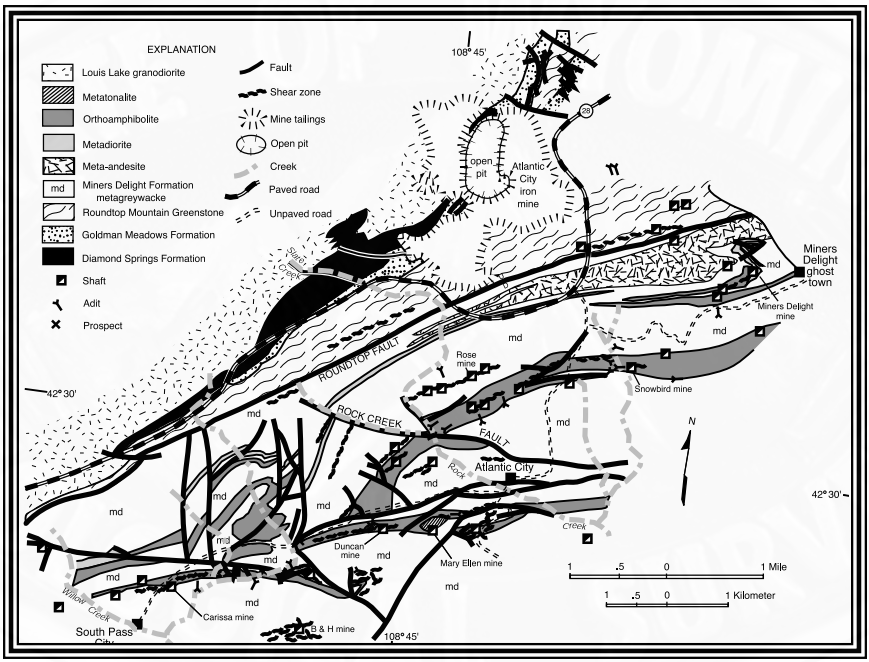
Wyoming Geo-notes

Number 67



Wyoming State Geological Survey
Lance Cook, State Geologist

Laramie, Wyoming
September, 2000

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Front cover: A generalized geologic map of the South Pass-Atlantic City mining district, as published in the new Bulletin 71 (Gemstones and other unique minerals and rocks of Wyoming). The district is important for historical gold discoveries and production as well as recent gold discoveries near the Carissa mine near South Pass City and Miners Delight to the east (see METALS AND PRECIOUS UPDATE, pages 43, 45, and 46).

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MINERALS UPDATE

OVERVIEW AND GENERAL COMMENTS

Lance Cook
State Geologist, Wyoming State Geological Survey

Coalbed methane continues to make headlines in Wyoming. Following this brief column is our August 8, 2000 press release on new coalbed methane resources for the Powder River Basin (PRB), Wyoming. To put the new recoverable resource figures into perspective, consider that the remaining natural gas resources for the Gulf of Mexico, including those in deep water, is estimated to be about the same as Wyoming's coalbed methane resource of 25 trillion cubic feet (TCF). This 25 TCF of recoverable gas reserves is equal to about 4.16 billion barrels of oil. We believe that the PRB coalbed methane play will produce a stable stream of income for Wyoming and its citizens for many years to come.

In the future, natural gas will become the bright spot in Wyoming's mineral industry. As more gas-fired electrical generating capacity is constructed nation wide, the demand for natural gas will increase. A 30 TCF per year gas demand is projected for the U.S. 10 years from now; currently, producers can supply about 22 to 24 TCF per year. Maintaining the current natural gas production level in the year 2010 plus adding another 6 to 8 TCF per year of production will require major capital expenditures at levels not seen since the mid-1980s.

Wyoming is well positioned from both a resource- and producer-based perspective to participate in the above activity. The increase in demand-driven activity is predicated on higher prices for energy, which many forecasters are suggesting. As an indication of how uncertain the future is for gas supplies to meet the 30 TCF per year target, those in industry are talking about a project to move gas from Alaska's North Slope to the lower 48 states. That gas won't be cheap, suggesting that natural gas will enjoy higher prices in the future.

Coalbed methane is not the only area of growth in natural gas for Wyoming. Jonah Field in southwestern Wyoming is growing, Madden Field in the Wind River Basin is growing, and new technological applications may help unlock tight gas resources (those contained in low-permeability, low-porosity reservoirs) that Wyoming is so rich in. Wyoming is headed towards another year of increased natural gas production, a trend that we expect to continue for years to come (**Table 1**). Based on the amount of activity related to the development of natural gas in the state, if the price of natural gas continues to climb, the revenue from its sale bodes well for Wyoming, and may help offset falling revenues elsewhere.

While most of our forecasts have not changed since the last quarter, there are indications that by year's end, we may see some changes in our projections, especially in oil and natural gas. Second-quarter developments that affect Wyoming's mineral production (**Table 1**) and prices (**Table 2**) are summarized in the individual update sections that follow.

Table 1. Wyoming mineral production (1985-1999) with forecasts to 2006[1].

Calendar Year	Oil[2,3]	Methane[3,4]	Carbon Dioxide[3,4]	Helium[4,5]	Coal[6]	Trona[7]	In-situ Uranium[7,8]	Sulfur[3,9]
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	1,040.7	151.0	1.10	281.5	19.4	2.2	1.23
1998	65.7	1,072.6	151.0	1.10	314.9	18.6	2.3	1.20
1999	61.4	1,130.9	161.0	1.10	336.5	17.8	2.8	1.20
2000	57.4	1,137.1	161.0	1.10	347.1	19.5	1.8	1.20
2001	54.3	1,163.1	161.0	1.10	352.3	20.0	1.6	1.20
2002	51.3	1,189.6	161.0	1.10	355.8	20.0	1.6	1.20
2003	48.5	1,216.6	161.0	1.10	359.4	21.1	1.6	1.20
2004	45.8	1,244.2	161.0	1.10	363.0	22.0	1.6	1.20
2005	43.3	1,272.3	161.0	1.10	366.6	22.0	1.6	1.20
2006	40.9	1,301.0	161.0	1.10	370.3	22.0	1.6	1.20

[1]Modified from CREG's Wyoming State Government Revenue Forecast, February, 2000; [2]Millions of barrels; [3]Wyoming Oil & Gas Conservation Commission, 1985-1999; [4]Billions of cubic feet; [5]Based on Exxon's estimate that the average helium content in the gas processed at Shute Creek is 0.5%; [6]Millions of short tons (Wyoming State Inspector of Mines, 1985-1999); [7]Wyoming Department of Revenue, 1985-1999; [8]Millions of pounds of yellowcake (not available [N/A] for 1985 and previous years because it was only reported as taxable value); [9]Millions of short tons.

Press Release–August 8, 2000

COALBED METHANE RESOURCES IN POWDER RIVER BASIN MORE THAN DOUBLED

New data indicate that about 25 trillion cubic feet (TCF) of coalbed methane may be recoverable from coal beds in the Powder River Basin, Wyoming. This eclipses previous estimates of recoverable gas that ranged from 9 to 12 TCF; and the new estimate represents a significant increase in coalbed methane resources for the area and for Wyoming.

The data were made available to the State of Wyoming by Goolsby and Associates of Casper, a geologic consulting and exploration firm, and are based on information from 8,600 wells. The new resource data provide an up-to-date assessment of the coalbed methane resource within the Powder River Basin and represent the integration of coal thicknesses, coal depths, and gas saturation data.

Wyoming Governor Jim Geringer commented that "the new reserve estimate will help secure Wyoming's position as one of the nation's top energy producers for years to come. The 25 TCF of gas in the Powder River Basin coal beds is a world-class resource. In view of the environmentally positive aspects of methane as a clean fuel, this is also good news for our environment. With the cooperation of our State agencies, our citizens, and the coalbed methane industry, this resource can be a positive factor in Wyoming's future for years to come."

According to State Geologist Lance Cook, "the new resource estimates are based on gas yields from coals at specific depths as well as accurate estimates

Table 2. Average prices paid for Wyoming oil, methane, coal, and trona (1985-1999) with forecasts to 2006[1].

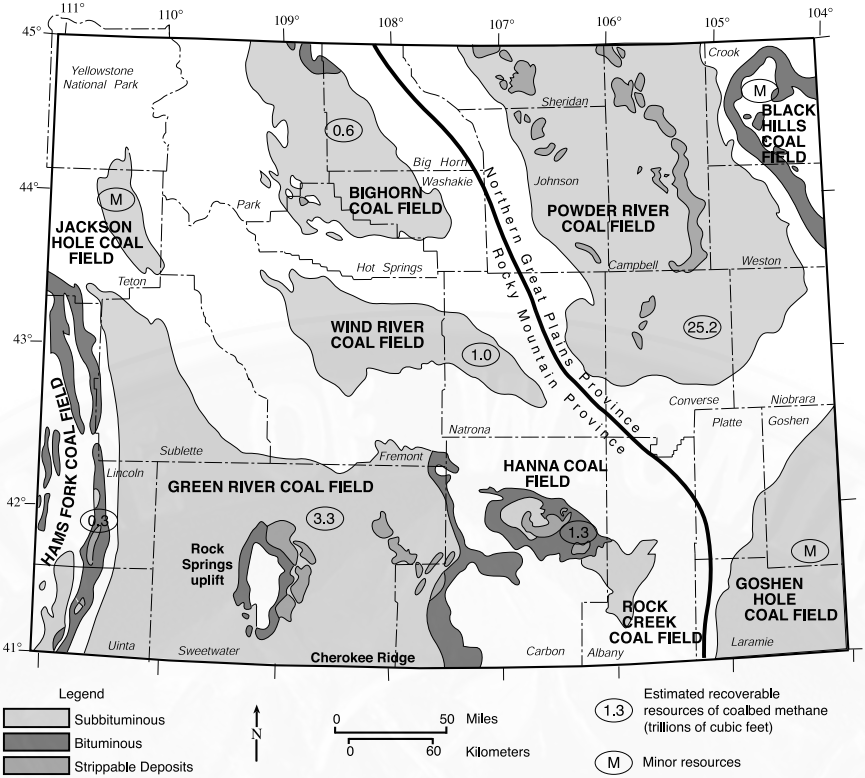
Calendar Year	Oil[2]	Methane[3]	Coal[4]	Trona[5]
1985	24.67	3.03	11.36	35.18
1986	12.94	2.33	10.85	34.80
1987	16.42	1.78	9.80	36.56
1988	13.43	1.43	9.16	36.88
1989	16.71	1.58	8.63	40.76
1990	21.08	1.59	8.43	43.70
1991	17.33	1.46	8.06	44.18
1992	16.38	1.49	8.13	43.81
1993	14.50	1.81	7.12	40.08
1994	13.67	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	5.41	41.29
1999	16.44	2.06	5.14	37.58
2000	15.00	1.85	5.13	37.81
2001	15.00	1.85	4.99	38.32
2002	15.00	1.85	4.99	38.86
2003	15.00	1.85	5.03	39.36
2004	15.00	1.85	5.05	39.64
2005	15.00	1.85	5.07	39.64
2006	15.00	1.85	5.08	39.64

[1]Modified from CREG, Wyoming State Government Revenue Forecast, February, 2000; [2]First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Source: Energy Information Administration, 1985-1999; [3]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); [4]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, 1991-1999; [5]Dollars per ton of trona, not soda ash. Source: Wyoming Department of Revenue, 1985-1998.

of the amount of coal in place, utilizing data from the relatively recent drilling in those areas being developed for the coal gas resource. We are excited at the size of this resource and believe that it will have a positive impact on the State and its citizens."

The increased reserves will have several important impacts. The income to the State of Wyoming just from royalties and severance taxes is estimated to total $7.5 billion. Market forces may demand a daily production rate of 2 billion cubic feet of gas per day. This rate provides a reserve/production ratio of about 35 years, and suggests that the State of Wyoming will receive a substantial revenue stream for an extended period of time. The $7.5 billion income figure does not include additional revenue such as ad valorem taxes, sales and use taxes for equipment, and payroll multiplier effects. Additionally, benefits are expected from royalty payments made to private mineral owners, who will see a substantial economic reward from development.

Coal fields, rank of coal, and recoverable resources of coalbed methane in Wyoming. Data for resources in the Powder River Basin are from Goolsby and Associates (July, 2000) for coals greater that 20 feet thick and deeper than 200 feet (assuming a recovery factor of 67%). Other data are from the Gas Research Institute (1999) and the Wyoming State Geological Survey (2000).



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OIL AND GAS UPDATE

Rodney H. De Bruin
Staff Geologist–Oil and Gas, Wyoming State Geological Survey

Production and prices

The average price paid for Wyoming crude oil in June of $28.50 (**Table 3**) was the highest average monthly price in the last four years (**Figure 1**). Prices paid to Wyoming oil producers during the second quarter of 2000 averaged $25.83 per barrel, $10.87 higher than for the second quarter of 1999. Crude oil prices may drop somewhat in the third quarter of 2000 since Saudi Arabia has hinted that it will increase production by 0.5 million barrels per day. The production increase of 1.7 million barrels per day from the Organization of Petroleum Exporting Countries (OPEC) had very little effect on crude oil prices in the second quarter, except for April when the increase was announced.

Table 3. Monthly average price of a barrel of oil produced in Wyoming (1997 through July, 2000).

	1997		1998		1999		2000	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	$22.56	$22.56	$12.79	$12.79	$9.30	$9.30	$23.94	23.94
FEB	$19.45	$21.01	$12.16	$12.48	$9.09	$9.20	$26.40	$25.17
MAR	$17.99	$20.00	$10.97	$11.97	$11.77	$10.05	$27.00	$25.78
APR	$16.81	$19.20	$11.54	$11.87	$14.34	$11.13	$22.92	$25.16
MAY	$17.74	$18.91	$11.19	$11.73	$15.16	$11.93	**$26.07**	**$25.34**
JUN	$15.90	$18.41	$9.63	$11.38	$15.36	$12.50	**$28.50**	**$25.87**
JUL	$16.29	$18.11	$10.20	$11.21	$17.39	$13.20	**$27.00**	**$26.03**
AUG	$16.61	$17.92	$9.58	$11.01	$18.43	$13.86		
SEP	$16.42	$17.75	$11.19	$11.03	$20.97	$14.65		
OCT	$17.89	$17.77	$11.04	$11.03	$20.01	$15.18		
NOV	$16.51	$17.65	$9.64	$10.90	$22.20	$15.82		
DEC	$14.72	$17.41	$8.05	$10.67	$23.22	$16.44		
Avg. yearly price	**$17.41**		**$10.67**		**$16.44**			

Source: All averages are derived from published monthly reports by the Energy Information Administration, except that averages in bold print for 2000 are estimated from various unpublished bulletins listing posted prices.
Wyoming State Geological Survey, Oil and Gas Section, July, 2000.

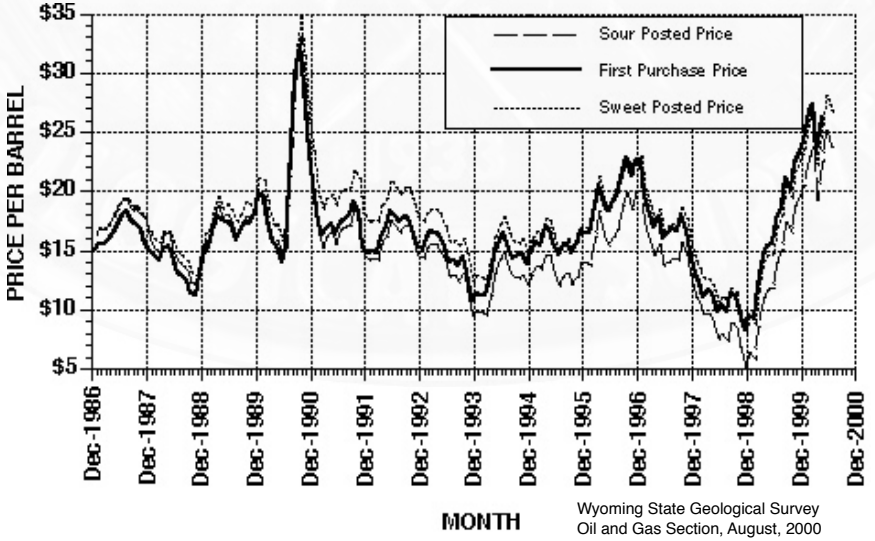

Figure 1. Wyoming posted sweet and sour crude oil prices and first purchase prices, averaged by month (January, 1987 through July, 2000).

Oil production in Wyoming for the first quarter of 2000 was 15.2 million barrels (**Table 4**), according to figures from the Wyoming Oil and Gas Conservation Commission (WOGCC). This production is a drop of only 1.2% from the first quarter of 1999. The decline in production has moderated over the past several months because of higher prices for Wyoming oil.

The spot price for natural gas at Opal, Wyoming was the highest second quarter price ever recorded in Wyoming, averaging $3.02 during the second quarter of 2000. This is $1.15 higher than the average price for the second quarter of 1999 (**Table 5** and **Figure 2**).

Natural gas production in Wyoming for the first quarter of 2000 was 354.1 billion cubic feet (BCF) according to production figures from the WOGCC. This production is up 12.9% from the first quarter of 1999 (**Table 6**). Coalbed methane production from the Powder River Basin (PRB) accounted for 27.0 BCF or 7.6% of Wyoming's first quarter total.

We have not yet changed our forecasts for either oil and gas production (**Figures 3** and **4**) or for oil and gas prices (**Figures 5** and **6**) since the last Wyoming Geo-notes (No. 66, June, 2000).

Industry projects and transactions

Williams Energy Services completed an expansion project at its natural gas plant in Opal, Wyoming. A third cryogenic processing train was added, two existing cryogenic trains were modified, and control systems and field compression were enhanced. The expansion costs exceeded $60 million and boosted processing capacity to 735 million cubic feet (MMCF) of gas per day and natural gas liquids extraction capacity to 43,000 barrels per day. The expansion makes the facility one of the largest producers of natural gas liquids in the United States.

Trailblazer Pipeline had an open season to determine if extension and/or expansion of its gas transmission system are warranted. Trailblazer proposed two projects and shippers were invited to bid on one or both. Based on the bids, Trailblazer will inform shippers which project or combination of projects it intends to develop. The proposed extension/expansion project would begin in Glenrock, Wyoming, interconnect with Thunder Creek, Kansas-Nebraska Interstate, and Fort Union pipelines, and ultimately end in Gage County, Nebraska. This project would require installation of 149 miles of 24-inch pipeline and construction of additional compression facilities.

The expansion project starts at Rockport, Colorado and terminates in Gage County, Nebraska. This project would require two new compressor stations, additional horsepower at an existing compressor station, and possibly a 36-inch loop. Either project or a combination of projects would help Wyoming producers market their natural gas.

Devon Energy and Santa Fe Snyder have agreed to merge in a deal that would create one of the largest independent oil and gas companies in the U.S. in terms of market capitalization, total proved reserves, and annual production. When combined, the company would have total proved reserves of about 1.1 billion barrels of oil

Table 4. Monthly oil production from Wyoming in barrels (1996 through March, 2000).

	1996		1997		1998		1999		2000	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	6,153,037	6,153,037	5,964,848	5,964,848	5,846,364	5,846,364	5,333,197	5,333,197	5,169,474	5,169,474
FEB	5,693,084	11,846,121	5,459,518	11,424,366	5,233,502	11,079,866	4,744,781	10,077,978	4,840,582	10,010,056
MAR	6,176,805	18,022,926	6,014,780	17,439,146	5,759,176	16,839,042	5,296,409	15,374,387	5,176,019	15,186,075
APR	5,977,362	24,000,288	5,729,869	23,169,015	5,534,568	22,373,610	5,065,245	20,439,632		
MAY	6,035,505	30,035,793	6,050,971	29,219,986	5,626,125	27,999,735	5,200,074	25,639,706		
JUN	5,916,019	35,951,812	5,761,549	34,981,535	5,335,463	33,335,198	4,999,440	30,639,146		
JUL	6,076,992	42,028,804	5,964,005	40,945,540	5,464,514	38,799,712	5,163,191	35,802,337		
AUG	6,414,850	48,443,654	5,868,789	46,814,329	5,287,415	44,087,127	5,187,507	40,989,844		
SEP	6,180,180	54,623,834	5,710,557	52,524,886	5,109,053	49,196,180	5,079,840	46,069,684		
OCT	6,186,019	60,809,853	5,949,974	58,474,860	5,274,269	54,470,449	5,161,449	51,231,133		
NOV	6,221,912	67,031,765	5,800,811	64,275,671	5,232,287	59,702,736	5,008,425	56,239,558		
DEC	6,330,701	73,362,466	5,900,791	70,176,462	5,078,909	64,781,645	5,085,618	61,325,176		
Total Barrels Reported [1]		**73,362,466**		**70,176,462**		**64,781,645**		**61,325,176**		
Total Barrels Not Reported [2]		**525,957**		**52,364**		**897,131**				
Total Barrels Produced [3]		**73,888,423**		**70,228,826**		**65,678,776**				

[1] Monthly production reports from Petroleum Information/Dwights LLC, except for 1999 and 2000 which are from the Wyoming Oil and Gas Conservation Commission.

[2] (Total barrels produced) minus (total barrels reported by Petroleum Information/Dwights LLC).

[3] Wyoming Oil and Gas Conservation Commission.

Wyoming State Geological Survey, Oil and Gas Section, July, 2000.

Table 5. Monthly average spot sale price for a thousand cubic feet (MCF) of natural gas at Opal, Wyoming (1997 through July, 2000).

