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The Geological Survey of Wyoming
Gary B. Glass, State Geologist

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WYOMING GEO-NOTES
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Cover: Slump structures in Cretaceous rocks just east of Rock Springs, Wyoming along Interstate-80. Person for scale is 1.59 m in height (Photo by T.A. Moore). See p. 54 of this issue of *Wyoming Geo-notes* for more details. .

The Geological Survey of Wyoming
P.O. Box 3008, University Station
Laramie, Wyoming 82071-3008
(307) 766-2286
FAX (307) 766-2605

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MINERALS UPDATE

OVERVIEW

by Gary B. Glass
State Geologist, Geological Survey of Wyoming

Based on preliminary figures for 1992, our revised forecast for natural gas in the last issue of *Wyoming Geo-notes* fell short by about 11.75 billion cubic feet. Total production of natural gas in Wyoming, including carbon dioxide and helium, was a record-setting 1,011.75 billion cubic feet, which was a five percent increase over 1991 (**Table 1** and **Figure 1**). Developments in natural gas are the bright spots in Wyoming's energy industry right now. There are new pipelines and new gas processing plants planned, and development drilling continues, especially in the Greater Green River Basin. The outlook for natural gas remains bright with production increases forecast and with a much strengthened price (**Table 2** and **Figures 2** and **3**). Spot gas prices at Opal, for example, averaged $1.88 in the first quarter of this year.

Although our production forecast for oil was revised downward in the last quarter, it was not lowered quite far enough. In 1992, oil production from Wyoming slipped under 97 million barrels, to 96.8 million barrels (**Table 1** and **Figure 4**). This is a three percent decrease in oil production from 1991 and continues the

Table 1. Wyoming mineral production, with forecast to 1995[1].

Calendar Year	Oil[2]	Natural Gas[3]	Carbon Dioxide[4]	Helium[5]	Coal[6]	Trona[6]	Mined Uranium[7,8]	In-situ Uranium[9]	Sulfur[10]
*1981	122.1	408.4	—	—	102.8	11.8	4.6	—	0.05
*1982	118.7	424.7	—	—	107.9	10.1	2.1	—	0.07
*1983	120.9	444.0	—	—	112.2	10.5	3.0	—	0.57
*1984	127.8	516.7	—	—	130.7	11.0	1.6	—	0.71
*1985	131.0	416.6	—	—	140.4	10.8	0.6	—	0.80
*1986	122.4	403.3	23.8	0.15	136.3	11.9	0.2	0.04	0.76
*1987	115.9	498.0	114.2	0.86	146.5	12.4	0.2	0.06	1.19
*1988	114.3	509.1	110.0	0.83	163.6	14.9	0.3	1.16	1.06
*1989	109.1	587.4	126.1	0.94	171.1	16.2	0.1	1.07	1.17
*1990	104.0	692.5	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	*16.1	0.4	1.1	1.18
1992	*96.8	*871.5	*139.2	*1.05	*189.5	16.3	0.1	0.8	1.20
1993	93.1	884.0	140.0	1.00	194.3	16.6	—	0.8	1.20
1994	89.4	909.0	140.0	1.00	199.3	17.0	—	0.8	1.25
1995	85.8	934.0	140.0	1.00	204.3	17.2	—	0.8	1.25

*Actual values for comparison; [1]Geological Survey of Wyoming, April, 1993; [2]millions of barrels; [3]billions of cubic feet (Gross production less carbon dioxide and helium); [4]Billions of cubic feet; [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 percent; [6]millions of tons; [7]millions of tons of uranium ore (not yellowcake); [8]although the Shirley Basin mine is closing in 1992, some production of stockpiled ore may be reported in future years; [9]millions of pounds of yellowcake (U_3O_8), (unknown between 1981-1985 because it was reported only as taxable valuation; estimates for 1991-1995 are based on company information); [10]millions of short tons.

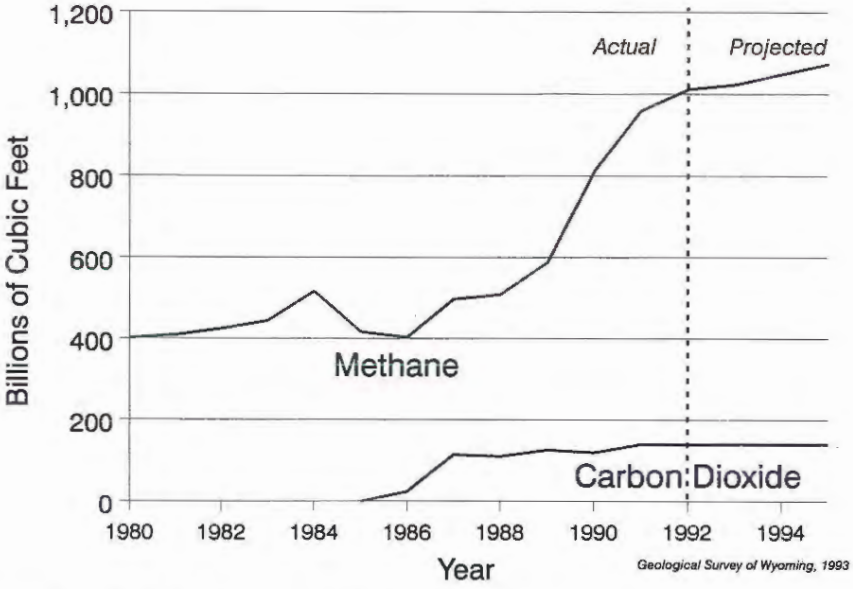


Figure 1. Annual natural gas production from Wyoming (1980 to 1992) with forecast to 1995.

Table 2. Average prices paid for Wyoming oil, methane, coal, trona, and uranium, forecast to 1995[1].

Calendar Year	Oil[2]	Methane[3]	Coal[4]	Trona[5]	Uranium[6]
*1985	23.61	3.03	11.35	35.18	36.82
*1986	13.10	2.51	10.71	34.80	52.45
*1987	16.50	2.02	9.54	36.56	43.55
*1988	13.41	1.74	9.09	36.88	25.77
*1989	16.64	1.64	8.63	40.76	22.09
*1990	20.10	1.54	8.31	41.86	21.16
*1991	14.41	1.44	*8.05	*44.18	21.00
1992	16.38 Prelim.	1.63	7.79	44.50	21.00
1993	15.75	1.80	7.39	46.35	21.00
1994	15.75	2.00	7.19	47.42	21.00
1995	15.75	2.20	7.03	49.00	21.00

* Actual value for comparison.

[1] Adapted from Consensus Revenue Estimating Group, Wyoming State Government Revenue Forecast FY93-FY96, January 12, 1993.

[2] First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Prelim.= Preliminary value.

[3] Wellhead price in dollars per MCF.

[4] Dollars per short ton (weighted average price for coal mined by surface and underground methods).

[5] Dollars per ton of trona, not soda ash.

[6] Uranium prices are all estimated by the Geological Survey of Wyoming; in dollars per pound of yellowcake (weighted average price for in-situ and surface-mined uranium).

