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Gary B. Glass, State Geologist

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WYOMING GEO-NOTES
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MINERALS UPDATE

OVERVIEW

by Gary B. Glass
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Based on final or best-available figures, production of oil, natural gas, and coal in Wyoming were all slightly higher than the estimates published in the last issue of *Wyoming Geo-notes*. Oil production was 700,000 barrels above our January estimate; natural gas was 27 billion cubic feet higher; and coal was 7.9 million tons greater (**Table 1** and **Figures 1, 2,** and **3**). In terms of percent error, the differences between actual and estimated production were 0.8%, 2.6%, and 3.9%, respectively. The strong showing of natural gas follows the expectations of many. And the increase in coal, though probably related to several factors, may reflect in part the long awaited effect of the Federal Clean Air Act Amendments.

Table 1. Wyoming mineral production (1981-1993) with forecasts to 1997[1].

Calendar Year	Oil[2]	Natural Gas[3]	Carbon Dioxide[4]	Helium[5]	Coal[6]	Trona[6]	Mined Uranium[7]	In-situ Uranium[8]	Sulfur[9]
1981	122.1	455.4	—	—	102.8	11.2	4.6	—	0.05
1982	118.7	465.1	—	—	107.9	10.9	2.1	—	0.07
1983	120.9	539.8	—	—	112.2	11.6	3.0	—	0.57
1984	127.8	600.1	—	—	130.7	11.7	1.6	—	0.71
1985	131.0	597.9	—	—	140.4	11.8	0.6	—	0.80
1986	122.4	563.2	23.8	0.15	136.3	13.0	0.2	0.04	0.76
1987	115.9	628.2	114.2	0.86	146.5	13.6	0.2	0.06	1.19
1988	114.3	700.8	110.0	0.83	163.6	14.9	0.3	1.16	1.06
1989	109.1	739.0	126.1	0.94	171.1	16.2	0.1	1.07	1.17
1990	104.0	777.2	119.9	0.90	184.0	16.2	0.2	1.1	1.04
1991	99.8	820.0	140.3	1.05	193.9	16.2	0.4	1.1	1.18
1992	96.8	871.5	139.2	1.05	189.5	16.4	0.1	1.2	1.20
1993	87.7	910.1	140.8	1.06	209.9	*16.2	—	*0.8	*1.20
*1994	80.9	941.0	140.0	1.00	211.0	16.8	—	0.8	1.25
*1995	75.2	984.0	140.0	1.00	220.4	16.9	—	0.8	1.25
*1996	70.0	1,029.0	140.0	1.00	230.2	17.0	—	0.8	1.25
*1997	65.1	1,076.0	140.0	1.00	240.5	17.1	—	0.8	1.25

*Forecast production by Consensus Revenue Estimating Group (CREG).
[1]Adapted from CREG, Wyoming State Government Revenue Forecast FY94-FY98, January, 1994; [2]Millions of barrels (Source: Petroleum Information, 1993; Wyoming Oil & Gas Conservation Commission, 1981-1992); [3]Billions of cubic feet (primarily methane with some hydrogen sulfide and nitrogen) (Source: Petroleum Information, 1993; Wyoming Oil & Gas Conservation Commission, 1981-1992); [4] Billions of cubic feet. Source: Wyoming Oil & Gas Conservation Commission, 1986-1992; [5]Billions of cubic feet, 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 (Sources: Wyoming Department of Revenue, 1981-1987; Wyoming State Inspector of Mines, 1988-1993); [7]Millions of short tons of uranium ore (not yellowcake) (Source: Wyoming Department of Revenue, 1981-1992); [8]Millions of pounds of yellowcake (U_3O_8) (Sources: Wyoming Department of Revenue, 1986-1992; unknown between 1981-1985 because it was only reported as taxable valuation; estimates for 1993-1997 are based on company information); [9]Millions of short tons (Source: Wyoming Oil & Gas Conservation Commission, 1981-1992).

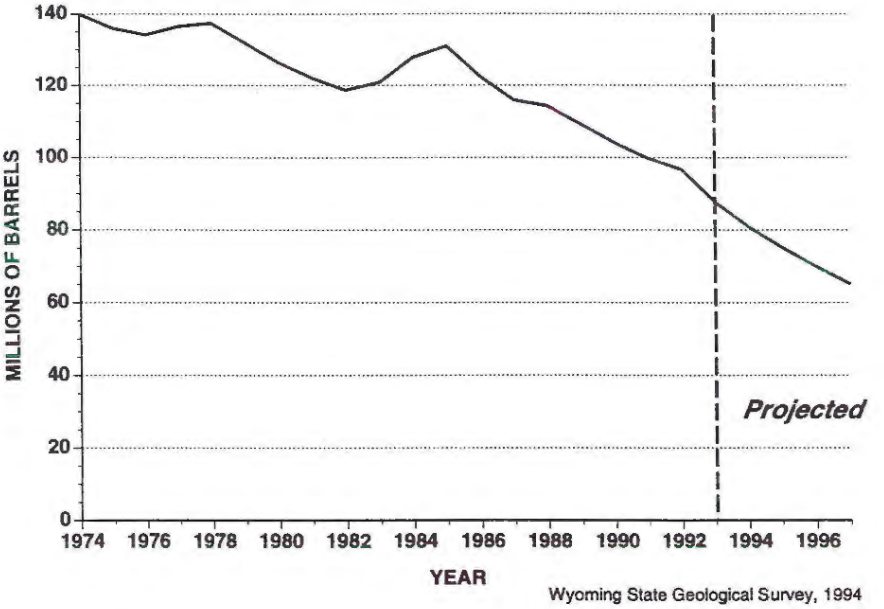

Figure 1. Annual oil production from Wyoming (1974 to 1993) with forecast to 1997.

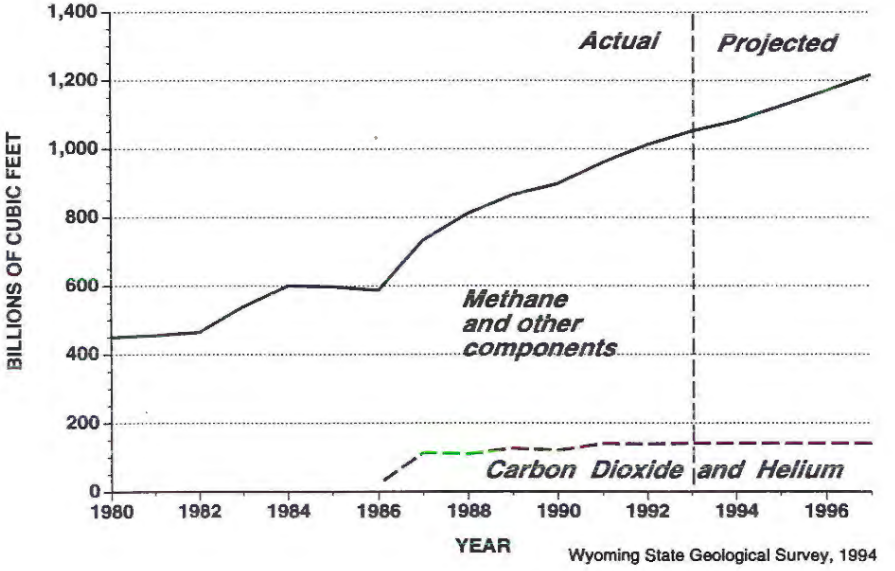

Figure 2. Annual natural gas production from Wyoming (1980 to 1993) with forecasts to 1997.

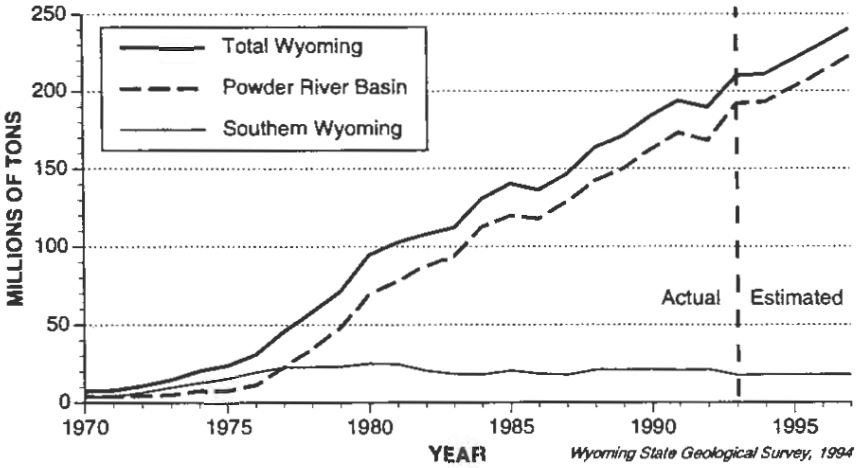

Figure 3. Annual coal production from Wyoming (1970-1993) with forecasts to 1997. *Data from the Wyoming Inspector of Mines (1970-1993) and the Wyoming Consensus Revenue Estimating Group (1994-1997).*

In support of this latter view, there are many rumors that coal producers in the Powder River Basin have already sold most of their 1994 production capacities. While there are some idled and proposed mines that can meet greater demands for Powder River Basin coal, this production cannot be brought on line without lead time in which to acquire additional equipment and manpower. While it remains to be seen if all demand can be met this year, it is apparent that monthly deliveries of Wyoming coal to power plants set new records in October and December of 1993 and again in January of 1994 (**see Coal Update**). Monthly deliveries were more than 19.3 million tons in January, which is the most recent data available. If deliveries stay this high, our coal production estimate for 1994 will likely be revised upward by next quarter.

In regard to energy prices, oil remained low in the first quarter, natural gas showed its seasonal dip and then started back up, and spot coal may have firmed or increased slightly. Based on posted oil prices, the average first purchase price for Wyoming crude was an estimated $11.00 in the first quarter. By mid-April, the price was beginning its seasonal increase and was averaging closer to $12.50 a barrel. For comparison, Sweet Crude Futures for May increased by about $2.00 a barrel in mid-April. **Table 2** and **Figures 4 and 5**; however, show that average Wyoming prices have not recovered from a decline which started in 1991.

Natural gas prices, which we track by watching the spot sale prices at Opal (**Figure 6**), have shown their traditional first-quarter decline, but overall they are holding strong compared to pre-1992 prices. Our forecast, which shows a gradual increase in price, seems on track (**Table 2** and **Figure 7**).

Table 2. Average prices paid for Wyoming oil, methane, coal, trona, and uranium (1985-1992) with forecasts to 1997[1].

Calendar Year	Oil[2]	Methane[3]	Coal[4]	Trona[5]	Uranium[6]
1985	24.67	3.03	11.36	35.18	36.82
1986	12.94	2.33	10.85	34.80	52.45
1987	16.42	1.78	9.80	36.56	43.55
1988	13.43	1.43	9.16	36.88	25.77
1989	16.71	1.58	8.63	40.76	22.09
1990	21.08	1.59	8.43	41.86	21.16
1991	17.33	1.46	8.09	44.18	21.00
1992	16.38	1.49	8.14	44.50	21.00
*1993	14.50	1.90	7.44	41.00	21.00
*1994	12.00	2.00	7.19	41.00	21.00
*1995	12.00	2.11	6.97	41.00	21.00
*1996	12.00	2.23	6.83	41.00	21.00
*1997	12.00	2.34	6.68	41.00	21.00

* Forecast prices by Consensus Revenue Estimating Group (CREG).
[1] Adapted from CREG, Wyoming State Government Revenue Forecast FY94-FY98, January, 1994.
[2] First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Source: Energy Information Administration, 1985-1992.
[3] Wellhead price in dollars per thousand cubic feet (MCF). Sources: Wyoming State Land and Farm Loan Office, 1989-1992 (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, 1985-1992.
[5] Dollars per ton of trona, not soda ash. Source: Wyoming Department of Revenue, 1985-1992.
[6] Uranium prices in dollars per pound of yellowcake (weighted average price for in-situ and(or) surface-mined uranium). Source: Energy Information Administration, 1985-1990; Wyoming State Geological Survey estimates 1991-1997.

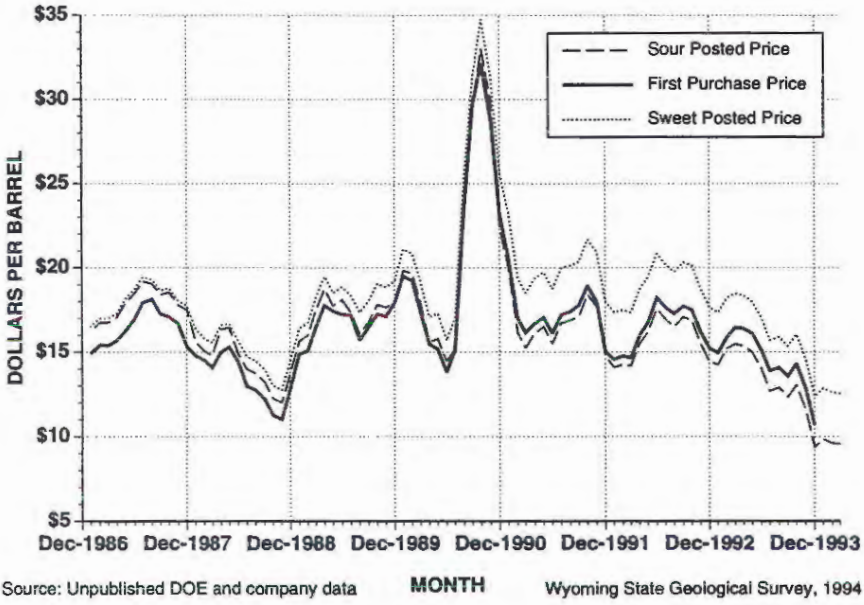

Figure 4. Wyoming posted Sweet and Sour crude prices and first purchase prices averaged by month (1987 to present).

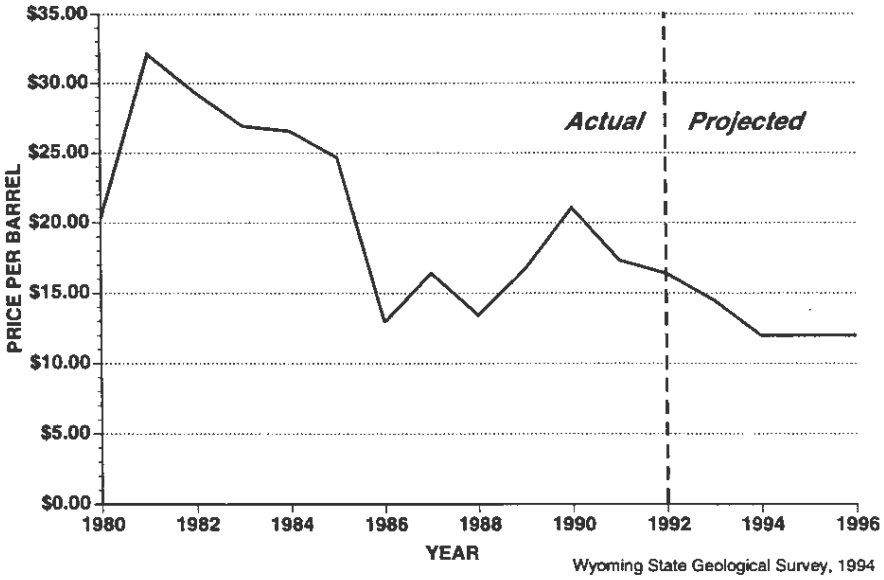

Figure 5. Average prices paid for Wyoming oil (1980 to 1992) with forecasts to 1997.

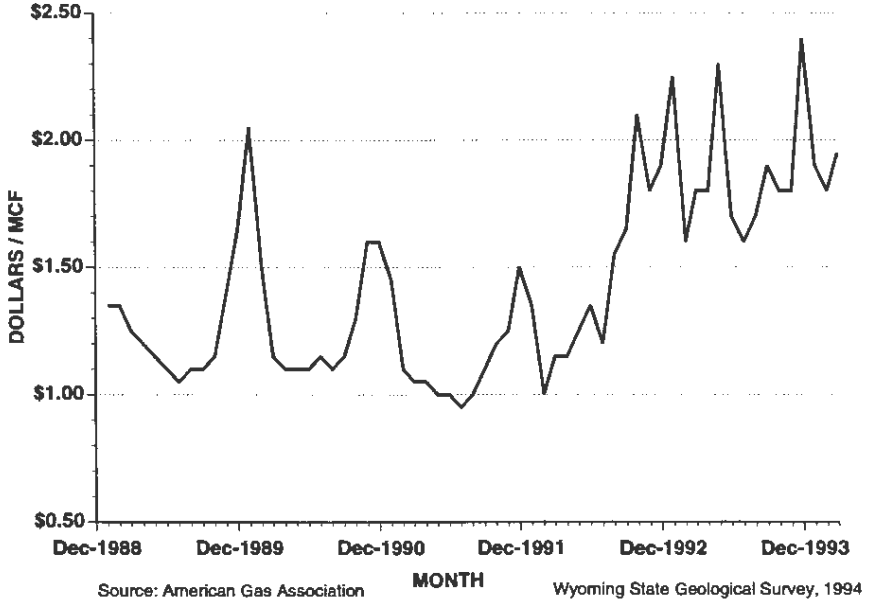

Figure 6. Spot prices for methane at Opal, Wyoming, averaged by month (1989 to present).

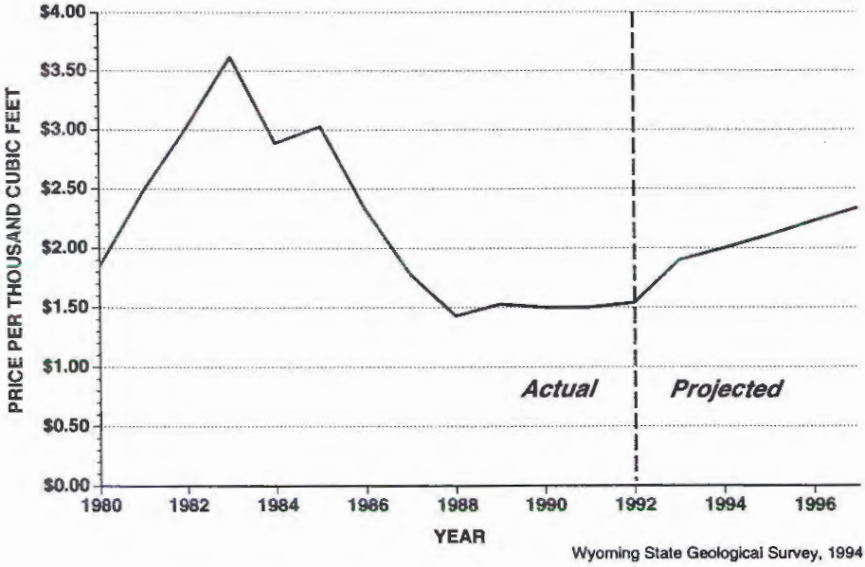

Figure 7. Average prices paid for Wyoming methane (1980 to 1992) with forecasts to 1997.

Coal prices are harder to track as there is no monthly reporting. While the average price paid for Wyoming coal will decrease in 1994, this decrease is the result of increasing percentages of low-cost coal offsetting older, higher priced, contract coal. **Tables 2** and **3**, and **Figure 8** show coal price trends and our forecast. In addition, **Table 5** in the **Coal Update** shows the gradual yearly increase in coal that is sold at low-cost. The tightening supply of coal from the Powder River Basin does offer hope that spot sale prices from that area might remain closer to $4.00-$4.50 than they have in recent years.

Oil and gas lease sales improved in the first quarter and additional in-fill drilling for natural gas in southwestern Wyoming is underway. In April, Louisiana Land & Exploration began construction of their gas-processing plant near Lysite in central Wyoming. Since August of 1993, Black Hills Power and Light has been building their new coal-fired power plant near Gillette. These and other activities are described in more detail in the **Oil and Gas** and **Coal Updates**.

