



Vitrinite Reflectance Data for Cretaceous Marine Shales and Coals in the Bighorn Basin, North-Central Wyoming and South-Central Montana

By Mark J. Pawlewicz and Thomas M. Finn

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Introduction

The Bighorn Basin is a large Laramide (Late Cretaceous through Eocene) structural and sedimentary basin that encompasses about 10,400 square miles in north-central Wyoming and south-central Montana (fig. 1). The basin is bounded on the northeast by the Pryor Mountains, on the east by the Bighorn Mountains, and on the south by the Owl Creek Mountains (fig. 2). The north boundary, as defined in this report, includes a zone of faulting and folding referred to as the Nye-Bowler lineament (Wilson, 1936). The northwest and west margins are formed by the Beartooth Mountains and Absaroka Range, respectively (fig. 2).

Important conventional oil and gas resources have been discovered and produced from reservoirs ranging in age from Cambrian through Tertiary (Fox and Dolton, 1989; 1996a, b; De Bruin, 1993). In addition, a potential unconventional basin-centered gas accumulation may be present in Cretaceous reservoirs (Johnson and Finn, 1998; Johnson and others, 1999; Surdam and others, 1997; Finn and others, 2010). In recent years, advances and success in horizontal drilling and multi-stage fracture stimulation have led to an increase in exploration and completion of wells in marine shales in other Rocky Mountain Laramide basins that were traditionally thought of as hydrocarbon source rocks. Important parameters that control hydrocarbon production from these shales include: reservoir thickness, amount and type of organic matter, and thermal maturity (Milici, 1993; Curtis, 2002). The purpose of this report is to present new vitrinite reflectance data collected from Cretaceous marine shales and coals in the Bighorn Basin to better characterize the thermal maturity and petroleum potential of these rocks. These new data supplement previously published data by Hagen (1986), Nuccio and Finn (1998), Yin (1997), and Finn and Pawlewicz (2007).

Ninety-eight samples from Lower Cretaceous and lowermost Upper Cretaceous strata (fig. 3) were collected from well cuttings from wells stored at the U.S. Geological Survey (USGS) Core Research Center in Lakewood, Colorado. Sample locations are shown on figure 2. All samples were analyzed by vitrinite reflectance to determine levels of thermal maturation. Preparation of samples for reflectance analysis required (1) crushing the larger pieces into 0.25- to 1-millimeter pieces, (2) casting the pieces with epoxy in pre-cut and drilled plugs, and (3) curing the samples overnight. Subsequently, a four-step grinding and polishing process was implemented that included sanding with progressively finer sandpaper (60 to 600 grit) followed by a two-step polishing process (0.3 and 0.05 micron). Vitrinite reflectance measurements were determined at 500 X magnification using plane-polarized incident white light and a 546-nanometer monochromatic filter in immersion oil. For samples containing sufficiently high quality vitrinite, at least 25 measurements were recorded. For samples of poorer quality, either due to a poor polish or to the presence of mineral or other inorganic material, fewer measurements were recorded. Analytical results are given in table 1.

