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7.7 Initial results of a newly installed acoustic array in Apatity

During the summer of 1994 a new type of sensors was incorporated in the existing data acquisition system of the Kola Regional Seismological Centre (KRSC) of the Russian Academy of Science (RAS). Three liquid microbarographs were installed at the Apatity seismic array site making up a triangle with the vertices beside the A1, A2 and A3 seismic sensors.

There are many natural and artificial phenomena that may be analyzed by such a device. Since the 1970s, there has been steady interest in developing an infrasound data acquisition system to detect, locate, identify and investigate the infrasonic waves generated by volcanoes (Tahira, 1982), ionospheric disturbances and geomagnetic activity in the polar regions (Maeda and Watanabe, 1964; Wilson, 1975), meteor-generated infrasound (Revelle et al, 1975), and infrasonic signals from thunderstorms (Few, 1970; Pibner & Rey, 1982). Microbarographs or geophones are widely used to provide an additional source of information to be utilized in detecting explosions (Cox et al, 1954; Glasstone & Dolan, 1977; Reed, 1989), rockets (Kaschak et al, 1970; Donn et al, 1975) and in investigations of stratosphere winds and temperatures (Rind & Donn, 1978).

Fig. 7.7.1 displays the array geometry along with the newly installed devices.

Installation and testing

Liquid microbarographs allow recording of infrasound signals in the most interesting frequency range 0.01-1 Hz and are simple to operate. This is the reason why this type of sensor has been selected.

A typical liquid microbarograph design is shown in Fig. 7.7.2. One of the input holes (4) is kept open into the atmosphere; the other is coupled with a volume (not shown) separated from the atmosphere. The relative liquid level in the capacitors (2) changes under a difference between the atmospheric pressure and the pressure in the volume. Deviations of the liquid level from the balance are transformed into an electric signal by a capacity-voltage converter.

Microbarographs are installed on concrete basements coupled with the bedrock. The outputs are connected to the analog-to-digital converter (ADC) in the central hub by symmetric communication lines in order to suppress interference. Three spare channels of the existing data acquisition system, sampling rate 40 Hz, were used to transfer data to the KRSC in Apatity. The effective frequency band of infrasound data is restricted to 0.1-1 Hz because these channels were originally designated to register seismic data with a sampling rate of 40 Hz. Therefore the frequency band and sampling rate are not quite conforming with infrasound signals. However, the bandwidth is large enough to record most interesting phenomena except the internal gravitational waves and pressure disturbances stimulated by aurora.

The operation of a set of infrasound sensors and of a seismic array is similar, therefore the microbarographs' relative phase responses should be either identical or carefully measured. To obtain the relative phase shifts the following measurements have been made:

All sensors were placed close to one another near the central hub and were linked with the data acquisition system. The input holes of sensors normally opened into the atmosphere were coupled by rubber tubes with a single puncture. Such a connection implies that the pressure in the measuring chambers of the microbarographs will be identical; thus the phase shifts between sensor outputs yield the relative phase responses. The data were recorded during several hours. For further processing, time histories free of spikes of about an hour in length have been chosen. To estimate relative phase shifts and coherency of signals, the method described in Bendat and Piersol (1986) has been applied.

Fig. 7.7.3a shows the coherency of the output signal; Fig. 7.7.3b represents the phase shifts. The high coherency of the analyzed signals confirms that the estimates are confident. These results will be used further by more comprehensive software when estimating arrival angles of infrasound signals.

The next step was to assess the threshold sensitivity. Fig. 7.7.4a and 7.7.4b show the response of the recording system obtained by imposing a step function 25.0 dyne/cm^2 and 2.5 dyne/cm^2 amplitude to the input of a microbarograph, respectively. In spite of this estimation being quite rough, it can be concluded that the threshold pressure sensitivity is of the order of 1 dyne/cm^2.

Software installed at the SUN workstation in KRSC extracts infrasound data from the data stream, filters it by an anti-aliasing Butterworth low pass filter with corner frequency 1.5 Hz and slope 80 dB/decade, resamples it to 4 Hz sampling rate and stores the outcome on the hard disk afterwards.

Infrasound recordings are often affected by wind-initiated air turbulence near the ground; hence careful data selection is necessary before the processing. An effective indicator of a true infrasound signal is the coherency between the sensor outputs. Fig. 7.7.5a and 7.7.5b present two samples of the quick-look plots obtained by calculating coherency spectra between MB1 and MB2 during 15-minute time intervals. The first sample may be associated with either a windy day when coherence was zeroed by uncorrelated noise or with the absence of an infrasound signal. The second sample shows two bursts of coherent signals for which further processing can be advantageous.

