# *Wyoming Geo-notes*

## Number 59

Wyoming State Geological Survey
Gary B. Glass, State Geologist

Laramie, Wyoming
September, 1998

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**WYOMING GEO-NOTES**

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**Cover:** In March, the State of Wyoming was one of 1,500 exhibitors at the 1998 International Tile and Stone Exposition held in Orlando, Florida. The State's booth was sponsored by the Department of Commerce's Division of Economic and Community Development, the Industrial Minerals and Uranium Section of the Wyoming State Geological Survey, the Casper Area Economic Development Alliance, the Laramie Economic Development Corporation, and the Wheatland Area Development Corporation. The white arrow points to the State's booth.

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# MINERALS UPDATE

## OVERVIEW

Gary B. Glass
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Since the last issue of *Wyoming Geo-notes*, there have been a few more changes to the production tabulations shown in **Table 1** and **Figures 1-3,** as year-end figures became available. Oil and gas production figures for 1997 are now actual values rather than estimates.

In the case of prices, the 1997 average oil price is now an actual value, the actual average methane prices for 1996 and 1997 were changed, and an actual average coal price for 1997 was added (**Table 2** and **Figures 4-6**).

In regard to oil, the production of 70.2 million barrels in 1997 is now a final figure. Continued low prices, however, suggest that 1998 production will decline more than projected in **Table 1** and **Figure 1**. While oil production was only an estimated 4.7% below last year's first quarter (**Table 4** on p. 10), the effect of sustained low prices will become more apparent once second and third quarter production figures are available. Companies are shutting in or plugging marginal wells. Exploration and development drilling for oil in Wyoming have both slowed substantially. As mentioned in the last issue of *Wyoming Geo-notes*, the current low prices will likely accelerate this year's decline

**Table 1. Wyoming mineral production (1985-1997) with forecasts to 2004[1].**

| Calendar Year | Oil[2,3] | Methane[3,4] | Carbon Dioxide[3,4] | Helium[4,5] | Coal[6] | Trona[6] | In-situ Uranium[7,8] | Sulfur[3,9] |
|---|---|---|---|---|---|---|---|---|
| 1985 | 131.0 | 597.9 | — | — | 140.4 | 11.8 | N/A | 0.80 |
| 1986 | 122.4 | 563.2 | 23.8 | 0.15 | 135.4 | 13.0 | 0.05 | 0.76 |
| 1987 | 115.9 | 628.2 | 114.2 | 0.86 | 146.5 | 13.6 | 0.00 | 1.19 |
| 1988 | 114.3 | 700.8 | 110.0 | 0.83 | 163.6 | 14.9 | 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 | 18.1 | 1.3 | 1.20 |
| 1996 | 73.9 | 1,023.4 | 149.0 | 1.10 | 278.4 | 17.5 | 1.9 | 1.22 |
| 1997 | 70.2 | 1,040.7 | 151.0 | 1.10 | 281.5 | 18.2 | 2.2 | *1.20 |
| 1998 | 66.3 | 1,122.9 | 151.0 | 1.10 | 297.5 | 20.0 | 3.0 | 1.20 |
| 1999 | 62.8 | 1,148.4 | 151.0 | 1.10 | 314.5 | 21.1 | 3.0 | 1.20 |
| 2000 | 59.5 | 1,174.4 | 151.0 | 1.10 | 334.6 | 21.8 | 3.0 | 1.20 |
| 2001 | 56.3 | 1,201.3 | 151.0 | 1.10 | 346.7 | 22.6 | 3.5 | 1.20 |
| 2002 | 53.3 | 1,228.0 | 151.0 | 1.10 | 350.2 | 23.5 | 3.5 | 1.20 |
| 2003 | 50.5 | 1,255.6 | 151.0 | 1.10 | 353.7 | 24.4 | 3.5 | 1.20 |
| 2004 | 47.8 | 1,283.8 | 151.0 | 1.10 | 357.2 | 25.9 | 3.5 | 1.20 |

*Estimated until official figures are available.
[1]Modified from CREG's Wyoming State Government Revenue Forecast, January, 1998; [2]Millions of barrels; [3]Wyoming Oil & Gas Conservation Commission, 1985-1997; [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, 1985-1997); [7]Wyoming State Inspector of Mines, 1985-1997; [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.

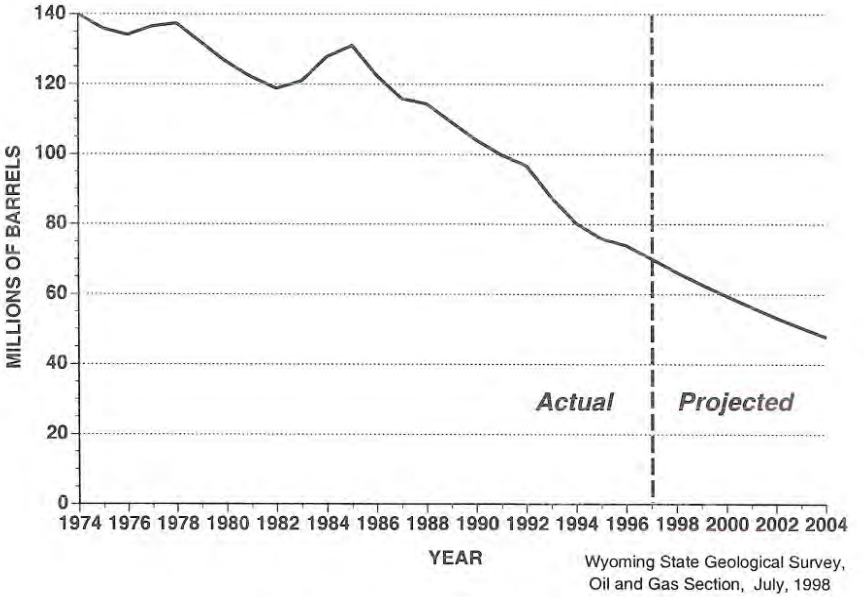


Figure 1. Annual oil production from Wyoming (1974 to 1997) with forecasts to 2004.

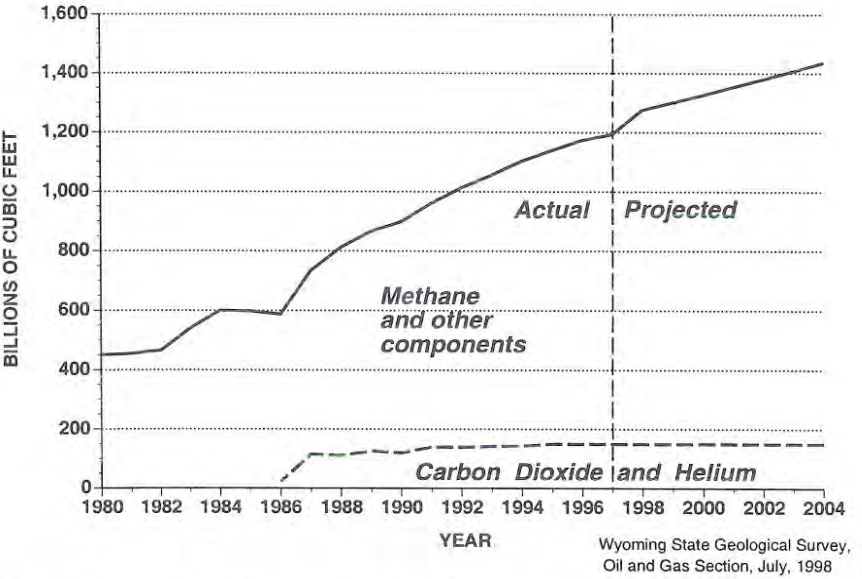


Figure 2. Annual natural gas production from Wyoming (1980 to 1997) with forecasts to 2004.

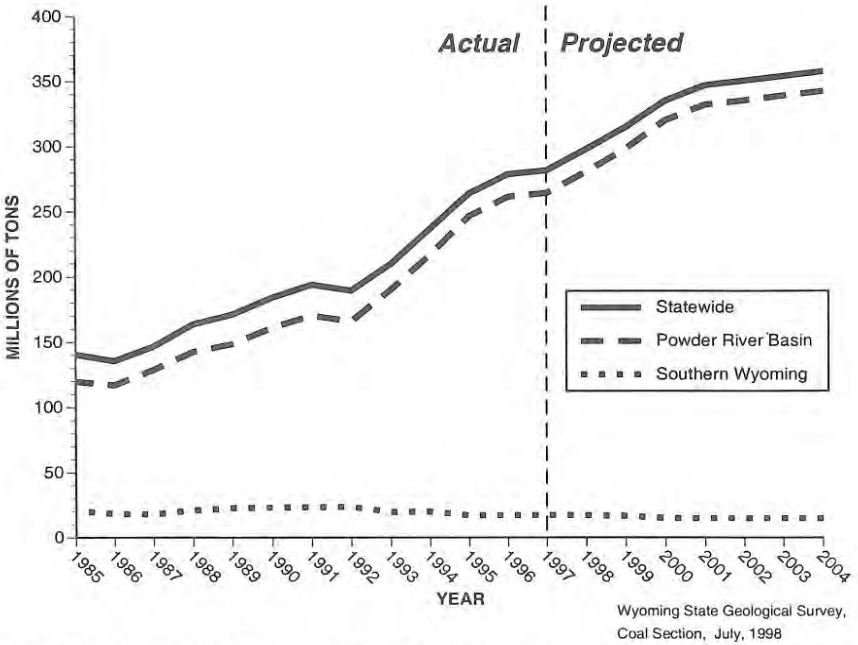


Figure 3. Annual coal production from Wyoming (1985-1997) with forecasts to 2004. Data from the Wyoming State Inspector of Mines (1985-1997) and Wyoming Consensus Revenue Estimating Group (1998-2004).

in oil production to somewhere between 6.6% and 9.9%. However, until the State's Consensus Revenue Estimating Group (CREG) meets and revises its estimates in October of this year, **Table 1** and **Figure 1** are showing their January 1998 estimates as are all the tables and figures in the **Overview** section of this issue of *Wyoming Geo-notes.*

Oil prices did not improve in the second quarter. Although the average oil price in Wyoming for the first six months of 1998 was $11.23, the average price for the month of June was only $9.20 (**Table 3** on p. 8). It is now looking like the average for the year will be closer to $10.00 or $11.00 than the forecast $15.00 in **Table 2** and **Figure 4**. And the average could be even lower.

In regard to natural gas, the actual production in 1997 was 1,192.8 billion cubic feet, which is 0.7 billion cubic feet more than shown in the last issue of *Wyoming Geo-notes* (**Table 1** and **Figure 2**). The production of methane and carbon dioxide in **Table 1** and **Figure 2**; however, are somewhat different because carbon dioxide production was a little higher than forecast. While the estimated production of both methane and carbon dioxide for 1998 through 2004 in **Table 1** is different than the last issue, the combined production of methane, carbon dioxide, and helium for these years still reflects CREG's January 1998 estimates for the production of natural gas. Cumulative natural gas

**Table 2. Average prices paid for Wyoming oil, methane, coal, and trona (1985-1997) with forecasts to 2004[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 | 41.86 |
| 1991 | 17.33 | 1.46 | 8.06 | 44.18 |
| 1992 | 16.38 | 1.49 | 8.13 | 44.50 |
| 1993 | 14.50 | 1.81 | 7.12 | 40.08 |
| 1994 | 13.67 | 1.63 | 6.62 | 38.96 |
| 1995 | 15.50 | 1.13 | 6.38 | 40.93 |
| 1996 | 19.56 | 1.46 | 6.15 | 45.86 |
| 1997 | 17.41 | 1.94 | *5.78 | *42.62 |
| 1998 | 15.00 | 1.50 | 5.97 | 43.34 |
| 1999 | 15.00 | 1.50 | 5.82 | 42.93 |
| 2000 | 15.00 | 1.50 | 5.64 | 43.25 |
| 2001 | 15.00 | 1.50 | 5.55 | 43.44 |
| 2002 | 15.00 | 1.50 | 5.48 | 43.92 |
| 2003 | 15.00 | 1.50 | 5.40 | 44.24 |
| 2004 | 15.00 | 1.50 | 5.32 | 44.45 |

* Estimated until official figures are available.
[1] Modified from CREG, Wyoming State Government Revenue Forecast, January, 1998; [2] First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Source: Energy Information Administration, 1985-1997; [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, 1991-1997; [5] Dollars per ton of trona, not soda ash. Source: Wyoming Department of Revenue, 1985-1997.

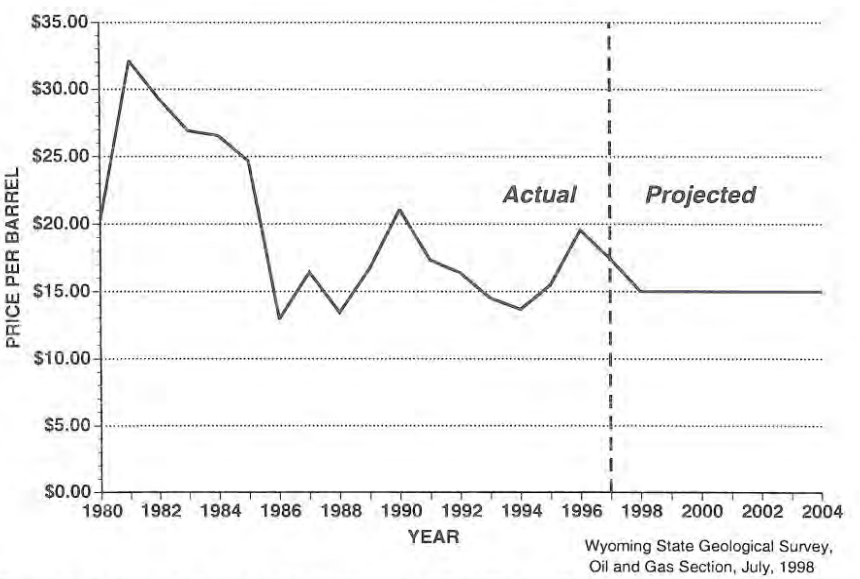


Figure 4. Average prices paid for Wyoming oil (1980 to 1997) with forecasts to 2004.

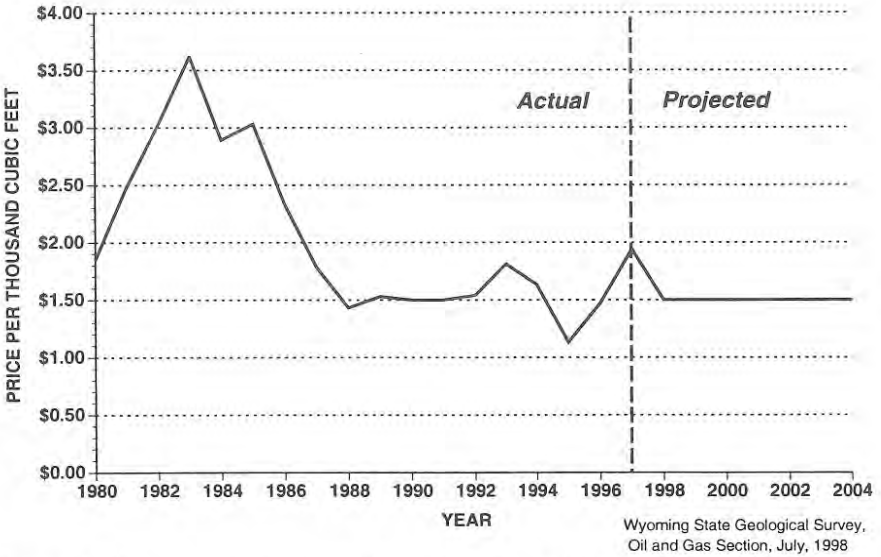


Figure 5. Average prices paid for Wyoming methane (1980 to 1997) with forecasts to 2004.

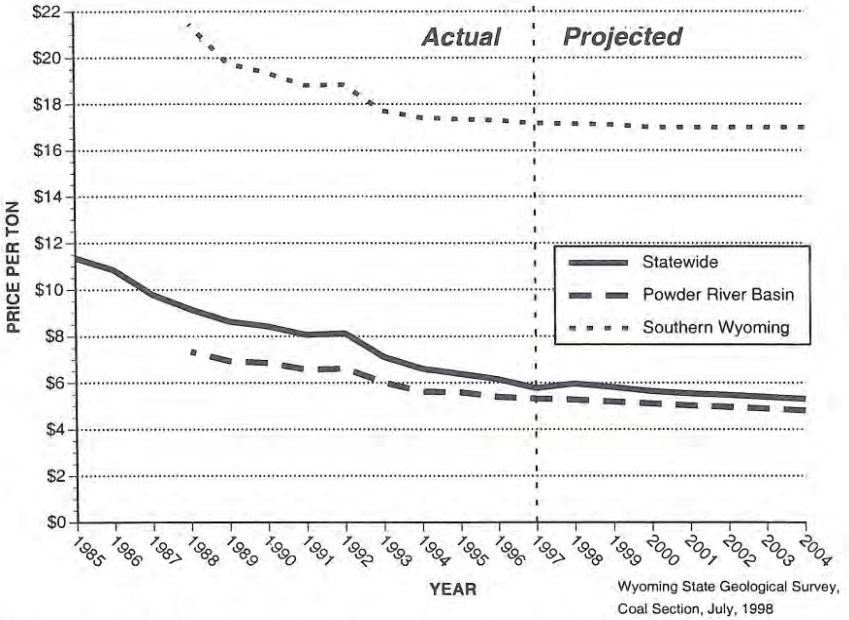


Figure 6. Average prices paid for Wyoming coal (1985 to 1997) with estimates to 2004. Sources: U.S. Energy Information Administration (1985-1990); Wyoming Department of Revenue (1991-1997); and Consensus Revenue Estimating Group (1998-2004).

production for the first quarter of 1998 was only 0.2% higher than in the first quarter of 1997 (**Table 6** on p. 13).

Methane prices for 1996 and 1997 were changed slightly in this issue. These were both derived from State royalty figures provided by the Office of State Lands and Investments. While the 1996 figure only decreased by a penny, the 1997 figure was increased by eight cents (**Table 2** and **Figure 5**). Although methane prices were relatively strong over the first six months of 1998, they averaged $1.86, which is 17 cents less than the same period in 1997. But it should be remembered that methane prices in late 1996 and early 1997 had been very high including a $3.90 average in January of 1997 (**Table 5** on p. 11). Methane prices in Wyoming are likely to average closer to $1.90 in 1998 than CREG's estimate of $l.50 (**Table 2** and **Figure 5**).

And the third quarter announcement that British Petroleum Co. would purchase Amoco Corp. for $53 billion in stock was big news in Wyoming (*Casper Star-Tribune*, 8/12/98). Amoco is a major producer of natural gas, condensate, and oil in the State and operates over 1,000 oil and gas wells, mostly in the Greater Green River Basin and the Overthrust Belt in southwestern and western Wyoming.

First quarter coal deliveries from Wyoming were 7.5% above the same quarter in 1997 (**Table 10**, p. 24). This is ahead of the 5.7% increase for 1998 that CREG forecast in January (**Table 1** and **Figure 3**) and helps confirm that the rail transport problems of last year have been substantially reduced.

In regard to price, preliminary figures from the Wyoming Department of Revenue indicate that the average price received for Wyoming coal in 1997 was only $5.78, which is 28 cents less than CREG's January forecast (**Table 2** and **Figure 6**). While this suggests that CREG's forecast coal prices for 1998 and at least some future years may be too high, the low price in 1997 coincided with a major disruption in transportation. The accelerated decline in price may be an anomaly rather than a new trend in price. There was an indication that some coal companies were shipping their lower-cost spot sales ahead of their higher-cost contract coal in an effort to appease customers, who were badly affected by disruptions in rail service.

In regard to trona and soda ash, information from the U.S. Geological Survey indicated that soda ash production early this year was 7% above 1997 production for the same period (see p. 43). However, despite this early good start, the weakened export demand from Asia may cause trona production and prices in 1998 to dip below those of 1997 (**Tables 1** and **2**). By the third quarter, FMC Corp. had announced its plan to layoff 100 employees, and OCI of Wyoming had announced that although it would complete its plant expansion, it probably would not add any new employees (*Casper Star-Tribune*, 8/11/98).

