NORSAR

ROYAL NORWEGIAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

NORSAR Scientific Report No. 1-85/86

FINAL TECHNICAL SUMMARY

1 April - 30 September 1985

L. B. Loughran (ed.)

Kjeller, December 1985

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

VII. SUMMARY OF TECHNICAL REPORTS/PAPERS PREPARED

VII.1 Propagation characteristics of regional phases recorded at NORSAR

About 170 regional events recorded at NORSAR during the period 1971-1985 have been analyzed with respect to propagation characteristics for the phases Sn and Lg in particular. The motivation for our study was to obtain calibration data for the real time processing of data recorded on the new NORESS array. In addition, it is expected that such a study will shed some light on the general relationship between characteristics of regional seismic phases and large-scale geological features.

The event location algorithm of the current version of the NORESS online processing package (RONAPP) is based on the assumption that the largest secondary phase detected is Lg, propagating at a group velocity of 3.5 km/s. This assumption is valid for many propagation paths to regional distance from the NORSAR and NORESS arrays. There are, however, notable exceptions to this simplified picture, as illustrated in Fig. VII.1.1.

Data analysis procedure

For the 170 events in the data base, event files of appropriate lengths to include all phases of interest were copied from the tape archive. In order to minimize possible effects from the geology near the receiver site, the analysis was carried out on data from the same seismic channel (02B01) for nearly all events. Fig. VII.1.2 shows an example of the output resulting from the processing of events in our data base. The seismograms in this figure are shown for unfiltered data (top) and three band-pass filters. We needed criteria for picking phase onsets, which are independent of the human analyst's personal judgement. To this end, we computed and plotted the logarithm of the STA/LTA-ratio for each trace. The STA/LTA-algorithm used here for a single sensor is equivalent to the one used in the detection procedure in the RONAPP processing package, where STA/LTA is computed for a number of beams. In this manner, our analysis ties in with the current automatic processing of NORESS data. For this study, we specified an STA/LTA threshold of 3.0 for acceptance of a signal as a true phase arrival. This level would correspond to a somewhat higher (and operationally acceptable) detection threshold for the real time array processing, due to the SNR gain offered by the array beamforming.

Now, our analysis procedure has been to go through 170 plots of the kind shown in Fig. VII.1.2 and characterize the arrivals in the S wavetrain for each of the three filter bands. The case of dominant Lg (over Sn) was subdivided into three different codes as follows:

(1) Only Lg can be seen in the S wavetrain.
(2) Lg is the dominating phase, but Sn can be discerned.
(3) Lg is still the dominating phase, but Sn is not very much smaller.

An equivalent subdivision, also on a three-point scale, was adopted for the case of dominant Sn. Finally, a code was assigned to the case of comparable Lg and Sn amplitudes. Phases with corresponding group velocities in the interval 3.80-4.70 km/s were classified as Sn, with Lg corresponding to group velocities in the range 3.30-3.80 km/s.

Analysis results -- source area mapping

Fig. VII.1.3 shows the results derived from analysis of the data in our data base. In this figure, we assign the character of the S wavetrain as observed in the NORSAR seismometer record, to the source area. We have confined ourselves to the use of three codes only in this figure -- corresponding to (1) dominant Lg, (2) comparable Lg and Sn and (3) dominant Sn. Areas with no events or for which the available data were inconclusive with respect to appropriate characterization of the S wavetrain appear unshaded in the figure. Color-coded maps including all 7 codes defined above have also been prepared. These maps offer more details and often show gradual transitions from dominating Lg to dominating Sn in certain directions. Several conclusions can be drawn from Fig. VII.1.3:

- For an area covering almost all of Norway, Sweden, Finland and the Baltic Sea, Lg is consistently the largest secondary phase for all three frequency bands.

- 1 Hz Lg-waves are clearly observed at NORSAR for sources in all of Poland and major parts of the western U.S.S.R. up to distances of about 20^{o}.

