National and Global Petroleum Assessment

Assessment of Undiscovered Gas Resources of the Sacramento Basin Province in California, 2019

Using a geology-based assessment methodology, the U.S. Geological Survey estimated undiscovered, technically recoverable mean resources of 512 billion cubic feet of gas in the Upper Jurassic–Neogene Total Petroleum System of the Sacramento Basin Province in California.

Introduction

The U.S. Geological Survey (USGS) quantitatively assessed the potential for undiscovered, technically recoverable gas resources in the Upper Jurassic–Neogene Total Petroleum System (TPS) of the Sacramento Basin Province in California (fig. 1). The Sacramento Basin and the San Joaquin Basin Provinces occupy the Great Valley of California, a remnant forearc basin that was situated between the Sierran-Klamath magmatic arc and the Franciscan accretionary complex (Ingersoll, 1979; Orme and Surpless, 2019). The Sacramento Basin and San Joaquin Basin are separated by the Stockton Arch.

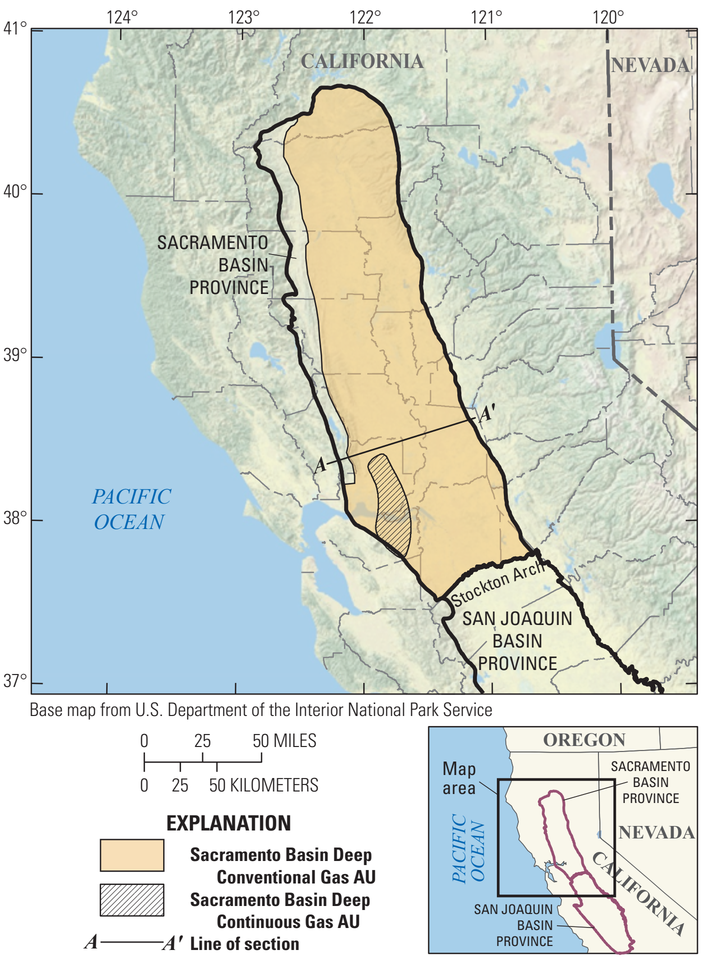

Figure 1. Map showing the location of two assessment units (AUs) of the Sacramento Basin Province in California.

More than 120 gas fields have been discovered in sandstone reservoirs from the Upper Cretaceous through the Tertiary. Reservoirs range from deltaic sandstones to deep-water slope-channel and basin-floor sandstones (Moore and Nilsen, 1990; Nilsen, 1990; Williams and Graham, 2013). Exploration for gas is at an extremely mature stage within the Upper Cretaceous Dobbins Shale (following the nomenclature of Edmonson, 1962) and younger stratigraphic units (Hosford Scheirer and others, 2007).

