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The Evolution of Paleo-Porosity in Basalts: Reversing Pore-Filling Mechanisms Using X-Ray Computed Tomography

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Basaltic rocks are considered excellent candidates for CO2 storage by in situ mineral trapping, due to their large presence on Earth' surface and their higher reactivity with CO2 to form calcium-rich minerals. Often carrying a high-volume fraction of vesicles, basaltic rocks can be an important reservoir horizon in petroleum systems. When the vesicle network has been filled by earlier mineralization the basalts can act as impermeable seals and traps. Characterizing the spatial and temporal evolution of the porosity and permeability is critical to understand the CO2 storage potential of basalts. We exploited X-ray computed tomography (XCT) to investigate the precipitation history of an amygdaloidal basalt containing a pore-connecting micro-fracture network now partially filled by calcite as an analogue for CO2 mineral trapping in a vesicular basalt. The fracture network likely represents a preferential pathway for CO2-rich fluids during mineralisation. We quantified the evolution of basalt porosity and permeability during pore-filling calcite precipitation by applying novel numerical erosion techniques to "back-strip" the calcite from the amygdales and fracture networks. We found that permeability evolution is dependent on the precipitation mechanism and rates, as well as on the presence of micro-fracture networks, and that once the precipitation is sufficient to close off all pores, permeability reaches values that are controlled by the micro-fracture network. These results prompt further studies to determine CO2 mineral trapping mechanisms in amygdaloidal basalts as analogues for CO2 injections in basalt formations.