Cautious optimism about future uranium prices and growth in Wyoming's uranium industry faltered late in the second quarter, following the privatization of U.S. Enrichment Corp., which was previously a government-owned entity.

While U.S. Energy halted work on its Jackpot underground mine, International Uranium Corp. noted that although it would continue the permitting process for its proposed in-situ operation, its development plans were dependent on uranium prices and demand.

In regard to other minerals, recent interests in silica sand, decorative and dimensional stone, and zeolites are noted in the **Industrial Minerals and Uranium Update**. The **Metals and Precious Stones Update** discusses current interest in diamonds, platinum, and palladium. The **Rock Hound's Corner** features quartz and is Part I of a two-part article.

The **Geologic Mapping, Paleontology, and Stratigraphy Update** features a discussion of the availability of digital topographic data, raster graphics, and GIS coverage for Wyoming.

In regard to geologic hazards, this issue includes Part II of a special three-part article on Wyoming's study of the sensitivity of its aquifers to contamination (p. 54-58).

## OIL AND GAS UPDATE

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During the second quarter of 1998, prices paid to Wyoming oil producers averaged $10.48 per barrel, which is $6.34 lower than for the second quarter of 1997. Although the average price for the first six months of 1998 was $11.23, the average in June was only $9.20 (**Table 3**). **Figure 7** shows the posted Sweet and Sour crude prices and first purchase price for Wyoming oil averaged by month.

Saudi Arabia, Mexico, and Venezuela announced in March that they would cut production to alleviate some of the oversupply of crude oil on the world market. In June, several members of the Organization of Petroleum Exporting Countries (OPEC) announced additional cuts that they hoped would keep crude oil prices from falling even more. OPEC had decided last November to raise production by 10 percent. The extra oil started flooding the market just as the Asian economic crisis began cutting into demand for crude oil.

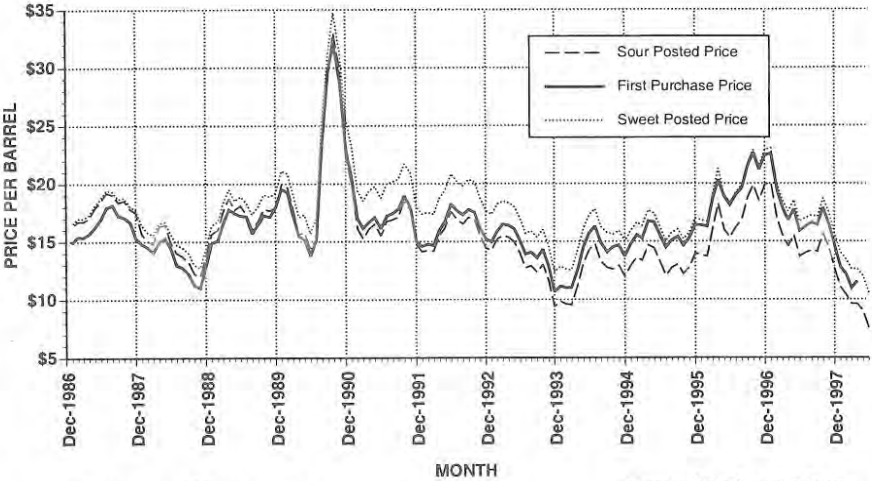
Oil production in Wyoming for the first quarter of 1998 was 16.6 million barrels (**Table 4**), according to figures from the Wyoming Oil and Gas Conservation Commission (WOGCC). This production is a drop of about 4.7% from last year's first quarter oil production, as reported by Petroleum Information/ Dwights LLC (PI/D). PI/D's reported production is generally less than one percent below the WOGCC's preliminary figures, but some late reporting and cor-

Table 3. Monthly average price of a barrel of oil produced in Wyoming (1995 to June, 1998).

| | 1995 Monthly | 1995 Cumulative | 1996 Monthly | 1996 Cumulative | 1997 Monthly | 1997 Cumulative | 1998 Monthly | 1998 Cumulative |
|---|---|---|---|---|---|---|---|---|
| JAN | $ 14.77 | $ 14.77 | $16.38 | $16.38 | $22.56 | $22.56 | $12.79 | $12.79 |
| FEB | $ 15.55 | $ 15.16 | $16.28 | $16.33 | $19.45 | $21.01 | $12.16 | $12.48 |
| MAR | $ 15.26 | $ 15.19 | $18.63 | $17.09 | $17.99 | $20.00 | $10.97 | $11.97 |
| APR | $ 16.73 | $ 15.58 | $20.29 | $17.90 | $16.81 | $19.20 | $11.54 | $11.87 |
| MAY | $ 16.65 | $ 15.79 | $18.85 | $18.08 | $17.74 | $18.91 | **$10.70** | **$11.63** |
| JUN | $ 15.52 | $ 15.75 | $18.15 | $18.10 | $15.90 | $18.41 | **$ 9.20** | **$11.23** |
| JUL | $ 14.50 | $ 15.57 | $18.98 | $18.22 | $16.29 | $18.11 | | |
| AUG | $ 15.09 | $ 15.51 | $19.59 | $18.39 | $16.61 | $17.92 | | |
| SEP | $ 15.41 | $ 15.50 | $21.48 | $18.74 | $16.42 | $17.75 | | |
| OCT | $ 14.67 | $ 15.42 | $22.63 | $19.13 | $17.89 | $17.77 | | |
| NOV | $ 15.32 | $ 15.41 | $21.19 | $19.31 | $16.51 | $17.65 | | |
| DEC | $ 16.43 | $ 15.50 | $22.42 | $19.56 | $14.72 | $17.41 | | |
| Average yearly price | | $ 15.50 | | $19.56 | | $17.41 | | |

Source: All averages are derived from published monthly reports by the Energy Information Administration, except that averages in bold print in 1998 are estimated from various unpublished bulletins listing posted prices.

*Wyoming State Geological Survey, Oil and Gas Section, July, 1998*




Source: Unpublished DOE and company data

Wyoming State Geological Survery
Oil and Gas Section, July, 1998

Figure 7. Wyoming posted Sweet and Sour crude oil prices and first purchase prices, averaged by month (January, 1987, to June, 1998).

rections accounted for a larger difference between the two in the first quarter of this year.

Spot prices for methane at Opal, Wyoming, averaged $1.83 during the second quarter of 1998. This is 36 cents higher than last year's second quarter average price of $1.47. For the first six months of 1998, methane averaged $1.86 (**Table 5** and **Figure 8**).

Natural gas production in Wyoming for the first quarter of 1998 was 296.1 billion cubic feet according to production figures from the WOGCC (**Table 6**). This is 0.2% above first quarter production in 1997, as reported by PI/D. Mild winter weather in the State's market area contributed to lack luster production gains in the first quarter.

In a related item, March production figures from PI/D show that the average coalbed methane well in the Powder River Basin accounts for 182,500 cubic feet of gas per day. Collectively, coalbed methane wells in the basin accounted for 1.6 billion cubic feet of gas in March 1998.

Barrett Resources' plan to drill 76 new coalbed methane wells on the Thunder Basin National Grassland was approved by the U.S. Forest Service. The wells are in the Black Thunder Project area and are some of the last approved under the environmental impact statement that allowed 640 new wells south of Gillette. Forty-four of the wells will be drilled on the National Grasslands, and the remaining 32 will be drilled on private land.

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

| | 1995 Monthly | 1995 Cumulative | 1996 Monthly | 1996 Cumulative | 1997 Monthly | 1997 Cumulative | 1998 Monthly | 1998 Cumulative |
|---|---|---|---|---|---|---|---|---|
| JAN | 6,700,000 | 6,700,000 | 6,153,037 | 6,153,037 | 5,964,848 | 5,964,848 | 5,811,159 | 5,811,159 |
| FEB | 6,100,000 | 12,800,000 | 5,693,084 | 11,846,121 | 5,459,518 | 11,424,366 | 5,183,923 | 10,995,082 |
| MAR | 6,300,000 | 19,100,000 | 6,176,805 | 18,022,926 | 6,014,780 | 17,439,146 | 5,617,212 | 16,612,294 |
| APR | 6,200,000 | 25,300,000 | 5,977,362 | 24,000,288 | 5,729,869 | 23,169,015 | | |
| MAY | 6,300,000 | 31,600,000 | 6,035,505 | 30,035,793 | 6,050,971 | 29,219,986 | | |
| JUN | 6,200,000 | 37,800,000 | 5,916,019 | 35,951,812 | 5,761,549 | 34,981,535 | | |
| JUL | 6,300,000 | 44,100,000 | 6,076,992 | 42,028,804 | 5,964,005 | 40,945,540 | | |
| AUG | 6,100,000 | 50,200,000 | 6,414,850 | 48,443,654 | 5,868,789 | 46,814,329 | | |
| SEP | 6,100,000 | 56,300,000 | 6,180,180 | 54,623,834 | 5,710,557 | 52,524,886 | | |
| OCT | 6,300,000 | 62,600,000 | 6,186,019 | 60,809,853 | 5,949,974 | 58,474,860 | | |
| NOV | 6,100,000 | 68,700.000 | 6,221,912 | 67,031,765 | 5,800,811 | 64,275,671 | | |
| DEC | 6,300,000 | 75,000,000 | 6,330,701 | 73,362,466 | 5,900,791 | 70,176,462 | | |
| **Total Barrels Reported[1]** | | **75,000,000** | | **73,362,466** | | **70,176,462** | | |
| **Total Barrels Not Reported[2]** | | **554,113** | | **525,957** | | **52,364** | | |
| **Total Barrels Produced[3]** | | **75,554,113** | | **73,888,423** | | **70,228,826** | | |

[1]Monthly production reports from Petroleum Information/Dwights LLC, except for 1995 which was estimated by the Wyoming State Geological Survey and February and March, 1998, which is 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, 1998.*

Table 5. Monthly average spot sale price for a thousand cubic feet (MCF) of methane at Opal, Wyoming (1995 to June, 1998).

| | 1995 Monthly | 1995 Cumulative | 1996 Monthly | 1996 Cumulative | 1997 Monthly | 1997 Cumulative | 1998 Monthly | 1998 Cumulative |
|---|---|---|---|---|---|---|---|---|
| JAN | $ 1.40 | $ 1.40 | $1.25 | $1.25 | $3.90 | $3.90 | $2.05 | $2.05 |
| FEB | $ 1.10 | $ 1.25 | $1.20 | $1.23 | $2.50 | $3.20 | $1.70 | $1.88 |
| MAR | $ 1.05 | $ 1.18 | $1.20 | $1.22 | $1.40 | $2.60 | $1.90 | $1.88 |
| APR | $ 1.05 | $ 1.15 | $1.05 | $1.18 | $1.45 | $2.31 | $1.90 | $1.89 |
| MAY | $ 1.10 | $ 1.14 | $0.95 | $1.13 | $1.60 | $2.17 | $1.95 | $1.90 |
| JUN | $ 1.15 | $ 1.14 | $1.10 | $1.13 | $1.35 | $2.03 | $1.65 | $1.86 |
| JUL | $ 1.00 | $ 1.12 | $1.20 | $1.14 | $1.45 | $1.95 | | |
| AUG | $ 0.90 | $ 1.09 | $1.25 | $1.15 | $1.40 | $1.88 | | |
| SEP | $ 1.05 | $ 1.09 | $1.20 | $1.16 | $1.50 | $1.84 | | |
| OCT | $ 1.05 | $ 1.09 | $1.30 | $1.17 | $2.05 | $1.86 | | |
| NOV | $ 1.25 | $ 1.10 | $2.45 | $1.29 | $3.00 | $1.96 | | |
| DEC | $ 1.30 | $ 1.12 | $3.50 | $1.47 | $1.95 | $1.96 | | |
| **Average yearly price** | | **$ 1.13** | | **$1.46** | | **$1.94** | | |

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

*Wyoming State Geological Survey, Oil and Gas Section, July, 1998*

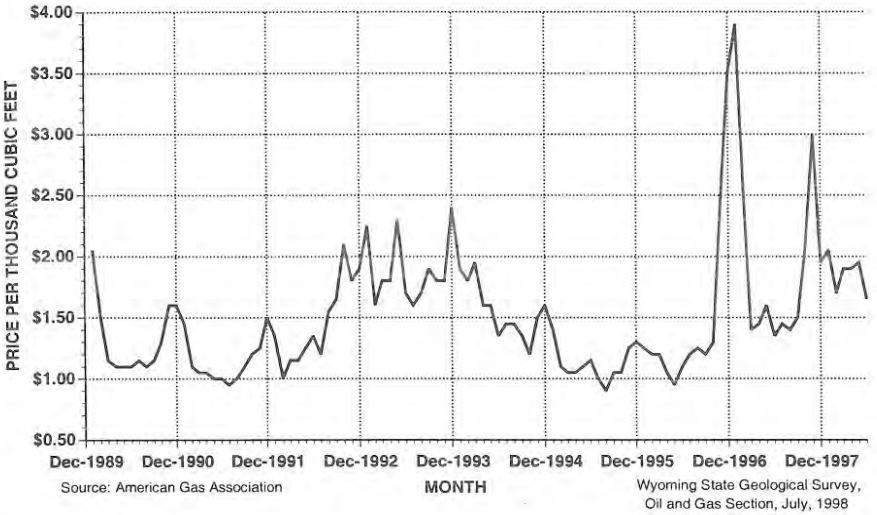



Figure 8. Spot sale prices for methane at Opal, Wyoming, averaged by month (January, 1990, to June, 1998).

The State is billing Express Pipeline $3 million this year to offset declines in the price and production of crude oil since the startup of the pipeline in April 1997. According to the Wyoming Office of State Lands and Investments, the decline in State revenues amounted to $1.7 million based on a formula developed by Express and the State. Express is obligated to pay the $3 million minimum payment based on an agreement it signed with the State in 1996.

Snyder Oil acquired 75 percent of Amoco Production's interest in the Beaver Creek Unit and in two gas plants in the Wind River Basin's Beaver Creek Field. Snyder exchanged the property for its Mesaverde and shallower interests in Jonah Field. Snyder retains the rights in Jonah Field below the Mesaverde Formation. The trade resolves litigation regarding Amoco's prior agreement to sell the Beaver Creek assets to Howell Petroleum. Howell agreed to relinquish its contractual rights to purchase the Beaver Creek assets and Amoco agreed to sell Howell a working interest in the Higgins Unit in Sweetwater County and an overriding royalty interest in a field in Utah for $11 million. Snyder plans to double or triple production from the Beaver Creek Unit by the end of 1999, after the gas plants' capacities are increased. Beaver Creek currently produces about 30 million cubic feet of gas per day. The company plans to drill 12 to 15 wells this year and 20 to 30 wells annually over the next two years.

Union Pacific Resources signed a contract with an affiliate of Petroleum Strategies to purchase interests in four oil and gas fields in Wyoming as well as assets in Louisiana. The properties were sold by Occidental Petroleum. In Wyoming, the four properties are in the Wamsutter area and in the Overthrust Belt. The properties contain 31 producing wells, which collectively produce an

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

| | 1995 Monthly | 1995 Cumulative | 1996 Monthly | 1996 Cumulative | 1997 Monthly | 1997 Cumulative | 1998 Monthly | 1998 Cumulative |
|---|---|---|---|---|---|---|---|---|
| JAN | 100,224,249 | 100,224,249 | 101,359,648 | 101,359,648 | 99,579,818 | 99,579,818 | 101,968,543 | 101,968,543 |
| FEB | 86,691,577 | 186,915,826 | 96,303,300 | 197,662,948 | 91,766,159 | 191,345,977 | 92,623,502 | 194,592,045 |
| MAR | 94,344,991 | 281,260,817 | 103,541,127 | 301,204,075 | 104,157,578 | 295,503,555 | 101,471,363 | 296,063,408 |
| APR | 93,929,323 | 375,190,140 | 99,479,609 | 400,683,684 | 99,459,039 | 394,962,594 | | |
| MAY | 95,791,327 | 470,981,467 | 97,900,863 | 498,584,547 | 101,070,371 | 496,032,965 | | |
| JUN | 92,140,614 | 563,122,081 | 87,069,612 | 585,654,159 | 91,905,308 | 587,938,273 | | |
| JUL | 92,796,301 | 655,918,382 | 100,219,275 | 685,873,434 | 100,129,497 | 688,067,770 | | |
| AUG | 90,393,416 | 746,311,798 | 99,874,019 | 785,747,453 | 97,673,622 | 785,741,392 | | |
| SEP | 92,589,092 | 838,900,890 | 93,510,551 | 879,258,004 | 100,028,888 | 885,770,280 | | |
| OCT | 98,386,458 | 937,287,348 | 95,441,022 | 974,699,026 | 102,206,875 | 987,977,155 | | |
| NOV | 94,939,660 | 1,032,227,008 | 94,015,007 | 1,068,714,033 | 100,752,128 | 1,088,729,283 | | |
| DEC | 99,314,617 | 1,131,541,625 | 99,141,298 | 1,167,855,331 | 103,415,430 | 1,192,144,713 | | |
| **Total MCF Reported[1]** | | **1,131,541,625** | | **1,167,855,331** | | **1,192,144,713** | | |
| **Total MCF Not Reported[2]** | | **6,448,396** | | **5,663,874** | | **683,432** | | |
| **Total MCF Produced[3]** | | **1,137,990,021** | | **1,173,519,205** | | **1,192,828,145** | | |

[1] Monthly production reports from Petroleum Information, Inc./Dwights LLC except for February and March 1998, which are from the 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, July, 1998*

average of 256 barrels of oil and 8.5 million cubic feet of gas per day. Union Pacific Resources assigned 36 billion cubic feet of natural gas equivalent reserves to the Wyoming wells and has identified 21 possible drilling locations with a reserve potential of 22 billion cubic feet of gas equivalent.

Leasing activity at the U.S. Bureau of Land Management's (BLM's) June sale was concentrated in the Powder River Basin (**Figure 9**). The total revenue from this $14.7 million sale set a record. Total revenue from the first three BLM sales this year is already $30.3 million, just short of last year's record of nearly $32 million for six sales (**Table 7**). Snyder Oil made the sale's top per-acre bid of $430 for a 1,957.96-acre lease that covers all of sections 20, 30, and 32 and NW NW section 28, T21N, R93W (location A, **Figure 9**). The parcel is about two miles east of Lewis and Almond gas production in Siberia Ridge Field. The sale's second high per-acre bid was $340 by Amirmex for a 165.38-acre parcel that covers parts of section 31, T45N, R71W (location B, **Figure 9**). The lease is within a mile of Niobrara oil production at Goer Draw Field. There were 108 tracts at this sale that received bids of $50 or more per acre.

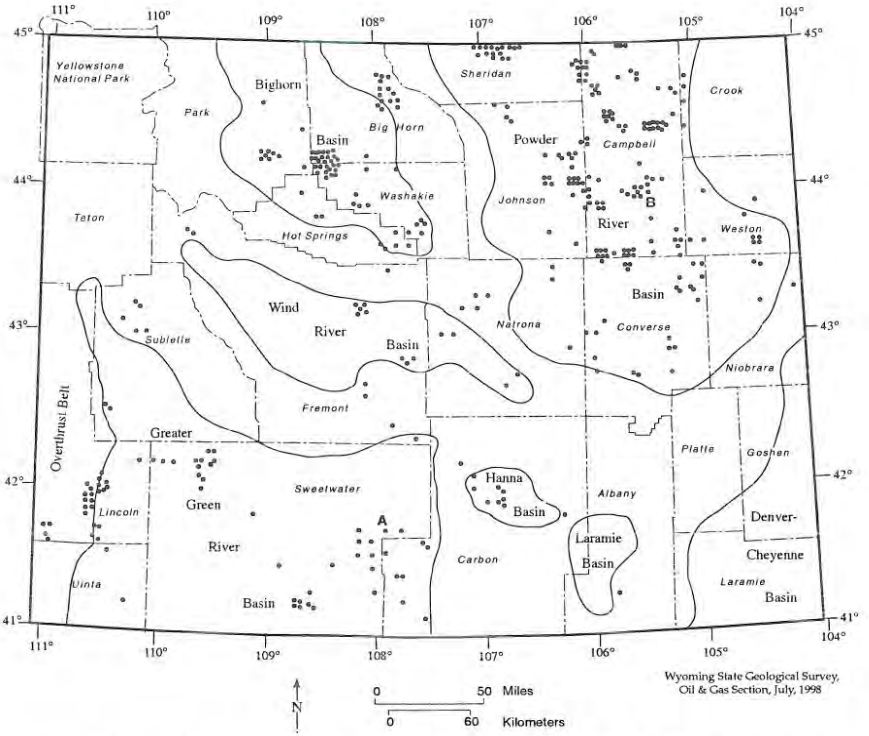



Figure 9. Locations of Federal oil and gas tracts leased by the U.S. Bureau of Land Management at its June, 1998, sale.

