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VI.2 An Experimental Small Subarray within the NORSAR Array: Location of Local and Regional Events

Since November 1979 one of the NORSAR subarrays (6 seismometers, each with an 8 Hz lowpass filter) has been operated with station distances from 125 to 2051 meters. The purpose of this NORSAR Experimental Small-Aperture Subarray (NORESS) has been to obtain SP data from closely spaced sensors in order to

- Investigate noise and signal coherencies at high frequencies
- Identify P, S and Lg phases from regional seismic events
- Detect and locate regional events.

This paper describes a location procedure that has been developed for local and regional events, using NORESS. Briefly, the location algorithm consists of the following steps:

1. Identification of the P and Lg phases for each event using high-resolution frequency-wavenumber analysis
2. Manual pick of onset times for P and Lg
3. Epicenter azimuth determination based on the high-resolution analysis results
4. Epicenter distance determination using Lg-P travel time differences and a standard crustal model.

The efforts at this stage have been focused at obtaining a very simple procedure, with no attempt made to optimize location accuracy, e.g., by using azimuth-dependent travel time tables. The crustal model used for determining P wave travel times has been as follows:

Depth	P_n Velocity
0-16 km	6.20 km/s
16-40 km	6.70 km/s
40-95 km	8.15 km/s
95- km	8.25 km/s

The group velocity of Lg has been set to 3.5 km/s, which is consistent with earlier results obtained for Fennoscandia.

The data base for the study has consisted of:

- 16 regional events from Fennoscandia
- Distance range from NORESS 200-1200 km
- Magnitude range (M_L) 2.0-3.5

Note that 15 of the events have been located independently using the Fennoscandian seismograph network. These location estimates have subsequently been used to evaluate the accuracy of the developed location procedure.

The first step of the location procedure, the high-resolution analysis of recorded waveforms, has been conducted as follows:

- Each phase processed at 5 frequencies: 1, 2, 3, 4 and 5 Hz
- For each phase: azimuth and phase velocity is obtained from the frequency with largest signal power
- Phase (P or Lg) is then identified from the estimated phase velocity.

For further discussion of the results here, it is referred to subsection VI.1. We note only that the 'side lobe' problem discussed there implies a need for further refinement of the sensor deployment.

With respect to the third step of the location procedure, azimuth determination, we have investigated and assessed several alternatives:

a) P_n azimuth from high-resolution analysis
b) Azimuth from 'best' P phase (P_n og P_g)
c) Lg azimuth
d) Average of P and Lg azimuths.

The results of the location evaluation are shown in Figs. VI.2.1-VI.2.4 for various alternative ways of azimuth determination. The dots on each figure correspond to the epicenter determined via the Fennoscandian network, while the end of each arrow indicates the location obtained using NORESS alone. Best result (Fig. VI.2.2) is achieved using the azimuth computed from the largest P phase.

In Figs. VI.2.5 and VI.2.6 we compare the NORESS estimated azimuth with those corresponding to the network determinations. Similarly, in Fig. VI.2.7, the respective epicenter distance estimates are plotted against each other.

In summary, our main conclusions are:

Phase Identification

- Accurate separation has been achieved between P and secondary phases (S, Lg)
- It is difficult to distinguish S from Lg based on phase velocity alone.

Distance Estimates

- Median 'error' is 11 km using Lg-P times
- No clear azimuth-dependent effect is apparent

Azimuth Estimates

- From Lg phase: Median 'error' is 6°
- From largest P phase: Median 'error' is 3°

Location Estimates

- Using Lg azimuth: Median 'error' is 45 km
- Using P azimuth: Median 'error' is 30 km.

It should be noted that the above 'errors' are relative to the location results from the Fennoscandian network, and that these locations are uncertain by typically 10-30 km or more. Thus the majority of the processed events can be located with a difference from the network location that is within the uncertainty limits of the latter.

Our future plans for the small aperture array developments include:

- Design array to minimize the side lobe problem
- Develop criteria for automatic identification of S and Lg phases
- Automate the picking of phase arrival times
- Refine the techniques for computing distance and azimuth from a NORESS type array
- Obtain an extended data base for evaluation
- Compare the results to those obtained using three-component location procedures, and possibly combine the two approaches.

