Royal Norwegian Council
for Scientific and Industrial Research
(NTNF)

NORSAR

NORSAR Scientific Report No. 1-89/90

Semiannual Technical Summary

1 April — 30 September 1989

Kjeller, December 1989

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

7.3 Analysis of data from the China Digital Seismograph Network (CDSN) for Soviet nuclear explosions

This paper is a follow-up to earlier work (Ringdal and Marshall, 1989; Hansen *et al*, 1989) aimed at evaluating the stability of seismic Lg magnitudes for yield estimation purposes. In particular, these efforts have involved analyzing available Lg data from Soviet nuclear explosions at the Shagan River, Semipalatinsk test site, and conducting comparative analyses of Lg and P recordings at various seismograph stations.

Hansen *et al* (1989) analyzed data recorded at four digital stations installed by IRIS in the Soviet Union, and found an excellent correspondence between Lg measurements at these stations and the NORSAR M(Lg) estimates published by Ringdal and Marshall (1989). Furthermore, they noted the very high Lg signal-to-noise ratio observed at the IRIS stations, in particular ARU and GAR, and concluded that reliable Lg measurements at these stations would be possible for explosions as small as $m_b = 4.0$, assuming normal noise conditions.

In this paper, we extend the analysis to data from the China Digital Seismograph Network (CDSN), which is operated by the USGS in cooperation with the State Seismological Bureau, Beijing. Two of the CDSN stations, WMQ in Urumqi and HIA in Hailar, have particularly good Lg propagation paths from Semipalatinsk, and we have based our analysis on data from these two stations.

Fig. 7.3.1 shows the locations of the two stations in relation to the test site, as well as locations of the NORSAR and the IRIS stations. WMQ has an epicentral distance to Shagan River of 960 km, whereas HIA is at a distance of about 3000 km. Both stations show excellent Lg recordings of Semipalatinsk explosions, as illustrated by the examples in Figs. 7.3.2 and 7.3.3.

In our analysis of WMQ and HIA Lg recordings, we have employed the exact same procedure as described for IRIS data by Hansen *et al* (1989), and the details will not be repeated here. Data from a total of 12 Shagan River explosions, dating back to 1987, were provided to us for this analysis by the Center for Seismic Studies. Table 7.3.1 lists these events along with the estimated parameters.

Fig. 7.3.4 shows a comparison of WMQ and NORSAR log RMS (Lg) estimates for these 12 events. The slope of the plot has been restricted to 1.00, and the standard deviation of the differences between the two stations is only 0.034 units. This is essentially the same scatter found earlier by Hansen *et al* (1989) when comparing data from NORSAR and the Soviet station ARU, and confirms the excellent stability of the RMS Lg estimates.

Fig. 7.3.5 shows a comparison of HIA and NORSAR log RMS (Lg) estimates. In this case, the slope of the least squares linear relationship (1.48) is significantly different from unity, and we note that a similar observation was also made by Ringdal and Marshall (1989) when comparing NORSAR and Gräfenberg Lg. We will not go into any detail discussing possible underlying physical reasons for this variability in slopes. For our purpose, the important point is to note that the scatter of the relationship is still very small; the standard deviation in the y-axis direction being 0.041 units. The "orthogonal" standard deviation relative to the straight line fit is 0.023, which in fact compares very closely to the orthogonal standard deviation of 0.024 which can be inferred from the WMQ-NORSAR data shown in Fig. 7.3.4.

In Fig. 7.3.6 we plot the HIA versus WMQ log RMS (Lg) values, and again observed that the least-squares slope (1.36) is significantly different from unity. Once more, the scatter is very small, with an orthogonal standard deviation of 0.028 units.

Fig. 7.3.7 is a plot comparing WMQ Lg data with maximum likelihood ISC m_b estimates. Compared to the previous figures, this plot shows a somewhat greater standard deviation of 0.060 measured in the y-axis direction. This scatter is still quite small, but it must be noted that only one event from the northeast part of Shagan is in the data base. Thus, we cannot assess whether the M(Lg) versus m_b bias earlier found for this subregion (Ringdal and Marshall, 1989) is also present when measuring Lg at WMQ.

Finally, Fig. 7.3.8 compares the signal-to-noise ratios (defined as Lg signal to pre-P noise) for stations at various distances, using 5 large explosions. It is noteworthy that WMQ shows the best SNR for all the events. The figure suggests that WMQ would be able to give Lg measurements for events two magnitude units smaller than the NORSAR threshold of approximately 5.5. Unfortunately, there were no low magnitude events in our data base, so we have not been able to confirm this hypothesis.

