Investigation of Methods to Improve Utica Shale Hydraulic Fracturing in the Appalachian Basin*

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Search and Discovery Article #40391(2009)
Posted March 16, 2009

*Adapted from extended abstract presented at AAPG Convention, San Antonio, TX, April 20-23, 2008

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Abstract

The primary purpose of stimulating fractured shale reservoirs is the extension of the drainage radius via creation of a long fracture sand pack that interconnects with natural fractures thereby establishing a flow channel network to the wellbore. However, there is limited understanding of a successful method capable of stimulating Utica Shale reservoirs. Indeed, most attempts to date have yielded undesirable results. This could be due to several factors, including formation composition, entry pressure, and premature pad fluid leak-off. Furthermore, stimulation of Utica shale reservoirs with acid alone has not been successful. This treatment method leads to a fracture length and drainage radius less than expected, resulting in poor well productivity.

In this work, geological data is first examined for the reservoir. Laboratory data are then presented to address the unique mineralogy and mechanical properties of the Utica Shale. The high percentage of acid soluble carbonate and dolomite suggests an acid treatment to lower entry pressures. This treatment can be the main stimulation of a vertical or horizontal well since natural fractures are present, or the acid breakdown can precede a gelled acid or proppant-laden water frac or crosslinked fracturing fluid treatment. Experimental results reveal the impact of clays, potential generation of fines both siliceous and organic, acid solubility, low temperature biological activity, potential for scale generation and the prevalent problem of recovery of injected fluids. Acid solubility is presented vs. time and acid strength. Conductivity data is presented for gas fracs, matrix acidizing and proppant fracturing of the shale. The adsorption, as well as the regained relative permeability to gas is examined vs surfactant type to allow the selection of an additive package that will optimize fluid recovery and improve relative permeability to gas. Information obtained from this study can be used to optimize fracturing treatments of Utica Shale reservoirs in the Appalachian Basin.

As interest in drilling and producing shale reservoirs throughout North America increases due to the success of the Barnett, Woodford, and Fayetteville shales, numerous potential reservoirs that have previously been undeveloped are being examined for their potential. The organic-rich, low-permeability Upper Ordovician Utica Shale is one such reservoir that displays many attributes which may result in a commercially viable play of great areal extent. This interest is driven largely by increased natural gas prices and improved completion technologies. Indeed, there may be no better example of the role of technology in natural gas recovery than the Late Mississippian Barnett Shale of the Fort Worth Basin, which provides an analog for exploration of similar unconventional reservoirs throughout North America. Nevertheless, there is no universal production model method of stimulating each and every unconventional reservoir that exists. The Utica Shale compares favorably with such organic-rich units as the Middle Devonian Marcellus Shale of the Appalachian Basin and the Upper Cretaceous Lewis Shale of the Green River Basin. Nevertheless, most unconventional reservoirs vary in terms of basic stratigraphic facies distribution, mineralogy (i.e., quartz content, clay type and content), natural fracture parameters (length, orthogonal spacing, connectivity, anisotropy), porosity and permeability, and rock mechanical properties.

The tight, organic-rich black shale deposits generating the interest of explorationists are the Utica Shale and the Devonian Marcellus and Rhinestreet shales of the Appalachian Basin. A previous publication described promising results of an experimental investigation of hydraulic fracturing and post-fracturing cleanup of the Upper Devonian Rhinestreet Shale of the Appalachian Basin. However, several recently drilled Utica Shale wells have not responded well to the normal shale fracturing practices. An understanding of Utica Shale mineralogy and rock mechanics is necessary before a stimulation method and fluid are selected.

