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Assessment of Continuous Oil and Gas Resources in the Ordovician Collingwood Formation and Utica Shale of the Michigan Basin Province, 2019

Using a geology-based assessment methodology, the U.S. Geological Survey estimated undiscovered, technically recoverable mean resources of 290 milllion barrels of shale oil and 7.9 trillion cubic feet of shale gas in the Ordovician Collingwood-Utica Shale Total Petroleum System of the Michigan Basin Province.

Introduction

The U.S. Geological Survey (USGS) quantitatively assessed the potential for undiscovered, technically recoverable continuous shale-oil and shale-gas resources in the Ordovician Collingwood-Utica Shale Total Petroleum System (TPS) of the Michigan Basin Province (fig. 1). The structural evolution of the intracontinental Michigan Basin may be more complex than its usual depiction as a bowl-shaped depression throughout the early Paleozoic. The basement of the Michigan Basin is partly occupied by an arm of the mid-continent Proterozoic rift system, which contains at least 5,000 feet of Proterozoic synrift sediments (Fisher and Barratt, 1985). The Proterozoic basement, in addition to the rift basin, is highly faulted in a rectilinear pattern, with numerous faults outlining a series of basement horsts and grabens (Fisher and Barratt, 1985; Catacosinos and others, 1990; Ma, 2009). The hypothesis in this study, which follows discussions of basement structure by Fisher and Barratt (1985), Fisher and others (1988), Catacosinos and others (1990), Ma (2009), and Swezey and others (2015), is that repetitive movement along basement faults is the ultimate cause of the accommodation space and the thermal anomalies that may have been associated with prerift and postrift regimes. The Cambrian to Mississippian sedimentary section is a series of shallow water carbonate, shale, and evaporite sequences separated by regional unconformities. Prerift thermal expansion would have resulted in erosion, and postrift thermal relaxation would create accommodation space. The Upper Ordovician Collingwood Formation is a calcareous marl that was deposited in a basinal setting adjacent to a carbonate platform; the Collingwood is overlain by the Utica Shale, which has a more regional extent in the Michigan Basin Province (Harrison, 2016).

The thermal evolution of the Michigan Basin has been difficult to elucidate for several reasons, including a lack of data from deep wells, an absence of vitrinite from much of the lower Paleozoic section, and conflicting estimates of the scale and timing of erosion across the basin (Cercone, 1984; Gardner and Bray, 1984; Nunn and others, 1984; Vugrinovich, 1988; Wang and others, 1994; Hybza and others, 2018). However, several horizontal wells drilled into the shale of the Collingwood Formation in the central part of the basin produced shale gas, demonstrating that these shales have reached the thermal generation windows for oil and gas (Harrison, 2016) and that gas and perhaps oil have been retained within the Collingwood. This study assessed the potential for shale-oil and shale-gas resources primarily from the shale of the Collingwood Formation, but oil and gas are potentially recoverable from the lower part of the Utica Shale.

Total Petroleum System and Assessment Units

The USGS defined the Ordovician Collingwood-Utica Shale TPS to encompass potential shale-oil and shale-gas resources primarily within the Ordovician Collingwood Formation with the possible contribution of oil and gas from the lower part of the Utica Shale. The Collingwood-Utica Shale Oil Assessment Unit (AU) and the Collingwood-Utica Shale Gas AU were defined within the TPS based largely on mapping by Harrison (2016). The AUs were defined based on the following criteria: (1) the greater than 20-foot thickness of the shale of the Collingwood Formation; (2) the thermal onset of oil and gas generation at a current depth of about 6,500 feet (Harrison, 2016); and (3) a minimum depth of 2,000 feet for the northern boundary of the Collingwood-Utica Shale Oil AU.

The geologic model underlying the assessment of the Ordovician Collingwood-Utica Shale TPS is for oil to have been generated within the organic-rich Collingwood and the lower part of the Utica Shale. The model further requires that some portion of the oil and gas was retained within the organic-rich shales. Overpressure is present in part of the basin (Gardner and Bray, 1984), but the degree of overpressure in the Collingwood or Utica is not known.

