Wyoming Geo-notes
Number 76

In this issue:

Wyoming State Geological Survey
Lance Cook, State Geologist

Laramie, Wyoming
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Featured Articles

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WYOMING GEO-NOTES: This quarterly digest on the state's geology, mineral resources, and activities of the Wyoming State Geological Survey is available by subscription (four issues for $15.00) or as single copies at $5.00 each. Two-year subscriptions are accepted.

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****Please note: all email addresses for WSGS staff have changed; the new addresses are included on the back cover.**

Richard W. Jones,
Wyoming PG-2972
Editor

Jaime R. Moulton
Layout and design

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Front cover: A tethered, helium-filled blimp was used to photograph the Yellow Brick Road Dinosaur Tracksite near Shell, Wyoming. The 6-meter long blimp, equipped with both still and video cameras, enabled researchers to locate, measure, and plot trends in the dinosaur tracks from directly overhead. The Bighorn Mountains are on the skyline, with Shell Canyon located approximately below the cameras on the blimp. Authors of the article that appears on pages 28 to 32 of this issue of *Wyoming Geo-notes* are in this photograph. Thomas Adams is directly below the blimp and Brent Breithaupt is farthest right. Photograph by Alan J. Ver Ploeg.

MINERALS UPDATE

Overview

Lance Cook, Wyoming PG-2577

State Geologist, Wyoming State Geological Survey

This issue of *Wyoming Geo-notes* includes updated mineral production and price forecasts from the State of Wyoming's Consensus Revenue Estimating Group (CREG) made in October, 2002 and January, 2003. Natural gas (methane), oil, and coal production forecasts have been revised upward from previous estimates while production forecasts for mined trona and *in situ* uranium were revised downward (**Table 1**). In the latter part of 2002, mineral commodity prices strengthened in the energy sector; coal and crude oil price forecasts have increased slightly (**Table 2**). Despite the increases in natural gas prices shown in the latter part of 2002 (see the **Oil and Gas Update** for details), the CREG estimate for 2002 was reduced slightly to $2.00 per thousand cubic feet (MCF). Hopefully, the estimate for 2003 will be higher than the predicted $2.00 per MCF.

While the oil and coal prices in the CREG estimates may seem conservative, there are several risk factors that must be considered. Crude oil prices are currently being driven by market uncertainties surrounding political unrest in Venezuela and the myriad uncertainties surrounding war in the Middle East. Oil prices are moving upwards on the short term, influenced by increased demand from a colder than expected winter in the high population regions of the U.S. Prices for Wyoming coal are moving upwards in 2002 as demand increased in the late summer and fall, reducing stockpiles that then had to be replenished for the winter months (see **Coal Update** for details).

Natural gas prices are also being driven upwards by a number of factors. The rapid withdrawal of natural gas from storage during the cold winter months is causing some concern. These immediate market forces, coupled with longer-term concerns about declining deliverabilities from the major gas-producing states (Texas, New Mexico, Kansas, and Oklahoma) have combined to radically change the longer-term outlook for Wyoming's natural gas. Although we continue to suffer from an adverse pricing differential in

Table 1. Wyoming mineral production (1987 through 2001) with forecasts to 2008[1].

Calendar Year	Oil[2,3]	Methane[3,4]	Carbon Dioxide[3,4]	Helium[4,5]	Coal[6]	Trona[7]	*In situ* Uranium[8]
1987	115.9	628.2	114.2	0.86	146.5	12.4	0.00
1988	114.3	700.8	110.0	0.83	163.6	15.1	0.09
1989	109.1	739.0	126.1	0.94	171.1	16.2	1.1
1990	104.0	777.2	119.9	0.90	184.0	16.2	1.0
1991	99.8	820.0	140.3	1.05	193.9	16.2	1.0
1992	97.0	871.5	139.2	1.05	189.5	16.4	1.2
1993	89.0	912.8	140.8	1.06	209.9	16.0	1.2
1994	80.2	959.2	142.6	1.07	236.9	16.1	1.2
1995	75.6	987.5	148.8	1.11	263.9	18.4	1.3
1996	73.9	1023.4	149.0	1.10	278.4	18.6	1.9
1997	70.2	1040.7	151.0	1.10	281.5	19.4	2.2
1998	65.7	1072.6	151.0	1.10	315.0	18.6	2.3
1999	61.3	1133.1	161.0	1.10	336.5	17.8	2.8
2000	60.6	1293.3	161.0	1.10	338.9	17.8	2.1
2001	57.5	1437.6	174.0	1.20	368.8	17.7	1.6
2002	54.2	1524.8	174.0	1.20	373.0	18.0	1.7
2003	51.2	1602.8	196.0	1.20	380.0	18.0	1.7
2004	48.4	1682.8	196.0	1.20	384.3	18.0	1.6
2005	45.7	1762.8	196.0	1.20	388.1	18.5	1.6
2006	43.2	1842.8	196.0	1.20	392.0	18.5	1.6
2007	40.8	1922.8	196.0	1.20	395.9	18.5	1.5
2008	38.6	2002.8	196.0	1.20	399.9	18.5	1.5

[1]From CREG's Wyoming State Government Revenue Forecast, October, 2002 and January, 2003; [2]Millions of barrels; [3]Wyoming Oil and Gas Conservation Commission, 1987 through 2001; [4]Billions of cubic feet, estimates for methane include coalbed methane; [5]Based on ExxonMobil's estimate that the average helium content in the gas processed at La Barge is 0.5%; [6]Millions of short tons (Wyoming State Inspector of Mines, 1987 through 2001); [7]Millions of short tons (Wyoming Department of Revenue, 1987 through 2001; Wyoming State Inspector of Mines, 2001); [8]Millions of pounds of yellowcake (Wyoming Department of Revenue, 1987 through 1999; Wyoming State Inspector of Mines, 2000 and 2001).

Table 2. Average prices paid for Wyoming oil, methane, coal, and trona (1987 through 2001) with forecasts to 2008[1].

Calendar Year	Oil[2]	Methane[3]	Coal[4]	Trona[5]
1987	16.42	1.78	9.80	36.56
1988	13.43	1.43	9.16	36.88
1989	16.71	1.58	8.63	40.76
1990	21.08	1.59	8.43	43.70
1991	17.33	1.46	8.06	44.18
1992	16.38	1.49	8.13	43.81
1993	14.50	1.81	7.12	40.08
1994	13.67	1.63	6.62	38.96
1995	15.50	1.13	6.38	40.93
1996	19.56	1.46	6.15	45.86
1997	17.41	1.94	5.78	42.29
1998	10.67	1.81	5.41	41.29
1999	16.44	2.06	5.19	38.49
2000	26.87	3.42	5.40	37.28
2001	21.59	3.66	5.75	38.00
2002	22.00	2.00	5.90	38.00
2003	20.00	2.00	5.90	38.00
2004	18.00	2.25	5.97	38.00
2005	18.00	2.25	6.04	38.00
2006	18.00	2.25	6.12	38.00
2007	18.00	2.25	6.20	38.00
2008	18.00	2.25	6.28	38.00

[1]From CREG's Wyoming State Government Revenue Forecast, October, 2002 and January, 2003; [2]First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Source: Energy Information Administration, 1987-2001; [3]Wellhead price in dollars per thousand cubic feet (MCF), includes coalbed methane. Source: American Association, 1998-2001; Wyoming Office of State Lands and Investments, 1989-2001 (derived from State royalty payments); and Minerals Management Service, 1987-1988 (derived from Federal royalty payments); [4]Dollars per short ton (weighted average price for coal mined by surface and underground methods). Source: Energy Information Administration, 1987-1990 and derived from Department of Revenue, 1991-2001; [5]Dollars per ton of trona, not soda ash. Source Wyoming Department of Revenue, 1987-2001.

Wyoming due to transportation issues, we have probably seen the bottom of natural gas prices for some time to come. The CREG estimates for future years may even be on the conservative side.

Coalbed methane (CBM) continues to be the brightest star in Wyoming's natural gas industry, not only in the Powder River Basin (PRB), but in nearly all the state's other coal fields as well (see **Coalbed Methane Update**). The PRB Oil and Gas Environmental Impact Statement has been released in final form. The U.S. Bureau of Land Management (BLM) should issue a record of decision in March, 2003, which will set the scene for legal challenges and maneuvers to delay resumption of federal well permitting in the PRB CBM play. If federal well permitting resumes in the spring, the CBM play should resume increased production rates. The end of 2002 saw a daily production rate of almost 1 billion cubic feet of gas per day from this play, or about 1.5% of total U.S. natural gas demand.

The CREG estimates for trona production have been revised slightly downward after showing a slight rebound from 2001 (**Table 1**) although forecast prices appear to be stabilizing (**Table 2**). Production of most other industrial minerals is going to increase in 2002 but *in situ* uranium production continues to decline (see **Industrial Minerals and Uranium Update**).

The issue of concurrent development of trona and natural gas has moved back onto center stage. The Joint Interest Committee (JIC), who was charged with investigating this issue, has had their report reviewed and updated by outside contractors. The BLM has been working with Anadarko Petroleum, the largest landowner in the Union Pacific Railroad strip, and the State of Wyoming to formulate a plan to deal with the recommendation of the JIC. The likely outcome will be a partial closure of the Known Sodium Leasing Area (KSLA) for deep gas drilling to protect the trona miners and their industry. The remaining area may be opened to gas leasing and drilling, subject to the Oil and Gas Conservation Commission's Special Sodium Drilling Area rules. Once the BLM has formally announced their proposal, we will publish a map showing outlines of the various areas.

As seen on the cover of this issue of *Wyoming Geo-notes*, we are publishing the first article in a two-part series on the Middle Jurassic dinosaur track site identified on a State section in the northeastern Bighorn Basin. This first article discusses the methodology and types of documentation used in studying this site. The site contains evidence of terrestrial deposition in a dominantly marine sequence as well as evidence of the existence of dinosaurs in this part of Wyoming during this time.

This issue of *Wyoming Geo-notes* describes the continued exploration for platinum-group metals in southeastern Wyoming in response to rising prices and increased demand. The interest in gold continued as prices for this element continued to rise (see **Metals and Precious Stones Update**). Finally, in the **Geologic Mapping, Paleontology, and Stratigrapy Update**, the National Park Service (NPS) announced a new, detailed mapping program for the area around Fossil Butte National Monument. The Wyoming State Geological Survey has agreed to review and publish 12 quadrangle maps of the area in support of the NPS objective to develop a more complete geologic story of the fossil-rich Green River Formation in Fossil Basin.

Oil and Gas Update

Rodney H. De Bruin, Wyoming PG-3045

Senior Staff Geologist—Oil and Gas, Wyoming State Geological Survey

Wyoming oil and gas producers received higher prices for oil and lower prices for natural gas in the third quarter of 2002 compared to prices received during the third quarter of 2001. Oil production declined 5.2% while natural gas production increased 6.9% during the first nine months of 2002 when compared to the same period in 2001. Natural gas production for the first three quarters of 2002 was again boosted by a large increase in coalbed methane (CBM) production in the Powder River Basin (PRB), which made up 18.8% of Wyoming's total gas production. Without a 59.0 billion cubic feet (BCF) increase in CBM production during the first nine months of 2002 when compared to the first nine months of 2001, Wyoming's natural gas production would have increased only 23.8 BCF, rather than an increase of 82.8 BCF. The new oil and gas projections by the Consensus Revenue Estimating Group (CREG) for the State of Wyoming were made in October, 2002 and revised slightly in January, 2003. These projections showed increases in natural gas production and oil prices and decreases in natural gas prices (**Tables 1** and **2**) from previous projections (see *Wyoming Geo-notes No. 75*, December, 2002, p. 1). Oil production is projected to decline, but slightly less than in the previous CREG estimate (**Table 1**).

A major expansion of the Kern River Pipeline System broke ground in the third quarter and is scheduled for completion in May, 2003. This expansion should help Wyoming natural gas producers obtain higher prices than they would receive without the expansion and may help alleviate the large differential that presently exists between Opal prices and Henry Hub prices. In the third quarter, one federal lease sale brought in $858,686. The average price per acre at that

sale was only $9.68. The number of applications for permit to drill remained healthy, although lower than for the third quarter of 2001, while geophysical activity was slightly lower. The average rig count in the third quarter of 2002 was 22 less than for the same period last year, although still higher than expected considering the very low price for natural gas so far this year.

Prices and production

Prices paid to Wyoming oil producers during the third quarter of 2002 averaged $24.34 per barrel, $1.59 higher than for the third quarter of 2001, and $1.94 higher than for the second quarter of 2002 (**Table 3**). Over the last three years, the average monthly price for Wyoming crude oil has been over $20 per barrel for all but five months. The new CREG estimates project that the average price per barrel will be $22 for all of 2002, $20 for all of 2003, and will stabilize around $18 thereafter (**Figure 1**). The posted sweet and sour crude oil prices and first purchase price for Wyoming oil averaged by month shows the gradual rebound in oil prices from about a year ago (**Figure 2**).

Oil production reported by the Wyoming Oil and Gas Conservation Commission (WOGCC) for the first nine months of 2002 was about 41.0 million barrels (**Table 4**), a drop of about 5.1% from production for the same period in 2001. The new CREG estimates show an annual decrease in oil production of about 5.5% (**Figure 3**).

Spot prices for natural gas at Opal, Wyoming averaged $1.35 per thousand cubic feet (MCF) during the third quarter of 2002, $0.78 per MCF lower than the average price for the third quarter of 2001, and $0.90 per MCF lower than for the second quarter of 2002 (**Table 5** and **Figure 4**). The new CREG estimates for Wyoming natural gas prices are $2.00 per MCF for 2002 and 2003 and $2.25 for 2004 and beyond (**Figure 5**).

Natural gas production in Wyoming for the first nine months of 2002 was about 1.3 trillion cubic feet (TCF), according to production figures from the WOGCC. Production is up 6.9% from the first nine months of 2001 (**Table 6**). CBM production from the PRB accounted for 239.6 BCF of that total and 18.8% of Wyoming's natural gas production through three quarters of 2002. CBM production in the PRB is now approaching one BCF per day and now accounts for over 20% of Wyoming's natural gas production on a monthly basis. According to the January, 2003 CREG estimates, natural gas production is expected to increase each of the next six years, with CBM accounting for most of the increase in the next two years and all of the increase the following four years

Table 3. Monthly average price of a barrel of oil produced in Wyoming (1998 through December, 2002).

	1998		1999		2000		2001		2002	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	$12.79	$12.79	$9.30	$9.30	$24.01	$24.01	$24.62	$24.62	$15.70	$15.70
February	$12.16	$12.47	$9.09	$9.20	$26.48	$25.25	$24.82	$24.72	$16.63	$16.17
March	$10.97	$11.97	$11.77	$10.05	$27.24	$25.91	$22.71	$24.05	$20.64	$17.66
April	$11.54	$11.87	$14.34	$11.12	$22.92	$25.16	$22.85	$23.75	$22.63	$18.90
May	$11.19	$11.73	$15.16	$11.93	$26.06	$25.34	$23.68	$23.74	$22.86	$19.69
June	$9.63	$11.38	$15.36	$12.50	$28.31	$25.84	$22.99	$23.61	$21.71	$20.03
July	$10.20	$11.21	$17.39	$13.20	$27.12	$26.02	$22.55	$23.46	$23.29	$20.49
August	$9.58	$11.01	$18.43	$13.86	$28.18	$26.29	$23.67	$23.49	$24.27	$20.97
September	$11.19	$11.03	$20.97	$14.65	$30.22	$26.73	$22.02	$23.32	$25.47	$21.47
October	$11.04	$11.03	$20.01	$15.18	$28.75	$26.93	$17.71	$22.76	$24.27	$21.75
November	$9.64	$10.90	$22.20	$15.82	$29.63	$27.17	$16.44	$22.19	**$21.75**	**$21.75**
December	$8.05	$10.67	$23.22	$16.44	$23.60	$26.88	$14.86	$21.58	**$24.75**	**$22.00**
Average yearly price		**$10.67**		**$16.44**		**$26.88**		**$21.58**		**$22.00**

All averages are derived from published monthly reports by the Energy Information Administration, except that averages in bold print in 2002 are estimated from various unpublished bulletins listing posted prices. *Wyoming State Geological Survey, Oil and Gas Section, January, 2003.*

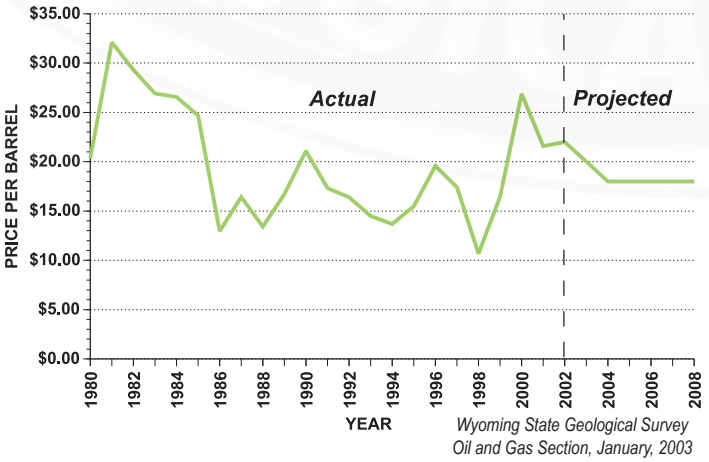

Figure 1. Average prices paid for Wyoming crude oil (1980 through 2002) with forecasts to 2008.

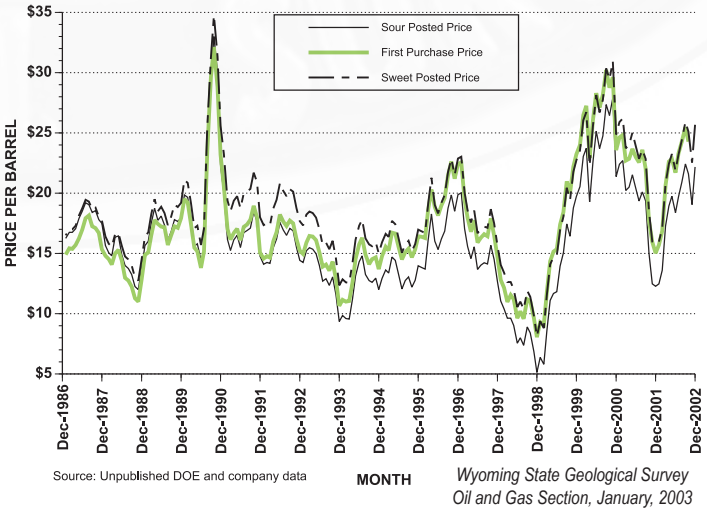

Figure 2. Wyoming posted sweet and sour crude oil prices and first purchase prices, averaged by month (January, 1987 through December, 2002).

Table 4. Monthly oil production from Wyoming in barrels (1998 through October, 2002).

	1998		1999		2000		2001		2002	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	5,846,364	5,846,364	5,333,257	5,333,257	5,185,683	5,185,683	5,001,928	5,001,928	4,709,652	4,709,652
February	5,233,502	11,079,866	4,744,527	10,077,784	4,871,733	10,057,416	4,493,565	9,495,493	4,238,310	8,947,962
March	5,759,176	16,839,042	5,297,674	15,375,458	5,202,533	15,259,949	4,969,821	14,465,314	4,627,788	13,575,750
April	5,534,568	22,373,610	5,065,591	20,441,049	5,003,812	20,263,761	4,802,352	19,267,666	4,557,602	18,133,352
May	5,626,125	27,999,735	5,200,031	25,641,080	5,201,564	25,465,325	4,930,856	24,198,522	4,686,559	22,819,911
June	5,335,463	33,335,198	5,000,039	30,641,119	5,001,932	30,467,257	4,664,829	28,863,351	4,489,540	27,309,451
July	5,464,514	38,799,712	5,164,705	35,805,824	5,077,548	35,544,805	4,846,220	33,709,571	4,590,797	31,900,248
August	5,287,415	44,087,127	5,190,052	40,995,876	5,093,558	40,638,363	4,761,492	38,471,063	4,619,502	36,519,750
September	5,109,053	49,196,180	5,081,384	46,077,260	4,983,126	45,621,489	4,718,493	43,189,556	4,464,591	40,984,341
October	5,274,269	54,470,449	5,163,165	51,240,425	5,156,755	50,778,244	4,821,224	48,010,780	4,528,233	45,512,574
November	5,232,287	59,702,736	5,010,985	56,251,410	4,877,512	55,655,756	4,645,045	52,655,825		
December	5,078,909	64,781,645	5,090,959	61,342,369	4,970,686	60,626,442	4,744,316	57,400,141		
Total Barrels Reported[1]		**64,781,645**		**61,342,369**		**60,626,442**		**57,400,141**		
Total Barrels not Reported[2]		**897,131**								
Total Barrels Produced[3]		**65,678,776**								

[1]Monthly production reports for 1998 from Petroleum Information/Dwights LLC.; 1999 through October, 2002 are from Wyoming Oil and Gas Conservation Commission; [2](Total barrels produced) minus (total barrels reported by Petroleum Information/Dwights LLC.); [3]Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, January, 2003.*

Table 5. Monthly average spot sale price for a thousand cubic feet (MCF) of natural gas at Opal, Wyoming (1998 through December, 2002).

