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Assessment of the Marcellus Shale, Utica Shale, and East Coast Mesozoic basins in the eastern United States – a review

Robert C. Milici, U.S. Geological Survey, Reston, Virginia 20192 (Retired)
rmilici@usgs.gov

James L. Coleman, U.S. Geological Survey, Reston, Virginia 20192

Mark A. Kirschbaum, U.S. Geological Survey, Denver, Colorado 80225 (Retired)

Summary

The U.S. Geological Survey (USGS) has recently assessed the technically recoverable, undiscovered hydrocarbon resources of three continuous (unconventional) hydrocarbon accumulations in the eastern United States: the Utica Shale (Ordovician) (Kirschbaum and others (2012), the Marcellus Shale (Devonian) in the Appalachian Basin Province (Coleman and others, 2011), and the East Coast Mesozoic basins (Milici and others, 2012), which are located onshore in the Appalachian, Piedmont, Blue Ridge, and New England Provinces, beneath the Atlantic Coastal Plain Province, and offshore in the state waters of the Continental Shelf. The volumes of natural gas calculated in the more recent assessments of the Marcellus Shale and Mesozoic basins are significantly greater than those assessed previously by the USGS for these plays. Although four continuous assessment units sourced by the Utica Shale and containing sandstone reservoirs were defined within the continuous oil and gas resources of the Utica-Lower Paleozoic Total Petroleum System in the 2002 assessment of the Appalachian Basin (Milici and others, 2003), the Utica Shale source rock was not quantitatively assessed as a self-sourced continuous reservoir at that time. Subsequently, the recent (2012) assessment of the Utica Shale by the USGS was largely in response to the recent development of the Utica Shale by industry as well as the development of extensive continuous shale gas resources elsewhere in the U.S.

Introduction

With the advent of bedding-parallel or horizontal drilling in combination with hydraulic fracture stimulation, the continuous shale gas accumulations of the eastern U.S. are currently being extensively explored and developed. Both the Marcellus Shale (figs. 1 and 2) and Utica Shale (fig. 3) extend over large areas of the Appalachian Basin foreland and, in places, are prone to produce oil, natural gas, and natural gas liquids. The Marcellus Shale was assessed previously by the USGS within the last decade (Milici and others, 2003), but prior to the use of horizontal drilling combined with hydraulic fracture technology to develop this continuous gas and oil accumulation. The impact of these recent technological advances on well performance has greatly improved the potential for oil and gas development in the region. At the time of the 2002 assessment almost all of the available production data from the Marcellus Shale was from vertical wells in central Pennsylvania (fig. 1), where the thickness of the formation is 100 feet or more, the formation contains a relatively high total organic carbon (TOC), is thermally mature to overmature with regard to hydrocarbon generation, and kerogen

types are gas prone (Zeilinski and McIver, 1982). The Appalachian Basin Province Assessment Team estimated that, at the mean, the gas resources in only seven percent of the assessment unit area would be added to reserves over the next several decades. Subsequent exploration and development by industy has demonstrated that a much larger area of the Marcellus is conducive to the economic production of natural gas and natural gas liquids, especially where horizontal drilling and hydraulic fracturing are used. Accordingly, in 2011 the Marcellus Shale was re-assessed by the USGS (Coleman and others, 2011).

