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National Assessment of Oil and Gas

Assessment of Undiscovered Oil and Gas Resources of the Ordovician Utica Shale of the Appalachian Basin Province, 2012

Introduction

The U.S. Geological Survey (USGS) assessed unconventional oil and gas resources of the Upper Ordovician Utica Shale and adjacent units in the Appalachian Basin Province. The assessment covers parts of Maryland, New York, Ohio, Pennsylvania, Virginia, and West Virginia (fig. 1). The geologic concept is that black shale of the Utica Shale and adjacent units generated hydrocarbons from Type II organic material in areas that are thermally mature for oil and gas. The source rocks generated petroleum that migrated into adjacent units, but also retained significant hydrocarbons within the matrix and adsorbed to organic matter of the shale. These are potentially technically recoverable resources that can be exploited by using horizontal drilling combined with hydraulic fracturing techniques.

Utica Shale Self-Sourced Reservoirs

The Utica Shale and Late Ordovician age equivalents are the primary source rocks in the Utica–Lower Paleozoic Total Petroleum System (TPS) of Milici and others (2003). The shales are mainly present in New York, Ohio,

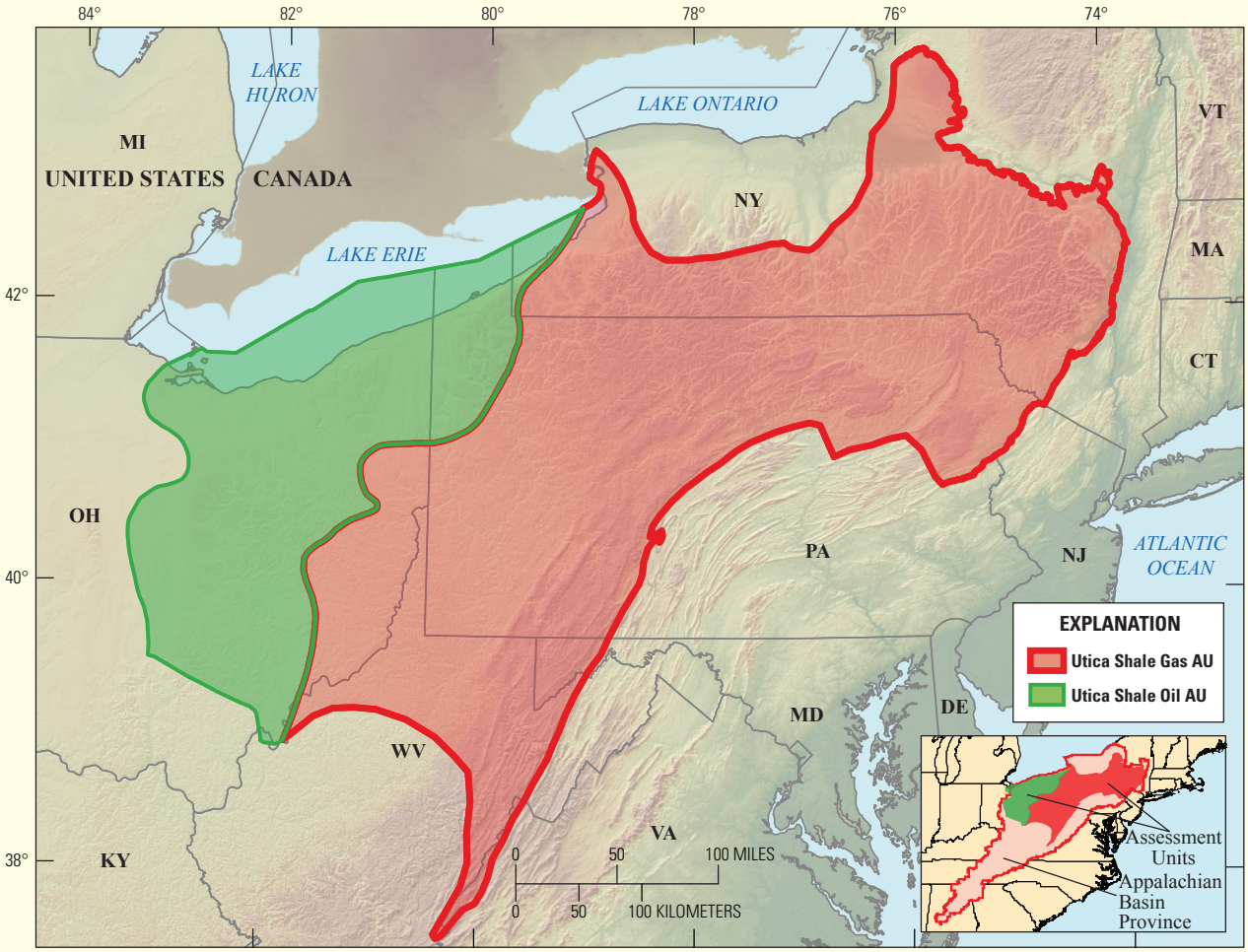

Figure 1. Location of the oil and gas assessment units (AU) for the Utica Shale in the Appalachian Basin Province.