	1998		1999		2000		2001		2002	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	$2.05	$2.05	$1.80	$1.80	$2.20	$2.20	$8.75	$8.75	$2.35	$2.35
February	$1.70	$1.88	$1.65	$1.73	$2.40	$2.30	$6.60	$7.68	$1.75	$2.05
March	$1.90	$1.88	$1.50	$1.65	$2.35	$2.32	$4.90	$6.75	$2.00	$2.03
April	$1.90	$1.89	$1.60	$1.64	$2.70	$2.41	$4.55	$6.20	$2.85	$2.24
May	$1.95	$1.90	$2.00	$1.71	$2.70	$2.47	$4.10	$5.78	$2.30	$2.25
June	$1.65	$1.86	$2.00	$1.76	$3.65	$2.67	$2.60	$5.25	$1.60	$2.14
July	$1.60	$1.82	$2.00	$1.79	$3.90	$2.84	$2.05	$4.79	$1.25	$2.01
August	$1.75	$1.81	$2.20	$1.84	$3.10	$2.88	$2.25	$4.48	$1.60	$1.96
September	$1.60	$1.79	$2.60	$1.93	$3.40	$2.93	$2.10	$4.21	$1.20	$1.88
October	$1.65	$1.78	$2.40	$1.98	$4.30	$3.07	$1.25	$3.92	$2.04	$1.89
November	$2.00	$1.80	$2.85	$2.05	$4.35	$3.19	$2.60	$3.80	$3.04	$2.00
December	$2.00	$1.81	$2.10	$2.06	$6.00	$3.42	$2.15	$3.66	$3.08	$2.09
Average yearly price		**$1.81**		**$2.06**		**$3.42**		**$3.66**		**$2.09**

Source: American Gas Association's monthly reports. *Wyoming State Geological Survey, Oil and Gas Section, January, 2003.*

(**Figure 6**). Production of CBM in Wyoming is predicted to average a 15% increase each year over this six-year period and by 2006 will account for over one-third of the state's natural gas production.

Reports, projects, and transactions

The U.S. Energy Information Administration (EIA) released its new reserve estimates for crude oil, natural gas, and natural gas liquids in the U.S. Among the top ten states at the end of 2001, Wyoming ranked second in dry natural gas reserves, third in natural gas liquids reserves, and seventh in crude oil reserves (**Table 7**). Wyoming had the largest increase in proved reserves of natural gas with 2.24 TCF of additions (**Table 8**) and placed the state ahead of New Mexico for the first time. Colorado had the second largest increase in proved reserves with 2.1 TCF of additions. Texas, with 1.45 TCF of additions, was the only other state that had an increase greater than one TCF. Wyoming's increase came from an additional 757 BCF in proved CBM reserves in the PRB, and from successful development drilling on the

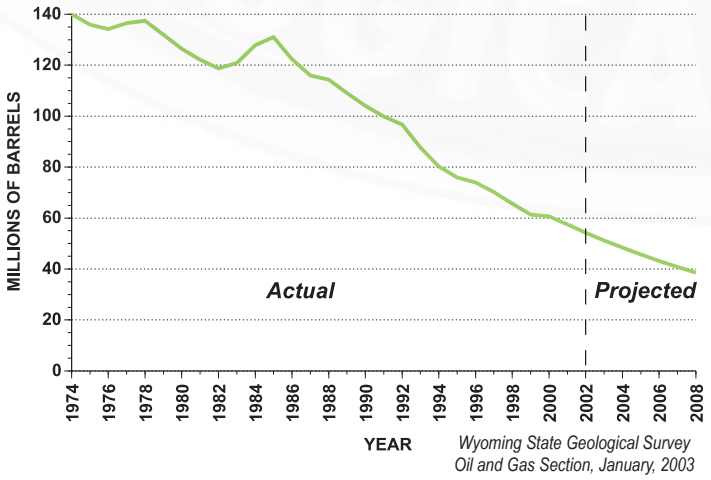

Figure 3. Annual crude oil production from Wyoming (1974 through 2002) with forecasts to 2008.

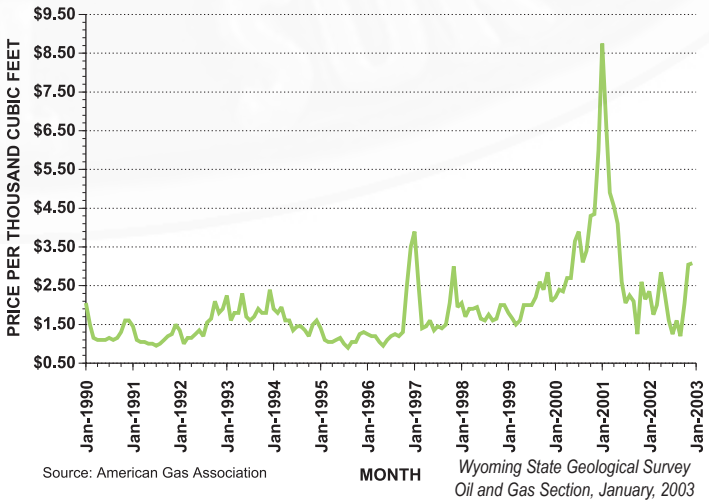

Figure 4. Spot sale prices for methane at Opal, Wyoming, averaged by month (January, 1990 through December, 2002).

CALENDAR OF EVENTS

Talks

HINTS FOR GOLD PROSPECTING–*W.D. Hausel*: Cheyenne Chapter of Gold Prospectors of America, Cheyenne, Wyoming, January 7, 2003, 7 pm.

GEOLOGY AND GEOCHEMISTRY OF GOLD MINERALIZATION AT SOUTH PASS, WYOMING–*W.D. Hausel*: Rock Springs SME Chapter, March 19, 2003, 7 pm.

CORDIERITE AND CORUNDUM IN WYOMING—NEW GEMSTONES FOR THE COWBOY STATE–*W.D. Hausel*: Industrial Minerals Forum, Sparks, Nevada, May 21, 2003.

Meetings, conferences, exhibits, etc.

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS (AAPG) 2003 ANNUAL MEETING–*various WSGS staff*: Salt Palace Convention Center, Salt Lake City, Utah, May 11-14, 2003.

INDUSTRIAL MINERALS FORUM 2003 ANNUAL MEETING–*various WSGS staff*: John Ascuaga's Nugget, Reno-Sparks-Tahoe, Nevada, May 18-24, 2003.

AMERICAN ASSOCIATION OF STATE GEOLOGISTS (AASG)-U.S. GEOLOGICAL SURVEY (USGS) WORKSHOP ON DIGITAL MAPPING TECHNIQUES–*P.A. Ranz*: Millersville, Pennsylvania, June 1-4, 2003.

EIGHTH INTERNATIONAL KIMBERLITE CONFERENCE–*W.D. Hausel*: Vancouver, British Columbia, Canada, June 22-27, 2003.

WYOMING GEOLOGICAL ASSOCIATION FIELD CONFERENCE–*various WSGS staff*: Casper, Wyoming, September 7-12, 2003.

DENVER GEM AND MINERAL SHOW–*various WSGS staff*: Denver Merchandise Mart, Denver, Colorado, September 12-14, 2003.

GEOLOGICAL SOCIETY OF AMERICA (GSA) 2003 ANNUAL MEETING–*R.W. Jones and L. Cook*: Washington State Convention and Trade Center, Seattle, Washington, November 2-5, 2003.

ASSOCIATION OF EARTH SCIENCE EDITORS (AESE) ANNUAL MEETING–*R.W. Jones*: Seattle, Washington, November 1-3, 2003.

Field Trips

KIMBERLITE AND LAMPROITES OF COLORADO AND WYOMING, USA–*H. Coopersmith, R. Motten, and W.D. Hausel*: 8th International Kimberlite Conference, June 16-21, 2003 (for more information see http://www.venuewest.com/8IKC/ftinfo.htm).

Pinedale anticline (northern Green River Basin) and in the Madison Limestone at Madden Field (Wind River Basin). The increase in Wyoming's reserves came despite production of over 1.6 TCF of natural gas in 2001.

Wyoming's proved reserves of crude oil once again slipped, placing Wyoming seventh among the states (**Table 7**), but two enhanced oil projects announced by Anadarko in 2002 should help slow down or possibly reverse the decline in reserves. The EIA also revised Wyoming's proved reserves of natural gas liquids downward (**Table 8**), but Wyoming still managed to stay in third place among the states (**Table 7**).

The U.S. Bureau of Land Management (BLM) issued a Finding Of No Significant Impact (FONSI) for an extensive 3-D seismic survey in an area south of Jonah Field. The project was proposed as a Vibroseis® project by Veritas DGC Land Inc. and will cover approximately 389 square miles including the southwestern part of Jonah Field and the Blue Forest Unit on the Moxa arch.

Calgary-based Synergy Technologies Corp. has entered into a memorandum of understanding with Nielson & Associates Inc. to construct a heavy-oil upgrading facility in Wyoming. The facility will use Synergy's process for upgrading heavy crude oils into more valuable lighter crude oils. Wyoming-based Nielson & Associates will provide the heavy-oil production and the land for the facility. The first facility is expected to take 14 to 18 months to complete and will have an initial capacity of at least 1000 barrels per day. Construction cost of the facility at a yet-to-be-announced location will be between $7 million and $8 million. This plant is a perfect example of a value-added project for Wyoming's vast petroleum reserves.

During the third quarter of 2002, Kern River Gas Transmission Co. received permission from the Federal Energy Regulatory Commission (FERC) to construct and operate the Kern River 2003 Expansion Project from southwestern Wyoming to southern California. Groundbreaking began in August, 2002 in order to meet a May, 2003 in-service date. The expansion will provide an additional 906 million cubic feet (MMCF) of gas per day to customers in southern California, Utah, and Nevada. The $1.2 billion expansion consists of 717 miles of loop pipeline adjacent to the existing pipeline system, 163,700 horsepower of compression, and modifications to five existing meter stations. The expansion will more than double the amount of natural gas that Kern River transports to 1.73 BCF of gas per day.

RME Petroleum Co., a subsidiary of Anadarko Petroleum Corp., announced plans to construct, operate, and maintain

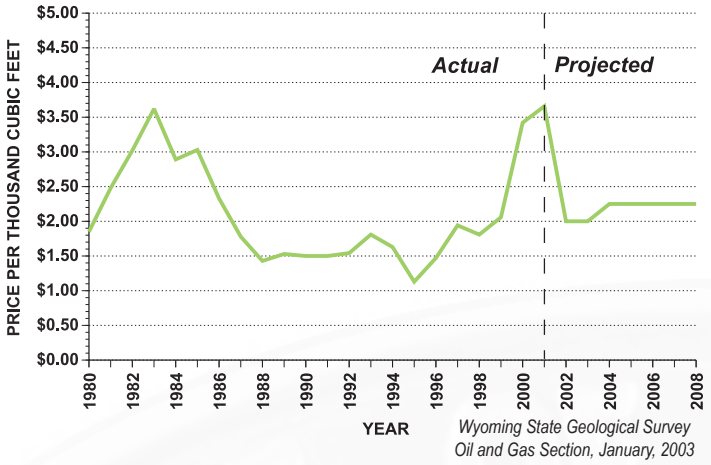

Figure 5. Average prices paid for Wyoming methane (1980 through 2001) with forecasts to 2008.

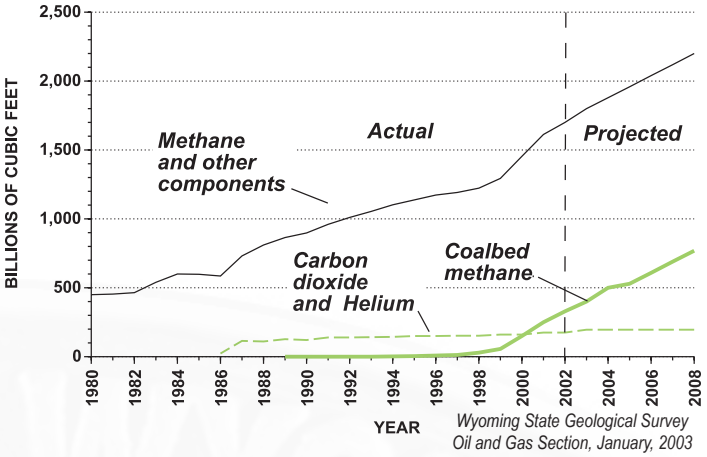

Figure 6. Annual natural gas production from Wyoming (1980 through 2002) with forecasts to 2008.

a buried carbon dioxide gas pipeline and related facilities to transport carbon dioxide gas from an existing valve terminal on ExxonMobil's Shute Creek carbon dioxide pipeline (section 15, T23N, R100W) to the existing RME-operated Monell Unit in Patrick Draw Field (section 11, T18N, R99W). The BLM has issued a scoping notice for the project to the begin the environmental analysis process. The pipeline would be about 33 miles long and would consist of six- and eight-inch outside diameter pipe. RME plans to use carbon dioxide transported by the pipeline to flood the Almond Formation and produce oil that would be left in the ground without the flood.

The BLM has reaffirmed the FONSI for the Vermillion Basin Natural Gas Exploration and Development Project about 45 miles southeast of Rock Springs. Two wilderness proposals were received following appeal of the original FONSI. The proposals are known as the Citizen's Wilderness Inventories for Kinney Rim North and Kinney Rim South. The BLM considered the proposals and has made a preliminary determination that public lands within the project area do not contain wilderness qualities due to human intrusions. Several companies proposed to drill up to 56 additional wells in the area over the next 10 to 20 years targeting the Mesaverde Group.

Table 6. Monthly natural gas production from Wyoming in thousands of cubic feet (MCF) (1998 through October, 2002).

	1998		1999		2000		2001		2002	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	103,640,214	103,640,214	108,524,793	108,524,793	122,078,095	122,078,095	135,968,875	135,968,875	143,440,476	143,440,476
February	94,501,819	198,142,033	94,288,888	202,813,681	114,204,669	236,282,764	123,372,642	259,341,517	132,964,076	276,404,552
March	103,906,999	302,049,032	111,012,987	313,826,668	121,104,908	357,387,672	138,969,778	398,311,295	143,631,269	420,035,821
April	98,201,007	400,250,039	102,363,550	416,190,218	118,775,280	476,162,952	132,559,769	530,871,064	140,958,804	560,994,625
May	96,741,237	496,991,276	104,746,697	520,936,915	118,462,106	594,623,058	138,100,005	668,971,069	146,875,549	707,870,174
June	98,413,520	595,404,796	102,717,295	623,654,210	116,887,377	711,512,435	126,733,129	795,704,198	141,314,660	849,184,834
July	102,055,968	697,460,764	106,733,493	730,387,703	120,690,168	832,202,603	131,151,216	926,855,414	145,714,177	994,899,011
August	105,378,334	802,839,098	107,536,099	837,923,802	122,412,623	954,615,226	132,329,266	1,059,184,680	139,354,817	1,134,253,828
September	98,474,782	901,313,880	108,200,542	946,124,344	119,730,975	1,074,346,201	130,725,850	1,189,910,530	142,186,604	1,276,440,432
October	96,470,624	997,784,504	118,545,893	1,064,670,237	127,507,997	1,201,854,198	136,704,129	1,326,614,659	148,095,221	1,424,535,653
November	103,445,859	1,101,230,363	110,904,046	1,175,574,283	122,846,630	1,324,700,828	136,260,720	1,462,875,379		
December	99,339,043	1,200,569,406	119,648,215	1,295,222,498	130,711,331	1,455,412,159	142,912,497	1,605,787,876		
Total MCF Reported[1]		**1,200,569,406**		**1,295,222,498**		**1,455,412,159**		**1,605,787,876**		
Total MCF not Reported[2]		**22,955,142**								
Total MCF Produced[3]		**1,223,524,548**								

[1]Monthly production reports for 1998 from Petroleum Information/Dwights LLC.; 1999 through October, 2002 are from Wyoming Oil and Gas Conservation Commission; [2](Total MCF produced) minus (total MCF reported by Petroleum Information/Dwights LLC.); [3]Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, January, 2003.*

Table 7. Wyoming's ranking in proved reserves of crude oil (billions of barrels), dry natural gas (trillions of cubic feet), and natural gas liquids (billions of barrels) at the begining of 2002.

State	Crude oil	State	Dry natural gas	State	Natural gas liquids
Texas	4.944	Texas	43.527	Texas	2.653
Alaska	4.851	**Wyoming**	**18.398**	New Mexico	0.873
California	3.627	New Mexico	17.414	**Wyoming**	**0.710**
New Mexico	0.715	Oklahoma	13.558	Oklahoma	0.694
Louisiana	0.564	Colorado	12.527	Alaska	0.405
Oklahoma	0.556	Louisiana	9.811	Louisiana	0.391
Wyoming	**0.489**	Alaska	8.800	Colorado	0.345
North Dakota	0.328	Kansas	5.101	Kansas	0.302
Utah	0.271	Utah	4.579	Utah	0.187
Montana	0.260	Alabama	3.915	California	0.076

Source: U.S. Department of Energy, 2002. *Wyoming State Geological Survey, Oil and Gas Section, February, 2003.*

The [Jonah] field contains 2 to 4 TCF of natural gas reserves, making it one of the largest discoveries in North America.

Table 8. Comparison of Wyoming's proved reserves of crude oil (billions of barrels), dry natural gas (trillions of cubic feet), and natural gas liquids (billions of barrels) for the years 1980 through 2001.

Date	Crude oil	Dry natural gas	Natural gas liquids[1]
1980	0.928	9.100	0.239
1981	0.840	9.307	0.269
1982	0.856	9.758	0.477
1983	0.957	10.227	0.552
1984	0.954	10.482	0.602
1985	0.951	10.617	0.664
1986	0.849	9.756	0.665
1987	0.854	10.023	0.647
1988	0.825	10.308	0.808
1989	0.815	10.744	0.627
1990	0.794	9.944	0.568
1991	0.757	9.941	0.524
1992	0.689	10.826	0.462
1993	0.624	10.933	0.420
1994	0.565	10.789	0.395
1995	0.605	12.166	0.415
1996	0.603	12.320	0.505
1997	0.627	13.562	0.600
1998	0.547	13.650	0.535
1999	0.590	14.226	0.515
2000	0.561	16.158	0.750
2001	0.489	18.398	0.710

Source: U.S. Department of Energy, 2002. [1] Estimated from U.S. Department of Energy figures. *Wyoming State Geological Survey, Oil and Gas Section, January, 2003.*

The Interstate Oil and Gas Compact Commission (IOGCC) was happy over key findings of a U.S. Environmental Protection Agency (EPA) study on hydraulic fracturing. The report found that thousands of natural gas wells drilled annually into coal seams and hydraulically fractured have provided no evidence that any drinking water wells have been contaminated due to the fracturing. The report indicated that further study is not necessary. The study was a result of an environmental group's lawsuit against the EPA claiming that hydraulic fracturing contaminated Alabama's groundwater.

EnCana Oil & Gas (USA) Inc., the U.S. subsidiary of Calgary-based EnCana Corp., increased its holdings in the giant Jonah Field by purchasing The Williams Companies' holdings in the field for $350 million. The acquisition consists of reserves of about 600 BCF of natural gas equivalent. The purchase increases EnCana's productive capacity from Jonah to more than 400 MMCF of natural gas equivalent per day. Jonah Field was discovered in 1975 and rediscovered (using advances in completion technology for tight gas sands) in 1992. Since then, the field has produced over 0.5 TCF of natural gas and over 5 million barrels of condensate. The field contains 2 to 4 TCF of natural gas reserves, making it one of the largest discoveries in North America.

Lease sales

Leasing activity at the August BLM sale was the heaviest in the PRB and in southwestern Wyoming (**Figure 7**). The high per-acre bid of $205 was made by Infinity Oil and Gas for a 1389.51-acre lease that covers parts of sections 22, 24, and 28, T18N, R100W (**location A, Figure 7**). The lease is near Infinity's CBM development in sections 12 and 13, T18N, R100W, from the Mesaverde Group. Rocky Mountain Land and Leasing made the second high per-acre bid of $59 for a 97.46-acre parcel that covers parts of sections 10, 11, and 12, T32N, R113W (**location B, Figure 7**). The parcel is about 2 to 4 miles east of gas production from the Mesaverde Forma-

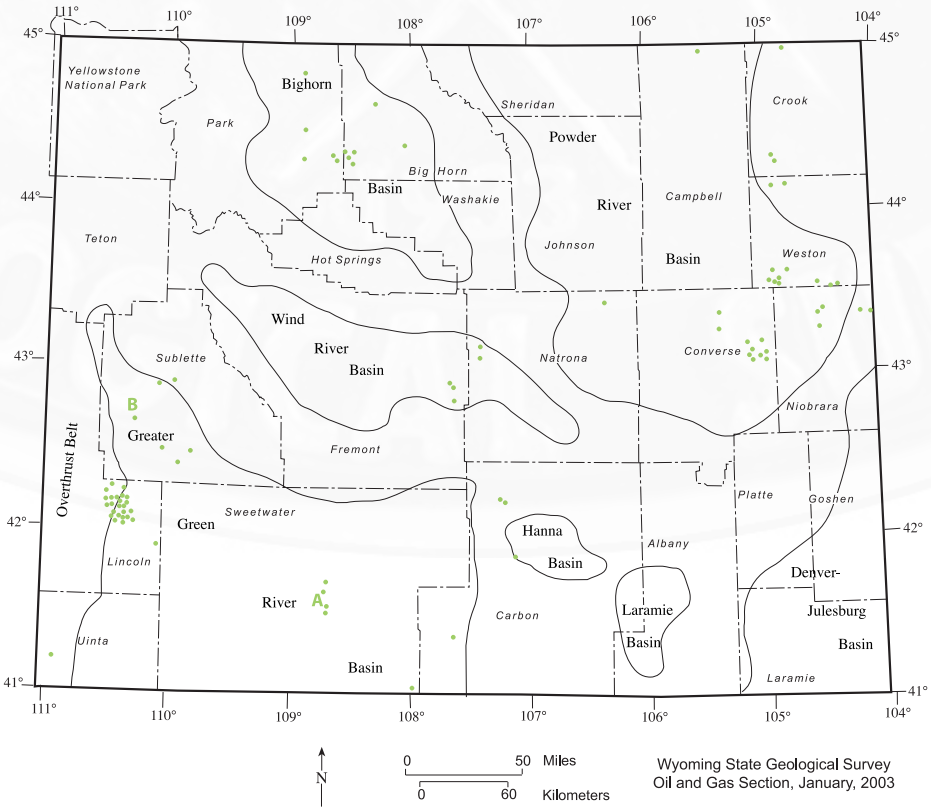

Figure 7. Location of federal oil and gas tracts leased by the U.S. Bureau of Land Management at its August, 2002 sale. Locations are approximate and may represent more than one tract.

tion at Mickelson Creek Field. There were only four leases at this sale that received bids of $50 or more per acre. The sale generated only $858,686 in revenue and the average per-acre bid was only $9.68 (**Table 9**). The slowdown in leasing and leasing income for the last two BLM sales is more due to a lack of parcels in general and a lack of high-quality parcels in particular than to lower natural gas prices.