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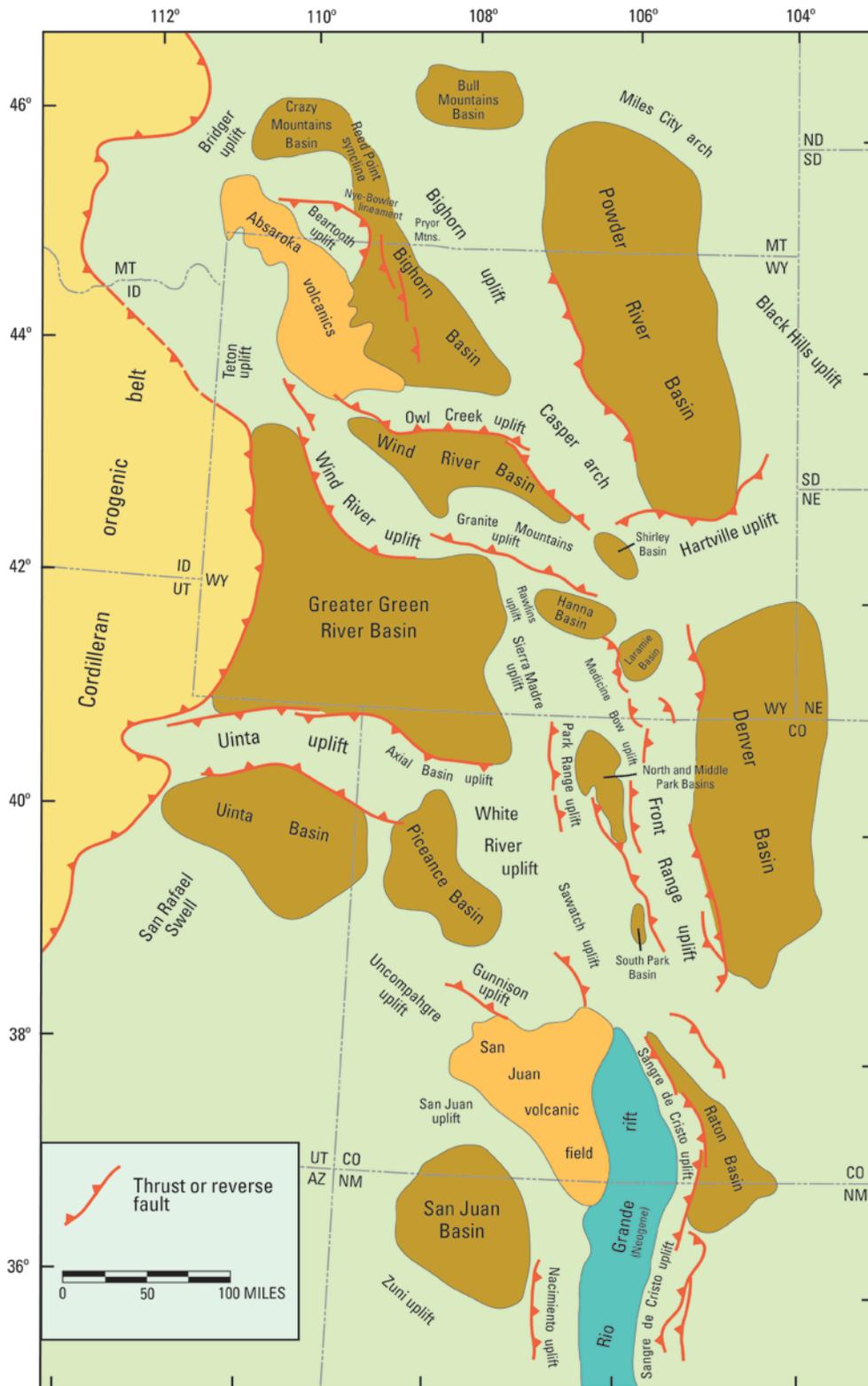


Figure 1. Map of the Rocky Mountain region extending from southern Montana to northern New Mexico showing locations of Laramide sedimentary and structural basins and intervening uplifts. Modified from Dickinson and others (1988).

