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Structure Contour and Overburden Maps of the Niobrara Interval of the Upper Cretaceous Cody Shale in the Wind River Basin, Wyoming

Pamphlet to accompany
Scientific Investigations Map 3427

U.S. Department of the Interior
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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above sea level.

Structure Contour and Overburden Maps of the Niobrara Interval of the Upper Cretaceous Cody Shale in the Wind River Basin, Wyoming

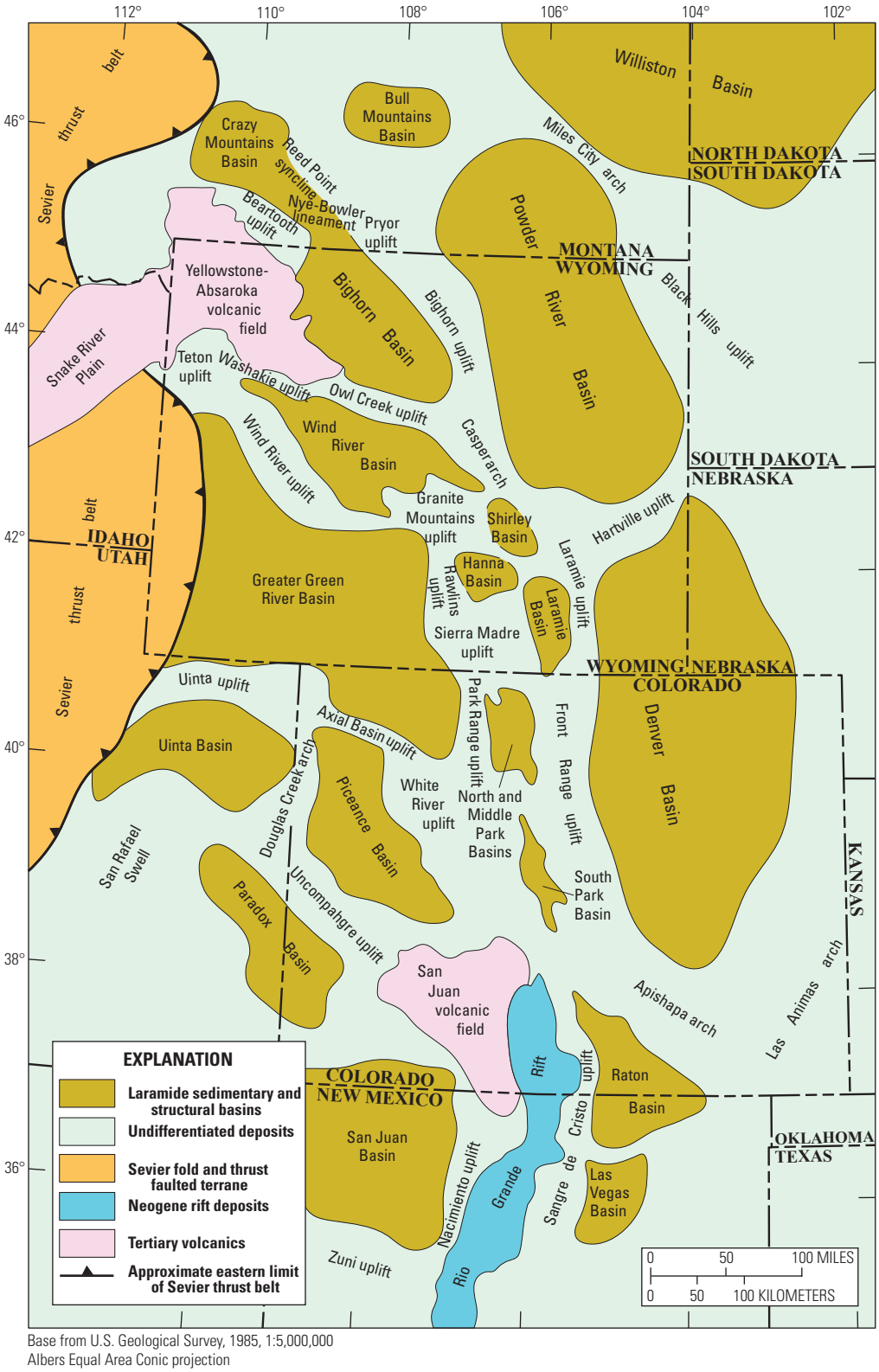
By Thomas M. Finn

Introduction

The Wind River Basin is a large northwest-trending structural depression that is nearly 200 miles (mi) long, 70 mi wide, and encompasses about 7,400 square miles (mi^2) in central Wyoming (fig. 1). The present-day structure of the Wind River Basin developed during the Laramide orogeny, a period of crustal instability that began during latest Cretaceous time and ended in the early Eocene (Gries, 1983; Love, 1988). Many of the structures are the result of compressional deformation characterized by Precambrian basement-involved thrust faults and strongly folded and faulted anticlines and synclines. The north, west, and south margins of the basin are bounded by basement-cored uplifts referred to as the Washakie, Owl Creek, Bighorn, Wind River, and Granite Mountains uplifts (fig. 2). The Casper arch, a major northwest-trending structural upwarp with a thrust faulted, steeply dipping west limb forms the east margin of the basin (Keefer, 1970) (fig. 2). These uplifts are flanked by highly folded and faulted sedimentary rocks that range from Paleozoic to Paleocene in age, whereas the central part of the basin is covered by nearly flat-lying lower Eocene and undifferentiated Tertiary and Quaternary rocks that mask the structure of the older rocks in the central part of the basin (Keefer, 1966; Keefer, 1970; Love and Christiansen, 1985) (fig. 3).

