processed in real time at the NORSAR data center at Kjeller. The data used in the detection processing comprise 25 SPZ channels, deployed over an area 3 km in aperture and sampled at a 40 Hz rate. The detection algorithm has been described by Mykkeltveit and Bungum (1984), and briefly consists of

- Digital narrow-band filtering (six filters)
- Beamforming (conventional and incoherent)
- STA/LTA detector applied to each beam
- Frequency-wavenumber analysis of detected signals
- Association of regional phases to aid in locating events.

In the following, initial results from this processing are described, together with recommendation for future research.

Teleseismic events

The P-wave signal-to-noise ratio at NORESS typically peaks in the 2-4 Hz band for teleseismic events in Eurasia, whereas lower dominant frequency is often observed for signals from the western hemisphere and for epicentral distances exceeding 70 degrees. Signal coherency is naturally very good for teleseismic P across NORESS, even at very high frequencies. Depending on signal frequency, the best beam SNR is obtained using various subsets of the array; e.g., at 2 Hz the best subset consists of the center instrument A0 together with the C and D rings (see Fig. VII.1.1). Using this subset, the beamforming gain meets or exceeds $\sqrt{N}$, due to the noise suppression characteristics described in Section VII.2.

An example of teleseismic processing results from NORESS is given in Fig. VII.1.2. The improvement in SNR on the beam relative to the single sensors is quite remarkable.

The on-line procedure uses steered teleseismic beams rather than a single infinite-velocity beam for each filter. The resulting SNR gain is, as an example, 4-5 dB for an apparent velocity of 16 km/s, at 3 Hz frequency. For lower frequencies or higher velocities, the gain is less. Thus, applying only infinte-velocity beamforming for teleseismic detection is a viable alternative, in view of the possibility of operating at a lower detection threshold with the same false alarm rate.

The NORESS array detects many teleseismic signals not observed at the large aperture NORSAR array, which, like NORESS, is located in southeastern Norway; especially from selected regions in Eurasia. On the other hand, the signal focusing effects underneath NORSAR cause some instruments to have up to an order of magnitude stronger signals than NORESS sensors, for regions such as Hindu Kush and the Kuriles. For these regions, NORESS does not match the NORSAR detection capability.

Because of the small aperture of NORESS, only a very coarse automatic estimate of the location of teleseismic events is currently being made. Azimuth errors depend on phase velocity and frequency, and are often around 5-10 degrees for small events. Slowness estimates from the automatic process are typically about 1 sec/deg different from those of NORSAR. Nevertheless, it is clear that location estimates from a small array like NORESS will be very valuable to provide a starting point for association procedures using a seismic network.

Regional corrections and more detailed off-line analysis are required to assess the eventual capabilities of the array in this regard.

Local and regional events

At local and regional distances, the best SNR for the P wave varies from 3-5 Hz (at around 1000 km) to more than 8 Hz (local distances). Consequently, either steered beams or incoherent beamforming is necessary to exploit the array capability. P-signal coherency at NORESS is usually good enough to utilize the full array for F-K processing of local and regional P-phases, at least up to about 6-8 Hz.

The Lg phase is usually of slightly lower frequency than P. Conventional beamforming is not very efficient for Lg, since the preceding coda (from Sn) comes in with about the same phase velocity and azimuth. Consequently, little "noise" suppression takes place. A promising approach is that of performing narrow-band filtering at several frequencies for the purpose of Lg detection. It turns out that the SNR is greatly improved in those frequency bands where P and Sn coda energy are low relative to the Lg energy. Combining narrow-band filtering with incoherent beamforming has been found particularly effective.

An example of a complete record from a regional event processed at NORESS is given in Fig. VII.1.3. The detection times for P and Lg are marked on the panel of Fig. VII.1.3a, whereas Fig. VII.1.3b shows F-K solutions for P and Lg together with short plots of each phase in an expanded time scale. The estimated azimuths for P and Lg differ by 2 degrees in this case; and a deviation of 0-5 degrees is common. However, a difference of 10 degrees and more is also fairly often observed in the automatic solution.

