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Possible Alteration of Mineral Wettability due to Interaction with Reservoir and Hydraulic Fracturing Fluids

A. Younis, H. Yarveicy, C.R. Clarkson, C. DeBuhr, H.J. Deglint, A. Ghanizadeh
Department of Geoscience, University of Calgary

Summary

Tight oil reservoirs are composed of a variety of minerals (inorganic matter) and organic matter and are commonly highly heterogeneous with respect to composition. It is well-understood that, combined with rock fabric, the relative proportions of elements/minerals partly govern the wettability characteristics of tight rocks. At subsurface conditions, reservoir rocks interact continuously with 1) reservoir fluids (brine, oil) prior to production and 2) hydraulic fracturing fluids immediately preceding and at the onset of production – it is not however clear to what extent the interaction history with these native/non-native fluids alters the virgin wettability characteristics of reservoir rocks. For primary and enhanced recovery forecasts, therefore, it is important to understand the possible mechanisms affecting the wettability characteristics of minerals – which are the primary components of reservoir rocks – as a result of interaction with reservoir and hydraulic fracturing fluids.

The primary objective of this work is to examine the impact of reservoir (water, brine, oil) and hydraulic fracturing fluid interaction with tight rock on the alternation of mineral fabrics/surfaces, and therefore, their wettability characteristics. Focusing on a diverse suite of pure porous/non-porous minerals, micro-scale contact angle and spontaneous imbibition measurements are conducted under different treatment conditions: 1) “as-received” and 2) after a series of sequential and repetitive immersion experiments into reservoir (water, brine, oil) and hydraulic fracturing fluids over different periods of time (e.g. seconds, hours, weeks).

Theory / Method / Workflow

Pure mineral specimens were purchased from Boreal Science® (Canada). Purity of the mineral phases was initially verified using X-ray diffraction (XRD) analysis (MultiFlex X-Ray Diffractometer; Rigaku®). The diffraction patterns were interpreted using PDXL software (version 2.8.1.1; Rigaku®). Mineral specimens were subsequently polished using coarser to finer grit on a polishing lap to achieve 1-mm thick polished stubs. Polished stubs were carefully observed under stereoscope to ensure a scratch-free, smooth and flat surface. Subsequently, polished stubs were cleaned in ethanol (sonication, 30 minutes) and deionized (DI) water (sonication, 30 minutes) sequentially. The specimens were further rinsed with DI water thoroughly before drying with compressed air. The primary purpose of rigorous polishing and cleaning was to obtain a clean surface because surface roughness and impurities can introduce uncertainty in contact angle measurements (Deglint et al. 2019). Subsequently, mineral specimens were placed in a beaker filled with various reservoir and hydraulic fracturing fluids for different periods of time. Each specimen was then dried at room conditions prior to wettability analysis.

The micro-scale wettability measurements were performed using an environmental field emission scanning electron microscope (E-FESEM), equipped with X-ray mapping capability. Contact angle and spontaneous imbibition rate measurements were performed using the evaporation/condensation technique (distilled water) and a state-of-the-art microinjection system (oil, brine, hydraulic fracturing fluids) following the work of Deglint et al. (2017). The micro-injection system is currently considered to be the most promising method for investigating micro-scale fluid-rock interaction in tight rocks using different fluids. Application of the microinjection system was of particular importance to this study to place a micro-droplet of reservoir and hydraulic fracturing fluids on pure/seasoned mineral surfaces at the same locations – the latter capability is not possible using the evaporation/condensation technique. Contact angle profiles and spontaneous imbibition rates (for porous minerals) were evaluated using open-source (ImageJ) and in-house software/algorithm developed based on parametrizing the Young-Laplace equation (Deglint et al. 2019).

An Example of Observations

An example of a micro-injection experiment is provided in **Fig. 1**, illustrating a micro-droplet of (distilled) water on a polished quartz surface. A contact angle of about 41° was identified between quartz and (distilled) water (**Fig. 2**), using the ImageJ software by generating the profile along the boundary of the drop (white lines; Fig. 2).

