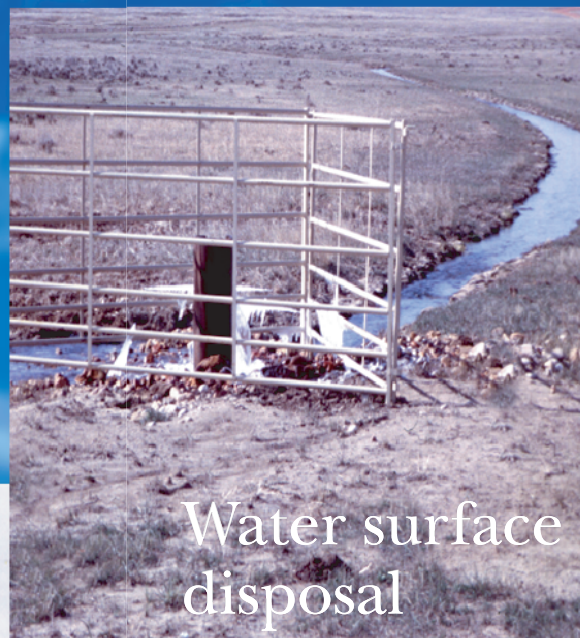


A FIELD CONFERENCE ON IMPACTS OF COALBED METHANE DEVELOPMENT IN THE POWDER RIVER BASIN, WYOMING

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Livingston⁵, and M. Craig Jennings⁶

Digital products by Scott A. Kinney¹,
Heather Mitchell¹, and Steve Dunn¹

Open-File Report 01-126



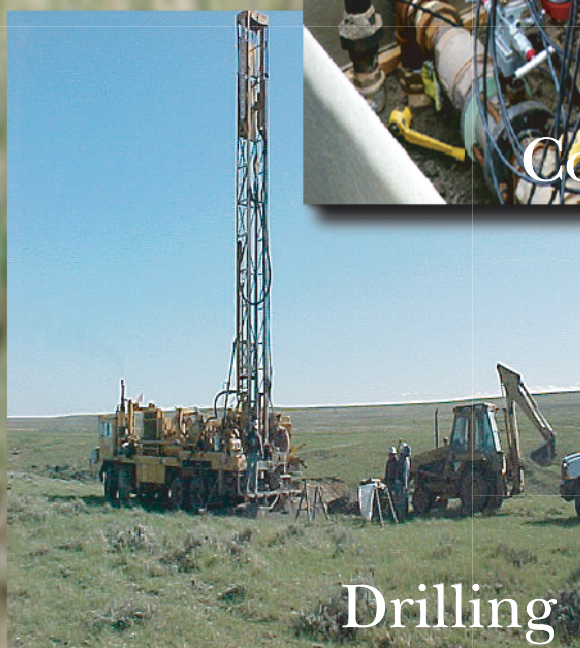
Water surface
disposal



Production



Completion



Drilling

Prospect

¹U.S. Geological Survey, Denver, Colorado 80025

²U.S. Bureau of Land Management, Casper, Wyoming 82601

³Barrett Resources Corporation, Gillette, Wyoming 82717

⁴Bear Paw Energy Inc., Denver Colorado 80202

⁵Jacobs Ranch Coal Company, Gillette, Wyoming 82717

⁶Peabody Natural Gas LLC, Gillette, Wyoming 82717

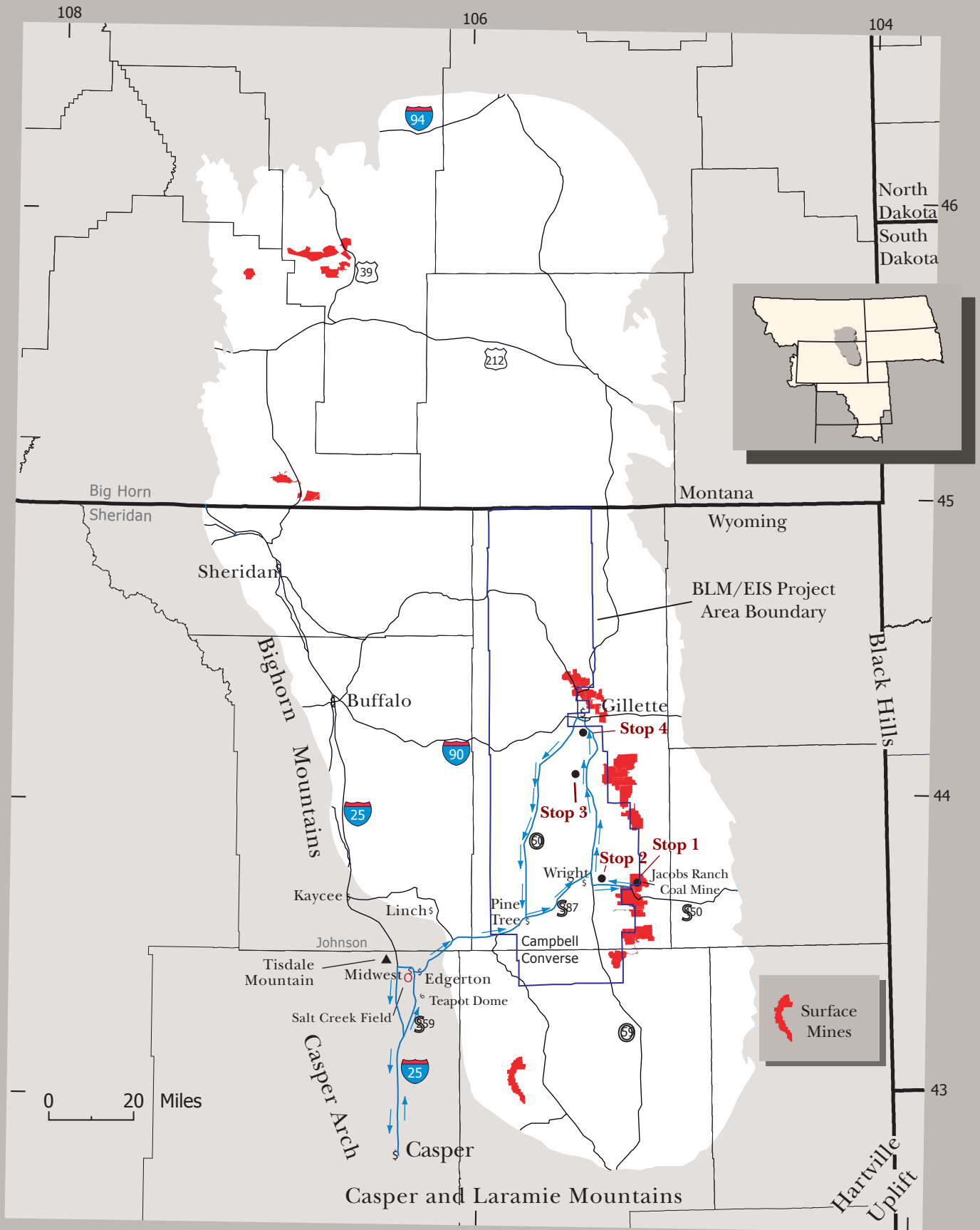


Figure 1

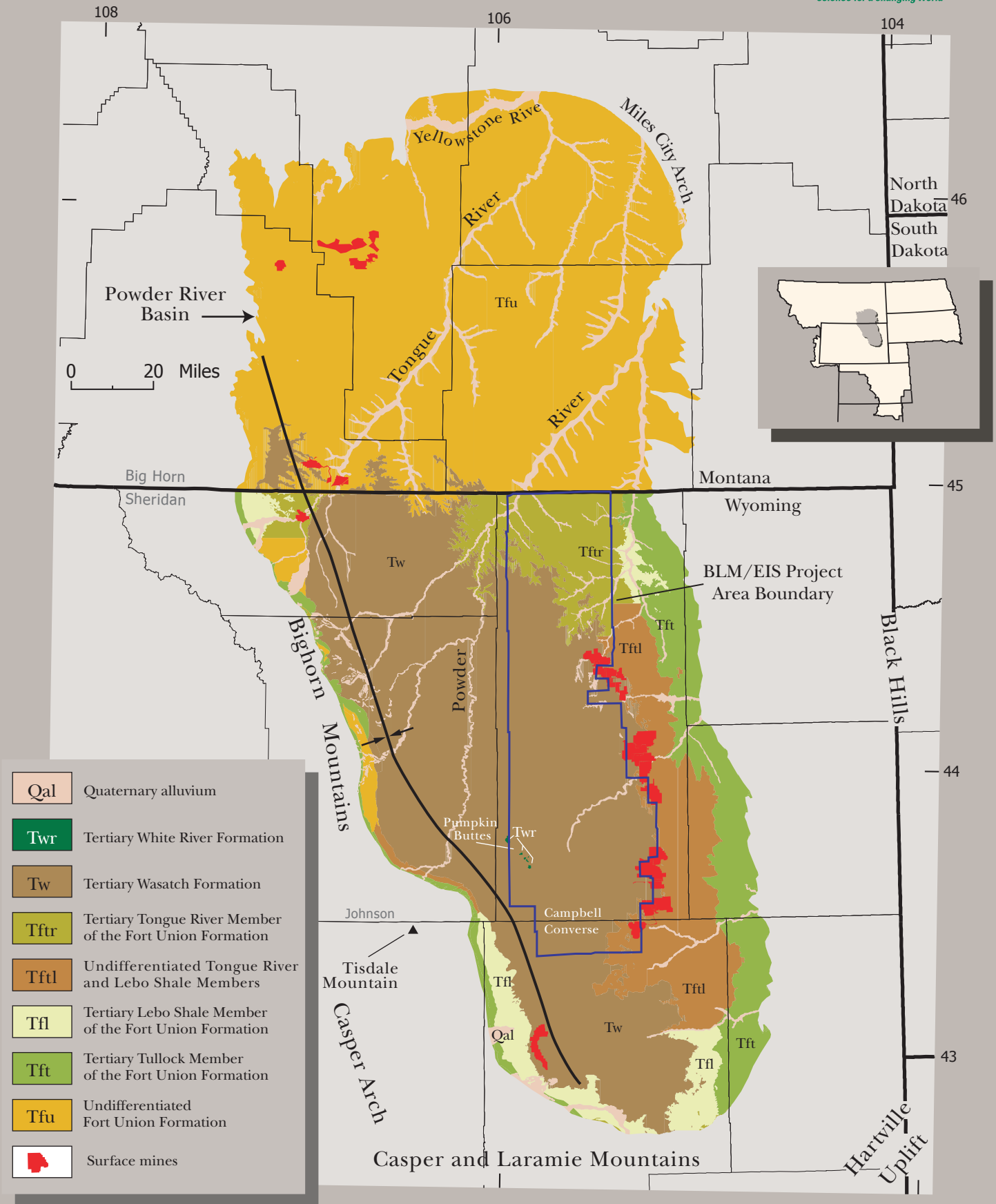
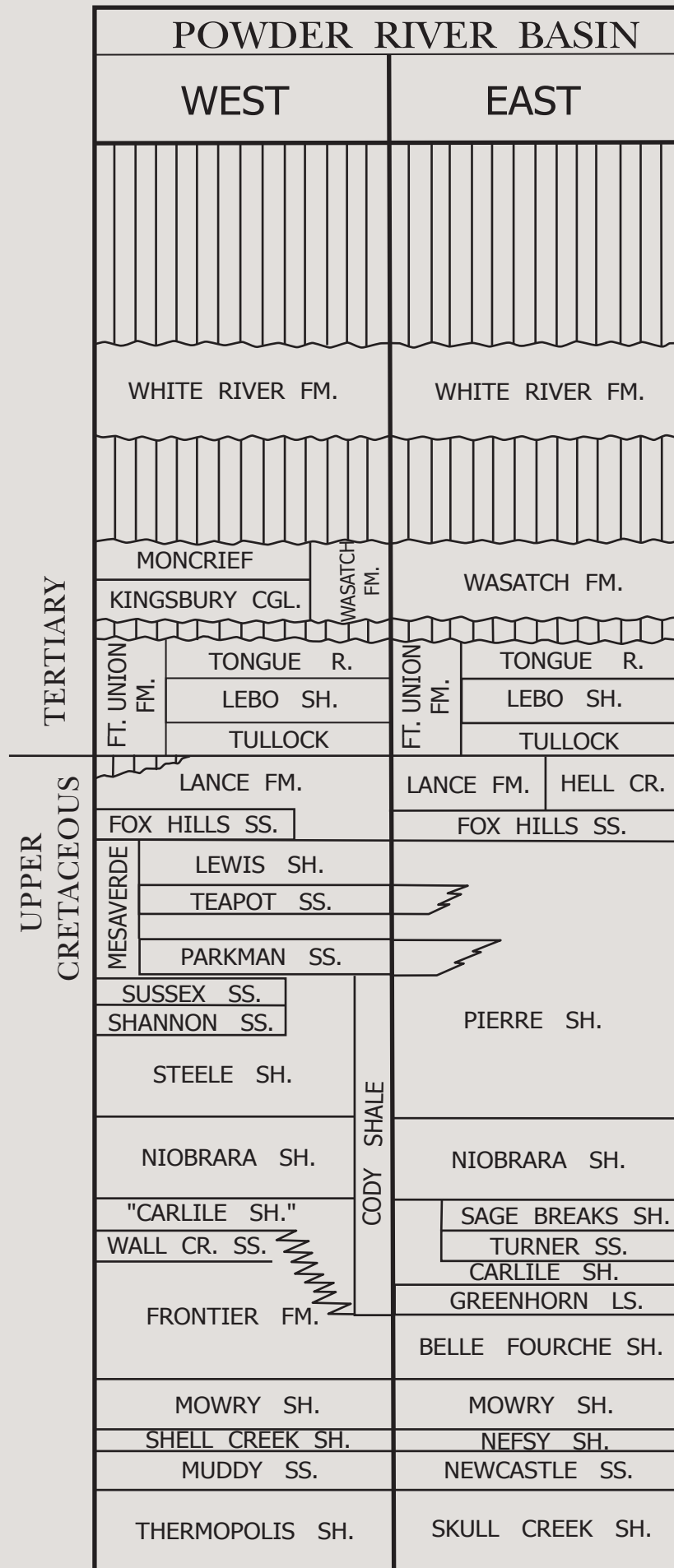


