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GEOPHYSICS

New Results of Monitoring Acoustic Noise in the Kola Superdeep Borehole

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Geophysical observations in the Kola superdeep borehole have been resumed after a prolonged interval. Previous geoacoustic investigations in this borehole were mainly casual and short-term. Moreover, the sensitivity and frequency range of the instrumentation applied were insufficient for registration of weak high-frequency acoustic vibrations.

For new long-term investigations in the borehole, we applied new measurement equipment (high-sensitivity magnetoresistant geophones [1]) and an observation technique [2] that provided continuous observations and time-unlimited record of the average value of amplitudes in narrow frequency bands of the wideband geoacoustic signal in 1-min intervals. One geophone was installed in the borehole at a depth of 3050 m, while the other geophone was installed at the surface near the borehole. The data acquired with the new wideband sensitive instrument confirmed the high efficiency of their application for investigation of seismoacoustic noise variations in a monitoring mode. New data on the structure of the acoustic signal field in crystalline rocks of the Earth's crust were acquired.

Figure 1 shows a fragment of variations in acoustic noise intensity for the period of October 22 to 25, 2005, i.e., diagrams of eight frequency channels designated as follows (from top to bottom): LZ01 and LZ05 (in the borehole and at the surface, respectively) for 30-Hz bands; LZ02 and LZ05 for 160-Hz bands; LZ03 and LZ07 for 500-Hz bands; and LZ04 and LZ08 for 1000-Hz bands. The vertical axis of the diagrams shows 1-min average displacement amplitudes in nanometers for all diagrams except LZ03 and LZ04 (in picometers, 10^{-12} m). The lower diagram LZ09 corresponds to the 0.3- to 10-Hz seismic channel in the borehole, and its vertical axis is shown in conventional units. The average displacement amplitudes for frequency bands in borehole SG3 differ only slightly from the respective amplitudes measured at a depth of 900 m in the Pripyat Depression [3].

Visual examination of the diagrams reveals that the acoustic noise intensity in the 0.3- to 10-Hz band is noticeably lower during weekends (the first two days of the fragment) than on workdays. This is regularly observed for all the weekends. In the 500-Hz band at a depth of 3050 m, we recorded an anomalously high (as compared with other frequency bands) noise level, the night variation of which is well synchronized with the night variation of the intensity of the solar component of the tidal deformation (Fig. 2). There was no explanation for the regular daytime rise of the acoustic noise level that was not synchronized with the tidal deformation. However, long-term observations revealed that these variations with a stable apparent period of 8 h (480 min) are related to the three-shift schedule of operation of the local mining plant. This inference is supported by the following fact: all the characteristic differences of the registered noise processes show a shift of 1 h from the moment of transition to daylight saving time. It should be noted that diagrams for the 500-Hz frequency band and the surface demonstrate anomalously high displacement amplitudes with a prominent low-frequency trend, and daily variations are not detected against the background of this trend.

Against the background of acoustic noise variations observed in the borehole and at the surface, one can see regular daily surges (Fig. 1) registered around 6 a.m. and 3 p.m. local time (3 a.m. and 12 p.m. GMT before October 30; 4 a.m. and 1 p.m. GMT after October 30). In the above moments, we recorded in the course of half an hour every day three to eight surges of a pattern very