According to Knight (1897) and Rountree (1984), the first documented account of oil in what is now the State of Wyoming was discovered at a seep along the banks of the Popo Agie River, about 8 mi southeast of the present-day town of Lander near the southwestern margin of the Wind River Basin (fig. 2). For several decades following its discovery in 1833, this seep, referred to as the "great tar spring," was used by local hunters and fur trappers for medicinal purposes, and later by the military and pioneers for axle grease and lubrication (Knight, 1897; Rountree, 1984). Then in 1884, Mike Murphy completed the first commercial oil well in Wyoming next to the "great tar spring" establishing the first oil production in Wyoming at the Dallas oil field (Biggs and Espach, 1960; Keefer, 1969; Cardinal and others, 1989) (fig. 2). Since then, many important conventional and unconventional oil and gas resources have been discovered and produced from reservoirs ranging in age from Mississippian through Tertiary (Keefer, 1969; Fox and Dolton, 1989, 1996; De Bruin, 1993; Johnson and others, 1996, 2007) (fig. 2). It has been suggested that various Upper Cretaceous marine shales are the principal hydrocarbon source rocks for many of these accumulations (see, for example: Meissner and others, 1984; Fox and Dolton, 1989, 1996; Johnson and Rice, 1993; Nuccio and others, 1996; and Schelling and Wavrek, 1999, 2001). With recent advances in horizontal drilling and multi-stage hydraulic fracture stimulation, equivalent Upper Cretaceous marine source rock intervals, in particular the Niobrara Formation, have become important continuous (unconventional) shale gas or shale oil objectives in other Rocky Mountain Laramide basins (Matthews, 2011; Sonnenberg, 2011; Williams and Lyle, 2011; Durham, 2012a,b, 2013; Taylor and Sonnenberg, 2014; Hawkins, 2016). In the Wind River Basin, the Niobrara is represented by shales, calcareous shales, marls, siltstones, and sandstones in the lower shaly member of the Upper Cretaceous Cody Shale (Finn, 2017) (fig. 4).

The maps presented in this report were constructed as part of a project carried out by the U.S. Geological Survey (USGS) to better characterize the geologic framework of potential undiscovered continuous (unconventional) oil and gas resources in the Niobrara interval of the Upper Cretaceous Cody Shale in the Wind River Basin in central Wyoming (sheets 1 and 2). The structure contour map is drawn at the base of the "chalk kick" marker bed, a distinctive zone or peak on resistivity logs in the lower 50–300 feet (ft) of the Cody Shale that according to Finn (2017) represents the base of the Niobrara interval in the Wind River Basin (fig. 5). This horizon was selected because it is easily identified on most well logs, is present throughout the basin, and has been identified by the author in about 630 wells (Finn, 2019). Data from an additional 90 wells that penetrated the upper part of the Niobrara interval or overlying Cody Shale were incorporated by projecting thicknesses from nearby wells and estimating a pick for the "chalk kick" marker (Finn, 2019). The structure contouring is based on interpretation of the well data and surface geologic mapping by Keefer (1970), Keefer and Troyer (1964), Love and Christiansen (1985), Green and Drouillard (1994), Sutherland and Hausel (2003), and Johnson



Base from U.S. Geological Survey, 1985, 1:5,000,000
Albers Equal Area Conic projection

Figure 1. Map of the Rocky Mountain region showing locations of Laramide basins.