Initial recordings

As an sample illustrating the interaction of a seismo-acoustic system, we present two recordings of quarry explosions at the Rassvumchorr plateau (Khibiny Massif) about 33 km from the array site. In Figs. 7.7.6 and 7.7.7 the three top traces represent the acoustic data, whereas the next 15 traces are recordings of 9 Apatity seismic array elements, together with the broad-band 3-component station (APZ9) in the city of Apatity and the high-frequency 3-component station situated at the center of the array site.

As is clearly seen from these figures, the installed infrasound sensors integrated into the existing data acquisition system KRSC RAS may be successfully used for investigating artificial and natural disturbances in the atmosphere.

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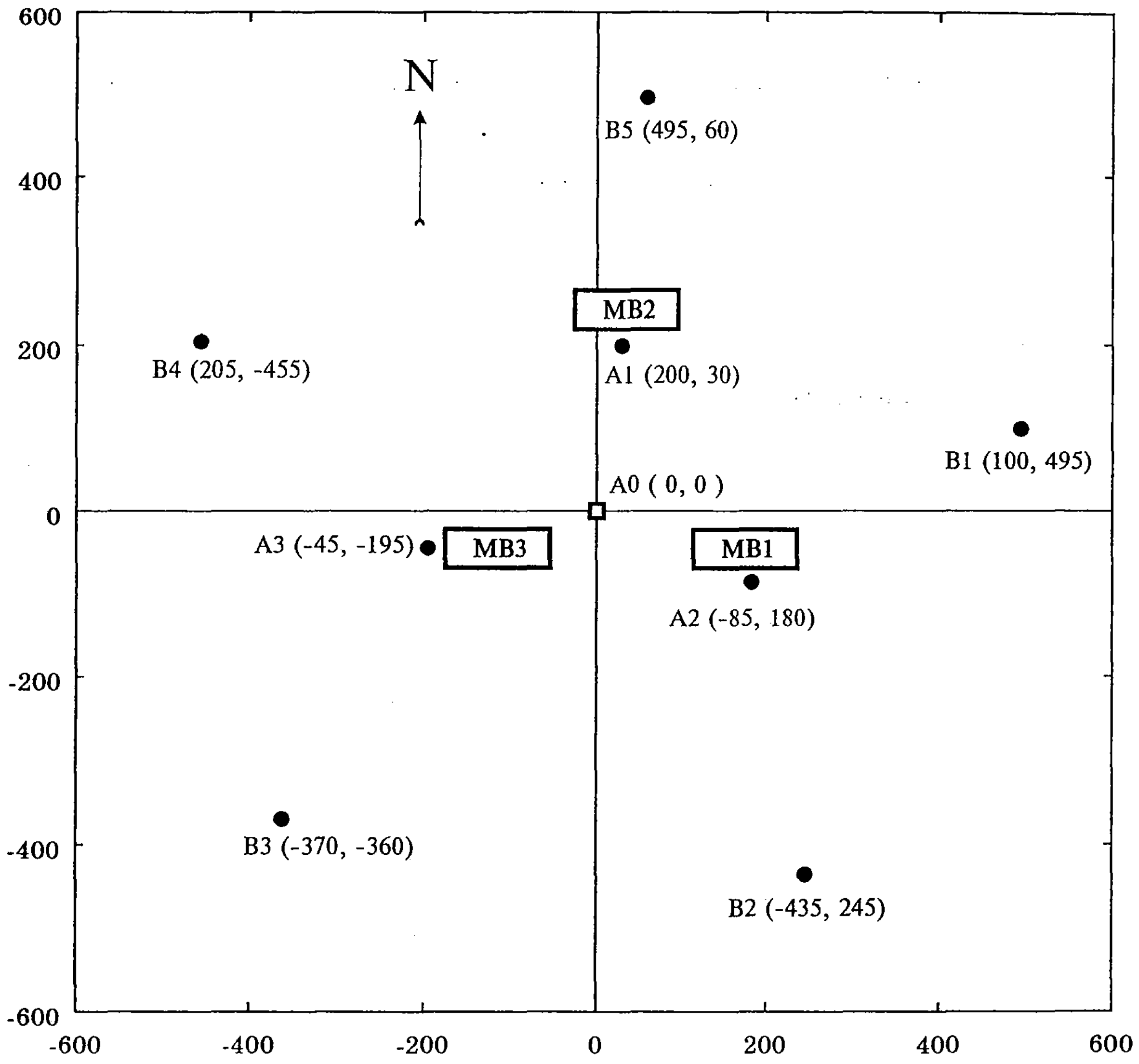

Fig. 7.7.1. Array geometry along with the infrasound sensors (microbarographs). Values in parentheses indicate position with respect to center in meters. MB1, MB2, MB3 denote the microbarographs.

