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National Assessment of Oil and Gas Fact Sheet

Assessment of Undiscovered Oil Resources in the Bakken and Three Forks Formations, Williston Basin Province, Montana, North Dakota, and South Dakota, 2013

Using a geology-based assessment methodology, the U.S. Geological Survey estimated mean undiscovered volumes of 7.4 billion barrels of oil, 6.7 trillion cubic feet of associated/dissolved natural gas, and 0.53 billion barrels of natural gas liquids in the Bakken and Three Forks Formations in the Williston Basin Province of Montana, North Dakota, and South Dakota.

Introduction

The U.S. Geological Survey (USGS) recently completed a geology-based assessment of conventional and continuous oil and gas resources of the Devonian Three Forks Formation and Devonian and Mississippian Bakken Formation in the Williston Basin Province of North Dakota, Montana, and South Dakota (fig. 1). Since the 2008 USGS assessment of the Bakken Formation (Pollastro and others, 2008), more than 4,000 additional wells have been drilled, providing significant geologic data about the Bakken and Three Forks Formations. Furthermore, the Three Forks Formation was not assessed in 2008 by the USGS and accordingly warranted assessment based on significant increases in drilling and production in this formation. Oil is being produced from the Bakken and Three Forks Formations using both horizontal drilling technology, which exposes a larger amount of reservoir to the wellbore than vertical wells, and hydraulic fracturing, which stimulates movement of hydrocarbons in tight-oil reservoirs. Approximately 450 million barrels of oil (MMBO) have been produced from the Bakken and Three Forks Formations in the United States since the 2008 assessment of the Bakken Formation.

Geologic Summary of the Bakken and Three Forks Formations

The Bakken Total Petroleum System (TPS) encompasses strata from the Devonian Three Forks Formation, Bakken Formation, and lower part of the Mississippian Lodgepole Formation that may contain Bakken-sourced oil. The TPS is defined by the postulated maximum extent of petroleum fluids within the Bakken and Three Forks Formations. The Devonian and Mississippian Bakken Formation consists of four members in ascending order: (1) the Pronghorn Member (formerly known as "Sanish sand") (LeFever and others, 2011), (2) lower shale member, (3) middle member, and (4) upper shale member. The sandstones and siltstones of the Pronghorn Member represent the first transgressive unit of the Bakken Formation and are limited in extent. The maximum thickness of the Pronghorn is 58 feet (LeFever and others, 2011). The upper and lower shale members are the primary source rocks for the Bakken TPS, with present-day total organic carbon (TOC) values from <1 weight percent to 35 weight percent (Lillis, 2013). The shale members are present in parts of Montana and North Dakota and extend into the Canadian provinces of Saskatchewan and Manitoba, though the Canadian provinces were not assessed. The lower shale member reaches a maximum thickness of 56 feet along the east flank of the Nesson anticline (fig. 1). The middle member of the

