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Cracked rocks with positive and negative Poisson's ratio: real-crack properties extracted from pressure dependence of elastic-wave velocities

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We report results of analysis of literature data on P- and S-wave velocities of rocks subjected to variable hydrostatic pressure. Out of about 90 examined samples, in more than 40% of the samples the reconstructed Poisson's ratios are negative for lowest confining pressure with gradual transition to the conventional positive values at higher pressure. The portion of rocks exhibiting negative Poisson's ratio appeared to be unexpectedly high. To understand the mechanism of negative Poisson's ratio, pressure dependences of P- and S-wave velocities were analyzed using the effective medium model in which the reduction in the elastic moduli due to cracks is described in terms of compliances with respect to shear and normal loading that are imparted to the rock by the presence of cracks. This is in contrast to widely used descriptions of effective cracked medium based on a specific crack model (e.g., penny-shape crack) in which the ratio between normal and shear compliances of such a crack is strictly predetermined. The analysis of pressure-dependences of the elastic wave velocities makes it possible to reveal the ratio between pure normal and shear compliances (called q-ratio below) for real defects and quantify their integral content in the rock. The examination performed demonstrates that a significant portion (over 50%) of cracks exhibit q-ratio several times higher than that assumed for the conventional penny-shape cracks. This leads to faster reduction of the Poisson's ratio with increasing the crack concentration. Samples with negative Poisson's ratio are characterized by elevated q-ratio and simultaneously crack concentration. Our results clearly indicate that the traditional crack model is not adequate for a significant portion of rocks and that the interaction between the opposite crack faces leading to domination of the normal compliance and reduced shear displacement discontinuity can play an important role in the mechanical behavior of rocks.