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Mapping CO2 migration pathways in 3D heterogeneous sedimentary structures

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Carbon storage is being increasingly relied upon by governments to reach their net-zero obligations. Leakage through permeable pathways such as abandoned wells and faults is identified as a potential risk for successful CCS implementation. Storage failure presents risks of environmental impacts to water resources, atmospheric emissions and reduction to the value of carbon credits. Gas migration pathways can be highly complex, rendering detection and assessment of leaks at surface challenging. It is therefore critical to understand the pathways gas may take when migrating through the subsurface. As gas migrates from the source, viscous forces are reduced, and gas migration is dominated by gravity and capillary forces. Consequently, the capillary entry pressures of the medium are a major control on migration. Small-scale heterogeneity has been shown to impact plume migration in storage reservoirs (Jackson & Krevor, 2020; Li & Benson, 2015). In the shallow subsurface heterogeneities are known to cause lateral migration away from leaking wells, and create 'hot-spot'gas distributions, impacting surface flux as well as dissolution in groundwater (Calvert et al., 2024; Forde et al., 2019). These processes can occur at much finer scales than can typically be considered in continuum field-scale models.

A strong body of work has developed on the role of subscale heterogeneities in storage applications. We apply a similar lens to understand the impact of centimetre-scale heterogeneities on the migration of gas in the shallow subsurface. Following the methodology of Meckel et al. (2017), we generate 3D metre-scale realistic sedimentary structures with varied depositional and petrophysical characteristics. Neglecting viscous forces, we are able to apply macroscopic invasion percolation (MIP) to domains with much higher resolutions than are typically feasible (e.g., 10s of millions of elements) while accurately capturing the capillary dominated flow observed in gas migration studies. Given the computational efficiency of MIP, we are able to simulate thousands of gas injections at high resolutions, and analyse the ensemble of results. This talk will present findings from simulations of gas migration through multiple 3D sedimentary structures at the metre-scale to better understand the migration pathway controls in the shallow subsurface. These findings help to improve our understanding of gas source zones, and controls on vertical and lateral migration.

Country

United Kingdom

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