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Mechanical and chemical closure of single fractures

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In most geothermal or hydrocarbon reservoirs fractures are an important feature, which act as conduits or barriers and significantly co-determine if the reservoir is productive or not. Typically, most reservoir models are based on discrete fracture network (DFN) models, whose performance however relies on reliable input parameters representing actual fracture properties. This study summarizes three state-of-the-art methods, which are able to reproduce mechanical or chemical fracture closure geometries and provide the basis to find representative fracture properties such as apertures or permeability. A novel contact mechanical approach, which is implemented in a free web-app and accounts for pure elastic as well as elastic-plastic contact deformations, is introduced and validated for a tensile granodiorite fracture in order to simulate normal fracture closure. Furthermore, medical X-ray computed tomography (CT) scans and a calibration approach based on the missing attenuation method are used to simulate stress-dependent permeability changes in a fracture. Lastly, a phase-field model (PFM) for hydrothermally induced quartz growth is used to understand the effect of sealing structures on fracture hydraulics. It is found that, depending on the (mechanical or chemical) fracture problem, these methods can be used in different ways to estimate hydraulic properties of rock fractures. The results of the contact model indicate that particularly the elastic-plastic module of the web-app is able to reproduce experimentally derived normal closure with a root-mean-square error of 15 μm and provides a useful basis for subsequent fluid flow simulations. Flow simulations based on CT-scans show that the calibration approach is able visualize stress-dependent flow phenomena and to approximate actual experimental fluid flow data particularly for fractures with small apertures (< 35 μm). The PFM-based models show that fluid flow and hydraulic properties in sealing fractures significantly depend on the evolving crystal geometries. Consequently, a new equation to estimate hydraulic apertures is introduced, which factors in a geometry factor α for different crystal geometries (α = 2.5 for needle quartz and α = 1.0 for compact quartz). Thus, the three suggested methods are able to improve future DFN simulations.