NORSAR

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VI.6. Magnitudes from P coda and Lg using NORSAR data

The objective of this study is to investigate the stability of magnitude estimates based on P coda and Lg, compared to that of conventional P-wave magnitudes. Using NORSAR recordings of presumed explosions from Semipalatinsk as a data base, the purpose has been in particular to evaluate amplitude variations across the array as well as compare NORSAR magnitude estimates to those of ISC and NEIS.

For the purpose of this study, NORSAR recordings of 25 presumed explosions from Semipalatinsk (Table VI.6.1) were used as a data base. The epicentral distance is about 38 degrees for these events, and Lg is usually only slightly stronger than the preceding P coda (Fig. VI.6.1). It is noteworthy that the coda energy stays significantly above the noise level for several minutes following Lg, in the case of high magnitude events. However, we have found that below $m_b = 5.5$ the noise influence on the Lg arrival becomes significant except during very quiet noise conditions.

We will first consider the amplitude variations across NORSAR for a given event. The significant variability of P amplitudes across NORSAR is well known, as illustrated in Fig. VI.6.2. The standard deviation is frequency dependent, and typically ranges from about 0.20 to 0.25 m_b units. Furthermore, the amplitude pattern is strongly regionally dependent (Berteussen and Husebye, 1974; Ringdal, 1977). Fig. VI.6.3 shows that the variability of the P coda is significantly lower (between 0.07 and 0.10 m_b units standard deviation of peak amplitudes in 30 second windows using a 0.6-3.0 Hz filter) and in fact remains fairly constant out to and beyond the Lg arrival. Furthermore, the variability of the P coda across NORSAR is similar to that of the noise preceding P, if equal time windows are used. If RMS values are considered, the standard deviations are slightly lower, and average about 0.06 m_b units.

We may therefore conclude that considering P coda or Lg reduces the receiver 'focusing' effects in the sense that the standard deviations across NORSAR are reduced by a factor between 2 and 3 compared to the first few cycles of P.

The near receiver 'focusing' effects observed for P-waves across NORSAR might be expected to have counterparts in near-source 'focusing'. Although the actual physical interpretation is uncertain, it is nevertheless clear that significant regionally dependent bias values are observed at NORSAR even within a very limited source area. Fig. VI.6.4 shows NORSAR m_b plotted against ISC m_b (or NEIS m_b where ISC data are not available). The most noteworthy feature is the consistently low NORSAR magnitudes for Degelen Mountains events compared to events from Shagan River. However, there is considerable variability even within the latter region. For the entire event set, the NORSAR bias (at instrument 01A04) varies from 0.0 to about 0.7 m_b units, with a mean of 0.42 and a standard deviation of 0.21. Since the amplitude pattern across NORSAR is fairly stable for Semipalatinsk events, these relative bias values remain also when averaging magnitudes across the NORSAR array.

Fig. VI.6.5 is similar to Fig. VI.6.4, except that NORSAR m_b is replaced by log RMS Lg amplitudes at NORSAR. The standard deviation is reduced to 0.10 logarithmic units, i.e., about half of that obtained using conventional m_b. Furthermore, the Degelen Mountain events now fall into the general trend of Shagan River events. As shown in Figure 6, the scatter between average and single instrument Lg observations is small.

We can conclude that magnitudes based on Lg effectively reduce bias due to near-receiver as well as near-source effects. The question of how accurately m_b estimates can be obtained using Lg from a single station (or an array) for a region like Semipalatinsk remains open, but it seems reasonable that the standard deviation of 0.10 m_b units represents an upper bound. Indeed, it is quite common that m_b estimates by NEIS and ISC differ by 0.1 m_b units or more, even though many of the same stations are used. Furthermore, about half of the stations used in these estimates are located in Central Europe, thus implying that the NEIS and ISC estimates may be severely biased because of the lack of homogeneous geographical station distribution. Thus it is quite possible that single station m_b (Lg) magnitudes may have an accuracy at least as good as those of NEIS or ISC. Additional improvements may of course be obtained by averaging Lg magnitudes from a well-distributed network of stations.

