

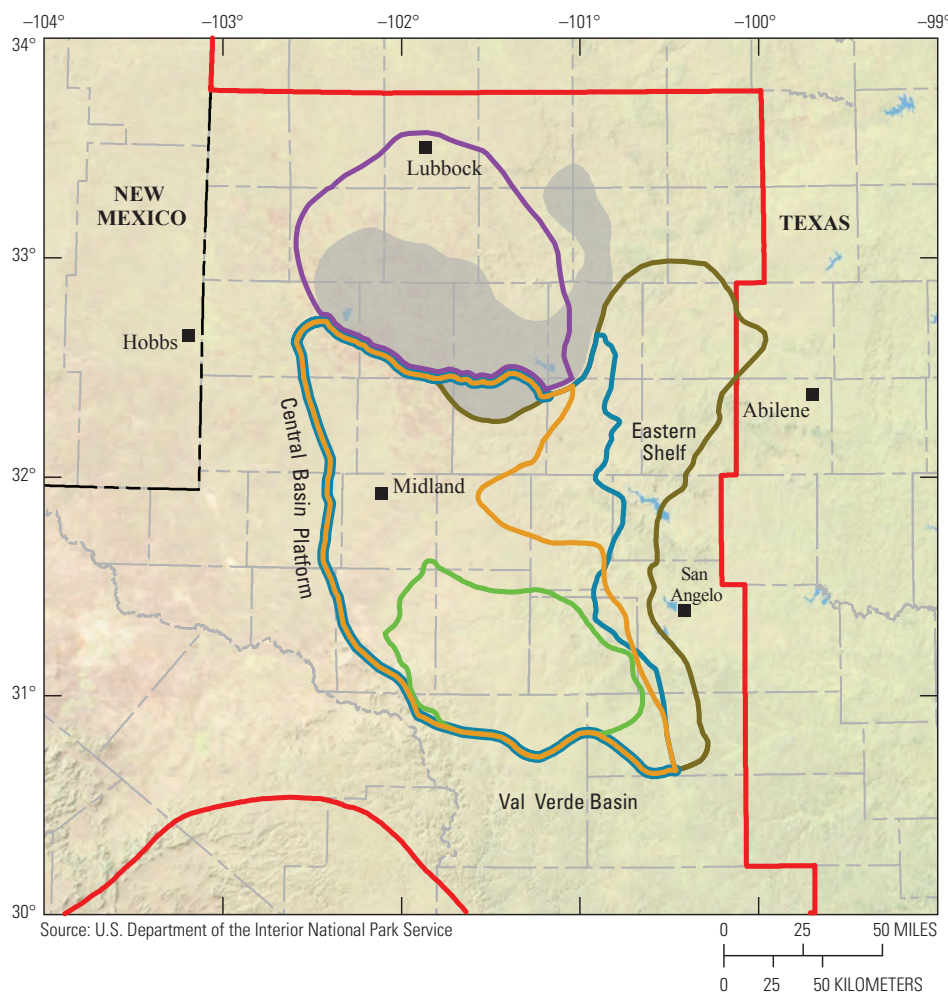
Assessment of Undiscovered Continuous Oil Resources in the Wolfcamp Shale of the Midland Basin, Permian Basin Province, Texas, 2016

Using a geology-based assessment methodology, the U.S. Geological Survey assessed technically recoverable mean resources of 20 billion barrels of oil and 16 trillion cubic feet of gas in the Wolfcamp shale in the Midland Basin part of the Permian Basin Province, Texas.

Introduction

In 2016, the U.S. Geological Survey (USGS) completed a geology-based assessment of undiscovered, technically recoverable continuous petroleum resources in the Pennsylvanian–Permian Wolfcamp shale (informal name) in the Midland Basin of the Permian Basin Province of west Texas (fig. 1). This is the first USGS evaluation of continuous resources in the Wolfcamp shale in the Midland Basin. Since the 1980s, the Wolfcamp shale in the Midland Basin has been part of the “Wolfberry” play that encompasses Mississippian, Pennsylvanian, and Lower Permian reservoirs (Hamlin and Baumgardner, 2012). This play has traditionally been developed using vertical wells that are completed and stimulated in multiple productive stratigraphic intervals that include the Wolfcamp shale and overlying Spraberry Formation. The Wolfcamp shale is being drilled for continuous oil using horizontal wells that are hydraulically fractured. More than 3,000 horizontal wells have been drilled and completed in the Midland Basin Wolfcamp section (IHS Markit™, 2016).

Figure 1. Map showing the Midland Basin, Permian Basin Province, Texas, and the extent of the six assessment units (AU). The Midland Basin Wolfcamp A Continuous Oil AU and Midland Basin Wolfcamp B Upper Continuous Oil AU have the same extent.