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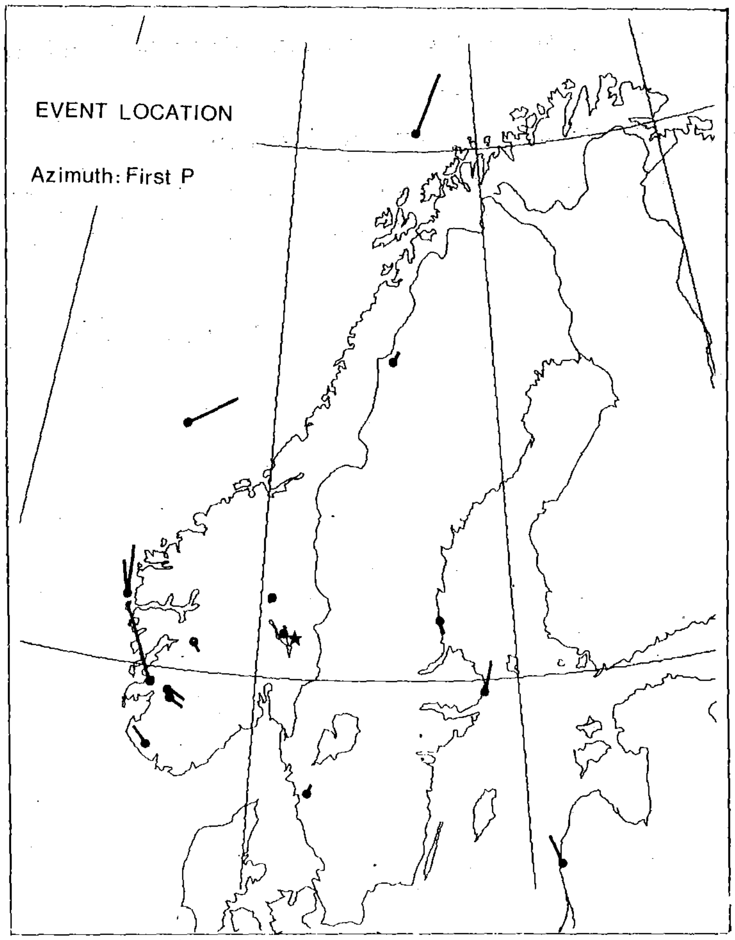

Fig. VI.2.1 'Location errors' using NORESS (with azimuths determined from the first P phase) for regional event location. Dots indicate epicenters determined by the Fennoscandia station network, while the end of the arrows indicate locations from NORESS processing.

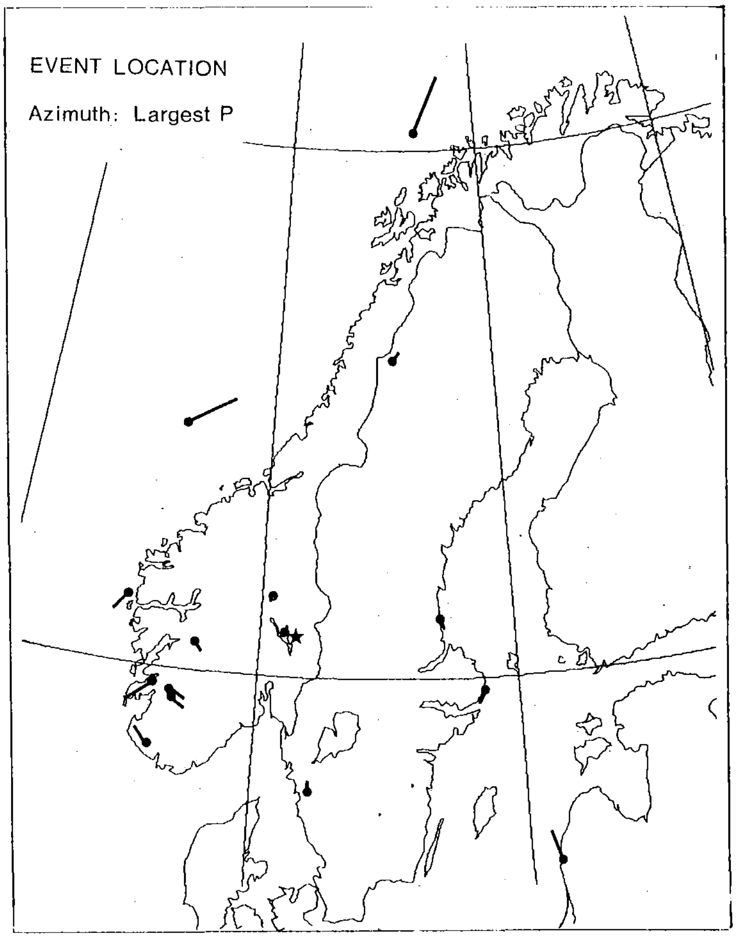

Fig. VI.2.2 Same as Fig. VI.2.1, but with NORESS azimuths determined from the largest P phase.