In conclusion, our studies confirm that Lg magnitude estimates of Semipalatinsk explosions are remarkably consistent between stations widely distributed in epicentral distance and azimuth. It thus appears that a single station with good signal-to-noise ratio can provide M(Lg) measurements with an accuracy (one standard deviation) of about 0.03–0.04 magnitude units. Thus, the Lg phase shows considerable promise for use in yield determination, although more data will be needed before the accuracy of Lg-estimated yields can be firmly established.

R.A. Hansen
F. Ringdal

References

Hansen, R.A., F. Ringdal and P.G. Richards (1989): Analysis of IRIS data for Soviet nuclear explosions, *NORSAR Semiannual Tech. Summary, 1 Oct 1988 - 31 Mar 1989*, NORSAR Sci. Rep. 2-88/89.

Ringdal, F. and P.D. Marshall (1989): Yield determination of Soviet underground nuclear explosions at the Shagan River Test Site, *NORSAR Semiannual Tech. Summary, 1 Oct 1988 - 31 Mar 1989*, NORSAR Sci. Rep. 2-88/89.

No.	Date	m_b	NAO Lg	WMQ Lg	HIA Lg
1	87171	6.03	3.012	3.851	2.189
2	87214	5.83	2.911	3.693	2.072
3	87319	5.98	3.014	3.870	2.298
4	87347	6.06	3.133	3.907	2.352
5	87361	6.00	3.086	3.851	2.339
6	88044	5.97	3.082	3.911	–
7	88094	5.99	3.103	3.925	2.307
8	88125	6.09	3.084	3.958	–
9	88258	6.03	3.014	3.827	2.224
10	88317	5.20	2.307	3.104	–
11	88352	5.80	2.846	3.636	1.947
12	89043	5.90	2.836	3.619	1.921

Table 7.3.1 Magnitudes (m_b) and log RMS Lg values at NORSAR, WMQ and HIA for 12 explosions analyzed in this study.