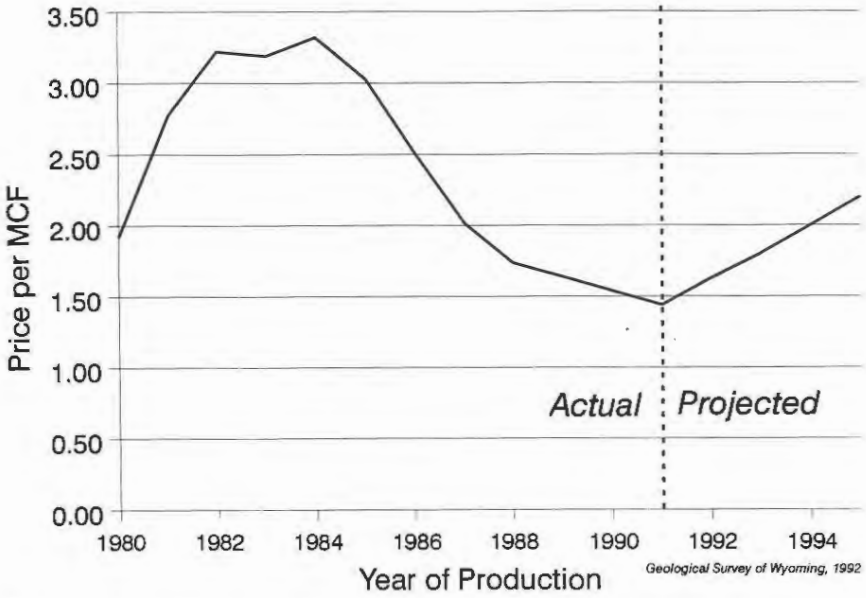


Figure 2. Average prices paid for Wyoming methane gas (1980 to 1991) with forecast to 1995.

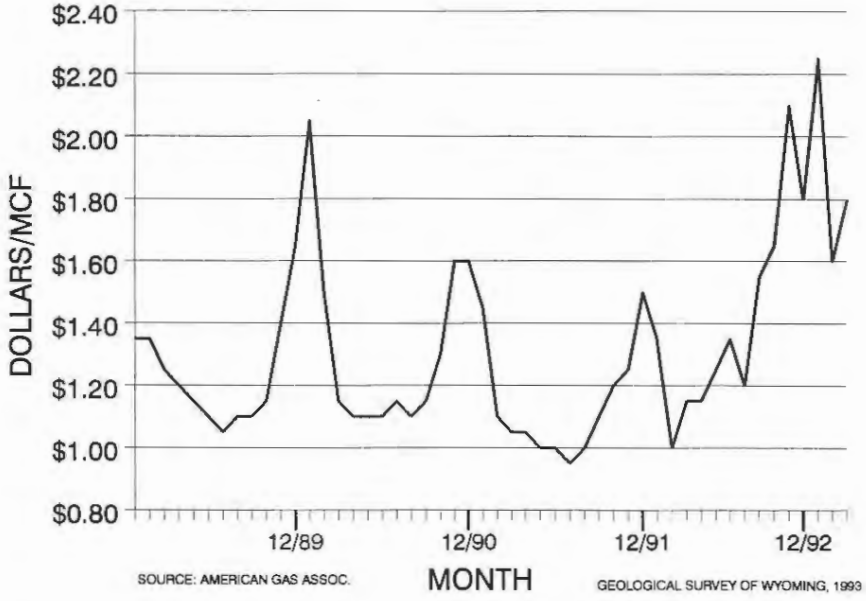


Figure 3. Spot prices for natural gas sales at Opal, Wyoming, averaged by month (1989 to present).

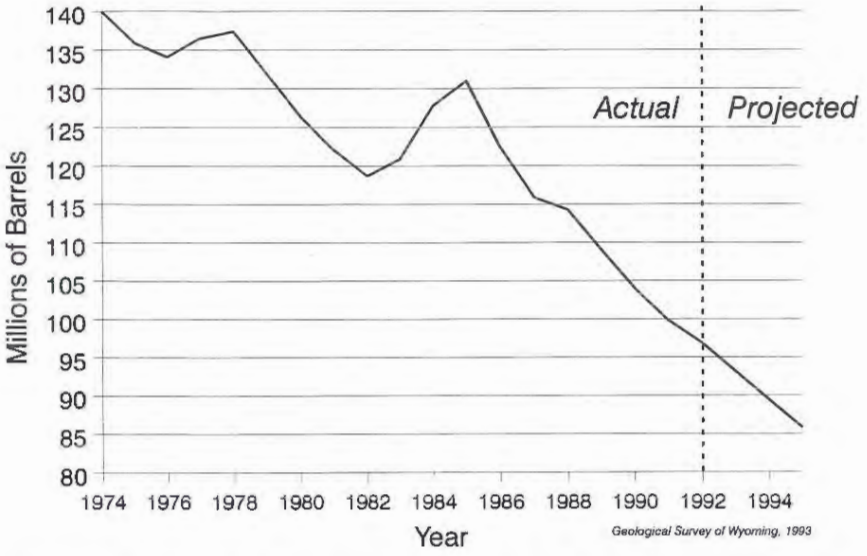


Figure 4. Annual oil production from Wyoming (1974 to 1992) with forecast to 1995.

decline that started in 1986. At least the average oil price increased slightly in 1992 (**Table 2** and **Figures 5** and **6**).

In the case of coal, our guarded optimism that production for 1992 might be somewhat higher than forecast was unfounded. Year-end production from Wyoming was 189.5 million tons or 1.5 million tons less than our forecast and 4.4 million tons less than 1991 (**Table 1** and **Figure 7**). Wyoming did, however, maintain its position as the largest coal producing state.

While this is only the second time since 1967 that annual coal production from Wyoming did not increase over the previous year, the decrease was only a little over two percent. Looking at **Figure 7**, it is obvious that gains in coal production slowed between 1974 and 1975 and again between 1980 and 1983; that 1986 production actually fell below that of 1985; that production gains slowed again between 1988 and 1989; and that production fell below the previous year again in 1992. There is a faint semblance of periodicity in these production trends. All of these changes in rate of increase followed a year (two years in the case of the 1986 decline) of accelerated production. While one can come up with a number of possible explanations for these observations, it does look like what was a decline in the rate of increase in some years may have translated into an actual production decrease in 1986 and 1992. It could be that through the mid-1980s, changes in demand due to weather or stockpiling may have been masked by the signing of numerous contacts, the completion of many new mines, and the commissioning of quite a few new power plants. Now that the number of new mines and new power plants each year have dwindled significantly, relatively

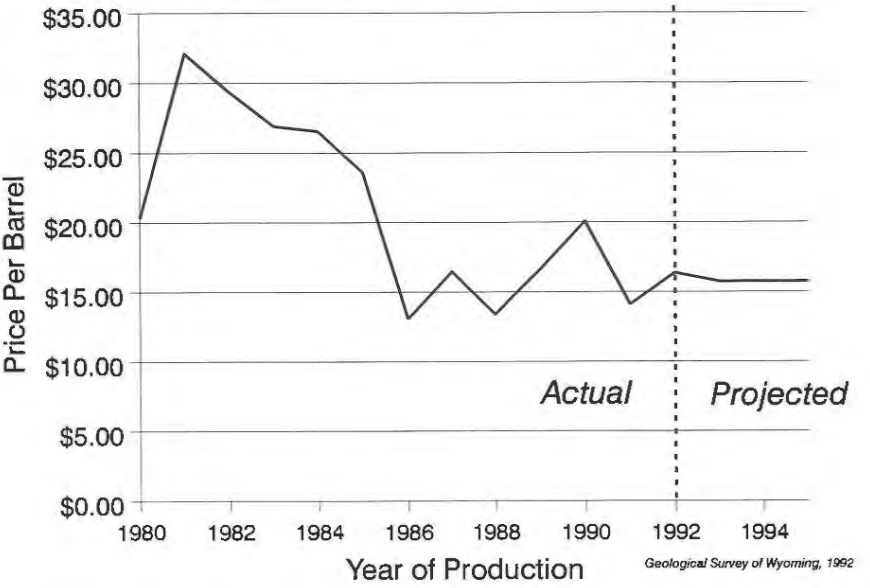


Figure 5. Average prices paid for Wyoming oil (1980 to 1992) with forecast to 1995.

