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Role of fault and fracture networks to de-risk geological leakage from subsurface energy sites

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The success of geological carbon capture and storage projects depends on the integrity of the top seal, confining injected CO_2 in the subsurface for long periods of time. Here, faults and related fracture networks can compromise sealing by providing an interconnected pathway for injected fluids to reach overlying aquifers or even the surface or sea bottom. In this work, we apply an integrated workflow [1] that, combining single fracture stress-permeability laboratory measurements and detailed fault and fracture network outcrop data, builds permeability models of naturally faulted caprock formations for in situ stress conditions.

We focus our study on two-dimensional (2D) fault-related fracturing within caprock sequences cut by extensional faults. 2D data of fault and fracture networks were collected from an Upper Jurassic to Lower Cretaceous shale-dominated succession in the Konusdalen area (Nordenskioldland, Svalbard, Norway). The studied rock succession represents the regional caprock and seal for the reservoir of the nearby Longyearbyen CO_2 Lab. By digitising all the visible features over the images and then inputting them into the open-source toolbox FracPaQ [2], we obtain information about the fault and fracture networks. In particular, we study the variations in fracture size (i.e., length, height) and density distribution near and away from the fault zone(s), together with the connectivity of fractures within the network. These three parameters are fundamental to establish if the network provides permeable pathways. They also enable us to statistically reproduce and upscale a fracture network in a realistic way.

Combining laboratory single fracture stress-permeability measurements with outcrop fracture network data allow us to create an accurate coupled mechanical-hydromechanical model of the natural fracture network and to evaluate the effective permeability of a fault related fracture network. These results are also compared against analytical estimates of effective permeability [3]. With this workflow, we overcome the geometrical simplifications of synthetic fracture models, thus allowing us to establish representative stress-permeability relationships for fractured seals of geological CO2 storage.

Reference: [1] March et al., 2020, Preprint; [2] Healy et al., 2017, JSG; [3] Seavik & Nixon, 2017, WRR