Figure 2



TERTIARY

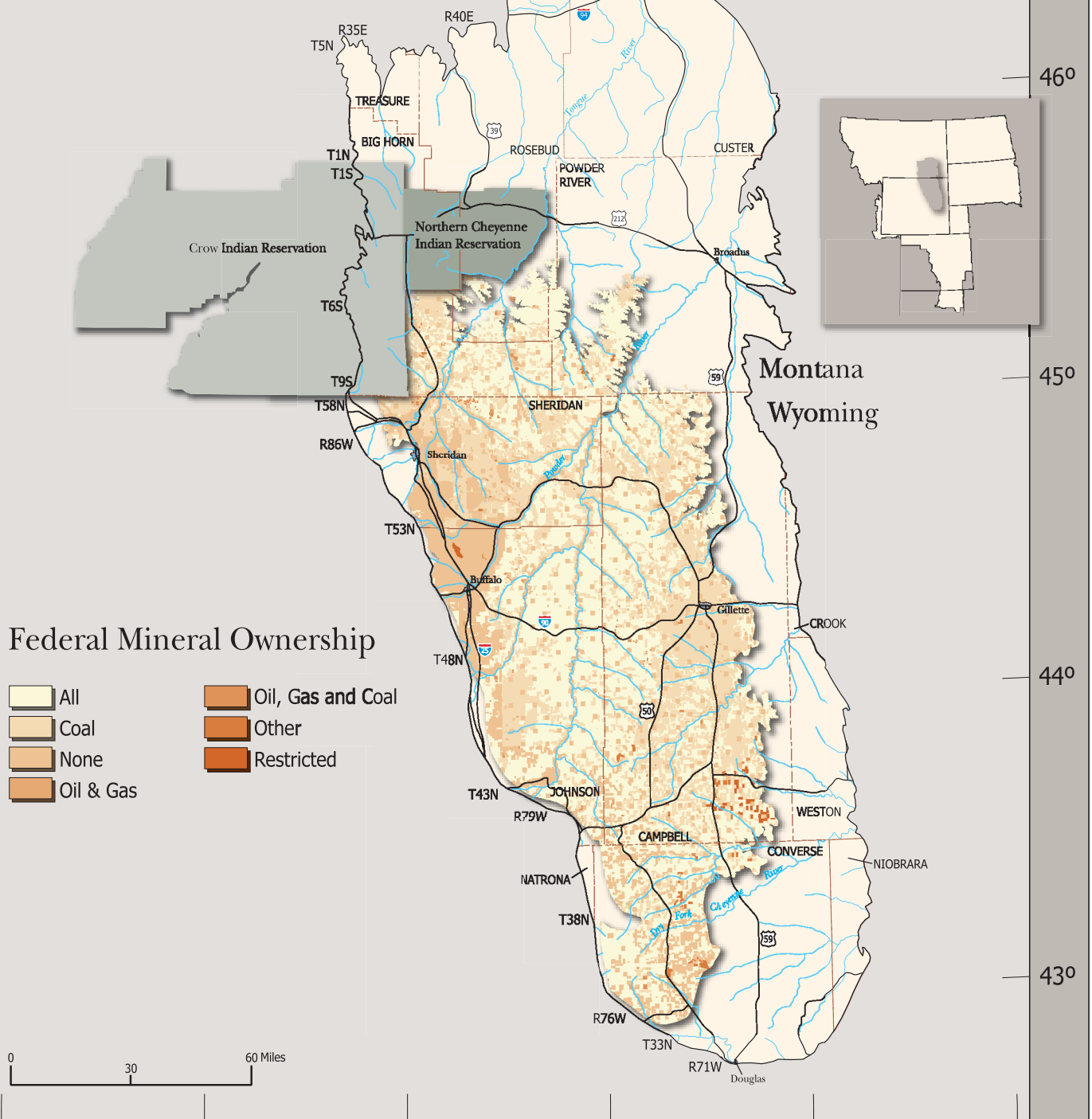
UPPER CRETACEOUS

CODY SHALE

Figure 3

109° 108° 107° 106° 105° 104°

Powder River Basin



Federal Mineral Ownership

- | | | | |
|--|-----------|--|-------------------|
| | All | | Oil, Gas and Coal |
| | Coal | | Other |
| | None | | Restricted |
| | Oil & Gas | | |

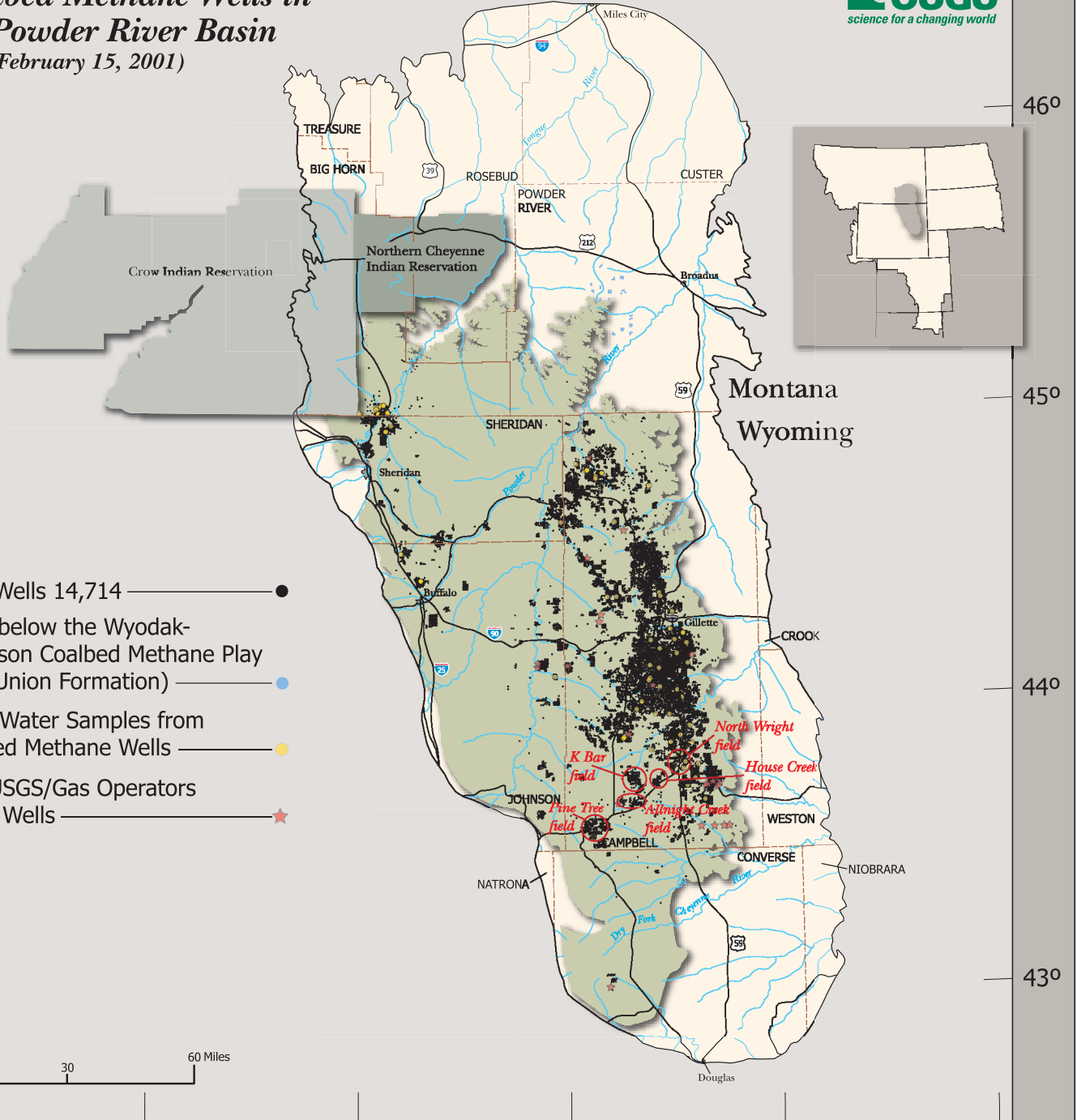
0 30 60 Miles

Figure 4

109° 108° 107° 106° 105° 104°

Coalbed Methane Wells in the Powder River Basin

(as of February 15, 2001)



- Total Wells 14,714 ●
- Wells below the Wyodak-Anderson Coalbed Methane Play (Fort Union Formation) ●
- USGS Water Samples from Coalbed Methane Wells ●
- BLM/USGS/Gas Operators Cored Wells ★

