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Hysteresis in permeability evolution of a virtual sandstone simulated by mineral precipitation and dissolution

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Mineral dissolution and precipitation can substantially affect rock permeability, which is a critical parameter for a broad range of subsurface applications, including geothermal energy production, geological storage, petroleum engineering and subsurface contaminant transport. In order to quantify trends in rock properties, virtual experiments on digital pore-scale samples represent a powerful and flexible approach to fundamentally understand the impact of microstructural alterations on evolving permeability.

In the present study, cycles of secondary mineral precipitation and subsequent dissolution are simulated on a synthetic sandstone sample [1]. For that purpose, the flow velocity magnitude is used as a proxy for solvent flux to depict characteristic transport-limited alteration patterns, whereas the inner surface area is used to constrain reaction-limited processes [2,3]. The corresponding hydraulic property evolutions are computed for combinations of reaction- and transport-limited precipitation and subsequent dissolution. Hysteresis can be observed for most of the geochemical reaction pathways, where the permeability trend for the dissolution differs significantly from that of precipitation. Transport-limited mineral dissolution initially shows a considerably higher permeability increase due to the widening of existing main flow paths, whereas the subsequent dissolution of new flow paths leads to a comparably lower permeability increase. The determined discontinuity in permeability evolution clearly demonstrates that microstructural changes as the opening or closure of flow paths might not be simply an inversion of the geochemical processes on an identical reaction pathway. The simulated porosity-permeability relationships are further discussed in the context of property trends observed in nature. Current analytical approaches are not able to reflect the evolution for these dynamic processes, since they describe permeability as a simple function of porosity. Hence, pore-scale modelling approaches are required to describe permeability trends and further develop understanding of reservoir behaviour, since hydraulic property changes resulting from mineral precipitation and dissolution clearly depend on geochemical processes and their history.

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