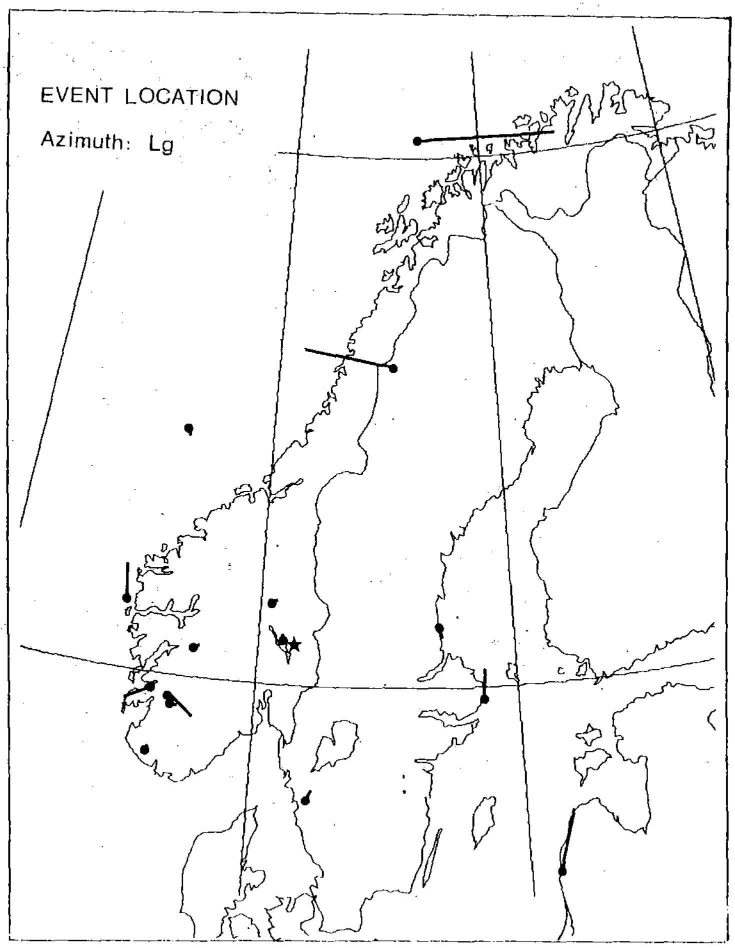

Fig. VI.2.3 Same as Fig. VI.2.1, but with NORESS azimuths determined from the Lg phase.

