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Near-distance seismological monitoring of the Lansjärv neotectonic fault region
Part II: 1988

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January 1989

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Information on SKB technical reports from 1977-1978 (TR 121), 1979 (TR 79-28), 1980 (TR 80-26), 1981 (TR 81-17), 1982 (TR 82-28), 1983 (TR 83-77), 1984 (TR 85-01), 1985 (TR 85-20), 1986 (TR 86-31) and 1987 (TR 87-33) is available through SKB.

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ABSTRACT

During five months in 1988, a mobile seismic network (six stations) was operated near the Lansjärv neotectonic fault in Swedish Lapland. This was a continuation of an investigation in the same area in 1987. Some 30 local earthquakes were recorded, 18 of which have been located. A restrained focal depth has been obtained for six of these, and the depths range from 5 to 12 km. There is no clear spatial association of the earthquakes with the lateglacial fault segments, but many epicentres lie close to an older fault with the trend perpendicular to that of the lateglacial fault segements. Seismic moments from 10^{10} to 10^{12} Nm, fault radii 30 - 100 m, average dislocations 0.03 - 3 mm and stress drops 0.01 - 4 MPa have been computed from Sg-wave amplitude spectra. Focal mechanisms are not well constrained due to the small number of stations, and their tectonic interpretation is uncertain.

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1 INTRODUCTION

The Swedish Nuclear Fuel and Waste Management Co (SKB) is undertaking and interdisciplinary project on neotectonics in the Lansjärv region, Swedish Lapland. There is geological evidence that the spectacular Lansjärv fault, with up to more than 20 m vertical uplift of one block, was created by one or a few large earthquakes during the late phase of the last deglaciation in Fennoscandia some $9 \cdot 10^3$ - $10 \cdot 10^3$ years ago. The contribution from the Seismological Department, Uppsala University, has been to investigate the current seismicity by operating a mobile network of analog and digital seismic stations in the near area during five months in each of 1987 and 1988. Station data and results from the first year's operation was reported by Wahlström et al. (1987). This report gives the corresponding information for 1988.

2 STATION OPERATION AND DATA REDUCTION

The network consisted of four three-component digital stations and two one-component analog stations. Station locations are shown in Table 1 and Fig. 1, periods of operation in Fig. 2 and technical data in Table 1. Technical and other problems to maintain continuous operation were of similar nature to, but smaller extent than, those in 1987. Two larger interruptions were due to encoder breakdown at station C (from October 10) and motor failure at station F (most of August). The station Långberget (B1) was moved to Skravelberget (B2), about 1.5 km to the north, on August 1 due to "cultural noise" (curious people).

Table 1. Locations and technical data of the stations.

Station	Code	Type	Location Lat. (°N)	Lon. (°E)	Filter (Hz)	Gain (dB)
Livasape	A	DIG	66.405	21.814	0-40	66
Långberget	B1	DIG	66.358	22.182	0-80	66
Skravelberget	B2	DIG	66.369	22.177	0-80	66
Passeberget	C	DIG	66.514	21.854	0-80	66
Skaitas	D	DIG	66.478	22.069	0-40	GR
Kalvberget	E	ANA	66.413	22.160	10-50	90
Kängelberget	F	ANA	66.636	22.112	10-50	90

ANA Analog vertical-component station. Teledyne-Geotech Portacorder RV-320B and seismometer S-500. Continuous recording.

DIG Digital 3-component station. Lennartz Encoder 5000 (station D 5800) and Mark seismometer L4A-3D. Trigger mode recording.

GR Gain-ranging amplifier.

As in 1987, the OMEGA time signal from Norway was used, except during a period in August, when it was out of operation for maintenance, and substituted by the West German DCF signal, however with poor reception quality at our stations.

The data reduction was performed according to similar procedures as the year before (Wahlström et al., 1987). An improvement was that a computer search algorithm was used to identify events simultaneously recorded at different digital stations.