- Sn is the dominant phase for events from the U.K., Belgium, Iceland and the North Atlantic mid-ocean ridge, and for events located to the west of the escarpment of the Norwegian continental shelf.

- The maps tend to be richer in details for higher frequencies, with more pronounced boundaries between source regions.

Wave propagation characteristics related to tectonic features

The map of Fig. VII.1.4 shows the tectonic features that tentatively could be related to the characteristics of propagation of regional phases in the area surrounding the NORSAR array. Indeed, we find a very close relationship between the tectonic features and the character of the S wavetrain. By comparing the maps in Figs. VII.1.3 and VII.1.4 and bearing in mind also the significance of unshaded areas in Fig. VII.1.3, the following points can be made:

- Lg wave propagation is very efficient for propagation paths that are confined to continental shield type structures and not intersected by major tectonic units. In these directions, 1 Hz Lg waves propagate to 20^{o} from the source, while at 4 Hz Lg is seen out to about 10^{o} from NORSAR.

- No Lg is observed, or Sn dominates over Lg for propagation paths that cross significant tectonic features like graben structures and continental margins.

- Particularly at 4 Hz there is a close connection between some of the finer tectonic details and the propagation characteristics. Since Lg is a phase mostly composed of waves trapped in the crust, this phase is likely to be highly susceptible to changes in the crustal structure. This effect should be more pronounced at higher frequencies, i.e., for shorter wavelengths. At 4 Hz, even a feature like the Törnquist line seems to be an effective barrier to the propagation of Lg.

Implications for real time data processing

The basic assumption in RONAPP that for regional events, Lg is the strongest phase in the S wavetrain, is not valid throughout the area of interest. However, the maps in Fig. VII.1.3 will enable the analyst to assess the likelihood of a detected secondary phase being either Sn og Lg, when reviewing the results from the automatic event processing. On this basis, the epicentral distance estimate could be corrected, if necessary. In some cases, the phase identification will still be ambiguous, and research is continuing towards developing further criteria.

A next step would be to utilize the regionalization contained in this contribution for an improvement of the real time processing. We think that the results from this study and knowlegde about the general seismicity pattern of the area together with the information already available from the detection processing (direction of arrival, signal frequency and possibly travel time differences between several arrivals in the S wavetrain), constitute a basis for such improvements. Eventually, this information may assist in an expert system's approach to regional array processing.