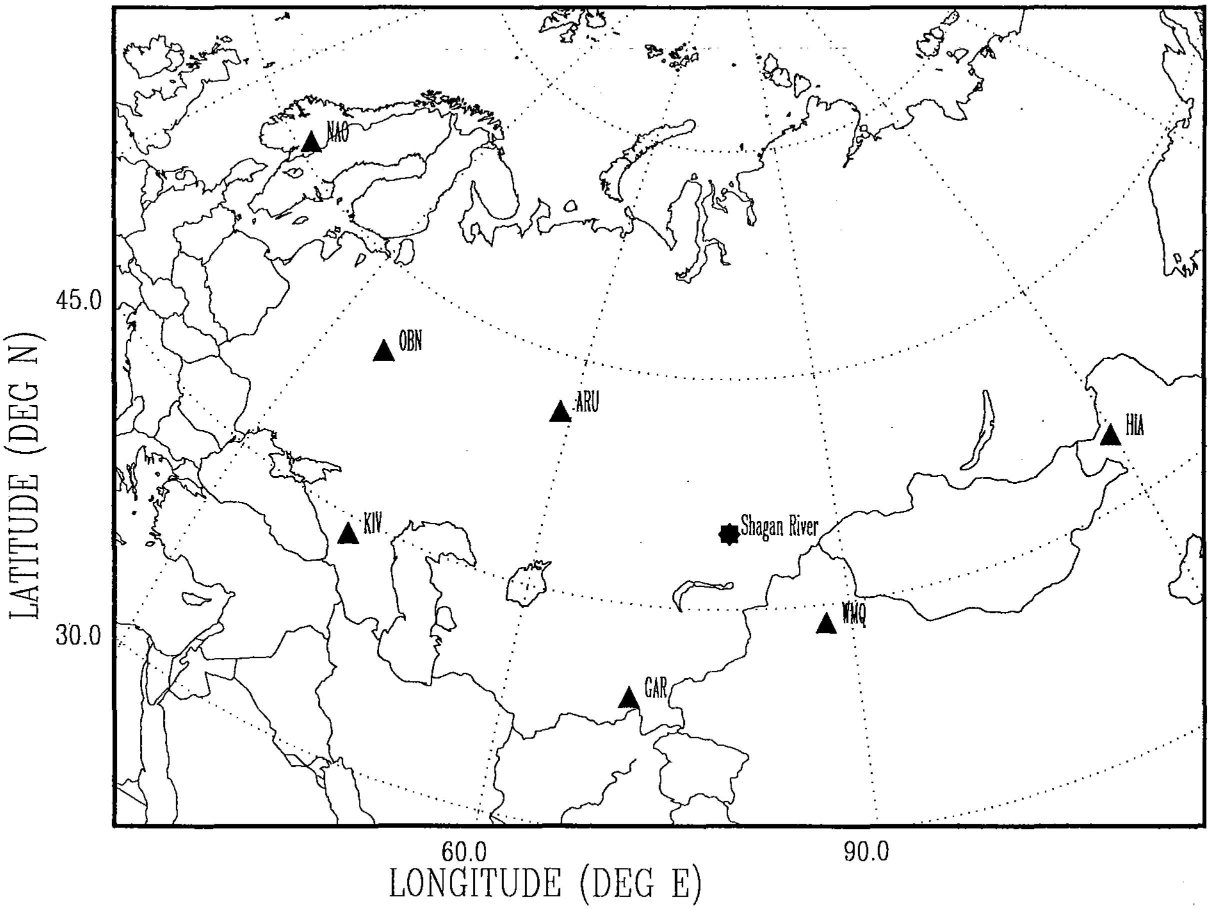

Fig. 7.3.1 Map indicating the locations of the Shagan River Test Site, the IRIS stations in the USSR, the NORSAR array in Norway and the stations WMQ and HIA in China.

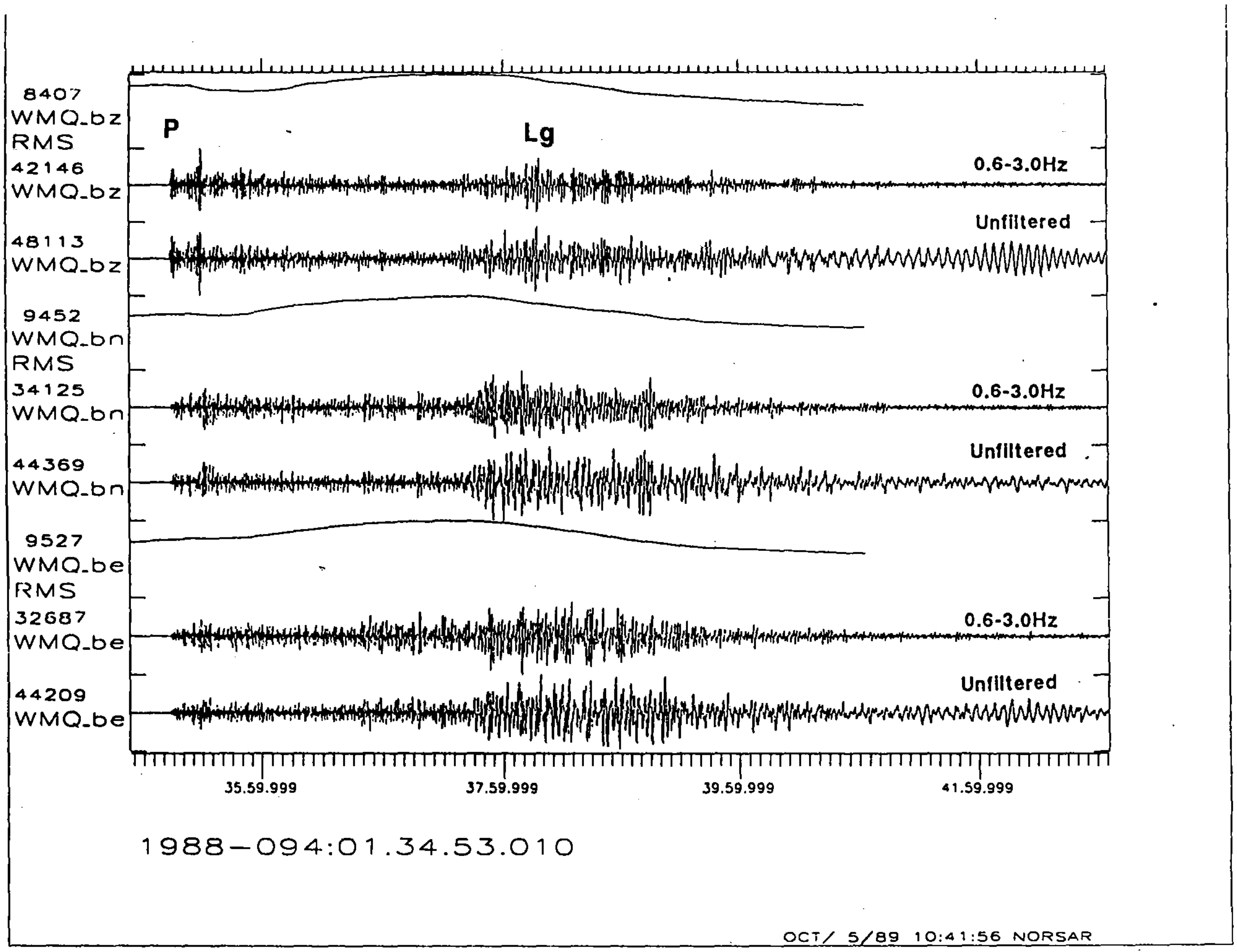

Fig. 7.3.2 Example of recordings from a Soviet nuclear explosion (3 April 1988) at the station WMQ. For each of the three components we show the unfiltered trace (bottom), the filtered trace (0.6–3.0 Hz) and the 120-second window RMS measure (top) as a function of time.