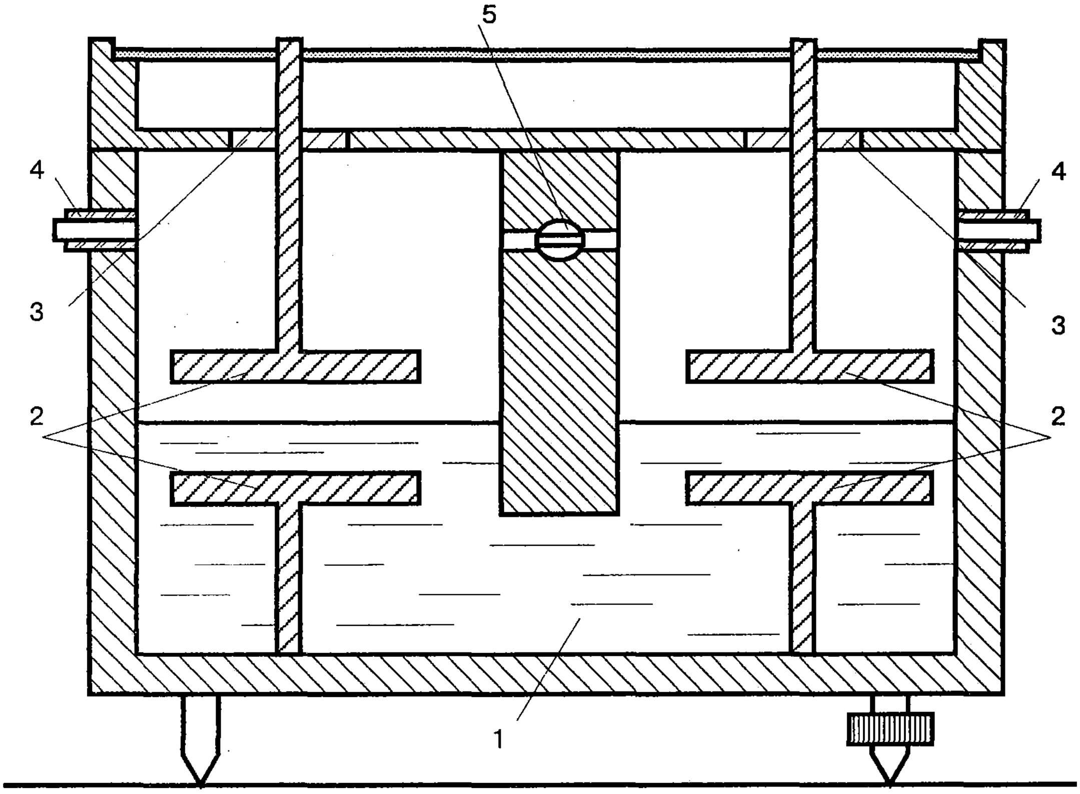

Fig. 7.7.2 Liquid microbarograph design. 1 — dielectric liquid (oil); 2 — capacitors; 3 — isolator; 4 — input holes; 5 — tap.