The location accuracy of NORESS for regional events is currently being studied. No statistically reliable results are available so far due to the limited data base of known locations. The procedure of locating events by associating P and Lg is applicable only up to about 1200 km distance. At greater distances, the Lg usually is too weak to be detected automatically, but can sometimes be identified by visually inspecting the waveform plots.

In conclusion, the initial results obtained from NORESS are very encouraging, and have met and in some cases exceeded the expectations. Data quality has been excellent, and the operational stability has been very satisfactory, taken into account the complexity of the system. Particularly noteworthy is the excellent P detection in the 2-4 Hz band, which is due to greater than $\sqrt{N}$ noise suppression combined with strong P-wave energy. The automatic detection of secondary phases needs refinement, and in particular the narrow-band filter bank processing should be further investigated.

F. Ringdal

References

Mykkeltveit, S. and H. Bungum (1984). Processing of regional seismic events using data from small-aperture arrays, Bull. Seis. Soc. Am., 74, 2313-2333.

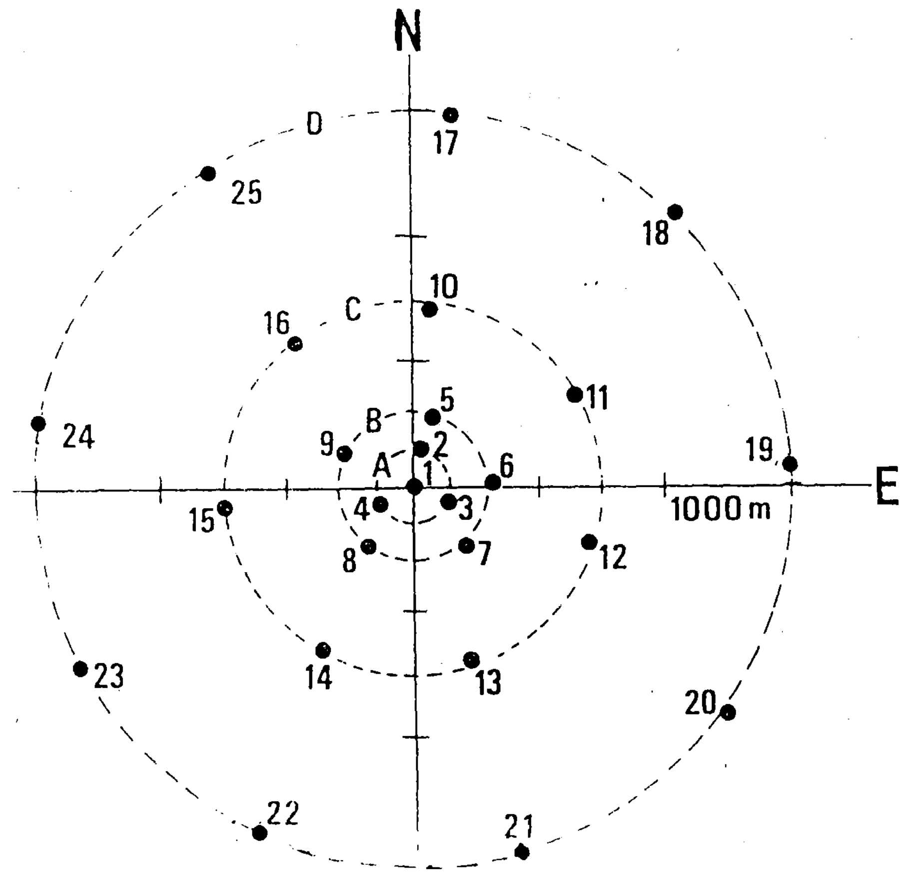

Fig. VII.1.1 Geometry of the NORESS array. The array comprises 25 SPZ seismometers over an area 3 km in diameter. The four rings - A, B, C, D - are marked on the figure.

