

Microscale characteristics and macroscale disequilibria in hydraulically fractured Utica shale

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The Utica Shale has seen renewed investigation as a major source of unconventional gas. Both drillers and geochemists are concerned with ion mobilization after hydraulic fracturing. Flowback water from this formation contains elevated concentrations of barium, strontium, and radium, and answers are sought on how to predict and mitigate contamination to reduce environmental impact.

These macroscale phenomena are the outcome of nano- and microscale characteristics and processes. Shales in their natural state combine high specific surface area and pervasive surface interactions with confined fluid geometries and anisotropic permeability. Geochemical reactions therefore equilibrate rapidly locally, and only over geologic timescales regionally. Hydraulic fracturing enhances permeability, which is equivalent to expanding the volume of fluid in effective communication with reactive surfaces by many orders of magnitude. This, in combination with an influx of less-saline waters with distinct Eh and pH, drives ion-mobilizing reactions as the system re-equilibrates.

To understand this dynamic, a suite of samples varying systematically in organic content, maturity, and proportions of clays and carbonates has been interrogated. Optical and electron microscopy, with EDS and XRD, yield spatially-resolved mineralogy and pore-mineral associations. Small-angle neutron scattering, and mercury porosimetry and permeametry on whole plugs, yields both axis-specific surface area as a function of pore size and measures of pore connectedness. Additionally, these data yield mineral-specific reactive surface area using a novel technique particularly applicable to shales. These methods are applied to each lithology and a variety of samples to describe the formation as a whole. Reaction modeling for key minerals is performed using The Geochemist's Workbench, combining reactive surface area, degree of disequilibrium, and rate constant.