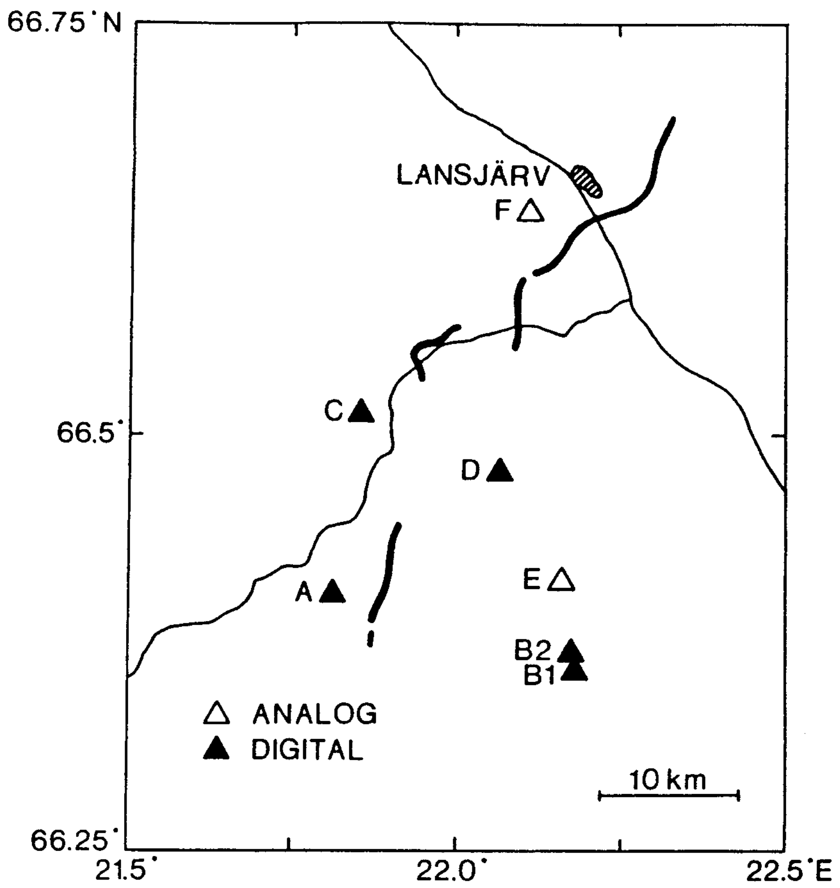

Fig. 1 Locations of stations in 1988. Thick lines show the Lansjärv lateglacial fault segments, thin lines roads.

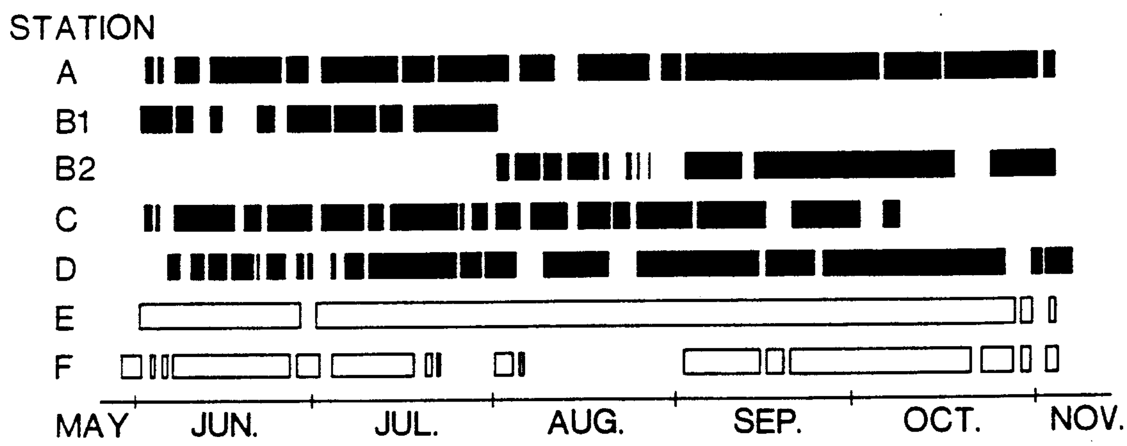

Fig. 2 Periods of station operations in 1988. Filled bars denote digital stations, open bars analog stations (cf. Table 1 and Fig. 1). Station B1 was changed to B2 on August 1.

3 EVENT LOCATIONS

A travel-time model with wave velocities 5.76 km/s and 3.33 km/s for Pg and Sg, respectively, was used for the localization of earthquakes at distances smaller than 40 km. 13 events have sufficient arrival time data to be located with the computer program HYPOINV1 (Klein, 1978). Six of the solutions have a reliable estimate of the focal depth. They range from 5 km to 12 km; four of them are between 8 km and 10 km, similar to the two reliable depths obtained from the 1987 data (Wahlström et al, 1987). Five more events, although recorded by only two stations, can also be uniquely located, in most cases thanks to azimuthal discrimination from three-component digital data. For another five events, two possible solutions are obtained. Epicentres of the 18 located earthquakes are plotted in Fig. 3, superimposed on a tectonic map from Henkel (1987). The two-solution cases are plotted in Fig. 4.

Still ten local events were recorded only at the station Kalvberget (E), 2 km to 13 km from the station. It is hard to determine whether they are all earthquakes. Table 2 gives times and, where obtained, locations of the identified 33 events. Fig. 5 gives a display of record sections at the digital station Passeberget (C) and the analog station Kalvberget (E) for the event on June 9, 04:51.