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

**FEDERAL SALES (BUREAU OF LAND MANAGEMENT)**

| Month | Total Revenue | Number of parcels offered | Number of parcels leased | Total acres | Acres leased | Average price per acre leased | High price per acre |
|---|---|---|---|---|---|---|---|
| **1995** | | | | | | | |
| TOTAL | $13,047,246 | 2,649 | 1,264 | 2,326,988 | 1,109,711 | $11.76 | $1,100.00 |
| **1996** | | | | | | | |
| February | $1,635,668 | 455 | 192 | 358,478 | 137,901 | $11.86 | $220.00 |
| June | $1,438,325 | 460 | 282 | 337,440 | 181,338 | $ 7.93 | $210.00 |
| August | $2,021,488 | 289 | 182 | 261,321 | 118,267 | $17.09 | $145.00 |
| October | $3,058,248 | 363 | 255 | 280,434 | 163,054 | $18.76 | $270.00 |
| December | $3,333,838 | 261 | 214 | 165,771 | 138,945 | $23.99 | $1,450.00 |
| TOTAL | $11,487,567 | 1,828 | 1,125 | 1,403,444 | 739,505 | $15.53 | $1,450.00 |
| **1997** | | | | | | | |
| February | $2,463,137 | 267 | 210 | 222,486 | 148,148 | $16.63 | $250.00 |
| April | $2,612,013 | 145 | 137 | 98,865 | 90,948 | $28.72 | $400.00 |
| June | $4,642,113 | 285 | 249 | 313,519 | 262,682 | $17.67 | $310.00 |
| August | $4,636,555 | 426 | 365 | 430,213 | 327,172 | $14.17 | $600.00 |
| October | $12,133,207 | 286 | 227 | 234,561 | 169,264 | $71.68 | $400.00 |
| December | $5,489,578 | 378 | 297 | 279,294 | 208,428 | $26.34 | $410.00 |
| TOTAL | $31,976,603 | 1,787 | 1,485 | 1,578,938 | 1,206,642 | $26.50 | $600.00 |
| **1998** | | | | | | | |
| February | $5,262,908 | 369 | 285 | 366,787 | 241,654 | $21.78 | $415.00 |
| April | $10,287,111 | 247 | 227 | 192,561 | 162,393 | $63.35 | $395.00 |
| June | $14,737,117 | 463 | 367 | 498,339 | 368,816 | $39.96 | $430.00 |

**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 |
|---|---|---|---|---|---|---|---|
| **1995** | | | | | | | |
| TOTAL | $1,656,218 | 799 | 492 | 323,887 | 202,708 | $8.17 | $130.00 |
| **1996** | | | | | | | |
| March | $308,927 | 199 | 96 | 85,369 | 41,909 | $7.37 | $108.00 |
| June | $656,177 | 250 | 114 | 103,621 | 48,638 | $13.49 | $206.00 |
| October | $663,241 | 300 | 134 | 115,495 | 54,538 | $12.16 | $175.00 |
| December | $697,152 | 300 | 164 | 113,626 | 61,729 | $11.29 | $86.00 |
| TOTAL | $2,325,497 | 1049 | 508 | 418,111 | 206,814 | $11.24 | $206.00 |
| **1997** | | | | | | | |
| April | $719,005 | 300 | 189 | 119,436 | 80,548 | $8.93 | $170.00 |
| June | $1,008,470 | 300 | 185 | 108,470 | 62,447 | $16.16 | $162.00 |
| October | $627,935 | 300 | 165 | 102,802 | 63,003 | $ 9.97 | $115.00 |
| December | $795,610 | 298 | 165 | 107,588 | 57,202 | $13.91 | $340.00 |
| TOTAL | $3,151,020 | 1198 | 704 | 438,296 | 263,230 | $11.97 | $340.00 |
| **1998** | | | | | | | |
| April | $1,203,792 | 300 | 161 | 115,646 | 63,848 | $18.85 | $320.00 |
| June | $1,660,438 | 300 | 148 | 108,654 | 52,501 | $31.63 | $600.00 |

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

Leasing activity at the Wyoming Office of State Lands and Investments' June lease sale also was concentrated in the Powder River Basin (**Figure 10**). This sale was the best State sale in several years in terms of total revenue (**Table 7**). The sale's high per-acre bid of $600 was made by North American Petroleum for a 600-acre lease that covers all of section 16, T48N, R72W except SWSW (location A, **Figure 10**). The parcel is about a half mile east of oil production from the Minnelusa at Bone Pile Field. Amirmex made the sale's second highest per-acre bid of $250 for a 560-acre lease that covers NE, E/2 NW, and S/2 of section 16, T45N, R75W. The lease is about a mile northeast of oil production from the Shannon at Hartzog Draw Field. The sale had 19 parcels that received bids of $50 or more per acre.

There were 1,078 Applications for Permit to Drill (APDs) in the first half of 1998 (**Table 8**). APDs for the first half exceeded the number of APDs in the first half of 1997 by 351. Campbell County led with over 62% of the total APDs that were approved, and the majority of those were for shallow coalbed methane tests.

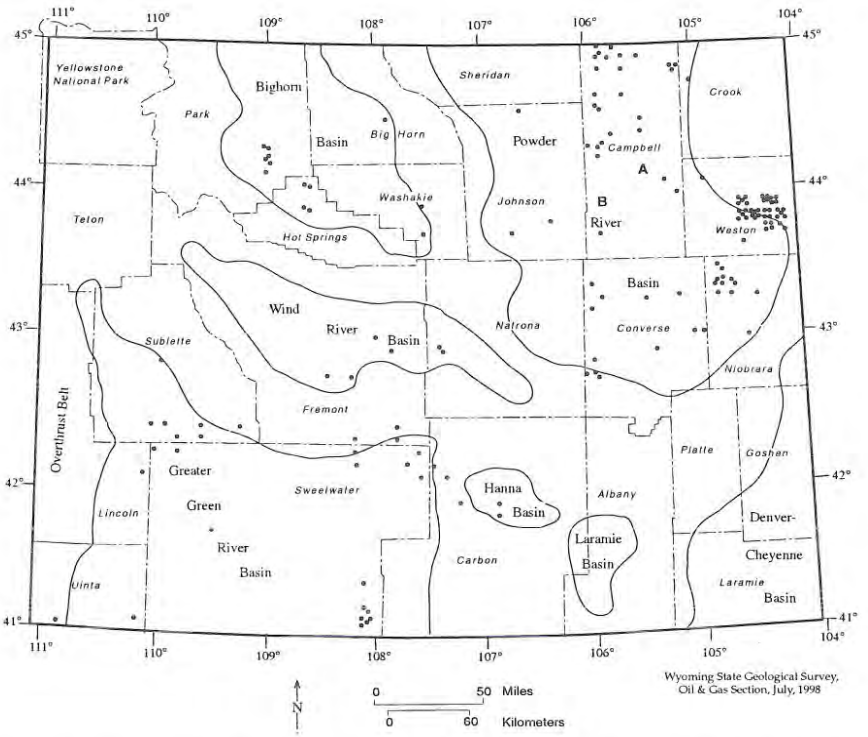



Figure 10. Locations of State oil and gas tracts leased by the Office of State Lands and Investments at its June, 1998, sale.

**Table 8. Number of Applications for Permit to Drill (APD) approved by the Wyoming Oil and Gas Conservation Commission (1995 through June, 1998).**

| County | 1994 APDs | 1995 APDs | 1996 APDs | 1997 APDs | 1998 APDs |
|---|---|---|---|---|---|
| Albany | 0 | 1 | 1 | 0 | 0 |
| Big Horn | 3 | 16 | 53 | 59 | 11 |
| Campbell | 105 | 151 | 554 | 941 | 678 |
| Carbon | 135 | 50 | 77 | 84 | 30 |
| Converse | 74 | 29 | 20 | 16 | 5 |
| Crook | 9 | 15 | 37 | 26 | 22 |
| Fremont | 46 | 30 | 26 | 58 | 22 |
| Goshen | 0 | 0 | 0 | 0 | 0 |
| Hot Springs | 4 | 13 | 24 | 42 | 0 |
| Johnson | 16 | 6 | 16 | 6 | 14 |
| Laramie | 15 | 10 | 2 | 3 | 1 |
| Lincoln | 103 | 64 | 55 | 122 | 55 |
| Natrona | 63 | 80 | 74 | 59 | 14 |
| Niobrara | 4 | 4 | 7 | 8 | 5 |
| Park | 18 | 20 | 30 | 25 | 6 |
| Platte | 2 | 0 | 0 | 0 | 0 |
| Sheridan | 3 | 0 | 0 | 2 | 7 |
| Sublette | 113 | 61 | 118 | 179 | 108 |
| Sweetwater | 204 | 153 | 136 | 210 | 82 |
| Teton | 0 | 0 | 0 | 0 | 0 |
| Uinta | 11 | 11 | 10 | 27 | 9 |
| Washakie | 12 | 31 | 30 | 36 | 7 |
| Weston | 6 | 10 | 10 | 5 | 2 |
| **TOTALS** | **946** | **755** | **1280** | **1908** | ***1078** |

Source: All data are from the Wyoming Oil and Gas Conservation Commission.
*Number of APDs issued in the first half of 1998.

*Wyoming State Geological Survey, Oil and Gas Section, July, 1998.*

The Wyoming Oil and Gas Conservation Commission permitted 34 seismic projects in the first half of 1998 (**Table 9**). Sweetwater, Carbon, and Sublette counties in the Greater Green River Basin and Campbell and Converse counties in the Powder River Basin accounted for most of the permitted conventional miles as well as the 3-D square miles.

The average daily rig count for the second quarter of 1998 was 35. This average is seven less than in the first quarter of 1998, but is still fairly high considering the low prices for Wyoming crude oil. **Figure 11** shows the Wyoming daily rig count averaged by month.

**Table 9. Number of seismic projects and miles permitted by the Wyoming Oil and Gas Conservation Commission (1995 through June, 1998).**

| | 1995 | | | 1996 | | | 1997 | | | 1998 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| County | Permits | Conventional Miles | 3-D Square Miles | Permits | Conventional Miles | 3-D Square Miles | Permits | Conventional Miles | 3-D Square Miles | Permits | Conventional Miles | 3-D Square Miles |
| Albany | 0 | 0 | 0 | 1 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Big Horn | 1 | 16 | 0 | 2 | 3 | 66 | 2 | 0 | 45 | 0 | 0 | 0 |
| Campbell | 12 | 24 | 43 | 32 | 56 | 220 | 20 | 52 | 79 | 10 | 15 | 100 |
| Carbon | 1 | 0 | 16 | 2 | 5 | 18 | 3 | 7 | 190 | 2 | 0 | 197 |
| Converse | 4 | 39 | 20 | 1 | 4 | 0 | 1 | 5 | 0 | 2 | 12 | 110 |
| Crook | 1 | 0 | 5 | 5 | 3 | 20 | 7 | 8 | 18 | 2 | 2 | 4 |
| Fremont | 6 | 32 | 56 | 2 | 5 | 15 | 6 | 43 | 126 | 1 | 50 | 0 |
| Goshen | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 227 | 0 | 0 | 0 | 0 |
| Hot Springs | 2 | 70 | 9 | 4 | 17 | 29 | 1 | 8 | 0 | 3 | 11 | 0 |
| Johnson | 1 | 4 | 0 | 0 | 0 | 0 | 2 | 7 | 17 | 1 | 4 | 0 |
| Laramie | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lincoln | 2 | 18 | 110 | 0 | 0 | 0 | 3 | 7 | 116 | 0 | 0 | 0 |
| Natrona | 3 | 27 | 3 | 0 | 0 | 0 | 5 | 14 | 101 | 1 | 0 | 70 |
| Niobrara | 0 | 0 | 0 | 2 | 0 | 23 | 0 | 0 | 0 | 0 | 0 | 0 |
| Park | 0 | 0 | 0 | 6 | 20 | 82 | 4 | 56 | 58 | 1 | 16 | 0 |
| Platte | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sheridan | 0 | 0 | 0 | 1 | 5 | 0 | 0 | 0 | 0 | 1 | 14 | 0 |
| Sublette | 2 | 0 | 162 | 2 | 21 | 52 | 1 | 0 | 61 | 2 | 1 | 115 |
| Sweetwater | 9 | 17 | 497 | 8 | 17 | 670 | 4 | 66 | 296 | 3 | 214 | 33 |
| Teton | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Uinta | 0 | 0 | 0 | 1 | 0 | 40 | 0 | 0 | 0 | 1 | 0 | 42 |
| Washakie | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 36 | 0 | 3 | 41 | 30 |
| Weston | 1 | 13 | 0 | 1 | 0 | 16 | 1 | 0 | 17 | 1 | 0 | 35 |
| **TOTALS** | **45** | **260** | **921** | **70** | **174** | **1251** | **65** | **536** | **1124** | ***34** | ***380** | ***736** |

Source: All data are from the Wyoming Oil and Gas Conservation Commission.
*Number of seismic projects and miles permitted during the first half of 1998.

*Wyoming State Geological Survey, Oil and Gas Section, July, 1998.*

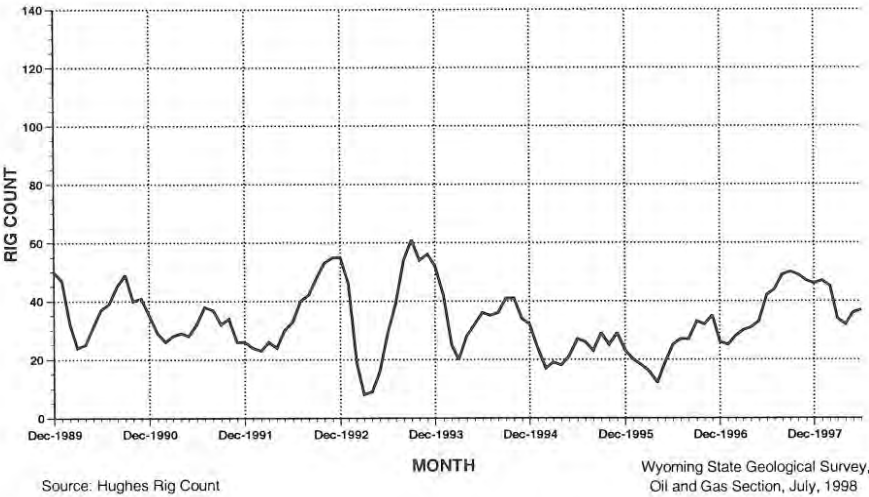



Figure 11. Wyoming daily rig count averaged by month (December, 1989, to June, 1998).

## Exploration and Development

Company data, news releases, and information compiled and published by Petroleum Information/Dwights LLC indicate the following significant exploration and development events occurred in Wyoming during the second quarter of 1998. The numbers preceding discussions below refer to locations on **Figure 12**.

1. Chevron USA completed a new horizontally-drilled Nugget Sandstone producer in Painter Reservoir East Field. The Chevron USA 14-8AH-PRU well in SE SW section 8, T15N, R119W flowed 2,225 barrels of oil and 7.3 million cubic feet of gas per day. True vertical depth of the well was not reported. This was the fourth horizontal infill well drilled in Painter Reservoir East Field.
2. Amoco Production completed a Madison Limestone producer in Whitney Canyon-Carter Creek Field. The 5 Champlin 457 well in SW SE section 7, T17N, R119W flowed gas at the rate of 60 million cubic feet per day from above 13,590 feet. The daily production rate of this well is the highest of any well in the field in the last 15 years.
3. Petral Exploration completed a wildcat in SE NE section 9, T15N, R113W. The 20-9 Cinderella well flowed 967,000 cubic feet of gas, 67 barrels of condensate, and 48 barrels of water per day from the Muddy Sandstone between 13,087 and 13,142 feet. The new well is about a mile and a half northwest of a shut-in Frontier discovery at Big Dry Creek Field.
4. Celsius Energy completed a Muddy discovery at its 2-2 Thompson-Federal well in NW SE section 2, T17N, R113W. The well flowed 2.5 million cubic feet of gas per day from between 12,396 and 12,436 feet.

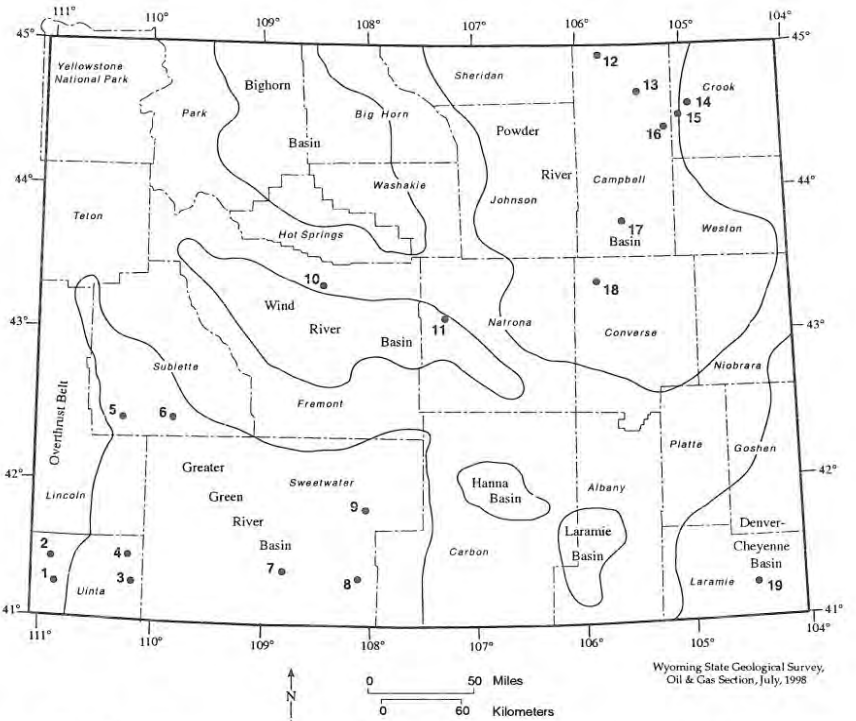



Figure 12. Oil and gas exploration and development activities in Wyoming during the second quarter of 1998 (exclusive of coalbed methane activities).

5. Enron Oil & Gas completed a new well in the Big Piney/La Barge area. The 164-19H Burly well in SW NE section 19, T28N, R113W pumped 193 barrels of oil, 104,000 cubic feet of gas, and 78 barrels of water per day. Production is from the Mesaverde between 2,100 and 2,103 feet and between 2,600 and 2,604 feet.
6. Activity remains high in the Jonah/Pinedale anticline area. McMurry Oil completed two new wells in Jonah Field. The 11-35 Stud Horse Butte well in NE SW section 35, T29N, R108W flowed 10.6 million cubic feet of gas, 82 barrels of condensate, and 55 barrels of water per day from an undisclosed Lance interval above 11,410 feet. McMurry also completed the 7-13 Yellow Point well in SW NE section 13, T28N, R109W. The well flowed 16.1 million cubic feet of gas per day from six intervals in the Lance above 10,600 feet. Snyder Oil also completed a well in Jonah Field. The 3-26-29-108 Stud Horse Butte well in NE NW section 26, T29N, R108W flowed 15.2 million cubic feet of gas and 212 barrels of condensate per day from a number of undisclosed intervals in the Lance above 11,592 feet. Ultra Resources completed a wildcat well on the Pinedale anticline. The 11-8 Lizard Head well in NE SW section 8, T31N, R108W flowed 1.5 million cubic feet of gas per day from the Lance between 12,830 and 12,962 feet. The company

indicated that up to four additional fracture jobs would be required to fully complete the well. Ultra also announced plans to drill at least 29 additional wells in 1998 in the Jonah/Pinedale anticline area.