The main objective of this paper is to examine methods of stimulating the Utica Shale. An overview of the geology of the Utica Shale is presented first. Laboratory data are then examined to address the unique mineralogy and mechanical properties of the Utica Shale. The high percentage of acid soluble carbonate and dolomite suggests that an acid treatment to lower entry pressures will be required. This treatment may be the main stimulation of a vertical or horizontal well since natural fractures are present, or the acid breakdown can precede a gelled acid or proppant-laden water frac or crosslinked fracturing fluid treatment. Experimental results reveal the impact of clays on extraction, potential generation of fines both siliceous and organic, acid solubility, low temperature biological activity, the potential for scale generation and the prevalent problem of recovering injected fluids. Acid solubility vs. time and acid strength is also presented. Conductivity data for gas fracs, matrix acidizing and proppant fracturing of the shale is considered. The adsorption as well as the regained permeability to gas is examined vs. surfactant type to allow the selection of an additive package that will optimize fluid recovery and improve relative gas permeability.

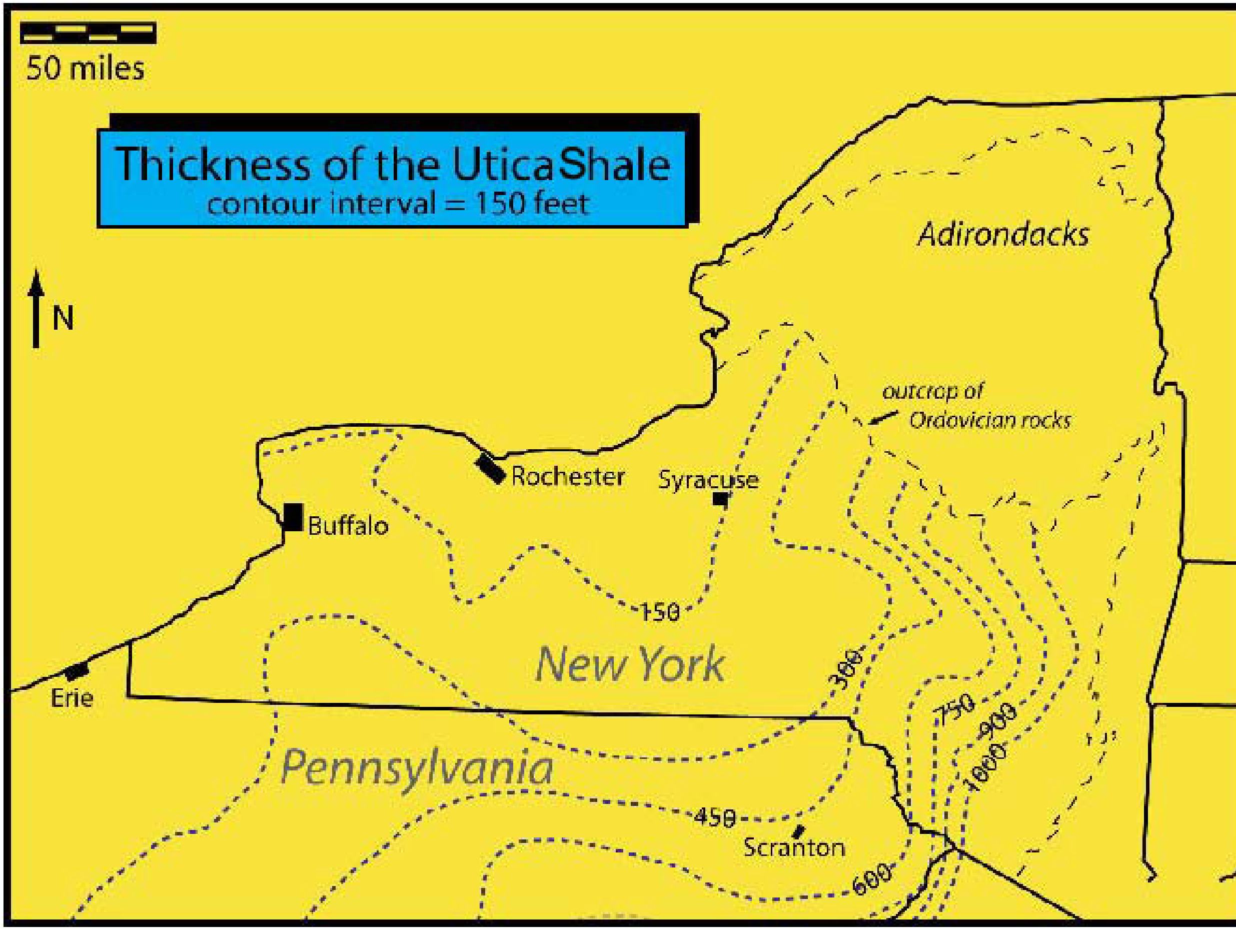

Figure 1. Map showing the thickness of the Utica Shale in New York State and northern Pennsylvania.

