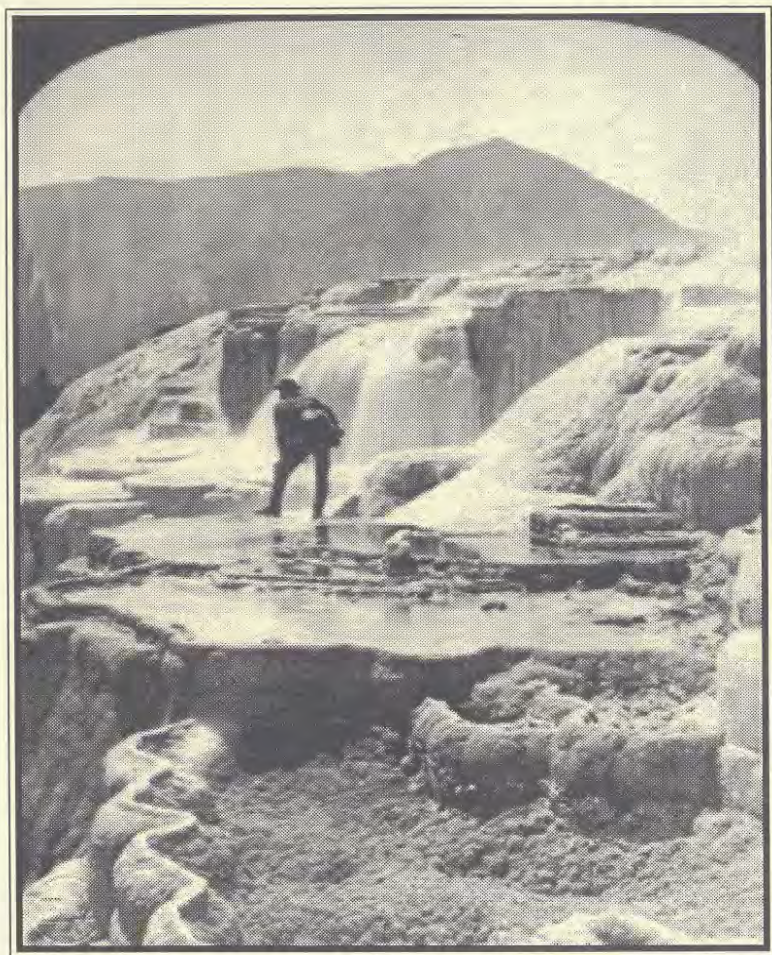


# Wyoming Geo-notes

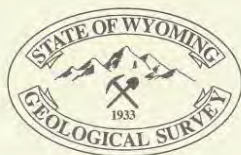
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Number 62



Wyoming State Geological Survey  
Lance Cook, State Geologist

Laramie, Wyoming  
May, 1999



# WYOMING STATE GEOLOGICAL SURVEY

Lance Cook, *State Geologist*

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FAX: (307) 766-2605

Email: [wsgs@wsgs.uwyo.edu](mailto:wsgs@wsgs.uwyo.edu)  
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**Front cover:** Upper Basin, Mammoth Hot Springs, Yellowstone National Park. From albumen print by William Henry Jackson, photographer for the U.S. Geological Survey of Territories, 1871, lead by F.V. Hayden. The man in the scene is the famous western artist Thomas Moran. This is stereopair #37 in the "Yellowstone Series" published by E. & H.T. Anthony & Co., New York. From the personal collection of Lance Cook.

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# OVERVIEW OF THE STATE GEOLOGICAL SURVEY

Lance Cook

*State Geologist, Wyoming State Geological Survey*

This is the first issue of *Wyoming Geo-notes* that I have been closely involved with. As the new State Geologist, I would like to give our readers some information about myself, my vision for the future, and the issues that the Survey will be facing.

## PERSONAL INFORMATION

I come to the Survey from the oil and gas industry, where I have spent the past 20 years exploring for hydrocarbons. My background; however, is not just in petroleum geology. I am an explorationist, and I have been involved in applications of new technology and development of non-conventional plays. My areas of interest are in structural geology, tectonics, geochemistry, and non-conventional resource development. Of my 20 years in the oil industry, most of them were spent working on projects in Wyoming or the Rocky Mountain province. My area of expertise is in the Sevier Thrust Belt of the Cordillera, and I have worked that play from Canada to Mexico.



My formal education in geology began at Texas Christian University in Fort Worth, where I received a Bachelor of Science degree in 1976. Upon graduation, I moved on to the University of New Mexico in Albuquerque, where I concentrated on mineralogy and geochemistry for my Masters degree. My thesis work involved fluid inclusion and stable isotope analysis of the Harding Pegmatite in the Picuris Range of the Sangre de Cristo Mountains in New Mexico.

Like so many of my peers, upon graduation in 1978, I went to work for Shell Oil Company in the oil industry. Jobs were plentiful and dollars were easy. I worked in the Western Region, primarily in Rocky Mountain basins and plays. In 1984, I went to work for Champlin Petroleum, which became Union Pacific Resources. Much of my detailed exposure to Wyoming geology came during these years, since UPR is the heir to the Union Pacific Railroad and the UP Land Grant.

On the personal side, I am a collector. I collect fine mineral specimens and antique photography. Photographs of the Geological Expeditions in the west

are my passion, and I have worked hard to uncover details of the various Surveys and their photographic artifacts.

I have been privileged to work with many fine geologists in the past 20 years and the experience and knowledge that I bring to this job is a reflection of the quality of my co-workers and professors. I am pleased and excited to join the Wyoming State Geological Survey as State Geologist and will faithfully execute my duties to the best of my abilities.

## **THE SURVEY**

Wyoming faces a developing project of unprecedented magnitude with the coalbed methane play in the Powder River Basin. Surface disturbances, air quality, water disposal, gas transportation, mineral ownership, and coexistence with the coal industry and agricultural interests are all serious issues that we recognize as future challenges to be dealt with. The work of our Coal Section and Oil and Gas Section will emphasize coalbed methane, as the play continues its inexorable growth. We will soon update our very popular coalbed methane map, and we will produce regular updates in the future. Coalbed methane development is the largest single challenge the Survey faces. Because the issues are so broad and cover such a wide spectrum of disciplines, we will propose the initiation of an inter-agency project with other State agencies, county agencies, the University of Wyoming, and Federal agencies.

Modern mapping methods are upon us, and the Survey will begin producing more maps and much of its data in digital form. We will not abandon our hard copy formats, but the power of modern mapping and GIS software demands that we supply the data to our constituents so that they can take advantage of this new technology. Some of our mapping projects will be released as GIS data sets on CD-ROM, allowing people with access to GIS application software to generate customized maps. Data sets completed for use with GIS software will not be available just as digital data, as we will also make extracted maps available in hard copy format for those who do not have GIS processing abilities. We will produce more maps as plots rather than prints, so they can be plotted on demand and help reduce our inventory expenses. We will look for ways to make some popular out-of-print Survey publications available, either through the Internet or as scanned images on CD-ROM.

Our diamond project continues to make progress in mapping and identifying prospective diamondiferous kimberlite pipes. New technology in exploration methods is about to reduce the exploratory risk in this endeavor. The Survey will continue to promote this potential new industry, which we believe can be successful in Wyoming.

Our Geologic Hazards Section will conduct an Earthquake Hazards workshop in Jackson this summer. We believe that we have a responsibility to con-

tinue working to reduce public risk from geologic causes, and we will continue working towards this goal.

We will continue in our traditional areas of geologic mapping, consultation and assistance to the mineral industry, public education, and cooperation with State, county, and Federal agencies.

Another significant challenge to the Survey will come from problems associated with funding. Money drives all issues these days, and the State of Wyoming is about to begin budgeting for a new biennium with an expected budgetary shortfall in the range of \$127 million dollars. We cannot look to the State for additional funding to help the Survey grow or deal with new problems. Instead, we will look more to industry partners, scientific grants, and Federal matching funds to finance necessary changes and new activities. Because we will be hard pressed to maintain current levels of State funding, outside sources of funding will be essential to our continued survival and our ability to meet the needs of our constituents in the coming years.

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## MINERALS UPDATE

### OVERVIEW

By Gary B. Glass  
*Contributing Contract Editor,  
Wyoming State Geological Survey*

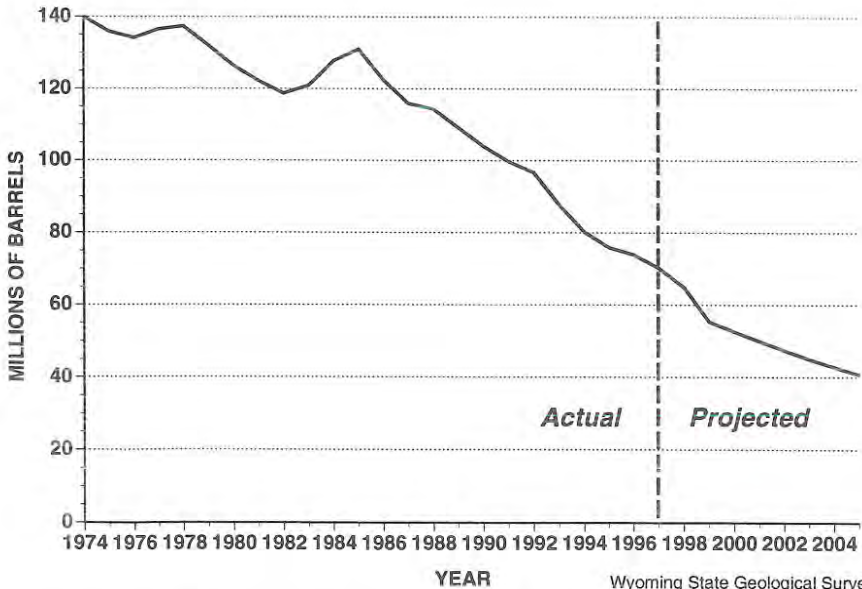
It now looks like oil production in 1998 may have been somewhat higher than the State's January forecast of 63.2 million barrels, which was made by the Consensus Revenue Estimating Group (CREG, 1999). Production figures released by Petroleum Information/Dwights LLC (PI/D) show production from Wyoming at 64.8 million barrels. Because of corrected and (or) late filings, the production tabulated by PI/D has often been lower than the official oil production figures for the State, which are tabulated by the Wyoming Oil and Gas Conservation Commission (WOGCC). As a cautionary note; however, reporting errors by some companies in recent years have occasionally rendered PI/D figures higher than the State's final figures. Consequently, because the WOGCC figures are not yet available, the 1998 production in **Table 1** and **Figure 1** continue to reflect CREG's January estimate.

It also looks like the average price received for Wyoming oil in 1998 was slightly higher than the State's January forecast of \$10.50 (CREG, 1999). Figures released by the U.S. Department of Energy's Energy Information Administration (EIA) show Wyoming oil averaged \$10.67 last year, or 17 cents more

**Table 1. Wyoming mineral production (1985-1997) with forecasts to 2005<sup>1</sup>.**

Calendar Year	Oil <sup>2,3</sup>	Methane <sup>3,4</sup>	Carbon Dioxide <sup>3,4</sup>	Helium <sup>4,5</sup>	Coal <sup>6</sup>	Trona <sup>7</sup>	In-situ Uranium <sup>7,8</sup>	Sulfur <sup>3,9</sup>
1985	131.0	597.9	—	—	140.4	10.8	N/A	0.80
1986	122.4	563.2	23.8	0.15	135.4	11.9	0.05	0.76
1987	115.9	628.2	114.2	0.86	146.5	12.4	0.00	1.19
1988	114.3	700.8	110.0	0.83	163.6	15.1	0.09	1.06
1989	109.1	739.0	126.1	0.94	171.1	16.2	1.1	1.17
1990	104.0	777.2	119.9	0.90	184.0	16.2	1.0	1.04
1991	99.8	820.0	140.3	1.05	193.9	16.2	1.0	1.18
1992	97.0	871.5	139.2	1.05	189.5	16.4	1.2	1.20
1993	89.0	912.8	140.8	1.06	209.9	16.0	1.2	1.14
1994	80.2	959.2	142.6	1.07	236.9	16.1	1.2	1.10
1995	75.6	987.5	148.8	1.11	263.9	18.4	1.3	1.20
1996	73.9	1,023.4	149.0	1.10	278.4	18.6	1.9	1.22
1997	70.2	1,040.3	151.0	1.10	281.5	19.4	2.2	1.23
1998	63.2	1,052.9	151.0	1.10	315.0	18.5	2.5	1.20
1999	55.3	1,064.8	151.0	1.10	333.7	18.2	2.5	1.20
2000	52.5	1,089.1	151.0	1.10	353.8	18.2	2.5	1.20
2001	49.9	1,113.9	151.0	1.10	366.0	18.4	2.5	1.20
2002	47.4	1,139.2	151.0	1.10	369.5	18.6	2.5	1.20
2003	45.0	1,165.1	151.0	1.10	373.2	18.8	2.5	1.20
2004	42.8	1,191.4	151.0	1.10	377.0	19.0	2.5	1.20
2005	40.7	1,218.3	151.0	1.10	380.6	19.2	2.5	1.20

<sup>1</sup>Modified from CREG's Wyoming State Government Revenue Forecast, January, 1999; <sup>2</sup>Millions of barrels; <sup>3</sup>Wyoming Oil & Gas Conservation Commission, 1985-1997; <sup>4</sup> Billions of cubic feet; <sup>5</sup>Based on Exxon's estimate that the average helium content in the gas processed at Shute Creek is 0.5%; <sup>6</sup>Millions of short tons (Wyoming State Inspector of Mines, 1985-1997); <sup>7</sup>Wyoming Department of Revenue, 1985-1997; <sup>8</sup>Millions of pounds of yellowcake (not available [N/A] for 1985 and previous years because it was only reported as taxable value); <sup>9</sup>Millions of short tons.



Wyoming State Geological Survey,  
Oil and Gas Section, April, 1999

Figure 1. Annual oil production from Wyoming (1974 to 1997) with forecasts to 2005.



than CREG's estimate. Since the EIA's annual estimate is always very close to final figures derived by the State, it is now shown in **Table 2** and **Figure 2**.

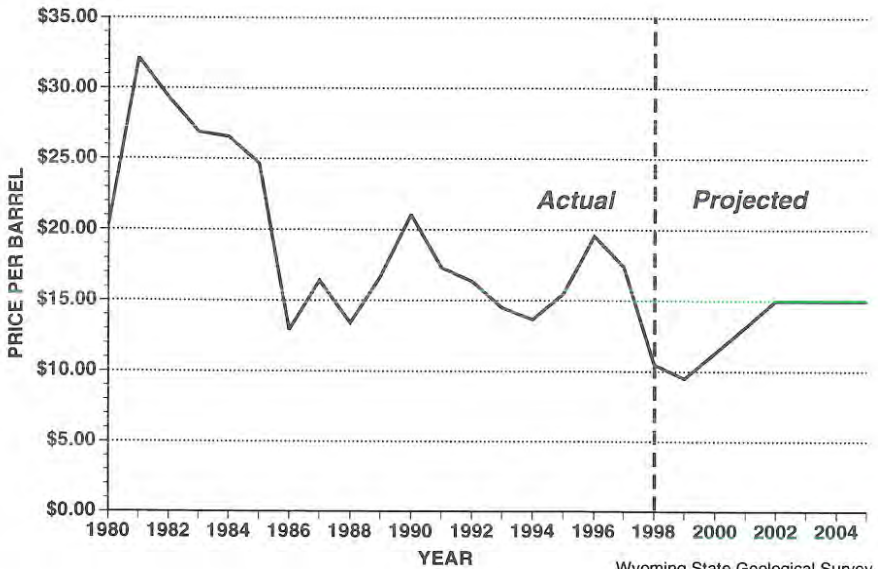
There is also some cautious optimism that the average price paid for Wyoming crude in 1999 will be higher than CREG's price forecast in **Table 2** and **Figure 2** (CREG, 1999). In support of this optimism, Wyoming crude averaged \$11.25 a barrel in March of this year. And Oil Futures are posting prices above \$17.00 for Light Sweet Crude. OPEC's production cutbacks, the Government's purchases for the Strategic Oil Reserve, as well as its storage offers are three things that are helping to reduce the supply of oil, thereby bringing prices up. It is anyone's guess how long the prices will stay propped up or how high they will go. There are; however, some predictions that the price of Light Sweet Crude might reach \$20.00 a barrel before the end of the year. The latter prediction seems a little overly optimistic.

For Wyoming, significantly higher oil prices may be a short-lived help. The reduced flow of Canadian oil into Wyoming's market area has been a direct function of low prices. Canadian producers have cut back their exports enough that many Wyoming producers are receiving bonuses for their oil. If more Canadian oil starts to flow into the area as prices increase, those bonuses are

**Table 2. Average prices paid for Wyoming oil, methane, coal, and trona (1985-1997) with forecasts to 2005<sup>1</sup>.**

Calendar	Oil <sup>2</sup>	Methane <sup>3</sup>	Coal <sup>4</sup>	Trona <sup>5</sup>
1985	24.67	3.03	11.36	35.18
1986	12.94	2.33	10.85	34.80
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	5.68	42.29
1998	10.67	1.81	5.42	41.29
1999	9.50	1.75	5.31	39.91
2000	11.33	1.75	5.17	40.26
2001	13.16	1.75	5.04	41.24
2002	15.00	1.75	5.04	42.04
2003	15.00	1.75	5.04	42.53
2004	15.00	1.75	5.04	42.96
2005	15.00	1.75	5.04	43.15

<sup>1</sup> Modified from CREG, Wyoming State Government Revenue Forecast, January, 1999; <sup>2</sup> First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Source: Energy Information Administration, 1985-1998; <sup>3</sup> Wellhead price in dollars per thousand cubic feet (MCF). Source: Wyoming Office of State Lands and Investments, 1989-1997 (derived from State royalty payments); Minerals Management Service, 1985-1988 (derived from Federal royalty payments); <sup>4</sup> Dollars per short ton (weighted average price for coal mined by surface and underground methods). Source: Energy Information Administration, 1985-1990 and derived from Department of Revenue, 1991-1997; <sup>5</sup> Dollars per ton of trona, not soda ash. Source: Wyoming Department of Revenue, 1985-1997.



Wyoming State Geological Survey,  
Oil and Gas Section, April, 1999

Figure 2. Average prices paid for Wyoming oil (1980 to 1998) with forecasts to 2005.

likely to quickly disappear. And based on past experiences, head to head competition has favored Canadian rather than Wyoming producers.

In regard to last year's natural gas production from Wyoming, the figure released by PI/D is 1,200.6 billion cubic feet (BCF), which is very slightly lower than the State's January forecast of 1,205.0 BCF (CREG, 1999). Here again PI/D's production figures are traditionally slightly lower than the official figures tabulated by the WOGCC. Therefore, **Table 1** and **Figure 3** still reflect the CREG estimate.

Monthly reports from the American Gas Association indicate that spot sale prices of methane from Opal, Wyoming, averaged \$1.81 in 1998. CREG (1999) estimated \$1.80 per thousand cubic feet of gas for 1998, suggesting its estimate would be very close to the final State figure. The CREG estimate is reflected in **Table 2** and **Figure 4**.

In regard to coal production and price, **Tables 1** and **2** and **Figures 5** and **6** are unchanged from the last issue of *Wyoming Geo-notes*. While the coal production forecasts in **Table 1** and **Figure 5** are now significantly larger than CREG's January estimates, they reflect the same annual percentage increases as forecast by CREG (1999). The production forecast was increased when 1998 production exceeded CREG's forecast by 33.5 million tons. The surprising production gain in 1998 marked a return to a double digit percentage increase, something that had not been seen since 1995 when production increased by 11.4%. In fact, one must go back to the 12.9% increase in 1994 to top the

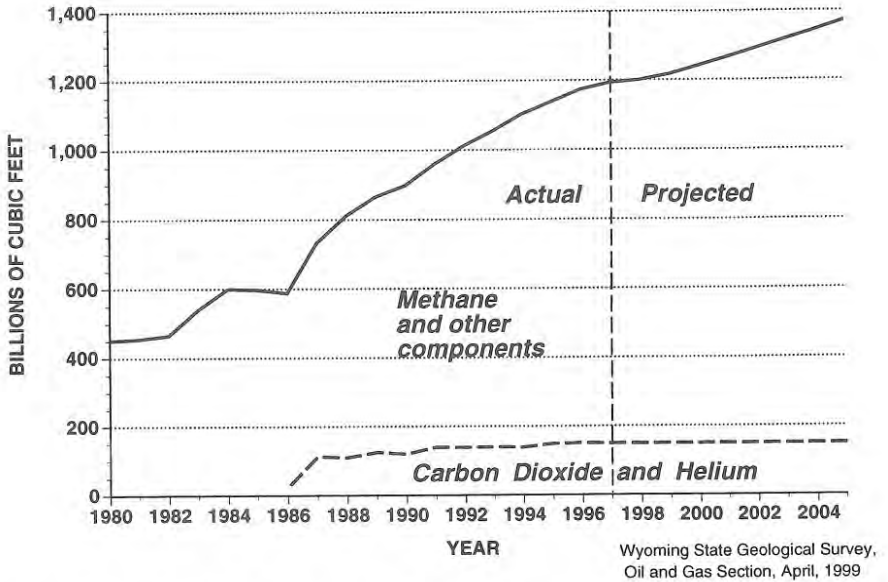


Figure 3. Annual natural gas production from Wyoming (1980 to 1997) with forecasts to 2005.

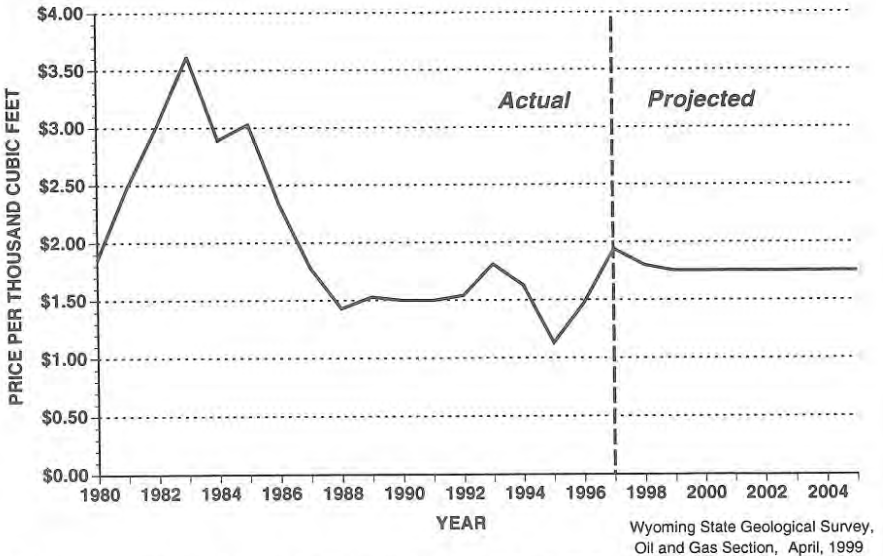


Figure 4. Average prices paid for Wyoming methane (1980 to 1997) with forecasts to 2005.

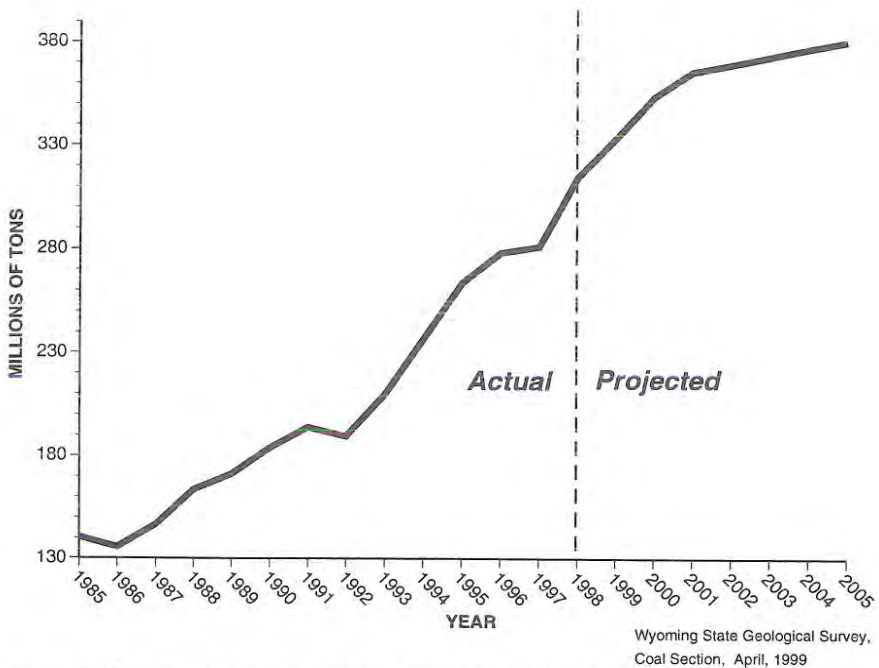


Figure 5. Annual coal production from Wyoming (1985-1998) with forecasts to 2005. Sources: Wyoming State Inspector of Mines (1985-1998) and Wyoming State Geological Survey (1999-2005).

11.9% increase in 1998. The forecast shows production increasing by only 6% in 1999. A portion of the increase in 1998 is likely related to the delays in rail deliveries in 1997.

The forecast coal prices in **Table 2** and **Figure 6** are still those of CREG (1999).

No changes were made to the forecast production or prices of other commodities in **Tables 1** and **2**. They are still those from CREG (1999).

In addition to its first-quarter updates for oil and gas and other minerals, this issue of *Wyoming Geo-notes* includes a summary article on mineral and oil and gas exploration in Wyoming for 1998. There is also a brief discussion of the need for earthquake preparedness in Carbon County, a discussion on re-authorization of the National Geologic Mapping Act of 1992, and a description of collectible aluminosilicate minerals found in Wyoming.