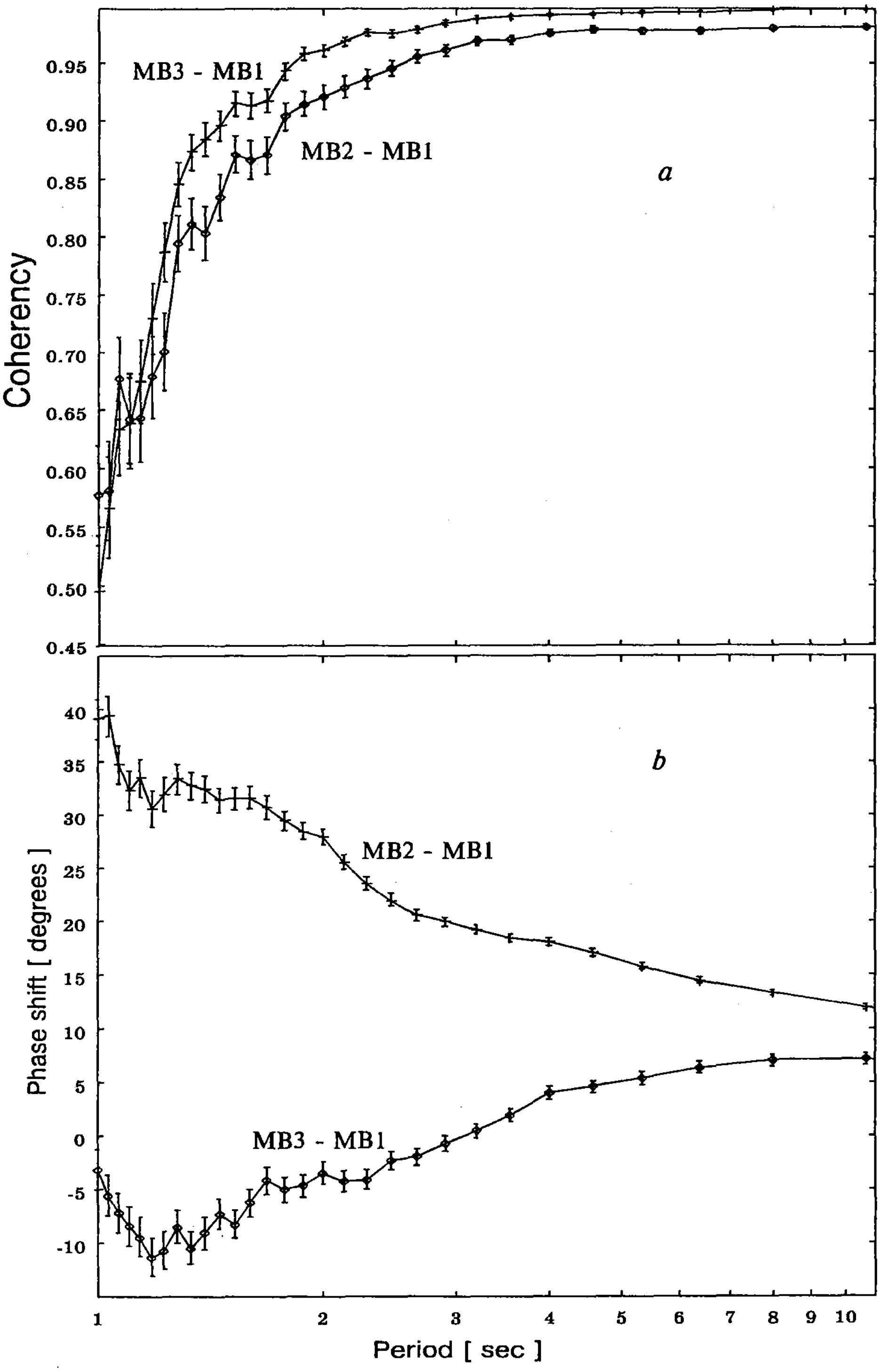

Fig. 7.7.3 Coherency (upper panel) and relative phase responses (lower panel) vs period. Vertical bars show 95% confidence interval. Coherency and phase shifts are measured between pairs of instruments and are marked MB2-MB1 and MB3-MB1, respectively.