The **Industrial Minerals Update** in this issue discusses plans for expanding cement production from Wyoming and documents an increase in the number of decorative dimensional stone and aggregate quarries operating or planned in the State. In addition, there is a historical summary of gypsum production in Wyoming. The **Metals and Precious Stones Update** features information on diamond, copper, lead, zinc, and molybdenum, including historical copper

Table 3. Breakdown of average prices paid for coal from northeastern Wyoming, southern Wyoming, and Wyoming as a whole (1988-1992) with forecasts to 1997.

YEAR	NORTHEASTERN	SOUTHERN	STATEWIDE
1988	**$7.35**	**$21.45**	**$9.16**
1989	**$7.02**	**$19.97**	**$8.63**
1990	**$6.92**	**$19.90**	**$8.43**
1991	**$6.68**	**$19.80**	**$8.09**
1992	**$6.54**	**$19.19**	**$8.14**
1993	**$6.18**	**$18.86**	**$7.44**
1994	**$5.98**	**$18.75**	**$7.19**
1995	**$5.80**	**$18.72**	**$6.97**
1996	**$5.70**	**$18.69**	**$6.83**
1997	**$5.60**	**$18.67**	**$6.68**

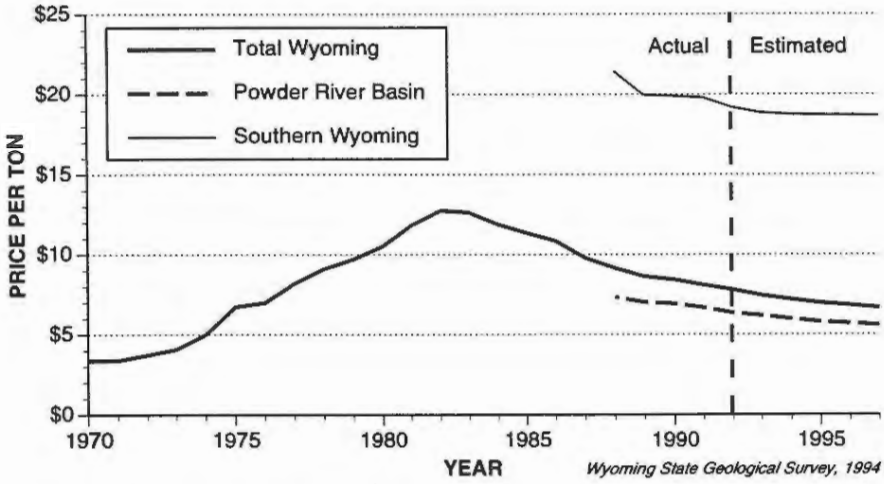

Figure 8. Average prices paid for Wyoming coal (1980 to 1992) with forecasts to 1997. *Data from the U.S. Energy Information Administration (1980-1992) and the Wyoming Consensus Revenue Estimating Group (1993-1997).*

production. In regard to the uranium industry, there is some cautious optimism that it could improve. The **Uranium Update** also notes that Wyoming now leads the nation in uranium production. Following the **Minerals Update** is a staff article summarizing 1993 exploration activities for metals and precious stones, industrial minerals, coal, and uranium.

OIL AND GAS UPDATE

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

The rig count in Wyoming dropped sharply in the first quarter of 1994, which follows the trend set in recent years (**Figure 9**). The count should improve during the next several months as companies begin large infill-drilling projects in southwestern Wyoming. Three of the largest projects are the Creston/Blue Gap Development Project (up to 250 wells), the Greater Wamsutter Area Natural Gas Project (70-320 wells), and the Expanded Moxa Arch Natural Gas Development Project (up to 300 wells).

There were 636 well completions in Wyoming in 1993, compared to 434 in 1992 (Petroleum Information, 1994). The 345 gas well completions in 1993 compared to 157 gas well completions in 1992. The total completions in 1993 are the highest in the last four years and gas completions now are more than half of the total completions (**Figure 10**).

The spot price for natural gas at Opal, Wyoming, averaged $1.88 per thousand cubic feet during the first quarter of 1994, which was the same as the average price for the first quarter of 1993. The spot price showed less volatility during the first quarter this year than last year (**Figure 6**).

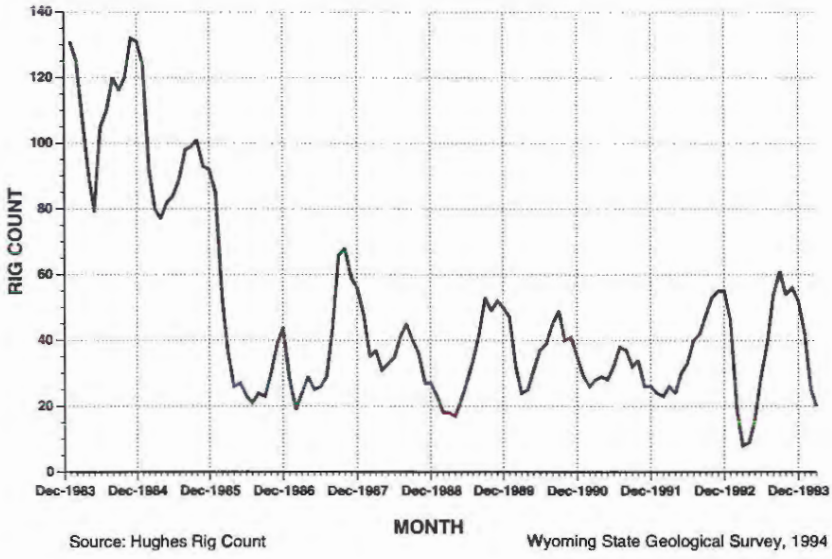

Figure 9. Wyoming daily rig count averaged by month (1984 to present).

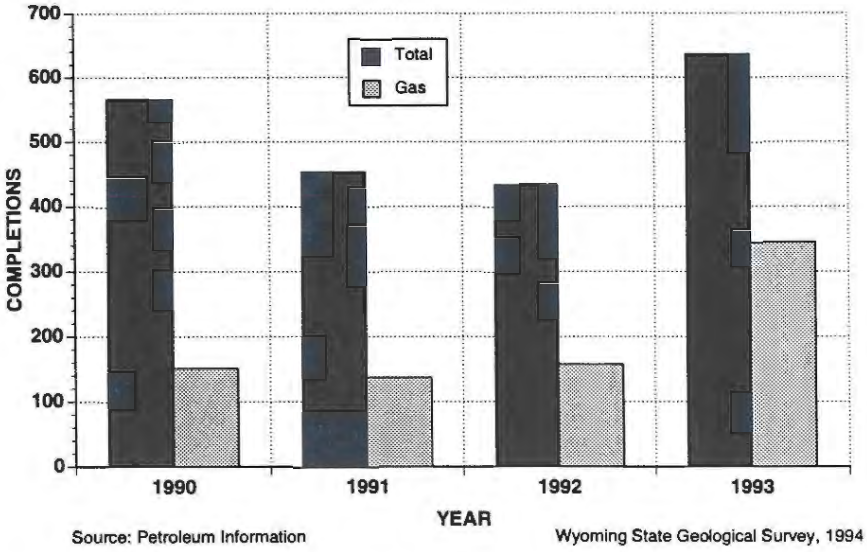

Figure 10. Yearly gas well and total well completions in Wyoming (1990 to 1993).

The longer oil prices remain low, the more stripper or marginal oil production will be abandoned early. Wyoming currently has 3,126 stripper wells, which produce over six million barrels of oil per year. A report by the Interstate Oil and Gas Compact Commission (1994) states that if all of Wyoming's stripper wells were abandoned, lost earnings would be over $17 million and 757 jobs would be lost. The oil and gas industry would lose 339 of those jobs and $10 million of the earnings. Although the study did not address taxes, Wyoming State and local governments would also lose significant revenue in severance and ad valorem taxes and in Federal and State royalties.

The two oil and gas lease sales held in Wyoming during the first quarter of 1994 showed considerable improvement from others in the last three years. The State sale was the best in terms of total revenue, acres leased, and average price per acre since the January, 1991 sale (**Table 4**). The U.S. Bureau of Land Management (BLM) sale had the best total revenue since the February, 1991 sale (**Table 4**). Acres leased in the BLM sale were more than in any sale since October, 1988.

The BLM's February sale had a high per-acre bid of $160. The bid was made by Lario Oil & Gas for a 394.04-acre lease that covers parts of sections 2, 3, and 4, T23N, R112W. The parcel is less than three miles north of Frontier production in Emigrant Springs Field and less than four miles southwest of Dakota production in Lincoln Road Field. Petral Exploration LLC bid $150 per acre for a lease that includes parts of sections 2, 4, 12, 28, and 32, T20N,

Table 4. Federal and State competitive oil and gas lease sales in Wyoming.

BLM SALES

Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
			1990				
TOTAL	$17,997,133	2,971	1,593	2,169,138	967,293	$18.61	$340.00
			1991				
TOTAL	$12,934,277	2,815	1,147	2,191,462	675,777	$19.14	$16,000.00
			1992				
February	$940,581	342	126	213,469	67,205	$14.00	$210.00
April	$331,199	355	109	229,407	58,951	$5.62	$112.00
June	$425,183	314	86	168,230	37,701	$11.28	$220.00
August	$1,395,060	335	109	196,600	54,530	$25.58	$230.00
October	$657,029	351	73	259,482	43,843	$14.99	$2,500.00
December	$1,029,888	425	161	366,880	102,248	$10.07	$260.00
TOTAL	$4,778,940	2,122	664	1,434,268	364,478	$13.11	$2,500.00
			1993				
February	$1,637,233	464	246	346,357	155,272	$10.54	$220.00
April	$2,116,184	478	259	351,465	177,989	$11.89	$220.00
June	$1,415,793	463	179	351,130	86,435	$16.38	$390.00
August	$1,877,405	462	262	374,274	208,495	$9.00	$400.00
October	$2,636,127	458	247	367,281	186,274	$14.15	$285.00
December	$3,259,266	444	276	275,435	180,879	$18.02	$320.00
TOTAL	$12,942,008	2,769	1,489	2,065,942	995,344	$13.00	$400.00
			1994				
February	$3,909,085	442	290	374,969	237,761	$16.44	$160.00

STATE SALES

Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
			1990				
TOTAL	$4,979,094	1,199	732	478,098	380,382	$13.09	$270.00
			1991				
TOTAL	$4,457,885	1,295	1,037	479,975	405,910	$10.98	$401.00
			1992				
January	$138,165	200	96	72,027	37,840	$3.65	$65.00
March	$200,000	200	114	70,294	41,034	$4.88	103.00
May	$208,166	200	93	60,687	28,605	$7.28	$230.00
November	$200,407	199	116	74,747	43,134	$4.65	$87.00
TOTAL	$745,738	799	419	277,755	150,613	$4.95	$230.00
			1993				
March	$601,400	200	137	74,940	54,723	$10.99	$400.00
May	$362,840	200	141	82,388	56,770	$6.39	$90.00
September	$505,587	200	141	80,428	56,845	$8.89	$225.00
November	$510,290	200	143	73,517	53,801	$9.48	$155.00
TOTAL	$1,980,017	800	562	311,273	222,139	$8.91	$400.00
			1994				
March	$917,380	200	169	84,571	73,061	$12.56	$170.00

Sources: Wyoming State Land and Farm Loan Office, Petroleum Information Corporation - Rocky Mountain Region Report, and U.S. Bureau of Land Management.

R113W. Portions of the lease offset Frontier production in Wilson Ranch and Whiskey Butte fields. R.K. O'Connell bid $150 per acre for a parcel that includes parts of sections 11, 12, and 13, T14N, R103W. The lease is adjacent to Frontier, Dakota, and Lakota production in Salt Wells Field.

Twenty-six parcels at this BLM sale drew bids of $50 or more. Ten Powder River Basin leases and 16 southwestern Wyoming leases received bids of $50 or higher. The oil leases in the Powder River Basin sold well; but, not as well as the gas leases in southwestern Wyoming. Although the majority of leases sold at the BLM sale were in southwestern Wyoming, there were also many sold in the Powder River Basin (**Figure 11**).

The State Land and Farm Loan Office's sale in March had a high per-acre bid of $170 for a 40-acre tract that covers SE SW section 31, T15N, R91W. The lease is less than a mile from Mesaverde production in Blue Gap Field. The second highest bid of $165 per acre was made for a tract that covers section 36, T18N, R94W. This tract is less than a mile from Almond production in Standard Draw Field. Both of these leases are in the Creston/Blue Gap Development Project proposed by Snyder Oil and other operators. The project may include the drilling of up to 250 new wells in and adjacent to Barrel Springs, Blue Gap, Fillmore, Creston, and Robbers Gulch fields. An Environmental Impact Statement on the project is due for completion in May, 1994.

In the case of this sale, a greater majority of leases that were sold were in southwestern Wyoming (**Figure 12**).

Louisiana Land & Exploration Co. (LL&E) began construction of a new gas processing plant in the Lysite/Lost Cabin area in the northern Wind River Basin. The plant, which will process 50 million cubic feet of gas per day, could be expanded to process twice that much gas. The $80 million project is scheduled for completion in December, 1994. There will be a construction workforce of about 300 this summer and 33 permanent employees upon completion. Production for the plant initially will be from two wells in the Madden Field: the 1-5 Bighorn well in NW NE section 5, T38N, R90W and the 2-3 Bighorn in NW SE section 3, T38N, R90W. Both wells were completed in the Madison Limestone below 23,500 feet and production from these wells will be the deepest in the Rocky Mountain region. The gas plant will remove hydrogen sulfide, which is 12% of the gas stream, and convert it into about 200 tons of sulfur per day. According to LL&E estimates, the Madison Limestone at Madden Field contains over 500 billion cubic feet of gas reserves.

Exploration and development

Company data and information compiled and published by Petroleum Information indicate the following significant exploration and development events occurred in Wyoming during the first quarter of 1994. Activities related to horizontal drilling are discussed in a separate section. The letters preceding discussions below refer to locations on **Figure 13**.

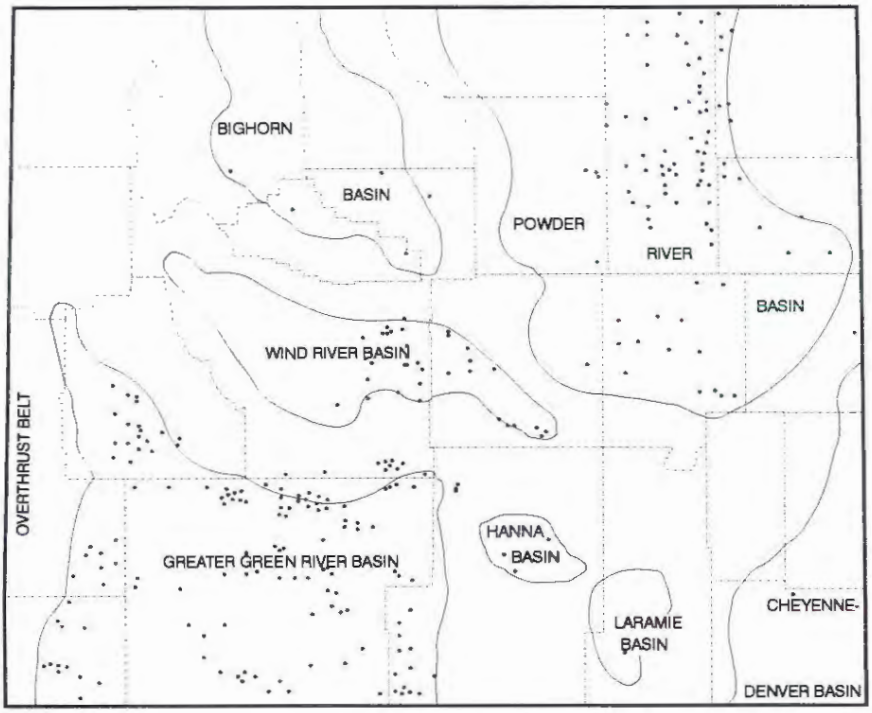

Figure 11. Locations of Federal oil and gas leases sold during the first quarter of 1994.

A. Chevron USA completed two development wells in Painter Reservoir Field. The 327A Painter Reservoir Unit well in SE NW section 7, T15N, R119W flowed 230 barrels of oil and 1.1 million cubic feet of gas per day from perforations in the Nugget Sandstone between 12,035 and 12,265 feet. The 43-6A Painter Reservoir Unit well in NW SE section 6, T15N, R119W flowed 164 barrels of oil and 421,000 cubic feet of gas per day from perforations between 12,411 and 12,540 feet in the Nugget Sandstone.

B. Chevron USA staked a location for a 10,100-foot wildcat well. The 1-8 Chevron USA-Federal will be drilled in NW NW section 8, T23N, R114W in the area of the Darby thrust fault. The well is about five miles northeast of Horse Trap Field, a shut-in Amsden gas and condensate producer. The objective horizon for the well was not disclosed.

C. Amoco Production, Union Pacific Resources, Wexpro/Celsius, Bannon, Marathon, Presidio Exploration, and several other companies have submitted plans to the U.S. Bureau of Land Management (BLM) for the drilling of approximately 300 new wells in the Moxa arch area beginning in 1994 and continuing into 1995. In addition to wellheads and production units,

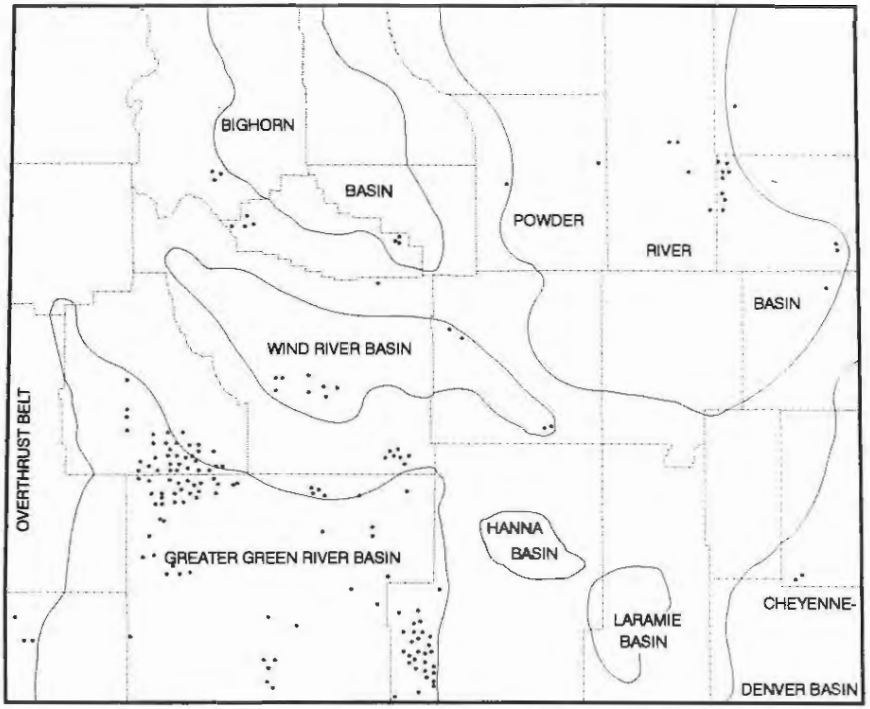

Figure 12. Locations of State oil and gas leases sold during the first quarter of 1994.

associated facilities will include access roads, pipeline gathering systems, and tank facilities for individual wells. The existing wells plus the planned development wells would result in about 1,000 producing wells within the expanded Moxa arch area.

D. Washington Energy Exploration completed its 23-35 Farson-Federal well in NE SW section 35, T24N, R111W. The well flowed 643,000 cubic feet of gas and 440 barrels of oil per day from perforations in the second Frontier between 10,430 and 10,470 feet. Washington Energy reported that this well is producing from a lower interval of second Frontier than other wells in Mesa Field. Presidio also completed a new producer in Mesa Field. The 30-25 Platinum-Federal well in NW SW section 25, T24N, R111W produced an average of 6.5 million cubic feet of gas and 17 barrels of condensate per day during its first month of production. The well is producing from an undisclosed interval in the Frontier.