	1997		1998		1999		2000	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	$3.90	$3.90	$2.05	$2.05	$1.80	$1.80	$2.20	$2.20
FEB	$2.50	$3.20	$1.70	$1.88	$1.65	$1.73	$2.40	$2.30
MAR	$1.40	$2.60	$1.90	$1.88	$1.50	$1.65	$2.35	$2.32
APR	$1.45	$2.31	$1.90	$1.89	$1.60	$1.64	$2.70	$2.41
MAY	$1.60	$2.17	$1.95	$1.90	$2.00	$1.71	$2.70	$2.47
JUN	$1.35	$2.03	$1.65	$1.86	$2.00	$1.76	$3.65	$2.67
JUL	$1.45	$1.95	$1.60	$1.82	$2.00	$1.79	$3.90	$2.84
AUG	$1.40	$1.88	$1.75	$1.81	$2.20	$1.84		
SEP	$1.50	$1.84	$1.60	$1.79	$2.60	$1.93		
OCT	$2.05	$1.86	$1.65	$1.78	$2.40	$1.98		
NOV	$3.00	$1.96	$2.00	$1.80	$2.85	$2.05		
DEC	$1.95	$1.96	$2.00	$1.81	$2.10	$2.06		
Avg. yearly price	**$1.96**		**$1.81**		**$2.06**			

Source: American Gas Association's monthly reports.

Wyoming State Geological Survey, Oil and Gas Section, July, 2000.

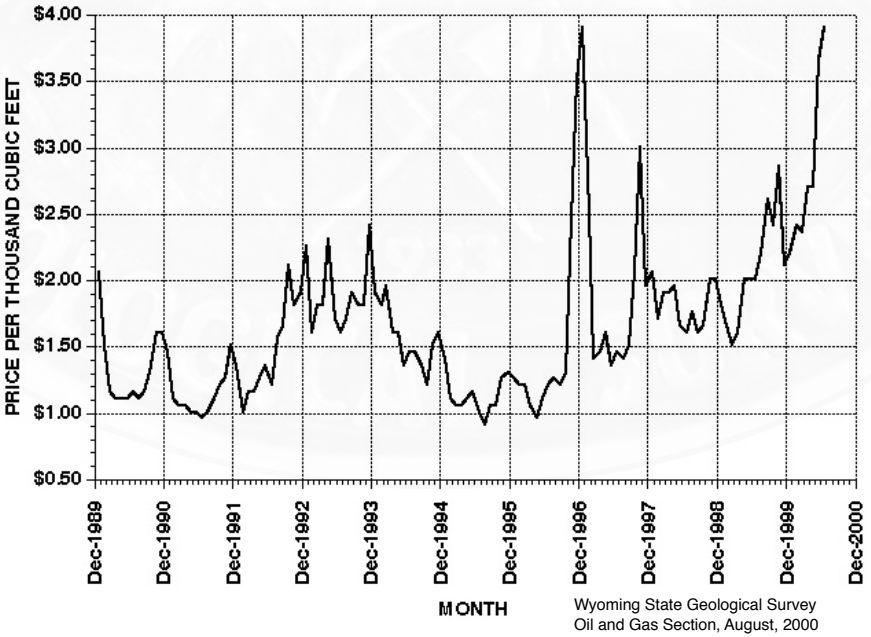

Figure 2. Spot sale prices for methane at Opal, Wyoming, averaged by month (January, 1990 through July, 2000).

Table 6. Monthly natural gas production from Wyoming in thousands of cubic feet (MCF) (1996 through March, 2000).

	1996		1997		1998		1999		2000	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	101,359,648	101,359,648	99,579,818	99,579,818	103,640,214	103,640,214	108,497,612	108,497,612	121,748,109	121,748,109
FEB	96,303,300	197,662,948	91,766,159	191,345,977	94,501,819	198,142,033	94,219,338	202,716,950	111,754,013	233,502,122
MAR	103,541,127	301,204,075	104,157,578	295,503,555	103,906,999	302,049,032	110,966,801	313,683,751	120,590,447	354,092,569
APR	99,479,609	400,683,684	99,459,039	394,962,594	98,201,007	400,250,039	102,145,793	415,829,544		
MAY	97,900,863	498,584,547	101,070,371	496,032,965	96,741,237	496,991,276	104,734,539	520,564,083		
JUN	87,069,612	585,654,159	91,905,308	587,938,273	98,413,520	595,404,796	102,558,416	623,122,499		
JUL	100,219,275	685,873,434	100,129,497	688,067,770	102,055,968	697,460,764	106,556,921	729,679,420		
AUG	99,874,019	785,747,453	97,673,622	785,741,392	105,378,334	802,839,098	107,402,965	837,082,385		
SEP	93,510,551	879,258,004	100,028,888	885,770,280	98,474,782	901,313,880	108,040,059	945,122,444		
OCT	95,441,022	974,699,026	102,206,875	987,977,155	96,470,624	990,880,952	119,404,538	1,064,526,982		
NOV	94,015,007	1,068,714,033	100,752,128	1,088,729,283	103,445,859	1,101,230,363	110,861,984	1,175,388,966		
DEC	99,141,298	1,167,855,331	103,415,430	1,192,144,713	99,339,043	1,200,569,406	119,385,197	1,294,774,163		
Total MCF Reported [1]		**1,167,855,331**		**1,192,144,713**		**1,200,569,406**		**1,294,774,163**		
Total MCF Not Reported [2]		**5,663,874**		**683,432**		**22,955,142**				
Total MCF Produced [3]		**1,173,519,205**		**1,192,828,145**		**1,223,524,548**				

[1] Monthly production reports from Petroleum Information/Dwights LLC except for 1999 and 2000 which are from Wyoming Oil and Gas Conservation Commission.

[2] (Total MCF produced) minus (total MCF reported by Petroleum Information/Dwights LLC).

[3] Wyoming Oil and Gas Conservation Commission.

Wyoming State Geological Survey, Oil and Gas Section, August, 2000.

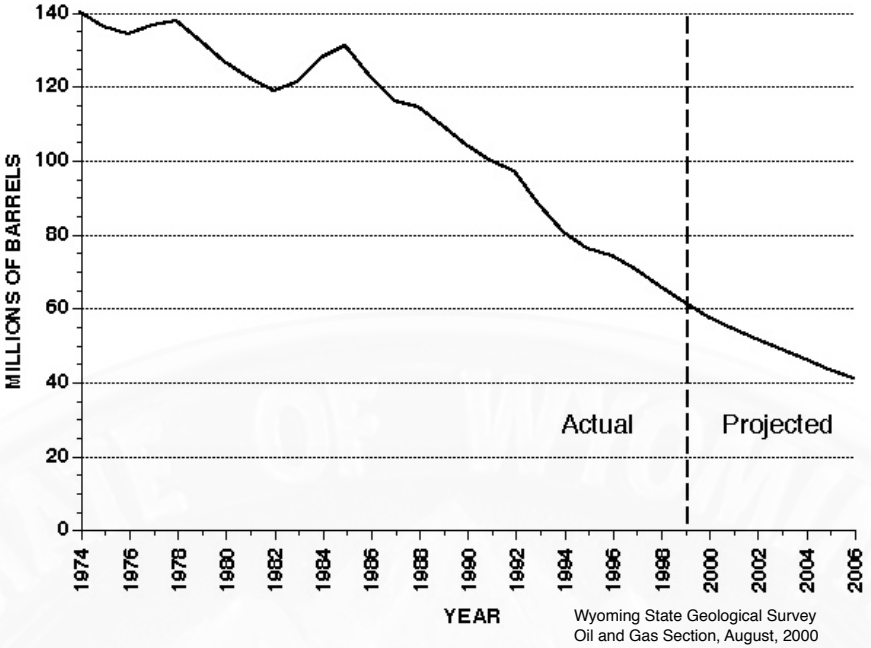

Figure 3. Annual crude oil production from Wyoming (1974 through 1999) with forecasts to 2006.

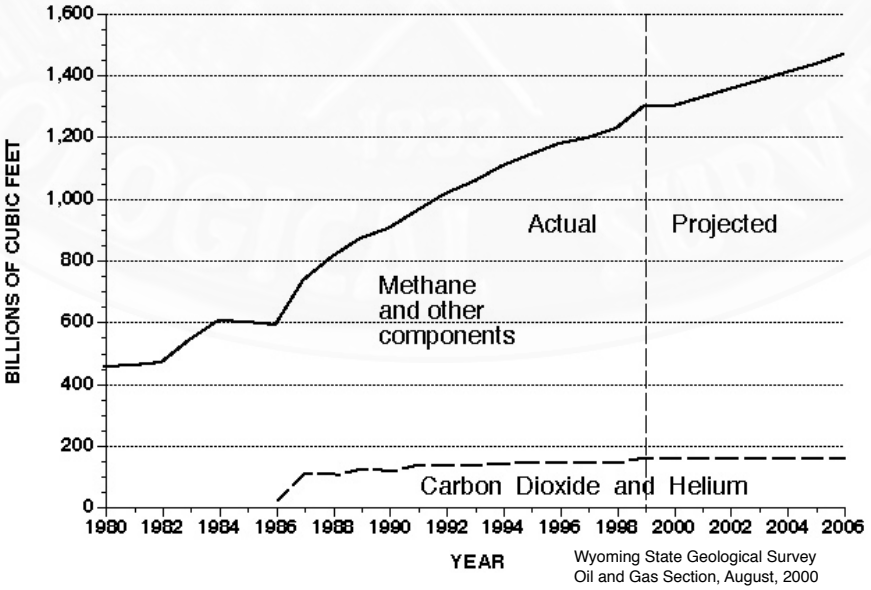

Figure 4. Annual natural gas production from Wyoming (1980 through 1999) with forecasts to 2006.

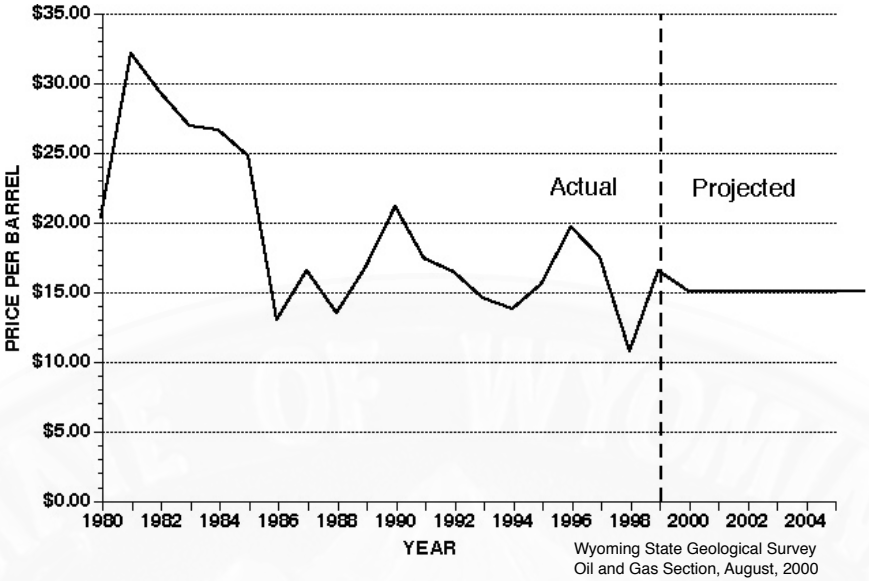

Figure 5. Average prices paid for Wyoming crude oil (1980 through 1999) with forecasts to 2006.

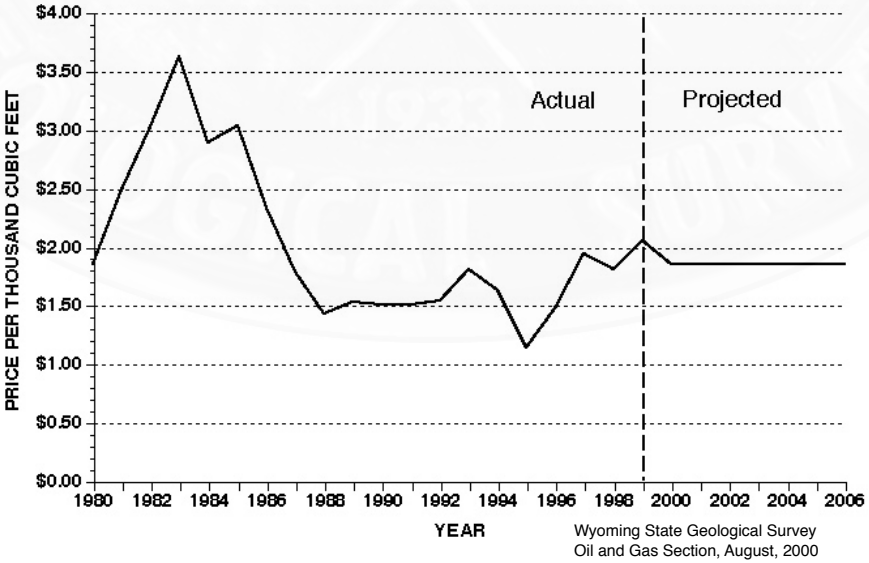

Figure 6. Average prices paid for Wyoming methane (1980 through 1999) with forecasts to 2006.

equivalent. The company will retain the name Devon Energy and will remain based in Oklahoma City. Both companies were active in Wyoming before the merger.

Tom Brown Inc. acquired an additional working interest in Pavillion Field in the Wind River Basin for $16.2 million. The acquired interests include reserves of about 22 BCF of natural gas equivalent and current net daily production of 8 MMCF of gas per day.

Samson Resources paid $34 million to Abraxas Petroleum for working interest in 57 gas wells and a gross leasehold of approximately 15,000 acres in Sweetwater and Carbon counties, Wyoming. Proceeds will be used to fund Abraxas' capital expenditure program for 2000, which is focused primarily on exploitation of existing properties through horizontal drilling. Abraxas has drilled, or is in the process of drilling, several horizontal wells in Brooks Draw Field of the PRB (see item 24 in the Exploration and development section, below).

The U.S. Bureau of Land Management (BLM) began the scoping process for a gas development project in the Desolation Flats area northwest of Baggs, Wyoming. An environmental impact statement (EIS) will be prepared for the project. Marathon Oil and a number of other operators propose to drill as many as 385 wells in the area, which is generally located in Townships (Ts) 13N to 16N, Ranges (Rs) 93W to 96W. The area currently has 68 producing wells, production-related facilities, roads, and pipelines.

The Buffalo Field Office of the BLM has held a number of scoping meetings on the Oil and Gas EIS for the PRB. The EIS is necessary to continue federal oil and gas development in the PRB and to analyze the impacts of this action. The BLM predicted that there will be 35,000 coalbed methane wells in the basin in ten years and as many as 70,000 coalbed methane wells during the lifetime of the play. The schedule calls for the draft EIS to be completed in July, 2001, the final EIS in November, 2001, and the Record of Decision in December, 2001.

The BLM issued a Record of Decision for the Continental Divide/Wamsutter II Natural Gas Project. The Record of Decision allows up to 2130 wells with 1065 of those wells on federal land. The operators in the project area originally proposed 3000 wells; 1500 wells are on federal land. Allowance for the additional 870 wells will be reconsidered after a planning review of the Great Divide Resource Area Management Plan is completed.

The BLM released the final EIS for the Pinedale Anticline Natural Gas Exploration and Development Project. The preferred alternative allows drilling 900 new wells to achieve 700 producing wells. The analysis assumed that 200 dry holes would be drilled. The project area is located between the town of Pinedale and Jonah Field, about 30 miles south of Pinedale.

Lease sales

There were two federal (BLM) and two state oil and gas lease sales held in Wyoming in the second quarter of 2000. Leasing activity at the April BLM sale was concentrated in the PRB and southwestern Wyoming (**Figure 7**). Meany Land & Exploration made the sale's high per-acre bid of $440 for a 466.37-acre lease that covers parts of sections 4, 12, and 20, T44N, R76W (**location A, Figure 7**). The

lease is 2 to 3 miles west of current coalbed methane development. Hanson & Strahn made the sale's second high per-acre bid of $350 for a 75-acre lease covering lots 14 and 20, section 7, T45N, R75W (**location B, Figure 7**). The lease is about 2 miles northwest of coalbed methane development in the Fort Union Formation. There were a total of 26 parcels at this sale that received bids of $50 or more per acre. There were 161 parcels leased and the sale generated about $3.1 million (**Table 7**).

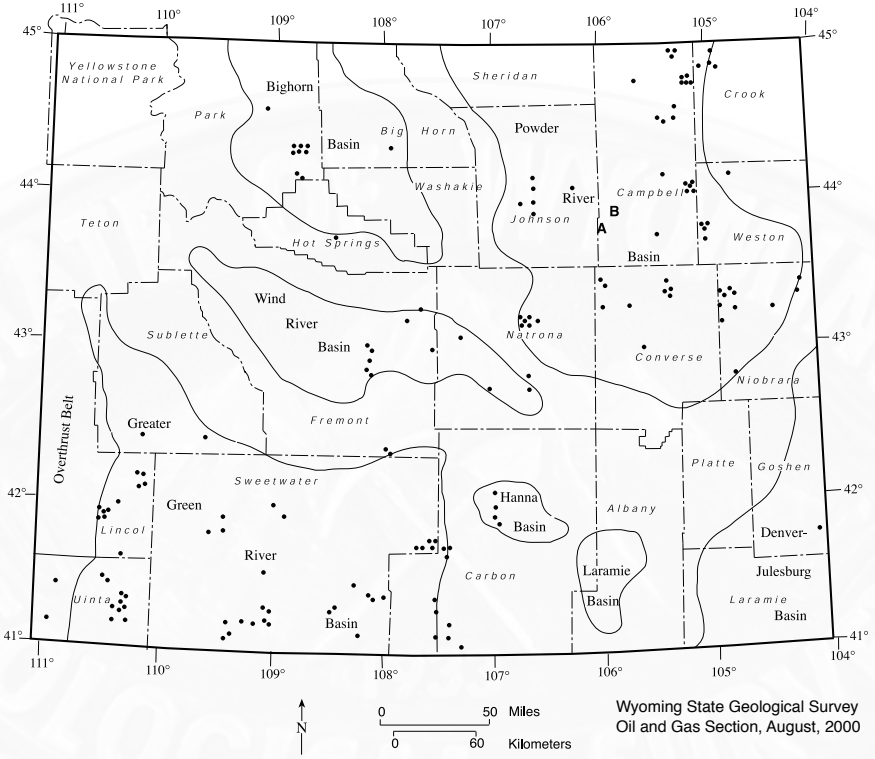

Figure 7. Locations of federal oil and gas tracts leased by the U.S. Bureau of Land Management at its April, 2000 sale.

Leasing activity at April's state sale conducted by the Wyoming Office of State Lands and Investments was centered in the PRB (**Figure 8**). Powder River Resources made the sale's high per-acre bid of $525 for a 40-acre tract covering SE SE section 1, T49N, R75W (**location A, Figure 8**). The lease is a mile south of coalbed methane development in the Fort Union Formation. The sale's second highest per-acre bid of $450 for a 40-acre parcel covering SW SE section 14, T49N, R74W (**location B, Figure 8**), was made by 21st Century # 1 Energies. The lease is within a mile southeast of coalbed methane development in the Lazy B Field area. Twenty-five leases at this sale received per-acre bids of $50 or more with the 191 parcels leased drawing about $1.5 million in revenues to the State of Wyoming (**Table 7**).

Table 7. Federal and State competitive oil and gas lease sales in Wyoming (1996 through June, 2000).

FEDERAL SALES (BUREAU OF LAND MANAGEMENT)								STATE SALES (OFFICE OF STATE LANDS AND INVESTMENTS)							
Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre	Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
				1996							1996				
TOTAL	$11,487,567	1828	1125	1,403,444	739,505	$15.53	$1,450.00	TOTAL	$2,325,497	1049	508	418,111	206,814	$11.24	$206.00
				1997							1997				
TOTAL	$31,976,603	1787	1485	1,578,938	1,206,642	$26.50	$600.00	TOTAL	$3,151,020	1198	704	438,296	263,230	$11.97	$340.00
				1998											
Feb	$5,262,908	369	285	366,787	241,654	$21.78	$415.00								
Apr	$10,287,111	247	227	192,561	162,393	$63.35	$395.00				1998				
Jun	$14,737,117	463	367	498,339	368,816	$39.96	$430.00	Apr	$1,203,792	300	161	115,646	63,848	$18.85	$320.00
Aug	$8,033,029	306	245	349,605	278,095	$28.89	$500.00	Jun	$1,660,438	300	148	108,654	52,501	$31.63	$600.00
Oct	$10,251,074	455	308	421,900	293,141	$34.97	$430.00	Oct	$1,313,792	298	178	98,856	65,212	$20.14	$590.00
Dec	$15,229,257	407	278	388,783	277,538	$54.87	$800.00	Dec	$1,045,447	300	187	121,551	77,852	$13.43	$215.00
TOTAL	$63,800,496	2247	1710	2,217,975	1,621,637	$39.34	$800.00	TOTAL	$5,223,469	1198	674	444,707	259,413	$20.14	$600.00
				1999											
Feb	$2,734,442	170	138	157,779	124,880	$21.90	$325.00								
Apr	$2,121,220	124	116	129,358	121,421	$17.47	$280.00				1999				
Jun	$8,358,363	179	155	233,599	207,978	$40.19	$32,000.00	Apr	$1,815,526	299	196	123,119	89,194	$20.35	$890.00
Aug	$3,294,339	206	197	215,631	208,777	$15.78	$290.00	Jun	$1,002,039	300	190	108,310	69,858	$14.34	$400.00
Oct	$4,395,288	214	175	195,827	142,525	$30.84	$580.00	Oct	$2,369,527	300	216	109,140	77,261	$30.67	$475.00
Dec	$5,598,020	176	164	128,480	124,093	$28.99	$410.00	Dec	$956,113	291	129	115,502	51,674	$18.50	$500.00
TOTAL	$24,197,991	1,069	945	1,060,674	929,674	$26.03	$32,000.00	TOTAL	$6,143,205	1,190	731	456,071	287,987	$21.33	$890.00
				2000							2000				
Feb	$5,497,834	192	180	130,289	120,219	$45.73	$525.00	Apr	$1,475,661	299	191	120,319	71,933	$19.54	$525.00
Apr	$3,057,278	189	161	160,712	128,063	$23.87	$440.00	Jun	$2,119,198	300	197	127,798	79,743	$26.58	$775.00
Jun	$6,387,887	230	184	260,294	190,306	$33.57	$410.00								

Sources: Wyoming Office of State Lands and Investments, Petroleum Information/Dwights LLC - Rocky Mountain Region Report, and U.S. Bureau of Land Management. Wyoming State Geological Surey, Oil and Gas Section, August, 2000.