7. Union Pacific Resources completed another high-volume, horizontally-drilled Phosphoria producer in Brady Field. The 42P-H Brady well in NW SW section 11, T16N, R101W flowed 10.5 million cubic feet of gas and 1,504 barrels of condensate per day from an undisclosed interval in the Phosphoria. Both this well and an earlier completion will supply gas to the new $27 million Brady sweetening plant. When the plant reaches full capacity, it will produce about 35 million cubic feet per day of sweet gas.
8. Celsius Energy completed two new wells in Mulligan Draw Field. The 4 Wedge Unit well in SW NE section 11, T15N, R95W flowed 4.1 million cubic feet of gas per day from the Almond between 12,876 and 12,900 feet. The 3 Wedge Unit well in SW NW section 35, T16N, R95W flowed 5.8 million cubic feet of gas per day from the Almond between 12,608 and 12,628 feet.
9. Three new wells were completed in the Siberia Ridge/Wamsutter Field area. Amoco Production completed the 26-3 C.G. Road Unit well in SE NE section 26, T21N, R94W. The well flowed 3.6 million cubic feet of gas per day from the Lewis between 9,194 and 9,350 feet and from the Almond between 10,580 and 10,910 feet. Amoco also completed the 26-4 C.G. Road Unit well in SE SE section 26, T21N, R94W. The well flowed 2.6 million cubic feet of gas per day from the Lewis between 9,283 and 9,470 feet and from the Almond between 10,772 and 11,038 feet. Samedan Oil's 4-14 Micelli well in C SE section 14, T21N, R94W flowed 841,000 cubic feet of gas, 10 barrels of condensate, and 154 barrels of water per day from the Lewis between 8,518 and 9,496 feet and from the Almond between 10,550 and 10,560 feet.
10. Tom Brown completed its 24-32 Tribal Sand Mesa well in SW NE section 24, T4N, R4E. The well flowed 3.5 million cubic feet of gas per day from the Fort Union between 11,400 and 14,200 feet with 700 net feet of pay.
11. The BLM approved Intoil's proposal to drill up to an additional 73 natural gas wells in Cooper Reservoir Field. The field produces primarily from the Fort Union, but has produced from the Lance as well.
12. Bellevue Resources completed its 31-36 Boley-Fee discovery well in NW NE section 36, T57N, R74W. The well produced an average of 139 barrels of oil per day from the Minnelusa between 8,609 and 8,619 feet during its first month on line. Bellevue also completed an offset well in SW NE section 36, T57N, R74W. The 1-36 State well produced an average of 327 barrels of oil and 24 barrels of water per day during its first month on line. The well is producing from the Minnelusa between 8,562 and 8,576 feet.
13. Trend Exploration completed a wildcat well in SW SW section 36, T54N, R71W. The 36-1 Boothill-State well pumped 159 barrels of oil and 152 barrels of water per day from the Minnelusa between 8,042 and 8,043 feet.
14. L&J Operating completed a new well in NE SW section 17, T53N, R67W. The 2 Montana-Berger well flowed 110 barrels of oil per day from the Minnelusa between 6,105 and 6,112 feet.
15. Westport Oil & Gas completed the first horizontally-drilled Minnelusa producer in Mellott Ranch Field. The 11-12H Mellott Ranch Unit well in NW NW section 12, T52N, R68W produced an average of 371 barrels of oil and 40

barrels of water per day during its first two days on line. The well was drilled to a true vertical depth of approximately 6,600 feet.

16. Fancher Oil completed a new well in Garner Lake North Field. The 3 North Garner Lake Unit well in SE SE section 21, T51N, R69W pumped 70 barrels of oil per day from the Minnelusa between 7,942 and 7,955 feet.
17. Devon Energy completed five more Sussex Sandstone producers in House Creek Field. The 115-2 House Creek well in SW SE section 33, T44N, R72W pumped 344 barrels of oil and 56 barrels of water per day from between 7,915 and 7,930 feet. The 52-2 House Creek Unit well in NW NW section 9, T44N, R73W pumped 98 barrels of oil and 292 barrels of water per day from between 8,092 and 8,114 feet. The 135-2 House Creek well in NE NW, section 9, T43N, R72W, flowed 320 barrels of oil per day from between 8,048 and 8,067 feet. The 141-3 House Creek well in SW SE section 9, T43N, R72W, pumped 224 barrels of oil and 56 barrels of water per day from between 8,128 and 8,154 feet. The 71-2 well in SW NW section 22, T44N, R73W, pumped 82 barrels of oil and 372 barrels of water per day from between 8,220 and 8,241 feet. Devon Energy purchased House Creek Field several years ago and began drilling additional wells in the field. Devon has increased oil production at House Creek Field to over a million barrels per year and the field now ranks as Wyoming's thirteenth largest oil field in terms of yearly production.
18. Vastar Resources has a new discovery in SW SW section 22, T39N, R75W. The 1-22 African Swallow well flowed gas at rates of 5.6 to 5.9 million cubic feet per day and condensate at rates of 819 to 974 barrels per day during a seven-day test. The well was tested in the Muddy Sandstone between 14,118 and 14,128 feet. The nearest Muddy production is four miles southwest at Nutcracker Field.
19. Union Pacific Resources completed two horizontally-drilled wells in Silo Field. The 1H Bishop 41-27 well in NE NE section 27, T15N, R63W pumped 80 barrels of oil and 80 barrels of water per day from the Niobrara. The well was drilled to a true vertical depth of around 7,400 feet. The 1-23HA McConnaughey well in C NE section 23, T16N, R65W pumped 245 barrels of oil and 182,000 cubic feet of gas per day from the Niobrara. The well was drilled to a true vertical depth of about 8,200 feet.

## COAL UPDATE

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

Coal production, as derived from the Federal Energy Regulatory Commission's (FERC's) Form 423, showed the State's coal producers got off to a great start in January by setting a new monthly steam coal delivery record for Wyoming at 26,536,217 short tons (tons). This was a healthy increase of 3.4% over the 25,165,405 tons delivered in January of 1997.

Steam coal deliveries for the first quarter of 1998, as reported on FERC Form 423, again show Wyoming leading the nation. Wyoming deliveries for the quarter totaled 73,596,841 tons (**Table 10**). Wyoming deliveries for the same period in 1997 totaled 68,474,641 tons. While the 1997 deliveries only increased by two million tons over the 268.9 million tons delivered in 1996, 1998 deliveries are already running over five million tons (7.5%) above last year's figures for the same period. **Figure 13** shows monthly coal deliveries over the past three years. **Figure 14** breaks these monthly deliveries into spot sales and contract sales.

**Table 11** depicts historic and projected coal production by county. It also provides an estimate of the percentage of coal from the Powder River Basin, which sells for more than $5.00/ton. The tonnage sold at these higher prices is the remaining, older, long-term contracts that had escalation clauses built into them. **Table 12** shows a breakdown of the average prices for coal produced in northeastern Wyoming and southern Wyoming over the last 10 years. Preliminary figures from the Department of Revenue indicate that the average price received for coal from northeastern Wyoming in 1997 was $5.03, which is 30 cents below our estimate of earlier this year. Based on this and other preliminary figures from the Department of Revenue, the average price received for Wyoming coal in 1997 was $5.78 (**Tables 2** and **12**).

## Developments in the Powder River Basin

A U.S. Bureau of Land Management (BLM) panel has officially awarded Powder River Coal Co. (Peabody Group, Inc.) the Powder River Lease by Application (LBA) tract (**Figure 15**, p. 30). Pending a routine U.S. Department of Justice review of the company, the effective lease date of the LBA will be September 1, 1998 (*Coal Daily*, 7/6/98).

In the *Federal Register* (5/20/98), the BLM outlined some of the details of the Powder River LBA. The LBA consists of 4,224 acres and is underlain by the Wyodak coal bed, which averages 74 feet in thickness. Overburden depth to the coal is 200 to 300 feet. The reserves have an average in-place strip ratio of 3:1. Average coal quality of the reserves on an as-received basis is reported as 8,744 Btu/lb., 27.93% moisture, 4.21% ash, 0.18% sulfur, and 1.84% sodium.

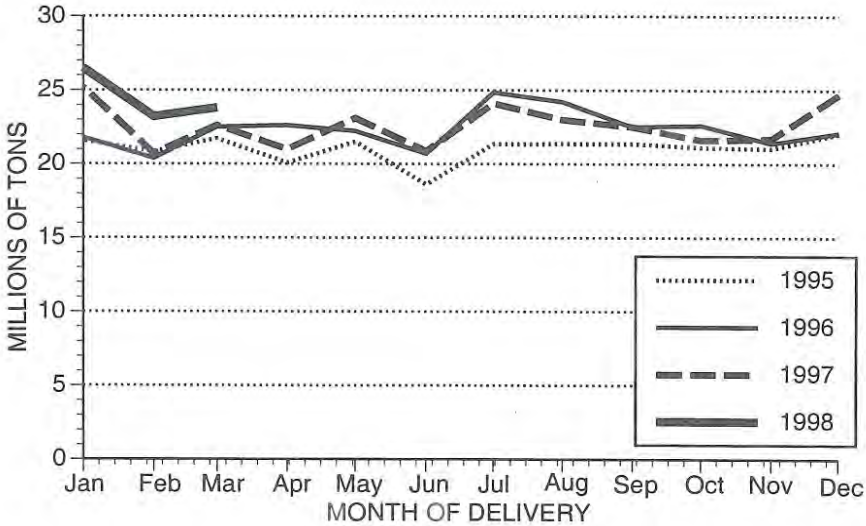
Powder River Coal Co. will use the new reserves to extend the life of their North Antelope and Rochelle operations. Each mine will gain approximately seven years of reserves from the new acquisition.

Powder River Coal Co. was the only bidder. Their bid for the 532-million-ton coal lease, was $109.6 million (20.6 cents/ton). The State of Wyoming will receive $54.8 million or half of the sale's proceeds in five annual installments. In an article in the *Casper Star-Tribune* (5/6/98), it was estimated that the new coal lease could lead to direct coal-related tax and royalty income to Wyoming of $538 million, as well as another more than $2 billion in indirect benefits.

Table 10. Monthly coal deliveries from Wyoming's mines in short tons (1995 to March, 1998).

| | 1995 Monthly | 1995 Cumulative | 1996 Monthly | 1996 Cumulative | 1997 Monthly | 1997 Cumulative | 1998 Monthly | 1998 Cumulative |
|---|---|---|---|---|---|---|---|---|
| JAN | 21,586,303 | 21,586,303 | 21,793,387 | 21,793,387 | 25,165,405 | 25,165,405 | 26,536,217 | 26,536,217 |
| FEB | 20,839,926 | 42,426,229 | 20,374,055 | 42,167,442 | 20,743,224 | 45,908,629 | 23,196,152 | 49,732,369 |
| MAR | 21,707,422 | 64,133,651 | 22,507,800 | 64,675,242 | 22,566,012 | 68,474,641 | 23,861,472 | 73,593,841 |
| APR | 20,066,616 | 84,200,267 | 22,579,959 | 87,255,201 | 20,961,008 | 89,435,649 | | |
| MAY | 21,509,916 | 105,710,183 | 22,216,016 | 109,471,217 | 23,102,867 | 112,538,516 | | |
| JUN | 18,602,505 | 124,312,688 | 20,698,814 | 130,170,031 | 20,862,610 | 133,401,126 | | |
| JUL | 21,334,608 | 145,647,296 | 24,842,971 | 155,013,002 | 24,074,929 | 157,476,055 | | |
| AUG | 21,356,870 | 167,004,166 | 24,421,537 | 179,434,539 | 23,002,254 | 180,478,309 | | |
| SEP | 21,355,730 | 188,359,896 | 23,339,792 | 202,774,331 | 22,452,566 | 202,930,875 | | |
| OCT | 21,178,610 | 209,538,506 | 22,615,721 | 225,390,052 | 21,623,057 | 224,553,932 | | |
| NOV | 21,042,260 | 230,580,766 | 21,421,085 | 246,811,137 | 21,695,072 | 246,249,004 | | |
| DEC | 22,032,910 | 252,613,676 | 22,105,530 | 268,916,667 | 24,695,740 | 270,944,744 | | |
| **Total Tonnage Reported[1]** | | **252,613,676** | | **268,916,667** | | **270,944,744** | | |
| **Total Tonnage Not Reported[2]** | | **11,324,347** | | **9,508,289** | | **10,536,772** | | |
| **Total Tonnage Produced[3]** | | **263,938,023** | | **278,424,956** | | **281,481,516** | | |

[1] COALDAT Marketing Reports by Resource Data International, Inc. (1995); and from bulletin board of the Federal Energy Regulatory Commission (FERC) in 1996-1998.
[2] Includes estimates of residential, industrial, and exported coal, plus tonnages not reported on FERC's Form 423.
[3] Wyoming State Mine Inspector's Annual Reports.
*Wyoming State Geological Survey, Coal Section, July, 1998.*




Wyoming State Geological Survey, Coal Section, July, 1998

Figure 13. Reported monthly deliveries from Wyoming coal mines (1996 through March, 1998). From the Federal Energy Regulatory Commission's bulletin board.

In a *Business Wire* news release (6/8/98), Rio Tinto announced its wholly-owned subsidiary, Kennecott Energy, had agreed to buy Kerr-McGee Corporation's Jacobs Ranch mine for $400 million. This purchase was reportedly completed in July. Kennecott Energy also operates the Antelope and Cordero-Rojo coal mines in Wyoming and the Spring Creek coal mine in Montana.

Currently, the Jacobs Ranch mine has permits to produce up to 35 million tons per year. In 1997, the mine produced 27.1 million tons. The mine's estimated remaining leased reserves total 216 million tons. Kennecott Energy is hoping to acquire the 3,545.03-acre Thundercloud LBA, which would add an additional 412 million tons to the mine's reserves (**Figure 15**, p. 30). Bids on this LBA are due on October 1, 1998.

In April, Kerr-McGee reportedly (*Coal Daily*, 4/23/98) acquired 1,102 acres of land adjacent to the Jacobs Ranch mine from the U.S. Forest Service in an exchange of unused, isolated properties the company had under lease. The swap was part of a program to eliminate isolated private land holdings and consolidate public lands along the Cheyenne River in the Thunder Basin National Grasslands.

In May, Kennecott Energy asked the BLM to amend the Horse Creek LBA, by deleting 126 acres and then adding 1,493 new acres to the coal lease tract (**Figure 15**, p. 30). As amended, the LBA covers 2,838 acres containing an estimated 356.5 million tons of coal. The BLM in a June notice in the *Federal*

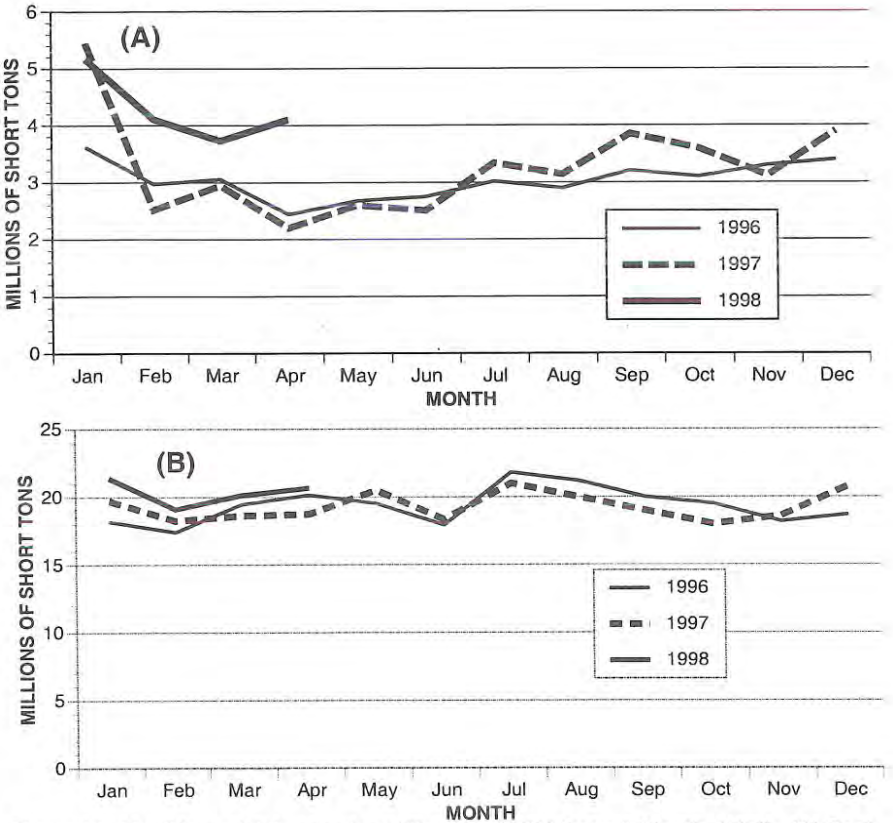



Figure 14. Monthly coal deliveries from Wyoming (1996 through March, 1998). (A) Coal sold on the spot market and (B) coal sold on contract. From the Federal Energy Regulatory Commission's bulletin board.

*Register* (6/18/98) said it would submit the revised LBA for public scoping, and would prepare an environment impact statement.

**Table 13** is a summary of the Lease by Application coal activity in the Powder River Basin since the program began in 1989. **Figure 15** shows the location of the various LBAs.

Arch Coal (company news release of 6/3/98) completed its acquisition of the domestic coal operations of ARCO, including ARCO's Black Thunder and Coal Creek mines in Wyoming (*Wyoming Geo-notes No. 58*, p. 29). Arch reportedly plans to run its marketing efforts out of St. Louis.

On May 19, 1998, Texas Utilities, the successful bidder for The Energy Group, completed its sale of both Peabody Holding Co. and Citizens Power to

**Table 11. Wyoming coal production by county (in millions of tons), from 1994 to 1997 with forecasts to 2004.**

| | 1994[1] | 1995[1] | 1996[1] | 1997[1] | 1998[2] | 1999[2] | 2000[2] | 2001[2] | 2002[2] | 2003[2] | 2004[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Campbell County | 205.2 | 232.4 | 245.3 | 246.3 | 265.3 | 282.5 | 304.3 | 316.4 | 319.9 | 323.4 | 326.9 |
| Converse County | 11.7 | 14.1 | 15.8 | 17.8 | 15.0 | 15.3 | 15.3 | 15.3 | 15.3 | 15.3 | 15.3 |
| Sheridan County | 0.1 | M | M | M | M | M | M | M | M | M | M |
| Carbon County | 4.4 | 3.8 | 4.7 | 5.0 | 4.2 | 3.7 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Sweetwater County | 11.2 | 9.1 | 8.2 | 7.8 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| Lincoln County | 4.3 | 4.5 | 4.4 | 4.6 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Total Wyoming | 236.9 | 263.9 | 278.4 | 281.5 | 297.5 | 314.5 | 334.6 | 346.7 | 350.2 | 353.7 | 357.2 |
| Annual Change | 12.9% | 11.4% | 5.5% | 1.1% | 5.7% | 5.7% | 6.4% | 3.6% | 1.0% | 1.0% | 1.0% |
| Higher-priced coal[3] | 33% | 26% | 24% | 22% | 17% | 13% | 9% | 6% | 4% | 4% | 4% |

[1]Tonnages from the Wyoming's State Inspector of Mines, 1994-1997.

[2]County estimates by the Wyoming State Geological Survey, July, 1998; [3]Estimated percentage of Powder River Basin coal production that is sold at prices above $5.00 [older long-term contracts that have not yet expired]. M means minor tonnage (less than 0.1 million tons).

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

| 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 |

Statewide data for 1988-1990 are from reports by the U.S. Department of Energy's Energy Information Administration; data for 1991-1997 are derived from the Wyoming Department of Revenue.

P&L Coal Holding Corp., an affiliate of Lehman Brothers Merchant Banking Partners.

The price was reportedly $2.3 billion, including assumed debt (*Coal Daily*, 5/20/98). With the close of the purchase, Peabody Group is now an independent and privately held company. The new owner helped finance the purchase using bonds worth $900 million.

Restructuring of the Peabody Group began just a few days after the announced sale. As part of a major cost-cutting effort, the company issued warning notices to all salaried personnel. *Coal Daily* (5/26/98) reported that Peabody's restructuring includes plans to close their offices in Henderson, Kentucky, and in Flagstaff, Arizona. A five-person office located in Evansville, Indiana, will apparently replace the Kentucky office. Peabody will centralize their marketing, business development, resource management, and new mine development in a proposed new office building in suburban St. Louis.