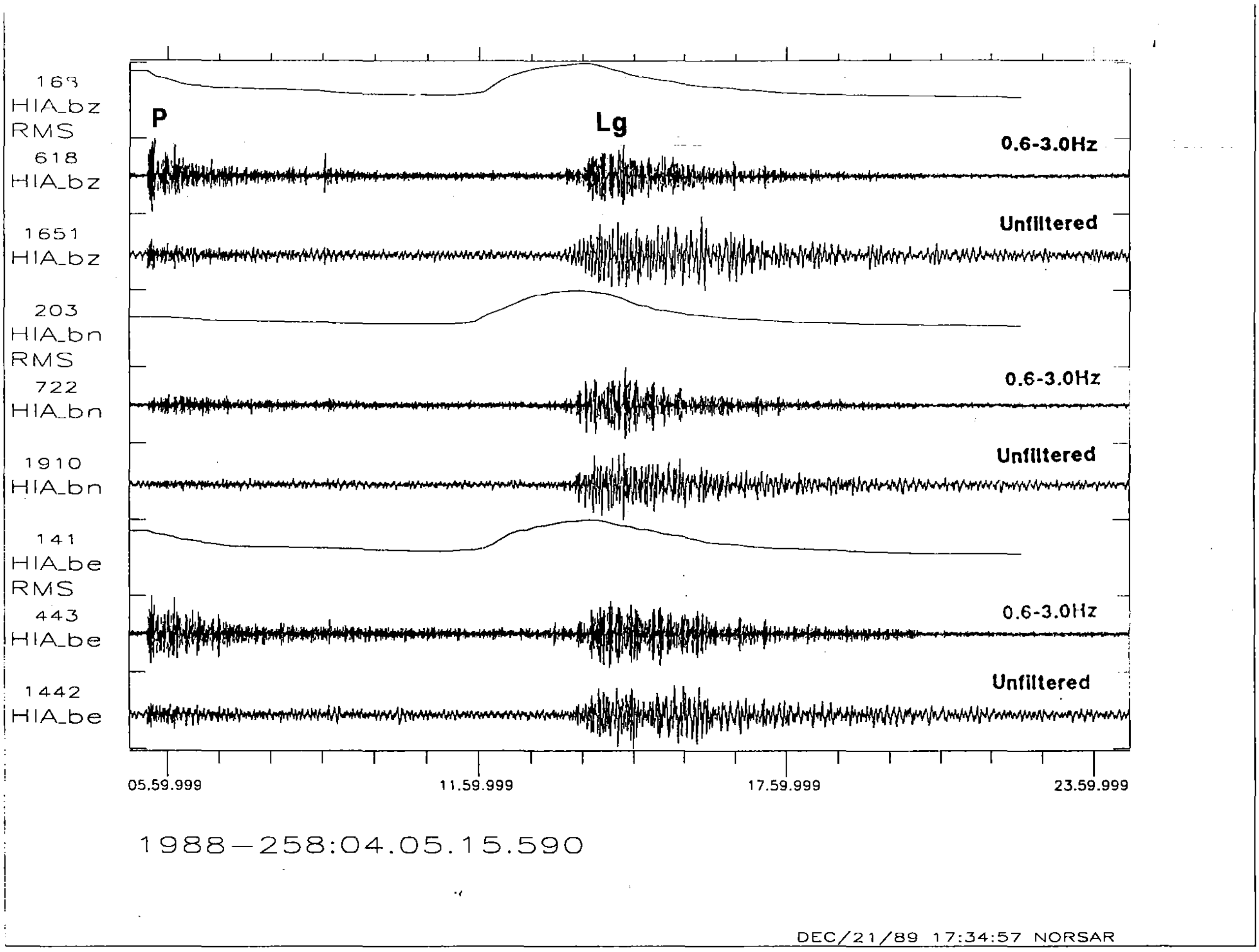

Fig. 7.3.3 Example of recordings from the Soviet JVE explosion (14 Sep 1988) at the station HIA. The three traces for each component are as on Fig. 7.3.2.