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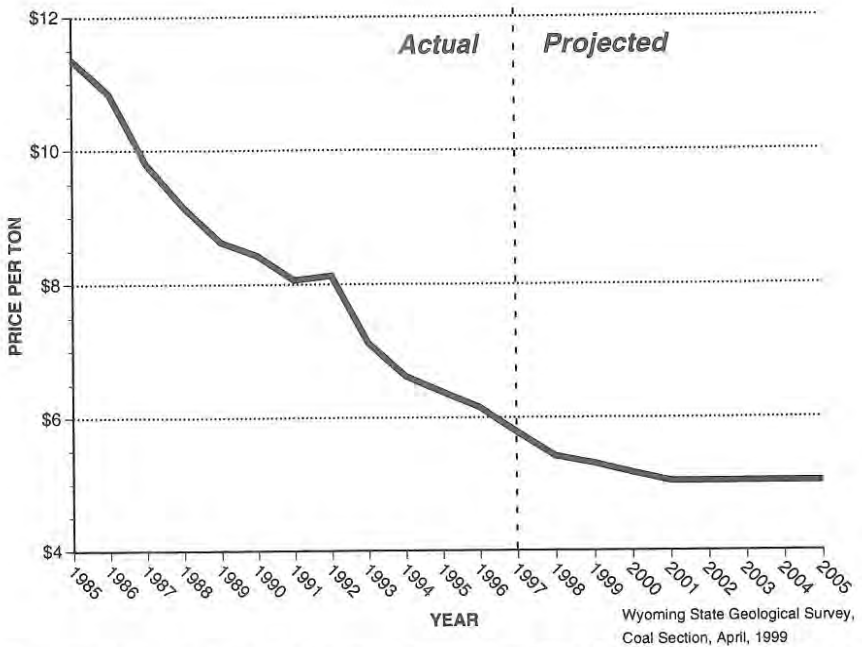


Figure 6. Average prices paid for Wyoming coal (1985 to 1997) with forecasts to 2005. Sources: U.S. Energy Information Administration (1985-1990); Wyoming Department of Revenue (1991-1997); and Wyoming Consensus Revenue Estimating Group (1998-2005).

## OIL AND GAS UPDATE

Rodney H. De Bruin

*Staff Geologist-Oil and Gas, Wyoming State Geological Survey*

Prices paid to Wyoming oil producers during the first quarter of 1999 only averaged \$9.78 per barrel. While this average price is \$1.05 higher than for the fourth quarter of 1998, it is \$2.19 lower than for the first quarter of 1998. However, the average price in March had risen to \$11.25, which is the highest average monthly price since April, 1998 (Table 3). OPEC's decision to cut its future crude oil production by two million barrels a day apparently had a significant effect on crude oil prices in March. Figure 7 shows the posted Sweet and Sour crude prices and first purchase price for Wyoming oil averaged by month, through March of this year.

According to figures from Petroleum Information/Dwights LLC (PI/D), oil production in Wyoming for 1998 was 64.8 million barrels (Tables 1 and 4). This production is a drop of about 7.7% from last year's oil production, as reported by PI/D. For comparison, the decline in oil production between 1996 and 1997 was only 5.0%. The higher rate of decline in 1998 is attributed to the much lower oil prices.

**Table 3. Monthly average price of a barrel of oil produced in Wyoming (1996 to March, 1999).**

	1996		1997		1998		1999	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	\$16.38	\$16.38	\$22.56	\$22.56	\$12.79	\$12.79	\$9.48	\$9.48
FEB	\$16.28	\$16.33	\$19.45	\$21.01	\$12.16	\$12.48	<b>\$8.60</b>	<b>\$9.04</b>
MAR	\$18.63	\$17.09	\$17.99	\$20.00	\$10.97	\$11.97	<b>\$11.25</b>	<b>\$9.78</b>
APR	\$20.29	\$17.90	\$16.81	\$19.20	\$11.54	\$11.87		
MAY	\$18.85	\$18.08	\$17.74	\$18.91	\$11.19	\$11.73		
JUN	\$18.15	\$18.10	\$15.90	\$18.41	\$9.63	\$11.38		
JUL	\$18.98	\$18.22	\$16.29	\$18.11	\$10.20	\$11.21		
AUG	\$19.59	\$18.39	\$16.61	\$17.92	\$9.58	\$11.01		
SEP	\$21.48	\$18.74	\$16.42	\$17.75	\$11.19	\$11.03		
OCT	\$22.63	\$19.13	\$17.89	\$17.77	\$11.04	\$11.03		
NOV	\$21.19	\$19.31	\$16.51	\$17.65	\$9.64	\$10.90		
DEC	\$22.42	\$19.56	\$14.72	\$17.41	\$8.05	\$10.67		
<b>Avg. yearly price</b>		<b>\$19.56</b>		<b>\$17.41</b>		<b>\$10.67</b>		

Source: All averages are derived from published monthly reports by the Energy Information Administration, except that averages in bold print in 1999 are estimated from various unpublished bulletins listing posted prices.

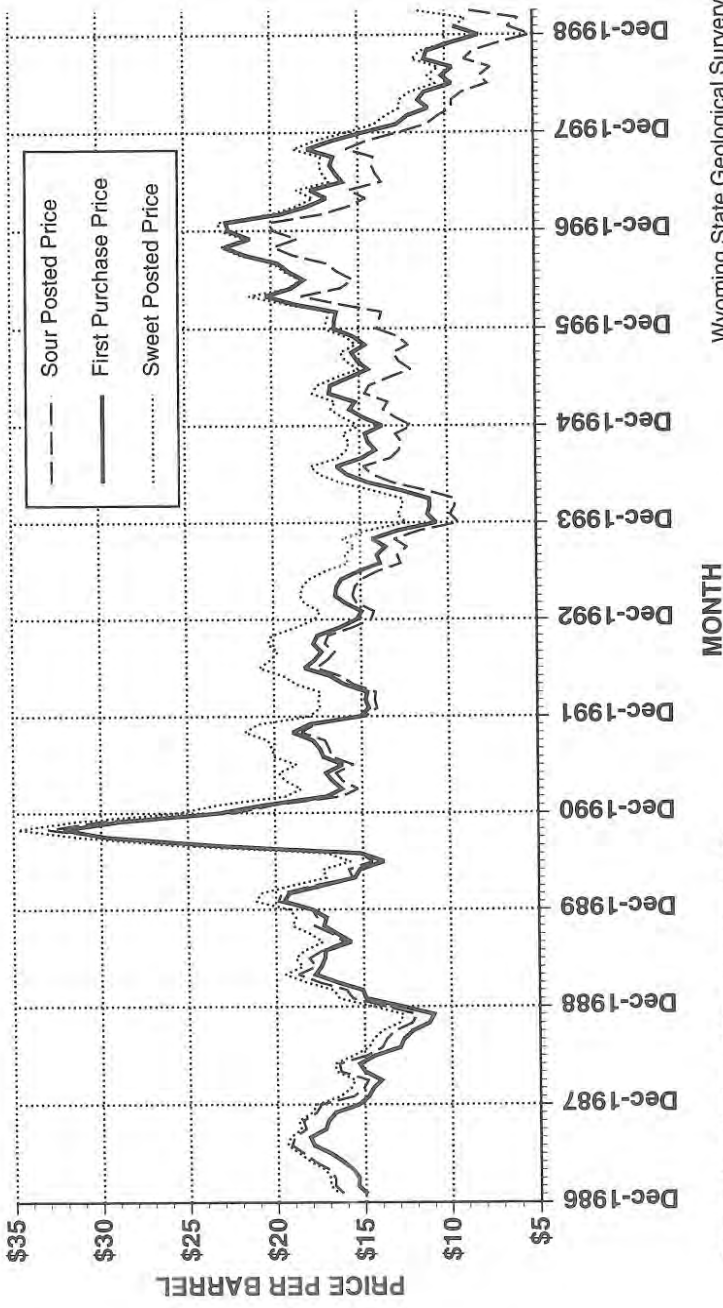
*Wyoming State Geological Survey, Oil and Gas Section, April, 1999.*

Spot prices for natural gas at Opal, Wyoming, averaged \$1.65 during the first quarter of 1999. This is 23 cents lower than last year's first quarter average price of \$1.88 (Table 5 and Figure 8). The average price during the first quarter of this year is lower because of a mild winter and smaller than normal use of stored natural gas.

According to production figures from PI/D, natural gas production in Wyoming for 1998 was 1,200.6 billion cubic feet (Table 6). Production in 1998 was up only 0.7% from that reported by PI/D for 1997.

Several new pipelines were proposed or started construction during the first quarter of 1999. While two are discussed here, others are described in the section on **Coalbed Methane Developments** in the **COAL UPDATE** of this issue.

Burlington Resources and Enron Capital & Trade Resources have formed Lost Creek Gathering LLC. Plans are for Lost Creek to build a 127-mile-long, 24-inch gathering pipeline from the Lost Cabin gas plant at Madden Field in central Wyoming to Western Gas Resources' Red Desert gas processing plant near Wamsutter in southern Wyoming. The system will transport Burlington Resources' gas from Madden Field as well as contracted gas from third parties located near the proposed gathering route. Processed gas from the Red Desert plant will go into the CIG and/or WIC mainline systems. The system will be capable of delivering 120 million cubic feet per day without compression. With compression, its capacity could be expanded to 275 million cubic feet per day. The project also includes a 36-mile-long, 12-inch lateral pipeline, with control facilities and a compressor station at the southern end of the lateral. The lateral will connect Snyder's Beaver Creek gas plant to the larger Lost Creek line.



Wyoming State Geological Survey  
Oil and Gas Section, April, 1999

Source: Unpublished DOE and company data

Figure 7. Wyoming posted sweet and sour crude oil prices and first purchase prices, averaged by month (January, 1987, to March, 1999).

**Table 4. Monthly oil production from Wyoming in barrels (1995 to September, 1998).**

	1995			1996			1997			1998		
	monthly	cumulative		monthly	cumulative		monthly	cumulative		monthly	cumulative	
JAN	6,700,000	6,700,000		6,153,037	6,153,037		5,964,848	5,964,848		5,846,364	5,846,364	
FEB	6,100,000	12,800,000		5,693,084	11,846,121		5,459,518	11,424,366		5,233,502	11,079,866	
MAR	6,300,000	19,100,000		6,176,805	18,022,926		6,014,780	17,439,146		5,759,176	16,839,042	
APR	6,200,000	25,300,000		5,977,362	24,000,288		5,729,869	23,169,015		5,534,568	22,373,610	
MAY	6,300,000	31,600,000		6,035,505	30,035,793		6,050,971	29,219,986		5,626,125	27,999,735	
JUN	6,200,000	37,800,000		5,916,019	35,951,812		5,761,549	34,981,535		5,335,463	33,335,198	
JUL	6,300,000	44,100,000		6,076,992	42,028,804		5,964,005	40,945,540		5,464,514	38,799,712	
AUG	6,100,000	50,200,000		6,414,850	48,443,654		5,868,789	46,814,329		5,297,415	44,087,127	
SEP	6,100,000	56,300,000		6,180,180	54,623,834		5,710,557	52,524,886		5,109,053	49,196,180	
OCT	6,300,000	62,600,000		6,186,019	60,809,853		5,949,974	58,474,860		5,274,269	54,470,449	
NOV	6,100,000	68,700,000		6,221,912	67,031,765		5,800,811	64,275,671		5,232,287	59,702,736	
DEC	6,300,000	75,000,000		6,330,701	73,362,466		5,900,791	70,176,462		5,078,909	64,781,645	
<b>Total Barrels Reported</b> <sup>1</sup>		<b>75,000,000</b>			<b>73,362,466</b>			<b>70,176,462</b>			<b>64,781,645</b>	
<b>Total Barrels Not Reported</b> <sup>2</sup>		<b>554,113</b>			<b>525,957</b>			<b>52,364</b>				
<b>Total Barrels Produced</b> <sup>3</sup>		<b>75,554,113</b>			<b>73,888,423</b>			<b>70,228,826</b>				

<sup>1</sup> Monthly production reports from Petroleum Information/Dwights LLC, except for 1995, which is estimated by the Wyoming State Geological Survey.

<sup>2</sup> (Total barrels produced) minus (total barrels reported by Petroleum Information/Dwights LLC).

<sup>3</sup> Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, April, 1999.*



**Table 5. Monthly average spot sale price for a thousand cubic feet (MCF) of methane at Opal, Wyoming (1996 to March, 1999).**

	1996		1997		1998		1999	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	\$1.25	\$1.25	\$3.90	\$3.90	\$2.05	\$2.05	1.80	1.80
FEB	\$1.20	\$1.23	\$2.50	\$3.20	\$1.70	\$1.88	1.65	1.73
MAR	\$1.20	\$1.22	\$1.40	\$2.60	\$1.90	\$1.88	1.50	1.65
APR	\$1.05	\$1.18	\$1.45	\$2.31	\$1.90	\$1.89		
MAY	\$0.95	\$1.13	\$1.60	\$2.17	\$1.95	\$1.90		
JUN	\$1.10	\$1.13	\$1.35	\$2.03	\$1.65	\$1.86		
JUL	\$1.20	\$1.14	\$1.45	\$1.95	\$1.60	\$1.82		
AUG	\$1.25	\$1.15	\$1.40	\$1.88	\$1.75	\$1.81		
SEP	\$1.20	\$1.16	\$1.50	\$1.84	\$1.60	\$1.79		
OCT	\$1.30	\$1.17	\$2.05	\$1.86	\$1.65	\$1.78		
NOV	\$2.45	\$1.29	\$3.00	\$1.96	\$2.00	\$1.80		
DEC	\$3.50	\$1.47	\$1.95	\$1.96	\$2.00	\$1.81		
<b>Avg. yearly price</b>		<b>\$1.46</b>		<b>\$1.94</b>				

Source: American Gas Association's monthly reports, except for the average yearly price, which comes from Wyoming's Office of State Lands and Investments.

*Wyoming State Geological Survey, Oil and Gas Section, April, 1999.*

The U.S. Bureau of Land Management's (BLM's) scoping meetings in April will help determine whether the project will require an environmental impact statement or just an environmental assessment. Burlington Resources would like the pipeline operational in the first quarter of 2000.

Another pipeline that began construction is not good news for Wyoming producers. The Alliance Pipeline is designed to initially offer at least 1.325 billion cubic feet of gas per day of firm delivery service to markets in the Midwestern U.S. and eastern Canada. The gas would come from producing areas in northeastern British Columbia and northwestern Alberta. Because Wyoming gas producers depend on markets in the Midwest, they will have to compete with increased amounts of Canadian gas when the Alliance Pipeline is completed in October of 2000.

In the near future, the BLM is expected to release a draft environmental impact statement regarding the drilling of up to 3,000 new gas wells in an area southwest of Rawlins. Union Pacific Resources, BP Amoco, and Yates Petroleum are the major companies involved in the Continental Divide and Wamsutter II projects, which were combined for analysis in 1997. According to the BLM, the complexity of addressing potential impacts to air quality has delayed release of the document.

In April, the Wyoming Oil and Gas Conservation Commission (WOGCC) adopted some new drilling, completion, and plugging rules for an area in southwestern Wyoming called the Special Sodium Drilling Area (SSDA). This area includes BLM's Known Sodium Leasing Area (KSLA) as well as some buffer areas beyond it. The WOGCC's new rules were an outgrowth of recommendations by the Policy Committee of a Joint Industry Committee (JIC), which has

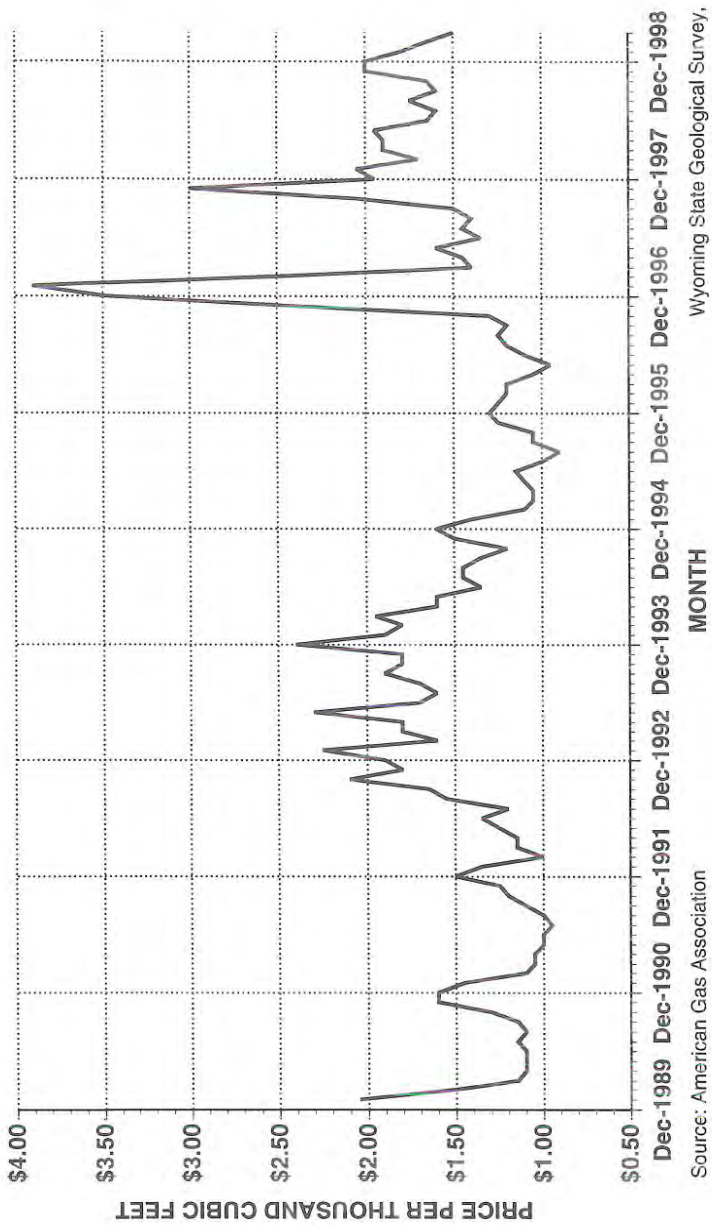


Figure 8. Spot sale prices for methane at Opal, Wyoming, averaged by month (January, 1990, to March, 1999).

**Table 6. Monthly natural gas production from Wyoming in thousands of cubic feet (MCF) (1995 to December, 1998).**

	1995			1996			1997			1998		
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	100,224,249	100,224,249	101,359,648	101,359,648	99,579,818	99,579,818	103,640,214	103,640,214	103,640,214	103,640,214	103,640,214	103,640,214
FEB	86,991,577	186,915,826	96,303,300	197,662,948	91,766,159	191,345,977	94,501,819	198,142,033	94,501,819	198,142,033	94,501,819	198,142,033
MAR	94,344,991	281,260,817	103,541,127	301,204,075	104,157,578	295,503,555	103,906,999	302,049,032	103,906,999	302,049,032	103,906,999	302,049,032
APR	93,929,323	375,190,140	99,479,609	400,683,684	99,459,039	394,962,594	98,201,007	400,250,039	98,201,007	400,250,039	98,201,007	400,250,039
MAY	95,791,327	470,981,467	97,900,863	498,584,547	101,070,371	496,032,965	96,741,237	496,991,276	96,741,237	496,991,276	96,741,237	496,991,276
JUN	92,140,614	563,122,081	87,069,612	585,654,159	91,905,308	587,938,273	98,413,520	595,404,796	98,413,520	595,404,796	98,413,520	595,404,796
JUL	92,796,301	655,918,382	100,219,275	685,873,434	100,129,497	688,067,770	102,055,968	697,460,764	102,055,968	697,460,764	102,055,968	697,460,764
AUG	90,393,416	746,311,798	99,874,019	785,747,453	97,673,622	785,741,392	105,378,334	802,839,098	105,378,334	802,839,098	105,378,334	802,839,098
SEP	92,589,092	838,900,890	93,510,551	879,258,004	100,028,888	885,770,280	98,474,782	901,313,880	98,474,782	901,313,880	98,474,782	901,313,880
OCT	98,386,458	937,287,348	95,441,022	974,699,026	102,206,875	987,977,155	96,470,624	990,880,952	96,470,624	990,880,952	96,470,624	990,880,952
NOV	94,939,660	1,032,227,008	94,015,007	1,068,714,033	100,752,128	1,088,729,283	103,445,859	1,101,230,363	103,445,859	1,101,230,363	103,445,859	1,101,230,363
DEC	99,314,617	1,131,541,625	99,141,298	1,167,855,331	103,415,430	1,192,144,713	99,339,043	1,200,569,406	99,339,043	1,200,569,406	99,339,043	1,200,569,406
<b>Total MCF Reported <sup>1</sup></b>	<b>1,131,541,625</b>	<b>1,167,855,331</b>	<b>1,167,855,331</b>	<b>1,167,855,331</b>	<b>1,192,144,713</b>	<b>1,192,144,713</b>	<b>1,200,569,406</b>	<b>1,200,569,406</b>	<b>1,200,569,406</b>	<b>1,200,569,406</b>	<b>1,200,569,406</b>	<b>1,200,569,406</b>
<b>Total MCF Not Reported <sup>2</sup></b>	<b>6,448,396</b>	<b>6,448,396</b>	<b>5,663,874</b>	<b>5,663,874</b>	<b>683,432</b>	<b>683,432</b>	<b>683,432</b>	<b>683,432</b>	<b>683,432</b>	<b>683,432</b>	<b>683,432</b>	<b>683,432</b>
<b>Total MCF Produced <sup>3</sup></b>	<b>1,137,990,021</b>	<b>1,173,519,205</b>	<b>1,173,519,205</b>	<b>1,173,519,205</b>	<b>1,192,828,145</b>	<b>1,192,828,145</b>	<b>1,199,902,838</b>	<b>1,199,902,838</b>	<b>1,199,902,838</b>	<b>1,199,902,838</b>	<b>1,199,902,838</b>	<b>1,199,902,838</b>

<sup>1</sup> Monthly production reports from Petroleum Information/Dwights LLC.

<sup>2</sup> (Total MCF produced) minus (total MCF reported by Petroleum Information/Dwights LLC).

<sup>3</sup> Wyoming Oil and Gas Conservation Commission.

Wyoming State Geological Survey, Oil and Gas Section, April, 1999.

been studying concurrent development of the two resources for the last five years. The JIC is made up of the five producing trona companies in the trona patch, the Oil and Gas and Minerals divisions of Union Pacific Resources, the Petroleum Association of Wyoming, and the Wyoming Mining Association. The Policy Committee, which also included the Wyoming State Geologist and a representative of the BLM, forwarded the committee's recommendations to the WOGCC in an effort to help assure the safety of underground trona miners as well as safeguard the trona deposits that underlie that area of the State.

The World-Class trona deposits in southwestern Wyoming overlie significant natural gas resources. Conventional development of those gas resources would involve drilling through the trona deposits, which are currently developed by underground mines. For concurrent development, the safety of the underground miners is a paramount concern of all parties, because the leakage of high-pressure, deeper gas into the mines could result in not only catastrophic loss of life, but also irreparable damage to further development of trona reserves in the area. For background, there are no other significant trona deposits in the U.S., and the plants that process the trona now supply more than 90% of the U.S. demand for soda ash and more than 34% of the world's demand.

The new rules, which should become effective in the second quarter of the year, require the setting of surface casing below all the trona beds and into the top of the Wasatch Formation. In addition, the new rules include some special completion and plugging procedures for wells drilled within the SSDA, which is also defined in the rules. Copies of the new rules are available from the WOGCC at P.O. Box 2640, Casper, WY 82602-2640; telephone: (307) 234-7147; and fax: (307) 234-5306.

Governor Jim Geringer signed a bill into law that gives tax relief to Wyoming's oil producers. House Enrolled Act No. 104 (House Bill 274), the Oil Producers Recovery Act, not only reduces the existing severance tax on stripper wells from four to three percent, but also reduces the tax on all other oil wells from six to four percent. The effective date of the bill was January 1, 1999. The tax reductions remain in effect until December 31, 2000, or until the average price of oil reported to the Wyoming Department of Revenue exceeds \$20 per barrel for three consecutive months. The new law also exempts oil producers from paying sales tax on electricity used for oil production.

The U.S. Department of the Interior (DOI) is allowing independent oil producers who drill on public lands to suspend operations for up to two years without losing their leases. DOI hopes this action will help slow down the premature plugging of stripper wells. A stripper well is one that produces 15 barrels or less of oil per day.

Secretary of Energy Bill Richardson has decided to add 28 million barrels of oil to the Strategic Petroleum Reserve. The oil will be royalty-in-kind from Federal offshore tracts. Since oil has been selling at historically low prices, adding oil to the reserve at this time will save taxpayers money and may assist

producers by helping reduce the current oversupply of oil. The Department of Energy has also offered to store up to an additional 70 million barrels in the Reserve under commercial arrangements. Taking this much oil off the open market should help increase crude oil prices.

Marathon Oil Co. announced plans to sell their interest in seven unspecified Wyoming properties. According to an article in the *Casper Star-Tribune* (3/26/99), the sale would eliminate 15 jobs in the company's Cody-based Rocky Mountain region. Company officials feel this realignment of property holdings will help strengthen their economic presence in Wyoming.

Sinclair Oil will expand the capacity of its refinery at Sinclair, Wyoming. The addition of a new 11,000-barrel-per-day hydrocracker and a 26 million cubic feet per day hydrogen factory at the refinery will increase its capacity to 65,000 barrels of crude oil per day. The Sinclair refinery is the largest refinery in the Rocky Mountain Region.

Howell Corp. sold its interest in the La Barge project in southwestern Wyoming to Exxon USA for \$15,750,000. Howell's average net production from the project was 3.5 million cubic feet of methane per day, plus volumes of helium, sulfur, and carbon dioxide. Howell also sold its interest in Grass Creek and Pitchfork fields in the Bighorn Basin to Marathon Oil for \$12,275,000. Howell's interest in 280 wells produced an average of 1,500 barrels of heavy oil per day. Howell acquired a number of Wyoming properties from BP Amoco in December of last year, which included the above properties. Howell retains ownership of the interests it acquired from BP Amoco in Salt Creek and Elk Basin fields. Howell operates both of those fields.

Leasing at the BLM's February sale was predominantly in the Greater Green River Basin and the Powder River Basin (**Figure 9**). The sale's high per-acre bid of \$325 was made by Meany Land & Exploration for a 483.39-acre lease that covers parts of sections 1 and 12, T42N, R71W (location **A**, **Figure 9**). The lease is on the eastern flank of Porcupine Field, which produces from the Turner and Sussex sandstones. The second high per-acre bid of \$160 was made by Pennaco Energy for a 963.29-acre tract that covers parts of sections 3 and 34, T51N, R74W (location **B**, **Figure 9**). The lease is in an area of active coalbed methane development. There were a total of 21 parcels at this sale that received bids of \$50 or more per acre.

When compared with the last ten Federal lease sales, the \$2,734,442 netted by the February sale indicates very much slackened leasing activity in the Powder River Basin (**Table 7**). The heightened leasing in the latter half of 1997 and all of 1998 was in no small measure a result of the coalbed methane play in northeastern Wyoming. Leasing at the February sale fell back to levels seen prior to that play.

