Assessment of Undiscovered Continuous Oil and Gas Resources in the Wolfcamp Shale and Bone Spring Formation of the Delaware Basin, Permian Basin Province, New Mexico and Texas, 2018

*U*sing a geology-based assessment methodology, the U.S. Geological Survey assessed undiscovered, technically recoverable continuous mean resources of 46.3 billion barrels of oil and 281 trillion cubic feet of gas in the Wolfcamp shale and Bone Spring Formation of the Delaware Basin in the Permian Basin Province, southeast New Mexico and west Texas.

Introduction

In 2018, the U.S. Geological Survey (USGS) completed a geology-based assessment of undiscovered, technically recoverable continuous oil and gas resources in the Pennsylvanian–Permian Wolfcamp shale (informal name; age follows Hamlin and Baumgardner, 2012) and the early Permian Bone Spring Formation of the Delaware Basin in the Permian Basin Province, southeast New Mexico and west Texas (figs. 1–3). The Delaware Basin is the western subbasin of the Permian Basin Province and is separated from the eastern Midland Basin by the uplifted Central Basin Platform. The Delaware Basin is rimmed by carbonate platforms, including the Central Basin and Diablo Platforms and the Northwest Shelf. The Wolfcamp shale was deposited throughout the Permian Basin and consists of interbedded, organic-rich shales and carbonates in both the Midland and Delaware Basins; however, the Wolfcamp shale in the Delaware Basin is thicker, deeper, and more thermally mature than in the Midland Basin. The overlying Bone Spring consists of alternating sandstone, carbonate, and shale cycles and is time-equivalent to the Spraberry Formation in the Midland Basin.

Recent USGS assessments of continuous oil and gas resources in the Permian Basin Province include the Wolfcamp shale (Gaswirth and others, 2016) and the Spraberry Formation (Marra and others, 2017) in the Midland Basin. The Bone Spring Formation was assessed for conventional oil and gas resources in 2007 (Schenk and others, 2008).

This is the first USGS assessment of continuous resources in the Wolfcamp shale and Bone Spring Formation of the Delaware Basin. Both the Wolfcamp shale and the Bone Spring Formation are subdivided into stratigraphic units based on petrophysical log signatures and landing zones for horizontal wells. This assessment used data from the Enerdeq™ and ProdFit™ databases (IHS Markit®, 2018a, b) for information on well landing zones, well production, and unit depths and thicknesses.
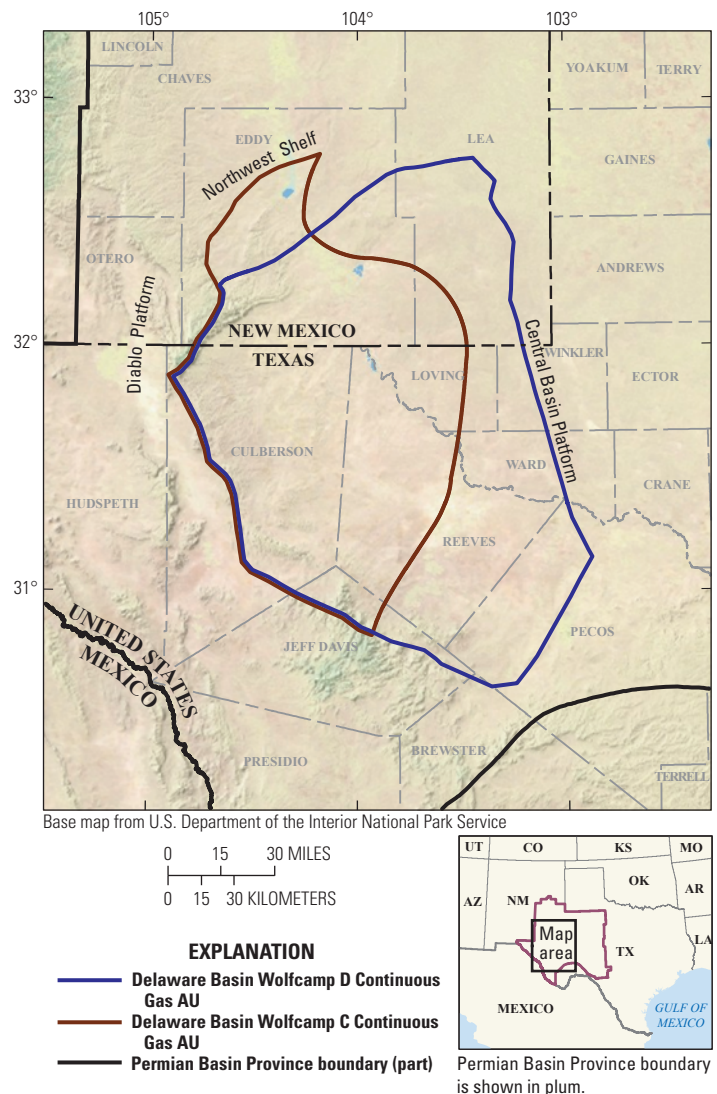

Base map from U.S. Department of the Interior National Park Service

EXPLANATION
— Delaware Basin Wolfcamp D Continuous Gas AU
— Delaware Basin Wolfcamp C Continuous Gas AU
— Permian Basin Province boundary (part)

Permian Basin Province boundary is shown in plum.

