

National and Global Petroleum Assessment

Assessment of Undiscovered Continuous Gas Resources in Upper Devonian Shales of the Appalachian Basin Province, 2017

Using a geology-based assessment methodology, the U.S. Geological Survey estimated mean undiscovered, technically recoverable continuous resources of 10.7 trillion cubic feet of natural gas in Upper Devonian shales of the Appalachian Basin Province.

Introduction

In 2017, the U.S. Geological Survey (USGS) completed a geology-based assessment of undiscovered, technically recoverable continuous (unconventional) natural gas resources in the Upper Devonian Cleveland and Huron Members of the Ohio Shale, Pipe Creek Shale Member of the Java Formation, Rhinestreet Shale Member of the West Falls Formation, and Middlesex Shale Member of the Sonyea Formation in the Appalachian Basin Province. The assessed area comprises parts of Kentucky, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia (fig. 1).

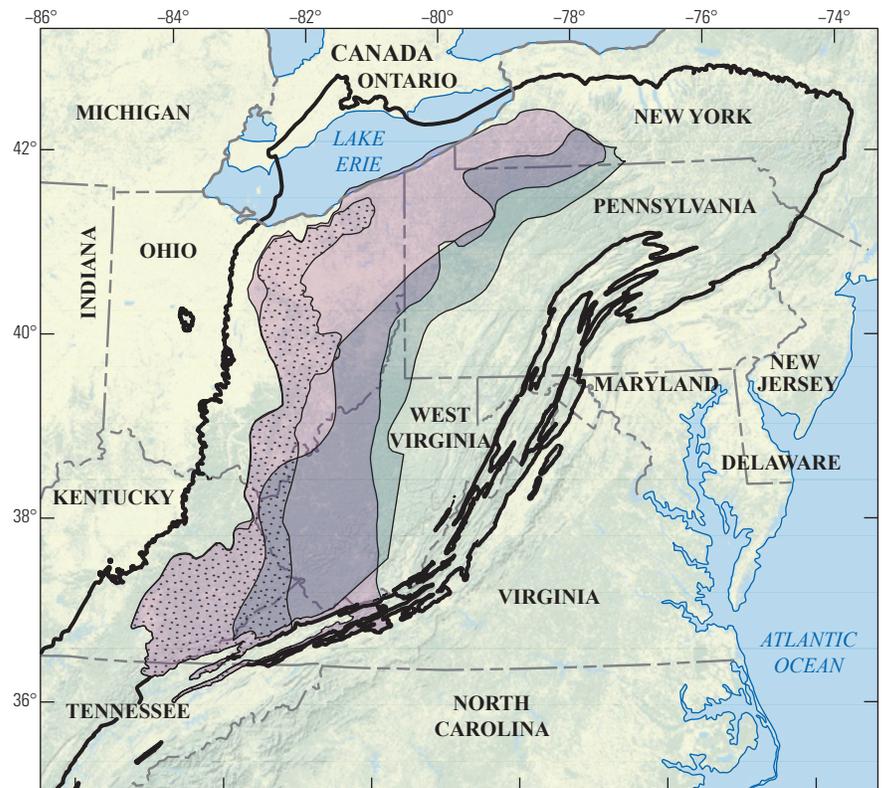
Geologic Model for Assessment

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 richness and levels of thermal maturation and associated oil and gas generation and adsorption); (2) reservoir rock type (continuous), distribution, and properties (mineral composition, porosity, permeability, brittleness); and (3) types and distribution of reservoirs and seals and timing relative to petroleum generation. The assessed Upper Devonian shales primarily consist of organic-rich marine shales, and the contained hydrocarbon resources are considered self-sourced mostly on the basis of levels of thermal maturation in hydrocarbon productive areas.

Using this geologic framework, the USGS defined eight continuous assessment units (AUs) within the Devonian Shale–Middle and Upper Paleozoic TPS and quantitatively estimated undiscovered, technically recoverable natural gas and natural gas liquid (NGL) resources for three of the eight AUs (tables 1 and 2). Although historical oil production has been reported from the Ohio Shale and the Huron Member of the Ohio Shale, the assessment team concluded that future production likely will be dominated by natural gas and NGLs. The unassessed Pipe Creek Continuous Gas AU, Pipe Creek Continuous Oil AU, Rhinestreet Continuous Oil AU, Middlesex Continuous Gas AU, and Middlesex Continuous Oil AU are categorized as hypothetical because data were insufficient for quantitative resource assessment. Input data used to assess three continuous AUs are listed in table 1.

