A Regional Perspective of the Devonian Shale and Ordovician Utica Shale Total Petroleum Systems of the Appalachian Basin

Robert T. Ryder[1], Michael H. Trippi[1], Christopher S. Swezey[1], Robert C. Milici[1], John E. Repetski[1], Leslie F. Ruppert[1], and Elisabeth L. Rowan[1]

[1]U.S. Geological Survey, Reston, VA 20192, rryder@usgs.gov

The Devonian Shale-Middle and Upper Paleozoic and the Utica-Lower Paleozoic Total Petroleum Systems (TPS) are the prominent Appalachian basin TPSs defined by the USGS. They have known petroleum volumes (cumulative production + proved reserves), through 2008, of about 2.6 BBO/59.1 TCFG and 0.9 BBO/10.7 TCFG, respectively. A mean recoverable undiscovered gas resource of 61.3 TCFG (USGS 2002 assessment) from tight sandstone and black shale in both TPSs is conservative because it did not account for the full potential of the Devonian Marcellus Shale and did not include an assessment of the Ordovician Utica Shale.

Plots of known oil and gas accumulations, together with associated Ordovician, Devonian, and Pennsylvanian conodont CAI and (or) $\%R_o$ isograds and restored overburden thicknesses, on regional geologic cross sections provide several insights regarding the evolution of Appalachian shale-gas TPSs. First, these plots suggest that in both TPSs oil and gas migrated vertically at least 1,000 ft through relatively impermeable shale and carbonate, probably facilitated by fractures and faults. For example, oil and gas generated and expelled from the Marcellus Shale in N.Y., Ohio, Pa., and W.Va. probably migrated vertically through about 1,500 to 4,000 ft of overlying shale and siltstone into Upper Devonian and Mississippian sandstone. In addition, a short time after vertical migration, large volumes of Marcellus Shale gas (from cracked oil or kerogen conversion) were expelled a short distance into underlying Lower Devonian sandstone and migrated either into adjoining anticlines or updip as far as 50 miles. Furthermore, oil and gas generated and expelled from the Utica Shale in Ohio and Pa. suggest the following migration patterns: 1) westward across-dip migration for 30 to 80 miles through about 1,000 ft of underlying Ordovician carbonate rocks before entrapment in Cambrian reservoirs, and 2) vertical migration through about 1,500 ft of overlying Ordovician shale followed by updip migration as far as 50 miles before entrapment in Lower Silurian sandstone. Commonly, Devonian and Ordovician oils have migrated as much as 50 miles beyond the updip limit of oil generation. Secondly, the plots may offer clues why gas is the dominant in-place hydrocarbon in the largely oil-prone (type II kerogen) Marcellus, Ohio, and Utica Shales. Several observations imply that oil migrated from the shale source rocks into available reservoirs early in the maturation history leaving abundant in-place mobile gas and immobile oil, such as in the Ohio Shale of Big Sandy gas field, the emerging Marcellus shale-gas accumulation, and the potential Utica shale-gas (or shale-oil) accumulation. For example, in Ky., oil that was generated from the Ohio Shale early in the maturation process was expelled a short distance into underlying karsted Silurian-Devonian “Corniferous” strata and then migrated 30 to 50 miles updip into unconformity traps prior to major gas generation (from cracked oil or kerogen conversion) that left abundant in-place mobile gas in the Ohio Shale. Similar events are envisioned for the Marcellus and Utica Shales. In N.Y., Ohio, Pa., and W.Va., oil that was generated and expelled

from the Marcellus Shale migrated vertically into Upper Devonian and Mississippian sandstone prior to major gas generation that left abundant in-place mobile gas in the Marcellus Shale. By comparison, oil that was generated and expelled from the Utica Shale migrated westward into traps in Cambrian dolomite in central Ohio and in Ordovician carbonates in the Lima-Indiana field in northwestern Ohio prior to gas generation that left abundant in-place mobile gas in the Utica Shale.