Figure 1. Map showing the Delaware Basin, Permian Basin Province, New Mexico and Texas, and the extent of the two Wolfcamp shale-gas continuous assessment units (AUs). Province boundary is from Klett and others, 1997.

Definition of Assessment Units

Eleven continuous assessment units (AUs) were defined and quantitatively assessed in the Wolfcamp shale and the Bone Spring Formation of the Delaware Basin in the Permian Basin Province, southeast New Mexico and west Texas. Six are in the Pennsylvanian–Permian Wolfcamp shale, and five are in the Permian Bone Spring Formation. The AUs are all within the Permian Basin Paleozoic Composite Total Petroleum System (Schenk and others, 2008) and are as follows, from oldest to youngest in age: (1) Delaware Basin Wolfcamp D Continuous Gas AU, (2) Delaware Basin Wolfcamp C Continuous Gas AU, (3) Delaware Basin Wolfcamp C Continuous Oil AU, (4) Delaware Basin Wolfcamp B Lower Continuous Oil AU, (5) Delaware Basin Wolfcamp B Upper Continuous Oil AU, (6) Delaware Basin Wolfcamp A Continuous Oil AU, (7) Third Bone Spring Continuous Oil AU, (8) Second Bone Spring Continuous Oil AU, (9) First Bone Spring Continuous Oil AU, (10) Lower Avalon Shale Continuous Oil AU, and (11) Upper Avalon Shale Continuous Oil AU.

Assessment unit boundaries are constrained by the Delaware Basin boundary, as defined by Dutton and others (2005) and Hamlin and Baumgardner (2012); extent of basinal facies; thermal maturation data (Pawlewicz and others, 2005); one-dimensional burial history modeling; isopach thickness of individual units; and structural top data (IHS Markit, 2018b). Assessment input data for the 11 AUs are summarized in table 1.

Undiscovered Resources Summary

The USGS quantitatively assessed undiscovered, technically recoverable continuous oil and gas resources for six AUs in the Wolfcamp shale and five AUs in the Bone Spring Formation (table 2) of the Delaware Basin of the Permian Basin Province. Estimated mean resources are 46,271 million barrels of oil (MMBO), or 46.3 billion barrels of oil, with an F95–F5 range from 26,729 to 71,075 MMBO; 280,630 billion cubic feet of gas (BCFG), or 281 trillion cubic feet of associated gas, with an F95–F5 range from 108,583 to 490,074 BCFG; and 19,917 million barrels of natural gas liquids (MMBNGL) with an F95–F5 range from 7,417 to 37,349 MMBNGL (table 2).
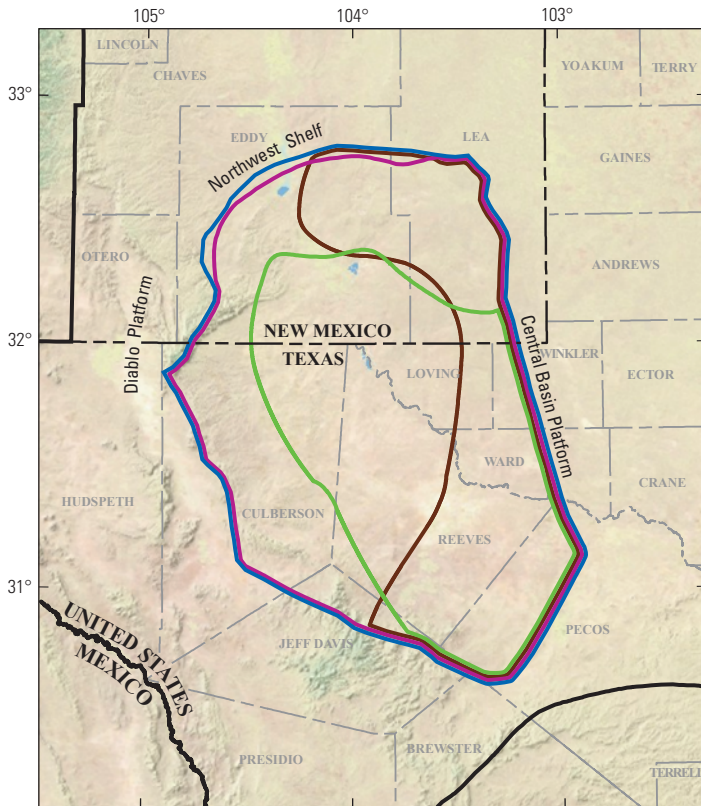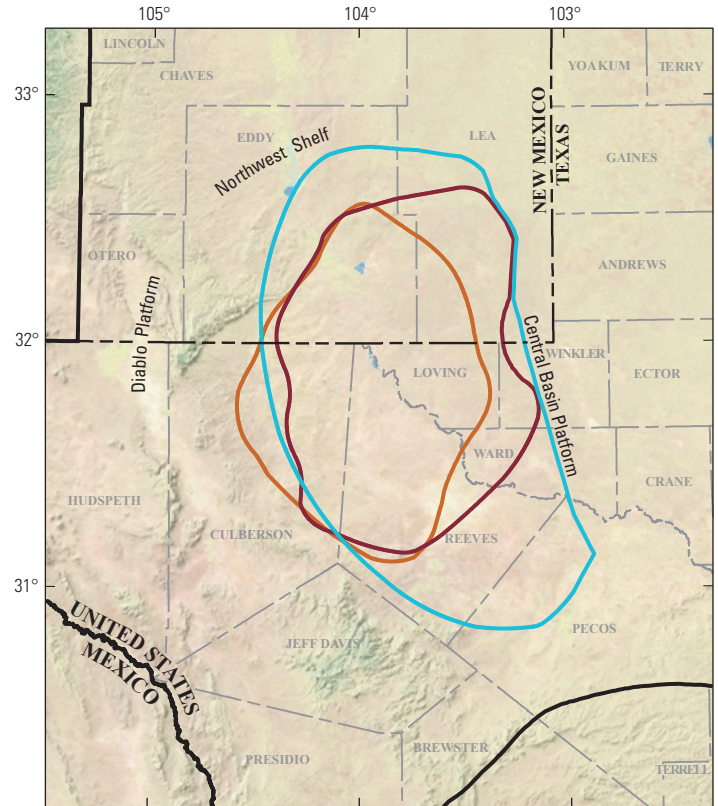

