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National and Global Petroleum Assessment

# Assessment of Undiscovered Oil and Gas Resources in the North-Central Montana Province, 2017

Using a geology-based assessment methodology, the U.S. Geological Survey estimated mean undiscovered, technically recoverable resources of 55 million barrels of oil and 846 billion cubic feet of gas in the North-Central Montana Province.

## Introduction

The U.S. Geological Survey (USGS) quantitatively assessed the potential for undiscovered, technically recoverable conventional and continuous (unconventional) oil and gas resources in the North-Central Montana Province (fig. 1). The geologic evolution of the province is the result of a series of tectonic events that affected the western margin of North America (Petersen, 1986; Anna and others, 2011). These events include (1) the development of Neoproterozoic rifts and a regional lineament system; (2) an early to middle lower Paleozoic passive margin (Cambrian–Silurian); (3) the east–west trending central Montana trough coeval with the development of the Williston Basin (Petersen, 1986; Maughan, 1989); (4) Late Devonian through Mississippian subduction and compression during the Antler orogenic event; (5) Pennsylvanian uplift and erosion related to the Ouachita event; (6) Jurassic to Early Cretaceous high-angle subduction and compression during the

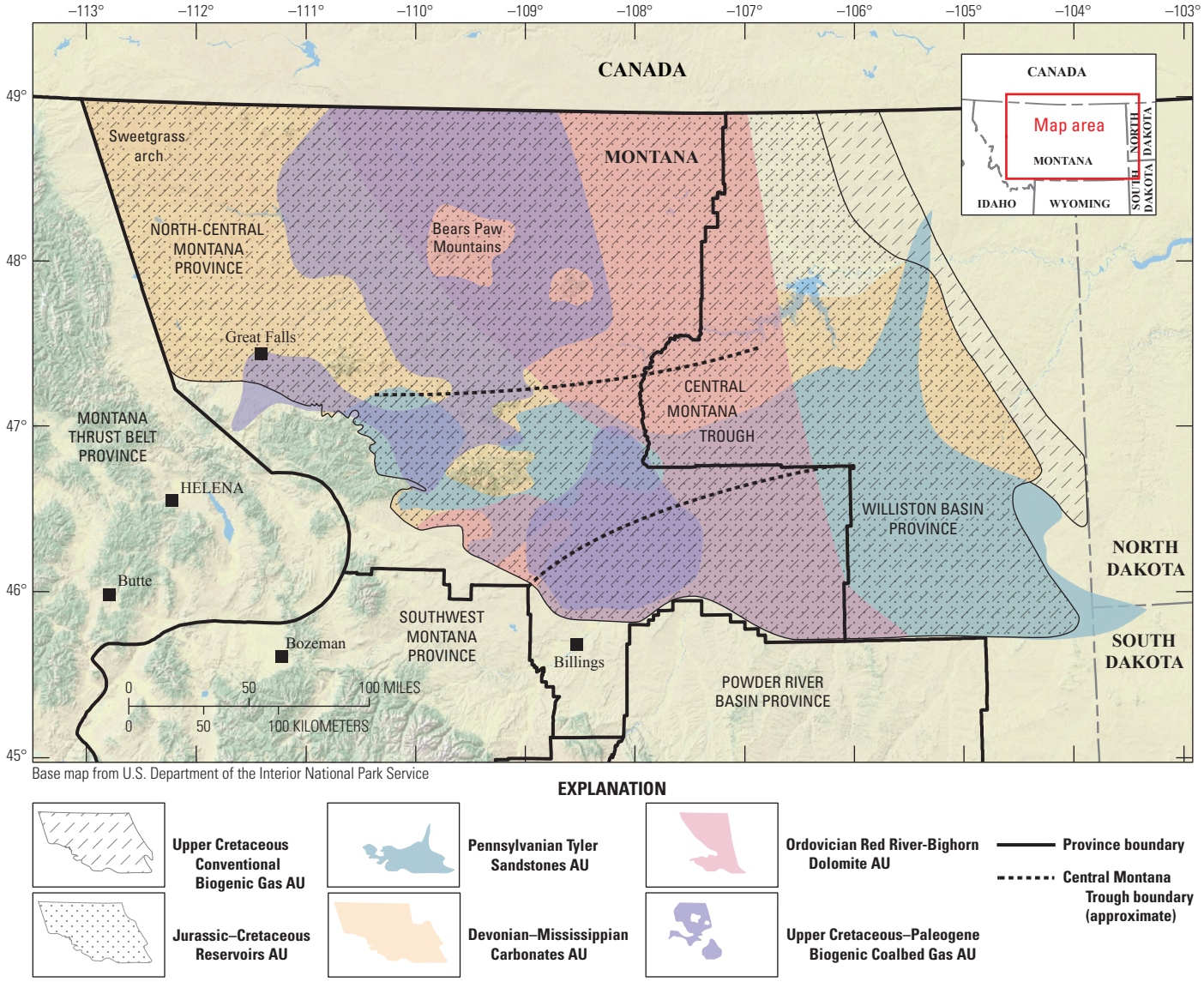
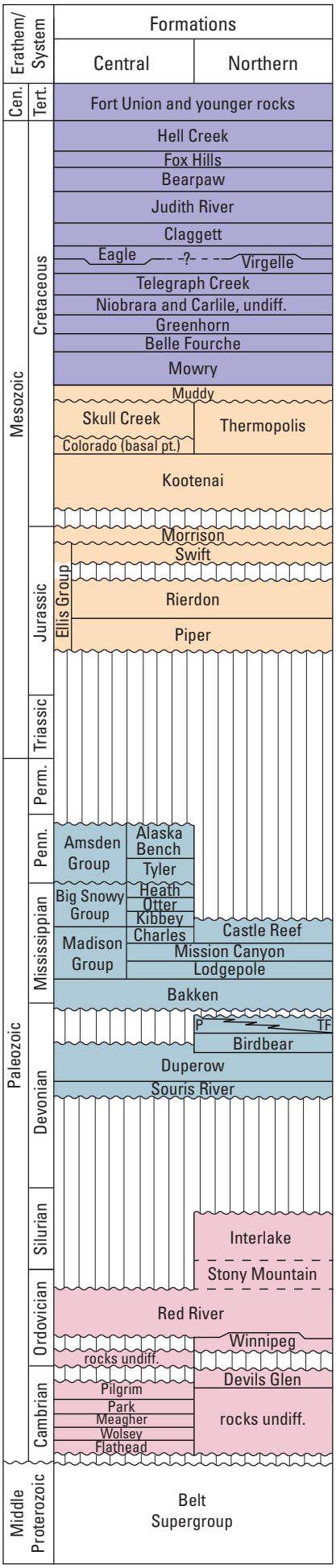



