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Analysis of propagation mechanisms of stimulation-induced fractures in rocks

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Effectivity of geothermal energy production depends crucially on the heat exchange between the penetrated hot rock and the circulating water. Hydraulic stimulation of rocks at depth intends to create a network of fractures that constitutes a large area for exchange. Two endmembers of stimulation products are typically considered, tensile hydro-fractures that propagate in direction of the largest principal stress and pre-existing faults that are sheared when fluid pressure reduces the effective normal stress acting on them. The understanding of the propagation mechanisms of fractures under in-situ conditions is still incomplete despite intensive research over the last decades. Wing-cracking has been suggested as a mechanism of fracture extension from pre-existent faults with finite length that are induced to shear. The initiation and extension of the wings is believed to be in tensile mode. Open questions concern the variability of the nominal material property controlling tensile fracture initiation and extension, the mode I facture toughness K_{IC}, with in-situ conditions, e.g., its mean-stress dependence. We investigated the fracture-propagation mechanism in different rocks (sandstones and granites) under varying conditions mimicking those representative for geothermal systems. To determine K_{IC}-values we performed 3-point bending experiments. We varied the confining pressure, the piston velocity, and the position of the chevron notch relative to the loading configuration. Additional triaxial experiments at a range of confining pressures were performed to study wing crack propagation from artificial flaws whose geometrical characteristics, i.e., length, width, and orientation relative to the axial load are varied. We monitored acoustic emissions to constrain the spacio-temporal evolution of the fracturing. We found a significant effect of the length of the artificial flaw and the confining pressure on wing-crack initiation but did not observe a systematic dependence of wing-crack initiation on the orientation of the initial flaw in the range of tested angles. In fact, wings do not develop for artificial flaws shorter than 3 mm. The force required to initiate wing cracking increases with increasing confining pressure as does the apparent fracture toughness. So called “anti-wing cracks” were observed too, probably an artifact of the geometrical constraints imposed on the sample in a conventional triaxial compression test.