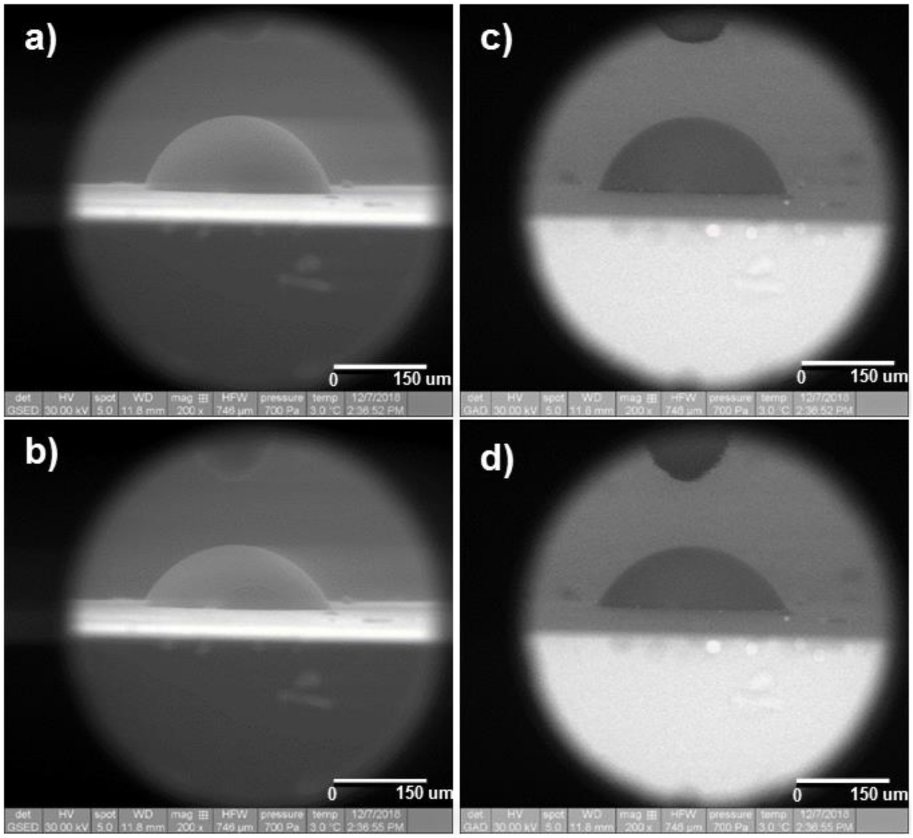

Fig. 1: A micro-droplet of (distilled) water on a polished quartz surface. Images “a-b” (secondary electron images) were captured immediately after placing the droplet on the surface (t = 0 seconds), while images “c-d” (backscatter electron images) were captured at t = 3 seconds. Experiments were performed at 3 ˚C and at 700 Pa. The size of the micro-droplet has reduced in the SEM chamber over time due to the evaporation.

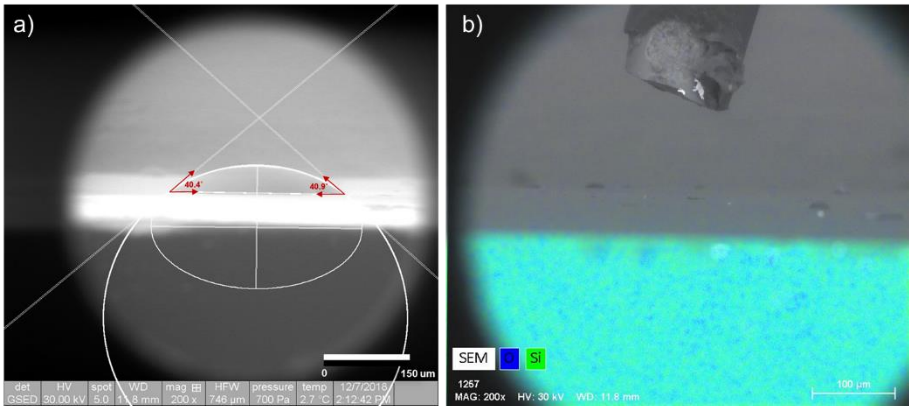

Fig. 2: a) Secondary electron image showing the evaluated contact angle on the polished quartz surface. b) Colour-coded elemental X-ray map of quartz; microinjection tube is visible on the top of the image.

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