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Temperature dependence of acoustic emission from impact fractured granites

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ABSTRACT

Pre-failure damage accumulation in deformed rock as well as crack propagation in fracturing geomaterials is accompanied with the generation of elastic (acoustic) waves. These processes are similar in main features in tectonic formations and under laboratory conditions. Therefore, the data obtained in acoustic emission (AE) experiments are widely used for interpreting some trends in natural seismic processes. However, the laboratory experiments on rock loading are usually performed at room temperature, while the temperature of geostructures at the depth of faulting can reach a few hundred degrees. In this communication, we present results of the AE study of impact-induced damage in granites of two grain sizes performed at different temperatures. The energy release distributions in AE time series (dependences of event number on event energy) were found to follow the Gutenberg–Richter type relation in the temperature range 20 °C to 300 °C; the *b*-value in this range showed a trend to decrease with the increase of the sample temperature. At higher temperatures (up to 600 °C), the energy distributions exhibited the Poissonian-type (exponential) behavior, thus evidencing the stochastic character of the process. The distributions of time intervals between successive pulses exhibited the same trend but less pronounced.

1. Introduction

The acoustic emission (AE) method of detecting the nucleation and growth of microscopic cracks in rocks is used over half a century in studies of pre-failure damage accumulation under external loading. A lot of experiments evidenced the spatial (Kuksenko et al., 2007; Zang et al., 1998) and temporal (Kapiris et al. 2004; Davidsen et al., 2007) invariances of the "microseimic" process, which was concluded from the power law space and time distributions of AE events. As regards the energy distributions in laboratory experiments (Lei and Satoh, 2007; Rabinovich et al., 2002), the frequency–size dependences were found to be close to the Gutenberg–Richter relation $\log_{10}N(M>) \propto -bM$ where N is the number of (micro-) seismic events whose magnitude is higher than M (the magnitude is proportional to the logarithm of released energy, E, with a factor that varies between 1 and 1.5 (Kanamori, 1978; Ekström and Dziewonski, 1988)). This direct similarity between laboratory-scale processes and natural seismicity encouraged many researchers to regard the AE time series as analogs of earthquake sequences (Scholz, 1968; Zavyalov et al., 1988; Kapiris et al. 2004; Amitrano, 2012; Davidsen et al., 2007). Accordingly, the processes of nucleation and clustering of hypocenters in compressed rocks were considered in the framework of a model scenario for large-scale precursor phenomena and faulting in Earth.

The AE experiments with granites are usually performed at room temperature. These experiments are not fully adequate to the real situation, because a great part of earthquakes occur at the depth up to ~70 km, where the ambient temperatures reach a few hundred degrees. In order to assess the possible role of rock temperature on the microseimic process, we carried out a laboratory study of the shock-induced damage in granites, and determined the energy and time distributions in AE time series at different temperatures.

2. Experimental

2.1. Samples and experimental setup

Granites of two kinds quarried in the vicinity of the Gulf of Finland (Baltic Sea), viz, large-grained (3–7 mm) red Rapakivi granite and mid-grained (2–3 mm) Kuru Grey granite, were used in experiments. The samples were shaped to blocks with dimensions of 20 × 20 × 15 mm. A schematic diagram of the experimental setup is depicted in Fig. 1. The blocks were placed on a heated plate; a steel striker was positioned on the upper plane of the sample. A weight of 100 g retained by a solenoid dropped onto the striker. The impact produced a round hole of about 1 mm in diameter and ~0.5 mm in depth. Photographs of damaged granites at two temperatures are shown in Fig. 2. One can see a difference in the damage morphology between the samples treated at room and elevated temperatures. In heated samples, the damage

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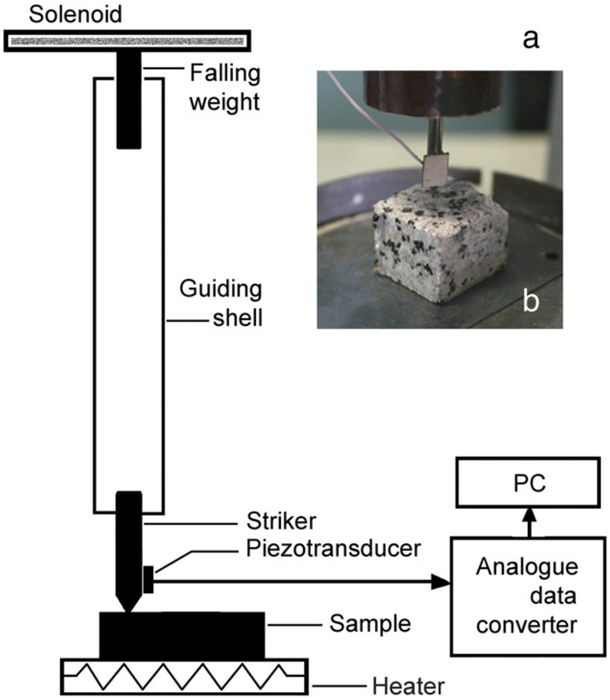

Fig. 1. Schematic diagram (a) and photograph (b) of the experimental setup.

size was larger, and newly-formed coarse cracks manifested themselves along the grain boundaries.