E. Union Pacific Resources completed a new producer in Wilson Ranch Field. During its first month of production, the 3-18 Altrogge-Federal well in SW NW section 18, T19N, T112W flowed an average of 11.7 million cubic feet

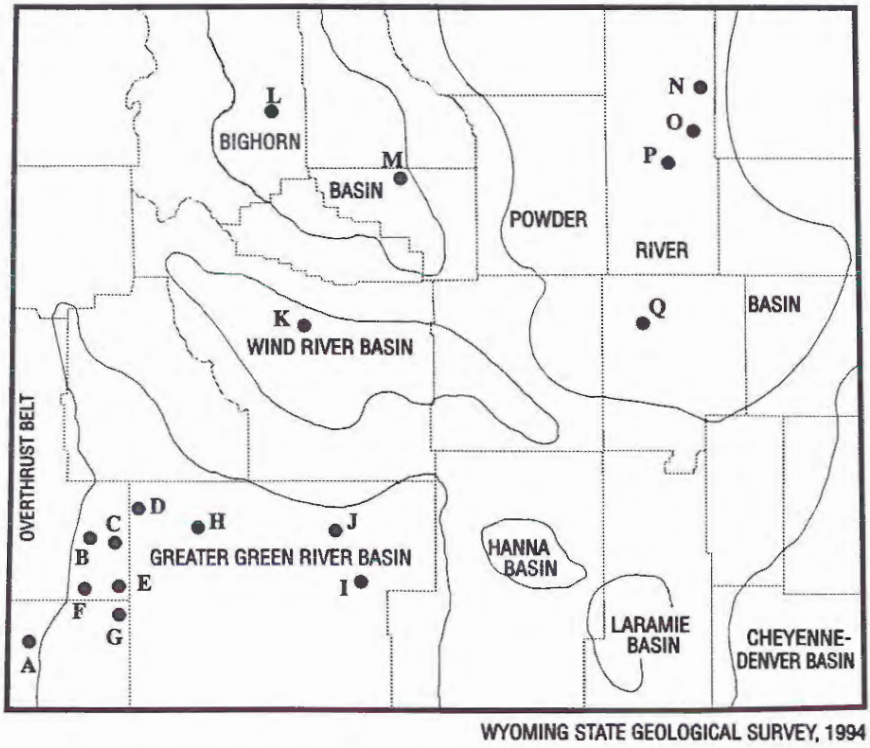

Figure 13. Oil and gas exploration and development activity in Wyoming during the first quarter of 1994 (exclusive of horizontal drilling and coalbed methane activities).

of gas, 80 barrels of condensate, and 14 barrels of water per day from an undisclosed interval in the Dakota.

F. Two different groups of companies have announced plans to open gas marketing centers at Opal, Wyoming. One group consists of Tenneco, Questar, and Entech and the other group consists of Kern River, Questar, Northwest Pipeline, Union Pacific, Colorado Interstate, and Altamont. The proposed centers would allow electronic trading of natural gas from anywhere in the world.

G. Wexpro completed its 32 Bruff Unit well in C SE section 21, T18N, R112W. The well flowed 6.0 million cubic feet of gas from perforations between 12,258 and 12,330 feet in the Dakota.

H. Texaco Exploration & Production completed its 3 Stage Coach Draw Unit well in SW NE section 28, T23N, R107W. The well flowed 1.0 million cubic feet of gas per day from an undisclosed interval in the Almond Formation. Texaco plans to drill up to 60 wells in T22-24N and R107-108W over the next five to seven years.

I. Presidio Exploration completed its 22-17 Strike Unit well in SE NW section 17, T22N, R95W. During the first month of production, the well produced an average of 715,000 cubic feet of gas, 112 barrels of condensate, and seven barrels of water per day from an undisclosed interval in the Lewis Shale.

J. Presidio Exploration completed its 13 Great Divide Unit well in SW SW section 18, T23N, R96W. The well flowed 3.7 million cubic feet of gas per day from perforations in the Lewis Shale between 9,355 and 9,384 feet.

K. Tom Brown Inc. completed a new gas well in Pavillion Field. The 11-10 well in NW NW section 10, T3N, R2E flowed 2.1 million cubic feet of gas per day from perforations between 5,719 and 5,744 feet in the Fort Union Formation.

L. Marathon Oil will deepen a Tensleep producer in Oregon Basin Field to test the Cambrian Flathead Sandstone. The 11 Cactus-A well in SE SW section 5, T51N, R100W will be drilled to 5,910 feet.

M. Enigma Field has a new Tensleep Sandstone producer. The 4R Cynthia well in NE NE section 10, T48N, R91W pumped 258 barrels of oil and 287 barrels of water per day from perforations between 4,610 and 4,810 feet.

N. Ampolex Inc. completed a new discovery in an undisclosed Minnelusa interval. The 22-26 Pickrel-Federal well in SE NW section 26, T54N, R69W is presently producing oil, although no details are available.

O. Samedan Oil completed a new Minnelusa producer in Kuehne Ranch Field. The 8 Kuehne Ranch Unit well in NE SE section 12, T51N, R70W produced an average of 82 barrels of oil and 105 barrels of water per day from an undisclosed interval.

P. Axem Resources' 17-35 Bone Pile Unit well in SE NW section 17, T48N, R72W produced an average of 670 barrels of oil and 43,000 cubic feet of gas per day during its first month of production from an undisclosed Minnelusa interval.

Q. Balcron Oil completed a new discovery in the Frontier Formation. The 23-22 Henry-Fee well in NE SW section 22, T37N, R74W flowed 43 barrels of oil per day from perforations between 12,764 and 12,830 feet.

Horizontal drilling

During the first quarter of 1994, the following significant activities related to horizontal drilling occurred. The letters preceding the discussions below refer to locations on **Figure 14**. The discussions are based on company data and on information compiled and published by Petroleum Information.

A. In the Cheyenne-Denver Basin, Union Pacific Resources completed their 1H Mark 41-15 well drilled from a surface location in C NE NE section 15, T15N, R63W to a true vertical depth of 7,464 feet. During its first month of

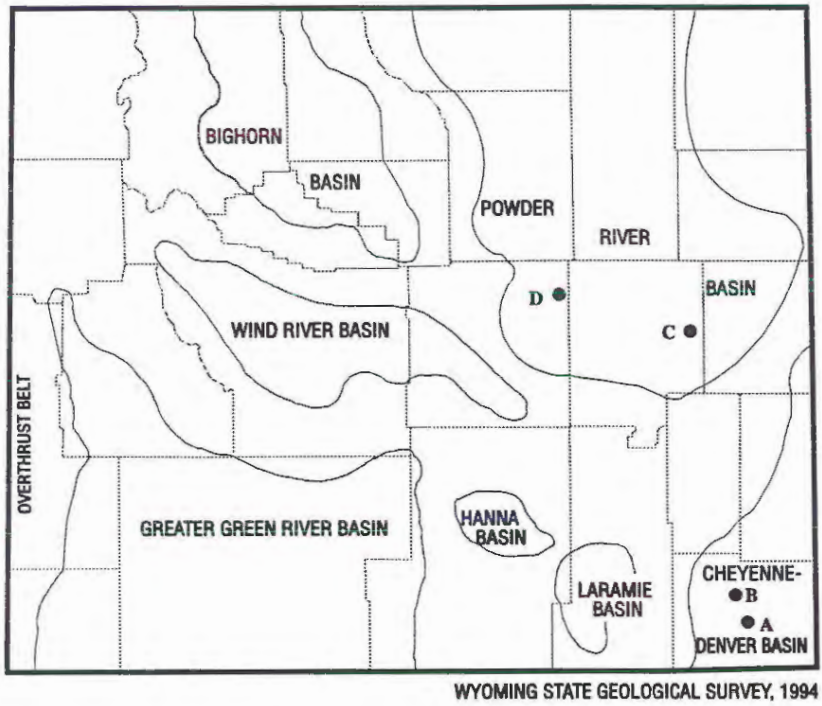

Figure 14. Horizontal drilling activity in Wyoming during the first quarter of 1994.

production, the well produced an average of 184 barrels of oil and 55 barrels of water per day. Union Pacific Resources also scheduled two more tests in the Dale Field area. The 1H Medicine Bow 14-10 well will be drilled from a surface location in SW SW section 10, T15N, R63W to a true vertical depth of 7,364 feet. The 1H Flintstone 41-20 will be drilled from a surface location in NE NE section 20, T15N, R63W to a true vertical depth of 7,660 feet.

B. Activity in the Niobrara Formation at Silo Field remains high. Union Pacific Resources completed its 1H Snowy Range 41-35 well drilled from a surface location in NE NE section 35, T16N, R64W. The well was drilled to a true vertical depth of approximately 7,729 feet. Production for the first month averaged 337 barrels of oil and 71 barrels of water per day. Union Pacific also completed their 1-H Barney 41-15 well drilled from a surface location in NE NE section 15, T15N, R64W to a true vertical depth estimated at about 7,800 feet. The well produced an average of 153 barrels of oil and nine barrels of water per day during its first month of production. Union Pacific Resources reached true vertical depth of approximately 8,000 feet at its 1H-X Goertz well drilled from a surface location in N/2 N/2 section 12, T15N, R65W. No other details are available. Union Pacific Resources will drill the IH Elk Mountain 41-36 well from a surface location in NE NE section 36,

T16N, R64W to a true vertical depth of 7,702 feet. Wilshire Oil Co. will drill its 1-14H McConnaughey well from a surface location in SW SW section 14, T16N, R65W to a true vertical depth of 8,083 feet. Production at Silo Field in 1993 was 1.54 million barrels of oil and 587.43 million cubic feet of gas. Production in 1992 was only 0.72 million barrels of oil and 289.43 million cubic feet of gas.

C. Meridian Oil Inc. has reached total depth at the 31-15H RE Manning well drilled from a surface location in SW SE section 31, T35N, R67W to a true vertical depth of 9,194 feet in the Turner Sandy Member of the Carlile Shale. This is the second lateral drilled in this well and both laterals encountered collapse problems. It is unknown what, if anything, the company will do at this well.

D. EP Operating plugged and abandoned its 1 H East Flank Unit well drilled from a surface location in SW SW section 30, T39N, R77W to a true vertical depth of 5,000 feet. The well tested an objective in the Smoky Gap Member of the Niobrara, but EP reported that fractures in the Smoky Gap were filled with calcite.

Helium

Wyoming ranked second in helium production in 1993 and currently supplies about one-third of domestic production. Production of salable helium from Wyoming was an estimated 1.06 billion cubic feet. All of this helium came from natural gas produced at Fogarty Creek and Lake Ridge fields and was processed at Exxon's Shute Creek plant in western Wyoming. The natural gas is from the Madison Limestone and contains approximately 0.5% helium, 66% carbon dioxide, 22% methane, seven% nitrogen, and 4.5% hydrogen sulfide.

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Petroleum Information, 1994, Rocky Mountain region report: Newsletter edition, v. 67, no. 5, p. 6.

Interstate Oil and Gas Compact Commission, 1994, Marginal oil: fuel for economic growth: Oklahoma City, Oklahoma, 20 p.

COAL UPDATE

by P. Daniel Vogler
Staff Geologist-Coal, Wyoming State Geological Survey

For 1994, the National Coal Association predicts a 4.4% increase in the production of western coal. They also indicate that most of the increase in western coal production will come from mines on Federal leases. Wyoming

producers mined a record tonnage in 1993, producing over 209.9 million tons (**Tables 5** and **6**). Production in 1992 was only 189.5 million tons. A relatively severe winter in the midwestern states, a union strike in eastern mines, and compliance switching are suggested reasons for such a dramatic increase in production last year. The largest coal delivery months were October (contract) and December (spot) with 10.5% and 10.1% increases over corresponding months in 1992, respectively (**Figure 15**). Delivered coal tonnage set an all time monthly record in January 1994 when it exceeded 19.3 million tons (**Figure 16**)! Campbell County had the largest annual production increase with a 9.7% increase over 1992 levels (**Table 5**). Although this quick increase in production reportedly caused some railway congestion, the congestion obviously did not prevent the record monthly deliveries since last September.

In 1993, there was a 2% decrease in coal-related employment statewide, the largest employment decrease since 1987 (**Figure 17**).

Burlington Northern railroad has committed $650 million for new locomotives over the next 3.5 years in order to increase rail capacity. And Union Pacific will have invested $250 million between 1992 and 1995 in order to increase its capacity.

The U.S. Bureau of Land Management (BLM) is seeking public comments on whether or not the 10-year diligence requirements for coal leases should be linked to the date when leases are combined into an approved Logical Mining Unit (LMU) or to the date when the leases are first issued. The BLM is also asking for comments on whether or not the 10-year diligence requirement should begin with the date of the youngest lease in an LMU.

Developments in western and southwestern Wyoming

Arch Minerals laid off 27 employees at its Medicine Bow mine in February. Officials at the mine cite the loss of a contract to a Kansas utility as causing the layoffs. This contract accounted for approximately one-third of the mine's annual production.

Ark Land Co., a division of Arch Minerals, has relinquished its Preference Right Lease Applications on the Bean Springs property near Rock Springs. The one-million-ton-per-year mine originally proposed for this area would have employed nearly 100 people.

Layoffs were avoided at Black Butte Co.'s mine near Rock Springs when 175 employees took early buy-out (retirement) offers. Officials with Black Butte Co. also cited the loss of a 3-million-ton-per-year contract as the main reason for downsizing its work force.

A mine fire, which had been smoldering for fifty years in an area outside of Rock Springs, ignited again after the mine's roof collapsed, providing more oxygen to the fire. Officials believe it could cost up to $100,000 in earth moving expenses to fill the hole and possibly solve the problem.

Table 5. Coal production (1984-1992) with forecasts to 1997 (millions of tons).

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994*	1995*	1996*	1997*
Campbell County	106.8	113.9	111.0	122.3	135.7	143.8	154.7	164.9	159.6	181.9	183.0	191.9	201.2	211.0
Converse County	3.3	3.6	4.8	5.1	5.7	6.1	7.9	8.2	8.5	10.2	10.3	10.8	11.3	11.8
Sheridan County	2.5	2.4	1.4	1.2	0.9	0.1	0.1	0.2	0.1	0.1	M	M	M	M
Carbon County	5.1	3.3	1.5	2.2	4.1	4.3	4.5	4.7	4.1	4.4	4.4	4.4	4.4	4.4
Sweetwater County	8.9	13.2	12.9	11.8	12.2	12.0	11.9	11.4	12.6	9.2	9.2	9.2	9.2	9.2
Lincoln County	4.1	4.3	4.0	3.8	4.9	4.8	4.7	4.4	4.6	4.1	4.1	4.1	4.1	4.1
Hot Springs County	M	M	M	M	M	M	0.1	0.1	M	M	M	M	M	M
Total Wyoming	130.7	140.7	135.6	146.4	163.5	171.1	183.9	193.9	189.5	209.9	211.0	220.4	230.2	240.5
Annual Change	14.2%	7.1%	-3.8%	7.4%	10.5%	4.4%	7.0%	5.2%	-2.3%	9.7%	0.6%	4.3%	4.3%	4.3%
Low-priced coal[1]		6%	7%	8%	10%	17%	24%	31%	37%	42%	47%	51%	57%	62%

* Forecast by Wyoming State Geological Survey, January 1994. [1]Estimated percentage of total production that is sold on the spot market, through short-term contracts [less than one year duration], or through renegotiated, longer-term contracts all at prices under $5.00. M means less than 0.1 million tons.

Table 6. Coal deliveries by month from Wyoming mines[1].

	1990 Monthly	1990 Cumulative	1991 Monthly	1991 Cumulative	1992 Monthly
JAN	15,059,530	15,059,530	14,960,450	14,960,450	16,407,150
FEB	13,328,290	28,387,820	15,480,110	30,440,560	14,604,480
MAR	14,535,270	42,923,090	16,278,870	46,719,430	14,429,650
APR	14,155,470	57,078,560	14,820,240	61,539,670	14,063,060
MAY	13,882,590	70,961,150	14,589,790	76,129,460	14,518,590
JUN	13,649,070	84,610,220	14,007,600	90,137,060	14,655,600
JUL	15,368,280	99,978,500	16,451,090	106,588,150	15,592,050
AUG	16,046,910	116,025,410	15,940,620	122,528,770	16,467,100
SEP	15,166,020	131,191,430	15,314,490	137,843,260	14,878,150
OCT	15,244,760	146,436,190	14,810,510	152,653,770	15,122,820
NOV	15,569,280	162,005,470	14,783,000	167,436,770	14,757,230
DEC	14,479,970	176,485,440	16,716,630	184,153,400	16,096,150
Total Tonnage Reported		**176,485,440**		**184,153,400**	
Total Tonnage Not Reported		**7,521,261**		**9,710,406**	
Total Tonnage Produced[2]		**184,006,701**		**193,863,806**	

[1] Source: COALDAT Marketing Reports by Resource Data International, Inc., compiled from FERC Form 423 filed monthly by electric utilities
[2] Source: State Mine Inspector's Annual Reports

Developments in the Powder River Basin

In the Montana portion of the Powder River Basin, the Spring Creek mine was recently awarded a contract with PacificCorp to ship 1.6 million tons of coal to its Centralia power plant in Olympia, Washington.

In a recent legal decision, Peter Kiewit and Sons Mining Co. received over $195 million from the Federal government. The award stems from a lawsuit filed jointly in 1977 by Kiewit and Sons and Whitney Benefits Corp. of Sheridan. The 1977 suit was filed because the Federal government declared land leased to Kiewit by Whitney Benefits was not minable due the Surface Mining Law of 1977. Kiewit will receive 67.5% of the award, while Whitney Benefits has declared that their share (32.5%) will go to local charities.

Construction of Black Hills Power Co.'s new $124 million, 80-megawatt power plant (Neil Simpson No. 2) began last August. The new plant is located near the Wyodak and Neil Simpson No. 1 plants, which are east of Gillette.

Cyprus/Amax Coal recently signed a spot contract for 1.2 million tons of coal from its Belle Ayr mine. It will deliver the coal to Georgia Power's jointly-owned Scherer plant in the first quarter of 1994. Two Wyoming coal producers signed

Table 6. *continued*

1992 Cumulative	1993 Monthly	1993 Cumulative	1994 Monthly	1994 Cumulative
16,407,150	15,931,150	15,931,150	19,326,770	19,326,770
31,011,630	14,646,090	30,577,240		
45,441,280	17,112,970	47,690,210		
59,504,340	16,259,770	63,949,980		
74,022,930	16,085,470	80,035,450		
88,678,530	16,473,920	96,509,370		
104,270,580	15,296,480	111,805,850		
120,737,680	16,682,090	128,487,940		
135,615,830	17,310,330	145,798,270		
150,738,650	18,300,070	164,098,340		
165,495,880	18,007,907	182,106,310		
181,592,030	19,034,530	201,140,840		
181,592,030		**201,140,840**		**19,326,770**
7,878,226		**8,784,986**		
189,470,256		**209,925,826**		

contracts for deliveries to the jointly-owned Scherer plant in October and November of 1993:

1) **Belle Ayr** (Oct.-Nov.): 46,910 short tons, 8,548 Btu, 0.29% Sulfur, 0.67 lbs of SO_2/million Btu, 4.59% Ash, $23.94 delivered, $20.41 cost of transportation, $3.53 FOB mine.

2) **Caballo Rojo, Inc.** (Oct.-Nov.): 23,400 short tons, 8,542 Btu, 0.33% Sulfur, 0.79 lbs of SO_2/million Btu, 4.91% Ash, $24.40 delivered, $21.00 cost of transportation, $3.40 FOB mine.

Alabama Power Co. has issued a solicitation for more than 2 million tons of contract coal from the Powder River Basin. The response to this solicitation may be an indication how near the mines are to their current production capacity.

Recently Cordero was awarded a contract by the Lower Colorado River Authority (LCRA). Cordero will ship 1.2 million tons in addition to its present 1.8-million-ton contract with LCRA.