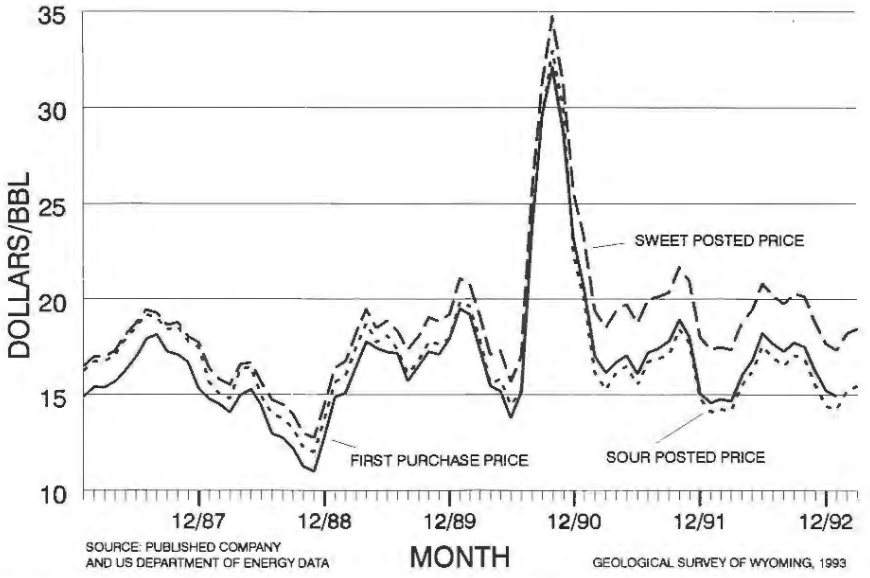


Figure 6. Wyoming posted Sweet and Sour crude prices and first purchase prices averaged by month (1987 to present).

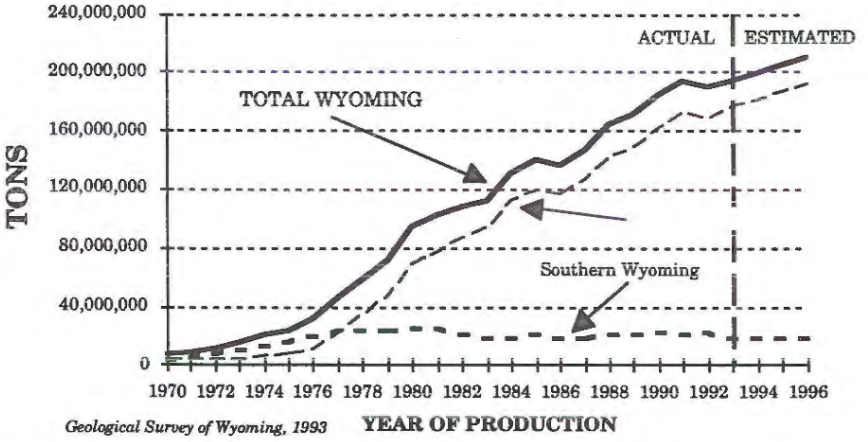


Figure 7. Annual coal production from Wyoming (1970 to 1992) with forecast to 1996.

subtle factors like mild or bad weather will have a more noticeable affect on annual production from Wyoming. Consequently, it does not seem unreasonable to expect 2-3 percent increases and decreases in annual production at least until there is a steady resurgence in new markets for Wyoming coal.

That next resurgence could be in response to the recent amendments to the Clean Air Act. Obviously, 1992 production does not indicate any increase in demand for Wyoming coal, but many changes related to the Clean Air Act could be deferred until 1993 or 1994. Coal forecasts on **Tables 2** and **3** and **Figure 8** have not been revised since last quarter, and there is nothing to suggest that major revisions will be needed.

The **Coal Update** section now includes a tabulated listing of new coal contracts and sales (**Table 10**). This listing is more user friendly and makes it a lot easier to see what is happening in coal marketing. It also now looks like Black Hills Power & Light Co. has gotten permission to build its new unit at the Wyodak mine near Gillette, WY.

The **Industrial Minerals and Uranium Update** notes a milestone in Kennecott Energy's plans to open an underground uranium mine in Wyoming. That milestone was the U.S. Bureau of Land Management's call for public comments in preparation for writing an environmental assessment on the project.

With the exception of a production estimate for decorative stone, there are still no 1992 production figures for industrial minerals or uranium (**Table 4**).

The **Metals and Precious Stones Update** provides some historical and recent information on the Broadway property, a potentially valuable metal deposit in the Sierra Madre. It also notes that a Wyoming gold mine is up for sale.

For those readers interested in radon, the section on **Geologic Hazards** describes the results of a study that might make it easier and more cost effective to delimit an area's potential for the occurrence of radon. This study indicated that ground-based, background gamma-radiation measurements exhibited some observable relationships with both soil-gas radon levels and with radon levels from home sampling.

Table 3. Breakdown of average prices paid for coal from northeastern Wyoming, southern Wyoming, and Wyoming as a whole, with forecasts for 1992 through 1996.

	Northeastern	Southern	Statewide
1988	7.25	21.45	9.09
1989	7.03	20.21	8.63
1990	6.84	19.62	8.31
1991	6.68	19.50	8.05
1992	6.45	19.44	7.80
1993	6.25	19.15	7.39
1994	6.07	19.02	7.19
1995	5.93	18.99	7.03
1996	5.86	18.96	6.93

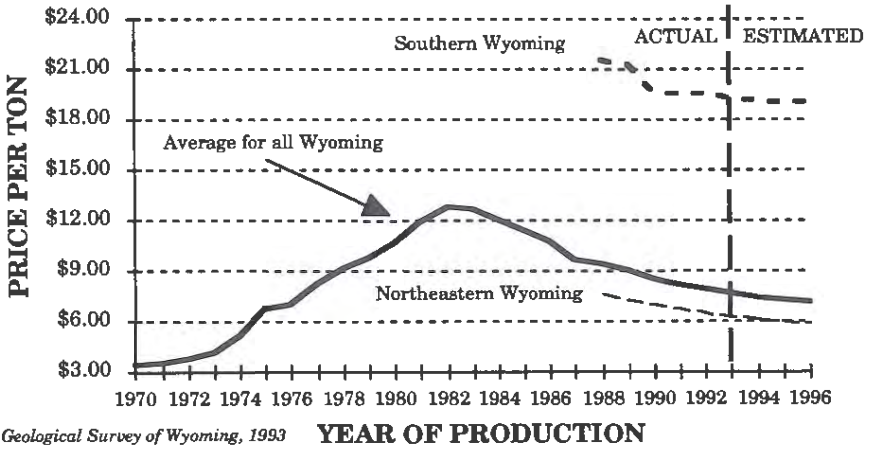


Figure 8. Average prices paid for Wyoming coal (1980-1991 with forecast to 1996 [Data from U.S. Energy Information Administration (1980-1984) and Wyoming Department of Revenue and Consensus Revenue Estimating Group (1985-1996).

Table 4. Production history of selected Wyoming mineral commodities[1].