Pennsylvania, and West Virginia. For this assessment, black shale facies of the Utica are combined with equivalent units — Antes Shale in central Pennsylvania and the Point Pleasant Formation in Ohio and Pennsylvania (Patchen and others, 2006). Thickness of the black shale facies is as much as 700 ft in southwestern Pennsylvania (Patchen and others, 2006) and New York (Ryder, 2008), but typically ranges from 150 to 350 ft (Ryder, 2008).

The facies consist of calcareous to clay-rich mudrock with total organic carbon (TOC) values commonly in excess of 1 weight percent (wt %) (fig. 2). There is a broad northeast-southwest-trending area that extends across western and southern Pennsylvania, eastern Ohio, northern West Virginia, and southeastern New York where TOC values are in the 2 to 3 wt % range (fig. 2; Wallace and Roen, 1989; Ryder and others, 1998). The Utica is an oil-prone source rock containing Type II kerogen (Ryder and others, 1998). Conodont color alteration index (CAI) isograds (fig. 3), based on samples from the Ordovician rocks (Repetski and others, 2008), indicate that a pod of mature Utica source rocks underlies most of the TPS. The Utica source rocks are within a thermal region that generates oil between a CAI of 1 to 2 and generates gas above 2 (fig. 3; Ryder, 2008).

Geologic Model for Assessment

The geologic model used in the assessment of the Utica Shale and adjacent organic-rich shale is that oil and gas were generated in the organic-rich shale and occupies matrix porosity as well as organic porosity in the same shale. A TOC lower cutoff of 1 wt % was used for potential source rocks. The thermal window for oil was based on a CAI greater than 1, and the window for gas and oil cracking to gas used a CAI of 2. A comparison of preliminary production from the Utica in southeastern Ohio confirmed that a CAI of 2 approximates the oil/ gas boundary in eastern Ohio with some degree of confidence; however, all contour lines are subject to geologic uncertainty. The oil/gas boundary is based on a gas-to-oil ratio of 20,000 cubic feet of natural gas per barrel of oil. The

