Geoacoustic emission in deep boreholes as an indicator of geodynamic processes in crystalline rocks massifs

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This paper was prepared for presentation during the 11th International Congress of the Brazilian Geophysical Society held in Salvador, Brazil, August 24-28, 2009.

Abstract

The results of experimental investigations of geoacoustic emission (GAE) in deep boreholes were considered. Temporal changes of geoacoustic signal amplitude level, signal envelope spectra and dominating in them periodicities were analysed. GAE potential as an indicator of geodynamic processes in crystalline rock massifs was shown.

Introduction

Mechanical vibrations of geoenvironment volume, caused by the sources of different nature, form the levels of geoacoustic emission (GAE) signal, different in amplitude. In spatial distribution the maximum GAE signal level does not depend on borehole depth and selected in it observation point. GAE anomalies spatially (as per depth) coincide with disturbed rock zones (fractured, crushed) and represent geodynamic process intensity and its change in time. These changes may affect variations of amplitude value of recorded signal within the limits of selected GAE anomaly or spatial movement of GAE anomaly boundaries. Emergence of new GAE anomalies along a borehole's shaft and disappearance of the before revealed ones point to specific character of geodynamic processes manifestation in this rock massif.

Theory

The recorded geoenvironment microvibrations within the frequency range of 100-5000 Hz have dominating periodicities, which may be singled out in temporal intervals of different duration. For example, in order to detect periods, identical with storm microseisms, i.e. 4-10 s, 10-20 s and more (up to 100 s), the record time at a point, taking into account the peculiarities of measurement with program-equipment complex BN 4008, makes up 7 min. And if geoenvironment responds to the influence of deformation processes, caused by passage of microseismic waves, we may judge of its physical – mechanical properties, of strength in particular. With weak strength the periods of influencing process are manifested in fluctuations of acoustic emission averaged level, i.e. the effect of high-frequency acoustic signal modulation by low-frequency (up to 100 s) deformation processes will be observed. In strong rocks the influence of deformation processes is not accompanied by intensive GAE, as stresses, originating in the environment volume, are not sufficient for microdestructions and the environment does not respond to these influences.

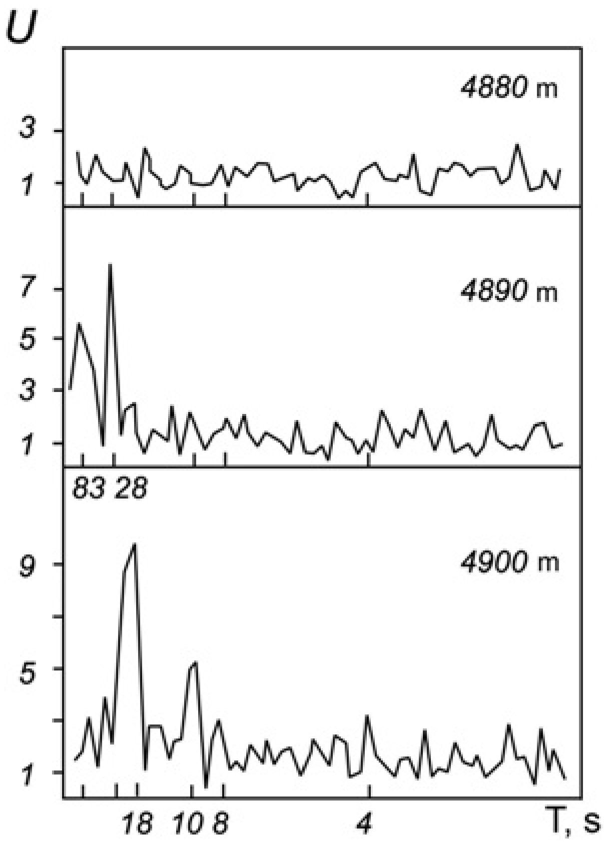

Figure 1: The spectra of geoacoustic signal envelope in frequency range 100-5000 Hz at different depths. The Ural superdeep borehole SD-4.