In Gillette, the computing, accounting, and materials management staff of Peabody's Powder River Coal Co. will reportedly be trimmed to between 5 and 20 employees. There are apparently no plans to idle or close any of the company's Wyoming mines.

The pending sale of Zeigler Coal Holding Co. (Zeigler) was not clear until early August. At that time, it was announced that AEI Resources and Zeigler would merge in an $855 million stock deal (*Casper Star-Tribune*, 8/5/98). Zeigler's coal holdings in Wyoming include the Buckskin and North Rochelle mines, which contain reserves of 466.4 million tons and 329.0 million tons, respectively.

Zeigler's North Rochelle mine has begun the removal of overburden and hopes to begin shipping coal on a regular basis by November. On May 1st, the

**Table 13. Summary of Leases by Application (LBA) in the Powder River Coal Field of Wyoming.**

| LBA Name/ Company Applicant | Application Date | Applied for Acreage | Applied for Tons | Offered for Bid Acreage | Offered for Bid Tons | Status | Total of Bid | Cents/ton |
|---|---|---|---|---|---|---|---|---|
| Jacobs Ranch/Kerr-McGee | 10/10/89 | 1,465 | 123 MM | 1,709 | 147.4 MM | Accepted 9/26/91 | $20,114,930 | 13.6 |
| West Black Thunder/ Thunder Basin Coal Co. | 12/22/89 | 3,225 | 400 MM | 3,492 | 429 MM | Accepted 8/12/92 | 71,909,282 | 16.8 |
| North Antelope & Rochelle/ Powder River Coal Co. | 03/03/90 (2 applications) | 954<br>1,196 | 120 MM<br>150 MM | 3,064 | 403.5 MM (Offered as 1 Tract) | Accepted 9/28/92 | 86,987,765 | 21.6 |
| West Rocky Butte/ Northwestern Resources Co. | 12/04/90 | 390 | 50 MM | 463 | 56.7MM | Rejected 12/3/92<br>Accepted 1/07/93 | 14,200,000<br>16,500,000 | 25.8<br>29.1 |
| Eagle Butte/AMAX Land Co. | 07/21/91 | 915 | 150 MM | 1,059 | 166.4 MM | Accepted 4/05/95 | 18,470,400 | 11.1 |
| North Rochelle/Zeigler Coal Co. | 07/22/92 | 1,440 | 144 MM | 1,482 | 157.6 MM | Rejected 7/29/97<br>Accepted 9/26/97 | 26,800,000<br>30,600,000 | 17.0<br>19.4 |
| Antelope/Antelope Coal Co. | 12/29/92 | 617 | 60 MM | 617 | 60.4 MM | Rejected 9/18/96<br>Accepted 12/4/96 | 6,645,045<br>9,064,600 | 11.0<br>15.0 |
| Powder River/Powder River Coal Co. | 03/23/95 | 4,200 | 555 MM | 4,224 | 532 MM | Accepted 7/03/98 | 109,600,000 | 20.6 |
| Thundercloud/Kennecott Energy | 04/14/95 | 3,396 | 427 MM | 3,546 | 432 MM | Sale set for September, 1998 | | |
| New Keeline/ Evergreen Enterprises | 05/13/96 | 7,841 | 675 MM | na | na | PRRCT reviewed this on 4/23/97 and recommended this LBA not be considered at that time. | | |
| Horse Creek/ Antelope Coal Co. (Amended) | 02/14/97<br>05/01/98 | 1,471<br>2,838 | 177.5 MM<br>356.5 MM | na<br>na | na<br>na | PRRCT reviewed this and approved it to proceed (4/23/97)<br>Reopened scoping period 6/18/98 | | |
| Belle Ayr/AMAX Land Co. | 03/20/97 | 1,032 | 200 MM | na | na | PRRCT reviewed this and approved it to proceed (4/23/97) | | |

Adapted from the 1997 Draft EIS for the Powder River & Thundercloud leases prepared by the U.S. Bureau of Land Management, and revised by the Coal Section of the Wyoming State Geological Survey in July, 1998. MM =million; PRRCT =Powder River Regional Coal Team.

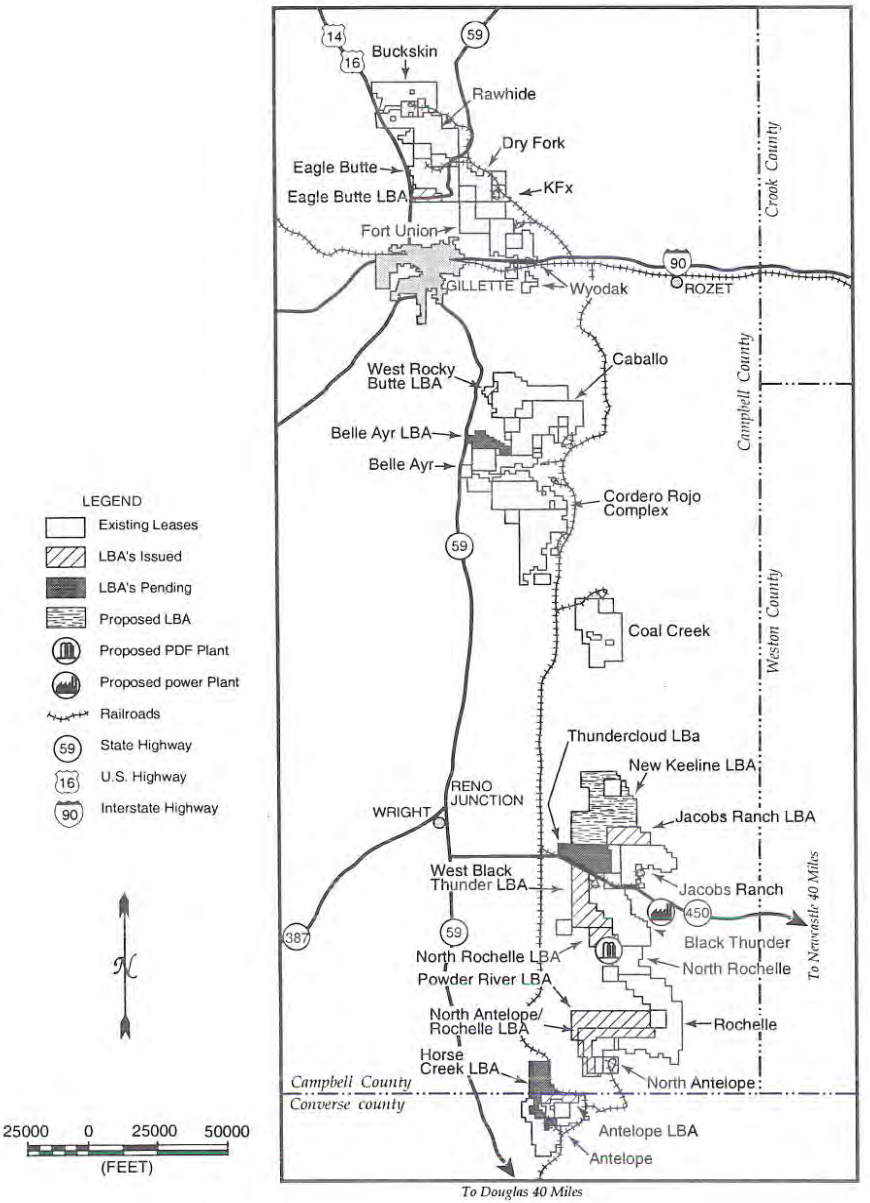



Figure 15. Lease by Application coal tracts in the Powder River Basin of Wyoming. Modified from the 1997 Final EIS, Powder River Coal Lease Application and Thundercloud Coal Lease Application (U.S. Bureau of Land Management).

mine awarded a $16.3 million contract to a Gillette construction firm to build most of the surface structures on the mine site, which is located 55 miles south of Gillette.

SGI International (*Coal Outlook*, 5/18/98) exercised an option to terminate its TEK-KOL partnership with Zeigler. Prior to Zeigler's merger with AEI Resources, SGI was reportedly negotiating with Zeigler to acquire the ENCOAL benefaction plant, plus all permits, rights, and ancillary agreements required to build a Liquid Fuels from Coal (LFC) plant at the North Rochelle mine. SGI was also negotiating a long-term supply contract for coal from the Buckskin or North Rochelle mines.

KFx Corp. announced the hiring of investment bankers, Raymond, James, & Associates, to help identify prospective investments in other energy technologies. KFx's immediate interest is the development of an activated carbon business. Activated carbon can be used as a filter to remove mercury and other toxic air emissions from flue gas scrubbers.

In April, KFx shipped 15 tons of their K-Fuel to Southern Company's combustion testing facility in Birmingham, Alabama. A joint news release (6/16/98) by KFx and Kennecott Energy indicated the test exceeded their expectations. The test compared the new fuel against coal from the Dry Fork mine as well as a compliant eastern coal. The K-Fuel proved lower in SOx and NOx emissions than either coal.

KFx is stockpiling their product, so that they can begin shipments to their main customer, American Electric Power Co. (AEP). AEP has an option to buy up to 500,000 tons of the fuel for use at the Ohio Valley Electric Co.

Black Hills Corp. may host up to four agglomerating units at its Wyodak mine. Each of the units will make about 150 tons of coal briquettes per hour. The project is in cooperation with Earthco, a company based in Indianapolis, Indiana.

The briquetting technology is proprietary to Earthco, which will operate the units. The agglomerating units are designed to convert coal fines into briquettes, raising the feedstock's 8,000 to 8,200 Btu/lb. heat values to around 10,000 Btu/lb. The product reportedly contains less moisture and is easier to transport than the coal feedstock. To attain full capacity, the Wyodak mine may have to increase its production rate to 6,000,000 tons a year. In 1997, the mine produced 3,250,969 tons.

## Developments in southern Wyoming

In July, the U.S. Bureau of Land Management (BLM) issued a Draft Environmental Impact Statement for the possible leasing of 5,235.15 acres of Federal coal lands in the Carbon Basin. The Lease by Application (LBA) tract contains an estimated 149.7 million tons of minable coal reserves. Ark Land

Co. filed the LBA. Its subsidiary, Arch of Wyoming, would do the mining if Ark Land were successful in acquiring the lease. Arch's plans include both a surface mine (Elk Mountain mine) and an underground mine (Saddleback Hills mine). Ark Land had applied for the coal lease to replace dwindling reserves at their Medicine Bow and Seminoe II mines in the nearby Hanna Basin.

Arch Technology Corp. (ATC), a subsidiary of Arch Coal, Inc., formally introduced their Archveyor technology at the annual meeting of the Society of Mining Engineers, held in Orlando, Florida, this past March. ATC is marketing the Archveyor system for contract mining or joint-venture applications on a worldwide scale. Their marketing efforts spotlight the use of this highwall mining technology at Arch of Wyoming's Medicine Bow mine in Carbon County, Wyoming. The system, first installed in 1992, has worked at grades as steep as 30%. According to ATC (*Coal Age*, June, 1998), the system has evolved from a prototype automated highwall mining system to a consistently safe, productive, and low cost producer. The Archveyor, which uses two employees per shift, has reportedly produced in excess of 135,000 tons per month.

A fire at the inactive Lion coal mine, east of Rock Springs, destroyed several structures at the mine. The underground mine closed in August of 1996. Most of the mine's exterior assets were apparently sold at that time to pay down taxes and debts, and the mine has been the subject of bankruptcy proceedings since then. The *Laramie Boomerang* (5/14/98) reported that the mine owes $3 million in royalties and back taxes, and is in danger of forfeiture of a $36,000 reclamation bond. The article also reported that at the time of the fire, White Oak Mining of Colorado was considering a purchase of the mine. White Oak officials said that the fire damage was not be a major consideration since the destroyed structures needed major changes anyway.

## Transportation developments

In the second quarter, Johnstown America Corporation (JAC) made three major deliveries of their BethGon Coalporters and automatic discharge Autoflood II hopper cars to users of Wyoming coal. In May, Detroit Edison received 480 of the aluminum Coalporters and placed an order for an additional 495 for late 1998 delivery. The new cars will carry coal from Powder River Basin mines to the utility's plants in southeastern Michigan. Also in May, Western Fuels Association, Inc. (WFA) acquired 220 of the Autoflood II hopper cars. WFA will form two unit trains with their new cars to move coal from the Powder River Basin to the Sikeston Board of Municipal Utilities and to the Kansas City Board of Public Utilities (*Coal Daily*, 5/20/98).

In June, JAC delivered 480 of their BethGon Coalporters to Commonwealth Edison Co. (*Coal Daily*, 6/22/98). These new cars will carry coal from Powder River Basin mines to the utility's plants in northern Illinois. This raises Commonwealth Edison's coal fleet up to roughly 4,500 all-aluminum cars.

In April, the Union Pacific/Southern Pacific (UP/SP) Railroad announced that it would add 42 miles of third main track between O'Fallons and Gibbon

Junction, Nebraska, as part of a $400-million-dollar improvement project (*Coal Outlook*, 4/13/98). The UP/SP also intends to add 24 miles of second main track between Gibbon Junction and Kansas City, giving them 143 miles of double trackage on that segment.

UP/SP's improvement plan also includes more than 100 miles of replacement trackage along their line across southern Wyoming. This summer, UP/SP crews will replace about 86,000 railroad cross ties in that portion of the State.

According to *Coal Daily* (6/12/98), neither the Burlington Northern/Santa Fe (BN/SF) nor the UP/SP railroads are participating in the Surface Transportation Board's (STB's) proceedings on the Dakota, Minnesota, & Eastern Railroad's planned new line into the Powder River Basin. However, several other railroads are. They are the Illinois Central and its subsidiary Cedar River Railroad, the Canadian Pacific Railway, and the Wisconsin Central and Nebkota Railway.

Entergy Corp. is seeking to have the STB grant BN/SF access to their White Bluff plant via the existing UP/SP line (*Coal Daily*, 5/25/98). The power plant claims that UP/SP's inability to deliver contracted coal has cost them more than $25 million in increased expenses buying more costly substitutes. According to Entergy, White Bluff's coal inventory, "... has remained far below normal levels since last November. It has had to restrict coal burns from between 20 to 65% below full capacity."

In June (*Coal Daily*, 6/12/98), Entergy took its first barge-delivered coal at their White Bluff plant, which is located on the Arkansas River. The Ingram Barge Line will deliver 500,000 tons of Powder River Basin (PRB) coal to the plant as part of Entergy's plan to make up for chronic shortfalls in deliveries by the UP/SP. *Coal Week* (5/4/98) reports that Thunder Bay is looking for some PRB coal business. Located on Lake Superior about 250-miles north of Duluth, Thunder Bay traditionally transloads western Canadian coal for lake delivery to the plants of Ontario Hydro.

In a related story in *Coal Outlook* (6/22/98), Thunder Bay claims to have five million tons of available capacity now ready to move PRB coal onto the lake for shipment to U.S. and Canadian utilities.

## Coalbed methane developments

In a news release (*BN Wire*, 5/5/98), Barrett Resources noted that they produced more than 1.1 billion cubic feet of coalbed methane gas from the Powder River Basin (PRB) in the first quarter of the year. After expenses, this netted the company $1.09 per thousand cubic feet of gas.

The U.S. Bureau of Land Management (BLM) is no longer accepting Notices of Staking (NOS) or Applications for Permit to Drill (APD) for coalbed methane wells on Federal leases in another portion of the PRB. This latest moratorium or ban pertains to the area within the Gillette North Environmental Impact Statement (EIS) and was effective on May 15th. The drilling moratorium was called because the ceiling of 250 wells allowed under the current EIS had been reached. In an earlier action in March of this year, the BLM also closed the area covered by the Gillette South EIS (*Wyoming Geo-notes No. 58*, p. 35). Both of these moratoriums will at least last until the new Wyodak Coalbed Methane EIS is completed near the middle of next year. **Figure 16** shows the location of the various coalbed methane EIS study areas in the PRB.

Pennaco Energy, Inc. (*PR Newswire*, 7/1/98) reported the acquisition of oil and gas leasehold interests on approximately 485,000 gross/400,000 net acres in northeastern Wyoming. The prospective coalbed-methane acreage is located along the east, north, and west flank of the PRB. The news release also noted that coalbed methane in the PRB is one of the most active onshore U.S. natural gas plays today. With its extensive reserves of low-cost, shallow, coalbed methane gas, the basin has attracted several independent E&P and midstream companies, including Barrett Resources, Devon Energy, Western Gas Resources, and MCN Energy.

Pennaco plans to begin an aggressive drilling program during the third quarter of 1998, as pipeline infrastructure and transportation partnerships are formalized. Pennaco also believes that by mid-1999 new pipeline construction and expansion projects will carry in excess of 350 million cubic feet of coalbed methane per day.

## Regulatory developments

During the first week of May, U.S. Representative Tom Allen (Maine) introduced a new mercury emission bill. As a companion to legislation introduced by U.S. Senator Patrick Leahy (Vermont), the bill would require affected facilities to comply with new mercury standards within five years of the bill's passage. The Environmental Protection Agency (EPA) would have to set new standards within 180 days after the bill passes Congress (*Coal Daily*, 5/13/98). H.R. 3791, which was introduced on May 5th, was referred to the House Commerce Committee. The Senate bill was introduced on April 2nd, and was referred to the Senate Environment and Public Works Committee.

A group of seven utilities, known as the Clean Energy Group, is urging EPA to get as much information as possible about mercury emissions before it sets any standards. The Group believes EPA should require companies to provide data on the mercury content of their coal feedstock, based on sampling done by the coal's supplier. The Group is also urging EPA to adopt some standard methods for determining the mercury content in different types of coal.

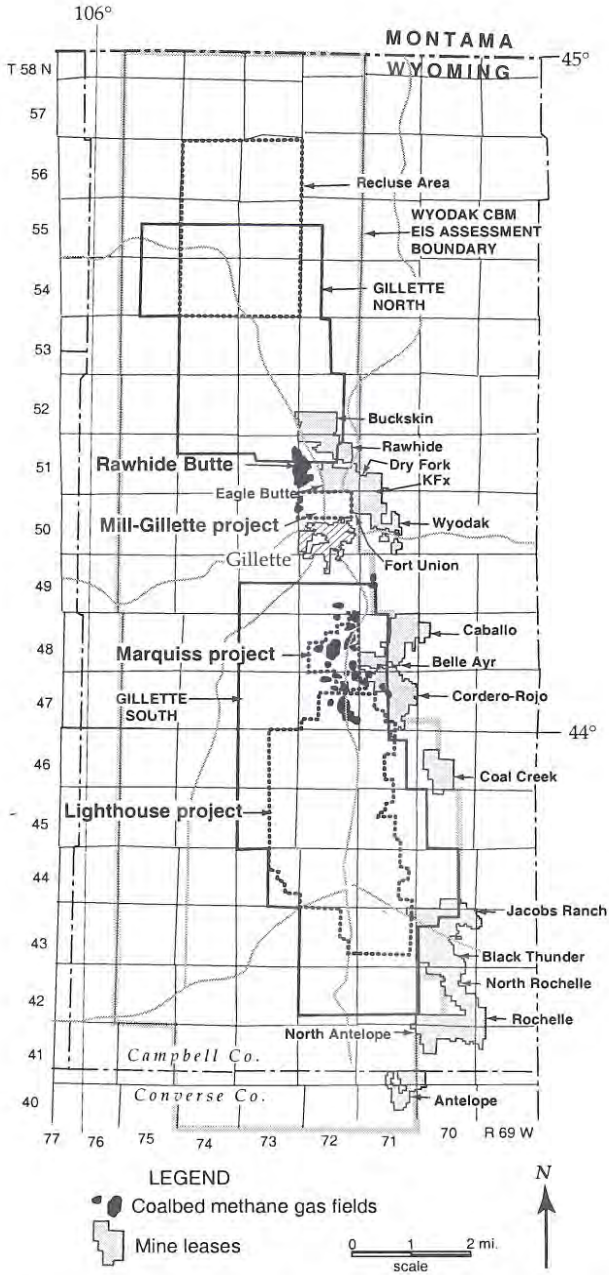



Figure 16. Environmental impact studies for coalbed methane developments in the Powder River Basin. (Modified from files of the U.S. Bureau of Land Management).