Figure 5

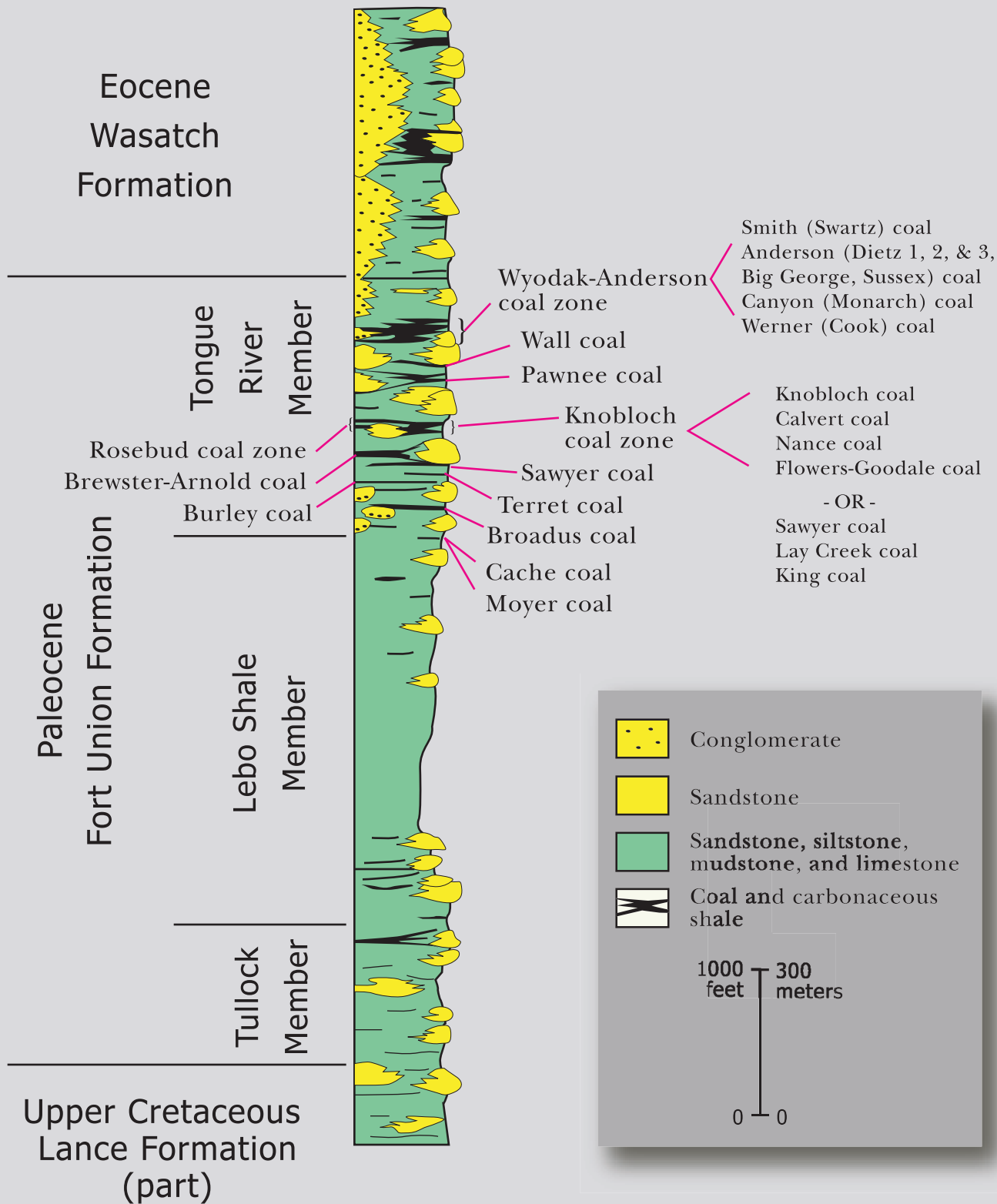


Figure 6

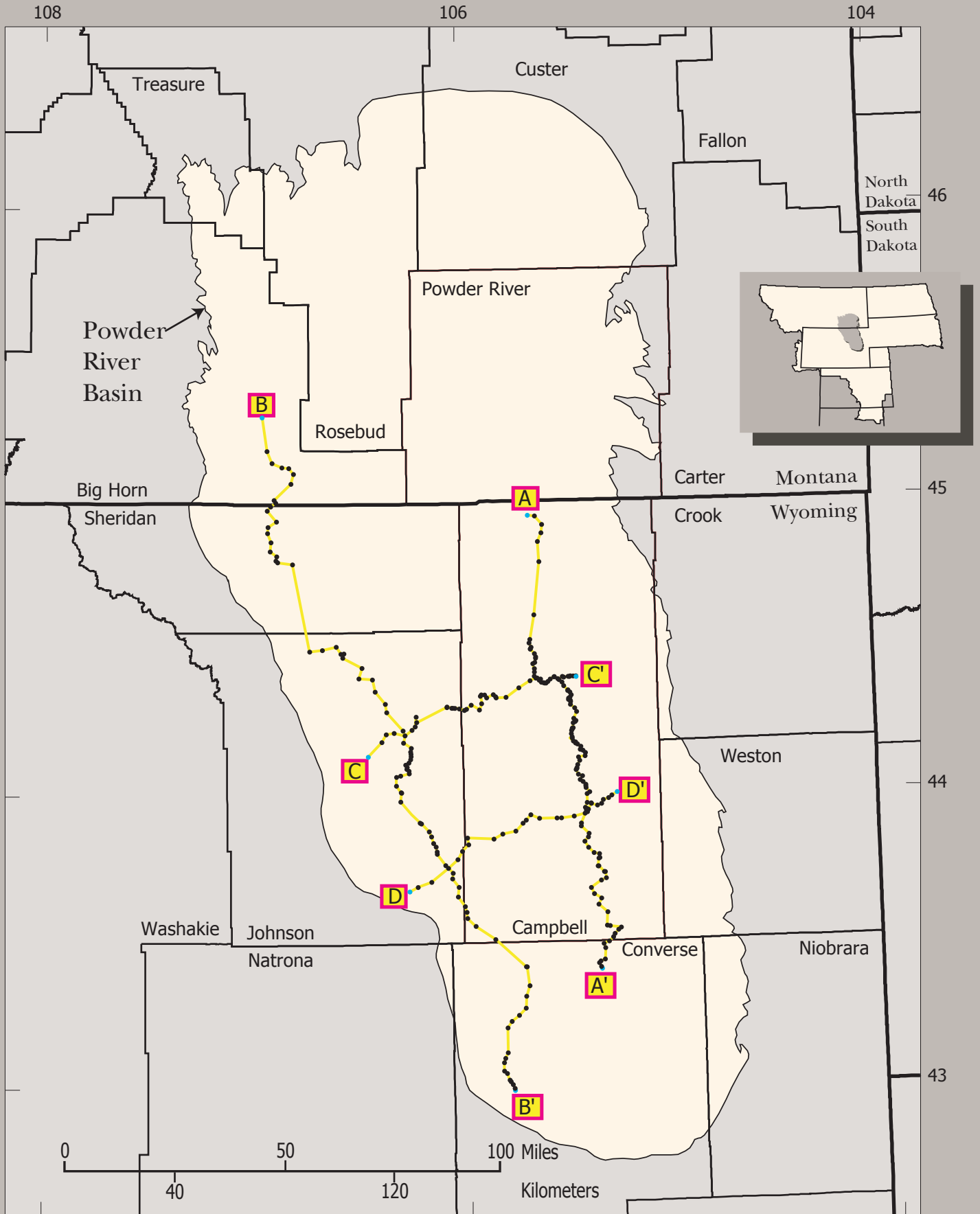


Figure 7

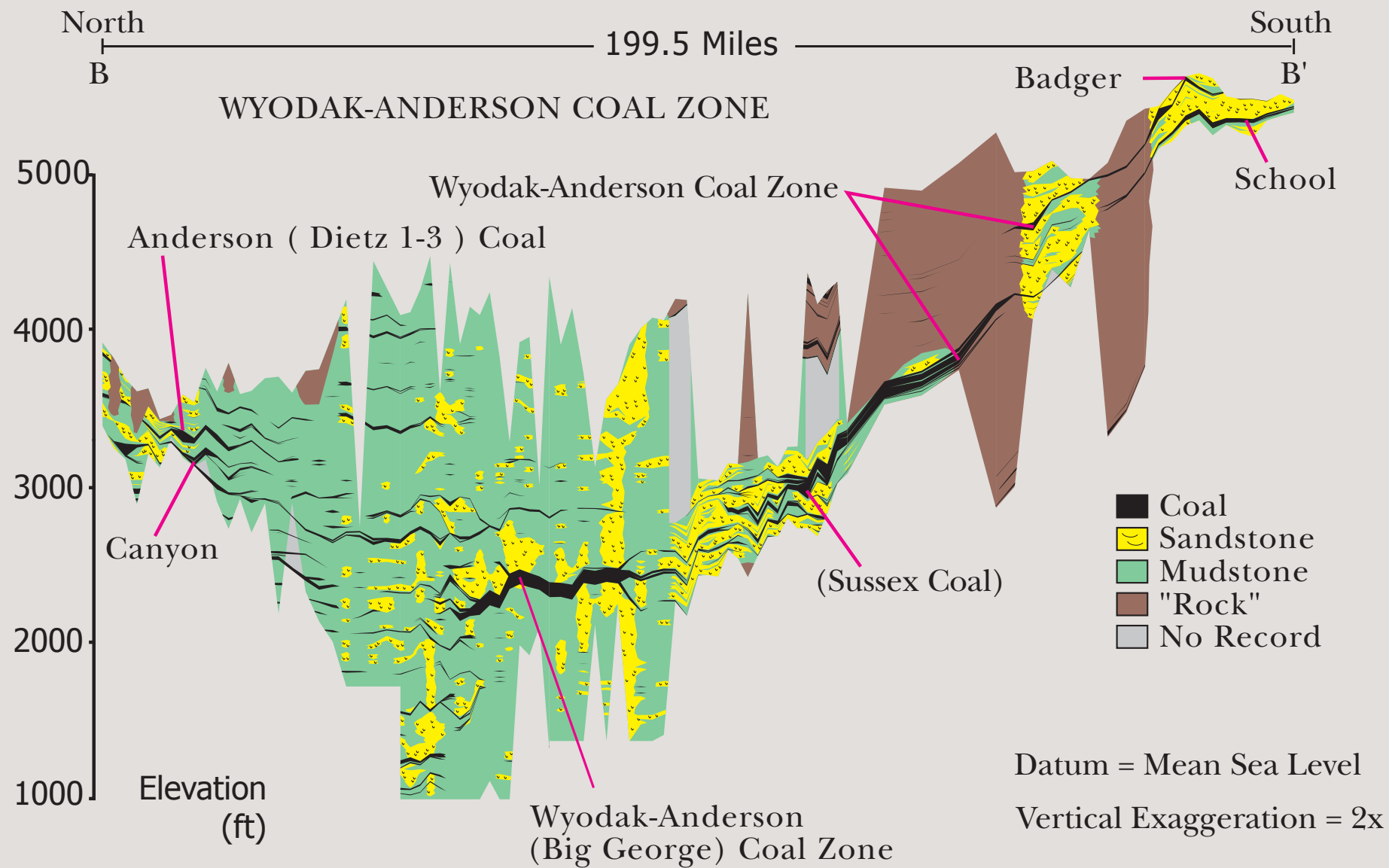


Figure 9

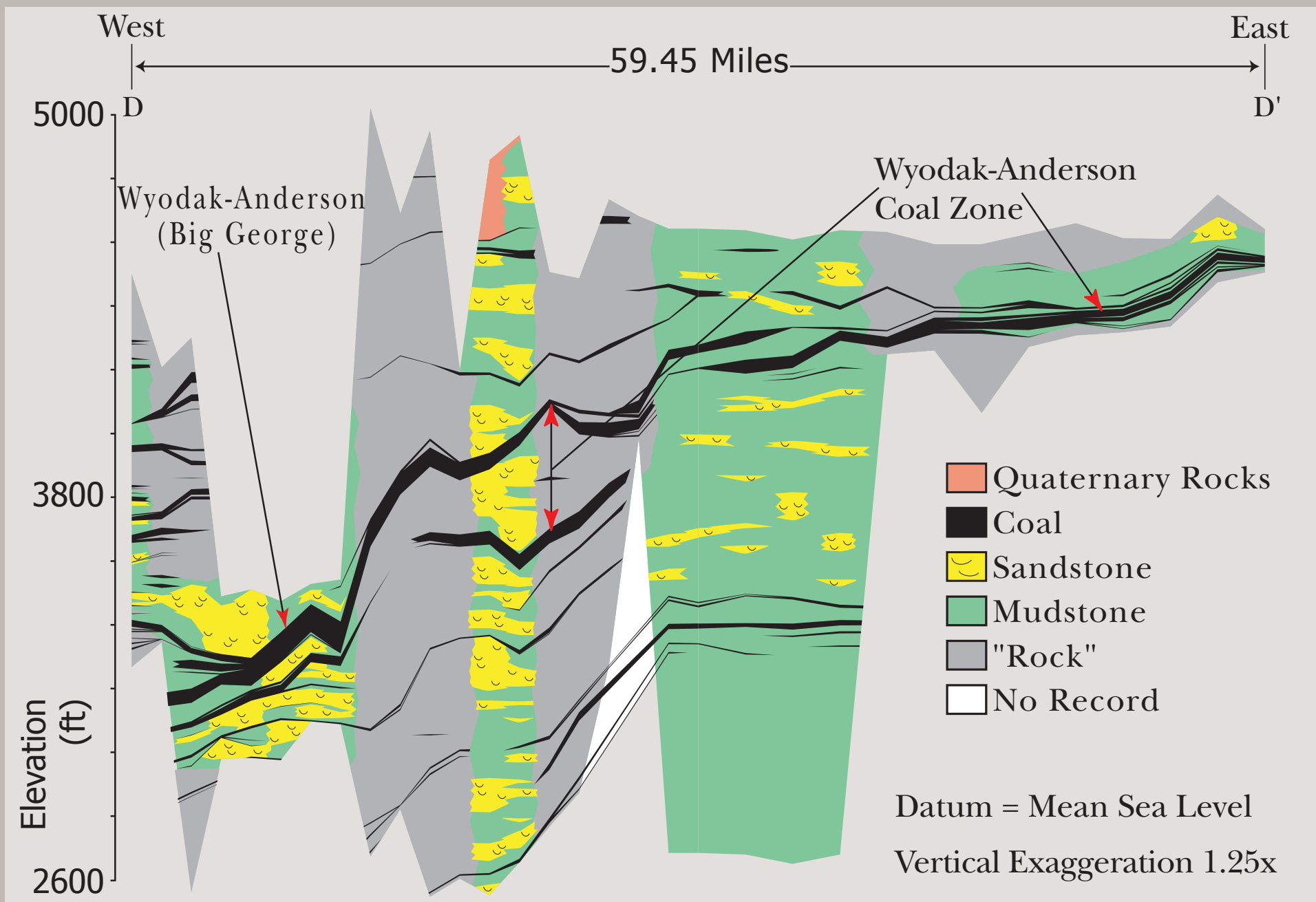


Figure 10

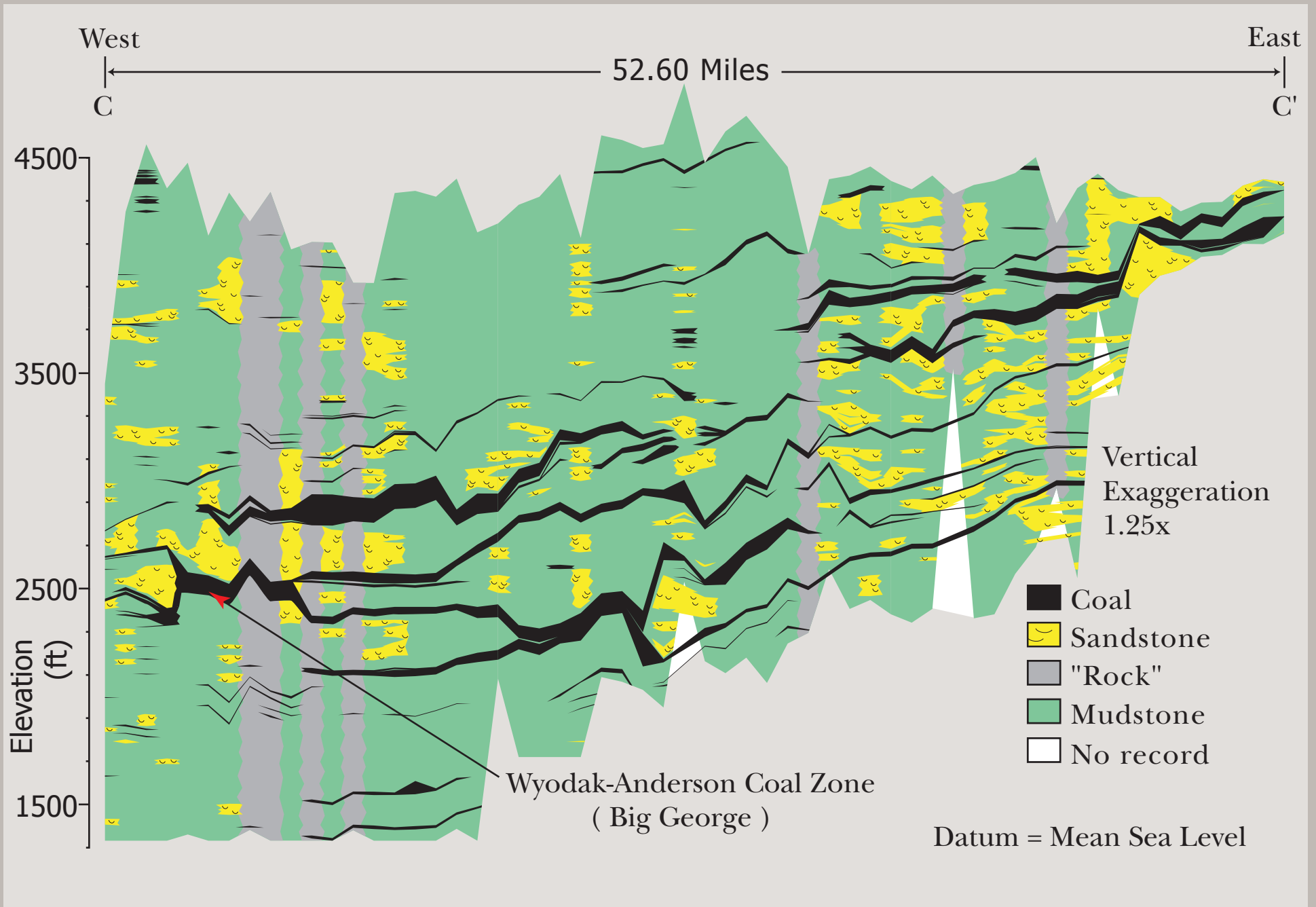


Figure 11