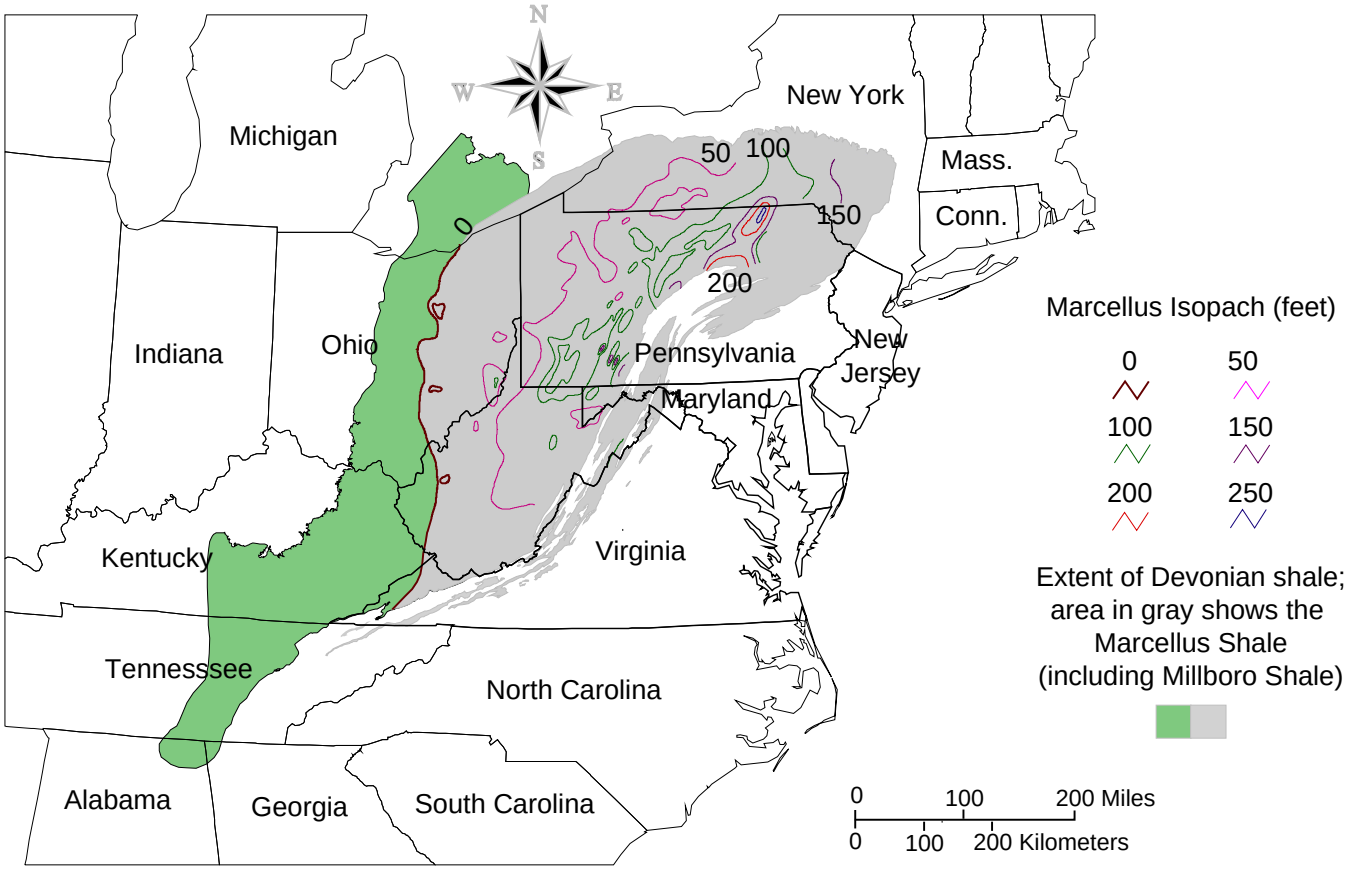

Figure 1. Thickness of the Marcellus Shale in the Appalachian Basin, showing the area of the Marcellus Shale assessment unit for the 2002 assessment (from Milici, 2005).

Theory

As a result of the development and combined use of horizontal drilling and hydraulic fracturing, continuous oil and gas resources, also known as unconventional hydrocarbon resources, are currently being extensively explored and developed in North America. Based on available well performance and analogue data from other continuous accumulations, recent assessments of the Marcellus and the East Coast Mesozoic basins by the USGS have significantly increased the estimates of their technically recoverable undiscovered hydrocarbons. The Utica Shale (fig. 3), which was not previously assessed in the USGS 2002 assessment, also appears to contain relatively large amounts of technically recoverable undiscovered hydrocarbons.