Revisions to Wyoming's gasoline tax, which became effective on July 1st, will mean higher costs for the State's coal mines. Wyoming had exempted some industries from gasoline taxes because of the large amount of fuel used by heavy equipment. But now, the coal industry is not exempted. In addition to the six cents per gallon hike in the gas tax, machinery and trucks used by the coal companies will be assessed two cents per gallon for the use of any road not maintained by the State of Wyoming.

## Market developments and opportunities

*Coal Daily* (6/21/98) said the spot market for Powder River Basin (PRB) coals was continuing to edge up during the second quarter of 1998, and reported, "... some industry sources are talking about chances for a significant bump in pricing through the next two quarters. The big news at the close of the second quarter was the business on the horizon for the month of July. Tens of millions of tons are at stake if one adds up all the RFPs calling for bids."

Ameren Corp. began a test-burn of 100% PRB coal at its Newton No. 1 unit in Illinois. In 1997, the unit burned coal from Indiana, the Hanna Basin of Wyoming, and Colorado.

Mid American Energy said that although it may take a year or more to do it, they plan to eventually wean their Neal station off Hanna Basin coal in favor of PRB coal (*Coal Week*, 7/6/98).

The New York Mercantile Exchange has reportedly begun gathering additional background information for a possible contract for PRB coal futures (*Coal Outlook*, 5/25/98). Talk of a coal futures market has been circulating for some time now.

In June, the Tennessee Valley Authority confirmed plans to begin burning low-sulfur PRB coal at its 2.54-megawatt Paradise steam plant as early as July (*Coal Week*, 6/1/98). The plant is located in Muhlenberg County, Kentucky. The move will displace coal from several western Kentucky mines.

Kentucky Utilities Co. (KUC) is evaluating bids and comparing transportation costs of eastern verses western compliance coals. KUC reportedly had not decided whether it would switch to PRB coal at their Ghent Units 3 & 4 (*Coal Daily*, 6/5/98).

Peabody COALTRADE sent out an RFP to nearly 300 companies seeking proposals on options for seven types of coal, as well as $SO_2$ emission allowances. It also allowed purchasers to pay for the options with power or allowances. The RFP included 8,800 Btu/lb. and 8,500 Btu/lb. PRB coals originating on the joint line of the BN/SF and UP/SP railroads (*Coal Daily*, 6/15/98).

Kinder Morgan Energy Partners L.P. announced that it had entered into a long-term marketing alliance with Southern Company's wholesale energy market affiliate, Southern Company Energy Marketing L.P. (*PR Newswire*, 7/8/98). The new alliance will jointly market coal using the transloading, blending, and

storage services at Kinder Morgan's Cora terminal, south of St. Louis, and its Grand Rivers terminal in western Kentucky.

The two partners believe that both Cora and Grand Rivers are strategically located to develop as important centers for buyers and sellers of coal originating from either Western or Illinois Basin production areas. The coal from the terminals can be transported via barge, truck, or rail throughout the Midwest, the East Coast, the southeastern U.S., as well as overseas markets.

**Table 14** is a tabulation of some of the contracts, spot sales, tests, and solicitations for Wyoming coal announced during the second quarter of 1998.

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Stauffenberg, D.G., 1997, Annual report of the State Inspector of Mines of Wyoming for the year ending, December 31, 1997: Office of the State Inspector of Mines, Rock Springs, 76 p.

**Table 14. Marketing activities for Wyoming coal producers during the second quarter of 1998[1].**

| | Utility | Power Plant | Coal Mine/Region | Activity | Tonnage | Comments |
|---|---|---|---|---|---|---|
| 1. | American Electric Power Service Corp. | Tanners Creek #4 | PRB | So | Unknown | 4th quarter 1999 delivery; 8,300 Btu/lb. minimum, < 1.2 lbs. $SO_2$/ million Btu; maximum of 29% moisture and 32% volatile matter. |
| 2. | Alabama Power | Miller | PRB | C | 10.5 million t | 1999 delivery from three unidentified suppliers. |
| 3. | Alliant Power | Unspecified | PRB | So | Up to 55 million t | 11 million t/y for up to 5 years. |
| 4. | Archer Daniels Midland | Des Moines plant | North Antelope/PRB | C | 60,000-70,000 t | Term per year; number & years unknown. |
| | | Mankato plant | North Antelope/PRB | C | 60,000 t | Term per year; number & years unknown. |
| 5. | City of Ames, Iowa | Ames City | PRB | So | Unknown | Delivery by end of summer, 1998; used 225,000 t in 1997. |
| 6. | Central & South West Services Corp. | Coleto Creek | PRB | Sp | 1.3 million t | For 1998 delivery. |
| | | Flint Creek & Welsh | PRB | Sp | 2.3 million t | For 1998 delivery. |
| | | Oklaunion | PRB | Sp | 1.0 million t | For 1998 delivery. |
| 7. | Commonwealth Edison | All plants | any type | So | Up to 30 million t | 10 million t/y for up to 3 years. |
| 8. | Consumers Energy | Campbell Station | Western subbituminous | So | 400,000 t | Minimum 8,650 Btu/lb. |
| | | All plants | PRB | So | Up to 1.4 million t | Seeking 200,000 for Jan.-Mar. 1999; up to 1.2 million t for Apr.-Dec. 1999. |
| 9. | Hastings Utilities | Hastings | PRB | So | Up to 1.0 million t | 1-, 3-, or 5-year contract for 114,000-200,000 t /y starting January, 1999. |
| 10. | Houston Lighting & Power | Parish | PRB | So | Up to 9.0 million t | 0.5 to 3 million t/y for one to three years. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11. | Mid-American Energy | Various plants | PRB | So | Up to 25 million t | 3-, 5-, or 7-year term for up to 5 million t/y. |
| | | Neal Station | Hanna Basin | So | 500,000 t | Late 1998 delivery. |
| 12. | New Century Energies | Arapaho | Caballo Rojo | Sp | 120,000 t | Delivery on BNSF. |
| 13. | PacifiCorp | Dave Johnston | PRB | So | 5.0 million t<br>12 million t<br>20 million t | Delivery over 15 months;<br>over a 3-year period; or<br>over a 5-year period. |
| 14. | Sierra Pacific Power | System | Green River Basin | So | Up to 1.8 million t | Delivery beginning June, 1998; may extend to Feb., 2001. |
| 15. | Southern Company Services | Scherer | PRB | So | Up to 12 million t | 1-, 3-, and 5-year terms starting in 1999 for 2.4 million t/y. |
| 16. | Texas Utilities Co. | System | PRB | So | 3.0 million t | 1- to 2-year term for 1.5 million t/y on joint rail line. |
| 17. | Wisconsin Electric Power Co. | System | PRB | So | Up to 37 million t | 5.8 to 7.4 million t/y for up to 5 years. |

[1]Data obtained from : Coal Week©, Coal Outlook©, Coal Daily©, FERC database, and personal contacts.
Note: C =contract coal; Sp =spot coal;So =solicitation; T =test burn; t =short ton; t/y =short tons per year; and PRB =Powder River Basin.
*Wyoming State Geological Survey, Coal Section, July, 1998.*

# INDUSTRIAL MINERALS AND URANIUM UPDATE

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## Construction aggregate

Umetco Minerals Corp. applied for permits to quarry granite from a location at the western end of the Rattlesnake Mountains in central Wyoming. The granite would be crushed and used to cover clay, which covers tailings from a former uranium mine in the eastern Gas Hills (**Figure 17**). This reclamation method is required by the U.S. Nuclear Regulatory Commission. This granite is the closest suitable rock to the point of use.

Several roads in Yellowstone National Park are being reconstructed this summer. According to Park Service requirements, gravel used in these projects must be free of weeds. This is a relatively costly process since aggregate brought into the park must be heated to burn or kill the weed seeds that sometimes remain in the material after sizing or crushing. The heating is accomplished by burning the gravel in an asphalt hot plant.

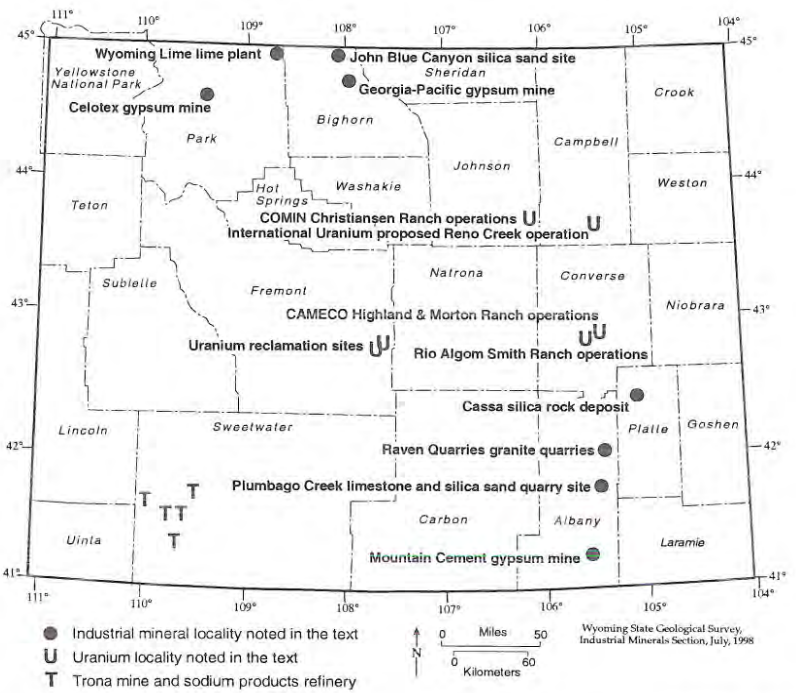


Figure 17. Map of Wyoming's industrial mineral and uranium localities of interest in the second quarter of 1998.

Gravel used on many of the road projects in Yellowstone this summer is hauled into the park from Montana. A source within the park at Sylvan Pass near the park's East Entrance is being used on road construction projects in that area. The Sylvan Pass source uses crushed andesite boulders from talus slopes. No quarry or pit will remain after the operation is completed.

## Dimensional stone

Dimensional stone is rock that is finished to specific dimensions and shapes. Usually it is quarried in large rectangular blocks, which are then fabricated into slabs, tile, and blocks (Power, 1994). Wyoming contains a large variety of rock suitable for dimensional stone (Harris, 1991). Recently, there has been considerable exploration and development activity in this resource.

Raven Quarries continues to produce black granite (Wyoming Raven) and a pink swirled granite (Fantastico) at its redesigned quarry in Albany County west of Wheatland (**Figure 17**). A partnership between Raven Quarries and V. A. Resources is also conducting preliminary tests at a dimensional limestone quarry site at the Plumbago Creek locality 30 miles northwest of Laramie (**Figure 17**). If the tests prove positive, Raven Quarries, as operator, could begin production later this summer.

Dimensional Stone Exploration (DSE), a Wyoming company owned by ICM, conducted quarry site studies at approximately two dozen locations in Wyoming in May and June of 1998. DSE is evaluating the results of these studies, with plans to develop those sites that prove minable. DSE is also studying possible fabricating plant sites in Wyoming. This spring, ICM already opened a marble quarry in Montana. ICM is an Italian-based dimensional stone equipment manufacturer and distributor.

Other companies conducting exploration for dimensional stone in Wyoming this summer include Vermont Quarries, which has Italian operators, and Cold Spring Granite, the largest U.S.-operated dimensional stone company.

Global Stone, based in Atlanta, Georgia, which was conducting exploration in Wyoming for dimensional stone quarry sites, has suspended its exploration programs. Global Stone will remodel its fabricating plant in Tucker, Georgia, and expand its distribution centers in North Carolina, Georgia, Florida, Texas, and California. The South African interest in the company was taken over by U.S. financiers, who changed the company's timetable. Global Stone may resume exploration in Wyoming in a couple of years, according to company officials.

While it is currently possible to obtain a 10-acre exemption permit (ET) from the Land Quality Division of the Wyoming Department of Environmental Quality (DEQ) to quarry dimensional limestone in Wyoming, a small mining permit (40-acre permit) is required to quarry other dimensional stones, including granite, marble, and others. A small mining permit takes longer to obtain and is more costly. Dimensional stone quarries are environmentally benign, because the goal is to obtain large unbroken blocks that are sawed or split, not

blasted, from the deposit, and the quarries are usually of small initial size. Dimensional stone companies and local economic development offices have asked the Wyoming Department of Environmental Quality to ask the Wyoming Legislature to consider adding dimensional stone to the list of operations permitted under an ET. The size and method of extraction of all dimensional stones are similar. Legislative supporters and others have met to draft this legislation for consideration in the 1999 legislative session.

Locating a dimensional stone quarry on Federal mineral lands managed by the U.S. Bureau of Land Management (BLM) may no longer be possible according to recent court interpretations and BLM regulations. Locating a claim on these lands requires that the materials to be mined or quarried have a unique property and be considered an uncommon variety of stone. However, a recent ruling by the BLM resulted in the determination that the fact that deposits may have characteristics superior to those of other deposits does not make them an uncommon variety. Raven Quarries, which had originally staked a claim on its granite deposit, was required to submit an "application for sale" and now purchases its stone from the BLM. Other operators intending to locate claims on BLM minerals may have to arrange for purchase of the stone from the BLM.

## Silica sand and the manufacture of glass

There has been continuous interest in silica sand deposits in Wyoming over the past ten years. Several plans to construct a glass plant in Wyoming, using one or more of the deposits described by reports published by the Wyoming State Geological Survey, have been proposed (Harris, 1988a and 1988b, and Harris and Warchola, 1992). A key to this interest is Wyoming's trona resources (p. 43 of this issue), which are mined and used to manufacture soda ash, a key ingredient in the manufacture of glass. Limestone and feldspar, necessary ingredients in some varieties of glass, are also found in Wyoming.

In 1997, the Wyoming Science, Technology, and Energy Authority (STEA) conducted an economic feasibility study regarding the State's glass plant potential. This study identified a company that was positioned to bid for the production of glass bottles for the Budweiser brewery northeast of Fort Collins, Colorado, 30 miles south of Cheyenne. Budweiser's current contract with the existing supplier of bottles, Ball-Foster Glass, was up for renewal in June. Ball-Foster purchases silica sand from Unimin in Oklahoma, soda ash from Wyoming, and manufactures the bottles in Oklahoma. The bottles are shipped to Fort Collins, a distance of about 700 miles, which is quite costly. Although the construction of an entirely new glass plant is a considerable investment, the transportation savings may justify the costs.

STEA and other Wyoming State agencies, including the Wyoming State Geological Survey, met with this company to report on raw materials, plant sites, regulatory requirements, and infrastructure possibilities. The company conducted its own feasibility studies in 1998 and on June 15th submitted a bid for the manufacture of bottles in Wyoming. Other companies have also submitted bids to Budweiser.

Budweiser's decision on a bottle supplier is not expected until October or later. In the meantime, this project is an example of how a study of a raw material that is unused or under-used in Wyoming may ultimately lead to an important development in the State. It also exemplifies the time it may take for a project like this to develop (in this case 10 years).

## Gypsum

Gypsum is mined in three locations in Wyoming (**Figure 17**). Celotex Corp. and Georgia-Pacific Corp. mine gypsum in the Bighorn Basin, calcine the material, and use it as the primary ingredient in wallboard, which is manufactured at nearby plants and shipped to consumers. Both of these operators are producing at plant capacity because wallboard is in demand for construction purposes. These producers together mined 459,960 tons of gypsum in 1997 according to the State Inspector of Mines of Wyoming.

Mountain Cement mines gypsum south of Laramie for an additive in cement (**Figure 17**). Gypsum is mined periodically from this site and stockpiled at the plant. No gypsum production from this site was reported in 1997, but some mining is expected in 1998.

## Lime

Heating high purity limestone ($CaCO_3$) produces lime (CaO) by the reaction $CaCO_3$ » $CO_2$ (carbon dioxide gas) + CaO. Lime is used in numerous industrial and construction products. Lime is produced in Wyoming at Wyoming Lime Producers' plant in northeastern Park County, near Frannie. Limestone quarried from the Mississippian Madison Limestone east of Warren, Montana, is the raw material used in the plant. This plant produced a record 141,262 tons of lime in 1997, up from 105,479 tons in 1996.

## Trona

Trona is mined at five locations in the Green River Basin west of Green River (**Figure 17**). This accounts for over 90% of all U.S. production of trona, with the remaining 10% coming from a surficial deposit of trona in the Mojave Desert area of southern California.

Trona is mined by underground methods supplemented in some places by solution mining techniques. Mined trona is refined at on-site plants into soda ash and other sodium-based products. Baking soda is purified soda ash. Soda ash is used primarily in the manufacture of glass. Increasing amounts of soda ash are being used in detergents and cleaners. Soda ash production set a record in 1997, and has been increasing recently with increasing exports.

According to the most recently released data from the U.S. Geological Survey, soda ash production so far this year is 7% higher than 1997. Domestic consumption is 2% higher, exports are 2% higher, and imports 24% lower than in 1997. However, stockpiles of soda ash are 29% greater than 1997 (Kostick, 1998). Orders to the Far East have fallen off recently. This is a result of that

region's well-publicized financial woes and constricting economies. A transportation problem that developed in late 1997 has also contributed to the increase in stockpiles of soda ash. It is expected that 1998 production and prices will fall below 1997 levels because of these factors. However, changing economies and markets could reverse this trend.

## Uranium

Uranium is produced in Wyoming by solution mining methods at three localities. These are the Highland-Morton Ranch operation in the southern Powder River Basin, 100% owned by CAMECO; the Smith Ranch project also in the southern Powder River Basin, operated by Rio Algom; and the Christiansen Ranch operation, operated by COMIN (**Figure 17**).

The price for uranium rose slightly in the second quarter of 1998, from $10.75 per pound of yellowcake to $10.90 per pound of yellowcake, according to Bob Odell as reported in the June, 1998, *Rocky Mountain Scout* (**Figure 18**). In June, uranium officials noted at the Wyoming Mining Association's annual meeting at Jackson Lake Lodge that the worldwide demand for uranium for nuclear power plants was growing, and there was some optimism that uranium prices might rise in the next year or two.

By the end of June, however, U.S. Energy announced a halt in their work on the Jackpot underground uranium mine on Green Mountain, south of Jeffrey City. Forty-five mine employees were laid off. U.S. Energy was far less

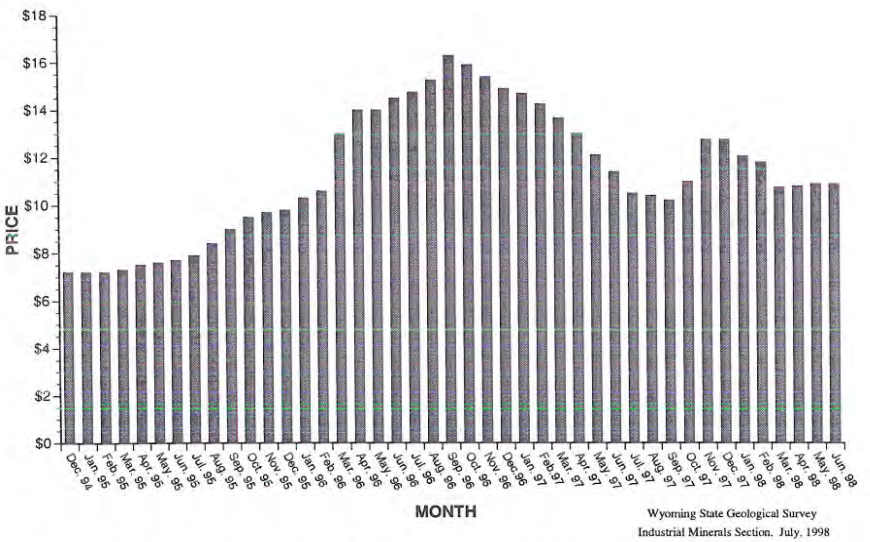


Figure 18. Domestic yellowcake prices, December, 1994, through June, 1998 (from *Rocky Mountain Scout*).

optimistic about future uranium prices, following privatization of the previously government-owned, U.S. Enrichment Corp.

International Uranium Corp. has applied for an in-situ mine permit at the Reno Creek site in southern Campbell County (**Figure 17**). Company officials hope to have permitting completed in early 1999, but that they will not decide whether to begin development and production until after that date. Their plans will depend on the price of uranium and its demand.