T. Kværna
S. Mykkeltveit

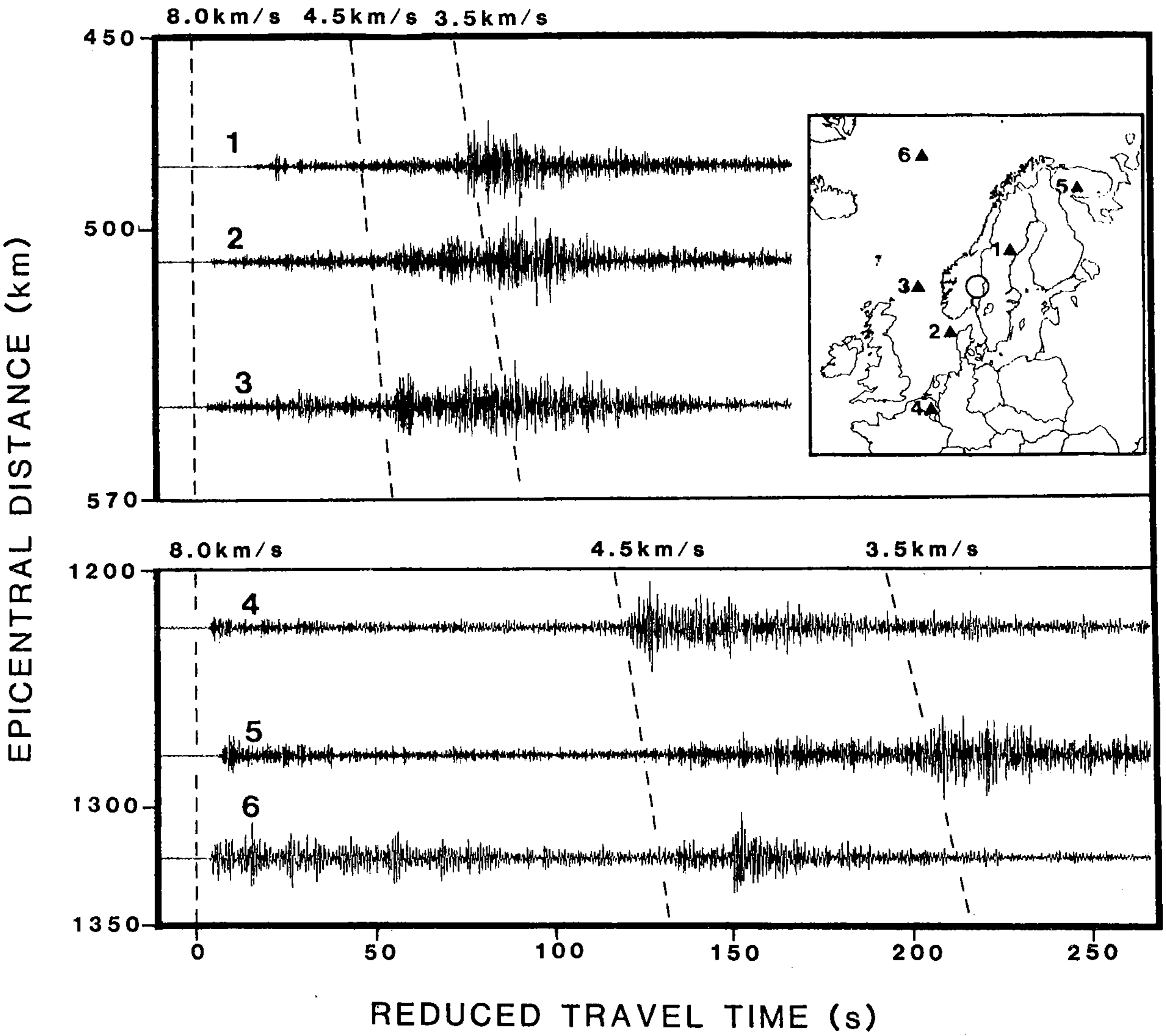

Fig. VII.1.1 Illustration of variation of relative importance of the phases Sn and Lg. The standard group velocities of 4.5 and 3.5 km/s, commonly assigned to Sn and Lg, respectively, are marked by dashed lines. The upper three traces cover the distance interval 480-550 km, while the lower three traces correspond to epicentral distances in the range 1225-1320 km. The location of the NORSAR array is denoted by a ring on the map, and the traces are from NORSAR seismometer 02B01. The data are bandpass filtered 1-5 Hz.