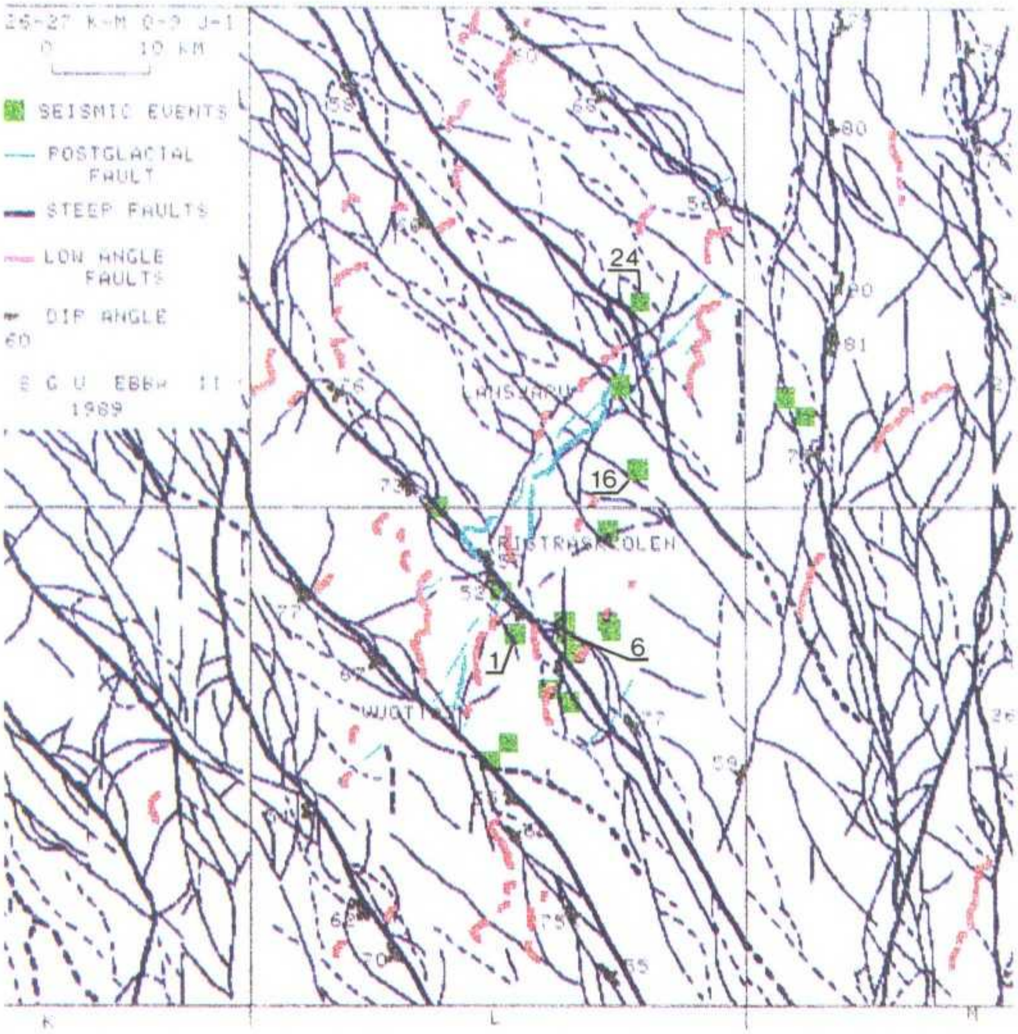

Fig. 3 Epicentres of 18 earthquakes in 1988 with unique solutions (cf. Table 2) plotted on a tectonic map from Henkel (1988). The four events with focal-mechanism solutions are marked by their corresponding numbers in Table 2.

