Visual and quantitative investigation of porosity across thermal maturity boundaries in the Duvernay Formation, Alberta

Erik O. Munson, R. Marc Bustin
The University of British Columbia

Abstract

The quantity, occurrence, and association of porosity within Duvernay Formation shales of Alberta has been investigated. The mode of occurrence of porosity has implications for many important reservoir properties such as wettability, compressibility, and permeability. Samples were taken as plugs from whole rock cores across a range of thermal maturities with varying total organic carbon (TOC) content and mineralogy to highlight controls on porosity distribution.

Visual examination of rock fabric by field emission scanning electron microscopy (FE-SEM) after focused ion beam milling was combined with quantitative measurements of porosity and pore size distribution using mercury injection porosimetry (MIP), gas adsorption, and confined total porosity to helium. Since electron microscopy techniques cannot resolve the entire pore size distribution of some mudstones, methods which use a probing fluid to quantify porosity must be used to fully understand the pore system. Mercury intrusion is able to quantify pore throat distributions in the macro- (> 50 nm) to mesopore (2–50 nm) range to a minimum pore throat diameter of ~3.6 nm, while low pressure carbon dioxide adsorption can quantify pore volume distributions in the micropore (< 2 nm) range and low pressure nitrogen adsorption can quantify pore volume distributions in the micro-, meso- and lower macropore (~200 nm) range.

A weak correlation between porosity and TOC content exists due to varying organic matter (OM) porosity development through a range of thermal maturities as measured by T_{max} (Figure 1). At low maturities, variable OM porosity development is more pronounced. Samples from the highest maturity zones (T_{max}: ~480) show more abundant OM porosity than samples from the lowest maturity zones (T_{max}: ~445). However, OM particles with little to no porosity development are observed in all maturity zones. In addition, OM porosity development is not homogenous for an individual particle. Porosity may occur in some parts of the OM particle while the rest of the particle shows little to no evidence of porosity development and there is no obvious evidence for selective development of the porosity.

Micropore and mesopore volumes as determined by low pressure nitrogen and carbon dioxide adsorption are correlated positively with total clay content but show little correlation with other minerals or TOC content. Nitrogen sorption isotherms for all samples display type H3 hysteresis which is indicative of slit-shaped pores associated with clay minerals particles. Where MIP pore throats overlap nitrogen gas adsorption pore volumes, the pore distributions display similar trends but different absolute volumes of pores due to fundamental differences in measurement theory (Figure 2). It is evident from gas adsorption that FE-SEM techniques cannot quantify the lower limits of mudstone porosity (Figure 2).