Examples

Marcellus Shale

The mean results of the 2002 and 2011 assessments of the Marcellus Shale in the Appalachian basin are shown in Table 1. The area that was defined as the Marcellus Shale Assessment Unit for the 2002 assessment of the Appalachian basin was restricted to the eastern part of the formation in the United States part of the basin; to the west the Marcellus Shale was included within several other Devonian shale assessment units. In contrast, for the 2011 assessment the entire area of the Marcellus Shale in the part of the Appalachian basin within the United States was studied as a single stratigraphic unit and it was divided into three assessment units: the Western Margin Marcellus AU (WMMAU), the Interior Marcellus AU (IMAU), and the Foldbelt Marcellus AU (FMAU) (fig. 2). The estimate for the percentage of untested assessment-unit area that has a potential for additions to reserves for each of these AUs is (WMMAU) 7 %, (IMAU) 37%, and (FMAU) 5%, with 97% of the resource in the IMAU (USGS Marcellus Shale Assessment Team, 2011). This is a significantly greater area than the 7% used by the 2002 assessment to calculate the size of the untested area of the Marcellus AU that had a potential for additions to reserves.

Table 1. Comparison of the USGS assessment results for the technically recoverable undiscovered natural gas resources of the Marcellus Shale AUs, East Coast Mesozoic Basin AUs, and the Utica Shale AU, in the eastern United States (Coleman and others, 2011; Milici, 1995, 2005, Milici and others, 2001, 2012); Kirschbaum and others, 2012;

Marcellus Shale				
2002 Assessment			**2011 Assessment**	
		BCFG		
F50	1,736		F50	78,683
F5	3,668		F5	144,145
Mean	**1,925**		**Mean**	**84,198**
Mesozoic basins				
95 Assessment			**2011 Assessment**	
		BCFG		
median	35		F50	3,533
P5	350		F5	7,056
Mean	**348**		**Mean**	**3,860**
Utica Shale				
2002 Assessment			**2012 Assessment**	
		BCFG		
Did not assess			F50	36,556
quantitatively			F5	60,932
			Mean	**38,212**