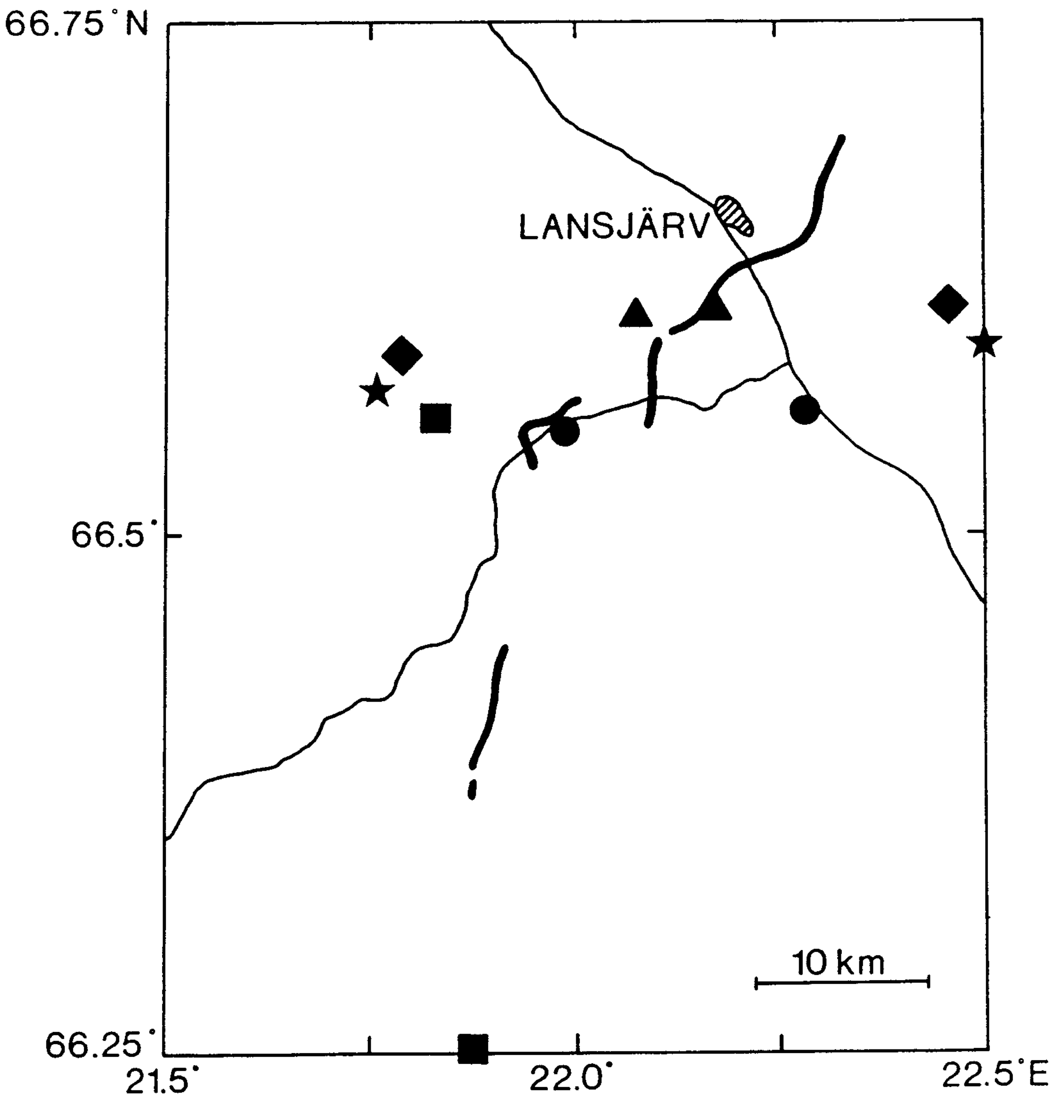

Fig. 4 Epicentres of five earthquakes in 1988 with two possible solutions (cf. Table 2). Each pair of symbols denotes the possible locations of one event.

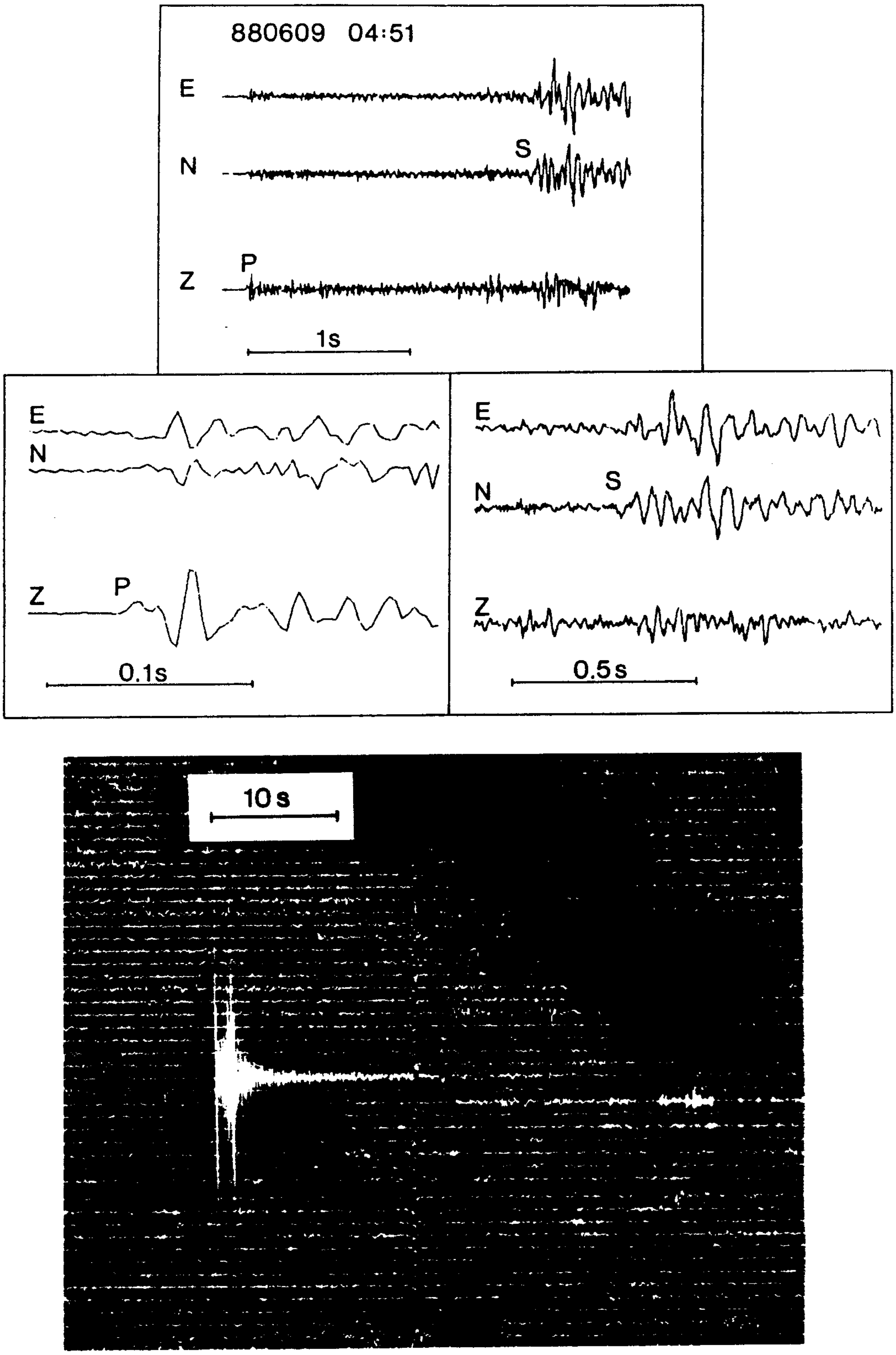

Fig. 5 Record sections from the stations Passeberget (C; digital, top) and Kalvberget (E; analog, bottom) for the event on June 9, 1988 at 04:51. For station C, P- and S-wave onsets are marked on playouts with different time resolution, and upward trace motion corresponds to ground motion to the W, S and down, respectively. For station E, upward trace motion corresponds to downward ground motion.

