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Transport-Related Consequences of Geochemical Interactions between Shale, Formation Brine, and Reactive Fluid

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The complex interplay of injected reactive fluid with shale minerals and resident formation brine has a potentially significant role in the rapid decline of hydrocarbon production following fracturing operations. A sudden inflow of reactive fluid into brine-bearing shales that are initially in equilibrium causes mineral dissolution and precipitation reactions. These reactions contribute dramatically to reaction-induced porosity and permeability reductions. Elucidating fracture fluid behavior in shale systems is crucially important for reducing environmental impacts by reusing water, prolonging recovery, and thereby improving sustainability. In this study, the influence of shale-mixing fluid interactions on flow properties was examined by means of representative core-flooding experiments and multiscale imaging tools. The study samples, cored parallel to bedding planes (2.54-cm diameter and ~7.6-cm length), were selected from the economically critical U.S. shale resources, namely Marcellus, and Wolfcamp plays with their diverse structural and mineralogical backgrounds. Basin-specific formulas (Marcellus and Midland) were used for brine and HCl-based fracture fluid (pH=2) solutions. In the flow experiments, brine and fracture fluid were injected sequentially under confining stress (up to 500 psi) at reservoir temperature (80°C). Reaction-related mineralogical, structural, and petrophysical alterations were investigated using X-ray diffraction, medical computed tomography (CT), microCT, scanning electron microscopy (SEM)-energy dispersive spectrometry (EDS), and pulse-decay permeability methods. Importantly, inductively coupled plasma - optical emission spectrometry/mass spectrometry (ICP-OES/MS) tool was utilized to probe chemical composition evolution of the core-flood effluents. Krypton flooding tests were conducted under in-situ X-ray CT that enables the pre-/post-reaction spatial and temporal evolutions in Kraccessible porosity distributions within the shales. CT-number distributions under totally vacuum states that are directly proportional to shale density revealed dissolution and scale precipitation paths across the core samples. Mineral reactions in response to acidic fluid reduced system porosity and core permeability. SEM-EDS results showed significant iron hydroxide precipitates in clay- and pyrite-rich samples due to partial oxidation of iron-bearing phases. Porosity reductions in carbonate-rich samples are related to compaction of cores under stress due to matrix softening with dissolution, and pore-filling by Fe, Al, and Mg-Al hydroxides, as well as barite and salts. ICP tests revealed time-resolved concentration trends in produced brine and reactive fluids that in turn complemented SEM-EDS based observations. The greatest release of metals to brines was in clay-rich systems indicating the importance of equilibrium between shale and synthetic brine prior to reactive fluid exposure. Based on reactive flow experiments, formation water in shales, mixing of brine with fracture fluid during flow, and shale mineralogy have a significant impact on scale precipitation. Experimental data was employed to calibrate transport modeling of reactive fluids and to reproduce the results of aqueous and kinetic reactions identified by SEM-EDS and ICP data. Reactive flow at approximate to reservoir conditions provides a critical basis for evaluating coupling between transport and geochemical processes and correlating the outcomes to the field conditions.

Time Block Preference

Time Block C (18:00-21:00 CET)

References

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