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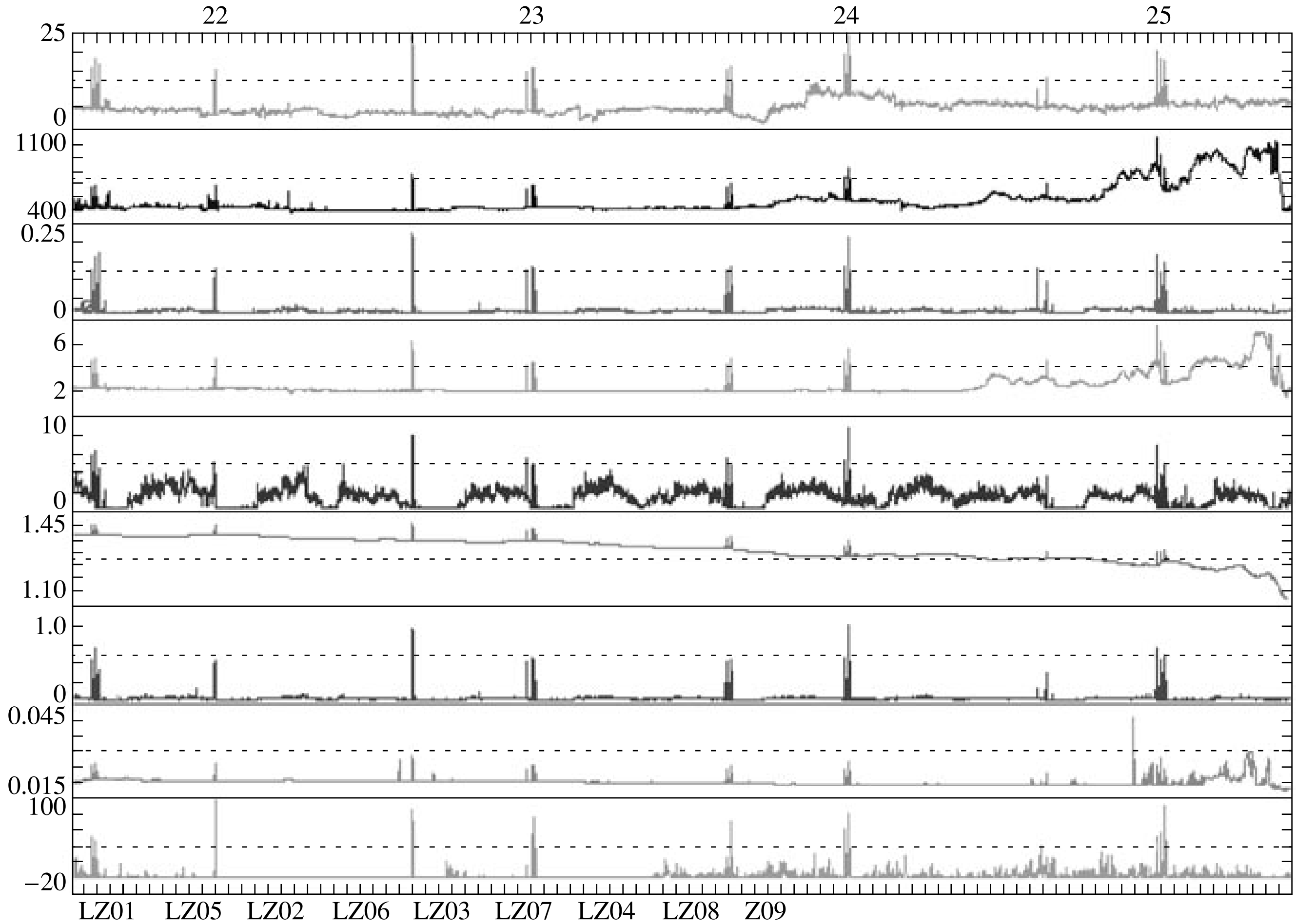

Fig. 1. Diagrams of the monitoring of acoustic emission for four days in 2005: Saturday–Sunday (October 22 and 23) and Monday–Tuesday (October 24 and 25).

similar to blasts in underground mines and open pits. Figure 3 illustrates a detailed schedule of daytime underground blasting. On average, the blasting processes are characterized by a tenfold or higher noise level increase against the background noise level (5, 0.2, $6 \cdot 10^{-3}$, and $4 \cdot 10^{-4}$ nm in 30-, 160-, 500-, and 1000-Hz bands, respectively).

Prior to our monitoring, we could hardly assume that anthropogenic and industrial noises could be so distinct at a depth of 3050 m. However, the influence of noises of both types appeared so strong that they almost completely masked the high-frequency natural geoacoustic noises due to endogenous processes. We could detect and reliably confirm this phenomenon only in the process of continuous long-term monitoring. The results of this monitoring revealed the following fact: both the time of blasting and the intervals between the three daily acoustic noise maximums are synchronized with the local standard time. It is evident that anthropogenic urban noise is manifested in the borehole in the 0.3- to 10-Hz frequency band in the following way: the noise level of this band is characterized by a regular and substantial decrease during the weekend (Saturday and Sunday). The industrial noise is obviously synchronized with the flowsheet of the local mining plant, where the heavy equipment operation schedule is three 8-h shifts per day with no days off. The three-shift operation (according to the monitoring data) was interrupted only once on New Year's Eve in 2005 (Fig. 4), when the typical endogenous noise and accompanying seismic emission were recorded for several hours.

Thus, relatively weak anthropogenic and industrial impacts, which are regularly recorded in deep (3050 m) and remote (approximately 6 km) areas from the source of noises, can completely mask the endogenous noise. This unexpected result of monitoring requires detail study of the daily vertical distribution of acoustic noise along the borehole. The results obtained can be related to the following fact: the chosen monitoring point is located near the bottom section of the Zhdanovskaya Formation (2250–2800 m) that hosts the Main Tectonic Zone of the Pechenga ore field at the surface.

