INTRINSIC ELASTIC ANISOTROPY OF WESTERLY GRANITE AND ITS EVOLUTION DUE TO THERMAL TREATMENT

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Granitic rocks are intensively studied because of their physical properties relevant to development of nuclear waste storage [1], geothermal energy technologies [2], rock mechanics experiments, and studies of crustal seismic anisotropy. One of the classical granitic rocks is Westerly granite from Rhode Island, USA, which is mostly composed by quartz and feldspars with small amount of mica and accessories. It is thoroughly investigated with respect to its composition, microstructure, elastic, thermal, and mechanical properties, etc. (e.g., [3-6]). Westerly granite is often described as an intrinsically elastically isotropic, or very weakly anisotropic rock. It was shown that deviatoric stresses, increased pressure and temperature, as well as temperature and pressure cycling, may lead to development of different crack systems in the granite, which are mostly related to elongated grain boundaries, or cleavage planes of feldspars and mica. The latter may have certain preferred orientation, and therefore induce shape texture for the microcracks, which may significantly enhance the granite elastic anisotropy.
To study this effect, a combination of optical and electron microscopy, neutron diffraction at the SKAT texture diffractometer in FLNP JINR (Dubna) [7], and multidirectional ultrasonic sounding at increased confining pressures using a special apparatus in Institute of Geology AS CR (Prague) [8] was applied to a set of Westerly granite samples preheated to different temperatures up to 600°C. Elastic wave velocities measured at different pressures were compared with the results of microstructure-based modelling of the granite properties using the Geo-Mix-Self algorithm [9].
Our results indicate that Westerly granite consists of 4 main minerals: plagioclase, orthoclase, quartz and biotite. Surprisingly, plagioclase has the sharpest preferred orientation, which strongly influences the intrinsic elastic anisotropy. Heating of the granite leads to formation of different systems of microcracks, depending on the maximum preheating temperature. The shape preferred orientation of cracks is linked to the structure and texture of feldspars and biotite. Experimental data and numerical modeling show that formed oriented cracks may completely invert the elastic anisotropy of Westerly granite, practically exchanging minimum and maximum elastic wave velocity directions. As a result, Westerly granite exhibits two characteristic types of elastic anisotropy, expressed by microcracks at low pressure and by crystal preferred orientations at high pressure where microcracks are closed. At intermediate pressures, the granite anisotropy should be lowest. Some implications of these results for rocks at crustal conditions are discussed.

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