F. Ringdal

References

Berteussen, K.-A. and E.S. Husebye (1974): Amplitude pattern effects on NORSAR P-wave detectability, NTNF/NORSAR Sci. Report No. 1, 1974/75.

Ringdal, F. (1977): P-wave amplitudes and sources of scattering in m_b-observations, J. Geophys. 43, 611-622.

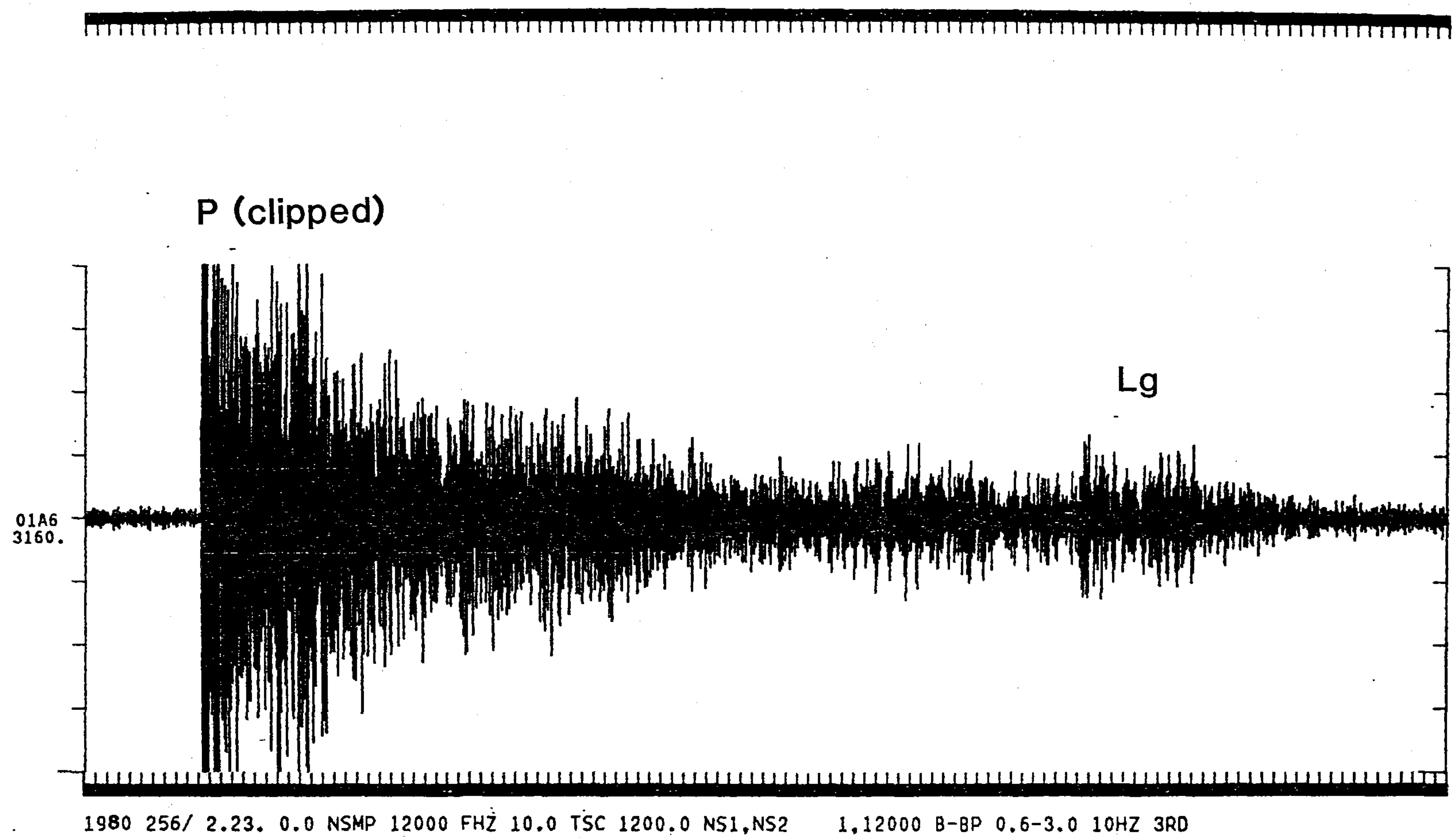

Fig. VI.6.1 Recordings on NORSAR instrument 01A06 for Event 22 of Table VI.6.1. The figure covers 20 minutes, and the data have been filtered in the band 0.6-3.0 Hz. For illustration purposes, the P signal has been clipped on the plot. Note that the P coda level exceeds the noise preceding P for the entire time window, and also that Lg is only slightly larger than the preceding P coda.