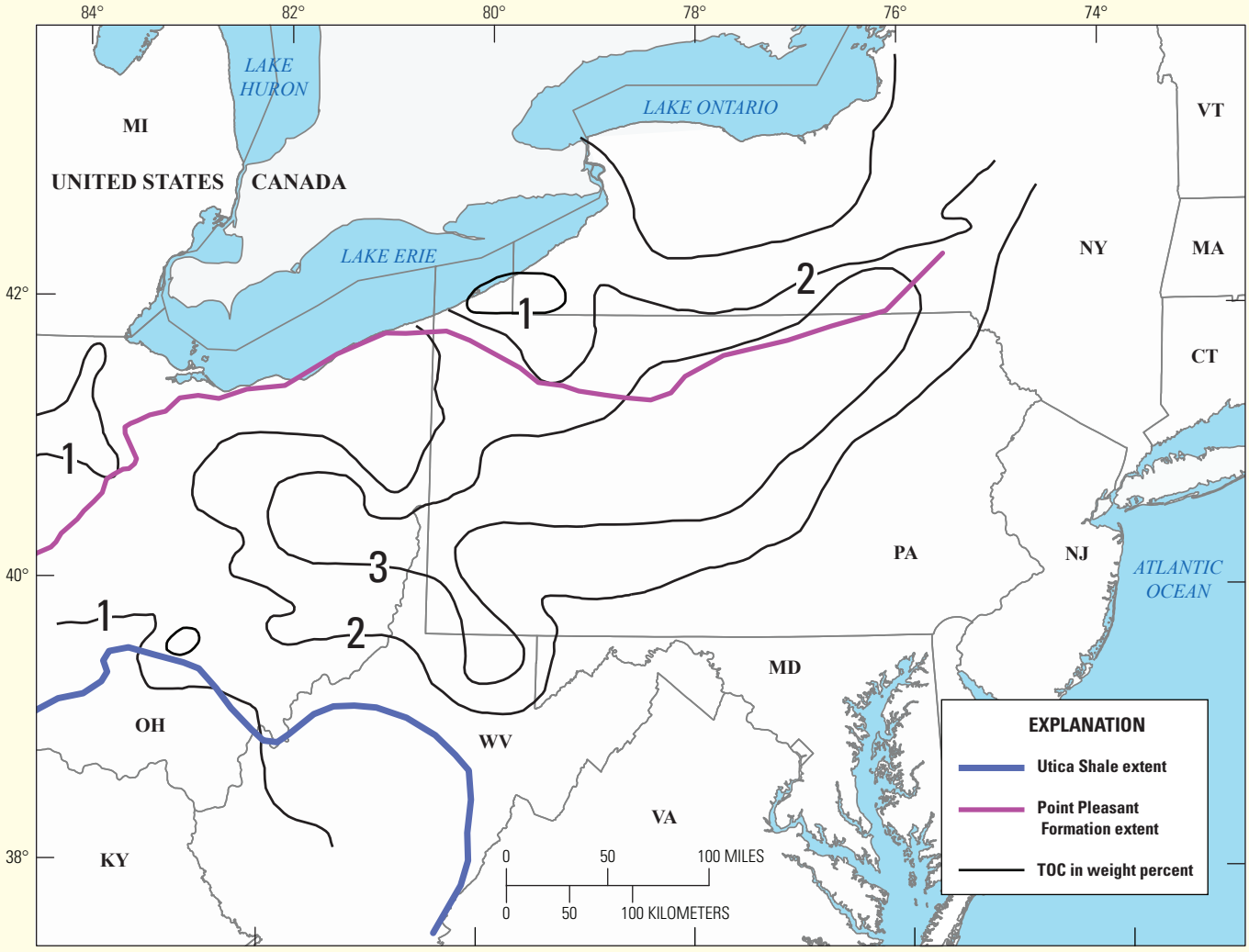

Figure 2. Map of total organic carbon (TOC) in weight percent from Ryder (2008), and mapped southern limit of Utica Shale (blue line) and mapped northern extent of the Point Pleasant Formation (purple line) from Patchen and others (2006).