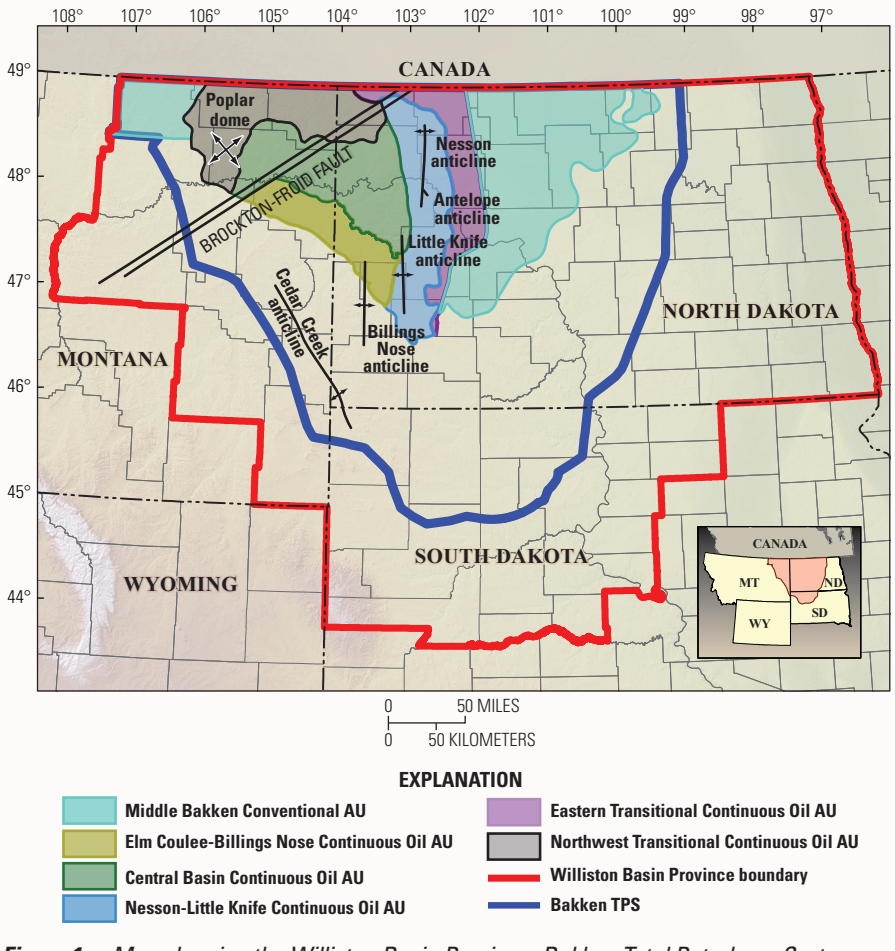

Figure 1. *Map showing the Williston Basin Province, Bakken Total Petroleum System (TPS), and the Bakken Formation Assessment Units (AUs). Major structural features are also shown. Inset map shows location of the Bakken TPS (pink).*

Bakken Formation varies in thickness and lithology and includes sandstone, siltstone, dolomite, and mudstone (LeFever, 1991). The middle member reaches a maximum thickness of 90 feet near the basin center in North Dakota along the east flank of the Nesson anticline (LeFever, 2008). The upper shale member of the Bakken is the most geographically extensive member of the Bakken Formation, and it represents the maximum depositional limit for the Bakken Formation. It is thickest to the east of the Nesson anticline with localized thickening (as much as 58 feet) in Stark County in southwestern North Dakota.

The Three Forks Formation consists of interbedded grayish-green dolomitic mudstones, pink to tan silty dolostones, and anhydrite. It is unconformably overlain by the Pronghorn Member of the Bakken Formation. The Three Forks Formation reaches a maximum thickness of 270 feet in the central portion of the basin (Bottjer and others, 2011) and is divided stratigraphically into lower and upper units, with variable oil saturations.

Geologic Model for Assessment

The geologic model for the assessment of the Bakken Formation and underlying Three Forks Formation is that oil generated in the upper and lower Bakken shale members migrated locally into low-permeability and variable-porosity reservoirs of the middle Bakken member, the Pronghorn Member of the Bakken Formation, and dolomitized units of the Three Forks Formation. Locally, oil was also retained in the low-porosity matrix and fractures of the upper and lower Bakken shale members. A hydrogen index (HI) value of 450 was used to define the boundary of thermally mature source rock in the upper Bakken shale member as indicated by recent USGS research.

The Pronghorn Member of the Bakken Formation, although geologically and stratigraphically defined as part of the Bakken Formation (LeFever and others, 2011), is assessed with the Three Forks Formation. Where present, the Pronghorn Member is in fluid communication with the underlying Three Forks reservoirs.

Assessment Units

Six continuous assessment units (AUs) and two conventional AUs were defined in the Bakken TPS. Five of the continuous AUs and one conventional AU are in the Bakken Formation, and one continuous and one conventional AU are in the Three Forks Formation. Key input data used to assess continuous AUs in the Bakken and Three Forks Formations are listed in table 1.

Bakken Formation

The Middle Bakken Conventional AU is a hypothetical AU defined by the extent of the middle Bakken member within the Williston Basin Province (fig. 1).