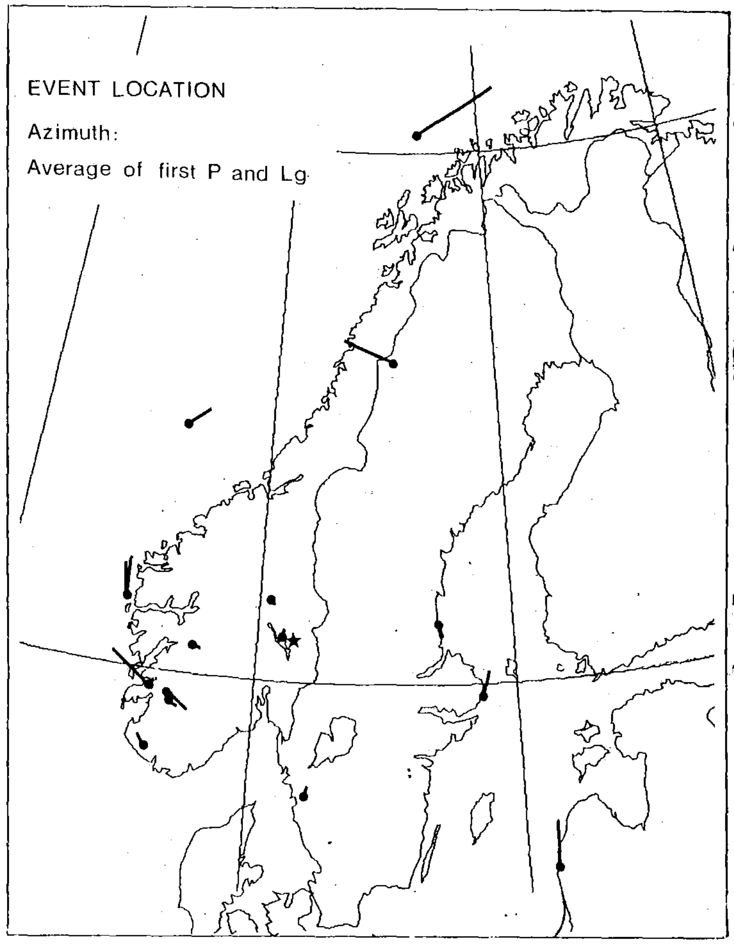

Fig. VI.2.4 Same as Fig. VI.2.1, but with NORESS azimuths determined from averaging the azimuths of the first P and the Lg phases.