Examples

Figure 1 adduces spectra of geoacoustic signal envelope, recorded in the Urals superdeep borehole SD-4 at depths of 4880m, 4890m and 4900m. In is obvious that on spectra there are observed dominating periods the range 3-83 s which point to dynamic activity of rocks at this depth (4890 and 4900m). In strong rocks at a depth of 4880m dominating periods in a spectrum are absent, i.e. there are no conditions for the development of fracturing with periodicity of influencing processes. Measurements with discrete record of signals in 15 minutes at a depth of more that 4500m in the Urals SD-4 were fulfilled to study if it was possible to single out periods of the Earth own vibrations in GAE variations (Fig.2).

Amplitude GAE level may considerably vary at depth in boreholes apart from each other within first hundreds of meters. (Fig. 3) Measurements were conducted during 6 hours, i.e. 2 hours for each borehole on the average. The same complete set of equipment was used. The greatest difference in amplitude levels (in 10 times) was observed at a depth of 200 m in boreholes 2085 and 2516.

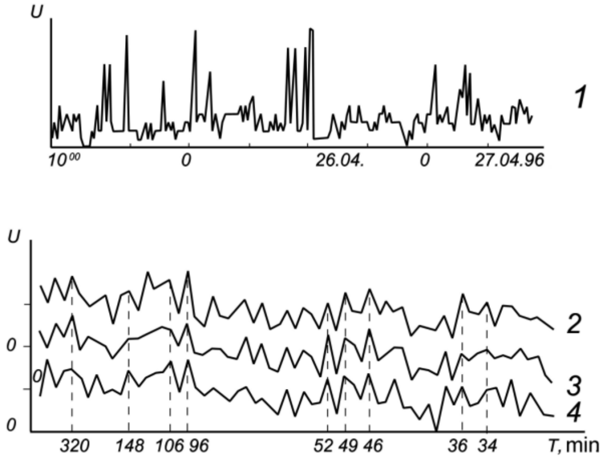

Figure 2: Temporal variations of geoacoustic emission (1) at a depth of 4500m and spectra of signal envelope (2, 3, 4). The Urals superdeep borehole SD-4.

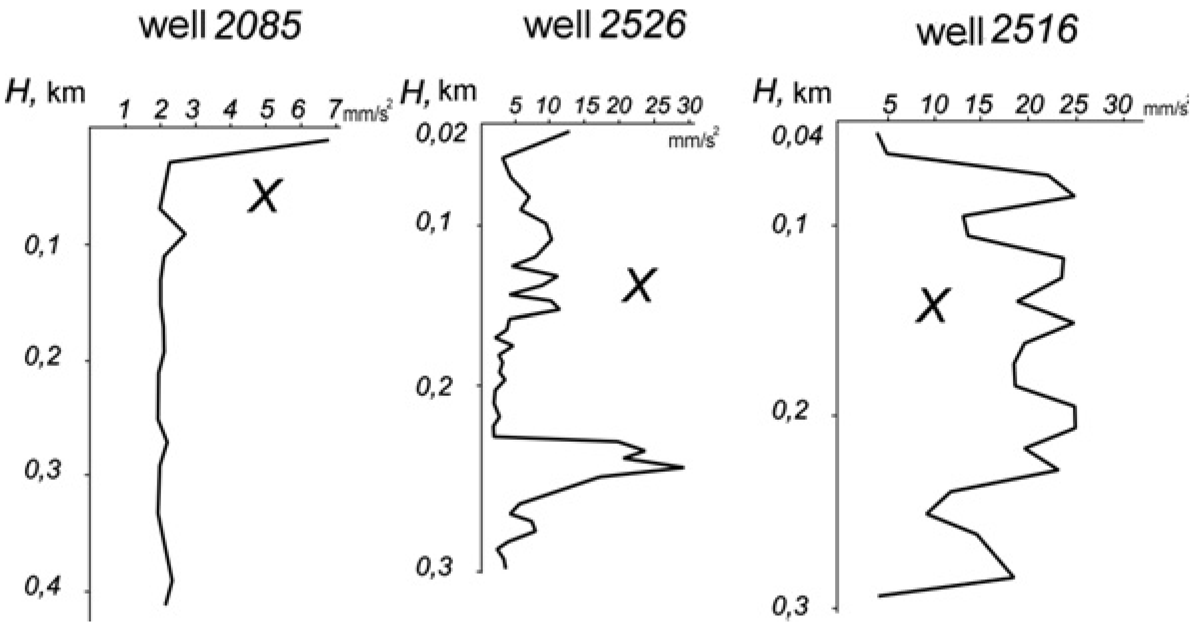

Figure 3: The variation of amplitude level of geoacoustic emission in boreholes. The Chusovskoye copper pyrite deposit, Middle Urals.