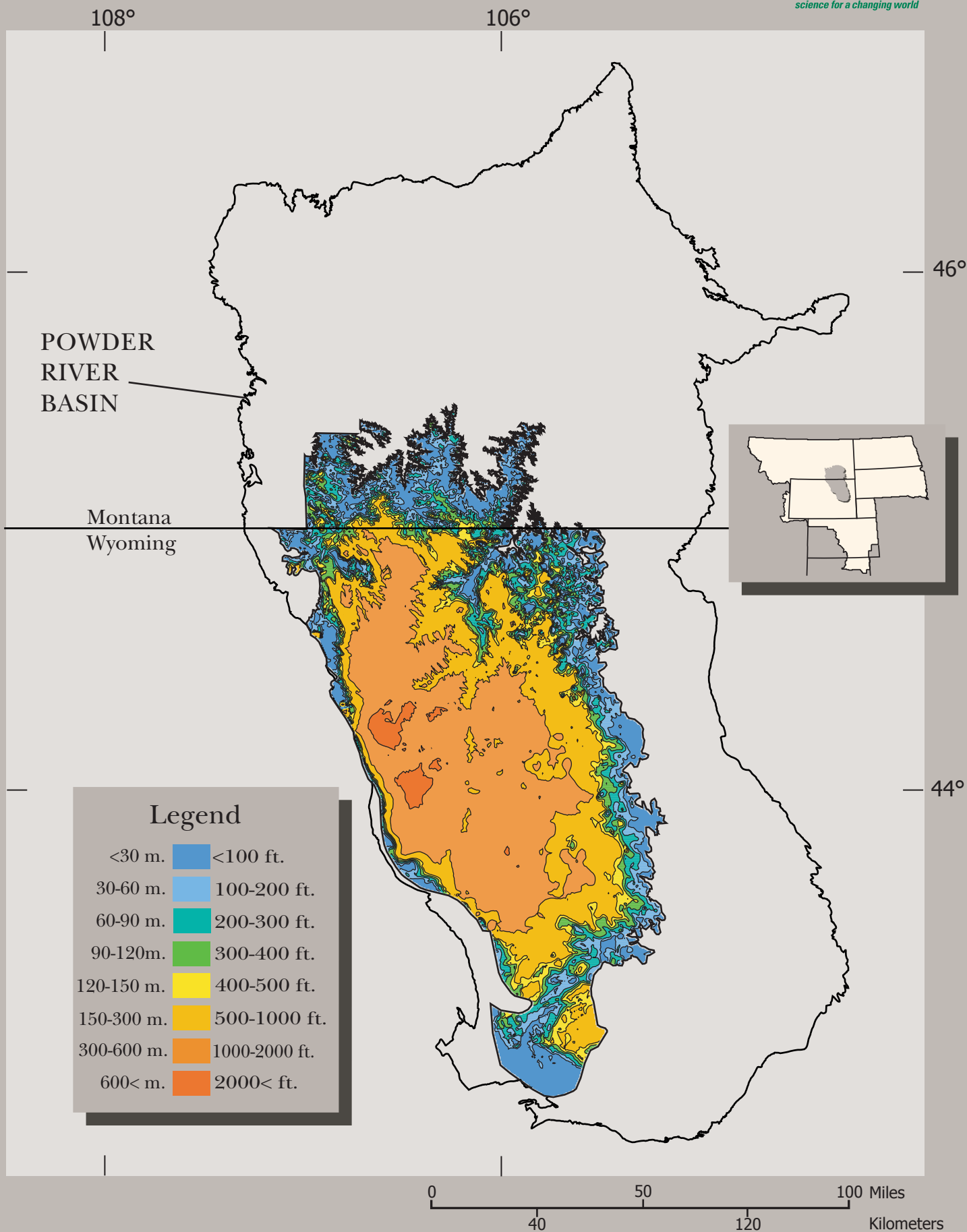
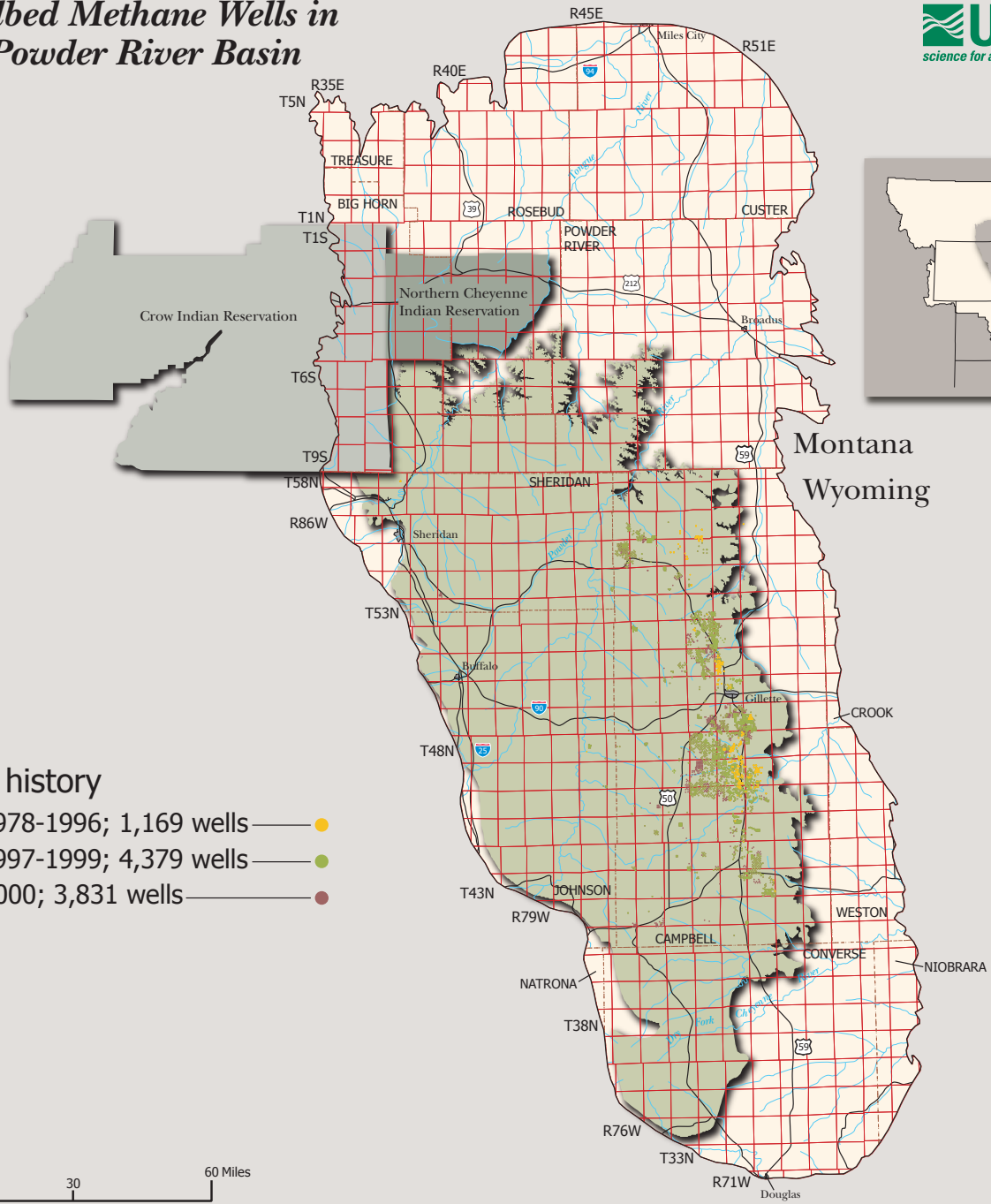


Figure 12

109° 108° 107° 106° 105° 104°

Coalbed Methane Wells in the Powder River Basin



Well history

- 1978-1996; 1,169 wells — ●
- 1997-1999; 4,379 wells — ●
- 2000; 3,831 wells — ●