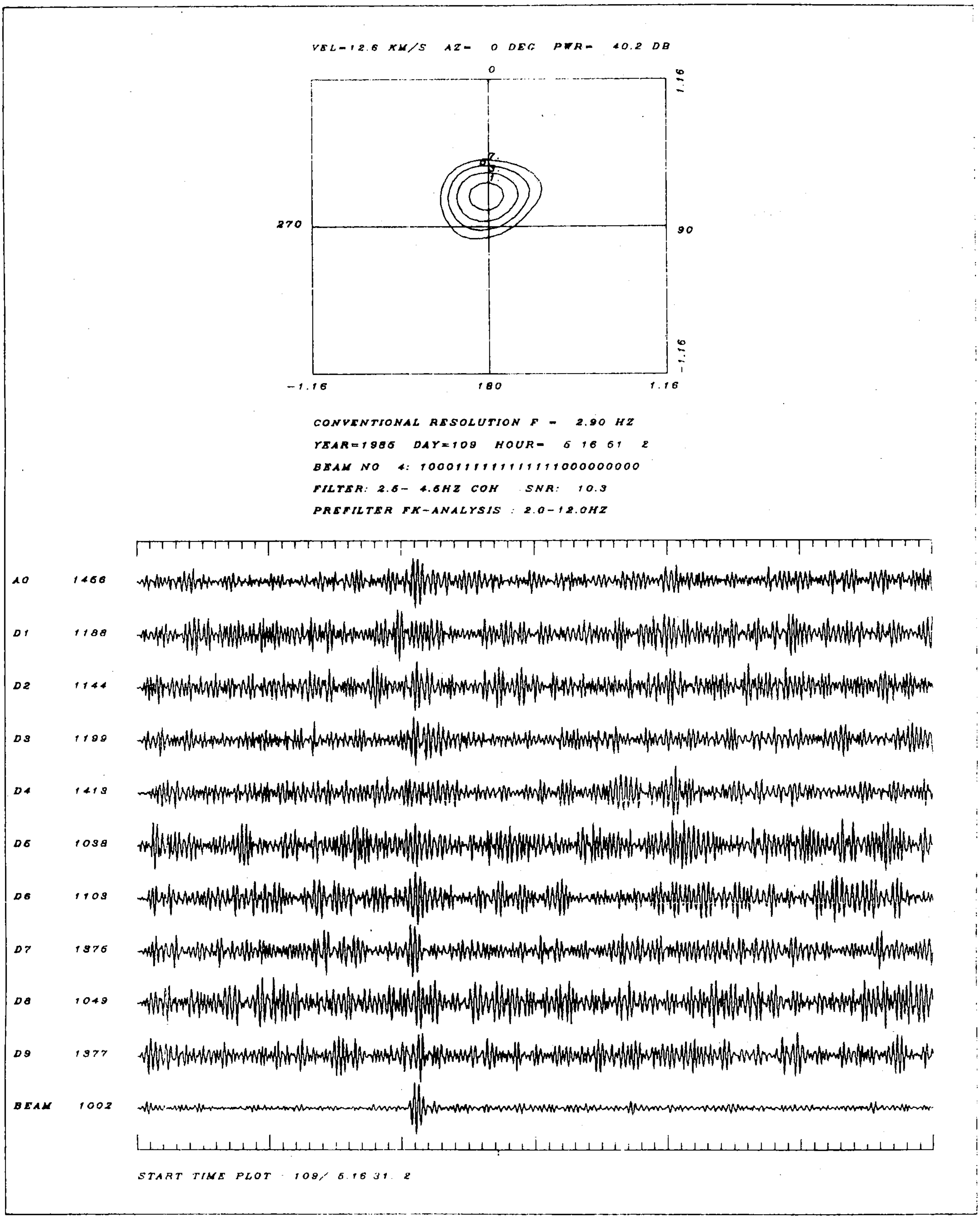

Fig. VII.1.2 Example of automatic processing of a teleseismic event using NORESS. The on-line F-K solution is shown at the top, together with detection parameters. Ten individual sensor traces (filtered 2.5-4.5 Hz) are plotted, together with the array beam (bottom).