The slowdown in drilling permits...is due to relatively lower prices and lack of CBM drilling locations on federal land.

Permitting and drilling

The WOGCC approved 1435 Applications for Permit to Drill (APDs) in the third quarter of 2002. This quarterly total is 1328 less than in the third quarter of 2001, but more than for the full years of 1995 and 1996 (**Table 10**). Campbell County again led with 36.8% of the total APDs that were approved in the third quarter. Sheridan and Johnson counties combined for another 39.4%. Nearly all of the approved APDs in these three counties were for CBM tests. The slowdown in drilling permits so far this year when compared to 2001 is due to relatively lower prices and lack of CBM drilling locations on federal land. This lack of drilling permits should be alleviated somewhat when the Record of Decision (ROD) for the PRB Oil and Gas Project Final Environmental Impact Statement (FEIS) is signed in early 2003. The FEIS was released in January, 2003.

The WOGCC permitted nine seismic projects in the third quarter of 2002 (**Table 11**). The number of permits issued is five less than for the third quarter of 2001 but the total is only three less than last year. The number of conventional miles permitted is 352 higher than for the third quarter of 2001, but the total square miles of 3-D seismic is 549 less than that for the third quarter of 2001. There were 964 more miles of conventional seismic permitted to date in 2002 than in 2001 but 738 fewer

Table 9. Federal and state competitive oil and gas lease sales in Wyoming (1996 through August, 2002).

FEDERAL SALES (BUREAU OF LAND MANAGEMENT)								STATE SALES (OFFICE OF STATE LANDS AND INVESTMENTS)							
Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre	Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
				1996								**1996**			
TOTAL	$11,487,567	1828	1125	1,403,444	739,505	$15.53	$1,450.00	TOTAL	$2,325,497	1049	508	418,111	206,814	$11.24	$206.00
				1997								**1997**			
TOTAL	$31,976,603	1787	1485	1,578,938	1,206,642	$26.50	$600.00	TOTAL	$3,151,020	1198	704	438,296	263,230	$11.97	$340.00
				1998								**1998**			
February	$5,262,908	369	285	366,787	241,654	$21.78	$415.00								
April	$10,287,111	247	227	192,561	162,393	$63.35	$395.00								
June	$14,737,117	463	367	498,339	368,816	$39.96	$430.00	April	$1,203,792	300	161	115,646	63,848	$18.85	$320.00
August	$8,033,029	306	245	349,605	278,095	$28.89	$500.00	June	$1,660,438	300	148	108,654	52,501	$31.63	$600.00
October	$10,251,074	455	308	421,900	293,141	$34.97	$430.00	October	$1,313,792	298	178	98,856	65,212	$20.14	$590.00
December	$15,229,257	407	278	388,783	277,538	$54.87	$800.00	December	$1,045,447	300	187	121,551	77,852	$13.43	$215.00
TOTAL	$63,800,496	2247	1710	2,217,975	1,621,637	$39.34	$800.00	TOTAL	$5,223,469	1198	674	444,707	259,413	$20.14	$600.00
				1999								**1999**			
February	$2,734,442	170	138	157,779	124,880	$21.90	$325.00								
April	$2,121,220	124	116	129,358	121,421	$17.47	$280.00								
June	$8,358,363	179	155	233,599	207,978	$40.19	$32,000.00	April	$1,815,526	299	196	123,119	89,194	$20.35	$890.00
August	$3,294,339	206	197	215,631	208,777	$15.78	$290.00	June	$1,002,039	300	190	108,310	69,858	$14.34	$400.00
Octoer	$4,395,288	214	175	195,827	142,525	$30.84	$580.00	October	$2,369,527	300	216	109,140	77,261	$30.67	$475.00
December	$5,598,020	176	164	128,480	124,093	$28.99	$410.00	December	$956,113	291	129	115,502	51,674	$18.50	$500.00
TOTAL	$24,197,991	1,069	945	1,060,674	929,674	$26.03	$32,000.00	TOTAL	$6,143,205	1,190	731	456,071	287,987	$21.33	$890.00
				2000											
February	$5,497,834	192	180	130,289	120,219	$45.73	$525.00								
April	$3,057,278	189	161	160,712	128,063	$23.87	$440.00					**2000**			
June	$6,387,887	230	184	260,294	190,306	$33.57	$410.00	April	$1,475,661	299	191	120,319	71,933	$19.54	$525.00
August	$5,213,595	240	222	174,040	154,920	$33.65	$475.00	June	$2,119,198	300	197	127,798	79,743	$26.58	$775.00
October	$5,028,610	147	129	149,934	124,724	$40.32	$510.00	October	$1,660,315	300	216	117,598	81,603	$20.35	$268.00
December	$6,352,525	185	179	182,935	180,380	$35.22	$725.00	December	$1,240,442	300	192	109,375	62,636	$19.80	$210.00
TOTAL	$31,537,729	1183	1055	1,058,204	898,612	$35.09	$725.00	TOTAL	$6,495,616	1199	796	475,090	295,915	$21.95	$775.00
				2001											
February	$9,138,921	202	159	224,225	148,972	$61.35	$1,475.00								
April	$10,976,580	185	184	221,147	221,067	$49.65	$530.00								
June	$3,088,796	158	149	144,738	138,088	$22.37	$360.00					**2001**			
August	$7,626,362	204	190	260,409	245,116	$31.11	$525.00	April	$2,250,353	300	212	112,379	82,834	$27.16	$450.00
October	$998,308	119	105	127,396	107,880	$9.25	$160.00	June	$1,754,320	300	192	111,507	66,829	$26.25	$650.00
December	$2,162,599	155	146	125,830	112,159	$9.28	$550.00	October	$679,343	300	129	112,255	53,396	$12.72	$120.00
TOTAL	$33,991,566	1023	933	1,103,745	973,282	$34.92	$1475.00	TOTAL	$4,684,016	900	533	336,141	203,059	$23.07	$650.00
				2002											
February	$5,137,024	219	164	271,248	177,117	$29.00	$345.00								
April	$2,969,094	142	127	136,864	117,852	$25.19	$375.00					**2002**			
June	$1,183,222	91	63	82,958	55,808	$21.20	$185.00	April	$465,104	200	90	74,321	35,084	$13.26	$105.00
August	$858,686	124	89	111,462	88,719	$9.68	$205.00	June	$517,143	200	124	74,608	46,841	$11.04	$525.00

Sources: Wyoming Office of State Lands and Investments, Petroleum Information/Dwights LLC - Rocky Mountain Region Report, and U.S. Bureau of Land Management. *Wyoming State Geological Survey, Oil and Gas Section, January, 2003.*

Table 10. Number of Applications for Permit to Drill (APDs) approved by the Wyoming Oil and Gas Conservation Commission (1996 through September, 2002).

County	1996 APDs	1997 APDs	1998 APDs	1999 APDs	2000 APDs	2001 APDs	2002 APDs
Albany	1	0	0	0	0	1	0
Big Horn	53	59	13	6	11	23	6
Campbell	554	941	1586	4461	5580	6204	2205
Carbon	77	84	96	127	174	261	145
Converse	20	16	6	19	70	25	38
Crook	37	26	29	30	47	20	12
Fremont	26	58	76	67	136	149	42
Goshen	0	0	0	0	0	0	1
Hot Springs	24	42	1	8	6	2	8
Johnson	16	6	49	304	769	805	621
Laramie	2	3	2	0	2	3	1
Lincoln	55	122	105	51	70	87	40
Natrona	74	59	36	51	53	45	39
Niobrara	7	8	8	5	18	15	9
Park	30	25	11	12	18	45	21
Platte	0	0	0	0	0	0	0
Sheridan	0	2	35	416	891	1811	983
Sublette	118	179	230	189	338	435	330
Sweetwater	136	210	181	124	335	534	261
Teton	0	0	0	0	0	0	0
Uinta	10	27	26	26	53	35	11
Washakie	30	36	9	0	7	10	0
Weston	10	5	6	4	20	7	1
Totals	**1280**	**1908**	**2505**	**5900**	**8598**	**10,517**	**4774**

Source: All data are from the Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, January, 2003.*

square miles of 3-D seismic permitted to date in 2002. Geophysical activity is a good indicator of future exploration and production drilling.

The average daily rig count for the third quarter of 2002 was 43. This average is 21 less than for the third quarter of 2001. The rig count does not include rigs drilling for CBM. The lower prices for natural gas in the last year are reflected in the fewer number of operating drilling rigs. **Figure 8** shows the Wyoming daily rig count averaged by month and by year.

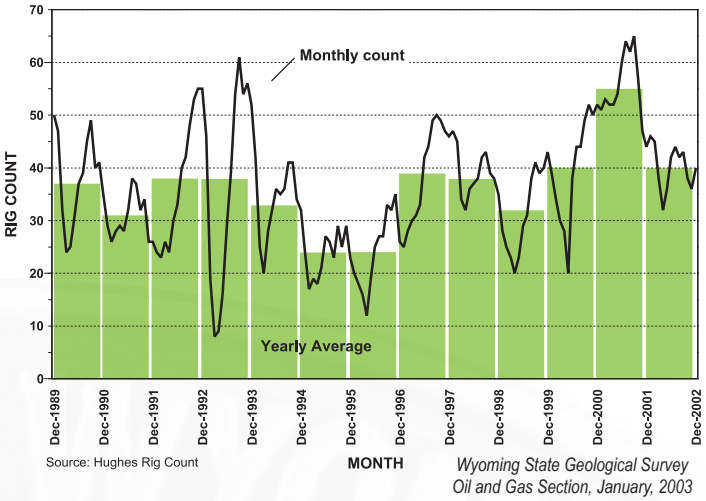

Figure 8. Wyoming daily rig count, exclusive of coalbed methane rigs, averaged by month and year (December, 1989 through December, 2002).

Exploration and development

Company data, news releases, and information compiled and published by Petroleum Information/Dwights LLC. are used to track oil and gas exploration and development activity in Wyoming. **Table 12** reports the most significant activities exclusive of CBM (see the **Coalbed Methane Update** for development in that industry) during the third quarter of 2002. The numbers correspond to locations on **Figure 9**.

Reference cited

Energy Information Administration, 2002, U.S. crude oil, natural gas, and natural gas liquids reserves: Annual Report 2001: Washington, D.C., 160 p.

Table 11. Number of seismic projects and miles permitted by the Wyoming Oil and Gas Conservation Commission (1998 through September, 2002).

	1998			1999			2000			2001			2002		
County	Permits	Conventional Miles	3-D Square Miles	Permits	Conventional Miles	3-D Square Miles	Permits	Conventional Miles	3-D Square Miles	Permits	Conventional Miles	3-D Square Miles	Permits	Conventional Miles	3-D Square Miles
Albany	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Horn	1	0	16	0	0	0	1	387	0	1	0	4	0	0	0
Campbell	14	18	182	4	4	10	14	64	132	5	38	3	9	49	0
Carbon	4	0	318	5	77	57	0	0	0	1	500	0	3	419	0
Converse	4	12	239	1	0	50	1	15	0	0	0	0	1	6	0
Crook	2	2	4	1	0	10	7	16	22	4	32	0	1	0	2
Fremont	2	100	0	1	0	88	4	25	116	2	70	15	1	160	0
Goshen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Springs	4	19	0	0	0	0	0	0	0	0	0	0	0	0	0
Johnson	1	4	0	0	0	0	4	35	0	2	4	4	1	16	0
Laramie	0	0	0	0	0	0	0	0	0	0	0	0	1	0	18
Lincoln	1	10	0	1	0	32	0	0	0	1	0	25	0	0	0
Natrona	6	12	214	2	0	230	5	36	135	2	19	63	3	1	72
Niobrara	0	0	0	5	16	31	1	0	25	1	0	16	3	3	52
Park	3	16	132	3	25	32	1	13	0	4	21	20	0	0	0
Platte	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sheridan	1	14	0	0	0	0	0	0	0	2	0	81	0	0	0
Sublette	2	1	115	3	0	308	4	77	44	10	261	374	1	464	0
Sweetwater	6	214	66	9	0	530	13	54	1004	11	129	802	6	338	485
Teton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uinta	2	0	147	1	0	26	0	0	0	1	259	0	2	196	0
Washakie	4	41	35	1	0	8	0	0	0	0	0	0	1	21	0
Weston	1	0	35	1	40	0	0	0	0	0	0	0	0	0	0
Totals	**58**	**463**	**1503**	**38**	**162**	**1412**	**55**	**722**	**1478**	**47**	**1333**	**1407**	**33**	**1673**	**629**

Source: All data are from the Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, January, 2003.*

Table 12. Significant exploration and development wells in Wyoming, third quarter of 2002[1]. Number corresponds to location on Figure 9.

	Company name	Well name/number	Location	Formation tested	Depth(s) interval(s) tested	Tested prod. (per day)	Remarks
1	BP America Production	1A Millis	NW NE sec 10, T14N, R120W	Nugget Ss.	13,773-13,969	1.5 MMCF 542 BBL cond 1,109 BBL H_2O	Directional redrill of the Glasscock Hollow Field discovery well
2	Chevron USA	4-21M Chevron-Federal	NW SE sec 31, T19N, R119W	Mission Canyon Ls. Lodgepole Ls.	14,241-15,582	7.1 MMCF 46 BBL cond 9 BBL H_2O	New producer, north end of Whitney Canyon-Carter Creek Field
	Amoco Production	6B Amoco-Chevron-Gulf	SW NW sec 19, T17N, R119W	Amsden Fm. Mission Canyon Ls.	12,421-14,100	12.8 MMCF 144 BBL H_2O	New producer, south end Whitney Canyon-Carter Creek Field
3	Mountain Petroleum	3-11 Bull Draw	NE SW sec 11, T28N, R107W	Lance Fm. Mesaverde Fm.	three intervals 10,232-11,525 11,914-12,137	2.8 MMCF 40 BBL cond 100 BBL H_2O	Workover of discovery well originally completed in 1994 flowed 300 MCF daily from Mesaverde at 12,192-12,240
4	McMurry Oil	14-33 Stud Horse Butte	SE SW sec 33, T29N, R108W	Lance Fm.	several intervals 9034-10,648	4.2 MMCF 63 BBL cond 38 BBL H_2O	New infill well in Jonah Field
	McMurry Oil	8-29 Stud Horse Butte	SE NE sec 29, T29N, R108W	Lance Fm.	eight intervals 9073-13,091	2.9 MMCF 18 BBL cond 23 BBL H_2O	New infill well in Jonah Field
	McMurry Oil	4-27 Stud Horse Butte	NW NW sec 27, T29N, R108W	Lance Fm.	several intervals 8016-10,883	6.4 MMCF 71 BBL cond 72 BBL H_2O	New infill well in Jonah Field
	McMurry Oil	12-27 Stud Horse Butte	NW SW sec 27, T29N, R108W	Lance Fm.	nine intervals 8070-10,801	5.6 MMCF 60 BBL cond 75 BBL H_2O	New infill well in Jonah Field
	McMurry Oil	2-1 Yellow Point-Federal	NW SE sec 1, T28N, R109W	Lance Fm.	12 intervals 7396-10,251	5.1 MMCF 91 BBL cond 17 BBL H_2O	New infill well in Jonah Field
5	Burlington Resources Oil & Gas	33-27 Muddy Creek Unit	NW SE sec 27, T30N, R111W	Lance Fm.	several intervals no details	unstabilized gas rate	New discovery 2.5 miles from nearest Lance production
6	Wexpro Co.	4-16D Mesa	SE NW sec 16, T32N, R109W	Lance Fm.	11 intervals 9183-13,389	8.1 MMCF 42 BBL cond 42 BBL H_2O	New producer on Pinedale anticline-Mesa Unit
	Wexpro Co.	14-16 Mesa Unit	SE SW sec 16, T32N, R109W	Lance Fm.	11 intervals 8810-12,846	11.2 MMCF 72 BBL cond 48 BBL H_2O	New producer on Pinedale anticline-Mesa Unit
	Wexpro Co.	9-7 Mesa Unit	NE SE sec 7, T32N, R109W	Lance Fm.	10 intervals 7744-10,651	7.1 MMCF 24 BBL cond 36 BBL H_2O	New producer on Pinedale anticline-Mesa Unit
	Wexpro Co.	6-16 Mesa Unit	SE NW sec 16, T32N, R109W	Mesaverde Fm.	two intervals 13,409-14,005	2.5 MMCF 20 BBL cond 50 BBL H_2O	New producer on Pinedale anticline-Mesa Unit
	Anschutz Exploration	8-28 Mesa	SE NE sec 28, T32N, R109W	Lance Fm.	several intervals 8437-12,172	6.6 MMCF 52 BBl cond 294 BBL H_2O	New producer on Pinedale anticline-Mesa Unit
	Shell Rocky Mountain Prod.	11-32-30-107D Rainbow	SE SW sec 32, T30N, R107W	Mesaverde Fm.	no details	5.2 MMCF 66 BBL cond	New producer on Pinedale anticline
	Shell Rocky Mountain Prod.	12-32-30-107D Rainbow	SW SW sec 32, T30N, R107W	Mesaverde Fm.	no details		New producer on Pinedale anticline, produced 52.2 MMCF of gas and 460 BBL cond in July
	Shell Rocky Mountain Prod.	13-32-30-107D Rainbow	SW SW sec 32, T30N, R107W	Mesaverde Fm.	no details		New producer on Pinedale anticline, produced 19.0 MMCF of gas and 345 BBL cond in July
	Ultra Petroleum	8-4 Riverside	SE NE sec 4, T31N, R109W	Lance Fm. Mesaverde Fm.	13 intervals 8180-12,445	17.8 MMCF[2] 160 BBL cond	New producer on Pinedale anticline.
	Ultra Petroleum	4-10 Riverside	NW NW sec 10, T31N, R109W	Lance Fm. Mesaverde Fm.	several intervals 8174-11,804 12,278-12,288	15.2 MMCF 104 BBL cond	New producer on Pinedale anticline
	Questar Exploration & Production	9-29D Stewart Point	SE SE sec 29, T33N, R109W	Lance Fm. Mesaverde Fm.	12 intervals 8942-13,796	12.0 MMCF 72 BBL cond 36 BBL H_2O	New producer on Pinedale anticline
7	BP America Production	13-1 Bitter Creek	SW SW sec 13, T16N, R99W	Mesaverde Fm.	two intervals 10,996-11,030 11,096-11,182	1.1 MMCF 5 BBL cond	New producer in Bitter Creek Field
	BP America Production	21-3 Bitter Creek	NW NW sec 21, T16N, R99W	Mesaverde Fm.	11,236-11,693 8901-11,368	1.9 MMCF 12 BBL cond	New producer in Bitter Creek Field

Table 12. Continued. Significant exploration and development wells in Wyoming, third quarter of 2002[1]. Number corresponds to location on Figure 9.