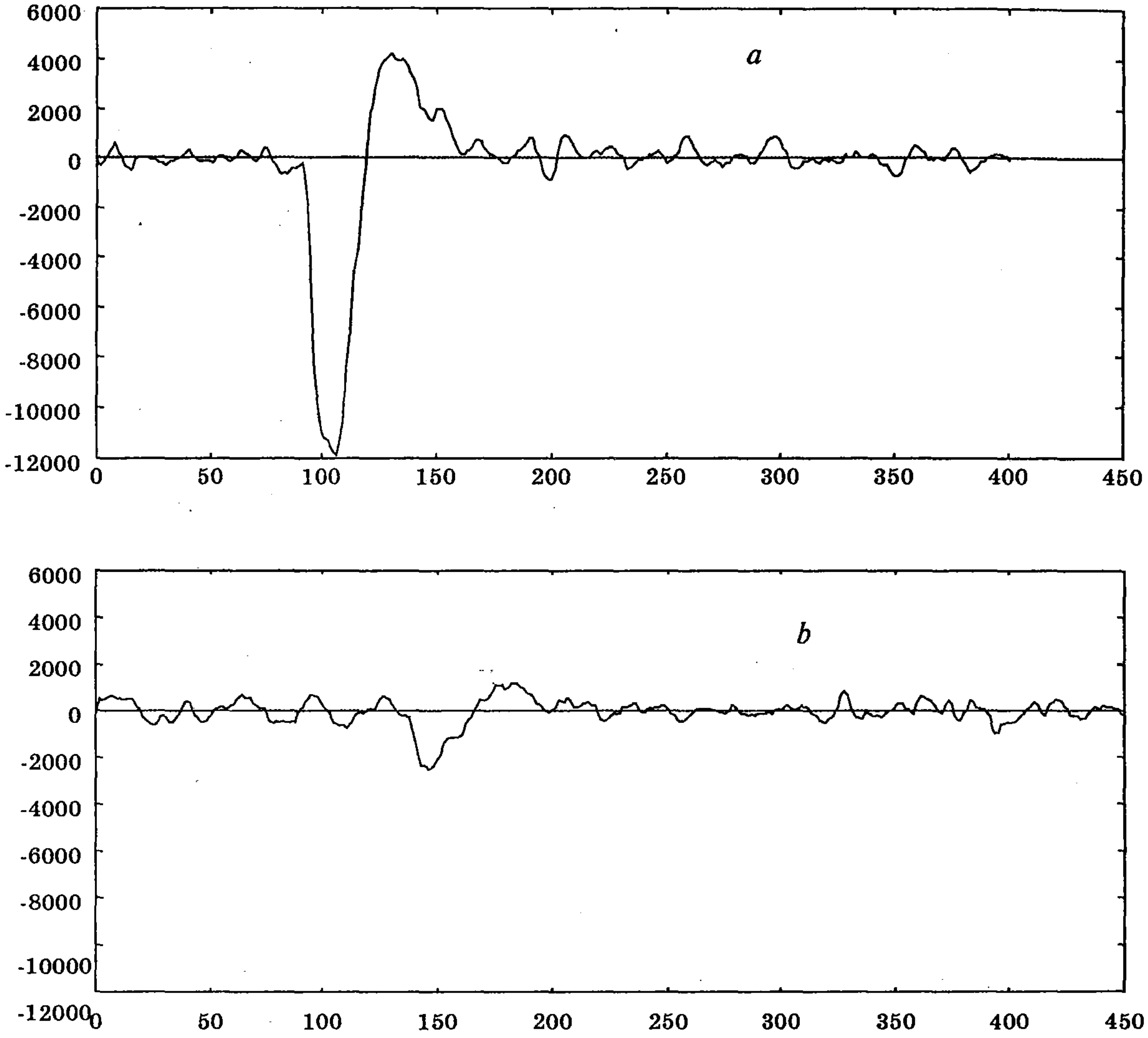

Fig. 7.7.4 Response of the recording system to a pressure step function 25 dyne/cm^2 (upper plot) and 2.5 dyne/cm^2 (lower plot).