While leasing for coalbed methane may have waned, Applications for Permit to Drill (APD) have not. There were 768 APDs in the first quarter of 1999 (**Table 8**). This is the largest number of APDs approved by the Wyoming Oil

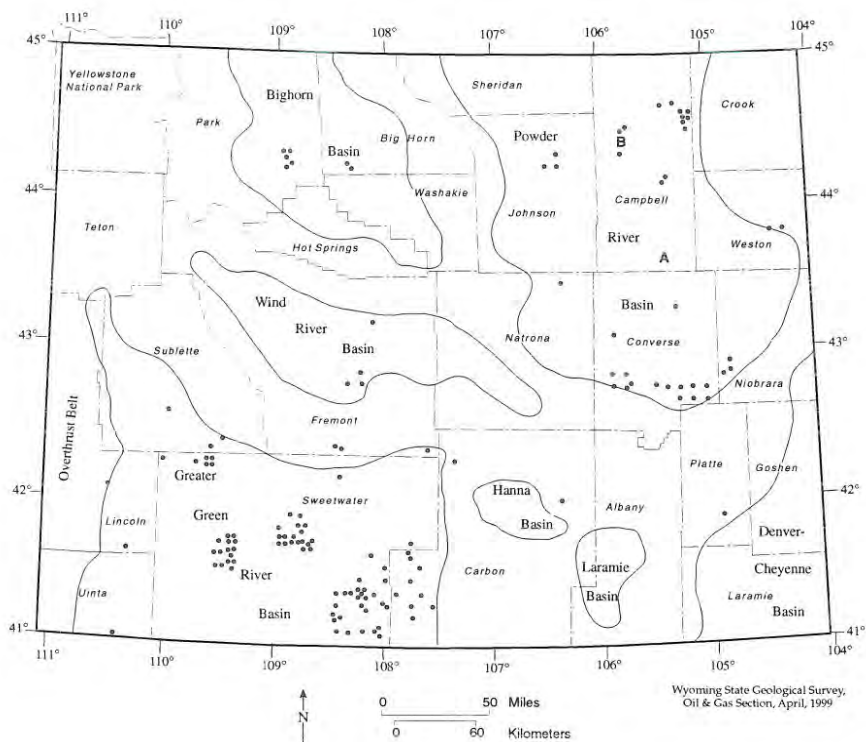


Figure 9. Locations of Federal oil and gas tracts leased by the U.S. Bureau of Land Management at its February, 1999, sale.

and Gas Conservation Commission (WOGCC) in the first quarter of a year since the drilling boom in the early 1980s, and was more than for the entire year of 1995. Campbell County again led with 71.6% of the total APDs that were approved. Sheridan and Johnson counties combined for another 10.4% of the total APDs that were approved. Nearly all of the approved APDs in these three counties were for coalbed methane tests.

On the other hand, the WOGCC only issued permits for two seismic projects in the first quarter of 1999 (Table 9). The small number of seismic projects means there will be much less exploration for oil and gas this year. For comparison, there were 11 permits for seismic projects issued during the first quarter of 1998.

The average daily rig count for the first quarter of 1999 was 25. This average is 17 less than in the first quarter of 1998, but does not include rigs drilling for coalbed methane. Most drilling presently is for natural gas. Figure 10 shows the Wyoming daily rig count averaged by month.

**Table 7. Federal and State competitive oil and gas lease sales in Wyoming.**

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
<b>1996</b>							<b>1996</b>								
TOTAL	\$11,487,567	1,828	1,125	1,403,444	739,505	\$15.53	\$1,450.00	TOTAL	\$2,325,497	1049	508	418,111	206,814	\$11.24	\$206.00
<b>1997</b>							<b>1997</b>								
TOTAL	\$31,976,603	1,787	1,485	1,578,938	1,206,642	\$26.50	\$600.00	TOTAL	\$3,151,020	1198	704	438,296	263,230	\$11.97	\$340.00
<b>1998</b>							<b>1998</b>								
February	\$5,262,908	369	285	366,787	241,654	\$21.78	\$415.00	April	\$1,203,792	300	161	115,646	63,848	\$18.85	\$320.00
April	\$10,287,111	247	227	192,561	162,393	\$63.35	\$395.00	June	\$1,660,438	300	148	108,654	52,501	\$31.63	\$600.00
June	\$14,737,117	463	367	498,339	368,816	\$39.96	\$430.00	October	\$1,313,792	298	178	98,856	65,212	\$20.14	\$590.00
August	\$8,033,029	306	245	349,605	278,095	\$28.89	\$500.00	December	\$1,045,447	300	187	121,551	77,852	\$13.43	\$215.00
October	\$10,251,074	455	308	421,900	293,141	\$34.97	\$430.00	TOTAL	\$5,223,469	1198	674	444,707	259,413	\$20.14	\$600.00
December	\$15,229,257	407	278	368,783	277,538	\$54.87	\$800.00								
TOTAL	\$63,800,496	2,247	1,710	2,217,975	1,621,637	\$39.34	\$800.00								
<b>1999</b>							<b>1999</b>								
February	\$2,734,442	170	138	157,779	124,880	\$21.90	\$325.00								

Sources: Wyoming Office of State Lands and Investments, Petroleum Information/Dwights LLC - Rocky Mountain Region Report, and U.S. Bureau of Land Management.

## Exploration and Development

Company data, news releases, and information compiled and published by Petroleum Information/Dwights LLC indicate the following significant exploration and development occurred in Wyoming during the first quarter of 1999. The numbers preceding discussions refer to locations on **Figure 11**. Activities related to the coalbed methane play are discussed in the **COAL UPDATE** of this issue.

1. BP Amoco completed a well in SW SE section 18, T17N, R119W. The 7 Amoco-Gulf well produced an average of 10.2 million cubic feet of gas and 70 barrels of condensate per day during its first month of production. The well is producing from an undisclosed interval in the Madison Limestone.

2. Chevron USA completed two horizontally-drilled wells in Painter Reservoir East Field. The 23-32B H PRU well in NW SW section 32, T16N, R119W flowed 1.7 million cubic feet of gas, 979 barrels of oil, and nine barrels of water per day from the Nugget Sandstone. The well was drilled to a true vertical depth of approximately 12,040 feet. The 21-8A H PRU well in SE SE section 6, T15N, R119W flowed 8.6 million cubic feet of gas, 2,360 barrels of oil, and 3

**Table 8. Number of Applications for Permit to Drill (APD) approved by the Wyoming Oil and Gas Conservation Commission (1996 through March, 1999).**

County	1996 APDs	1997 APDs	1998 APDs	1999 APDs
Albany	1	0	0	0
Big Horn	53	59	13	0
Campbell	554	941	1586	550
Carbon	77	84	96	20
Converse	20	16	6	3
Crook	37	26	29	0
Fremont	26	58	76	18
Goshen	0	0	0	0
Hot Springs	24	42	1	1
Johnson	16	6	49	35
Laramie	2	3	2	0
Lincoln	55	122	105	11
Natrona	74	59	36	6
Niobrara	7	8	8	0
Park	30	25	11	0
Platte	0	0	0	0
Sheridan	0	2	35	45
Sublette	118	179	230	47
Sweetwater	136	210	181	28
Teton	0	0	0	0
Uinta	10	27	26	4
Washakie	30	36	9	0
Weston	10	5	6	0
<b>Totals</b>	<b>1280</b>	<b>1908</b>	<b>2505</b>	<b>768</b>

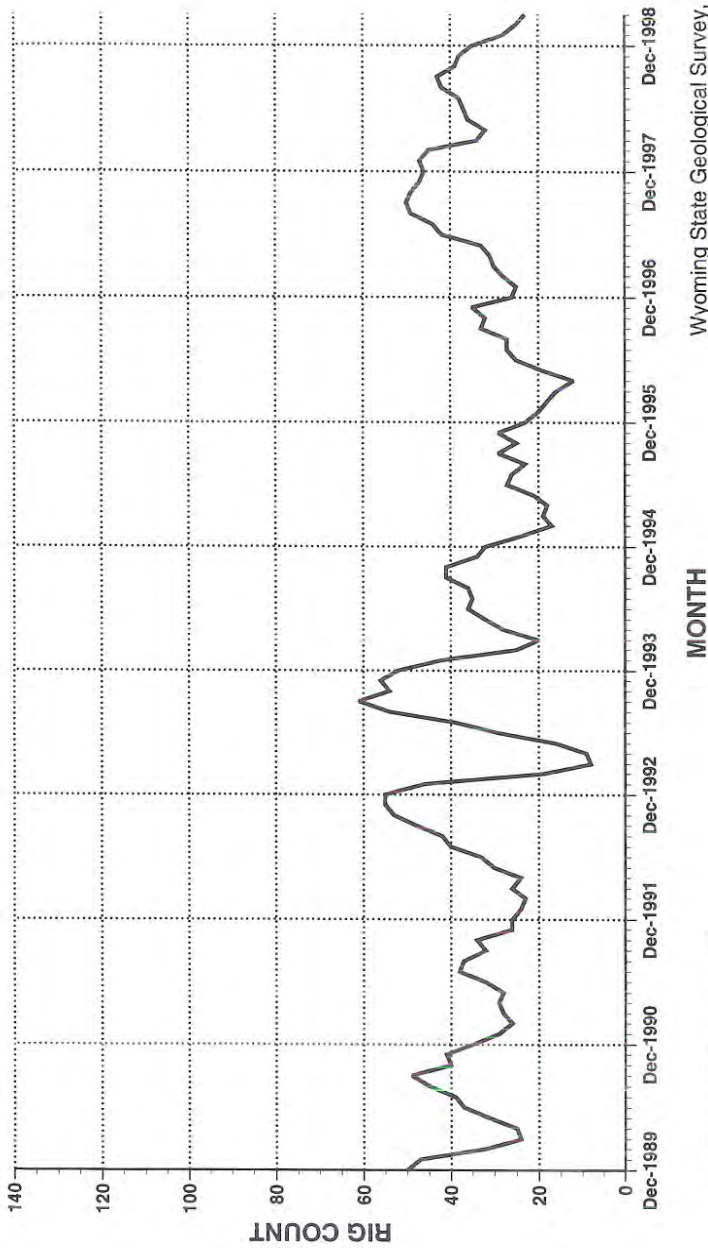
Source: All data are from the Wyoming Oil and Gas Conservation Commission.



**Table 9. Number of seismic projects and miles permitted by the Wyoming Oil and Gas Conservation Commission (1996 through March, 1999).**

County	1996			1997			1998			1999		
	Permits	Conventional Miles	3-D Sq Miles	Permits	Conventional Miles	3-D Sq Miles	Permits	Conventional Miles	3-D Sq Miles	Permits	Conventional Miles	3-D Sq Miles
Albany	1	18	0	0	0	0	0	0	0	0	0	0
Big Horn	2	3	66	2	0	45	1	0	16			
Campbell	32	56	220	20	52	79	14	18	182			
Carbon	2	5	18	3	7	190	4	0	318			
Converse	1	4	0	1	5	0	4	12	239			
Crook	5	3	20	7	8	18	2	2	4			
Fremont	2	5	15	6	43	126	2	100	0			
Goshen	0	0	0	2	227	0	0	0	0			
Hot Springs	4	17	29	1	8	0	4	19	0			
Johnson	0	0	0	2	7	17	1	4	0			
Laramie	0	0	0	0	0	0	0	0	0			
Lincoln	0	0	0	3	7	116	1	10	0			
Natrona	0	0	0	5	14	101	6	12	214			
Niobrara	2	0	23	0	0	0	0	0	0			
Park	6	20	82	4	56	58	3	16	132			
Platte	0	0	0	0	0	0	0	0	0			
Sheridan	1	5	0	0	0	0	1	14	0			
Sublette	2	21	52	1	0	61	2	1	115	1	60	54
Sweetwater	8	17	670	4	66	296	6	214	66	1		
Teton	0	0	0	0	0	0	0	0	0			
Uinta	1	0	40	0	0	0	2	0	147			
Washakie	0	0	0	3	36	0	4	41	35			
Weston	1	0	16	1	0	17	1	0	35			
<b>Totals</b>	<b>70</b>	<b>174</b>	<b>1251</b>	<b>65</b>	<b>536</b>	<b>1124</b>	<b>58</b>	<b>463</b>	<b>1503</b>	<b>2</b>	<b>0</b>	<b>114</b>

Source: All data are from the Wyoming Oil and Gas Conservation Commission. Wyoming State Geological Survey, Oil and Gas Section, April, 1999.



Wyoming State Geological Survey,  
Oil and Gas Section, April., 1999

Source: Hughes Rig Count

Figure 10. Wyoming daily rig count averaged by month (December, 1989, to March, 1999).

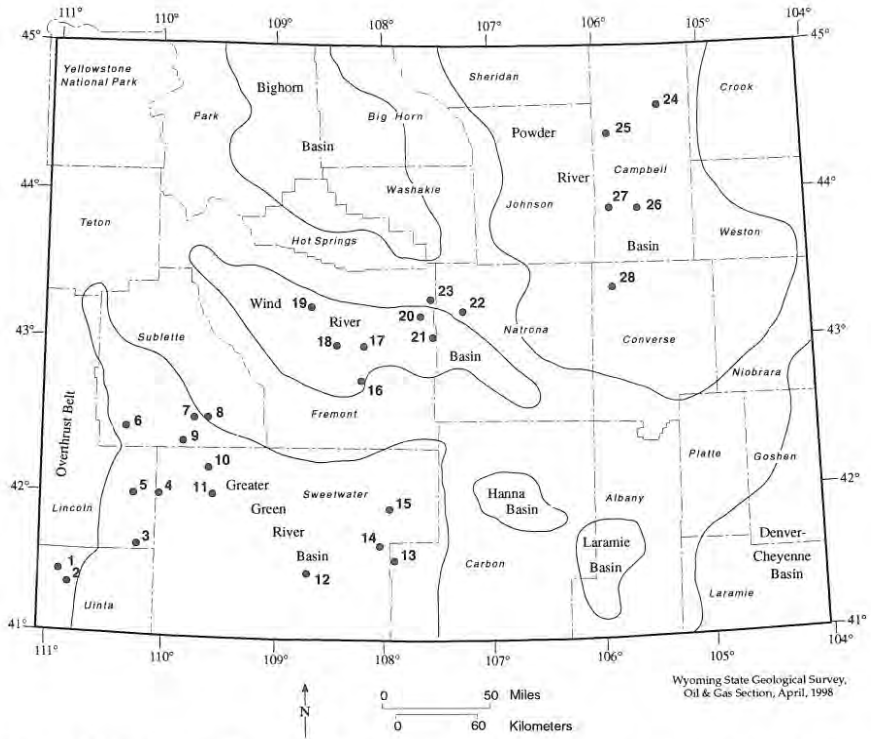


Figure 11. Oil and gas exploration and development activities in Wyoming during the first quarter of 1999 (exclusive of coalbed methane activities).

barrels of water per day from the Nugget. The true vertical depth of the well is 12,095 feet.

3. Celsius Energy completed an exploration well in NE SW section 15, T19N, R113W. The 1 Verne Valley Unit well flowed 257,000 cubic feet of gas per day from the Frontier Formation between 11,394 and 11,412 feet.

4. Marathon Oil completed a new well in Emigrant Springs Field. The 22-19 County Line well in SW SE section 19, T23N, R111W flowed 2.8 million cubic feet of gas per day through perforations in the Frontier between 10,592 and 10,608 feet.

5. Marathon also completed a step-out well from Shute Creek Field. The 21-12 Jackson Creek well in N/2 SW section 12, T23N, R113W flowed 1.1 million cubic feet of gas per day from the second Frontier sandstone between 10,592 and 10,740 feet.

6. Mobil Exploration & Producing completed three new wells at the Tip Top Unit. The T22X-24G Tip Top Unit well in NW NW section 24, T28N, R114W

flowed 2.7 million cubic feet of gas per day from the first Frontier sandstone between 5,418 and 5,454 feet, the second Frontier sandstone between 5,938 and 6,084 feet, and the Muddy Sandstone between 6,794 and 7,048 feet. The T72X-28 Tip Top Unit well in NE NE section 28, T28N, R113W flowed 2.0 million cubic feet of gas per day from the first Frontier between 6,240 and 6,264 feet and the second Frontier between 6,697 and 6,796 feet. The T27X-28G Tip Top Unit well in SW SW section 28, T28N, R113W flowed 1.7 million cubic feet of gas per day from the first Frontier between 6,102 and 6,122 feet and the second Frontier between 6,640 and 6,770 feet.

7. Activity continues in and around Jonah Field. McMurry Oil completed a step-out well in SE NW section 6, T29N, R108W. The 6-36 Stud Horse Butte well flowed 7.6 million cubic feet of gas per day from the Lance Formation between 9,243 and 11,458 feet.

8. BP Amoco completed a wildcat four miles northeast of Jonah Field. The 15-4 Antelope well in SW SE section 4, T29N, R107W flowed 21.9 million cubic feet of gas and 2,409 barrels of water per day from an undisclosed interval in the Lance.

9. McMurry Oil completed a wildcat well in SW NW section 1, T27N, R109W. The 5-1 HSR-Holmes-Federal well flowed 1.0 million cubic feet of gas per day from the Lance.

10. Yates Petroleum discovered gas at its 1 Gunsmoke Unit well in NW NW section 9, T25N, R108W. The well flowed 575,000 cubic feet of gas, 16 barrels of condensate, and 19 barrels of water per day from the Almond Formation between 8,900 and 8,910 feet.

11. Texaco Exploration & Production completed a new producing well in Stagecoach Draw Field. The 25 Stagecoach Draw Unit well in SE SW section 29, T23N, R107W flowed 6.2 million cubic feet of gas, 62 barrels of condensate, and 40 barrels of water per day from the Almond between 8,387 and 8,390 feet.

12. Union Pacific Resources recompleted a well in Brady Field. The 11 Brady Unit well in SW NW section 31, T17N, R100W flowed 643,000 cubic feet of gas, 84 barrels of condensate, and 3 barrels of water per day from the Phosphoria Formation between 14,166 and 14,180 feet.

13. BP Amoco completed several new wells in the Wamsutter area. The 27-3 Wamsutter Rim well in NW NW section 27, T18N, R94W flowed 6.1 million cubic feet of gas per day from several intervals in the Almond between 9,629 and 9,986 feet. The 3 Champlin 261 Amoco G well in NE SE section 17, T18N, R93W flowed 3.3 million cubic feet of gas per day between 9,084 and 9,362 feet. The 27-2 Wamsutter Rim well in SW NE section 27, T18N, R93W flowed 2.5 million cubic feet of gas per day between 9,611 and 9,962 feet. The 4 Champlin 261 Amoco G well in SE NW section 17, T18N, R93W flowed 2.2 million cubic feet of gas per day between 9,102 and 9,379 feet. Abraxas Petro-

leum also completed two new wells in the Wamsutter area. The 1-14 Echo Springs-Federal well in SE NW section 14, T19N, R93W flowed 1.8 million cubic feet of gas, 35 barrels of condensate, and 75 barrels of water per day from the Almond between 9,568 and 9,580 feet. The 1-36 State well in NE NW section 36, T19N, R93W flowed 1.0 million cubic feet of gas, 4 barrels of condensate, and 75 barrels of water per day from the Almond between 8,935 and 9,184 feet.

14. BP Amoco completed a new well in Frewan Field. The 12 Frewan Unit well in NW NE section 19, T19N, R94W flowed 1.7 million cubic feet of gas per day from the Almond between 9,686 and 9,726 feet and between 9,811 and 9,921 feet.

15. BP Amoco also completed three new wells in the Mesaverde Group at Siberia Ridge Field. The 4 Siberia Ridge 1-30 well in NW SE section 30, T22N, R93W flowed 4.3 million cubic feet of gas per day between 11,053 and 11,833 feet. The 2 Siberia Ridge 1-30 well was drilled from the same pad and flowed 3.0 million cubic feet of gas per day between 11,212 and 12,014 feet. A third well drilled from the same pad, the 3 Siberia Ridge 1-30 flowed 2.8 million cubic feet of gas per day between 11,074 and 11,830 feet.

16. Thorofare Resources confirmed its Muddy discovery at Sand Draw South Field. The 43-26 Mari-Federal was recompleted in an undisclosed Muddy zone and flowed 650,000 cubic feet of gas per day.

17. Snyder Oil completed a wildcat in NW SE section 32, T1S, R6E. The 10-32 North Alkali-Tribal well flowed 500,000 cubic feet of gas per day from the Dakota Sandstone between 6,667 and 6,673 feet, the Lakota Formation between 6,742 and 6,756 feet, and the Morrison Formation from between 6,853 and 6,858 and from between 6,922 and 6,942 feet.

18. Snyder also completed a step-out from Riverton Dome Field. The 52 Riverton Tribal well in NW SE section 24, T1S, R4E flowed 3.3 million cubic feet of gas and 7 barrels of water per day from the Muddy between 9,690 and 9,700 feet.

19. Tom Brown Inc. has two new producing wells in Pavillion Field. The 42X-9 Pavillion-Fee well in SE NE section 9, T3N, R2E flowed 3.5 million cubic feet of gas per day from the Fort Union Formation between 4,552 and 5,573 feet. The 41-11 Pavillion-Fee well in NE NE section 11, T3N, R2E flowed 1.7 million cubic feet of gas and 2 barrels of condensate per day from the Wind River Formation between 1,976 and 2,134 feet.

20. KCS Mountain Resources discovered gas at its 33-36 Squaw Butte well in NW SE section 36, T37N, R90W. The well flowed 757,000 cubic feet of gas and 117 barrels of water per day from the Lance between 9,398 and 10,600 feet.

21. Natural Gas Processing completed a step-out from Meigh Ranch Field. The 33-5 Santee-Federal well in NW SE section 5, T35N, R89W flowed 450,000

cubic feet of gas, 2 barrels of condensate, and 22 barrels of water per day from the Lance between 7,236 and 7,246 feet and from between 7,270 and 7,300 feet.

22. Prima Oil & Gas completed the westernmost producer in Waltman Field. The 25-43 NW Cave Gulch in NW SE section 25, T37N, R87W flowed 4.9 million cubic feet of gas, 29 barrels of condensate, and 80 barrels of water per day from several intervals in the Lance between 6,126 and 8,378 feet. Barrett Resources also completed three new wells in Waltman Field. The 5-30 Lak-Cave Gulch-Federal well in NW SE section 30, T37N, R86W flowed 6.0 million cubic feet of gas per day from an undisclosed interval in the subthrust Muddy. The well also has potential pays in the Frontier and Lakota. The 17 Cave Gulch Unit well in NE NE section 31, T37N, R86W flowed 2.4 million cubic feet of gas per day from an undisclosed interval in the upper Fort Union and 2.9 million cubic feet of gas per day from an undisclosed interval lower in the Fort Union. The 21 Cave Gulch Unit well in NW NW section 32, T37N, R86W flowed 4.3 million cubic feet of gas and 100 barrels of water from the Lance between 5,374 and 8,962 feet.

23. Louisiana Land & Exploration completed two new wells in Madden Field. The 2-3 Spratt-Madden Deep Unit well in NW NW section 3, T38N, R90W flowed 4.4 million cubic feet of gas and 20 barrels of water per day from perforations in the Lance between 13,005 and 13,022 feet. The 34 Madden Deep Unit well in SE NW section 5, T38N, R90W flowed 4.3 million cubic feet of gas and 20 barrels of condensate per day from several intervals in the Fort Union between 5,741 and 6,022 feet. Burlington Resources spudded a proposed 25,000-foot Madison Limestone test in Madden Field. The 5-6 Bighorn in SW NW section 6, T38N, R89W is about 2.5 miles east of the closest of three Madison gas producers in the field.

24. Trend Exploration completed a step-out from the discovery well at Coal Creek Field. The 1-1A Boothill-Federal well in SW SE section 1, T53N, R71W produced an undisclosed amount of oil during tests of the Minnelusa Formation between 8,069 and 8,071 feet.

25. Prima Oil & Gas completed three step-outs from Cedar Draw Field. The 11-23 Cedar Draw-Federal in SW NW section 11, T51N, R75W flowed 2.3 million cubic feet of gas, 254 barrels of condensate, and 5 barrels of water per day from an undisclosed interval in the Muddy. The 10-44 Cedar Draw-Federal well in SE SE section 10, T51N, R75W flowed 672,000 cubic feet of gas, 17 barrels of condensate, and 3 barrels of water per day from an undisclosed interval in the Muddy. The 15-21 Cedar Draw-Federal well in NE NW section 15, T51N, R75W flowed 470,000 cubic feet of gas per day from an undisclosed interval in the Muddy.

26. Devon Energy completed two new wells in the Sussex sandstone at House Creek Field. The 18-4 House Creek Unit well in SE SW section 19, T45N, R73W pumped 406 barrels of oil and 17 barrels of water per day between 8,094 and 8,114 feet. The 26-3 House Creek well in NW SE section 30,

T45N, R73W pumped 146 barrels of oil, 1,000 cubic feet of gas, and 32 barrels of water per day between 8,051 and 8,082 feet.

27. Exxon Corp. completed two new wells in Hartzog Draw Field. The 5824 Hartzog Draw Unit well in SW NE section 32, T45N, R75W pumped 400 barrels of oil, 78,000 cubic feet of gas, and 2 barrels of water per day from the Shannon Sandstone between 9,372 and 9,424 feet. The 5837 Hartzog Draw Unit well in SW SW section 33, T45N, R75W pumped 384 barrels of oil and 73,000 cubic feet of gas per day from the Shannon between 9,486 and 9,540 feet.

28. A Vastar Resources discovery, drilled in 1998, reported its first production. The 1-22 African Swallow well in SW SW section 22, T39N, R75W flowed an average of 7.6 million cubic feet of gas and 1,311 barrels of condensate per day during its first two days of production. It is producing from the Muddy between 14,118 and 14,128 feet.

## COAL UPDATE

Robert M. Lyman

*Staff Geologist-Coal, Wyoming State Geological Survey*

Coal production figures reported by the Wyoming State Inspector of Mines substantiate that Wyoming coal producers set yet another production record in 1998. Coal production from Wyoming totaled 314,962,091 short tons. This is an increase of 11.9% over the 281,481,516 tons produced in 1997.