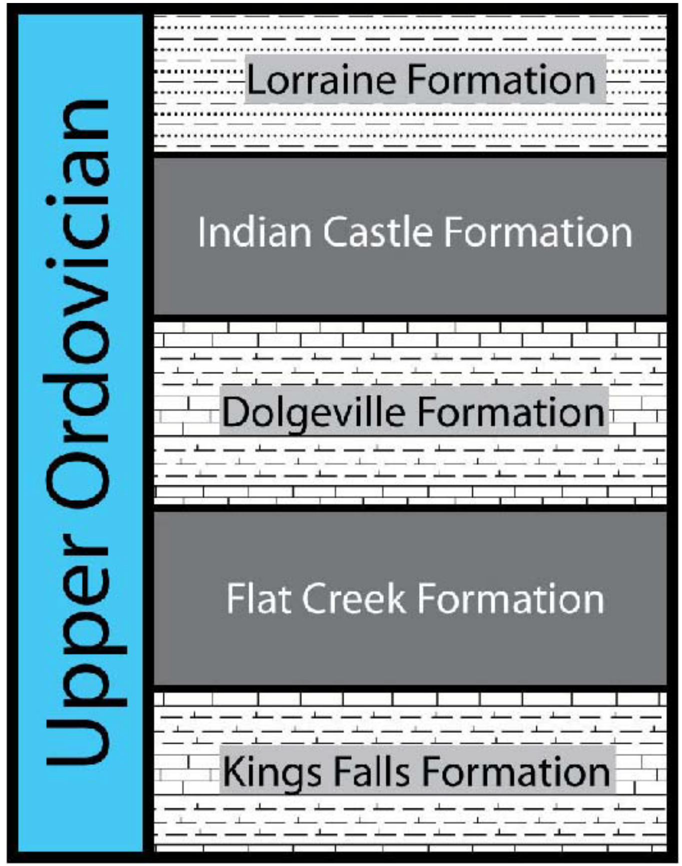

Figure 2. Simplified stratigraphic column of the Upper Ordovician interval of New York State (modified - not to scale).