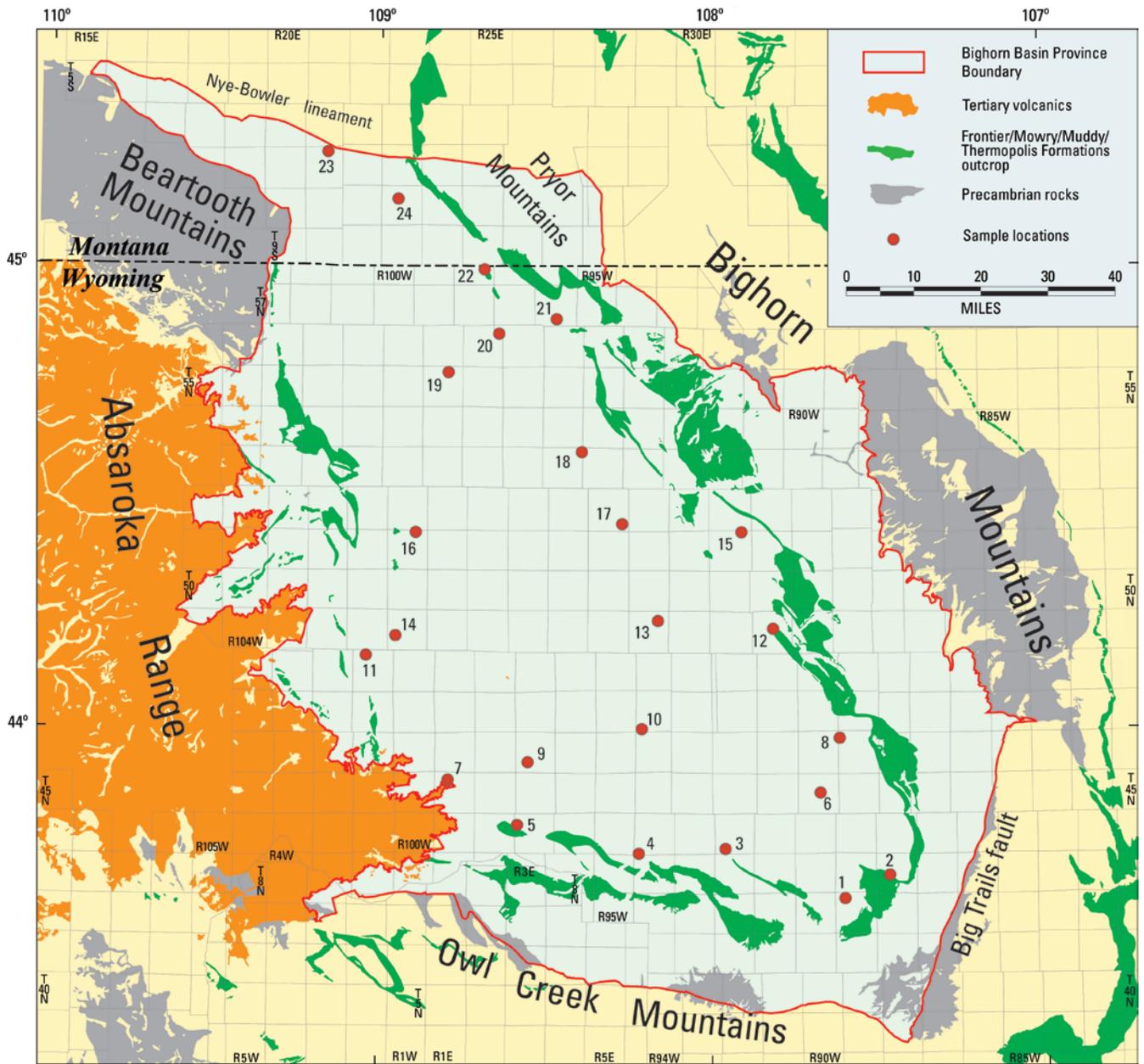


Figure 2. Map showing general outline of the Bighorn Basin, bordering mountain ranges, distribution of major rock units, and sample localities. Province boundary from Finn and others (2010). Outcrops from Green and Drouillard (1994), and Raines and Johnson (1995). Numbers refer to column 1 (location) in table 1.