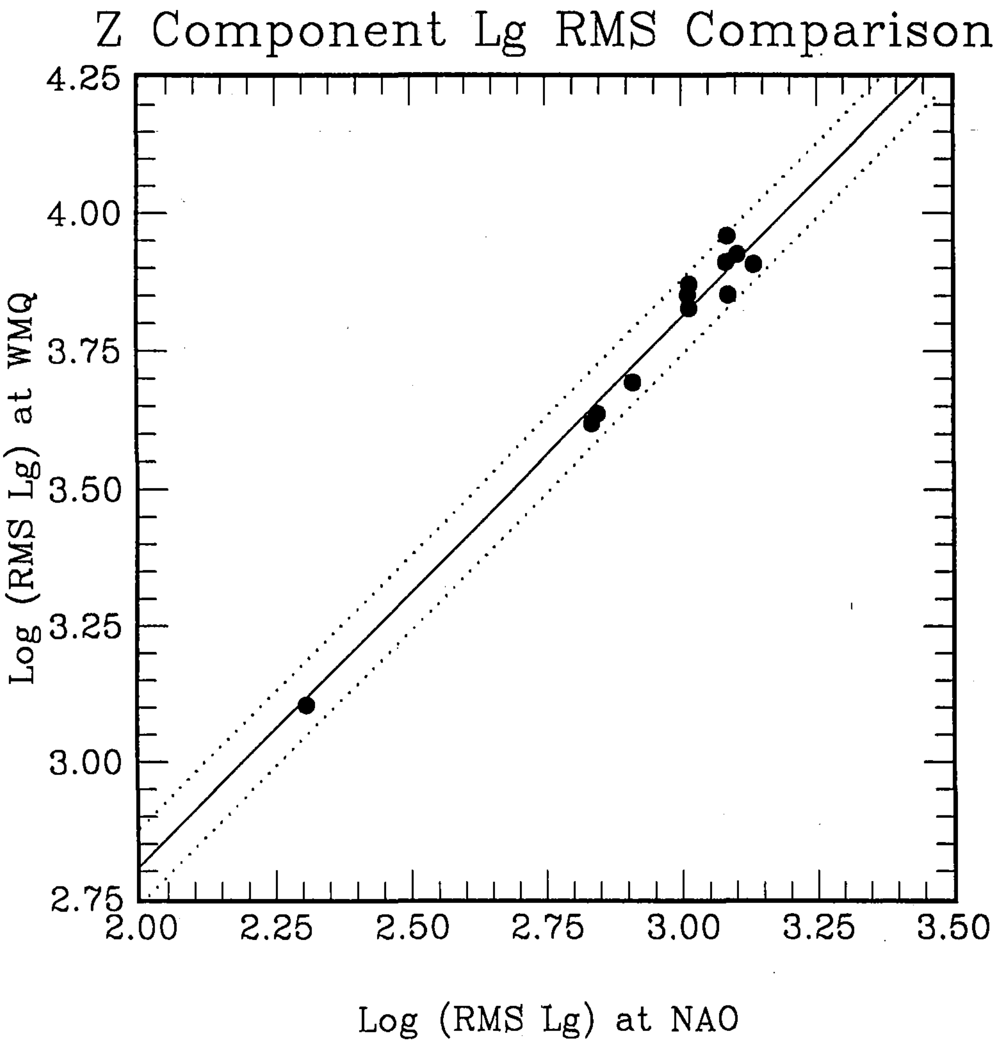

Fig. 7.3.4 Comparison of log RMS Lg measurements obtained at WMQ and NORSAR. The standard deviation of the differences is 0.034 in the y-direction and 0.024 orthogonal to the line. The dotted lines correspond to plus or minus two standard deviations.

