Treaty verification

Seismic noise and a test ban

from Thomas C. Bache

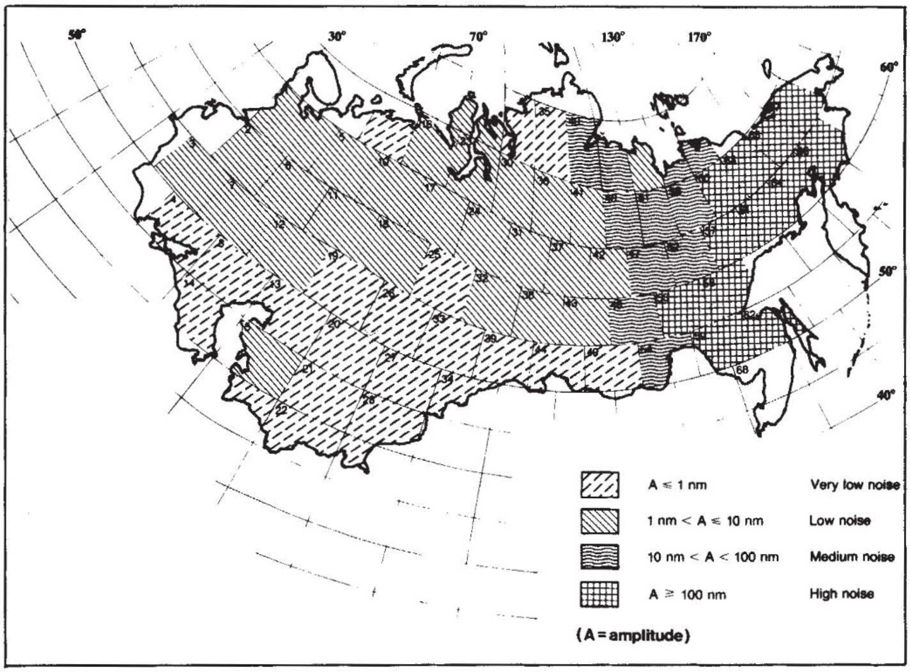
ONE of the major obstacles to agreement on a comprehensive test ban treaty (CTBT) on nuclear explosions is the concern about 'verification' — that is, the ability to detect and identify clandestine explosions. There has been a continuing debate among Western seismologists about the possibility of verification through a network of seismic stations located entirely outside the Soviet Union, but the consensus is that a significant clandestine testing programme could be concealed from such a network. Therefore, the United States and United Kingdom have always insisted that stations inside the Soviet Union are required for a verifiable treaty. For many years the Soviet Union rejected this position, but in the 1977–1980 negotiations, it agreed, in principle, to allow internal seismic stations for verification purposes, although many contentious issues about the numbers, locations and design of these stations remained unresolved when the negotiations went into recess in November 1980.

The most important advantage of internal stations is that they increase the network sensitivity; that is, they lower the threshold for detection of small events (or small signals from disguised explosions). Seismologists have developed simulation programs that map the detection threshold for different seismic network configurations[1,2], and the output of these programs depends on assumptions about signal amplitude decay as a function of distance and about the ambient 'noise' level at the stations (detection is essentially a function of the signal-to-noise ratio). Seismic noise is the ground motion background, out of which must be picked the discrete signals from earthquakes and explosions. Because it varies from region to region and site to site, actual data are needed to estimate the noise background even to within an order of magnitude, but there is an immense lack of reliable data from within the Soviet Union. In a report[3] published in 1984, P.W. Rodgers and A.J. Piwinskii of Lawrence Livermore National Laboratory have compiled the best available noise information from the Soviet literature.

The report includes an appendix with brief summaries of the twenty publications found to contain relevant information. Unfortunately, only a few of these give any useful data, and the data are very difficult to interpret because there is little description of how the noise measurements were made. (Attempts to resolve the problems by correspondence met with no success.) The most useful data on noise were found in a monograph by Rykunov[4] which gives noise estimates at 4, 5, 6 and 7 second periods for 3 x 10^5 km^2 quadrangles covering the entire country. Since the monograph does not say how these numbers were determined, Rodgers and Piwinskii assume they are spatially and temporally averaged peak-to-peak amplitudes in micrometers. Furthermore, the character of the tabulated values suggests that they are based on some interpolation or smoothing of values determined from seismograms recorded on paper. The most useful data from the internal stations are likely to be at frequencies of 1 Hz and more, so the most relevant results in the report appear on the 1-second noise map (reproduced here). The map was obtained by extrapolating from the Rykunov values at 4, 5 and 6 seconds, which is not an unreasonable procedure given the paucity of the information, but is certainly controversial.

The map seems to represent the best noise data available from within the Soviet Union but, unfortunately, will be of little help in making confident estimates of the ability to verify a CTBT. One reason is that the map gives so little information: very large regions are represented by a single value and we can only guess what this value actually means. Beyond that there are some surprising features of the map that are difficult to believe without corroborating evidence. For example, the range of 'average' noise spans more than two orders of magnitude, much more than on apparently comparable maps of North America. Also, for huge areas, the average noise at one-second periods is less than 1 nanometer. Such a low level of noise has only been observed at specially selected sites in North America[5]. Moreover, stations in adjacent countries (including Iran, Afghanistan and Turkey) are not so quiet.

The difficulty of estimating noise levels is typical of those encountered in addressing nearly all of the geophysical issues involved in estimating monitoring capabilities or in deciding whether or not Soviet explosions have exceeded the 150 Kt limit of the Threshold Test Ban Treaty. There is a vast open literature on nuclear explosions and earthquakes occurring in the United States and recorded at internal and external stations. Digital seismograms of such events and of station noise are openly available from the US Geological Survey. In contrast, though the Soviet Union apparently has an extensive research programme in seismology, few results and almost no usable data appear in open sources. As an example, while many Soviet stations routinely report the arrival time and amplitude of detected signals to the International Seismic Center in England, data on signals from nuclear explosions are always deleted from the reports. Thus, as far as a CTBT is concerned, poorly supported assumptions based on data recorded outside the Soviet Union are required to estimate the potential capability of stations within it. This is a major reason for the large differences in published estimates[2,5] of how effective such stations would be in assuring Western nations that the Soviet Union was actually complying with a comprehensive test ban treaty. □



1. Evernden, J.F. *Bull. Seis. Soc. Am.* **66**, 281 (1976).
2. Hannon, W.J. *Ener. & Tech. Rev. UCRL – 5200 – 83-5*, 50 (1983).
3. Rodgers, P.W. & Piwinskii, A.J. *Seismic Noise in the U.S.S.R. UCRL - 53328* (Lawrence Livermore National Laboratory, 1982).
4. Rykunov, L.N. *Microseisms, Experimental Characteristics at Periods 0.07-8 Seconds* (Nauka Press, Moscow, 1967).
5. Sykes, L. & Evernden, J.F. *Scient. Am.* **247**, 47 (1982).

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