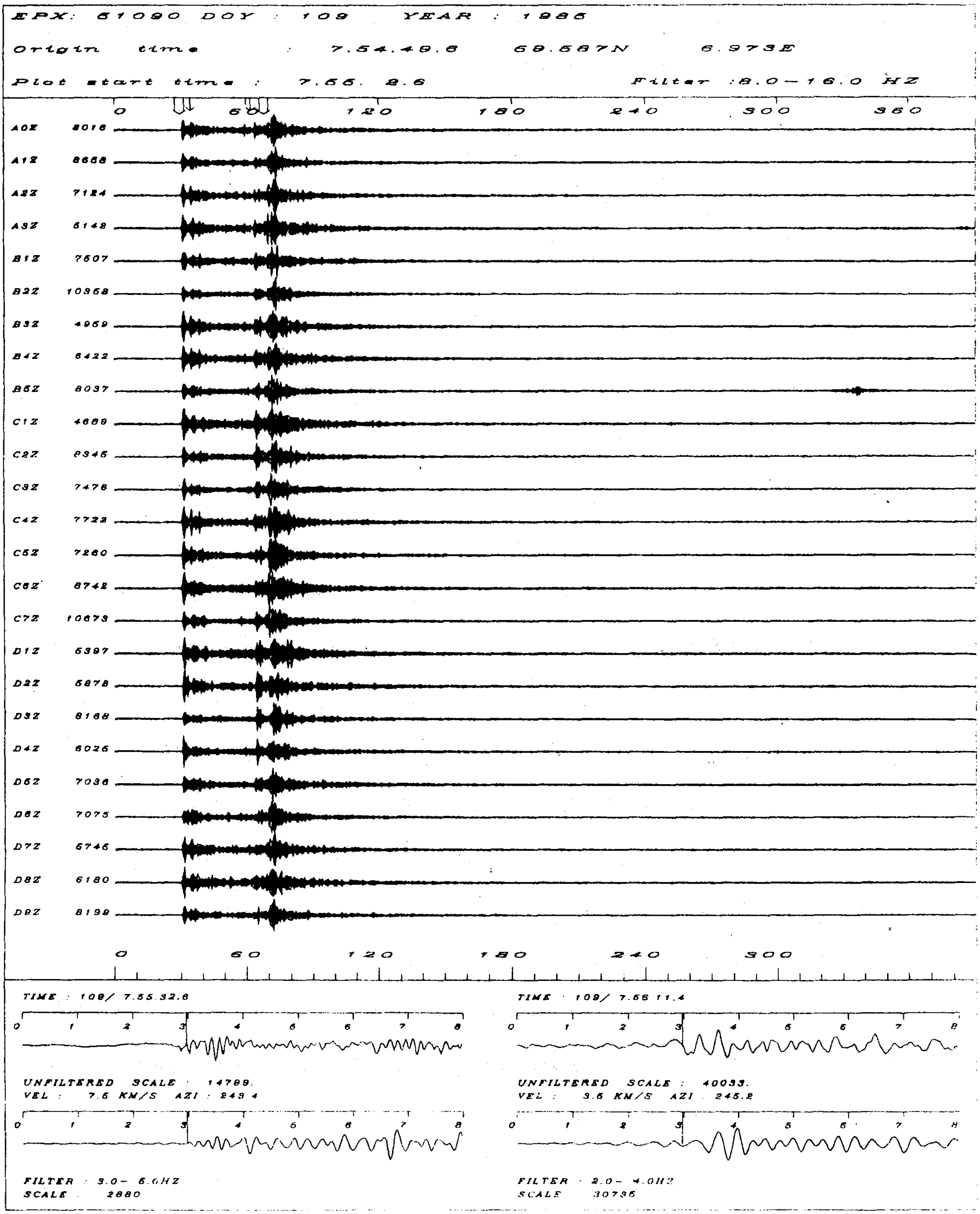

Fig. VII.1.3a Individual NORESS traces for regional event 19 April 1985. The panel covers 6 minutes of bandpass filtered records (8-16 Hz). P and Lg beams are also shown (bottom part).

