Geochemical Controls on Gas Shale Reservoir Quality

John Valenza, Nick Drenzek, and Mike Herron
Schlumberger-Doll Research, Cambridge, MA USA

Increasing natural gas production from unconventional shale systems is revolutionizing the energy sector. The economics of gas shale plays are complicated by ultra low permeabilities and porosities, rendering hydraulic stimulation necessary to achieve viability. The parameters that govern transport in shale matrices remain ill constrained, which bolsters uncertainty in operational parameters like fracture fluid composition, and transport mechanisms. These ambiguities are largely due to the intimate association of organic matter with mineral grains in these compositionally heterogeneous formations. The complex chemical and structural properties of organic matter in shales and its maturation history likely affect the transport of both liquid and gas species through the matrix. In order to better understand the interaction of fluids with the matrix constituents at a scale relevant to transport (permeability), we utilize conventional gas sorption to analyze the variation in microstructural properties (surface area, porosity, morphology, and pore size regime) from a suite of North American gas shale plays.

Native state samples exhibit slit like pore geometries and pore widths ranging from < 2 nm to > 100 nm while hydraulic radii, a proxy for mean pore size, unexpectedly trend toward smaller values at higher permeabilities. Although not clearly correlated with total organic carbon content, surface area are correlated with maturity as measured by both vitrinite reflectance and Rock-Eval pyrolysis. The surface area of mature samples increases due to the creation of micro- and mesoporosity in indigenous organic matter as kerogen and bitumen are thermochemically converted to gas. Surface area also increases upon the extraction of bitumen, and the magnitude of this effect grows at higher maturity. When combined with corresponding hydraulic radius data, these results suggest that bitumen is primarily associated with micropores made newly accessible to the analysis gas. Subsequent combustion of kerogen results in a similar increase in surface area for immature samples but a marked decline in their more mature counterparts. The latter underscores the loss of micropore-replete mature kerogen and the concomitant exposure of relatively low surface area meso- and macropore cavities. Moreover, the hydraulic radii of combusted samples increases with permeability, a relationship more characteristic of conventional reservoirs. Though changes in mineral composition accompanying the combustion process could complicate these interpretations, mineralogical analyses by Fourier transform infrared spectroscopy indicate little resulting modification. These data suggest that organic matter plays a role in governing mass transport through gas shale matrices.

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