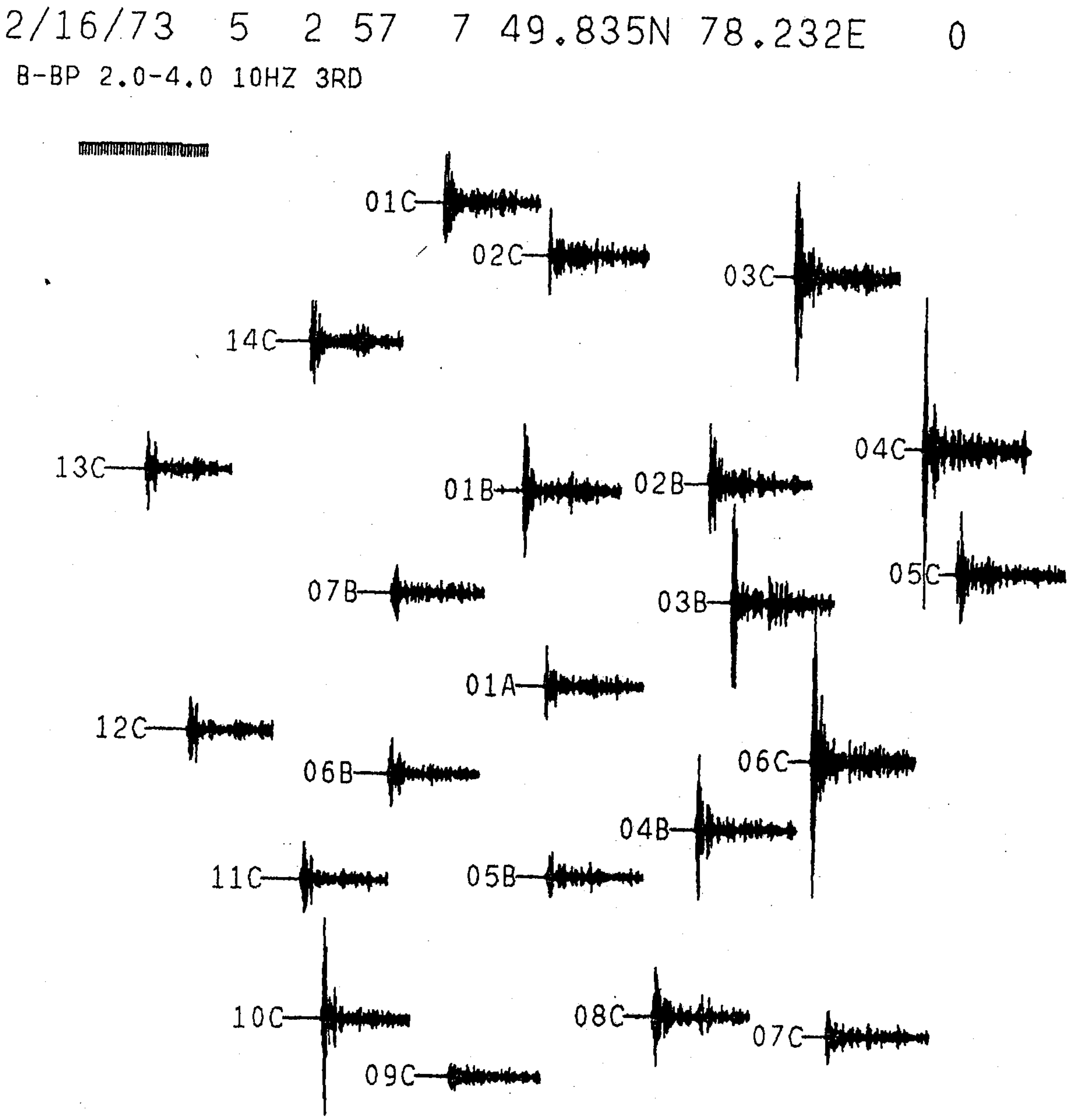

Fig. VI.6.2 Typical P-wave amplitude distribution across NORSAR for Semipalatinsk events. The figure covers 30 seconds of filtered SP data (2-4 Hz) for each center sensor of the 22 NORSAR subarrays. Amplitudes vary by a factor of 10 for the initial P onset, whereas the amplitude variation is less pronounced in the P coda.