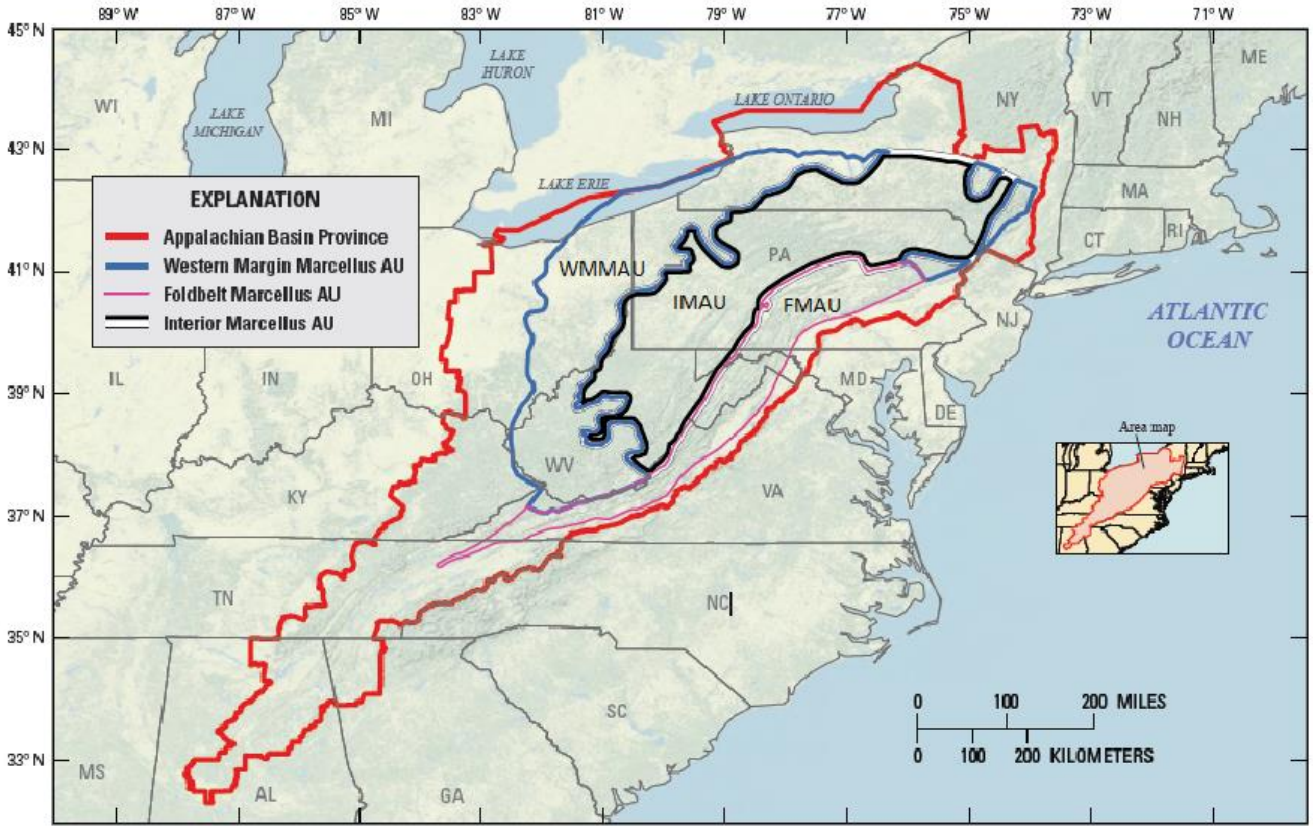

Figure 2. Marcellus Shale AUs for the 2011 assessment (slightly modified from Coleman and others 2011).