**Table 10** shows monthly coal deliveries, as reported on the Federal Energy Regulatory Commission's (FERC) Form 423, for the period 1995 to 1998. It also shows that eight out of the last twelve months of deliveries exceeded any monthly deliveries from previous years. The graph in **Figure 12** compares the record monthly deliveries in 1998, with those in 1996 and 1997. **Figure 13** breaks these monthly deliveries into spot sales and contract sales, and indicates that monthly spot sales in 1998 were consistently higher than the previous two years in all but January. Also, ten of the monthly contract sales were higher than the same months in 1996 and 1997, but only August set a new monthly record at 22 million tons. Data for these tables are available electronically at FERC's web page. The address is: <http://www.ferc.fed.us/electric/f423/form423.htm>

**Table 11** depicts historic and projected coal production by county. It also provides an estimate of coal from the Powder River Basin (PRB), which sells for more than \$5.00/ton. The tonnages sold at these higher prices are under the remaining, older, long-term contracts that had escalation clauses built into them. **Table 12** shows a breakdown of the average prices for coal produced in northeastern Wyoming and southern Wyoming over the past ten years, as well as projected average prices through 2005.

**Table 10. Monthly coal deliveries from Wyoming's mines in short tons (1995-December, 1998)**

	1995			1996			1997			1998		
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	21,586,303	21,586,303	21,793,387	21,793,387	25,165,405	25,165,405	26,536,217	26,536,217	23,196,152	49,732,369	23,196,152	49,732,369
FEB	20,839,926	42,426,229	20,374,055	42,167,442	22,566,012	68,474,641	23,861,472	73,593,841	24,768,989	98,362,830	24,768,989	98,362,830
MAR	21,707,422	64,133,651	22,507,800	64,675,242	20,961,008	89,435,649	25,278,960	123,641,790	24,450,835	148,092,625	24,450,835	148,092,625
APR	20,066,616	84,200,267	22,579,959	87,255,201	23,102,867	112,538,516	25,663,577	173,756,202	26,591,950	200,348,152	26,591,950	200,348,152
MAY	21,509,916	105,710,183	22,216,016	109,471,217	20,862,610	133,401,126	26,041,099	226,389,251	26,659,121	253,048,372	26,659,121	253,048,372
JUN	18,602,505	124,312,688	20,698,814	130,170,031	24,074,929	157,476,055	25,620,216	278,668,588	26,102,620	304,771,208	26,102,620	304,771,208
JUL	21,334,608	145,647,296	24,842,971	155,013,002	23,002,254	180,478,309	270,944,744	304,771,208	270,944,744	304,771,208	270,944,744	304,771,208
AUG	21,356,870	167,004,166	24,421,537	179,434,539	22,452,566	202,930,875	270,944,744	304,771,208	270,944,744	304,771,208	270,944,744	304,771,208
SEP	21,355,730	188,359,896	23,339,792	202,774,331	21,623,057	224,553,932	270,944,744	304,771,208	270,944,744	304,771,208	270,944,744	304,771,208
OCT	21,173,610	209,538,506	22,615,721	225,390,052	21,695,072	246,249,004	270,944,744	304,771,208	270,944,744	304,771,208	270,944,744	304,771,208
NOV	21,042,260	230,580,766	21,421,085	246,811,137	22,105,530	268,916,667	270,944,744	304,771,208	270,944,744	304,771,208	270,944,744	304,771,208
DEC	22,032,910	252,613,676	22,105,530	268,916,667	22,105,530	268,916,667	270,944,744	304,771,208	270,944,744	304,771,208	270,944,744	304,771,208
<b>Total Tonnage Reported<sup>1</sup></b>		<b>252,613,676</b>		<b>268,916,667</b>		<b>270,944,744</b>		<b>304,771,208</b>		<b>304,771,208</b>		<b>304,771,208</b>
<b>Total Tonnage Not Reported<sup>2</sup></b>		<b>11,324,347</b>		<b>9,508,289</b>		<b>10,536,772</b>		<b>10,190,883</b>		<b>10,190,883</b>		<b>10,190,883</b>
<b>Total Tonnage Produced<sup>3</sup></b>		<b>263,938,023</b>		<b>278,424,956</b>		<b>281,481,516</b>		<b>314,962,091</b>		<b>314,962,091</b>		<b>314,962,091</b>

<sup>1</sup>COALDAT Marketing Reports by Resource Data International, Inc. (1995); and from Federal Energy Regulatory Commission (FERC) Form 423, 1996-1998.

<sup>2</sup>Includes estimates of residential, industrial, and exported coal, plus tonnage not reported on FERC's Form 423.

<sup>3</sup>Wyoming State Mine Inspector's Annual Reports. Wyoming State Geological Survey, Coal Section, April, 1999.



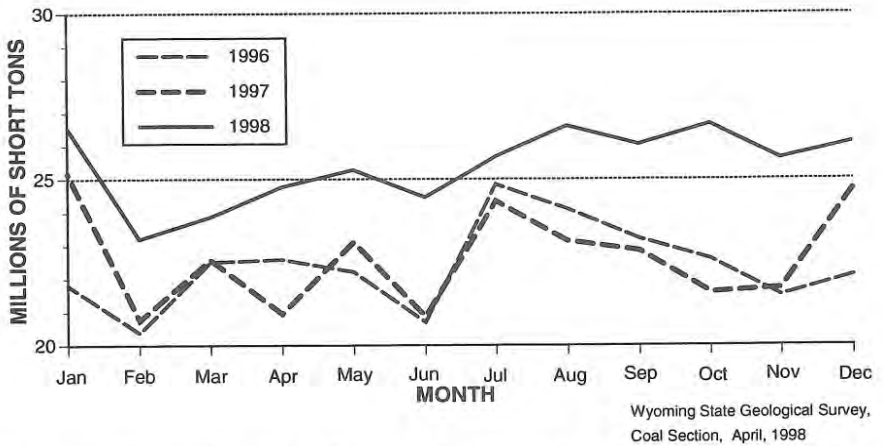


Figure 12. Reported monthly deliveries from Wyoming coal mines (1996 through 1998). Derived from data on the Federal Energy Regulatory Commission's Internet bulletin board.

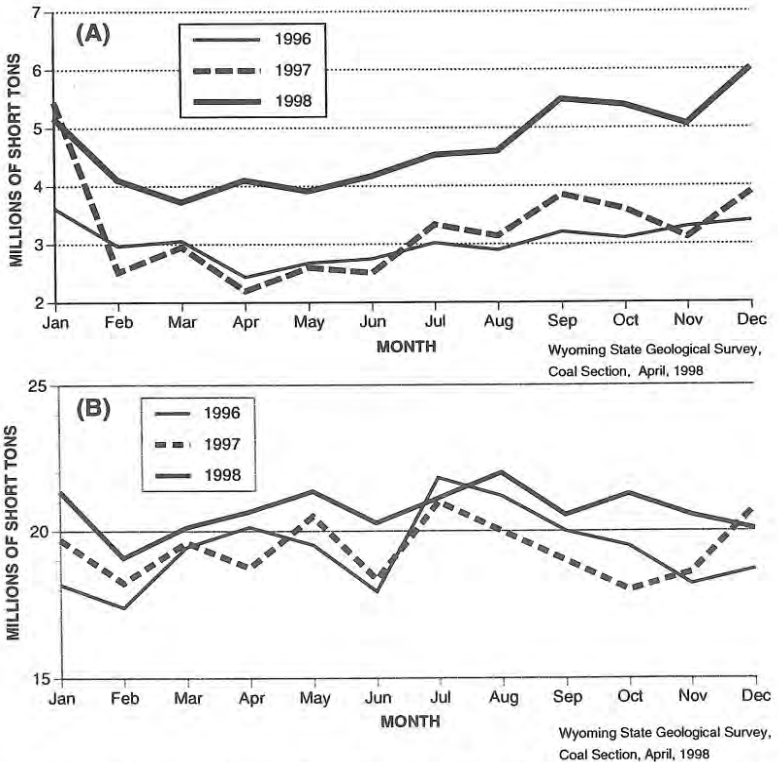


Figure 13. Monthly coal deliveries from Wyoming (1996 through 1998). (A) Coal sold on the spot market and (B) coal sold on contract. Derived from data on the Federal Energy Regulatory Commission's Internet bulletin board.

**Table 11. Wyoming coal production by county (in millions of tons), from 1995 to 1998 with forecasts to 2005.**

	1995 <sup>1</sup>	1996 <sup>1</sup>	1997 <sup>1</sup>	1998 <sup>1</sup>	1999 <sup>2</sup>	2000 <sup>2</sup>	2001 <sup>2</sup>	2002 <sup>2</sup>	2003 <sup>2</sup>	2004 <sup>2</sup>	2005 <sup>2</sup>
Campbell County	232.4	245.3	246.3	274.1	292.0	313.0	326.0	329.5	333.2	337.0	340.6
Converse County	14.1	15.8	17.8	23.4	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Sheridan County	M	M	M	M	M	M	M	M	M	M	M
Carbon County	3.8	4.7	5.0	3.5	3.7	2.8	2.0	2.0	2.0	2.0	2.0
Sweetwater County	9.1	8.2	7.8	9.2	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Lincoln County	4.5	4.4	4.6	4.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0
<b>Total Wyoming</b>	<b>263.9</b>	<b>278.4</b>	<b>281.5</b>	<b>315.0</b>	<b>333.7</b>	<b>353.8</b>	<b>366.0</b>	<b>369.5</b>	<b>373.2</b>	<b>377.0</b>	<b>380.6</b>
Annual Change	11.4%	5.5%	1.1%	11.9%	6.0%	6.0%	3.4%	1.0%	1.0%	1.0%	1.0%
Higher-priced coal <sup>3</sup>	26%	24%	22%	17%	13%	9%	6%	4%	4%	4%	4%

<sup>1</sup>Tonnages from the Wyoming State Inspector of Mines, 1995-1998.

<sup>2</sup>County estimates by the Wyoming State Geological Survey, April, 1999.

<sup>3</sup>Estimated percentage of Powder River Basin coal production that is sold at prices above \$5.00/ton (older long-term contracts that have not yet expired).

[M means minor tonnage (less than 50,000 tons)].

**Table 12. Breakdown of average prices paid for coal from northeastern Wyoming, southern Wyoming, and Wyoming as a whole (1988-1997) with forecasts to 2005.**

Year	Northeastern	Southern	Statewide
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	\$16.83	\$5.42
1999	\$4.66	\$17.11	\$5.31
2000	\$4.61	\$16.63	\$5.17
2001	\$4.51	\$16.89	\$5.04
2002	\$4.52	\$16.79	\$5.04
2003	\$4.52	\$16.91	\$5.04
2004	\$4.53	\$16.81	\$5.04
2005	\$4.54	\$16.70	\$5.04

Statewide data for 1988-1990 are from reports by the U.S. Department of Energy's Energy Information Administration; data for 1991-1997 are derived from Wyoming Department of Revenue information; estimates for 1998-2005 and for regional breakdowns are by the Wyoming State Geological Survey (April, 1999).

**Table 13** lists the current permitted annual capacity for each coal mine in Wyoming. These capacities are based on air quality permits issued by the Air Quality Division of the Wyoming Department of Environmental Quality. Permitted capacities of active Wyoming coal mines total 486.5 million short tons. Last year, Wyoming coal mines collectively produced at approximately 65% of this total permitted capacity.

**Figure 14** shows Wyoming coal mines that were active in 1998, as well as the locations of coal-fired power plants and plants that process coal-related products in Wyoming.

### **Developments in the Powder River Basin (PRB)**

Peabody announced plans to merge Powder River Coal Co.'s North Antelope and Rochelle mines into one large mine complex. The combining of these two mines would make the largest coal mine in the nation, with annual production at nearly 65 million tons. The company is merging the mines to streamline administration and increase flexibility for their customers (*Coal Outlook*, 1/18/99).

The North Rochelle mine shipped its first two unit trains on 12/21/98 (*Coal Outlook Supplement*, 1/18/99). While the permitted mine capacity at North Rochelle is 12.5 million tons per year, production for 1999 will depend on market conditions. The mine now has at least two long term contracts. One is with

**Table 13. Permitted capacities of active Wyoming coal mines in 1998.**

Mine	County	County Production in 1998 <sup>1</sup> (Million short tons)	Capacity in Million Tons/Year <sup>2</sup>
Belle Ayr	Campbell		25.0
Black Thunder	Campbell		55.0
Buckskin	Campbell		22.0
Caballo-Rocky Butte	Campbell		35.0
Coal Creek	Campbell		18.0
Cordero-Rojo	Campbell		60.0
Dry Fork	Campbell		15.0
Eagle Butte	Campbell		35.0
Fort Union	Campbell		3.7
KFx	Campbell		0.6
Jacobs Ranch	Campbell		35.0
North Antelope-Rochelle	Campbell		67.0
North Rochelle	Campbell		12.5
Rawhide	Campbell		24.0
Wyodak	Campbell		9.2
<b>Campbell County Subtotal</b>		<b>274.1</b>	<b>417.0</b>
Antelope	Converse		30.0
Dave Johnston	Converse		4.2
<b>Converse County Subtotal</b>		<b>23.4</b>	<b>34.2</b>
Big Horn	Sheridan		4.6
<b>Sheridan County Subtotal</b>		<b>0.1</b>	<b>4.6</b>
<b>Powder River Coal Field Subtotal</b>		<b>297.6</b>	<b>455.8</b>
Cyprus-Shoshone	Carbon		3.5
Medicine Bow	Carbon		3.3
Seminole II	Carbon		0.8
<b>Carbon County Subtotal</b>		<b>3.5</b>	<b>7.6</b>
<b>Hanna Coal Field Subtotal</b>		<b>3.5</b>	<b>7.6</b>
Black Butte-Leucite Hills	Sweetwater		9.5
Jim Bridger	Sweetwater		7.9
<b>Sweetwater County Subtotal</b>		<b>9.2</b>	<b>17.4</b>
<b>Green River Coal Field Subtotal</b>		<b>9.2</b>	<b>17.4</b>
Kemmerer-Skull Point	Lincoln		5.7
<b>Lincoln County Subtotal</b>		<b>4.7</b>	<b>5.7</b>
<b>Hams Fork Coal Field Subtotal</b>		<b>4.7</b>	<b>5.7</b>
<b>Grand Total</b>		<b>315.0</b>	<b>486.5</b>

<sup>1</sup> County production figures from the Wyoming State Inspector of Mines.

<sup>2</sup> Based on Air Quality Permits issued by the Air Quality Division, Wyoming Department of Environmental Quality.

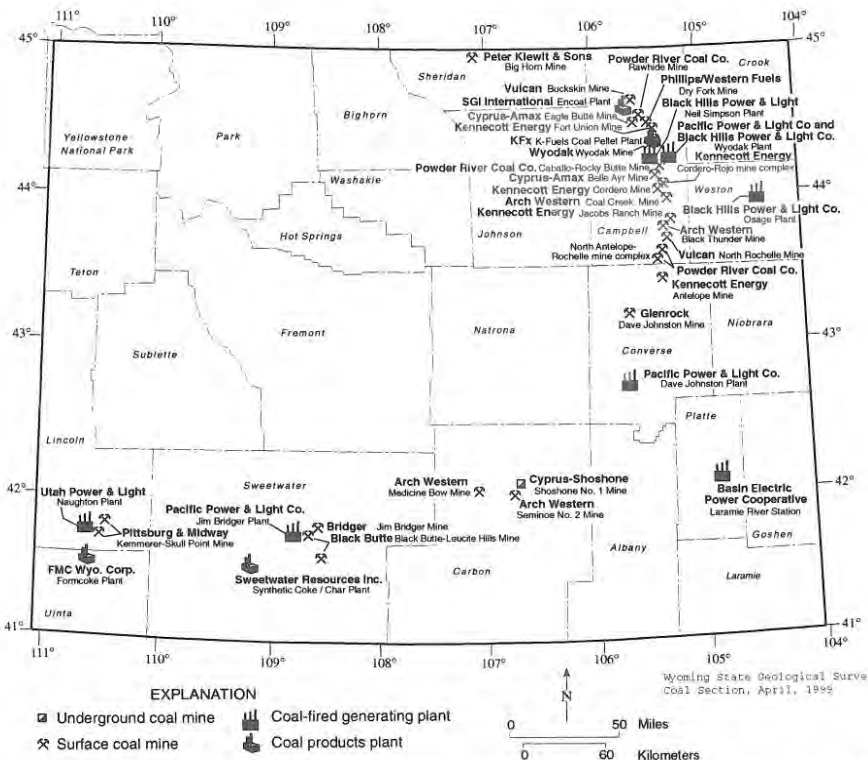


Figure 14. Map of coal mines, coal-fired power plants, and plants making coal-derived products in Wyoming.

Oklahoma Gas & Electric; the other is with Western Farmers Electric Co-op. North Rochelle will also ship 500,000 tons of spot coal to Commonwealth Edison this year. The North Rochelle mine, along with the Buckskin mine, is now owned by Vulcan Coal Holding Co. (VCH). Vulcan Partners own VCH, which in turn is operated by an administrative agent, Vulcan Capital Management.

The U.S. Bureau of Land Management (BLM) is working on a project to identify future coal leasing areas in the Powder River Basin (PRB). When completed, the BLM will issue a written report that will delineate areas in which Federal coal leasing will most likely occur over the next 15 years (*Coal Daily*, 1/28/99). For information on the study and report, contact the Casper field office of the BLM.

Rio Tinto PLC/Ltd. (2/25/99) said it planned to review the coal operations of its subsidiary, Kennecott Energy U.S. With Kennecott's acquisition of the Jacobs Ranch mine and its expanded facilities at the Antelope and Cordero-Rojo mines, its 1998 coal production increased nearly 50% from 1997, to 84.1 million tons. However, while production increased substantially, Kennecott's net profits fell 14% from the previous year, to \$60 million. Robert Wilson, Rio

Tinto's chairman, said that he did not anticipate a radical change in direction, later adding that the company was committed to staying in the coal business. He left the door open to speculation by further stating that Rio Tinto did not plan any major coal divestments, although it would entertain any offers at the right price. He went on to say, "But it's not in our minds to go out there with a view to selling."

The growth of production in the PRB is approaching the current load-out capacities for several of the mines in the area. In 1997, PRB mines were having trouble getting train sets on time for loading. In March of this year; however, the railroads were complaining that escalating load-out problems were idling many unit-trains for up to 12 hours at some mines (*Coal Daily*, 3/1/99). To find workable solutions to these sorts of problems, both sides of the issue agree that all the parties (producers, users, and the railroads) will have to cooperate more closely than they have in the past.

The Powder River Basin Regional Coal Team (PRBRCT), which met on 2/23/99, identified some concerns with Kennecott's Lease by Application (LBA) for the North Jacobs Ranch reserves. The main problem was the already extensive development of coalbed methane on the tract. Before going forward, the PRBRCT has asked for a study on how coal mining and coalbed methane production can be reconciled.

On March 29<sup>th</sup>, Arch Coal, Inc. announced the signing of an agreement with Kennecott Energy to transfer a portion of Arch's newly acquired Thundercloud LBA coal tract to Kennecott's Jacobs Ranch mine. In October of 1998, Arch was the successful bidder on the Thundercloud tract (*Wyoming Geo-notes No. 60*, p. 25). Arch will develop most of the tract via its Black Thunder mine. However, a portion of the tract, which lies on the western border of the Jacobs Ranch operation, was far enough removed from Arch's current, long-range, mine plans that Arch approached Jacobs Ranch with an offer that was beneficial to both companies. Kennecott will pay \$12 million dollars in cash and give Arch their Thundercloud baseline environmental data, which Jacobs Ranch collected during their evaluation of the LBA. For this, Arch will assign approximately 35 million tons of recoverable coal to Kennecott's Jacob Ranch mine.

While the environmental data will enable the Black Thunder mine to develop the remaining Thundercloud reserves more rapidly, the increased reserves at Jacobs Ranch will extend the life of that mine. Other parts of the agreement establish guidelines and overstrip rights designed to help the two adjoining mines in the efficient and orderly development of the reserves. The agreement is subject to regulatory approval.

In a March 3<sup>rd</sup> press release, KFx Inc. announced that it was pleased with the test burn of its K-Fuel product at Indiana-Kentucky Electric Corp.'s Clifty Creek power plant. In the five-day test in February, the plant burned a unit trainload of the enhanced PRB coal product. The plant's normal blend consists of 60% PRB coal and 30% low-sulfur, high-Btu, eastern coal. For the test, K-fuel was substituted for the PRB portion of the blend.

## **Developments in Southern Wyoming**

The Beacon Group, which is MAPCO Coal Inc.'s New York-based parent company, was reportedly negotiating to purchase Pittsburg & Midway Coal Mining's Kemmerer mine from Chevron (*Coal Week*, 2/1/99). The Beacon Group is expected to structure the deal to isolate the unionized Wyoming operation from their non-unionized MAPCO operations in Kentucky, Illinois, Maryland, and Virginia.

Arch of Wyoming announced a three-year delay in its startup of the new Elk Mountain surface mine in the Carbon Basin of south-central Wyoming. The mine is now slated to open in 2004. Plans for startup of its nearby Saddleback underground mine have been moved to 2011. Lagging markets were cited as reasons for the delays. The Elk Mountain mine was originally designed to pick up the demands now filled by Arch's Seminole II and Medicine Bow mines in the Hanna Basin. These two mines are slated for closure in 2001, as their reserves run out (*Casper Star-Tribune*, 4/9/99).

## **Transportation Developments**

Northern Indiana Public Service Co. (NIPSCO) awarded a railcar maintenance contract to the Grand Island, Nebraska, facility of DTE Transportation Services Inc. (DTETS). DTETS is a subsidiary of DTE Coal Services. The new three-year contract gives DTETS responsibility for the maintenance of more than 1,800 NIPSCO-owned and leased coal cars. Besides maintenance, DTETS will provide assistance with tax administration, new car acquisition, and fleet planning.

In Omaha, a U.S. District Court Judge ruled that the Union Pacific Southern Pacific railroad (UPSP) must pay Entergy Corp. (EC) for liquidation damages resulting from UPSP's failure to fill contracted coal deliveries during late 1997 and early 1998. Liquidation damages, which are specified in coal delivery contracts, are payable by a railroad if it fails to transport enough coal to satisfy a customer's needs under the contract (*Casper Star-Tribune*, 1/31/99). The judge turned down EC's request for a cancellation of their UPSP contract. He also ruled EC couldn't seek damages to cover the utility's cost for alternate fuel supplies that were required during the period of interrupted coal deliveries.

The Burlington Northern Santa Fe railroad (BNSF) hauled record coal tonnage in 1998. The railroad loaded 230.4 million tons of western coal. Of this record tonnage, 176 million tons came from Wyoming coal mines (*Coal Outlook*, 1/18/99).

The BNSF and UPSP railroads have agreed to move the UPSP dispatchers, who handle the UPSP line from North Platte, Nebraska to the PRB joint line, to BNSF's Network Operations Center in Fort Worth, Texas (*Coal Daily*, 2/9/99). The agreement is designed to simplify communications and help both railroads provide improved and more consistent dispatching service for their customers in the PRB.

This year, the BNSF and UPSP also plan to open coordinating dispatch centers in San Bernardino, California, and Kansas City, Missouri. Last year, the two railroads opened a joint dispatching office at Spring, Texas, which has helped improve their service to Houston and the Gulf Coast regions.

The BNSF and Detroit Edison agreed to an updated contract covering PRB coal delivered from both Wyoming and Montana. Under the revised contract, Detroit Edison will receive approximately 23 million tons of PRB coal during 1999 (*Coal Week*, 2/22/99).

The BNSF plans to spend \$2.5 billion in 1999 on the leasing of new locomotives; the laying of new track along key routes in Wyoming, Colorado, Texas, and New Mexico; and the building and expanding of a number of yards and facilities in California, Alabama, and New Mexico (*Wyoming Tribune-Eagle*, 3/9/99). In Wyoming, the BNSF will add 18 miles of triple track between the towns of Bill and Walker. Between Gratton and Guernsey, the railroad will build six miles of double track.

In late March, the UPSP railroad reported that it had broken its single-day loading record of 35 unit trains, which was set back in February of 1998. Like the earlier record, the new record of 36 trains was set in the Wyoming portion of the PRB. The railroad's PRB loadings in February, 1999, set a UPSP record of 829 trains, averaging 29.6 trains per day (*Coal Daily*, 4/1/99)

The Dakota, Minnesota, & Eastern railroad (DM&E) reached agreement with its Landowners Advisory Board on issues connected with its planned expansion into the PRB (*Coal Outlook*, 2/1/99). DM&E formed the advisory board as a liaison between the railroad and landowners along its proposed right of way. The agreement speaks to such issues as monetary compensation for land, impacts on landowners' businesses, mitigation of impacts on impacted lands, and economic opportunities. The advisory board has no connection with the Midstates Coalition for Progress, which opposes the DM&E's proposed expansion into the PRB.

On March 10<sup>th</sup>, the Surface Transportation Board (STB) released the scope of its planned Environmental Impact Statement (EIS) for DM&E's proposed build-in to the PRB (*Coal Daily*, 3/11/99). Included in the scope of the EIS was consideration of two new alternate routes not included in the railroad's initial filing. The City of Rochester, Minnesota, proposed a new route, which would bypass the city. The DM&E suggested another alternate route in response to environmental issues and concerns raised by the public and local governments after the initial filing.

DM&E's President and CEO, Kevin Schieffer, has said that the rest of this year is critical to the success or failure of his company's plans for a new rail line into the PRB of Wyoming. Delays continue to drive up costs. The \$1.4 billion project includes 260 miles of new track and rehabilitation of another 600 miles. DM&E plans to haul coal from the PRB across South Dakota and southern Minnesota to eastern power plants (*Casper Star-Tribune*, 4/14/99).



The South Dakota Senate and House approved a bill that restricts a railroad's ability to obtain rights of way through the use of eminent domain (*Coal Outlook*, 3/1/99). The bill provides that a railroad may exercise the right of eminent domain only by first gaining authority from the Governor or the State Transportation Authority. To do this, a railroad must show that the proposed project is for a public use consistent with public necessity. Also, the bill requires a railroad to have the financial resources necessary to complete the proposed construction or reconstruction via an irrevocable financing commitment from a lender with adequate capitalization to fulfill its commitment. In addition, the bill requires a railroad to show that it has negotiated in good faith to privately acquire sufficient property without invoking the use of eminent domain. Governor Bill Janklow said he would sign the bill into law (*Coal Daily*, 3/4/99). The effect this bill might have on DM&E's planned expansion into Wyoming is unclear at this time. Similar legislation was defeated in the 1999 Wyoming Legislative Session.