Figure 13

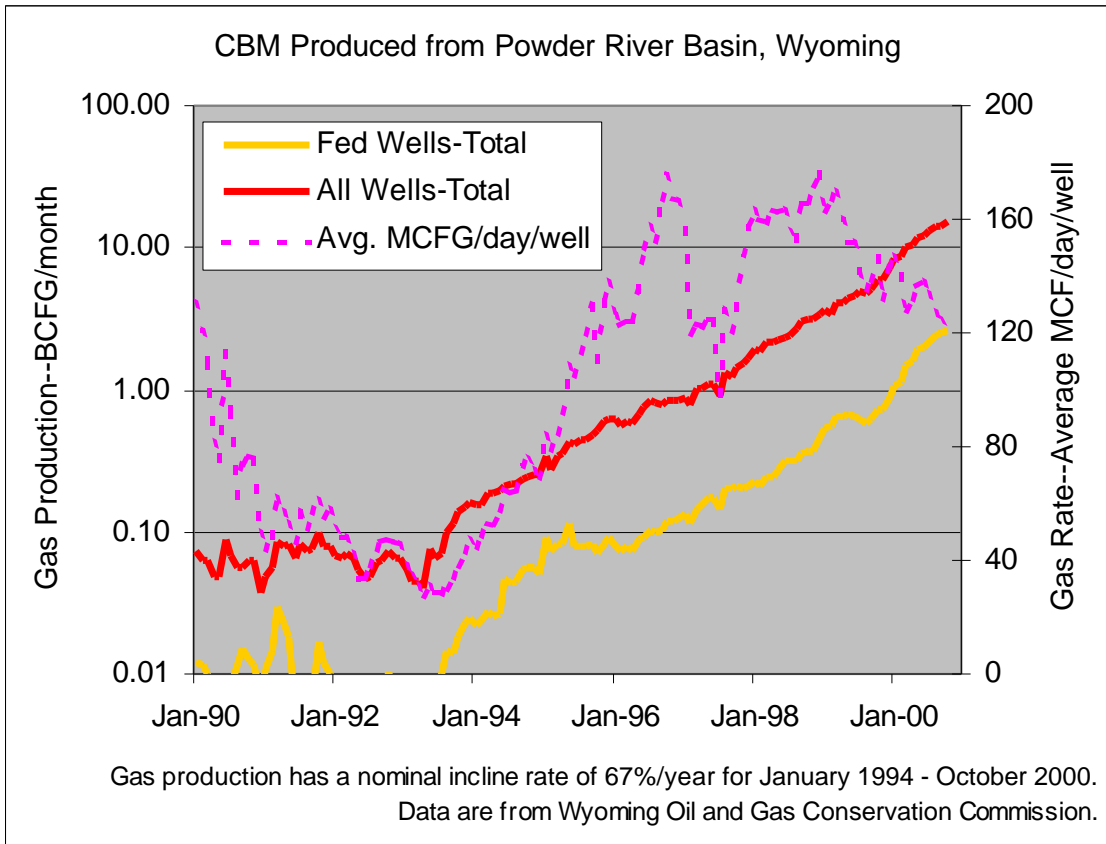


Figure 14

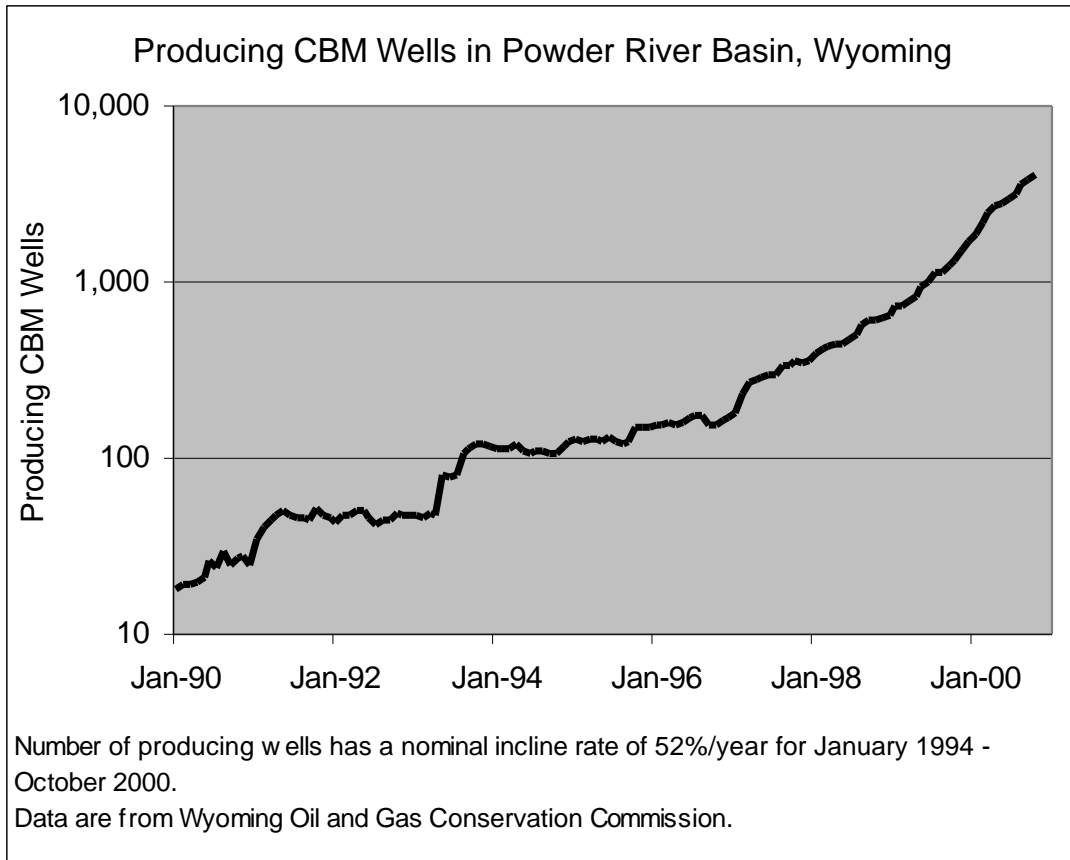


Figure 15

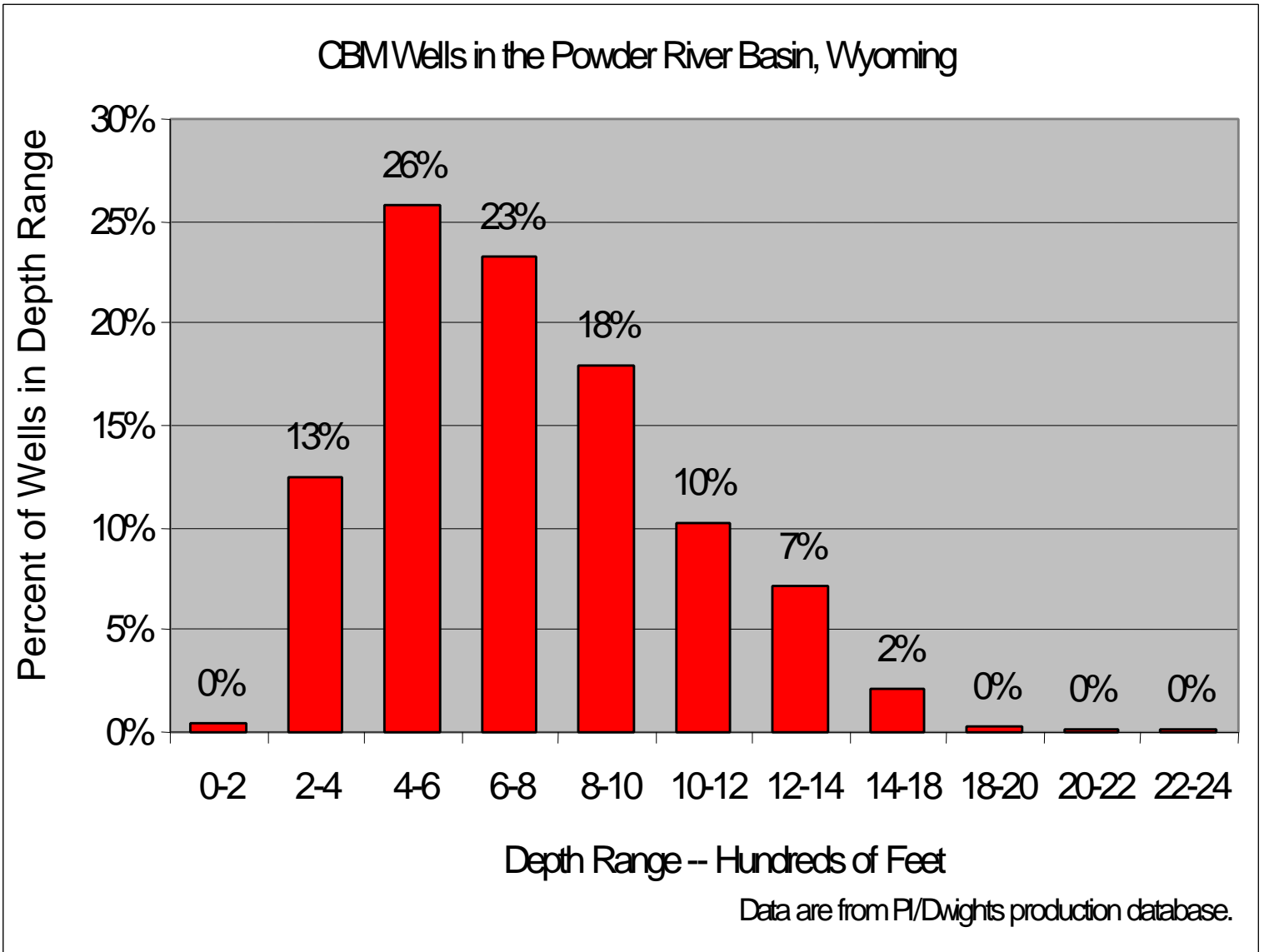
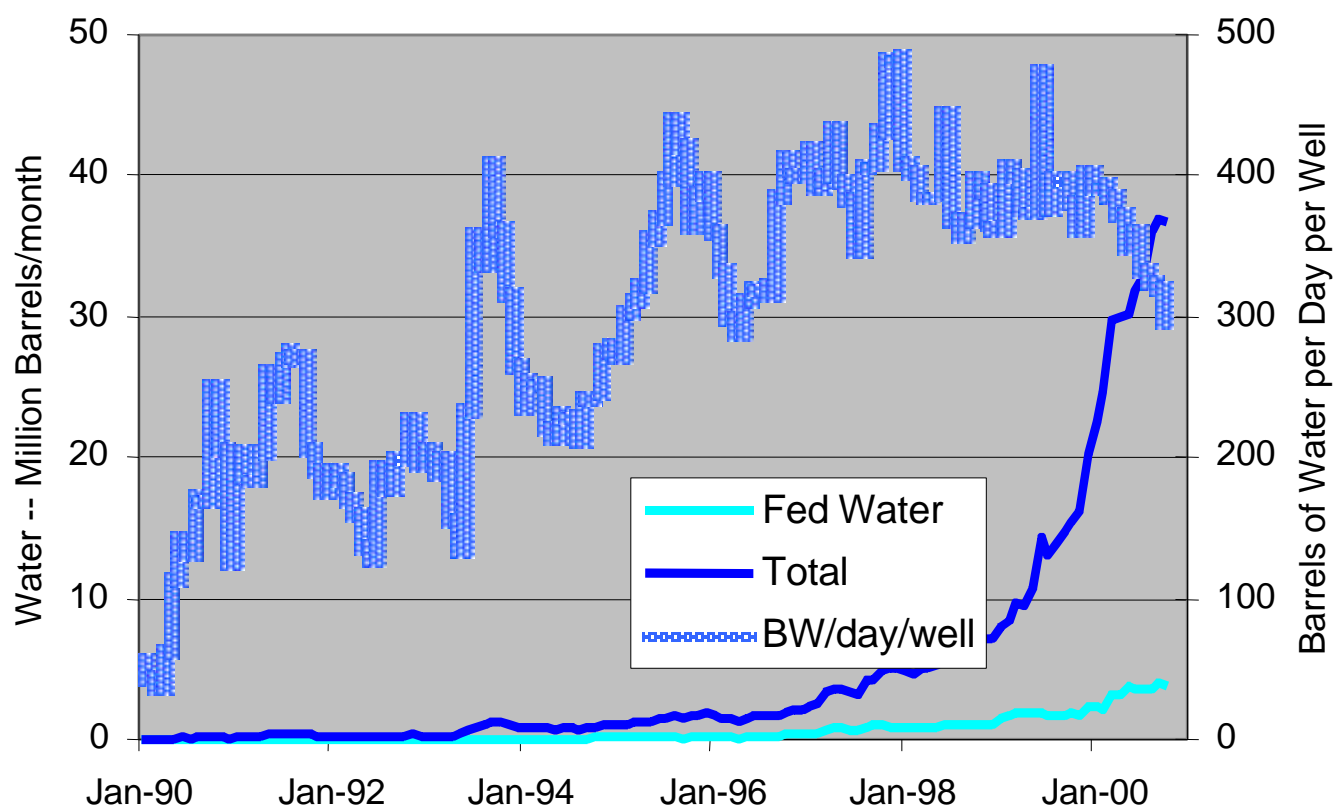


Figure 16



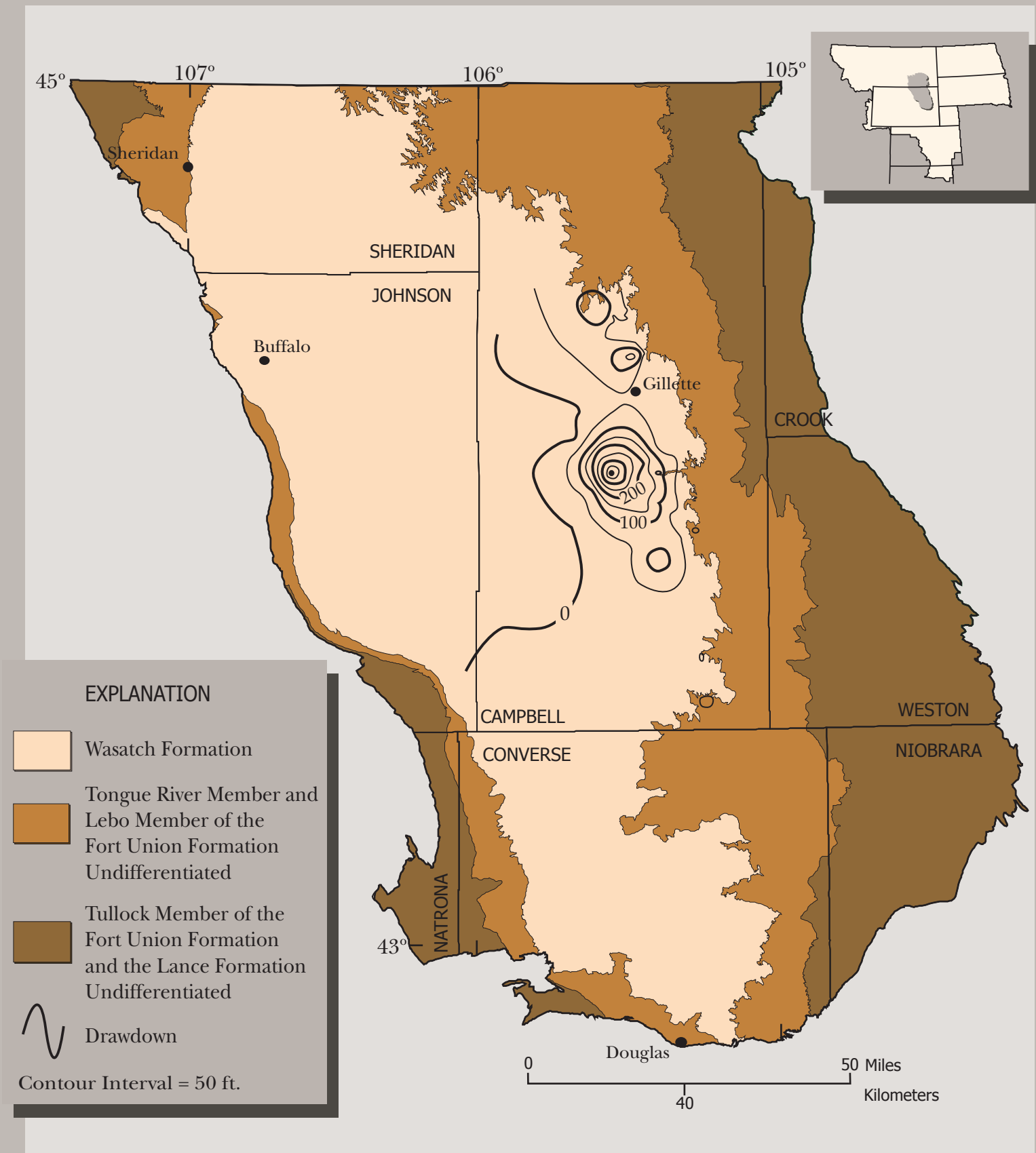
Water Produced from Powder River Basin, Wyoming



Water production has a nominal incline rate of 56%/year for January 1994 - October 2000.

Data are from WOGCC.

Figure 17



EXPLANATION

