

National and Global Petroleum Assessment

Assessment of Undiscovered Conventional Oil and Gas Resources of Upper Paleozoic Strata in the Williston Basin Province, 2020

Using a geology-based assessment methodology, the U.S. Geological Survey estimated undiscovered, technically recoverable mean oil and gas resources of 134 million barrels of oil and 81 billion cubic feet of gas in upper Paleozoic strata of the Williston Basin Province in North Dakota, Montana, and South Dakota.

Introduction

The U.S. Geological Survey (USGS) quantitatively assessed the potential for undiscovered, technically recoverable conventional oil and gas resources in six upper Paleozoic total petroleum systems (TPSs) of the Williston Basin Province in North Dakota, Montana, and South Dakota (figs. 1 and 2). Eight geologically defined assessment units (AUs) were assessed within these TPSs for undiscovered oil, gas, and natural gas liquids.

Total petroleum systems have been defined in the Williston Basin Province based mainly on oil geochemistry (Osadetz and Snowden, 1995; Jarvie, 2001; Lillis, 2012;

Nesheim, 2019). Using these studies as a framework, six TPSs were identified within upper Paleozoic strata and assessed for undiscovered conventional oil and gas resources (fig. 3). The Winnipegosis TPS encompasses oil generated from basinal organic-rich shales that migrated into carbonate platform-interior patch reef, platform margin, slope, and pinnacle reef reservoirs within the Winnipegosis Carbonate Reservoirs AU, with seals provided by overlying evaporites of the Prairie Formation (Ehrets and Kissling, 1987). Most oil production from carbonate reservoirs of the Winnipegosis Formation is in proximity to structures like the faulted Nesson anticline (Gerhard and others, 1987).

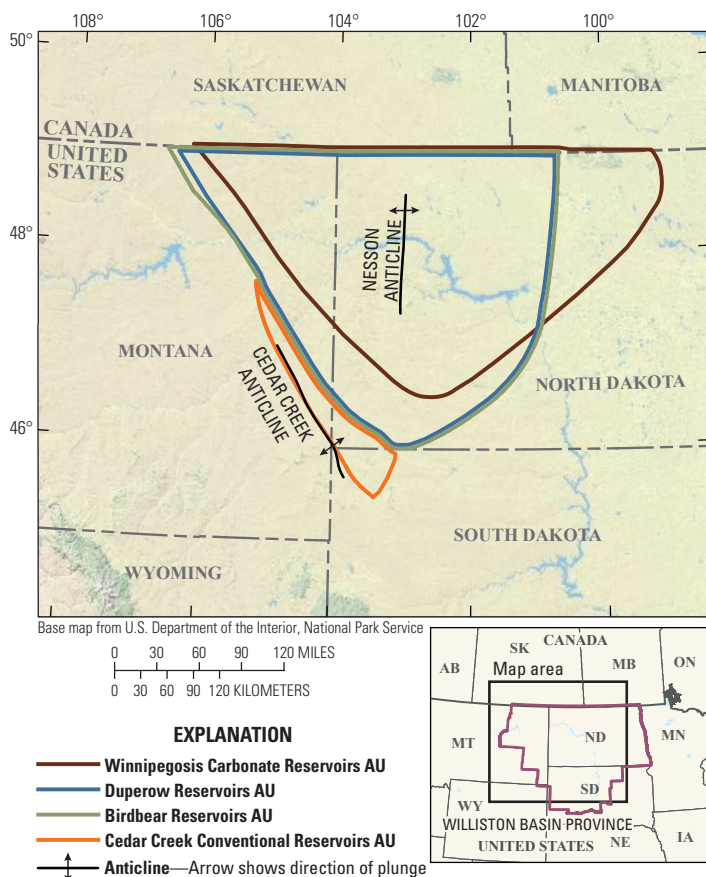


Figure 1. Map showing the location of four assessment units (AUs) in the Winnipegosis, Duperow, and Cedar Creek Paleozoic Composite Total Petroleum Systems in upper Paleozoic strata of the Williston Basin Province, North Dakota, Montana, and South Dakota. Adjacent lines indicate a shared boundary at the outermost line.