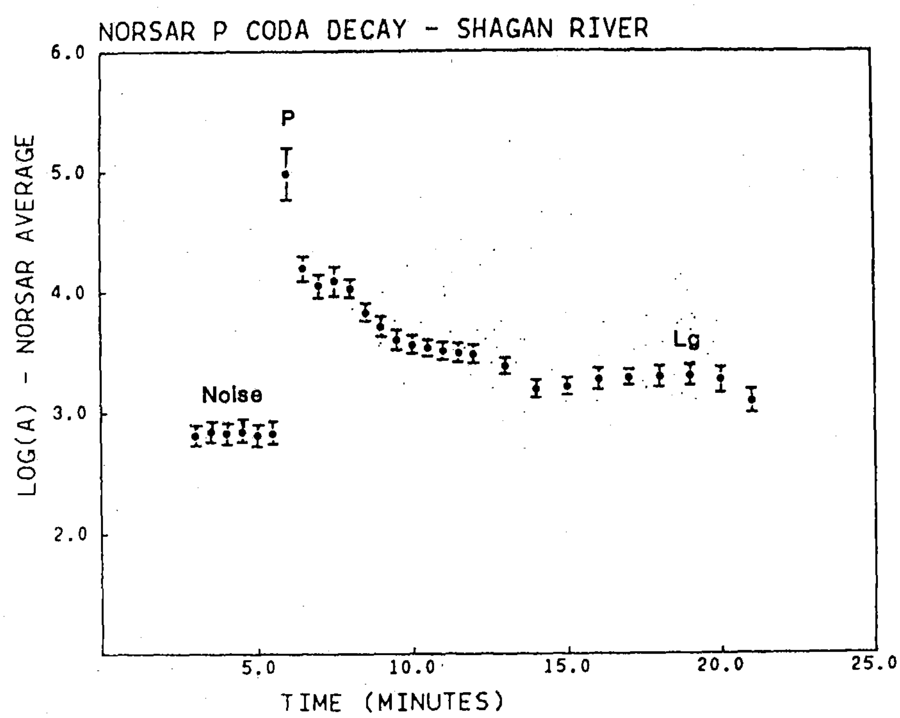

Fig. VI.6.3 Typical P coda decay of NORSAR recordings from Shagan River events. The standard deviations of peak amplitudes across NORSAR in 30 second windows are indicated by vertical bars. Data for the plot has been obtained by combining Events 2 and 8 of Table VI.6.1, and a filter of 0.6-3.0 Hz has been applied.