- Wasatch Formation
- Tongue River Member and Lebo Member of the Fort Union Formation
- Undifferentiated
- Tullock Member of the Fort Union Formation and the Lance Formation
- Undifferentiated

Drawdown

Contour Interval = 50 ft.

Figure 18

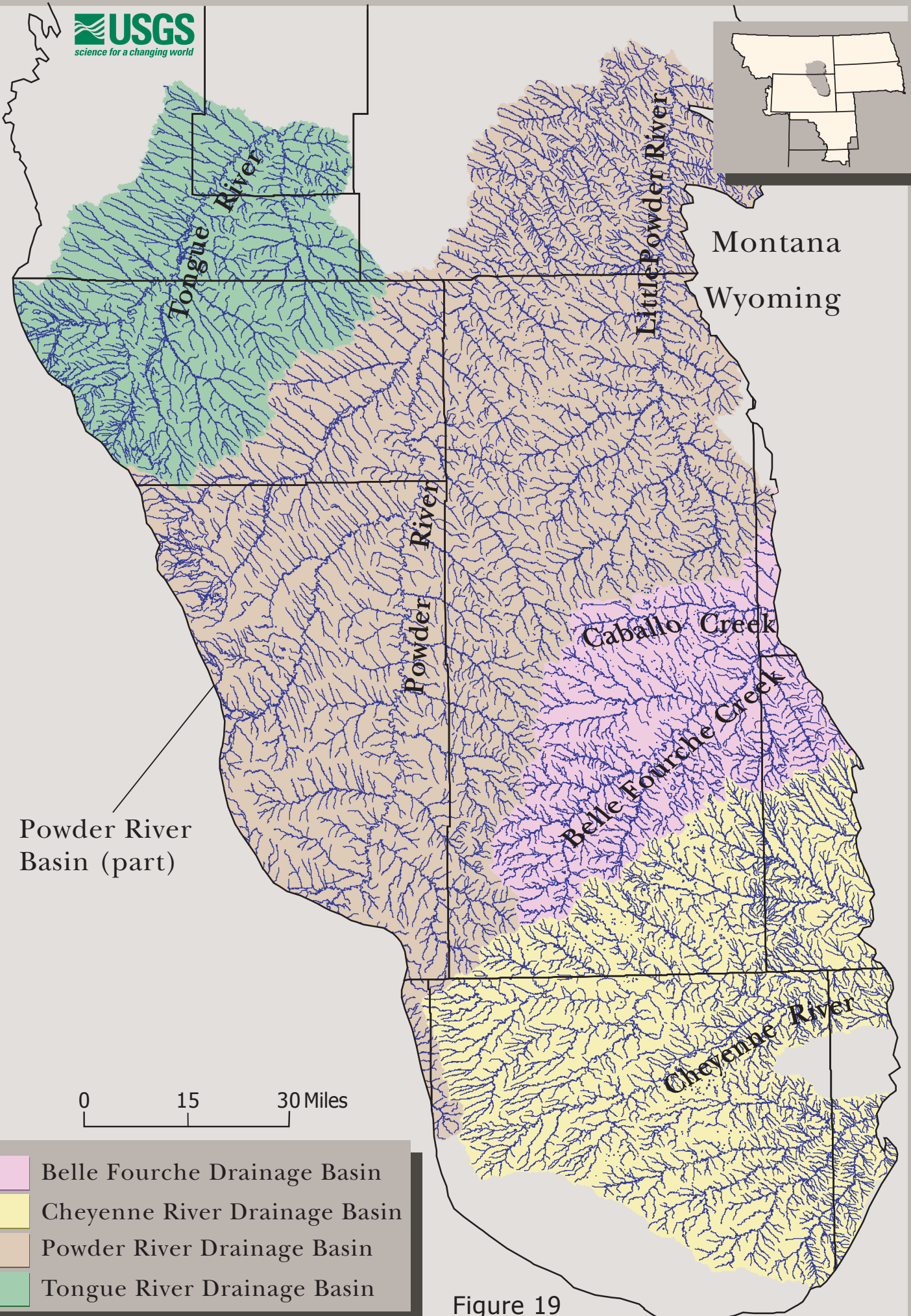
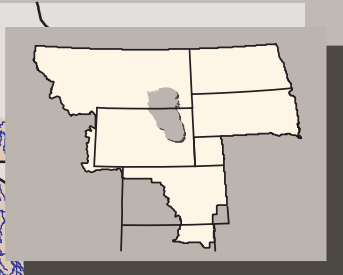
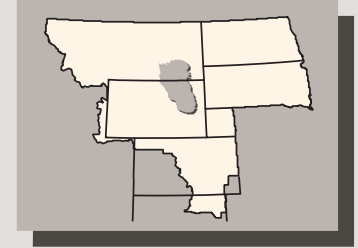
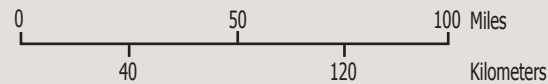
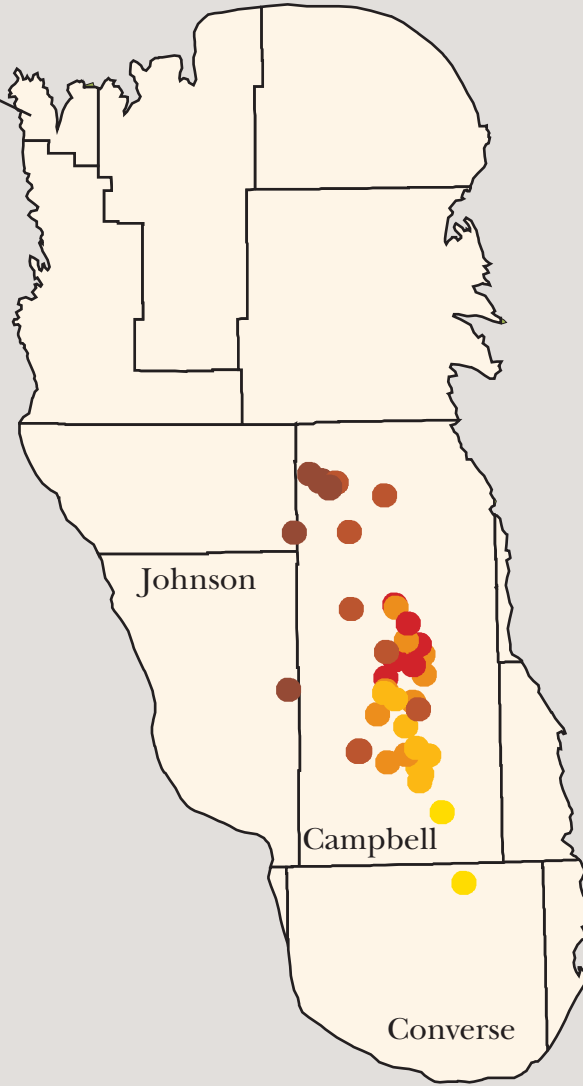