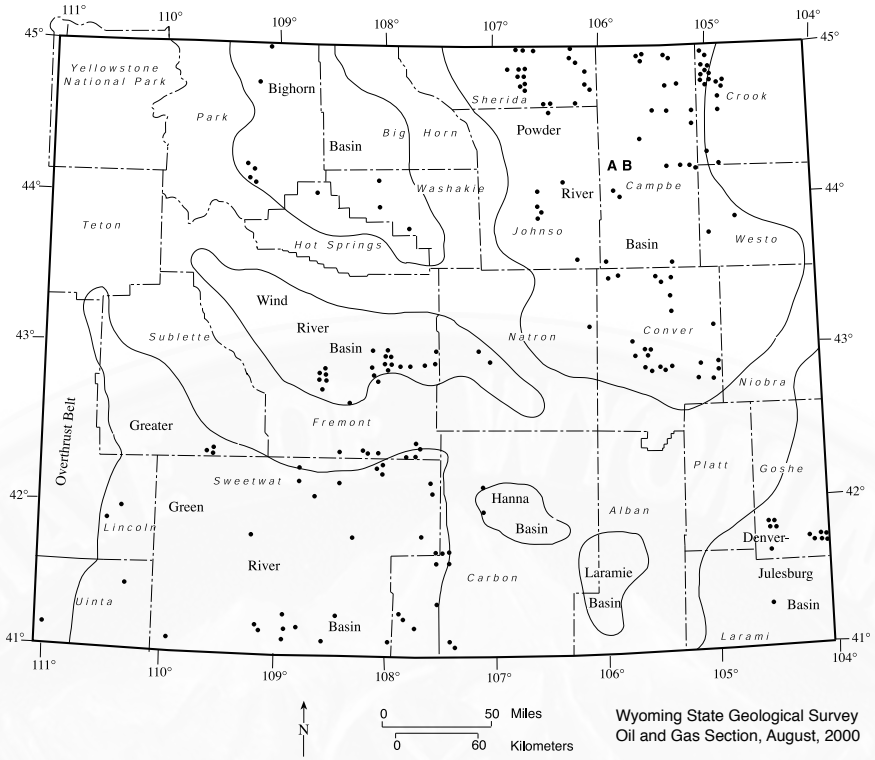

Figure 8. Locations of state oil and gas tracts leased by the Wyoming Office of State Lands and Investments at its April, 2000 sale.

The June BLM lease sale drew high bids that totalled nearly $6.4 million (**Table 7**). Leasing activity was heaviest in southwestern Wyoming and the PRB (**Figure 9**). Ann Trujillo made the sale's two highest per-acre bids of $410 each for a 640-acre lease covering all of section 26, T18N, R95W, and for a 560-acre lease covering N/2 SW and W/2 SE section 24, T18N, R95W (**location A, Figure 9**). The two tracts are within 2 miles of Almond gas production in Wildrose Field. Yates Petroleum made the sale's third highest per-acre bid of $390 for a 202.59-acre lease covering parts of sections 11 and 14, T47N, R75W (**location B, Figure 9**). The lease is in an area of coalbed methane development in the Fort Union Formation. Ann Trujillo made the sale's fourth highest per-acre bid of $380 for a 159.78-acre parcel covering parts of section 30, T16N, R98W (**location C, Figure 9**). The lease is within a mile of gas production from the Almond Formation and the Lewis Shale (Upper Cretaceous) at Alkaline Creek Field. Fifty leases at this sale received per-acre bids of $50 or more.

Leasing activity at June's state sale was heaviest in the PRB and in southwestern Wyoming (**Figure 10**). Reliance Resources made the sale's highest per-acre bid of $775 for a 321.6-acre lease that takes in parts of sections 25 and 26, T50N, R75W (**location A, Figure 10**). CTR Resources made the sale's second high per-acre bid of $550 for a 320-acre tract covering N/2 section 36, T43N, R75W (**location B, Figure 10**). Thomas J. Noonan made the sale's third high per-acre bid of $350

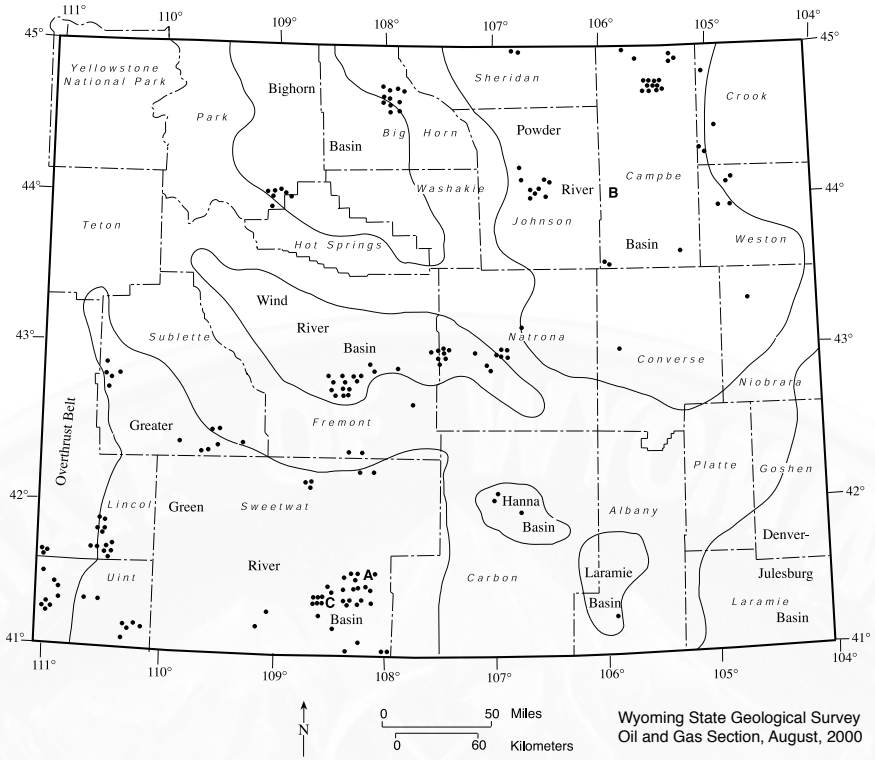

Figure 9. Locations of federal oil and gas tracts leased by the U.S. Bureau of Land Management at its June, 2000 sale.

for a 480-acre parcel covering NE and S/2 section 36, T43N, R76W (**location C, Figure 10**). All three of these tracts are in the vicinity of coalbed methane development in the Fort Union Formation. Twenty-three leases received per-acre bids of $50 or more at this sale. The 197 parcels leased drew revenues for the State of Wyoming of about $2.1 million (**Table 7**).

Permitting and drilling

There were 2356 Applications for Permit to Drill (APDs) approved by the WOGCC in the second quarter of 2000. The total for the first six months is more than the number of APDs approved for a full year in 1995, 1996, 1997, or 1998 and only 571 less than the total for 1999 (**Table 8**). Campbell County again led with 60% of the total APDs that were approved that quarter. Sheridan and Johnson counties combined for another 14.8% of the total APDs. Nearly all of the approved APDs in these three counties were for coalbed methane tests.

The WOGCC permitted 17 seismic projects in the second quarter of 2000. The number of permits and miles permitted is up substantially from the first half of last year. The number of permitted conventional miles is already higher than the

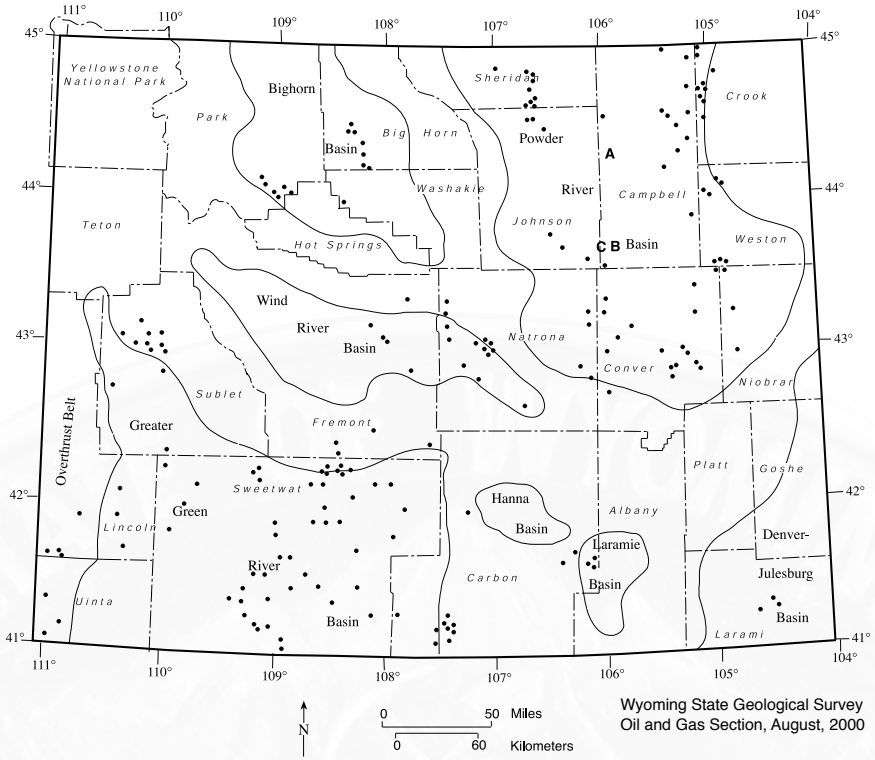

Figure 10. Locations of state oil and gas tracts leased by the Wyoming Office of State Lands and Investments at its June, 2000 sale.

total for 1998 and 1999 and the number of permitted 3-D square miles is nearing the total for all of 1997 (**Table 9**). Geophysical activity is a good indicator of future exploration and production drilling.

The average daily rig count for the second quarter of 2000 was 32, eight more than for the second quarter of 1999 (**Figure 11**). The rig count does not include rigs drilling for coalbed methane.

Exploration and development

Company data, news releases, and information compiled and published by Petroleum Information/Dwights LLC are used to track oil and gas exploration and development activity in Wyoming. **Table 10** reports the most significant activities exclusive of coalbed methane (see the COAL UPDATE for development activities in this industry) during the second quarter of 2000. The numbers correspond to locations on **Figure 12**.

In addition to the new wells in Jonah Field (**Table 10**), spacing for a federal unit in the field has now been established. The Pinedale Field Office of the BLM

Table 8. Number of Applications for Permit to Drill (APD) approved by the Wyoming Oil and Gas Conservation Commission (1995 through June, 2000).

County	1995 APDs	1996 APDs	1997 APDs	1998 APDs	1999 APDs	2000 APDs
Albany	1	1	0	0	0	0
Big Horn	16	53	59	13	6	8
Campbell	151	554	941	1586	4461	3654
Carbon	50	77	84	96	127	106
Converse	29	20	16	6	19	40
Crook	15	37	26	29	30	37
Fremont	30	26	58	76	67	86
Goshen	0	0	0	0	0	0
Hot Springs	13	24	42	1	8	5
Johnson	6	16	6	49	304	407
Laramie	10	2	3	2	0	2
Lincoln	64	55	122	105	51	46
Natrona	80	74	59	36	51	33
Niobrara	4	7	8	8	5	9
Park	20	30	25	11	12	9
Platte	0	0	0	0	0	0
Sheridan	0	0	2	35	416	452
Sublette	61	118	179	230	189	218
Sweetwater	153	136	210	181	124	176
Teton	0	0	0	0	0	0
Uinta	11	10	27	26	26	29
Washakie	31	30	36	9	0	0
Weston	10	10	5	6	4	12
Totals	**755**	**1280**	**1908**	**2505**	**5900**	**5329**

Source: All data are from the Wyoming Oil and Gas Conservation Commission.
Wyoming State Geological Survey, Oil and Gas Section, July, 2000.

approved 40-acre spacing instead of 80-acre spacing in an area of 29,200 acres constituting the Modified Jonah II Project Area.

AEC Oil & Gas has agreed to acquire all of the common shares of McMurry Oil and other private interests, which own a major interest in Jonah Field and in Jonah Gas Gathering. AEC also offered to purchase an additional 6% working interest from other field owners. AEC acquires an estimated 1.2 trillion cubic feet (TCF) of gas equivalent reserves for $615.1 million in cash. A division of AEC also agreed to purchase 92.5% of Green River Pipeline, which owns Jonah Gas Gathering. The division has also offered to acquire the remaining 7.5% of Green River Pipeline from other interests. The total acquisition cost for the Green River Pipeline is $162.2 million.

An excellent article chronicling the discovery, “rediscovery,” and development of the Jonah Field recently appeared in The Mountain Geologist, a publication of the Rocky Mountain Association of Geologists (Robinson, 2000). The article details how important drilling and well completion techniques can be in “tight” gas sandstone reservoirs and how new technology is working to unlock these reservoirs and create additional gas resources.

Reference cited

Robinson, J.W., 2000, Discovery of Jonah Field, Sublette County, Wyoming: The Mountain Geologist, v. 37, no. 3, p. 135-143.

Table 9. Number of seismic projects and miles permitted by the Wyoming Oil and Gas Conservation Commission (1997 through June, 2000).

County	1997 Permits	1997 Conventional Miles	1997 3-D Sq Miles	1998 Permits	1998 Conventional Miles	1998 3-D Sq Miles	1999 Permits	1999 Conventional Miles	1999 3-D Sq Miles	2000 Permits	2000 Conventional Miles	2000 3-D Sq Miles
Albany	0	0	0	0	0	0	0	0	0	0	0	0
Big Horn	2	0	45	1	0	16	0	0	0	1	387	0
Campbell	20	52	79	14	18	182	4	4	10	2	12	2
Carbon	3	7	190	4	0	318	5	77	57	0	0	0
Converse	1	5	0	4	12	239	1	0	50	1	15	0
Crook	7	8	18	2	2	4	1	0	10	1	0	4
Fremont	6	43	126	2	100	0	1	0	88	3	0	116
Goshen	2	227	0	0	0	0	0	0	0	0	0	0
Hot Springs	1	8	0	4	19	0	0	0	0	0	0	0
Johnson	2	7	17	1	4	0	0	0	0	1	3	0
Laramie	0	0	0	0	0	0	0	0	0	0	0	0
Lincoln	3	7	116	1	10	0	1	0	32	0	0	0
Natrona	5	14	101	6	12	214	2	0	230	4	36	0
Niobrara	0	0	0	0	0	0	5	16	31	0	0	0
Park	4	56	58	3	16	132	3	25	32	1	13	0
Platte	0	0	0	0	0	0	0	0	0	0	0	0
Sheridan	0	0	0	1	14	0	0	0	0	0	0	0
Sublette	1	0	61	2	1	115	3	0	308	1	0	35
Sweetwater	4	66	296	6	214	66	9	0	530	10	47	832
Teton	0	0	0	0	0	0	0	0	0	0	0	0
Uinta	0	0	0	2	0	147	1	0	26	0	0	0
Washakie	3	36	0	4	41	35	1	0	8	0	0	0
Weston	1	0	17	1	0	35	1	40	0	0	0	0
Totals	**65**	**536**	**1124**	**58**	**463**	**1503**	**38**	**162**	**1412**	**25**	**513**	**989**

Source: All data are from the Wyoming Oil and Gas Conservation Commission.
Wyoming State Geological Survey, Oil and Gas Section, July, 2000.

Table 10. Significant exploration and development wells in Wyoming during the second quarter of 2000[1]. Number corresponds to location on Figure 12.

	Company Name	Well name/number	Location
1	Questar Exploration & Production (QEP)	2 Verne Valley Unit	NW NE section 23, T19N, R113W
	QEP	4 Verne Valley Unit	NW SE section 23, T19N, R113W
	QEP	5 Verne Valley Unit	NE SW section 23, T19N, R113W
2	Lance Oil & Gas	15-8 HSR-Sherlock	SW SE section 8, T33N, R109W
	Wexpro	6 Mesa Unit	SW SW section16, T32N, R109W
3	Amoco Production	15-9 Rainbow	SW SE section 29, T30N, R107W
4	Amoco Production	5-29 Cabrito	SW NW section 29, T29N, R107W
	Forest Oil	23-13 Elm Federal	NW NE section 23, T28N, R109W
	McMurry Oil	1-4X Jonah-Federal	NE NE section 4, T28N, R108W
	McMurry Oil	11-34 Stud Horse Butte	NE SW section 34, T29N, R108W
	Amoco Production	7-19 Corona Unit	SE NE section 19, T29N, R108W
	McMurry Oil	15-35 Stud Horse Butte	SW SE section 35, T29N, R108W
5	Texaco Exploration & Production	16A Stagecoach Draw Unit	NW SE section 32, T23N, R107W
6	Kestrel Energy	27-3 UPRC	SE SW section 27, T19N, R106W
7	Tom Brown Inc.	10 Bravo Unit	NE SW section 10, T23N, R99W
	Tom Brown Inc.	9 Bravo Unit	NE NW section 14, T23N, R99W
8	Texaco Exploration & Production	115H Table Rock Unit	NW NE section 19, T19N, R97W
9	Amoco Production	3 Champlin 444 Amoco “A”	C NE section 17, T17N, T93W
	Amoco Production	4 Champlin 261 Amoco “B”	NW NW section 35, T19N, R93W
	Amoco Production	3 Champlin 222 Amoco-E	NE SE section 21, T19N, R93W
10	Union Pacific Resources	4-26 Clyde-Federal	C section 26, T18N, R94W
	Union Pacific Resources	3-26 Clyde-Federal	C section 26, T18N, R94W
	Union Pacific Resources	1-26 Clyde-Federal	C section 26, T18N, R94W
11	Marathon Oil	22-10 Standard Draw	NE SE section 10, T18N, R93W
12	Cabot Oil & Gas	40-5 Lookout Wash Unit	SE SE section 5, T14N, R93W
13	Tom Brown Inc.	30-23 Tribal-Muddy Ridge	NE SW section 30, T4N, R3E
14	Enre Corp.	36-1 Enre-Skull Creek	SE NE section 36, T55N, R103W

Table 10. Significant exploration and development wells (continued).

	Formation Tested	Depth(s) of Interval(s) Tested	Tested Production (Per day)	Remarks
1	Frontier Fm.	11,278-11,380	2.9 MMCF 93 BBL Cond	Southern Moxa arch
	Muddy Ss.	11,961-12,076	2.8 MMCF	Southern Moxa arch
	Frontier Fm.	11,388-11,406	2.0 MMCF	Southern Moxa arch
2	Lance Fm.	4 intervals 9839-12,610	1.8 MMCF 16 BBL Cond 61 BBL H_2O	Pinedale anticline
	Lance Fm.	N/R; fracture-stimulated	11.1 MMCF 89 BBL Cond	Pinedale anticline
3	Lance Fm.	N/R; >8912	650 MCF 3 BBL Cond 90 BBL H_2O	
4	Lance Fm.	6 intervals 10,997-12,263	3.5 MMCF	Jonah Field
	Lance Fm.	N/R; >8000	18.2 MMCF 123 BBL Cond	Jonah Field
	Lance Fm.	5 intervals 8892-10,834	10.0 MMCF 186 BBL Cond 15 BBL H_2O	Jonah Field
	Lance Fm.	6 intervals 8635-11,261	4.3 MMCF 80 BBL Cond 15 BBL H_2O	Jonah Field
	Lance Fm.	11 intervals 8150-11,260	9.0 MMCF	Jonah Field
	Lance Fm.	7 intervals 8951-11,574	10.4 MMCF 240 BBL Cond 15 BBL H_2O	Jonah Field
5	Almond Fm.	7990-7993	2.4 MMCF 36 BBL Cond 8 BBL H_2O	Stagecoach Draw Field
6	2nd Frontier ss.	N/R	>2.0 MMCF	Reiser Canyon Field2
7	Lewis Shale	6620-6644	3.2 MMCF	Sinkhole Field; in Lewis sandstone
	Lewis Shale	6776-6788	2.0 MMCF	Sinkhole Field; in Lewis sandstone
8	Frontier Fm.	14,418-14,522 True vert. depth	1.8 MMCF	Table Rock Field; horizontal producer
9	Almond Fm.	9204-9284 9318-9364	8.5 MMCF	Standard Draw Field area
	Almond Fm.	8848-8905 9017-9183	2.8 MMCF	Standard Draw Field area
	Almond Fm.	9124-9293 9326-9441	3.1 MMCF	Standard Draw Field area
10	Almond Fm.	9796-9990	2.6 MMCF 90 BBL Cond 4 BBL H_2O	
	Almond Fm.	9872-10,010 10,064-10,130	2.2 MMCF 49 BBL Cond 43 BBL H_2O	
	Almond Fm.	9982-10,084	117 MCF 46 BBL Cond 39 BBL H_2O	
11	Almond Fm.	8668-8678 8726-8752	3.0 MMCF 35 BBL Cond	West side standard Draw Field
12	Almond Fm.	10,922-10,931 10,934-10,944	4.6 MMCF 50 BBL Cond	Extension to Snowbank Field
13	Meeteetse Fm. Mesaverde Fm.	9680-10,884 11,524-12,306	1.5 MMCF 19 BBL Cond 31 BBL H_2O	Muddy Ridge Field;Wind River Indian Reservation
14	Frontier Fm.	4 intervals 3006-3079	1.7 MMCF 4 BBL Cond	Extension to Heart Mountain Field

Table 10. Significant exploration and development wells (continued).