- EXPLANATION**
- Horseshoe atoll
 - Midland Basin Wolfcamp A Continuous Oil AU
 - Midland Basin Wolfcamp B Upper Continuous Oil AU
 - Midland Basin Wolfcamp B Lower Continuous Oil AU
 - Midland Basin Wolfcamp C Continuous Oil AU
 - Midland Basin Wolfcamp D Continuous Oil AU
 - Midland Basin Northern Wolfcamp Continuous Oil AU
 - Permian Basin Province (part)
 - County boundary



Geologic Summary

The Permian Basin Province of west Texas and southeastern New Mexico contains two subbasins, the Delaware Basin to the west and the Midland Basin to the east, separated by the uplifted Central Basin platform. During the Pennsylvanian–Permian, the Wolfcamp was deposited as shallow-water carbonates on the Central Basin platform and Eastern shelf (fig. 1) and interbedded, finer-grained, organic-rich siliciclastic mud with organic-poor, clay-rich mud and fine-grained carbonates in the deeper part of the Midland Basin. The Wolfcamp shale throughout this region is mature for oil generation based on thermal maturation data (Pawlewicz and others, 2005). The petroleum industry has divided the Wolfcamp shale into four stratigraphic units based on petrophysical log signatures and landing zones for horizontal wells. The uppermost unit is the Wolfcamp A, followed by the underlying Wolfcamp B, C, and D units, respectively. The eastern margin of Wolfcamp shale deposition prograded westward through time, as indicated by the larger depositional areas delineated in the Wolfcamp C and D assessment units (AUs) when compared to the Wolfcamp A and B assessment units.

Definition of Assessment Units

Six continuous assessment units were defined and quantitatively assessed in the Wolfcamp shale in the Midland Basin of the Permian Basin Province: (1) Midland Basin Wolfcamp A Continuous Oil AU, (2) Midland Basin Wolfcamp B Upper Continuous Oil AU, (3) Midland Basin Wolfcamp B Lower Continuous Oil AU, (4) Midland Basin Wolfcamp C Continuous Oil AU, (5) Midland Basin Wolfcamp D Continuous Oil AU, and (6) Midland Basin Northern Wolfcamp Continuous Oil AU (fig. 1). The six assessment units are within the Permian Basin Paleozoic Composite Total Petroleum System (TPS) (Schenk and others, 2007). The Midland Basin Wolfcamp A Continuous Oil AU and Wolfcamp B Upper Continuous Oil AU were constrained by the Central Basin platform to the west, the southern edge of the Horseshoe atoll and an area of thick Wolfcamp strata to the north, the Eastern Shelf margin to the east, and the Val Verde Basin Canyon Sandstone AU (Schenk and others, 2016) to the south. The Midland Basin Wolfcamp B Lower Continuous Oil AU is restricted to the southern Midland Basin where the

thickness of the Wolfcamp B exceeds 500 feet and allows for placement of two lateral wells in the Wolfcamp B unit. The Midland Basin Wolfcamp C Continuous Oil AU is bounded by the Central Basin platform on the west, the southern edge of the Horseshoe atoll and an area of thick Wolfcamp strata to the north, the estimated extent of the Wolfcamp C depositional boundary using shelf edges mapped by Hentz and others (2016) to the east, and the Val Verde Basin Canyon Sandstone AU (Schenk and others, 2016) to the south. The Midland Basin Wolfcamp D Continuous Oil AU is defined by the Central Basin platform to the west, the southern edge of the Horseshoe atoll to the north, the mapped extent of Upper Pennsylvanian shale to the northeast and east, and the Val Verde Basin Canyon Sandstone AU (Schenk and others, 2016) to the south. The Midland Basin Northern Wolfcamp AU is defined by the Midland Basin shelf margin to the north and east and the southern edge of the Horseshoe atoll and the northern boundary of an area of thick Wolfcamp strata that was included in the AUs to the south. Assessment input data for the six AUs are summarized in table 1.

Table 1. Key assessment input data for six continuous assessment units in the Wolfcamp shale in the Midland Basin of the Permian Basin Province, Texas.

[AU, assessment unit; %, percent; EUR, estimated ultimate recovery per well; MMBO, million barrels of oil. The average EUR input is the minimum, median, and calculated mean. Shading indicates not applicable]