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Bentonite[2]	2.18	3.08	2.59	1.82	2.16	2.32	2.22[6]	2.43[6]	2.38[6]	
Clay[4]	36.4	59.6	35.9	23.2	1.31	61.1	23.6	---	---	---
Decorative Aggregate[2]	0.07	0.08	0.09	0.07	0.06	0.07[7]	0.06[6]	0.06[6]	0.7[6]	
Decorative Stone	---	---	---	---	---	---	---	---	0.24[7]	0.36[7]
Dolomite[2]	0.66	0.86	0.87	0.81	0.46	0.19[6]	0.15[6]	0.21[6]	0.23[6]	
Gypsum[2]	0.33	0.33	0.35	0.41	0.35	0.40[7]	0.20[6]	0.44[6]	0.42[6]	
Iron Ore[2]	2.48	---	---	---	---	---	minor[8]	minor[8]	---	---
Leonardite[4]	---	---	---	---	---	---	---	22.9[6]	33.3[6]	
Limestone[2,5]	0.56	0.65	0.32	0.33	0.32	0.64	0.60[6]	0.48[6]	0.49[6]	
Construction Aggregate[2,3]	6.72	8.31	6.40	5.01	4.12	3.15	6.46[6]	7.73[6]	8.62[6]	
Shale[4]	---	20.3	14.7	9.88	49.0	50.2	1.8	43.5[6]	158.2	
Sodium Sulfate[4]	3.19	3.25	2.71	2.03	---	2.10[6]	3.2	1.9[6]	1.5[6]	

Sources: [1]Wyoming Department of Revenue, unless otherwise noted. [2]Millions of short tons. [3]Includes ballast, scoria, and limestone used for aggregate. [4]Thousands of short tons. [5]Includes chemical grade limestone used for cement rock, sugar beet refining, and other uses. [6]Wyoming State Inspector of Mines. [7]Estimated by Geological Survey of Wyoming. [8]Less than 1,000 tons of iron ore were sold for pigment. Prepared by Geological Survey of Wyoming, April, 1993.

OIL AND GAS UPDATE

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

In 1992, 1.012 trillion cubic feet of gas were produced in Wyoming. This is the highest gas production in Wyoming's history (**Figure 1**). Also, for the first quarter of 1993, spot gas prices in southwestern Wyoming averaged $1.88 per thousand cubic feet (MCF). This compares with a first quarter average spot price of $1.45 per MCF in 1992 and $1.14 per MCF in 1991. The spot price increased from $1.60 per MCF in February to $1.80 per MCF in March (**Figure 3**). The last increase was caused in part by cold weather in several areas of the U.S. and to the drawdown of stored gas in February.

In addition to the better prices mentioned above, new pipeline capacity will also help Wyoming gas producers. Overland Trail Transmission Co., operated by Union Pacific Resources, is expanding its facilities to handle 100 million cubic feet

of gas per day. About 20 million cubic feet of that capacity is dedicated to the Rhone-Poulenc soda ash plant in the Green River Basin, which is 49 percent owned by Union Pacific. The expansion is scheduled for completion in May, 1993, and will consist of 260 miles of pipeline in Sweetwater and Lincoln counties and an interconnect with the Kern River pipeline, which has a capacity of 70 million cubic feet of gas per day. The capacity of the interconnect is expandable if demand develops for additional gas in California.

Union Pacific Resources is also automating their gas production facilities in Wyoming. By the end of 1992, the company had installed remote terminal units on 40 wells in Bruff and Wamsutter fields. They also plan to install the units on 50 additional wells in Wamsutter Field and 44 additional wells in Bruff. The remote terminal units allow for more efficient production of the wells from a central location.

In March, Northwest Pipeline Corp. completed its $500 million expansion project in the Rocky Mountain states, including a section of pipeline in Lincoln County, Wyoming. The expansion increased Northwest Pipeline's capacity by 433 million cubic feet per day.

Western Gas Resources (WSR) announced the completion of its purchase of Mountain Gas Resources. The acquisition includes two gas processing plants and 300 miles of gathering lines. The gas plants, Granger and Red Desert, can process 190 million cubic feet of gas per day. WSR plans to build a $10 million cryogenic plant to replace the Granger plant and to increase its production capacity for natural gas liquids by 150,000 gallons per day. WSR expects production of liquids to average 300,000 gallons per day at the two plants in 1993, which is a substantial increase over their average daily production of 144,000 barrels per day in 1992. The two facilities processed gas from 34 new wells in 1992 and added 18 new wells during the first quarter of 1993. WSR also expects to add an additional 24 gas wells to the Granger system.

Williams Field Services Company and Union Pacific Resources also each announced plans to build new gas processing plants in the Wamsutter area of the Greater Green River Basin. Combined, the two new plants will add an additional capacity of 200 million cubic of gas per day. Union Pacific's 50 million cubic feet per day plant and its gathering facilities will cost about $13 million.

Enron Oil and Gas announced that it replaced 135 percent of its annual natural gas equivalent production in 1993, due in large part to its operations in the Big Piney area of western Wyoming. In a similar announcement, Tom Brown Inc. noted that its activites in the Wind River Basin had helped increase its gas reserves by 40 percent in 1992.

Wyoming oil production, however, is not faring as well as gas production. Oil production decreased to 96.8 million barrels in 1992 and has been on a steady decline since 1985 (**Figure 4**). According to the U.S. Department of Energy, the average first purchase price in 1992 for all types of Wyoming crude was $16.38 per barrel. This is an improvement over 1991's average price (**Table 2**), but not

enough of an improvement to turn around the production decline. **Figure 6** shows the volatile oil prices that Wyoming producers have contended with since 1986.

Wyoming's rig count declined to a new low in March. The average for the month was only eight rigs. The expiration of the tax credits for tight gas sands and the normal first quarter slow-down in drilling each contributed to the decline during the quarter (**Figure 9**).

In 1993, the Wyoming Legislature passed the Oil and Gas Economic Recovery Act, which becomes law on July 1, 1993. The bill provides for a two-year, four percent, severance tax reduction on production that results from an approved workover or recompletion that begins between July 1, 1993, and December 31, 1996. The reduction also applies to some production from new wells. In this latter case, the first 240,000 cubic feet of gas or the first 40 barrels of oil production per day qualifies for the reduced severance tax rate. New horizontal and collection wells were exempted. If the price for the new production is equal to or greater than $25 per barrel of oil or $2.75 per thousand cubic feet of gas for a period of six months, the tax break is no longer given.

The State Board of Land Commissioners decided not to lower the royalty rates for oil and gas production on State lands from 16.67 percent to 12.5 percent. Wyoming annually receives over $20 million in oil and gas royalties from production on State lands. Proponents of the change said that a decreased royalty rate could encourage more companies to explore and develop State land.