The Cleveland Continuous Gas AU includes the areal extent of the Cleveland Member where the member is laterally contiguous with the correlative Chattanooga Shale AUs delineated in 2015 (Higley and others, 2016), the area downdip of where the temperature of maximum release of hydrocarbons during Rock-Eval kerogen pyrolysis (T_{max}) (Espitalie and others, 1985)

of Cleveland samples is 435 degrees Celsius ($^{\circ}\text{C}$) or more, and all areas of historical production from vertical and horizontal wells allocated to the Cleveland Member. The Huron Continuous Gas AU includes the areal extent of the Huron Member where the member is laterally contiguous with the correlative Chattanooga Shale AUs delineated in 2015 (Higley and others, 2016), the area downdip of where T_{max} of Huron samples is 435 $^{\circ}\text{C}$ or more, and all areas of historical production from vertical and horizontal wells allocated to the Huron Member. The Rhinestreet Continuous Gas AU includes the areal extent of the Rhinestreet Shale Member where the member is downdip of the Devonian thermal maturity 1.2 percent vitrinite reflectance contour of East and others (2012) and all areas of historical production from vertical and horizontal wells allocated to the Rhinestreet Shale Member.



Base map from U.S. Department of the Interior National Park Service

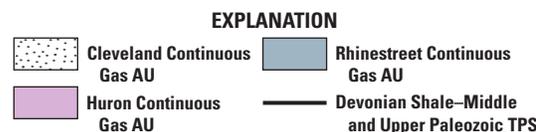
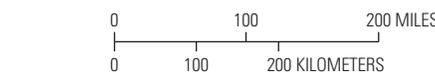


Figure 1. Map showing the boundaries of the three assessment units (AUs) that were quantitatively assessed in Upper Devonian shales of the Devonian Shale–Middle and Upper Paleozoic Total Petroleum System (TPS) in the Appalachian Basin Province.

Table 1. Key input data for three continuous assessment units in shales of the Cleveland, Huron, and Rhinestreet Members, Appalachian Basin Province.

[AU, assessment unit; %, percent; EUR, estimated ultimate recovery per well; BCFG, billion cubic feet of gas. Well drainage area, success ratio, and EUR are from U.S. shale-gas and tight-gas analogs. The average EUR input is the minimum, median, maximum, and calculated mean. Shading indicates not applicable]

Assessment input data—Continuous AUs	Cleveland Continuous Gas AU				Huron Continuous Gas AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	4,360	555,000	11,000,000	3,853,120	77,900	2,601,285	30,918,306	11,199,164
Average drainage area of well (acres)	80	120	200	133.3	80	120	220	140
Untested area (%)	90	95	99	94.7	75	85	95	85
Success ratio (%)	30	55	95	60	65	80	95	80
Average EUR (BCFG)	0.04	0.1	0.5	0.12	0.04	0.1	0.7	0.13
AU probability	1.0				1.0			
Assessment input data—Continuous AU	Rhinestreet Continuous Gas AU							
	Minimum	Mode	Maximum	Calculated mean				
Potential production area of AU (acres)	2,640	5,500,000	16,610,000	7,370,880				
Average drainage area of well (acres)	80	120	240	146.7				
Untested area (%)	95	97	99	97				
Success ratio (%)	10	40	60	36.7				
Average EUR (BCFG)	0.04	0.08	0.2	0.086				
AU probability	1.0							

Undiscovered Resources Summary

The USGS quantitatively assessed undiscovered continuous gas and NGL resources in three AUs within the Devonian Shale–Middle and Upper Paleozoic TPS (table 2). For total undiscovered resources in all three AUs, the estimated means are 10,657 billion cubic feet of gas (BCFG), or 10.7 trillion cubic feet of gas, with an F95–F5 (fractile value) range from 1,472 to 29,352 BCFG and 279 million barrels of natural gas liquids (MMBNGL) with an F95–F5 range from 33 to 811 MMBNGL. The estimated means for the Cleveland Continuous Gas AU are 1,991 BCFG with an F95–F5 range from 214 to 5,592 BCFG and 47 MMBNGL with an F95–F5 range from 5 to 136 MMBNGL. The estimated means for the Huron Continuous Gas AU are 7,096 BCFG with an F95–F5 range from 907 to 20,238 BCFG and 214 MMBNGL with an F95–F5 range from 24 to 631 MMBNGL. The estimated means for the Rhinestreet Continuous Gas AU are 1,570 BCFG with an F95–F5 range from 351 to 3,522 BCFG and 18 MMBNGL with an F95–F5 range from 4 to 44 MMBNGL.

Table 2. Results for three assessment units in shales of the Cleveland, Huron, and Rhinestreet Members, Appalachian Basin Province.

[MMBO, million barrels of oil; BCFG, billion cubic feet of gas; NGL, natural gas liquids; MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. For gas accumulations, all liquids are included in the NGL category. 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	Accumulation type	Total undiscovered resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Devonian Shale–Middle and Upper Paleozoic Total Petroleum System														
Cleveland Continuous Gas AU	1.0	Gas					214	1,466	5,592	1,991	5	33	136	47
Huron Continuous Gas AU	1.0	Gas					907	5,128	20,238	7,096	24	147	631	214
Rhinestreet Continuous Gas AU	1.0	Gas					351	1,357	3,522	1,570	4	15	44	18
Total undiscovered continuous resources							1,472	7,951	29,352	10,657	33	195	811	279

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>.