The periods identical to the Earth own vibrations were dictinguished on spectra of signal envelope. The spectra 2, 3 and 4 were obtained at different parts of the curve 1 but they are of the same type. This testifies to a certain stability of processes during investigations.

The differentiation of the curves is also diverse. In this case the records of horizontal transducer-accelerometer X allow to evaluate the section of borehole 2085 as dynamically passive. In borehole 2526 two sections with increased values of amplitude GAE level are distinguished which may be considered dynamically active. The borehole 2516 penetrated dynamically active rock massif. It should be noted that with great difference in signal values the time between measurements was negligible and difference in GAE level was in the first place bound with geodynamic state of rock massif. Thus, we may evaluate geodynamic processes in separate rock blocks according to GAE data.

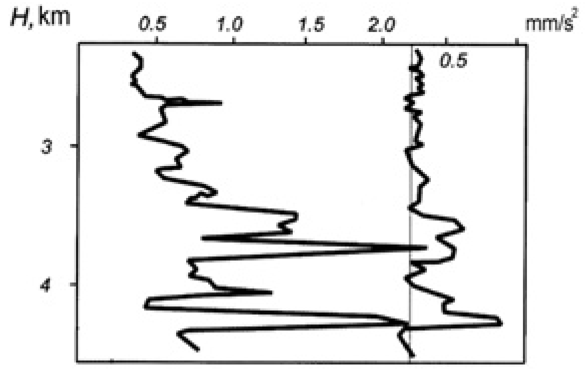

Figure 4: Initial and repeated GAE measurements in 16 hours.

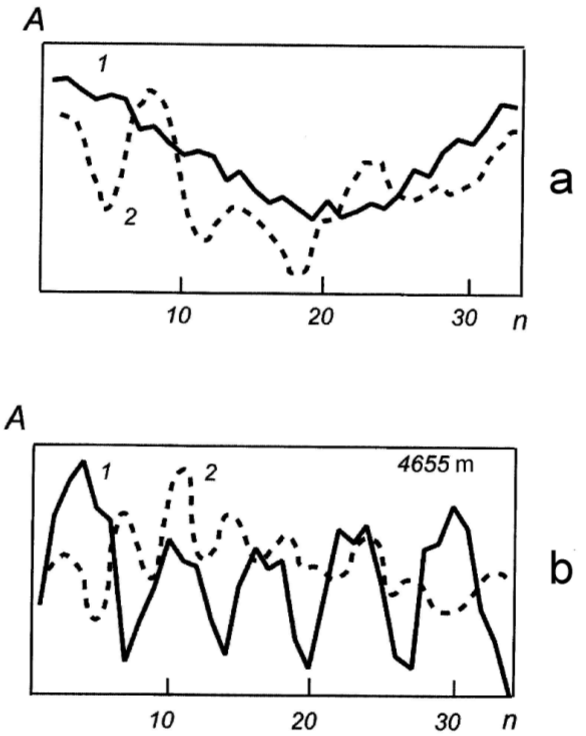

Figure 5: Variation of diurnal (a) and semi-diurnal (?) periods. 1-tidal increments of gravity; 2-GAE.

Let us consider the investigation results in the Vorotilov deep borehole (Vizhegorod region) as an example showing the significance of GAE as an indicator of geodynamic processes in crystalline rock massifs.

Figure 4 adduces diagrams of initial and repeated GAE measurements in 16 hours: During repeated measurements amplitude GAE level decreased in 4 times. This is an indication of geodynamic processes in GAE signals. The influence of lunar-solar tides on the Earth crust, leading to the change of its physical properties, was studied by many investigators. The acoustic response of the Earth crust and the relation between lunar-solar deformation processes and high-frequency seismic noises was for the first time discovered by Rykunov, Zhavroshkin, and Tsyplakov.

The processing of measurement results of GAE temporal variations at a depth of 4655m in the Urals SD-4 showed the following. The obtained plots of dynamics of diurnal periodicities in GAE variations and tidal increments of gravity during 11 days (Fig. 5a) have similar tendency of change in time. For semi-diurnal periodicity their plots of GAE and tidal increments of gravity are of more complex form, i.e., for example, both maxima and minima of amplitude GAE level may correspond to phases of the Earth crust compression (Fig. 5b). It may be explained by peculiarities of geodynamic processes at this depth.