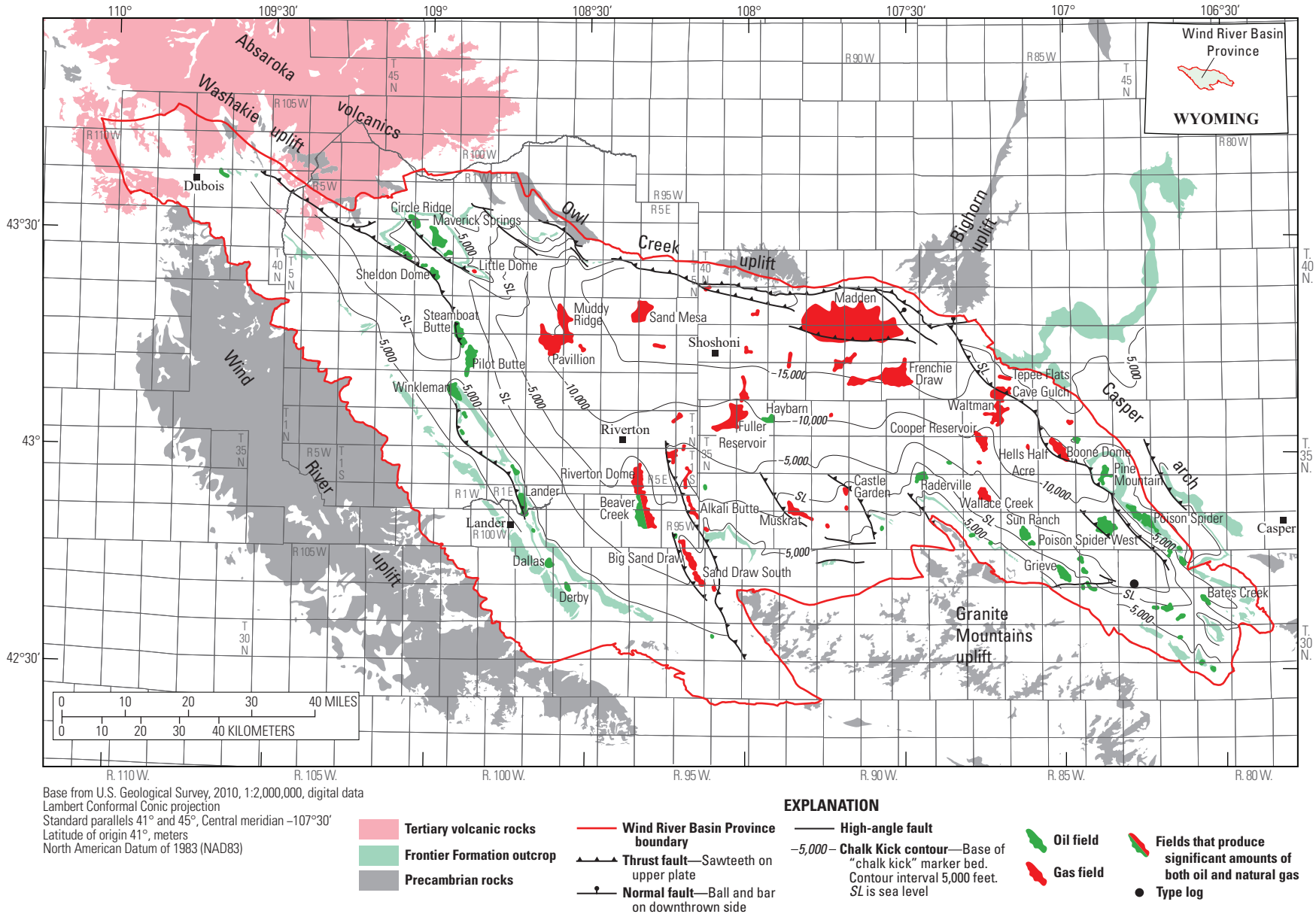
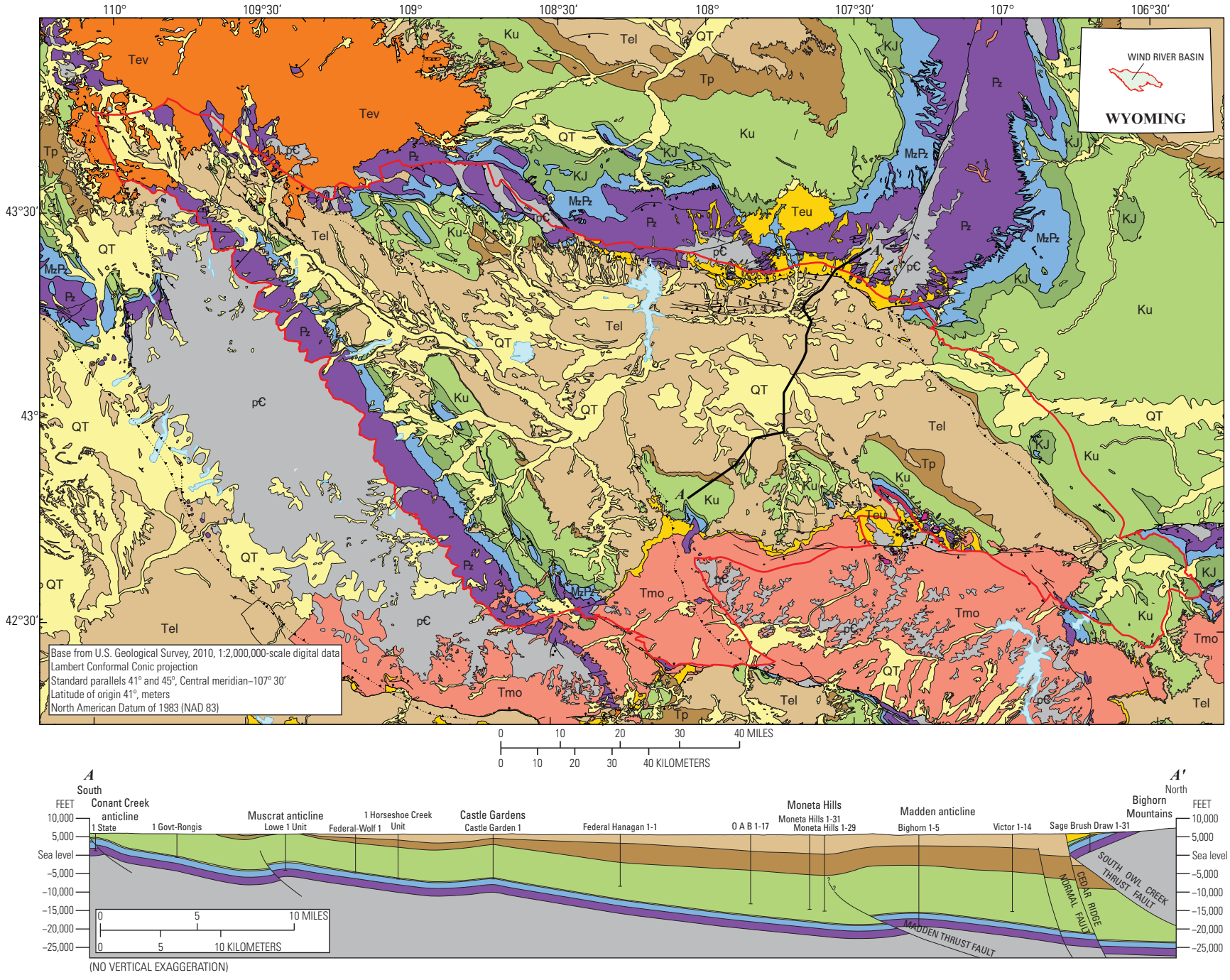