This assessment explores the possibility that there are potential undiscovered gas resources in Upper Jurassic and Cretaceous (prior to the formation of the Dobbins Shale) reservoirs in the western part of the Sacramento Basin Province, as few wells have been tested in this part of the stratigraphic section (Graham, 1981; Williams and others, 1998). The existence of Upper Jurassic rocks in the Sacramento Basin is uncertain (Surpless and others, 2006; Orme and Surpless, 2019). The concept is not new that older rocks along the western margin of the basin might host potential hydrocarbon accumulations (Graham, 1981; Jenden and Kaplan, 1989) because organic-rich marine shales deposited in anoxic water in the deep basin have been proposed in the past. Oil seeps along the western margin of the basin spurred exploration and geologic field studies as early as the late 1800s (fig. 2) (Watts, 1894; Trask and Hammar, 1934). The discovery of gas in Upper Cretaceous and Tertiary rocks in the 1930s shifted the emphasis of exploration to the shallower stratigraphic section throughout the basin.

In this study, the hypothesis is that marine shales within parts of the Upper Jurassic–Lower Cretaceous Stony Creek Formation (fig. 3) (Graham, 1981; Bertucci, 1983); Lower Cretaceous Lodoga Formation; and Upper Cretaceous Boxer, Venado, Yolo, Sites, Funks, and Guinda Formations may have been source rocks for oil and gas. In this hypothesis, oil that was generated would have mostly cracked to gas during maximum subsidence and burial in the Cretaceous (Moxon and Graham, 1987), and gas might remain reservoired in sandstones within deep structural traps or within low-permeability sandstones. Thermogenic gas that was ultimately derived from marine shales may have migrated into the shallower, thermally immature part of the section before mixing with gases from several other sources (Jenden and Kaplan, 1989).

Total Petroleum System and Assessment Units

The USGS defined the Upper Jurassic–Neogene TPS to encompass gases with mixed compositions from several sources throughout the Sacramento Basin Province (Jenden and Kaplan, 1989). The Sacramento Basin Deep Conventional Gas Assessment Unit (AU) was defined to include thermogenic gas and other gases within conventional reservoirs underlying the Dobbins Shale in deep structural traps (Sterling, 2018). The Sacramento Basin Deep Conventional Gas AU also includes the possibility for small gas accumulations in the Upper Cretaceous–Tertiary stratigraphic section, as these reservoirs were the focus of previous assessments (Beyer, 1988; Hosford Scheirer and others, 2007). The Sacramento Basin Deep Continuous Gas AU was defined to include the potential for thermogenic gas that may have migrated locally into low-permeability (tight) sandstones in the deep central part of the basin. Both AUs were assigned geologic risk associated with adequate hydrocarbon charge, and the Sacramento Basin Deep Conventional Gas AU was also assigned risk on the presence of adequate reservoir porosity and permeability.

The geologic model underlying the assessment of the Sacramento Basin Deep Conventional Gas AU is for oil and gas to have been generated within organic-rich Upper Jurassic–Lower Cretaceous marine shales. At present, the thermal window for oil generation begins at a depth of about 10,000 feet, as the Sacramento Basin throughout its history has had a low thermal gradient (Dumitru, 1988; Jenden and Kaplan, 1989). Oil may have cracked to gas with deep burial, and some gas may have migrated into deep-marine sandstone reservoirs within structural traps (Garcia, 1981; Cherven, 1983). The geologic model relies on some volume of gas being ultimately sourced from Type II marine kerogen rather than relying solely on Type III kerogen (Zieglar and Spotts, 1978). Numerous oil seeps along the western margin of the basin provide some evidence of oil generation (Graham, 1981; Jenden and Kaplan, 1989). The geologic model for the Sacramento Basin Deep Continuous Gas AU is for thermogenic gas to have migrated locally into low-permeability, deep-marine sandstones. Overpressure is present throughout much of the basin and is commonly ascribed to hydrocarbon generation, but overpressure in the Sacramento Basin may have a tectonic cause (McPherson and Garven, 1999).

Key assessment input data are shown in table 1.

Table 1. Key input data for two assessment units of the Sacramento Basin Province in California.