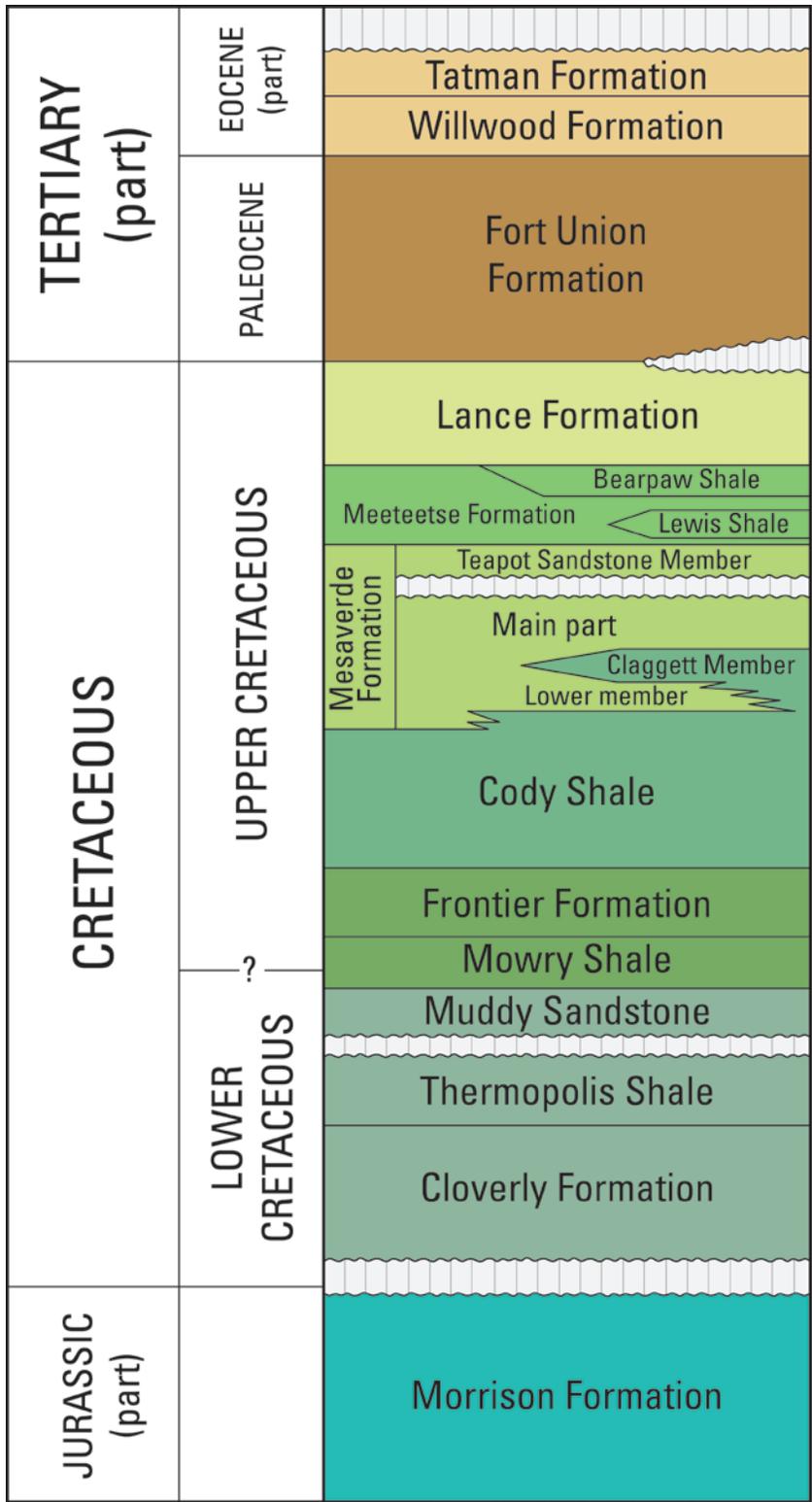


Figure 3. Generalized stratigraphic chart of uppermost Jurassic, Cretaceous, and lower Tertiary rocks in the Bighorn Basin.

Table 1. Vitrinite reflectance (Ro) data and locations for cuttings samples from wells drilled for oil and gas exploration and production in the Bighorn Basin, north-central Wyoming and south-central Montana. Map no. refers to sample location numbers shown on figure 2.

[API, well number assigned by American Petroleum Institute; Tnsp., township; Rng., range; Sec., section; Lith., lithology; %Ro, vitrinite reflectance measurement; n, number of readings per sample; nr, no reading. Queried (?) where uncertain. Depth is in feet.]