Table 2. Local earthquakes 1988.

Event	Date m d	Origin time h m s (GMT)	Location Lat. (°N)	Lon. (°E)	Focal depth km
1	0609	04 51 42	66.461	22.025	9.5
2	0609	05 22 52	66.551	21.990	8*
			66.561	22.282	
3	0614	00 35 37	66.569	21.758	8*
			66.593	22.500	
4	0622	09 12 16	66.609	22.173	4*
			66.606	22.075	
5	0714	15 58			
6	0715	00 49 08	66.458	22.141	8.6
7	0718	03 51 53	66.559	21.828	8*
			66.253	21.875	
8	0718	04 04 58	66.364	21.987	8*
9	0731	20 58 11	66.501	22.004	8.1
10	0803	19 30			
11	0803	21 13			
12	0809	18 28 46	66.581	21.880	(0)
13	0827	19 43			
14	0902	13 53 38	66.438	22.157	4*
15	0902	17 15			
16	0904	00 20 18	66.597	22.343	8.5
17	0911	06 28 12	66.409	22.089	8*
18	0913	15 11 47	66.545	22.260	8*
19	0927	01 09 23	66.628	22.732	(5)
20	0928	04 24 46	66.350	21.941	(1)
21	0928	04 31			
22	1006	16 32			
23	1009	15 54 19	66.467	22.141	6*
24	1010	12 47 15	66.746	22.387	(1)
25	1011	02 39 25	66.464	22.237	(3)
26	1011	23 59 06	66.590	21.789	8*
			66.613	22.458	
27	1012	06 30			
28	1019	03 29 01	66.395	22.133	5.3
29	1020	11 48 41	66.647	22.693	(6)
30	1022	06 00 04	66.674	22.322	12
31	1026	09 29 12	66.456	22.244	(2)
32	1027	20 41			
33	1027	20 41			

If the origin time is only given in hr and min, only one station has recorded the earthquake and no localization is possible.

* marks the assumed focal depth for graphically located events. It is 8 km, if focal distances (S-P times) do not indicate smaller depth.

The focal depth for computer-located events (no *) is in brackets, if the solution is not well restrained as to depth.

4 FOCAL MECHANISMS

Pg-polarities and Sg/Pg amplitude ratios were used as input to a modified version of the computer program FOCMEC (Snoke et al., 1984, Wahlström, 1987) to derive fault types and orientations, and deviatoric stress axes, for four earthquakes. The APPENDIX shows input data, nodal planes and stress axes in separate plots. The June 9 event suggests various possible solutions. The July 15 event is strike-slip and September 4 more diffuse, but both have a strong horizontal component of the pressure (P) axis with a trend roughly SW-NE. The October 10 event is strong dip-slip faulting with an almost vertical P-axis and a horizontal T-axis.

A horizontal P-axis with trend roughly NW-SE, i.e., opposite that found for the July 15 and September 4 events, would be expected to explain the mechanisms with ridge push from the North Atlantic plate boundary, a plausible cause of the Fennoscandian seismicity (see Wahlström, 1989). However, we must remember that the sparse input data make the obtained mechanisms not very well constrained, and tectonic implications are uncertain.

5 DYNAMIC SOURCE PARAMETERS

Application of the same spectral technique and fault model used in the analysis of 1987 year's events yields estimates of source parameters for 15 events. Fig. 6 illustrates the steps of this technique for the earthquake on June 9, 04:51, recorded at the station Passeberget (C); for details, see Wahlström et al. (1987). The corner frequency and the low-frequency level vary from 10 Hz to 57 Hz, and $4 \cdot 10^{-5}$ μm-s to $5 \cdot 10^{-3}$ μm-s, respectively. Seismic moments range from 10^{10} Nm to 10^{12} Nm, fault radii 30 m to 100 m, average dislocations 0.03 mm to 3 mm, and stress drops 0.01 MPa to 4 MPa (Table 3).

Magnitudes, M_L(UPP), computed from the relationship with seismic moment derived by Kim et al. (1989), are also given in Table 3 and are in the interval 0.7-2.4. No earthquake was recorded at the closest station of the permanent Swedish network, Kiruna, at a distance of about 170 km, and therefore no independent direct M_L(UPP) estimate was obtained. However, for one event in 1987, there was good agreement between the two measures (Wahlström et al., 1987).