EXPLANATION

— Delaware Basin Wolfcamp C Continuous Oil AU
— Delaware Basin Wolfcamp B Lower Continuous Oil AU
— Delaware Basin Wolfcamp B Upper Continuous Oil AU
— Delaware Basin Wolfcamp A Continuous Oil AU
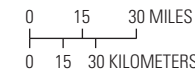— Permian Basin Province boundary (part)

Permian Basin Province boundary is shown in plum.

Figure 2. Map showing the Delaware Basin, Permian Basin Province, New Mexico and Texas, and the extent of the four Wolfcamp shale-oil continuous assessment units (AUs). Province boundary is from Klett and others, 1997.

Base map from U.S. Department of the Interior National Park Service

0 15 30 MILES
0 15 30 KILOMETERS

EXPLANATION

— Third Bone Spring Continuous Oil AU
— Second Bone Spring Continuous Oil AU
— First Bone Spring Continuous Oil AU
— Lower Avalon Shale Continuous Oil AU
— Upper Avalon Shale Continuous Oil AU
— Permian Basin Province boundary (part)

Figure 3. Map showing the Delaware Basin, Permian Basin Province, New Mexico and Texas, and the extent of the five Bone Spring Formation continuous assessment units (AUs). The Third, Second, and First Bone Spring AUs have the same extent. Province boundary is from Klett and others, 1997.

Table 1. Key input data for 11 continuous assessment units (AUs) in the Wolfcamp shale and Bone Spring Formation of the Delaware Basin, Permian Basin Province, New Mexico and Texas.

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

Assessment input data— Continuous AUs	Delaware Basin Wolfcamp D Continuous Gas AU				Delaware Basin Wolfcamp C Continuous Gas AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	2,000	5,100,000	7,100,000	4,067,333	1,500	3,000,000	4,400,000	2,467,167
Average drainage area of wells (acres)	80	100	160	113.3	80	100	160	113.3
Area untested in AU (%)	97	98	99	98	95	98	99	97.3
Success ratio (%)	70	80	90	80.0	50	70	90	70
Average EUR (BCFG)	1.0	2.5	4.5	2.579	1.0	2.5	4.5	2.579
AU probability	1.0				1.0			

Assessment input data— Continuous AU	Delaware Basin Wolfcamp C Continuous Oil AU				Delaware Basin Wolfcamp B Lower Continuous Oil AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	1,000	2,500,000	3,300,000	1,933,667	1,000,000	3,800,000	4,500,000	3,100,000
Average drainage area of wells (acres)	60	80	160	100	60	80	160	100
Area untested in AU (%)	100	100	100	100	91	97	98	95.3
Success ratio (%)	10	50	90	50	90	95	99	94.7
Average EUR (MMBO)	0.01	0.16	0.35	0.167	0.1	0.18	0.4	0.191
AU probability	1.0				1.0			