The results of annual measurements during 6 years (1984-1989) in one borehole at the Lomonosovskoye iron-ore deposit are adduced in Figure 6. For more convenient comparison of amplitude GAE levels the value 0,5 mm/s2 is marked by a dashed line in each diagram. Analogous level changes were observed in the Urals SD-4. On these grounds it was possible to trace the movement of slow stress waves from the south to the north with the velocity of 200km/year (see e.g. Dyakonov and Troyanov(1994)).

Conclusions

Thus, we may consider geoacoustic emission as an indicator of modern geodynamic processes.

Acknowledgments

The work was supported by Russian Fund of Fundamental Investigations (RFFI), grant 08-05-01084.

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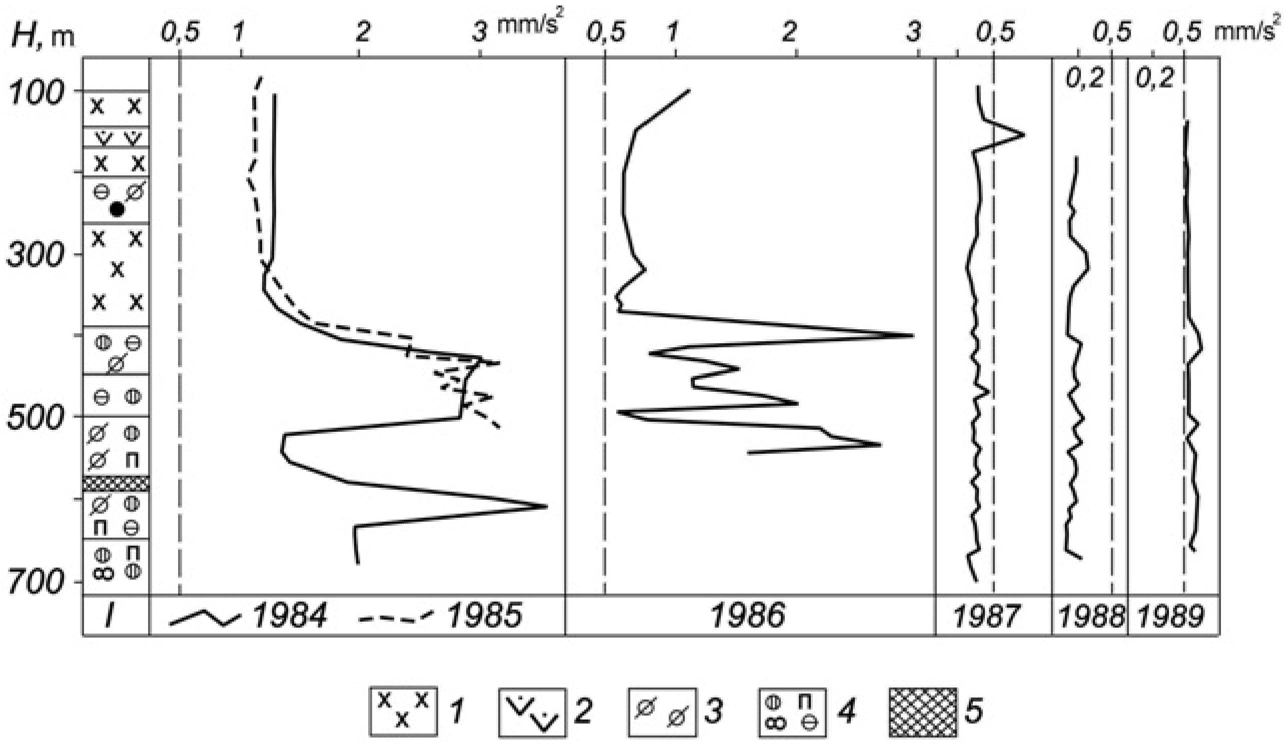

Figure 6: Annual variations of amplitude GAE level in a borehole. The Lomonosovskoye iron-ore deposit, Northern Kazakhstan. 1 – geological column. Legend: 1 – porphyrites;2 – tuff; 3 – pyroxene scarns; 4 – metasomatites; 5 – magnetite ore.