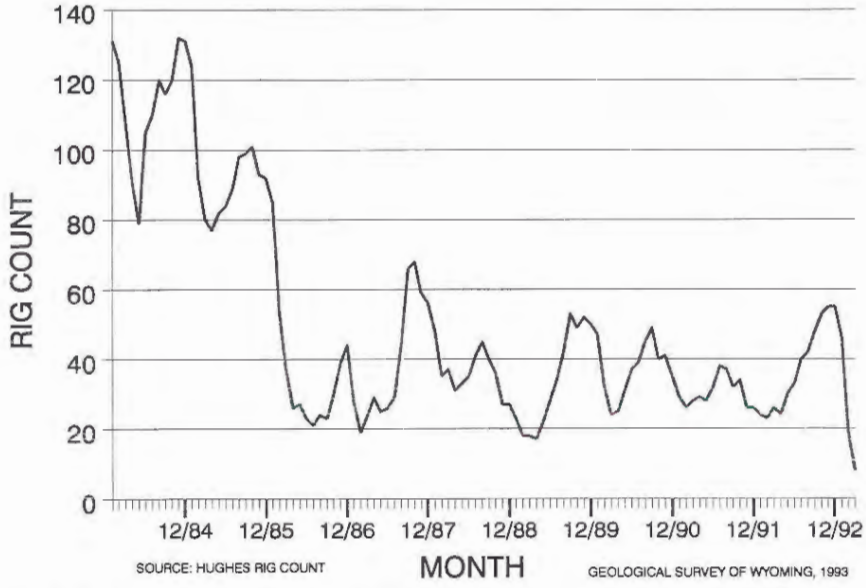


Figure 9. Wyoming daily rig count averaged by month (1984 to present).

According to Stan Smith, the State Treasurer, the change in rate would have only applied to new leases. It would not have lowered royalty rates on existing leases.

The State Land and Farm Loan Office's oil and gas lease sale in March raised as much as the combined last three sales in 1992 (**Table 5**). Brown Operating Inc. made the sale's highest per-acre bid of $400 for a 160-acre tract that encompasses SE section 36, T49N, R72W. Brown also bid $280 per acre for SW section 36 and $260 per acre for NW section 36, T49N, R72W. Natural Gas Processing bid $120 per acre for a 640-acre lease that includes all of section 16, T39N, R93W. The lease is less than one half mile from Lance production at Howard Ranch Field.

The U.S. Bureau of Land Management's (BLM's) sale in February was equally good and raised the most total revenue since the August, 1991, sale (**Table 5**). Contex Energy Co. made the sale's high per-acre bid of $220 for a 320-acre lease covering E/2 section 26, T25N, R112W. The lease is on the Moxa arch and is less than a mile west of Frontier production in Fontenelle Field. The sale's best total revenue bid was made by Yates Petroleum Corp. for a 732.97-acre lease that included parts of sections 11, 14, 15, 19, and 31, T54N, R68W. Yates paid nearly $77,000 ($105 per acre) for the lease, which is near Minnelusa and Muddy production.

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 1993. Activities related to horizontal drilling are discussed in a separate section. The letters preceding discussions below refer to locations on **Figure 10**.

A. In the Overthrust Belt, Chevron USA reached total depth of 17,000 feet at their 1-14 Chevron-Federal well in SW NW section 14, T14N, R120W. The wildcat is a mile and a half southeast of Nugget production at Glassock Hollow Field and was drilled to test the Twin Creek and Nugget.

B. Wexpro completed a new well in Church Buttes Field. The 124 Church Buttes Unit well in SW NW section 14, T17N, R112W flowed 4.5 million cubic feet of gas per day from the Frontier between 11,938 and 11,994 feet. Celsius Energy completed their 12-2 Thompson-Federal well in Church Buttes Field. The well is in NE SE section 12, T17N, R113W and flowed 3.2 million cubic feet of gas per day from the Dakota between 12,642 and 12,702 feet.

C. Several new wells were completed in Bruff Field. Wexpro completed their 10-3 Mountain Fuel-Federal well in NE NE section 10, T19N, R112W. The well flowed 8.0 million cubic feet of gas per day from the Dakota between 11,958 and 11,986 feet. Wexpro also completed their 3-9 Champlin well in C NE section 9, T17N, R112W. The well flowed 4.4 million cubic feet of gas from

Table 5. Federal and State competitive oil and gas lease sales in Wyoming.

BLM SALES								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	Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
				1988								1988			
TOTAL	$27,688,861	4,119	1,591	4,412,513	1,350,897	$20.50	$6,500.00	TOTAL	$6,202,724	1,200	873	445,953	331,943	$18.69	$465.00
				1989								1989			
TOTAL	$15,832,105	4,286	1,360	4,028,750	972,403	$16.28	$3,000.00	TOTAL	$3,123,984	1,199	792	461,852	311,274	$10.04	$540.00
				1990								1990			
February	$3,301,479	524	259	335,275	141,555	$23.32	$340.00	January	$190,921	200	100	74,987	38,884	$4.91	$46.00
April	$2,163,988	513	218	399,790	138,909	$15.58	$275.00	March	$668,262	200	132	79,405	54,193	$12.33	$85.00
June	$3,480,557	511	315	305,550	172,798	$20.14	$240.00	May	$690,310	199	146	79,667	60,986	$11.32	$270.00
August	$2,892,191	533	251	493,185	187,259	$15.44	$325.00	July	$521,824	200	154	78,507	62,999	$8.28	$60.00
October	$2,580,072	423	265	255,886	141,707	$18.21	$200.00	September	$1,472,248	200	200	80,197	80,197	$18.75	$240.00
December	$3,578,846	467	285	379,452	185,065	$19.34	$260.00	November	$1,435,529	200	192	85,335	83,133	$17.27	$265.00
TOTAL	$17,997,133	2,971	1,593	2,169,138	967,293	$18.61	$340.00	TOTAL	$4,979,094	1,199	732	478,098	380,382	$13.09	$270.00
				1991								1991			
February	$4,333,861	370	200	275,600	122,225	$35.46	$16,000.00	January	$2,050,868	300	295	117,677	115,998	$17.68	$401.00
April	$1,880,742	470	217	332,764	132,278	$14.22	$170.00	March	$642,191	197	170	69,652	62,226	$10.32	$110.00
June	$2,002,440	490	176	430,576	120,992	$16.55	$275.00	May	$539,556	199	173	79,156	70,081	$7.70	$77.00
August	$2,005,511	557	211	472,103	120,292	$16.67	$325.00	July	$396,569	200	124	73,179	52,850	$7.50	$70.00
October	$1,616,314	507	175	397,011	94,899	$17.03	$340.00	September	$411,971	200	146	69,025	50,908	$8.09	$260.00
December	$1,095,409	421	168	283,408	85,091	$12.87	$1,600.00	November	$416,730	199	129	71,286	53,847	$7.74	$130.00
TOTAL	$12,934,277	2,815	1,147	2,191,462	675,777	$19.14	$16,000.00	TOTAL	$4,457,885	1,295	1,037	479,975	405,910	$10.98	$401.00
				1992								1992			
February	$940,581	342	126	213,469	67,205	$14.00	$210.00	January	$138,165	200	96	72,027	37,840	$3.65	$65.00
April	$331,199	355	109	229,407	58,951	$5.62	$112.00	March	$200,000	200	114	70,294	41,034	$4.88	103.00
June	$425,183	314	86	168,230	37,701	$11.28	$220.00	May	$208,166	200	93	60,687	28,605	$7.28	$230.00
August	$1,395,060	335	109	196,800	54,530	$25.58	$230.00	November	$200,407	199	116	74,747	43,134	$4.65	$87.00
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	$280.00								
TOTAL	$4,778,940	2,122	664	1,434,268	364,478	$13.11	$2,500.00	TOTAL	$745,738	799	419	277,755	150,613	$4.95	$230.00
				1993								1993			
February	$1,637,233	464	246	346,357	155,272	$10.54	$220.00	March	$601,400	200	137	74,940	54,723	$10.99	$400.00