Map no.	API	Tnsp.	Rng.	Sec.	Operator	Well	Top depth	Bottom depth	Formation	Lith.	%Ro	n
1	49043050090000	42N	89W	5	Superior Oil	24-5 Unit Orchard	550	560	Cody	shale	0.49	2
1	49043050090000	42N	89W	5	Superior Oil	24-5 Unit Orchard	1,070	1,080	Frontier	shale	0.60	3
1	49043050090000	42N	89W	5	Superior Oil	24-5 Unit Orchard	1,820	1,830	Mowry	shale	0.61	6
1	49043050090000	42N	89W	5	Superior Oil	24-5 Unit Orchard	2,050	2,060	Thermopolis	shale	0.67	1
2	49043202510000	43N	88W	20	Ashland Exploration	1-20 Chabot-Govt.	300	360	Frontier	shale	0.45	4
2	49043202510000	43N	88W	20	Ashland Exploration	1-20 Chabot-Govt.	540	570	Mowry	shale	nr	
2	49043202510000	43N	88W	20	Ashland Exploration	1-20 Chabot-Govt.	720	750	Mowry	shale	nr	
2	49043202510000	43N	88W	20	Ashland Exploration	1-20 Chabot-Govt.	940	970	Thermopolis	shale	0.75	6
3	49043050610000	44N	92W	32	Continental Oil	1 Govt. Mann	360	370	Cody	shale	0.59	9
3	49043050610000	44N	92W	32	Continental Oil	1 Govt. Mann	1,080	1,090	Frontier	shale	0.73	11
3	49043050610000	44N	92W	32	Continental Oil	1 Govt. Mann	1,740	1,750	Mowry	shale	0.73	11
3	49043050610000	44N	92W	32	Continental Oil	1 Govt. Mann	2,010	2,020	Thermopolis	shale	0.97	9
4	49017200830000	44N	94W	31	Bagdad Oil	1 Lyke	250	280	Cody	shale	0.54	8
4	49017200830000	44N	94W	31	Bagdad Oil	1 Lyke	1,330	1,360	Mowry	shale	0.55	1
4	49017200830000	44N	94W	31	Bagdad Oil	1 Lyke	1,600	1,630	Thermopolis	shale	0.37	1
5	49017058630000	44N	97W	7	Westates Petroleum	2-7 Lewis	720	740	Frontier	shale	0.64	4
5	49017058630000	44N	97W	7	Westates Petroleum	2-7 Lewis	1,040	1,080	Mowry	shale	nr	
5	49017058630000	44N	97W	7	Westates Petroleum	2-7 Lewis	1,200	1,220	Mowry	shale	0.67	7
5	49017058630000	44N	97W	7	Westates Petroleum	2-7 Lewis	1,450	1,470	Thermopolis	shale	nr	

Table 1. Vitrinite reflectance (Ro) data and locations for cuttings samples from wells drilled for oil and gas exploration and production in the Bighorn Basin, north-central Wyoming and south-central Montana. Map no. refers to sample location numbers shown on figure 2.—Continued

[API, well number assigned by American Petroleum Institute; Tnsp., township; Rng., range; Sec., section; Lith., lithology; %Ro, vitrinite reflectance measurement; n, number of readings per sample; nr, no reading. Queried (?) where uncertain. Depth is in feet.]