The Elm Coulee-Billings Nose Continuous Oil AU is defined on the north by the Devonian Prairie Evaporite dissolution edge, to the northwest by the Brockton-Froid fault zone, on the south by the five-foot isopach of the middle Bakken member,

Table 1. Key assessment input data for continuous assessment units in the Bakken TPS.

[EUR, estimated ultimate recovery per well; MMBO, million barrels of oil; AU, assessment unit. The average EUR input is the minimum, median, maximum, and calculated mean]

Assessment input data	Elm Coulee-Billings Nose Continuous Oil AU 50310161				Central Basin Continuous Oil AU 50310162			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	1,400,000	1,600,000	1,800,000	1,600,000	2,800,000	3,100,000	3,400,000	3,100,000
Average drainage area of wells (acres)	320	400	600	440	320	400	600	440
Percent of AU untested	51	69	80	67	80	87	91	86
Percent of AU in sweet spots	24	27	30	27	24	29	70	41
Input data for geologic sweet spots								
Success ratios (%)	98	99	100	99	98	99	100	99
Average EUR (MMBO)	0.15	0.18	0.22	0.182	0.225	0.25	0.325	0.254
Input data for geologic non-sweet spots								
Success ratios (%)	85	90	95	90	80	90	95	88
Average EUR (MMBO)	0.06	0.1	0.15	0.102	0.075	0.15	0.25	0.154
	Nesson-Little Knife Continuous Oil AU 50310163				Eastern Transitional Continuous Oil AU 50310164			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	2,600,000	2,800,000	3,000,000	2,800,000	1,800,000	1,900,000	2,000,000	1,900,000
Average drainage area of wells (acres)	320	400	600	440	320	400	600	440
Percent of AU untested	65	76	84	75	70	79	93	81
Percent of AU in sweet spots	35	38	85	53	10	15	20	15
Input data for geologic sweet spots								
Success ratios (%)	98	99	100	99	98	99	100	99
Average EUR (MMBO)	0.26	0.3	0.35	0.302	0.375	0.425	0.55	0.431
Input data for geologic non-sweet spots								
Success ratios (%)	90	95	100	95	90	95	100	95
Average EUR (MMBO)	0.125	0.175	0.25	0.178	0.175	0.225	0.35	0.231
	Northwest Transitional Continuous Oil AU 50310165				Three Forks Continuous Oil AU 50310166			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	500,000	2,000,000	3,100,000	1,866,667	5,000,000	10,000,000	25,000,000	13,333,333
Average drainage area of wells (acres)	320	400	600	440	220	400	600	407
Percent of AU untested	94	98.8	99.5	97	89	96.5	99.2	95
Percent of AU in sweet spots	10	15	45	23	10	50	90	50
Input data for geologic sweet spots								
Success ratios (%)	80	90	95	88	80	90	95	88
Average EUR (MMBO)	0.075	0.15	0.25	0.154	0.18	0.22	0.275	0.222
Input data for geologic non-sweet spots								
Success ratios (%)	10	40	80	43	10	40	80	43
Average EUR (MMBO)	0.005	0.05	0.15	0.055	0.01	0.08	0.2	0.085

and to the southeast at the boundary of the Nesson-Little Knife Continuous Oil AU. The AU includes production from the Elm Coulee field and along the Billings Nose anticline or "Bakken fairway," which was used to define a geologic "sweet spot" based upon favorable reservoir properties in the Elm Coulee field and structural enhancement of the Billings Nose anticline.

The Central Basin Continuous Oil AU is defined largely by the 450-hydrogen index (HI) contour for the upper Bakken shale member. The 450-HI contour includes the Poplar dome region, but this particular area was largely discounted for the addition of potential resource because of the migration of Bakken oil into overlying units in this structure (Lillis, 2013) and the absence of oil in the Bakken Formation. The southern and eastern boundaries of this AU are constrained by the Elm Coulee-Billings Nose and Nesson-Little Knife Continuous Oil AUs, respectively. The geologic "sweet spot" is defined as an area with pressure gradients equal to or greater than 0.68 pounds per square inch per foot (psi/ft), based on a contour map by Theloy and Sonnenberg (2013).