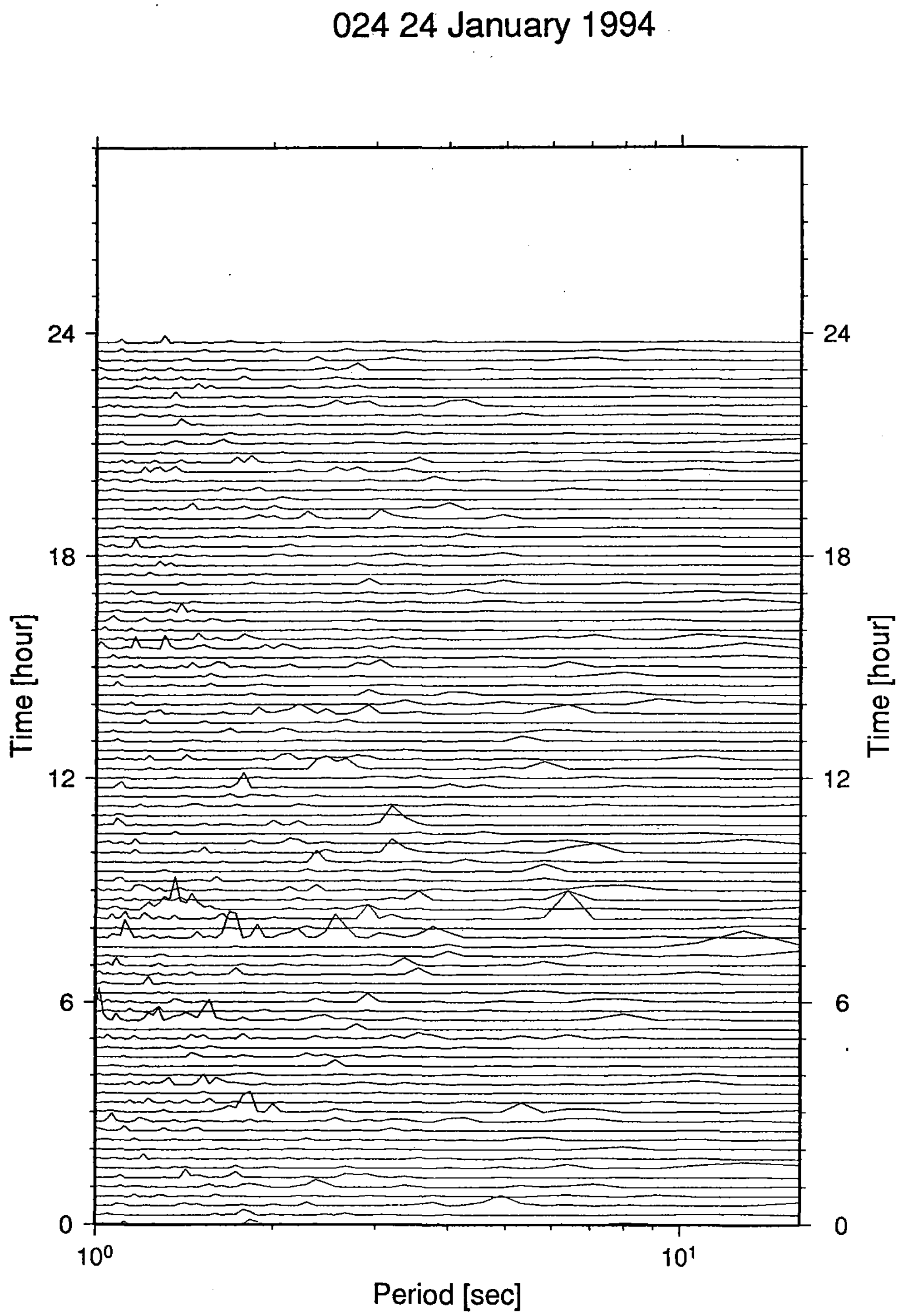

Fig. 7.7.5a Coherency spectra vs time during noise conditions (24 January 1994).