Table 3. Dynamic source parameters

Event	Seismic moment (Nm)	Magnitude M_L(UPP)	Fault radius (km)	Average dislocation (mm)	Stress drop (MPa)
1	$0.1 \cdot 10^{12}$	1.4	0.06	0.4	0.2
6	$0.4 \cdot 10^{11}$	1.0	0.07	0.09	0.07
12	$0.4 \cdot 10^{12}$	2.0	0.06	1	0.7
16	$0.1 \cdot 10^{13}$	2.4	0.08	2	0.9
17	$0.4 \cdot 10^{11}$	1.0	0.03	0.7	1
18	$0.1 \cdot 10^{11}$	0.4	0.04	0.06	0.06
19	$0.2 \cdot 10^{11}$	0.7	0.03	0.4	0.6
20	$0.2 \cdot 10^{12}$	1.7	0.03	3	4
23	$0.4 \cdot 10^{11}$	1.0	0.07	0.1	0.06
24	$0.7 \cdot 10^{12}$	2.3	0.1	0.7	0.3
25	$0.1 \cdot 10^{12}$	1.4	0.06	0.3	0.5
28	$0.2 \cdot 10^{11}$	0.7	0.06	0.07	0.05
29	$0.1 \cdot 10^{13}$	2.4	0.08	2	0.9
30	$0.2 \cdot 10^{11}$	0.7	0.09	0.03	0.01
31	$0.9 \cdot 10^{11}$	1.4	0.05	0.3	0.2

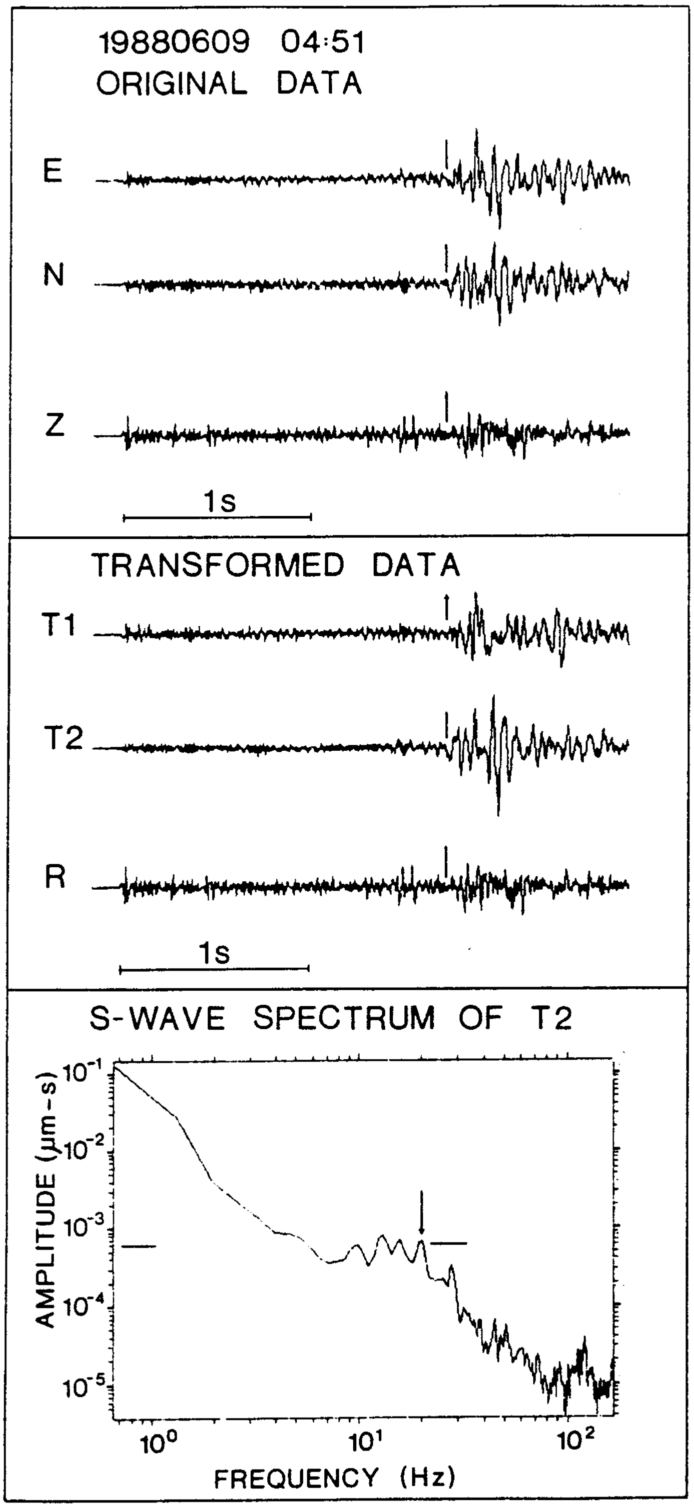

Fig. 6 Record sections and spectrum for the event on June 9, 1988 at 04:51, at the station Passeberget (C).
Top: E, N, Z components
Centre: Transverse (T1, T2) and radial (R) components.
Bottom: Sg-wave amplitude spectrum of T2 with the low-frequency level and corner frequency marked.
For details, see Wahlström et al. (1987).

6 DISCUSSION AND CONCLUSIONS

The frequency of local earthquakes in the vicinity (< 40 km) of the Lansjärv neotectonic region is somewhat greater than one event per week. Lacking detailed investigations from other parts of Sweden, it is hard to say if this represents an abnormally high rate. The vast majority of the events occurred to the east of the mapped segments of the lateglacial fault, several of them within a smaller area. In part, this result may be a bias of the location of the station network, although there is, like the year before, indications that the seismicity is partially related to other, older faults, the movements of which are related to the lateglacial ones. Many events are located at depths of 8-10 km, so if the lateglacial fault is dipping to the east with low angle, a more immediate causal relationship between the fault and the current seismic activity cannot be excluded. Cf. similar results for the Stuoragurra fault in northern Norway (Olesen, 1988).