	Company Name	Well name/number	Location
15	Flying J Oil & Gas	20H Shad	SW SE section 6, T43N, R91W
16	Double Eagle Petroleum & Mining	1 Allen Deep	SE NW section 26, T39N, R90W
17	Barrett Resources	5-12 Bullfrog	SW SE section 12, T36N, R87W
18	BreitBurn Energy	2Lost Dome-Federal	NW NE section 13, T37N, R83W
19	True Oil	31-9 Spring Hole	NW NE section 9, T53N, R69W
20	Prima Oil & Gas Draw-Federal	11-31 Cedar	NE SW section 11, T51N, R75W
21	Independent Production	1 Gaither	NW SW section 9, T47N, R73W
22	Ocean Energy	22-34 House Creek North Unit	SE NW section 34, T46N, R74W
23	Ballard Petroleum	21-3 Durham Ranch	NE NW section 3, T44N, R73W
24	Abraxas Petroleum	4H-16-38-67 Turner	SE SE section 16, T38N, R67W
	Abraxas Petroleum	3H-10-38-67	SW SW section 10, T38N, R67W
	Abraxas Petroleum	Staked location	section 14, T38N, R67W
	Abraxas Petroleum	Staked location	section 22, T38N, R67W

[1]Abbreviations include: N/R=not reported; N/A=not applicable; MMCF=millions of cubic feet of natural gas; MCF=thousands of cubic feet of natural gas; BBL=barrels; Cond=condensate; H_2O=water.
[2]Near abandoned production from Muddy Sandstone and Frontier Formation.
[3]An earlier test recovered up to 16.0 MMCF fo gas from the Lakota Formation; 3rd and 5th Frontier sandstones and Muddy Sandstone will probably be tested.
[4]Well was to test the Turner Sandstone but encountered various problems and was ultimately completed in the Niobrara.

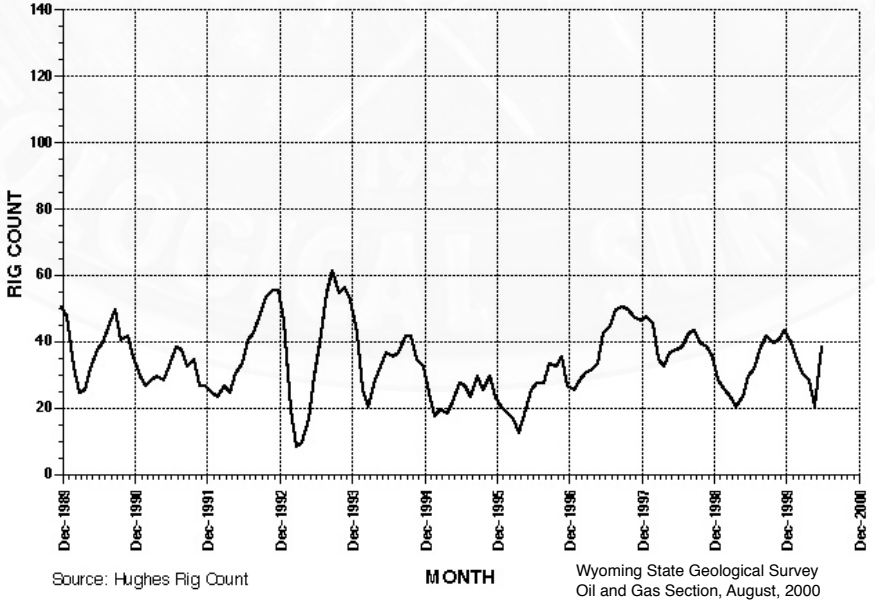

Figure 11. Wyoming daily rig count, exclusive of coalbed methane rigs, averaged by month (December, 1989 through June, 2000).

Table 10. Significant exploration and development of wells (continued).

	Formation Tested	Depth(s) of Interval(s) Tested	Tested Production (Per day)	Remarks
15	Crow Mtn. Ss.	N/A	N/A	Murphy Dome Field;horizontal redrill to evaluate “Curtis sand”
16	Fort Union Fm.	11,681-11,688 11,697-11,718	1.7 MMCF 37 BBL Cond	Exploratory well
17	1st Frontier ss.	17,821-17,850	6.8 MMCF	Subthrust producer in Waltman Field[3]
18	Tensleep Ss.	4942-5547	175 BBL Oil	4th producer in Lost Dome Field
19	Minnelusa Fm.	7162-7170	229 BBL Oil	Spring Hole Field
20	Muddy Ss.	9514-9526	1.9 MMCF 81 BBL Cond 15 BBL H_2O	Cedar Draw Field
21	Parkman Ss.	6551-6572	83 BBL Oil 17 BBL H_2O	Extends Parkman production in Gaither Draw Field about 3/4 mile south
22	Sussex Ss.	8189-8207	157 BBL Oil 9 MCF 20 BBL H_2O	House Creek Field
23	Minnelusa Fm.	12,501-12,505	60 BBL Oil	Length of test N/R
24	Niobrara Fm.	N/R	209 BBL Oil	Brooks Draw Field; horizontally drilled[4]
	Turner ss.	N/A	N/A	Horizontally drilled; awaiting completion
	Turner ss.	N/A	N/A	Horizontal test
	Turner ss.	N/A	N/A	Horizontal test

Wyoming State Geological Survey, August, 2000.

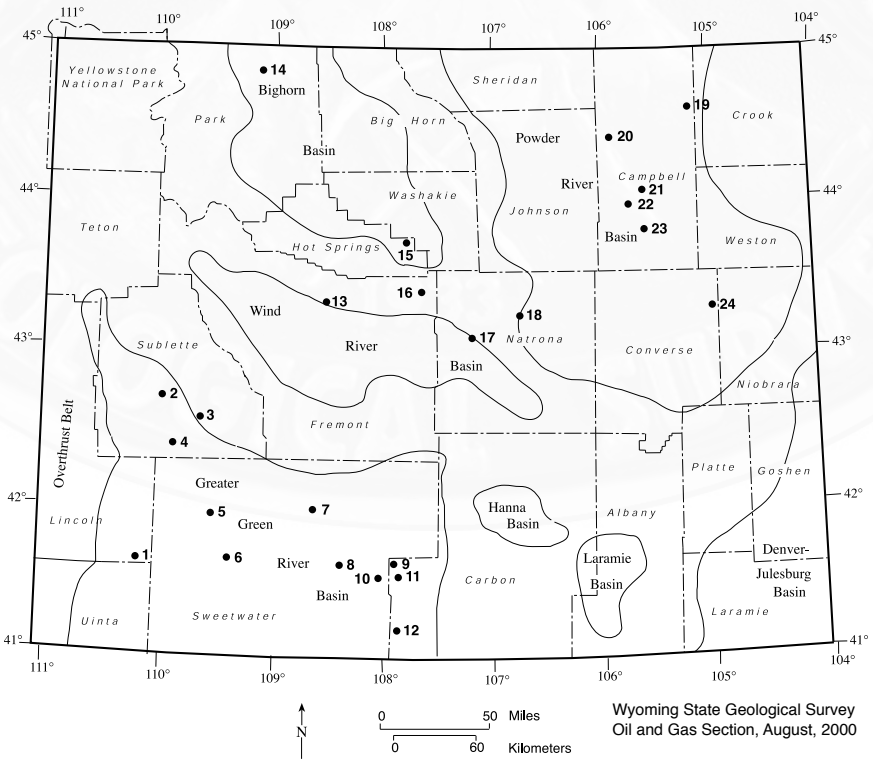

Figure 12. Oil and gas exploration and development activities in Wyoming during the first quarter of 2000, exclusive of coalbed methane activities. Locations are approximate and may represent more than one well location or project.

COAL UPDATE

Robert M. Lyman
Staff Geologist–Coal, Wyoming State Geological Survey

Wyoming continued to lead the nation in coal production through the first quarter of 2000 but lagged behind last year's production. Total coal deliveries from Wyoming mines to the domestic steam market in the first quarter of 2000 were 4.2 million short tons or roughly 5.2% less than for the same period of 1999 (**Table 11**). Monthly coal deliveries from January, 1997 through March, 2000 (**Figure 13**) and contract sales (**Figure 14a**) were between the 1998 level and 1999's record production year. Total deliveries of spot steam coal were 1.6 million short tons behind 1999 (**Figure 14b**).

Historical and projected coal production in Wyoming by county (**Table 12**) contains final production figures for 1999 and provides an estimate of the percentage of coal from the Powder River Basin (PRB) that sells for more than $5.00 per ton (termed higher-priced coal). The tonnage sold at these higher prices is the remaining older, long-term contracts (signed years ago) that had escalation clauses built into them.

While the first half of Wyoming's coal production in 2000 appears to be fairly even with 1999, we are now estimating a 3.15% growth rate in production for the year 2000 (**Table 12**). This projection is slightly less than the 3.5% increase we estimated in Wyoming Geo-notes No. 66 (June, 2000) because of decreased production at the Kemmerer mine in Lincoln County due to a strike (see **Developments in southern Wyoming**, below). However, due to the newly found production discipline emerging from the top three PRB coal producers, our estimate of coal production in 2001 has been reduced to only a 1.5% increase over our current estimate for year 2000.

A breakdown of the average prices for coal produced in northeastern Wyoming and southern Wyoming over the past eleven years and projected average prices through 2006 is shown on **Table 13**. The coal prices we estimated earlier this year have not changed from the last two issues of Wyoming Geo-notes.

During the second quarter of 2000, prices for Wyoming coal on the spot market appear to have bottomed out. In response to the slack first quarter spot market as reported in Wyoming Geo-notes No. 66 (June, 2000, p. 20), the top three PRB coal producers announced in the second quarter that they plan to reduce production or delay planned production increases until they see some additional strengthening of coal prices.

Developments in the Powder River Basin

KFx Inc. announced the sale of its K-Fuel plant (**location 1, Figure 15**) to Black Hills Corp. Under the terms of the agreement, Black Hills will take control of the facility and attempt to restart production of the enhanced coal fuel by August of this year. The new start up is contingent on the group's success in finding $10 to

Table 11. Monthly coal deliveries from Wyoming's mines in short tons (January, 1996 through March, 2000)

	1996		1997		1998		1999		2000	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	21,793,387	21,793,387	25,165,405	25,165,405	26,536,217	26,536,217	26,970,936	26,970,936	26,451,057	26,451,057
FEB	20,374,055	42,167,442	20,743,224	45,908,629	23,196,152	49,732,369	25,675,015	52,645,951	24,375,342	50,826,399
MAR	22,507,800	64,675,242	22,566,012	68,474,641	23,861,472	73,593,841	28,082,331	80,728,282	25,693,360	76,519,759
APR	22,579,959	87,255,201	20,961,008	89,435,649	24,768,989	98,362,830	25,836,684	106,564,966		
MAY	22,216,016	109,471,217	23,102,867	112,538,516	25,278,960	123,641,790	28,414,354	134,979,320		
JUN	20,698,814	130,170,031	20,862,610	133,401,126	24,450,835	148,092,625	24,508,742	159,488,062		
JUL	24,842,971	155,013,002	24,074,929	157,476,055	25,663,577	173,756,202	27,986,592	187,474,654		
AUG	24,421,537	179,434,539	23,002,254	180,478,309	26,591,950	200,348,152	28,066,096	215,540,750		
SEP	23,339,792	202,774,331	22,452,566	202,930,875	26,041,099	226,389,251	26,836,683	242,377,433		
OCT	22,615,721	225,390,052	21,623,057	224,553,932	26,659,121	253,048,372	26,311,074	268,688,507		
NOV	21,421,085	246,811,137	21,695,072	246,249,004	25,620,216	278,668,588	26,316,687	295,005,194		
DEC	22,105,530	268,916,667	24,695,740	270,944,744	26,102,620	304,771,208	26,308,752	321,313,946		
Total Tonnage Reported[1]		**268,916,667**		**270,944,744**		**304,771,208**		**321,313,946**		
Total Tonnage Not Reported[2]		**9,508,289**		**10,536,772**		**10,190,883**		**15,145,992**		
Total Tonnage Produced[3]		**278,424,956**		**281,481,516**		**314,962,091**		**336,459,938**		

[1]From Federal Energy Regulatory Commission (FERC) Form 423, 1996-1999.
[2]Includes estimates of residential, industrial, and exported coal, plus tonnage not reported on FERC's Form 423.
[3]Wyoming State Mine Inspector's Annual Reports.
Wyoming State Geological Survey, Coal Section, July, 2000.

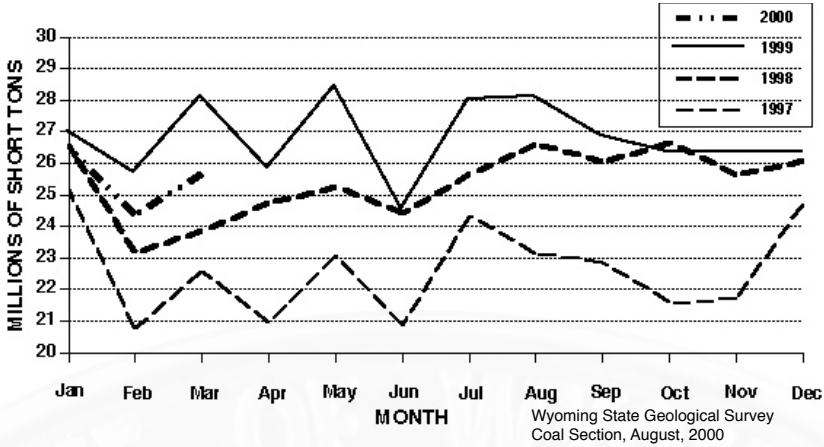

Figure 13. Reported monthly deliveries from Wyoming coal mines (1997 through March, 2000). Derived from data on the Federal Energy Regulatory Commission's (FERC's) Internet bulletin board and Form 423.

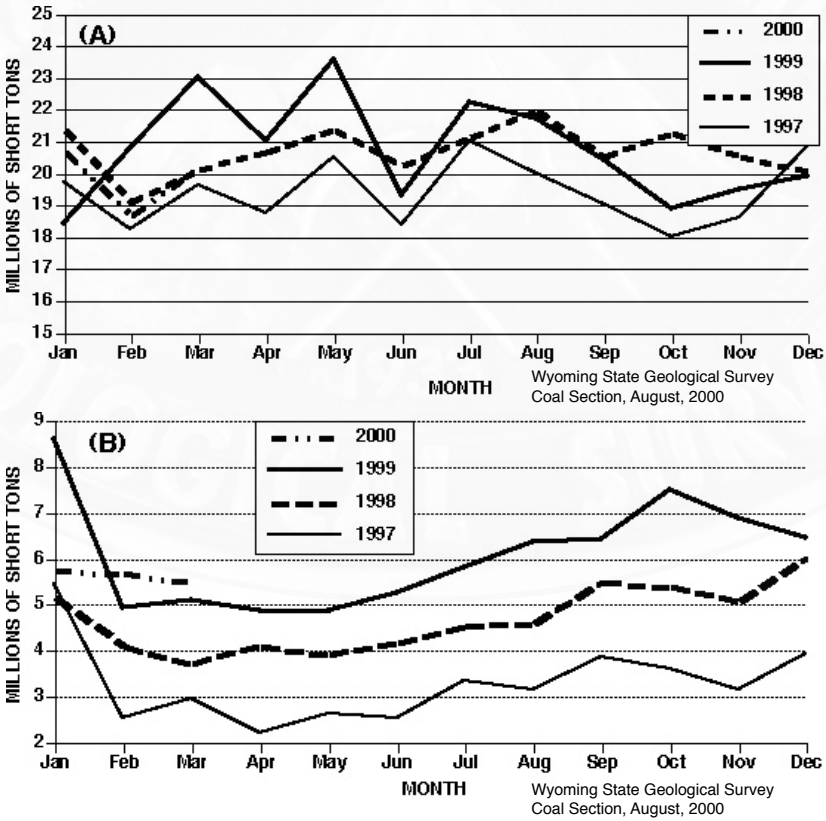

Figure 14. Monthly coal deliveries form Wyoming coal mines (1997 through March, 2000). (A) Coal sold on contract and (B) coal sold on the spot market. Derived from data on FERC's Internet bulletin board and Form 423.

Table 12. Wyoming coal production by county[1, 2] (in millions of short tons) from 1995 to 1999 with forecasts to 2006.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Powder River Basin												
Campbell County	232.4	245.3	246.3	274.1	296.3	306.3	309.3	312.8	314.4	323.0	325.6	329.3
Converse County	14.1	15.8	17.8	23.4	24.0	27.0	30.0	30.0	30.0	25.0	25.0	25.0
Sheridan County	M	M	M	M	M	M	M	M	M	M	M	M
Southern Wyoming												
Carbon County	3.8	4.7	5.0	3.5	3.5	2.0	M	M	2.0	2.0	3.0	3.0
Sweetwater County	9.1	8.2	7.8	9.2	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Lincoln County	4.5	4.4	4.6	4.7	4.7	3.8	5.0	5.0	5.0	5.0	5.0	5.0
Total Wyoming[3]	**263.9**	**278.4**	**281.5**	**314.9**	**336.5**	**347.1**	**352.3**	**355.8**	**359.4**	**363.0**	**366.6**	**370.3**
Annual Change	11.4%	5.5%	1.1%	11.9%	6.86%	3.15%	1.5%	1.0%	1.0%	1.0%	1.0%	1.0%
Higher-priced coal[4]	**26%**	**24%**	**22%**	**17%**	**13%**	**9%**	**6%**	**4%**	**4%**	**4%**	**4%**	**4%**

[1]Tonnage from the Wyoming State Inspector of Mines, 1995-1999 (Stauffenberg, D.G., 1999).
[2]County estimates by the Wyoming State Geological Survey, April, 2000, for 2000-2006.
[3]Estimate modified from CREG's Wyoming State Government Revenue Forecast, October, 1999.
[4]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)].
Wyoming State Geological Survey, Coal Section, April, 2000.

Table 13. Breakdown of average prices paid for coal from northeastern Wyoming, southern Wyoming, and Wyoming as a whole (1988-1999) with forecast to 2006.

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	$17.15	$5.41
1999	$4.57	$16.22	$5.14
2000	$4.63	$16.20	$5.13
2001	$4.65	$16.50	$4.99
2002	$4.75	$16.75	$4.99
2003	$4.75	$16.91	$5.03
2004	$4.80	$17.00	$5.05
2005	$4.80	$17.00	$5.07
2006	$4.80	$17.00	$5.08

Statewide data for 1988-1990 are from reports by the U.S. Department of Energy's Energy Information Administration; data for 1991-1999 are derived from Wyoming Department of Revenue information; estimates for 2000-2006, and all regional breakdowns are estimated by the Wyoming State Geological Survey (August, 2000).

12 million in third party financing to make the necessary modifications to the plant (COAL Daily, 4/17/00).

During the last week of April, Peabody Coal announced plans to cut production of coal at their Caballo mine (**location 2, Figure 15**) by roughly 8 million tons due to the current soft demand and associated low coal prices. Consequently, the Caballo mine idled a production unit. Last year the mine produced 26.5 million short tons of coal, but because the mine is currently in an area of lower overburden, Peabody still plans to produce 25 to 27 million tons this year. While idling one of their production units this year, the major impact on output will occur in 2001. As the mine returns to an area of higher overburden, Peabody estimates that next year their operation will only be able to produce 18 to 21 million short tons (COAL Daily, 5/1/00).

Peabody will also delay the 30-million-ton-per-year expansion plan for their North Antelope-Rochelle mine complex (**location 3, Figure 15**), until sale margins begin to show a proper return on the venture.