**Figure 1.** Map showing the location of six assessment units (AUs) in the North-Central Montana Province.




Sevier event; (7) Late Cretaceous through early Tertiary subhorizontal subduction and compression from the Laramide orogenic event; and (8) uplift, erosion, and structural trap formation related to the emplacement of intrusive rocks in the Eocene (Baker and Johnson, 2000). These events shaped the structural and stratigraphic evolution and the development of petroleum systems in the North-Central Montana Province (fig. 2).

## Total Petroleum Systems and Assessment Units

The USGS defined four total petroleum systems (TPSs) and six assessment units (AUs) within these TPSs, guided by previous work (Dyman and others, 1995; Anna, 2010). The Upper Cretaceous–Paleogene Biogenic Gas TPS includes the Upper Cretaceous Conventional Biogenic Gas AU and the Upper Cretaceous–Paleogene Biogenic Coalbed Gas AU. This TPS is defined by the presence of recoverable biogenic gas contained within shallow sandstone and coal reservoirs (Payenberg and others, 2003; Anna, 2010; Fishman and others, 2012). Gas was generated through biologic processes acting on thermally immature shales and coals, and accumulations of biogenic gas are the principal petroleum resources in the province.

The Jurassic TPS, which includes the Jurassic–Cretaceous Reservoirs AU, is poorly understood, and petroleum source rocks might be present along the flanks of the Sweetgrass arch in the western part of the province (fig. 1). Based on limited data, Jurassic source rocks have total organic carbon (TOC) values up to 3.5 weight percent and contain Type II organic matter (Aram, 1993).

