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A systematic investigation of the intrinsic flow properties of fractures using a combined 3D printing and micro-computed tomography approach

Content

Geological storage operations spanning energy, nuclear material and carbon dioxide (CO2) storage, require meticulous understanding of the integrity of geological seals over a range of temporal and spatial scales. Fluid-conductive fault and fracture systems in otherwise low-permeability rocks may threaten seal performance and compromise subsurface storage projects. The understanding of these systems is complicated by the occurrence of anisotropic aperture distribution caused by inherent surface roughness. Difficulties predicting fluid flow through fractures stems from our limited understanding of the fundamental controls on their intrinsic permeabilities, and the prevalence, severity and complexity of hydromechanical responses arising from the coupling of multiphase flow, pore pressure and effective stress. In this study, we systematically investigated the effect of surface roughness on the transport properties of 3D-printed (Acrylonitrile Butadiene Styrene resin) fracture surfaces with micrometre surface roughness distributions. We printed 11 separate fractures, 7 of which are synthetically generated self-affine surfaces encompassing a range of fractal dimensions (Df = 1.2 to 2.4) observed in nature. The remaining 4 are acquired from micrometre-scale surface scans from natural fractures within the Carmel mudrock, a caprock from a natural CO2 leakage site in Utah, USA. Fluid flow experiments using single (brine) and multiple fluids (decane and brine) are undertaken to investigate the fluid pathways and interactions between each phase across a range of effective stresses (5 to 25 bar). We investigate the interplay between multiphase flow dynamics, surface roughness and hydraulic aperture distribution to gain insight into the intrinsic transport properties of fractures with different origins of roughness. Experiments are performed and imaged using a micro-computed tomography scanner (EMCT; (Bultreys et al., 2016)), where the results can be used to further the understanding of the governing parameters influencing fracture transmissivity, while also constraining surface roughness inputs for single- and multiphase fracture flow models.

References

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