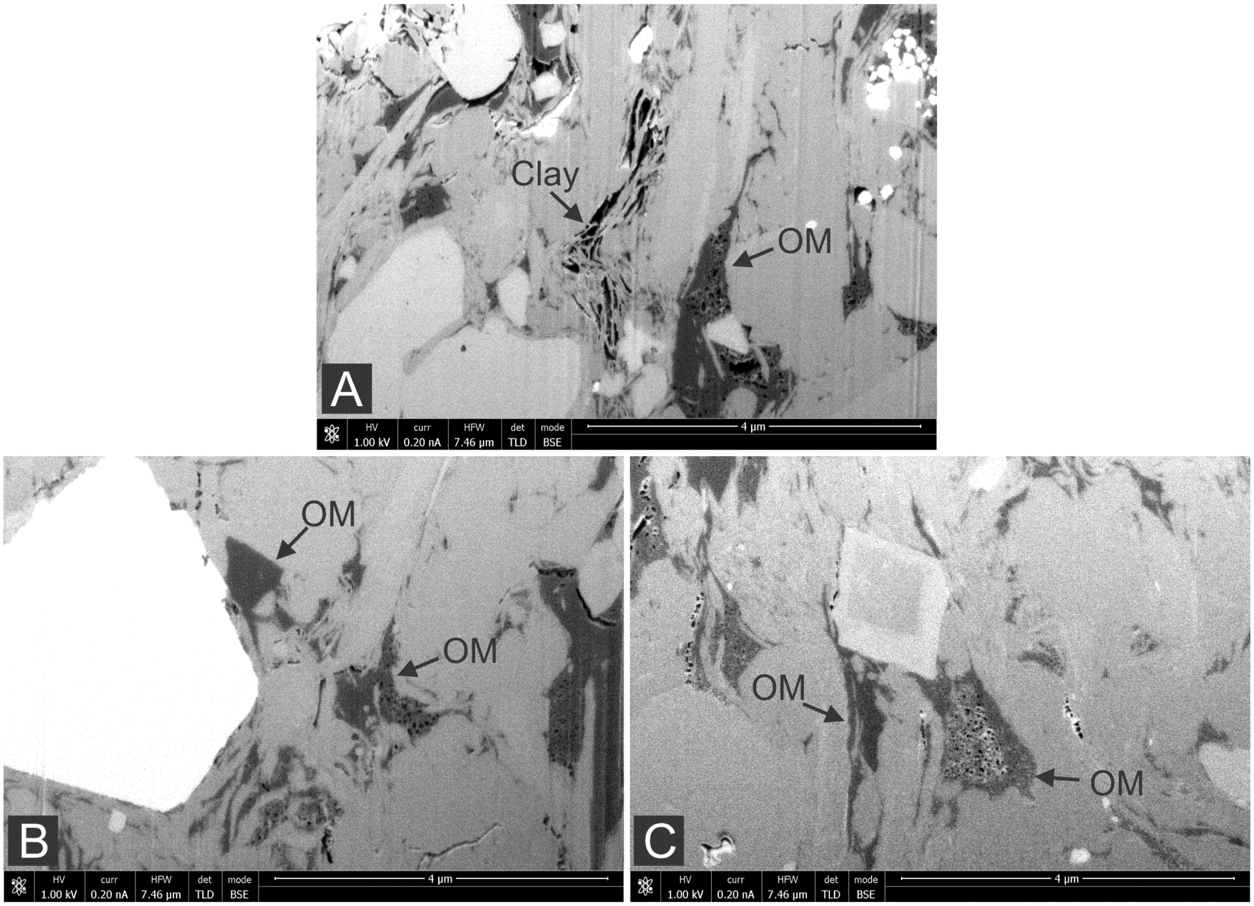

Figure 1. *A.* Highest maturity sample (T_{max}: ~480) showing variably developed organic matter porosity and porosity associated with clays. *B.* Middle maturity sample (T_{max}: ~469) showing variably developed organic matter porosity. *C.* Lowest maturity sample (T_{max}: ~445) showing some porosity associated with organic matter.

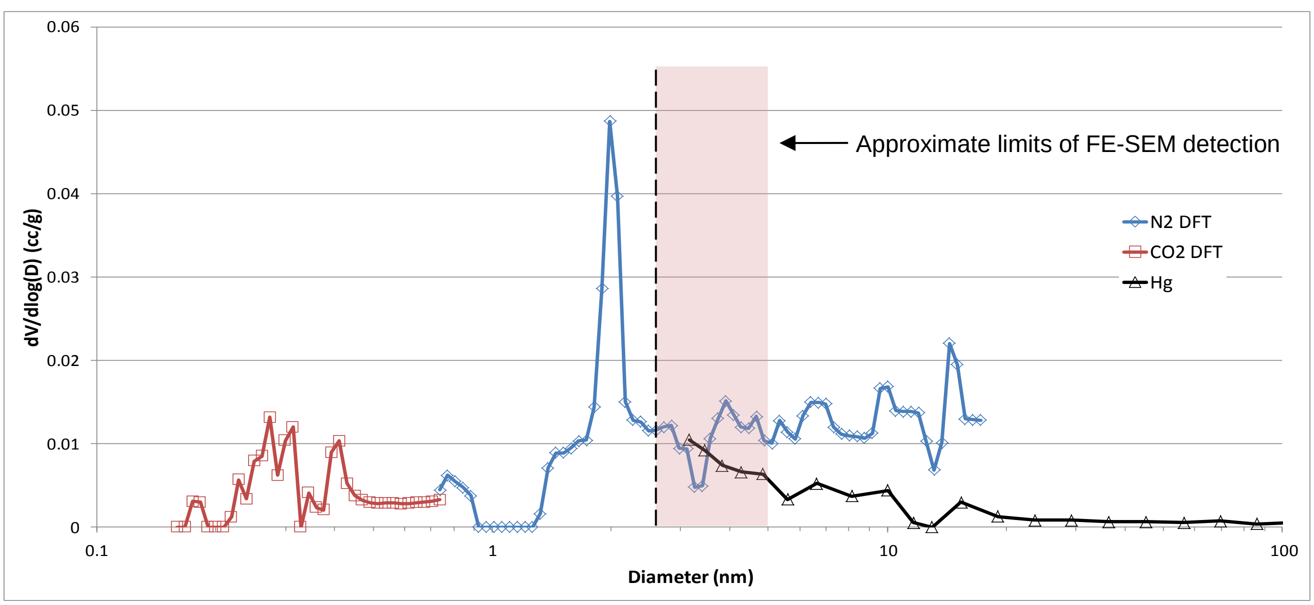

Figure 2. Mercury pore throat distributions combined with nitrogen and carbon dioxide pore volume distributions. Where mercury and nitrogen pore sizes overlap, mercury measures pore throats while nitrogen measures pore volume which leads to some discrepancy in measured volume.