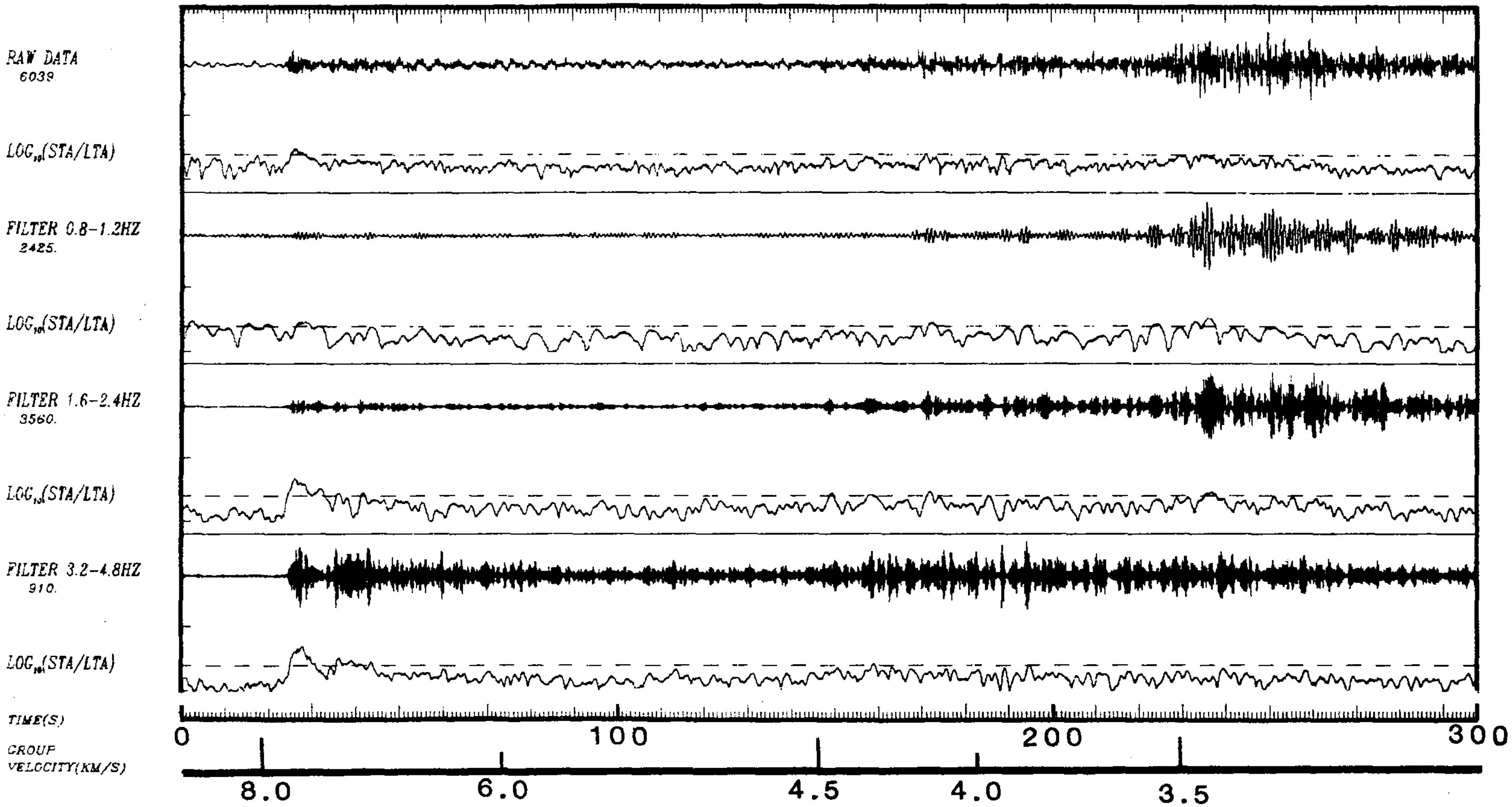

Fig. VII.1.2 Example of output from our processing of regional events. The four seismograms correspond to raw data (top) and three traces of bandpass-filtered data. For each trace, the logarithm of the STA/LTA-ratio is plotted beneath, and a threshold of 3.0 for STA/ LTA is indicated by a dashed line. For an event to be included in our data base, at least one arrival in the S wavetrain must exceed this threshold for at least one of the three filters. This event is also shown as event no. 5 in Fig. VII.1.1.