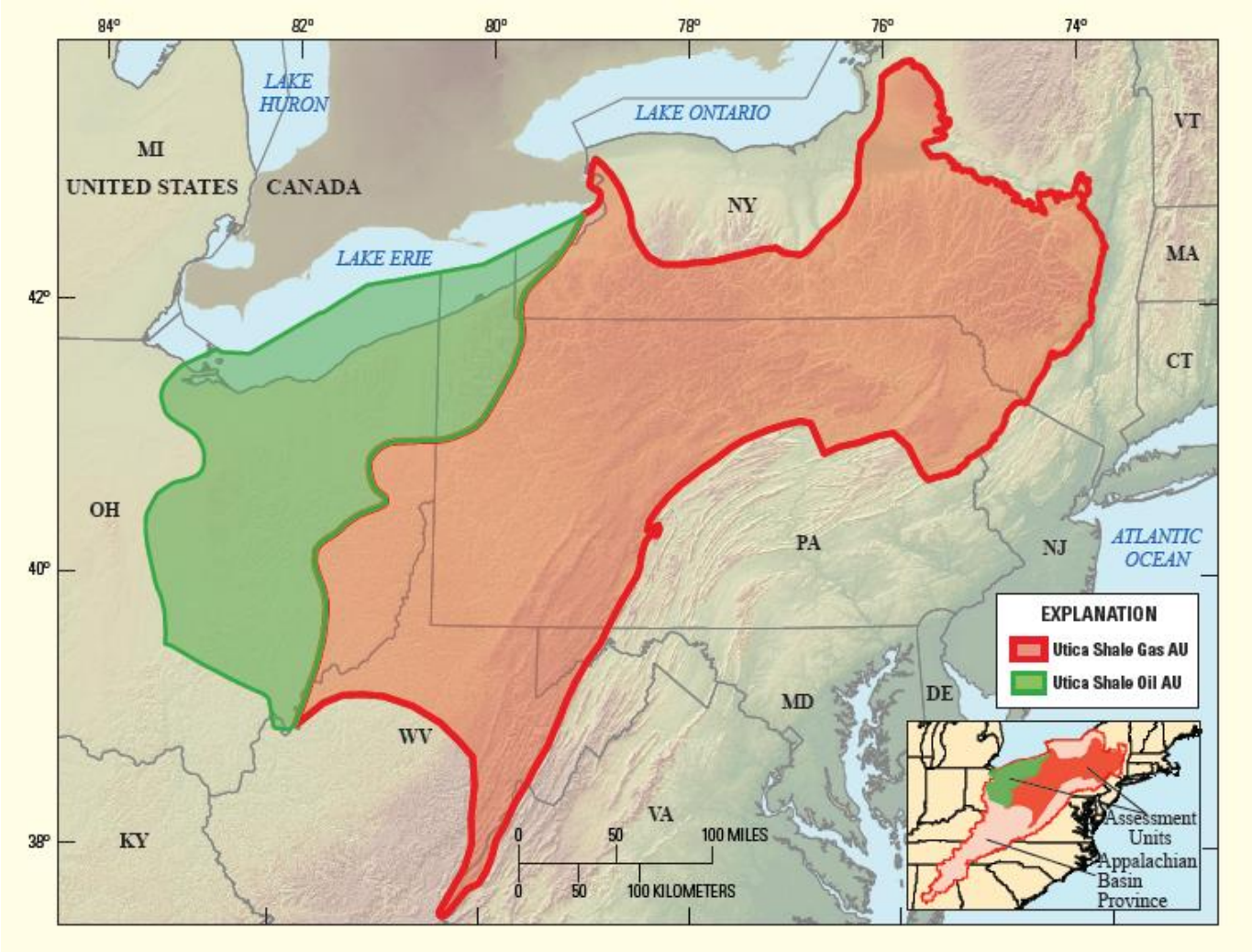

Figure 3. Utica Shale AUs for the 2012 assessment (from Kirschbaum and others, 2012).

East Coast Mesozoic basins

The mean results for the 1995 and 2011 assessments of the East Coast Mesozoic basins are shown in Table 1 and their distribution is shown in Figure 4. In the 1995 assessment, the East Coast Mesozoic Basin play was assessed as a single assessment unit that occurred within four geologic provinces, the Piedmont, Blue Ridge, Atlantic Coastal Plain, and New England provinces. The relatively low amounts of geologic data together with the tendency to focus on technically recoverable undiscovered conventional resources in structural, stratigraphic, and combination traps resulted in the generation of a relatively low estimate of gas for the assessment. In contrast, the 2011 assessment was based on the potential for continuous resources in these basins. Source rocks of black shale and coal beds occur in almost all of these basins, and may be effective as self-sourced reservoirs. In addition, there is a considerable potential for continuous hydrocarbon accumulations within associated tight sandstones in some of the basins, and the assessment team elected to combine source beds and sandstones into continuous tight gas assessment units within the five basins that were considered to have the highest potential for gas generation and accumulation (fig. 4).