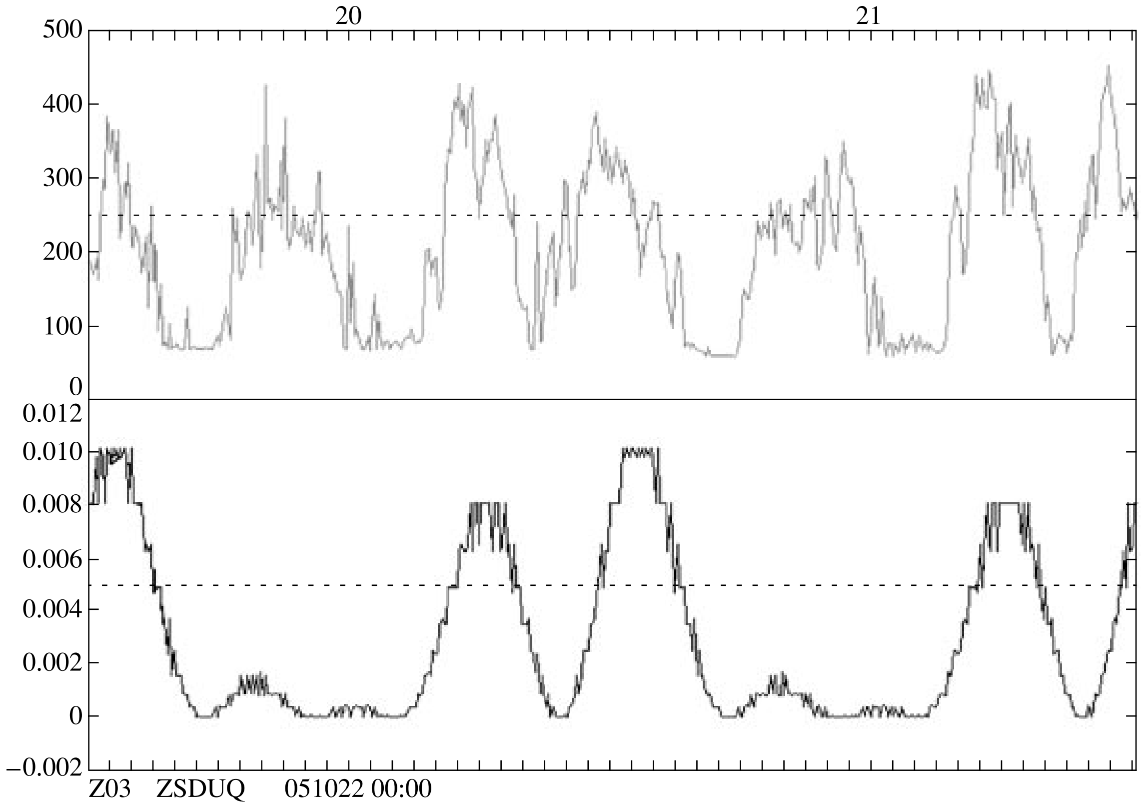

Fig. 2. Subsurface noise variations in 500-Hz band (Z03) in conventional units and a calculated diagram of the relative deformation intensity vs. solar gravitation (ZSDVQ) in nanostrains (10^{-9}).