	Company name	Well name/number	Location	Formation tested	Depth(s) interval(s) tested	Tested prod. (per day)	Remarks
8	BP America Production	3-2 Wamsutter Rim	NW SE sec 3, T18N, R94W	Mesaverde Fm.	9672-9706 9809-9968	1.0 MMCF 5 BBL cond	Wildcat discovery
9	BP America Production	29-3 Monument	NW SE sec 29, T22N, R93W	Lewis Sh. Mesaverde Fm.	10,780-10,815 two intervals 11,280-11,560	512 MCF 607 BBL H_2O	Wildcat discovery 12 miles north-northeast of Stagecoach Draw Field
10	Marathon Oil	16 Phelps	SE NE sec 11, T49N, R102W	Tensleep Ss.	several intervals 3774-3938	760 BBL oil 1208 BBL H_2O	Infill well in Spring Creek Field
11	Howell Petroleum	1-31 Howell-USA	NE NE sec 31, T58N, R99W	Sundance Fm. Morrison Fm.	3384-3404 3448-3466 3158-3178	2.0 MMCF 1.7 MMCF	First production from Sundance and Morrison Fms. in Elk Basin Field
12	Gulf Production	11-13 Echeta Road-Federal	NE SW sec 13, T51N, R75W	Muddy Ss.	9292-9296 9309-9312 9347-9352	470 MCF 50 BBL cond	New well 0.5 miles from Echeta Field discovery well
13	Merit Energy	3 Toro	NW NE sec 7, T49N, R70W	Minnelusa Fm.	9171-9180	50 BBL oil	Stepout from Timber Creek Field
14	Goldmark Engineering	12 Wilson	SE SW sec 18, T17N, R76W	Casper Fm.	5320-5410	30 BBL oil 1050 BBL H_2O	New producer in Quealy Field

[1]Abbreviations include: MCF=thousands of cubic feet of natural gas; MMCF=millions of cubic feet of natural gas; BBL=barrels; cond=condensate; H_2O=water; Ss.=Sandstone; Ls.=Limestone; Fm.=Formation; Sh.=Shale. [2]Ultra said the well would have initially flowed over 20.0 MMCF/day had it not been constrained by surface facilities. *Wyoming State Geological Survey, January, 2003.*

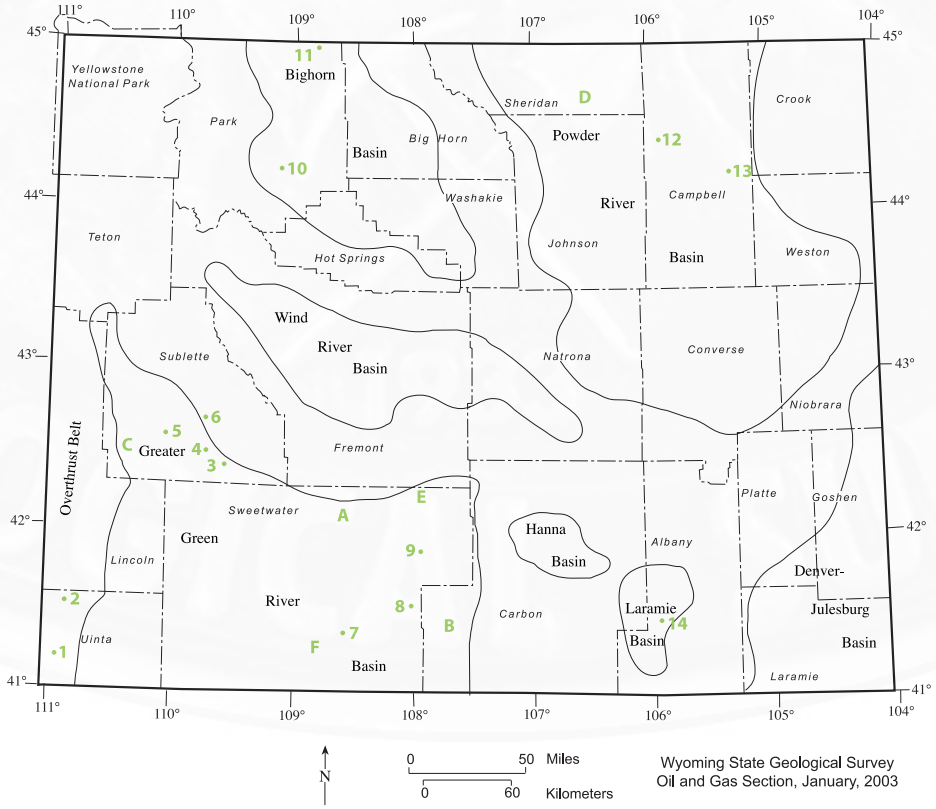

Figure 9. Oil and gas exploration and development activities in Wyoming during the third quarter of 2002. Letters indicate coalbed methane developments described in the Coalbed Methane Update. Locations are approximate and may represent more than one well location or project.

Coal Update

Robert M. Lyman, Wyoming PG-656

Staff Geologist—Coal, Wyoming State Geological Survey

The third quarter of 2002 saw a return of hot summer weather to the central U.S., causing utility companies to burn down their fuel inventories. More coal was needed to replenish their stockpiles for the upcoming winter, and our projected 2% decrease in Wyoming coal production had to be revised upward. By the end of September, most coal producers in the Powder River Basin (PRB) had sold out their scheduled remaining production for 2002. We expect another record coal production of approximately 373 million short tons, an increase of nearly 1.2% over last year's production.

Prices for Wyoming coal in the third quarter stabilized somewhat higher than those reported earlier in the year and our year-end, statewide coal price for 2002 is projected at $5.90 per short ton [Freight on Board (FOB) the mine]. This is about $0.15 higher than our earlier forecast for 2002 and also $0.15 higher than last year's average price of $5.75 per short ton.

The proposed sale of Triton Coal and its two Wyoming coal mines to Atlas Pipeline Partners has been terminated, but evidently Triton is still on the sales block. Pittsburg and Midway Coal Mining Company's (P&M's) Ash Creek mine proposed for Sheridan County continues in the planning stage, but is probably contingent on finding markets for the coal and decisions from P&M's parent company. The Black Butte mine in Sweetwater County announced cutbacks in production and offered severance packages to their employees.

Coal production is projected to reach 373 million short tons in 2002, which is a modest 1.19% increase over 2001 production.

The state's coal industry continues to make inroads farther south and east into traditional eastern coal markets. This is resulting from federal approval of the proposed expansion railroad into the PRB; another Midwest port planning to capitalize on handling more Wyoming coal; and sales taxes on coal in some states favoring Wyoming coal over in-state coal. For example, a port on the Ohio River in southeastern Indiana has made test shipments (via barge on the Tennessee River) of Wyoming coal to a Tennessee Valley Authority (TVA) plant in Alabama; a Georgia power plant has abandoned Appalachian coal for 100% PRB coal; Wisconsin Public Service is adding a new 500-megawatt (MW) unit that is destined to burn PRB coal; and PRB coals are being blended with eastern coals at power plants on Lake Erie (western New York).

Production and prices

By the end of the third quarter 2002, estimated Wyoming coal production was up 2.2% from the same period in 2001. Wyoming mines reportedly shipped 95.7 million short tons of coal in the third quarter, compared to 92.2 million short tons in 2001 (**Table 13**). Monthly coal deliveries in 2002 have averaged slightly higher overall than in 2001 (**Figure 10**) with increased contract coal deliveries on a monthly basis (**Figure 11a**) offsetting decreased spot coal deliveries (**Figure 11b**).

There was a third quarter surge in coal production brought about by the electric utility companies using up their coal stockpiles during the hot weather in the late summer and early fall. Coal inventories were expected to be replenished in the fourth quarter in preparation for the winter ahead, and most of Wyoming's major PRB coal producers were saying "sorry, sold out for 2002," for the last quarter. For these reasons, the Consensus Revenue Estimating Group (CREG) for the State of Wyoming increased their coal production estimate for 2002. Coal production is projected to reach 373 million short tons in 2002, which is a modest 1.19% increase over 2001 production (**Tables 1** and **14**).

Most of the projected production increases for 2003 through 2008 will be from coal mines in Campbell County, with smaller increases in Converse County. The annual percentage increase in statewide production is estimated at only 1 or 2%, but remember that even a 1% increase translates to nearly 4 million short tons (**Tables 1** and **14**). By 2008, we expect Wyoming's coal production to be nearly 400 million short tons (**Figure 12**).

Southern Wyoming coal production may increase slightly in 2003 as Carbon County production makes a slight comeback. Overall production from 2004 through 2008 in the three southern counties is expected to stabilize, as most production will continue to fuel captive mine-mouth operations (**Figure 13**). Out-of-state markets for southern Wyoming coal have nearly dried up from the ultra-competitive PRB coals.

Spot coal prices in the third quarter of 2002 were stable to slightly higher than previous quarters and settled above the lows reached in the latter part of the first quarter (**Figure 14**), which had caused many operators to withdraw production from the spot arena and concentrate on term coal deliveries.

Table 13. Estimated monthly coal deliveries from Wyoming's mines in short tons (January, 1998 through September, 2002).

	1998		1999		2000		2001		2002	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
January	26,536,217	26,536,217	27,105,791	27,105,791	27,773,610	27,773,610	27,743,000	27,743,000	28,406,666	28,406,666
February	23,196,152	49,732,369	25,803,390	52,909,181	25,594,109	53,367,719	27,827,000	55,570,000	30,041,748	58,448,414
March	23,861,472	73,593,841	28,222,743	81,131,923	28,262,696	81,630,415	33,739,000	89,309,000	33,409,797	91,858,211
April	24,768,989	98,362,830	25,965,867	107,097,791	25,549,039	107,179,454	27,302,000	116,611,000	27,534,057	119,392,268
May	25,278,960	123,641,790	28,698,498	135,796,288	26,222,515	133,401,969	27,752,000	144,363,000	34,704,299	154,096,567
June	24,450,835	148,092,625	24,753,829	160,550,118	25,085,516	158,487,485	33,968,000	178,331,000	26,674,488	180,771,055
July	25,663,577	173,756,202	28,266,458	188,816,576	28,881,862	187,369,347	29,200,000	207,531,000	27,885,210	208,656,265
August	26,591,950	200,348,152	28,346,757	217,163,333	29,075,295	216,444,642	27,662,000	235,193,000	35,670,535	244,326,800
September	26,041,099	226,389,251	27,373,417	244,536,749	25,865,389	242,310,032	35,369,000	270,562,000	32,234,471	276,561,271
October	26,659,121	253,048,372	26,837,295	271,374,045	26,441,615	268,751,646	29,869,000	300,431,000		
November	25,620,216	278,668,588	26,843,021	298,217,066	27,400,245	296,151,892	29,308,000	329,739,000		
December	26,102,620	304,771,208	26,834,927	325,051,993	28,300,773	324,452,665	29,984,000	359,723,000		
Total Utility Tonnage[1]		**304,771,208**		**325,051,993**		**324,452,665**		**359,723,000**		
Total Tonnage Other [2]		**10,190,883**		**11,407,945**		**14,399,483**		**8,955,135**		
Total Tonnage Produced[3]		**314,962,091**		**336,459,938**		**338,852,148**		**368,678,135**		

[1]From Federal Energy Regulatory Commission (FERC) Form 423 for 1998; FERC Form 423 as modified by WSGS for 1999 through September, 2002. [2]Includes estimates of residential, industrial, and exported coal. [3]Wyoming State Mine Inspector's Annual Reports. *Wyoming State Geological Survey, Coal Section, February, 2003.*

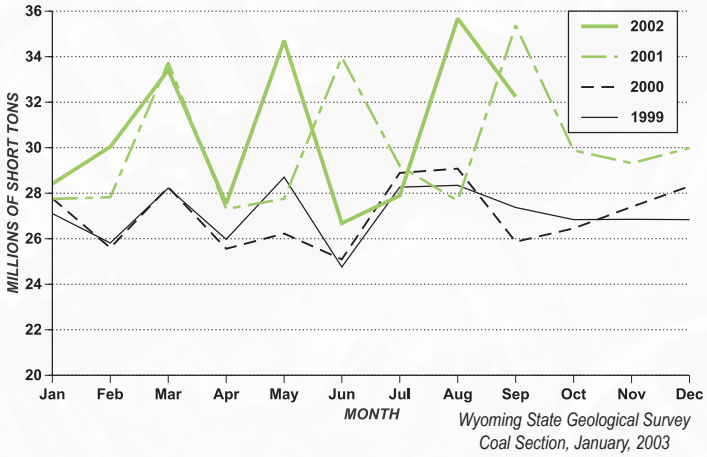

Figure 10. Reported monthly deliveries from Wyoming coal mines (1999 through September, 2002). From Form 423 of the Federal Energy Regulatory Commision (FERC) as modified by the WSGS for 1999 through 2002.

At the end of September, 8800-Btu coal from the southern PRB was moving on the spot market at $6.20 per short ton; compare this to the $5.03 per short ton at the end of February. Spot coal prices for 8400-Btu coal from the northern PRB at the end of September were estimated at $5.20 per short ton compared to the end-of-February price of $4.05 per short ton. Overall spot coal prices are $1.00 to $2.00 per short ton lower than they were a year ago.

The average price for Wyoming coal in 2002 and beyond has been revised upward slightly from last year's CREG estimates, based primarily on stronger coal prices observed for PRB coal (**Tables 2** and **15**). The actual price for 2001 has been corrected to $5.75 per short ton. Because PRB coal dominates Wyoming production (representing 96% of all the state's coal production), its price trends dictate the statewide trends (**Figure 15**). Southern Wyoming coal prices might rebound slightly to $15.20 per short ton in 2005 through 2008, primarily as markets are found to support new and proposed mines.

Developments in the Powder River Basin

Atlas Pipeline Partners has terminated its January, 2002 agreement (described in *Wyoming Geo-notes No. 74*, July, 2002, p. 15) to acquire Triton Coal from New Vulcan Coal Holdings and take it public. Triton owns and operates the North Rochelle and Buckskin coal mines in the PRB and has coal reserves in excess of 770 million short tons (U.S. Coal Review, 8/5/2002). Termination of the agreement has directed attention to companies that own coal mines adjacent to the Triton properties. Both Peabody and Arch are rumored to have a logical interest in acquiring mines, in particular the North Rochelle operation. However, such rumors have drawn criticism from several utility companies that have said they would file formal complaints with the U.S. Securities and Exchange Commission if any current coal company in the PRB tries to acquire the Triton holdings (U.S. Coal Review, 9/30/2002).

Table 14. Wyoming coal production by county[1,2] (in millions of short tons), 1997 through 2001 with forecasts to 2008.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Powder River Basin												
Campbell County	246.3	274.1	294.3	299.5	329.5	334.0	338.5	341.3	344.1	347.0	349.9	352.9
Converse County	17.8	23.4	25.6	23.6	24.6	25.0	26.0	27.0	28.0	29.0	30.0	31.0
Sheridan County	M	M	M	M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	264.1	297.5	320.0	323.1	354.1	359.0	364.5	368.3	372.1	376.0	379.9	383.9
Southern Wyoming												
Carbon County	5	3.5	2.7	2.0	0.5	M	2.0	2.0	2.0	2.0	2.0	2.0
Sweetwater County	7.8	9.2	9.4	10.0	9.5	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Lincoln County	4.6	4.7	4.3	3.7	4.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Subtotal	17.4	17.4	16.4	15.7	14.5	14.0	16.0	16.0	16.0	16.0	16.0	16.0
Total Wyoming[3]	**281.5**	**314.9**	**336.5**	**338.9**	**368.6**	**373.0**	**380.5**	**384.3**	**388.1**	**392.0**	**395.9**	**399.9**
Annual change	**1.1%**	**11.9%**	**6.9%**	**0.7%**	**8.8%**	**1.2%**	**2.0%**	**1.0%**	**1.0%**	**1.0%**	**1.0%**	**1.0%**

[1]Reported tonnage from the Wyoming State Inspector of Mines (1997 through 2001). [2]County estimates by the Wyoming State Geological Survey, February, 2003 for 2002 through 2008. Totals may not agree because of independent rounding. [3]Estimate modified from CREG's Wyoming State Government Revenue Forecast, October, 2002 and January, 2003. M=minor tonnage (less than a million tons). *Wyoming State Geological Survey, Coal Section, February, 2003.*

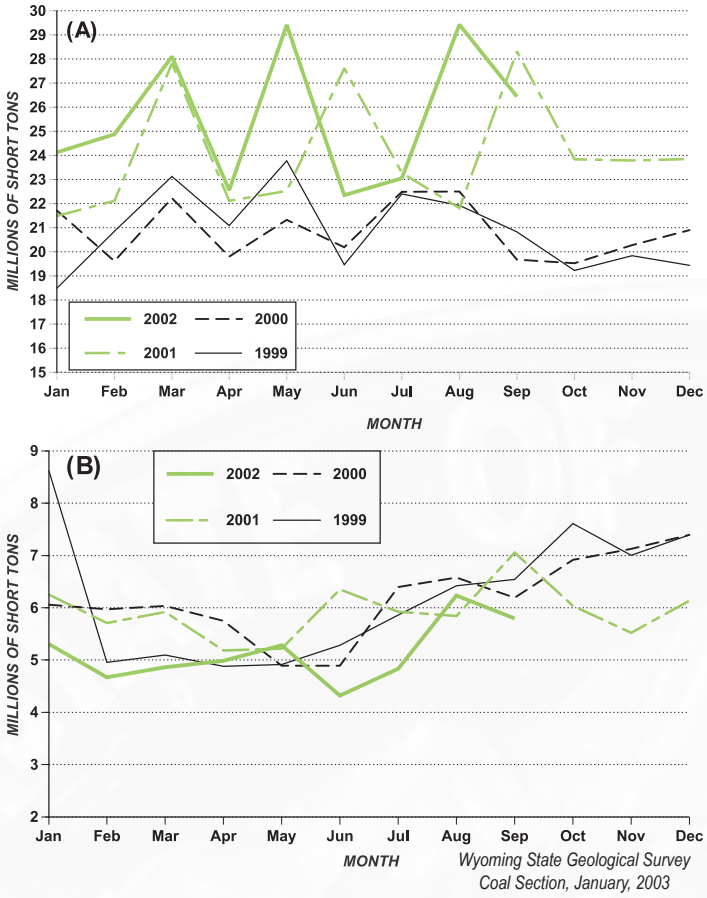

Figure 11. Monthly coal deliveries from Wyoming (1999 through September, 2002). (A) Coal sold on contract and (B) coal sold on the spot market. From Form 423 of the Federal Energy Regulatory Commision (FERC) as modified by the WSGS for 1999 through 2002.

Four major PRB coal producers indicated in August that their coal production is basically sold out for the remainder of year 2002. Evidently Kennecott Energy, Arch Coal, RAG American, and Triton have all committed their scheduled production through 2002 (U.S. Coal Review, 8/19/2002). In September, Peabody joined the group.

The Wyoming Supreme Court reversed a district court ruling that said holders of coal rights also own the methane trapped in the coal. The new ruling now agrees with the U.S. Supreme Court, which had ruled that the gas (coalbed methane) remains with the oil and gas estate. Because several PRB mines relied on the early district court view (i.e., the right to mine the coal also gave them the right to remove the gas), the new decision could mean that those coal mines may have to pay the proceeds they received from the sale of gas back to owners of the oil and gas estate (U.S. Coal Review, 9/16/2002).

P&M continues to work on their plans to open a new mine in Sheridan County (see *Wyoming Geo-notes No. 75*, December, 2002, p. 15). If a market is found for the coal, the Ash Creek project hopes to open in 2008. This would be Sheridan County's first coal production since 2000, when the Bighorn mine last reported production. The proposed new mine is located north of the Bighorn mine.

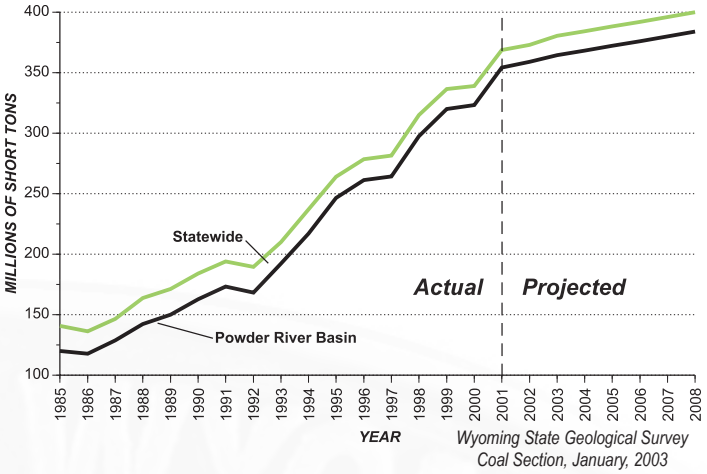

Figure 12. Annual coal production from Wyoming and the Powder River Basin (1985 through 2001) with forecasts to 2008. Sources: Wyoming State Inspector of Mines (1985 through 2001), CREG (2002 through 2008), and the Wyoming State Geological Survey.

If the mine were developed, it would be the first new "built from scratch" coal mining operation in the PRB in nearly 20 years. Presumably this coal would have to compete with coal produced in the Decker area just across the border in Montana. Besides the marketing question, some skeptical observers have doubts that P&M's parent company, ChevronTexaco Corp., would be in the mood to fund the project. Recently, ChevronTexaco has been trying to exit the coal business by closing two of their five active mines and unsuccessfully trying to sell the rest of their coal interests. The planned mine north of Sheridan would produce 10 million short tons per year from the Dietz 1 and Dietz 3 coal seams in the Fort Union Formation (Coal Trader, 7/17/2002).

Figure 13. Complex nature of coal deposition, including differential compaction and splitting coal seams, in the Adaville Formation (Upper Cretaceous) at the coal mine operated by Pittsburg and Midway Coal Mining Company (P&M), near Kemmerer. The mine fuels the nearby Naughton power plant. Photograph by Nicholas R. Jones, 2002, used with permission from P&M.

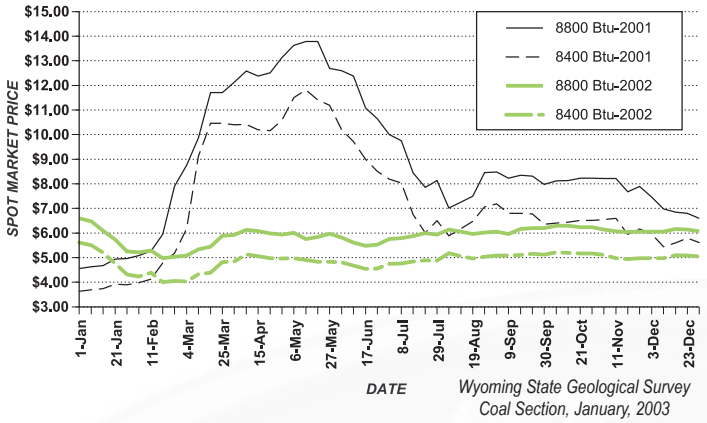

Figure 14. Wyoming PRB coal spot price watch (January 1, 2001 through December 31, 2002). Modified from COAL Daily's spot market index, and Coal Week's short-term spot market price index.

The Spanish utility company Endesa announced in July that it had sold its 2.52% interest in Arch Coal, which was acquired in 1982 through its Carboex subsidiary. Earlier, the utility extended an agreement through 2004 that calls for shipment of 700,000 short tons per year of coal from the Black Thunder mine to Spain (Coal Trader, 7/26/2002).

Developments in southern Wyoming

Operators of the Black Butte coal mine announced in September that it would be laying off 38 hourly positions and some salaried jobs due to poor coal sales. The mine, located at Point of Rocks, shipped 4.3 million short tons of coal in 2001 primarily to the neighboring Jim Bridger power plant. This year, however, Black Butte estimates that they will only be able to sell slightly under 3 million short tons of their production. To avoid some of the involuntary layoffs, the company offered severance packages to all employees for a period of 45 days prior to the targeted rift date of October 25 (Casper Star-Tribune, 9/17/2002).