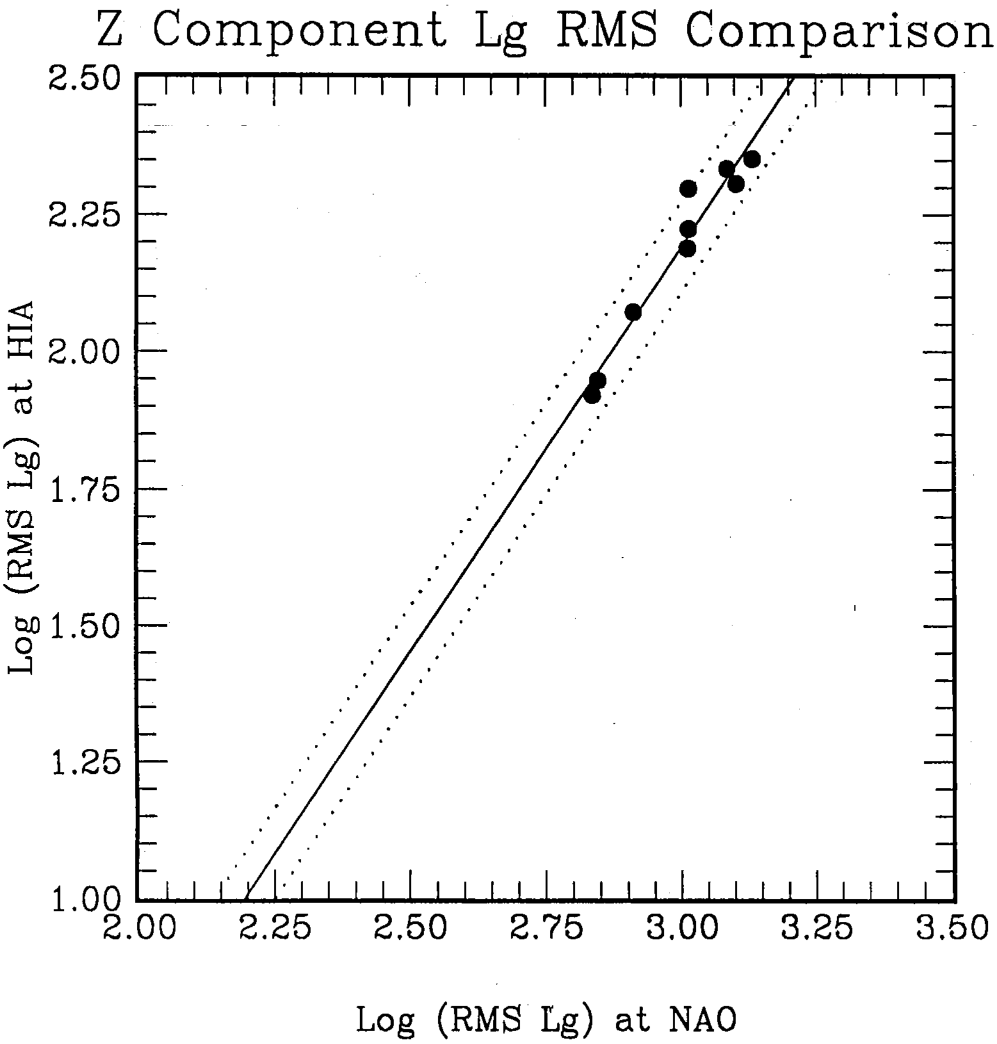

Fig. 7.3.5 Comparison of log RMS Lg measurements at HIA and NORSAR. The slope of the line is 1.48 and the standard deviation of the misfit of the line to the data is 0.04 in the y-direction and 0.023 orthogonal to the line. The dotted lines correspond to plus or minus two standard deviations.