| Assessment input data | Midland Basin Wolfcamp A Continuous Oil AU | | | | Midland Basin Wolfcamp B Upper Continuous Oil AU | | | |
|---|--|-----------|-----------|-----------------|---|-----------|-----------|-----------------|
| | Minimum | Mode | Maximum | Calculated mean | Minimum | Mode | Maximum | Calculated mean |
| Potential production area of AU (acres) | 3,000,000 | 3,495,500 | 5,814,000 | 4,103,000 | 3,000,000 | 3,523,000 | 5,814,000 | 4,112,333 |
| Average drainage area of wells (acres) | 60 | 80 | 160 | 100 | 60 | 80 | 160 | 100 |
| Percentage of area untested in AU | 83 | 85 | 91 | 86.3 | 83 | 85 | 91 | 86.3 |
| Success ratios (%) | 92 | 95 | 99 | 95.3 | 92 | 95 | 99 | 95.3 |
| Average EUR (MMBO) | 0.12 | 0.16 | 0.3 | 0.167 | 0.12 | 0.16 | 0.3 | 0.167 |
| AU probability | 1.0 | | | | 1.0 | | | |
| Assessment input data | Midland Basin Wolfcamp B Lower Continuous Oil AU | | | | Midland Basin Wolfcamp C Continuous Oil AU | | | |
| | Minimum | Mode | Maximum | Calculated mean | Minimum | Mode | Maximum | Calculated mean |
| Potential production area of AU (acres) | 700,000 | 742,000 | 2,012,000 | 1,151,333 | 1,000,000 | 2,373,000 | 6,703,000 | 3,358,667 |
| Average drainage area of wells (acres) | 60 | 80 | 160 | 100 | 60 | 80 | 160 | 100 |
| Percentage of area untested in AU | 68 | 70 | 89 | 75.7 | 47 | 77 | 92 | 72 |
| Success ratios (%) | 92 | 95 | 99 | 95.3 | 50 | 70 | 90 | 70 |
| Average EUR (MMBO) | 0.12 | 0.16 | 0.3 | 0.167 | 0.03 | 0.08 | 0.15 | 0.083 |
| AU probability | 1.0 | | | | 1.0 | | | |
| Assessment input data | Midland Basin Wolfcamp D Continuous Oil AU | | | | Midland Basin Northern Wolfcamp Continuous Oil AU | | | |
| | Minimum | Mode | Maximum | Calculated mean | Minimum | Mode | Maximum | Calculated mean |
| Potential production area of AU (acres) | 2,000,000 | 4,885,000 | 8,915,000 | 5,266,667 | 1,000 | 1,633,000 | 3,266,000 | 1,633,333 |
| Average drainage area of wells (acres) | 60 | 80 | 160 | 100 | 60 | 80 | 160 | 100 |
| Percentage of area untested in AU | 73 | 89 | 94 | 85.3 | 97 | 99 | 100 | 98.7 |
| Success ratios (%) | 75 | 85 | 95 | 85 | 10 | 50 | 90 | 50 |
| Average EUR (MMBO) | 0.06 | 0.12 | 0.25 | 0.126 | 0.02 | 0.06 | 0.14 | 0.064 |
| AU probability | 1.0 | | | | 1.0 | | | |

Table 2. Assessment results for six continuous assessment units in the Wolfcamp shale in the Midland Basin of the Permian Basin Province, Texas.

[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 under the natural gas liquids (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 unit (AU) | 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 |
| Permian Basin Paleozoic Composite Total Petroleum System | | | | | | | | | | | | | | |
| Midland Basin Wolfcamp A Continuous Oil AU | 1.0 | Oil | 3,754 | 5,633 | 8,483 | 5,815 | 2,540 | 4,453 | 7,457 | 4,652 | 223 | 436 | 806 | 465 |
| Midland Basin Wolfcamp B Upper Continuous Oil AU | 1.0 | Oil | 3,769 | 5,644 | 8,505 | 5,829 | 2,557 | 4,454 | 7,482 | 4,663 | 224 | 437 | 811 | 466 |
| Midland Basin Wolfcamp B Lower Continuous Oil AU | 1.0 | Oil | 794 | 1,342 | 2,351 | 1,430 | 554 | 1,056 | 2,023 | 1,144 | 49 | 104 | 215 | 114 |
| Midland Basin Wolfcamp C Continuous Oil AU | 1.0 | Oil | 577 | 1,306 | 2,728 | 1,433 | 417 | 1,018 | 2,299 | 1,146 | 38 | 100 | 241 | 115 |
| Midland Basin Wolfcamp D Continuous Oil AU | 1.0 | Oil | 2,420 | 4,658 | 8,262 | 4,920 | 1,733 | 3,657 | 7,096 | 3,936 | 156 | 357 | 753 | 394 |
| Midland Basin Northern Wolfcamp Continuous Oil AU | 1.0 | Oil | 116 | 458 | 1,139 | 521 | 86 | 357 | 953 | 417 | 8 | 35 | 100 | 42 |
| Total undiscovered continuous resources | | | 11,430 | 19,041 | 31,468 | 19,948 | 7,887 | 14,995 | 27,310 | 15,958 | 698 | 1,469 | 2,926 | 1,596 |



View from County Road 221 (formerly the Bankhead Highway) in the Sweetwater vicinity of Nolan County, Texas, west of Abilene. Photograph used with permission from the Texas Historical Commission.

Undiscovered Resources Summary

The USGS quantitatively assessed undiscovered, technically recoverable continuous oil and gas resources for six AUs defined in the Midland Basin Wolfcamp shale of the Permian Basin Province (table 2). Assessed mean resources are 19,948 million barrels of oil (MMBO), or 20 billion barrels of oil, with an F95–F5 range from 11,430 to 31,468 MMBO; 15,958 billion cubic feet of associated gas (BCFG), or 16 trillion cubic feet of associated gas, with an F95–F5 range from 7,887 to 27,310 BCFG; and 1,596 million barrels of natural gas liquids (MMBNGL) with an F95–F5 range from 698 to 2,926 MMBNGL.

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Pumpjack in rural Texas. Photograph from the Carol M. Highsmith Archive, Library of Congress, Prints and Photographs Division.

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For More Information

Assessment results are available at the USGS Energy Resources Program Web site at <http://energy.usgs.gov>.