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Impact of chaotic mixing on reactive transport: experiment in porous media at high Pe and Da

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Solute transport in porous media plays a key role in a range of chemical and biological processes, including contaminant degradation, precipitation, dissolution and microbiological dynamics. Increasing evidences have shown that the conventional complete mixing assumption at the pore scale can lead to a strong overestimation of reaction rates. Recent 3D imaging experiments of mixing in porous media suggest that these pore scale chemical gradients may be sustained by chaotic mixing dynamics. However, the consequences of such chaotic mixing on reactive processes are unknown.

In this work, we use reactive transport experiments coupled to 3D imaging to investigate the impact of micro-scale chaotic flows on mixing-limited reactions in the fluid phase. We use optical index matching and laser-induced fluorescence to characterize the pore scale distribution of reactive product concentration for a range of Peclet and Damkhöler numbers. We use these measurements to develop a reactive lamellar theory that quantifies the impact of pore scale chemical gradients induced by chaotic mixing on effective reaction rates. These results provide new perspectives for upscaling reactive transport processes in porous media.