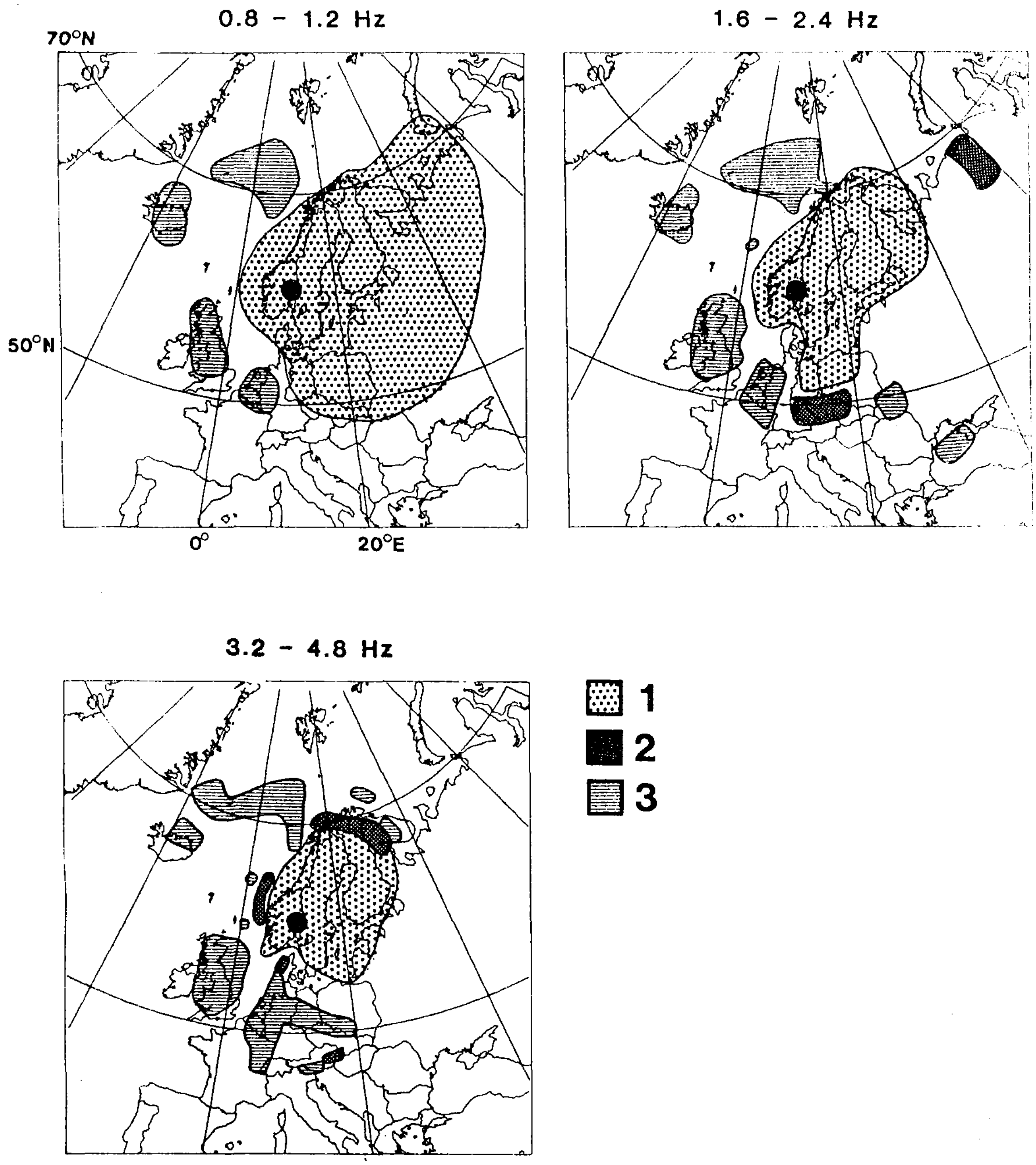

Fig. VII.1.3 Characterization of Lg versus Sn propagation efficiency, for the three different filter bands. The shading codes are as follows: (1) Lg dominant phase in the S wavetrain; (2) Lg and Sn comparable and (3) Sn dominant. Note that the codes are assigned to the source area, and all characterizations are related to seismograms as they appear on NORSAR (filled circle) seismometers.