Excellent Pg first-motion, and Pg- and Sg-amplitude data are obtained, but unfortunately the number of stations is not large enough to provide well constrained mechanism solutions. The addition of two or three digital stations would have significantly increased the number and reliability of obtained mechanisms, and facilitated a more detailed seismotectonic description of the region.

7 ACKNOWLEDGEMENTS

We are indebted to the local resident P.-A. Jönsson, who assisted in the field work. L. Frisk have made software development with relevance for the data analysis. Fig. 3 was processed with the EBBA graphic system at the Geological Survey of Sweden, thanks to H. Henkel.

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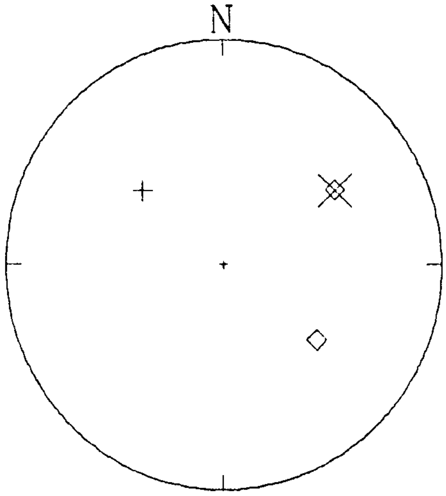
9 APPENDIX

Input data and focal-mechanism solutions. Each page shows equal-area, lower-hemisphere projection plots of the focal sphere with, from top to bottom, the input data (Pg-polarities and Sg/Pg amplitude ratios), the set of possible pairs of nodal planes, and the corresponding set of possible stress axes and null vectors.

Symbols

Top plot:	⊞	impulsive compression (weight 1)
	◇	impulsive dilatation (weight 1)
	+	emergent compression (weight 1/2)
	x	log {ampl(Sg)/ampl(Pg)} (size of symbol increases with increasing ratio)
Bottom plot:	P	deviatoric compressive-stress axis
	T	deviatoric tensile-stress axis
	B	null vector (intersection of pair of nodal planes)



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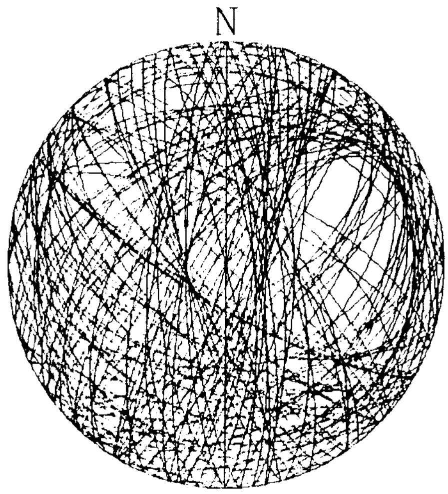

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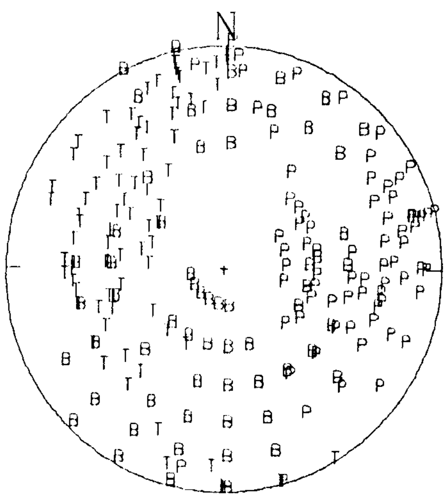

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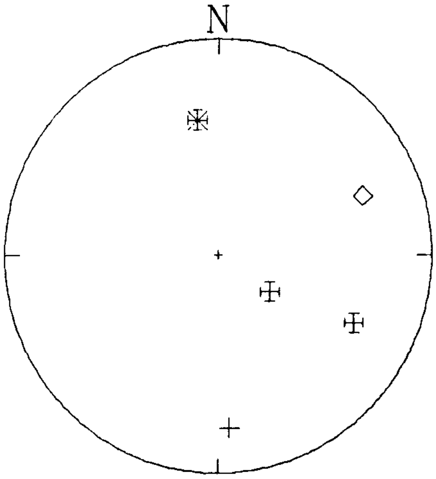

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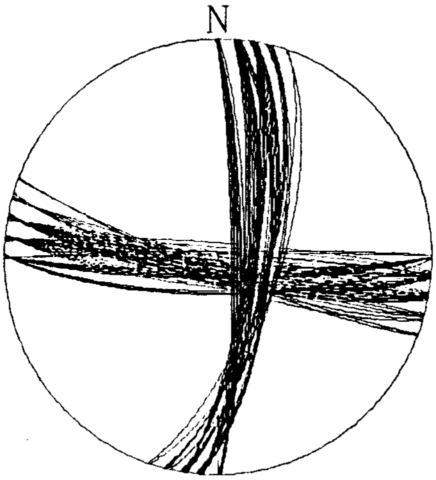