In the Powder River Basin, there are four Lease By Application sales (LBAs) pending with the U.S. Bureau of Land Management: Eagle Butte

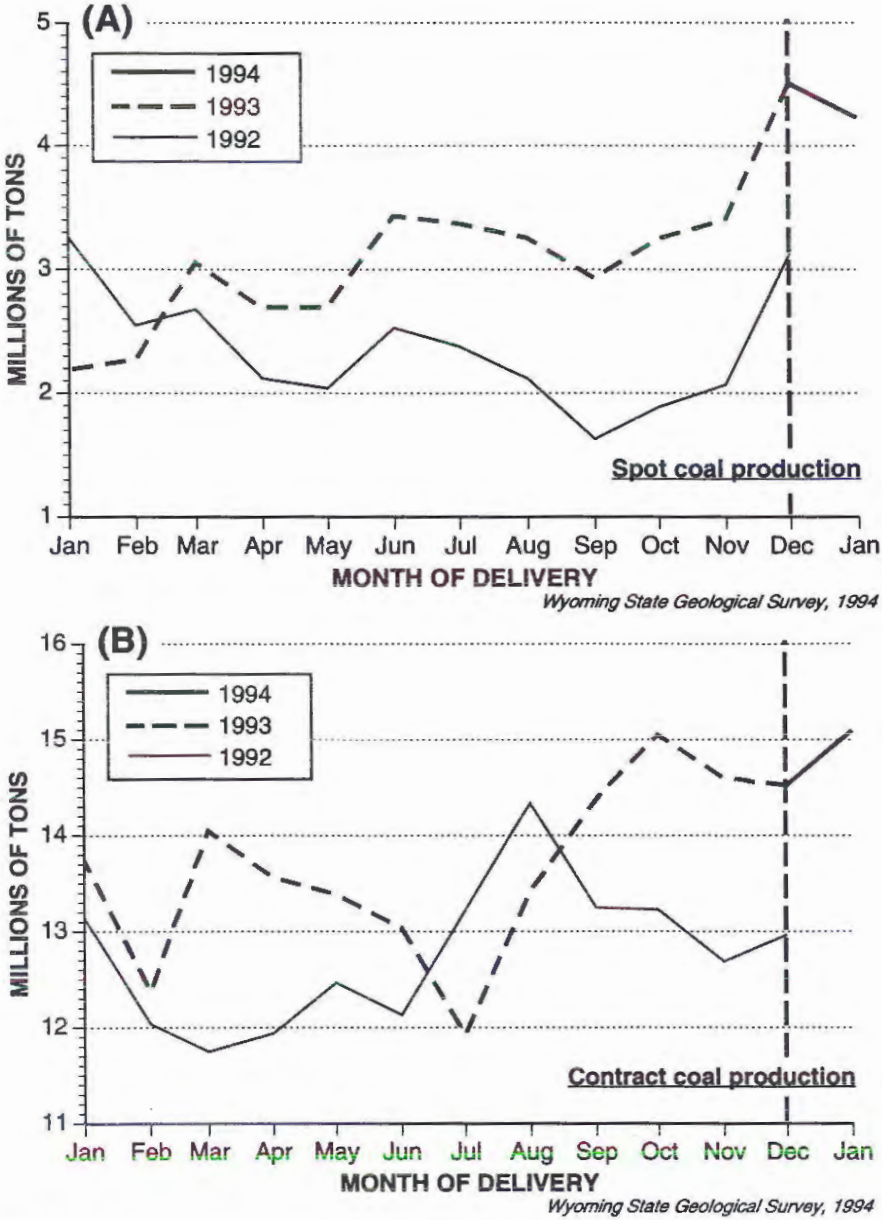

Figure 15. Monthly coal deliveries from Wyoming (1992 through January, 1994). (A) Coal sold on the spot market and (B) coal sold on contract. *(From COALDAT Marketing Report by Resource Data International, Inc., compiled from FERC Form 423 filed monthly by electric utilities).*

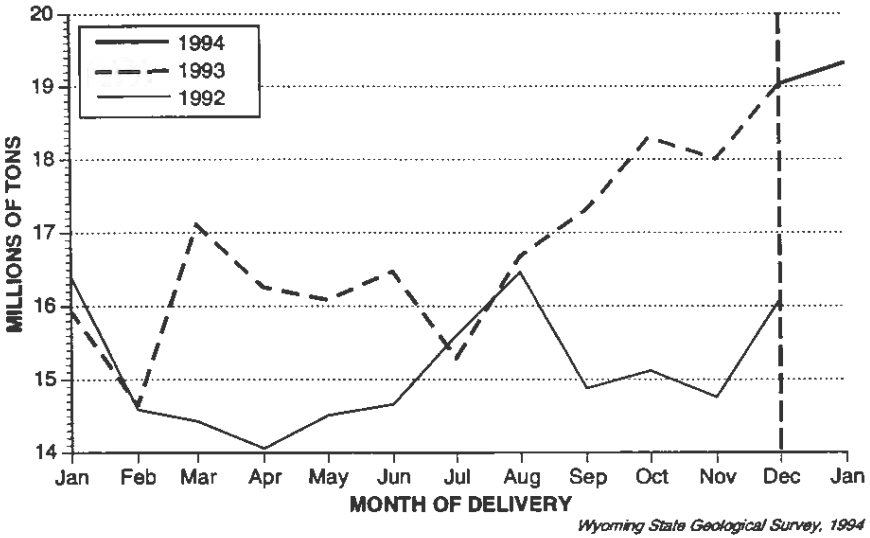

Figure 16. Reported deliveries from Wyoming coal mines (1992 through January, 1994). *(From COALDAT Marketing Report by Resource Data International, Inc., compiled from FERC Form 423 filed monthly by electric utilities).*

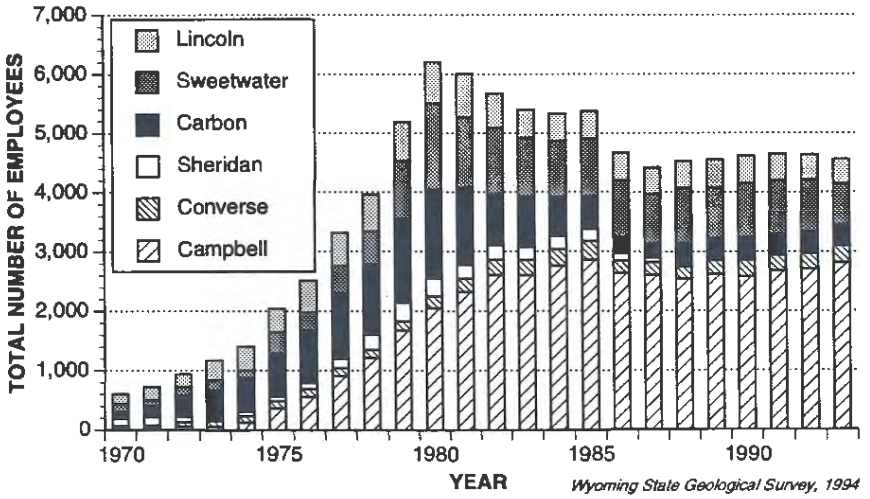

Figure 17. Employment trends in Wyoming coal mines, by county (1970 to 1993).

(Cyprus/Amax Coal - Eagle Butte mine), Antelope (Kennecott Energy - Antelope mine), North Roundup (Ziegler - North Rochelle mine), and Western Energy Company (Western Energy Co.- Rosebud mine). This latter LBA is in Montana.

Sources state that the Eagle Butte LBA would supply an additional 150-180 million tons of coal and add 10 years to the life of the Eagle Butte mine. Although the LBA falls within a "buffer" zone around Gillette, there has been no opposition, and city officials have been quoted as being "in favor" of the Eagle Butte LBA sale. A draft Environmental Assessment (EA) by the U.S. Bureau of Land Management (BLM) has been released for public comment.

The Antelope LBA is for a 462.2-acre tract adjacent to the Antelope mine. It contains 60 million tons of coal. A scoping meeting was held in Douglas on February, 2, 1994, and a draft EA is being prepared.

The BLM has stated that an Environmental Impact Statement (EIS) will be prepared for the North Roundup LBA. This LBA is a 1,430-acre tract containing approximately 150 million tons of coal.

The Western Energy LBA, a 2,061-acre tract containing approximately 39.3 million tons, has had a draft EIS released. This tract in Montana is adjacent to the Rosebud mine.

Contracts

New coal contracts, test burns, solicitations, and spot sales for the first quarter of 1994 are summarized in **Table 7.**

Coalbed methane

In February, Energx Ltd. began drilling a 300-foot hole on an Arco tract 11 miles southeast of Wright in the Powder River Basin. The company is evaluating the coalbed methane potential of the Fort Union Formation. Metfuels, Inc. continues to develop its project in the Hanna Coal Field..

INDUSTRIAL MINERALS UPDATE

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

Aggregate (Construction)

In February, Rissler and McMurry Company withdrew their application for a permit to expand their limestone quarry on Bessemer Mountain west of

Casper. They also filed a $40 million lawsuit against the State, claiming that their right to mine the limestone on that lease had been taken from them.

The National Park Service's (NPS's) plan to use aggregate sources within Grand Teton National Park for road construction projects (Wy*oming Geo-notes No. 41*, p. 30 - 31) was withdrawn because of public opposition. The NPS had argued that using in-park sources would save the government more than $25 million in hauling costs associated with bringing aggregate into the park from outside sources. According to the NPS, the withdrawal of the plan will give them time to further study the environmental impact of each possible aggregate source.

Decorative stone

Wyoming's potential to become a major decorative stone producer is nearer realization. Richard Cosgrove and Dean Cummins of Mesa Marble Company announced in mid-February that they had enough sales commitments to open a marble quarry near Tensleep in Washakie County (**Figure 18**). Cosgrove said initial sales would be flagstone and slab for high-end *(e.g. expensive)* homes under construction in the Jackson area of Wyoming. The marble deposit is in Triassic rocks northwest of Tensleep. The upper layers are brown, gray, buff, and green hard flagstone. Beneath this zone are thick beds of dark brown marble and brown wood-grained marble. Mesa Marble's stone is illustrated in the Wyoming State Geological Survey's 1991 publication on the decorative stones of Wyoming (Harris, 1991, p. 23). Production should begin in May.

Mesa Marble's quarry will be the third dimensional stone quarry to open in Wyoming since the State Survey's publication on decorative stones. The other stone quarries are Sunrise Stone's "Wyoming Raven" black granite quarry and its adjoining "Fantastica" swirled pink granite quarry, both in northeastern Albany County (**Figure 18**). Sunrise Stone is currently building a fabricating plant southwest of Wheatland (**Figure 18**). Toby Ser Voss, owner of Sunrise Stone, says he has enough orders for the quarries and plant to keep the current crew busy for two years. Mr. Ser Voss anticipates that a crew of four, quarriers and fabricators, will be employed when the facility reaches full operation this summer.

A fourth dimensional stone quarry may open this spring. As noted in *Wyoming Geo-notes No. 41*, the Arbor Rock Company of Longmont, Colorado, will produce flagstone from a quarry south of Douglas (**Figure 18**).

There are at least five decorative aggregate quarries active in Wyoming this year, with two more possibly opening later this summer. Georgia Marble produces about 80,000 tons of white marble aggregate a year at its Wheatland plant. This stone is quarried west of Wheatland (**Figure 18**), and marketed throughout the U.S. as "Wyoming White". Pacer Corporation of Pringle, South

Table 7. State activities involving coal producers in Wyoming during the fourth quarter of 1994[1].

Utility	Power Plant	Coal Mine or Region	Activity	Tonnage	Comments
Alabama Power Co.	Miller	Powder River Basin	So	600,000 t	8-month test burn.
	Unit No. 3	Powder River Basin	So	1.0-2.8 million t	3-year contract.
Central Illinois Light Co. (CILCO)	Edwards	Black Thunder	T	50,000 t	
Commonwealth Edison	Powerton	Caballo Rojo	T	250,000 t	
	Unspecified plants	Belle Ayr	T	250,000 t	
	Unspecified plants		So	0.3-0.4 milltion t	Maximum of 1.8 lbs. SO_2/million Btu.
Consumers Power Electirc	Unspecified plants		So	0.3-1.0 million t	
Dairyland Electric Power	Unspecified plants	Caballo/Rawhide	Sp	160,000 t	
Detroit Edison	Unspecified plants		So	100,000 t	Need first-quarter coal to make up for power loss caused by a non-radioactive accident at a nuclear power plant.
Georgia Power Co.	Various plants		So	780,000 t	
Georgia Power Co.	Scherer	Belle Ayr	Sp	1.02 million t	First-quarter tonnage.
Georgia Power Co.	Scherer	Powder River Basin	So	0.4-0.6 million t	
				N.D.	
Hastings [NE] Utility Dept.	Hastings	Caballo Rojo	Sp	0.05-0.2 million t	
IES Industries, Inc.	Burlington	Jacobs Ranch	Sp	350,000 t	
	Ottumwa	Cordero	Sp	500,000 t	
		Rawhide	Sp	300,000 t	
	Prairie Creek	Jacobs Ranch	Sp	465,000 t	
		Rawhide	Sp	200,000 t	
	Sutherland	Jacobs Ranch	Sp	200,000 t	
Indiana-Kentucky Electric Corp.	Clifty Creek	Antelope	C	1.5 million t	
		Rochelle	C	1.5 million t	
		Cordero	Sp	312,000 t	

Table 7. Sales activities involving coal producers in Wyoming during the fourth quarter of 1994[1] *(Continued)*.

Utility	Power Plant	Coal Mine or Region	Activity	Tonnage	Comments
Indiana-Michigan Power Co.	Rockport	Belle Ayr/Eagle Butte	Sp	735,000 t	
Lower colorado River Authority	Fayette Power Project Unit No. 3	Cordero	C	1.2 million t	Existing contracts is > 1.8 million tpy. This tonnage is above that requirement.
Midwest Power Systems	Council Bluffs	Eagle Butte	Sp	1.0 million t	
		Rawhide	Sp	300,000 t	
	Neal Units 1 & 2	Medicine Bow	C	500,000 t	
	Neal Unit No. 4	Belle Ayr	Sp	800,000 t	
Northern Indiana Public Service Co. (NIPSCO)	Dean H. Mitchell	Cordero	Sp	40,000 t	Januear-February
		Antelope	Sp	99,000 t	March-April
		Belle Ayr	Sp	11,000 t	March
	Michigan City	Black Thunder	Sp	111,000 t	January-February
		Shoshone	C	261,000 t	January-March
		Belle Ayr	Sp	99,000 t	March-April
	R.M. Schahfer	Shoshone	C	288,000 t	January-March
		Cordero	Sp	33,000 t	February
			So	N.D.	Spot coal for second-quarter.
			So	0.5-2.0 million t	Two five-year contracts.
Northern States Power	Unspecified plants		So	0.75-1.25 million t	A short-term contract for 1994.
Otter Tail Power Co.	Big Stone		So	1.5 million t	Contract for 2-5 years.
Portland General Electric	Boardman	Caballo Rojo	Sp	N.D.	
Springfield [MO] City Utilities	Southwest	Antelope	T	40,000 t	
	James River		So	0.4-0.5 million t	
West Texas Utility	Oklaunion	Caballo Rojo	Sp	350,000 t	
		Cordero	T	N.D.	

[1]Data obtained from : Coal Week, trade journals, periodicals, FERC database, and personal contacts.
N.D. =no data available; C =contract coal; T =Test burn; Sp =Spot coal; So =solicitation; t =short ton; tpy =tons per

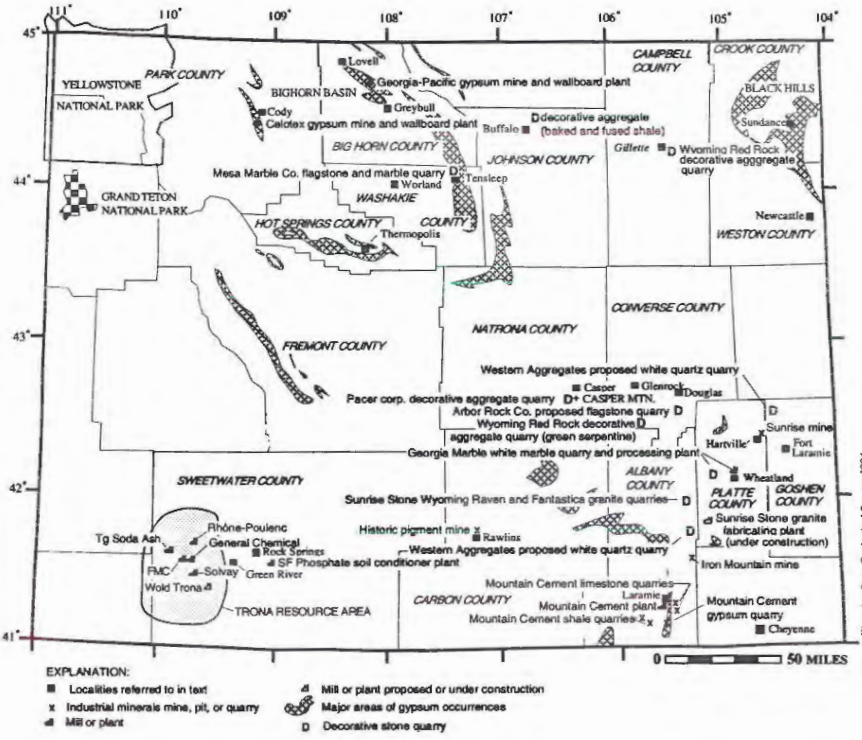

Figure 18. Industrial minerals activities in Wyoming during the first quarter of 1994.

Dakota, operates a feldspar quarry on Casper Mountain, south of Casper (**Figure 18**). Wyoming Red Rock of Gillette, sells green serpentine from a quarry south of Glenrock, and red baked and fused shale (clinker or scoria) from a quarry near Gillette (**Figure 18**). Wyoming Red Rock also purchases and sells other decorative stone from Wyoming and the region. Similar decorative red baked and fused shale is also quarried near Buffalo (**Figure 18**). This summer, Western Aggregates of Boulder, Colorado, hopes to open two white quartz aggregate quarries, one north of Fort Laramie and one west of Wheatland (**Figure 18**). This spring or summer they will conduct exploratory tests to determine the tonnage of the white quartz at each site.

At the end of 1993, Ifint, S.A. a European investment concern, purchased Georgia Marble Co. from its former parent company, First Chicago Corp. Georgia Marble is headquartered in Kennesaw, Georgia, and has operations in 6 states, including the Wyoming marble operation at Wheatland. The company will continue to operate under the name of Georgia Marble.

Gypsum

Gypsum has been produced in Wyoming in small amounts ever since the earliest settlements were established. Towns near gypsum deposits, especially Laramie, Sundance, Newcastle, Lovell, Greybull, Worland, Thermopolis, and Cody (**Figure 18**) had small gypsum workings for the production of plaster and whitewash. Most of these workings are no longer identifiable. The following information is summarized from published and unpublished data from the Wyoming State Board of Equalization, the Wyoming Ad Valorem Tax Division, the Wyoming State Inspector of Mines, the U.S. Bureau of Mines, and the Wyoming State Geological Survey.

Gypsum was mined near Laramie, and used in plaster and locally manufactured cement even before the town was established. These products were used by the U.S. Army at Fort Sanders in the construction of the first structures at the post, which was originally established to protect travelers on the Overland Trail.

In the 1920s and 1930s, there was a small plaster plant about six miles south of Laramie along the Union Pacific Railroad at Willow Creek. Before that time, other plaster plants operated in the Bighorn Basin and Black Hills areas of Wyoming, although production records before 1920 are incomplete or nonexistent. The Laramie plaster plant processed both gypsum from the Triassic Chugwater Formation and gypsite, an evaporite consisting of gypsum, from Quaternary deposits.