Figure 2. Index map of the Wind River Basin in central Wyoming showing major structural elements, and principal oil and gas producing fields. Structure contours drawn at base of the chalk kick marker bed of the Niobrara interval of the Cody Shale. Contour interval is 5,000 feet. *SL*, sea level.


110°
109°30′
109°
108°30′
108°
107°30′
107°
106°30′
43°30′
43°
42°30′
WIND RIVER BASIN
WYOMING
Tev
Tp
Tel
QT
Ku
KJ
Pz
MzPz
pC
Teu
Tmo
A
A′
Base from U.S. Geological Survey, 2010, 1:2,000,000-scale digital data
Lambert Conformal Conic projection
Standard parallels 41° and 45°, Central meridian–107° 30′
Latitude of origin 41°, meters
North American Datum of 1983 (NAD 83)
0 10 20 30 40 MILES
0 10 20 30 40 KILOMETERS
South
North
Conant Creek anticline
Muscrat anticline
Castle Gardens
Moneta Hills
Madden anticline
Bighorn Mountains
1 State
1 Govt-Rongis
Lowe 1 Unit
Federal-Wolf 1 Unit
1 Horseshoe Creek
Castle Garden 1
Federal Hanagan 1-1
O A B 1-17
Moneta Hills 1-31
Moneta Hills 1-29
Bighorn 1-5
Victor 1-14
Sage Brush Draw 1-31
FEET
10,000
5,000
Sea level
–5,000
–10,000
–15,000
–20,000
–25,000
SOUTH OWL CREEK THRUST FAULT
CEDAR RIDGE NORMAL FAULT
MADDEN THRUST FAULT
0 5 10 MILES
0 5 10 KILOMETERS
(NO VERTICAL EXAGGERATION)