Figure 19



Powder River
Basin



Sodium
Absorption
Ratio

mg/L

- 0-6.0
- 6.1-6.9
- 7.0-7.9
- 8.0-8.9
- 9.0-21
- 22-31.7

Figure 20

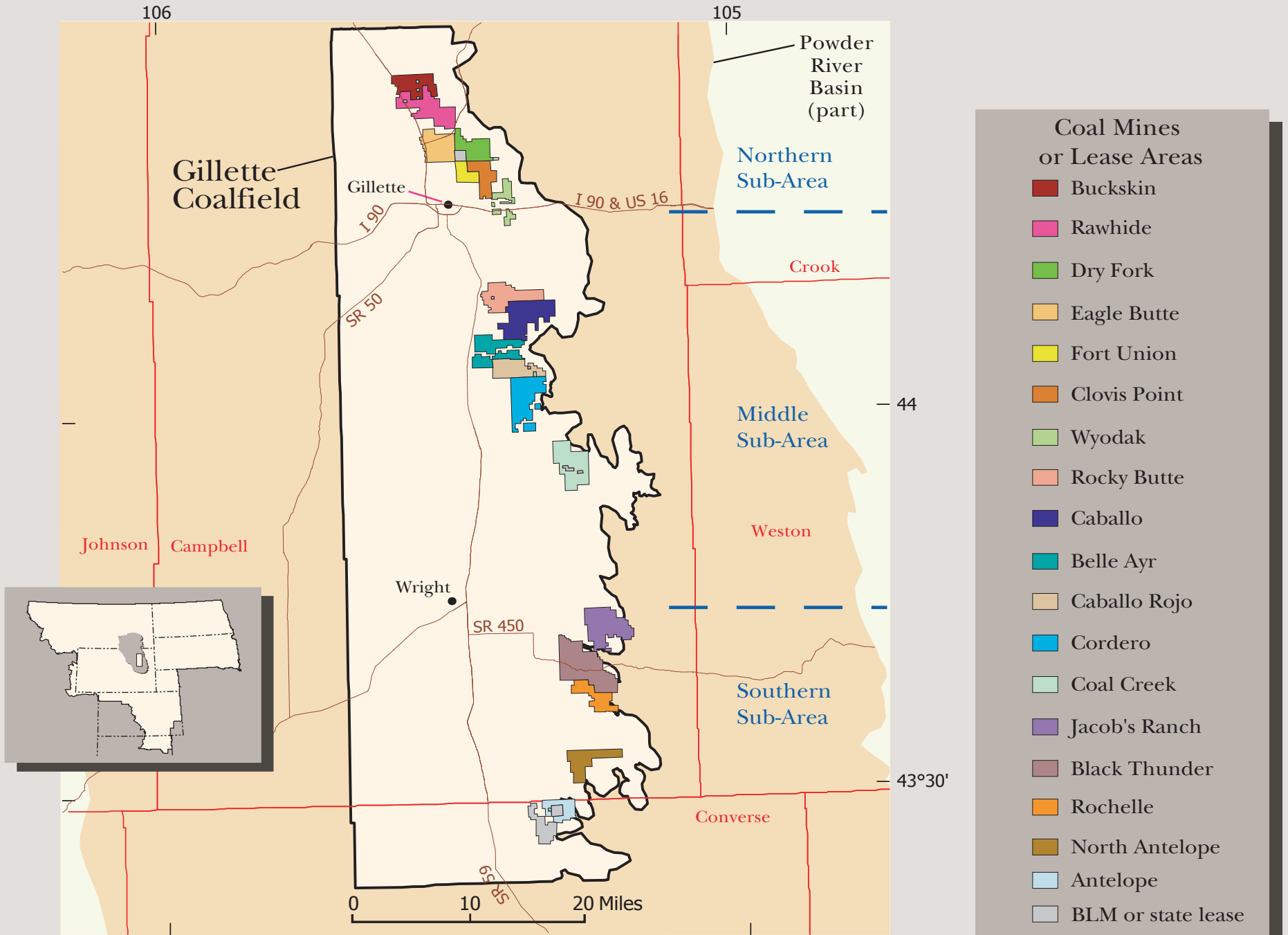


Figure 21

JACOBS RANCH COAL COMPANY

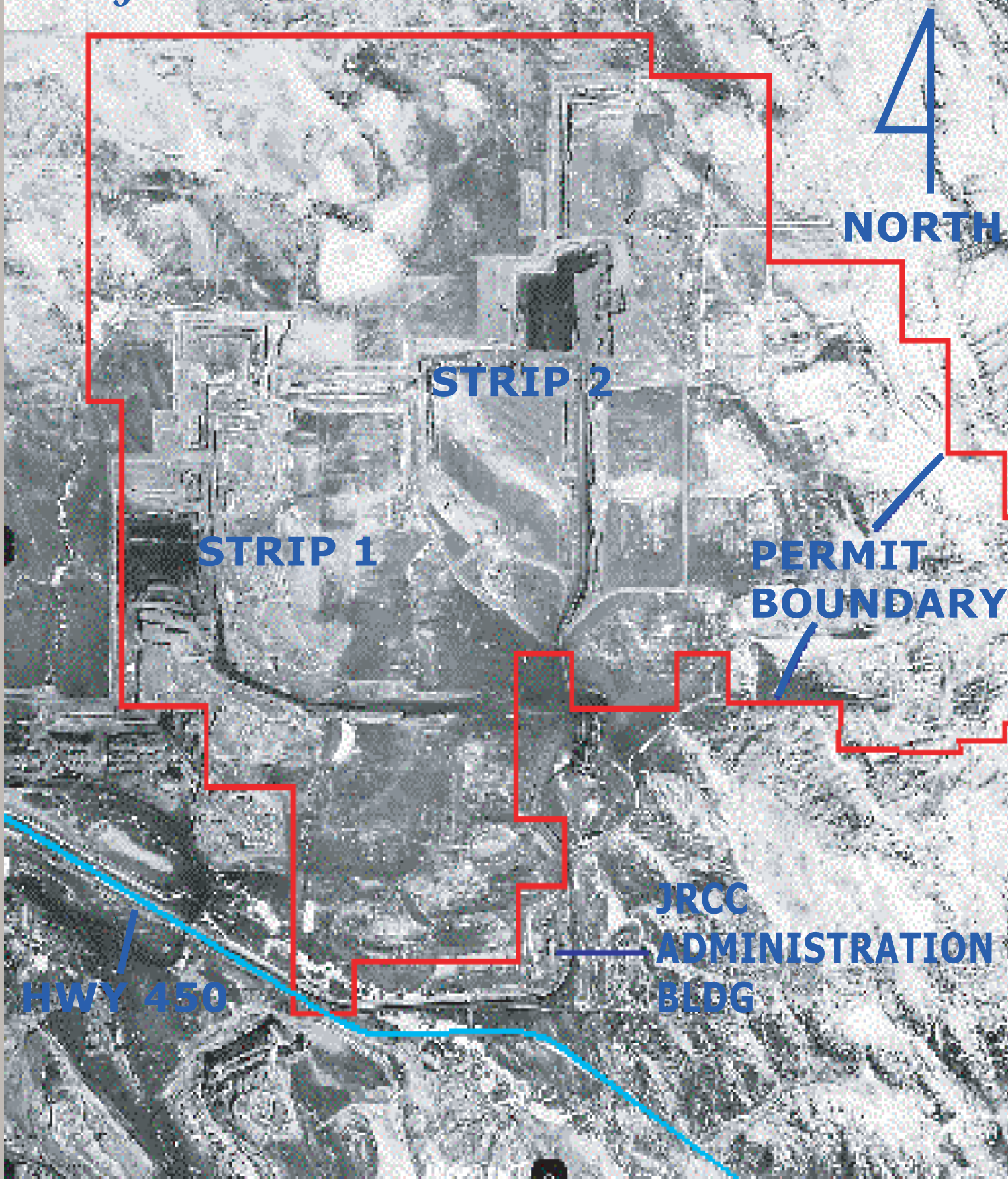


Figure 22



Figure 23

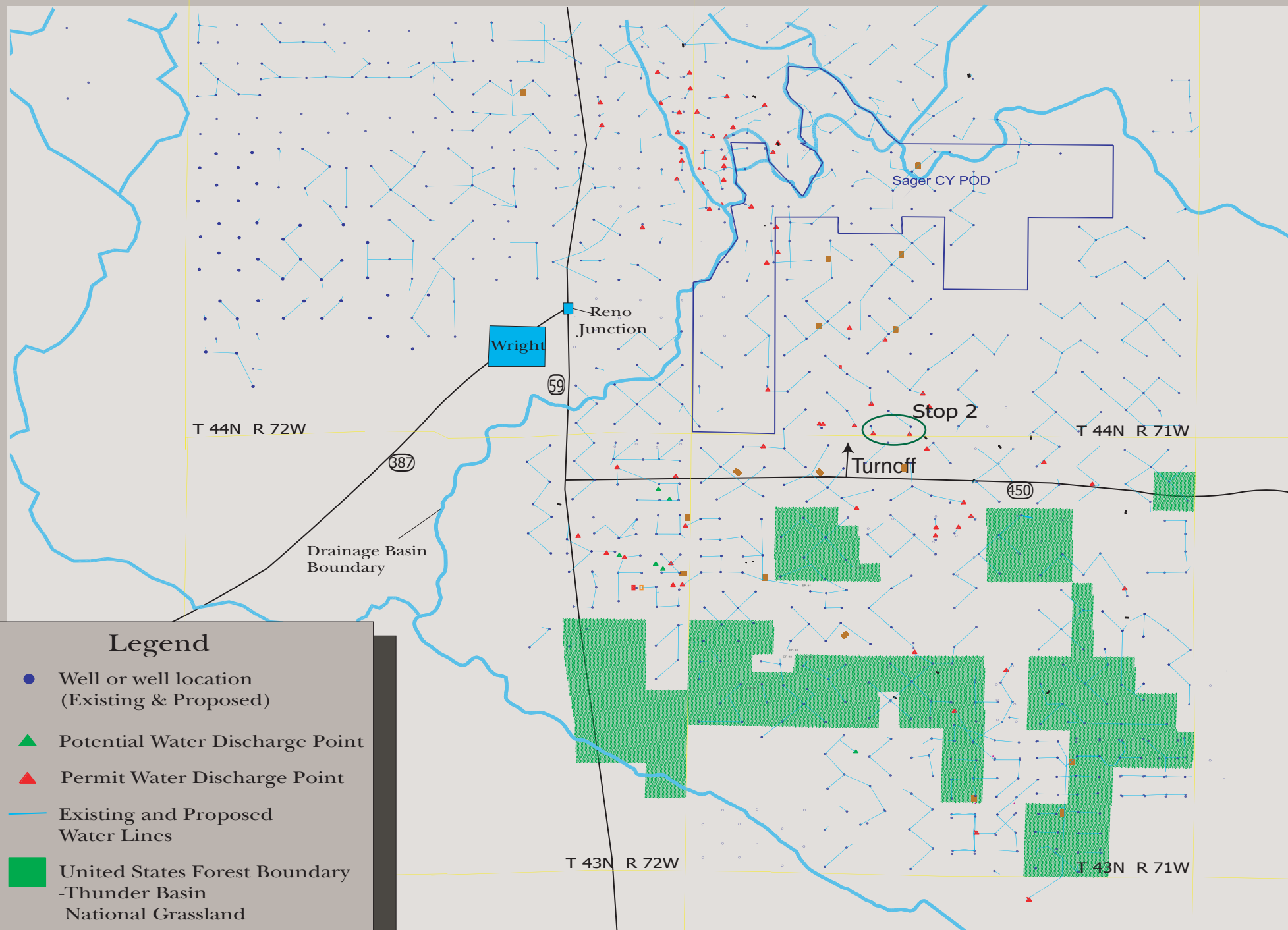
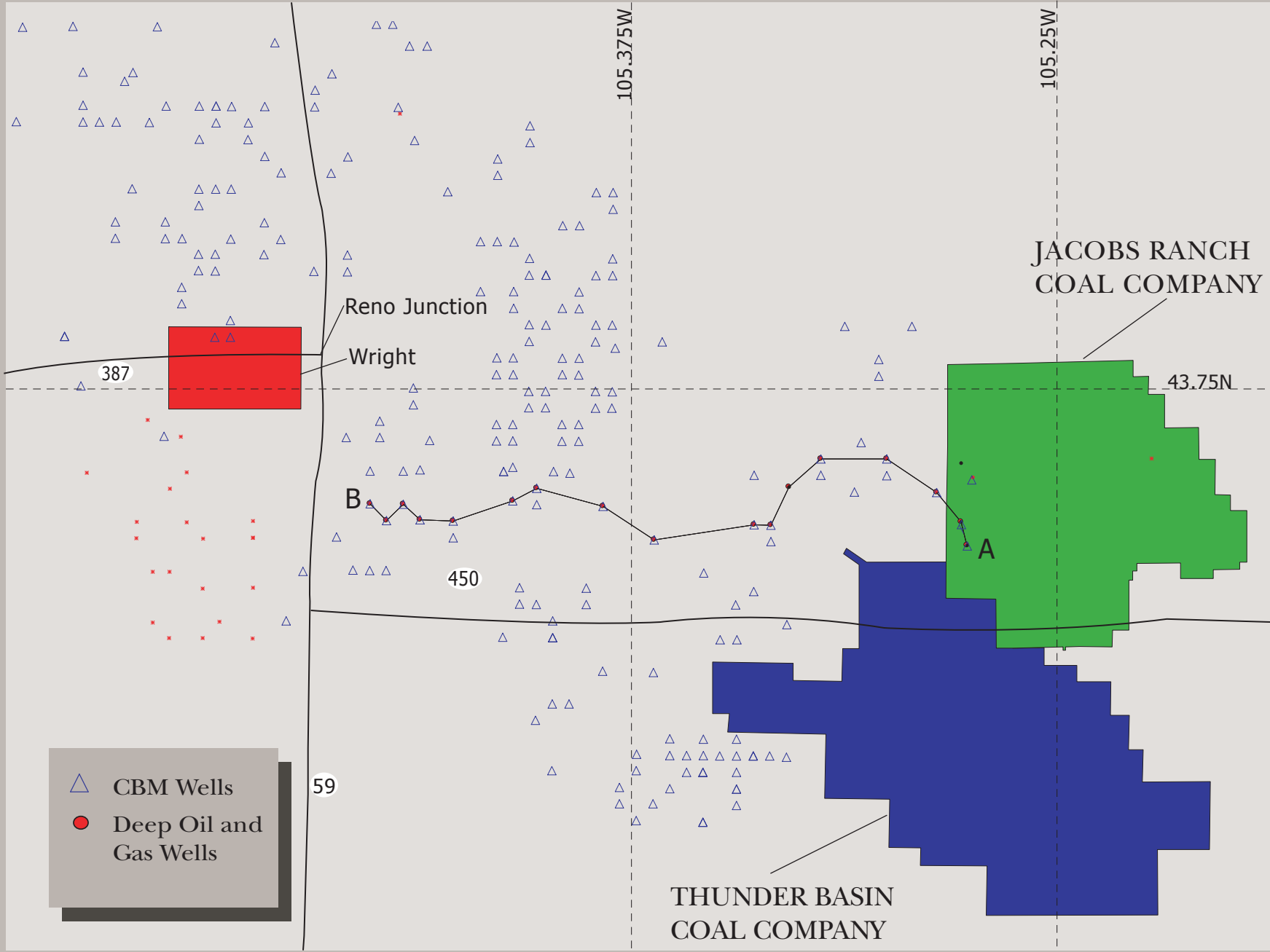