Assessment input data— Continuous AU	Delaware Basin Wolfcamp B Upper Continuous Oil AU				Delaware Basin Wolfcamp A Continuous Oil AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	1,800,000	5,600,000	7,750,000	5,050,000	4,000,000	5,600,000	7,600,000	5,733,333
Average drainage area of wells (acres)	60	80	160	100	60	80	160	100
Area untested in AU (%)	95	98	99	97.3	92	95	96	94.3
Success ratio (%)	90	95	99	94.7	90	95	99	94.7
Average EUR (MMBO)	0.12	0.18	0.4	0.192	0.14	0.24	0.5	0.253
AU probability	1.0				1.0			

Assessment input data— Continuous AU	Third Bone Spring Continuous Oil AU				Second Bone Spring Continuous Oil AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	4,000,000	5,000,000	5,600,000	4,866,667	3,600,000	5,000,000	5,600,000	4,733,333
Average drainage area of wells (acres)	120	160	180	153.3	120	160	180	153.3
Area untested in AU (%)	96	97	98	97	95	96	97	96
Success ratio (%)	90	95	99	94.7	90	95	99	94.7
Average EUR (MMBO)	0.14	0.22	0.45	0.232	0.1	0.18	0.3	0.185
AU probability	1.0				1.0			

Assessment input data— Continuous AU	First Bone Spring Continuous Oil AU				Lower Avalon Shale Continuous Oil AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	2,000	3,500,000	5,600,000	3,034,000	400,000	1,400,000	3,000,000	1,600,000
Average drainage area of wells (acres)	120	160	180	153.3	80	120	160	120
Area untested in AU (%)	97	98	99	98	91	95	97	94.3
Success ratio (%)	70	80	90	80	70	80	90	80
Average EUR (MMBO)	0.1	0.13	0.25	0.137	0.05	0.11	0.2	0.114
AU probability	1.0				1.0			

Assessment input data— Continuous AU	Upper Avalon Shale Continuous Oil AU			
	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	500,000	2,500,000	3,600,000	2,200,000
Average drainage area of wells (acres)	80	120	160	120
Area untested in AU (%)	93	96	97	95.3
Success ratio (%)	70	80	90	80
Average EUR (MMBO)	0.05	0.11	0.2	0.114
AU probability	1.0			

Table 2. Results for 11 continuous assessment units (AUs) in the Wolfcamp shale and Bone Spring Formation of the Delaware Basin, Permian Basin Province, New Mexico and Texas.

[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. 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 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
Permian Basin Paleozoic Composite Total Petroleum System														
Delaware Basin Wolfcamp D Continuous Gas AU	1.0	Gas					22,718	72,821	124,966	72,920	850	2,794	5,405	2,917
Delaware Basin Wolfcamp C Continuous Gas AU	1.0	Gas					11,757	37,793	67,845	38,510	438	1,455	2,924	1,539
Delaware Basin Wolfcamp C Continuous Oil AU	1.0	Oil	382	1,467	3,477	1,635	5,585	21,685	52,927	24,486	404	1,667	4,517	1,961
Delaware Basin Wolfcamp B Lower Continuous Oil AU	1.0	Oil	2,642	5,297	8,838	5,458	9,519	20,616	38,280	21,815	869	2,011	4,078	2,181
Delaware Basin Wolfcamp B Upper Continuous Oil AU	1.0	Oil	4,606	8,861	14,657	9,154	16,524	34,608	63,189	36,601	1,486	3,382	6,799	3,661
Delaware Basin Wolfcamp A Continuous Oil AU	1.0	Oil	8,406	12,791	19,556	13,229	14,297	25,219	42,988	26,492	1,259	2,476	4,626	2,648
Third Bone Spring Continuous Oil AU	1.0	Oil	4,941	6,468	9,521	6,739	7,906	12,975	20,851	13,485	501	896	1,551	943
Second Bone Spring Continuous Oil AU	1.0	Oil	3,869	5,096	6,878	5,191	6,201	10,120	15,435	10,370	391	696	1,158	725
First Bone Spring Continuous Oil AU	1.0	Oil	658	2,113	3,588	2,113	2,492	8,119	15,564	8,451	165	555	1,147	592
Lower Avalon Shale Continuous Oil AU	1.0	Oil	507	1,096	1,984	1,153	4,810	10,790	20,864	11,527	440	1,053	2,210	1,151
Upper Avalon Shale Continuous Oil AU	1.0	Oil	718	1,573	2,576	1,599	6,774	15,379	27,165	15,973	614	1,496	2,934	1,599
Total undiscovered continuous resources			**26,729**	**44,762**	**71,075**	**46,271**	**108,583**	**270,125**	**490,074**	**280,630**	**7,417**	**18,481**	**37,349**	**19,917**

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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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