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Reactive Imbibition of Acidic Fluids in Unconventional Shales: A New Experimental Approach to Pore-Scale Reactive Transport Modeling

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Imbibition –the process of a wetting fluid displacing a nonwetting fluid in porous media –profoundly affects geochemical reaction networks in stimulated geological formations. Current quantitative models of fluid transport in such formations widely assume that imbibition of fluids into porous media occurs on a faster time scale than geochemical reaction front evolution. This assumption provides a considerable simplification of an otherwise highly complex reactive transport problem. Yet a body of literature suggests that the rates of fluid transport, porosity generation, and geochemical reactions may be coincident and closely coupled during the imbibition process [1-3], with implications for geological stimulation strategies.

Here, we report direct temporal and spatial observations of contemporaneous porosity modification and fluid imbibition within shale cores in contact with acidic aqueous fluids commonly used in fracture stimulation processes. To obtain these data, we tracked acidic fluid transport in shales by monitoring the rate and spatial extent of bromide tracer transport using synchrotron X-ray fluorescence mapping combined with compositional analysis of the bulk acidic hydraulic fracturing fluids (HFFs). Our approach yields a direct record of time-resolved selective ion transport resulting from the penetration of HFFs and attendant mineral transformations. Our experiments highlight that the penetration of acidic HFFs and calcite dissolution occur at similar rates in oil/gas shales, and indicate that reaction fronts evolve rapidly during imbibition of HFFs. We also show that the variability in mineralogy and chemical reactivity of shales can directly affect the rate and spatial extent of imbibition. For example, although the reaction of the acid spear head with carbonates in shales enhances calcite dissolution and increases porosity, the spatial extent of calcite dissolution in the shale matrix is limited due to a rapid neutralization of pH. In addition, rapid secondary mineral precipitation, such as precipitation of Ba-bearing minerals, reduces porosity and helps explain the significant reduction in the spatial extent of the reaction front and the lower rate of fluid imbibition.

Although models of fluid-shale interactions frequently omit a direct feedback between imbibition and reactive chemical/mineralogical alteration of pore structure, our study demonstrates that neglecting geochemical reactivity and pore space modification during imbibition will create major uncertainties in model simulations and potentially impacted the performance and associated risks of subsurface stimulation technologies.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

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3. X. Zhou, N. Morrow, S. Ma, Interrelationship of wettability, initial water saturation, aging time, and oil recovery by spontaneous imbibition and waterflooding. SPE Journal. 5(2), 21-24 (2000).

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