

National and Global Petroleum Assessment

Assessment of Undiscovered Continuous Oil and Gas Resources in Upper Cretaceous Marine Shales of the Raton Basin-Sierra Grande Uplift Province, Colorado and New Mexico, 2022

Using a geology-based assessment methodology, the U.S. Geological Survey estimated means of 1.04 billion barrels of oil, 3.9 trillion cubic feet of gas, and 11 million barrels of natural gas liquids in Upper Cretaceous marine shales in the Raton Basin-Sierra Grande Uplift Province in Colorado and New Mexico.

Introduction

The U.S. Geological Survey (USGS) quantitatively assessed the potential for undiscovered, technically recoverable, continuous (unconventional) oil and gas resources in the Upper Cretaceous Niobrara Formation and Pierre Shale in the Raton Basin-Sierra Grande Uplift Province in Colorado and New Mexico (fig. 1). In the Raton Basin-Sierra Grande Uplift Province, the marine Niobrara Formation consists of two members: (1) the lower Fort Hays Limestone Member, composed of limestone and calcareous shale, and (2) the upper Smoky Hill Shale Member, composed of calcareous shale, sandy shale, and limestone (Scott, 1986; Scott and others,

1986; Broadhead, 2008). The Pierre Shale is predominantly medium-dark gray non-calcareous marine shale, with minor beds of limestone, siltstone, and fine-grained sandstone (Scott, 1986; Scott and Cobban, 1986; Broadhead, 2008). The strata were deposited in the Western Interior Seaway, which during much of the Cretaceous occupied an elongate north-south foreland basin that developed to the east of the North American Cordilleran orogenic belt (DeCelles, 2004). At its maximum extent, the Western Interior Seaway extended north-south for more than 3,000 miles and connected the Arctic Ocean to the Gulf of Mexico (Kauffman, 1977). The latest Cretaceous through early Eocene Laramide orogeny fragmented the central part of the foreland basin into numerous smaller basins. These smaller basins, such as the Raton Basin, were depocenters for the accumulation of thick synorogenic sediments during the Laramide orogeny (Lindsey, 1998).