A week after the Peabody production cuts were announced, Kennecott Energy's President and CEO Gary Goldberg said his company has chosen to slow production

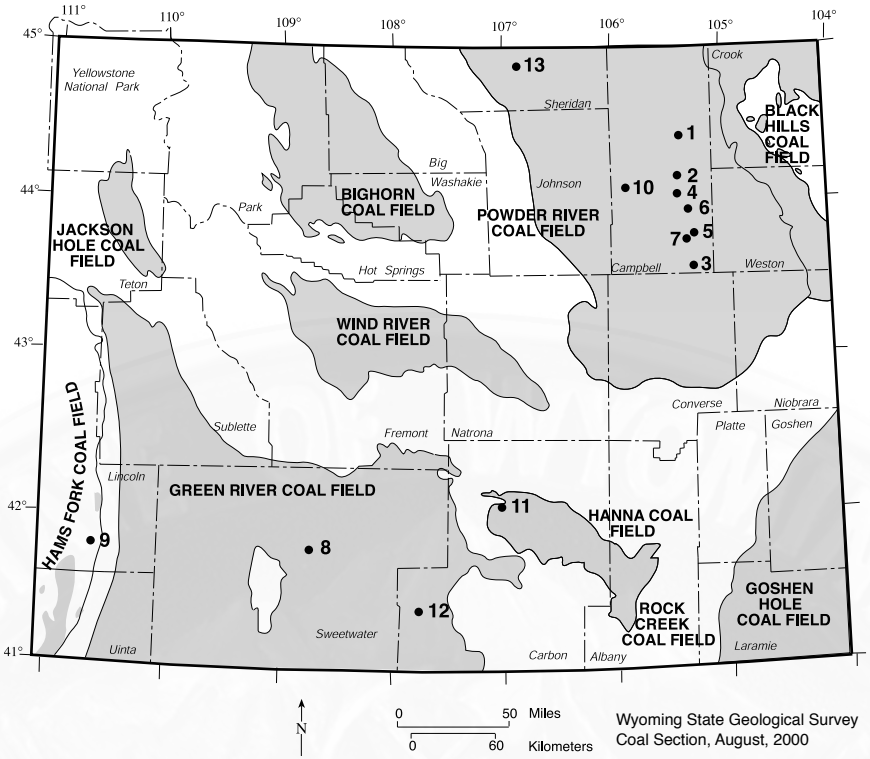

Figure 15. Coal development and coalbed methane activities in Wyoming during the second quarter of 2000.

rather than accept prices that do not provide an acceptable return on its investment. The company will reduce its coal production by approximately 8 million tons per year. Most of the reduction will come from Kennecott's Cordero Rojo mine complex (**location 4, Figure 15**) and the Jacobs Ranch mine (**location 5, Figure 15**). Layoffs are not expected at the mines (COAL Daily, 5/9/00).

On May 17, Arch Coal Company Inc. joined the parade, announcing a plan to shift their Coal Creek coal supply agreements to their Black Thunder operation. The move is aimed at possibly idling the Coal Creek mine (**location 6, Figure 15**) until the soft coal prices rebound. The company also said it would most likely delay a 20-million-ton-per-year expansion at their Black Thunder operation (**location 7, Figure 15**) (COAL Daily, 5/17/00).

Last year the Coal Creek mine produced 10.2 million tons of coal and the Black Thunder mine produced 48.7 million tons of coal. Arch had planned to expand Black Thunder to the 80-million-ton-per-year level over the next few years, but now Arch will hold the production level near the 60-million-ton-per-year level until higher coal prices return. The announcement means that while Arch Coal Company's PRB production levels may increase slightly this year, the future growth of their Powder River coal operations may be slower than currently projected.

Since the first of the year, three Lease By Application (LBA) tracts have been submitted to the U.S. Bureau of Land Management (BLM) for consideration. **Table 14** shows LBAs acted upon as well as those LBAs currently pending in the Wyoming portion of the Powder River Basin (**Figure 16**). In late January, the State Section LBA containing 8494 acres was nominated by Evergreen Enterprises as a new start mine. All but approximately 3753 acres overlap with the North Jacobs Ranch LBA that Kennecott applied for in October, 1999. The State Section tract nominated includes all the New Keeline tract, which Evergreen Enterprises applied for on May 13, 1996. The New Keeline LBA was rejected in June, 1997, and is currently under appeal.

The BLM on June 20, 2000, issued a favorable Record of Decision on the Horse Creek Federal Coal Lease Application. Antelope Coal Company applied for the tract, which consisted of 2838 surface acres containing an estimated 356 million tons of coal in place. Antelope's mine plan shows that if Antelope succeeds in acquiring the LBA, approximately 264.5 million short tons of mineable coal will be added to the operation. Under the Record of Decision's proposed action, the Horse Creek LBA Tract will be offered at a competitive lease sale.

In March, Powder River Coal Company applied for an LBA known as the NARO tracts. This LBA consists of a north parcel covering 2368.3 acres and containing an estimated 323 million recoverable tons of coal and a south parcel covering 2132.7 surface acres and containing an estimated 241 million tons of recoverable coal.

On March 23, 2000, Thunder Basin Coal Co. submitted their application for the Little Thunder LBA. The area nominated consists of 2709.5 acres and contains approximately 384 million tons of coal in place.

Developments in southern Wyoming

PacifiCorp and Idaho Power Co. took bids in April for 50,000 tons of test coal from the PRB to be delivered to the Bridger power plant (**location 8, Figure 15**). The companies are looking at the economics of a possible fuel switch at the plant. The Bridger plant currently burns approximately 9 million tons of coal from the captive Jim Bridger mine and the neighboring Black Butte mine (COAL Daily, 4/28/00).

Union workers at the Kemmerer mine (**location 9, Figure 15**) began a strike after their 5-year labor agreement with Pittsburg & Midway Coal Mining Company (P&M) expired at midnight on May 26. Members of the United Mine Workers of America (UMWA) said the main issue involved the company's effort to eliminate traditional contracted scheduling policies such as requiring 12-hour days. Also, P&M wants to change overtime by requiring no overtime pay until the miner reaches 40 hours for the week. Under the old contract a miner was eligible to draw overtime after working eight hours on any given day. UMWA also wants to increase pension levels more in line with the agreement signed by the Bituminous Coal Operators Association back in December, 1997 (COAL Daily, 6/1/00).

By the end of June the strike was still not settled. Since the walk out by the 224 members of UMWA Local 1307, no formal meetings were reported to have taken place. However, both sides indicated that some dialog between the parties had begun (Casper Star Tribune, 7/1/00) and by the end of July, the strike had

Table 14. Summary of Leases by Application (LBAs) in the Powder River Coal Field, Wyoming.[1]

LBA tract name/ Company applicant	Application date	Applied for Acres	Applied for Tons x 10^6	Offered for Bid Acres	Offered for Bid Tons x 10^6	Status	Total bid	Cents/Ton
Jacobs Ranch/Kerr-McGee	10/10/89	1,465	123	1,709	147.4	Accepted 9/26/91	$20,114,930	13.6
West Black Thunder/ Thunder Basin Coal Co.	12/22/89	3,225	400	3,492	429	Accepted 8/12/92	$71,909,282	16.8
North Antelope & Rochelle/ Powder River Coal Co.	03/03/90 (2 Applications)	954 1,196	120 150	3,064 (Offered as 1 Tract)	403.5	Accepted 9/28/92	$86,987,765	21.6
West Rocky Butte/ Northwestern Resource Co.	12/04/90	390	50	463	56.7	Rejected 12/3/92 Accepted 1/7/93	$14,200,000 $16,500,000	25.8 29.1
Eagle Butte/AMAX Land Co.	07/21/91	915	150	1,059	166.4	Accepted 4/5/95	$18,470,400	11.1
North Rochelle/Zeigler Coal Co.	07/22/92	1,440	144	1,482	157.6	Rejected 7/29/97 Accepted 9/26/97	$26,800,000 $30,600,000	17.0 19.4
Antelope/Antelope Coal Co.	12/29/92	617	60	617	60.4	Rejected 9/28/96 Accepted 12/4/96	$6,645,045 $9,064,600	11.0 15.0
Powder River/ Powder River Coal Co.	03/23/95	4,200	555	4,224	532	Accepted 7/3/98	$109,600,000	20.6
Thundercloud/Kerr-McGee[2]	04/14/95	3,396	427	3,545	412	Accepted 10/1/98	$158,000,009	38.3
New Keeline/Evergreen Enterprises	05/13/96	7,841	675	na[4]	na	PRRCT[3] reviewed 4/23/97 and recommended		
Horse Creek/Antelope Coal Co.	02/14/97	1,471	177.5	na	na	PRRCT reviewed & approved to proceed 4/23/97		
Amended	05/01/98	2,838	356.5	2,819	356	Record of Decision released 6/20/00		
Belle Ayr/AMAX Land Co.	03/20/97	1,579	200	na	na	PRRCT reviewed & approved to proceed 4/23/97		
North Jacobs Ranch/Jacobs Ranch	10/02/98	4,821	519	na	na	PRRCT reviewed & approved to proceed 10/27/99		
State Section/Evergreen Enterprises	01/31/00	8,494	712	na	na	Waiting on PRRCT review		
NARO/ Powder River Coal Co.	03/10/00	4,501	564	na	na	Waiting on PRRCT review		
Little Thunder/ Thunder Basin Coal Co.	03/23/00	2,710	384	na	na	Waiting on PRRCT review		

[1]Adapted from 1997 Draft EIS, Powder River and Thundercloud leases, prepared by the U.S. Bureau of Land Management; revised by Wyoming State Geological Survey, Coal Section, June, 2000.
[2]Arch Coal Successful Bidder
[3]PRRCT = Powder River Regional Coal Team.
[4]na = not available.

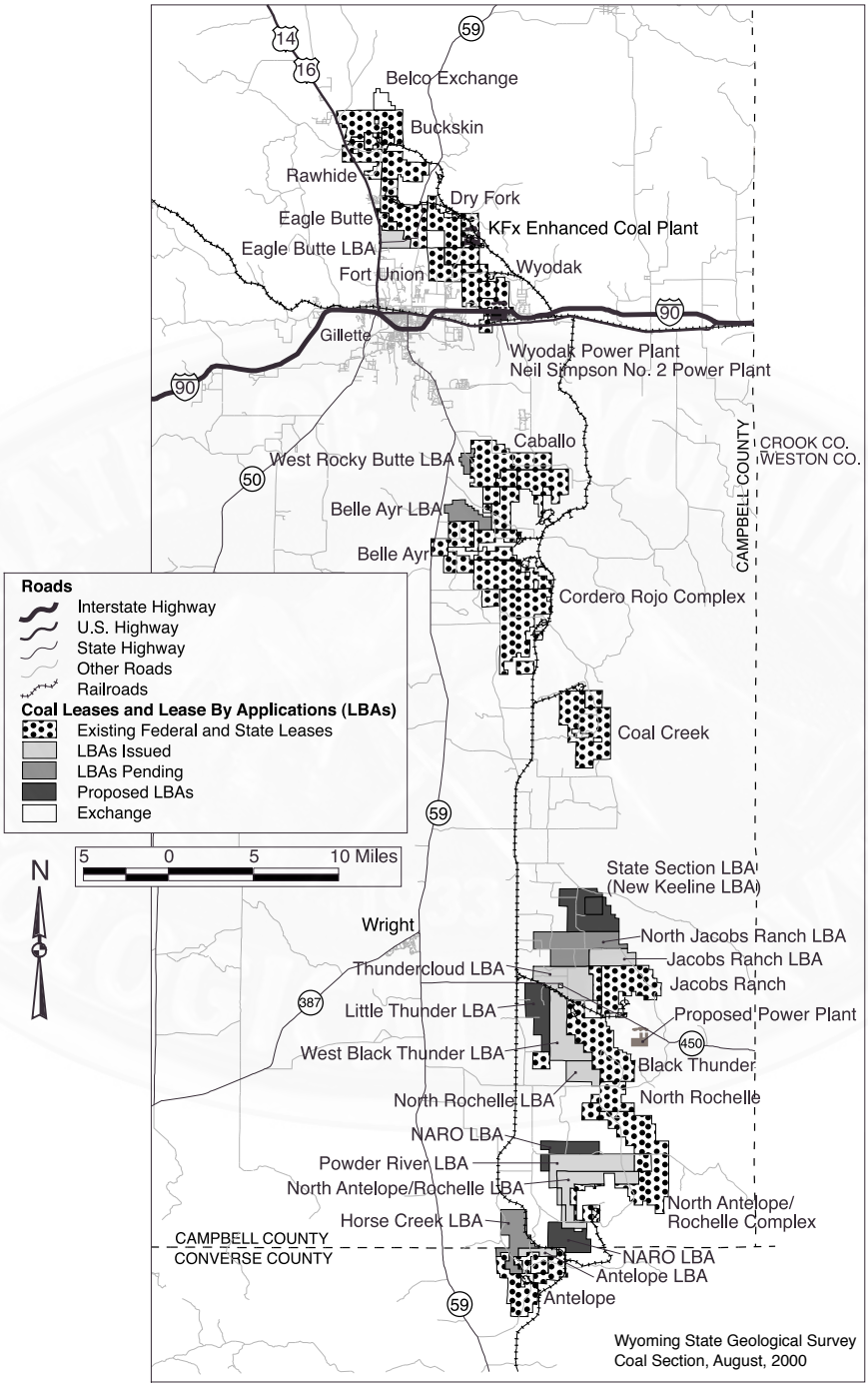

Figure 16. Locations of existing federal coal leases, exchanges, and issued, pending, and proposed LBAs, eastern Powder River Basin, Wyoming.

been settled. Details of the new agreement will be summarized in the next issue of Wyoming Geo-notes.

PacifiCorp reportedly has purchased coal from the Black Butte mine in Sweetwater County, to replace coal from the Kemmerer mine which is used nearby at Utah Power and Light Company's Naughton plant. The amount of coal was not known, and probably is dependent on the length of the labor dispute at the Kemmerer mine (COAL WEEK, 6/12/00).

Transportation developments

DTE Coal Services (DTE) has signed a coal transportation service agreement with Louisiana Generating LLC. Under the new 5-year contract, DTE will manage rail capacity and services to the Big Cajun II power plant. DTE will supply the power company with aluminum railcars as well as provide maintenance and scheduling services for the movement of approximately 6 million tons of coal the plant receives annually (COAL Daily, 4/13/00).

Coal shippers on the Great Lakes are facing record low water levels, which are impeding coal movements. The lakes are at their lowest levels in 35 years. The National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory (GLERL) expects the low water levels to persist over the summer shipping season. This means that coal users will incur higher shipping costs as smaller shiploads will be required to navigate the lakes (COAL Daily, 5/11/00).

On September 1, 2000, the Dakota Minnesota & Eastern Railroad (DM&E) expects the Surface Transportation Board (STB) to release a Draft Environmental Impact Statement (DEIS) covering DM&E's proposed new railroad into the PRB. The DEIS is expected to consist of some 2000 pages covering a wide range of environmental issues, alternatives, and recommended environmental mitigation issues. The document will be available for viewing on the STB web site at www.stb.dot.gov (COAL Daily, 6/6/00).

Another group known as the Cowboy Line is testing the water on yet another proposed rail line into the PRB from Nebraska. Currently the line runs from Crawford to O'Neill, Nebraska, but a firm map of the proposed system has yet to be drawn. The eastern terminus of the line may be Sioux City, Omaha, or Kansas City, depending on market sectors that may be targeted by the route. Although it is in an early stage of planning, the proponents of the Cowboy Line want to be ready to move forward as the third railroad serving the PRB if the DM&E build-in falters (Coal Daily, 6/12/00).

Ameren Corp. submitted applications to the Army Corps of Engineers for construction of two new transloading facilities to be located on the Mississippi River. Ameren seeks to build a new transloading facility at milepost 209.5/R at its Sioux plant in Missouri. Capacity of the new facility will be nearly 3 million tons per year, and includes mooring and staging areas for a maximum of 76 barges. Original plans called for the facility to unload petcoke and to load dry ash and slag, but Ameren is also planning to move coal through the facility. The plan calls for five sections of 48-inch conveyors to transfer petcoke or coal to the plant's coal yard or into trucks of up to 90-ton capacity. The Sioux plant burns mainly PRB coals.

Ameren is also seeking to construct a similar transloading facility at its Rush Island, Missouri plant. The capacity of the new facility would be approximately 5 million tons per year. Like the Sioux plant, the Rush Island plant also burns coal from the PRB. The Rush Island proposal may face tough permitting problems due to the current congestion in the river at the proposed site (COAL Daily, 6/26/00).

The Burlington Northern Santa Fe and Union Pacific railroads have filed a joint lawsuit in Federal District Court in Wyoming seeking to overturn two new taxes passed earlier this year by the Wyoming State Legislature (see Wyoming Geo-notes No. 66, June, 2000, p. 26). Signed into law by Governor Jim Geringer, the new taxes are known as the Wyoming train mile tax and the coal transportation tax. The suit claims both new taxes violate federal law. The new coal transportation tax, having the larger impact of the two taxes, would cost the railroads approximately $3 million annually based on 1999 shipment levels (COAL WEEK, 6/19/00).

Coalbed methane developments

The U.S. Senate Energy Committee approved the coalbed methane bill (S. 1950) sponsored by Wyoming Republican Senators Craig Thomas and Michael Enzi, which proposes to resolve disputes between coal companies and coalbed methane producers on federal lands in the PRB. The bill would amend the Mineral Leasing Act of 1920 to allow the resource with greater economic value to be developed if a mutual resolution could not be worked out (COAL WEEK, 6/12/00).

State of Wyoming officials announced they would temporarily place a moratorium on water discharge permits following sodium concerns raised in the Montana portion of the Powder River Basin coalbed methane play. The Wyoming Department of Environmental Quality (DEQ) said they would put water discharge permits on hold until the coalbed methane operators could submit additional water quality test results (COAL Daily, 5/2/00).

Pennaco Energy Inc. (Pennaco) recorded its first operating profit during the first quarter of 2000, citing record natural gas production, revenues, and cash flow. Cash flow from their operations was $1.1 million. The company recorded sales of 35 million cubic feet (MMCF) of gas per day in the first quarter, at an average price of $1.97 per thousand cubic feet (MCF). For the quarter, their natural gas revenues totaled $6.2 million.

Pennaco has spent $13.8 million for lease acquisitions including the purchase of 36 existing coalbed methane wells, $9.2 million for drilling, and $7.0 million for water discharge, gas gathering, and power facilities. The company acquired 24,300 net acres of undeveloped leases near its House Creek project in the Gillette area. The House Creek project is located in the central Wyodak coal fairway (**location 10, Figure 15**).

Pennaco reported that its current gross gas production from the PRB is approximately 72 MMCF per day. The production comes from 415 of Pennaco's coalbed methane wells and 44 wells in the Pennaco/CMS Oil & Gas Area of Mutual Interest (PI/Dwights Plus Drilling Wire, 5/5/2000, p. 5).

The Rawlins office of the BLM asked for public comments to review a coalbed methane exploration project proposed by Dudley & Associates near Seminoe Res-

ervoir (**location 11, Figure 15**). The project, in Ts 23 and 24N, R85W, calls for drilling 19 wells and constructing a pipeline to the town of Sinclair (located approximately 20 miles southeast of the project). The project area encompasses about 8320 acres, which includes 4240 acres of federal surface and mineral lands. The BLM hopes that an environmental assessment will suffice, but depending on the results of the public scoping, the analysis may have to be raised to the environmental impact statement level. Regardless, any expansion of development beyond the project's current scope would require additional environmental scrutiny (PI/Dwights Plus Drilling Wire, 6/12/00, p.10).

Double Eagle Petroleum and Mining Company (Double Eagle) reported coalbed methane production from the Mesaverde Group in the Cow Creek field (**location 12, Figure 15**), located 23 miles north of Baggs. The company is currently selling 100 MCF of gas per day, and pumping 857 barrels of water per day. The well, a workover of an older 4109-foot well originally completed in 1963 and shut in in 1997, is located in NW SE section 12, T16N, R92W. Production is reportedly from Mesaverde coals at a depth of 1268 feet.

Double Eagle is currently re-completing a second well in the area and plans to drill four more coalbed methane wells in the project area this summer. The company owns a 100% working interest in these wells, and a 50% working interest in an additional 40,000 acres of the area's coalbed methane play (PI/Dwights Plus Drilling Wire, 6/22/00, p. 2).

Bighorn Gas Gathering LLC. (Bighorn) has signed an agreement to provide gas gathering services to J. M. Huber Corp.'s (Huber's) coalbed methane wells in the PRB (**location 13, Figure 15**). Bighorn will construct a 56-mile, 20-inch diameter extension of its gathering system in Sheridan County. Construction of the new extension will run westward from Bighorn's current western terminus in southeastern Sheridan County to T57N, R83W, where Huber's production is located. The estimated completion date of the gathering line project is November, 2000 (PI/Dwights Plus Drilling Wire, 6/20/00).

Regulatory developments

U.S. Senators Michael Enzi (R-WY), Craig Thomas (R-WY), and Robert Bennett (R-UT) introduced legislation that would amend federal coal leasing rules that limit the amount of federal coal acreage that can be leased to a single company. Introduced by Senator Thomas as the Coal Market Competition Act of 2000 (S. 2300), the bill proposes to raise the state cap to 75,000 acres and the national cap to 150,000 acres (COAL Daily, 4/17/00).

The U.S. Environmental Protection Agency (EPA) announced in late April that it would not reclassify coal combustion waste (mainly coal ash) as a hazardous substance regulated under Subtitle C of the Resource Conservation and Recovery Act (RCRA) (COAL Daily, 4/27/00). The April 25, 2000 decision was that coal combustion waste should fall under Subtitle D, nonhazardous solid waste, requirements of RCRA. The agency could revisit the decision "if the states and industry do not take steps to address these wastes adequately in a reasonable amount of time." Coal ash, besides being disposed of in landfills and surface impoundments,

is used as a fertilizer, for roadbeds, in cinder blocks, wallboard manufacturing, grit in blasting, and backfilling in underground mines (Mining Week, 5/1/00).

