

# Assessment of Undiscovered Gas Resources in the Middle Devonian Marcellus Shale of the Appalachian Basin Province, 2019

Using a geology-based assessment methodology, the U.S. Geological Survey estimated undiscovered, technically recoverable continuous mean resources of 96.5 trillion cubic feet of gas in the Middle Devonian Marcellus Shale of the Appalachian Basin Province.

## Introduction

In 2019, the U.S. Geological Survey (USGS) completed a geology-based assessment of undiscovered, technically recoverable continuous (or unconventional) gas and natural gas liquids (NGL) resources in the Middle Devonian Marcellus Shale of the Appalachian Basin Province. The assessed area comprises parts of Kentucky, Maryland, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia (fig. 1).

## Geologic Model for Assessment

The assessment was based on the geologic elements of the Devonian Shale–Middle and Upper Paleozoic Total Petroleum System (TPS), including (1) hydrocarbon source rocks (source-rock composition, richness, and levels of thermal maturation and associated oil and gas generation and retention); (2) reservoir rock type (continuous), distribution, and properties (mineral composition, brittleness, fractures, thickness, porosity, and permeability); and (3) types and distribution of reservoir traps and seals and their timing relative to oil and gas generation (Higley and Enomoto, in press; Higley and others, in press). The assessed Marcellus Shale is primarily organic-rich marine mudrock, and contained petroleum resources are self-sourced based mostly on levels of thermal maturation in petroleum productive areas.

Using this geologic framework, the USGS defined and quantitatively estimated undiscovered, technically recoverable gas and NGL resources for six continuous assessment units (AUs). Input data used to assess the six continuous AUs are in table 1. Current gas and NGL productive wells for the Middle Devonian Genesee Shale Member of the Genesee Formation and Burket Shale produce gas and NGL from less than 100 wells in the basin; these wells closely overlie the Marcellus Shale and associated production and decline rates. Primarily for those reasons, the Genesee and Burket Shales were not assessed separately but are included as a minor part of Marcellus Shale resources. The extent of potential Marcellus Shale resources is based mainly on depths to the base of the mudrock of greater than 1,000 feet (ft) (304.8 meters [m]), a vitrinite reflectance equivalent of 0.5 percent and greater, and 25 ft (7.6 m) and greater thicknesses of organic-rich and brittle lithofacies. Information on Marcellus Shale thickness, depth, faulting and fracturing, levels and history of thermal maturation, pressure distribution, lithofacies composition, and other local-to-regional controls on resources include Zagorski and others (2012), Wang and Carr (2013), Higley and Enomoto (in press), and Higley and others (in press).

## Undiscovered Resources Summary

The USGS quantitatively assessed undiscovered continuous gas and NGL resources within six AUs defined for the Devonian

Shale–Middle and Upper Paleozoic TPS (table 2). Estimated total undiscovered mean resources in the six AUs are 96,479 billion cubic feet of gas (BCFG), or 96.5 trillion feet of gas, with an F95–F5 (fractile value) range from 34,359 to 181,427 BCFG and 1,527 million barrels of NGL (MMBNGL) with an F95–F5 range from 506 to 3,028 MMBNGL.