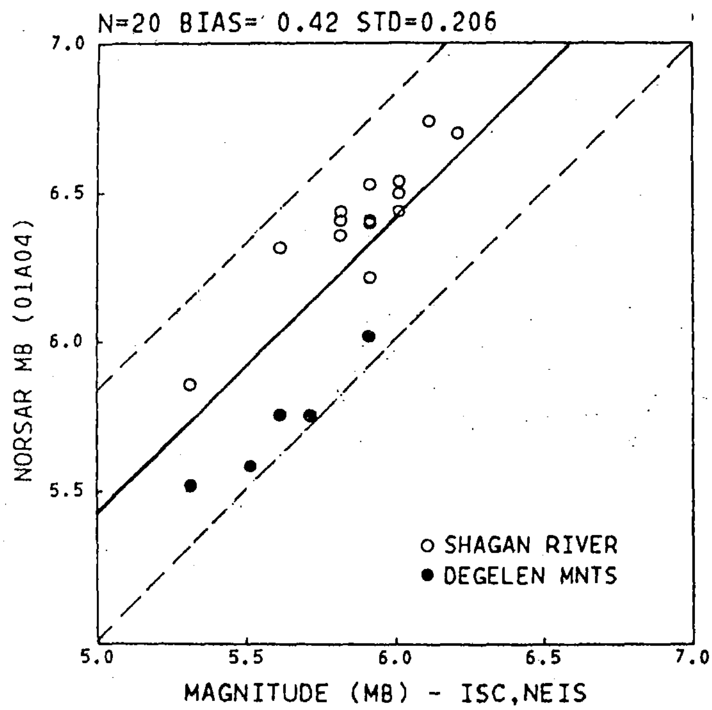

Fig. VI.6.4 NORSAR m_b (instrument 01A04) versus ISC or NEIS m_b (ISC data used when available). Note the difference in m_b bias between events from Shagan River and Degelen Mountains. The stippled lines correspond to plus and minus two standard deviations.

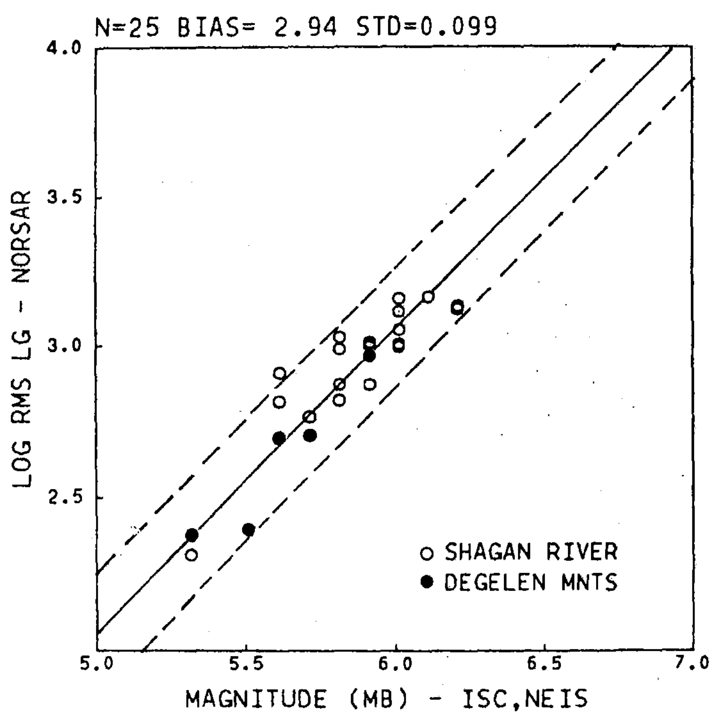

Fig. VI.6.5 Same as Fig. VI.6.4, except that NORSAR m_b has been replaced by an Lg energy estimate. This estimate has been obtained by averaging log RMS of individual NORSAR sensor traces filtered in the band 0.6-3.0 Hz. The time window is 2 minutes, starting 40 seconds before Lg arrival. Note that Shagan River and Degelen Mountain events now show good consistency.