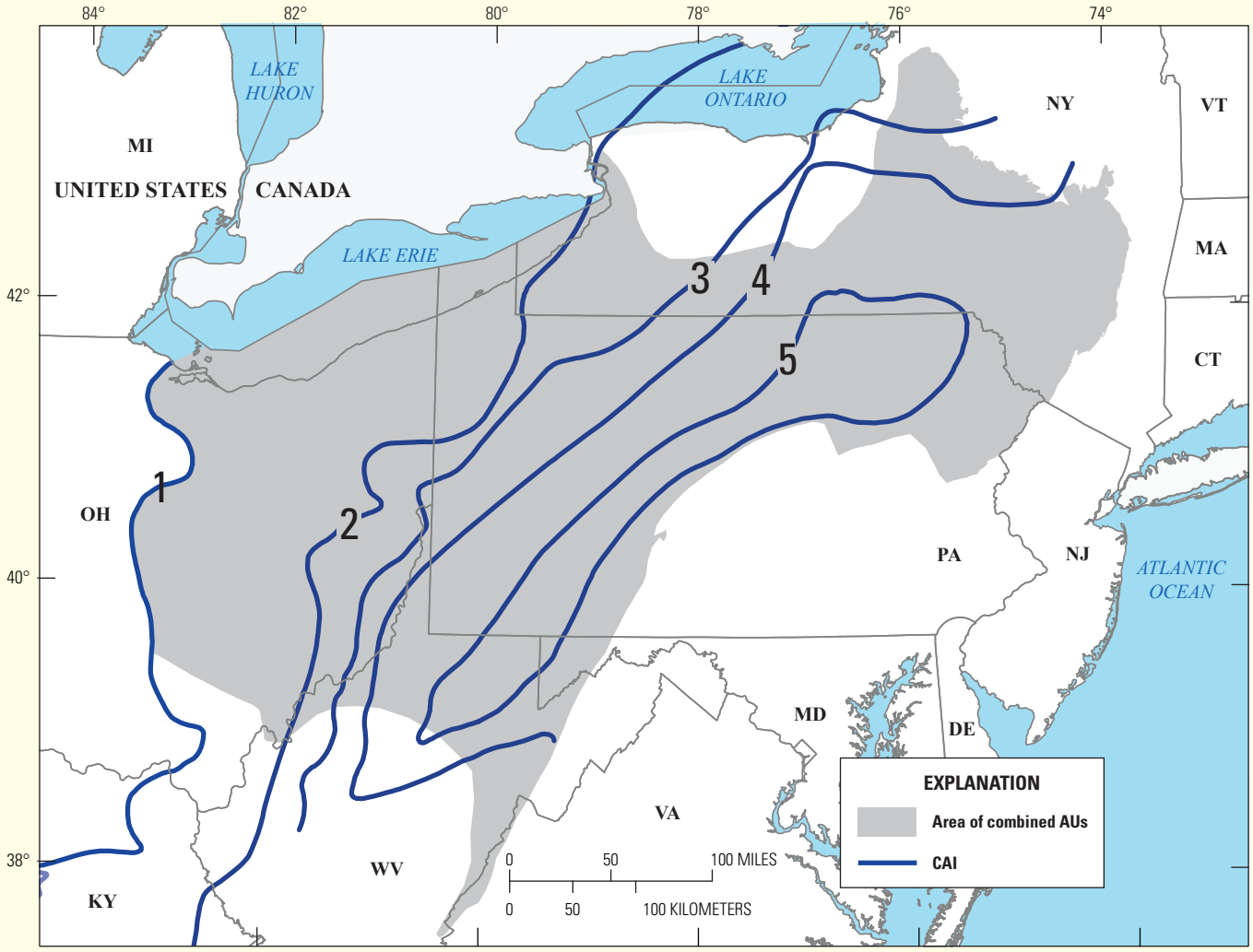

Figure 3. Map of conodont alteration index (CAI) for the Utica Oil and Gas Assessment Units (AU) after Repetski and others (2008, their fig. 5). The 1+ isograd is used to estimate the generation threshold for oil; the 2 isograd is used to estimate the gas threshold.

Utica has little history of production, therefore production data were supplemented with analog data from the Devonian Marcellus Shale, Cretaceous Eagle Ford Shale, and Cretaceous Niobrara Formation. The Marcellus is an analog mainly for its proximity and similar geologic setting, and the Cretaceous units for their facies similarity. Analog data include estimated ultimate recoveries (EUR), mean drainage areas of wells, and ranges of well success ratios. Key assessment input data are listed in table 1.

Assessment Units

The Utica Shale Gas Assessment Unit (AU) is defined where the thermal maturity of the organic matter is greater than a CAI of 2 (fig. 3) and by several constraints that determine the boundaries: total organic carbon (TOC) of greater than 1 wt % (fig. 2), the Allegheny structural front to the southeast, the outcrop of the Utica in New York to the east, and where the unit changes facies into carbonates to the south (see Patchen and others, 2006) (fig. 1).

The Utica Shale Gas AU "sweet spot" is defined as an area in which Utica Shale and equivalents contain TOC greater than 2 wt % and also is underlain by the black shale facies of the Point Pleasant Formation (fig. 4). A possible limiting factor for the sweet spot is whether the Point Pleasant in Ohio and Pennsylvania forms a continuous accumulation with the lower part of the Utica Shale (Flat Creek Member) in New York. A further limiting factor is the possible degradation of reservoir quality in both the deeper and shallower parts of the AU. The sweet spot has been modified to encompass current drilling in the AU where EURs are greater than the minimum cutoff of 0.02 billion cubic feet of gas (BCFG).

The Utica Shale Oil AU (fig. 1) is defined by the presence of the Utica Shale and equivalents based on Ryder (2008) and Patchen and others (2006). It is limited to an area of the Utica that has a thermal maturity greater than a CAI of 1 (Repetski and others, 2008) and TOC content greater than 1 wt% (Wallace and Roen, 1989;

Table 1. Key assessment input data for shale oil and shale gas assessment units for the Utica Shale in the Appalachian Basin.