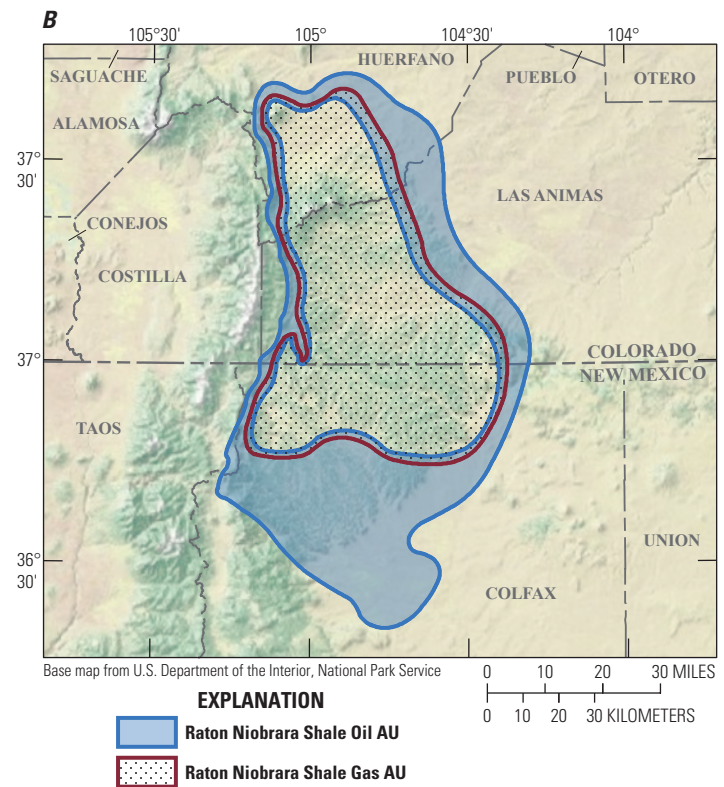
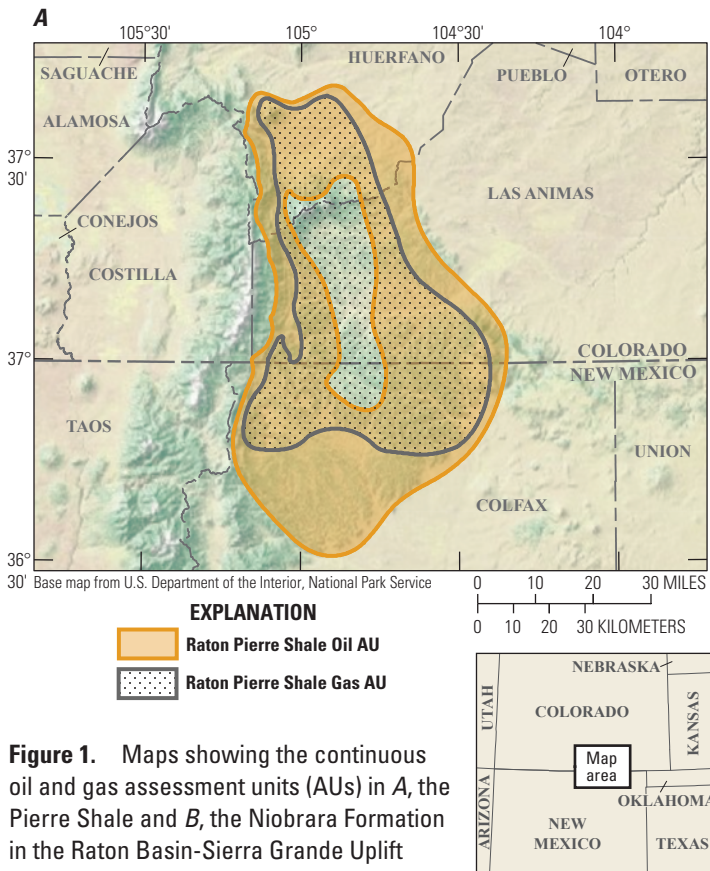


Figure 1. Maps showing the continuous oil and gas assessment units (AUs) in *A*, the Pierre Shale and *B*, the Niobrara Formation in the Raton Basin-Sierra Grande Uplift Province, Colorado and New Mexico.

Total Petroleum System and Assessment Unit

Schenk and others (2023) defined the Upper Paleozoic–Cenozoic Composite Total Petroleum System (TPS) in the Raton Basin-Sierra Grande Uplift Province to include strata from the base of the Pennsylvanian to the Paleocene Poison Canyon Formation. The Niobrara Formation and Pierre Shale are elements of the Upper Paleozoic–Cenozoic Composite TPS and include both source and reservoir rocks. According to Finn (2023), source rocks in the Niobrara Formation occur in the Smoky Hill Shale Member and have total organic carbon (TOC) contents as much as 6 weight percent and contain Type II and mixed Type II/III kerogen, with hydrogen index (HI) values as much as 586 milligrams of hydrocarbon per gram of TOC (mg HC/g TOC). Source rocks in the Pierre Shale are found in the Sharon Springs Member and have total TOC contents as much as 4 weight percent and contain Type II and mixed Type II/III kerogen, with HI values as much as 387 mg HC/g TOC (Gautier and others, 1984). Potential reservoirs are likely the carbonate-rich zones within the Niobrara Formation and the more brittle sandy and silty zones within the clay-rich Pierre Shale (Woodward, 1984, 1997). Natural fractures are expected to enhance reservoir productivity (Woodward, 1984, 1997; O’Farrell and others, 2010; Lorenz and Cooper, 2021). Thermal maturity mapping, based on vitrinite reflectance (R_o) of

overlying coal-bearing strata, indicate that the Niobrara Formation and Pierre Shale are thermally mature for oil generation (0.6–1.35 percent R_o) along the shallow margins of the basin and mature for gas generation (greater than 1.35 percent R_o) in the deeper central parts of the basin (Tyler and others, 1995; Nuccio and others, 2002). The Laramide orogeny and post-Laramide burial is considered to have thermally matured these organic-rich shales (Woodward, 1997; Higley, 2004).