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

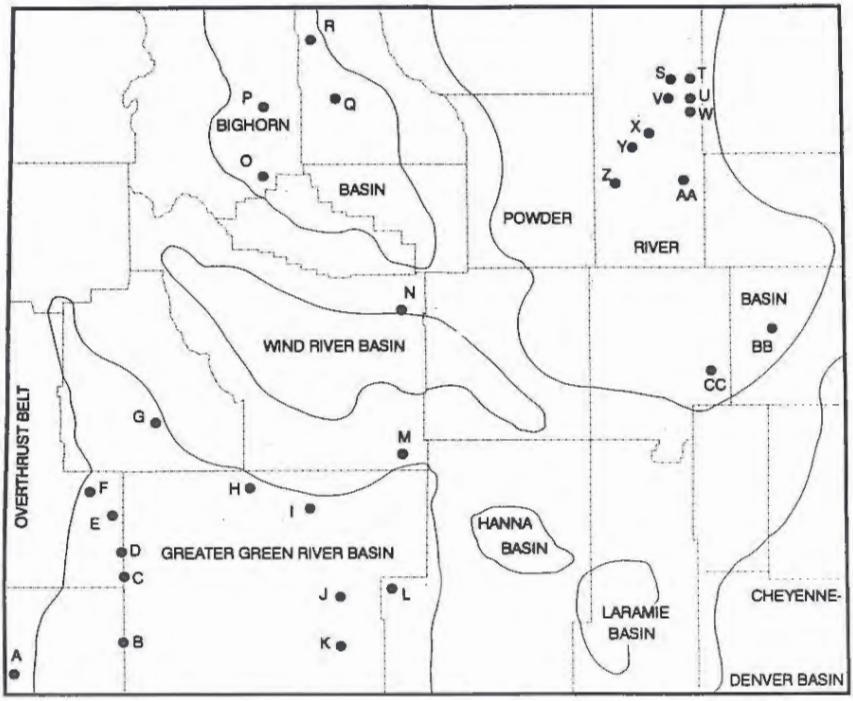


Figure 10. Oil and gas exploration and development activity in Wyoming during the first quarter of 1993 (exclusive of horizontal drilling and coalbed methane activities).

the Frontier between 12,128 and 12,180 feet. Union Pacific completed four new producers in Bruff Field. Their 4 Wyoming NCT-2 well in NW SW section 36, T19N, R112W flowed 2.4 million cubic feet of gas and 40 barrels of water per day from the Frontier between 11,540 and 11,610 feet. Their 4 Wyoming UNCT-1 well in SW SW section 24, T19N, R112W flowed 1.8 million cubic feet of gas, eight barrels of condensate, and 11 barrels of water per day from the Frontier between 11,524 and 11,572 feet. Their 3 Tripp well in SE NE section 14, T19N, R112W flowed 8.9 million cubic feet of gas, 98 barrels of condensate, and two barrels of water per day from the Dakota between 12,010 and 12,071 feet. Their B-3 Bruff 285 well in SE NW section 3, T19N, R112W flowed 2.1 million cubic feet of gas, 12 barrels of condensate, and 25 barrels of water per day from the Frontier between 11,368 and 11,450 feet and from the Dakota between 12,024 and 12,051 feet.

D. Bannon Energy completed two wells in Whiskey Butte Field. Their 1 Champlin 243 Amoco "A" well in NE NE section 31, T21N, R111W flowed 22.7 million cubic feet of gas and 24 barrels of water per day from the second Frontier between 11,243 and 11,250 feet. Their 2 Champlin 243 Amoco "A" well in C

SW section 31, T21N, R111W produced an average of 7.7 million cubic feet of gas and 25 barrels of condensate per day during its first month of production from an undisclosed Dakota interval.

E. Washington Energy Exploration completed their 10-1 Reservoir Unit well in SE NW section 1, T24N, R112W. The well flowed 94,000 cubic feet of gas per day from the Frontier between 9,450 and 9,582 feet.

F. Yates Petroleum completed their 1 Names Hill Unit wildcat well in NW SW section 35, T26N, R113W. The well produced 6.8 million cubic feet of gas and seven barrels of condensate during 30 days in December, 1992. The well was drilled to a total depth of 10,100 feet and was to test the Frontier.

G. The Wyoming Oil and Gas Conservation Commission recommended to the Federal Energy Regulatory Commission that it designate the Lance Formation, underlying T27N-T29N, R107W-R108W; T29N, R109W; T30N, R108W; and T30N, R109W, a tight formation.

H. Coastal Chemical tested a shut-in Muddy discovery completed by Davis Oil in 1981. The 1 Buccaneer Unit well in SW SE section 23, T26N, R102W produced an average of 625,000 cubic feet of gas per day during six days of tests. The producing zone is between 17,702 and 17,718 feet.

I. Presidio Exploration completed a new Lewis well in Hay Reservoir Field. Their 4JT-Federal well in N/2 SE section 13, T23N, R97W flowed 5.9 million cubic feet of gas, 214 barrels of condensate, and one barrel of water per day from perforations between 9,313 and 9,353 feet.

J. Barrett Resources completed their 1-1 Two Rim Unit wildcat well in NE NW section 3, T18N, R95W. The well flowed 2.4 million cubic feet of gas, 62 barrels of condensate, and 30 barrels of water per day from the Almond between 10,129 and 10,300 feet.

K. Celsius Energy completed three new wells in the Washakie Basin. Their 8 Dripping Rock well in SW NE section 17, T14N, R94W flowed 6.1 million cubic feet of gas per day from the Almond between 12,410 and 12,432 feet. Their 19 Mulligan Draw Unit well in SW SW section 25, T15N, R95W flowed 1.8 million cubic feet of gas per day from the Almond between 12,926 and 12,960 feet. Their 1 Fairway Unit well in SW NE section 4, T15N, R95W flowed 4.6 million cubic feet of gas per day from the Almond between 13,036 and 13,056 feet.

L. Amoco Production and Union Pacific Resources each have two new producing wells in Echo Springs Field. Amoco's 2 Champlin 242 Amoco A well in NW NE section 1, T19N, R93W produced an average of 3.1 million cubic feet of gas, 41 barrels of condensate, and 31 barrels of water per day during its first 11 days of production from the Almond. Total depth is 9,975 feet. Amoco's 2 Champlin 222 Amoco C well in NE NE section 15, T19N, R93W produced an average of 1.5 million cubic feet of gas, 12 barrels of condensate, and two

barrels of water per day during its first 21 days of production from the Almond. Total depth was planned for 9,759 feet. Union Pacific's 2 Echo Springs 337-G well in C NE section 29, T19N, R93W produced an average of 193,000 cubic feet of gas, 24 barrels of condensate, and nine barrels of water per day during its first 13 days of production from the Almond between 9,348 and 9,370 feet. Union Pacific's 2 Echo Springs 276B in C NE section 7, T19N, R92W produced an average of 828,000 cubic feet of gas and 10 barrels of condensate per day during its first 14 days of production from the Almond between 9,626 and 9,697 feet.

M. Wold Oil Properties deepened an abandoned Frontier producer in Happy Springs Field and completed it in the Nugget. The 2 Happy Springs Unit well in NW SW section 16, T28N, R93W pumped 54 barrels of oil and 71 barrels of water per day through perforations between 7,282 and 7,290 feet.

N. Louisiana Land & Exploration completed a new Mesaverde producer in Madden Field. Their 4-4 Christie-Federal well in SW NW section 4, T38N, R90W flowed 11.2 million cubic feet of gas per day through perforations between 15,831 and 15,850 feet.