Figure 24



△ CBM Wells
● Deep Oil and Gas Wells

0 1.5 3.0 Miles

Figure 25

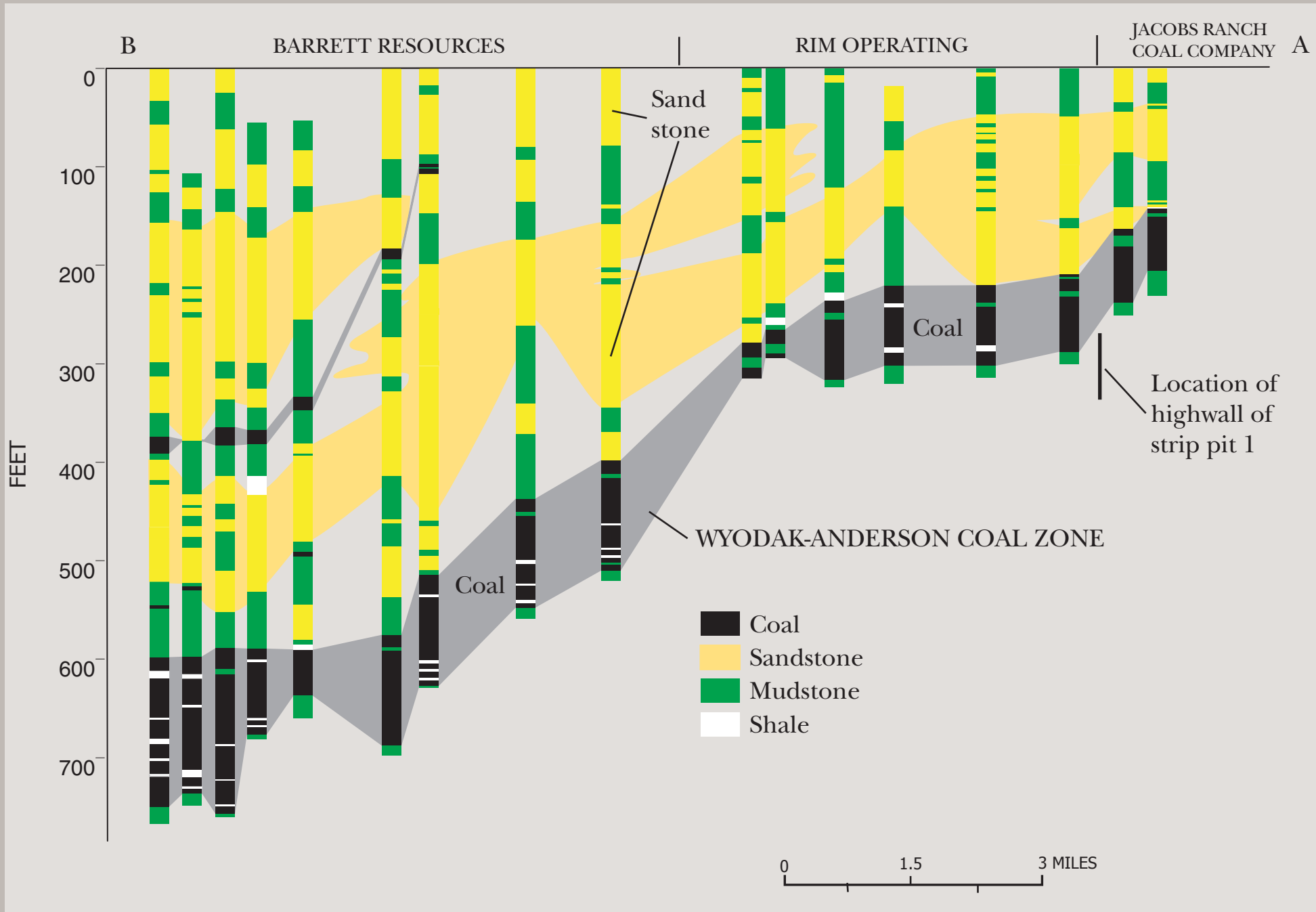


Figure 26

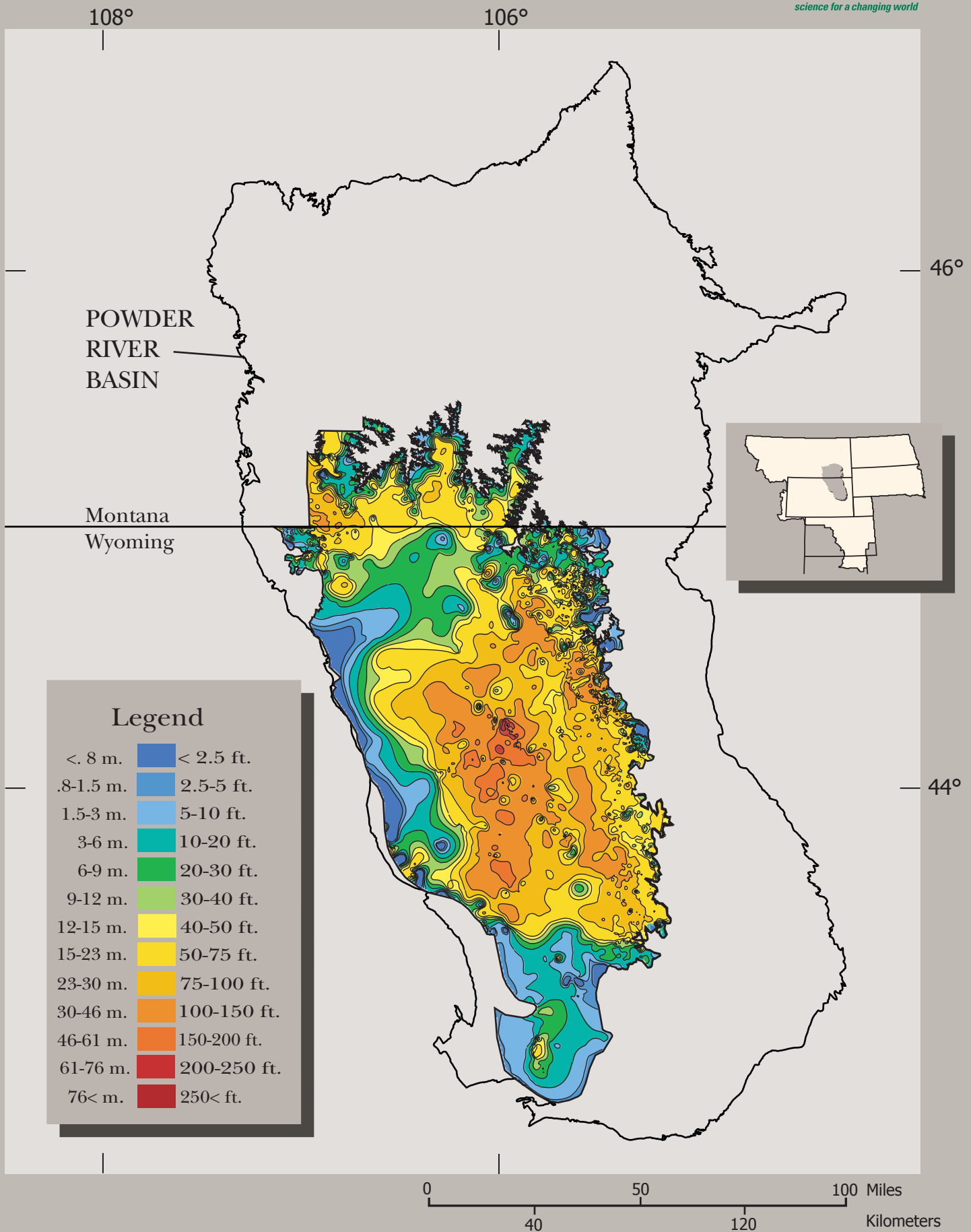


Figure 27

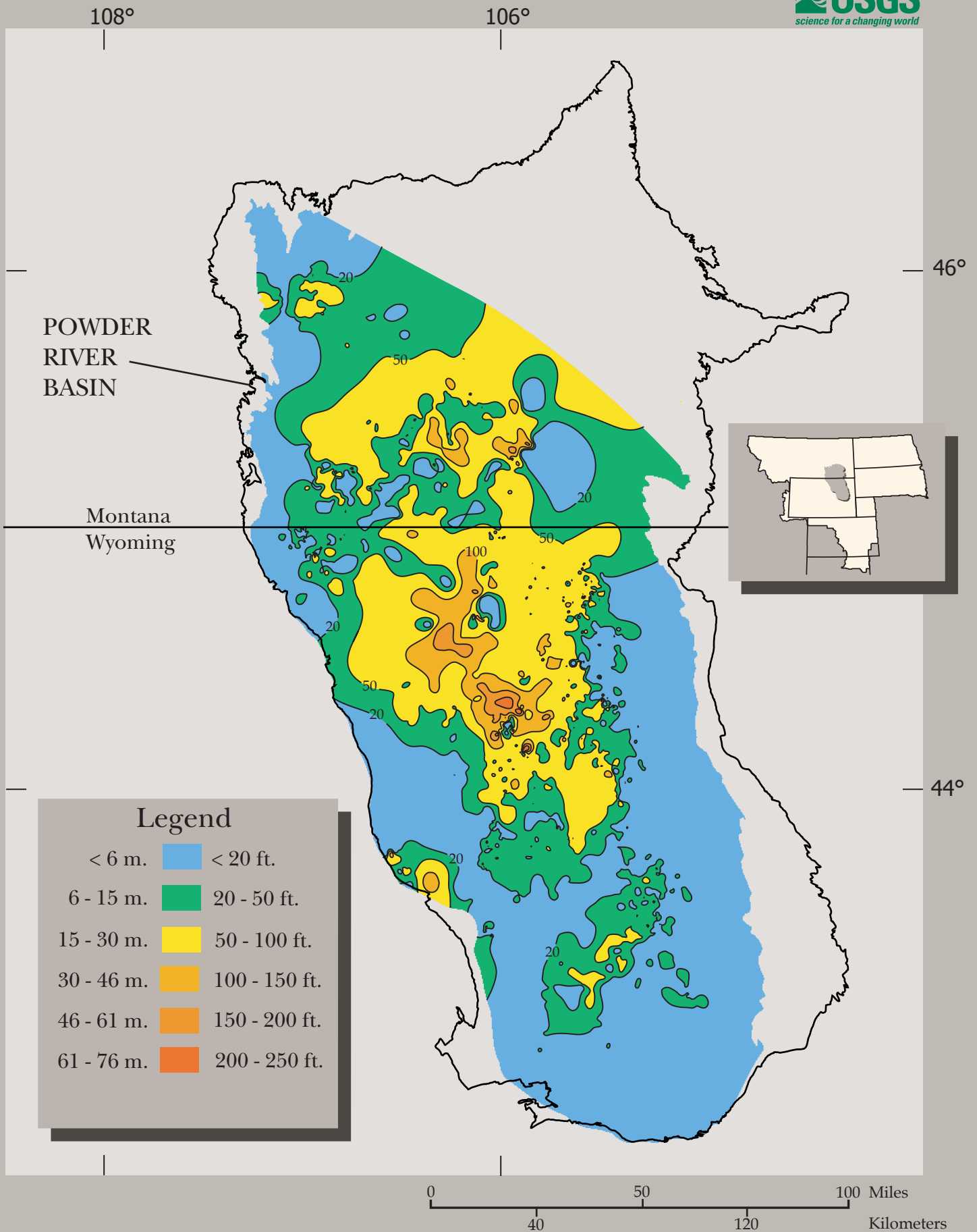


Figure 28

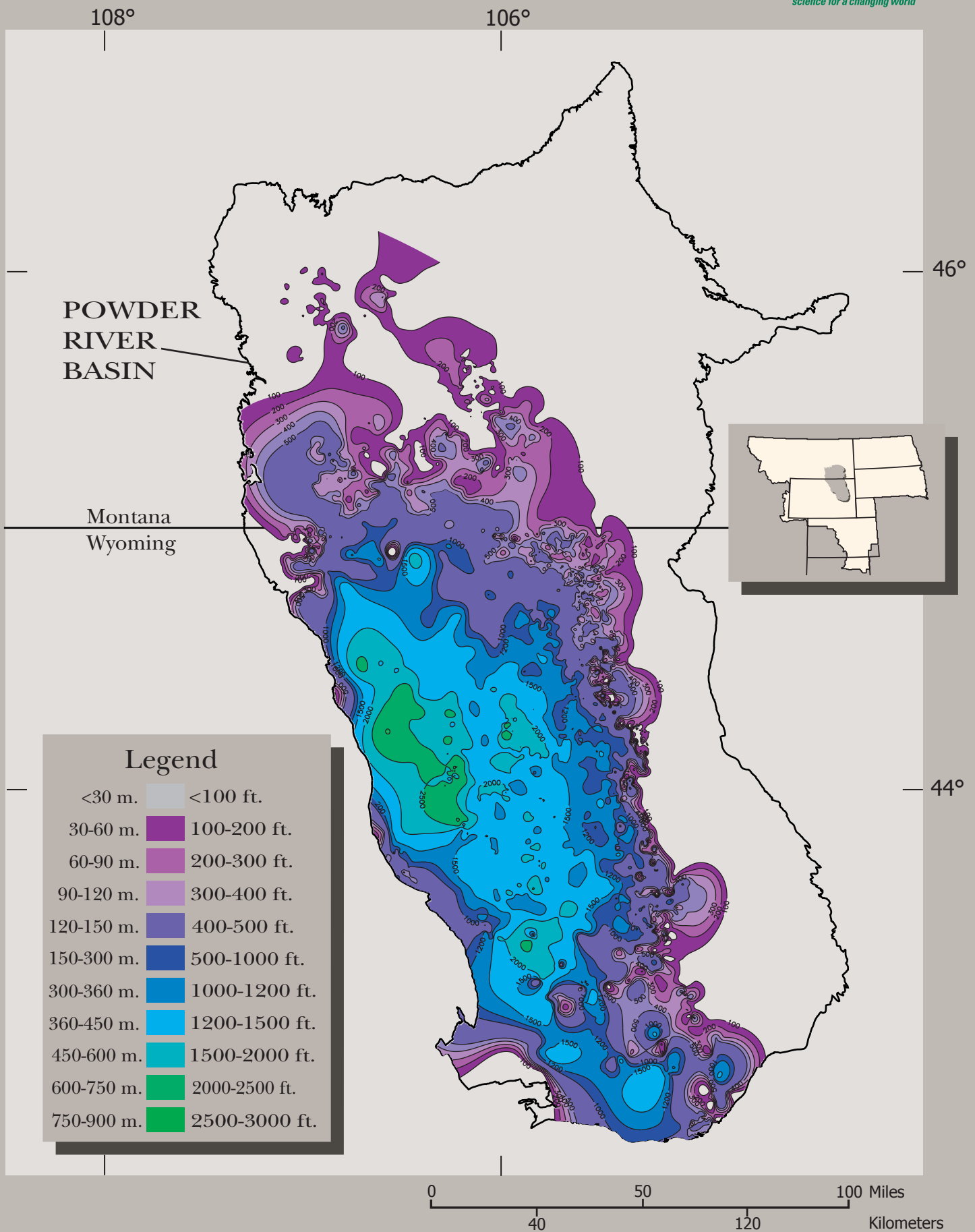


Figure 29



Figure 30

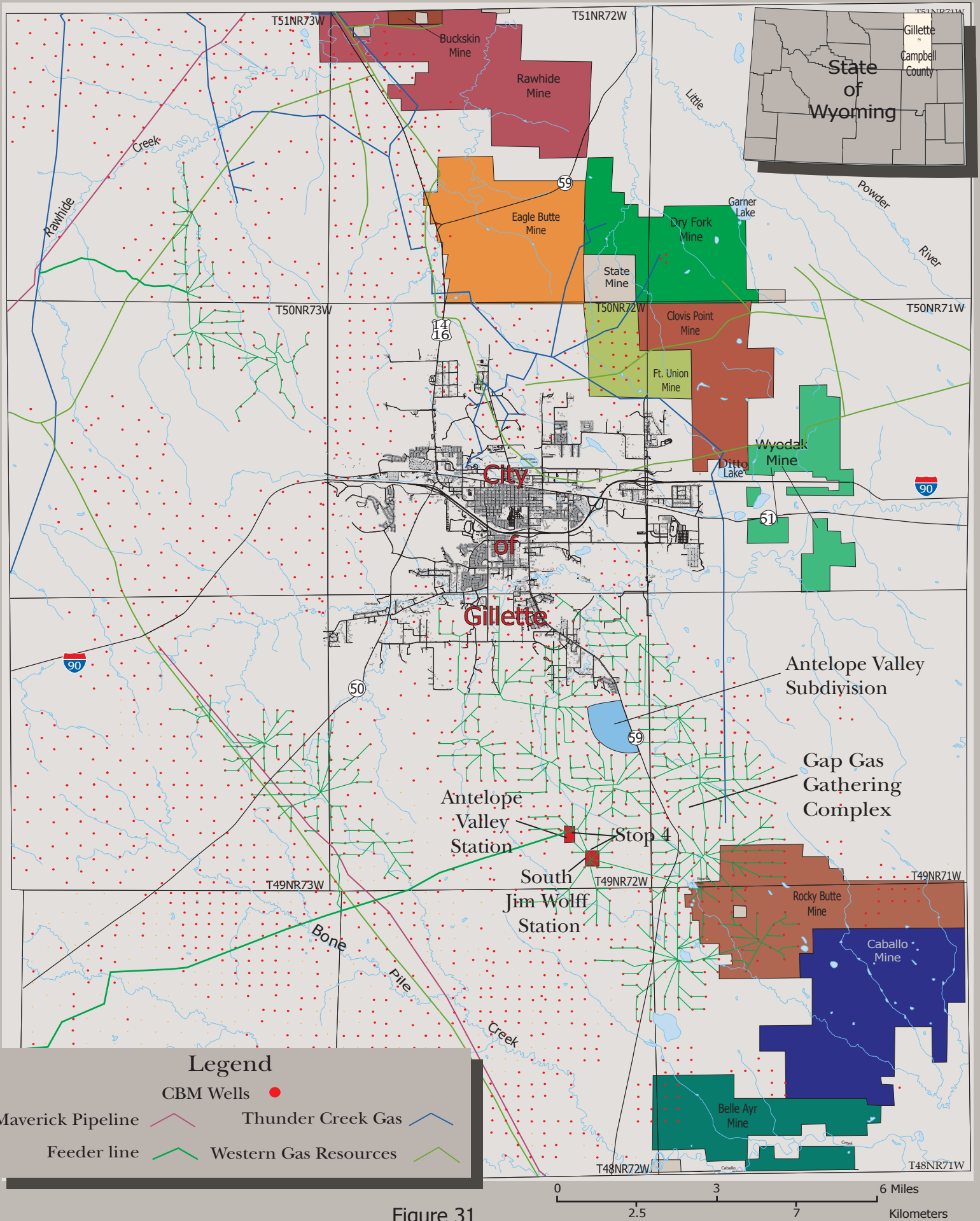


Figure 31

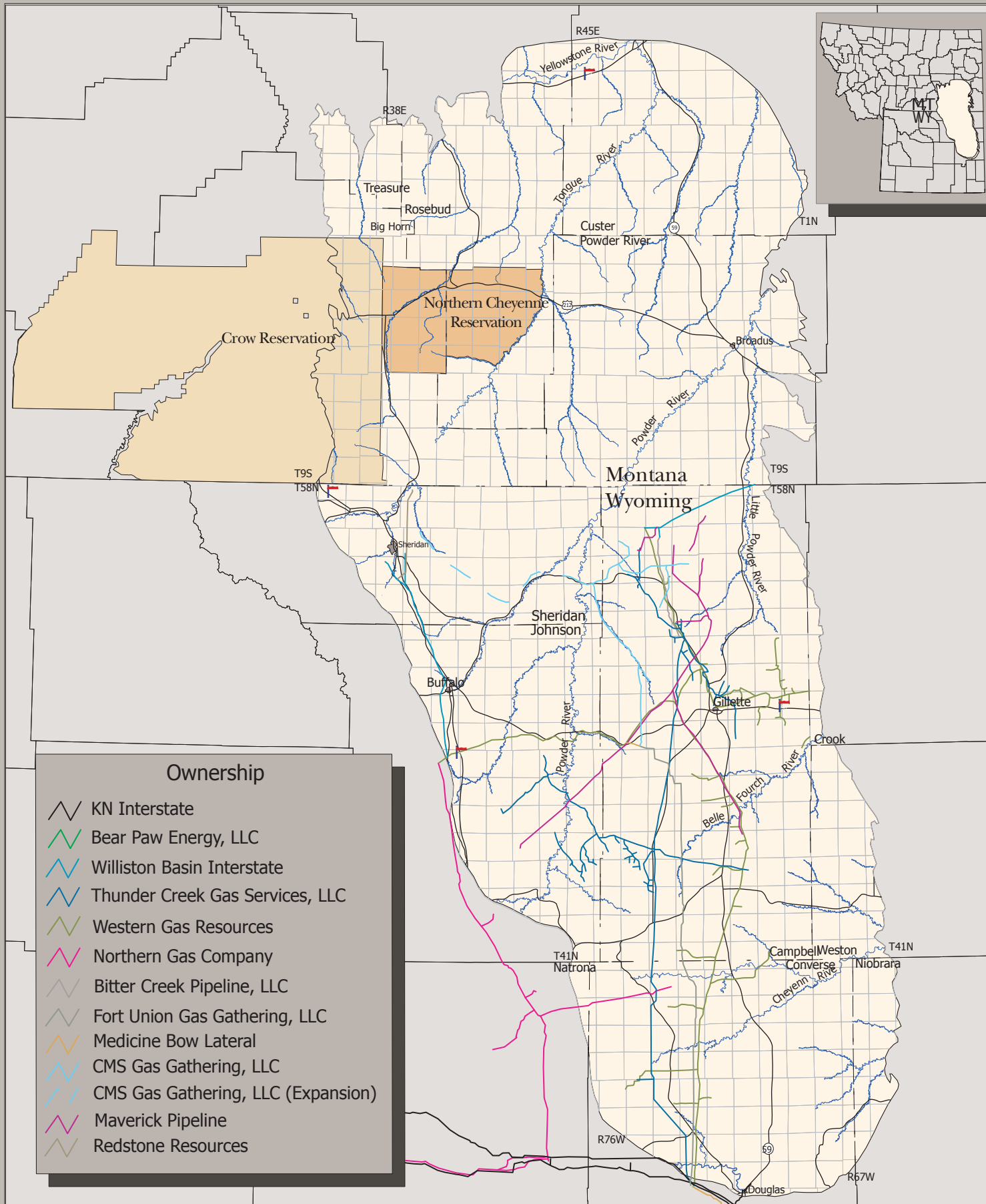
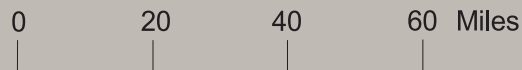


Figure 32



Powder River Basin Produced Water Composition mg/L (except pH)

h = 48

| | <u>Range</u> | <u>Average</u> | <u>DWS</u> |
|-------------|--------------|----------------|------------|
| pH | 6.8-7.6 | 7.2 | 6.5-8.5 |
| TDS | 300-1900 | 740 | 500 |
| Chloride | 5.3-64 | 16 | 250 |
| Sulfate | 0-17 | 3.3 | 250 |
| Bicarbonate | 330-2300 | 850 | --- |
| Calcium | 9.1-69 | 35 | --- |
| Potassium | 4.1-19 | 9.3 | --- |
| Magnesium | 3.4-46 | 17 | --- |
| Sodium | 110-710 | 240 | --- |

DWS = Drinking Water Standard

--- = No recommended values

Adopted from Rice and others, 2000

Table 1