Large scale development of the gypsum resources in Wyoming began in the early to mid-1960s (**Figure 19**). In 1961, Monolith Portland Cement now owned by Mountain Cement first reported gypsum production for use in its Laramie cement plant. Until 1989, gypsum for the plant was mined from deposits in the Triassic Chugwater Formation at Red Mountain, 40 miles southwest of Laramie. The present source of gypsum for the plant; however, is the Chugwater Formation at Willow Creek, south of Laramie (**Figure 19**). This, incidentally was the source for the gypsum used by the old plaster mill that was mentioned earlier.

Big Horn Gypsum started production of gypsum for wallboard in 1963 near Cody (**Figure 18**). In 1966, this plant was bought by the Celotex Corporation, the current operator.

Georgia Pacific Co.'s gypsum mine and wallboard plant began production in 1967 southeast of Lovell (**Figure 18**), and have been in continuous production ever since. The gypsum is mined, appropriately enough, from the Jurassic Gypsum Spring Formation.

As illustrated in **Figures 19** and **20**, the production of gypsum has in general increased since these early beginnings, despite a recent decline in the price of gypsum. The downturns in production in the late 1960s, 1974-1975, and the early 1980s reflect national recessions that affected business and manufacturing.

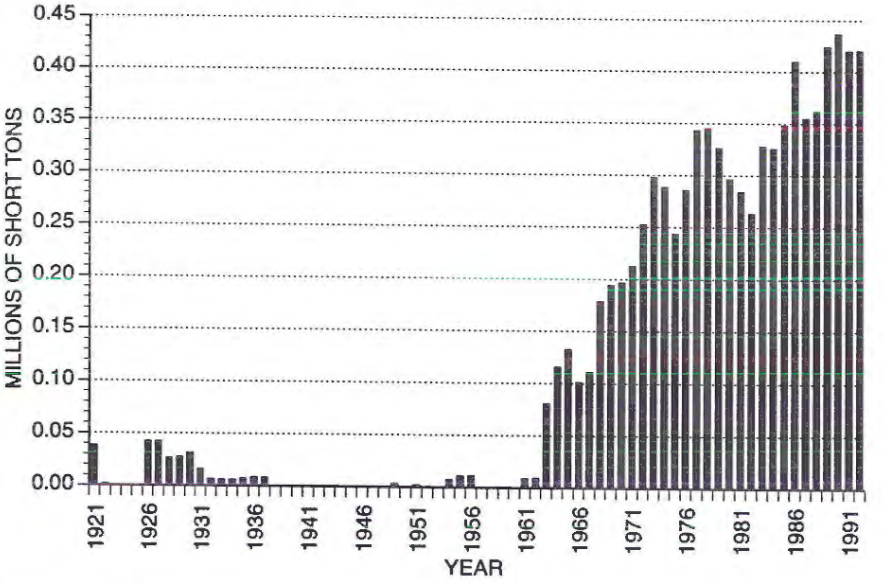

Figure 19. Historical gypsum production from Wyoming (1921- 1992).

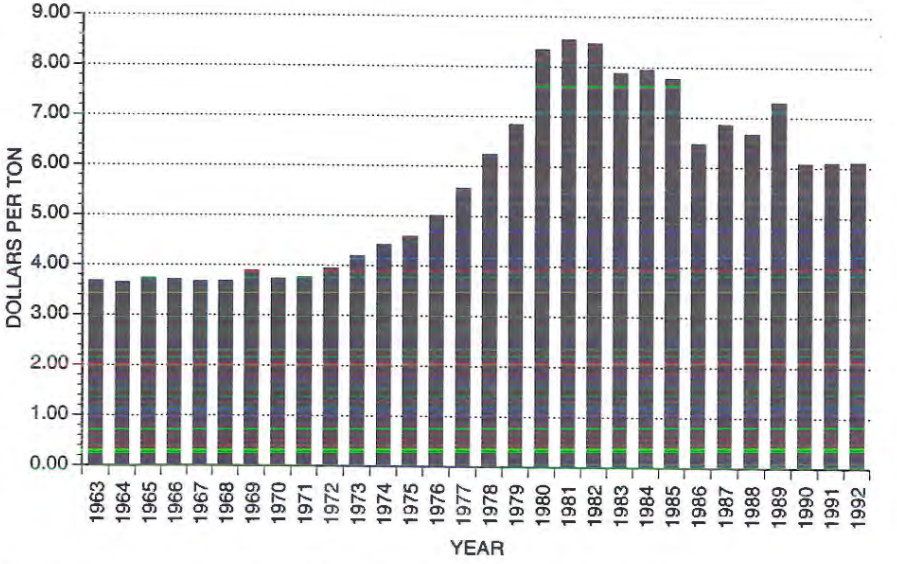

Figure 20. Average prices paid for Wyoming gypsum (1963 to 1992).

Gypsum is used primarily in the manufacture of wallboard, but about 18% of the total U.S. consumption is for cement retarders, soil conditioners, or plasters (**Figure 21**) (Davis, 1992; 1993). The production of gypsum is closely tied to regional construction activity. The market for Wyoming's gypsum is the northern Rocky Mountains and the Pacific Northwest (Celotex and Georgia-Pacific wallboard plants) and the Colorado Front Range (Mountain Cement). Although there is a cement plant at Fort Collins, Colorado, Wyoming's production is the closest to the Pacific Northwest, an important area of construction growth (Jorgensen, 1994).

Iron minerals (Industrial)

In 1993, the Colorado Lien cement plant near Fort Collins, Colorado, bought 250 tons of iron-rich tailings from the Sunrise iron mine east of Hartville (**Figure 18**). The tailings are from the ore processed at the beneficiation plant that operated at Sunrise until 1980. The cement plant uses the iron-rich tailings as a strengthener and weighting additive in certain types of cement products. In March of this year, an additional 500 tons were mined and shipped to the Fort Collins cement plant. The operator, Less Wahl, plans to market about 25,000 tons of this material in 1994.

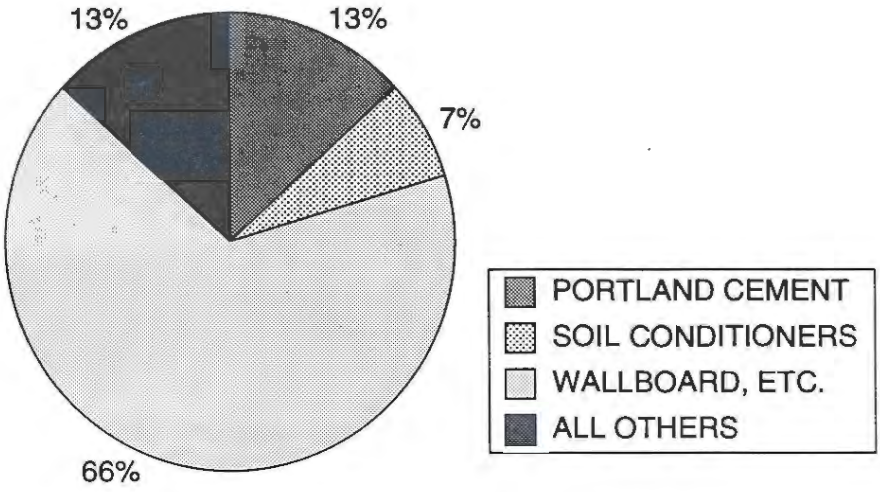

Figure 21. 1992 consumption of gypsum in the U.S. in percent.

In recent years, Red Dog Minerals sold pond fines from the tailings at Sunrise to Solomon Bros. Inc. These fines were used in cosmetics and boxcar paint. In the past, some goethite (hydrous iron oxide) found north of Rawlins was also used as pigments for boxcar paint (**Figure 18**).

Mountain Cement of Laramie uses titaniferous-magnetite tailings from the abandoned Iron Mountain mine in Albany County in the production of some of its cement (**Figure 18**).

Lime and cement

In early January, Mountain Cement announced tentative plans to increase the capacity of its Laramie cement plant by 30 to 40 percent. The company expects to make a final decision on the expansion by mid-1994. This project would include the reconstruction of an electrostatic precipitator and the replacement of a kiln that has been inactive since 1986. Mountain Cement completed a major modernization in 1987. Since then, the plant has been operating near its design capacity of 550,000 tons of cement products per year. The increased capacity would boost annual production to 770,000 tons. Increased construction activity, and an associated increased demand for cement, especially in the Colorado Front Range area, is the reason for the proposed expansion.

Sulfur

Despite a worldwide setting of falling prices and declining demand (Foster, 1994), Wyoming's production of recovered sulfur increased in 1993, and Wyoming remained second among states in the production of recovered sulfur. Recovered sulfur is a by-product of the desulfurization of sour natural gas. World sulfur production fell for the fifth straight year and the worldwide demand for sulfur of all kinds also declined. This decline is primarily a reflection of decreasing demand for fertilizers and soil conditioners (Mew, 1994; Foster, 1994). Most of Wyoming's recovered sulfur is sold out-of-state; however, some is used at SF Phosphate's fertilizer/soil conditioner plant southeast of Rock Springs (**Figure 18**). SF Phosphate is a 50-50 joint venture between J.R. Simplot and Farmland Industries, Inc.

Trona

Natural trona is mined in Wyoming from five underground mines west of Green River and refined into soda ash and other sodium compounds at the refinery complexes associated with the mines (**Figure 18**). See p. 35-36 in *Wyoming Geo-notes No. 41* for a summary of trona production and prices.

The nation's soda ash production was 9.89 million short tons in 1993 (Kostick and Arguellas, 1994). Because about 90% of this production came from Wyoming, soda ash production from the State in 1993 is estimated at 8.91 million short tons. The 1993 domestic production of soda ash is 450,000 short tons

below that of 1992. Most of this decline in production was due to a drop in exports, particularly to Japan, but also to Europe, which is in an economic recession. The domestic demand for soda ash, which is used in the manufacture of glass, detergents, chemicals, pulp-and-paper processing, and control agents for stack emissions, increased slightly. Some of this increase was in the production of automotive and flat glass. Recycling, on the other hand, cut into the use of soda ash for new container glass (bottles, etc.). The use of soda ash in emissions control remains a growth possibility (Breunig, 1994).

FMC announced in early March that it was going ahead with a $140 million expansion project in Wyoming. A $90 million phase, which will increase mining efficiency and result in the underground storage of tailings, is to begin as soon as permits are obtained. Later, the remaining $50 million would be used to increase the processing capacity of the soda ash plant.

In late March, the Wyoming Industrial Siting Division (ISD) indicated it would approve FMC's initial $90 million phase, but not the remaining $50 million expansion of capacity. The ISD said that it still had concerns about possible adverse socio-economic effects since FMC was one of several companies with development or expansion projects in the Green River area. At issue are Wold Trona's plans for a new trona mine and refinery complex as well as possible expansion plans by the other four producers: General Chemical, Rhône-Poulenc, Solvay Minerals, and Tg Soda Ash.

General Chemical announced the layoff of about 30 workers in early March. General cited a decline in demand for soda ash as a reason for reducing production and laying off the workers.

For 1994, the production of soda ash from mined trona in Wyoming may decline or increase slightly. What happens depends a lot on soda ash exports. If the U.S. and Japan get into a trade war, exports and Wyoming production will likely decrease. In the absence of a trade war, a modest increase in domestic consumption of soda ash, coupled with a flat export market, could result in a small increase in production.

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URANIUM UPDATE

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

NUEXCO spot market uranium prices are presented here to give information about the relative prices of yellowcake and price trends (**Table 8**). These prices are not necessarily the figure at which yellowcake is being sold. Add-ons and other factors increase the sale price of uranium compounds. Actually, most uranium produced in Wyoming is sold under contract at substantially higher prices than the market price reported by NUEXCO.

Currently, all uranium production in the U.S. comes from four states: Florida, where uranium is produced as a by-product of the processing of land-pebble phosphate mining, and Nebraska, Texas, and Wyoming, where uranium is produced by in-situ solution recovery methods (**Figure 22**). There is no longer any conventional (surface or underground) mining of uranium ore in this country. At the present time, Wyoming leads in uranium production, followed by Florida, Texas, and Nebraska, in that order (derived from personal communication with COMIN and data from the Energy Information Administration).

Uranium is produced in Wyoming at Power Resources' Highland and North Morton Ranch in-situ facilities north of Glenrock in Converse County, and by COMIN at the Christiansen Ranch and Irigary Ranch in-situ sites west of the Pumpkin Buttes in Johnson County (**Figure 23**). All of this current production comes from roll front-type uranium deposits in the Eocene Wasatch and Paleocene Fort Union Formations. The uranium product produced at these sites is yellowcake, a uranium oxide of varying chemical composition. Yellowcake is sold to utilities where it is refined and enriched into nuclear fuel-grade uranium.

Table 8. NUEXCO end-of-month spot market price of yellowcake, October, 1992, to November, 1993 in current dollars.

Month	UNADJUSTED PRICE	ADJUSTED PRICE
Oct 1992	$8.00	
Nov 1992	7.90	
Dec 1992	7.85	
Jan 1993	7.65	
Feb 1993	7.60	
Mar 1993	7.45	
Apr 1993	7.10	
May 1993	7.00	
Jun 1993	7.00	
Jul 1993	6.90	10.00
Aug 1993	6.90	10.00
Sep 1993	6.90	10.20
Oct 1993	6.90	10.15
Nov 1993	6.90	9.90
Dec 1993	6.95	9.85
Jan 1994	7.00	9.50
Feb 1994	7.00	9.45

COGEMA S.A., is the French corporation that owns 100% of COGEMA, Inc., of Bethesda, Maryland. COGEMA, Inc. is the owner of COGEMA Resources, Inc., the North American uranium mining subsidiary, headquartered in Saskatoon, Saskatchewan, Canada. In Wyoming, there are two wholly-owned subsidiaries of COGEMA Resources, Inc., COMIN (COGEMA MINing) and Pathfinder Mines Corp. COMIN is the operator of the Christiansen Ranch and Irigary Ranch properties. Malapai Resources, a subsidiary of Arizona Power Co., is the owner of the Christiansen and Irigary Ranch properties. Pathfinder Mines Corp. owns 25% of the Highland operation (with Power Resources, the operator, owning the remaining 75%); all of

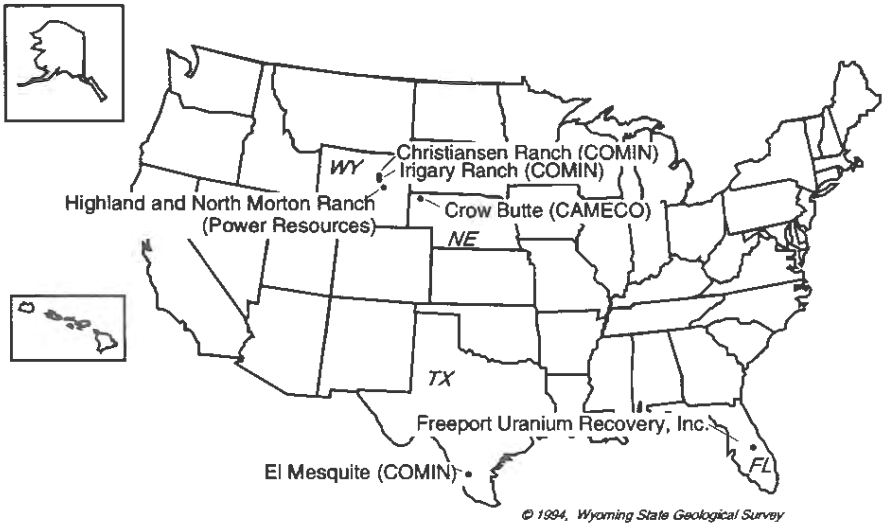

Figure 22. Locations of active uranium producers in 1993.

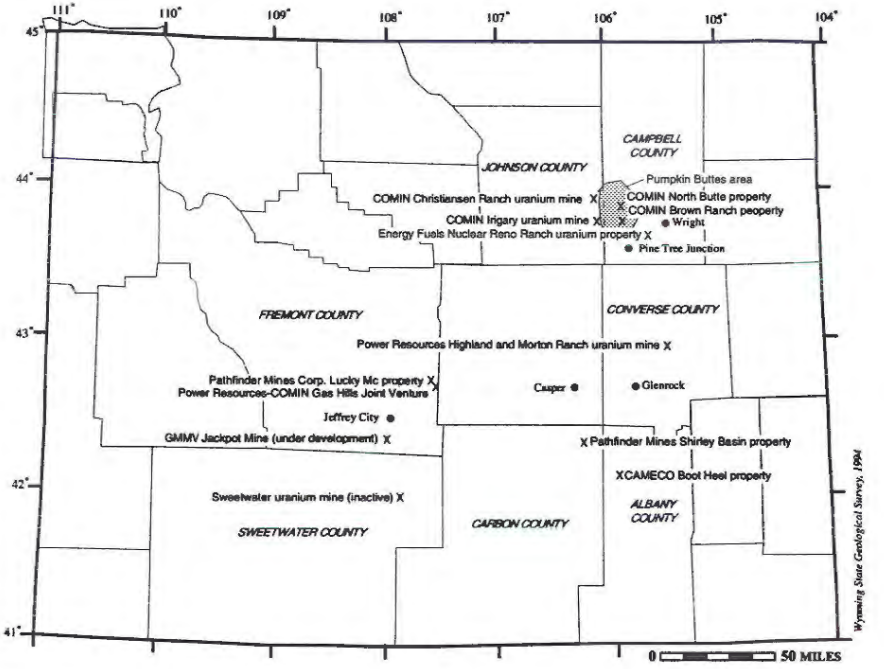

Figure 23. Uranium activities in Wyoming during the first quarter of 1994.

the North Butte and Brown Ranch properties in Campbell County (neither of which are in production); and 25% of the Gas Hills Joint Venture (with Power Resources having the remaining 75% interest) (also not currently in production). Pathfinder Mines also owns the properties under reclamation at the Lucky Mc and Shirley Basin mines and mills (**Figure 23**). The writer is indebted to Donna Wichers of COMIN for providing the information regarding COGEMA's corporate structure and the COMIN and Pathfinder Mines properties.

In addition to acquiring property near the Boot Heel in northern Albany County, CAMECO, a Canadian corporation, has acquired property in the Pumpkin Buttes area of southwestern Campbell County (**Figure 23**), and has established an office in Casper. As of April, 1994, CAMECO had not announced any plans to begin production.

The Green Mountain Mining Venture (GMMV), a joint venture between Kennecott Energy and U.S. Energy Corp., is proceeding with its plans to develop an underground uranium mine on the south slope of Green Mountain, south of Jeffrey City in Fremont County (**Figure 23**). The GMMV has already spent over $3 million for the Federal and State permitting processes, according to a GMMV spokesman. The U.S. Bureau of Land Management has issued a Scoping Statement in preparation for an Environmental Impact Statement.

In mid-January, Energy Fuels Nuclear (EFN), announced that it was planning to begin construction of an in-situ recovery plant and well field at its Reno Ranch property this year (**Figure 23**). EFN has applied to the U.S. Nuclear Regulatory Commission for a materials handling license. The property could be operational by the end of 1994 or in early 1995, according to EFN spokesmen. When operational, the Reno Ranch property would be the third active in-situ uranium recovery operation in Wyoming.

The use of nuclear power continues to increase worldwide, with the notable exception of the U.S. According to the U.S. Energy Information Administration (EIA), the use of nuclear power is expected to increase between 0.4 and 1.5 percent annually until 2010, which represents an increase in nuclear generating capacity from 351 gigawatts per year in 1993 to 427 gigawatts per year by 2010. The EIA report notes that although the U.S. currently leads the world in nuclear capacity with 99 gigawatts or 23% of the world's total, the EIA forecasts no increase for the U.S. by 2010. There are no new nuclear power plants projected or under construction in the U.S., making it the only developed nation in the world that is not increasing its nuclear-powered electrical generating capacity (EIA, 1993).

