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Investigating multiphase flow dynamics in rock fractures via XCT imaging for hydrogen storage optimization

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The global climate change crisis has heightened the current focus on sustainable energy solutions, where hydrogen has emerged as a promising candidate for clean and efficient energy storage. However, effective and scalable storage of hydrogen remains a major challenge. Underground rock formations, including fractured reservoirs, offer a potentially impactful solution for hydrogen storage. This research investigates multiphase flow dynamics within rock fractures to optimize hydrogen storage strategies. We focus on a karstic aquifer formation currently used to store natural gas in Loenhout, Belgium. Leveraging state-of-the-art X-ray micro-computed tomography (XCT) imaging, we study the dynamic behavior of gas displacing the brine within intricate networks of rock fractures.

We employ core flooding experiments coupled with XCT imaging to investigate the pore-scale dynamics of drainage and imbibition in rock fractures. Recognizing the challenges of sampling natural fractures, we induce artificial fractures in samples with low initial permeability from the Loenhout formation, using the Brazilian tensile test method. The experiments are conducted on mm-scale cores featuring fractures with a size on the order of 102 microns, allowing us to capture intricate flow features at a resolution of 6 microns. The study involves the injection of three different gases; hydrogen, methane, and a hydrogen-methane mixture—through brine-saturated fractures.

We analyse the fluid distribution and differential pressure response throughout drainage and imbibition at two different capillary numbers. This research methodology integrates advanced image processing and computational fluid dynamics simulations to extract quantitative data from the XCT images. This approach facilitates a nuanced understanding of gas transport mechanisms, capillary pressure effects, and the influence of fracture characteristics on multiphase flow dynamics under varying gas compositions.

Preliminary results offer insights into fracture permeability, aperture distribution, and the impact of geological heterogeneity on hydrogen migration. The study also aims to highlight the impact of different gases on preferential flow paths within fractures, thereby influencing the spatial distribution and storage efficiency of hydrogen and methane .

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References

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