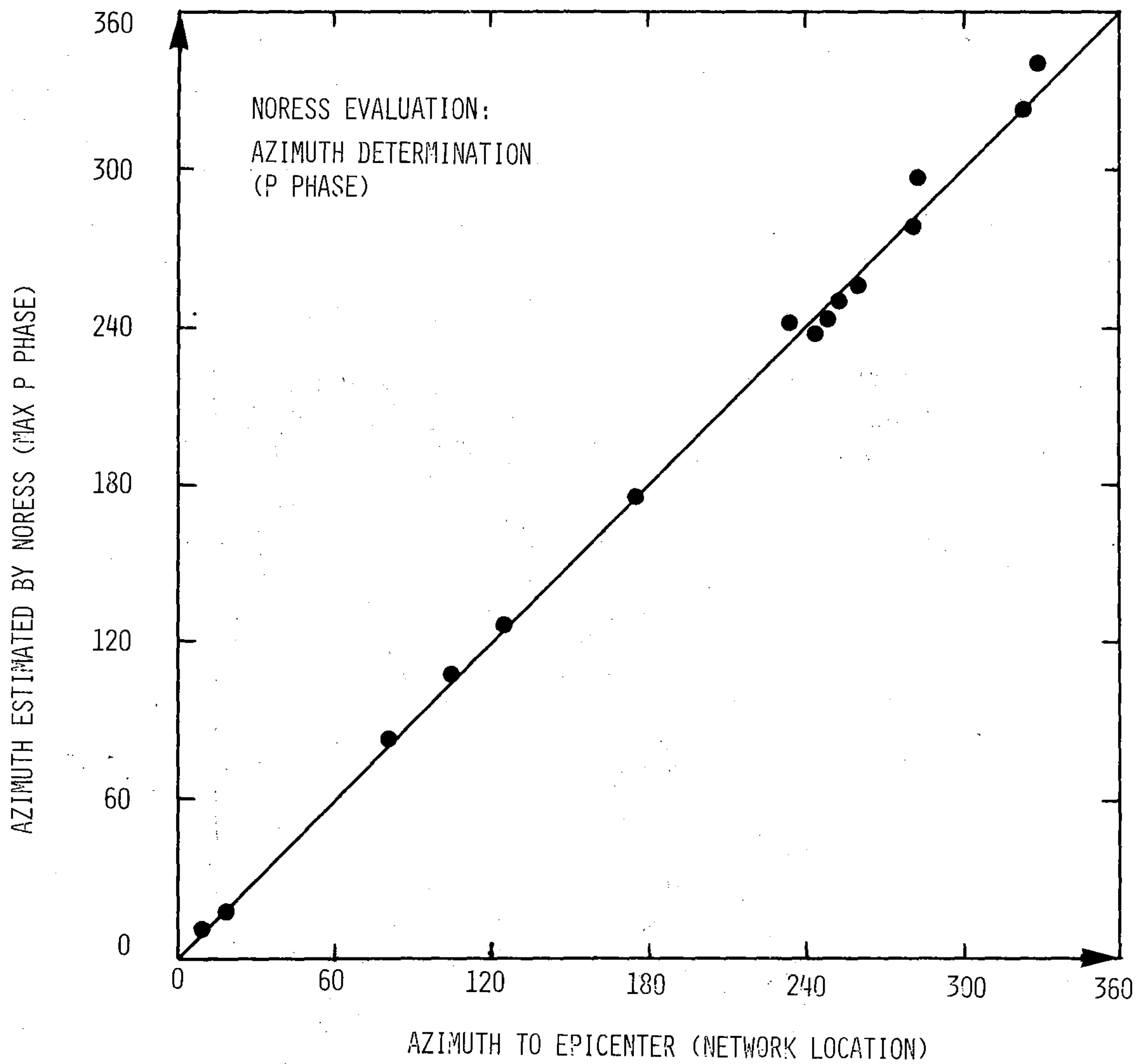

Fig. VI.2.5 Comparison of azimuths determined from NORESS processing (largest P phase) with those based on Fennoscandian network locations.

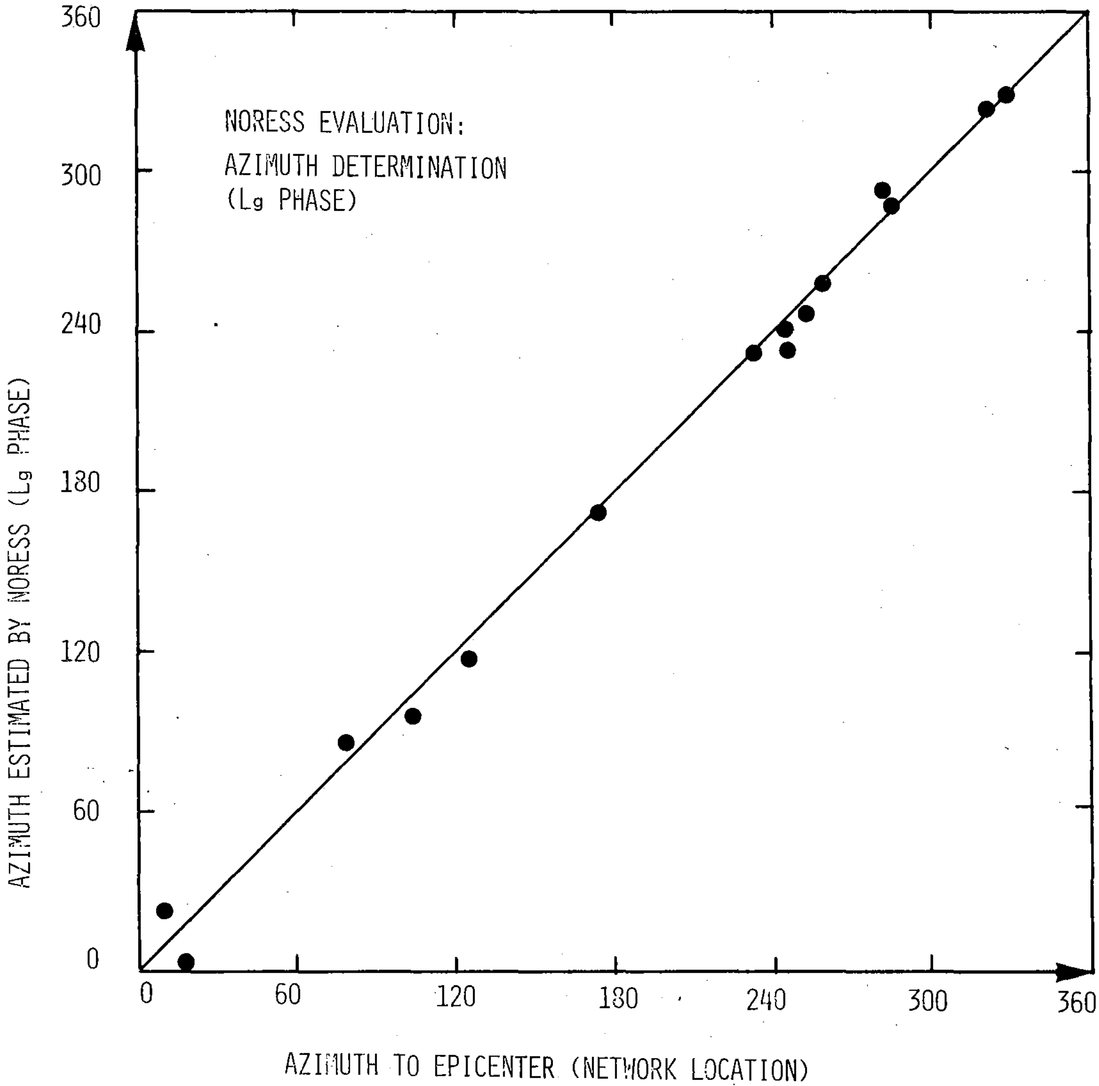

Fig. VI.2.6 Comparison of azimuths determined from NORESS processing (Lg phase) with those based on Fennoscandian network locations.