The EIA also reports that the total amount of spent nuclear fuel generated by U.S. nuclear power plants, since the first plant began operating in 1957, amounts to 28,660 tons of material (EIA, 1993). Other countries recycle spent fuel into reprocessed nuclear fuel through re-enrichment processes. The EIA estimates that U.S. nuclear power plants, between now and 2030, will generate 93-123 more tons of spent fuel (EIA, 1993). In the U.S., Federal law, prevents the reprocessing of spent fuel into nuclear fuel. Instead, spent fuel is stored at nuclear power plant sites throughout the country. There are several sites under study in the U.S. for temporary or permanent storage of the high-level radioactive waste.

The EIA (1993) also states that 2.6-2.9 billion pounds of uranium will be needed to fuel the world's nuclear power plants between 1993 and 2010. Currently, the best estimates of world uranium resources (recoverable at $20.00 per pound) are 2.3 billion pounds (EIA, 1993). This is exclusive of the CIS, People's Republic of China, and eastern Europe. These statistics indicate that the price of uranium in the world market could increase in the next 16 years, as a result of supply and demand. For the first time since 1979, there may be an incentive to increase uranium exploration and mining. It is still too early to say if this increase in worldwide demand for uranium will result in a significant recovery for Wyoming's uranium industry. Since Wyoming's producers are competing in a world market, the comparatively high domestic costs of mining, environmental protection, transportation, and the like will affect their ability to compete. However, the recent increase in Wyoming's in-situ production may reflect this projected demand, and gives some hope to uranium investors.

However, in a recent article in the *Engineering and Mining Journal*, a note of pessimism was sounded by Thomas C. Pool, Vice President of NUEXCO. Pool (1994) writes:

> "Just when the uranium industry could begin to draw some comfort from a rapidly expanding gap between consumption and production, the possibility of huge supplies from the conversion of nuclear weapons has moved from an abstract concept to a near-term probability."

Pool refers to a process where weapons-grade uranium, containing over 95% of the fissionable isotope ^{235}U is diluted to nuclear fuel-grade, containing only about 3% ^{235}U. One can see that very small amounts of weapons-grade uranium can be converted to significant amounts of power plant fuel. As of this writing, no weapons have been converted to fuel, but the possibility has contributed to keeping uranium prices low. It has been estimated that over one billion pounds of yellowcake that would otherwise have to come from mined uranium could be supplanted with converted weapons-grade uranium, (Pool, 1994).

In March, the U.S. and Russia signed an amendment to a trade agreement which prohibits the sale of Russian uranium in the U.S. until the market price of yellowcake reaches $13 per pound. Russia reportedly has vast amounts of stockpiled uranium. The signing of this agreement was met with some cautious relief by U.S. uranium producers. In June, 1992, Russian uranium was selling in the U.S. at prices up to 84.2% below the established market price.

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METALS AND PRECIOUS STONES UPDATE

by W. Dan Hausel
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According to the *Northern Miner* (3/28/94, p. 3), Annabel Gold Mines of Vancouver budgeted $700,000 for exploration of the Carissa mine near South Pass City in the South Pass greenstone belt in western Wyoming. The mine is owned by Hol-Lac Gold Mines of Canada. Surface and underground drilling in

1989 showed mineralization to at least a depth of 650 feet. At that depth, the mineralized zone was 80 feet wide. Annabel plans to begin exploration in early May.

An Associated Press article in the *Laramie Boomerang* (3/27/94) reported that the U.S. Forest Service intends to withdraw the site of the old Kirwin mining town in the Absaroka Mountains of northwestern Wyoming. While the withdrawal is to protect the structures remaining on the site, it may well include the Wolf shaft, which is close by. The Kirwin porphyry represents Wyoming's largest known reserves of economically recoverable copper with associated values in molybdenum, silver, gold, lead, zinc, and titanium (See discussions of copper, lead, zinc, and molybdenum below).

Diamond

The Colorado-Wyoming kimberlite province includes more than 100 kimberlite intrusives, one of the largest lamproite fields in the world, and dozens of unexplored geophysical, remote sensing, and heavy mineral anomalies. One district within the province, known as the Colorado-Wyoming State Line district, consists of about 35 Early Devonian kimberlite dikes and diatremes (many of which are diamondiferous). This district extends 3 miles north into Wyoming and 10 miles south into Colorado (**Figure 24**). A&E Resources, Bald Mountain

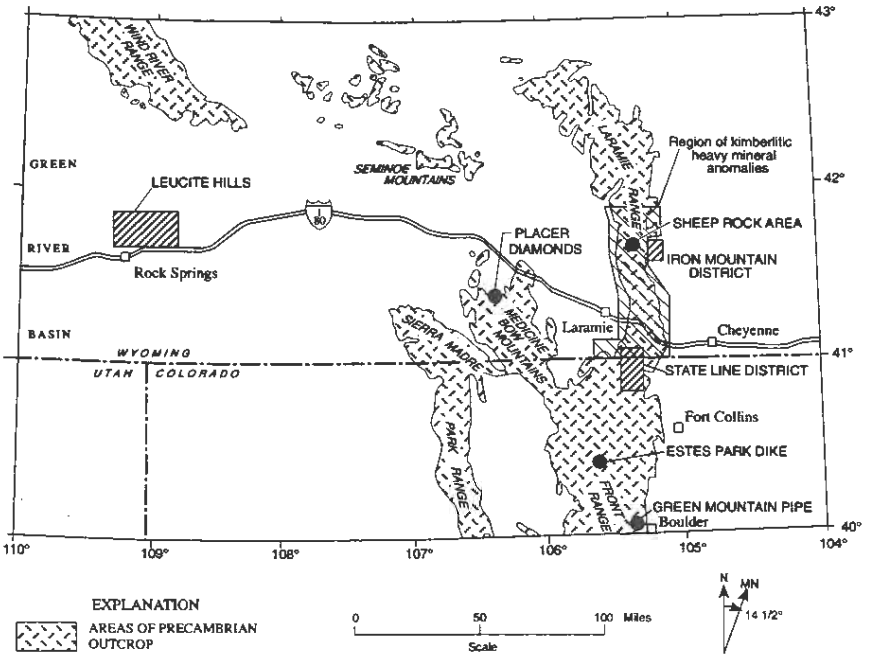

Figure 24. Sites and districts in the Colorado-Wyoming Province which contain kimberlite, lamproite, and(or) kimberlitic heavy mineral anomalies.

Mining Co., Colorado Diamond Co. Diamond Co., N.L., Fleck Resources, LENCA, MPH Consulting, Redaurum Red Lakes, Royal Star, Union Pacific Resources, and others are currently exploring this district.

Total diamond production from the district amounts to more than 100,000 gem and industrial diamonds (McCallum and Waldman, 1991). The recovered diamonds range from micro-diamonds to a 6.2 carat gemstone recovered last Fall by the Colorado Diamond Co. Overall, the gem to industrial quality ratios are favorable, with some deposits having as much as 50% gemstones (Hausel, 1993). To date, the district has been the most productive in North America as far as the total number of diamonds recovered.

North of the State Line district, nearly 300 kimberlitic heavy mineral anomalies (pyrope garnet, chromian diopside, and(or) picroilmenite) were identified over a 1,200-square-mile area in the Laramie Mountains (Hausel and others, 1988). Heavy mineral anomalies have also been identified in the Seminoe Mountains greenstone belt of central Wyoming and in the Medicine Bow Mountains and the Green River Basin of southern Wyoming. The anomalies in the Green River Basin are scattered over a few hundred square miles in anthills and road cuts. Most of these anomalies remain unexplored.

The Green River Basin also hosts one of the three major lamproite fields in the world, known as the Leucite Hills. The Leucite Hills are receiving some exploration activity, and the Wyoming State Geological Survey is currently processing a small bulk sample of olivine-bearing lamproite for diamond.

Copper, lead, zinc, and molybdenum

At the turn of the century, Wyoming was an important source of copper. Copper was mined and produced from several districts including the Encampment, Silver Crown, Copper Mountain, Hartville, and Lake Alice, to name a few. According to the available production statistics, Wyoming may have produced as much as 63.8 million pounds of copper from 1882 to 1946 (**Figure 25**) (Hausel, 1989). Production was intermittent and under 2000 pounds per year after 1924. The majority of the copper was recovered from the Ferris-Haggarty. Lead production in the State was minor and amounted to only about 30,000 pounds. No statistics are available for zinc or molybdenum production.

Currently, significant copper resources are known in the Absaroka Mountains of northwestern Wyoming, the Laramie Mountains in southeastern Wyoming, at Copper Mountain in central Wyoming, in the Sierra Madre of southeastern Wyoming, and in the Overthrust Belt of western Wyoming. These deposits are polymetallic and host several other metals in addition to copper.

Absaroka Mountains: The Absaroka Mountains contain several porphyry copper deposits with sizable reserves, resources, and potential resources. Four porphyries have been sufficiently drilled to establish reserves. The Bald Mountain porphyry at Kirwin (T45-46N, R104W) contains at least 196 million

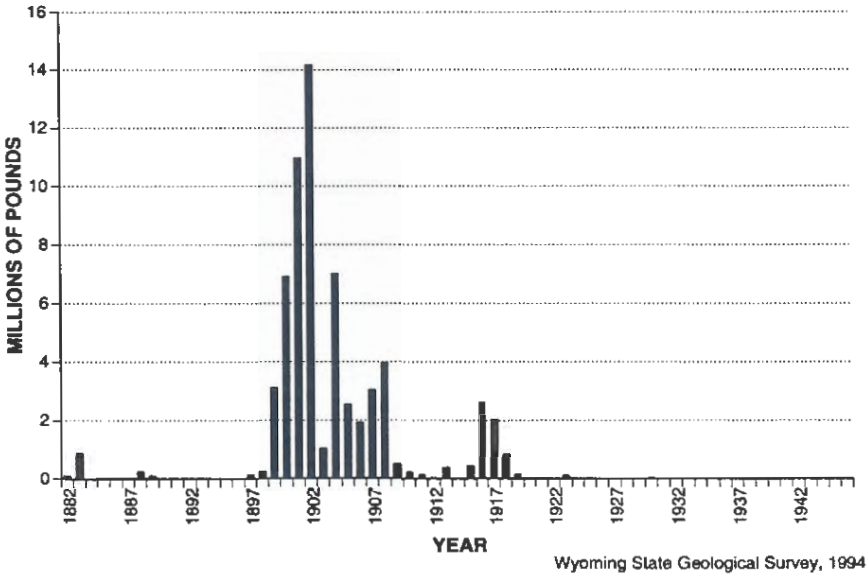

Figure 25. Histogram showing annual copper production from Wyoming in millions of pounds. The increase in production from 1899 to 1908 was principally the production from the Ferris-Haggarty mine.

tons of ore averaging 0.505% Cu and 0.022% MoS_2 at a 0.3% Cu cutoff grade (**Table 9**). One estimate suggests the value of the contained metals is more than $200 million. Reserves amenable to open pit mining were calculated at 160.8 million tons (Rostad, 1983). A 1991 study indicated the deposit was also amenable to in-situ leaching at recovery costs of only $0.309/pound Cu (Ora Rostad, pers. comm., 1992). Copper currently is valued at $0.85/pound.

Veins in the district have been explored along strike for only limited distances even though some are traceable for as much as 2,500 feet. Some yield strong mineralization over minable widths (Wilson, 1964; Rostad, 1982). The Oregon vein, for example, yielded ore grade values across widths of 3 feet (17.8 ounce per ton [opt] Ag and 0.08 opt Au). The Little Johnnie vein yielded values of 64.7 opt Ag and 0.12 opt Au across widths of 1.5 feet. The best values in these two adits were obtained next to the mine face. A select sample across 0.5 feet of the Mendota vein from the Galena Ridge tunnel averaged 101.35 opt Ag and 0.283 opt Au. The average of 31 samples taken over a strike distance of 98 feet on the Bryan vein on Spar Mountain averaged 0.13 opt Au, 29.5 opt Ag, and 0.73% Cu (Rostad, 1982).

The district also has potential for undiscovered mineralized breccia pipes. Spar Mountain, south of Bald Mountain, may also represent a separate miner-

Table 9. In-place tonnages and minable reserves reported for the Bald Mountain copper porphyry deposit at Kirwin (after Rostad, 1982).

	0.3% Cutoff Grade
In-place tonnage	196 million
Minable reserves	160.8 million
% Cu (total)	0.505
% Cu (sulfide)	0.467
% MoS2	0.022
Waste: Ore ratio	0.57:1
Pre-production stripping	8.5 million

alized center with possible secondary copper enrichment. There is also potential for skarn and replacement deposits in the underlying sediments. Alluvial gravel is abundant in the Wood River downstream from Kirwin. The gravels are 60 to 150 feet thick with an estimated potential for more than 100 million cubic yards of unexplored gravel. It does not appear that the gravel has ever been explored for gold, even though geologic evidence suggests some has to be mineralized (Rostad, 1982).

Two types of mineralization are recognized in the Sunlight district north of Kirwin: disseminated and vein mineralization. At Horseshoe Hill between Sunlight and Stinkingwater Peaks, a mineralized intrusive was explored by Skyline Corp. in the 1960s. They reported ore that averaged 1.62% Cu with values in gold and silver. The tonnage was estimated at 23 million tons (Thomas, 1960).

Reserves were also established in the Stinkingwater district (enclosed by the Washakie Wilderness) between the Kirwin and Sunlight districts. Based on sparse drilling, the Silver Creek porphyry contains estimated resources of 27 million tons of 0.5% Cu (John Wells, personal communication, 1982). The nearby Needle Creek porphyry includes an altered area of disseminated copper-molybdenum with high gold and silver values in the peripheral zone. The size of the deposit is not accurately known since the porphyry was only partially explored. Phelps Dodge Corp. estimated the deposit had a potential for 131,657,200 tons of ore averaging 0.35% Cu. Reserves were established at 96,378,267 tons with an average grade of 0.35% Cu (**Table 10**) (Lukanuski, 1969).

Laramie Mountains: The Copper King deposit in the Silver Crown district, 20 miles west of Cheyenne, occurs as a large-tonnage, low-grade, porphyry copper-gold deposit. The ore body is hosted by calc-alkaline intrusives with average granodiorite and quartz monzonite composition.

Mineralization occurs in veinlets, fracture fillings, and disseminations. The deposit contains an estimated 35 million tons of ore at an average grade of 0.21% Cu and 0.022 opt Au (**Table 11**). Spectrographic analyses also showed traces of lead, zinc, and tungsten, and 0.5 to 3.0% TiO_2.

In 1987, Caledonia Resources Ltd. of Canada leased the property. The company reported preliminary gold estimates on the order of 4.5 million tons of ore averaging 0.044 opt Au. Sampling suggests the deposit has a minimum strike length of 600 to 700 feet with a 300-foot width and is open at depth.

Geochemical and geophysical anomalies suggest that the known resource may be substantially larger. For example, a large magnetic anomaly (1,000 feet wide x 2,000 feet long, and 450-gamma magnitude), almost identical to that reflected by the Copper King ore deposit, was identified in a gravel covered area 4,500 feet to the southeast. Soil samples over this anomaly returned some anomalous values for the pathfinder elements mercury, zinc, and arsenic. Geological and geophysical evidence also suggests the presence of sulfides down plunge to the southwest and to the east. An I.P. survey identified a moderate to shallow, metal-factor anomaly trending east-northeast of the principal mineralized area. Compass Minerals out of Reno is currently exploring this deposit.

Table 10. Copper plus molybdenum reserves for the Needle Creek porphyry (Lukanuski, 1969).

Cutoff (Cu + MoS_2)	Tonnage	Grade
0.2%	96,378,267	0.35%
0.3%	50,205,867	0.44%
0.35%	30,043,467	0.51%
0.40%	19,376,800	0.58%
0.50%	14,596,800	0.62%
0.60%	4,720,000	0.76%

Overthrust Belt: The Overthrust Belt in western Wyoming includes a number of scattered copper-rich red bed deposits. The principal district is the Lake Alice district near Cokeville.

Selected grab samples from the Lake Alice district assayed as high as 24% Cu, 1.5% Pb, 7.25% Zn, and 45 opt Ag (Loose and Boberg, 1987). A core hole drilled in the highly mineralized area at the Griggs mine yielded mineralized zones from depths of less than 40 feet that ran 5 feet of 0.26% Cu, 10 feet of 0.48% Cu, and 13 feet of 0.37% Cu; 3 feet of 0.77% Zn, 5 feet of 0.37% Zn, 2 feet of 0.21% Pb, and 5

Table 11. Reported reserves for the Copper King mine, Silver Crown district.

Tons (millions)	Cu (%)	Au (opt)	Stripping ratio (waste/ore)
2.8	0.36	0.044	0.5
6.0	0.32	0.038	1.2
13.5	0.26	0.028	1.8
35.0	0.21	0.022	2.0

Opt =ounces/ton

feet of 0.24% Pb; and 3 feet of 1.3 opt Ag and 5 feet of 4.5 opt Ag (Boberg, 1984; Loose and Boberg, 1987). Based on limited exploration and drilling in the area, Boberg (1984) indicated the Lake Alice district could have a 100-million-ton deposit with grades of 0.5 to 1.0% Cu and 2 to 5 opt Ag at depths of only 20 to 150 feet below the surface.

Copper Mountain district: The Copper Mountain district lies within the Owl Creek Mountains of central Wyoming. Copper, gold, silver, iron, tungsten, feldspar, lithium, beryl, tantalum, uranium, and petroleum have been reported. Production of metals from the district included minor amounts of tungsten during the Second World War, some feldspar, minor aquamarine beryl, minor amounts of gold and silver, and some copper. The available production reports indicate that at least 568,000 pounds of mill concentrates of copper with some gold and silver were shipped from the district between 1906 and 1918. Nearly all of the production was reported from the DePass mine in 1917 and 1918. This mine was developed in a 30- to 50-foot-wide mineralized Proterozoic mafic dike (Hausel and others, 1985).

Encampment district: The first known mining claims in the Encampment district were staked in 1868. A significant discovery of metals; however, was not made until 1874. This discovery led to the development of the Doane-Rambler mine in 1881. Sixteen years later, another important copper deposit was discovered that led to the development of the Ferris-Haggarty mine.

Shortly after the Ferris-Haggarty mine opened, it was sold to the Penn-Wyoming Copper Co. and was capitalized at $20 million. The mine was ranked as the 27th largest copper producer in the world between 1900 and 1908 (Short, 1958).

The Ferris-Haggarty mine was developed in a flexure fold along a massive quartzite-felsic schist contact where a 20-foot-thick ore shoot was localized in the brecciated footwall quartzite. Locally, the shoot was as much as 65 feet thick. The shoot averaged 6 to 8% Cu. High-grade ore varied from 30 to 40% Cu with some silver and 0.1 to 0.4 opt Au. The ore body was 250 to 300 feet long and may have extended to a vertical depth of 560 feet prior to termination of the mine operations in 1908.

High-grade ore at the Doane-Rambler mine consisted of brecciated Proterozoic quartzite cemented by chalcopyrite and chalcocite. Mineralization also occurred in siliceous mylonite, mica schist, and brecciated dolomite (Menzer, 1981). According to Armstrong (1970), the Doane-Rambler ores may have contained as much as 4% cobalt. Samples collected by McCallum and Menzer (1982) yielded 25 ppm to 2.1% Cu and none to 6.8 ppm Ag. It was estimated that 25,000 tons of ore were recovered from the underground workings that averaged 10% Cu (Menzer, 1981). In other words, as much as 5 million pounds of copper may have been produced.

The Charter Oak was another important mine in the district near the turn of the century. The Charter Oak vein contains chalcopyrite, chalcocite, bornite, and azurite in a gangue of quartz, jasperoid, schistose wall rock, calcite, and some chalcedony (Spencer, 1904). Some high-grade gold ore was found on the property (Beeler, 1905).

The mineralized rock was traced 2 miles on the surface and varied in width from 14 feet at the Charter Oak shaft to 100 feet elsewhere. It has been reported that the ores carried as much as 4 to 5% cobalt (Armstrong, 1970).

The Kurtze-Chatterton mine was one of the three most productive mines from the Encampment district. Widespread copper mineralization was found in veins and shears in Sierra Madre granite. The property reportedly contained five distinct veins ranging in width from 18 to 44 feet. The ore consisted of chalcocite and chalcopyrite (Spencer, 1904).

