

# Assessment of Continuous Gas Resources in the Permian Phosphoria Formation of the Southwestern Wyoming Province, Wyoming, 2019

Using a geology-based assessment methodology, the U.S. Geological Survey estimated undiscovered, technically recoverable mean resources of 1.4 trillion cubic feet of continuous gas in the Phosphoria Formation of the Southwestern Wyoming Province, Wyoming.

## Introduction

The U.S. Geological Survey (USGS) quantitatively assessed the potential for undiscovered, technically recoverable continuous resources in organic-rich shales of the Permian Phosphoria Formation within the Southwestern Wyoming Province (fig. 1). The Phosphoria Formation represents a complex stratigraphic unit that was deposited in an oceanic embayment along the west-facing Permian continental margin (Sheldon, 1963). During Guadalupian time, cold, nutrient-rich currents from the north swept the embayment, resulting in deposition of phosphatic mudstone, organic-rich shale, and chert in what was otherwise a sediment-starved basin (Piper and Medrano, 1994; Carroll and others, 1998). The deep-water lithologies of the basin transition eastward to shallow-water shelf carbonates of the Permian Park City Formation and finally to continental red mudstone and evaporites of the Permian Goose Egg Formation. Much of the area with the deepwater facies of the Phosphoria Formation is within the Wyoming Thrust Belt Province, but there are deepwater deposits in which the Phosphoria Formation is as much as 10,000 meters (m) deep in the western part of the Southwest Wyoming Province. The purpose of this assessment is to estimate technically recoverable shale-gas resources within Phosphoria Formation shales.

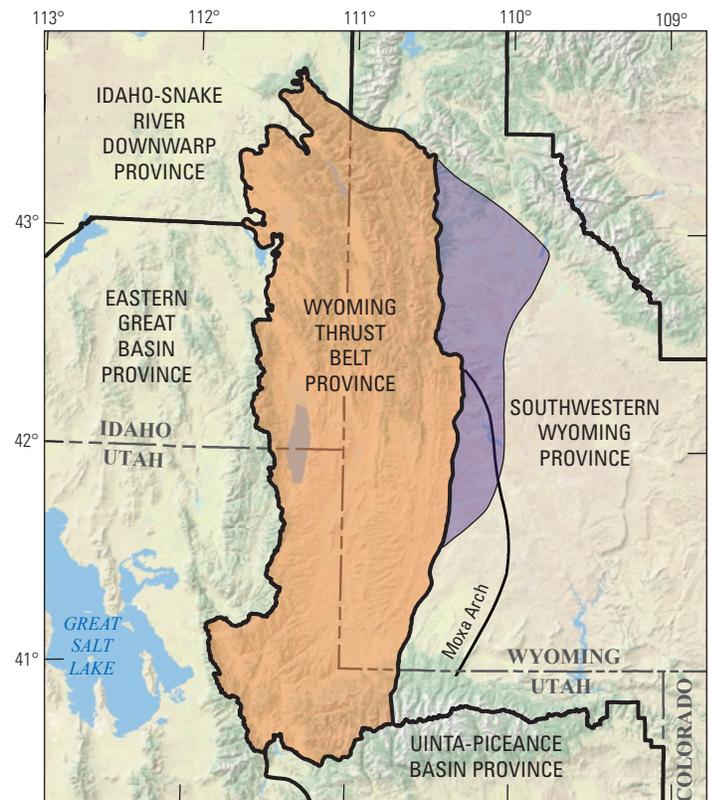
## Total Petroleum System and Assessment Unit

The USGS defined the Phosphoria Total Petroleum System (TPS) and the Phosphoria Shale Gas Assessment Unit (AU) within this TPS. The Phosphoria TPS includes petroleum generated from the organic-rich shales of the Meade Peak and Retort Shale Members of the Permian Phosphoria Formation (Maughan, 1984). Organic-rich shales of the Phosphoria Formation contain marine Type IIS organic matter (Lillis and Selby, 2013) and have total organic carbon content averaging from 4 weight percent to as much as 13 weight percent (Claypool and others, 1978). Organic-rich shales are as much as 60 m thick for the Meade Peak Member and as much as 30 m thick for the Retort Member (Maughan, 1984). Phosphoria Formation shales are largely in the dry gas to postmature zone of thermal maturity (Edman and Surdam, 1984; Burtner and Nigrini, 1994). Production tests in several wells along the northern part of the Moxa Arch have shown that the Phosphoria Formation contains gas (Stilwell, 1989), possibly in shales. The assessment input data are summarized in table 1.