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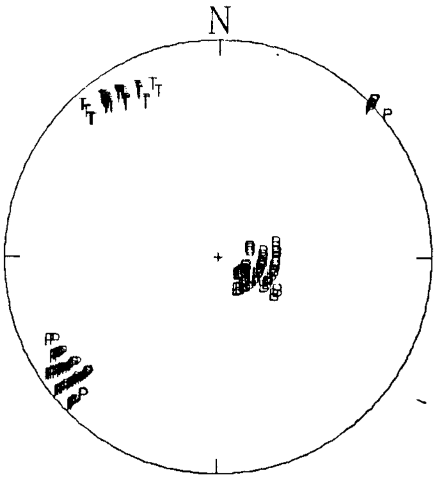

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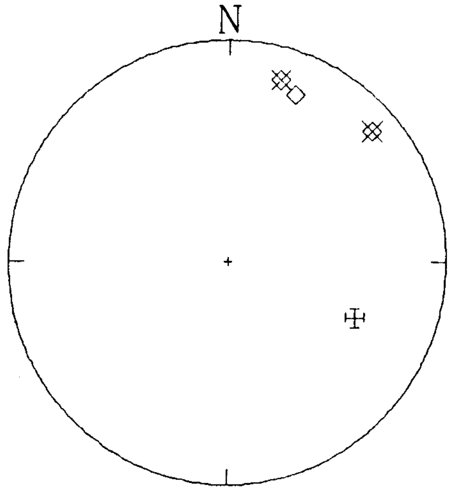

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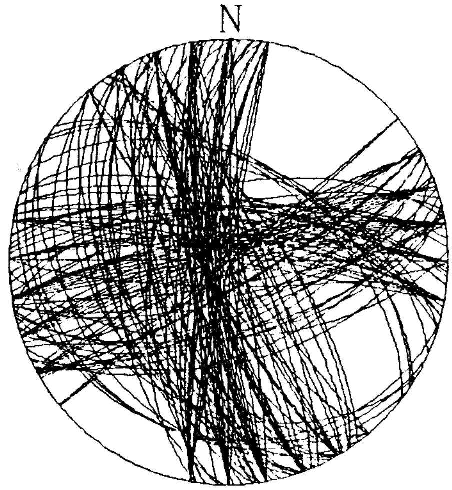

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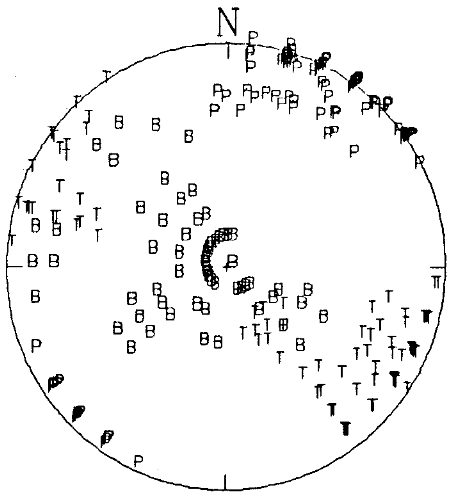

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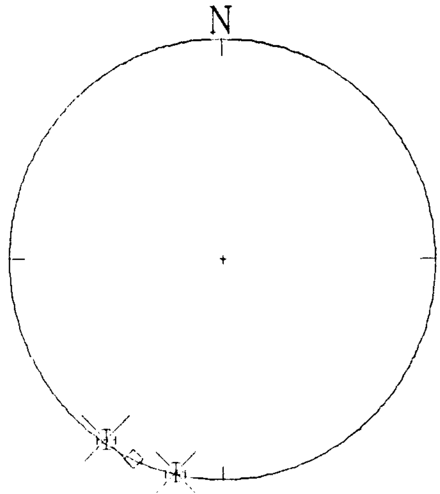

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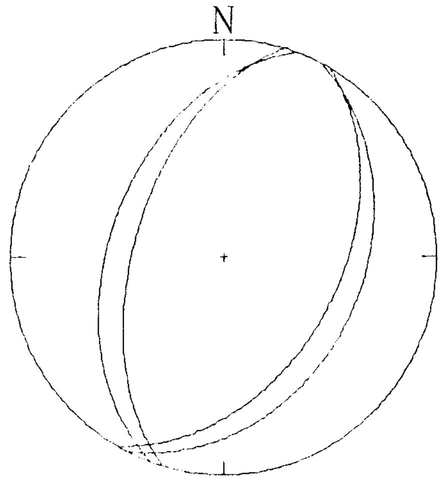

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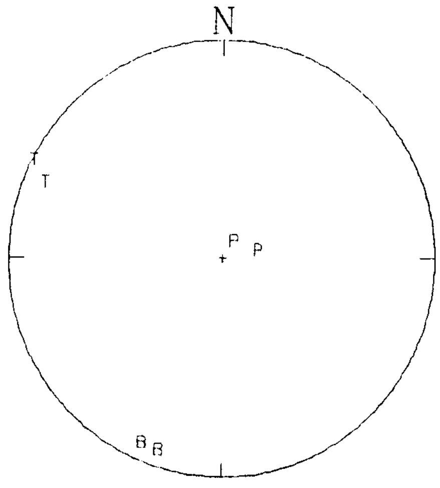

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