Map no.	API	Tnsp.	Rng.	Sec.	Operator	Well	Top depth	Bottom depth	Formation	Lith.	%Ro	n
6	49043205120000	45N	90W	15	Pike Resources	1-15 Federal	4,780	4,810	Cody	shale	0.86	8
6	49043205120000	45N	90W	15	Pike Resources	1-15 Federal	6,100	6,120	Frontier	shale	0.97	1
6	49043205120000	45N	90W	15	Pike Resources	1-15 Federal	6,800	6,830	Mowry	shale	0.86	5
6	49043205120000	45N	90W	15	Pike Resources	1-15 Federal	7,040	7,060	Thermopolis	shale	0.93	7
7	49017206620000	45N	99W	5	Apache Corporation	5-16 Federal	3,180	3,210	Cody	shale	0.99	4
7	49017206620000	45N	99W	5	Apache Corporation	5-16 Federal	4,560	4,570	Frontier	shale	0.76	12
7	49017206620000	45N	99W	5	Apache Corporation	5-16 Federal	5,420	5,430	Mowry	shale	0.75	11
7	49017206620000	45N	99W	5	Apache Corporation	5-16 Federal	5,750	5,760	Thermopolis	shale	0.73	5
8	49043201380000	46N	89W	6	Chorney Oil	2 Shoal Unit	5,030	5,040	Frontier	shale	0.75	6
8	49043201380000	46N	89W	6	Chorney Oil	2 Shoal Unit	5,270	5,280	Frontier	shale	0.98	5
8	49043201380000	46N	89W	6	Chorney Oil	2 Shoal Unit	5,750	5,760	Mowry	shale	0.90	12
8	49043201380000	46N	89W	6	Chorney Oil	2 Shoal Unit	6,000	6,020	Thermopolis	shale	0.73	10
9	49017060990000	46N	97W	29	Midwest Oil	1 Gywnn Ranch	4,870	4,900	Cody	shale	0.98	9
9	49017060990000	46N	97W	29	Midwest Oil	1 Gywnn Ranch	6,230	6,250	Frontier	shale	1.07	9
9	49017060990000	46N	97W	29	Midwest Oil	1 Gywnn Ranch	6,950	6,970	Mowry	shale	0.97	12
9	49017060990000	46N	97W	29	Midwest Oil	1 Gywnn Ranch	7,250	7,280	Thermopolis	shale	1.05	8
10	49043203090000	47N	94W	31	National Coop	1-31 Federal	9,290	9,320	Cody	shale	nr	
10	49043203090000	47N	94W	31	National Coop	1-31 Federal	10,100	10,120	Cody	shale	1.16	14
10	49043203090000	47N	94W	31	National Coop	1-31 Federal	10,810	10,820	Frontier	shale	1.23	14
10	49043203090000	47N	94W	31	National Coop	1-31 Federal	11,460	11,480	Mowry	shale	1.36	12
10	49043203090000	47N	94W	31	National Coop	1-31 Federal	11,710	11,720	Thermopolis	shale	1.29	4

Table 1. Vitrinite reflectance (Ro) data and locations for cuttings samples from wells drilled for oil and gas exploration and production in the Bighorn Basin, north-central Wyoming and south-central Montana. Map no. refers to sample location numbers shown on figure 2.—Continued

[API, well number assigned by American Petroleum Institute; Tnsp., township; Rng., range; Sec., section; Lith., lithology; %Ro, vitrinite reflectance measurement; n, number of readings per sample; nr, no reading. Queried (?) where uncertain. Depth is in feet.]