Locally, the granite exhibits potassic alteration. Reconnaissance of the property in 1991 identified a mineralized zone extending over a strike length of 4,000 feet. The zone swelled from a relatively narrow width to possibly 800 feet wide. Samples collected on the property yielded none to 28.10 ppm Au, none to 7.24 ppm Ag, 4.0 ppm to 12.55% Cu, and none to 0.8% TiO_2, with trace amounts of lead and zinc.

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MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING

PETROLEUM

Remaining Resources (January 1, 1994)		
Discovered (Includes 10 billion barrels recoverable by enhanced recovery techniques)	12.4	billion barrels[1]
Undiscovered	7.6	billion barrels[1]
Total	20.0	billion barrels
Remaining Reserve Base (January 1, 1994)		
Measured reserves (Proved reserves) (Includes oil, gas liquids, and condensate)	1.28	billion barrels[2]
Indicated and inferred reserves	2.80	billion barrels[1]
Total	4.08	billion barrels

NATURAL GAS

Remaining Resources (January 1, 1994)		
Discovered (Includes 20.1 trillion cubic feet (TCF) of methane[1] and 122.0 TCF of CO_2[3])	140.0	trillion cubic feet
Undiscovered (Includes 58 TCF of conventional methane[1]; 7 TCF of coalbed methane[4]; 3,611 TCF of methane in tight gas sands in the Green River Basin[5]; and 31.2 TCF of CO_2[3])	3,707.2	trillion cubic feet
Total	3,847.2	trillion cubic feet
Remaining Reserve Base (January 1, 1994)		
Measured reserves (Proved reserves) (Includes 10.4 TCF of methane[2] and 60.4 TCF of CO_2[3])	70.8	trillion cubic feet

COAL

Remaining Resources (January 1, 1993)		
Identified and Hypothetical (Discovered)	1,428.0	billion tons[6]
Speculative (Undiscovered)	31.5	billion tons[6]
Total	1,459.5	billion tons
Remaining Reserve Base (January 1, 1993)		
Demonstrated strippable (Measured and indicated reserve base)	26.4	billion tons[7]
Demonstrated underground-minable (Measured and indicated reserve base)	42.5	billion tons[7]
Total	68.9	billion tons

TRONA

Original Resources (1990 estimate)		
Trona	81.0	billion tons[8]
Mixed trona and halite	52.7	billion tons[8]
Total	133.7	billion tons

URANIUM

Remaining Resource (December 31, 1989)	1.99	billion pounds U_3O_8[9]
Remaining Reserve Base (December 31, 1989)		
Uranium oxide recoverable at $30.00 per pound	66	million pounds[9]

OIL SHALE

Original Resources (January 1, 1981)		
Identified (Discovered)	320	billion barrels of shale oil[10]

[1] Modified from Barlow, J.A., Jr. and Doelger, M.J., 1983, Wyoming mineral resources: Barlow and Haun, Inc., Casper, 14 p.
[2] Modified from Energy Information Administration, 1993, U.S. crude oil, natural gas, and natural gas liquids reserves: 1992 Annual Report, October, 153 p.
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[6] Modified from Wood, G.H., Jr. and Bour W.V., III, 1988, Coal map of North America: U.S. Geological Survey Special Geologic Map, 1:5,000,000-scale (color) and 44 p. pamphlet.
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WYOMING MINERAL EXPLORATION-1993

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METALS AND PRECIOUS STONES

Diamonds dominated much of the exploration activity in Wyoming during 1993. More than a dozen companies from the U.S., Australia, and Canada, obtained land positions in the Colorado-Wyoming State Line district in southeastern Wyoming and in northern Colorado. And over 100,000 diamonds have been recovered from the district, making this region the most productive diamond district in North America. Additional activity was reported in the Green River Basin of southwestern Wyoming.

The interest in the State Line district was stimulated by the presence of as many as 35 kimberlite diatremes and dikes. Many of these have yielded diamonds. Grades of some tested kimberlites have ranged from 0.005 to 1.351 carats/tonne.

Testing continued along the state line on a group of kimberlites (and associated alluvial deposits) known as the Kelsey Lake intrusives. In a press release by Redaurum Red Lake Mines Limited (RRLML) of Toronto (August 24, 1993), it was reported that a bulk sample of the two largest Kelsey Lake kimberlites yielded a total of 58.3 carats of gem and industrial diamonds.

The results of more recent bulk samples of alluvial material associated with the Kelsey Lake kimberlites were also encouraging. RRLML reported (November 4, 1993) that the Kelsey Lake joint venture recovered the largest reported diamond from the State Line diamond district, to date. The gem quality stone weighed 6.2 carats. Another alluvial sample yielded a 1.1 carat gemstone.

According to RRLML, the Kelsey Lake project has now produced 268 diamonds larger than 2 mm from kimberlite and associated alluvium. Of these, 60% are gem quality and 25% weigh more than one carat. The project manager of the joint venture, the Colorado Diamond Corp., advised Redaurum Red Lake Mines that it would expand its diamond recovery plant during the 1993-94 winter in preparation for a 100,000-tonne (110,250-short ton) trial mining program to commence in the Spring of 1994.

Royal Star and its associates obtained exploration rights on the Sloan 1 and 2 kimberlite diatremes in the Prairie Divide region in the southern portion of the State Line district in Colorado. Previous testing of these intrusives in the early 1980s yielded grades of 0.061 to 0.253 carat/tonne. The Royal Star venture is driving an adit to test the various phases of the kimberlite.

In the early 1980s diamonds recovered from the Schaffer-Aultman kimberlite intrusives north of the Kelsey Lake kimberlites by Cominco American Inc., included several gemstones. The largest was a 0.86 carat gem. The testing of this property yielded grades of 0.005 to 0.01 carat/tonne. Additionally, an airborne INPUT survey over the region in the early 1980s suggested the presence of several pipes along the northern edge of the district. Although none of these anomalies have been investigated, this area was acquired by Fleck Resources of Vancouver. Fleck Resources was reportedly collecting stream-sediment samples in the district as well as farther north in the Wyoming craton.

Exploration was also reported by several companies north of the State Line district within the Laramie Mountains. This activity was the direct result of previous stream-sediment sampling surveys conducted by the Wyoming State Geological Survey over a 12-year period and published as Open File Report 88-11 (revised in 1993). The State Geological Survey has identified 300 kimberlitic heavy mineral anomalies in the southern and central Laramie Mountains in more than 1,600 stream-sediment samples. Several of these anomalies were identified in the Archean craton. Some additional anomalies were also detected in the Medicine Bow and Seminoe Mountains to the west, within the craton.

Similar heavy mineral anomalies have been identified in the southern Green River Basin of southwestern Wyoming. Some exploration was reported in the southern portion of the basin where chromian diopside and pyrope garnet grains up to 6 mm (0.25 in.) have been recovered from anthills and roadcuts. The surface extent of these anomalies covers many square miles and lies within the craton.

Four companies also obtained property positions in the Leucite Hills of the Green River Basin during 1993. The Leucite Hills encompasses one of the largest lamproite fields in the world. The Wyoming State Geological Survey is currently processing a bulk sample of olivine-bearing lamproitic agglomerate from the Leucite Hills. The testing is part of a grant-related project funded by Union Pacific Resources to study the diamond potential of the lamproites.

During 1993, the Wyoming State Geological Survey also began mapping in the historical Jelm Mountain district in the Medicine Bow Mountains of southeastern Wyoming. The Jelm Mountain district consists of an isoclinally folded metamorphosed succession of amphibolite-grade volcanogenic gneisses and schists. The succession is part of a larger Proterozoic succession of island arc volcanogenic schists and gneisses found in the southern portion of the Laramie, Medicine Bow, and Sierra Madre mountains. Samples collected from various prospects in 1993 yielded 26 ppm to 1.39% Cu, none to 0.1% Pb, 29 ppm to 0.43% Zn, none to 4.0 ounce/ton (opt) Ag, and none to 0.07 opt Au. The area was explored by Red Mountain Mining Co. in 1992 and 1993.

During the 1993 field season, the Wyoming State Geological Survey also completed mapping of 40 square miles of previously undifferentiated Archean rocks of the Rattlesnake Hills supracrustal terrane in the Granite Mountains.

The Rattlesnake Hills are part of a greenstone belt located 50 miles west of Casper, Wyoming. Assays of metachert from this terrane ranged from <0.2 to 2.0 ppm Ag, <5 ppb to 7.55 ppm Au, 38 ppm to 0.04% Cu, 11 ppm to 0.13% Pb, and <0.010 ppm to 0.021 ppm Hg. The mineralization is Archean with possible overprinting during the Tertiary.

Samples of brecciated metamorphics yielded <5 to 925 ppb Au and 37 ppm to 0.14% Cu. Some samples yielded anomalous arsenic (25 ppm to 1.65%) and mercury (0.012 to 0.078 ppm). Samples of a breccia vein within this disrupted succession yielded 92 to 367 ppb Au. The Tertiary volcanics, which disrupted the Precambrian rocks, are also anomalous. Composite chip samples of volcanic rock collected along the flank of Sandy Mountain yielded 44 ppb and 370 ppb Au.

Samples of banded iron formation (BIF) yielded <5 ppb to 5.0 ppm Au, and a sample of the gneiss in contact with the supracrustals yielded 300 ppb Au.

The preliminary results verify the presence of anomalous gold in Archean structures as well as in the Tertiary volcanics, breccias, and jasperoids in the district. Economic interest in the Rattlesnake Hills had been minor until significant gold anomalies were independently identified by the Wyoming State Geological Survey in 1982, and by the American Copper and Nickel Co. in 1983. Currently, three companies are exploring this terrane.

The Absaroka Mountains in northwestern Wyoming continued to generate some interest for copper, gold, and silver. The Absaroka Mountains represent a deeply dissected Tertiary volcanic plateau with several mineralized porphyries.

Of principal interest is the Kirwin porphyry located southwest of Cody. This property was held by Amax Exploration for nearly 30 years. According to the company reports, Amax outlined in-place reserves totaling 196 million tons of ore averaging 0.505% Cu and 0.022% Mo at a 0.3% Cu cutoff grade with by-product credits in Au and Ag. A 1991 study indicated the deposit was amenable to in-situ leaching at recovery costs of $0.309 per pound of copper (Ora Rostad, pers. comm., 1992). The property was sold to the Mellon Foundation, which subsequently donated it to the U.S. Forest Service. According to the Forest Service, the property is now held in Acquired Land Status.

Some company interest was generated by field investigations conducted by the Wyoming State Geological Survey on the Quaking Asp Mountain silicified zone located 10 miles south of Rock Springs. The silicified zone covers an area of 30 square miles and continues to a minimum depth of 3,700 feet based on oil and gas drilling logs. The silicified zone includes secondary kaolinite, alunite, travertine, free sulfur, banded chert, and jasperoid. A seismic profile through the hill suggests the presence of a shallow intrusive.

Samples taken from the silicified zone by the State Geological Survey showed enrichment in Ag, Cu, Zn, Pb, Mo, and As comparable to epithermal gold

deposits reported elsewhere in the U.S. The Sb, Hg, and Au contents; however, are comparatively low. Gold was detected in 18 of 110 chip samples, but the values were very low (trace to 0.110 ppm). To date, no bulk samples have been taken.

A study of the Seminoe Mountains greenstone belt in southeastern Wyoming was completed by the Wyoming State Geological Survey and published in the Wyoming Geological Association's annual field conference guidebook for 1993. The results of the two-year study indicate that the Seminoe Mountains consist of a folded succession of metabasalt, amphibolite, peridotitic and basaltic komatiite, metapelite, and banded iron formation (BIF).

Numerous altered BIF samples were collected throughout the district. These yielded anomalous gold (none to 1.36 opt), silver (trace to 0.5 opt), and a zinc anomaly (0.28%). Some amphibolites mapped near the western edge of the district are moderately to pervasively altered to chlorite, carbonate, actinolite, and epidote. Vein samples from this area ranged from <0.05 ppm to 89.3 ppm Au, <1.0 to 55.0 ppm Ag, 0.03 to 3.75% Cu, 3.0 ppm to 0.39% Pb, and 22 ppm to 4.3% Zn. Two altered wallrock samples were assayed: one limonite-stained metatholeiite with secondary quartz yielded 9.8 ppm Au, 12.0 ppm Ag, and 0.81% Cu. Another sample of chloritized metatholeiite yielded 0.12 ppm Au, <1.0 ppm Ag, and 0.09% Cu.

A sample collected from a paleoplacer along the northern flank of the Seminoe Mountains yielded some gold as well as several purple and lavender pyrope garnets and some chromian diopside. The source of these heavy minerals is probably the Bradley Peak area along the western edge of the district.

The Copper King prospect in the Silver Crown district in the southern Laramie Mountains was explored by Compass Minerals in 1993. The property is interpreted as a low-grade, Proterozoic-age, Cu-Au porphyry. Based on previous exploration efforts in the area, the deposit is mineralized over a 600 by 300 feet area with potential for expansion. Previous drilling on the property outlined a 35-million-ton ore body averaging 0.21% Cu and 0.022 opt Au. A higher grade 4.5-million-ton core averages 0.044 opt Au.

In 1993, some interest was also reported in the South Pass greenstone belt in the Wind River Range of western Wyoming. According to the *Northern Miner* (July 12, 1993), Hol-Lac Gold Mines was negotiating for financing to continue sampling and drilling the historical Carissa gold mine. Earlier work by Hol-Lac showed the Carissa shear continued to a depth of at least 150 feet below the old mine workings. At 650 feet below the surface, Hol-Lac intersected an 80-foot-wide shear zone that yielded values ranging from a trace to 2.5 opt Au.

Earlier sampling of the shear zone by the Wyoming State Geological Survey identified a 100-foot-wide mineralized shear. The Carissa gold mine was Wyoming's most productive historical gold mine.

A second Canadian company picked up an option on another gold property within the greenstone belt. Exploration on this property will search for the source of a large auriferous paleoplacer.

INDUSTRIAL MINERALS

In 1993, there was exploration activity for bentonite, construction aggregate, decorative aggregate and decorative stone, limestone, trona, and zeolites in Wyoming. There were also inquiries about silica sand, mica, and vermiculite.

All five of the producing soda ash companies in Wyoming have expressed interest in leasing additional trona in a proposed Federal lease sale, now scheduled for 1994 or 1995. U.S. Borax and Church & Dwight, though not presently mining trona in Wyoming, also showed interest in the leases. In addition, Wold Minerals continued with its development plans to open a sixth trona mine and a refinery.

Property acquisition by bentonite companies slowed considerably in 1993. Also, The Bentonite Corp. sold its Colony mill and Wyoming mining properties to NL Baroid.

In 1993, Lamb Construction sold its limestone and other aggregate production to Pete Lien, Inc. The National Park Service explored for construction aggregate both in Grand Teton National Park and in Yellowstone National Park for in-park road construction projects. A quarry was opened in talus from Tertiary volcanic rocks west of Sylvan Pass, near the East Entrance to Yellowstone. In Grand Teton, an environmental assessment of several aggregate sites in the park was prepared and distributed for public comment.

There was continued exploration for high-calcium limestone in Wyoming in 1993. Dakota Lime opened a lime plant at Frannie, early in the year. Their limestone source; however, is from a quarry in Montana. Mountain Cement at Laramie continued to test nearby limestone deposits for future expansion.

For the past four years, exploration for decorative aggregate and decorative stone has increased in Wyoming. In 1993, Sunrise Stone completed exploration and development of a swirled pink and grey gneiss, which it began marketing under the name "Fantastica". Sunrise Stone also began constructing a fabricating plant 20 miles from its "Wyoming Raven" and "Fantastica" quarries. Mesa Marble Co. of Powell, explored for and began limited production of a brown marble and flagstone quarry near Tensleep. Western Aggregates of Boulder, Colorado, applied for exploration permits on two sources of white quartz. Gideon Stone Co., Ltd., and Firmhold International, Inc., both of Taiwan, explored for red and black granites for Taiwan markets. At year's end, Georgia Marble's parent company, First Chicago Corp., sold Georgia Marble to Ifint, S.A., a European investment concern. Georgia Marble is headquartered in Kennesaw, Georgia, and has operations in six states, including the white marble

aggregate operation at Wheatland, Wyoming. The company will still operate under the name Georgia Marble.

There was considerable interest in zeolites in 1993, and three companies studied and sampled surface occurrences. The zeolite deposits that received the most interest were located in the Washakie Basin southeast of Rock Springs. Unfortunately, investment interest and development of these deposits is thwarted by an existing oil shale withdrawal, which prohibits the location of claims for zeolites and other minerals.

By year's end, several companies had contacted the Wyoming State Geological Survey regarding interest in Wyoming's silica sand, mica, or vermiculite occurrences and resources. Two of these companies scheduled field exploration for silica sand for the spring of 1994; another two plan to investigate mica occurrences; and two others firmed up visits to inspect occurrences of vermiculite in the summer of 1994.

COAL

Although annual coal production in Wyoming rose from 189.5 million tons in 1992 to a record high of 209.9 million tons in 1993, there was very little if any actual exploration for coal in Wyoming in 1993. Activities regarding new Federal coal leases provide the best indication of interest in new properties or property expansions. The most lease activity is still in the Powder River Basin where there were five pending lease applications.

In 1991, Meadowlark Farms, a subsidiary of Amax Coal Company, applied for a Lease by Application (LBA) sale to expand its Federal lease at the Eagle Butte mine in central Campbell County. The new lease would add approximately 150 million tons of coal to the Eagle Butte property. Public comment on the environmental assessment for this sale ended on December 31, 1993, with a tentative sale date set for late in 1994.

Similarly, in 1992, SMC Mining Co., a subsidiary of Zeigler Coal, applied to the U.S. Bureau of Land Management (BLM) asking the BLM for the "North Roundup" LBA sale of 140 million tons of coal adjacent to their North Rochelle mine in southern Campbell County. Officials from Zeigler feel the mining of this coal might begin as early as 1996.

Carter Mining is still negotiating with the BLM in regard to a 1992 application for a bypass lease. If approved, the new lease would add about 20 acres to their Caballo mine property in central Campbell County. The BLM cannot modify the lease nor order Carter Mining to mine coal that might be bypassed until they receive a fair market value bonus from Carter Mining. If the BLM and Carter Mining cannot agree on a bonus amount, one million tons of coal will be bypassed. This tonnage is less than one month of production from the Caballo mine.

Kennecott Coal also filed an LBA in 1992 for a possible bypass lease tract with an estimated 60 million tons of coal. A public scoping meeting on this proposed sale was set for early in 1994. The environmental assessment for this tract, which is adjacent to Kennecott's Antelope mine in northern Converse County, will commence in the Spring of 1994.

In December of 1993, the BLM approved Northwestern Resources' application for the Rocky Butte lease tract in Campbell County. This lease combines an old and a new lease into a new logical mining unit (LMU), which now contains an estimated 575 million tons of coal. Northwestern's proposed mine is planned to start before the end of this decade.

In another area of the State, Energy International's December submittal of the "Indian Springs" LBA was ruled deficient by the BLM. This LBA, which is located in the Green River Basin, involves in-situ gasification of the coal reserves. The BLM indicated that additional data were needed from Energy International before the application could be processed.

The BLM also announced that it was reviewing its rules on "leasing by application", "due diligence", the formation of "logical mining units", and the awarding of leases that are under appeal to the Interior Board of Land Appeals (IBLA).

In February of 1993, PacifiCorp sold its 82% share of Nerco, Inc. to Kennecott Coal Corp. which is owned by Britain's RTZ Corp. With this sale, Kennecott Coal now owns the Antelope mine in Converse County. In 1992, Kennecott also purchased Sun Co.'s Cordero mine in Campbell County.

In June of 1993, two leading U.S. mining companies with coal mines in Wyoming merged to form the nation's second largest coal company. Amax Inc. of New York and Cyprus Minerals Co. of Englewood, Colorado, combined to form Cyprus-Amax, which now produces over 70 million tons of coal a year.