[EUR (estimated ultimate recovery per well), well drainage area, and success ratios are from U.S. shale oil and shale gas analogs. MMBO, million barrels of oil; BCFG, billion cubic feet of gas; AU, assessment unit; %, percent. The average EUR input is the minimum, median, maximum, and calculated mean]

Assessment input data	Utica Shale Oil AU				Utica Shale Gas AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	13,500,000	15,000,000	16,500,000	15,000,000	25,800,000	31,600,000	37,400,000	31,600,000
Average drainage area of wells (acres)	150	250	350	250	120	150	180	150
Percentage of AU in sweet spots (%)	7	14	22	14	9	21	50	27
Input data for sweet spots								
Average EUR (MMBO, oil; BCFG, gas)	0.04	0.08	0.2	.086	0.2	0.6	1.1	0.619
Success ratios (%)	70	80	90	80	75	85	95	85
Input data for nonsweet spots								
Average EUR (MMBO, oil; BCFG, gas)	0.01	0.03	0.1	0.034	0.04	0.10	0.60	0.128
Success ratios (%)	5	20	35	20	10	40	70	40

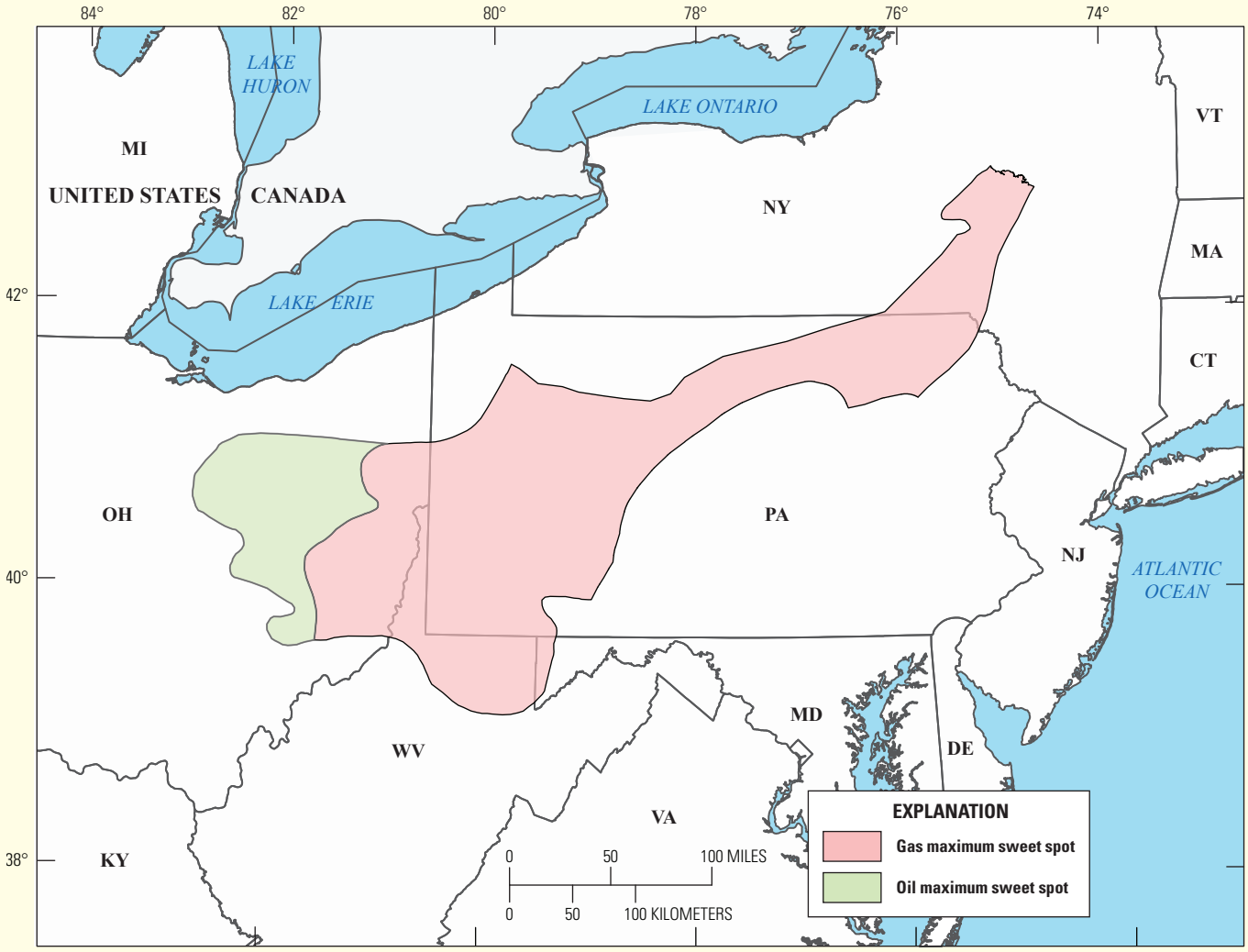

Figure 4. Map of maximum extent of the oil and gas sweet spots. The boundaries are based on total organic carbon, extent of Point Pleasant Formation, and current (2012) understanding of well completions. See table 1 for percentages.