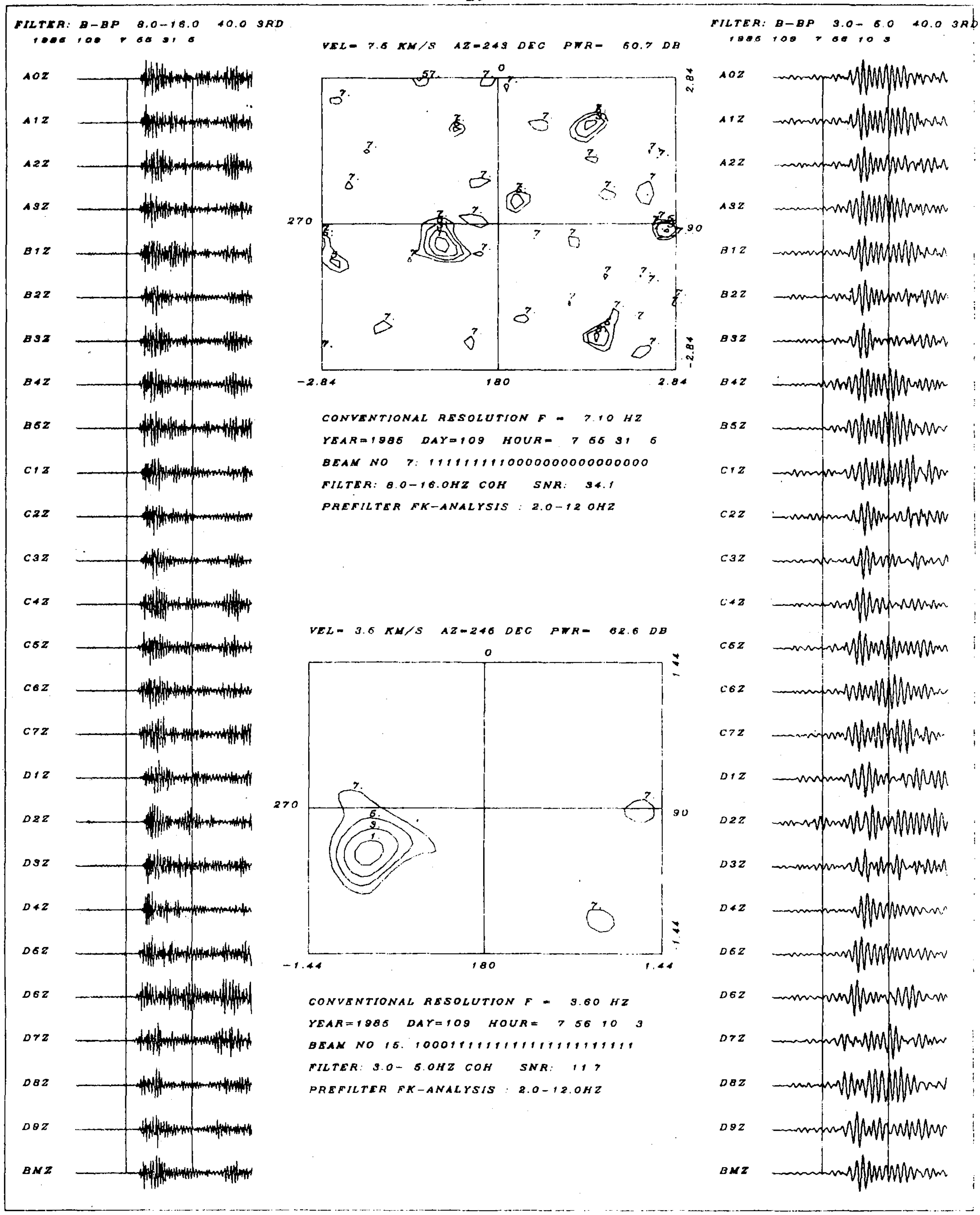

Fig. VII.1.3b NORESS automatic analysis results for the event of Fig. VII.1.3a. The P-phase (left) and Lg phase (right) are shown for all SPZ instruments. F-K solutions are shown for P (top) and Lg (bottom).