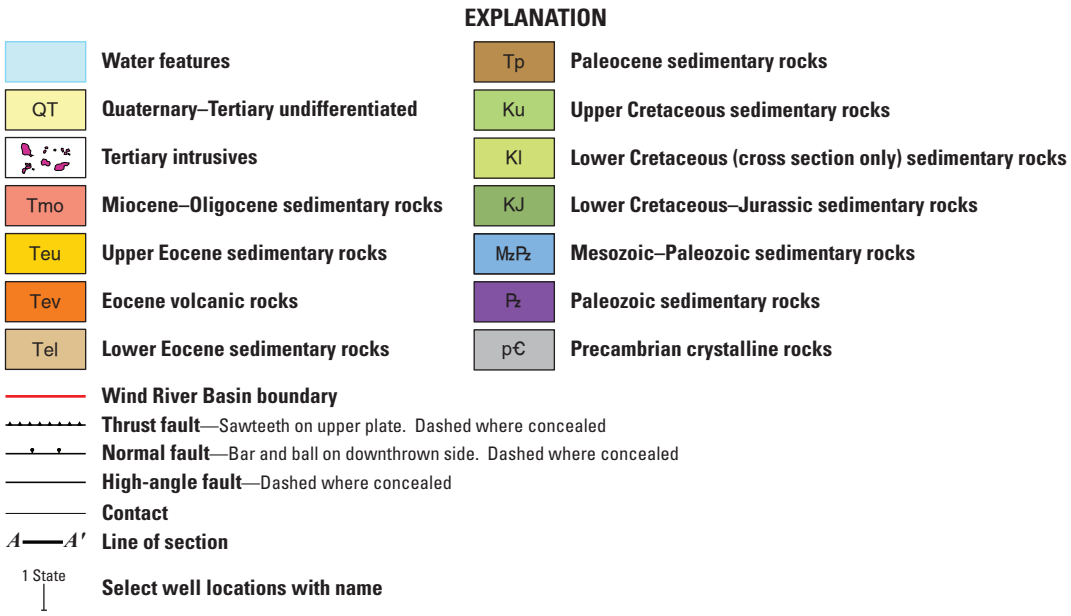


Figure 3. (above and previous page) Generalized geologic map and cross section of the Wind River Basin in central Wyoming. Geologic map modified from Love and Christiansen (1985), and Green and Drouillard (1994). Cross section segment north of the Madden anticline is modified from Ray and Keefer (1985).

and Sutherland (2009). Additional sources of geologic data include structural cross sections and (or) subsurface maps by Biggs and Espach (1960), Keefer (1970), Skeen and Ray (1983), Sprague (1983), Ray and Keefer (1985), Dunleavy and Gilbertson (1986), Cardinal and others (1989), Blackstone (1990), Natali and others (2000), and Montgomery and others (2001). The structure contour map is at a scale of 1:500,000, the contour interval is 1,000 ft, and the datum is mean sea-level (sheet 1). The overburden map was constructed by using the well data (Finn, 2019) and by calculating the difference between the surface elevation and the structure contours. This map is at a scale of 1:500,000, and the contour interval is 1,000 ft (sheet 2).

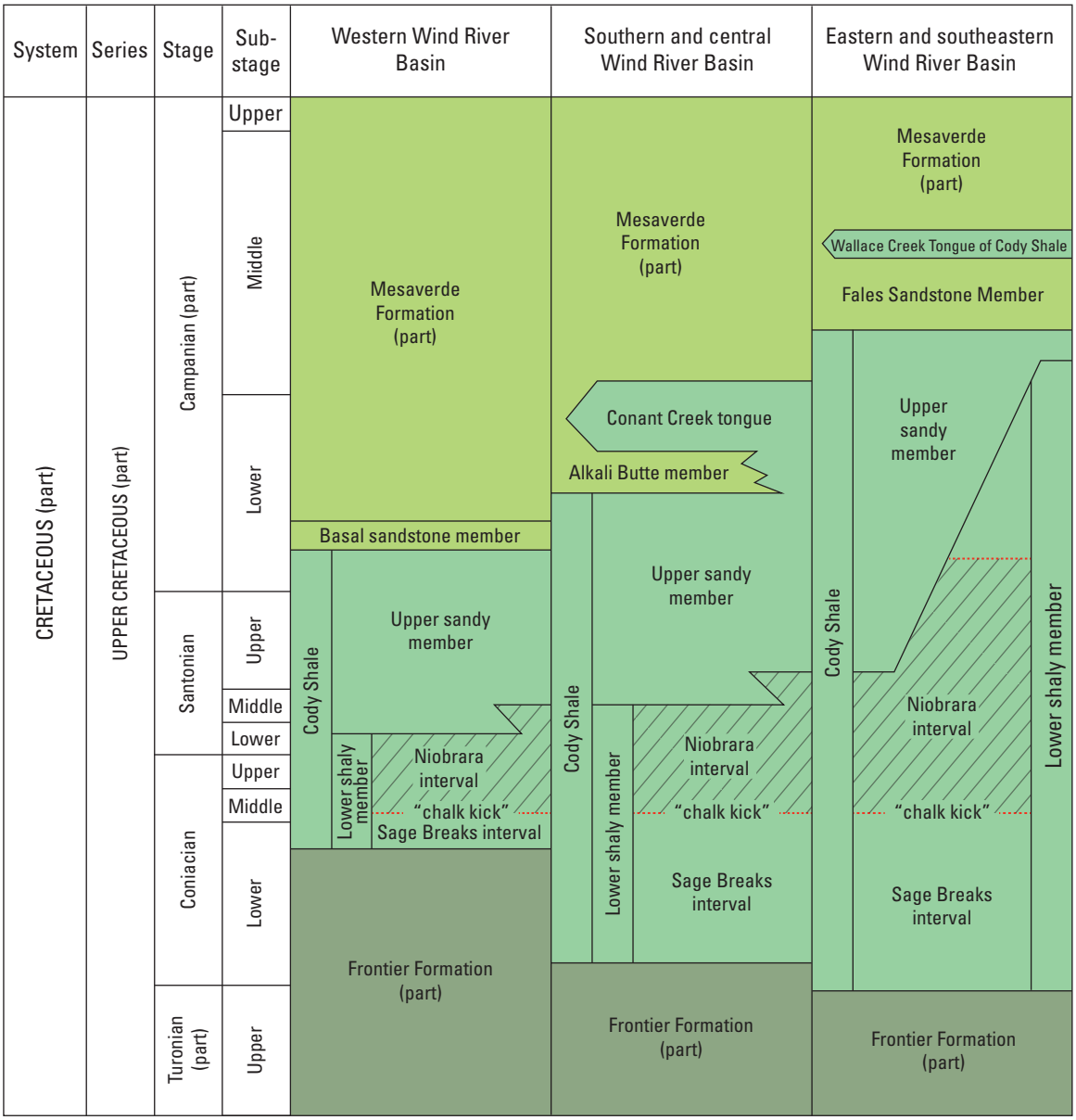


Figure 4. Correlation diagram of the Upper Cretaceous Cody Shale and associated strata in the Wind River Basin, Wyoming. The diagonal lines represent the Niobrara interval in the Wind River Basin, as defined in this report. Modified from Finn (2017).