### **Coalbed Methane Developments**

The U.S. Supreme Court agreed to hear arguments in the coalbed methane dispute between the Southern Ute Tribe in Colorado and a group of oil companies and private individuals, collectively known as the Amoco defendants. The Supreme Court hearings began in April, with a decision due by the end of June. A ruling of the 10<sup>th</sup> U.S. Circuit Court of Appeals upheld the tribe's claim to ownership of the coalbed methane contained in coal deposits underlying its tribal lands. The Amoco defendants hold that their oil and gas leases include coalbed methane. While Wyoming filed a friend-of-the-court brief supporting Amoco's position on the ownership of coalbed methane, the National Mining Association has filed a brief supporting the tribal view.

In November of last year, President Clinton signed a bill that exempted or "grandfathered" other existing coalbed methane leases from the earlier 10<sup>th</sup> Circuit's decision. But all subsequent leases will fall under the 10<sup>th</sup> Circuit ruling unless it is overturned by the Supreme Court (*Casper Star-Tribune*, 4/15/99). Congress passed the "grandfathering" bill because the earlier ruling reversed about 89 years of Federal policy and affected thousands of property rights, including many in the PRB of Wyoming.

In a February press release, Barrett Resources listed its 1998 coalbed methane production from the PRB at 6.8 billion cubic feet. The company also stated that its coalbed methane reserves in the PRB totaled 142.3 billion cubic feet at the end of 1998.

Pennaco Energy Inc. announced plans to spend \$9.4 million to drill 330 wells in the coalbed methane play in the PRB. An additional \$9 million has been approved for lease acquisitions in the PRB play. Pennaco will use the drilling funds both within and outside their joint venture with CMS Energy Corp. Pennaco also signed a definitive agreement with Bear Paw Energy Inc. (BPE), which is the natural gas services subsidiary of TransMontaigne. Under the agreement, BPE will construct, own, and operate gas-gathering systems in the

PRB. The agreement covers Pennaco's "South Gillette" project area. This area includes over 8,600 gross leasehold acres and 200 potential well locations. Pennaco has completed its first 100 wells in that area. The BPE gathering system will connect the gas from Pennaco's wells to Western Gas Resources' MIGC pipeline, to the recently announced Fort Union Gas Gathering System, and to the proposed Thunder Creek pipeline.

Last year, CMS Energy Corp., Enron Capital & Trade Resources, and Western Gas Resources formed Fort Union Gas Gathering System. In March of this year, construction began on Fort Union Gas' 106-mile-long gas gathering system in the PRB. The \$46 million project should be finished in September, 1999. Fort Union Gas will gather coalbed methane from as far as 30 miles north of Gillette and transport it to Glenrock.

Fort Union Gas Gathering System will also receive gas from a joint project between CMS Energy Corp. subsidiaries and Pennaco Energy Inc. They plan a \$190 million northern gathering system. Initially, this system will be located in northern Campbell and Sheridan counties of Wyoming. CMS anticipates extending the system into Montana as well. The system will consist of 110 miles of 24-, 20-, and 16-inch high-pressure lines and about 40 miles of 6- and 8-inch gathering laterals. Construction will begin in July, 1999. Completion of the first phase of this project is expected by November of 1999.

Thunder Creek Gas Services, a joint venture of Devon Energy and KN Energy, started construction on its 126-mile-long natural gas gathering system in the PRB. This \$100 million system should be fully operational by the fall of 1999. The 24-inch trunkline will have an initial capacity of 450 million cubic feet of gas per day. This pipeline and Fort Union Gas' pipeline will certainly help development of coalbed methane in the PRB.

The U.S. Bureau of Land Management (BLM) is reviewing scoping comments on a coalbed methane project that has been proposed 20 miles northeast of Sheridan, Wyoming. J.M. Huber Co. is seeking to drill up to 190 wells. About 12% of the project is on Federal lands. The Huber project is adjacent to Redstone Gas Partners' coalbed methane development, which is on fee lands.

The water issues related to coalbed development in the PRB have become an increased concern as development has grown. Following an informational meeting in mid-April, industry representatives, State and Federal regulators, county officials, and others started plans for a "Coalbed Methane Gas Fair" to be held sometime this summer. The fair will be designed to bring all interested parties together so that concerns and information can be shared. Hopefully, the fair can at least provide some answers or alternatives to the many questions that came out of the April and previous meetings.

### **Regulatory Developments**

Connie Holmes, Chair of the Global Climate Coalition, released a response to President Clinton's State of the Union address. In a January 20<sup>th</sup> news re-

lease, she said, "The debate has already begun regarding industry credit for action on emissions reductions. New legislation that rewards companies for early actions is an interesting approach that recognizes the important voluntary efforts business and industry have made in the past five years, and it will serve as the basis of constructive debate in 1999." She went on to say, "Interest by some companies in official credit for their voluntary action should not be confused with endorsing the Kyoto Protocol, which would cap family and business use of heating oil, electricity, coal, gasoline, and natural gas." The Global Climate Coalition was established in 1989 to coordinate participation in the scientific and policy debate on global climate change. Its membership is made up of trade associations and private companies.

The Wyoming Legislature passed House Engrossed Act No. 45 (House Bill 0113), which extends the severance tax limitation on coal, formerly known as the 80 cents per ton exemption. The bill lowers the cap to 60 cents per ton for surface mined coal and 30 cents per ton for deep mined coal. The bill also extends the exemption through December 31, 2003 (*Coal Daily*, 1/22/99). Governor Jim Geringer signed the bill into law with an effective date of July 1, 1999.

### **Market Developments and Opportunities**

Dayton Power & Light is in the early stages of testing the burning of Powder River Basin (PRB) coal at its 850-megawatt (850-MW) Stuart and 446-MW Killen plants (*Coal Daily*, 1/21/99). The utility is expected to ask for bids on test coals later this year. Last year, the two plants burned 5.7 million tons of West Virginia and Kentucky coals. Both plants are located in Ohio along the Ohio River.

The Tennessee Valley Authority (TVA) wants to start burning a blend of PRB and eastern coal at their 1,700-MW Kingston plant in Tennessee. The key to the blending is construction of a new coal receiving and blending system at the plant. TVA also wants two railroads to have direct access to the plant. The cost of the coal-handling and rail upgrade projects is an estimated \$16-\$20 million. TVA estimates its annual cost savings at \$14.5-\$17.0 million (*Coal Outlook*, 1/18/99).

Illinois Power Co. (IPC) announced its intention to retrofit its 1,890-MW Baldwin and 300-MW Hennepin plants to use Wyoming coal, instead of Illinois coal. The \$125 million investment would reduce the plants' sulfur dioxide emissions and save IPC an estimated \$47-65 million a year. The United Mine Workers of America have met with the utility, hoping to change its decision. IPC is apparently open to the possibility of at least blending some Illinois coal with the low-sulfur Wyoming coal. The utility hopes to complete the plant conversions by the first quarter of 2000 (*Casper Star-Tribune*, 4/8/99).

**Table 14** is a tabulation of some of the contracts, spot sales, tests, and solicitations for Wyoming coal announced during the first quarter of 1999.

**Table 14. Marketing activities for Wyoming coal producers during the first quarter of 1999.<sup>1</sup>**

Utility	Power Plant	Region/Coal Mine	Activity	Tonnage	Comments
1. Alliant Power	Columbia	PRB/Caballo mine	Sp	0.15 million t	1999 delivery
2. Ameren	System System	PRB PRB	So C	0.5-2.0 million t up to 4.0 million t/y	1999 delivery Three to four years, starting in 2000
3. American Electric Power Co.	System	PRB	Sp	Unspecified	Beginning in 2nd quarter 1999; bids due 3/12
4. Arizona Public Service	System	PRB/Black Thunder	Sp	50,000 t	1999 delivery
5. Eastern Kentucky Power Corp.	Spurlock	PRB & eastern coals	So	40,000 t/month	Four years, starting in Jan. 2000
6. Kansas City Board of Public Utilities	Nearman	PRB/Dry Fork	Sp	0.2 million t	No other details
7. Kentucky Utilities Co.	Ghent Ghent	PRB/Powder River Coal Co. PRB & eastern coals	T Sp	0.3 million t up to 60,000 t/month	Test burn of PRB coal Delivered over 3-12 months
8. Lower Colorado River Authority	Fayette	PRB	Sp	0.15 million t	1st quarter 1999
9. Minnesota Power	Clay Boswell	PRB	C	2.5 million t/y	Five years, starting in 2000
10. Northern States Power Co.	System System	PRB (Select mines) PRB (Select mines)	Sp C	Unspecified Unspecified	2000 delivery 2001-2003 delivery
11. Public Service Co. of Colorado	Arapahoe	PRB	So	55,000 t	April to June delivery
12. St. Joseph Power & Light	Lake Road	Hanna Basin/Seminole II	C	Est. 0.25 million t	1999 tonnage; shipped via UPSP railroad
13. Tennessee Valley Authority	System	Western coal & eastern coal	C	1.0-8.0 millions t/y	Contracts of various duration
14. Texas Utilities Electric Co.	Martin Lake Big Brown	PRB PRB	Sp T	0.5 million t 1.5-2.0 million t	2000 delivery Test burn of PRB coal and lignite blend
15. Wisconsin Electric Power Co.	Oak Creek	PRE/North Antelope-Fochelle	C	Unspecified	Multi-year, starting in 2000; blend with eastern bituminous coal

<sup>1</sup>Data obtained from: *Coal Week, Coal Outlook, Coal Daily*, FERC database, and personal contacts.

Note: C = contract coal; Sp = spot coal; So = solicitation; T = test burn; t = short ton; ty = short tons per year; and PRB = Powder River Basin. *Wyoming State Geological Survey, April, 1999.*

## INDUSTRIAL MINERALS AND URANIUM UPDATE

Ray E. Harris

*Geologist - Industrial Minerals and Uranium, Wyoming State  
Geological Survey*

### Construction Aggregate

The production of construction aggregate in Wyoming is expected to increase in 1999 due to increased Federal funding for highway construction projects.

Umetco, a uranium mining company, is currently reclaiming uranium open pit mines and mills active in the 1970s in the Gas Hills area of central Wyoming. As a part of this reclamation, the Nuclear Regulatory Commission, which oversees the reclamation of these areas, requires a covering of rip-rap-sized rock over reclaimed tailings. The U.S. Bureau of Land Management (BLM) has studied two sites proposed by Umetco for the source of this stone, a proposed site and an alternate site. The BLM favors the development of the alternate site in the Pennsylvanian Tensleep Sandstone in the Rattlesnake Hills east of the uranium mining area (**Figure 15**). This site is six miles farther from the point of use than the proposed quarry site favored by Umetco. If the alternate site is used, it will cost Umetco an additional \$300,000 to transport the stone that additional distance.

### Dimensional Stone

Two companies are nearing production of dimensional limestone in Wyoming. V.A. Resources (VAR) is planning to quarry two blocks from its permitted quarry site at Plumbago Creek, 30 miles northeast of Laramie in Albany County (**Figure 15**). It will ship these blocks to a fabricator for processing into polished and honed tile or slab. VAR will show these samples to purchasers of processed stone to test its acceptance on the market. Polished limestone tile and slab is commonly used in flooring and interior wall panels in buildings. Limestone recently has been popular as flooring in shopping malls. The relatively low cost to process limestone results in a lower wholesale and retail cost. As a result, limestone is the most commonly used decorative stone in the U.S.

IMC is continuing its development plans for a decorative limestone quarry at its Horse Creek site (**Figure 15**) in Albany County (*Wyoming Geo-notes No. 61*, p. 36). The company has agreements with the BLM and the surface lessee regarding plans for quarrying and construction of an access road. Quarry development is proceeding, pending the completion of a state mining permit. IMC operates a marble quarry near Townsend, Montana. If these and possibly other quarries are in production, and the product sales reach a predetermined amount, IMC plans to construct a limestone, marble, and travertine fabricating plant in Wyoming. This plant would fabricate these materials into slab and tile.

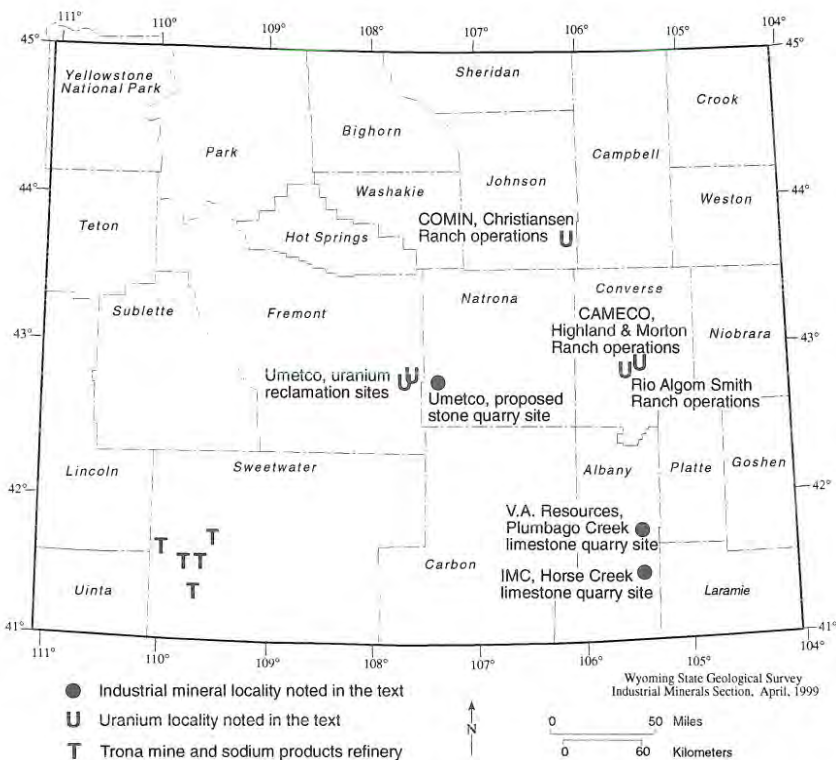


Figure 15. Map of selected industrial mineral and uranium localities in Wyoming.

## Trona

Trona is mined at five locations in southwestern Wyoming and processed into soda ash and other sodium products in refineries located near their underground mines (Figure 15). About 18.5 million tons of trona are mined annually in Wyoming.

To provide more protection for underground trona miners in southwestern Wyoming, the Wyoming Oil and Gas Conservation Commission has recently adopted some new drilling, completion, and plugging rules for oil and gas drilling in the trona patch. They are discussed in the **OIL AND GAS UPDATE** in this issue.

FMC, which is the largest of the Wyoming producers of soda ash, has offered to purchase Tg Soda Ash. Tg is the smallest producer of soda ash and has been for sale for some time. Company officials are currently negotiating the purchase. A Federal limit on the total trona lease acreage that any one company can hold is an obstacle to the purchase. FMC would exceed this limit

if it were to acquire Tg's trona leases. The companies are reportedly discussing this limitation with the BLM.

In mid-April, China said it might lower its trade barriers to the import of U.S. soda ash and some other commodities. They offered to lower soda ash tariffs to 5.5% by 2003, down from the current 12%. As a condition to this better offer, however, China wants membership in the World Trade Organization. While membership is not likely to happen quickly, there were some who felt it could happen even this year. Lower tariffs would certainly help the soda ash producers in Wyoming whose future growth is tied to exports (Casper Star-Tribune, 4/13/99). The U.S. market share in China, which was 30% in 1989, has dropped to only 1.4%. China is the world's largest producer of synthetic soda ash (Casper Star-Tribune, 4/27/99). In fact, between 1985 and 1996, China has not only become nearly independent of imports of soda ash, but it has also developed a significant export market (Raleigh and Harben, 1998; and Chegwidan, 1998).

### Uranium

The price of uranium increased in the first quarter of 1999. It increased from \$8.75 per pound of yellowcake on January 1st to \$10.85 per pound of yellowcake on January 31<sup>st</sup>. It remained constant at that price in February and March, according to both the Uranium Exchange and as reported by Bob Odell in the *Rocky Mountain Scout* (Figure 16).

Wyoming remains the largest producer of yellowcake in the U.S. Other producing states include Colorado, Nebraska, New Mexico, Texas, and Utah. Uranium in Wyoming is produced exclusively by in-situ recovery techniques and is converted to yellowcake at three localities in Wyoming (Figure 15).

The market for fuel-grade uranium, which is used in nuclear power plants, is currently extremely volatile. This is despite the fact that the worldwide demand for uranium is increasing, that stockpiles of processed uranium are low, and that uranium consumption significantly exceeds mine production. The reason for this seemingly contradictory market condition relates to secondary sources of uranium, which continue to keep uranium prices low and market volume uncertain. Secondary sources include reprocessed spent fuel in countries other than the U.S., the sales of government inventories of uranium ore and fuel, and the conversion of highly enriched, weapons-grade uranium into fuel-grade uranium. These secondary sources are generally much cheaper than mined uranium. For example, the price for converted uranium from Russia is equivalent to \$3.50 per pound of yellowcake. More importantly; however, the supply of these secondary sources is highly variable in itself (Pool, 1999).

Along these lines, three companies have signed an agreement to purchase 550 short tons of highly enriched uranium from Russia's nuclear weapons arsenal and dilute it to fuel-grade uranium for sale to U.S. nuclear power plants. According to an article in *The Northern Miner* (4/12/99), this purchase is a

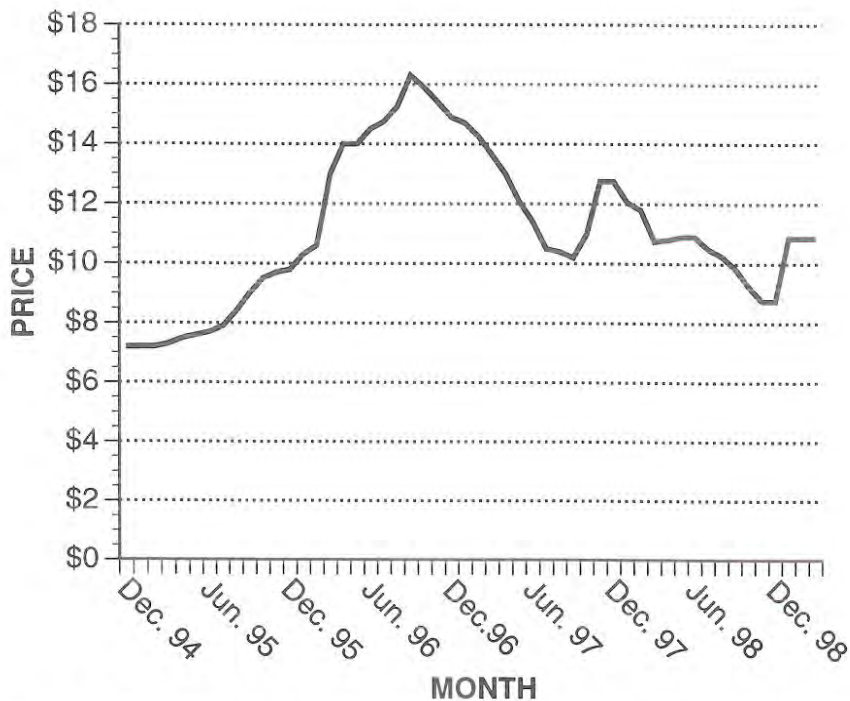


Figure 16. Domestic yellowcake prices, December, 1994, through March, 1999 (from Uranium Exchange).

result of a 1993 trade agreement between the U.S. and Russia. The three companies are CAMECO, a Canadian-owned company; COGEMA, a French-owned company; and Nukem, a German-owned company. The first two of these companies currently have uranium mining subsidiaries in northeastern Wyoming.

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## METALS AND PRECIOUS STONES UPDATE

by W. Dan Hausel, Robert W. Gregory, Roger Motten, and Wayne M. Sutherland  
*Wyoming State Geological Survey*

During the past quarter, the Wyoming State Geological Survey (WSGS) responded to inquiries from the general public, companies, government agencies, and various educational institutions searching for information on metals and precious stones in Wyoming. The various inquirers sought information on gold, platinum, palladium, iron, titanium, diamond, various other gemstone occurrences, mining history, geology of mining districts, and Precambrian geology. Some companies and groups also requested that the WSGS lead field trips or tours to mineral deposits and mining districts this summer.

### Diamond

The WSGS offered a *Diamond Recognition and Prospecting* course on April 17th at the WSGS building in Laramie. Attendees included members of the Ft. Collins Rocky Mountain Prospector's and Treasure Hunter's Club, the president of a mining company, and geologists from Casper, Cheyenne, Nebraska, and Denver. These courses are offered to help educate prospectors and geologists on the characteristics of diamond deposits. Wyoming has favorable geology for the discovery of diamond deposits, and the discovery of just one major diamond deposit in Wyoming could lead to significant revenue and diversification in the State's economy.

Thousands of diamonds have been recovered from several kimberlites in the Colorado-Wyoming State Line district south of Laramie, many of which have been very high-quality gemstones. Gem-quality diamonds can have a very high value. In some cases, rare diamonds have been valued 500,000 times more than an equivalent weight of gold! Some extremely rare pink and red diamonds from Argyle, Australia, have sold for as much as \$1 million (US) per carat. One of the gemstones recovered from the Kelsey Lake mine in the Colorado portion of the Colorado-Wyoming State Line district yielded a canary yellow, 16.8-carat gem, cut from a 28.2-carat raw diamond. The diamond had a minimum asking price of \$300,000 (an equivalent mass of gold would only have a value of about \$30).

Not all the diamonds found in Wyoming have come from the Colorado-Wyoming State Line district. Diamonds have also been reported in the Powder River Basin, the central and northern Laramie Mountains, the Medicine Bow Mountains, the Greater Green River Basin, the Wind River Range, the Granite Mountains, and the Gros Ventre Range. And kimberlitic indicator minerals have been reported from hundreds of other localities in the State.

The WSGS continued its work on diamond deposits, looking for indicator minerals and diamonds in samples of kimberlite that were collected from the Iron Mountain district in the central Laramie Mountains. Reports of previously

discovered diamonds in the district (Gordon Marlatt, personal communication, 1998) have not yet been verified. However, the geochemistry of some recently examined kimberlitic indicator minerals indicates that diamonds could indeed occur in a few of the district's kimberlites.

The WSGS is analyzing indicator minerals on an electron microprobe at the University of Wyoming's Department of Geology and Geophysics. The WSGS is very grateful for the Department's cooperation, and especially for Dr. Susan Swapp's expertise and technical assistance with the microprobe.

The microprobe work involves crushing the kimberlite to grain sizes of about 2 mm or less. After crushing, heavy minerals (including kimberlitic indicator minerals) are concentrated on a Wilfley side-shaking concentrating table. Since the densities of the indicator minerals are all greater than 3.3 gms/cm<sup>3</sup>, they will collect with the heaviest grains in the sample concentrate. The indicator minerals are picked out, mounted, and polished for microprobe analysis. The microprobe measures the geochemistry of the minerals in the form of weight percent of the various oxides.

**Figure 17** shows the weight percent of calcium oxide (CaO) plotted against that of chromium oxide (Cr<sub>2</sub>O<sub>3</sub>). The data are from pyrope garnets from numerous kimberlites in the Iron Mountain district. Chromium-rich pyrope garnets that have low calcium and plot to the left of the inclined line are classified as G10. These garnets have similar chemistry to garnets occurring as inclusions in diamonds. These G10 garnets are believed derived from subcalcic harzburgites within the diamond-stability field in the upper mantle. In other words, G10 garnets predict that diamonds will probably occur in the kimberlite as long as they were not resorbed during emplacement. Garnets with higher calcium and lower chromium are derived from lherzolite, and most lherzolites are not diamond-bearing. Thus, the geochemistry generated to date suggests the probability that a few of the Iron Mountain kimberlites were originally diamondiferous. Whether or not any of the diamonds were preserved is unknown.

Several stream-sediment samples were collected during the past field season in an effort to locate other kimberlites in the Laramie Mountains. Some kimberlitic indicator minerals have been recovered from these samples. Also, several potential kimberlites were identified from aerial photography. These localities will be examined on the ground this coming field season.

### **Barlow Gap Mapping Project**

Using aerial photography, the WSGS continued mapping the 1:24,000-scale Barlow Gap Quadrangle during the winter season. Thin sections of rock collected in the area also were studied for petrography and mineralogy, and other samples were analyzed for whole-rock geochemistry. This Archean terrane lies immediately south of the Rattlesnake Hills district in the northern Granite Mountains of central Wyoming.

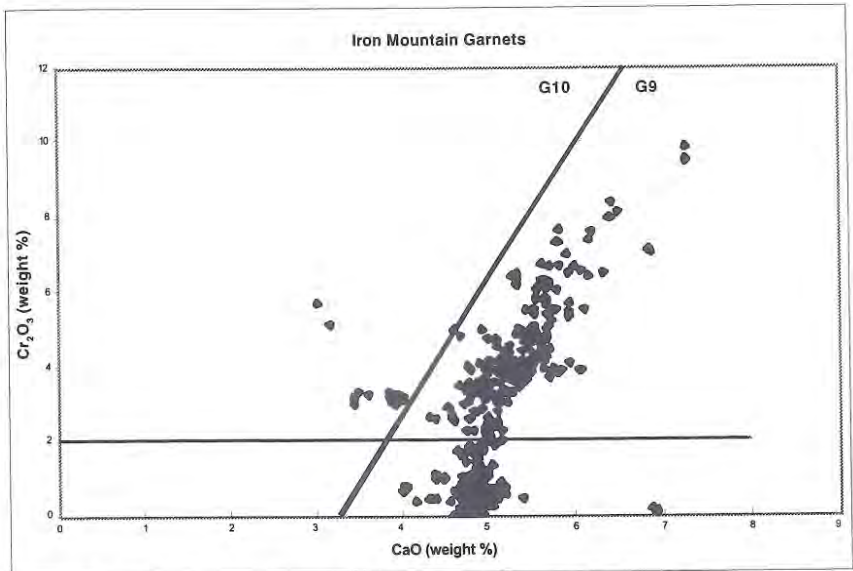


Figure 17. Electron microprobe geochemistry of pyrope garnets from the Iron Mountain district of southeastern Wyoming.

Archean rocks in the Barlow Gap area include banded iron formation, amphibolite, pelitic schist, and mica schist infolded in granite gneiss that is intruded by granite plutons and mafic dikes. The northwestern margin of the map area was intruded by Tertiary alkalic volcanic rocks similar to those in Rattlesnake Hills. Based on its geology, the Barlow Gap area may have potential resources of gold, iron, lapidary minerals, and gemstones. In 1981, the WSGS discovered significant gold mineralization in the adjacent Rattlesnake Hills district that continues to attract company interest (Hausel, 1996). Gold resources of 250,000 contained ounces that were identified in part of the Rattlesnake Hills district may in fact exceed 1 million contained ounces, based on re-evaluation of company drilling data (Dave Miller, personal communication, 1999).