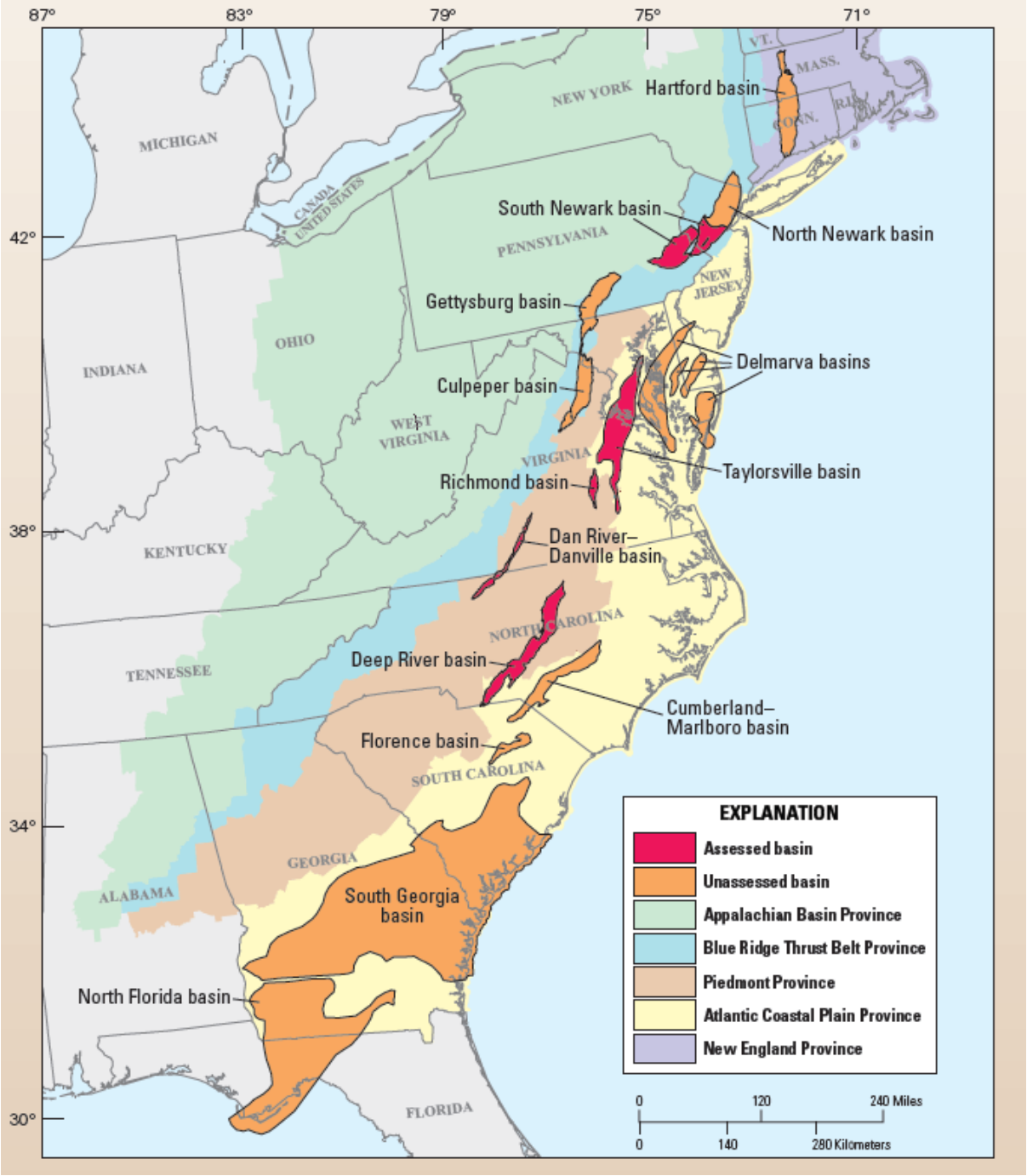

Figure 4. Location of the major Mesozoic basins in the eastern U.S. The unassessed basins are those that are known to possess a potential for hydrocarbon generation and production, although there was not sufficient data to conduct a quantitative assessment of them in 2011 (from Milici and others, 2012). For the 1995 assessment, the Mesozoic basins were combined into one assessment unit.

Conclusions

As a result of improved analogues and assessment methodology, together with advances in exploration, drilling and production technology within continuous resources, we recently estimated that there is about 11 times more technically recoverable undiscovered gas in the East Coast Mesozoic basins and 44 times more gas in the Marcellus Shale than had been estimated in previous assessments. In addition, the Utica Shale (Table 1, fig. 3) has been added as an important exploration target in the Appalachian Basin.

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