The Nesson-Little Knife Continuous Oil AU western boundary is defined from a structure contour map of the Bakken Formation and includes the Nesson and Little Knife anticlines. The eastern boundary is defined by the 450-HI contour, and the southern boundary is the edge of the Bakken Formation. The geologic "sweet spot" is defined as the area where the formation pressure is equal to or exceeds 0.68 psi/ft (Theloy and Sonnenberg, 2013).

The Eastern Transitional Continuous Oil AU is defined by the 450-HI contour on the west and wraps around to the 100-ohm resistivity line of Hester and Schmoker (1985) and the 650-HI contour line used by Pollastro and others (2008). Bakken production in northern Divide County, in northwestern North Dakota, was also included in this AU because the thermal maturity in that area is similar to that along the eastern margin of the Eastern Transitional Continuous AU, and it reflects the transitional nature of the thermal maturity from the center of the basin outward. The geologic "sweet spot" is defined as the area where the formation pressure gradient is equal to or exceeds 0.68 psi/ft (Theloy and Sonnenberg, 2013) and includes Parshall field and the eastern portion of Sanish field.

The Northwest Transitional Continuous Oil AU is also defined on the basis of lower thermal maturities (>450 HI). The western boundary is defined by the 100-ohm resistivity line and 650-HI contour, the northern boundary is placed along the U.S.-Canadian border, and the remainder of the AU follows the 450-HI contour used to define the Central Basin Continuous Oil AU.

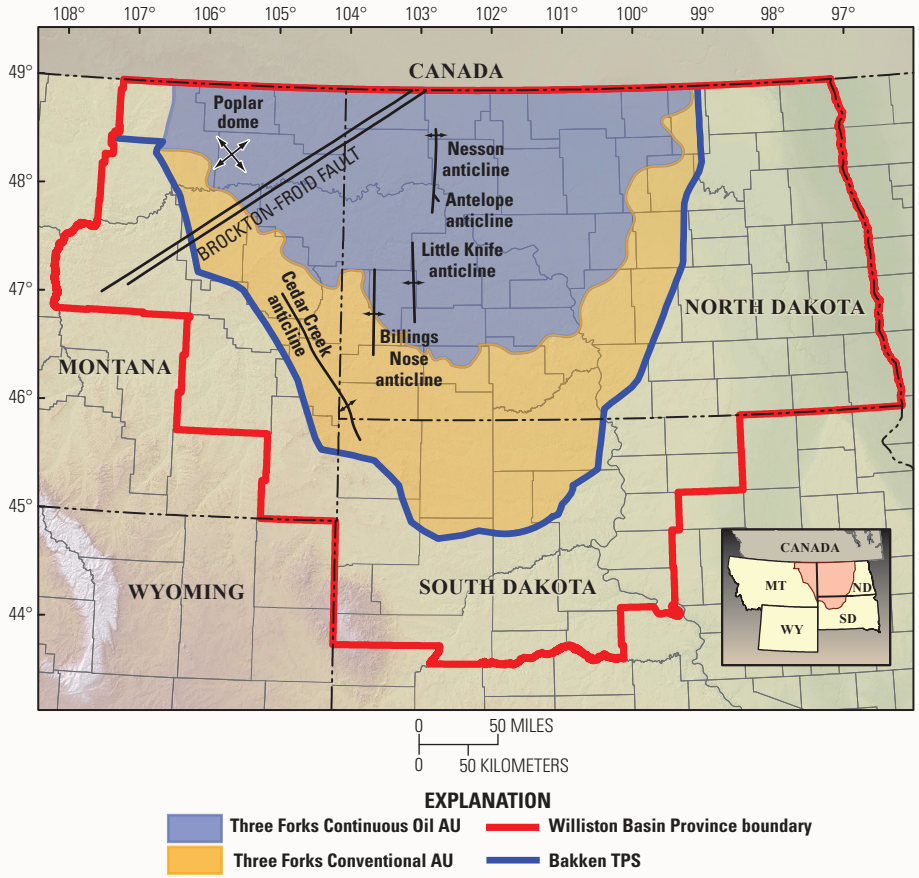

Figure 2. *Location of the Three Forks Formation Assessment Units (AUs) in the Williston Basin Province. Inset map shows location of the Bakken TPS (pink).*

Three Forks Formation

The Three Forks Conventional AU is a hypothetical AU defined outside of the continuous AUs by the maximum extent of the Three Forks Formation, which extends beyond the Bakken shale source intervals (fig. 2).