### **Copper-King Gold-Copper Porphyry**

A report on Mountain Lake Resources' exploration and drilling activities on the Copper King porphyry in the Silver Crown district west of Cheyenne was recently made available to the Wyoming State Geological Survey. The property has potential as a commercial gold and copper deposit and is located on Wyoming State land with excellent access.

The company's report indicates the property has an identified resource of 9,650,000 tonnes of rock at an average grade of 0.04 ounce per tonne Au and 0.30% Cu. Mountain Lake Resources also indicates the deposit should include 383,240 ounces of gold and 58,642,703 pounds of copper. The report also indicates that the mineralization is apparently open at depth, as the Copper King has not been explored below 600 feet. It suggests that drilling down

dip to depths of 1,200 feet could possibly double the present resource estimate (Mountain Lake Resources, Inc., 1997).

### **Section 3809 Regulations, U.S. Bureau of Land Management**

At the end of March, the U.S. Bureau of Land Management (BLM) held two hearings in Casper to seek public input on a Draft Environmental Impact Statement regarding proposed revisions of its Section 3809 regulations. These hearings were among 15 scheduled nationwide. The 3809 regulations govern the exploration and development of locatable minerals, such as precious metals, iron, copper, lead, zinc, gypsum, phosphate, and sulfur.

According to the BLM, this effort started about eight years ago and is aimed at preventing "unnecessary or undue degradation" of public lands by mining operations. U.S. Secretary of the Interior Bruce Babbitt has directed the BLM to focus their revisions on the establishment of adequate bonding to cover clean-up contingencies, tightening up the definition of degradation, implementation of performance standards for mining and reclamation, altering or eliminating the five-acre exemption, and coordination with State regulators (*Casper Star-Tribune*, 3/31/99). The comment period ended on May 10<sup>th</sup>.

The BLM listed the following points of contact: BLM Administrative Record, Nevada State Office, P.O. Box 12000, Reno, NV 89520 or Email: [wocomment@wo.blm.gov](mailto:wocomment@wo.blm.gov). Email contacts should refer to AD-22.

### **Planned Field Projects**

This summer, the WSGS has already scheduled several field projects related to metals and precious stones. These include (1) mapping in the northern Iron Mountain district for additional kimberlites; (2) searching a major structure in the Green River Basin for olivine lamproite; (3) sampling several ultramafic and ultrabasic intrusives for platinum, palladium, and nickel; (4) searching the Granite Mountains for additional gemstones; and (5) examining several serpentinites, metapelites, and vermiculite deposits for ruby and sapphire.

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## **1998 MINERAL AND OIL AND GAS EXPLORATION SUMMARY - WYOMING**

by Robert M. Lyman, Ray E. Harris, W. Dan Hausel, Rodney H. De Bruin, and Gary B. Glass,  
*Wyoming State Geological Survey*

### **COAL**

Although there was not much coal exploration in Wyoming in 1998, coal production was a record 315.0 million short tons. This is 11.9% higher than the 281.5 million tons produced in 1997. Improved railroad performance, together with mild fall and winter weather in the Powder River Basin, contributed to the significant increase in production. And Wyoming remained the leading coal producing state in the country.

"Coal mine for sale" was the dominant theme of Wyoming's coal industry throughout 1998. At one point, mines representing nearly 82% of the coal production from Wyoming's Powder River Basin were either up for sale, thought to be for sale, or in the process of being sold.

In March of 1998, ARCO's domestic coal operations were sold to Arch Coal in a transaction valued at \$1.14 billion. As a result, the Black Thunder and Coal Creek mines became part of Arch Western Resources LLC, which also includes Arch's existing operations in Wyoming's Hanna Basin.

In May, Texas Utilities (TU) acquired The Energy Group, which is the parent company of the Peabody Group. The price was \$10.4 billion. TU immediately sold Peabody Holding and Citizens Power to P&L Coal Holding Corp., an affiliate of Lehman Brothers Merchant Banking Partners. The price of that sale was \$2.3 billion, including assumed debt.

Through its wholly-owned subsidiary, Kennecott Energy, Rio Tinto bought Kerr-McGee Corp.'s Jacobs Ranch mine. In July, the mine and its estimated 285 million tons of reserves were purchased for \$400 million.

In August, Zeigler Coal Holding Co. was sold to AEI Resources in an \$855 million stock deal. Included in the transaction were the Buckskin and North Rochelle mines. In December, AEI sold the Wyoming mines to Vulcan Capital Management. The price tag was \$275 million. Together, the two Powder River Basin mines have leases on approximately 630 million tons of recoverable coal.

By the end of 1998, Cyprus-Amax Coal Co. and Chevron's subsidiary, Pittsburg & Midway Coal, were also up for sale. The Wyoming holdings of these two operating companies represent nearly one billion tons of recoverable coal. By May of 1999, Cyprus-Amax was apparently sold to a German mining conglomerate. RAG International Mining GmbH, Germany's largest coal producer, offered about \$1.05 billion for Cyprus-Amax's remaining coal holdings in Wyoming, Pennsylvania, Utah, Colorado, and Illinois. They also assumed about \$50 million in debts. In February of 1999, MAPCO's parent company, the Beacon Group, was reportedly negotiating to purchase Pittsburg & Midway Coal.

Two companies in the Powder River Basin also increased their reserves in 1998 by successfully bidding on Federal coal leases. In September, Arch Coal had the winning bid on a 3,545-acre Lease by Application (LBA). The Thundercloud LBA contains an estimated 412 million tons of Federal coal reserves and sold for a bonus bid of \$158,000,009 (38.3 cents/ton). The newly acquired reserves will enable Arch Coal to expand operations at their Black Thunder mine.

Earlier in the year, Powder River Coal Co. (PRCC), which is part of the Peabody Coal Group, made the successful bid on the 4,224-acre Powder River LBA tract. This Federal lease, which contains an estimated 532 million tons of coal, was won with a bonus bid of \$109,600,000 (20.6 cents/ton). This coal lease will enable PRCC to bring their North Antelope and Rochelle mines together as a single, world-class, mine complex.

## **COALBED METHANE**

The coalbed methane play in the Powder River Basin of Wyoming has become the hottest play in the Rocky Mountain region. By the end of 1998, over 600 coalbed methane wells were reporting production. This compares with 355 producing coalbed wells at the end of 1997. An informal survey of the four largest players indicated that they would drill over 1,900 new coalbed methane wells in Wyoming during 1999. As another example of the interest, a September symposium on Wyoming coalbed methane, which was held in Casper, unexpectedly drew nearly three hundred attendees.

By October of 1998, production of coalbed methane had increased to about 2% of all the natural gas produced in Wyoming, or about 60 million cubic feet per day of the 325 million cubic feet of gas produced daily. And daily production of coalbed methane was still increasing.

The play is currently developing on the Wyodak coal zone in the Paleocene Fort Union Formation. While this coal zone is sometimes a single coal bed up to 175 feet thick (averaging 100 feet thick), the zone is also frequently two or more coal beds, which are themselves up to 70 feet thick. The coal beds in this zone include the Wyodak or Wyodak-Anderson, Anderson, Canyon, and Cook beds as well as a number of other less persistent beds.

While the coalbed methane play is currently centered just west of the large surface coal mines in eastern and northern Campbell County, interest in the more central and western portions of the Powder River Basin is growing. The "Big George" bed underlies portions of western Campbell County and eastern Johnson County at depths of 1,000 or more feet. This bed, which may be roughly correlative with at least a portion of the Wyodak coal zone, is reportedly up to 200 feet thick, and averages about 113 feet thick. It too, is sometimes more than one coal bed. The "Big George" bed, as well as the coals in the Wyodak coal zone, are subbituminous in rank and are apparently yielding biogenic, rather than thermogenic gas.

Due to the size of the play, the U.S. Bureau of Land Management is preparing an environmental impact statement, which covers Campbell County and the northern part of Converse County. In the meantime, there is a moratorium on new wells on Federal lands within the study area. Consequently, new drilling for coalbed methane has centered on private and State lands.

The 10<sup>th</sup> U.S. Circuit Court of Appeals' decision on the mineral ownership of coalbed methane has gone to the Supreme Court on appeal. At stake is whether coalbed methane belongs with the coal estate or with the oil and gas rights. At least for many older existing leases, the U.S. Congress passed an act in 1998 that left the coalbed methane on those leases with the oil and gas rights. Unless the Circuit Court's ruling is overturned, leases purchased after the effective date of that new act will place coalbed methane with the coal estate.

With its extensive reserves of relatively shallow coalbed methane, the Powder River Basin play has attracted many independent E&P and mid-stream companies. These include Barrett Resources, Devon Energy, Western Gas Resources, MCN Energy, Pennaco Energy, and Redstone Resources, to name a few.

In July, Devon Energy made a \$15.4 million acquisition of natural gas properties in Wyoming. The acquisition included both developed coalbed methane reserves, as well as an estimated 150,000 net acres of undeveloped properties in Campbell County. Devon estimated the proven gas reserves on these properties at 5.3 billion cubic feet.

Pennaco Energy reported the acquisition of oil and gas leasehold interests on approximately 400,000 net acres in northeastern Wyoming. The prospective coalbed methane acreages are located along the east, north, and west flank of the Powder River Basin. In the third quarter of 1998, Pennaco started an aggressive drilling program. They had eight rigs committed to the play by the end of the year.

KN Energy expressed interest in building a new gas pipeline into the Powder River Basin to carry coalbed methane production. Western Gas Resources had already agreed to add additional compressor and transmission facilities to handle their new coalbed methane production from the area.

## INDUSTRIAL MINERALS

Exploration and expansion of dimensional stone resources continued in Wyoming. Raven Quarries, which produces a black granite (*Wyoming Raven*) and a pink swirled granite (*Fantastico*), added another pink granite (*Mirage*) to its product line. *Mirage* is quarried adjacent to the Wyoming Raven quarry. Raven Quarries also closed its Wyoming fabricating plant in 1998. It now ships all of its quarried blocks to Western Granite for processing in Tijuana, Mexico.

At year's end, an Italian company was seeking a permit to quarry dimensional limestone near Horse Creek in Laramie County. And at least three other companies had acquired stone deposits suitable for quarrying.

Basin Electric changed the source of limestone used for emissions control at its Laramie River Station near Wheatland. Colorado Lien's Hartville quarry has replaced Divide Construction's Bass quarry as Basin's supplier. The Hartville quarry is twenty miles closer to the coal-fired power plant than the Bass quarry. The Mississippian-Devonian Guernsey Limestone, which is quarried at the Hartville quarry, is the same rock unit as quarried at the Bass quarry.

Exploration continued for additional chemical-grade and aggregate-quality limestone resources for use in the Powder River Basin and the Green River Basin. Both these areas are limestone- and aggregate-poor.

The Burlington Northern Santa Fe railroad is double-tracking its main lines to the Powder River coal field, and the Dakota, Minnesota, and Eastern railroad is planning to construct a new line into the same area. Both of these projects will require rock for base, sub-base, and ballast. Consequently, exploration for railroad ballast has increased. Several companies have been testing sources for these materials from sites near the Hartville uplift, in the northern Laramie Mountains, and in the Black Hills.

In 1998, there was interest in constructing a glass plant to produce brown beer bottles in Wyoming. There was also continued exploration for raw materials used in the manufacture of glass. Budweiser, which operates a brewery in Colorado, about 30 miles south of Cheyenne, announced that it was seeking an increased beer bottle supply and accepting bids for bottles. At least two major manufacturers of container glass bid for the bottle contract in mid-1998. One bidder planned to produce the bottles in Wyoming. However, Budweiser decided to extend its existing contract with Ball-Foster Glass in Oklahoma for another year while it evaluates another beer producer's test marketing of plastic bottles.

During the year, exploration for silica sand concentrated on Quaternary sand dunes and older sandstones in southeastern and central Wyoming. One company was reportedly exploring and testing high-silica sand in the northern Bighorn Basin.



Bentonite production continued at record levels in 1998. Expanding markets for most uses of bentonite contributed to this increase, especially the growing market for kitty litter. Existing bentonite companies expanded their reserves by permitting and testing bentonite in the areas near their plants in the Black Hills, Kaycee area, and eastern Bighorn Basin.

U.S. Zeolite, which mined 1,500 tons of the zeolite, clinoptilolite, in 1997, sold its Bitter Creek mine and its Utah processing plant to Addwest Minerals in Denver, Colorado. The mine is located southeast of Bitter Creek in Sweetwater County, Wyoming. In 1998, Addwest hauled some stockpiled ore from the mine to the Utah facility for refining and shipping to markets. About 1,000 tons of clinoptilolite ore are stockpiled at the mine site.

## **METALS AND PRECIOUS STONES**

In the South Pass granite-greenstone belt near the southern tip of the Wind River Range of western Wyoming, Newmont Exploration dropped their interests in the Lewiston district. However, another major company picked up the property. This region has high potential for the discovery of significant gold mineralization, based on sampling by the Wyoming State Geological Survey. The South Pass region is similar to several gold districts in greenstone terranes in southern Africa, western Australia, and Canada. The South Pass granite-greenstone terrane is also the source of some very large, auriferous, Tertiary-age paleoplacers, including the Twin Creek placer along the northern flank of the belt and the Dickie Springs-Oregon Buttes placer along the southern flank of the granite-greenstone belt.

Claim-staking activity was reported in the Dickie Springs-Oregon Buttes paleoplacer. This area contains one of the largest auriferous paleoplacers on North America. The U.S. Geological Survey estimated that resources could be as high as 28.5 million ounces of gold. Under favorable economic conditions, much of this resource might be amenable to open-pit mining.

Prospectors continued to find nuggets in the greenstone terrane at South Pass. One prospector found a 7.5-ounce nugget along with some other smaller nuggets. Another prospector recovered more than 40 nuggets using a metal detector. Prospectors also reported success in the Douglas Creek district of the Medicine Bow Mountains of southeastern Wyoming.

Elsewhere in Wyoming, some interest was shown for large-tonnage gold deposits. Wyoming has a number of potentially bulk-minable gold deposits that remain relatively unexplored. Several of the better targets lie within the Rattlesnake Hills greenstone terrane in the Granite Mountains of central Wyoming. The Rattlesnake Hills greenstone belt has been disrupted by 50 Tertiary alkalic and felsic intrusives. Past drilling on one mineralized intrusive and adjacent breccia by ACNC, Canyon Resources, and Newmont identified a large-tonnage, low-grade, gold deposit with an estimated resource of 250,000 ounces that is

open at depth and laterally. Recent reevaluation of the drilling data suggests that the resource may have been greatly underestimated and could possibly be increased to one million ounces (Dave Miller, personal communication, 1999). Additionally, the Rattlesnake Hills district contains dozens of exhalitive, brecciated, hydrothermally altered, and stockwork targets that are relatively unexplored. The Rattlesnake Hills could represent one of the better grass-roots exploration targets for gold in the western U.S.

At the Copper King copper-gold porphyry west of Cheyenne in southeastern Wyoming, Mountain Lake Resources' evaluation of existing and new drill data indicated a potential resource of more than 383 thousand ounces of gold and more than 58 million pounds of copper. This property is only partially explored and further exploration could result in expansion of the resources.

Platinum-group metals continued to attract attention in southeastern Wyoming. Much of the interest was centered on Proterozoic-age mafic complexes at Lake Owen in the Medicine Bow Mountains and Puzzler Hill in the Sierra Madre mountains of southeastern Wyoming. Both complexes have yielded highly anomalous mineralization. Other complexes of potential interest for platinum-group metals, nickel, gold, and titanium include the Mullen Creek complex in the Medicine Bow Mountains, the Tony Ridge peridotite and the Laramie anorthosite-gabbro complex in the Laramie Mountains, and the Woods and Elkhorn Mountain complexes in the Sierra Madre. Activity was reported in some of these areas in 1998.

Some interest and claim staking was also reported for some of Wyoming's iron and titanium deposits. Sizable iron resources occur in the South Pass and Seminoe Mountains greenstone belts, the Copper Mountain region, and in the Hartville uplift. Large resources are also found complexed with titanium in titaniferous magnetite in the Laramie anorthosite.

The Wyoming State Legislature increased the Wyoming State Geological Survey's (WSGS's) diamond research budget to allow for geochemical analyses of kimberlitic indicator minerals, expanded geological mapping, diamond testing, and remote sensing in the search for potential diamondiferous host rocks. As a result, the WSGS initiated reconnaissance in the Bighorn Basin in northwestern Wyoming and in the Laramie Mountains and Hartville uplift in eastern Wyoming. Initial work in the Bighorn Basin recovered rounded, pink, red (with slight purple coloration), and yellow-orange garnets. One garnet yielded an index of refraction  $<1.760$ , which is characteristic of pyrope.

Sampling and mapping in the Iron Mountain district in the Laramie Mountains, 35 miles northwest of Cheyenne, resulted in the discovery of several previously unknown kimberlites. Based on mapping by the WSGS, four major kimberlite dike/blow complexes occur in the district. The largest has a strike length of 2.5 miles with scattered blows from tens of feet to 1,000 feet across. In addition to the dike complexes, a kimberlite sill was also discovered by the WSGS.

Geologic evidence, as well as the presence of kimberlitic indicator minerals found elsewhere in the district, suggests the presence of other undiscovered kimberlites. The geologic evidence includes the discovery of kimberlitic indicator minerals upstream from any known kimberlite, the presence of topographic lows along kimberlite trends, and the presence of an extensive Tertiary conglomerate that contains kimberlitic microilmenite megacrysts. The WSGS plans to conduct EM and magnetic surveys in the district in 1999.

Geochemical analyses of kimberlitic indicator minerals from some of the Iron Mountain kimberlites suggest that a few of the intrusives originated within the diamond stability field. Both calcic (G9) and subcalcic (G10) chrome-pyropes have been recovered. A small number of eclogitic garnets have also yielded favorable chemistry. In the fall, samples of the kimberlites were collected by the WSGS for diamond testing. These samples will be processed in 1999.

The WSGS also began follow-up exploration of several kimberlitic anomalies found by the agency in past years. In particular, research began at Grant Creek where the WSGS discovered a significant kimberlitic anomaly, and where microdiamonds have since been reported, although not verified. The Eagle Rock and Elmers Rock regions of the Laramie Mountains are also under investigation.

The WSGS has mapped and sampled the Leucite Hills lamproite field in southwestern Wyoming. Field investigations were also conducted to search for hidden olivine lamproite in the northern portion of the district, where a major lineament has been recognized. Mapping identified several northeasterly-trending structures that controlled the emplacement of the more than 20 lamproite extrusives. Although no diamonds have been recovered from the lamproites, the WSGS has continued its geochemical and petrographic studies of the Leucite Hills lamproites.

The WSGS also continued to accumulate information on other gemstones and semi-precious stones in the State. In addition to diamond, other valuable minerals found in Wyoming include jade, ruby, sapphire, aquamarine, garnet, diopside, enstatite, cordierite, agate, jasper, and gold. Many occurrences of these minerals are described in Mineral Report MR 98-3, which was recently published by the WSGS.

The WSGS investigated a corundum schist near Jeffrey City in the Granite Mountains of central Wyoming. Known as the Red Dwarf ruby deposit, this schist has a strike length of 5,000 feet with widths of 20 to 40 feet. The schist contains numerous, purplish-red, translucent and opaque, corundum crystals that are microscopic to 2 inches across. Some specimens cut into cabochons have produced attractive, semi-precious gemstones (Robert Odell, personal communication, 1998).

## OIL AND GAS

### Drilling Activities and Well Completions

Based on data available from Petroleum Information/Dwights LLC (1999), Wyoming ranked first in the Rocky Mountain region and sixth in the U.S., with 918 well completions in 1998. This is a marked increase from the 790 completions in 1997 (**Figure 18**). Of the 918 completions, 132 were exploration wells and 786 were development wells.

There were a total of 281 coalbed methane completions, which was 30.6% of the total completions in Wyoming. The success rate for exploration wells was 44.7%, compared to a success rate of 35.8% for exploration wells in 1997. There were 17 new oil discoveries and 42 new gas discoveries in 1998. In all, 788 wells found oil or gas for a success rate of 85.8%, compared to a success rate of 81.0% in 1997.

As reported by Hughes Rig Count, the average daily rig count in 1998 was 39, which is the same as in 1997 (**Figure 19**). Rigs in Wyoming drilled over 5.7 million feet in 1998, an increase of 1.1 million feet over 1997 (**Figure 20**). The average depth of all wells drilled in Wyoming in 1998 was 6,267 feet (**Figure 21**). Numerous shallow coalbed methane wells drilled in the Powder River Basin played a major role in lowering the average depth of all wells drilled in Wyoming in 1998. The average depth of an exploration well in Wyoming in 1998 was 8,155 feet, which is 514 feet deeper than in 1997 (**Figure 21**).

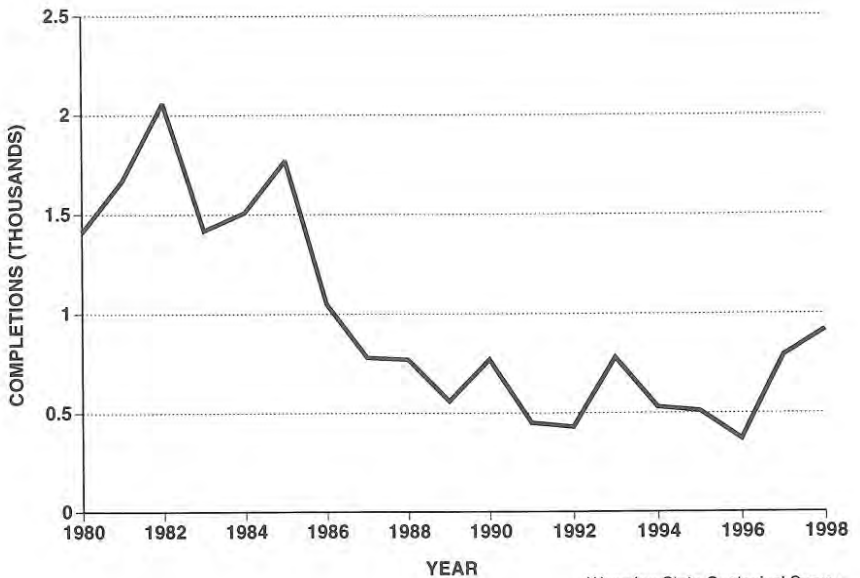
### Lease Sales

The six Federal lease sales held by the U.S. Bureau of Land Management (BLM) in 1998 grossed over \$63.8 million (**Figure 22**), with an average price per acre of \$39.34 (**Figure 23**). In 1997, the six Federal sales only grossed somewhat more than \$31.9 million, with an average price per acre of \$26.50. Of the 2.2 million acres that were available for lease in 1998, 73.1% were leased. In 1997, 76.4% of the 1.6 million acres available at Federal sales were leased.

The four lease sales held by the Wyoming Office of State Lands and Investments in 1998 grossed over \$5.2 million (**Figure 22**), with an average price per acre of \$20.14 (**Figure 23**). Of the 445,000 acres available for lease in 1998, 58.3% were leased. For comparison, the four sales in 1997 grossed over \$3.1 million. Of the 438,000 acres available for lease that year, 60.1% were leased, at an average price of \$11.97 per acre.

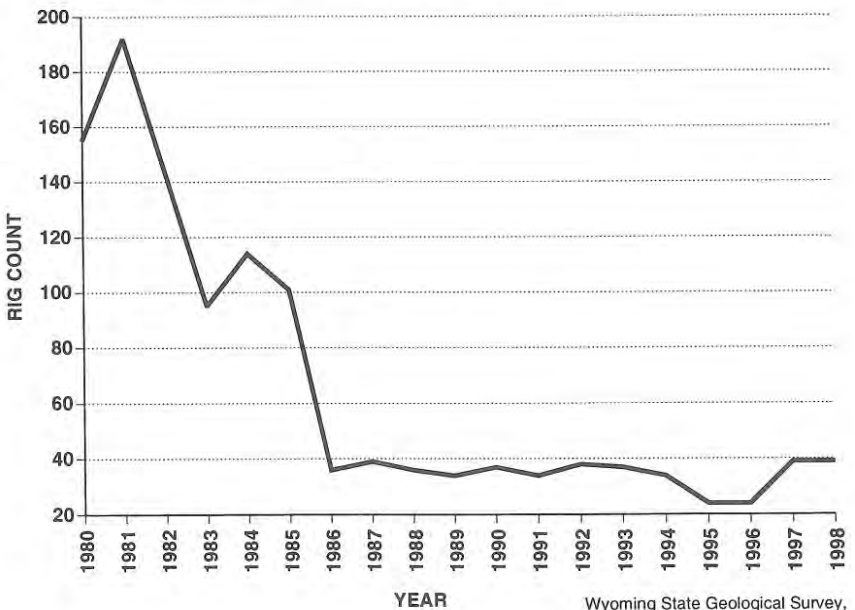
### Applications for Permit to Drill

There were 2,505 Applications for Permit to Drill (APDs) approved by the Wyoming Oil and Gas Conservation Commission in 1998 (**Figure 24**). This was an increase of 597 over the number approved in 1997 and the largest total in the last seven years. Over 55% of the total APDs were for coalbed methane



Wyoming State Geological Survey,  
Oil and Gas Section, April, 1999

Figure 18. Number of oil and gas well completions by year (1980-1998) (from Petroleum Information/Dwights LLC, 1999).



Wyoming State Geological Survey,  
Oil and Gas Section, April, 1999

Figure 19. Average daily rig county by year (1980-1998) (from Hughes Rig Count).