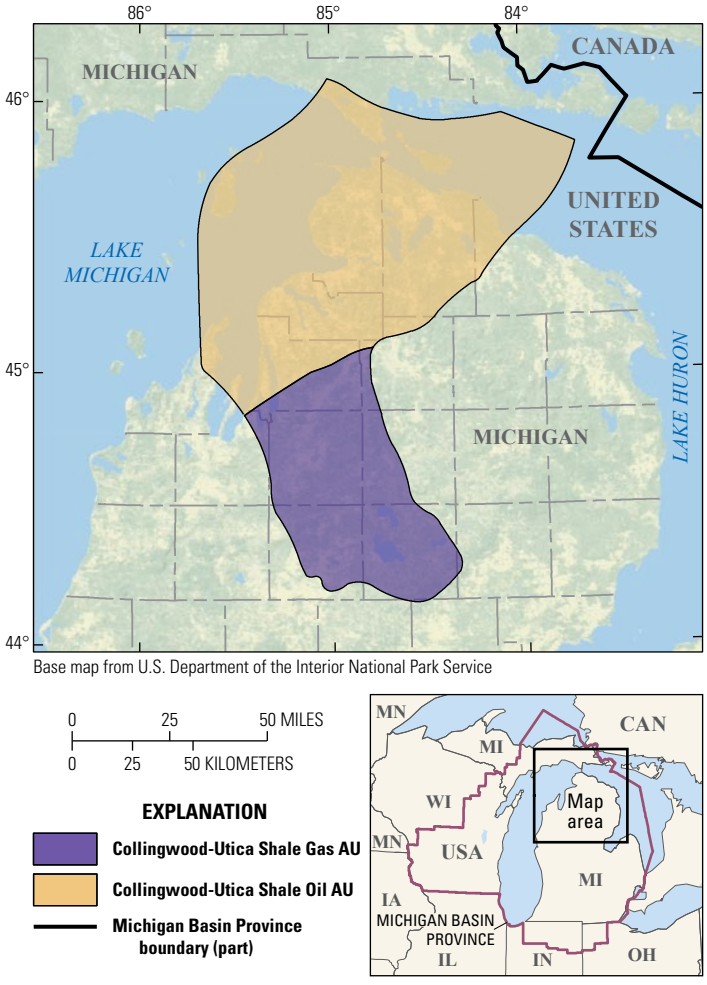

Figure 1. Map showing the location of two continuous assessment units (AUs) in the Michigan Basin Province. The province boundary overlies the border between the United States and Canada.

Table 1. Key input data for two continuous assessment units in the Ordovician Collingwood-Utica Shale Total Petroleum System of the Michigan Basin Province.

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

Assessment input data—Continuous AUs	Collingwood-Utica Shale Oil AU				Collingwood-Utica Shale Gas AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	1,000	611,000	3,088,000	1,233,333	1,000	931,000	1,862,000	931,333
Average drainage area of wells (acres)	80	120	160	120	80	120	160	120
Untested area in AU (%)	100	100	100	100	100	100	100	100
Success ratio (%)	10	50	90	50	40	60	80	60
Average EUR (MMBO, oil; BCFG, gas)	0.04	0.06	0.12	0.063	0.5	1.5	4.5	1.656
AU probability	0.9				1.0			

Table 2. Results for two continuous assessment units in the Ordovician Collingwood-Utica Shale Total Petroleum System of the Michigan Basin Province.

[Results shown are fully risked estimates. F95 represents a 95-percent chance of at least the amount tabulated; other fractiles are defined similarly. Shading indicates not applicable. MMBO, million barrels of oil; BCFG, billion cubic feet of gas; NGL, natural gas liquids; MMBNGL, million barrels of natural gas liquids]

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
Ordovician Collingwood-Utica Shale Total Petroleum System														
Collingwood-Utica Shale Oil AU	0.9	Oil	0	239	749	290	0	177	568	217	0	3	9	3
Collingwood-Utica Shale Gas AU	1.0	Gas					2,034	6,846	15,991	7,645	27	98	260	114
Total undiscovered continuous resources			**0**	**239**	**749**	**290**	**2,034**	**7,023**	**16,559**	**7,862**	**27**	**101**	**269**	**117**

Assessment input data are summarized in table 1. The input data for drainage area, estimated ultimate recovery, and success ratio were guided by the assessment input of the similar age Point Pleasant Formation and Utica Shale in the Appalachian Basin Province (Enomoto and others, 2019).

Undiscovered Resources Summary

The USGS quantitatively assessed undiscovered continuous shale-oil and shale-gas resources within the Ordovician Collingwood-Utica Shale TPS of the Michigan Basin Province (table 2). The fully risked mean totals are 290 million barrels of oil (MMBO) with an F95–F5 range from 0 to 749 MMBO; 7,862 billion cubic feet of gas (BCFG), or 7.9 trillion cubic feet of gas, with an F95–F5 range from 2,034 to 16,559 BCFG; and 117 million barrels of natural gas liquids (MMBNGL) with an F95–F5 range from 27 to 269 MMBNGL. The zero at the F95 fractile reflects risk on geologic elements of the Collingwood-Utica Shale Oil AU.

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Differences in the capitalization of Michigan Basin in the references cited section reflect the original authors' usage.

For More Information

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

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