

## **In-situ Characterization of Mixed Wettability in Carbonate Rock: A Cryo-BIB-SEM Approach**

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**Abstract.** Injection of SmartWater brines with tuned ionic compositions into carbonate rocks has shown a significant effect on reservoir wettability alteration from oil-wet toward a water-wet state and improved oil recovery. Multi-scale techniques have been extensively used in the last decade to decrypt the underlying mechanisms impacting rock wettability and oil mobility, although it is challenging to understand the behavior of reservoir fluids and carbonate rocks at nanoscale with conventional methods. Therefore, there is a need for advanced visualization technologies to identify fluid phases, distributions and interactions within the complex carbonate porous matrix.

Cryogenic scanning electron microscopy with broad ion beam (Cryo-BIB-SEM) is utilized to study carbonate-oil-brine interfaces at nano-scale and characterize rock porosity and connectivity. High resolution energy dispersive spectroscopy (EDS) identifies oil and brine distribution and quantifies length of oil-carbonate interfaces as well as contact angle distributions.

The study is conducted on carbonate rock samples aged in crude oil and saturated with brines with various compositions, to include the effect of salinity gradient and ionic strength. The results show the distribution and connectivity of crude oil within carbonate pore structure with clear identification of oil-brine-carbonate interfaces at nano-scale. The effect of the brine ionic composition on interfaces, fluids distribution and contact angle was monitored, bringing new insights about effect of salinity gradients and potential determining ions on carbonate wettability alteration and oil mobility.