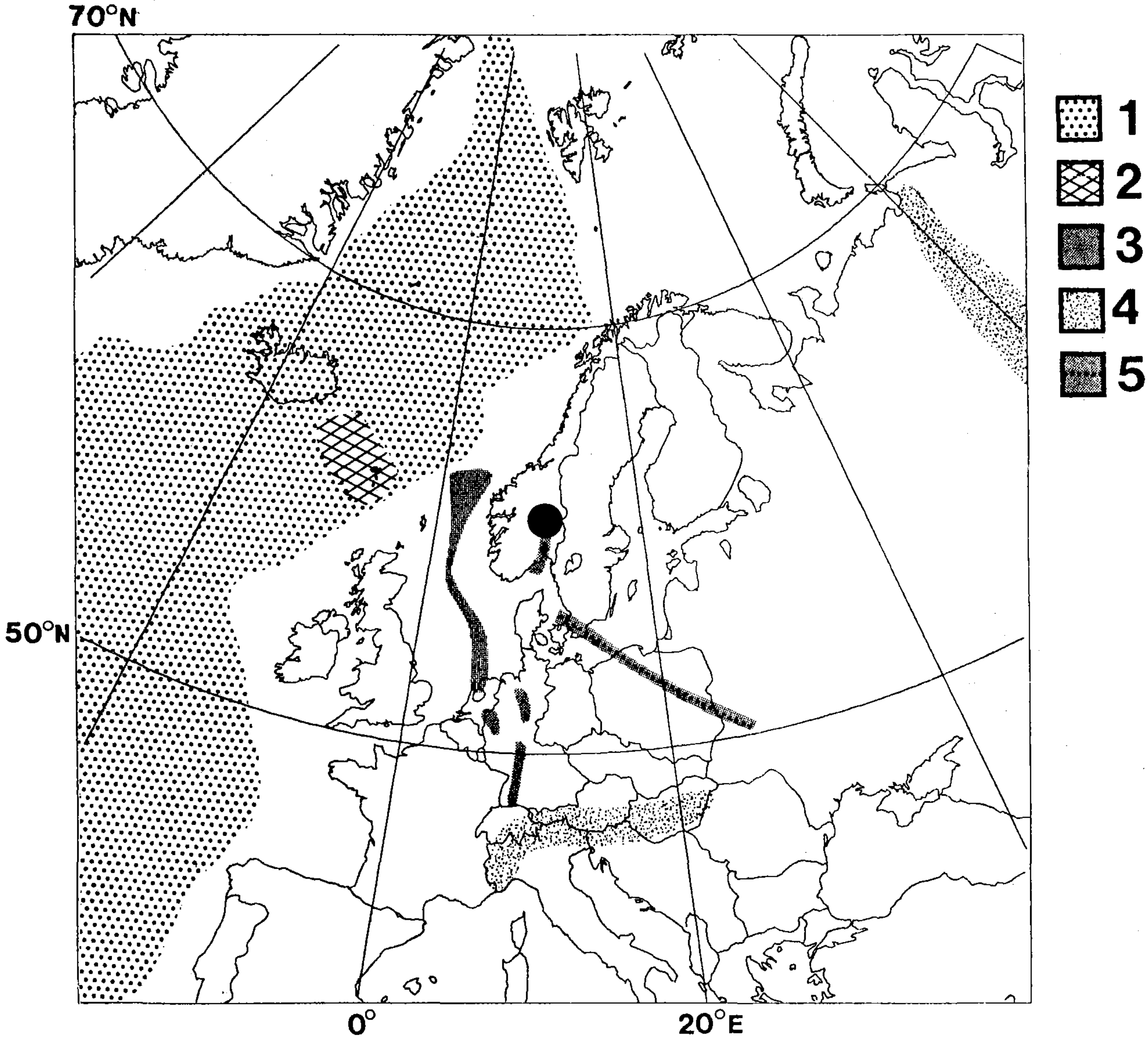

Fig. VII.1.4 Map showing geological features that are related to characteristics of propagation of regional phases to the NORSAR array. Shading codes are (1) Oceanic or oceanic type crust in the North Atlantic; (2) The Iceland-Faeroe Ridge; (3) Graben structures; (4) Major mountain belts; and (5) The Törnquist line. Unshaded areas (except in the Mediterranean region) are of continental type without significant orogenic features.