Map no.	API	Tnsp.	Rng.	Sec.	Operator	Well	Top depth	Bottom depth	Formation	Lith.	%Ro	n
11	49029052770000	48N	101W	5	Heep Oil	Rawhide Unit 2	700	710	Cody	shale	nr	
11	49029052770000	48N	101W	5	Heep Oil	Rawhide Unit 2	1,760	1,770	Frontier	shale	0.84	1
11	49029052770000	48N	101W	5	Heep Oil	Rawhide Unit 2	2,530	2,540	Mowry	shale	0.71	3
11	49029052770000	48N	101W	5	Heep Oil	Rawhide Unit 2	2,850	2,860	Thermopolis	shale	0.52	4
12	49003051760000	49N	91W	15	Chandler & Simpson	1 Empire	580	600	Frontier	shale	0.37	8
12	49003051760000	49N	91W	15	Chandler & Simpson	1 Empire	790	820	Mowry	shale	0.51	9
12	49003051760000	49N	91W	15	Chandler & Simpson	1 Empire	1,000	1,030	Mowry	shale	0.56	8
12	49003051760000	49N	91W	15	Chandler & Simpson	1 Empire	1,230	1,260	Thermopolis	shale	nr	
12	49003051760000	49N	91W	15	Chandler & Simpson	1 Empire	1,430	1,450	Cloverly	shale	0.66	6
13	49003204660000	49N	94W	11	Excel Energy	1-11 Dobie Creek	8,550	8,570	Cody	shale	1.07	9
13	49003204660000	49N	94W	11	Excel Energy	1-11 Dobie Creek	9,790	9,820	Frontier	shale	1.12	7
13	49003204660000	49N	94W	11	Excel Energy	1-11 Dobie Creek	10,460	10,500	Mowry	shale	1.14	10
13	49003204660000	49N	94W	11	Excel Energy	1-11 Dobie Creek	10,730	10,740	Thermopolis	shale	1.21	7
14	49029207390000	49N	100W	20	Panther Exploration	2 Bar TL	4,380	4,410	Cody	shale	1.25	7
14	49029207390000	49N	100W	20	Panther Exploration	2 Bar TL	5,290	5,300	Frontier	shale	1.19	4
14	49029207390000	49N	100W	20	Panther Exploration	2 Bar TL	6,140	6,160	Mowry	shale	0.98	15
14	49029207390000	49N	100W	20	Panther Exploration	2 Bar TL	6,510	6,540	Thermopolis	shale	1.26	7
15	49003055300000	51N	92W	2	Amerada	1 White Sheep	540	550	Cody	shale	0.63	4
15	49003055300000	51N	92W	2	Amerada	1 White Sheep	1,070	1,080	Frontier	shale	0.64	16
15	49003055300000	51N	92W	2	Amerada	1 White Sheep	1,690	1,700	Mowry	shale	0.76	5
15	49003055300000	51N	92W	2	Amerada	1 White Sheep	1,960	1,970	Thermopolis	shale	0.78	1

Table 1. Vitrinite reflectance (Ro) data and locations for cuttings samples from wells drilled for oil and gas exploration and production in the Bighorn Basin, north-central Wyoming and south-central Montana. Map no. refers to sample location numbers shown on figure 2.—Continued

[API, well number assigned by American Petroleum Institute; Tnsp., township; Rng., range; Sec., section; Lith., lithology; %Ro, vitrinite reflectance measurement; n, number of readings per sample; nr, no reading. Queried (?) where uncertain. Depth is in feet.]

Map no.	API	Tnsp.	Rng.	Sec.	Operator	Well	Top depth	Bottom depth	Formation	Lith.	%Ro	n
16	49029210090000	51N	100W	2	Hunt/Impel	1 Katrine Loch	18,760	18,770	Cody	shale	1.86	7
16	49029210090000	51N	100W	2	Hunt/Impel	1 Katrine Loch	19,530	19,540	Frontier	shale	1.72	2
16	49029210090000	51N	100W	2	Hunt/Impel	1 Katrine Loch	20,300	20,310	Mowry	shale	2.10	11
16	49029210090000	51N	100W	2	Hunt/Impel	1 Katrine Loch	20,620	20,630	Thermopolis	shale	1.85	5
17	49003203160000	52N	95W	26	Gulf Oil	1 Otto Federal	9,950	9,960	Cody	shale	1.05	11
17	49003203160000	52N	95W	26	Gulf Oil	1 Otto Federal	11,330	11,360	Frontier	shale	1.34	10
17	49003203160000	52N	95W	26	Gulf Oil	1 Otto Federal	11,900	11,910	Mowry	shale	1.36	9
17	49003203160000	52N	95W	26	Gulf Oil	1 Otto Federal	12,140	12,150	Thermopolis	shale	1.43	15
18	49003057770000	53N	96W	1	Sinclair Oil & Gas	1 Govt.	9,200	9,220	Cody	shale	0.55	21
18	49003057770000	53N	96W	1	Sinclair Oil & Gas	1 Govt.	10,250	10,280	Frontier	shale	1.52	12
18	49003057770000	53N	96W	1	Sinclair Oil & Gas	1 Govt.	10,940	10,970	Mowry	shale	1.23	20
18	49003057770000	53N	96W	1	Sinclair Oil & Gas	1 Govt.	11,270	11,290	Thermopolis	shale	1.67	14
19	49029058940000	55N	99W	3	Tidewater Oil	1 Atteberry	8,520	8,540	Cody	shale	1.26	6
19	49029058940000	55N	99W	3	Tidewater Oil	1 Atteberry	9,500	9,510	Frontier	shale	1.00	7
19	49029058940000	55N	99W	3	Tidewater Oil	1 Atteberry	10,450	10,470	Mowry	shale	1.30	4
19	49029058940000	55N	99W	3	Tidewater Oil	1 Atteberry	10,700	10,710	Thermopolis	shale	1.26	8
20	49029059970000	56N	98W	1	C.E. Brehm	1 Deaton Govt.	2,840	2,860	Frontier	shale	0.63	3
20	49029059970000	56N	98W	1	C.E. Brehm	1 Deaton Govt.	3,240	3,260	Frontier	shale	0.63	11
20	49029059970000	56N	98W	1	C.E. Brehm	1 Deaton Govt.	3,780	3,800	Mowry	shale	0.53	6
20	49029059970000	56N	98W	1	C.E. Brehm	1 Deaton Govt.	4,170	4,200	Thermopolis	shale	0.90	6