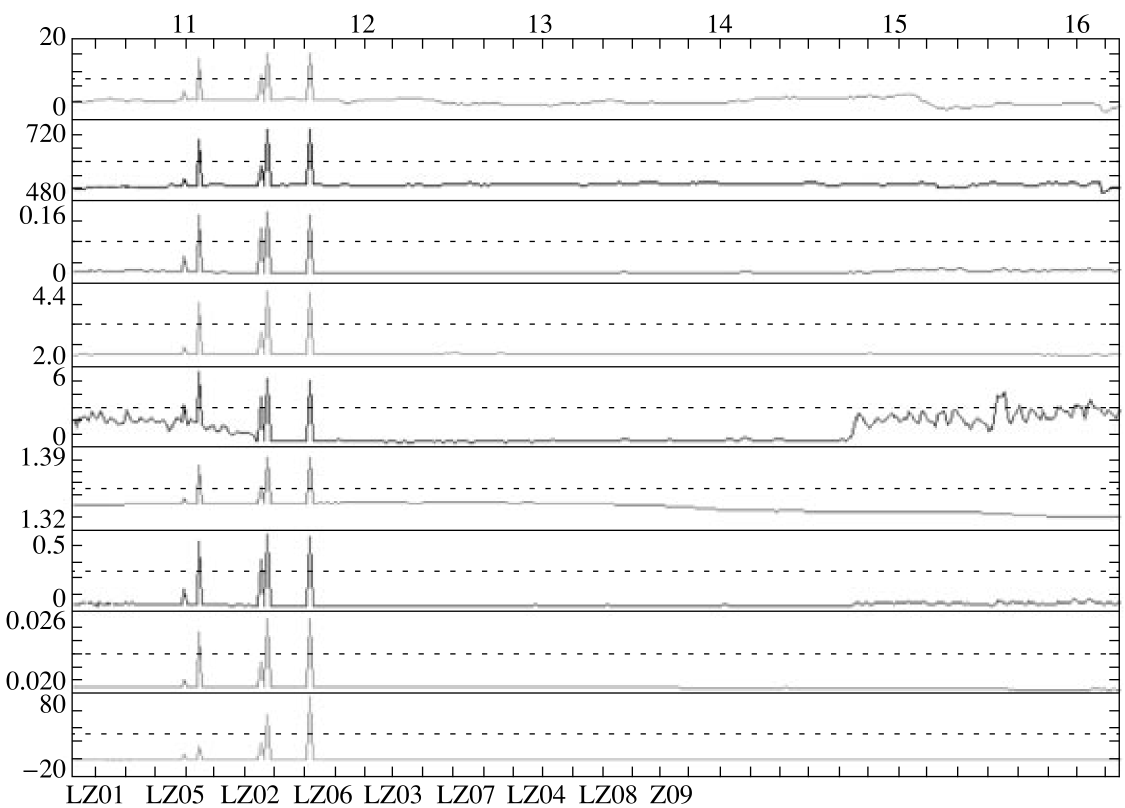

Fig. 3. A daytime series of remote commercial blasting.

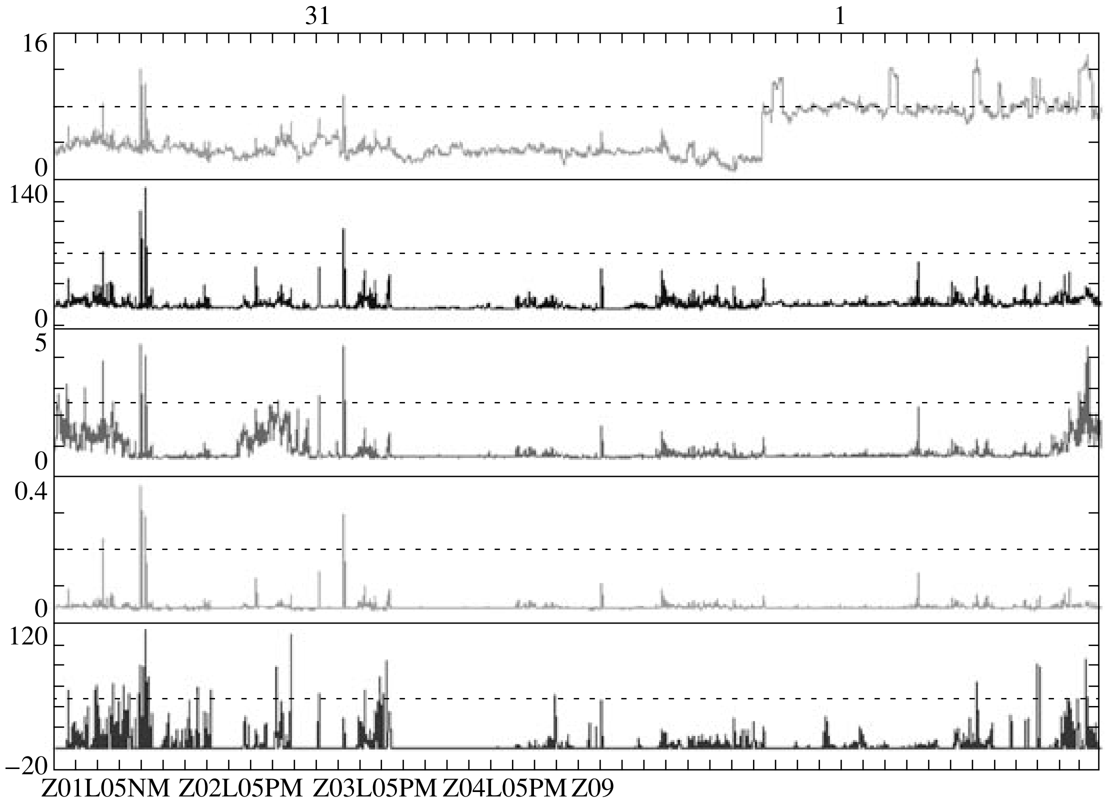

Fig. 4. Subsurface noise on December 31, 2005, and January 1, 2006. The vertical axis shows the noise amplitude in nanometers (upper diagram), picometers (second, third, and fourth diagrams), and conventional units (lower diagram).

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REFERENCES

1. A. S. Belyakov and A. V. Nikolaev, Fiz. Zemli. **7**, 74 (1993).
2. A. S. Belyakov and A. V. Nikolaev, Fiz. Zemli. **8**, 89 (1995).
3. A. S. Belyakov, V. S. Lavrov, A. V. Nikolaev, and L. L. Khudzinskii, Dokl. Earth Sci. **348**, 657 (1996) [Dokl. Akad. Nauk. **348**, 383 (1996)].