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Characterisation of Solute Spreading and Dilution during Miscible Displacement in Bentheimer Sandstone

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The prediction of solute transport in subsurface flow is important for a number of applications, including groundwater contamination, enhanced oil recovery and CO_2 sequestration. However, the nature of the subsurface, in particular rock heterogeneities, provides a significant challenge. To understand and describe how miscible fluids behave, two displacement mechanisms must be considered: 'spreading' and 'dilution' [1]. Dilution (or mixing) refers to the actual spatial distribution of the solute concentration within the plume, while spreading provides a measure of the spatial extent of the solute plume. As spreading is essentially driven by advective mechanisms, it is strongly affected by spatial variations in the permeability of the medium. Accordingly, the distinction between these two mechanisms is necessary when considering porous material in the subsurface. To this aim, novel laboratory protocols are needed to probe the mixing process by measuring the spatial structure of the concentration field in the medium [2].

Here, we report a systematic investigation on miscible pulse-tracer experiments in a Bentheimer sandstone core sample (10x5cm). The tests have been conducted in both transmission- and echo-mode. If subcore-scale permeability heterogeneity is present, reversing the direction of flow during echo-mode experiments can decouple the effects of spreading and dilution [3] by removing solute plume distortion. Experimental breakthrough curves and internal concentration profiles have been analysed using the Advection-Diffusion Equation (ADE) to establish representative dispersivity values of the sample. To further understand the spatial extent of the injected tracer plume, we have imaged the flow using both X-ray Computed Tomography (CT) and Positron Emission Tomography (PET). Both these imaging techniques allow the flow patterns that arise upon mixing to be visualised at a spatial resolution of approximately (2x2x2)mm^3. This has allowed quantification of local measures of mixing, such as the dilution index and probability density function (PDF) of the solute concentration to be directly calculated from the PET images. Furthermore, by deploying a moment analysis to the experimental PET data it is possible to estimate subcore permeability heterogeneity.

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