In regard to coalbed methane, the BLM approved Metfuel Wyoming, Inc.'s Hanna Basin Coalbed Methane Project in an area about 7 miles north of Hanna in Carbon County. The project will begin with a 32-well pilot program with additional drilling to be done in phases. Metfuel plans to drill 123 coalbed methane wells on 160-acre spacing over the next four years. In addition, Texas-based, Tiger Oil Co., drilled some exploratory coalbed methane holes near Gillette, and Martens and Peck, a Denver-based firm, also drilled two more coalbed methane holes in the Gillette area.

URANIUM

Although there was no exploration for new uranium occurrences in 1993, property sales increased. Total Minerals, a subsidiary of Electricitié de France, was purchased by COGEMA Resources, Inc. about mid-year. CAMECO, a large Canadian uranium mining company, acquired property in the Pumpkin

Buttes and Shirley Basin areas of Wyoming. Energy Fuels Nuclear acquired the Reno Ranch property southeast of the Pumpkin Buttes from Union Pacific Railroad—Minerals, and they are considering the construction of an in-situ production facility on the property.

The Green Mountain Mining Venture (GMMV) continued to develop its Jackpot underground mine on Green Mountain south of Jeffrey City. Permitting and environmental assessment work occupied the GMMV for most of 1993.

GEOLOGIC MAPPING AND STRATIGRAPHY

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

LARAMIE AREA MAPPING FUNDED

The Wyoming State Geological Survey recently received $12,000 to support geologic field mapping in the Laramie Basin of Albany County. The Geologic Mapping Section applied for funding through the State Geologic Mapping Program (STATEMAP), which is administered by the U.S. Geological Survey. STATEMAP is a component of the National Geologic Mapping Act of 1992 in which States and the Federal government share dollar for dollar in the cost of geologic mapping projects. For the 1994-1995 funding period, there was approximately $1.65 million available to State Geological Surveys for these kinds of proposals.

The awarded funding will support geologic mapping in the Laramie area. Mapping of the Laramie 1:24,000-scale quadrangle (**Figure 26**) will begin in the first year of a three-year project in which a total of six 1:24,000-scale quadrangles will be mapped. After these maps are completed, they and other existing mapping will be compiled at 1:100,000-scale to produce the Laramie 30' X 60' color geologic map. As they are completed, the 1:24,000-scale quadrangles will be published as Open File Reports.

Very little in the way of published geologic mapping exists for much of the area included in the Laramie (1:100,000-scale) Quadrangle and the city of Laramie is the only larger city in Wyoming without a published larger scale geologic map to cover it. Accurate geologic information enhances the chances of finding good water well sites in the area, aids in the location of needed sand, gravel, limestone, and other construction materials, and helps in land-use planning.

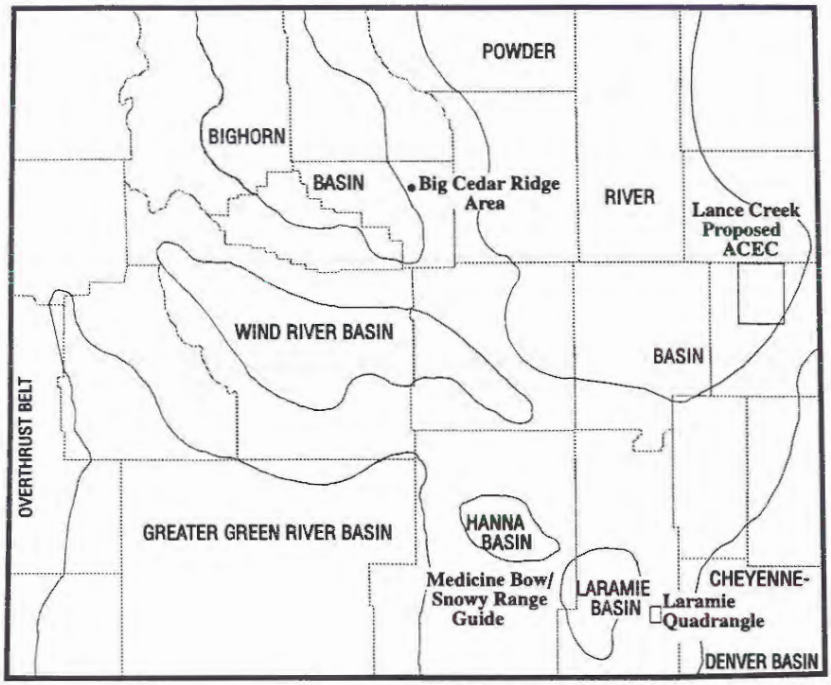


Figure 26. Index to selected geologic activities and recently released maps and reports on Wyoming geology.

FOSSIL PROTECTION IN BIG CEDAR RIDGE AREA

The U.S. Bureau of Land Management (BLM) recently announced intentions to protect the unique fossil plant remains located in the Big Cedar Ridge area southwest of Tensleep, Wyoming (**Figure 26**). Julie Coleman-Fike of the Worland BLM office, indicated that these well preserved plant fossils resulted from quick burial due to a volcanic ash fall during Early Cretaceous time. The fossils are found in the Upper Cretaceous Meeteetse Formation, which is more than 72 million years old. Over 100 new fossil plant species have been identified by scientists working in this area.

The area is temporarily withdrawn for two years while the feasibility of permanent withdrawal is evaluated by the BLM. If permanent withdrawal is utimately approved, the land would be removed from settlement, sale, location, or entry under the general land laws, including mining laws, for a period of 20 years. The BLM is taking comments on the proposed withdrawal until May 5th.

LANCE CREEK ACEC PROPOSED

The U.S. Bureau of Land Management (BLM) recently proposed designation of more than 560 square miles in Niobrara County as an Area of Critical Environmental Concern (ACEC) to help protect the paleontologic values in the area. This area, located north of the town of Lance Creek (**Figure 26**), was designated as the Lance Creek National Natural Landmark in 1966. The first horned dinosaurs as well as the first Cretaceous mammals 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. The University of California, alone, has collected more than 30,000 fossil vertebrates representing at least 75 species from these deposits.

The area's present designation as a National Natural Landmark, includes stipulations on activites that disturb the surface in an effort to protect undiscovered fossils. Designating the area as an ACEC apparently will not create additional protection for fossils, but it will require an inventory of the paleontologic resources. Governor Sullivan and others have expressed concern regarding the large size of the proposed ACEC and the potentially high cost for the management and the inventory of the area.

SNOWY RANGE SCENIC BYWAY REPORT AND EARTHQUAKE EPICENTERS MAP PUBLISHED

Two new geologic reports, Public Information Circular (PIC) 32 and Open File Report (OFR) 94-1 have recently been published by the Wyoming State Geological Survey. PIC 32 is a comprehensive description of the geology, mining districts, and ghost towns of the Medicine Bow Mountains and the Snowy Range Scenic Byway in southern Wyoming (**Figure 26**). It is an excellent publication for anyone interested in the economic and general geology and history of the Snowy Range area. OFR 94-1 discusses earthquake epicenters and active faults with surface expression in Wyoming and is an update and revision of OFR 90-10. The complete citations for these two new publications are given on p. 61 of this issue.

GEOLOGIC HAZARDS IN WYOMING

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

EARTHQUAKES IN THE STAR VALLEY AREA

Since January 30, 1994, a series of earthquakes have been felt in the Star Valley area in western Wyoming. A few have caused minor damage, including the largest, a magnitude 5.9 event on February 3, 1994. Many of the aftershocks from the February 3rd quake; however, were too small to be felt.

There have been some conflicting reports on the locations of these earthquakes. Some reports have the larger events in Wyoming (**Figure 27**), and some have them in Idaho (**Figure 28**). The reasons for the differences in locations are complex, and perhaps not even completely understood, but there are a few possible explanations.

In order to accurately determine the location and depth of an earthquake, readings from a number of seismic stations are required. A seismic station

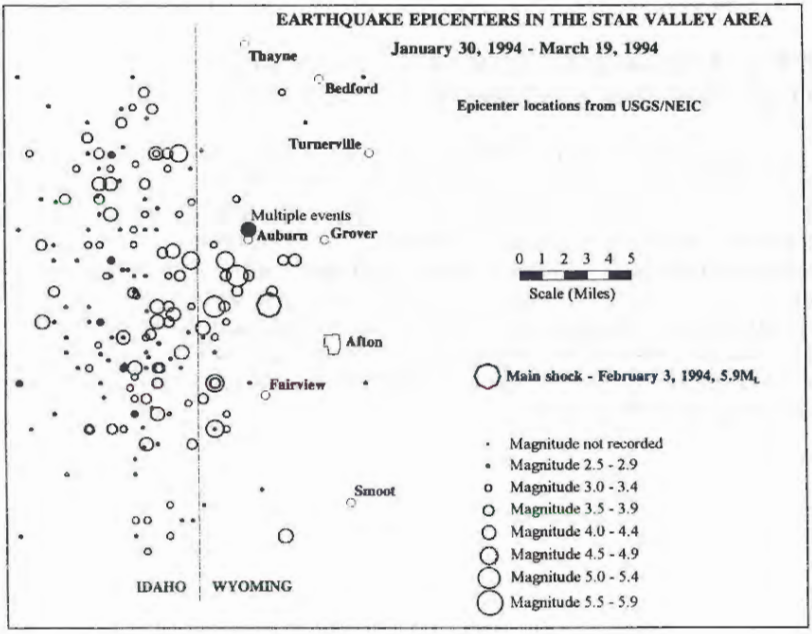


Figure 27. Locations of the National Earthquake Information Center's epicenters for the January 30-March 19, 1994, earthquakes in the Star Valley area of Wyoming and in adjacent portions of Idaho.

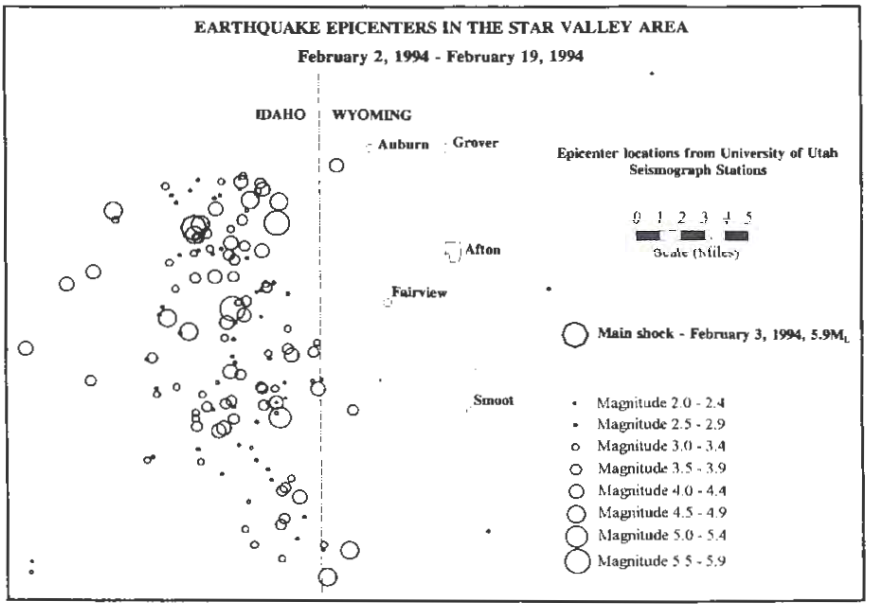


Figure 28. Locations of the University of Utah's epicenters for the January 30-March 19, 1994, earthquakes in the Star Valley area of Wyoming and in adjacent portions of Idaho.

usually has a few seismic wave detection and recording instruments as well as a transmitter to relay the information. After the data on an earthquake are collected, seismologists use that data to determine the earthquake's location. In order to analyze the data, the seismologists have to use velocity models that they have generated for the area of concern. A velocity model may include known information on the local and regional geology, as well as the seismic wave transmission properties of bedrock and surficial materials. When possible, information on known faulting and other features, such as the presence of magma chambers, may be included in the model.

As mentioned above, seismologists collect and analyze data received from their seismic stations. In or near Wyoming, there are a number of seismic stations and networks (**Figure 29**). The University of Utah operates networks in Yellowstone National Park as well as throughout Utah; the U.S. Bureau of Reclamation operates a network in the Jackson Lake area; the Idaho National Engineering Laboratory operates a network in southeastern Idaho; Ricks College operates a few stations in western Wyoming and eastern Idaho; and the Montana Bureau of Mines and Geology operates a network in Montana. The U.S. Geological Survey's National Earthquake Information Center (NEIC), in addition to financially supporting a few of the above networks, also operates a small network in Boulder, Wyoming. The NEIC also receives data from a portion

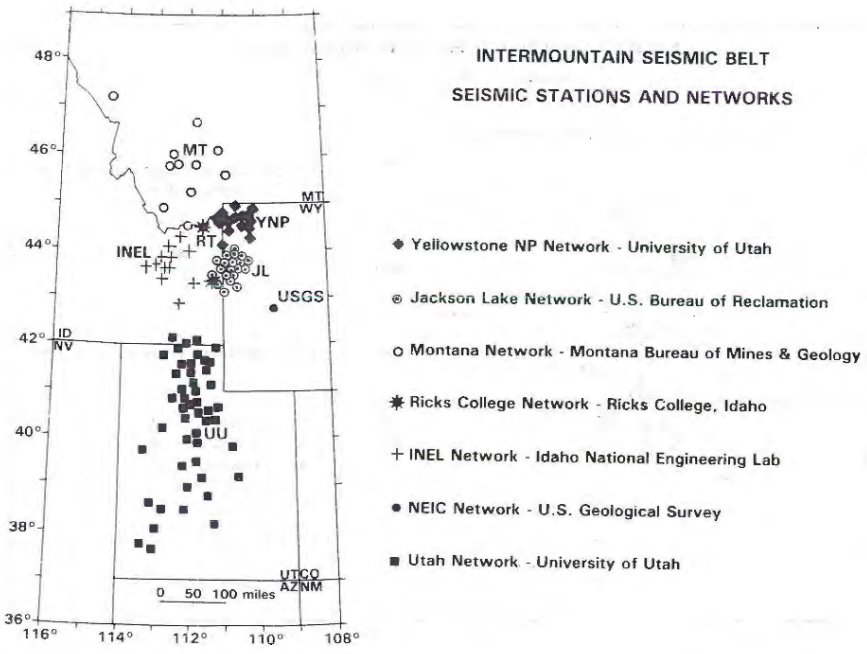


Figure 29. Permanent seismic stations and networks in the Intermountain Seismic Belt.

of the University of Utah network and periodic updates from the U.S. Bureau of Reclamation.

If a seismic network is not in the immediate vicinity of an earthquake, the earthquake will not be as accurately located as when a network is right on top it. In the case of the recent earthquakes felt in the Star Valley, there were no existing networks on top of the epicentral areas. The U.S. Bureau of Reclamation and the University of Utah had the nearest networks, but they were still miles away from the February 3, 1994, magnitude 5.9 main shock. The NEIC Boulder, Wyoming, site was even farther away from the epicentral areas. As a result, there were some differences in the location of the main shock. This was further compounded by the slightly different velocity models that are used by the various network operators. After the magnitude 5.9 earthquake, the University of Utah set up a series of portable seismic stations in the Star Valley, Wyoming, to Draney Peak, Idaho, area. The portable stations provided more accurate locations and depths for the earthquakes that followed the main shock.

In an effort to minimize reporting differences in the future, the Wyoming State Geological Survey has contacted all the networks about options that may

increase information exchange and provide more consistent reporting of earthquake epicenters. For further information on the recent earthquakes that were felt in the Star Valley area, contact Jim Case at (307) 766-2286.

NEW PUBLICATIONS OF THE WYOMING STATE GEOLOGICAL SURVEY

Geology of Wyoming, dedicated to Donald L. Blackstone, Jr., and J. David Love, edited by A.W. Snoke, J.R. Steidtmann, and S.M. Roberts: Memoir 5, 1993.- $75.00 plus postage and handling. Wyoming addresses include 6% sales tax before adding postage. Add first class postage of $5.00 (Wyoming), $10.00 (other states), and $20.00 (International, including Canada).

Guide to the geology, mining districts, and ghost towns of the Medicine Bow Mountains and Snowy Range Scenic Byway, by W.D. Hausel: Public Information Circular 32, 1993.-$10.00

Sixtieth Annual Report of the Geological Survey of Wyoming, Fiscal Year 1993, by G.B. Glass and S.G. Bruhnke.-free.

*Open File Report 94-1. Earthquake epicenters and suspected active faults with surficial expression in Wyoming, compiled by J.C. Case, L.L. Larsen, C.S. Boyd, and J.C. Cannia. (Revision of OFR 90-10).-$3.00.

*Reprint 55. Changing ideologies in Wyoming coal petrography, by J.C. Shearer:-$3.00.

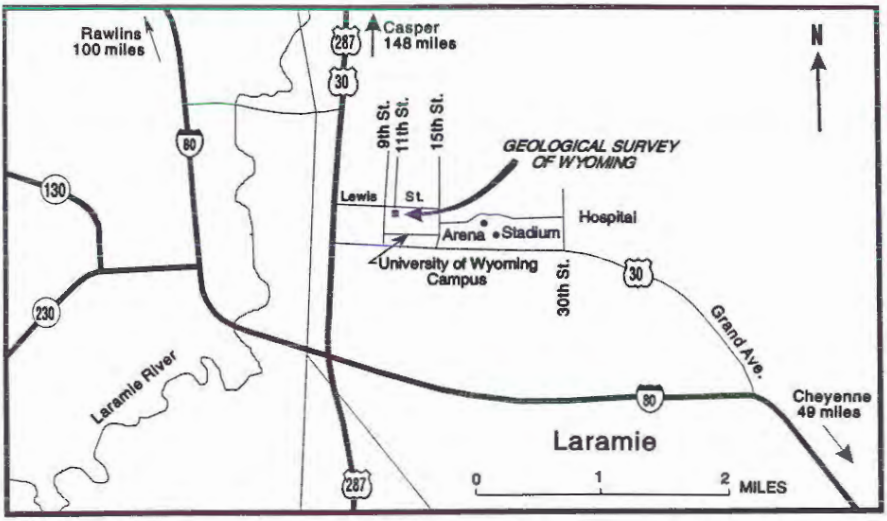
*Reprint 56. Mining history and geology of some of Wyoming's metal and gemstone deposits, by W.D. Hausel.-$3.00.

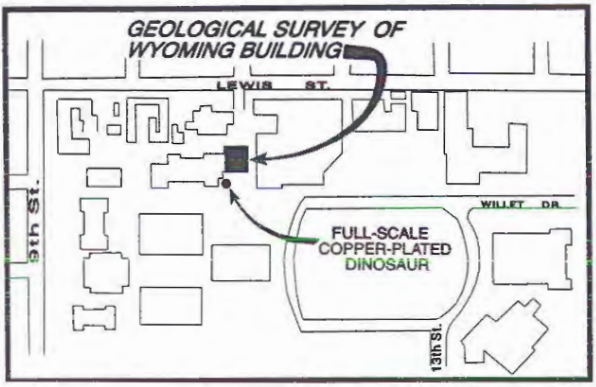
*New releases since the last issue of *Wyoming Geo-notes*.

The Wyoming State Geological Survey sells the Atlas of Major Rocky Mountain Gas Reservoirs, a publication prepared by the state geological surveys of New Mexico, Colorado, Utah, and Wyoming.- $99.75. Available over-the-counter or PREPAID, by mail from the Wyoming State Geological Survey in Laramie. Checks must be made out to: New Mexico Bureau of Mines and Mineral Resources. (Price includes postage and handling).

"Order these and other publications from: Wyoming State Geological Survey, P.O. Box 3008, University Station, Laramie, Wyoming 82071-3008. Phone: (307) 766-2286. Many of these publications are also available over-the-counter at the Wyoming Oil and Gas Conservation Commission (Basko Building) in Casper, Wyoming."

WYOMING STATE GEOLOGICAL SURVEY
LOCATION MAPS





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