## Geologic Model for Assessment

Mesozoic burial is interpreted to have thermally matured organic-rich shales of the Phosphoria Formation prior to the formation of most Mesozoic Sevier thrust structures in the Wyoming Thrust Belt (Warner, 1982; Burtner and Nigrini, 1994). Much of the Phosphoria oil generated prior to thrust development migrated eastward into structural traps in what are now the Laramide basins in Wyoming, Montana, and Utah (Sheldon, 1967; Lillis and Selby, 2013). Thrust

loading to the west placed Phosphoria Formation shales within the thermal window for dry gas or postmature for gas generation (Edman and Surdam, 1984). Following migration, any oil retained within the Phosphoria Formation shales in the Southwestern Wyoming Province would have cracked to gas with progressive burial in the foredeep. Gas within Phosphoria Formation shales may contain high percentages of hydrogen sulfide. In this assessment, the retention of oil in Phosphoria Formation shales following migration and the retention of gas within the shales during burial are the main factors in consideration of geologic uncertainty.

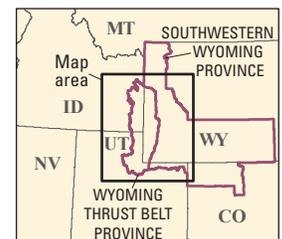


Base map from U.S. Department of the Interior National Park Service

0 30 60 MILES  
0 30 60 KILOMETERS

**EXPLANATION**

- Phosphoria Shale Gas AU (Wyoming Thrust Belt Province)
- Phosphoria Shale Gas AU (Southwestern Wyoming Province)



**Figure 1.** Map showing location of the Phosphoria Shale Gas Assessment Unit (AU) in the Southwestern Wyoming Province, Wyoming.

**Table 1.** Input data for one continuous assessment unit in the Phosphoria Formation of the Southwestern Wyoming Province in Wyoming.

[AU, assessment unit; %, percent; EUR, estimated ultimate recovery per well; BCFG, billion cubic feet of gas. Well drainage area, success ratio, and EUR 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]

| Assessment input data—<br>Continuous AUs | Phosphoria Shale Gas AU |         |           |                 |
|--|-------------------------|---------|-----------|-----------------|
|  | Minimum                 | Mode    | Maximum   | Calculated mean |
| Potential production area of AU (acres)  | 1,000                   | 700,000 | 1,433,000 | 711,333         |
| Average drainage area of wells (acres)   | 80                      | 120     | 160       | 120             |
| Success ratio (%)                        | 10                      | 50      | 90        | 50              |
| Average EUR (BCFG)                       | 0.2                     | 0.5     | 1.1       | 0.528           |
| AU probability                           | 0.9                     |         |           |                 |

## Undiscovered Resources Summary

The USGS quantitatively assessed the potential for shale-gas resources within organic-rich shales of the Phosphoria Formation in the Southwestern Wyoming Province (table 2). The estimated mean totals for undiscovered, technically recoverable resources are 1,406

billion cubic feet of gas (BCFG), or 1.4 trillion cubic feet of gas, with an F95–F5 range from 0 to 3,286 BCFG and 6 million barrels of natural gas liquids (MMBNGL) with an F95–F5 range from 0 to 14 MMBNGL. Zeros at the F95 fractiles reflect geologic risk on the retention of gas within shales of the Phosphoria Formation.

**Table 2.** Results for one continuous assessment unit in the Phosphoria Formation of the Southwestern Wyoming Province in Wyoming.

[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 unit (AU) | AU probability | Accumulation type | Total undiscovered resources |              |              |              |              |          |           |          |
|---|----------------|-------------------|------------------------------|--------------|--------------|--------------|--------------|----------|-----------|----------|
|   |                |                   | Gas (BCFG)                   |              |              |              | NGL (MMBNGL) |          |           |          |
|   |                |                   | F95                          | F50          | F5           | Mean         | F95          | F50      | F5        | Mean     |
| Phosphoria Total Petroleum System               |                |                   |                              |              |              |              |              |          |           |          |
| Phosphoria Shale Gas AU                         | 0.9            | Gas               | 0                            | 1,265        | 3,286        | 1,406        | 0            | 5        | 14        | 6        |
| <b>Total undiscovered continuous resources</b>  |                |                   | <b>0</b>                     | <b>1,265</b> | <b>3,286</b> | <b>1,406</b> | <b>0</b>     | <b>5</b> | <b>14</b> | <b>6</b> |

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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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