# Major and Minor Element and Radium Geochemistry of Produced Water Samples from the Marcellus Shale in New York, Pennsylvania, and West Virginia

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The inorganic geochemistry of produced water from the Marcellus Shale has been compared with analyses of waters produced from adjacent Devonian strata, including sandstone in the overlying Bradford Group, and the underlying Onondaga Limestone and Oriskany Sandstone using published data combined with a limited number of new analyses. Total dissolved solids values in waters produced from the Marcellus are similar to those produced from adjacent formations, and most commonly range from 100,000 to 300,000 mg/L. The waters produced from these formations are Na-Ca-Cl dominant, with low bicarbonate and sulfate concentrations. Low sulfate is consistent with the minimal barite precipitated from the produced waters, but only partially accounts for the high concentrations of dissolved barium (hundreds to thousands of mg/L), whose solubility remains poorly understood. Na/Br and Cl/Br ratios indicate mixtures of brines, with a major component of salinity derived from evaporatively concentrated seawater.

The Marcellus Shale is known to be enriched in uranium, based in part on its high gamma-ray response on geophysical logs. Radiochemical analyses of produced water from the Marcellus Shale show elevated radium-226, and lesser amounts of radium-228, the decay products of uranium-238 and thorium-232, respectively, with total radium activities of 100s to 10,000s of picocuries/liter. Produced waters from the overlying and underlying strata generally have lower radium activities than the Marcellus. The virtual absence of dissolved uranium in the produced waters reflects its low solubility in the reducing environments at depth that characterize most oil and gas reservoirs. Uranium thus remains predominantly as a solid phase while the more soluble element, radium, is brought to the surface with produced water.