The Edison Electric Institute in June asked the EPA to delay regulations on mercury emissions until more information is received. The utility group wants the EPA to look at the National Academy of Sciences' recommendations on mercury, expected to be out in early July; the Food and Drug Administration's nationwide examination of American dietary habits, scheduled to be out late this summer; and the Seychelles Islands study, which reportedly shows no relationship between fish consumption and human health problems. New information on the Seychelles Island study is scheduled for release this fall (Coal Daily, 6/15/00).

Market developments and opportunities

The Electric Power Research Institute (EPRI) study entitled "Energy-Environmental Policy Integration and Coordination," paints a sobering picture on the future of the nation's coal-fired electric generating plants. Assuming the government continues its current policy direction in regard to SO^2, NO^2, and especially CO^2, the report predicts that coal will fire only 10% of the nation's electricity in 2020 compared to its 55% share today. Natural gas will increase its role in electric generation from 15% today to nearly 60% over the same period.

The report said that governmental policy regarding CO^2 emission reductions will cause large shifts in fuel use and that natural gas prices will face major increases. The EPRI in its report warns that the current policy of the government "will cause electricity prices to rise 50% by 2020 and force the U.S. economy to slow" (COAL Daily, 4/10/00).

ADA Environmental Solutions is developing a new fluxing agent which can be added to boilers to more efficiently burn PRB coal. The primary targets for the new product are utilities operating cyclone units designed for burning eastern bituminous coals (COAL Daily, 4/18/00).

NRG Energy will possibly test PRB coal at its Huntley plant, located on the Niagara River at Tonawanda, New York. The 750-megawatt plant currently burns coal from the Pittsburgh seam. The timing and details of the test have not yet been decided (COAL Daily, 5/31/00).

Table 15 tabulates some of the contract, spot sales, test burns, and solicitations for Wyoming coal announced during the first quarter of 2000.

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

Stauffenberg, D.G., 2000, Annual report of the State Inspector of Mines of Wyoming for the year ending December 31,1999: Office of the State Inspector of Mines, Rock Springs, Wyoming, 80 p.

Table 15. Marketing activities for Wyoming coal producers during the second quarter of 2000*.

	Utility	Power Plant	Coal Mine/Region	Activity	Tonnage	Comments
1.	Aliant Energy	Columbia	PRB	C	up to 5 million t	Term of 1-3 years starting in 2001; originates on BNSF and delivered to plant by Canadian Pacific.
2.	Archer- Daniels-Midland (industrial plants)	Several Midwest plants	PRB	T	up to 1 million t	8800 Btu coal to qualify PRB coals for use at its facilities in Iowa, Minnesota, and Nebraska.
3.	Arizona Electrical Power Coop.	Apache	Western coal	So	900,000 to 1.4 million t	Delivery in 2001 and beyond.
4.	City Public Service Board of San Antonio	Deely and Spruce	PRB	So	1 million t	2001 coal needs will also look at offers for 2002 and beyond.
5.	Consumers Energy	System	PRB	Sp	480,000 t	Delivery in August through December 2000.
6.	Consumers Energy	System	PRB	Sp	up to 1 million t	Delivery in first and second quarter of 2001.
7.	Grand River Dam Authority	Grand River Dam	PRB (producers only)	C	1.6 to 2 million t/yr	Two separate contracts up to 4 million t/yr for one, three, seven, or ten years starting in 2001.
8.	Kansas City Power & Light Co.	System	PRB	Sp	2.25 million t	For delivery 2001.
9.	Public Service of Colorado	Arapahoe	Black Thunder/PRB	Sp	40,000 t	Purchased from Duke Energy for second quarter delivery.
10.	Salt River Project	Coronado	Jacobs Ranch/PRB	Sp	150,000 t	Delivery during remainder of year 2000.
11.	Southern Co., for Georgia Power	Scherer	PRB	C	up to 3 million t/yr	Term of up to 5 years.
12.	TVA	System	Eastern & Western coals	Sp	up to 2 million t	Delivery from 7/1/2000 to 6/30/2001 terms of 3, 6, or 12 months.
13.	Texas Municipal Power Agency	Gibbons Creek	PRB	C	1.5 to 2 million t/yr	Term up to 3 years starting January, 2001.
14.	Wisconsin Public Service Corp.	Pulliam and Weston	PRB	C	Approximately 2 million t/yr	Term of 1 to 5 years beginning on January 1, 2001.

*Data obtained from: COAL WEEK, Coal Daily, Coal Age, FERC database, and personal contacts.

Note: C = contract; Sp = spot coal; So = solicitation; T = test burn; t = short ton; t/y = short tons per year; and PRB = Powder River Basin.

Wyoming State Geological Survey, July, 2000

INDUSTRIAL MINERALS AND URANIUM UPDATE

Ray E. Harris
Staff Geologist–Industrial Minerals and Uranium, Wyoming State Geological Survey

Internet site

The Internet site for the Industrial Minerals and Uranium Section of the Wyoming State Geological Survey (WSGS) has been completely revised with photographs, pages for each major commodity produced in Wyoming, and links to producers' sites. Visit it at http://www.wsgsweb.uwyo.edu/minerals/about.htm. Statistics for Wyoming industrial mineral and uranium production have been updated by the section for the calendar year 1999 and are posted on the Internet site. Click on "Production Statistics" at the bottom of the web page.

Bentonite

The amount of bentonite mined in Wyoming in 1999 was about 4,073,765 short tons, 10% less than the amount mined in 1998, according to a new production report (Stauffenberg, 2000). The decrease in 1999 is principally due to the use of bentonite that was mined in 1998 and stockpiled at the plant sites. Plant production (of refined bentonite) was down about 3% in 1999. The amount of bentonite mined in both 1997 and 1998 was a near record; the record production occurred in 1981 (**Figure 17**).

Bentonite is a clay with special properties including expanding when wet, adsorbing chemicals, and acting as a sealant and barrier agent. It is used in a wide variety of products including kitty litter, wastewater treatment, well drilling fluids, and as a

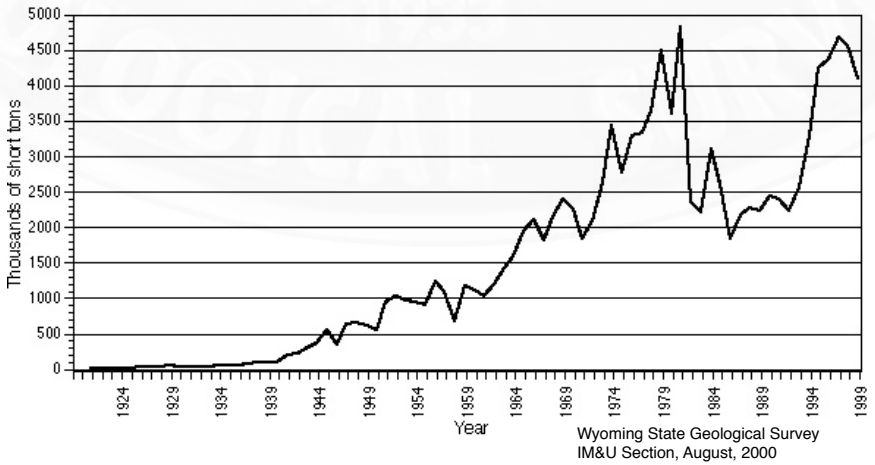

Figure 17. Historic annual production of Wyoming bentonite in thousands of short tons. Sources: Wyoming Board of Equalization (1920-1957), Wyoming Ad Valorem Tax Division (1958-1987), and Wyoming State Inspector of Mines (1988-1999).

mineral filler. Ten plants (mills) in Wyoming refine bentonite mined from various pits into the different products (**Figure 18**). There is also a bentonite plant west of Belle Fourche, South Dakota that refines bentonite mined in Wyoming. This plant is 5 miles east of the Wyoming-South Dakota border.

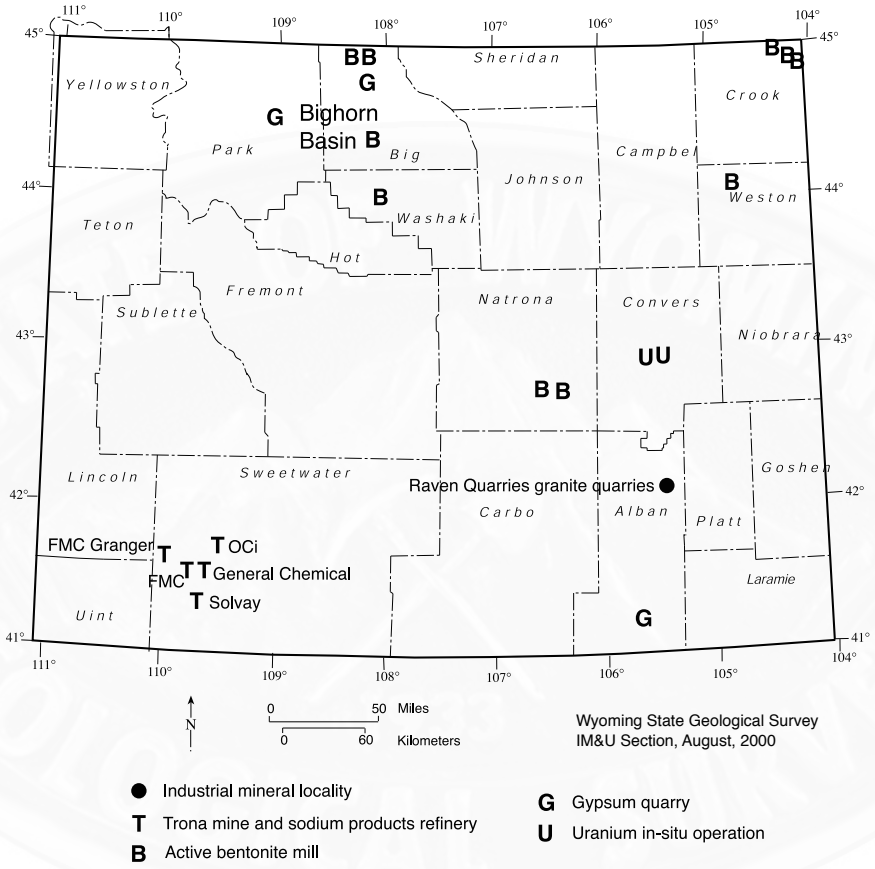

Figure 18. Index map of Wyoming showing the location of industrial mineral and uranium sites mentioned in the text.

Construction aggregate

Construction aggregate includes sand and gravel, scoria (clinker, baked and fused shale), crushed stone, shale, and other material used in construction. About 15 million short tons of construction aggregate were produced in Wyoming in 1999. This is an increase over 1998's production of about 11.2 million short tons. Construction aggregate production is often estimated by the producers and is subject to variabilities from producer to producer, so there is no highly accurate record of this production.

Decorative and dimensional stone

Raven Quarries operates a granite dimensional stone quarry in Albany County, Wyoming (**Figure 18**). The owners of Raven Quarries have announced that the quarry is for sale and it is advertised in Stone World Magazine. Meanwhile, Raven Quarries continues to produce a pink granitic rock called Mirage (see photograph in Wyoming Geo-notes No. 66, June, 2000, p. 31). Blocks from this quarry are shipped to Tijuana, Mexico for cutting and polishing into slab and tile. Some stone from this quarry is also processed into polished slab by Strid Marble and Granite (Strid) in Cheyenne.

Strid cuts and polishes all types of decorative stone into slab under contract with the quarrier. The final product is owned and sold by the quarrier.

Gypsum

Gypsum production in 1999 was around 560,000 short tons (Stauffenberg, 2000), an increase of about 30,000 short tons over 1998. Gypsum production has been nearly constant for the past five years. The two wallboard plants in the Bighorn Basin, Celotex and Georgia Pacific (**Figure 18**), have been operating at capacity during this time period. Gypsum producers are reluctant to increase domestic capacity even though the demand for wallboard, the principal product produced from gypsum, is high and increasing. Contrary to demand increases, the price of raw gypsum dropped in 1998 and 1999, due possibly to the low-cost production of wallboard in other countries. The threat of low-cost wallboard and imports of other gypsum products may prevent short-term investment in domestic gypsum.

Small amounts of gypsum are periodically quarried by Mountain Cement south of Laramie in Albany County (**Figure 18**). Gypsum is used here as a retardant in the manufacture of cement.

Trona

Trona is mined at five locations in Wyoming and processed into soda ash and other sodium-based chemicals at plants near the mines (**Figure 18**). FMC also recovers trona from water that has flooded abandoned underground mine workings. Trona production declined in 1999 to 17,794,438 short tons according to the Wyoming Department of Revenue, a decrease of 4.5% from 1998 (**Figure 19**). The decrease was due to a weakening of the soda ash market in the Pacific Rim countries and a reduction in production by FMC at the Granger mine, which was purchased by FMC from Tg Soda Ash early this year.

Uranium

Uranium production in Wyoming in 1999 increased 16% over the amount produced in 1998, according to figures released by the State Inspector of Mines of Wyoming (Stauffenberg, 2000). The 1999 production was 2,760,255 pounds of yellowcake. All of Wyoming's uranium is produced by in-situ methods at two

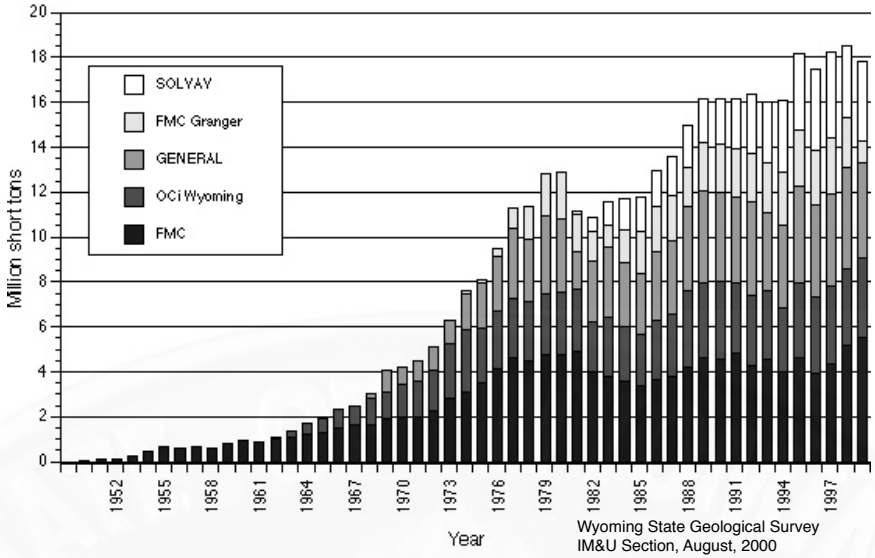

Figure 19. Annual production of Wyoming trona (1949 through 1999) in million short tons.

localities in Converse County (**Figure 18**). Production is expected to decrease in 2000 with the shutdown of COGEMA's Christiansen Ranch operations in southeastern Johnson County. Despite this, Wyoming remains the nation's leader in uranium production.

The spot market price of yellowcake continued to fall during the second quarter of 2000. At the end of the quarter, the price according to the Uranium Exchange web site (http://www.uxc.com/top_review.html) was $8.05, its lowest since July, 1995 (**Figure 20**). The price drop is due to international purchases of Russian uranium from stockpiles and the decommissioning of uranium-based weapons. Russia and other countries of the former Soviet Union continue to sell yellowcake on the world market at US$6.75 per pound, according to the Uranium Exchange.

However, the U. S. Enrichment Corporation (USEC), the U. S. government agent for selling Russian uranium in the United States, is purchasing Russian uranium for enrichment in the United States at prices higher than the U. S. spot market price ($8.05) under terms of a Clinton administration agreement. The contract between the USEC and Russia is up for renegotiation in 2002.

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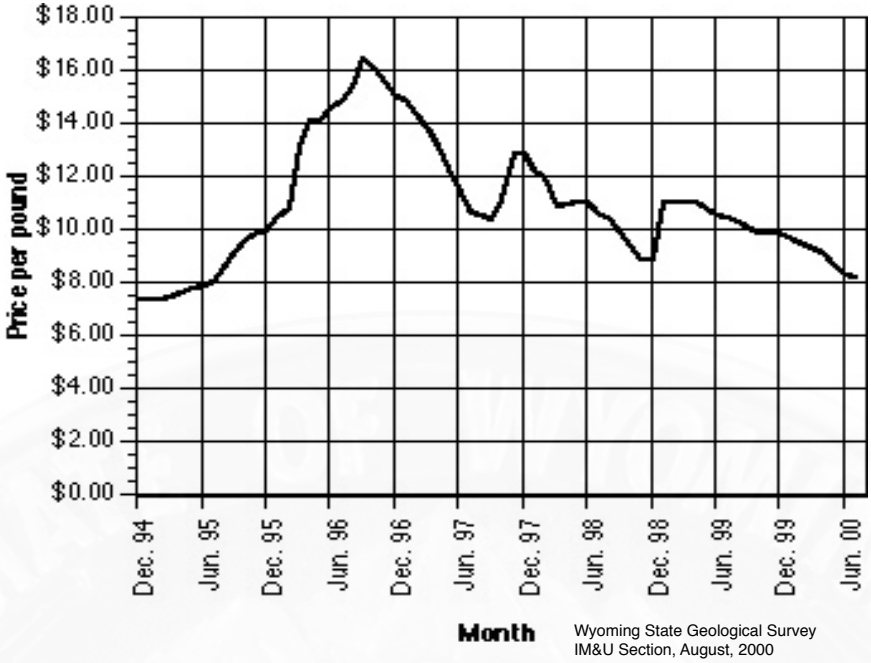

Figure 20. Spot market yellowcake prices, as of June, 2000. Source: Uranium Exchange weekly reports.

METALS AND PRECIOUS STONES UPDATE

W. Dan Hausel
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Precious metals activities

During the past year, platinum-group metals (PGMs) attracted considerable worldwide interest due to rising prices and reported shortages. Wyoming is poised to benefit from this price increase, as the state is partially underlain by rocks favorable for PGMs. In fact, during the early 1900s these metals were recovered from mines in the New Rambler and Centennial Ridge districts in the Medicine Bow Mountains.

Last fall, John Glasscock, a geologist with Cowboy Exploration in Jelm, Wyoming, described some Wyoming PGM targets at a conference in Laramie. Before the conference, General Minerals held several mining claims within the Lake Owen complex in the Medicine Bow Mountains. The Lake Owen complex has similarities to the Stillwater complex in Montana, where platinum and palladium are currently being recovered by the Stillwater Mining Company. After the conference, prices for

PGMs skyrocketed, and several exploration companies filed hundreds of mining claims on all the available ground in the Lake Owen, Mullen Creek, and Puzzler Hill complexes. Still, several other targets in the Wyoming platinum-palladium-nickel province remain unexplored (see information on the WSGS web site http://www.wsgsweb.uwyo.edu/metals/metals.htm).

Gold exploration is at an all-time low in Wyoming, due to the reported manipulation of the international gold markets. Gold prices remained extremely low (around $278 per ounce) during the last quarter. However, a prospector from Lander, Wyoming recently discovered a gold-bearing shear zone in the South Pass area. The shear zone is hidden under a thin eluvial cover, but can be recognized by the presence of rock chips of chloritized and hematitized metagreywacke with some chips of quartz in the soil. A backhoe trench exposed the hidden shear zone and the prospector recovered quartz from it. The quartz was crushed and several flakes of visible gold were recovered from panned concentrates. Channel samples from the shear are currently being examined by the WSGS.

During mapping of the South Pass greenstone belt, the WSGS found evidence of several hidden shear zones in the Crow's Nest and Lewiston areas of the South Pass belt. Most of these hidden shear zones have never been explored–yet they represent excellent gold targets.

Some gold exploration was reported by a major gold company searching for sediment-hosted gold deposits in the Wyoming basins. Other company exploration was minimal.

Due to several requests, the Section began mapping the Centennial Ridge and Gold Hill districts in the Medicine Bow Mountains for the purpose of preparing a guide for prospectors. The guide will be designed to show prospectors and the general public how to search for gold and platinum deposits.

Gemstones

Kimberlites are one of two host rocks that contain commercial amounts of diamond, and the WSGS has identified hundreds of possible diamond targets in Wyoming (Hausel, 1999), indicating most of Wyoming has high potential for the discovery of commercial diamond deposits. Two of the most promising areas in the state are the Iron Mountain and Guide Rock districts in the Laramie Mountains.

During the past quarter, exploration for diamonds in the Iron Mountain district slowed considerably. Sample processing for diamond-indicator minerals and diamonds from the Iron Mountain district is essentially at a standstill, due to the termination of a grant and loss of contractual employees. Samples collected from the anomalies in the nearby Indian Guide district have yet to be processed. The WSGS had discovered dozens of new kimberlites and identified what may be the largest kimberlite district in the United States (see Wyoming Geo-notes No. 66, June, 2000). Prior to funding cuts, the WSGS had identified 18 probable diamond targets in this area.

Last year, the WSGS also discovered a group of probable hidden kimberlite pipes during geologic mapping in the Iron Mountain district. In recent weeks, an exploration company exposed a few of these by backhoe trenching, which revealed

the characteristic blue ground associated with weathered kimberlite. Small bulk samples of this material were collected by the WSGS for diamond testing. The material will be processed as time permits. Some mapping is still continuing in the district, and a few new kimberlite extensions were found in recent weeks.