Ryder, 2008) (fig. 2). The downdip limit is placed at a thermal maturity greater than a CAI of 2 (fig. 3). The AU boundary also ends at the United States–Canadian border and where the shale changes facies into carbonates to the south (fig. 1).

The Utica Shale Oil AU "sweet spot" encompasses an area of Utica Shale and equivalents and the underlying Point Pleasant Formation (fig. 4), where TOC is consistently greater than 2 wt% (fig. 2; Repetski and others, 2008; Riley and others, 2012). The sweet spot also includes current wells where EURs are considered to be greater than the minimum of 0.002 million barrels of oil (MMBO).

Resource Summary

The USGS assessed technically recoverable continuous (unconventional) oil and gas resources for the two AUs of the Ordovician Utica and Point Pleasant black shale of the Appalachian Basin Province, resulting in estimated means of 940 MMBO, 38.2 trillion cubic feet of gas (TCFG), and 208 million barrels of natural gas liquids (MMBNGL) (table 2).

wells at the mean to be drilled in the nonsweet spot to extract the resource.

The Utica Shale Oil AU is an area of about 15,000,000 acres at the mean and is divided into a sweet spot and a nonsweet spot. The estimated mean resource volumes are 940 MMBO (range from 590 to 1,386 MMBO), 939 BCF of associated gas (range from 505 to 1,517 BCF), and 9 MMBNGL (range from 4 to 16 MMBNGL). Estimates of average drainage area for the AU and separate estimates of average EUR and success ratio are made for the sweet and nonsweet spots (table 1). Because there is a limited amount of existing oil production from the Utica, EUR distributions for sweet and nonsweet spots are estimated from distributions of other shale oil assessment units (U.S. Geological Survey Oil and Gas Assessment Team, 2012, their fig. 4). Based on these input parameters, recovery of the resource would require at the mean about 7,000 wells to be drilled within the sweet spot and an additional 10,500 wells at the mean to be drilled in the nonsweet spot to extract this potential resource.

Table 2. Assessment results for potential unconventional oil and gas resources of Utica Shale in the Appalachian Basin.

[MMBO, million barrels of oil; BCFG, billion cubic feet of gas; MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. For gas accumulations, all liquids are included under the NGL (natural gas liquids) category. Undiscovered gas resources are the sum of nonassociated and associated gas. F95 represents a 95 percent chance of at least the amount tabulated–other fractiles are defined similarly. Fractiles are additive under the assumption of perfect positive correlation. AU probability is the chance of at least one well within the AU having a production capacity of the minimum estimated ultimate recovery. Gray shading indicates not applicable]

Provinces, Total petroleum systems (TPS), and Assessment Units (AU)	AU probability	Accumulation type	Total undiscovered resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Utica-Lower Paleozoic TPS														
Utica Shale Gas AU	1.0	Gas					20,601	35,659	59,415	37,273	71	183	382	199
Utica Shale Oil AU	1.0	Oil	590	911	1,386	940	505	897	1,517	939	4	9	16	9
Total unconventional resources			590	911	1,386	940	21,106	36,556	60,932	38,212	75	192	398	208

The Utica Shale Gas AU is an area of about 31,600,000 acres at the mean and is divided into sweet spot and nonsweet spot areas. The estimated mean resource volumes are 37,273 BCFG (range from 20,601 to 59,415 BCFG) and 199 MMBNGL (range from 71 to 382 MMBNGL). Estimates of average drainage area are made for the AU, and separate estimates of average EUR and success ratio are made for the sweet and nonsweet spots (table 1). Because there is a limited amount of existing gas production from the Utica, EUR distributions for sweet spot and nonsweet spots are estimated from distributions of other shale gas AUs (U.S. Geological Survey Oil and Gas Assessment Team, 2012, their fig. 1). Based on these input parameters, recovery of the potential resource would require at the mean about 48,000 wells to be drilled within the sweet spot and an additional 62,000

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For Additional Information

Supporting geologic studies of Utica Shale and Assessment Units, and reports on the assessment methodology used in the assessment can be found at the USGS Energy Resources Program website (*http://energy.usgs.gov*).

Hand-tinted photo of Ordovician Utica Shale with interbedded sandstone of the Ordovician Lorraine Shale above, Jefferson County, New York. Photograph 1889 by C.D. Wolcott, third Director of the USGS. *http://library photo.cr.usgs.gov.*