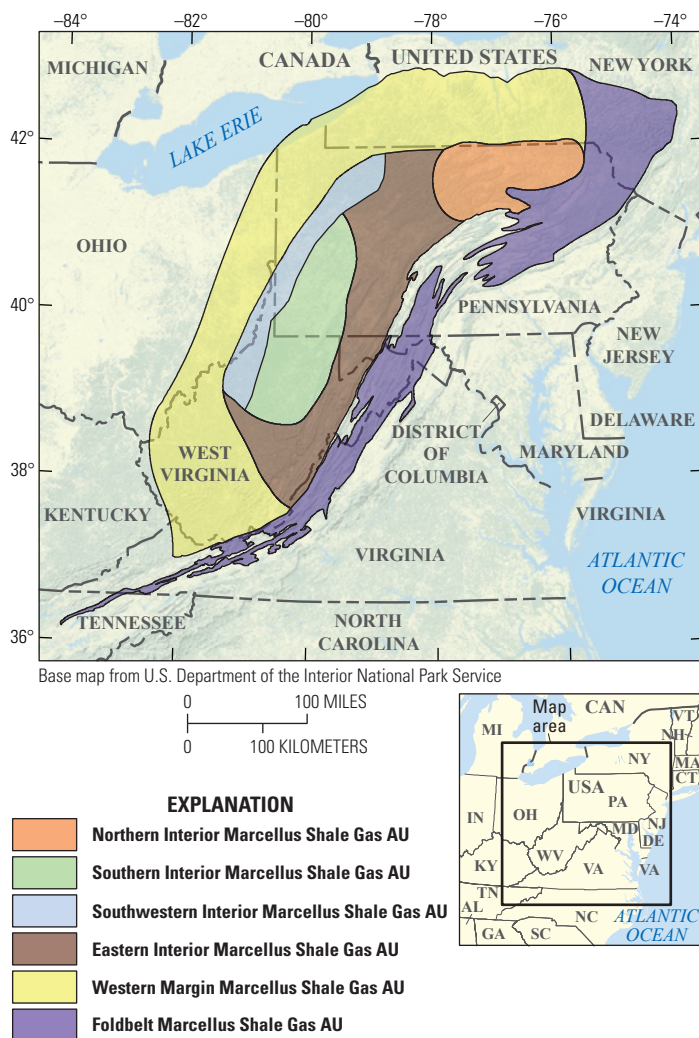


Figure 1. Map showing boundaries of the six assessment units (AUs) that were quantitatively assessed in the Middle Devonian Marcellus Shale of the Appalachian Basin Province.

**Table 1.** Key input data for six continuous assessment units in the Middle Devonian Marcellus Shale of the Appalachian Basin Province.

[AU, assessment unit; %, percent; EUR, estimated ultimate recovery per well; BCFG, billion cubic feet of gas. The average EUR input is the minimum, median, maximum, and calculated mean. Shading indicates not applicable]

Assessment input data— Continuous AUs	Northern Interior Marcellus Shale Gas AU				Southern Interior Marcellus Shale Gas AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	500,000	2,000,000	3,800,000	2,100,000	500,000	3,700,000	5,300,000	3,166,667
Average drainage area of wells (acres)	80	120	240	146.7	80	120	240	146.7
Success ratio (%)	60	75	90	75	50	70	90	70
Untested area in AU (%)	65	75	85	75	80	85	90	85
Average EUR (BCFG)	1	3	6	3.125	1	2	4	2.093
AU probability	1.0				1.0			
Assessment input data— Continuous AUs	Southwestern Interior Marcellus Shale Gas AU				Eastern Interior Marcellus Shale Gas AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	300,000	1,600,000	3,370,000	1,756,667	70,000	2,300,000	9,384,000	3,918,000
Average drainage area of wells (acres)	80	120	240	146.7	80	120	240	146.7
Success ratio (%)	70	80	90	80	50	80	90	73.3
Untested area in AU (%)	80	85	90	85	90	96	99	95
Average EUR (BCFG)	1	2	4	2.093	0.5	1	3	1.109
AU probability	1.0				1.0			
Assessment input data— Continuous AUs	Western Margin Marcellus Shale Gas AU				Foldbelt Marcellus Shale Gas AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	15,000	10,750,000	21,500,000	10,755,000	1,000	5,000,000	12,082,000	5,694,333
Average drainage area of wells (acres)	60	80	110	83.3	60	80	110	83.3
Success ratio (%)	20	30	40	30	10	20	40	23.3
Untested area in AU (%)	98	98.5	99.9	98.8	98	98.5	99.9	98.8
Average EUR (BCFG)	0.04	0.1	0.2	0.104	0.03	0.04	0.1	0.043
AU probability	1.0				1.0			

**Table 2.** Results for six continuous assessment units in the Middle Devonian Marcellus Shale of the Appalachian Basin Province.

[BCFG, billion cubic feet of gas; NGL, natural gas liquids; MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. 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. Shading indicates not applicable]

Total petroleum system and assessment units (AUs)	AU probability	Accumula- tion type	Total undiscovered resources							
			Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean
Devonian Shale—Middle and Upper Paleozoic Total Petroleum System										
Northern Interior Marcellus Shale Gas AU	1.0	Gas	10,676	24,215	46,319	25,801	0	0	0	0
Southern Interior Marcellus Shale Gas AU	1.0	Gas	10,672	26,489	48,207	27,594	219	589	1,260	644
Southwestern Interior Marcellus Shale Gas AU	1.0	Gas	6,755	16,497	31,611	17,495	247	643	1,344	700
Eastern Interior Marcellus Shale Gas AU	1.0	Gas	4,925	18,103	46,283	20,914	16	71	229	90
Western Margin Marcellus Shale Gas AU	1.0	Gas	1,158	3,777	7,575	3,993	24	84	195	93
Foldbelt Marcellus Shale Gas AU	1.0	Gas	173	611	1,432	682	0	0	0	0
<b>Total undiscovered continuous resources</b>			<b>34,359</b>	<b>89,692</b>	<b>181,427</b>	<b>96,479</b>	<b>506</b>	<b>1,387</b>	<b>3,028</b>	<b>1,527</b>

**References Cited**

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**For More Information**

Assessment results are also available at the USGS Energy Resources Program website at <https://energy.usgs.gov>.

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