Applications of Neutron Scattering Techniques for the Characterization of Pore Structure and Fluids Interactions in Tight-Rocks

N.A. Solano[1], C.R. Clarkson[1], F.F. Krause[1], Y.B. Melnichenko[2], L. He[2], and T. Blach[3]

[1] Geoscience Department, University of Calgary

[2]Oak Ridge National Laboratories

[3]Queensland University of Technology

Abstract

Hydrocarbon production from low-and ultra-low permeability reservoirs requires a reasonable understanding of the flow mechanisms and major interactions at the fundamental scale: pores and pore-throats. Average dimensions of these structural features can be up to 1000 times smaller in these tight-rocks compared to their conventional counterparts, with pore size distribution (PSD) commonly spanning up to five orders of magnitude[1]; so full scale characterization of these elements usually relies on the combined results of several analytical techniques in which measurements/interpretations are ground on totally different underlying physics. In this context, small angle scattering of neutrons and x-rays represents an emerging alternative for the investigation of PSD and other features of interest in sedimentary rocks.

For the case of small (SANS) and ultra-small angle (USANS) neutron scattering experiments the sample is irradiated with a neutron beam producing a scattering signal which is processed to obtain a scattering angle vs. intensity profile. The application of well-established physical models to this data yields the PSD and specific surface area (SSA) for structural features with sizes between ~1nm and ~10,000nm[1]. Additional advantages unique to the SANS/USANS experiments include: a) investigation of accessible porosity as a function of pore size, b) bulk-volume measurements on relatively large samples, c) measurements at in-situ pressure and temperature conditions, and d) investigation of fluid-fluid and fluid-rock interactions using relevant fluids (water, oil, CO_2, etc.). This presentation shows the application of SANS/USANS techniques for the characterization of rock samples from several low-permeability hydrocarbon reservoirs across North America [2].

For most samples, SANS/USANS derived PSD and SSA are in good agreement with the correspondent values calculated from CO_2/N_2 adsorption (pores smaller than ~100nm). Some important differences arise from the comparison of SANS/USANS vs. mercury intrusion porosimetry (MIP) data; these differences are interpreted to result from a combination of several factors: a) crushing of fragile pore walls due to high mercury injection pressures (mostly on smaller pores), b) poor accessibility/connectivity (mostly affecting larger pores), and c) MIP-data likely reflecting pore-throats rather than pore body dimensions [for (pore throat / pore body) <<< 1].

Ongoing experiments using low-permeability rock samples suggests the applicability of SANS/USANS techniques for the investigation of phase changes on brine- and oil-CO_2 systems at the nm-scale, with potential applications for detailed analysis of more complex systems like brine- gas condensate saturated rocks. An improved understanding of these mutual interactions between reservoir fluids and the encasing pore system translates into more accurate predictive models for primary and enhanced hydrocarbon recovery, and CO_2 sequestration projects.

Acknowledgements

This research was funded in part by the Tight Oil Consortium at the University of Calgary, and also by the ORNL Postdoctoral Research Associates Program, administered jointly by the ORNL and the Oak Ridge Institute for Science and Education. The elements of this work utilizing the BT-5 instrument at the NCNR were supported in part by the National Science Foundation under agreement No. DMR-0454672.

References

1. **Radlinski, A., et al., *Angstrom-to-millimeter characterization of sedimentary rock microstructure.* Journal of colloid and interface science, 2004. 274(2): p. 607-612.**
2. **Clarkson, C.R., et al., *Pore structure characterization of North American shale gas reservoirs using USANS/SANS, gas adsorption, and mercury intrusion.* Fuel, 2012.**