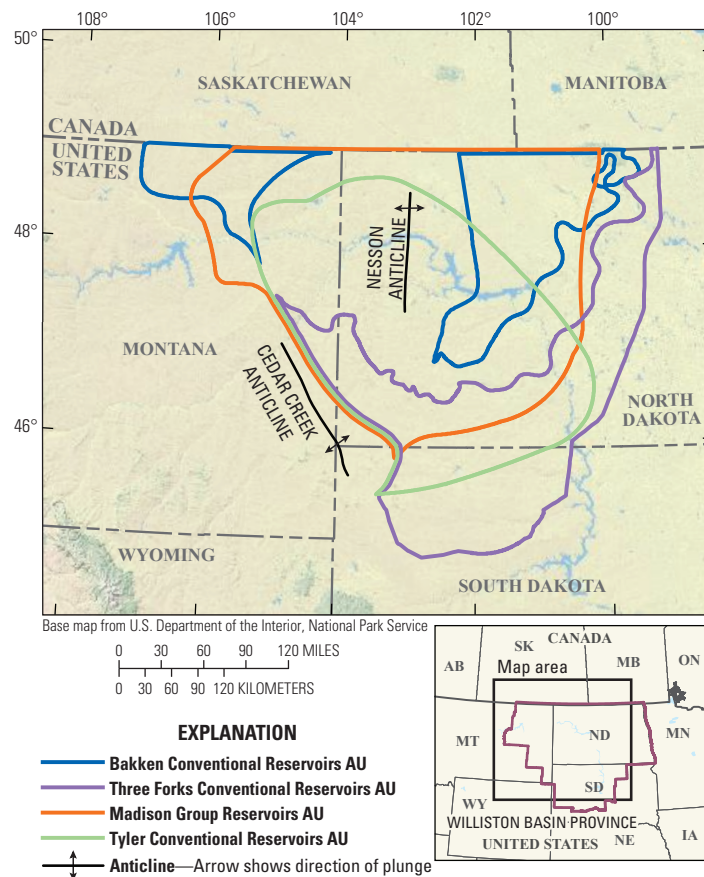


Figure 2. Map showing the location of four assessment units (AUs) in the Bakken, Madison Composite, and Pennsylvanian Total Petroleum Systems in upper Paleozoic strata of the Williston Basin Province, North Dakota, Montana, and South Dakota. Adjacent lines indicate a shared boundary at the outermost line.

Period	Unit	Total Petroleum Systems
Tertiary	Fort Union	Cedar Creek Paleozoic Composite (part)
Cretaceous	Pierre	
Jurassic	Nesson	
Triassic	Spearfish	
Permian	Minnekahta Opeche	
	Minnelusa Amsden	
Pennsylvanian	Tyler	
	Otter	
Mississippian	Kibbey	
	Charles	
	Mission Canyon	
	Lodgepole	
Devonian	Bakken	
	Three Forks	
	Birdbear	
	Duperow	
	Souris River	
	Dawson Bay	
	Prairie	
	Winnipegosis	
	Ashern	

Figure 3. Stratigraphy and related total petroleum systems in upper Paleozoic strata of the Williston Basin Province, North Dakota, Montana, and South Dakota. Modified from Anna (2013).

The Duperow TPS includes oil possibly generated from basinal Duperow Formation and adjacent shales that migrated into carbonate platform interior, platform margin, slope, and pinnacle reef reservoirs in the Dawson Bay Formation, Duperow Formation, and Birdbear Formation (Anna, 2013). The Duperow Reservoirs AU and Birdbear Reservoirs AU were defined within this TPS. Most production is along regional fault trends like the Winnipegosis TPS.

The Bakken TPS was defined to include oil generated from organic-rich shales of the informal upper and lower members of the Bakken Formation that migrated into the informal middle Bakken siliciclastic reservoirs (Pollastro and others, 2013) and into carbonate reservoirs of the upper part of the underlying Three Forks Formation (Nesheim, 2019). The Middle Bakken Conventional Reservoirs AU and the Three Forks Conventional Reservoirs AU are within this TPS. Much of the oil generated within the Bakken TPS in North Dakota remains within the middle

part of the Bakken Formation as a continuous (unconventional) oil accumulation rather than in conventional accumulations, but a significant volume of Bakken oil has migrated north into conventional accumulations in southern Saskatchewan (Higley and Gianoutsos, 2016). The Madison Composite TPS was defined to include oil generated from basinal shales of the Madison Group that migrated into Lodgepole Formation, Mission Canyon Limestone, and Charles Formation carbonate reservoirs within a series of stacked carbonate-evaporite cycles (Gaswirth and others, 2013). The Madison Group Reservoirs AU is within this TPS.

The Pennsylvanian Tyler TPS represents a change from the carbonate-dominated Madison Composite TPS to a predominantly siliciclastic TPS. Organic-rich shale source rocks in the Tyler Formation were deposited within a restricted marine environment that was connected to the Panthalassa Ocean by the east-west trending Big Snowy trough. Pennsylvanian Tyler TPS oil migrated into fluvial-deltaic to shelf sandstone reservoirs (Nesheim and Nordeng, 2016). The Tyler Conventional Reservoirs AU is within this TPS.

The Cedar Creek Paleozoic Composite TPS was defined to include oil and gas sourced by all Paleozoic TPSs within the Williston Basin Province (Anna, 2013). The Cedar Creek structure was a barrier to fluids migrating to the southwest within the Williston Basin Province, and it is a focal point for mixing of oils from multiple source rocks. The Cedar Creek Conventional Reservoirs AU is within this TPS.