The excited AE signals were detected with a broadband piezoceramic transducer attached to the flat side face of the pointed striker. This schedule provided efficient heat isolation of the transducer from the heated sample. It has been shown in a recent AE study (Shcherbakov et al., 2012) that the damage accumulation curve in granite samples is qualitatively the same both under compression and impact load despite a great difference in the time scale.

The upper limit of the AE frequency range was 1 MHz. A low-frequency filtration was applied at the level of 50 kHz in order to cut off parasitic acoustic radiation from the oscillating setup. Signals from the transducer were converted into the digital form and stored in a PC. The duration of detected time series was 0.4 ms. Typical halfwidth of an individual pulse was about 0.5 μs.

The measurements were performed at 7 temperatures in the range 20 °C to 600 °C; sample temperature was measured with a remote infrared pyrometer CONDTROL IR-T4.

2.2. Energy release

The seismic activity is characterized not only by the main shock but also by series of foreshocks and aftershocks. Under laboratory conditions, the former ones are available from compression experiments. The impact loading gives one a possibility to observe the “aftershock” time series occurring in the sample bulk.

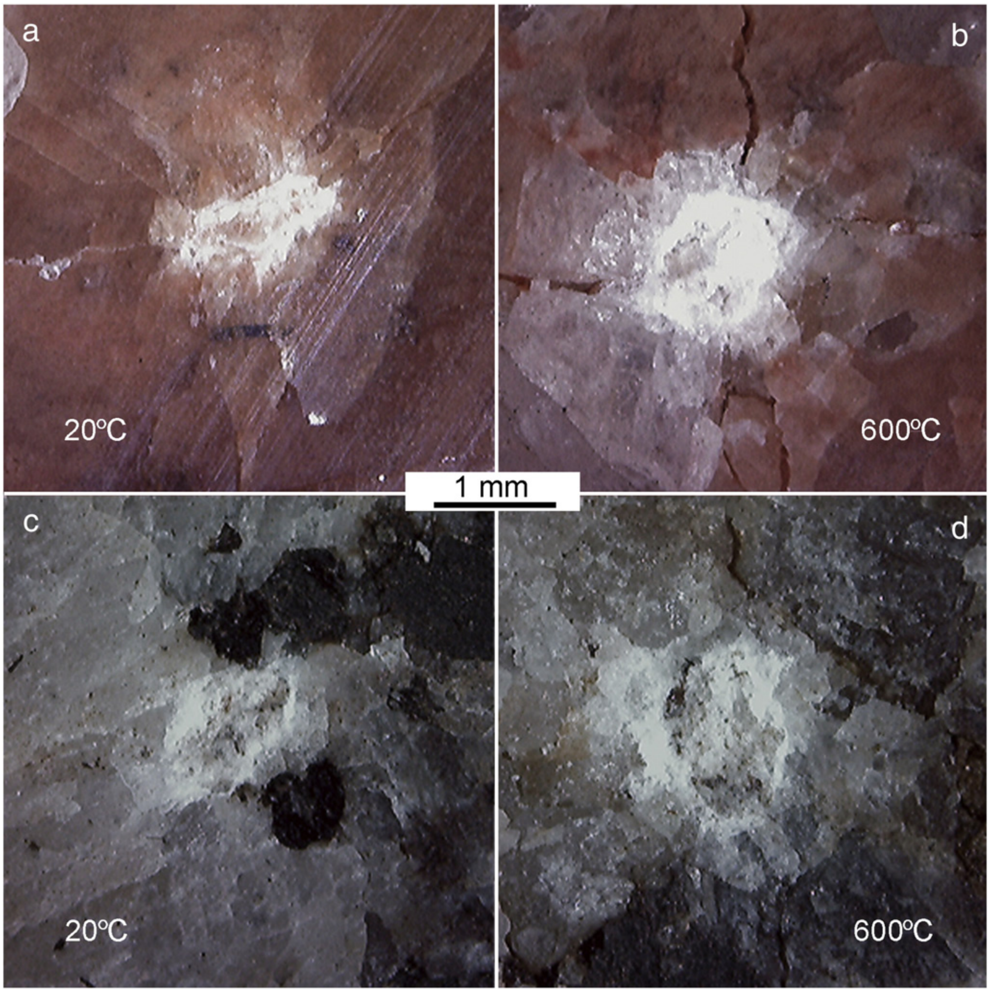

Fig. 2. Impact-induced damages in Rapakivi (a, b) and Kuru Grey (c, d) granites produced at different temperatures.