The 10th Circuit Court of Appeals in Denver dismissed a federal lawsuit brought by the Sweetwater County Commissioners and the Memorial Hospital of Sweetwater County against the State of Wyoming concerning how monies from the State Miners Hospital Fund would be distributed statewide. The court ruled that the county does not have legal standing in the matter, and that it is up to the Wyoming Legislature to decide how the money should be distributed. The court also stated that "Similarly, the parties do not dispute that miners disabled while working in Wyoming mines were the intended beneficiaries of the alleged trust, not Sweetwater County and not any particular state hospital" (Casper Star-Tribune, 8/13/2002).

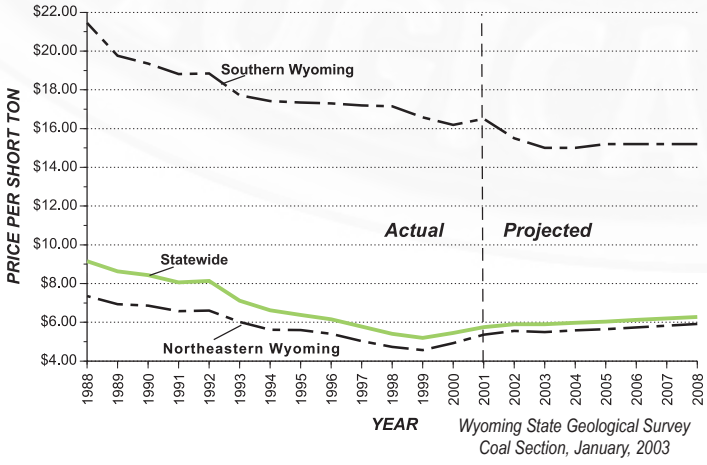

Figure 15. Average prices paid for Wyoming coal by producing area (1988 through 2001) with forecasts to 2008. Sources: U.S. Energy Information Administration (1988 through 1990); Wyoming Department of Revenue (1991 through 2001); and CREG (2002 through 2008).

Table 15. Breakdown of average prices paid for coal from northeastern Wyoming, southern Wyoming, and Wyoming as a whole (1988 through 2001) with forecasts to 2008.

	Year	Northeastern	Southern	Statewide
ACTUAL	1988	$7.35	$21.45	$9.16
	1989	$6.94	$19.76	$8.63
	1990	$6.86	$19.36	$8.43
	1991	$6.58	$18.81	$8.06
	1992	$6.61	$18.84	$8.13
	1993	$6.02	$17.72	$7.12
	1994	$5.62	$17.42	$6.62
	1995	$5.60	$17.35	$6.38
	1996	$5.40	$17.30	$6.15
	1997	$5.03	$17.19	$5.78
	1998	$4.73	$17.15	$5.41
	1999	$4.57	$16.58	$5.19
	2000	$4.93	$16.19	$5.40
	2001	$5.36	$16.50	$5.75
FORECAST	2002	$5.55	$15.50	$5.90
	2003	$5.50	$15.00	$5.90
	2004	$5.58	$15.00	$5.97
	2005	$5.65	$15.20	$6.04
	2006	$5.73	$15.20	$6.12
	2007	$5.82	$15.20	$6.20
	2008	$5.91	$15.20	$6.28

Statewide data for 1988 through 1990 are from reports by the U.S. Department of Energy's Energy Information Administration; data for 1991 through 2001 are derived from Wyoming Department of Revenue information; estimates for 2002 through 2008, and all regional breakdowns by the *Wyoming State Geological Survey, Coal Section, February, 2003.*

Transportation developments

Operators of an Indiana port believe western coal may present an opportunity to increase their coal throughput. Southwind Maritime Centre, a port located on the Ohio River in Mt. Vernon, Indiana, began test shipments of PRB coal received via Alliance Coal by way of the CSX Railroad. The test shipments are transferred by barge at the port for delivery via the Tennessee River to TVA's Widows Creek power plant in northeastern Alabama. As more eastern consumers seek PRB coal, hopefully there will be potential for increased business through this port (U.S. Coal Review, 7/1/2002).

A two-inch rain at the end of August snarled train movements on the PRB joint line. Delays on the high-density line occurred when flooding problems at many coal mines interrupted their usual production schedules. About 30 unit train sets were holding for about a day. Gradual improvements were seen over the next several days and the train loading schedule finally got back to normal on September 6 (Coal Trader, 9/9/2002).

In a September speech, South Dakota Governor Bill Janklow noted that the proposed expansion of the Dakota,

Minnesota & Eastern Railroad (DM&E) into the PRB would bring $21 million in property tax revenue and $14 million in sales tax revenue into his state each year. In the speech he said "I think it's a great thing for our schools and a fabulous thing for our working people" (Coal Outlook, 9/23/2002).

Meanwhile in the third quarter, DM&E opponents focused their attack against the expansion project by filing briefs with the 8th Circuit Court of Appeals, which is hearing the petitions to review the Surface Transportation Board (STB) decision to approve the DM&E project. One unique argument raised in a brief filed by the Sierra Club and the Minnesotans for an Energy Efficient Economy charged that the EIS "did not adequately consider the massive amounts of air pollution that will result from the project," referring to the increased access the project would give to coal for power generation (Coal Trader, 9/24/2002).

The DM&E is aiming to begin service out of the PRB by the end of 2006. The railroad wants to begin construction of the expansion line in the spring of 2004 provided they resolve three major hurdles: 1) resolve the court cases that currently have been launched by opponent groups; 2) finish arranging partnerships and complete financing for the project; and 3) successfully deal with a number of regulatory issues (Coal Outlook, 9/30/2002).

Regulatory developments

Ramifications from the recent Haden ruling, which will impact mining in the Central Appalachian Coal Field, may reach the Wyoming coal industry in a market-driven way. Coal availability will possibly be reduced in this part of the eastern U.S. and this in turn may help spur utilities there to show more interest in our western coals (U.S. Coal Review, 7/1/2002).

After nearly a year of investigation, the U.S. Department of Justice has closed its inquiry into coal pricing and production in the PRB. The investigation included interviews with coal company officials, review of both written and e-mail documents, and even review of the similarity of speeches given at various trade shows. While no charges seem to be on the horizon, companies seem more reluctant to authorize their employees to speak at conferences, and have been more careful in explaining their production strategies and other moves that might impact the coal market (U.S. Coal Review, 7/1/2002).

The Wyoming Environmental Quality Council, after imposing a temporary rule requiring RAG American's Eagle Butte mine to notify residents when blasting will occur, agreed to continue a hearing on blasting restrictions at the mine. The temporary rule will be in force until October, 2002 when the hearing is scheduled to be continued. Issues had been raised concerning dust and toxic fumes produced by blasting. Eagle Butte has requested easing a restriction that currently forbids the use of explosives within 5000 feet of homes located near a coal mine (U.S. Coal Review, 9/9/2002).

The National Park Service (NPS) has requested more time to review the Wyoming Department of Environmental Quality's proposed permit for Black Hills Corp.'s proposed coal-fired Wygen II plant to be built near Gillette. The NPS is concerned that the new power plant could reduce visibility at the Badlands and Wind Cave national parks in South Dakota (Coal Trader, 7/8/2002).

Market developments and opportunities

Near the end of the third quarter of 2002, with world events leading to a U.S.-lead war against Iraq, many coal industry observers feel that the saber rattling is beginning to creep into the utility coal market. The possible disruption of oil supplies from the Middle East is causing coal buyers to reconsider the usual terms of new coal agreements. In the past couple of years, the trend for coal supply agreements has been toward shorter one- to three-year contracts. If the other major fuel sources in the U.S. are disrupted, coal price spikes could result.

If the other major fuel sources in the U.S. are disrupted, coal price spikes could result.

Sales taxes levied by several states continue to favor using Wyoming coal over their in-state coal products. Illinois has a 6.25% sales tax for FOB coal purchased from within or outside the state. PRB coals currently priced at $6 per short ton would have a $0.375 per short ton sales tax while Illinois coal priced at $20 per short ton would have a sales tax of $1.25. Thus, the tax hurts the competitiveness of higher-priced local coal. Illinois is trying to counter this tax differential by offering their state's coal producers tax credit offsets.

Georgia's 5% sales tax may have been a major consideration in Southern Company's recent decision to move their Scherer power plant to a 100% PRB operation. $30 per short ton central Appalachian coal is no longer feasible—the difference in sales tax alone gives PRB coal an advantage of $1.20 per short ton. These are just two examples of how states cause their basic industries to be less competitive and productive (U.S. Coal Review, 7/15/2002).

In Wyoming, some politicians are suggesting that the state should increase the amount of severance tax imposed on coal. Opponents to this increase point out that increasing the severance tax on Wyoming coal would tend to stagnate future growth in the state's coal industry. They just point north to Montana (which has the highest severance tax on coal in the country) and compare Wyoming's 2001 coal production of 368 million short tons to Montana's 38 million short tons (Coal Outlook, 8/5/2002).

Wisconsin Public Service Corp. is looking at adding a new 500-MW coal-fired generating unit to its Weston plant. The company is targeting start-up for the new unit by 2008. Currently the company only burns PRB coal at their opera-

tion, and it is expected that the new $650 to $700 million unit would also burn PRB coal (Coal Trader, 9/26/2002).

NRG Energy is burning a blend of PRB and eastern coals at its Dunkirk and Huntley power plants. The plants, located on the eastern shore of Lake Erie, can receive the western coal by either rail or a combination of rail-barge movements (U.S. Coal Review, 9/30/2002).

Table 16 tabulates some of the contract, spot sales, test burns, and solicitations for Wyoming coal, announced during the third quarter of 2002.

References cited

Federal Energy Regulatory Commission (FERC) Electric Form 423 (http://www.ferc.fed.us/electric/f423/form423.htm)

Stauffenberg, D.G., 2001, Annual report of the State Inspector of Mines of Wyoming, for the year ending December 31, 2001: Wyoming Department of Employment, Office of the State Inspector of Mines, Rock Springs, Wyoming, 81 p.

Table 16. Marketing activities for Wyoming coal producers during the third quarter of 2002*.

Utility	Power Plant	Coal Mine/Region	Activity	Tonnage	Comments
City Public Service of San Antonio	Deely and Spruce	PRB	So	up to 1.5 mt	Delivery in 2003
Consumers Energy	System	PRB	Sp	200,000 t	Delivery in 2002
Dairyland Power	Madget	PRB	So	462,000 t	Delivery in 2002
East Kentucky Power Co-op	Spurlock	PRB and other coals	So	up to 1.5 mt/y	Up to three years beginning in 2004
Grand River Dam Authority	Chouteau	PRB	Sp	15 trainloads	Late 2002 through first quarter 2003
Hastings Utilities	Hastings	Rawhide/PRB	C	0.3 mt/y	Delivery starting in 2003 up to three years
Kansas City Power & Light	System	PRB	Sp	5 or 6 trains/month	Delivery in second half of 2002
Lansing Board of Water & Light	Eckert	PRB	So	1.2 mt	Delivery in 2003
Midwest Generation	Baldwin& Hennepin	PRB	So	up to 5 mt/y	Delivery in 2003
Muscatine Power & Water	Muscatine	Buckskin/PRB	C	1 mt/y	Three year extension of current contract
Northern Indiana Public Service	Baily and Schahfer	PRB	So	0.75 mt/y	Up to five years, delivery beginning in 2003
Omaha Public Power District	System	PRB	So	2.4 mt	Delivery in 2003
PacifiCorp	Dave Johnston	Wyodak/PRB	C	up to 7.8 mt	Delivery through 2007
Portland General Electric	Boardman	PRB	So	1.75 mt	Delivery in 2003
Reliant Energy	Limestone	Cordero-Rojo/PRB	T	1 mt	Delivery in second half of 2002
Southern Company Services	Scherer	Black Thunder/PRB	C	7.5 mt	Delivery 2003 to 2005
Xcel Energy	Arapahoe	Black Thunder/PRB	Sp	seven trainloads	Delivery in second half of 2002

*Data obtained from: Coal Outlook, COAL Daily, U.S. Coal Review, FERC database, and personal contacts. Note: C = contract; mt = million short tons; mt/y = million short tons per year; PRB = Powder River Basin; Sp = spot coal; So = solicitation; t = short tons; and T = test burn. *Wyoming State Geological Survey, Coal Section, February, 2003.*

Coalbed Methane Update

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Total production of coalbed methane (CBM) in Wyoming had reached 239.6 billion cubic feet (BCF) through three quarters of 2002 and is expected to reach 330 BCF by year's end. Daily production of CBM from the Powder River Basin (PRB) alone will be one BCF by the end of 2002. About one-fifth of Wyoming's natural gas production is now from coal beds. Drilling of CBM wells in the PRB has continued to decline throughout the year as low prices for natural gas and the suspended leasing of federal lands pending completion of environmental studies have both contributed.

Exploration for CBM is continuing in other parts of Wyoming with several new projects announced in the third quarter. Fort Union Formation coal beds are targeted for exploration in the north central Great Divide Basin; Mesaverde Formation coal beds are targeted for the Atlantic Rim area in the eastern Washakie Basin; the La Barge area in the western Green River Basin is the site of a development project in Mesaverde coal beds; a pilot project has been proposed for Fort Union coal beds in the northeastern Great Divide Basin; and an exploration program for CBM in

Almond Formation coal beds is planned for the southeastern flank of the Rock Springs uplift.

Production and drilling

CBM production reported by the Wyoming Oil and Gas Conservation Commission (WOGCC) for the first nine months of 2002 was 239.6 billion cubic feet (BCF) (**Table 17**). This was 18.8% of Wyoming's total gas production through three quarters of 2002, and nearly a 33.0% increase over CBM production for the same period in 2001. On a monthly basis, CBM now accounts for an average of over 20% of Wyoming's total natural gas production (it was 20.6% in September, 2002). There were 10,057 producing wells and 3649 shut in wells in September, 2002. The Consensus Revenue Estimating Group (CREG) for the State of Wyoming now predicts that 330 BCF of CBM will be produced in 2002, an average of 27.5 BCF per month. Production through the first nine months is averaging 26.6 BCF; however, production in September was nearly 29.3 BCF for only 30 days. CBM production should be averaging one BCF per day from the PRB by the end of 2002.

...drilling on federal land has been stalled pending completion of the PRB Oil and Gas Project Final Environmental Impact Statement (FEIS).

There has been a large decline in applications for permit to drill (APDs) in Wyoming during the first nine months of 2002 when compared to the same period in 2001. Part of the reason for the decline is that drilling on federal land has been stalled pending completion of the PRB Oil and Gas Project Final Environmental Impact Statement (FEIS). The lack of drilling permits issued on federal land should be alleviated somewhat when the Record of Decision (ROD) for this FEIS (released in January, 2003) is signed in early 2003.

Activities of coalbed methane companies

Kennedy Oil applied for drilling permits for the first seven wells in an exploratory CBM project on its federal oil and gas leases in Ts24 and 25N, R98W, approximately 35 miles northwest of Wamsutter (**location A, Figure 9**). Among the proposed new wells is the 21-22 SW Kennedy Central proposed in NE NW section 22, T24N, R98W, which is designed to evaluate coal zones in the Fort Union Formation to a depth of 5532 feet. Kennedy also applied for drilling permits for six other Fort Union tests in sections 25 and 26, T25N, R98W, that are projected to depths ranging from 4365 to 4552 feet. The project area encompasses about 10,240 acres, of which 9090 are federal surface and minerals. Kennedy plans to explore two CBM areas (or *pods*). The northern and southern pods would both contain 10 dewatering wells and one reinjection well. The wells, with the exception of the reinjection wells, would be located on 160-acre spacing. All produced water would be reinjected into a water "sand" containing water of equal or lesser quality. No permanent discharge of produced water is proposed, and all potable water would be protected. Kennedy believes that 10 dewatering wells in each of the pods is necessary to dewater the coal sufficiently to allow the gas to desorb and thus, to determine whether gas production is economically viable in the project area.

The U.S. Bureau of Land Management (BLM) approved a proposed CBM program to be operated by Petroleum Development Corp. (PEDCO) in the Blue Sky project of the Atlantic Rim area approximately 20 miles northeast of Baggs (**location B, Figure 9**). The Blue Sky Pod will include up to 23 CBM wells, two reinjection wells, access roads, gathering lines, and a compressor station. Nineteen of the wells would be on federal minerals and the remaining four wells would be on state minerals, while all 23 wells are located on surface lands administered by the BLM.

Drilling in the Blue Sky Pod as well in other pods is expected to provide information for use in an ongoing environmental study of the Atlantic Rim Coalbed Methane Project. An Environmental Impact Statement (EIS) is now underway for the project, which includes proposals by the operators to drill up to 3800 new wells in the area. The BLM will allow about 200 test wells in the area to determine the economic and environmental feasibility of such a large-scale project.

Infinity Inc. received approval from the Wyoming Department of Environmental Quality (DEQ) for the installation of

Table 17. Monthly and cumulative Wyoming coalbed methane production[1] in MCF[2] (1998 through November, 2002).

	1998		1999		2000		2001		2002	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	1,962,669	1,962,669	3,660,434	3,660,434	8,461,780	8,461,780	18,201,908	18,201,908	25,448,478	25,448,478
February	1,882,421	3,845,090	3,462,685	7,123,119	8,706,458	17,168,238	16,892,486	35,094,394	23,216,353	48,664,831
March	2,134,042	5,979,132	4,110,431	11,233,550	9,872,362	27,040,600	19,707,066	54,801,460	25,854,359	74,519,190
April	2,154,252	8,133,544	4,040,989	15,274,539	10,565,807	37,606,407	19,541,037	74,342,497	25,157,840	99,677,030
May	2,254,160	10,387,257	4,422,581	19,697,120	11,831,227	49,437,634	20,620,560	94,963,057	27,094,026	126,771,056
June	2,369,015	12,756,559	4,605,167	24,302,287	12,199,486	61,637,120	20,411,571	115,374,628	26,220,780	152,991,836
July	2,455,931	15,212,490	4,877,924	29,180,211	13,024,856	74,661,976	21,418,942	136,793,570	27,978,275	180,970,111
August	2,654,655	17,867,145	4,793,060	33,973,271	14,180,161	88,842,137	22,250,477	159,044,047	29,362,903	210,333,014
September	2,988,544	20,855,689	5,125,811	39,099,082	14,390,965	103,233,102	21,550,038	180,594,085	29,271,209	239,604,223
October	3,158,168	24,013,857	5,961,192	45,060,274	15,393,978	118,627,080	23,996,891	204,590,976	30,639,740	270,243,963
November	3,188,985	27,202,842	5,947,893	51,008,167	15,220,163	133,847,243	23,768,106	228,359,082	30,170,359	300,414,322
December	3,434,905	30,637,747	7,180,697	58,188,864	16,852,924	150,700,167	25,622,941	253,982,023		
Total		**30,637,747**		**58,188,864**		**150,700,167**		**253,982,023**		

[1]Data from the Wyoming Oil and Gas Conservation Commission. [2]MCF=thousands of cubic feet. *Wyoming State Geological Survey, January, 2003.*

a 1340-horsepower compressor at its La Barge CBM project in T29N, Rs113 and 114W (**location C, Figure 9**). The new compressor will have the rated capacity to deliver about 5 million cubic feet (MMCF) of gas per day to the Opal Hub. Infinity was using a 95-horsepower compressor with a capacity of about 400 thousand cubic feet (MCF) of gas per day. The new compressor will help to accelerate dewatering and will allow increased production volumes from coal beds in the Mesaverde Formation. Infinity also agreed to purchase an additional 3427 acres of CBM leases located on fee land about 6 miles east of the company's current production. This acquisition will allow Infinity to proceed with a second five-well pilot. The company believes it will be able to drill at least 21 wells on the new acreage. The company is moving forward with the EIS that must precede further drilling in the area where the five initial La Barge wells are located.

Rocky Mountain Gas Inc. recently completed an extended pilot dewatering program at its 7900-acre Clearmont property in south-central Sheridan County (**location D, Figure 9**). The company has drilled and completed 31 wells on the property, and it has constructed the necessary water containment reservoirs and gas gathering systems to service individual wells. There are currently 12 CBM wells in the Anderson coal bed and seven CBM wells in the Roland coal bed in various stages of dewatering. The company reports that the eight wells that have been dewatering the longest demonstrate water and gas flow rates typical of CBM wells in this part of the PRB.

The BLM asked the public to comment on a proposal by Patina Oil & Gas Corp. to drill a CBM pilot project on the Pappy Draw Unit in section 4, T26N, R93W (**location E, Figure 9**). The pilot would consist of five 3800-foot deep wells on 80-acre spacing to test the CBM potential of Fort Union coal beds. The project is about 19 miles west of Bairoil.

Flying J Oil & Gas plans to drill two CBM exploratory wells in T14N, R101W, to test the potential of the section above the Ericson Sandstone (Mesaverde Group). North of the Flying J project, CP Resources is in the process of evaluating a 10,000-acre farmout from True Oil. CP Resources has drilled one well and is drilling another to evaluate CBM potential of the Almond Formation at a depth of about 2000 to 2600 feet in T15N, Rs101 and 102W (**location F, Figure 9**).

Industrial Minerals and Uranium Update

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Industrial minerals continue to be a key element in Wyoming's economy. Trona, bentonite, limestone, construction aggregate, and gypsum are the major industrial minerals produced in Wyoming. In the third quarter of 2003, industrial minerals production in Wyoming continued at high to record levels. The only exception was a small and probably temporary decrease in trona production caused by a dockworkers' lockout on the West Coast, from where most trona is exported.