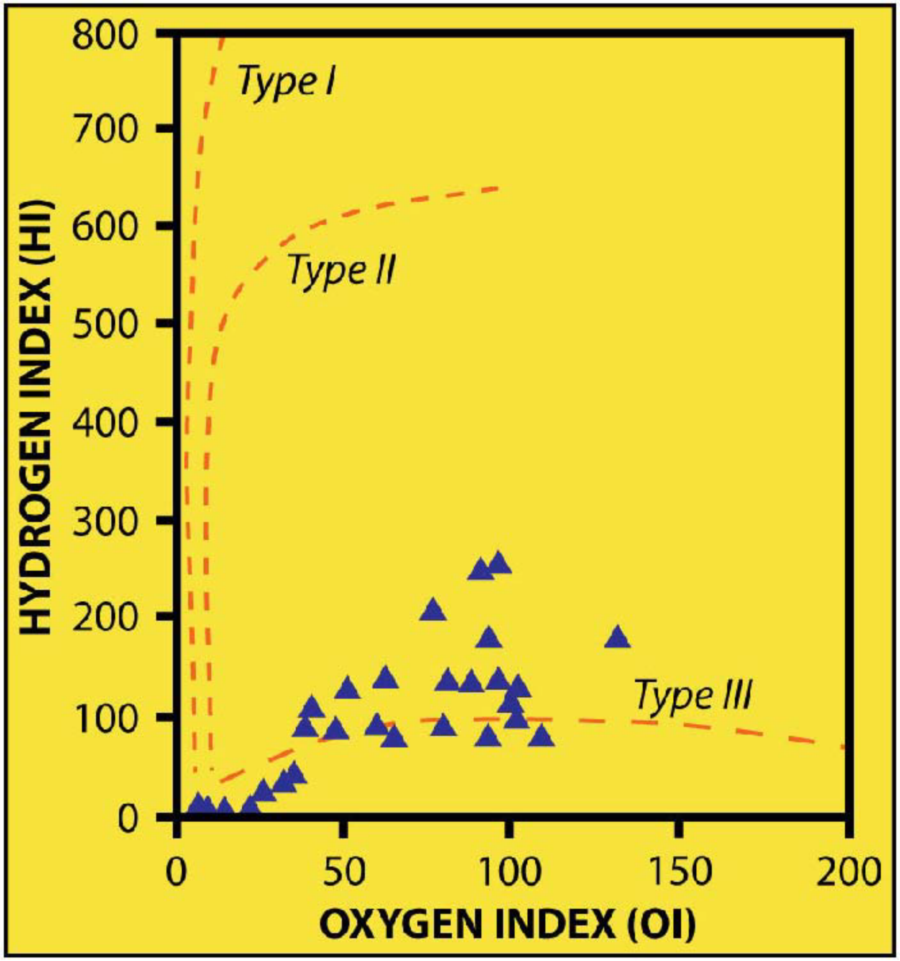

Figure 3. Crossplot of Rock-Eval hydrogen index (HI) vs oxygen index (OI) showing hydrocarbon generative (kerogen) types for the Utica Shale, New York State.

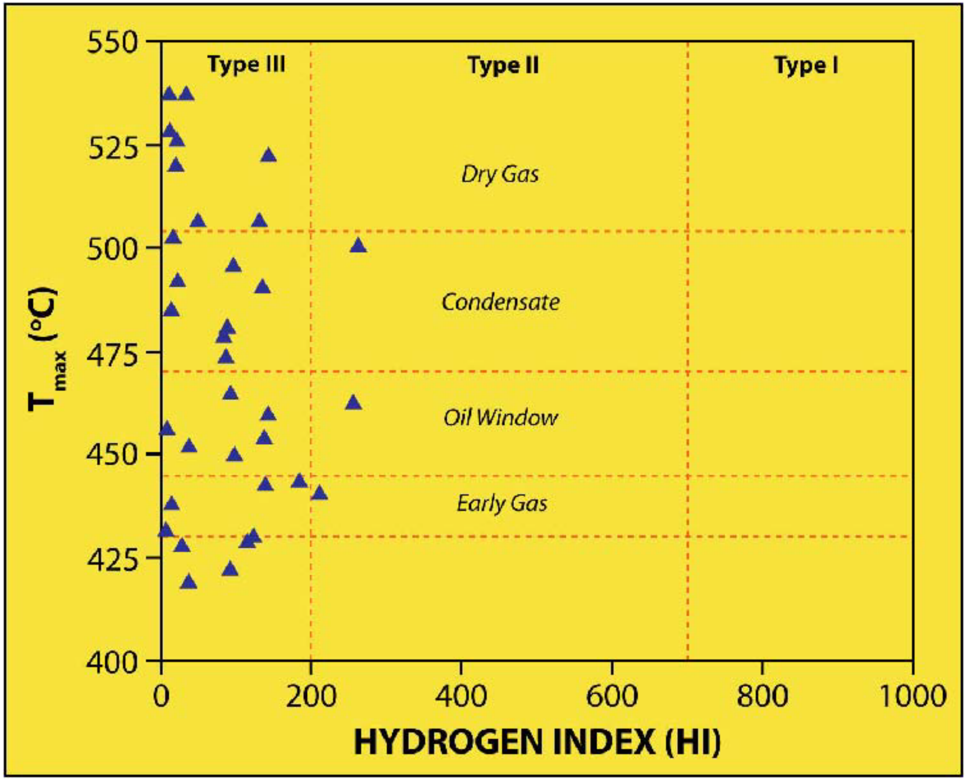

Figure 4. Crossplot of Rock-Eval T max vs hydrogen index (HI) data showing the range in thermal maturity of Utica Shale samples as well as hydrocarbon generative (kerogen) types for the Utica Shale, New York State.