O. MW Petroleum completed their 39 NWD well in NE NW section 3, T47N, R100W as a Muddy producer. The well flowed 1.3 million cubic feet of gas per day from perforations between 2,328 and 2,348 feet.

P. Marathon completed the drilling of a 6,000-foot test of a deeper structural feature in Oregon Basin Field. The 1 Sholtz-Federal well in NW SW section 6, T51N, R100W will test the Phosphoria, Tensleep, and Madison.

Q. Medallion Production is completing a possible Dakota producer. The 1 Greybull-Federal in SW SE section 26, T52N, R94W was drilled to 10,300 feet.

R. WYOP Inc. recovered 10 barrels of oil and 40 barrels of water per day during swab tests. The 1 Sand Draw well in SW SW section 31, T55N, R96W was tested in the Tensleep between 6,838 and 6,858 feet.

S. Lario Oil & Gas completed a new Minnelusa well in Deer Fly South Field. The 1 Ox-Federal in SW SE section 13, T53N, R70W pumped 103 barrels of oil per day from perforations between 7,478 and 7,491 feet.

T. Fancher Oil completed a well in Wagonspoke Field. The P-6 Federal well in SW SE section 34, T53N, R69W produced 161 barrels of oil and 60 barrels of water per day on pump from the Minnelusa between 7,348 and 7,368 feet and between 7,389 and 7,393 feet.

U. Flying J pumped 146 barrels of oil per day at their 10-19 Clearwater-Federal wildcat well in NW SE section 19, T52N, R69W. The well produces from the Minnelusa between 7,574 and 7,586 feet.

V. Pendragon Energy Partners completed a new producer in Adon Road Field. Their 2 Adon Road Unit well in NW NE section 26, T52N, R70W flowed 250 barrels of oil per day from the Minnelusa between 7,842 and 7,880 feet.

W. Apache Corp. discovered oil at their 22-9 Zoe Draw-Federal wildcat well in SE NW section 9, T51N, R69W. The well produced 236 barrels of oil and 20 barrels of water per day on pump from the Minnelusa between 7,868 and 7,885 feet.

X. Flying J pumped 456 barrels of oil per day from their 8-29 K.M. wildcat well in SE NE section 29, T50N, R71W. The well was tested in the Minnelusa between 9,552 and 9,562 feet.

Y. Conley P. Smith completed a new well in Mallard/McCreery Field. Their 34-9A McCreery well in NE SE section 34, T49N, R72W produced 40 barrels of oil and 125 barrels of water per day from the Minnelusa between 10,550 and 10,561 feet.

Z. Apache Corp. is planning to drill five wells to test the Sussex Sandstone. The wells are projected to total depths that range from 8,376 to 8,490 feet. The wells are planned for NW NW section 9, T46N, R75W; SE SE section 16, T46N, R75W; SW NW section 29, T47N, R75W; SW NW section 32, T47N, R75W; and NW NE section 32, T47N, R75W.

AA. Brown Operating recovered gas and oil from two drillstem tests in the Minnelusa between 9,850 and 9,884 feet and between 9,891 and 9,905 feet. The 1-27 Sparrow well is in NW NE section 27, T47N, R70W.

BB. Klabzuba Operating completed a new well in Swede Draw Field. The 1-36 Swede Draw-State well in SE SE section 36, T37N, R64W produced 240 barrels of oil and 250,000 cubic feet of gas per day on pump from the Leo between 6,860 and 6,900 feet.

CC. Club Oil and Gas recovered oil and gas at their 31-15 Manning wildcat well in SW SE section 31, T35N, R67W. Oil flowed to the surface after a core was cut in the Niobrara between 9,162 and 9,223 feet. Gas from the zone supported a seven-foot-high flare.

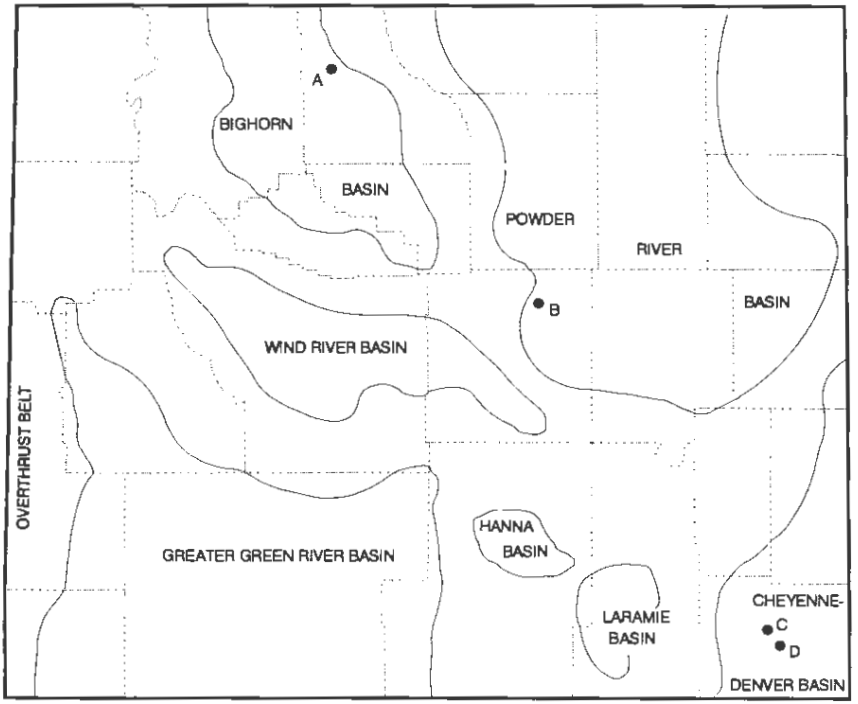
Horizontal drilling

During the first quarter of 1993, the following significant activities related to horizontal drilling occurred. The letters preceding the discussions below refer to locations on **Figure 11**. The discussions are based on company data and on information compiled and published by Petroleum Information.

A. Marathon Oil completed their 3HI Lindsay well as a producer in the Tensleep Sandstone. The well was drilled from a surface location in E/2 section 23, T56N, R97W. No test details are available. True vertical depth was projected to 5,168 feet.

B. E P Operating scheduled a horizontal test of the Steele Shale on the southern flank of Teapot Dome. The 1H Federal 26-9 well will be drilled from a surface location in NE SE section 26, T38N, R78W, to a true vertical depth of 3,500 feet.

C. Several more Niobrara wells were completed or planned in Silo Field. Union Pacific Resources drilled a second lateral leg at the 1H McGahan 21-5 well from a surface location in NW section 5, T15N, R64W, to a true vertical depth of 8,197 feet. The well tested 312 barrels of oil, 237,000 cubic feet of gas, and three barrels of water per day. Union Pacific will drill the 1-H Wilma 41-17 well from a surface location in NE section 17, T15N, R64W, to a true vertical depth of 8,048 feet. Union Pacific completed their 1-H Patricia 41-22 well from a surface location in NE NE section 22, T16N, R65W, to a true vertical depth of 8,300 feet. The well produced an average of 219 barrels of oil and 28 barrels of water per day during 24 days of production in December, 1992. The well has produced over 15,000 barrels of oil since it was completed in October, 1992. Union Pacific also completed their 1-H Earl F. Anderson 14-28 well. The well was drilled from a surface location in SW SW section 28, T16N, R65W, to a true vertical depth of 8,715 feet. The well produced an average



GEOLOGICAL SURVEY OF WYOMING, 1993

Figure 11. Horizontal drilling activity in Wyoming during the first quarter of 1993.

of 173 barrels of oil and 23 barrels of water per day during 31 days of production in December, 1992. Kachina Exploration completed their 2-9 State well from a surface location in NE SE section 2, T15N, R64W, to a true vertical depth of 7,780 feet. The well flowed 810 barrels of oil and 140,000 cubic feet of gas per day. Kachina completed their 12-13H State well from a surface location in SW SW section 12, T15N, R64W, to a true vertical depth of 7,747 feet. The well flowed 850 barrels of oil and 210,000 cubic feet of gas per day.