Uranium continues to be produced at two *in situ* localities in Wyoming. Uranium production continues to decline, although Wyoming produces twice as much uranium as Nebraska, the only other uranium producing state. However, the price of yellowcake, which declined in the first quarter of 2002, resumed its slow but steady increase since December, 2000.

Bentonite

Wyoming's 14 bentonite mills (**Figure 16**) continue to produce near-record amounts of refined bentonite products from raw bentonite, which is mined from several pits for each mill. Bentonite production for 2002 is close to exceeding the record amount of 4.8 million tons mined in 1981. Almost all of the bentonite produced in 1981 was used to make mud used in oil well drilling. Currently, bentonite is used in a great variety of products including absorbents such as kitty litter, clay barriers, mineral fillers, and many others (see *Wyoming Geo-notes No. 75*, December, 2002, p. 19).

Cement raw materials

Cement is manufactured in Laramie from high-calcium limestone, gypsum, siliceous shale, and other additives (**Figures 16** and **17**). High-calcium limestone is the primary ingredient. In 2001, Mountain Cement mined 600,000 short tons of limestone and produced 540,000 short tons of cement. That year, 100,000 short tons of gypsum were mined, although some of this was stockpiled. Other additives include varying amounts of siliceous shale, iron (mill slag), marl, clay, and sand.

Construction aggregate

Construction aggregate production in Wyoming is mainly seasonal and peaks during the summer highway and outdoor structure construction season. Since there was more highway construction in 2002 than 2001, construction aggregate production in Wyoming is expected to increase.

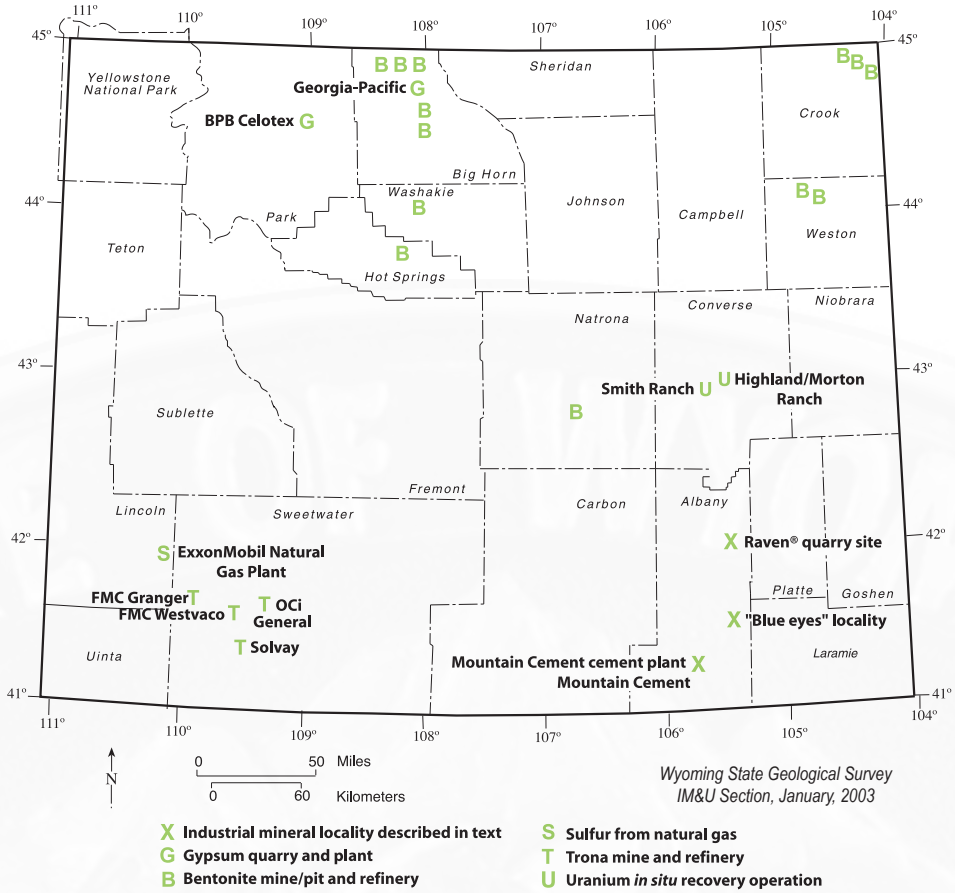

Figure 16. Index map of Wyoming showing the location of industrial mineral and uranium sites mentioned in the text. Localities are approximate and may represent more than one site.

Decorative and dimensional stone

Gallegos Wyoming withdrew from its venture with Raven Quarries in which it operated Raven's quarry west of Wheatland (**Figure 16**) and produced pink swirled granite (geologically a migmatite) called Mirage®. At the end of the third quarter, 2002, the Raven Quarry site became inactive.

Meanwhile, Vermont Quarries continued to apply for exploration permits for an area underlain by gray anorthosite that contains blue iridescent labradorite (a feldspar) known unofficially as "blue eyes" (**Figures 16** and **18**). Vermont Quarries planned to drill the site by the end of the year.

Gypsum

Gypsum is produced in Wyoming at three locations: south of Lovell by Georgia-Pacific (GP), at Cody by BPB Celotex (BPB), and south of Laramie by Mountain Cement (**Figure 16**). GP and BPB calcine gypsum and manufacture wallboard at their locations, while Mountain Cement uses gypsum in the manufacture of Portland cement. These producers have been operating at capacity for seven years, except for the brief closure of the Cody operation when BPB purchased Celotex. There is potential to expand gypsum production in Wyoming, either by existing producers or new operations.

Sulfur

Sulfur is produced in Wyoming as a product recovered from the desulfurization of natural gas containing hydrogen sulfide (H_2S). Since increasing amounts of sulfur are also recovered through the desulfurization of exhaust gases at coal-fired power plants within and outside Wyoming, the demand for sulfur from Wyoming is decreasing. ExxonMobil announced that it was going to close its sulfur recovery operation at La Barge (**Figure 16**). There is no way to determine exactly how much sulfur is produced in Wyoming, since this figure is not reported to any State of Wyoming agency.

Trona

Trona production in Wyoming slowed during the third quarter due to the West Coast dockworkers' slowdown and lockout. However, according to the U. S. Geological Survey, total production was down only 2% nationally. The State of Wyoming's Consensus Revenue Estimating Group (CREG) estimated that 18 million short tons of trona would be mined in 2002, and predicted the same figure for calendar years 2003 and 2004 (**Table 1**). A slight increase in trona production to 18.5 million short tons was predicted for 2005 through 2008. Prices for mined trona are predicted to stabilize at $38.00 per short ton for 2002 through 2008 (**Table 2**).

Figure 17. Mountain Cement's plant south of Laramie. Limestone and other ingredients are blended in the silos at the right and loaded into two large rotating kilns (the long dark cylinder in the center of the photograph). After traveling the length of the kiln and heating to as high as 1900°C, the resulting material is ground and treated to make Portland cement.

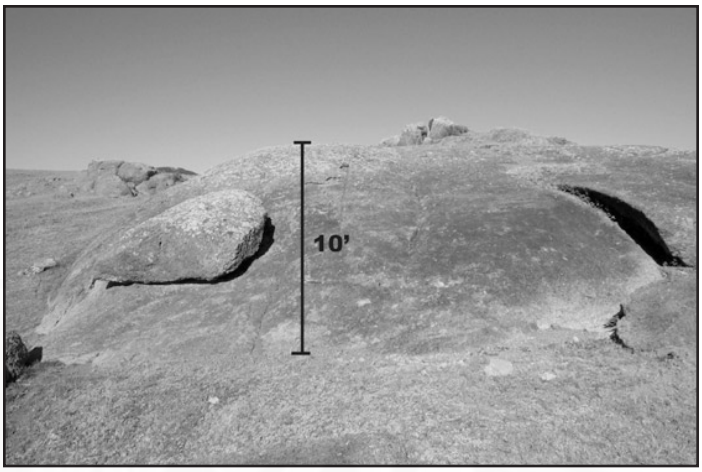

Figure 18. Outcrop of "blue eyes" anorthosite, Shanton Creek area, Albany County, Wyoming. Note relative absence of jointing or veining. Vertical line drawn for scale represents about 10 vertical feet.

Trona is mined in Wyoming at five underground mines and refined into soda ash and other sodium compounds at mine-mouth plants. Four companies [FMC, General Chemical Soda Ash Partners (General), OCi, and Solvay Minerals] operate the mines and refining plants (**Figure 16**).

In September, a manufacturing company called Powerball Technologies announced plans to build a pilot plant in connection with the FMC Westvaco sodium products plant west of Green River. Powerball plans to convert sodium hydroxide produced by FMC to elemental sodium, a highly reactive metal. Elemental sodium would then be shipped out of Wyoming to another plant where it would be used to manufacture a material containing sodium, pelletized, and used to store and release elemental hydrogen, which is used for cooling, as a fuel, and several other uses.

Uranium

The spot market price of yellowcake (oxidized uranium—the product of Wyoming's uranium mills) increased during the third quarter to $9.90 per pound from $9.85 per pound, according to the Ux Consulting Company, LLC., the Uranium Exchange Company (http://www.uxc.com/review/uxc_prices.html), and the Rocky Mountain Minerals Scout. Uranium is produced in Wyoming by CAMECO at two *in situ* recovery sites, Smith Ranch and Highland/Morton Ranch (**Figure 16**). CAMECO, of Saskatoon, Saskatchewan, also owns the only other current uranium production in the U.S., Crow Butte, Nebraska.

In September, 2002, CREG estimated that 1.70 million pounds of yellowcake would be produced in Wyoming in 2002, down from 1.75 million pounds as estimated in September, 2001. This is only a 3.7% increase, as opposed to a 6.7% increase predicted earlier. No changes in this rate of yellowcake production are forecast for calendar year 2003, followed by a slight decrease to 1.6 million pounds in 2004 through 2006 and another decrease to 1.5 million pounds in 2007 and 2008. [Note: uranium production was erroneously reported in short tons instead of pounds in *Wyoming Geo-notes No. 73*, April, 2002, p. 23 and in *Wyoming Geo-notes No. 75*, December, 2002, p. 20. The author was not responsible for this error; the editor regrets the mistake.]

Metals and Precious Stones Update

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With prices for platinum-group metals (PGMs) rising from increased demand, some favorable areas in southeastern Wyoming are currently being explored. URSA Minerals had applied for permits to conduct a drilling program near the New Rambler mine in the Medicine Bow Mountains based on anomalies identified by their earlier geologic mapping, soil geochemistry, and geophysical surveys. Gold prices are also rising and generating interest in some known gold areas in the state. Most of the diamond exploration and development activity in North America is currently in Canada.

Minerals exploration

Exploration for platinum-group mineralization continued within southeastern Wyoming, primarily because these

metals are very rare. They are found only in a few localities worldwide in anomalous amounts. The geology of a few local areas in Wyoming appears to be favorable for the discovery of significant PGMs.

The price of PGMs continued to rise last quarter due to increased demand. Selling prices for some of the PGMs on January 21, 2003 were $629 per ounce for platinum, $260 per ounce for palladium, $590 per ounce for rhodium, $1280 per ounce for rhenium, and $345 per ounce for osmium.

Wyoming has several restricted and favorable geological features that are known to contain anomalous amounts of some PGMs. For example, a commercial mine (New Rambler) operating during the first two decades of the 1900s in the Medicine Bow Mountains produced some palladium, along with copper, gold, silver, and platinum.

URSA Minerals announced in an October 24, 2002 press release that they had scheduled a drilling program in the vicinity of this historical mine. According to the press release, the project was selected

> *… on the Company's high-grade platinum group metal (PGM) and base metal targets on the West Rambler Property in southeastern Wyoming, U.S.A. The first target is an area of high-grade float samples with values up to 89.2 g/t palladium plus significant platinum, gold and copper values associated with a coincident soil geochemical anomaly and an EM conductor that is located approximately 3 km west of the past-producing New Rambler Mine. The second target is a strong EM geophysical conductor and related magnetic high located 2 km west of the New Rambler mine. The targets have not been previously tested and at least one hole will be drilled on each target.*
>
> *URSA Minerals'… West Rambler property consists of 30 lode mining claims located on U.S. federal lands. The claims are on strike from the past-producing New Rambler copper-PGM mine along an east-west trending shear zone and a strong linear magnetic gradient. The claims were staked based on proximity to the New Rambler mine and previous work by Anaconda Copper Mining Co. in the 1980's that reported gossanous float with high palladium-copper values and an airborne EM anomaly similar in character to that associated with the New Rambler Mine.*
>
> *URSA Minerals' drill targets have been defined by geological mapping, soil geochemistry and ground electromagnetic (EM)/magnetic geophysical surveys. On the first target area, mapping identified several mineralized float samples over a 500 meter strike length that assayed from 10.39 g/t to 89.22 g/t palladium, 3.23 g/t to 20.24 g/t platinum and 2.92% to 32.50% copper. The mineralized float blocks are similar in grade and description to ore in the gossan cap and oxide zone of the past-producing New Rambler Mine. A soil survey subsequently defined several oxidation anomalies with concentrations of palladium, platinum, gold, copper, nickel, and cobalt. The soil anomalies are coincident with the location and trend of the mineralized float samples and a regional shear zone. The largest anomaly has dimensions of approximately 300 by 200 metres and is flanked by smaller anomalies. …Ground geophysical surveys have identified a moderate EM conductor and a strong magnetic gradient over a strike length of 600 m coincident with the PGM mineralized float and soil anomalies in the first target area. In addition, a strong geophysical conductor related to a magnetic high was also identified on the property 1 km east-northeast of the soil anomalies. This strong conductor reaches within 20 meters of the surface and is the second drill target. …The West Rambler property is part of a regional PGM exploration program that URSA Minerals has initiated in early Proterozoic rocks on the southern margin of the Wyoming geological province.*

Additional exploration for PGMs was also reported in Wyoming by Encampment Resources. PGMs are valuable strategic metals: for example, they are a necessary component of catalytic converters on internal combustion engines to provide a clean environment. The geology of the Wyoming platinum-palladium-nickel province was reviewed by Hausel (2000).

Rising gold prices ($356 per ounce on January 21, 2003) has spurred company, consultant, and prospector interest in this precious metal. Inquiries to the Metals and Precious Stones Section at the Wyoming State Geological Survey (WSGS) showed a dramatic increase in early 2003. Much of the interest to date has been for gold deposits located within the Rattlesnake Hills, South Pass, Dickie Springs, Seminoe Mountains, Bear Lodge Mountains, and the Laramie Mountains. Information on these occurrences is available in WSGS Bulletins 68 and 70.

Some diamond interest was also shown for Wyoming, but diamond exploration activity was minor during the past year. Much of the lack of interest is due to the major discoveries in Canada, where most exploration resources are being focused. To date, 538 kimberlites have been found in Canada, along with some unconventional diamond deposits; two mines have been placed in production since 1998 (see http://www.diavik.ca/; http://www.aber.ca/; and http://ekati.bhpbilliton.com/); and there are three other projects at an advanced development stage (Kjarsgaard and Levinson, 2002).

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Hausel, W.D., Gregory, R.W., Motten, R.H., and Sutherland, W.H., 2003, Geology of the Iron Mountain kimberlite district and nearby kimberlitic indicator mineral anomalies in southeastern Wyoming: Wyoming State Geological Survey Report of Investigations 54, 42 p.

Sutherland, W.M., and Hausel, W.D., 2002, Preliminary geologic map of the Rattlesnake Hills 1:100,000-scale Quadrangle, Fremont and Natrona Counties, central Wyoming: Wyoming State Geological Survey Open File Report (OFR) 2002-02, 2 plates and 32 p. text.

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Coopersmith, H.G., Mitchell, R.H., and Hausel, W.D., 2003, Kimberlites and lamproites of Colorado and Wyoming, USA: Field Excursion Guidebook for the 8th International Kimberlite Conference, June, 2003.

Erlich, E.I., and Hausel, W.D., 2003, Timing of kimberlite magmatism and different type of diamond-bearing complexes (abstract): Abstracts, 8th International Kimberlite Conference, Vancouver, B.C. [in press].

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Hausel, W.D., 2003, Cordierite (iolite) and corundum (sapphire, ruby) in Wyoming—new gemstones for Wyoming: Forum on the Geology of Industrial Minerals, Reno, Nevada [in preparation].

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Wyoming—A Rock Hound's Paradise

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Incredible treasures await the weekend rock hound and treasure hunter in Wyoming. Diamonds, rubies, sapphires, iolite, peridot, jasper, agate, jade, gold, platinum, garnet, emerald-green chromian diopside, aquamarine, and emerald have all been found in the Cowboy state (**Figure 19**). So why buy a lottery ticket when your chances of finding a king's ransom may be much better by prospecting in your own back yard.

"Gold is where you find it," so the old adage suggests, and I think I've been able to prove it. Ten years ago, one of my associates spotted a conglomerate in the highwall of the Laramie landfill. The conglomerate was deposited in the creek bed of a stream, which ran though the landfill possibly thousands of years ago. My associate (Eric Neilsen) sampled the conglomerate and sure enough, he panned gold out of it. During the same sampling program, we even found an old heretofore unknown gold mine, which operated in the late 1800s, within 100 feet of Interstate 80 just west of Arlington.

Gold attracts many people to Wyoming each year. People with this common interest have formed clubs to search for gold. In our area, we have members of the Wyoming Prospector's Association, the Rocky Mountain Prospectors and Treasure Hunters Club, and the Gold Prospectors Association of America, as well as numerous rock, mineral, and gem clubs who get together and search for gold most weekends of the summer.

One recluse treasure hunter from Arizona searched for gold in Wyoming's Sierra Madre west of Encampment several years ago. What he found near Strawberry Gulch wound up on a full-page advertisement for a metal detector manufacturer. In a little known area in the western part of the range, this treasure hunter reportedly recovered 399 gold nuggets using a metal detector. Just a few miles east of this area near Purgatory Gulch, I recovered samples of quartz from a vein. The quartz contained tiny flakes of visible gold. As a rule of thumb in gold prospecting, when you see visible gold on quartz with a 10-power magnifying lens, the sample will assay at least 1 ounce of gold per ton—this is considered high grade. Because of the gold in the quartz vein, Purgatory Gulch down slope of the vein probably would be a good place to search for nuggets.

About seven years ago, a prospector from Green River searched a creek near Atlantic City in an area that many locals claimed had been mined out. When his metal detector sounded an alarm during a sweep over some gravel, he recov-

Continued on next page.

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ered one of the largest nuggets found in Wyoming during the past 50 years, a 7.5-ounce gold nugget! Nearly every time I lead a field trip to South Pass, one or more people find samples with visible gold. Just last summer, a prospector from Riverton found a sample filled with visible gold that would probably assay anywhere between 20 to 200 ounces per ton.

Jade occurs in high enough abundance in Wyoming to be designated the State Gemstone. At one time, central Wyoming was scoured by rock hounds looking for jade, and some fabulous specimens were found, including boulders of high-quality jade that weighed as much as 3200 pounds. There was even a 6-ton boulder of black jade reportedly found in the Prospect Hills north of Rock Springs in 1978, although this remains to be verified.

Some high-quality jade was found near Jeffrey City, where jade has been found in both surficial cobbles and metamorphic rocks that are more than 3.2 billion years old. Most Wyoming jade occurs as black jade, but some high-quality apple- and emerald-green jade have also been found. The jade in Wyoming (nephrite) is mineralogically different from southeastern Asian jade (jadeite), even though these two types are impossible to distinguish without x-ray diffraction analysis. Some jade is still very valuable—a small Asian jade ring recently sold for $2.4 million to a private collector.

The jade in Wyoming was found in such abundance in the past that it has been referred to as "Wyoming Jade," even though the same variety is found elsewhere in the world. One can still find jade in old quarries near Jeffrey City. Next time you drive through Jeffrey City along Highway 287, look north to the nearby hills. You will see some old scars in the granite—many of these are sites where prospectors dug for jade 30 to 50 years ago.

Wyoming also has sapphires and rubies and the more we search, the more we find. In 1995, I came across a sapphire deposit west of Wheatland that contained another gemstone known as iolite. Since then, several nice sapphire and iolite gemstones have been cut and sold from this property by Eagle-Hawk Mining, a Colorado-based company (see http://wsgsweb.uwyo.edu/metals/gemstones.asp). I found one specimen of violet-blue, transparent iolite that weighed more than 3000 carats, which is one of the largest found in North America. Just two weeks before this article was written, Wayne Sutherland of the Wyoming State Geological Survey (WSGS) and I were mapping in the Sage Hen Rocks area of the Granite Mountains; Wayne found about a dozen nice specimens of sapphire at a previously unknown locality.

Wyoming appears to be rich with diamonds. Some diamonds are the most valuable gemstones on the surface of the earth. For example, rare pink diamonds from Australia are so valuable that they have sold for more than $1 million per carat (500,000 times more valuable than an equivalent weight in gold). It is exciting to know that some pink diamonds have been described in the State Line area south of Laramie near Tie Siding.

Diamonds have also been found in the Iron Mountain district west of Chugwater, and reported in the Cedar Mountain area southwest of Green River, in the Wind River Mountains, the Gros Ventre Range, the Medicine Bow Mountains, and the Granite Mountains. The majority of the diamonds found in Wyoming have been gem quality. Evidence of potentially hundreds of undiscovered pipes that could possibly contain diamonds has now been found in the Laramie, Medicine Bow, Sierra Madre, Seminoe, Gros Ventre, Wind River, Owl Creek, and Big Horn mountains, and the Hartville uplift, Green River Basin, Powder River Basin, and Denver-Julesburg Basin.