A variety of other gemstones could potentially be produced from Wyoming. A new book recently published by the WSGS describes hundreds of occurrences of gemstones and other rocks and minerals in Wyoming. Bulletin 71, Gemstones and other unique minerals and rocks of Wyoming – A field guide for collectors, (Hausel and Sutherland, 2000) indicates that Wyoming has one of the more diversified collections of gemstones, lapidary minerals, and unusual rock and mineral deposits in North America. Each year, hundreds of collectors and researchers visit the state in their quest for new rock and mineral specimens, and nearly every year, new discoveries are made. In just the past few years, the WSGS has discovered some ruby, sapphire, peridot, iolite, jade, agate, and jasper occurrences while gathering information for the book. To order this, see the **NEW PUBLICATIONS AVAILABLE** section for details and the ordering form in the back of this publication.

Field investigations and mapping of the Palmer Canyon corundum-cordierite-kyanite-sillimanite gneiss and schist by the Metals and Precious Stones Section identified a corundum-bearing kyanite schist with a strike length of approximately 1000 feet (although portions of the schist are covered by alluvium). The corundum includes translucent and transparent, white and pink sapphire, and red translucent ruby. Some rubies show tiny mineral inclusions, although others exhibit no visible inclusions when examined microscopically.

Iolite (transparent cordierite) discovered by the author a few years ago in Palmer Canyon, was also investigated. A cordierite-kyanite gneiss was found in place and mapped on the surface over a strike length of about 200 feet and continues under cover along strike both east and west of the outcrop. During mapping, some transparent detrital iolite gems were picked up about 300 feet (upslope) from the outcrop. These weighed 0.3, 1.2, and 2.8 grams (1.5, 6, and 14 carats, respectively). Samples of float gneiss found by the author a few years ago contained as much as 20% transparent iolite.

An August 16, 2000 press release from McKenzie Bay International indicates that the new operators of the Kelsey Lake diamond mine in the Colorado-Wyoming State Line district will commission their x-ray diamond sorter on August 21, and then shortly begin diamond recovery. McKenzie Bay is the new owner of the mine (see Wyoming Geo-notes No. 66, June, 2000) and Great Western Diamond Company, a wholly owned subsidiary, the new operators. The WSGS was also excited to hear that the newly appointed Diamond Recovery Process Manager will be Carl F. Brink. Carl worked for the WSGS on a diamond research project in the 1980s. Congratulations Carl.

New minerals found in Wyoming

Three minerals that were previously unreported in Wyoming, were found by collectors and identified by the WSGS. These include two minerals collected from Cedar Mountain near Cody by Robert Bratton and sent to the WSGS for X-ray dif-

fraction (XRD) analysis and a third mineral collected in the Jelm Mountain area and sent to us by John Saxton of Casper for identification.

The first mineral from Cedar Mountain is dark green, with massive to octahedral habit, that appears to fill breccia voids with prismatic quartz in a white to gray, siliceous host rock. The XRD pattern confirmed the mineral as variscite [$Al(PO^4)•2H^2O$]. Other localities for this mineral include Utah, Nevada, California, Arizona, Arkansas, Western Australia, Brazil, and Europe.

The second mineral from Cedar Mountain fills a fracture in a white, fine- to medium-grained sandstone. This mineral is light green with nodular, acicular, radiating crystals. The mineral was confirmed as minyulite [$KAl^2(PO^4)^2(OH,F)•4H^2O$] by XRD analysis. The Encyclopedia of Minerals reports only one other occurrence–Dandaragan, Western Australia.

The Jelm Mountain sample occurs as a light blue-green massive to botryoidal mineral that was suspected to be smithsonite. Instead, XRD analysis performed by Robert Gregory showed a good match for rosaite [$(Cu,Zn)^2(CO^3)(OH)^2$]. The identification of this mineral may have exciting implications for what is called the Green Mountain terrain in southeastern Wyoming. The Green Mountain terrain includes the south half of the Laramie, Medicine Bow, and Sierra Madre mountains where several zinc anomalies have been identified in recent years. The possibility of an important, unrecognized zinc province in southeastern Wyoming needs to be considered.

Reports in progress

The Metals and Precious Stones Section is currently preparing a final report on the geology of the Leucite Hills in southwestern Wyoming. The Leucite Hills include some of the rarest rocks on the earth's surface. These rocks are geologically young (1.1 to 3.1 million years old) ultrapotassic lavas located near Rock Springs. The Section is also near completing a final report on the Iron Mountain kimberlite district. This final report will include geological mapping, geophysical surveys, and considerable geochemical data. A guide to prospecting in the Medicine Bow National Forest is underway. This "how to" guide is designed for prospectors who want to search for valuable gold and other mineral deposits and will teach what things to look for. The Section is also working with a Russian geologist on a book on diamond deposits of the world, which is scheduled to be completed by next summer.

Lectures and field trips

During the past quarter, the Section presented several talks and led some field trips for various groups. The most recent field trips included a tour of the Centennial Ridge gold-platinum district during a raging snowstorm, and a trip to some kimberlites in the State Line district.

A large group of prospectors, geologists, and general public attended an August 11th field trip to the South Pass gold district. The field trip, led by W. Dan Hausel, examined many of the historic gold mines and provided prospectors with informa-

tion on how to recognize hidden gold deposits, and where to look for rich, unmined placers. On the trip, some samples of quartz with visible gold were found by attendees. A sample with some gold was found at Miners Delight by a prospector from the Rocky Mountain Prospectors and Treasure Hunters Club of Fort Collins. A beautiful sample of quartz with considerable wire gold was found by a Wyoming prospector at the Carissa mine (see map on **cover**) the following day. Although it is impossible to tell how much gold the sample contained, based on the size of the sample and the amount of gold, the sample could assay as high as 20 to 50 ounces of gold per ton.

Section news

Marquis Who's Who in the World has selected Dan Hausel for inclusion in their forthcoming 18th Edition for his lifelong achievements in the geological sciences.

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GEOLOGIC MAPPING, PALEONTOLOGY, AND STRATIGRAPHY UPDATE

Alan J. Ver Ploeg
Senior Staff Geologist-Geologic Mapping, Wyoming State Geological Survey

SHERIDAN COUNTY GEOLOGIC MAP COMPLETED

The Geologic Mapping Section, with the aid of funding from the STATEMAP 99 Program, recently completed compiling the geology for the Sheridan 1:100,000-scale Quadrangle. The recent activity in coalbed methane exploration and production and the fact that the Sheridan area is one of the more populated areas in the state prompted the Section to choose this quadrangle. These efforts began in August of 1999. Geologic mapping at a wide variety of scales and coverages existed for much of the quadrangle's area and this information was compiled at the 1:100,000 scale.

With expanding construction in the Sheridan area, as well as in other localities within the quadrangle, accurate, up-to-date mapping is needed by the construction and concrete industries to locate aggregate and construction materials. Clinker, rock baked or partially fused by recent naturally ignited coal fires, is used locally as aggregate and light duty construction material. As the new map shows, numerous clinker quarries already exist and additional clinker deposits are common in the weathered outcrops of the Wasatch and Fort Union formations, which occur over most of the quadrangle. The new mapping will aid in the mitigation of identified geologic hazards in the area, as numerous landslides have been mapped in the Wasatch Formation. In addition, accurate geologic information depicted on the map can enhance predictability in searching for coalbed methane and water well drill sites in the area.

The Sheridan Quadrangle is located in northern Wyoming, on the Wyoming-Montana border (**Figure 21**). The quadrangle includes bedrock ranging from Precambrian to Eocene in age. The structural axis of the Powder River Basin runs southeast to northwest through the west-central portion of the quadrangle, with the Bighorn Mountains uplift impinging on the southwest corner of the quadrangle. In the southwestern corner of the quadrangle, high angle reverse faulting brings the Piney Creek thrust block up and over Tertiary and Cretaceous rocks on the west flank of the structural basin. The remainder of the quadrangle is characterized by

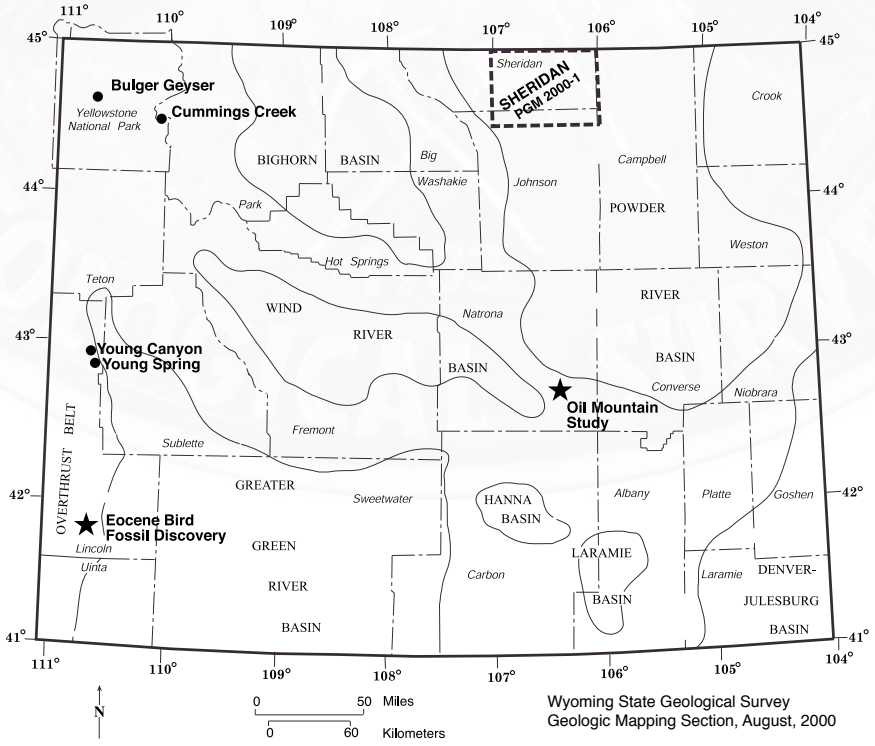

Figure 21. Index map to new geologic mapping, a new fossil discovery, recently named geographic features, and the site of a new geologic study in Wyoming.

relatively flat-lying Tertiary Wasatch and Fort Union formation outcrops containing numerous coal beds that historically have been both underground and surface mined and are currently being tested for coalbed methane.

The 1:100,000-scale geologic map series, as developed by the Wyoming State Geological Survey (WSGS), provides basic geologic information superimposed on a standard U.S. Geological Survey metric topographic base. The map area includes one-half degree of latitude and one degree of longitude and represents approximately 1800 square miles.

Preliminary geologic map of the Sheridan 30' x 60' Quadrangle, Sheridan, Johnson, and Campbell Counties, Wyoming and southern Montana by A.J. Ver Ploeg and C.S. Boyd is available as Preliminary Geologic Map PGM 2000-1. Along with the black line map is a pamphlet containing a detailed description of map units and map symbols and the sources of geologic data used in compilation. An entirely digital version of the geologic map and base will be completed as part of STATEMAP 2000; the map will be made available as either a plotted color geologic map or as a CD-ROM with the digital data by August of 2001.

SMITHSONIAN SCIENTIST TO STUDY FOSSIL BIRD FIND

Storrs Olson of the Division of Birds at the Smithsonian Institution has agreed to describe the Eocene fossil bird specimen featured on the cover of Wyoming Geo-notes (No. 66, June, 2000). Carl Ulrich of Ulrich's Fossil Gallery collected the specimen from the Green River Formation in the fossil-fish-rich area west of Kemmerer (**Figure 21**). The unusual specimen came from a State of Wyoming commercial fossil collecting permit. Ulrich prepared the specimen and recently donated it to the State of Wyoming. After viewing photos of the bird fossil, Storrs indicated that it was definitely a Limnofregata azygosternon, a species first described by Storrs (1977) in WSGS Bulletin 63 (Grande, 1984) and illustrated on page 208 of that publication. The bird was a frigate or sea bird known for its powers of flight. The specimen appears to have some bones or features preserved that are missing on the previously described specimen and the new fossil will hopefully provide new information on the species.

The fossil will be transported to Washington, D.C. where Storrs will study and describe it. The specimen will then be returned to the WSGS and tentative plans are to display it at the University of Wyoming's Geology Museum. Storrs plans to publish the results of the study of this specimen and another he has described.

NEW GEOGRAPHIC NAMES FOR NORTHWESTERN WYOMING

According to the recently published list of new geographic names in the U.S., Wyoming has four newly named geographic features, as approved by the U.S. Board on Geographic Names. The four features are Bulger Geyser, Cummings Creek, Young Canyon, and Young Spring (**Figure 21**). The name Bulger Geyser has been applied to a geyser located in Yellowstone National Park within the Upper Geyser Basin and just east of the Firehole River. It is approximately 0.6 mile northwest of Old Faithful and is named after nearby Bulger Spring.

The name Cummings Creek is applied to a stream in Yellowstone National Park that flows into Bear Creek, 1 mile southwest of Mount Chittenden. The creek is named for Lieutenant Joseph Franklin Cummings (1851-1912), a member of the party that attempted to establish the first wagon route into Yellowstone National Park from Wyoming Territory in 1881.

Young Canyon is the name now applied to a valley in Bridger-Teton National Forest, Lincoln County, Wyoming. This valley (canyon) connects to the Greys River valley and is named for Samuel A. Young and Rexford R. Young (now deceased), two brothers who built a cabin near the feature in the 1920s.

Young Spring is now the name of a spring located on the west bank of the Greys River in Bridger-Teton National Forest, Lincoln County, Wyoming. It is named for the same two brothers listed above for Young Canyon.

NEW PUBLICATION ON WYOMING GEOLOGY

Hennings, Olsen, and Thompson (2000) used outcrop data and three-dimensional structural models to characterize the fractured Frontier Formation reservoir in Oil Mountain anticline west of Casper (**Figure 21**). Oil Mountain anticline is an asymmetrical fold trending southeast to northwest on the western flank of the Casper arch in central Wyoming. The researchers measured the frequency and orientation of fractures on the outcrop of the Frontier Formation. The outcrop characterization was combined with three-dimensional structural models generated using digital topography, aerial photography, position of geologic contacts, bedding azimuth, well data, and seismic profiles. A relationship was noted between the intensity of fracturing and the rate of dip change and total azimuth curvature. This integration technique could aid in locating fractured or compartmentalized reservoirs.

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Grande, L., 1984, Paleontology of the Green River Formation, with a review of the fossil fish fauna, Second edition: Wyoming State Geological Survey Bulletin 63, 333 p.

Hennings, P.H., Olsen, J.E., and Thompson, L.B., 2000, Combining outcrop data and three-dimensional structural models to characterize fractured reservoirs: An example from Wyoming: American Association of Petroleum Geologists Bulletin, v. 84, no. 6, p. 830-849.

PROBABILITY OF DAMAGING EARTHQUAKES IN WYOMING

James C. Case
Staff Geologist–Geologic Hazards, Wyoming State Geological Survey

INTRODUCTION

Seismological characterizations of an area can range from analyzing historical seismicity to assessing the probability of earthquakes occurring in an area. A complete characterization usually includes a summary of historical seismicity, an analysis of active faults exposed at the surface, an analysis of the potential distribution and maximum magnitude of earthquakes associated with buried faults, and an analysis of the probability that earthquakes will occur within certain time frames. This article addresses probability analyses, and relates predicted ground motions to damage potential.

HISTORICAL EARTHQUAKES

The historical earthquake record for Wyoming is incomplete and fairly short, dating back only about 130 years. It is risky to examine only the historical record to predict what may occur in the future. For example, the Teton fault, which is known to be capable of generating a magnitude 7.5 earthquake, has not had any known historical activity associated with it. Only examining historical seismicity in Teton County would result in a significant underestimation of the true earthquake potential of the region. In parts of Wyoming with no active faults exposed at the surface, it is equally risky. For example, in southeastern Wyoming, the largest recorded earthquake had a magnitude of 5.5 and occurred in northern Albany County in 1984. In 1882, however, a magnitude 6.3 to 6.5 earthquake occurred just across the Colorado state line, somewhere between Laramie and Estes Park, Colorado. That event is used to indicate that in the Rocky Mountains, magnitude 6.5 events may occur in areas where active faults are not exposed at the surface. In this case, it is important to look at regional patterns of seismicity to get a better indication of what may be possible.

ACTIVE FAULTS

As mentioned above, there are areas of the state where active faults exposed at the surface can generate earthquakes in the magnitude 7.2 to 7.5 range. These faults occur from the Yellowstone National Park area in northwestern Wyoming to Uinta County in southwestern Wyoming (Wyoming Geo-notes No. 66, June, 2000). Any of these faults can be analyzed to determine what maximum magnitudes may be associated with the faults, and to determine how any generated seismic waves may be attenuated (lessened) with distance from the fault. These types of analyses are useful for designing structures in the near vicinity of the faults; however, other earthquake sources associated with buried faults may be overlooked.

PROBABILISTIC SEISMIC HAZARD ASSESSMENTS

Probabilistic seismic hazard assessments are generated by analyzing three elements and using a probability model (McGuire and Arabasz, 1990). The three elements are: 1) seismic sources or zones; 2) magnitude distribution and rate of occurrence for sources and zones; and 3) ground motion estimation.

The first element, seismic sources and seismic source zones, is generated using known active faults, historical earthquake records, regional patterns of seismicity, and knowledge of both local and regional geologic terrains and geologic structures. An exposed active fault may be considered a seismic source. In areas where there are no exposed active faults, seismic sources are zones or areas where earthquakes are assumed to be equally likely to occur throughout the area, have the same maximum magnitude and magnitude distribution, and are independent from event to event (McGuire and Arabasz, 1990). These types of zones are based upon local historical seismicity, regional patterns of seismicity, and knowledge of geologic structure. Wyoming has many seismic sources and source zones, which include active faults as well as broad areas that encompass large parts of the state. A more complete discussion on seismic source zones for Wyoming can be found in Frankel and others (1996).

The second element, magnitude distribution, is a probability distribution of earthquake magnitudes and rates of occurrence for each seismic source and zone. The magnitude distributions are based upon knowledge of historical seismicity, regional models, and studies on active faults. An expanded description of magnitude distributions can be found in McGuire and Arabasz (1990).

The third element is a ground motion equation, which is used to estimate what type of ground motion may occur at any site in a source zone or at any site near an active fault. This is done through a consideration of the various distances that all future earthquakes may occur with respect to the site. Models of seismic wave attenuation are used to determine how ground motion decreases with distance from an earthquake. In essence, the ground motions being considered at a specific site are those from all future possible earthquake magnitudes at all possible distances from that site (Perkins, 2000a).

Data from the three elements are used to calculate the probability that any ground motion will be exceeded within various time frames in an area of interest, which in this case is Wyoming. The final results of the probability analyses are maps that show the probability that a type of ground motion will be exceeded in 50 years. Most maps show ground motions that have either a 2%, 5%, or a 10% probability of being exceeded in 50 years. Another way to look at the maps is to assume that the 2% probability map is roughly equivalent to a map that shows ground motions that have a 100% chance of being exceeded in 2500 years. The 5% probability map is roughly equivalent to a map that shows ground motions that have a 100% chance of being exceeded in 1000 years. The 10% probability map is roughly equivalent to a map that shows ground motions that have a 100% chance of being exceeded in 500 years. The 2500-year map represents larger earthquakes than the 500-year map, because the more time that goes by, the greater the chance that a larger earthquake will occur.

Historically, ground motions have been represented as peak ground acceleration (PGA), spectral acceleration (SA), and/or peak ground velocity (PGV). Today, the most commonly used maps show PGAs and SAs, with accelerations in terms of percent of gravity (%g). A PGA represents what is experienced by a particle on the ground, and a SA approximates what is experienced by a building, as modeled by a particle on a massless vertical rod having the same natural period of vibration as the building.

Spectral Acceleration maps are often shown for periods of 0.2 second, 0.3 second, and 1.0 second. During an earthquake, seismic waves are generated that have a variety of periods. A building that has a natural period of vibration of 0.2 second (or a natural frequency of 5 cycles per second) will be subjected to the acceleration represented on a map that shows SA with a period of 0.2 second. Short buildings, less than seven stories, generally have periods in the 0.2- to 0.6-second range (Perkins, 2000b).

In 1996, the U.S. Geological Survey generated both PGA and SA (0.2-, 0.3-, and 1.0-second periods) maps for the United States (Frankel and others, 1996). Spectral acceleration maps can be observed or downloaded at the U.S. Geological Survey web site at http://geohazards.cr.usgs.gov/eq/. Copies of the maps can also be obtained through the Geologic Hazards Section at the Wyoming State Geological Survey. The spectral acceleration maps are now used in the new International Building Code, which is the current upgrade of the Uniform Building Code. The next issue of Wyoming Geo-notes will contain a more detailed analysis of the spectral acceleration maps for Wyoming.

Figures 22, 23, and **24** are Peak Ground Acceleration maps that were generated for the Wyoming State Geological Survey. The maps show peak ground accelerations that have a 10%, 5%, or 2% chance of being exceeded in 50 years.

In order to translate acceleration values into terms that are more understandable, Bolt (1988) generated a generalized comparison between the Modified Mercalli Intensity Scale and peak accelerations. A more detailed description of the Intensity Scale was presented in Wyoming Geo-notes No. 66 (June, 2000). Shown below (**Table 16**) are accelerations and selected intensities.

Table 16. Relationships between peak acceleration values and intensities of earthquakes (from Bolt, 1988).

Peak acceleration (%g)	Intensity (Modified Mercalli Scale)	Effects
1.5-2	IV	Sensation like heavy truck striking building.
3-4	V	Cracked plaster in a few places.
6-7	VI	Some fallen plaster and damaged chimneys.
10-15	VII	Damage negligible in well-designed and well-built structures, slight to moderate damage in well-built ordinary structures, considerable damage in poorly built structures.
25-30	VIII	Damage slight in specially designed structures, considerable in ordinary buildings with partial collapse, great in poorly built structures.
50-55	IX	Damage great in substantial buildings, with partial collapse. Underground pipes broken.
>60	X	Some well-built wooden structures and most masonry and frame structures destroyed. Landslides. Rails bent.