Most of the production from reservoirs within the six TPSs outlined in this study is proximal to major fault systems and regional structures (Anna, 2013). Each defined TPS contains oil that is isolated from the oil resources in the other TPSs. However, the proximity of most production to the fault systems suggests that mixing of oils from multiple sources may

be prevalent in reservoirs within the upper Paleozoic strata of the Williston Basin Province, like the oils within reservoirs along the Cedar Creek anticline. Key input data for the eight conventional AUs are shown in [table 1](#).

Undiscovered Resources Summary

The USGS quantitatively assessed undiscovered conventional oil, gas, and natural gas liquid resources within six upper Paleozoic TPSs of the Williston Basin Province in North Dakota, Montana, and South Dakota ([table 2](#)). The fully risked mean totals are 134 million barrels of oil (MMBO) with an F95–F5 fractile range from 68 to 217 MMBO; 81 billion cubic feet of gas (BCFG) with an F95–F5 range from 42 to 128 BCFG; and 6 million barrels of natural gas liquids (MMBNGL) with an F95–F5 range from 3 to 9 MMBNGL.

Table 1. Key input data for eight conventional assessment units in the upper Paleozoic strata of the Williston Basin Province, North Dakota, Montana, and South Dakota.

[Gray shading indicates not applicable. AU, assessment unit; MMBO, million barrels of oil]

Assessment input data— Conventional AUs	Winnepigosis Carbonate Reservoirs AU				Duperow Reservoirs AU			
	Minimum	Median	Maximum	Calculated mean	Minimum	Median	Maximum	Calculated mean
Number of oil fields	1	8	16	8.2	1	4	8	4.1
Size of oil fields (MMBO)	0.5	0.7	4	0.8	0.5	0.7	6	0.85
AU probability	0.9				0.9			
Assessment input data— Conventional AUs	Birdbear Reservoirs AU				Middle Bakken Conventional Reservoirs AU			
	Minimum	Median	Maximum	Calculated mean	Minimum	Median	Maximum	Calculated mean
Number of oil fields	1	8	16	8.2	1	8	24	8.5
Size of oil fields (MMBO)	0.5	0.7	6	0.85	0.5	0.7	10	0.92
AU probability	1.0				1.0			
Assessment input data— Conventional AUs	Three Forks Conventional Reservoirs AU				Madison Group Reservoirs AU			
	Minimum	Median	Maximum	Calculated mean	Minimum	Median	Maximum	Calculated mean
Number of oil fields	1	4	12	4.3	1	60	120	61.5
Size of oil fields (MMBO)	0.5	0.7	8	0.89	0.5	0.8	14	1.1
AU probability	0.9				1.0			
Assessment input data— Conventional AUs	Tyler Conventional Reservoirs AU				Cedar Creek Conventional Reservoirs AU			
	Minimum	Median	Maximum	Calculated Mean	Minimum	Median	Maximum	Calculated Mean
Number of oil fields	1	30	90	31.9	1	4	4	2.1
Size of oil fields (MMBO)	0.5	0.7	24	1.1	0.5	0.7	10	0.92
AU probability	1.0				0.9			

Table 2. Results for eight conventional assessment units in the upper Paleozoic strata of the Williston Basin Province, North Dakota, Montana, and South Dakota.

[Results shown are fully risked estimates. F95 represents a 95-percent chance of at least the amount tabulated; other fractiles are defined similarly. Gray 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 systems 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
Winnipegosis Total Petroleum System														
Winnipegosis Carbonate Reservoirs AU	0.9	Oil	0	6	10	6	0	3	5	3	0	0	0	0
Duperow Total Petroleum System														
Duperow Reservoirs AU	0.9	Oil	0	3	6	3	0	3	5	3	0	0	0	0
Birdbear Reservoirs AU	1.0	Oil	4	7	11	7	4	6	10	7	0	1	1	1
Bakken Total Petroleum System														
Middle Bakken Conventional Reservoirs AU	1.0	Oil	4	7	15	8	3	5	10	6	0	0	1	0
Three Forks Conventional Reservoirs AU	0.9	Oil	0	3	7	3	0	2	5	2	0	0	0	0
Madison Composite Total Petroleum System														
Madison Group Reservoirs AU	1.0	Oil	44	67	100	69	30	47	71	48	3	4	6	4
Pennsylvanian Tyler Total Petroleum System														
Tyler Conventional Reservoirs AU	1.0	Oil	16	33	64	36	5	10	20	11	0	1	1	1
Cedar Creek Paleozoic Composite Total Petroleum System														
Cedar Creek Conventional Reservoirs AU	0.9	Oil	0	2	4	2	0	1	2	1	0	0	0	0
Total undiscovered conventional resources			68	128	217	134	42	77	128	81	3	6	9	6

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For More Information

Assessment results are also available at the USGS Energy Resources Program website at <https://www.usgs.gov/energy-and-minerals/energy-resources-program/>.

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