The Devonian–Mississippian Composite TPS may include petroleum source rocks of the Bakken, lower part of the Madison, and the Heath Formations, which were deposited in the central Montana trough. These source rocks contain marine Type II organic matter, have TOC values up to 12 weight percent, and are in the thermal maturity window for oil generation (Jarvie, 2001; Jarvie and others, 2016). Continuous (unconventional) oil resources of the Heath TPS were assessed previously (Drake and others, 2017). The Devonian–Mississippian Composite TPS includes oil in the Pennsylvanian Tyler Sandstones AU and the Devonian–Mississippian Carbonates AU.

The Ordovician TPS was defined to encompass oil and gas generated from Ordovician marine organic matter in the central Montana trough. Similar Ordovician organic-rich shales in the Williston Basin have TOC values ranging up to 6 weight percent, and hydrogen index values to 800 milligrams of hydrocarbon per gram of total organic carbon (Nesheim, 2017). Thermal maturity of potential Ordovician source rocks is interpreted to be mainly in the oil-generation window. The TPS includes the Ordovician Red River-Bighorn Dolomite AU.

Undiscovered oil and gas resources within the Ordovician TPS and the Devonian–Mississippian Composite TPS are focused within the area of the central Montana trough, as the trough apparently was connected to the Williston Basin during the Ordovician Period through the Mississippian Subperiod.

The assessment input data are summarized in table 1. For the continuous assessment unit, well drainage areas, success ratios, and estimated ultimate recoveries are taken from U.S. coalbed-gas analogs.

## Undiscovered Resources Summary

The USGS quantitatively assessed undiscovered conventional and continuous oil and gas resources in six assessment units within the North-Central Montana Province (table 2). The estimated mean totals for undiscovered resources are 55 million barrels of oil (MMBO) with an F95–F5 range from 0 to 139 MMBO; 846 billion cubic feet of gas (BCFG) with an F95–F5 range from 145 to 2,144 BCFG; and 6 million barrels of natural gas liquids (MMBNGL) with an F95–F5 range from 0 to 15 MMBNGL. The estimated mean of 55 MMBO is subdivided as follows: 3 MMBO are in the Jurassic–Cretaceous Reservoirs AU, 7 MMBO are in the Pennsylvanian Tyler Sandstones AU, 25 MMBO are in the Devonian–Mississippian Carbonates AU, and 20 MMBO are in the Ordovician Red River-Bighorn Dolomite AU.

For the Upper Cretaceous Conventional Biogenic Gas AU, the estimated mean is 171 BCFG with an F95–F5 range from 35 to 459 BCFG, and in the Upper Cretaceous–Paleogene Biogenic Coalbed Gas AU, the estimated mean is 585 BCFG with an F95–F5 range from 110 to 1,454 BCFG. Biogenic gas accounts for about 90 percent of the estimated mean undiscovered, recoverable gas resources in the North-Central Montana Province.

**Figure 2.** Stratigraphic column for the North-Central Montana Province showing the stratigraphic extent of the four total petroleum systems defined in this study. Modified from Dyman and others, 1995. (Cen., Cenozoic; P, Potlach Formation; Penn.; Pennsylvanian; Perm., Permian; pt., part; Tert., Tertiary; TF, Three Forks Formation; undiff., undifferentiated)