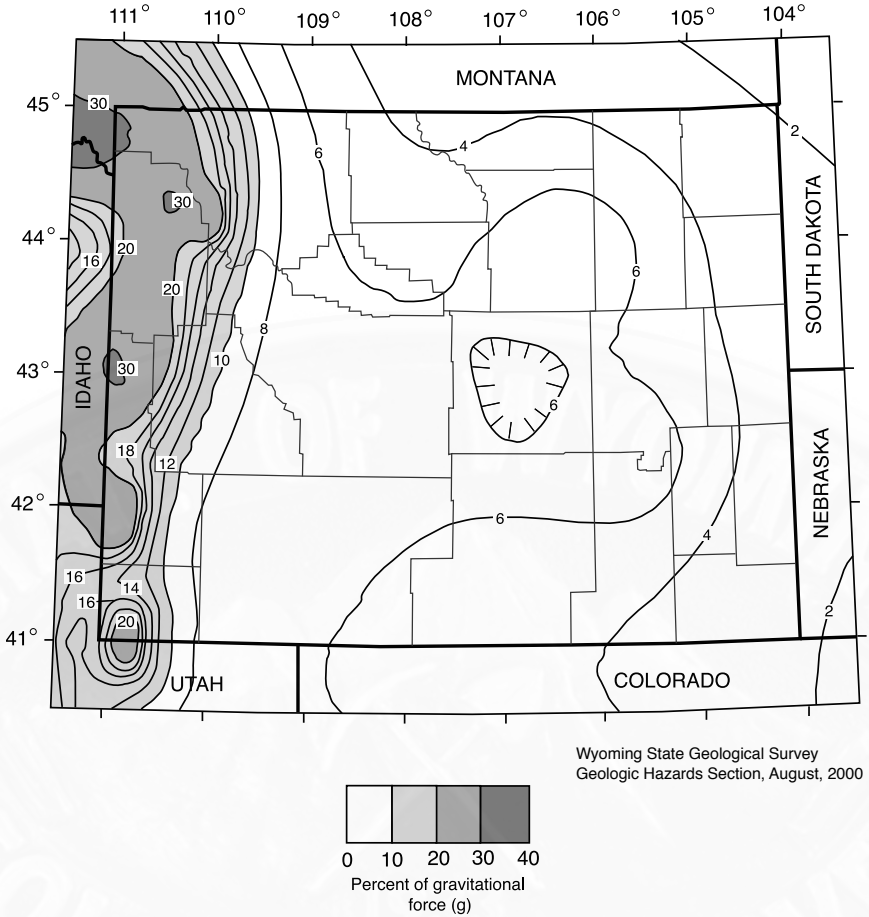

Figure 22. Peak ground acceleration map of Wyoming, in percent of gravitational force (g), for earthquake ground motions with a 10% probability of being exceeded in the next 50 years. Data for NEHRP B-C boundary site from the U.S. Geological Survey National Seismic Hazards Mapping Project. Albers Equal Area Projection, reduced from original map scale of 1:4,000,000.

The map in **Figure 24** shows that there is a 2% chance in the next 50 years of having an earthquake-related ground motion that could cause moderate to major damage in Wyoming, depending on which part of the state it occurs. In western Wyoming, the potential is greatest for major damage. It is important to keep in mind, however, that the maps above represent the current thought on earthquake potential in Wyoming. Unfortunately, there is always a possibility that future earthquakes will not fit the schedules suggested on the maps.

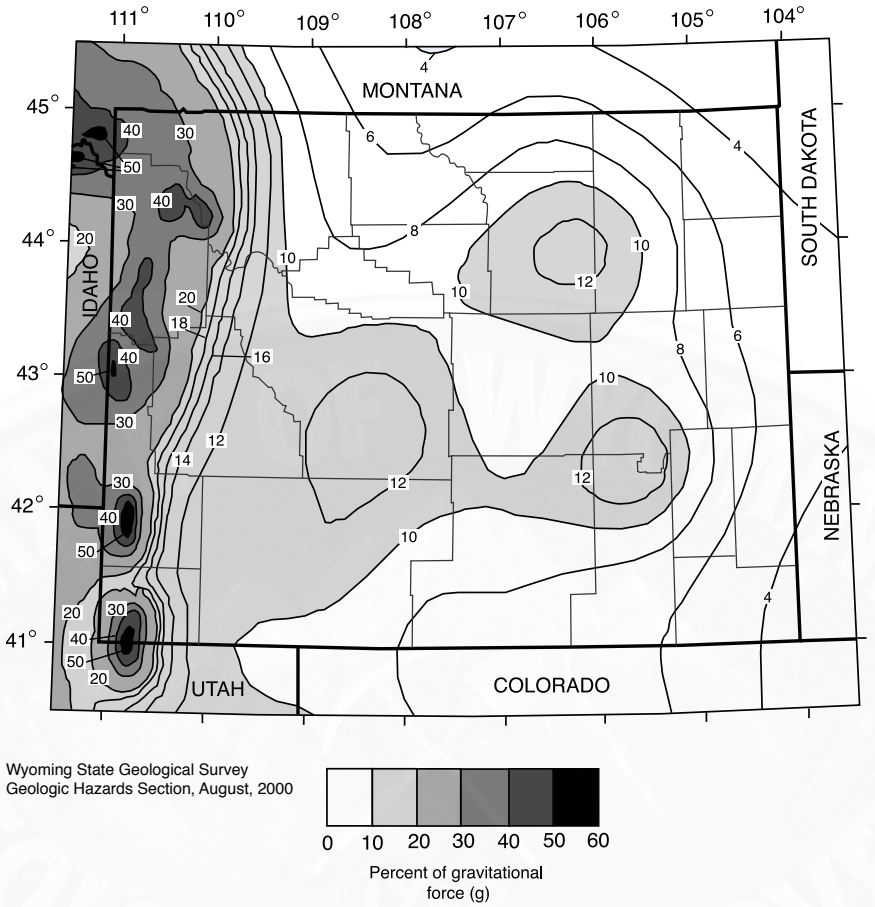

Figure 23. Peak ground acceleration map of Wyoming, in percent of gravitational force (g), for earthquake ground motions with a 5% probability of being exceeded in the next 50 years. Data for NEHRP B-C boundary site from the U.S. Geological Survey National Seismic Hazards Mapping Project. Albers Equal Area Projection, reduced from original map scale of 1:4,000,000.

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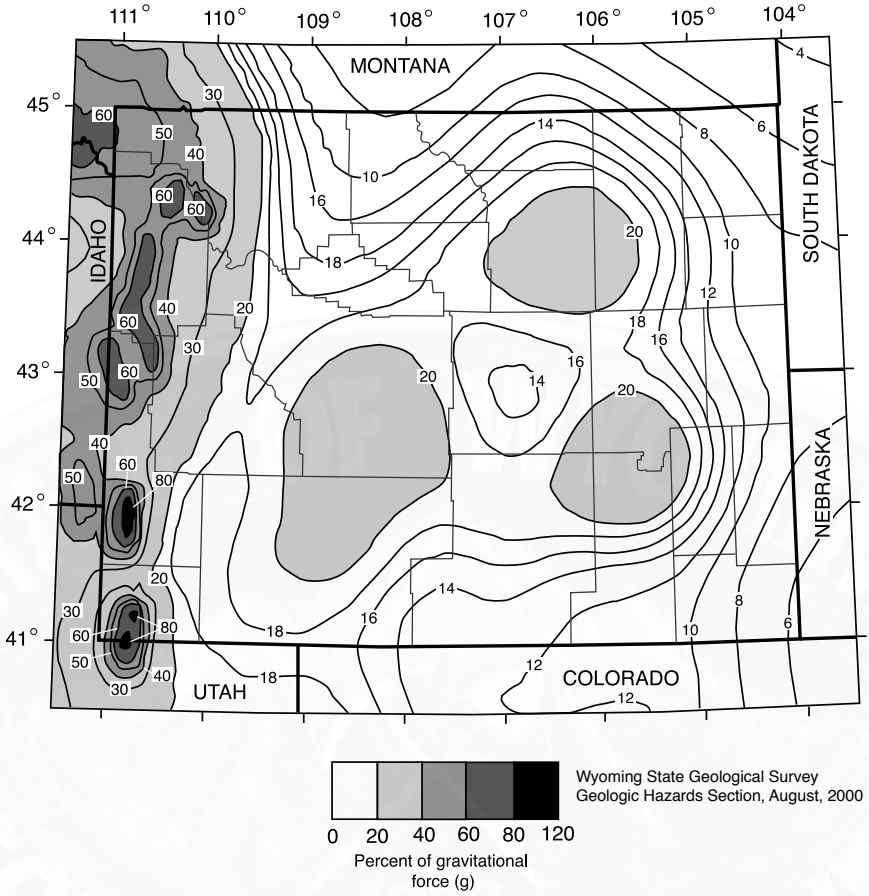

Figure 24. Peak ground acceleration map of Wyoming, in percent of gravitational force (g), for earthquake ground motions with a 2% probability of being exceeded in the next 50 years. Data for NEHRP B-C boundary site from the U.S. Geological Survey National Seismic Hazards Mapping Project. Albers Equal Area Projection, reduced from original map scale of 1:4,000,000.

McGuire, R.K., and Arabasz, W.J., 1990, An introduction to probabilistic seismic hazard analysis, in Ward, S.H., editor, Geotechnical and environmental geophysics, Volume I: Review and tutorial: Society of Exploration Geophysicists, Tulsa, Oklahoma, p. 333-353.

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Perkins, D., 2000b, How do I use these maps: U.S. Geological Survey National Seismic Hazard Mapping Project web page, http://geohazards.cr.usgs.gov/eq/faq/psha02.shtml, 2 p.

STAFF PROFILE—ROBERT M. LYMAN

Richard W. Jones
Editor/Geologist–Wyoming State Geological Survey

Robert M. "Bob" Lyman is the newest staff geologist with the Wyoming State Geological Survey (WSGS), having joined the agency as Head of the Coal Section in 1997. As the Survey's coal geologist (**Figure 25**), Bob keeps busy with coal-related activities in the number one coal-producing state in the U.S. He represents the Survey and the State of Wyoming on a number of coal issues, including coalbed methane. He answers a large number of inquiries each year from business and industry, academia, government (from the local and county level to statewide and national), and the general public as well as performs his own research and projects on Wyoming coal.

Figure 25. Robert M. Lyman is head of the Survey's Coal Section.

Bob represents the state on several committees and task forces, as a member of the Rocky Mountain Consortium of the National Coal Quality Inventory System (NaCQI) group, a member and chairman of the Northern Great Plains Consortium of the NaCQI group, and a member of the Consensus Revenue Estimating Group (CREG) for the State of Wyoming. As a member of CREG, Bob provides important advice and information to the State of Wyoming government regarding forecasts of coal production and prices for use in economic forecasting. His forecasts and summaries of coal activities in Wyoming each quarter form an integral part of each issue of Wyoming Geo-notes.

The Coal Section has some $85,000 in grants to fund various projects and employs two part-time geologists under Bob's supervision. The grants are funded in part by the U.S. Geological Survey and in part by the WSGS through matching funds. One grant, the National Coal Resources Data System (NCRDS), is an ongoing project for development of a computer-based data-handling program for quick retrieval and submission of coal data related to Wyoming. The other grant is under NaCQI and involves coal sampling and development of computer databases on elemental and trace element data related to Wyoming's Powder River Coal Field.

Bob is also involved with a third grant, a cooperative project with the Department of Geology and Geophysics at the University of Wyoming and the State of Wyoming's Abandoned Mine Lands program. This $93,000 grant is for the study of strontium isotopes in water from coals mined in the Powder River Basin. Bob helped with

the grant proposal, is assisting students and researchers with introductions to various industry personnel, and is furnishing technical expertise on coal geology and geochemistry.

Bob Lyman was born in Leon, Iowa, but because his father was a career U.S. Navy man, Bob grew up a "Navy brat," attending primary schools in Waukegan, Illinois, Long Beach and San Francisco, California, Guam, Garden Grove, Iowa, and finally Des Moines, Iowa. He graduated from East Des Moines High School in 1966 and went on to the University of Iowa in Iowa City, earning a B.S. in Geology in 1971 and an M.S. in Geology in 1973. While at the University of Iowa, he was employed as both an undergraduate and a graduate teaching assistant for geology courses. During his college days, Bob was exposed to Rocky Mountain geology, having survived geology field camp in Park City, Utah (Bob says they worked out of a ski lodge there, but the camp was "tough") and a field mapping/structural geology thesis on the northwestern flank of the Bighorn Mountains, Wyoming.

After graduation, Bob began his professional career as a project coal geologist with Paul Weir Company out of Chicago. One of his first assignments was in Wyoming, where he worked on the Lake DeSmet coal deposit near Buffalo. After five years with Weir, Bob moved on to Sun Energy Development Company, also out of Illinois, where he primarily worked Sun's eastern coal properties. Following a reorganization of Sun, Bob transferred to Knoxville, Tennessee in 1981, where he was Senior Coal Geologist with Elk River Resources, and following another reorganization in 1984, became Chief Coal Geologist with Sun Coal & Coke Company, also in Knoxville.

In 1994, Bob left Sun to start his own coal consulting business in Knoxville, called Reserve Services Company. He continues to operate this business (with clients outside Wyoming) even today, although now out of Laramie and despite his full-time duties with the WSGS. Bob is also active in teaching, having taught some short courses on coal and coal geology with the WSGS and now teaching an upper level course in the Department of Geology and Geophysics at the University of Wyoming entitled "Introduction to Coal Geology" for the fall semester, 2000.

Bob has authored numerous articles, maps, and publications on Wyoming coal and coalbed methane for both the WSGS and for outside publishers, and has given a number of talks and presentations on the same. He is a member of the Illinois Mining Institute, the Society of Mining Engineers of AIME, and a member of the Earth Science Honorary Society, Sigma Gamma Epsilon. He is Certified Professional Geologist No. 4921 with the American Institute of Professional Geologists, and a Registered Professional Geologist in the Commonwealth of Kentucky (No. 552), the State of Tennessee (TN 0089), the Commonwealth of Virginia (No. 160), and the State of Wyoming (PG 656).

Bob "enjoys following the Iowa Hawkeye and the Wyoming Cowboy NCAA sports teams, and the Chicago Cubs professional baseball team. [He] especially enjoys walleye fishing in lakes and reservoirs around Wyoming and tries every year to get to north central Wisconsin, where his mother-in-law owns a lake cottage, to plug for muskies and northern pike. [He] also travels to Wayne County, Iowa several times a year to help manage his mother's farm and a small herd of Red Angus cattle."

NEW PUBLICATIONS AVAILABLE

NEW MAP SERIES INITIATED

With financial help in the form of a grant from the U.S. Geological Survey, the Geologic Hazards and the Publications sections at the Wyoming State Geological Survey are involved in producing and publishing a new series of geologic maps. The J. David Love Map Series, Geology of the Teton-Jackson Hole Region, consists of 44 geologic maps at a scale of 1:24,000 covering most of the topographic quadrangles in Teton County, Wyoming, including all of Grand Teton National Park and the southernmost part of Yellowstone National Park.

The maps represent in total some 50 years of mapping and detailed field work by J.D. Love, distinguished and honored Wyoming geologist. Most of these quadrangle maps have never been published at this (1:24,000) scale. The color geologic maps will be released in totally digital form, including the base map information in vector format, and digitized geologic map contacts using ArcInfo® and ArcView®. Final map products will include all digital data arranged in layers, viewable map files, and a hard copy color map (which is plotted on demand). The first two maps in the series, Love Map Series (LMS) 1 and 2, will cover the Cache Creek and Teton Village quadrangles, respectively (see listing below). Several other maps are now in preparation, including Granite Basin, Gros Ventre Junction, and Moose quadrangles.

NEW PUBLICATIONS BY THE WYOMING STATE GEOLOGICAL SURVEY

*Gemstones and other unique minerals and rocks of Wyoming— A field guide for collectors, by W.D. Hausel and W.M. Sutherland, 2000: Bulletin 71 - ISBN 1-884589-15-4, $20.00.

*Geologic map of the Cache Creek Quadrangle, Teton County, Wyoming, by J.D. Love and C.M. Love, 2000: J. David Love Map Series, Geology of the Teton-Jackson Hole Region, Wyoming, LMS-1 - $20.00, plotted color map, rolled only; $10.00, CD-ROM [available in November, 2000] of digital map coverages in ArcInfo® format plus viewable, printable version in Mr. Sid®.

*Geologic map of the Teton Village Quadrangle, Teton County, Wyoming, by J.D. Love and J.C. Reed, Jr., 2000: J. David Love Map Series, Geology of the Teton-Jackson Hole Region, Wyoming, LMS-1 - $20.00, plotted color map, rolled only; $10.00, CD-ROM [available in November, 2000] of digital map coverages in ArcInfo® format plus viewable, printable version in Mr. Sid®.

*Preliminary geologic map of the Sheridan 30' x 60' Quadrangle, Sheridan, Johnson and Campbell Counties, Wyoming and southern Montana, by A.J. Ver Ploeg and C.S. Boyd, 2000: Preliminary Geologic Map PGM 2000-1 - $20.00, plotted 3-color map, rolled only.

Coalbed methane activity in the western Powder River Basin, Campbell, Converse, Johnson, Natrona, and Sheridan Counties, Wyoming, by R.H. De Bruin, R.M. Lyman, L.L. Hallberg, and M.M. Harrison, 2000: Coalbed Methane Map CMM 00-2 -, plotted color map, rolled only; $100.00, digital version (ArcInfo®/ArcView® format) on CD-ROM.

*Stream classification and drainage systems map of the northeast Wyoming coal bed methane development area, by Wyoming Department of Environmental Quality, 2000: Coalbed Methane Map CMM 00-3 - $15.00, plotted color map, rolled only; a digital version (ArcInfo®/ArcView® format) of this map is now included with the CD-ROM versions of Coalbed Methane Maps 00-1 and 00-2.

How to make your Wyoming home more earthquake resistant, by J.C. Case and J.A. Green, 2000: Information Pamphlet 5 – Free upon request.

Earthquakes in Wyoming, by J.C. Case and J.A. Green, 2000: Information Pamphlet 6 – Free upon request.

Coalbed methane in Wyoming, by R.H. De Bruin, R.M. Lyman, R.W. Jones, and L.W. Cook, 2000: Information Pamphlet 7 – Free upon request.

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)

Rodney H. De Bruin - Oil and gas

(Email: rdebru@wsgs.uwyo.edu)

Ray E. Harris - Industrial minerals and uranium

(Email: 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.

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, $13.00.

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, $18.00.

A correlated history of Earth, by Pan Terra, Inc., 1998: Full color wall chart, 38" high x 28" wide, laminated - $20.00.

ATTENTION TOPOGRAPHIC MAP PURCHASERS:

In addition to the All Topos: Wyoming set of CD-ROMs published by IGage available for $140.00 (or upgrade your old versions), we are now offering an additional product.

State Explorer, BLM Edition, Wyoming is topographic mapping software that contains all the 1:100,000-scale Bureau of Land Management (BLM) Surface Management Quadrangles in Wyoming. Published by MapTrails, Inc., these maps are contained on a single CD-ROM and include the following features:

- Public and private land status, BLM administrative lands, national parks and monuments, Indian lands or reservations, national grasslands, national forests, route markers, and state lands.
- County roads, BLM roads, roads with public access; recreational sites, trails, and areas; state, county, city, wildlife, park, and outdoor recreation areas; and other features found on the BLM series maps.
- Map interaction tools, including zoom levels, distance calculators, elevation profiling, and display of latitude, longitude, and elevation for any point.
- Map customization tools, including Waypoint Manager, capability to create custom trip databases, and capability to organize trip data.
- Navigational tools, including comprehensive search lists, printing capabilities (can print high-resolution custom maps of any area), and full GPS utility (can upload or download coordinates with GPS interface).

The entire package sells for $49.95 and can be purchased over the counter or by mail from the address below. Orders must be prepaid; we cannot invoice with shipment. Add $5.00 shipping and handling; Wyoming residents add 6% sales tax.

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.

OTHER NEWS IN THE PUBLICATIONS SECTION

There are two new staff members in the section, Jaime Bogaard and Paula Becker. Jaime is our new Editorial Assistant, having joined the Survey in January, replacing Janet Van Nuys, who left for Michigan's Upper Peninsula. Best of luck to Janet and her husband Frank, who begins a professorship at University of Michigan—Marquette. Jaime is a Laramie native and a senior at the University of Wyoming majoring in Animal Science with an option in Communications. She will complete her degree this December.

Figure 26. Jaime Bogaard is the Survey's new Editorial Assistant.

Figure 27. Paula Becker is the Survey's new Publication Sales Manager.

Paula Becker is our new Publications Sales Manager, replacing Kathy Hastreiter, who left in June for Nebraska. Almost anyone who ordered or bought maps and other Survey publications in the last three years probably talked to Kathy. Her trademarks included a good attitude, prompt customer service, and a high degree of professionalism and competence. Best of luck Kathy, everyone at the Survey will miss you! Paula comes to us from a career as a field biologist and ornithologist, most recently with Western EcoSystems Technology, Inc. (WEST, Inc.) in Cheyenne.