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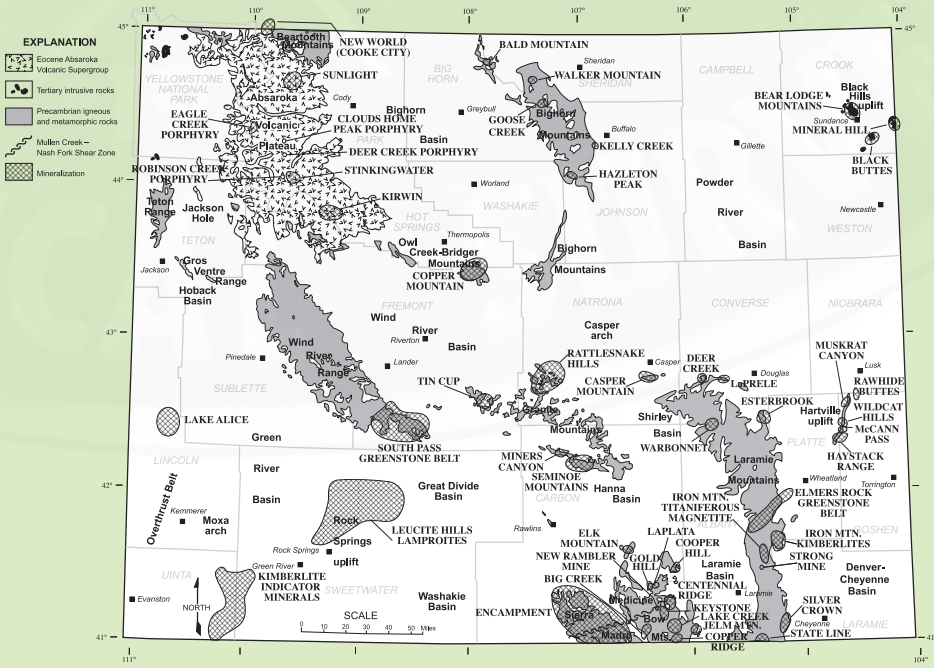

Figure 19. Principal mineralized areas and mining districts in Wyoming (from Hausel and Sutherland, 2000; original modified from Hausel, 1997).

GEOLOGIC MAPPING AND HAZARDS UPDATE

Geologic Mapping, Paleontology, and Stratigraphy Update

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New geologic mapping is now underway in the area centered around Fossil Butte National Monument west of Kemmerer. The monument showcases a unique resource of fossil fish and related fauna and flora of the Eocene Green River Formation. Staff at the monument desired larger-scale (1:24,000) mapping in and around the monument, as it is important to the region's geologic story. Their proposal to complete new field mapping of twelve 1:24,000-scale quadrangles over three years was approved and funded by the National Park Service (NPS). Work began this past summer. The Wyoming State Geological Survey (WSGS) will review and publish the maps as part of their digital map series.

Four new articles relating to Wyoming geology and paleontology were released recently. Topics included Powder River Basin (PRB) coalbed methane resources, Frontier Formation stratigraphy, structural geology in the Hanna/Carbon Basin, and a paleontological study in the Washakie Basin.

Mapping project near Fossil Butte National Monument

New geologic mapping efforts are now underway in an area centered around one of Wyoming's unique fossil resources showcased at Fossil Butte National Monument (**Figure 20**). The fossil record preserved within the Eocene Green River Formation of Fossil Basin is world-renowned and its fossils are found in museums around the world. Over one hundred years of intensive collecting has revealed a wide diversity of fossil fish, reptiles, birds, mammals, insects, and plants. New discoveries of fossil species continue to be reported from within the ancient lake sediments, expanding our understanding of the paleoecosystem. Intensive commercial fossil collecting from areas surrounding the monument (**Figure 21**) yields tens-of-thousands to hundreds-of-thousands of fossil fish each year.

Fossil Butte National Monument has, in its enabling legislation, a charge to develop the geologic story of Fossil Basin and the immediately surrounding thrust belt area for the general public. For this reason, monument staff desired larger-scale mapping (e.g., at 1:24,000 scale) for the area in and around the monument, and they submitted a proposal to complete new geologic maps of twelve 1:24,000-scale quadrangles over three years. The proposal was approved and funded by the Natural Resources Protection Program of the NPS; work began in the summer of 2002.

This new mapping effort is a result of completing the NPS Geologic Resources Inventory (GRI) for all national parks and monuments. The established goals of this inventory are to assemble a bibliography of associated geological resources for NPS units with significant natural resources and compile and evaluate a list of existing geologic maps for each unit; conduct a scoping session for each park; develop digital geologic map products; and complete a geologic report that synthesizes much of the existing geologic knowledge about each park or monument.

...larger-scale mapping will provide the best available data for managing the monument's geologic resources.

A geologic resources inventory workshop was held for Fossil Butte National Monument on May 23, 2002 to view and discuss the monument's geologic resources, to address the status of geologic mapping for compiling both paper and digital maps, and to assess resource management issues and needs. Cooperators from the NPS Geologic Resources Division (GRD), NPS Intermountain Region Geographic Information Systems (GIS) group, Fossil Butte National Monument, Colorado State University, and Loma Linda University were present for the workshop. The workshop involved a field trip to view the geology of the monument area and a scoping session to present overviews of the NPS Inventory and Monitoring (I&M) Program, the GRD, and the on-going GRI. Roundtable discussions involving geologic issues for the monument included interpretation, the status of geologic mapping efforts, sources of available data, and action items generated from this meeting.

Tim Connors (NPS GRD) presented overviews of the division, the I&M Program, the status of the natural resource inventories, and the GRI in particular. He also demonstrated some of the main features of the GRI digital geologic database. This has become the prototype for the NPS digital geologic map model as it reproduces all aspects of a paper map (i.e., it incorporates the map notes, cross sections, legend, etc.) with the added benefit of being geospatially referenced.

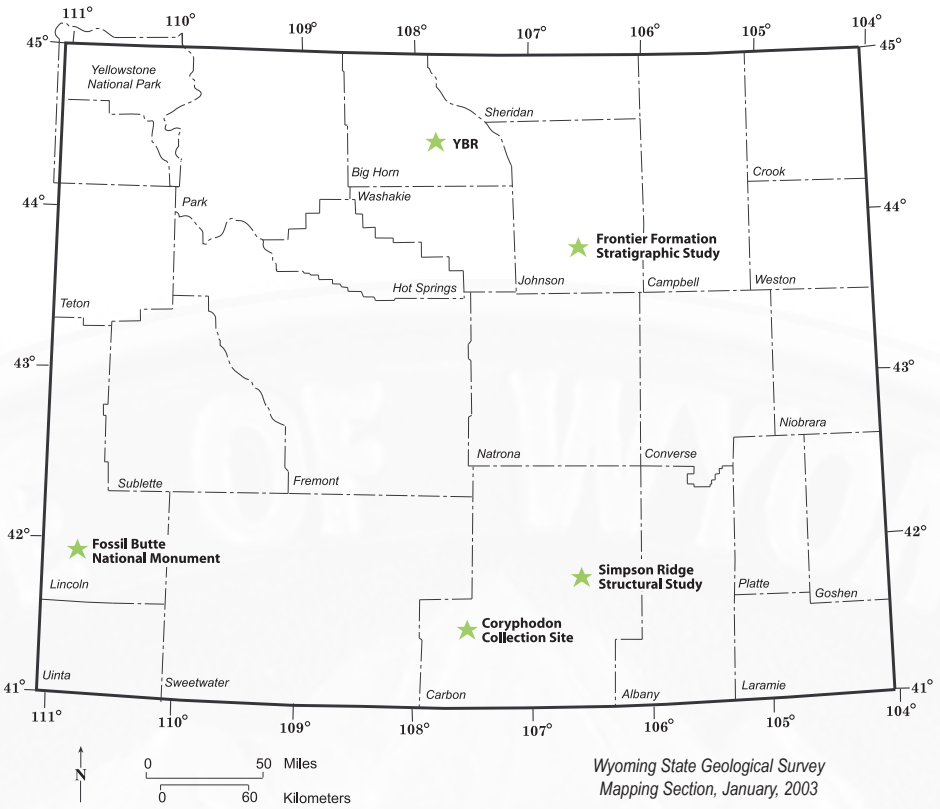

Figure 20. Index map to recently completed geologic and paleontologic studies in Wyoming, selected ongoing geologic mapping projects in Wyoming, and location of the Yellow Brick Road Dinosaur Tracksite (YBR).

At the scoping session, geologic bibliographies for the Fossil Butte area compiled from the American Geological Institute (AGI) GeoRef®, the U.S. Geological Survey (USGS) GeoIndex, and the ProCite® information taken from specific park libraries were distributed to cooperators. A separate search of the bibliographies was made for any existing surficial and bedrock geologic maps for the area. At present, two 1:100,000-scale geologic maps have been published by the USGS for the Kemmerer and Evanston 30'x60' quadrangles. Both are useful maps, but larger-scale mapping will provide the best available data for managing the monument's geologic resources. The twelve 1:24,000-scale quadrangles funded for mapping (**Figure 22**) and the years they will be mapped include Nugget, Fossil, Warfield Creek, and Bell Butte NE in 2002; Windy Point, Sage, Beckwith, and The Rock Slide in 2003; and Kemmerer Reservoir, Bell Butte, Elkol SW, and Little Dee Creek in 2004.

This new geologic quadrangle mapping is being coordinated by Dr. Paul Buchheim of Loma Linda University. He has excellent knowledge of the area and the Green River Formation in particular. Mapping is being conducted using the most current technology such as Geographic Positioning Systems (GPS) and GIS; digital geologic map products for the 12 quadrangles will be the end result. GRI staff will acquire the field sheets and any other GIS data from staff at the monument and will develop digital products for this work.

As GRI staff finish assembling the digitized maps, they will pass them onto the WSGS for review and publication as part of their ongoing geologic mapping program for the State of Wyoming. In addition, monument staff submitted technical assistance requests to digitize the published Kemmerer and Evanston 1:100,000-scale quadrangles. These were done earlier by the NPS Intermountain GIS support office and are available for download from the NPS-GIS Clearinghouse. However, several attributes required by the NPS GRI geologic model are missing and may require additional attribution if they are to be published. These digitized maps will be reviewed and the additional attribution completed by the WSGS (as part of a USGS STATEMAP project) and they will then be published by the WSGS as digital geologic maps.

New publications on Wyoming geology

In a recently published article, Ayers (2002) compared and contrasted two major U.S. coalbed methane (CBM) producing areas, the San Juan Basin of New Mexico and the PRB of Wyoming and Montana. In 2000, the San Juan Basin accounted for more than 80% of the U.S. CBM production. This basin contains a giant CBM play, the Fruitland fairway, which has produced more than 7 trillion cubic feet (TCF) of gas. The Fruitland CBM system and its key elements contrast with the Fort Union CBM play in the PRB. The Fort Union play is one of the fastest developing gas plays in the U.S. Its production escalated from 14 billion cubic feet (BCF) in 1997 to 147.3 BCF in 2000, when it accounted for 10.7% of the U.S. CBM production. By 2001, annual production from the basin was 244.7 BCF. According to the article, the key parameters

Figure 21. The main quarry operated by Ulrich's Fossil Fish Gallery in foreground with the Split Quarry on skyline. Both quarries are south of Fossil Butte National Monument; view is to southeast.

that control CBM resources and producibility are thermal maturity, maceral composition, gas content, coal thickness, fracture density, *in situ* stress, permeability, burial history, and hydrologic setting. These parameters vary greatly in the producing fields of these two CBM plays and were discussed in this article.

Dutton and others (2002) recently published the results of a comprehensive study of calcite cement distribution and its effect on fluid flow in the Frontier Formation on the west flank of the PRB (**Figure 20**). Dutton and co-workers looked at the size and distribution of calcite concretions in outcrops of the "Frewens sandstones" in the Frontier Formation. Calcite cements in the sandstones usually occur as irregularly distributed concretions in the upper and lower part of the "Frewens sandstones." The authors pointed out some interesting trends in the cementing which affect fluid flow, especially in the upper and lower parts of the Frewens. Completions of oil and gas wells in the lightly cemented middle part of the Frewens appear to yield the fastest fluid flow path.

Kraatz (2002) discussed the structural geology relating to the development of Simpson Ridge and the separation between the Hanna and Carbon basins (**Figure 20**). The author uses field mapping along with interpretation of well logs and seismic reflection data to determine the structural development of this feature. Evidence presented in the article indicates that a combination of basement-involved thrusting and thin-skinned, out-of-the basin thrusting is related to deeply rooted basement faults by a trishear deformational zone. Palynological data was used to date the Hanna Formation as late Paleocene and to place a maximum age of late Paleocene on the later Simpson Ridge deformation.

Work in Roehler's Coryphodon Catastophe Quarry, stratigraphically located in the Main body of the Wasatch Formation (lower Eocene), in the Washakie Basin (**Figure 20**), has yielded new information on intraspecific variation in *Coryphodon anthracoideus*, a large-bodied herbivorous browser. *Coryphodon anthracoideus* was one of the most widespread

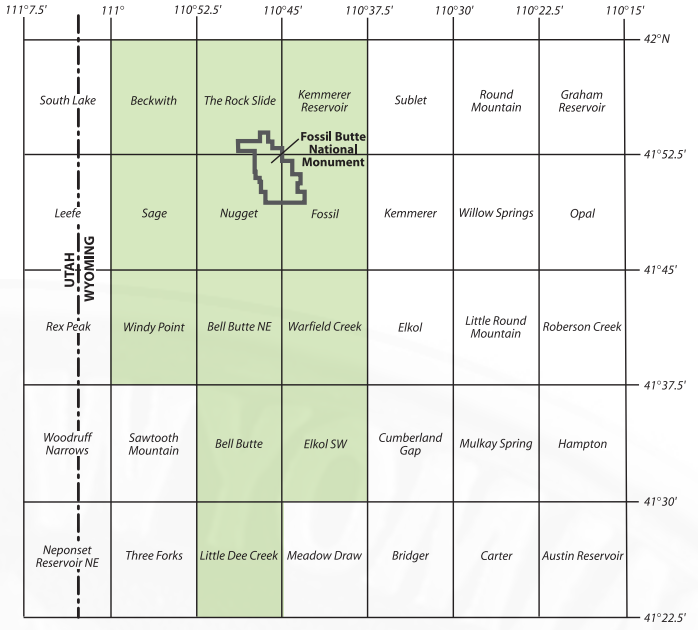

Figure 22. Index to 1:24,000-scale topographic quadrangles adjacent to Fossil Butte National Monument and quadrangles proposed for geologic mapping (green) in western Wyoming.

early Tertiary mammals, traditionally plagued with problems in identification of specimens to a specific level. McGee (2002) describes the lower dentition of *Coryphodon anthracoideus* from the quarry and assesses and compares intraspecific variation in this sample with samples from American Museum of Natural History Quarry 242 from New Mexico. The author examines variation in metric features of dentition including length, width, and molar area of samples.

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Documentation of Middle Jurassic Dinosaur Tracks at the Yellow Brick Road Dinosaur Tracksite, Bighorn Basin, Wyoming

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Brent H. Breithaupt, Wyoming PG-1551–Director, University of Wyoming Geological Museum

A student project to locate and study Middle Jurassic dinosaur tracks in the northeastern Bighorn Basin, Wyoming began in the summer of 2001. At the Yellow Brick Road Dinosaur Tracksite (YBR) located in section 16, T52N, R91W, Big Horn County, a unique assemblage of dinosaur footprints was discovered. The purpose of this study was to document the preserved tracks and to determine what these footprints might help tell us about Wyoming's Middle Jurassic dinosaur faunas. Tracks, trackways, and track-bearing units were studied to better understand the paleoecology of the tracksite and possible behavioral implications of the dinosaurs that left these footprints.

This is the first article in a two-part series dealing with our research on the dinosaur tracks at the YBR. In this report, we discuss the history of discovery, stratigraphic position, geologic significance, and methodologies used to document these tracks. The second article will discuss our results, interpretations, and conclusions on this previously unknown Middle Jurassic dinosaur population. Our work shows that estimations on dinosaur sizes, speeds, and activity patterns can be determined from the fossil record.

...the YBR has become a unique resource for University of Wyoming (UW) students doing paleontological research...

Introduction

In 1997, dinosaur tracks were reported from the Bighorn Basin (Breithaupt and others, 2001; Adams, 2001). One of these sites, the YBR (UW Locality V-2001-001) (**Figure 20**), has become a unique resource for University of Wyoming (UW) students doing paleontological research, especially since the site is located on a section of land owned by the State of Wyoming.

The tracks at the YBR are found in the lower Sundance Formation (Schmude, 2000). At this site, thousands of footprint impressions are preserved in exposures of an oolitic, gray, peritidal limestone approximately 165 million years old. This tracksite is a stratigraphically lateral equivalent to the Red Gulch Dinosaur Tracksite (RGDT) approximately 2 miles to the west. After five years of intensive study, and over 1000 tracks intensively documented, the RGDT is one of the largest tracksites in Wyoming and the most extensively studied dinosaur track locality in the world (Breithaupt and others, 2001). The tracks preserved at YBR have been studied in a similar fashion and appear to be even more numerous than at the RGDT. At the YBR over the past two field seasons, hundreds of the thousands of tridactyl pes (foot) impressions of theropod dinosaurs were surveyed and studied as part of a UW Geological Museum's undergraduate research program.

History

The initial discovery of dinosaur tracks in the Bighorn Basin was in the "dry wash" exposed along the Red Gulch/Alkali National Back Country Byway. Many locals have mentioned that the footprints were noticed prior to 1997. However, it wasn't until that year that a group of individuals (i.e., Row and Cliff Manuel, Fran Patton, Allen Archer, and Erik Kvale) made note of the site and reported it to the U.S. Bureau of Land Management (BLM). Although walked over and driven over for decades, the dinosaur tracks in this area were overlooked by many, presumably because the Sundance Formation has been historically defined as open-water marine in character (Darton, 1899). However, the discovery of dinosaur tracks and other recent work (Kilibarda and Loope, 1997; Schmude, 2000; Kvale and others, 2001) now demonstrate episodes of subaerial exposure during the Middle Jurassic in this region during regressive phases of the Sundance Sea.

In the vicinity of the town of Shell, the lower Sundance strata were deposited on a broad, shallow shelf adjacent to the paleotectonic feature named the Sheridan Arch by Peterson (1957). Schmude (2000) identified another Jurassic paleotectonic feature in this region which he named the Black Mountain High. These local paleohighs formed conditions which may have allowed for the creation and preservation of the paradoxical non-marine dinosaur ichnofauna in an otherwise marine depositional regime. The track-bearing limestones lie stratigraphically below the level of occurrence of the marine invertebrate fossil *Gryphaea nebrascensis* within the lower Sundance. Geological work in the area has assigned the track-bearing unit to the Middle Jurassic Bathonian stage (approximately 165 million years old) Canyon Springs Member of the Sundance Formation (Schmude, 2000) (**Figure 23**).

Any evidence of dinosaur activity from the Middle Jurassic is significant, as this was a period which preserved little terrestrial deposition worldwide, and a very limited vertebrate fossil record (Breithaupt and others, 2001). Existing dinosaur bone assemblages are relatively sparse from this time, only

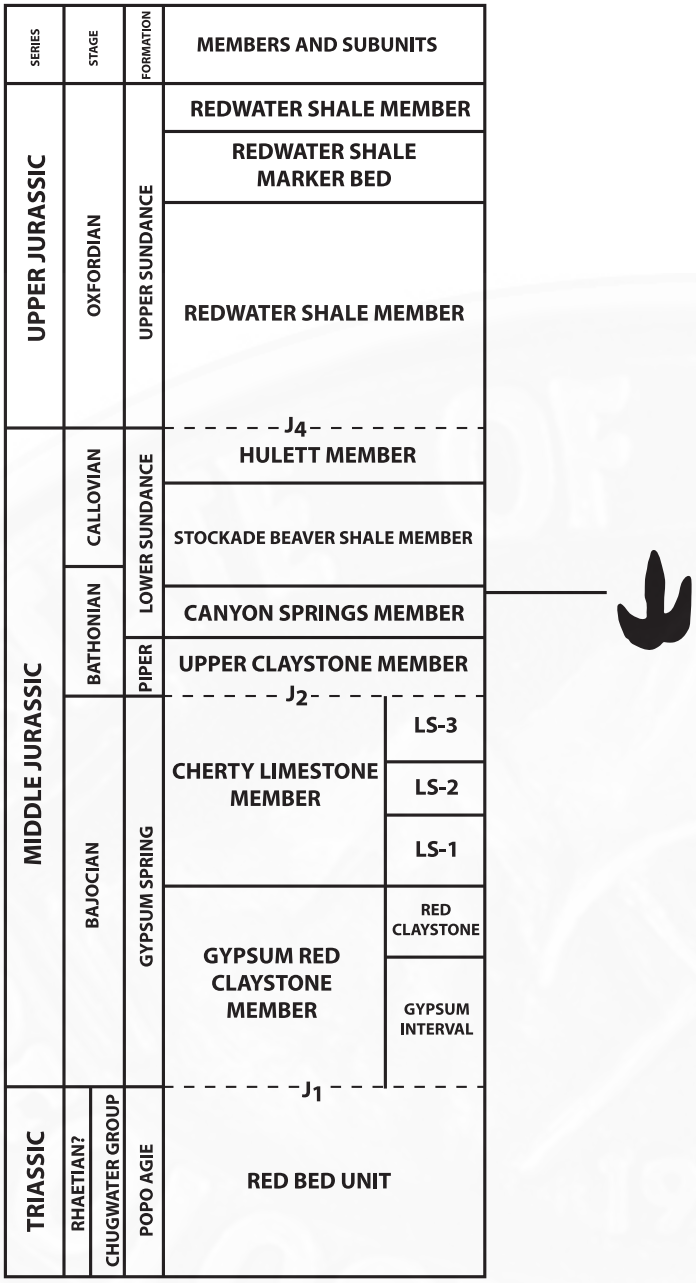

Figure 23. Stratigraphic position of the track-bearing Canyon Springs Member (dinosaur track indicates tracksite) of the Sundance Formation (modified from Schmude, 2000).

known from localities in China, Morocco, Algeria, Madagascar, England, France, Portugal, Argentina, Chile, Australia, and Mexico. Unfortunately, no Middle Jurassic dinosaur bone localities are known from the U.S. The dinosaur track record is equally limited. In the New World, existing Middle Jurassic dinosaur track records have been documented from Utah, Wyoming, Mexico, and Argentina. Worldwide, other Middle Jurassic tracks are only reported from England, Scotland, Portugal, Australia, and parts of Asia.