The geologic model for the Niobrara Formation and Pierre Shale continuous accumulations is for oil and gas to have been generated from oil-prone source rocks and partially retained following generation and migration into adjacent reservoirs. Four continuous assessment units (AUs) were defined: (1) the Raton Niobrara Shale Oil AU, (2) the Raton Niobrara Shale Gas AU, (3) the Raton Pierre Shale Oil AU, and (4) the Raton Pierre Shale Gas AU (fig. 1). The oil AUs encompass the area within the oil generation window (0.60–1.35 percent R_o), and the gas AUs include the area where oil has been cracked to gas (greater than 1.35 percent R_o).

Assessment input data are summarized in table 1 and in Finn (2024). Input data for estimated ultimate recoveries (EURs) of wells are based on the geologic analog in the Sand Wash Basin part of the Southwestern Wyoming Province.

Table 1. Key input data for four continuous oil and gas assessment units in the Raton Basin-Sierra Grande Uplift Province.

[The average estimated ultimate recovery (EUR) input is the minimum, median, maximum, and calculated mean. Gray shading indicates not applicable. AU, assessment unit; %, percent; MMBO, million barrels of oil; BCFG, billion cubic feet of gas]

Assessment input data— Continuous AUs	Raton Pierre Shale Oil AU				Raton Pierre Shale Gas AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area (acres)	1,000	685,500	1,373,000	686,833	1,000	494,000	988,000	494,333
Average drainage area (acres)	40	80	120	80	80	120	160	120
Success ratio (%)	10	50	90	50	50	70	90	70
Untested area (%)	100	100	100	100	100	100	100	100
Average EUR (MMBO, oil; BCFG, gas)	0.06	0.13	0.20	0.132	0.1	0.5	0.8	0.508
AU probability	1.0				1.0			
Assessment input data— Continuous AUs	Raton Niobrara Shale Oil AU				Raton Niobrara Shale Gas AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area (acres)	1,000	528,500	1,057,000	528,833	1,000	583,000	1,166,000	583,333
Average drainage area (acres)	40	80	120	80	80	120	160	120
Success ratio (%)	10	50	90	50	50	70	90	70
Untested area (%)	100	100	100	100	100	100	100	100
Average EUR (MMBO, oil; BCFG, gas)	0.06	0.13	0.2	0.132	0.1	0.5	0.8	0.508
AU probability	1.0				1.0			

Undiscovered Resources Summary

The USGS quantitatively assessed continuous oil and gas resources in four assessment units (table 2). For total undiscovered, technically recoverable continuous oil and gas resources in four AUs, the estimated means are 1,035 million barrels of oil (MMBO), with an F95–F5 fractile range from 249 to 2,173 MMBO; 3,943 billion cubic feet of gas (BCFG), with an F95–F5 fractile range from 1,135 to 7,391 BCFG; and 11 million barrels of natural gas liquids (MMBNGL), with an F95–F5 fractile range from 2 to 22 MMBNGL.

Table 2. Results for four continuous oil and gas assessment units in the Raton Basin-Sierra Grande Uplift Province.

[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 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
Upper Paleozoic—Cenozoic Total Petroleum System														
Raton Pierre Shale Oil AU	1.0	Oil	141	529	1,225	585	98	370	857	410	0	2	4	2
Raton Pierre Shale Gas AU	1.0	Gas					441	1,416	2,682	1,471	1	4	7	4
Raton Niobrara Shale Oil AU	1.0	Oil	108	406	948	450	75	284	666	315	0	1	3	1
Raton Niobrara Shale Gas AU	1.0	Gas					521	1,684	3,186	1,747	1	4	8	4
Total continuous resources			249	935	2,173	1,035	1,135	3,754	7,391	3,943	2	11	22	11

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For More Information

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

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