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Innovative Applications of Multiscale Imaging Workflows to Quantify Porosity, Pore Connectivity and Fluid Flow in Various Rock Types

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Abstract

Rocks are heterogeneous at all scales in composition, microstructure and petrophysical properties. Pore geometries and associated mineral phases and fluids are important properties in reservoir rocks and seals. Our multiscale imaging technology combines the advantages of novel virtual polarizing microscopy (ViP) with high-resolution scanning electron microscopy on broad-ion-beam polished sample cross-sections (BIB-SEM). Automated image registration and segmentation allow fast and reliable analysis of the microstructural features as well as the assessment of petrophysical properties such as porosity, effective pore connectivity, and permeability from the generated image data from core or cutting material.

Combining BIB-SEM with Liquid Metal Injection (LMI) enables the visualization of the preferred transport pathways and determining the controlling pore throat diameter and finally to infer the permeability. Liquid metal injection replaces the “blind” Mercury intrusion porosimetry with a controlled and verifiable method which allows a quantification of the quality of the generated data and does not employ any toxic Mercury.

BIB-SEM under cryogenic conditions allows direct study of the oil-water-mineral system in hydrocarbon-bearing reservoirs, at resolutions of 10 nm. We quenched a range of mudstones, and also sandstone and carbonate reservoir samples, equilibrated with oil and brine, to liquid nitrogen temperature and subsequently sectioned them using BIB-cutting under cryogenic conditions. The flat cross-sections with dimensions of 4 mm^2 allow cryo-SEM imaging of oil-brine-mineral interfaces, with high-resolution EDX-mapping for phase identification, with applications in CO_2-storage, geothermal technologies and enhanced oil/gas recovery.