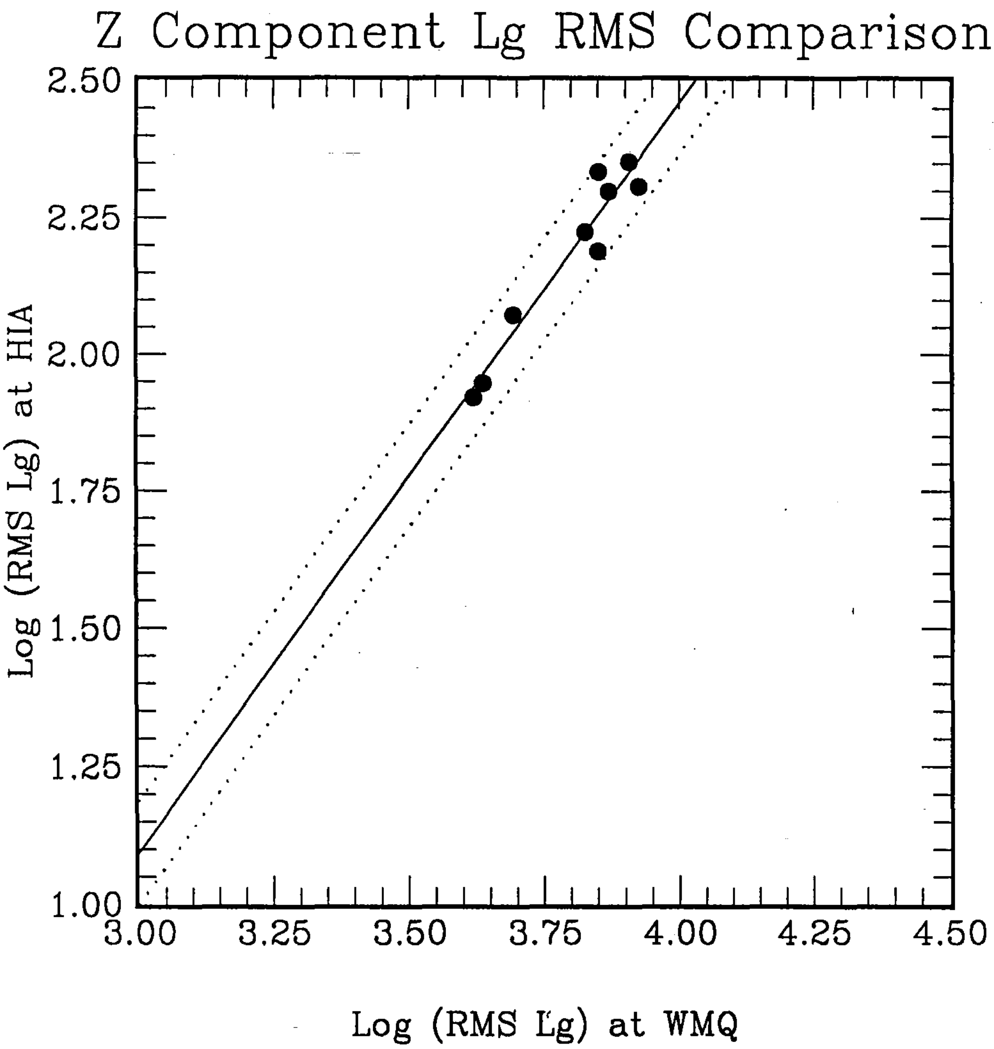

Fig. 7.3.6 Comparison of log RMS Lg measurements at HIA and WMQ. The slope of the line is 1.36 and the standard deviation of the misfit of the line to the data is 0.047 in the y-direction and 0.028 orthogonal to the line. The dotted lines correspond to plus or minus two standard deviations.