Methodology

At the YBR, tracks were documented utilizing a variety of data collecting methods established over previous summers in the Bighorn Basin (Breithaupt and others, 2001; Breithaupt and Matthews, 2001). During the summer of 2001, the state section was surveyed for tracks and other fossil material. Tracks that were discovered or reported previously were marked on topographic maps and aerial photographs of that area. Those areas with the greatest density of footprints were noted and marked with numbered flags on the track surface. Five of these areas have been studied intensively over the past two field seasons by UW students.

Following the traditional field methodologies for vertebrate ichnology set forth by Thulborn (1990) and Lockley (1991), the track surface of each study area was cleaned using brooms and brushes. A metric grid system was plotted on the surface with a compass bearing of north. Each track located on the grid system was drawn on a site map with a scale of 1 inch = 1 meter (**Figure 24**). To preserve the valuable paleontological data provided by each track, detailed measurements were taken. For hundreds of footprints, 14 separate measurements were taken, including foot length, foot width, azimuth, digit lengths, digit widths, the angles between each digit, depth, and left or right designation (**Figure 25**). Additional comments were made on any unique and important track and surface preservational features (e.g., sharp claws, digital pads, ripple marks, underprints). Based on the track

Figure 24. Thomas Adams mapping dinosaur tracks at the YBR.

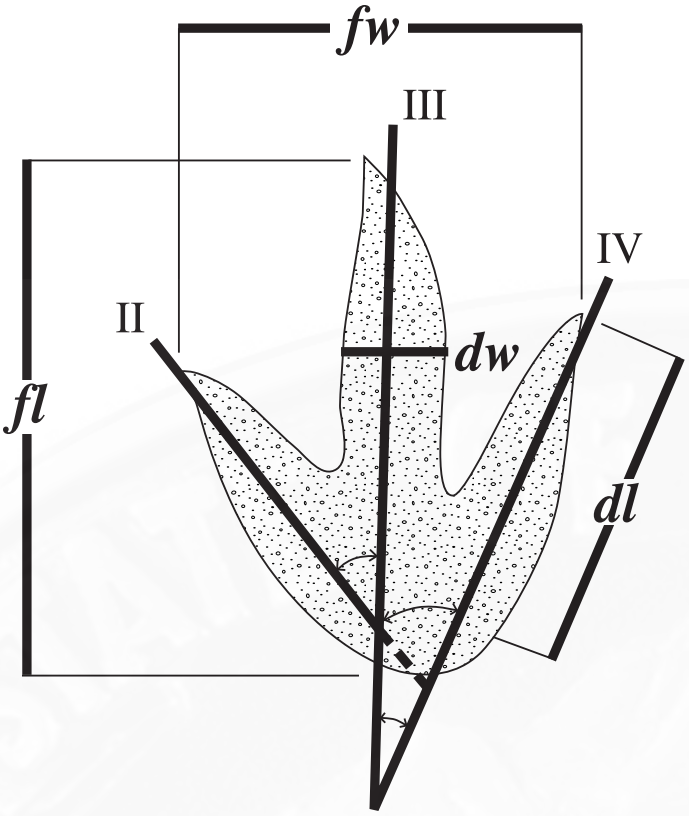

Figure 25. Track measurements taken at the YBR: fl=foot length, fw=foot width, dl=digit length, dw =digit width, and angles between digits. Roman numerals indicate digit designations.

morphology, determinations of left or right footprints could be made. Measurement of the distance between track steps and the stride length (the distance between steps of the same foot) was recorded for the tracks that occurred in trackways. On clear mylar sheets, tracings of the tracks for each site were drawn. These were used with measurements and photographs to create an accurate map of the individual tracksites. Finally, latex molds were taken of various tracks and surfaces (**Figure 26**). These molds allow for further analysis back in the lab and provide a permanent record of some of the more characteristic tracks. Whereas the detailed measurements taken of each track provided information on the type and approximate size of the track-making dinosaur, measurements of adjacent steps, stride lengths, and pace angles were used for gait and speed analysis (see Wright and Breithaupt, 2002). In addition, the type and approximate size of the dinosaur that made these tracks could be determined. It was planned that few tracks would be permanently removed from the YBR for study purposes, as it is generally best to leave fossil tracks *in situ*. However, those tracks in danger of destruction or theft were noted and removed from the study area.

To preserve the data of this unique paleontological resource and facilitate the scientific research, the YBR was intensively documented with photographs using a variety of photographic methods. The imagery ranged from 30-meter resolution satellite data to close-range photogrammetric images of a single track. The imagery found to be the most beneficial was the low-level aerial and close-range photo-

Figure 26. Thomas Adams and Brent Breithaupt making latex molds of dinosaur tracks at YBR.

grammetric images. Large format (9″x9″) natural color aerial photography was flown in the fall of 1998 at a scale of 1:1800; although individual tracks could not be detected from this photography, it proved to be a very valuable planning tool. In the summer of 2001, UW alumnus Bob Wallin agreed to provide "reconnaissance" flights in his 1969 Cherokee aircraft. The flight provided an excellent opportunity to view and photograph the YBR (**Figure 27**) and other outcrops of track-bearing limestone in the state section.

The close-range documentation process began as the site was cleared and the tracks located. Photogrammetry, which involves making precise measurements from photographs, was used as a noninvasive strategy for collecting three-dimensional data (Matthews and Breithaupt, 2001). Close-range photogrammetry at 174 cm above the surface was used to document the track surface using a metric camera. The advantages obtained by using a metric or calibrated camera are that the lens distortions have been measured and that a system of fiducials whose coordinates are known to the nearest micron are imprinted on each frame.

Figure 27. Aerial view of the YBR from 1969 Cherokee aircraft. The exposed top of the Canyon Springs Member of the Sundance Formation is the light-colored band of outcrop in the center of the photograph.

A 6-meter long, helium-filled, tethered blimp was employed with a 50 mm x 70 mm format camera (to provide low-altitude aerial photography) and a light-weight video camera (to photograph and document the track surface) (see **Front Cover**). These photographs along with those taken at ground level (**Figure 28**) were used in determining track and trackway relationships as well as the terrain of the surface itself. This combined use of aerial photography and ground-based photogrammetry has been used to good advantage to document and study other tracksites and bonebed localities (Matthews and Breithaupt, 2001; Breithaupt and Matthews, 2001; Breithaupt and others, 2001).

Dinosaur tracks

The majority of tracks found at the YBR are digitigrade (walking on the digits with the posterior of the foot more or less raised), pes impressions in concave epirelief. These subtle footprints are fairly shallow. The tracks are mesaxonic and tridactyl, with impressions of three narrow, tapering toes ending in sharp claws (**Figure 29**). The posterior region of the footprint or the "heel" (distal-most metapodium imprint) is very faintly impressed. The middle digit (digit III) often creates the best or only toe impression (often with an "S"-shaped curvature), as it was the dominant weight-bearing digit (**Figure 30**). The footprints have overall lengths greater than their widths. Generally the interdigital angles between digits II and III are greater than those between III and IV on any given track (see **Figure 25**).

Any evidence of dinosaurs from the Middle Jurassic is significant, as this was a period which preserved little terrestrial deposition, and a very limited vertebrate fossil record.

The overall track morphology seen at the YBR is similar to that observed at the RGDT and is consistent with that generally attributed to theropod dinosaurs. In addition, differences in track morphology both within and between trackways have been noted due to individual trackmaker characteristics, undertrack preservation, lateral and vertical substrate variations, and differential weathering. Thus, caution was exercised in categorizing these footprints into any particular ichnotaxa.

Figure 29. Yellow Brick Road Dinosaur Tracksite footprint.

Summary

The YBR is an important new vertebrate paleontological locality in northern Wyoming. At this site, thousands of dinosaur footprints are known. Paleontologic and geologic information gathered from the site adds to the limited knowledge of North American Middle Jurassic dinosaur fauna. This study has provided a better understanding of the activity patterns and behavior of Middle Jurassic

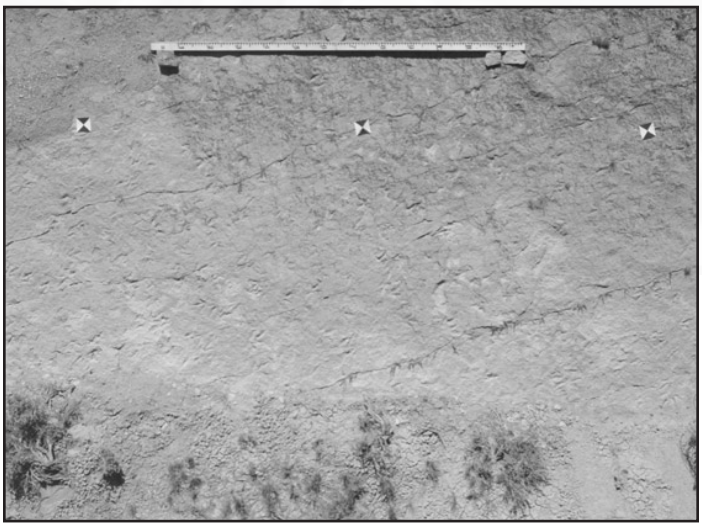

Figure 28. Low-level aerial photographs of tracks at the YBR taken from the blimp.

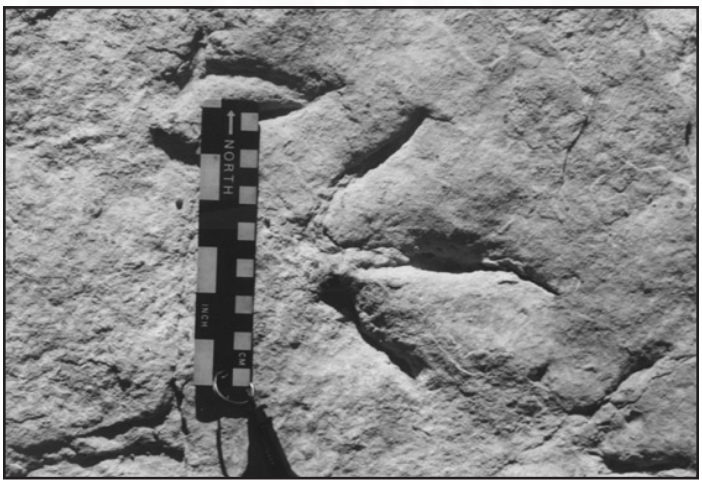

Figure 30. Yellow Brick Road Dinosaur Tracksite footprint.

dinosaurs, their environment, and the geological setting in which their tracks are preserved.

Any evidence of dinosaurs from the Middle Jurassic is significant, as this was a period which preserved little terrestrial deposition, and a very limited vertebrate fossil record. In the Western Interior of North America, Middle Jurassic dinosaur remains have yet to be found. Fortunately, trace fossils record the presence and activities of these animals. Our studies of Middle Jurassic dinosaur tracks in the Bighorn Basin of Wyoming have facilitated the understanding of a population of small- to medium-sized carnivorous dinosaurs on the tidally influenced shores of the Sundance Sea. Intensive study of the vertebrate ichnology data set allows for a unique glimpse of Middle Jurassic paleoecology and paleobiology. In addition, interpretations of the activities of these organisms provide a fascinating "live-action" glimpse of northern Wyoming 165 million years ago. As research on this data continues, a better understanding about the life and times of the Middle Jurassic of North America is coming to light.

Finally, this undergraduate research study has provided valuable experiences in setting up research projects, collecting data in the field, and interpreting these data. Additional results of this research will be presented in the next issue of *Wyoming Geo-notes*.

Acknowledgements

To facilitate the thorough documentation of the YBR, the authors utilized a diversity of volunteers to assist in the investigation of the site and the documentation of the paleontological resources. Appreciation is extended to all of the students and volunteers who devoted hundreds of hours of their time to assist us in the research. In particular Neffra Matthews, Beth Southwell, Jana Sizemore, Don Hopkins, Terry Lumme, Bob Wallin, and Pat Monaco were instrumental in the documentation of the YBR.

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PUBLICATIONS UPDATE

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Wyoming State Geological Survey publications

*2003 Calendar, *Exploring Wyoming's Geology*, by the Wyoming State Geological Survey, 2003: Poster – FREE.

*Coalbed methane activity in the eastern Powder River Basin, Campbell and Converse Counties, Wyoming, by R.H. De Bruin, R.M. Lyman, L.L. Hallberg, and N.R. Jones, 2003: Map Series MS-56 (updated in March, 2003, replaces CMM 02-4), on-demand plotted color map, rolled only – $30.00.

*Coalbed methane activity in the western Powder River Basin, Campbell, Converse, Johnson, Natrona, and Sheridan Counties, Wyoming, by R.H. De Bruin, R.M. Lyman, L.L. Hallberg, M.M. Harrison, and N.R. Jones, 2003: Map Series MS-57 (updated in March, 2003, replaces CMM 02-5), on-demand plotted color map, rolled only – $30.00.

*Coalbed methane activity in the Powder River Basin, Campbell, Converse, Johnson, Natrona, and Sheridan Counties, Wyoming, by R.H. De Bruin, R.M. Lyman, L.L. Hallberg, M.M. Harrison, and N.R. Jones, 2003: Map Series MS-58 (this is a reduced and combined version of MS-56 and MS-57 at 1:250,000 scale), on-demand plotted and laminated color map, rolled only – $50.00; on-demand plotted color map, rolled only – $40.00; ESRI ArcGIS®/ArcReader® format on CD-ROM (including MrSid® viewable files) – $50.00.

Geologic cross sections of the northern Overthrust Belt and Hoback Basin, Wyoming, by L. Cook, 2002: Open File Report 2002-03 – $15.00 (includes 1 oversize sheet and 15 p. text) + $5.00 shipping and handling.

*Geology of the Iron Mountain Kimberlite district and nearby kimberlitic indicator mineral anomalies in southeastern Wyoming, by W.D. Hausel, R.W. Gregory, R.H. Motten, and W.M. Sutherland, 2003: Wyoming State Geological Survey Report of Investigations No. 54, 42 p. plus 3 oversized plates – $10.00.

Oil and gas map of the Powder River Basin, Wyoming, by R.H. De Bruin, 2002: Map Series MS-51 (scale 1:350,000), on-demand plotted color map, rolled only – $25.00; ESRI ArcInfo®/ESRI ArcView® format on CD-ROM (including MrSid® viewable files), – $20.00.

Oil and gas map of the Greater Green River Basin and Overthrust Belt, Wyoming, by R.H. De Bruin, 2002: Map Series MS-52 (scale 1:350,000), on-demand plotted color map, rolled only – $25.00; ESRI ArcInfo®/ESRI ArcView® format on CD-ROM (including MrSid® viewable files), – $20.00.

Oil and gas map of the central and northwestern Wyoming basins, Wyoming, by R.H. De Bruin, 2002: Map Series MS-53 (scale 1:350,000), on-demand plotted color map, rolled only – $25.00; ESRI ArcInfo®/ESRI ArcView® format on CD-ROM (including MrSid® viewable files), – $20.00.

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Preliminary digital geologic map of the Buffalo 30′ x 60′ Quadrangle, Johnson and Campbell Counties, Wyoming, by A.J. VerPloeg and C.S. Boyd (digital cartography by J.T. Carreno, R.W. Lyons, and J.M. Mulbay), 2002, Digital Map Series 2002-01 (scale 1:100,000), on-demand plotted color map, rolled only – $25.00; CD-ROM under development – $10.00.

Preliminary digital geologic map of the Recluse 30′ x 60′ Quadrangle, Campbell and Crook Counties, Wyoming, by L.L. Hallberg, R.M. Lyman, C.S. Boyd, R.W. Jones, and A.J. VerPloeg (digital cartography by J.M. Mulbay, J.T. Carreno, and R.W. Lyons), 2002, Digital Map Series 2002-02 (scale 1:100,000), on-demand plotted color map, rolled only – $25.00; CD-ROM under development – $10.00.

Preliminary digital geologic map of the Midwest 30′ x 60′ Quadrangle, Natrona, Converse, and Johnson Counties, Wyoming, by L.L. Hallberg and J.C. Case (digital cartography by R.W. Lyons, J.T. Carreno, and J.M. Mulbay), 2002, Digital Map Series 2002-03 (scale 1:100,000), on-

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Preliminary geologic map of the Rattlesnake Hills 1:100,000 Quadrangle, Fremont and Natrona Counties, central Wyoming, by W.M. Sutherland and W.D. Hausel, 2002: Open File Report 2002-02 – $30.00 (includes 2 oversized sheets and 32 p. text) + $6.00 shipping and handling.

*Searching for Gold in Wyoming, by W.D. Hausel, 2002: Wyoming State Geological Survey Information Pamphlet 9 – FREE.

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*New releases since the last issue of *Wyoming Geo-notes*.

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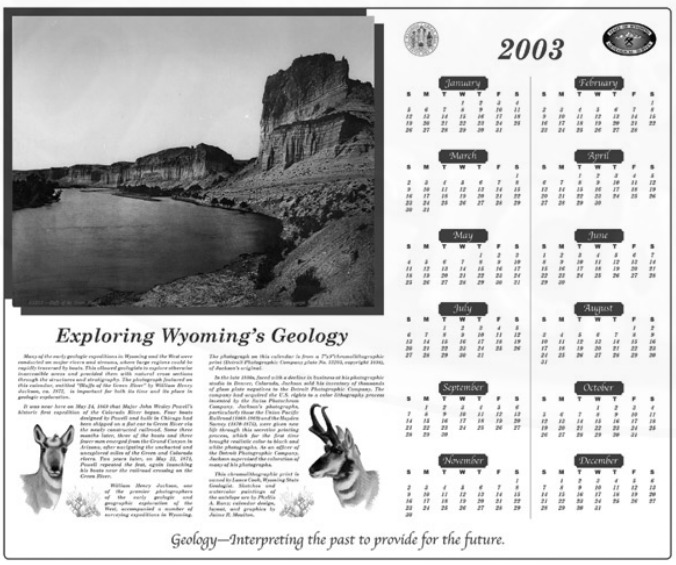

The Wyoming State Geological Survey (WSGS) has published the 2003 edition of its "Exploring Wyoming's Geology" calendar series. The new calendar features a colorized photograph of the towering cliffs above Green River by famous photographer of the West, William Henry Jackson. The calendar was designed by Jaime R. Moulton, Editorial Assistant at the WSGS, and uses two watercolor paintings of antelope and sketches of sagebrush and grass by Phyllis A. Ranz, cartographer and artist at the WSGS. The photograph was scanned from an original print owned by, and from the collection of, Lance Cook, Wyoming State Geologist. Obtain your complimentary copy of the 24" x 20" calendar by contacting the WSGS (see **Back Cover**).

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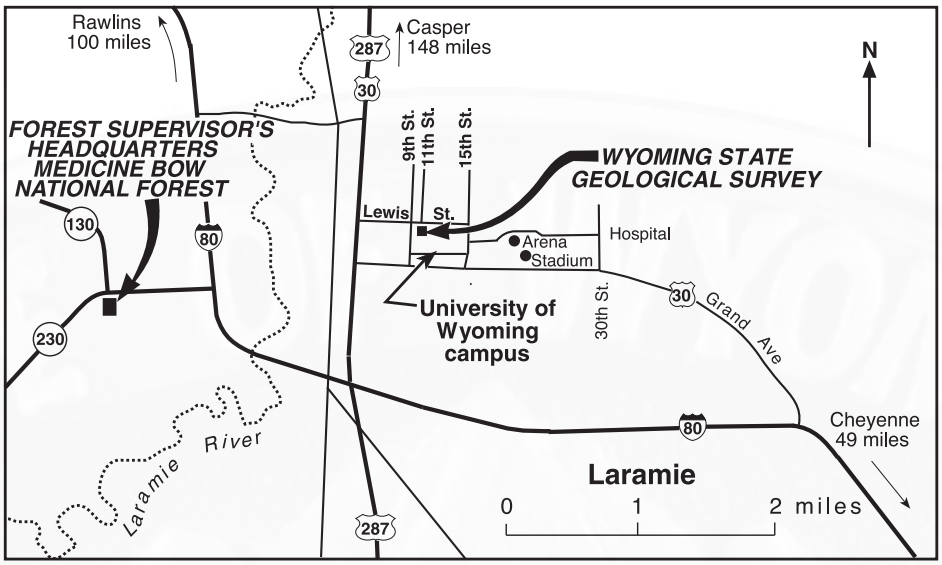

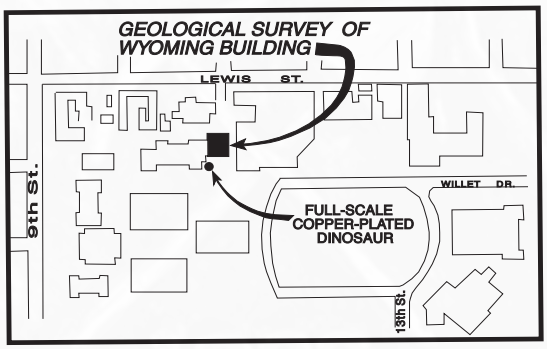

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