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Fracture-matrix interaction, fluid flow and chemical movement in low-permeability fractured media

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In low-permeability unsaturated fractured rock, fluid flows predominantly through the interconnected fracture network, with some fluid imbibing into the neighboring matrix rock. Imbibition (driven by capillary pressure gradient) advectively transports chemicals from fractures into the matrix. Diffusion (driven by concentration gradient) can diffusively transport chemicals into the matrix. Once in the matrix, sorbing chemicals can sorb onto matrix rock. All these interacting processes (imbibition, sorption, and diffusion) are important to understand in the naturally and hydraulically fractured low-permeability rock. Pore structure integrates both geometry and topology of the pore network of the matrix, giving rise to emergent first-order effects on fluid flow and chemical transport in the matrix. Low permeability media make it likely that flow and transport is limited by pore topology (e.g., density of connections) rather than geometry (e.g., radius). This work discusses various, and complementary, approaches to investigating pore structure, and the resulting anomalous imbibition and diffusion, in low-permeability Yucca Mountain welded tuff of Nevada, as well as various shales of USA and China undergoing active exploration and production. Using an innovative and complementary laboratory approaches, such as imbibition and diffusion tests employing a recipe with several nano-sized tracers and subsequent microscale mapping on the shale, our work indicates the limited fracture–matrix interactions in fractured shale, with low pore connectivity of predominantly nm-sized shale matrix pores and the consequent limited (sub-mm near the fracture face under atmospheric pressure and temperature) accessible porosity and anomalous diffusion to the stimulated fracture network and producing wellbore. The presentation will end with some ongoing work of coupled thermal-hydraulics-mechanical-chemical tests and gas-liquid flooding experiments of low-permeability media with lamina.

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