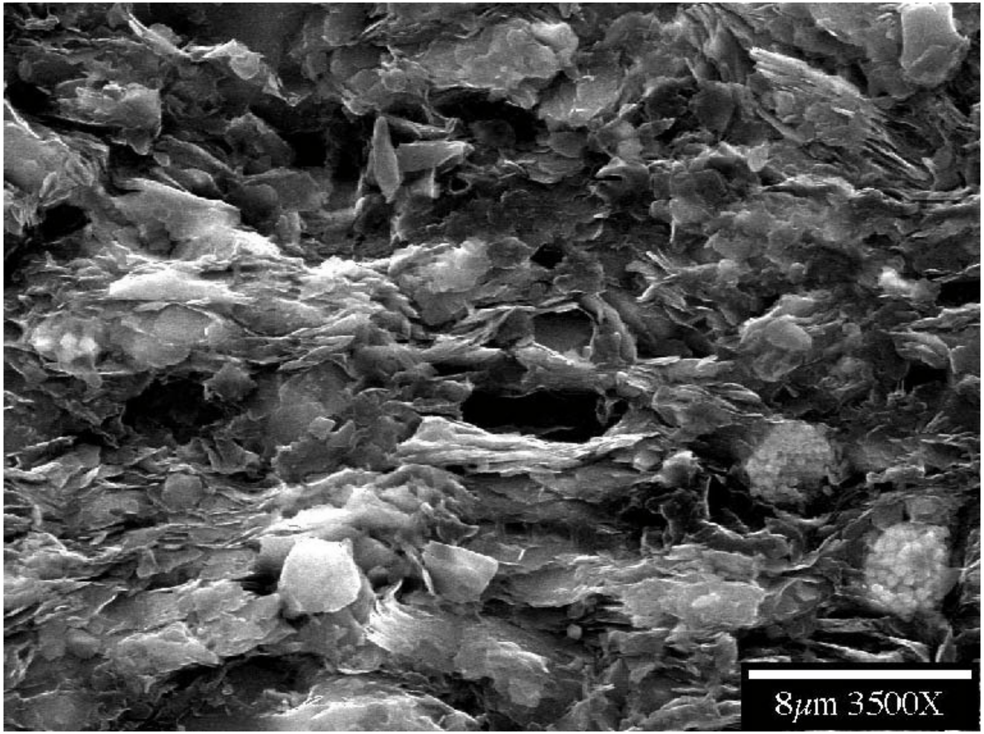

Figure 5a. Scanning electron images of Utica Shale samples; oversize quartz silt grain in an otherwise tight clay-grain matrix.