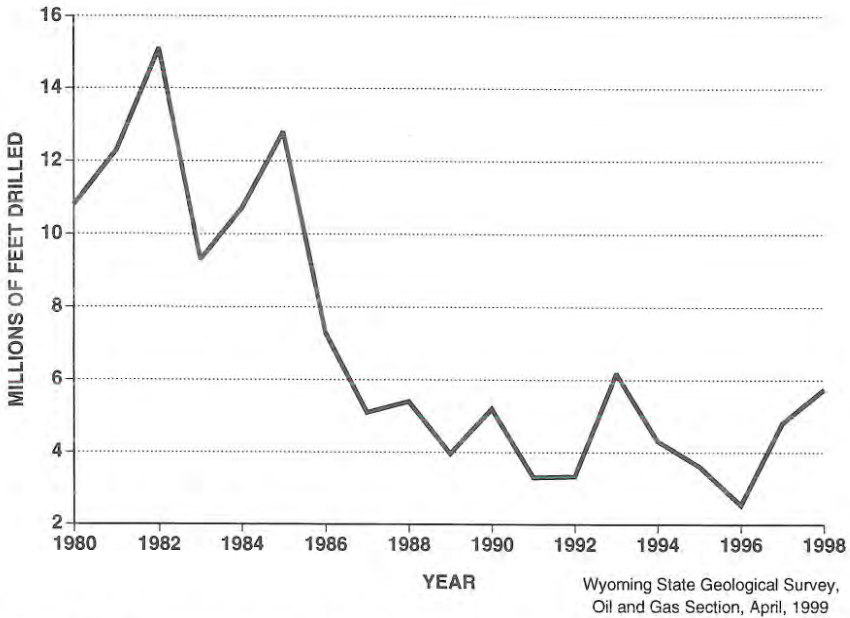


Figure 20. Millions of feet drilled for oil and gas by year (1980-1998) (from Petroleum Information/Dwights LLC, 1999).

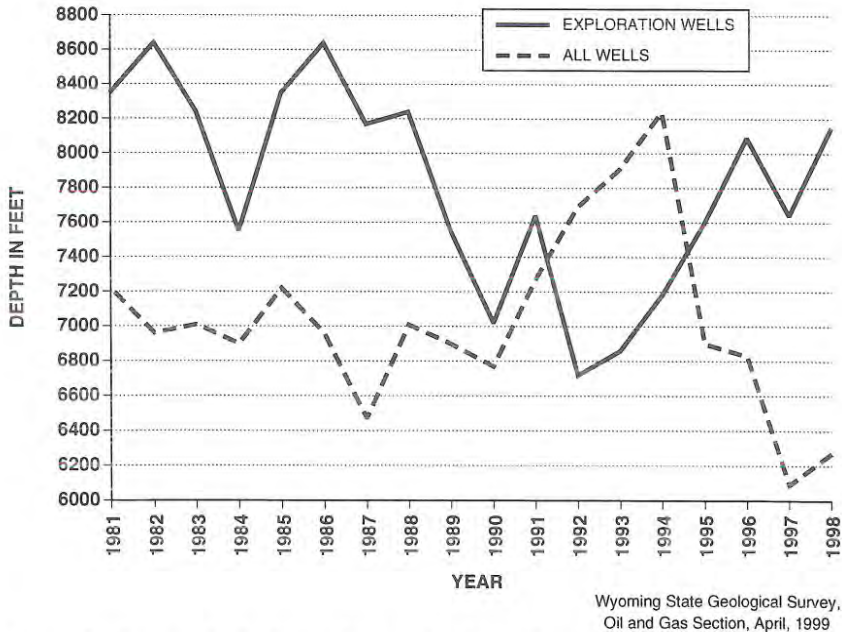
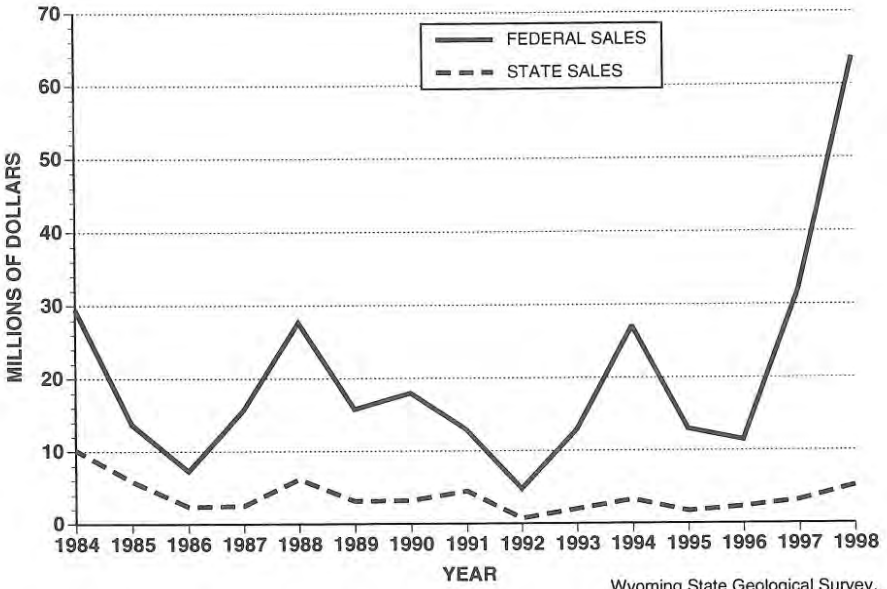
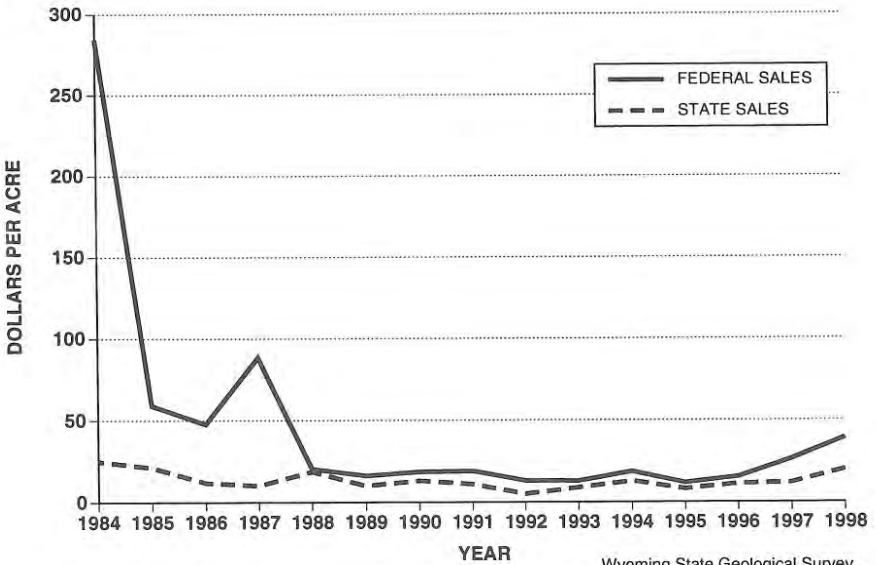


Figure 21. Average depth of oil and gas exploration wells and all oil and gas wells drilled by year (1981-1998) (from Petroleum Information/Dwights LLC, 1999).



Wyoming State Geological Survey,  
Oil and Gas Section, April, 1999

Figure 22. Millions of dollars paid for Federal and State oil and gas leases by year (1984-1998).



Wyoming State Geological Survey,  
Oil and Gas Section, April, 1999

Figure 23. Average price per acre paid for Federal and State oil and gas leases by year (1984-1998).

wells in the Powder River Basin. Wyoming accounted for 68.0% of all the coalbed methane APDs in the Rocky Mountain region.

### **Seismic Exploration**

During 1998, the seismic permits issued by the Wyoming Oil and Gas Conservation Commission covered 463 conventional miles and 1,503 3-D square miles. While the conventional miles decreased slightly from 1997, the 3-D square miles were the most in the last four years (Figure 25).

### **Powder River Basin**

Campbell County was the leading county in the U.S. in regard to the number of new field wildcats, with 27. Five of these wildcat wells found oil and three found gas. Among geologic provinces, the Powder River Basin was seventh nationally in terms of new field wildcats, with 46. Campbell County was also the leading county in the Rocky Mountain region and the second leading county in the U.S. in regard to the number of all wells completed, with 368. The 368 completions included 73 oil wells and 243 gas wells. Most of the gas wells were completed in subbituminous coals of the Paleocene Fort Union Formation, as activity in the coalbed methane play in the Powder River Basin accelerated. Most of the oil wells in the basin were completed in the Sussex sandstone, the Muddy Sandstone, or the Minnelusa Formation.

### **Greater Green River Basin**

Sweetwater County was the sixth leading county in the Rocky Mountain region in regard to the total number of well completions, with 123. Of the 123 well completions, 115 found gas. Most of the activity in Sweetwater County was committed to development drilling for gas from the Mesaverde Formation or the Lewis Shale in the eastern part of the county, and to development drilling for gas from the Frontier Formation, the Muddy Sandstone, or the Dakota Sandstone on the Moxa arch.

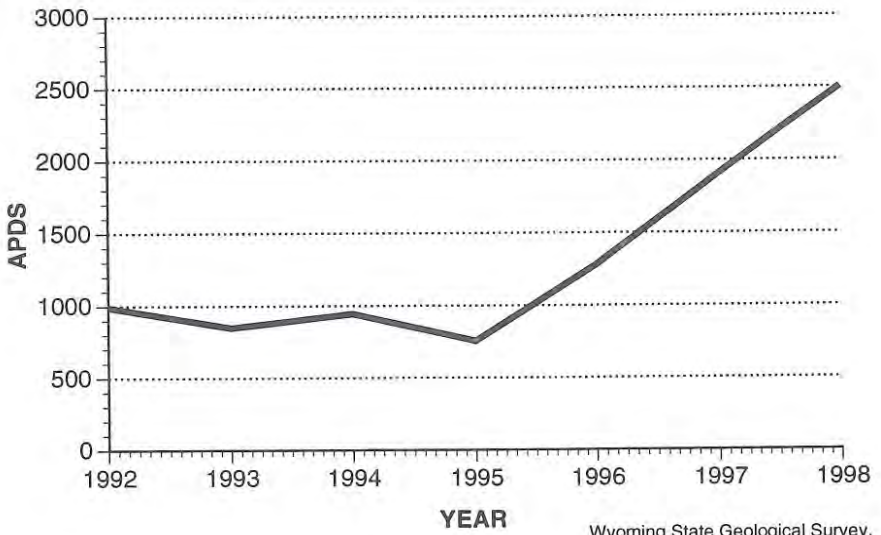
In regard to the number of new field wildcats, Sublette County tied for third in the Rocky Mountain region, with seven. Six of those wildcats found gas. Regarding the total number of well completions, Sublette County was tenth in the Rocky Mountain region, with 84. Of the 84 well completions, 14 found oil and 67 found gas. A good deal of the activity in Sublette County was development and exploration drilling in the Lance Formation in the Jonah Field/Pinedale anticline area.

Uinta County tied for sixth in the Rocky Mountain region in regard to the number of new field wildcats, with six. Two of the wells discovered gas on the flanks of the Moxa arch.

### **Wind River Basin**

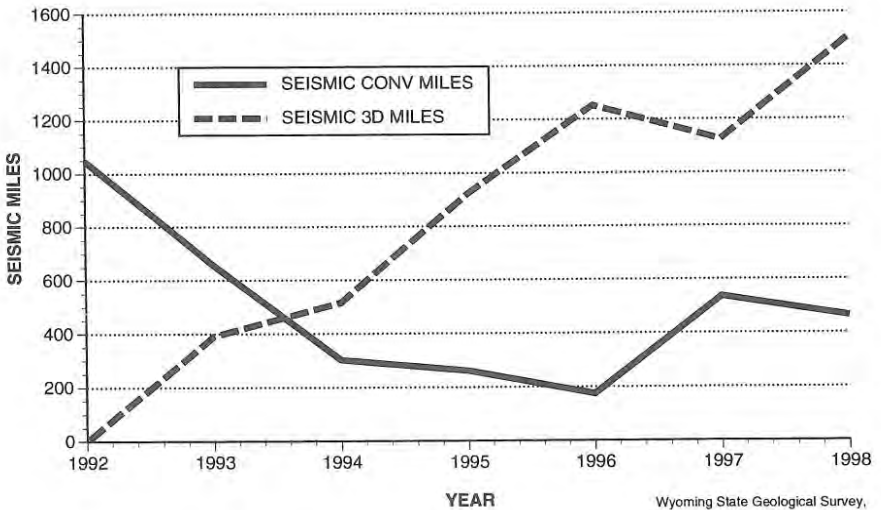
Fremont County tied for third in the Rocky Mountain region in regard to the number of new field wildcats, with seven. Unfortunately, all seven were dry holes.





Wyoming State Geological Survey,  
Oil and Gas Section, April, 1999

Figure 24. Applications for Permit to Drill approved by the Wyoming Oil and Gas Conservation Commission by year (1992-1998).



Wyoming State Geological Survey,  
Oil and Gas Section, April, 1999

Figure 25. Number of seismic conventional miles and 3-D square miles permitted by the Wyoming Oil and Gas Conservation Commission by year (1992-1998).

There were a number of development wells drilled in the Cave Gulch/Waltman area in 1998. Barrett Resources confirmed its subthrust Muddy discovery with the 3-29 Mad-Cave Gulch Federal well. The well flowed 61 million cubic feet of gas per day from a zone at about 18,200 feet. The well produced 1.95 billion cubic feet of gas in the last two months of 1998. Total production from Waltman Field in 1998 was 57.9 billion cubic feet of gas and 186,000 barrels of condensate.

Burlington Resources announced plans to drill a 25,000-foot Madison Limestone well in Madden Field. The 5-6 Bighorn well will be the fourth Madison well in the field, and will be drilled in SW NW section 6, T38N, R89W. The company signed a three-year drilling contract with Parker Drilling for a series of Madison wells in Madden Field. It has taken over a year to drill each of the previous three Madison wells in this field.

Tom Brown Inc. continued its drilling program in the basin. The company completed two high-volume gas wells in Frenchie Draw Field and one in Sand Mesa Field.

### **Overthrust Belt**

BP Amoco completed a Madison well in Whitney Canyon-Carter Creek Field that flowed 60.0 million cubic feet of gas per day, the highest production rate recorded in the field in the past 15 years. The well was part of an infill-drilling program that will increase production by 90 million cubic feet of gas per day.

Chevron continued its development of the Nugget Sandstone in Painter Reservoir East Field. Most of the new wells are horizontally drilled, and the initial potentials for the wells are each several million cubic feet of gas and over 1,000 barrels of oil per day.

### **Reference Cited**

Petroleum Information/Dwights LLC, 1999, 1998 annual review, Rocky Mountain region: Rocky Mountain Region Report, v. 72, no. 59, p.13-60.

## **URANIUM**

Most exploration for additional uranium resources involved drilling in and around producing deposits or in areas with known deposits. One company; however, was exploring in central Wyoming for unconformity-related uranium occurrences in areas with geology similar to the producing localities in the Athabasca Basin of central Canada.

# MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING

## PETROLEUM

Remaining Technically Recoverable Resources (January 1, 1993)	
Discovered (Includes oil, gas liquids, and condensate)	3.47 billion barrels <sup>1</sup>
Undiscovered	6.18 billion barrels <sup>1</sup>
Total	9.65 billion barrels
Remaining Reserve Base (January 1, 1998)	
Measured reserves (Proved reserves) (Includes: 0.627 billion barrels of oil and 0.600 billion barrels of gas liquids and condensate)	1.23 billion barrels <sup>2</sup>
Indicated and inferred reserves (Reserve growth in conventional fields)	2.41 billion barrels <sup>1</sup>
Total	3.64 billion barrels

## NATURAL GAS

Remaining Technically Recoverable Resources (January 1, 1998)	
Discovered (Includes 35.6 trillion cubic feet (TCF) of methane <sup>1</sup> and 121.5 TCF of CO <sub>2</sub> <sup>3</sup> )	157.1 trillion cubic feet
Undiscovered (Includes 14.72 TCF of conventional methane <sup>1</sup> ; 5.43 TCF of coalbed methane; 119.3 TCF of methane in tight gas sands in the Green River Basin; and 31.2 TCF of CO <sub>2</sub> <sup>3</sup> )	170.6 trillion cubic feet
Total	327.7 trillion cubic feet
Remaining Reserve Base (January 1, 1998)	
Measured reserves (Proved reserves) (Includes 13.6 TCF of methane <sup>2</sup> and 59.8 TCF of CO <sub>2</sub> <sup>3</sup> )	73.4 trillion cubic feet
Indicated and inferred reserves (Reserve growth in conventional fields)	22.8 trillion cubic feet
Total	96.2 trillion cubic feet

## COAL

Remaining Resources (January 1, 1999)	
Identified and Hypothetical (Discovered)	1,426.3 billion tons <sup>4</sup>
Speculative (Undiscovered)	31.5 billion tons <sup>4</sup>
Total	1,457.8 billion tons
Remaining Reserve Base (January 1, 1999)	
Demonstrated strippable (Measured and indicated reserve base)	24.7 billion tons <sup>5</sup>
Demonstrated underground-minable (Measured and indicated reserve base)	42.5 billion tons <sup>5</sup>
Total	67.2 billion tons

## TRONA

Original Resources	
Trona	76.0 billion tons <sup>6</sup>
Mixed trona and halite	51.0 billion tons <sup>6</sup>
Total	127.0 billion tons

## URANIUM

Remaining Resource (December 31, 1989)	1.99 billion pounds U <sub>3</sub> O <sub>8</sub> <sup>9</sup>
Remaining Reserve Base (December 31, 1989)	
Uranium oxide recoverable at \$30.00 per pound	66 million pounds <sup>7</sup>

## OIL SHALE

Original Resources (January 1, 1981)	
Identified (Discovered)	320 billion barrels of shale oil <sup>8</sup>

<sup>1</sup> Modified from U.S. Geological Survey National Oil and Gas Resource Team, 1995, 1995 National Assessment of United States oil and gas resources: U.S. Geological Survey Circular 1118, 20 p.

<sup>2</sup> Modified from Energy Information Administration, 1998, U.S. crude oil, natural gas, and natural gas liquids reserves: Advance Summary, 1997 Annual Report: Washington D.C., 12 p.

<sup>3</sup> De Bruin, R.H., 1991, Geological Survey of Wyoming Open File Report 91-6, 20 p.

<sup>4</sup> Modified from Wood, G.H., Jr. and Bour W.V., III, 1988, Coal map of North America: U.S. Geological Survey Special Geologic Map, 1:5,000,000-scale (color) and 44 p. pamphlet.

<sup>5</sup> Modified from Jones, R.W., and Glass, G.B., 1992, Demonstrated reserve base of coal in Wyoming as of January 1, 1991: Geological Survey of Wyoming, Open File Report 92-4, 26 p.

<sup>6</sup> Wiig, S.V., Grundy, W.D., and Dyni, J.R., 1995, Trona resources in the Green River Basin in southwest Wyoming: U.S. Geological Survey Open File Report 95-476, 88 p.

<sup>7</sup> Energy Information Administration, 1989, Uranium industry annual: U.S. Department of Energy Report DOE/EIA-0478(89), 121 p.

<sup>8</sup> Knutson, C.F., and Dana, G.F., 1982, Developments in oil shale in 1981: American Association of Petroleum Geologists Bulletin, Volume 66, no. 11, p. 2513.

# **GEOLOGIC MAPPING, PALEONTOLOGY, AND STRATIGRAPHY UPDATE**

Alan J. Ver Ploeg

*Senior Staff Geologist-Geologic Mapping, Wyoming State Geological Survey*

## **NATIONAL GEOLOGIC MAPPING ACT OF 1992**

The Association of American State Geologists (AASG) is spearheading efforts toward a second reauthorization of the National Geologic Mapping Act of 1992 (Act). The Act established a cooperative geologic mapping program, which involves the U.S. Geological Survey (USGS), state geological surveys, and geology departments at institutions of higher education in the U.S. The program's goal is to accelerate the detailed geologic mapping of critical areas in the U.S. by using the combined talents of the three participating groups mentioned above.

Between 1992 and 1998, funds from this cooperative program have helped the Wyoming State Geological Survey (WSGS) accelerate its geologic mapping efforts in Wyoming. The WSGS has already completed 9 maps using some funding from this program and 3 more maps are in progress. An additional 11 were completed independent of the program's funding. Nationally, state geological surveys have produced 1,907 geologic maps using program funds, with 296 maps still in preparation. Another 699 maps have been completed independent of these program funds.

Detailed geologic mapping is an important source of information for a broad range of societal activities. These include the delineation and protection of safe drinking water; identification and mitigation of natural hazards, such as earthquake-prone areas, landslides, and other ground failures, and many other land-use planning requirements; and assessments of coal, oil, natural gas, construction materials, metals, and other natural resources, to name a few.

In Wyoming and other states, state-specific mapping advisory committees have identified critical areas for geologic mapping. These critical areas include Federal, State, and local priorities. In the case of Wyoming, the identified priority is mapping the more populated areas in the State. About 20% of the Nation and less than 50% of Wyoming is mapped at a scale adequate to meet the societal needs mentioned above. The reauthorized Act will improve this situation by addressing these critical societal needs.

Funding for the STATEMAP and EDMAP portions of the Act is incorporated in the budget of the USGS. State geological surveys (STATEMAP) and university participants (EDMAP) receive funding through a competitive proposal process that requires dollar for dollar matching funds from the applicants.

Negotiations and agreements between the USGS and an AASG subcommittee have helped create a draft reauthorization bill. The AASG is hoping that Congresswoman Cubin (WY) and Senator Craig (ID) will introduce the House and Senate versions of the reauthorization bill in the near future. **Table 15** contains what the AASG and the USGS hope to have in reauthorization of the Act. In Federal fiscal year 1999, the net amount awarded to the state geological surveys through STATEMAP was \$3,844,060. For FY 2000, following the President's proposed budget, the net amount to state geological surveys under STATEMAP would be \$4,684,505. However, if Congress appropriated the fully authorized amount of \$30 million in FY 2000, the net amount to state surveys would increase to \$8,190,910. At the fully authorized \$64 million in FY 2005, the net amount to state surveys would be \$22,022,110. The \$22 million figure is the maximum amount that the state geological surveys can likely to match in any given year, based on a questionnaire they completed.

**Table 15. Previous appropriation and requested appropriations for the proposed reauthorization of the National Geologic Mapping Act of 1992.**

Fiscal Year	Program Authorization	Actual Appropriation	Administration's Proposed Budget	STATEMAP Allocation	Net amount to States through STATEMAP
1999	\$28,000,000	\$22,546,000		\$4,535,760	\$3,844,060
2000			\$21,381,000	\$5,527,440	\$4,684,505
2000	\$30,000,000			\$9,664,791	\$8,190,910
2001	\$37,000,000			\$13,024,791	\$11,038,510
2002	\$43,000,000			\$15,904,791	\$13,479,310
2003	\$50,000,000			\$19,264,791	\$16,326,910
2004	\$57,000,000			\$22,624,791	\$19,174,510
2005	\$64,000,000			\$25,984,791	\$22,022,110

## TEACHER'S WORKSHOP ON PALEONTOLOGY

The Big Horn Basin Foundation is sponsoring a teacher's workshop at the Wyoming Dinosaur Center in Thermopolis from June 21 through June 25. The workshop has been expanded over previous years with the aid of an Eisenhower Grant received by the foundation. The workshop will include extensive hands on experience digging for dinosaurs at the Warm Springs Ranch quarries. In addition, Mike Bies of the U.S. Bureau of Land Management, will lead a field trip to the Red Gulch dinosaur track site (**Figure 26**).

Speakers at the workshop will include Dave Trexler, on the evolution of dinosaurs; Jeb Schenck on learning theory; Peter Ellsworth on critical thinking and assessment; and Stuart Becher speaking on dinosaurs and the impact theory. For further information on the workshop, contact Shawna Creamer at the Big Horn Basin Foundation at (307) 864-2259.

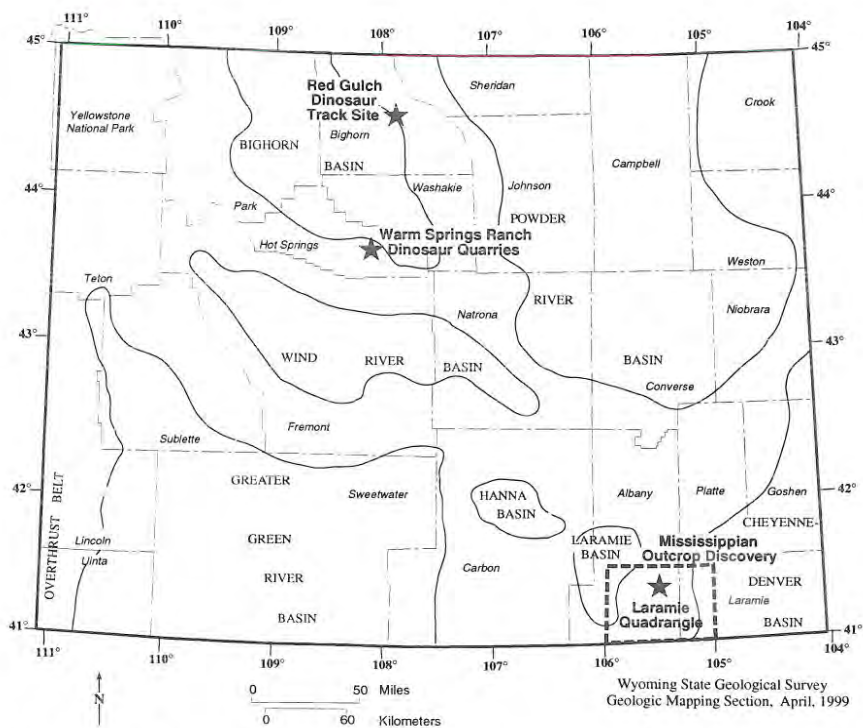


Figure 26. Index to selected paleontologic and geologic mapping activities in Wyoming.

## TATE '99 CONFERENCE ON FOSSIL REPTILES

The Tate Museum has announced its 1999 spring conference plans. The conference is scheduled for June 4-7 and will include a seminar with a full program of research papers on various paleontologic topics, but emphasizing fossil reptiles of Wyoming. Keynote speakers include Gaylen Holmes, who will speak on "Modern Reptiles" with a live demonstration on June 4<sup>th</sup>, and Dr. Judy Massare, who will speak on "Mesozoic Sea Monsters of Wyoming and the World" on June 5<sup>th</sup>. Several other research papers will be presented on this topic on Saturday, June 5<sup>th</sup>. In addition, there are opportunities for some first-hand field experience with a one-day field trip to Oligocene White River outcrops on Friday, June 4<sup>th</sup>, as well as a fossil-hunting trip to Jurassic rocks west of Casper on Sunday, June 6<sup>th</sup>.

Call the Tate Museum for more information on registration (307-268-2447) or email Dr. Kent Sundell at <[ksundell@acad.cc.whecn.edu](mailto:ksundell@acad.cc.whecn.edu)>. You can also access the Tate Museum web page for a Tate '99 conference schedule and registration information at: <<http://www.cc.whecn.edu/tate/webpage.htm>>.