The Three Forks Continuous Oil AU is defined by the lateral extent of the upper Bakken shale member in conjunction with the southernmost extent of the Pronghorn Member in North Dakota (fig. 2). The northern boundary is placed along the U.S.-Canadian border. The geologic "sweet spot" encompasses the region of maximum hydrocarbon generation (as determined by HI values), maximum formation pressures, and structural enhancements related to lineaments and the Nesson and Little Knife anticlines.

Resource Summary

The USGS assessed technically recoverable continuous (unconventional) resources for six AUs defined in the Bakken and Three Forks Formations resulting in estimated means of 7,375 million barrels of oil (MMBO), 6,723 billion cubic feet of gas (BCFG), and 527 million barrels of natural gas liquids (MMBNGL) (table 2). This includes mean-estimated oil resources from the Elm Coulee-Billings Nose Continuous Oil AU (283 MMBO), the Central Basin Continuous Oil AU (1,122 MMBO), the Nesson-Little Knife Continuous Oil AU (1,149 MMBO), the Eastern Transitional Continuous Oil AU (883 MMBO), the Northwest Transitional Continuous Oil AU (207 MMBO), and the Three Forks Continuous Oil AU (3,731 MMBO).

The two conventional AUs (Middle Bakken Conventional Assessment Unit and Three Forks Conventional Assessment Unit) have estimated mean-recoverable resources of 8 MMBO and 3 BCFG (table 2).

Table 2. Bakken and Three Forks Formations, Williston Basin Province assessment results.

[MMBO, million barrels of oil. BCFG, billion cubic feet of gas. MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. For gas accumulations, all liquids are included as NGL (natural gas liquids). 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. TPS, total petroleum system; AU, assessment unit. Gray shading indicates not applicable]

Total Petroleum Systems (TPS) and Assessment Units (AU)	Field type	Total Undiscovered Resources											
		Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
		F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Bakken TPS													
Elm Coulee-Billings Nose Continuous Oil AU 50310161	*Oil*	218	281	355	283	174	278	410	283	11	21	36	22
Central Basin Continuous Oil AU 50310162	*Oil*	892	1,113	1,379	1,122	699	1,103	1,604	1,122	46	85	139	88
Nesson-Little Knife Continuous Oil AU 50310163	*Oil*	907	1,139	1,423	1,149	714	1,130	1,648	1,149	47	87	144	90
Eastern Transitional Continuous Oil AU 50310164	*Oil*	706	876	1,082	883	275	435	629	441	18	33	55	35
Northwest Transitional Continuous Oil AU 50310165	*Oil*	90	197	357	207	57	134	268	145	4	10	22	11
Three Forks Continuous Oil AU 50310166	*Oil*	1,604	3,440	6,834	3,731	1,508	3,286	6,685	3,583	105	252	553	281
Total continuous resources		**4,417**	**7,046**	**11,430**	**7,375**	**3,427**	**6,366**	**11,244**	**6,723**	**231**	**488**	**949**	**527**
Bakken TPS													
Middle Bakken Conventional AU 50310101	*Oil*	1	4	10	5	0	2	4	2	0	0	0	0
	Gas					0	0	0	0	0	0	0	0
Three Forks Conventional AU 50310103	*Oil*	0	3	7	3	0	1	3	1	0	0	0	0
	Gas					0	0	0	0	0	0	0	0
Total conventional resources		**1**	**7**	**17**	**8**	**0**	**3**	**7**	**3**	**0**	**0**	**0**	**0**
Total undiscovered oil and gas resources		**4,418**	**7,053**	**11,447**	**7,383**	**3,427**	**6,369**	**11,251**	**6,726**	**231**	**488**	**949**	**527**

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For Additional Information

Supporting geologic studies of the Bakken and Three Forks Formations and the methodology used in the assessment are in progress. Please see the USGS Energy Resources Program Web site (*http://energy.usgs.gov*).