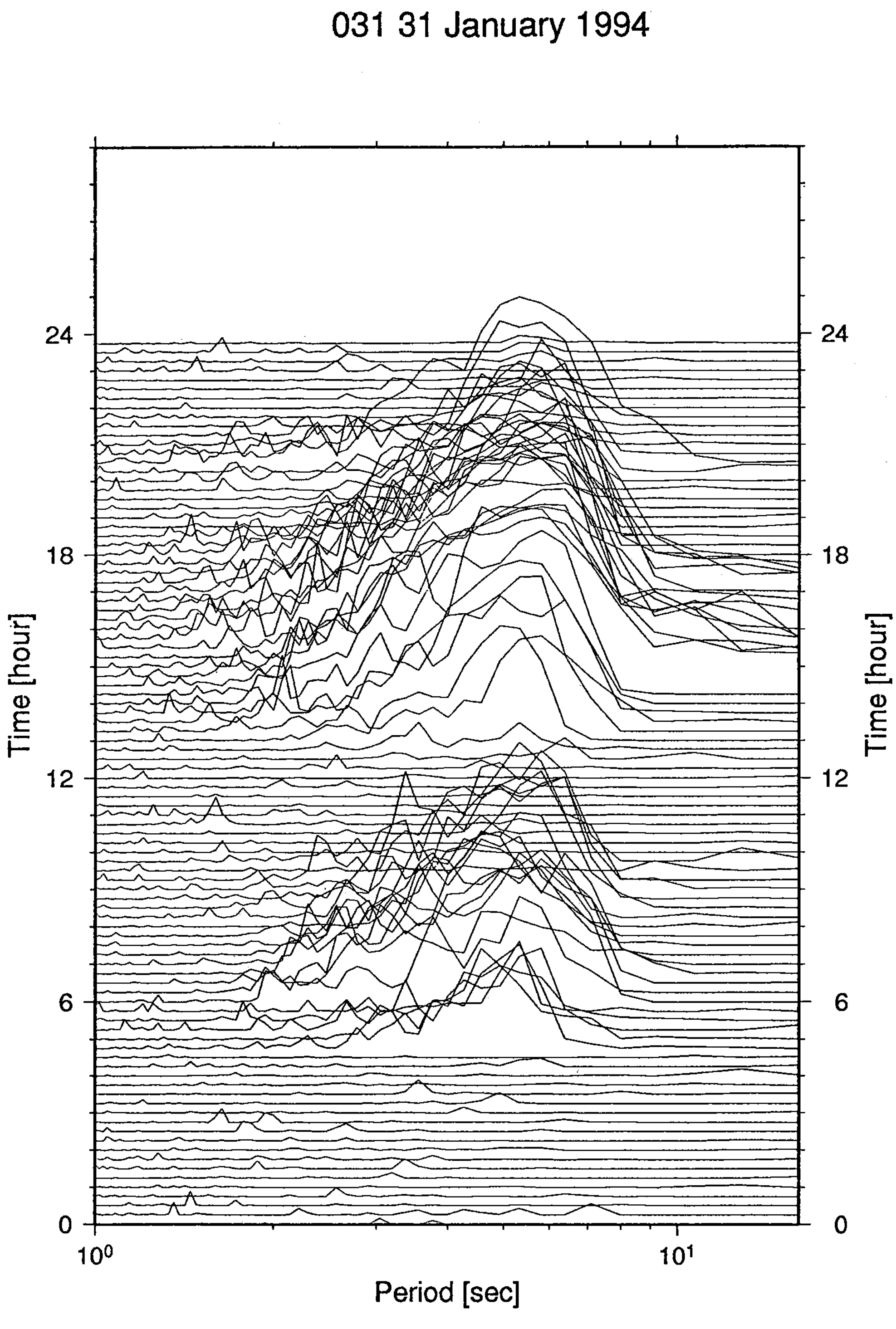

Fig. 7.7.5b Coherency spectra vs time 31 January 1994.

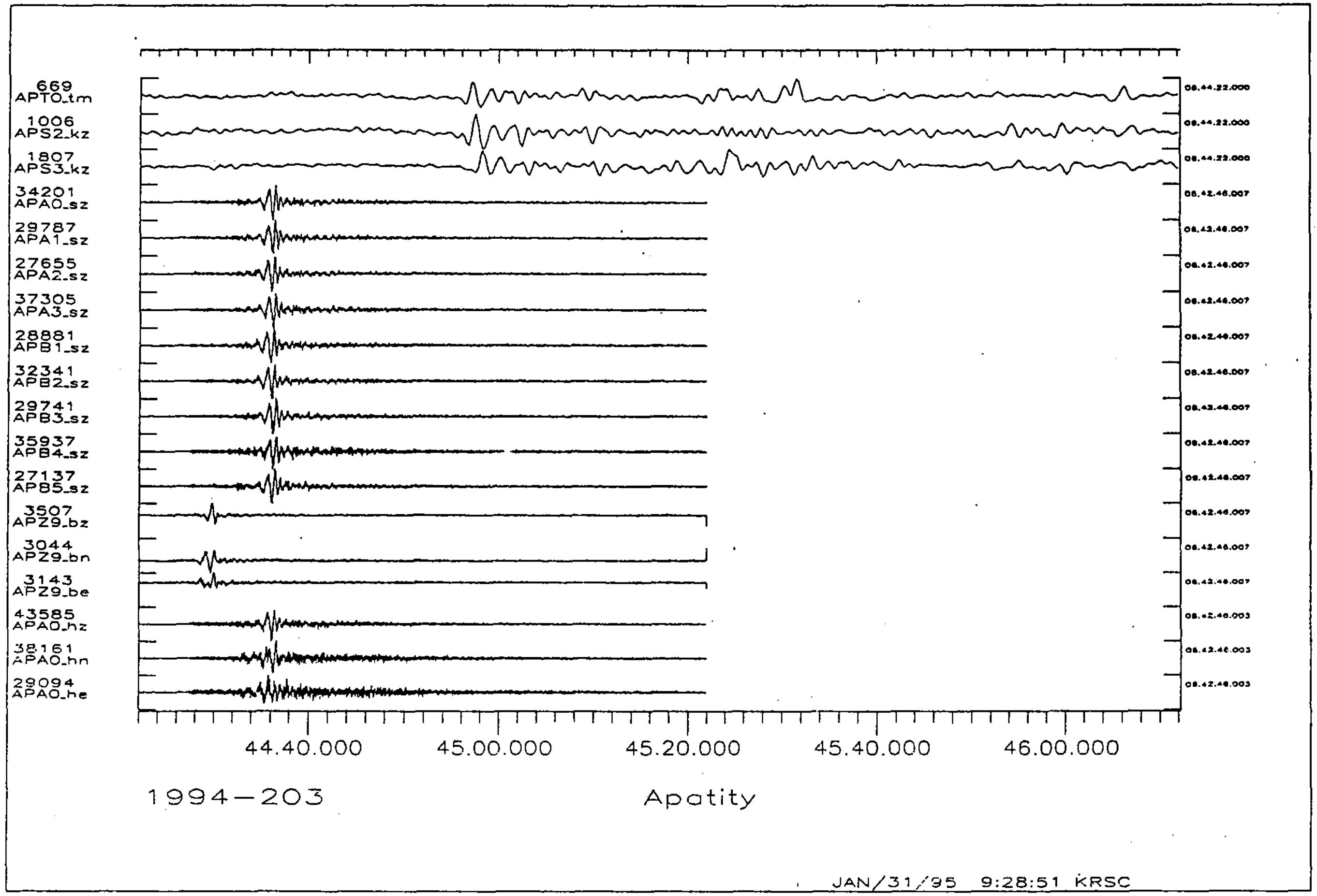

Fig. 7.7.6 Quarry explosion at the Rassvumchorr plateau (Khibiny Massif) 22 July 1994. The top three traces are acoustic recordings, the bottom 15 traces are seismic recordings from the Apatity array and the three-component seismic station APZ9 in the city of Apatity.