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

Assessment input data—Conventional AU	Sacramento Basin Deep Conventional Gas AU			
	Minimum	Median	Maximum	Calculated mean
Number of gas fields	1	12	48	13.2
Size of gas fields	3	6	1,500	22.5
AU probability	0.63			
Assessment input data—Continuous AU	**Sacramento Basin Deep Continuous Gas AU**			
	Minimum	**Mode**	**Maximum**	**Calculated mean**
Potential production area of AU (acres)	320	156,000	313,000	156,440
Average drainage area of wells (acres)	40	80	120	80
Success ratio (%)	10	50	90	50
Untested area in AU (%)	100	100	100	100
Average EUR (BCFG)	0.1	0.5	1.5	0.550
AU probability	0.6			

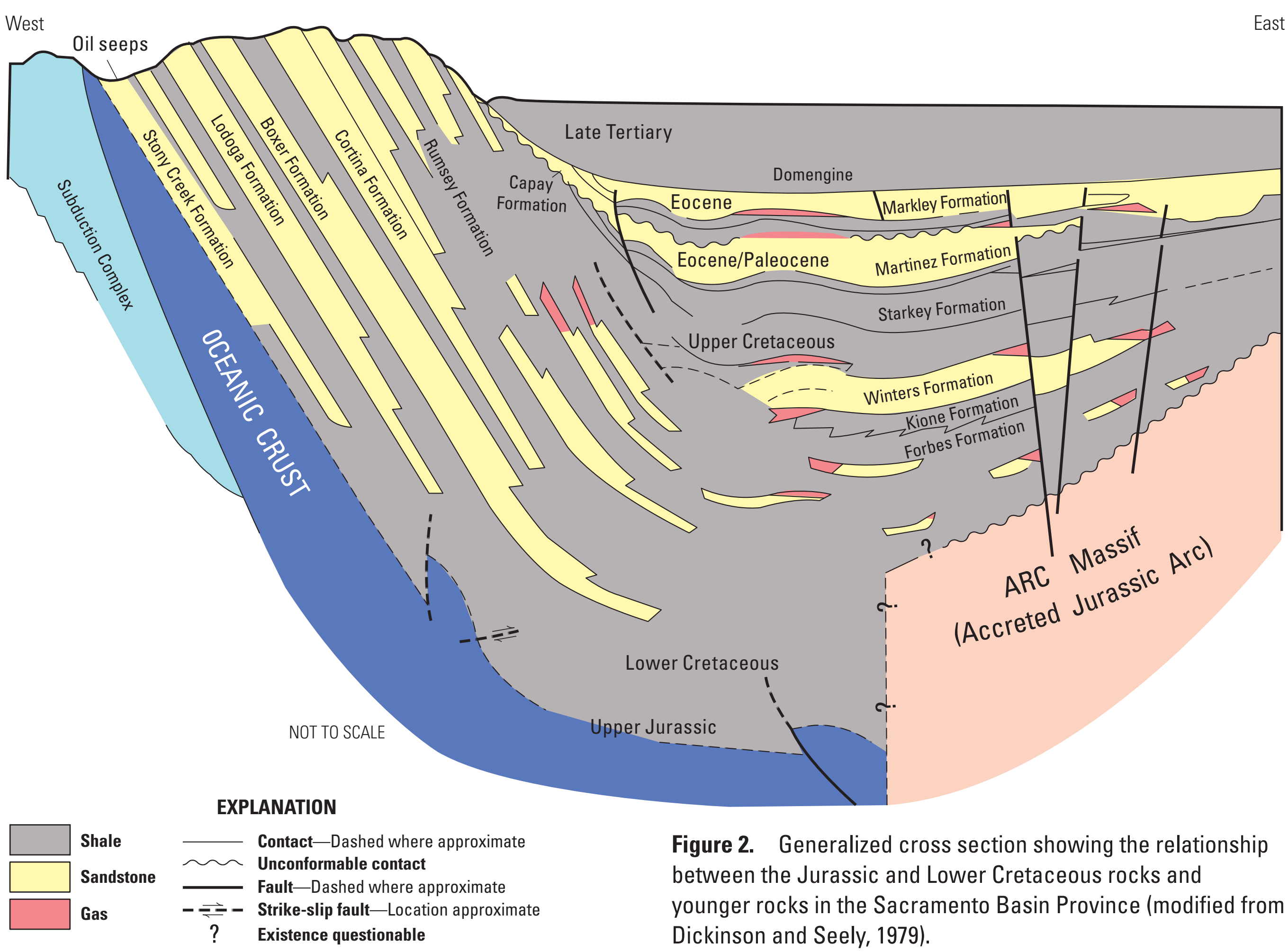

Figure 2. Generalized cross section showing the relationship between the Jurassic and Lower Cretaceous rocks and younger rocks in the Sacramento Basin Province (modified from Dickinson and Seely, 1979).