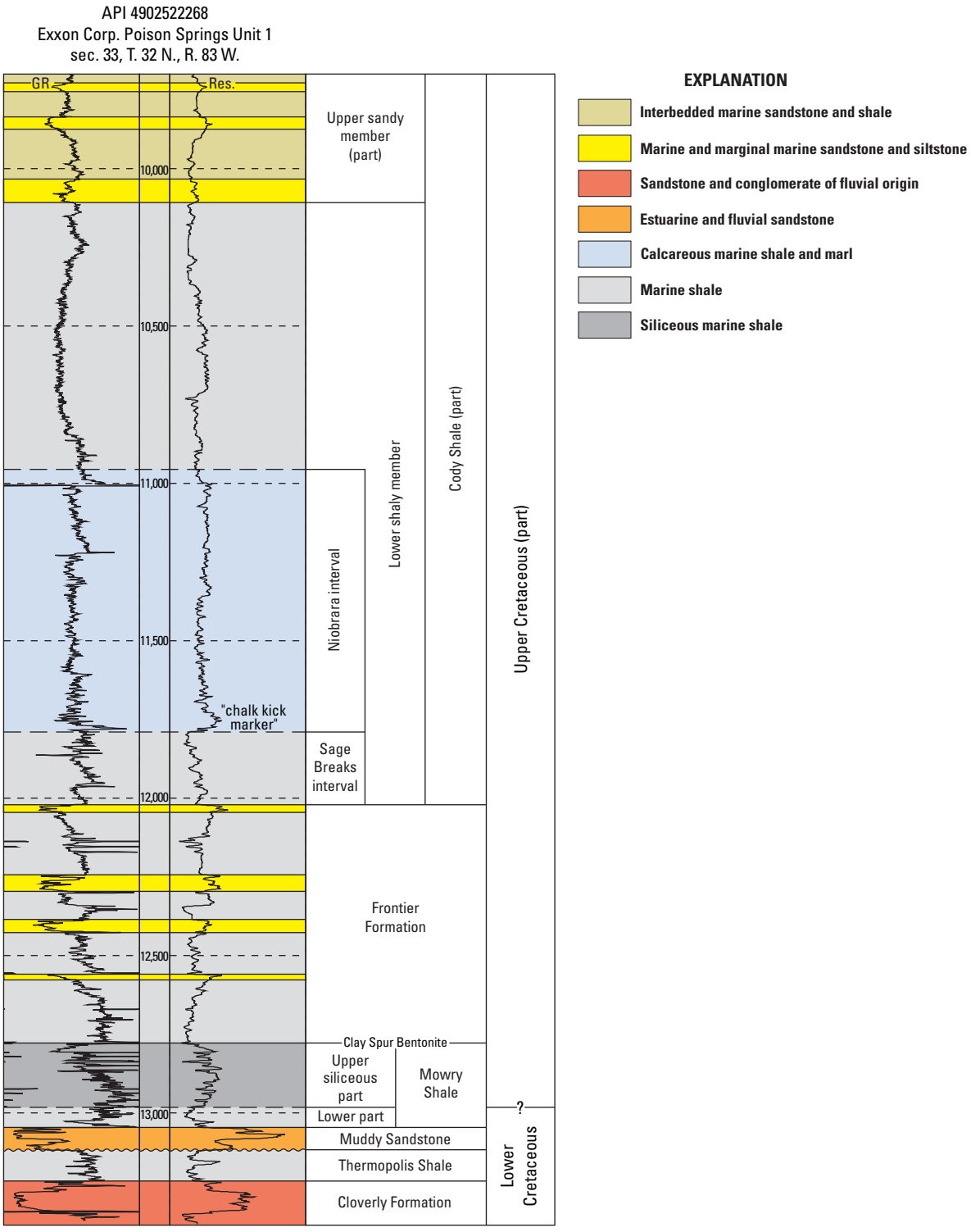


Figure 5. Type log of Lower and lowermost Upper Cretaceous rocks in the southeastern part of the Wind River Basin. GR, gamma ray log; Res., resistivity log. Location shown in figure 2. From Finn (2017).

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References

Biggs, P., and Espach, R.H., 1960, Petroleum and natural gas fields in Wyoming: U.S. Bureau of Mines Bulletin 582, 538 p. [Publications now held by the U.S. Geological Survey.]