The Abandoned Mine Lands Division of the Wyoming Department of Environmental Quality (AML) is reclaiming two abandoned, former, uranium open pit mines in the Gas Hills, the Day-Loma and the smaller Two States pit. Three million cubic yards of aggregate will be used to fill the Day-Loma mine. The contractor bid $3.9 million for the work.

## Zeolites

Addwest Minerals International, Ltd., a Canadian company, has purchased U.S. Zeolite, which mined about 500 tons of zeolite from its property southeast of Bitter Creek in Sweetwater County during the summer of 1997. TVanF Associates were the former owners. U.S. Zeolite, under its new owners, plans to process and sell the remaining 1,000 tons of zeolite stockpiled at the mine site. Zeolites are a group of minerals used in industrial processes as ion exchangers, in water softeners, in the refining of petroleum, and in odor control. The mine contains a reserve of the zeolite mineral, clinoptilite.

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## METALS AND PRECIOUS STONES UPDATE

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During the past quarter, the Wyoming State Geological Survey (WSGS) continued receiving numerous inquiries into the State's diamond resources. Some interest was also reported for iron ore resources, and several claims were staked for platinum and palladium during the early part of the summer.

Much of the exploration for platinum and palladium is related to layered Proterozoic-age mafic complexes in the Medicine Bow and Sierra Madre mountains in southeastern Wyoming. Within a few of these complexes, some significant precious metal anomalies have been identified in past years.

Several gold prospectors were successful in finding nuggets in the South Pass region in western Wyoming. Dozens of gold nuggets have been recovered in this historic district in recent months (*Wyoming Geo-notes* No. 58, p. 46-47). One prospector reported finding 40 nuggets with a metal detector. Other nuggets found in the district this summer included gold nuggets weighing up to one ounce.

Diamonds continued to be of interest. The WSGS recently published Report of Investigations 53, which summarizes diamond exploration targets in Wyoming, as well as in the rest of the U.S. The report entitled, *Diamonds and mantle source rocks in the Wyoming craton with a discussion of other U.S. occurrences*, describes hundreds of kimberlite, lamproite, and related igneous occurrences in the U.S., and indicates that a few hundred thousand diamonds have been found. These have been microdiamonds to 40 carats in weight. The report emphasizes that the Colorado-Wyoming State Line district has been the most productive diamond district in the country, and has produced several of the largest diamonds found in the U.S.

Another diamond project that is currently in progress by the WSGS is a study of the Iron Mountain district, located 35 miles northwest of Cheyenne, Wyoming. Recent mapping by the WSGS identified a relatively large, continuous, dike-blow kimberlite complex that has been traced for 2.5 miles along strike in the eastern portion of the district (**Figure 19**). The complex contains a few 'blows' (enlargements) up to 1,000 feet across. Mapping in the western portion of the district has shown a second kimberlite dike-blow complex, that is approximately one mile in strike length. This complex has at least two blows that are approximately 1,000 feet across.

Samples of kimberlite recovered from these blows contain abundant mantle-derived material, including common eclogitic and peridotitic garnets, as well as other kimberlitic indicator minerals. The presence of these garnets is encouraging as they should provide the WSGS with important information on the diamond potential of the kimberlites. The recovered garnets include several deep purple, lilac-colored, and yellow-orange pyropes. Initial electron microprobe

analyses of some peridotitic pyropes have yielded both G10 (diamond stability) and G9 compositions. Later research will include analyses of eclogitic pyropes, chromites, pyroxenes, and ilmenites to aid in an appraisal of the diamond potential of the kimberlites.

The WSGS will also collect large bulk samples to test for diamonds, and will conduct EM and magnetic geophysical surveys over several suspected targets in the district. Suspected targets are based on the recovery of kimberlitic indicator minerals and vegetation anomalies where no known kimberlites exist. Additionally, a large alluvial field in the western portion of the district may mask some intrusives, as some kimberlite trends project under the alluvium. The WSGS also identified kimberlitic indicator mineral anomalies upstream from any known kimberlite, and identified a group of structurally-controlled circular topographic depressions immediately west of the district.

The Iron Mountain district is located 40 miles north-northeast of the Colorado-Wyoming State Line district, where more than 40 known diamondiferous kimberlites have been identified. The State Line district has produced more than 130,000 diamonds ranging from tiny diamonds to gemstones up to 28.3 carats in weight.

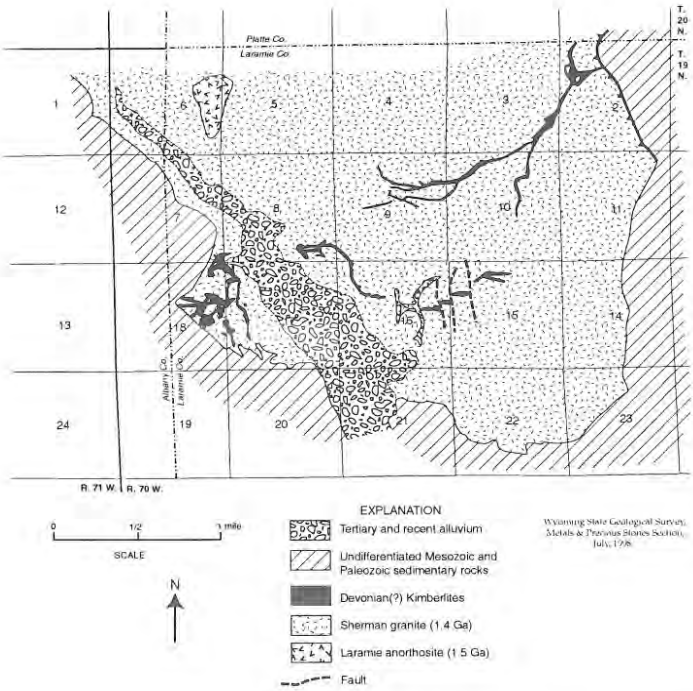


Figure 19. Preliminary geologic map of the Iron Mountain kimberlite district (prepared by W. Dan Hausel and Gordon Marlatt).

The WSGS began mapping the Granite Mountains in August. The Granite Mountains lie in the core of the Wyoming Province and consist of Archean granite and supracrustal rocks. The project will examine mineral deposits including gold, jade, ruby, sapphire, and other gemstones, and includes a cursory exploration program for diamond deposits.

# MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING

## PETROLEUM

Remaining Technically Recoverable Resources (January 1, 1998)

| | |
|---|---|
| Discovered (Includes oil, gas liquids, and condensate) | 3.47 billion barrels[1] |
| Undiscovered | 6.18 billion barrels[1] |
| Total | 9.65 billion barrels |

Remaining Reserve Base (January 1, 1998)

| | |
|---|---|
| Measured reserves (Proved reserves) (Includes: 0.563 billion barrels of oil and 0.537 billion barrels of gas liquids and condensate) | 1.10 billion barrels[2] |
| Indicated and inferred reserves (Reserve growth in conventional fields) | 2.54 billion barrels[1] |
| Total | 3.64 billion barrels |

## NATURAL GAS

Remaining Technically Recoverable Resources (January 1, 1998)

| | |
|---|---|
| Discovered (Includes 35.6 trillion cubic feet (TCF) of methane[1] and 121.5 TCF of $CO_2$[3]) | 157.1 trillion cubic feet |
| Undiscovered (Includes 14.72 TCF of conventional methane[1]; 5.43 TCF of coalbed methane; 119.3 TCF of methane in tight gas sands in the Green River Basin; and 31.2 TCF of $CO_2$[3]) | 170.6 trillion cubic feet |
| Total | 327.7 trillion cubic feet |

Remaining Reserve Base (January 1, 1998)

| | |
|---|---|
| Measured reserves (Proved reserves) (Includes 12.3 TCF of methane[2] and 59.8 TCF of $CO_2$[3]) | 72.1 trillion cubic feet |
| Indicated and inferred reserves (Reserve growth in conventional fields) | 24.1 trillion cubic feet |
| Total | 96.2 trillion cubic feet |

## COAL

Remaining Resources (January 1, 1998)

| | |
|---|---|
| Identified and Hypothetical (Discovered) | 1,426.6 billion tons[4] |
| Speculative (Undiscovered) | 31.5 billion tons[4] |
| Total | 1,458.1 billion tons |

Remaining Reserve Base (January 1, 1998)

| | |
|---|---|
| Demonstrated strippable (Measured and indicated reserve base) | 25.0 billion tons[5] |
| Demonstrated underground-minable (Measured and indicated reserve base) | 42.5 billion tons[5] |
| Total | 67.5 billion tons |

## TRONA

Original Resources

| | |
|---|---|
| Trona | 76.0 billion tons[6] |
| Mixed trona and halite | 51.0 billion tons[6] |
| Total | 127.0 billion tons |

## URANIUM

| | |
|---|---|
| Remaining Resource (December 31, 1989) | 1.99 billion pounds $U_3O_8$[7] |

Remaining Reserve Base (December 31, 1989)

| | |
|---|---|
| Uranium oxide recoverable at $30.00 per pound | 66 million pounds[7] |

## OIL SHALE

Original Resources (January 1, 1981)

| | |
|---|---|
| Identified (Discovered) | 320 billion barrels of shale oil[8] |

[1] Modified from U.S. Geological Survey National Oil and Gas Resource Team, 1995, 1995 National Assessment of United States oil and gas resources: U.S. Geological Survey Circular 1118, 20 p.
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# GEOLOGIC MAPPING, PALEONTOLOGY, AND STRATIGRAPHY UPDATE

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## WYOMING TOPOGRAPHIC MAPS ARE NOW AVAILABLE ON THE INTERNET

The Wyoming Office of Geographic Information Systems announced recently that scanned digital topographic data and digital raster graphics (DRGs) are now available for free download from the Wyoming GIS Data Clearinghouse. The Internet address is: http://wgiac.state.wy.us. These maps are scanned raster images of 24k, 100k, and 250k USGS topographic maps. The files are not edge matched and include scanned map white-over-edge data, with printed legend and other information. The USGS provides free Windows 95/NT DRG and DLG Map Viewer software that gives the user both NAD 27 UTM and latitude/longitude coordinates. This software allows the user to print portions of the topographic map. The DLG32 viewer is located at: http://mcmcweb.er.usgs.gov/viewers/dlg_view.html.

In regard to digital orthophotoquads (DOQs) and digital elevation models (DEMs) for Wyoming, the Wyoming GIS Data Clearinghouse or linked sites have partial coverage.

As a related note, the University of Wyoming's Institute for Energy Research (IER) recently completed an upgrade of their Wyoming Geologic Database (WGDB) web site. Working with geologic map indices for Wyoming generated by the Wyoming State Geological Survey, the site allows a user to select an area and determine what data exists in the WGDB for that area. Currently, the WGDB returns a bibliographic listing of geologic maps in a user specified area of interest. If desired, the user can print the retrieved data using their browser print command. The address of the WWW site is: http://wgdb.sdvc.uwyo.edu.

The geologic map data is a GIS coverage created from nineteen index maps, which were provided by the Wyoming State Geological Survey in the fall of 1996. Each index map corresponds to a particular type or source of geologic map. On each map, regions are outlined corresponding to indexed maps. The regions on each index map were digitized with attributes (citations). The results were entered into the database. Additional data types, including geologic maps, mineral occurrences, land cover, distributions of vertebrate species, basemaps showing depths to groundwater, USGS streamflow data, satellite images, and general reference maps (cities, counties, digital elevation models, land ownership, roads, streams, township and range grid, etc.), are now available in the database.

## LANCE CREEK FOSSIL AREA

In late 1993, the U.S. Bureau of Land Management (BLM) recommended designating more than 560 square miles in Niobrara County as an Area of Critical Environmental Concern (ACEC) with the intention of protecting the paleontologic values in the area. This area, located north of the town of Lance Creek (**Figure 20**), was designated as the Lance Creek National Landmark by the National Park Service in 1966. Paul McGrew of the University of Wyoming first nominated the area for landmark status based on the site's history of producing more than 30,000 fossil vertebrates from at least 75 species, a total that has increased significantly since then. Numerous horned dinosaurs and Late Cretaceous mammals, as well as the first *Tyrannosaurus* found in North America, came from the Lance Creek area. Fossils have been collected from the Upper Cretaceous Lance Formation in this area since 1888 when paleontologists from Yale University first collected in the area.

In an effort to protect undiscovered fossil resources, the area's present designation as a National Natural Landmark, includes stipulations on activities that disturb the surface. Designating the area as an ACEC apparently would not create additional protection for fossils, but would have required an inven-

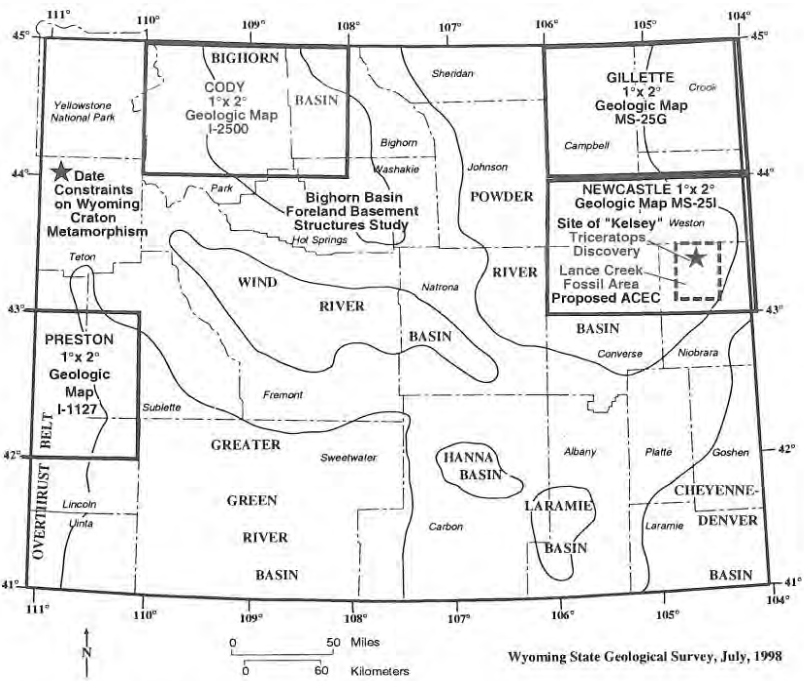


Figure 20. Index to recent paleontologic activities, geologic mapping, and geologic reports in Wyoming.

tory of the paleontologic resources. When the BLM announced the proposed designation in 1993, Governor Sullivan and others expressed concern regarding the size of the proposed ACEC and the potentially high cost for the management and inventory of the area, as well as the restrictions that would be put on multiple use in the area. Private land owners, controlling nearly 80% of the lands included in the proposed ACEC, also opposed the designation citing anticipated problems with managing their holdings.

In April of 1998, in a revised environmental impact statement for the Newcastle Resource Management Plan, the BLM reversed their 1993 recommendation. Under the new scenario, the fossil resources would still be protected as prescribed by the Landmark status with less restrictions on multiple use and no requirement for an expensive resource inventory. However, this recommendation had not been adopted at the time this article was written.

## NEW *TRICERATOPS* FIND IN EASTERN WYOMING

Workers from the Black Hills Institute of South Dakota exhumed a 25-foot-long *Triceratops*, which was found in the Upper Cretaceous Lance Formation on a ranch 40 miles north of Lusk, Wyoming (**Figure 20**). Workers estimated that they recovered approximately 50% of the skeleton of the *Triceratops*, which is significant because fewer than 10 specimens have been preserved with more than just the skull. The Zerbst family, owners of the ranch, found the specimen last October and named it "Kelsey". They contacted the Black Hills Institute, a commercial fossil-collecting group, to evaluate the find and recover it.

In addition to the *Triceratops*, workers found several associated teeth from the carnivores that consumed it. These teeth should provide more information about the carnivores that fed on the *Triceratops* and possibly provide new evidence relating to the controversy revolving around *Nanotyrannus* and *Tyrannosaurus*, i.e., whether the *Nanotyrannus* is a juvenile *Tyrannosaurus* or a separate genus.

## NEW PUBLICATIONS ON WYOMING GEOLOGY

Mitra and Mount (1998) completed an important new report characterizing foreland basement-involved structures using case studies from the Bighorn Basin of Wyoming (**Figure 20**), the Uinta Basin in Utah and Colorado, and the Central Basin platform in west Texas. The first part of the paper presents the structural theory and models, and the remainder of the paper presents case studies as examples.

Zartman and Reed (1998) recently published a report on new date constraints relative to Late Archean metamorphism in the western part of the Wyoming craton (**Figure 20**). Using U-Pb zircon geochronology, they dated the Webb Canyon Gneiss at about 2,680 million years old, representing what was probably the peak of regional metamorphism. They also dated the Mount Owen Quartz Monzonite at approximately 2,547 million years ago.

The U.S. Geological Survey (USGS) recently released a new, color, geologic map covering portions of Park, Big Horn, Washakie, and Hot Springs Counties, including the northern portion of the Bighorn Basin and part of the surrounding uplifts (**Figure 20**). The new map of the Cody Quadrangle (1:250,000-scale) covers approximately 7,200 square miles and was compiled by W.G. Pierce, primarily from his mapping efforts, which spanned an illustrious 43-year career with the USGS. Pierce is noted for his interpretation of the Heart Mountain detachment fault, which is depicted on this map, as well as his interpretation of the complicated structural geology that characterizes this portion of northwestern Wyoming.

The USGS published this map after Pierce's death in 1994, and it is part of a series of 1:250,000-scale maps, which were popular in the 70s and early 80s. For Wyoming, four, color, geologic maps have been published at this scale by either the USGS or the Wyoming State Geological Survey. These are the Cody, Newcastle, Gillette, and Preston Quadrangles (**Figure 20**). In addition, the USGS has published six, preliminary, black-line maps as Open File Maps at this same scale. These six are the Arminto, Casper, Lander, Sheridan, Thermopolis, and Torrington Quadrangles.

This new map is titled: *Geologic map of the Cody 1 degree X 2 degree Quadrangle, northwestern Wyoming*, and is designated USGS Miscellaneous Investigations Map I-2500. The new Cody map, as well as the other color and black-line, 1:250,000-scale maps, is available from the Wyoming State Geological Survey's Publications Section or the U.S. Geological Survey's Publications Branch.

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# PART II: STUDY OF THE SENSITIVITY OF AQUIFERS TO CONTAMINATION

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This is the second part of a three-part discussion on Wyoming's study of the sensitivity of aquifers to contamination. Part I addressed the project background and an overview of Wyoming's aquifer sensitivity analysis (Case, 1998). Part II addresses the factors or maps used to conduct the analysis as well as a portion of the contributions of the Wyoming State Geological Survey. Part III will conclude this series with discussions of the Geohydrologic Setting Sensitivity Analysis and the Vadose Zone Analysis.

## AQUIFER SENSITIVITY FACTORS

Six aquifer sensitivity factors or maps were used in this study. Those factors are depth to ground water, net aquifer recharge, geohydrologic setting sensitivity, soil, land surface slope, and vadose zone sensitivity. Each of the six aquifer sensitivity factors has an influence on the potential for a contaminant to reach ground water. As stated in Part I, all elements, media, or ranges of values for each factor were assigned a sensitivity rating, with the ratings ranging from 1 to 10. A generalized summary of each of the factors is presented below:

### Depth to Ground Water Factor/Map

Depth to ground water is important primarily because it determines the thickness of material through which a contaminant must travel before reaching the aquifer. The depth to ground water factor/map was created by the Wyoming Water Resources Center and Dr. Peter Huntoon at the University of Wyoming, using data supplied by the Wyoming State Engineer's Office.

### Net Recharge Factor/Map

Net recharge represents the amount of water, per unit area of land, which penetrates the ground surface and reaches the water table. This recharge water can transport a contaminant vertically to the water table and, ultimately, serve to transport a contaminant in an aquifer. In most cases, the greater the recharge, the greater the potential for ground-water pollution. Net recharge was estimated by multiplying a "percent of infiltration" factor, based on soils and vegetation, by the average annual precipitation. The net recharge factor/map was created by the Department of Renewable Resources at the University of Wyoming.