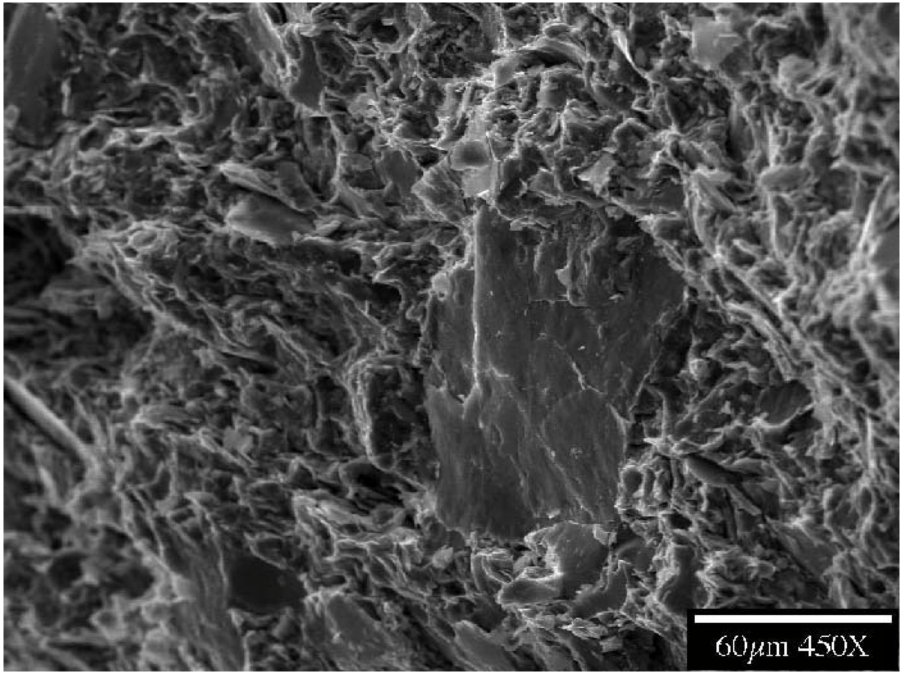

Figure 5b. Scanning electron images of Utica Shale samples showing planar clay-grain microfabric; note void in the center of the image.

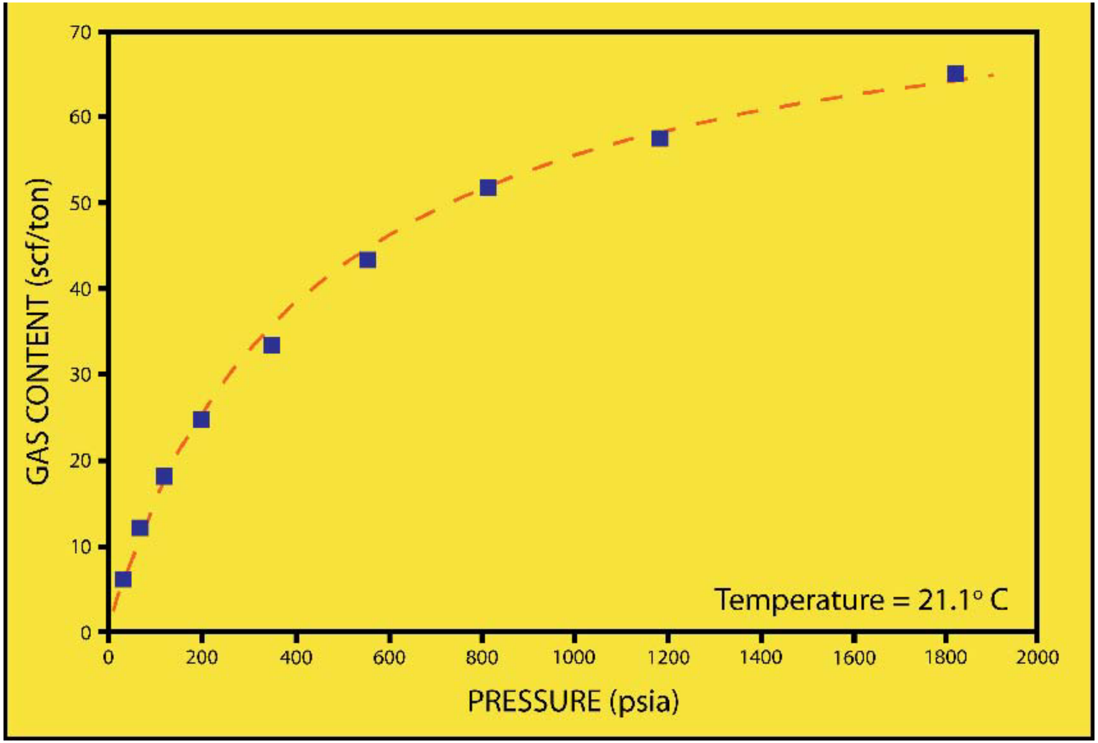

Figure 6. Methane adsorption isotherm for the Utica Shale.