Blackstone, D.L., Jr., 1990, Rocky Mountain foreland structure exemplified by the Owl Creek Mountains, Bridger Range, and Casper arch, central Wyoming, *in* Specht, R.W., ed., Wyoming sedimentation and tectonics, 41st Annual Field Conference Guidebook: Wyoming Geological Association Guidebook, p. 151–166.

Cardinal, D.F., Miller, T., Stewart, W.W., and Trotter, J.F., eds., 1989, Wyoming oil and gas fields symposium Bighorn and Wind River Basins: Wyoming Geological Association, 555 p.

De Bruin, R.H., 1993, Overview of oil and gas geology of Wyoming, *in* Snoke, A.W., Steidtmann, J.R., and Roberts, S.M., eds., Geology of Wyoming: Geological Survey of Wyoming Memoir no. 5, p. 836–873.

Dunleavy, J.M., and Gilbertson, R.L., 1986, Madden anticline—Growing giant, *in* Noll, J.H., and Doyle, K.M., eds., Rocky Mountain oil and gas fields: Wyoming Geological Association, p. 107–157.

Durham, L.S., 2012a, Mancos-Niobrara play full of surprises: American Association of Petroleum Geologists Explorer, v. 33, no. 8, p. 14–18.

Durham, L.S., 2012b, What is the tally of Niobrara value?: American Association of Petroleum Geologists Explorer, v. 33, no. 8, p. 20.

Durham, L.S., 2013, Rocky operators cautiously move ahead: American Association of Petroleum Geologists Explorer, v. 34, no. 6, p. 6, accessed February 2, 2017, at https://www.aapg.org/publications/news/explorer/2013/06jun.

Finn, T.M., 2017, Stratigraphic cross sections of the Niobrara interval of the Cody Shale and associated rocks in the Wind River Basin, central Wyoming: U.S. Geological Survey Scientific Investigations Map 3370, pamphlet 19 p., 1 sheet [cross section], accessed on February 2, 2018, at https://doi.org/10.3133/sim3370.

Finn, T.M., 2019, Tops file for the Niobrara interval of the Upper Cretaceous Cody Shale and associated strata in the Wind River Basin, Wyoming: U.S. Geological Survey data release, https://doi.org/10.5066/F7BZ65CN.

Fox, J.E., and Dolton, G.L., 1989, Petroleum geology of the Wind River and Bighorn Basins, Wyoming and Montana: U.S. Geological Survey Open-File Report 87–450–P, 41 p.

Fox, J.E., and Dolton, G.L., 1996, Wind River Basin Province (35), *in* Gautier, D.L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1995 National assessment of United States oil and gas resources—Results, methodology, and supporting data: U.S. Geological Survey Digital Data Series DDS–30, CD–ROM, release 2.

Green, G.N., and Drouillard, P.H., 1994, The digital geologic map of Wyoming in ARC/INFO format: U.S. Geological Survey Open-File Report 94–0425, 10 p.

Gries, R., 1983, North-south compression of Rocky Mountain foreland structures, *in* Lowell, J.D., and Gries, R., eds., Rocky Mountain foreland basins and uplifts: Rocky Mountain Association of Geologists Guidebook, p. 9–32.

Hawkins, S.J., 2016, Assessment of continuous (unconventional) oil and gas resources in the Late Cretaceous Mancos Shale of the Piceance Basin Province, Colorado and Utah, 2016: U.S. Geological Survey Fact Sheet 2016–3030, 4 p., accessed February 2, 2017, at https://pubs.er.usgs.gov/publication/fs20163030.

Johnson, J.F., and Sutherland, W.M., 2009, Geologic map of the Lander 30'×60' quadrangle, Fremont County, Wyoming: Wyoming Geological Survey Map Series 87, scale 1:100,000.

Johnson, R.C., and Rice, D.D., 1993, Variations in composition and origins of gases from coal beds and conventional reservoirs, Wind River Basin, Wyoming, *in* Keefer, W.R., Metzger, W.J., and Godwin, L.H., eds., Oil and gas and other resources of the Wind River Basin, Wyoming: Wyoming Geological Association, p. 319–335.

Johnson, R.C., Finn, T.M., Keefer, W.R., and Szmajter, R.J., 1996, Geology of Upper Cretaceous and Paleocene gas-bearing rocks, Wind River Basin, Wyoming: U.S. Geological Survey Open-File Report 96–090, 120 p.

Johnson, R.C., Finn, T.M., Kirschbaum, M.A., Roberts, S.B., Roberts, L.N.R., Cook, T., and Taylor, D.J., 2007, The Cretaceous-Lower Tertiary Composite Total Petroleum System, Wind River Basin, Wyoming, chap. 4 *of* Petroleum systems and geologic assessment of oil and gas resources in the Wind River Basin Province, Wyoming: U.S. Geological Survey Digital Data Series DDS 69–J–4, 96 p., CD–ROM.

Keefer, W.R., 1966, Paleozoic formations in the Wind River Basin, Wyoming: U.S. Geological Survey Professional Paper 495–B, 60 p.