## Geohydrologic Setting Sensitivity Factor/Map

The geohydrologic setting sensitivity factor represents the capability of a geologic formation to transmit water and to attenuate the transmission of a contaminant. The geohydrologic setting sensitivity factor/map was created by the Geologic Hazards Section of the Wyoming State Geological Survey and Dr. Peter Huntoon at the University of Wyoming, and used the 1:500,000-scale, *Geologic map of Wyoming* (Love and Christiansen, 1985) as a map base. Part III of this series will provide an expanded discussion on the geohydrologic setting sensitivity analysis.

## Soils Factor/Map

Soil has a significant impact on the amount of water that can infiltrate into the ground. The presence of fine-grained materials in most soils can also affect contaminant migration. Where soil is fairly thick, the attenuation processes of filtration, biodegradation, sorption, and volatilization may significantly affect the migration of contaminants (Aller and others, 1987). A new soils map for the State of Wyoming (Munn and Arneson, 1998) was generated for this study by the Department of Renewable Resources at the University of Wyoming. The new map was based upon the *Geologic map of Wyoming* (Love and Christiansen, 1985), surface elevations, and a new surficial geology map of Wyoming generated by the Geologic Hazards Section of the Wyoming State Geological Survey.

## Land Surface Slope Factor/Map

Land surface slope has an influence on whether a contaminant will either run off or will remain on the surface in one area long enough to infiltrate. The Wyoming Water Resources Center generated the land surface slope factor/map by resampling the 3-arc-second Digital Elevation Models from a 90-meter resolution to 100 meters, and then applying a slope calculation routine.

## Impact of the Vadose Zone Media Factor/Map

The vadose zone is the unsaturated zone above the water table and below the soil. The type of vadose zone media determines the attenuation characteristics of the material. The media also controls the path length and routing of a contaminant. The vadose zone analysis was generated by the Geologic Hazards Section of the Wyoming State Geological Survey. The map bases for the analysis were the *Geologic map of Wyoming* (Love and Christiansen, 1985) and the surficial geology map of Wyoming generated for the study by the Geologic Hazards Section of the Wyoming State Geological Survey (Case and others, 1998). Part III of this series will provide an expanded discussion on the vadose zone analysis.

## CONTRIBUTIONS OF THE WYOMING STATE GEOLOGICAL SURVEY

The Geologic Hazards Section at the Wyoming State Geological Survey was an active participant in the project from its inception. Section personnel generated a surficial geology map of Wyoming (Case and others, 1998), and conducted the geohydrologic setting sensitivity analysis and the vadose zone analysis.

### Surficial Geology Map

In late 1993, the Geologic Hazards Section of the Wyoming State Geological Survey began compiling and mapping the surficial geology of the State for the aquifer sensitivity to contamination project. Using aerial photography, existing mapping, and limited field checking, maps of the State were prepared at a scale of 1:100,000. The compilation and mapping were completed in early 1995. These 1:100,000-scale maps were used to create a somewhat simplified 1:500,000-scale statewide map, which was digitized by the Wyoming Water Resources Center. The 1:500,000-scale map has approximately 650 map units. For the aquifer sensitivity to contamination project, the 650 map units were combined into 25 units. The 25-element classification is presented below:

### 25-Element Classification

Ai Old alluvial plain with scattered eolian, residuum, and slopewash deposits

ai Alluvium with scattered terrace, slopewash, eolian, residuum, grus, and glacial deposits

aR Thin alluvium mixed with scattered bedrock outcrops

bi Bench including eolian, slopewash, outwash, and bench and/or mesa deposits

bdi Dissected bench with scattered residuum, slopewash, landslide, and eolian deposits

tdi Dissected terrace deposits mixed with alluvium, residuum, eolian, and slopewash deposits

ti Terrace deposits mixed with scattered alluvium, residuum, eolian, slopewash, and outwash deposits

tre Thin terrace deposits mixed with scattered eolian and residuum deposits

fi Alluvial fan and gradational fan deposits mixed with scattered slopewash, residuum, and eolian deposits

fdi Dissected alluvial fan and gradational fan deposits mixed with scattered deposits of slopewash and residuum

mi Mesa including scattered residuum and eolian deposits

ei Eolian deposits mixed with scattered deposits of residuum, alluvium, and slopewash

oai Glacial outwash and alluvium mixed with scattered bedrock outcrops and deposits of glacial, terrace, hot spring, residuum, slopewash, and grus

gi Glacial deposits mixed with scattered bedrock outcrops and/or slopewash, residuum, grus, alluvium, colluvium, and landslide deposits

li Landslide mixed with scattered slopewash and residuum deposits, Tertiary landslides, and bedrock outcrops; landslides too small and numerous to show separately

pea Playa deposits mixed with scattered alluvium, eolian, and residuum deposits; playa deposits too small to show separately

sci Slopewash and colluvium mixed with scattered bedrock outcrops and/or slopewash, residuum, grus, glacial, periglacial, alluvium, and eolian deposits

ri Residuum mixed with bedrock outcrops and/or alluvium, eolian, slopewash, and grus deposits

ui Grus mixed with bedrock outcrops and/or alluvium, eolian, and slopewash deposits

Ri Bedrock and glaciated bedrock, including hot spring deposits, mixed with scattered thin eolian, grus, slopewash, colluvium, residuum, glacial, and alluvium deposits

Mi Mined areas mixed with scattered bedrock outcrops and/or deposits of residuum and slopewash

Ki Karst areas mixed with scattered bedrock outcrops and/or deposits of residuum, slopewash, and alluvium

ki Clinker mixed with scattered bedrock outcrops and deposits of residuum, slopewash, and alluvium

xi Truncated bedrock mixed with scattered thin eolian, terrace, residuum, alluvium, old alluvial plain, bench, and slopewash deposits

Ti Structural terrace including and/or mixed with alluvium, eolian, residuum, slopewash, and terrace deposits

The 25-unit map was used as one of the bases in the generation of a new State soils map by the Department of Renewable Resources at the University of Wyoming. The soils map was used as the basis for the soil factor analysis described above. The 25-unit surficial geology map was also used in conjunction with the *Geologic map of Wyoming* (Love and Christiansen, 1985) to provide a basis for the vadose zone analysis.

The 25-unit and 650-unit surficial geology maps are both available on a CD-ROM (Case, Arneson, and Hallberg, 1998) through the Wyoming State Geological Survey. The CD-ROM is available as Geologic Hazards Section Digital Map 98-1 (HSDM 98-1) [see p. 63].

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# ROCK HOUND'S CORNER

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## PART I: QUARTZ (CHALCEDONY) IN WYOMING

This is Part I of a two-part discussion of quartz and chalcedony in Wyoming. The second part of this series will be published in the next issue of *Wyoming Geo-notes*.

Quartz, a common rock-forming mineral, comes in many shapes, forms, and colors. Many prospectors search for quartz veins as a possible host for gold, and rock hounds search for quartz for beautiful mineral specimens for bookends, paperweights, jewelry, etc.

Quartz is generally divided into two groups: (1) crystalline quartz, and (2) cryptocrystalline quartz. Crystalline quartz includes clear, transparent to translucent rock quartz, milky quartz, rose quartz, smoky quartz, citrine (reddish-brown) quartz, blue quartz, and violet to purple amethyst. Such minerals are found either as massive specimens with no noticeable crystal habit, or as well-formed, prismatic, hexagonal (six-sided) crystals terminated by a single pyra-

mid. Less often, specimens of doubly terminated quartz are found, such as the famous Herkimer 'diamonds' in New York. Quartz has a hardness of 7 and specific gravity ranging from 2.57 to 2.65.

Cryptocrystalline quartz consists of microcrystalline to granular quartz known as chalcedony. Varieties of chalcedony are numerous and include chrysoprase (*apple-green*), agate (*banded gray, often occurring as cavity fillings*), onyx (*banded with alternating layers of light and dark chalcedony*), moss agate (*translucent chalcedony enclosing moss-like manganese or iron oxide dendrites*), jasper (*dark red or reddish-brown opaque*), sard (*yellow, yellowish-brown or reddish-brown translucent*), carnelian (*translucent red to orange-red*), bloodstone (*green with red spots*), flint (*dark gray to black opaque*), silicified wood (*wood replaced by chalcedony*), chert (*dull, opaque white, or gray chalcedony*), botryoidal agate and jasper (*exhibiting an external form similar to a bunch of grapes*), dendritic agate (*moss agate with a distinct dendritic pattern*), flame agate (*red to orange plume jasper*), iris agate (*agate with a spectral display of colors due to microscopic diffraction grating caused by alternating bands of higher and lower refractive indices*), zebra flint (*a flint or agate banded in shades of brown or gray*), and others. Although good specimens of prismatic quartz are uncommon in Wyoming, the State has yielded many attractive specimens of chalcedony, and Wyoming has become a favorite collecting ground for collectors of agate, jasper, flint, and petrified wood.

**Figure 21** is a generalized map of the State that shows the quartz-bearing areas discussed below.

Chalcedony found near the town of Guernsey in the Hartville uplift of eastern Wyoming includes multicolored, cryptocrystalline jasper and agate in fractures, faults, seams, and nodules in the Guernsey Limestone (Mississippian) and Hartville Formation (Pennsylvanian-Permian) or as float derived from these formations. The agates and jaspers include red, purple, brown, and yellow jasper, as well as black moss agate; white stalactitic agate; agatized breccia; golden brecciated jasper; red, pink, and white scenic (irregularly banded) agate; polka-dot agate; and butterscotch agate (Sutherland, 1990).

These agates and jaspers have attracted rock hounds and mineral collectors for years, and many varieties have received local names. For example, an agate known as Youngite, is a distinct rehealed limestone breccia consisting of pink- to cream-colored Guernsey Limestone breccia clasts, that are rehealed and cemented by light-gray to grayish-blue, banded, drusy quartz and chalcedony. The drusy quartz fills fractures in the breccia and completely encases the brecciated limestone clasts. When polished, the contrasting colors of the quartz and breccia clasts produce very attractive lapidary stones. Under long wavelength fluorescent light, samples yield a blue network of fluorescence that follows the bands of drusy quartz.

Another popular agate found in the Hartville uplift is the Slater agate. Slater agates form concretionary masses with white coatings. When cut, the interior of the stones are typically dark gray to black agate which surrounds a milky,

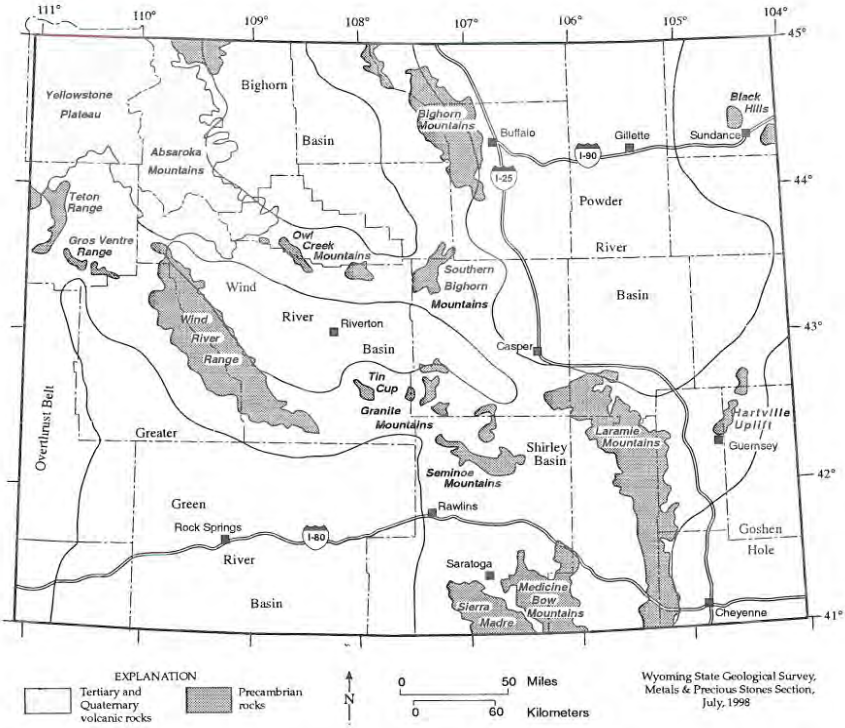


Figure 21. Generalized location map for quartz and chalcedony occurrences in Wyoming.

agatized, interior with small, fine, agatized dendrites. The surface of many of these agates is porous giving an impression of a fossilized sponge.

A mine was developed in this region in the early 1900s, just to mine agates. The mine, known as the Adams-Hartville agate mine, produced more than 12 tons of agate. The agate was clear to white with black dendritic moss-like inclusions.

Some petrified wood, quartz, and chalcedony are found nearby in southeastern Wyoming. Southeastern Wyoming includes the Laramie, Sierra Madre and Seminoe mountains, Shirley and Laramie Basins, Goshen Hole, and Saratoga valley. Most common forms of chalcedony in this part of Wyoming are agates and jaspers derived from the erosion of Paleozoic limestones, particularly the Casper Formation (Pennsylvanian-Permian), whereas some petrified woods were probably replaced by silica derived from Tertiary age volcanic ash falls. The chalcedony is extremely varied in appearance, and includes several colors of jasper, jasp-agate, white moss agate, black agate or flint, and carnelian agate (Sutherland, 1990).

In the Saratoga valley, agatized and opalized woods and dendritic agates are found on the flats north of Saratoga. The host rock appears to be tuffaceous sandstone, siltstone, and claystone of the North Park Formation (Miocene) (Sutherland, 1990).

Some beautiful specimens of jasperized iron formation are found in the Seminoe Mountains north of Sinclair, and northwest of Saratoga. These are magnetic and have alternating bands of black magnetite, dark gray quartz, and tawny to brown layers of jasper and grunerite. The source of this material is a banded iron formation in the vicinity of Bradley Peak, and much of the jasperized material is found downstream as cobbles and pebbles along Deeweese Creek and in alluvium along the north flank of the range as far east as the Miracle Mile in the vicinity of the North Platte River.

The Shirley Basin to the east of the Seminoe Mountains forms a Tertiary basin flanked by the Laramie Mountains along its east and northern margins. This basin is the source of several varieties of agates and jaspers, most of which have been derived from Casper Formation limestones and sandstones. One agate found in the basin is a reddish-brown jasper mixed with dark gray to black opaque agatized breccia in the Mine Hills and Crystal Hill area south of Marshall. This rock consists of pink breccia clasts of Casper Formation sandstone cemented with reddish-brown and massive black chert coated with tiny grains of psilomelane (metallic, manganese oxide).

To the south of the basin, the Shirley uplift contains silicified dinosaur bones on both sides of Como Bluff north of U.S. Highway 287/30 near Medicine Bow (Sinkankas, 1959). The Cheyenne Mineral and Gem Society (1965) reported that agatized wood fragments were also found in this area.

Near Battle Lake in the Sierra Madre mountains southwest of Saratoga, quartz crystals are reported in cavities and fractures in red granite. The quartz occurs as terminations on the granite and includes amethyst, rose, smoky, milky white, and clear quartz crystals. Most are small and less than two inches in length (Platt, 1947).

In the Absaroka Mountains in northwestern Wyoming, scattered petrified wood and agates are found in the Absaroka Volcanic Supergroup. Along the western margin of the Absaroka Mountains, Yellowstone Park is famous for its fossil forests at Specimen Ridge and Amethyst Mountain. Some prostrate fossilized trunks have been found in this region that are more than 50 feet long, and 5 feet in diameter (Sinkankas, 1959). Amethyst is also reported in the Yellowstone area at Amethyst Mountain, but it should be kept in mind that no collecting is allowed within the National Park.

Petrified wood in the form of silicified logs, trunks, and stumps have been found in this region, and includes upright pieces that resemble burned-out forests. Wood casts, fossil cone casts, agatized seeds, and oval nodules are also found. These materials are clear to gray to brown, yellow, green, and red with patterns that include fortifications, banding, spots, moss, tea leaf, and iris ag-

ate. Some oval nodules in this region may be remnants of chalcedony-filled vesicles in lava or scoria beds (Keenan, 1964). In addition, Wiggins Fork agates and petrified wood, and the Montana agates, are found along the Yellowstone River as far east as Glendive, Montana (Sutherland, 1990).

In the Bighorn Basin and Owl Creek Mountains east of the Absaroka Mountains, chert, agate, and jasper occur in Paleozoic limestones along the eastern flank of the basin, the southern margin of the Bighorn and Pryor Mountains, and the north side of the Owl Creek Mountains. Woodcast agates, possibly related to Tertiary volcanic debris from the Absaroka and Yellowstone regions, are reported along the Bighorn River and in several drainages on the western margin of the basin. Johnson (1973) also reported that green agate and crystal-lined geodes were found along Cottonwood Creek near Hamilton Dome.

A colorful red and white banded fortification-type agate, known as the Dryhead agate, weathers out of the Phosphoria Formation in the northern Bighorn Basin. Some bands in this material will fluoresce green under short wavelength ultraviolet light (Breitweiser, 1966). This agate is named for the barren Dryhead country headlands, which form the cliffs along the Bighorn River just north of the Wyoming-Montana state line (Sutherland, 1990).

In the Wind River Basin to the south of the Owl Creek Mountains, attractive rainbow agates are reported along the Wind River near Riverton.

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# NEW PUBLICATIONS OF THE WYOMING STATE GEOLOGICAL SURVEY

Geologic map of the Gillette 1° x 1/2° Quadrangle, Campbell, Crook, and Weston Counties, Wyoming (scale 1:100,000), compiled by C.S. Boyd and A.J. VerPloeg, 1998: Map Series 49 - $7.00 folded, $8.50 mailed rolled in a map tube.

*Diamonds and mantle source rocks in the Wyoming craton with a discussion of other U.S. occurrences, by W.D. Hausel, 1998: Report of Investigations 53 - $10.00.

Proceedings of the First International Soda Ash Conference, Volume I, edited by J.R. Dyni and R.W. Jones, 1998: Public Information Circular 39 - $10.00. ISBN 1-884589-12-x.

*Preliminary 1:500,000-scale digital surficial geology map of Wyoming, by J.C. Case, C.S. Arneson, and L.L. Hallberg, 1998: Geologic Hazards Section Digital Map HSDM 98-1 - $10.00, available only on CD-ROM, for use on PC-based computers using Windows 95/98 or Windows NT.

*Preliminary geologic map of the Guernsey Reservoir Quadrangle, Platte County, Wyoming, by R.E. Harris, 1998: Preliminary Geologic Map PGM 98-3 - $4.00.

Each geologic section of the Survey now 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]:

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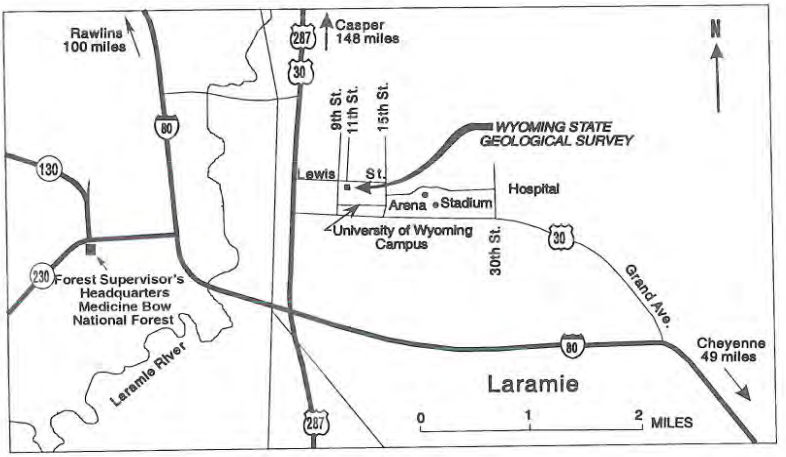


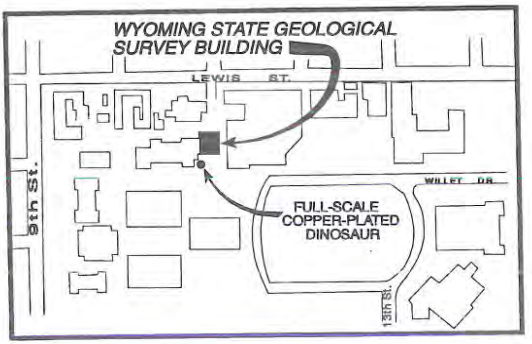

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