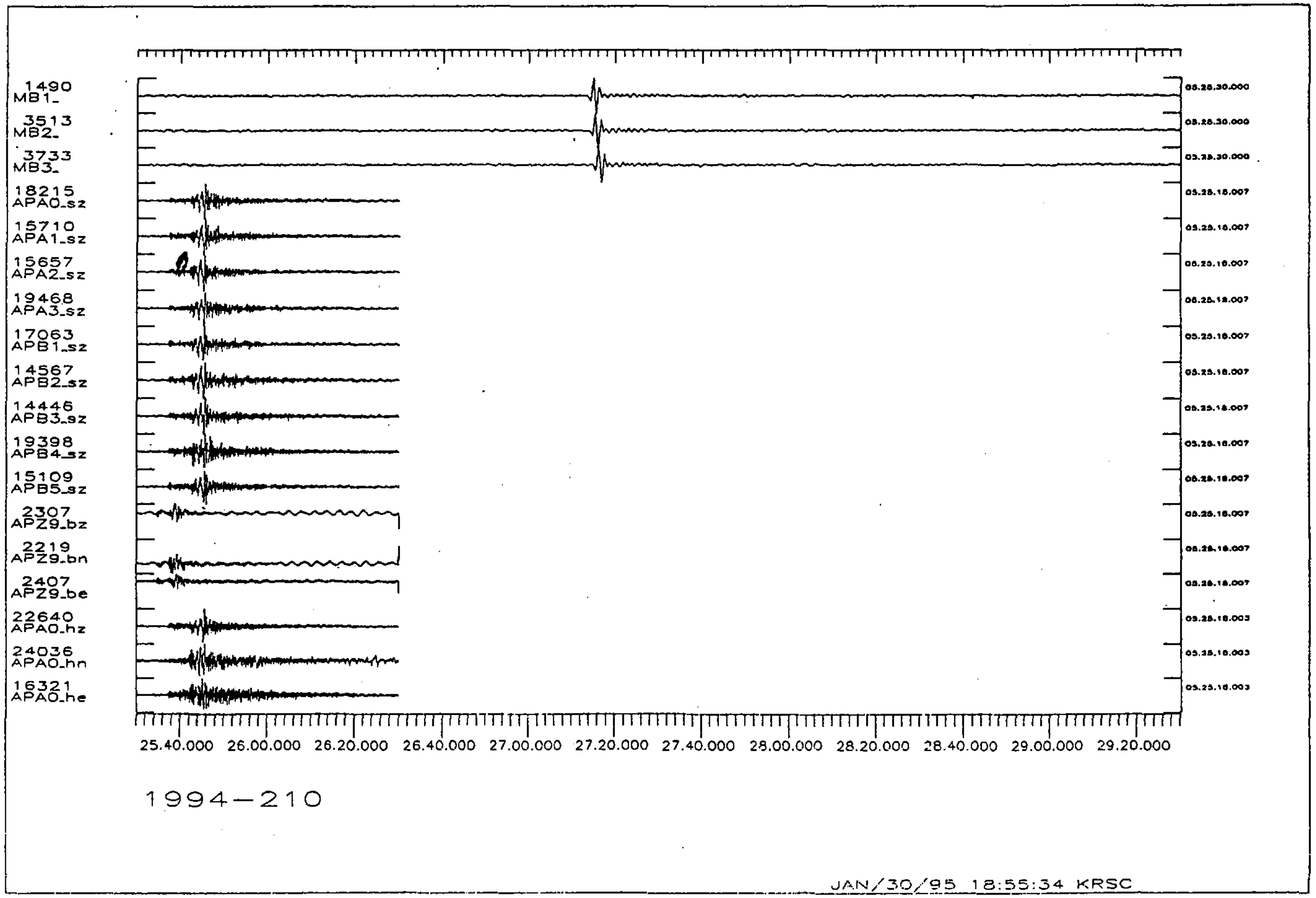

Fig. 7.7.7 Quarry explosion at the Rassvumchorr plateau (Khibiny Massif) 29 July 1994. See Fig. 7.7.6 for explanation.