## **MAPPING DISCOVERS OUTCROP OF MISSISSIPPIAN-AGED ROCKS**

Last field season, on the King Mountain Quadrangle northeast of Laramie, the Wyoming State Geological Survey (WSGS) discovered what appears to be a Mississippian fossiliferous chert bed (**Figure 26**). The chert bed is apparently in place and lying directly on Precambrian rocks. The bed is overlain by rocks of the Permian/Pennsylvanian Casper Formation and possibly a thin wedge of Pennsylvanian Fountain Formation. This discovery is potentially significant in that outcrops of Mississippian rocks had not previously been mapped in the southern Laramie Mountains, although Mississippian float rock had been found on the Precambrian surfaces in the general area.

The outcrop is located just east of the upper end of Rogers Canyon and was previously mapped as Precambrian. The sampled chert beds contain Mississippian fossils, including mainly the Mississippian brachiopod *Spirifer*, which were identified by Dr. Donald Boyd of the University of Wyoming's Department of Geology and Geophysics. This mapping is part of a STATEMAP project to map and compile the 1:100,000-scale Laramie Quadrangle (**Figure 26**). The WSGS will be examine the outcrop in greater detail this summer to determine the extent of the unit and more definitely establish its age.

## **NEW PUBLICATION ON WYOMING GEOLOGY**

Longman and others (1998) recently published an extensive paper detailing the integration of lithologic and wireline log data to establish subdivisions of the Upper Cretaceous Niobrara Formation. Interpretation of these data allowed regional mapping of these subdivisions in the Niobrara and led to new interpretations of the nature of depositional patterns and lithologies in the Western Interior Seaway during Coniacian-Santonian time. Because hydrocarbon production from the Niobrara is restricted to three major lithologies within the formation, the results of this ambitious effort should aid in the exploration for hydrocarbons in the Niobrara of the Rocky Mountain region.

### **Reference Cited**

- Longman, M.W., Luneau, B.A., and Landon, S.M., 1998, Nature and distribution of Niobrara lithologies in the Cretaceous Western Interior Seaway of the Rocky Mountain region: *The Mountain Geologist*, v. 35, no. 4, p. 137-170.

# **GEOLOGIC HAZARDS UPDATE**

by James C. Case

*Staff Geologist- Geologic Hazards, Wyoming State Geological Survey*

## **EARTHQUAKE PROGRAM IN WYOMING**

The author has been named the first Earthquake Program Manager for the State of Wyoming. To help fund the State's new Earthquake Program, in mid-December of last year, Federal funds were transferred to the Wyoming State Geological Survey from the Federal Emergency Management Agency (FEMA) through the Wyoming Emergency Management Agency (WEMA). The primary purposes of the program are the promotion of earthquake awareness, preparedness, and multi-hazard mitigation in Wyoming. One of the first projects will determine the potential effects of earthquakes and landslides on emergency shelters in Teton County. Another project will involve the preparation and publication of brochures on earthquakes in Wyoming as well as instructions on how to make your home "earthquake proof." Future issues of *Wyoming Geo-notes* will contain more information on the scope of the earthquake program and what it means to Wyoming.

## **THE NEED FOR EARTHQUAKE PREPAREDNESS IN CARBON COUNTY**

### **Most Recent Earthquake**

On April 5, 1999, a damaging, magnitude 4.2 earthquake occurred in southwestern Carbon County, approximately 35 miles southwest of Rawlins. The earthquake, which was felt in Rawlins, Sinclair, Baggs, Wamsutter, and Rock Springs, caused damage to two homes. A ranch house, located approximately 30 miles north of Baggs and within a few miles of the epicenter, suffered the most damage. The homeowner reported that concrete-block walls in the basement of the home cracked and separated. Similarly, a residence in Wamsutter also suffered cracks in the concrete walls of the basement. Based upon the damage observed, the earthquake probably had an intensity of V-VI.

### **Historic Earthquakes**

Historically, there have been a number of earthquakes in or near Carbon County, with a few causing damage. Because many of the historic earthquakes are described in Case (1997), only a summary is presented below:

<u>Date</u>	<u>Magnitude/Intensity</u>	<u>Comments</u>
November 7, 1882	V	Colorado earthquake.
March 28, 1896	IV	Rawlins area. Rattled windows.
March 10, 1917	IV	Rawlins area. Wooden buildings vibrated.
February 5, 1938	III	Medicine Bow area. Slightly felt.
August 28, 1952	IV	Medicine Bow area. Loose objects rattled.



April 13, 1973	—	Seminole Reservoir area.
May 29, 1973	—	Ferris Mountains area.
May 30, 1973	—	Seminole Reservoir area.
June 1, 1973	—	Seminole Reservoir area.
August 3, 1973	4.1	Seminole Reservoir area. Probable explosion.
August 10, 1973	3.6	Seminole Reservoir area. Probable explosion.
August 17, 1973	—	Seminole Reservoir area.
August 17, 1973	—	Medicine Bow area.
November 21, 1973	—	Seminole Reservoir area. Probable explosion.
December 26, 1973	—	Shirley Mountains area.
July 11, 1975	II	Seminole Reservoir area. Felt in Rawlins.
January 27, 1976	2.3, V	Rawlins area. Damaging earthquake.
March 3, 1977	4.2, V	Sierra Madre mountains area.
October 18, 1984	5.5, VI	Northern Albany County. Damaging.
November 1, 1989	3.0	Sierra Madre mountains area.
April 13, 1991	3.2	Seminole Reservoir area.
April 19, 1991	2.9	Seminole Reservoir area.
December 18, 1991	3.1	Seminole Reservoir area.
August 23, 1993	3.0	Seminole Reservoir area.
August 6, 1998	3.6	Rawlins area. Felt in Rawlins and Sinclair.
April 5, 1999	4.2, V-VI	Southwest of Rawlins. Damaging.

### **Earthquake Awareness and Preparedness**

Not everyone in Wyoming is aware of the earthquake hazard in Carbon County. As seen in the above listing; however, the county has had a number of earthquakes over the last 103 years. This lack of awareness of earthquake hazards in Wyoming is not limited to Carbon County. Many residents of the State are unaware that the U.S. Geological Survey and FEMA have classified Wyoming as having a very high seismic hazard (Case, 1995). While the classification is in large part due to the seismic hazard in Yellowstone National Park and western Wyoming, the hazard in the rest of the State was also considered. Historically, earthquakes have occurred in every county in the State.

The Wyoming State Geological Survey (WSGS), FEMA, and WEMA have published a number of articles, brochures, and books on earthquake awareness and preparedness. All the publications listed below are available through the WSGS and some are also available through the WEMA in Cheyenne:

“How to Make Your Wyoming Home More Earthquake Resistant.” Available through the WSGS. Published in *Wyoming Geo-notes No. 48*, p. 41-47. Free copy of article.

“Family Earthquake Safety Home Hazard Hunt and Drill.” Available through the WSGS. Published by the American Red Cross and FEMA, as FEMA 113. Free.

"Seismic Considerations for Communities at Risk." Available through the WSGS and WEMA. Published by FEMA, as FEMA 83. Free.

"Relationship Between Wyoming's Seismic Hazard and the Uniform Building Code." Available through the WSGS. Published in *Wyoming Geo-notes No. 47*, p. 51-55. Free copy of article.

"Earthquake Epicenters and Suspected Active Faults with Surficial Expression in Wyoming." Map available through the WSGS, as Preliminary Hazards Report 97-1. Map cost is \$1.50.

"Earthquakes and Active Faults in Wyoming." Available through the WSGS, as Preliminary Hazards Report 97-2. Report cost is \$9.25.

### References Cited

Case, J.C., 1995, Relationship between Wyoming's seismic hazard and the Uniform Building Code *in* Geologic hazards: Wyoming State Geological Survey, Wyoming Geo-notes No. 47, p. 51-55.

Case, J.C., 1997, Historical seismicity of south-central and southeastern Wyoming *in* Geologic hazards: Wyoming State Geological Survey, Wyoming Geo-notes No. 56, p. 54-59.

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## ROCK HOUND'S CORNER

by W. Dan Hausel,  
*Senior Economic Geologist, Wyoming State Geological Survey*

### **ALUMINO-SILICATE MINERALS (ANDALUSITE, CORDIERITE, KYANITE, SILLIMANITE, STAUROLITE) IN WYOMING**

Several of Wyoming's mountain ranges contain large regions of moderate to relatively high-grade metamorphic rock that was deeply buried during the geologic past. The lithostatic pressure from the thick pile of sedimentary rocks that buried these terranes resulted in metasomatic alteration of the rocks. In other words, the minerals in these rocks slowly changed to other minerals more suited to withstand the higher pressure and temperature.

In particular, many alumina-rich sedimentary rocks (such as shales) were greatly affected. Under the thick pile of sedimentary rock, these slowly changed to mica-schists with a distinct schistose fabric. In addition to mica, many of these schists also grew porphyroblasts of large crystals with aluminum-rich silicate minerals, known simply as alumino-silicates.

Much later in geologic history, dramatic forces within the earth uplifted large blocks of rock for many miles along faults, producing many of today's mountain ranges. Erosion has since removed much of the overlying sedimentary rock in those mountain ranges, exposing the old, metamorphic crystalline cores. The *Geologic map of Wyoming* indicates that these ancient Precambrian metamorphic rocks crop out in the cores of several mountain ranges (Love and Christiansen, 1985). Consequently, some of the best places to search for aluminosilicates are where outcrops of these metasedimentary rocks are indicated by the geologic map.

The aluminosilicate minerals are fun to look for, and some produce very attractive mineral and rock specimens. Some of my favorites are rock specimens with abundant sky-blue kyanite crystals; rocks in the South Pass area of the Wind River Range with porphyroblasts of andalusite and cordierite that have been called peanut schists; staurolite crosses in mica schists; and some gem-quality, sapphire-blue crystals of cordierite found west of Wheatland.

Aluminosilicate minerals that often are found in porphyroblasts (large metamorphic crystals) include andalusite, cordierite, kyanite, sillimanite, and staurolite. Usually, one or more of these aluminosilicates occur in the same metamorphic terrane and can provide a general barometer of the intense pressure and temperature that the mica schist was subjected to during the geologic past.

Three of these aluminosilicates are polymorphs. That is, they have the same chemical composition, but have a different crystal structure. Andalusite, kyanite, and sillimanite are polymorphs with the general chemical composition of  $Al_2(SiO_5)$ . Andalusite occurs as an orthorhombic mineral that forms dull, rough, prismatic crystals with square cross sections. Most often it is partially replaced by sericite (a fine-grained white mica). Most andalusite found in Wyoming is opaque, grey, to brown. Brownish-pink, white, rose-red, red-brown, green, yellow, and violet andalusite crystals have been reported elsewhere in the country. Andalusite has a hardness of 6.5 to 7.5 and specific gravity of 3.1 to 3.2. But because of the common partial replacement of andalusite by sericite, the specific gravity may be relatively low. Its hardness is also difficult to determine because of the softer sericite mica.

Kyanite is the triclinic polymorph. Kyanite often forms distinct light- to ocean-blue, bladed, opaque crystals with a specific gravity of 3.5 to 3.65. Good crystals of kyanite have a unique hardness, which is useful in identifying this mineral. Parallel to the greatest length of the crystal [(c-axis) or  $m(001)$ ], it has a hardness of 5 and can be scratched with a pocketknife. However, in the direction of the short axis, it has a hardness of 7 and can not be scratched with a pocketknife unless the mineral is altered or weathered. In other words, there should be a noticeable difference in the mineral's hardness depending on the direction it is scratched. This, along with its distinctive blue color, is useful in identifying kyanite.

Sillimanite, another orthorhombic polymorph, forms slender, prismatic, or fibrous white, colorless, to a very light green crystals with vitreous to silky luster. Sillimanite has a hardness of 6.5 to 7.5 and specific gravity of 3.23 to 3.27.

Staurolite, is another porphyroblast that is occasionally found in Wyoming. It is a complex aluminosilicate with the following chemical composition:  $(\text{Fe}, \text{Mg})_2(\text{Al}, \text{Fe})_9\text{O}_6(\text{SiO}_4)_4(\text{O}, \text{OH})_2$ . It is a monoclinic mineral with a hardness of 7 to 7.5, and commonly forms distinct brown, to yellow-brown, cruciform (cross-like) twins, although it may also occur as flat, elongated crystals. It is typically associated with kyanite, muscovite mica, and almandine garnet.

Cordierite is often found in the vicinity of other aluminosilicates. Cordierite  $(\text{Mg}, \text{Fe}^{2+})_2\text{Al}_4\text{Si}_5\text{O}_{18}$ , is an orthorhombic mineral that forms short prismatic pseudo-hexagonal crystals with rectangular cross sections, as well as massive, compact, mineral grains of various shades of blue, bluish-violet, grey, or brown. According to Sinkankas (1964), repeated twinning on  $m\{110\}$  produces cordierite crystals of nearly hexagonal (six-sided) cross section. Cordierite exhibits poorly developed cleavage, but parting parallel to  $m\{001\}$  may occur in some altered crystals. When unaltered, cordierite will have a hardness of 7 and low specific gravity of 2.55 to 2.75 (the specific gravity increases with increasing iron content). Sinkankas (1964) reports the specific gravity for transparent gem-quality cordierite is 2.57-2.61.

Most cordierite in Wyoming occurs as poor-quality opaque to translucent, white-grey to brown porphyroblasts in mica schist. When found as a gemstone, the mineral forms translucent to transparent cordierite known to gemologists as *iolite*, or *dichroite*. Gem-quality cordierite was unknown in Wyoming, until Hausel (1998) first identified it in the Palmer Canyon area of the Laramie Mountains west of Wheatland in eastern Wyoming.

Iolite has oily to vitreous luster, is sapphire-blue in color, and has marked pleochroism. When a mineral exhibits pleochroism, its color changes, depending on the direction from which it is viewed. As a result, the color of iolite varies from sapphire blue to violet blue.

Areas where these aluminosilicates have been reported in Wyoming include Copper Mountain in the Owl Creek Mountains (Hausel and others, 1985), South Pass in the Wind River Range (Hausel, 1991), the Seminole Mountains (Hausel, 1994), the Elmers Rock greenstone belt (Graff and others, 1985), and the Sierra Madre mountains. Hausel and Sutherland (1998) provide more detailed descriptions of these occurrences.

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Graff, P.J., Sears, J.S., Holden, G.S., and Hausel, W.D., 1982, Geology of the Elmers Rock greenstone belt, Laramie Range [sic], Wyoming: Wyoming State Geological Survey Report of Investigations 14, 28 p.

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- Hausel, W.D., and Sutherland, W.M., 1998, Preliminary report on gemstones, semi-precious stones, lapidary materials, ornamental stones, and other unique minerals and rocks of Wyoming- a collectors' guide: Wyoming State Geological Survey Mineral Report MR98-3, 170 p.
- Love, J.D., and Christiansen, A.C., 1985, Geologic map of Wyoming: U.S. Geological Survey map, scale 1:500,000.
- Sinkankas, J., 1964, Mineralogy: Van Nostrand Reinhold Company, New York, 585 p.
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## **NEW PUBLICATIONS BY THE WYOMING STATE GEOLOGICAL SURVEY**

- \*Oil and gas map of the Powder River Basin, Wyoming, by R.H. De Bruin, 1999: Map Series 51 - \$25.00, plotted color map, rolled only; also available on CD-ROM (please call for details and prices).
- Coalbed methane activity in the eastern Powder River Basin, Campbell and Converse Counties, Wyoming, by R.H. De Bruin, R.M. Lyman, and L.L. Hallberg, 1998: Coalbed Methane Map CMM 98-1 - \$25.00, rolled only.
- \*A self-guided geologic tour of the Chief Joseph Scenic Highway and surrounding area, northwestern Wyoming, by H.P. Heasler, C. Jaworowski, R.W. Jones, R.H. De Bruin, and A.J. Ver Ploeg, 1986: Public Information Circular 35 (Second printing) - ISBN 1-884589-09-X, \$15.00.

Digital geologic map of the Cheyenne 30' x 60' Quadrangle, southeastern Wyoming, western Nebraska, and northern Colorado, by A.J. Ver Ploeg, J.C. Case, and C.A. Jessen, 1998: Geologic Hazards Section Digital Map HSDM 98-2 - \$10.00 on CD-ROM for PC-based computers using Windows 95/98 or Windows NT; \$25.00 for plotted color map only.

Preliminary digital surficial geologic map of the Casper 30' x 60' Quadrangle, Natrona and Converse Counties, Wyoming, by J.C. Case, L.L. Hallberg, and C.A. Jessen, 1998: Geologic Hazards Section Digital Map HSDM 98-3 - \$10.00 on CD-ROM for PC-based computers using Windows 95/98 or Windows NT; \$25.00 for plotted color map only.

Preliminary digital surficial geologic map of the Cheyenne 30' x 60' Quadrangle, southeastern Wyoming, western Nebraska, and northern Colorado, by J.C. Case, L.L. Hallberg, and C.A. Jessen, 1998: Geologic Hazards Section Digital Map HSDM 98-4 - \$10.00 on CD-ROM for PC-based computers using Windows 95/98 or Windows NT; \$25.00 for plotted color map only.

Preliminary digital surficial geologic map of the Laramie 30' x 60' Quadrangle, Albany and Laramie Counties, Wyoming, by J.C. Case, L.L. Hallberg, and C.A. Jessen, 1998: Geologic Hazards Section Digital Map HSDM 98-5 - \$10.00 on CD-ROM for PC-based computers using Windows 95/98 or Windows NT; \$25.00 for plotted color map only.

Preliminary digital surficial geologic map of the Rawlins 30' x 60' Quadrangle, Carbon and Sweetwater Counties, Wyoming, by J.C. Case, L.L. Hallberg, and C.A. Jessen, 1998: Geologic Hazards Section Digital Map HSDM 98-6 - \$10.00 on CD-ROM for PC-based computers using Windows 95/98 or Windows NT; \$25.00 for plotted color map only.

[Note: Geologic Hazards Section Digital Maps HSDM 98-2 through 98-6 are also available on one CD-ROM for \$40.00; a set of all five separate CD-ROMs (purchased at one time) are also \$40.00.]

Preliminary report on gemstones, semi-precious stones, lapidary materials, ornamental stones, and other unique minerals and rocks of Wyoming, by W.D. Hausel and W.M. Sutherland, 1998: Mineral Report MR 98-3 - \$26.00.

Each geologic section of the Survey now prepares and releases some of its own numbered reports and maps. Please contact the following Staff Geologists for coverage, availability, prices, or further information on specific commodities or topics [Phone: (307) 766-2286; FAX: (307) 766-2605; or use the Email addresses included below]:

James C. Case - Geologic hazards and environmental geology

(Email: [jcase@wsgs.uwyo.edu](mailto:jcase@wsgs.uwyo.edu))

Rodney H. De Bruin - Oil and gas

(Email: [rdebru@wsgs.uwyo.edu](mailto:rdebru@wsgs.uwyo.edu))

Ray E. Harris - Industrial minerals and uranium

(Email: [rharri@wsgs.uwyo.edu](mailto:rharri@wsgs.uwyo.edu))

W. Dan Hausel - Metals and precious stones  
(Email: dhause@wsgs.uwyo.edu)  
Robert M. Lyman- Coal  
(Email: blyman@wsgs.uwyo.edu)  
Alan J. Ver Ploeg - Geologic mapping and stratigraphy  
(Email: averpl@wsgs.uwyo.edu)

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

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## **OTHER PUBLICATIONS NOW AVAILABLE FROM THE WYOMING STATE GEOLOGICAL SURVEY**

Interpreting the landscapes of Grand Teton and Yellowstone National Parks- Recent and ongoing geology, by J.M. Good and K.L. Pierce, 1996: Published by Grand Teton Natural History Association – ISBN 0-931895-45-6, \$12.95.

Geologic and historic guide to the Beartooth Highway, Montana and Wyoming, by H.L. James, 1995: Montana Bureau of Mines and Geology Special Publication 110 - \$20.00.

Roadside geology of Wyoming: by D.R. Lageson and D.R. Spearing, 1988: published by Mountain Press Publishing Company - ISBN 0-87842-216-1, \$9.95.

Order these and other publications from: Wyoming State Geological Survey, P.O. Box 3008, Laramie, Wyoming 82071-3008. Phone: (307) 766-2286; Fax (307) 766-2605; and Email: <sales@wsgs.uwyo.edu>. An order form is also included at the back of this issue of *Wyoming Geo-notes*. Many of these publications are also available over-the-counter at the Wyoming Oil and Gas Conservation Commission (Basko Building) in Casper, Wyoming. A free list of publications is available on request.

### **Wyoming Topographic Maps on CD-ROMS**

The Wyoming State Geological Survey is now a dealer for *All Topo Maps: Wyoming*, published by iGage. This is a packaged set of four CD-ROMs that contain all 1,885 U.S. Geological Survey quadrangle maps in Wyoming at a scale of 1:24,000 and 24 1° x 2° AMS (Army Map Service) quadrangles in Wyoming at a scale of 1:250,000. The maps are scanned digital raster images of the information contained on the topographic maps, including all the marginal data surrounding each quadrangle. Some of the many features of this product include:

- Compatible with Windows 95/98/NT and will run on 486 PC machines as well as on Macintosh machines with Virtual PC emulator. Requires at least 60MB of hard disk space, 2X/4X or higher CD-ROM reader, and a pointing device.
- Supports graphics-capable black and white/color printers that are supported by Windows. Can export to a clipboard and to many graphics programs.
- Viewing software has a continuous GPS coordinate display for cursor location; users can double click on a map border to move to an adjacent map; the display allows map annotations, zooming from 25% to 200%, and the printing and exporting of maps or sections of maps.
- Built in place-name and map-name databases allow searches by name or part of name to locate map features and/or retrieve maps.
- Continuous coordinate display options include latitude/longitude, UTM, and military grid systems. True geo-referenced maps allow continuous straight line and path tracing measurements in feet, meters, and miles. The software allows unlimited waypoints, the ability to jump to any entered waypoint, and a waypoint editor.
- Will be able to combine the set of Wyoming maps with similar coverages for Colorado, Utah, Idaho, and Montana (in press).

The set of four CD-ROMs sells for \$125.00; Wyoming addresses must include 6% sales tax. Available over-the-counter or prepaid only. For more information and a description of other features, please contact the Survey's sales office in Laramie.



### **Other Maps**

The Wyoming State Geological Survey carries U.S. Bureau of Land Management (BLM) Surface Management Status maps for the 1:100,000-scale metric topographic quadrangles in Wyoming- \$6.50 each. Coverage and inventory may be limited for specific areas; please call for map availability.

These maps (plus other topographic maps of Wyoming) are available over-the-counter at the Survey offices in Laramie or by mail. We do not offer quantity discounts and can make no exchanges or refunds on USGS or BLM maps. Sales tax of 6% is added to all sales for Wyoming addresses. Postage and additional charges for map tubes for rolled maps are added on when appropriate.

## **STATE GEOLOGICAL SURVEY INITIATES A SUMMER FIELD TRIP**

Have you ever wondered why the Medicine Bow Mountains exist, how they formed, and what shaped the spectacular peaks of the Snowy Range? Are you curious about the findings of historic gold prospectors and miners in these mountains and why the region is attracting modern prospectors? Are you interested in diamonds, gold, platinum, and palladium? Or are you interested in general geology, ground water, oil and gas, or other mineral resources in the area?

If you answered yes to any of these questions, then the State Geologist of Wyoming and the staff of the Wyoming State Geological Survey invite you to join them on Friday, August 20, 1999, for a geologic tour. This is the first of what is planned as an annual Geological Survey-sponsored field trip to an interesting part of Wyoming. The theme of these field trips is "Get to know your State's geologists, geology, and resources."

For this summer (1999), Wyoming citizens will have an opportunity to learn about the geology, geomorphology, glaciation, geologic hazards, mining history, and energy and mineral resources of the Medicine Bow Mountains and surrounding area. There will also be a chance for participants to do gold panning in a historic gold district.

The field trip will leave Laramie at 7:30 AM and head due west on State Highway 130 to Encampment. The return route will take State Highway 230 to Mountain Home and Foxpark. The trip proceeds north to Douglas Creek on Forest Service roads and continues east to Albany. Finally, the trip rejoins Highway 130 at Sheep Mountain and returns to Laramie. A guidebook to the area was published by the Wyoming State Geological Survey as Public Information Circular 32, *"Guide to the geology, mining districts, and ghost towns of the Medicine Bow Mountains and Snowy Range Scenic Byway,"* and is recommended for the trip.

Space is available for 75 people (reservations are needed). No geologic training or experience is assumed or required. The cost of the trip (which includes transportation, lunch, and beverages) is only \$15. For reservations, contact UW Conferences and Institutes at 800/448-7801, extension 121, or locally, 766-5249, and ask for Tom Barnett. For information on the field trip route or activities, contact W. Dan Hausel or Ray Harris at the Wyoming State Geological Survey at 307/766-2286.

# **-CALL FOR PAPERS-**

## **on the GEOLOGY OF WYOMING**

1999 Joint Conference  
Wyoming State Geological Survey  
Dept. of Geology and Geophysics, University of Wyoming  
Wyoming Geological Association

October 14 and 15, 1999

Wyoming Union, University of Wyoming campus  
Laramie, Wyoming

Papers and posters are invited on any aspect of the geology of Wyoming. Planned conference sessions include: Precambrian geology; Phanerozoic geology and paleontology; Industrial minerals, oil, gas, coal, and coalbed methane resources of Wyoming; and economic (hard rock) geology, metals, and gemstone resources of Wyoming.

Papers presented can be: (1) 25-minute oral presentations (20 minutes plus 5 minutes for questions), and/or (2) Posters on geological research and field projects.

Abstracts or extended abstracts will be available for registrants at the conference. Abstracts are due by September 1, 1999. Full papers are due November 1, 1999 and will be published in a proceedings volume by the Wyoming State Geological Survey in Year 2000. Please contact the Editor, Wyoming State Geological Survey for formats and editorial standards for abstracts and papers.

### *Conference Registration Fees - \$35*

For more information contact the following Chairpersons:

- Carol Frost - Precambrian geology (307/766-6265);
- Ray Harris - Phanerozoic geology and paleontology, industrial and energy mineral resources (307/766-2286);
- Dan Hausel - Economic geology, metals, and gemstone resources (307/766-2286).



Wyoming State Geological Survey  
P.O. Box 3008  
Laramie, Wyoming 82071-3008