Keefer, W.R., 1969, Geology of petroleum in the Wind River Basin, central Wyoming: American Association of Petroleum Geologists Bulletin, v. 53, no. 9, p. 1839–1865.

Keefer, W.R., 1970, Structural geology of the Wind River Basin, Wyoming: U.S. Geological Survey Professional Paper 495–D, 35 p.

Keefer, W.R., and Troyer, M.L., 1964, Geology of the Shotgun Butte area, Fremont County, Wyoming: U.S. Geological Survey Bulletin 1157, 123 p.

Knight, W.C., 1897, The petroleum of the Shoshone anticlinal: University of Wyoming Petroleum Series Bulletin, no. 2, 34 p.

Love, D.J., 1988, Geology of the Wind River Basin, central Wyoming, *in* Sloss, L.L., ed., Sedimentary Cover—North American Craton—U.S., The Geology of North America: Boulder, Colo., The Geological Society of America, v. D–2, p. 196–200.

Love, D.J., and Christiansen, A.C., 1985, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000. [Available at https://ngmdb.usgs.gov/Prodesc/proddesc_16366.htm.]

Matthews, V., 2011, Colorado's new oil boom—The Niobrara: Colorado Geological Survey Rock Talk, v. 13, no. 1, 11 p.

Meissner, F.F., Woodward, J., and Clayton, J.L., 1984, Stratigraphic relationships and distribution of source rocks in the greater Rocky Mountain region, *in* Woodward, J., Meissner, F.F., and Clayton, J.L., eds., Hydrocarbon source rocks of the greater Rocky Mountain region: Rocky Mountain Association of Geologists Guidebook, p. 1–34.

Montgomery, S.L., Barrett, F., Vickery, K., Natali, S., and Dea, P., 2001, Cave Gulch field, Natrona County, Wyoming—Large gas discovery in the Rocky Mountain foreland, Wind River Basin: American Association of Petroleum Geologist Bulletin, v. 85, no. 9, p. 1543–1564.

Natali, S., Roux, R., Dea, P., and Barrett, F., 2000, Cave Gulch 3D survey, Wind River Basin, Wyoming: The Mountain Geologist, v. 37, no. 1, p. 3–13.

Nuccio, V.F., Finn, T.M., and Johnson, R.C., 1996, Thermal maturity data used for the assessment of gas resources in the Wind River Basin, Wyoming: U.S. Geological Survey Open-File Report 96-064, 57 p.

Ray, R.R., and Keefer, W.R., 1985, Wind River Basin, central Wyoming, *in* Gries, R.R., and Dyer, R.C., eds., Seismic exploration of the Rocky Mountain Region: Rocky Mountain Association of Geologists, and Denver Geophysical Society, p. 201–212.

Rountree, R., 1984, Western Oil Reporter's Rocky Mountain oil history: Denver, Hart Publications Inc., 210 p.

Schelling, D.D., and Wavrek, D.A., 1999, Structural geology and petroleum systems of the Madden field, Wind River Basin, Wyoming: American Association of Petroleum Geologists, v. 83, no. 13 (supplement).

Schelling, D.D., and Wavrek, D.A., 2001, Structural geology and petroleum systems of the northwestern Wind River Basin, Wyoming: American Association of Petroleum Geologists, v. 85, no. 13 (supplement).

Skeen, R.C., and Ray, R.R., 1983, Seismic models and interpretation of the Casper arch thrust—Application to Rocky Mountain foreland structure, *in* Lowell, J.D., ed., Rocky Mountain foreland basins and uplifts: Rocky Mountain Association of Geologists Guidebook, p. 339–343.

Sonnenberg, S.A., 2011, The Niobrara Petroleum System—A new resource play in the Rocky Mountain region, *in* Estes-Jackson, J.E., and Anderson, D.S., eds., Revisiting and revitalizing the Niobrara in the central Rockies: Rocky Mountain Association of Geologists, p. 13–32.

Sprague, E.L., 1983, Geology of the Tepee Flats-Bullfrog fields, Natrona County, Wyoming, *in* Lowell, J.D., and Gries, Robbie, eds., Rocky Mountain foreland basins and uplifts: Rocky Mountain Association of Geologists Guidebook, p. 339–343.

Sutherland, W., and Hausel, W.D., 2003, Geologic map of the Rattlesnake Hills 30′×60′ quadrangle, Fremont and Natrona Counties, Wyoming: Wyoming Geological Survey Map Series 61, scale 1:100,000.

Taylor, J., and Sonnenberg, S.A., 2014, Reservoir characterization of the Niobrara Formation, southern Powder River Basin, Wyoming: The Mountain Geologist, v. 51, no. 1, p. 83–108, accessed February 2, 2016, at http://archives.datapages.com/data/mountain-geologist-rmag/data/051/051001/83_rmag-mg510083.htm.

Williams, P., and Lyle, D., 2011, Bring in the rigs, *in* Estes-Jackson, J.E., and Anderson, D.S., eds., Revisiting and revitalizing the Niobrara in the central Rockies: Rocky Mountain Association of Geologists, p. 33–40.

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