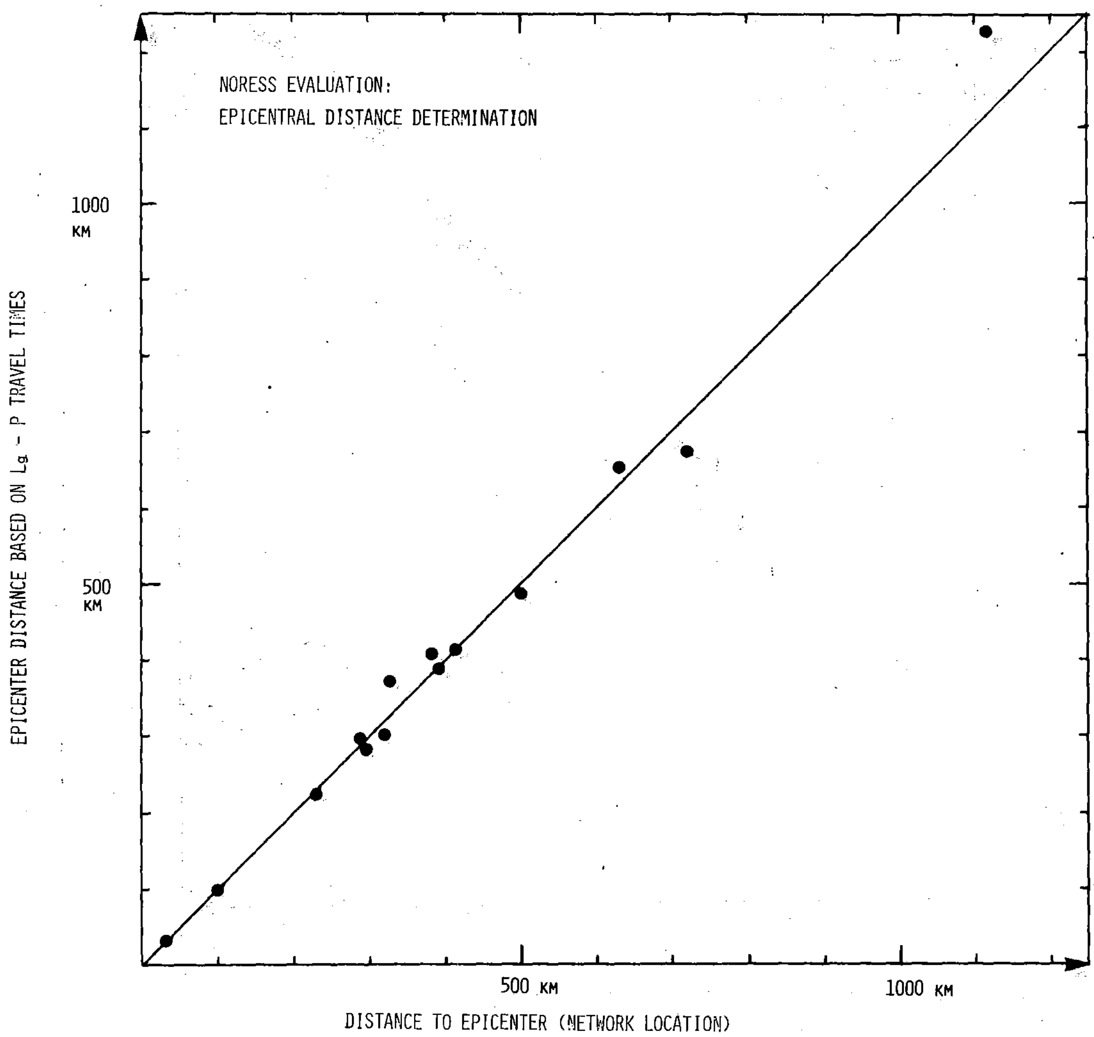

Fig. VI.2.7 Comparison between epicentral distance estimates using NORESS Lg-P travel time differences and the distance based on Fennoscandian network locations.