**Table 1.** Key input data for six assessment units in the North-Central Montana Province.

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

| Assessment input data—Conventional AUs | Upper Cretaceous Conventional Biogenic Gas AU | | | | Jurassic–Cretaceous Reservoirs AU | | | |
|---|---|---|---|---|---|---|---|---|
| | Minimum | Median | Maximum | Calculated mean | Minimum | Median | Maximum | Calculated mean |
| Number of oil fields | | | | | 1 | 3 | 10 | 3.2 |
| Number of gas fields | 1 | 10 | 50 | 11.4 | 1 | 2 | 4 | 2.1 |
| Sizes of oil fields (MMBO) | | | | | 0.5 | 1 | 10 | 1.3 |
| Sizes of gas fields (BCFG) | 3 | 6 | 600 | 14.9 | 3 | 6 | 60 | 7.7 |
| AU probability | 1.0 | | | | 0.8 | | | |
| **Assessment input data—Conventional AUs** | **Pennsylvanian Tyler Sandstones AU** | | | | **Devonian–Mississippian Carbonates AU** | | | |
| | Minimum | Median | Maximum | Calculated mean | Minimum | Median | Maximum | Calculated mean |
| Number of oil fields | 1 | 5 | 14 | 5.3 | 1 | 10 | 40 | 11.0 |
| Sizes of oil fields (MMBO) | 0.5 | 1 | 20 | 1.5 | 0.5 | 1 | 100 | 2.5 |
| AU probability | 0.9 | | | | 0.9 | | | |
| **Assessment input data—Conventional AU** | **Ordovician Red River-Bighorn Dolomite AU** | | | | | | | |
| | Minimum | Median | Maximum | Calculated mean | | | | |
| Number of oil fields | 1 | 15 | 60 | 16.6 | | | | |
| Number of gas fields | 1 | 3 | 12 | 3.3 | | | | |
| Sizes of oil fields (MMBO) | 0.5 | 1 | 20 | 1.5 | | | | |
| Sizes of gas fields (BCFG) | 3 | 8 | 1,500 | 8.9 | | | | |
| AU probability | 0.8 | | | | | | | |
| **Assessment input data—Continuous AU** | **Upper Cretaceous–Paleogene Biogenic Coalbed Gas AU** | | | | | | | |
| | Minimum | Mode | Maximum | Calculated mean | | | | |
| Potential production area of AU (acres) | 400 | 5,507,500 | 11,015,000 | 5,507,633 | | | | |
| Average drainage area of wells (acres) | 40 | 100 | 160 | 100 | | | | |
| Success ratio (%) | 2 | 7 | 25 | 11.3 | | | | |
| Average EUR (BCFG) | 0.04 | 0.08 | 0.3 | 0.092 | | | | |
| AU probability | 1.0 | | | | | | | |

**Table 2.** Assessment results for six assessment units in the North-Central Montana 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 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 |
| Upper Cretaceous–Paleogene Biogenic Gas Total Petroleum System | | | | | | | | | | | | | | |
| Upper Cretaceous Conventional Biogenic Gas AU | 1.0 | Gas | | | | | 35 | 128 | 459 | 171 | 0 | 0 | 0 | 0 |
| Jurassic Total Petroleum System | | | | | | | | | | | | | | |
| Jurassic–Cretaceous Reservoirs AU | 0.8 | Oil | 0 | 3 | 8 | 3 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 |
| | | Gas | | | | | 0 | 12 | 30 | 13 | 0 | 0 | 0 | 0 |
| Devonian–Mississippian Composite Total Petroleum System | | | | | | | | | | | | | | |
| Pennsylvanian Tyler Sandstones AU | 0.9 | Oil | 0 | 6 | 16 | 7 | 0 | 1 | 3 | 1 | 0 | 0 | 0 | 0 |
| Devonian–Mississippian Carbonates AU | 0.9 | Oil | 0 | 19 | 68 | 25 | 0 | 15 | 55 | 20 | 0 | 0 | 0 | 0 |
| Ordovician Total Petroleum System | | | | | | | | | | | | | | |
| Ordovician Red River-Bighorn Dolomite AU | 0.8 | Oil | 0 | 19 | 47 | 20 | 0 | 29 | 76 | 31 | 0 | 6 | 15 | 6 |
| | | Gas | | | | | 0 | 20 | 65 | 24 | 0 | 0 | 0 | 0 |
| **Total undiscovered conventional resources** | | | **0** | **47** | **139** | **55** | **35** | **206** | **690** | **261** | **0** | **6** | **15** | **6** |
| Upper Cretaceous–Paleogene Biogenic Gas Total Petroleum System | | | | | | | | | | | | | | |
| Upper Cretaceous–Paleogene Biogenic Coalbed Gas AU | 1.0 | Gas | | | | | 110 | 467 | 1,454 | 585 | 0 | 0 | 0 | 0 |
| **Total undiscovered continuous resources** | | | | | | | **110** | **467** | **1,454** | **585** | **0** | **0** | **0** | **0** |
| **Total undiscovered resources** | | | **0** | **47** | **139** | **55** | **145** | **673** | **2,144** | **846** | **0** | **6** | **15** | **6** |

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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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