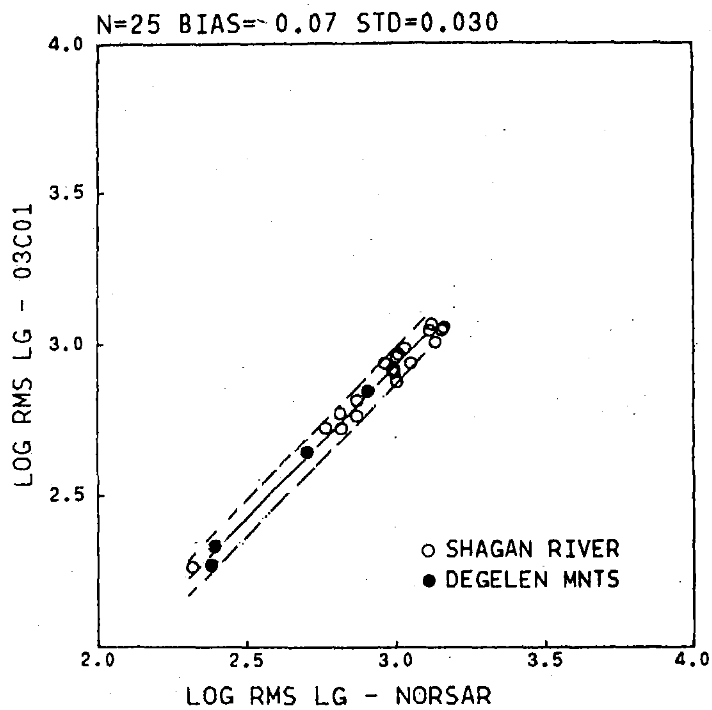

Fig. VI.6.6 Comparison of single sensor Lg energy estimate (subarray 03C, instrument 1) to the average values across NORSAR.

EVENT	DATE	OR. TIME	LAT	LON	MB NEIS	MB ISC	MB NORSAR	LOG LG ARRAY	STD	LOG LG 03C1
1	05/29/77	02 56 57	49.944N	78.846E	5.6	5.8	6.34	2.80	0.069	2.71
2	06/29/77	03 06 57	50.034N	78.927E	5.3	5.3	5.84	2.30	0.053	2.25
3	09/05/77	03 02 57	50.092N	78.961E	5.9	5.8	6.42	2.98	0.070	2.90
4	04/25/71	03 32 57	49.823N	78.092E	5.9	5.9	6.00	2.95	0.057	2.92
5	03/26/78	03 56 57	49.734N	78.074E	5.5	5.6	5.74	2.68	0.053	2.63
6	04/22/78	03 06 57	49.720N	78.175E	5.3	5.3	5.50	2.36	0.058	2.26
7	06/11/78	02 56 57	49.879N	78.838E	5.9	5.9	6.38	2.86	0.061	2.80
8	07/05/78	02 46 57	49.839N	78.906E	5.8	5.8	6.34	2.85	0.056	2.75
9	07/28/78	02 46 57	49.744N	78.168E	5.7	5.7	5.74	2.69	0.058	2.63
10	09/15/78	02 36 57	49.898N	78.925E	6.0	6.0	6.48	2.98	0.064	2.90
11	11/04/78	05 05 57	50.046N	78.983E	5.6	5.6	6.30	2.89	0.056	2.83
12	06/23/79	02 56 57	49.918N	78.915E	6.3	6.2	6.68	3.12	0.054	2.99
13	07/07/79	03 46 57	50.053N	79.065E	5.8	5.8	6.39	3.02	0.067	2.97
14	08/04/79	03 56 57	49.901N	78.959E	6.1	6.1	6.72	3.15	0.059	3.04
15	10/28/79	03 16 56	49.967N	79.060E	6.0	6.0	6.42	3.10	0.064	3.03
16	12/02/79	04 36 57	49.894N	78.843E	6.0	6.0	6.52	2.99	0.067	2.94
17	05/22/80	03 56 57	49.729N	78.100E	5.5	5.5	5.57	2.38	0.048	2.32
18	06/29/80	02 32 57	49.920N	78.849E	5.7	5.7	-	2.75	0.048	2.71
19	10/12/80	03 34 14	49.958N	79.085E	5.9	-	6.20	2.99	0.067	2.86
20	12/14/80	03 47 06	49.932N	79.005E	5.9	-	6.39	3.00	0.052	2.95
21	04/22/81	01 17 11	49.901N	78.901E	5.9	-	6.51	2.98	0.043	2.89
22	09/13/81	02 17 18	49.882N	78.971E	6.0	-	-	3.14	0.075	3.03
23	10/18/81	03 57 02	49.891N	78.877E	6.0	-	-	3.04	0.056	2.92
24	11/29/81	03 35 08	49.847N	78.852E	5.6	-	-	2.80	0.057	2.76
25	12/27/81	03 43 14	49.923N	78.876E	6.2	-	-	3.11	0.080	3.05

Table VI.6.1 List of events used in this study. The table gives event no., date, origin time, magnitude (m_b) by NEIS, ISC and NORSAR (instrument 01A04), log RMS Lg averaged across NORSAR and the corresponding standard deviation and log RMS Lg measured on instrument 03C01. Note that ISC and NORSAR mb values are not available for all events.