Table 1. Vitrinite reflectance (Ro) data and locations for cuttings samples from wells drilled for oil and gas exploration and production in the Bighorn Basin, north-central Wyoming and south-central Montana. Map no. refers to sample location numbers shown on figure 2.—Continued

[API, well number assigned by American Petroleum Institute; Tnsp., township; Rng., range; Sec., section; Lith., lithology; %Ro, vitrinite reflectance measurement; n, number of readings per sample; nr, no reading. Queried (?) where uncertain. Depth is in feet.]

Map no.	API	Tnsp.	Rng.	Sec.	Operator	Well	Top depth	Bottom depth	Formation	Lith.	%Ro	n
21	49003205680000	57N	96W	27	Forest Oil	1 Stevens	830	840	Mowry	shale	0.58	7
21	49003205680000	57N	96W	27	Forest Oil	1 Stevens	1,100	1,130	Mowry	shale	0.61	4
21	49003205680000	57N	96W	27	Forest Oil	1 Stevens	1,400	1,430	Thermopolis	shale	0.66	7
21	49003205680000	57N	96W	27	Forest Oil	1 Stevens	1,550	1,560	Cloverly	shale	nr	
22	49029065930000	58N	98W	23	Continental	6 Pacific	900	930	Frontier	shale	nr	
22	49029065930000	58N	98W	23	Continental	6 Pacific	1,090	1,110	Mowry	shale	0.67	2
22	49029065930000	58N	98W	23	Continental	6 Pacific	1,230	1,250	Mowry	shale	0.80	10
23	25009051910000	7S	21E	3	Ohio Oil Company	18 N.P.	2,900	2,910	lower Mesaverde	coal	0.60	25
23	25009051910000	7S	21E	3	Ohio Oil Company	18 N.P.	3,520	3,570	Cody	coal?	0.55	25
23	25009051910000	7S	21E	3	Ohio Oil Company	18 N.P.	4,120	4,155	Frontier	coal/carb	0.55	21
23	25009051910000	7S	21E	3	Ohio Oil Company	18 N.P.	4,990	5,010	Mowry	shale	0.58	2
23	25009051910000	7S	21E	3	Ohio Oil Company	18 N.P.	5,360	5,380	Thermopolis	shale	0.54	25
24	25009211550000	8S	23E	9	Arco	1 Hunt Creek	2,610	2,640	lower Mesaverde	coal	0.54	11
24	25009211550000	8S	23E	9	Arco	1 Hunt Creek	3,600	3,630	Cody	shale	0.87	4
24	25009211550000	8S	23E	9	Arco	1 Hunt Creek	4,500	4,520	Frontier	coal/carb	0.55	27
24	25009211550000	8S	23E	9	Arco	1 Hunt Creek	5,310	5,330	Mowry	shale	0.74	6
24	25009211550000	8S	23E	9	Arco	1 Hunt Creek	5,730	5,750	Thermopolis	shale	0.87	4