Undiscovered Resources Summary

The USGS quantitatively assessed undiscovered conventional and continuous gas resources within the Upper Jurassic–Neogene TPS of the Sacramento Basin Province in California (table 2). The fully risked, estimated mean total for the Sacramento Basin Province is 512 billion cubic feet of gas (BCFG) with an F95–F5 range from 0 to 1,794 BCFG. Of the estimated mean total of 512 BCFG, 188 BCFG are conventional gas resources with an F95–F5 range from 0 to 717 BCFG, and 324 BCFG are continuous gas resources with an F95–F5 range from 0 to 1,077 BCFG. The zeros at the F95 fractiles reflect geologic risk on elements of the TPS.

Table 2. Results for two assessment units of the Sacramento Basin Province in California.

[Results shown are fully risked estimates. F95 represents a 95-percent chance of at least the amount tabulated; other fractiles are defined similarly. Shading indicates not applicable. 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							
			Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean
Upper Jurassic–Neogene Total Petroleum System										
Sacramento Basin Deep Conventional Gas AU	0.63	Gas	0	101	717	188	0	0	0	0
Total undiscovered conventional resources			**0**	**101**	**717**	**188**	**0**	**0**	**0**	**0**
Sacramento Basin Deep Continuous Gas AU	0.6	Gas	0	217	1,077	324	0	0	1	0
Total undiscovered continuous resources			**0**	**217**	**1,077**	**324**	**0**	**0**	**1**	**0**
Total undiscovered resources			**0**	**318**	**1,794**	**512**	**0**	**0**	**1**	**0**

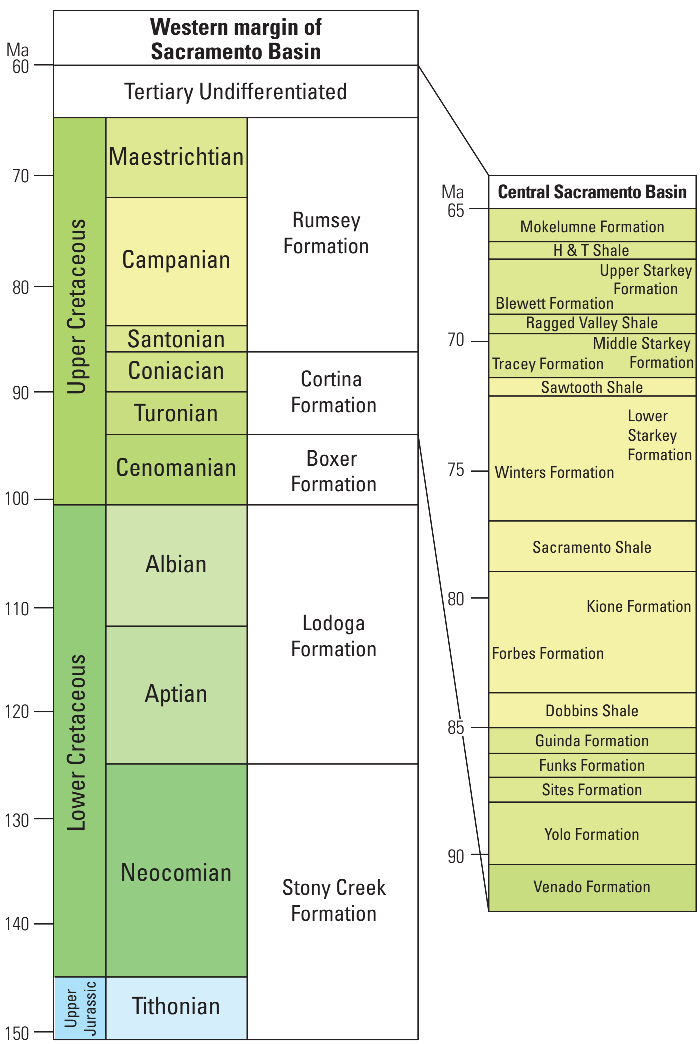

Figure 3. Stratigraphic column for the Sacramento Basin Province, California (modified from Moore and Nilsen, 1990; Nilsen, 1990; Ghosh and Lowe, 1993; Williams and Graham, 2013).

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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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