Visual Evidence of Iron Precipitation and Dolomite Dissolution in Low-permeability Siltstones due to Interaction with Hydraulic Fracturing Fluids

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Summary

Fluid-rock interactions between hydraulic fracturing fluids and low-permeability ('tight') hydrocarbon reservoirs could potentially alter the reservoir rock properties and chemistry of flowback and produced water. Characterizing such geochemical processes at multiple scales is critical to understand the effect of fracturing fluids on 'native' reservoir quality and hydrocarbon recovery. The present study utilizes a new experimental workflow, that combines visual analytical techniques and advanced cuttings analysis methods, to 1) visually characterize iron mineral precipitation and dolomite dissolution processes within the micrometer-sized pores of low-permeability siltstones (as a result of interaction with fracturing fluids) and 2) quantify their impact on 'native' reservoir quality.

Methods / Workflow

In total, four drill cutting samples were analyzed in this study. These drill cuttings samples were collected from two horizontal wells drilled in the low-permeability siltstone reservoirs of the Lower Triassic Montney Formation (Canada). Two lithological end-member samples, with highest (12-14 wt.%) and lowest (4 wt.%) clay contents were selected from each well based on the high-resolution along-well (~2000 m interval) mineralogical compositions. A new experimental workflow (**Fig. 1**) that combines scanning electron microscopy equipped with elemental mapping (SEM-EDS) and low-pressure gas (N_2) adsorption and rate of adsorption methods (Haghshenas et al., 2016; Yang et al., 2021) was developed and employed for proof-of-concept testing. Two sets of experiments with two commercial fracturing fluids were conducted to evaluate the application of the proposed workflow using drill cutting samples (~2-3 g each). Drill cutting samples were 'soaked' in fracturing fluids for a certain period (4 days) at two temperatures (25 °C and 70 °C). The variations in rock composition/fabric, (helium) porosity, and gas permeability/diffusivity were examined before and after interaction with hydraulic fracturing fluids.

Results / Observations

SEM observations, combined with elemental mapping (EDS), indicated the 1) "fluffy" structure of the precipitated iron hydroxide mineral and 2) pervasive etching and dissolution of dolomite after interaction with fracturing fluids. Larger reductions in specific surface area (up to 31%) and pore volume (up to 18%) were observed at ambient temperature (25 ˚C) compared to high temperature (70 ˚C). Pore size distribution analysis indicated a larger pore volume reduction for mesopores (2-50 nm) than macropores (50-300 nm) after interaction with fracturing fluids. The latter observation suggests that clay leaching and iron precipitation processes may impact the structure of mesopores more than micro/macropores. An increase in pore volume of 2-8 nanometer-sized pores was observed for clay-lean samples, likely associated with carbonate dissolution.

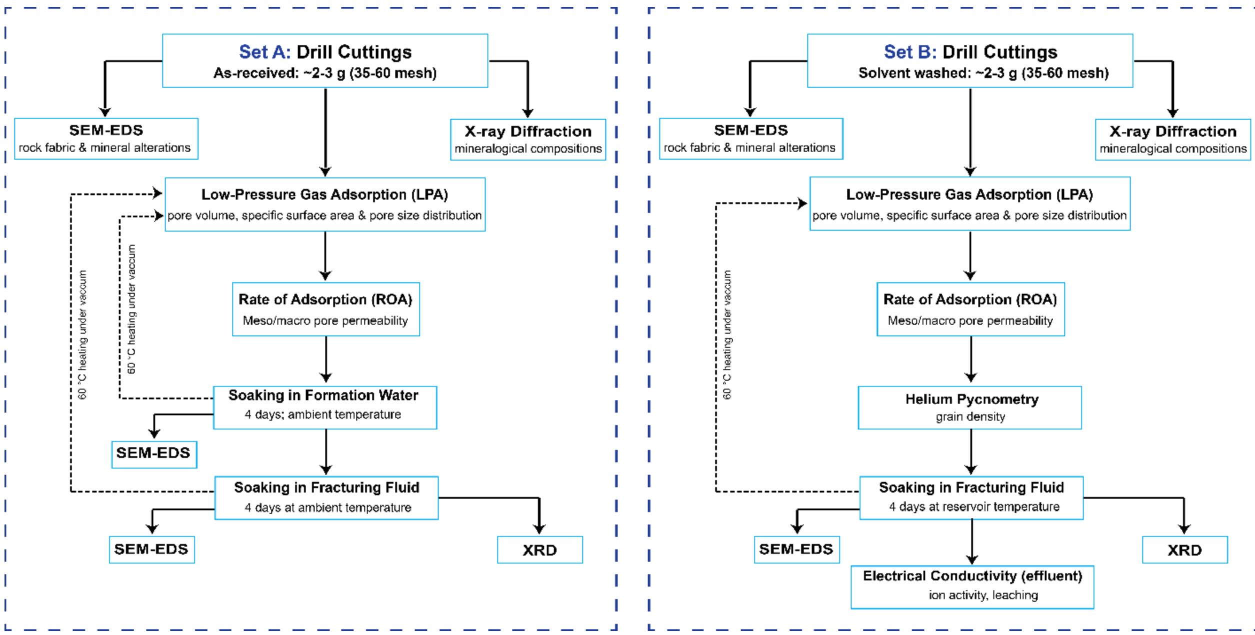

Fig. 1 – Experimental workflow developed to characterize the interactions between hydraulic fracturing fluids and low-permeability siltstones using small amounts (~2-3 grams) of drill cuttings samples.

Novelty

Integrating a diverse suite of laboratory and analytical techniques, a new experimental workflow was developed to characterize the interactions between hydraulic fracturing fluids and reservoir rocks at micro-scale. Using the proposed workflow, the iron precipitation and dolomite dissolution processes were visually detected and characterized, highlighting their impact on pore structure, pore connectivity, and permeability. The proposed workflow is particularly suitable for analyzing drill cuttings samples (~2-3 g) which are usually the only reservoir samples available from multi-fractured horizontal wells.

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