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Visualising Two-Phase Flow in a Natural Geological Fracture Using Synchrotron Imaging

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Subsurface fluid flow primarily transpires in porous rocks, however, in low-permeability formations, interconnected rock fractures can govern fluid flow. Synonymous with fracture flow is the immiscible displacement of a wetting phase (e.g., brine) by a non-wetting phase (e.g., CO2), a process called drainage, which is fundamental to many subsurface engineering applications. Robust modelling of fracture drainage on the field scale is required to effectively predict and manage the risk of fault-related leakage. Despite this, the controls on leakage through a single fracture are only partially understood. Fluid transport through a natural fracture is complicated by aperture heterogeneity, which arises from opposing rough walls and the presence of discrete contact points related to chemical/stress alterations. For two-phase flow, phase interference is high in fractures as flow predominantly transpires in 2D rather than the 3D pore space of a rock matrix. Recent modelling and experimental studies have provided insight into how drainage progresses through fractured materials, however, a lack of investigation using a truly representative sample (natural rough fracture) at sufficient spatial and temporal resolutions limits the predictive insights of such studies. Here, we used fast synchrotron X-ray tomography to image drainage in a natural geological fracture (6 mm diameter & 18 mm length) obtained from the Carmel Formation, a regional caprock sequence overlying a naturally leaking CO2-charged reservoir in Green River, Utah (USA). Drainage was imaged continuously over ~3 hrs by capturing consecutive volumes at 2.75 µm voxel size with a 1 s scan time. The experiment was performed with analogue fluids (brine and decane) at a controlled fluid flux (capillary regime) analogous to that anticipated during CO2 fracture leakage. In this contribution, we will discuss the results obtained, which provide new insight into the micrometre-scale displacement processes that directly impact global fracture saturations (and leakage rates), and the key challenges associated with imaging drainage in such small fractures using synchrotron imaging.

Participation

In-Person

References

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