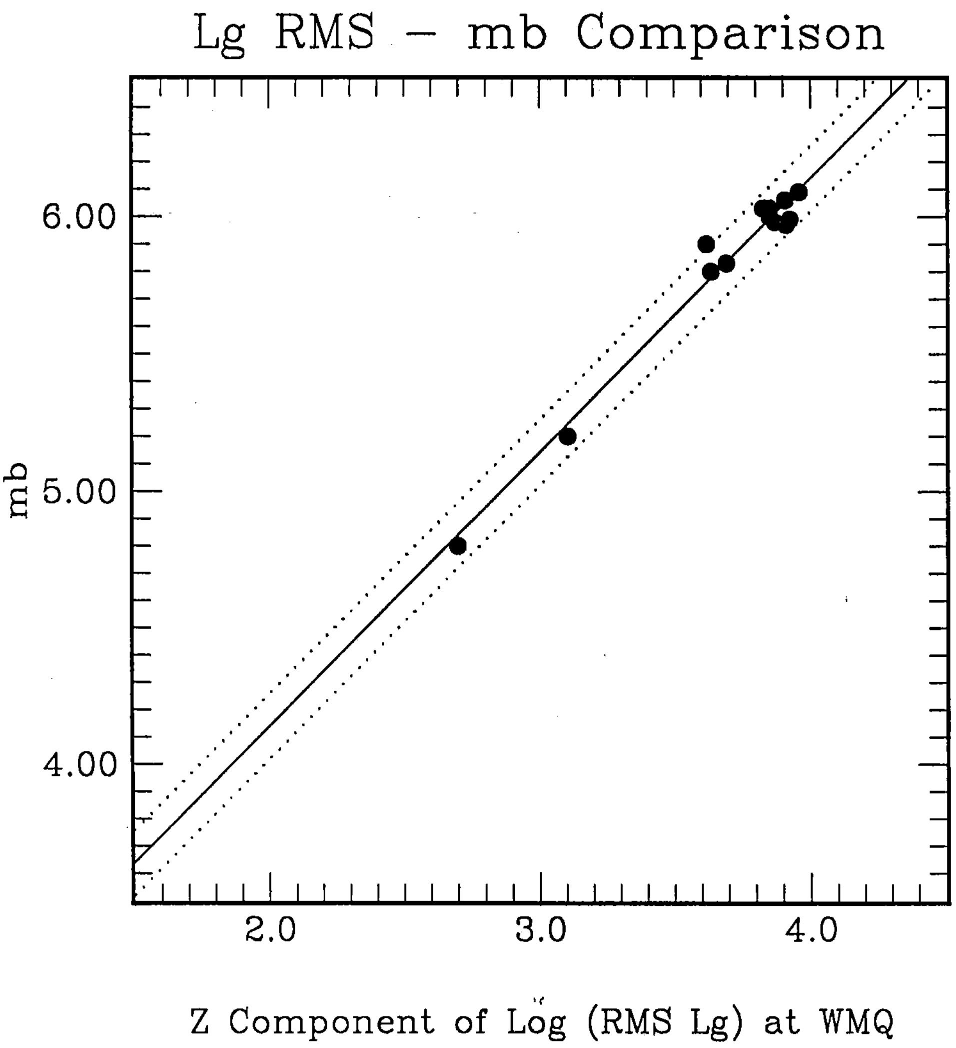

Fig. 7.3.7 Comparison of log RMS Lg at WMQ to world-wide m_b magnitude. Standard deviation is 0.060 units in the y-direction and 0.042 orthogonal to the line. The dotted lines correspond to plus or minus two standard deviations.

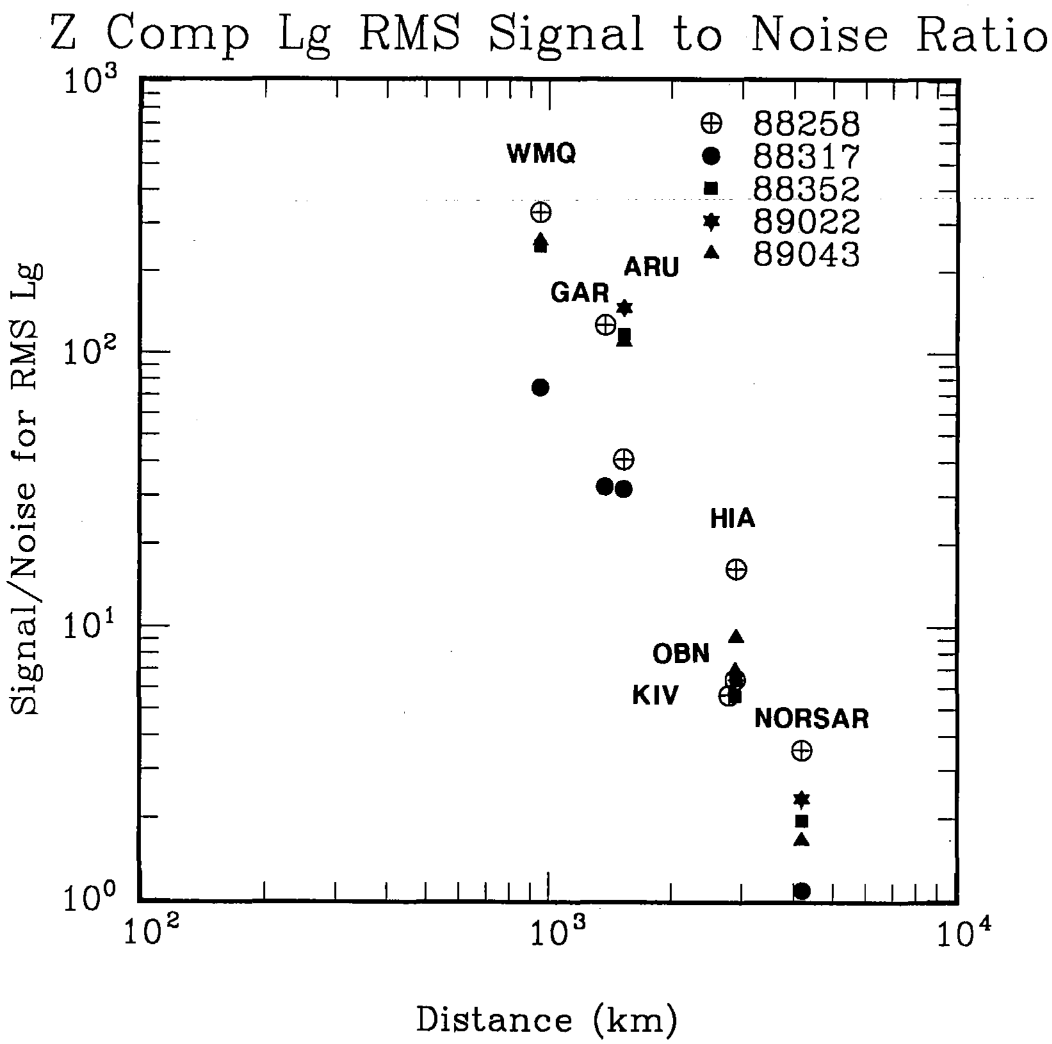

Fig. 7.3.8 Graph showing the variation of the signal-to-noise ratios (log RMS minus log RMS noise) from the four IRIS stations, the NORSAR array and the CDSN stations WMQ and HIA. Epicentral distance to the test site is plotted along the horizontal axis.