D. Union Pacific Resources completed their 1-H Bronco-State 41-16 well. The well was drilled from a surface location in NE section 16, T15N, R63W, to a true vertical depth of 7,587 feet. The well flowed 296 barrels of oil, 86,000 cubic feet of gas, and 10 barrels of water per day. Union Pacific also scheduled a new test from a surface location in NE NE section 15, T15N, R63W. The 1H Mark 41-15 well will be drilled to a true vertical depth of 7,464 feet.

COAL UPDATE

by Timothy A. Moore
Staff Geologist-Coal, Geological Survey of Wyoming

Preliminary figures released by the State Inspector of Mines indicate that production of Wyoming coal dropped 2.3 percent in 1992 as compared to production in 1991. However, Wyoming still led all other states last year in coal production. A total of 189.47 million short tons of coal were mined in 1992 as compared to the 193.86 million tons mined in 1991 (**Tables 1, 6, 7,** and **8**). The decrease in Wyoming coal production is the first since 1986 when it dropped by 3.8 percent. It is unclear as to the cause of the decrease in production, but it is widely believed that cool summers and mild winters in the western and midwestern states created less of a demand for coal by electrical utilities. On the longer term, production of Wyoming coal is still expected to increase annually by as much as 2.5 percent. Part of these projected increases is related to purchases from midwestern and possibly even eastern utilities as the Clean Air Act Amendments become effective.

During 1992, coal production in the U.S. increased 1.2 percent over 1991 levels, totaling 1.008 billion tons. For 1993, the National Coal Association (NCA) predicts that U.S. coal consumption will rise while the overall production will likely remain at about one billion tons. The NCA does, however, predict a slight decrease in coal exports in 1993.

Although the Powder River and Hanna coal fields (**Figure 12**) had overall decreases in production, the Hams Fork and Green River coal fields increased (**Tables 7** and **8**). Nevertheless, there was considerable variation in production from 1991 to 1992 between mines within coal fields. For example, the Black

Table 6. Coal production (1983 to 1992) with forecast to 1995 (millions of short tons).

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993*	1994*	1995*
Campbell County	88.2	106.8	113.9	111.0	122.3	135.7	143.8	154.7	164.9	159.6	167.8	172.1	176.4
Converse County	2.7	3.3	3.6	4.8	5.1	5.7	6.1	7.9	8.2	8.5	8.7	8.9	9.2
Sheridan County	2.9	2.5	2.4	1.4	1.2	0.9	0.1	0.1	0.2	0.1	M	M	M
Carbon County	4.8	5.1	3.3	1.5	2.2	4.1	4.3	4.5	4.7	4.1	4.6	4.8	4.9
Sweetwater County	9.5	8.9	13.2	12.9	11.8	12.2	12.0	11.9	11.4	12.6	8.6	8.8	9.0
Lincoln County	4.0	4.1	4.3	4.0	3.8	4.9	4.8	4.7	4.4	4.6	4.5	4.6	4.8
Hot Springs County	M	M	M	M	M	M	M	0.1	0.1	M	M	M	M
Total Wyoming	112.1	130.7	140.7	135.6	146.4	163.5	171.1	183.9	193.9	189.5	194.3	199.3	204.3
Annual Change	4.0%	14.2%	7.1%	-3.8%	7.4%	10.5%	4.4%	7.0%	5.2%	-2.3%	2.5%	2.5%	2.4%
Low-priced coal†			6%	7%	8%	10%	17%	24%	31%	37%	42%	47%	51%

* Forecast by Geological Survey of Wyoming, February 1993. † 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 minor tonnage (less than 0.1 million tons).

Thunder mine in the Powder River Coal Field dropped in production by over 2.2 million tons whereas the Rochelle mine increased production by nearly 4.5 million tons. Overall, monthly production of coal in 1992 was consistently lower than in 1991 (**Table 9** and **Figure 13**). The last quarter of 1992 saw slightly greater purchases of contract coal over that sold in 1991, but sales of spot coal were less (**Figure 14**).

Employment at coal mines in Wyoming dropped slightly from 4,663 in 1991 to 4,648 in 1992 (**Table 8** and **Figure 15**). Most of the decrease in work force occurred in the Hanna and Hams Fork coal fields while there was an increase in

Table 7 . 1992 Wyoming coal production and employment by county and coal field.

County	Production	Percent of Total Production	Number of Mines	Number of Employees
POWDER RIVER COAL FIELD				
Campbell	159,559,962	84.2%	16	2,703
Converse	8,517,680	4.5%	2	269
Sheridan	105,391	0.1%	2	13
TOTAL	168,183,033	88.8%	20	2,985
GREEN RIVER COAL FIELD				
Sweetwater	12,579,979	6.6%	4	927
HAMS FORK COAL FIELD				
Lincoln	4,594,061	2.4%	3	428
HANNA COAL FIELD				
Carbon	4,055,975	2.1%	4	294
BIGHORN COAL FIELD				
Hot Springs	57,208	<0.1%	1	14
TOTAL WYOMING	189,470,256	100.0%	32	4,648

Source: Wyoming State Inspector of Mines, preliminary data for 1992.

total employees at the mines located in the Powder River Coal Field. Interestingly, coal production in Wyoming has more than doubled while employment in the State's coal industry has dropped by about one-third since 1980. And the coal industry produced gross sales of about $1.5 billion in 1992, which is a 59% increase since 1980. But because many companies are losing sales of higher priced coal to lower priced spot sales, reductions in the work force will continue in order to help defray mining costs.

To help reduce the national deficit, the Clinton Administration has proposed a tax on fossil fuels. For fuels such as oil, coal, and natural gas, the tax will be 25.7 cents per million Btus. Although it was initially thought that the tax on coal would be assessed at the mine, President Clinton has shifted the point of collection to the electric utilities. This means that coal sent overseas or used in various manufacturing processes, including steel, would not be subject to the tax. On a tonnage basis, the tax is expected to average about $5.57 per ton of coal. However, because of transportation distances, it is still unclear what effect the energy tax will have on Wyoming coal.

Obviously, most coal producers are very concerned about any increase in taxes, especially if those new taxes adversely affect older contracts which were negotiated at a lower tax rate. Because contracts at $12 - $14 per ton are diminishing and most contracts are being renewed at $3.60 to $3.80/ton, the margin of profit is consistently narrowing. However, some market analysts in the private sector and academia believe that the Wyoming coal industry's biggest problem is not the specter of higher taxes, but rather the low prices set by the older, big mines in the State. These analysts feel that the smaller and newer mines are struggling to match very low spot market prices offered by the mines whose profits are propped up by higher-price, long-term contracts. Whether or not this is the case, overcapacity still remains one undeniable factor in the pricing of Wyoming coal.

The State of Wyoming has decided not to sue four midwestern states for passing laws that encourage utilities to burn coal that is produced in those states. Governor Mike Sullivan said that the State of Wyoming currently would have a difficult time showing injury as a result of the laws. However, Sullivan pointed out that the State does "reserve the right to take action at a later time." Wyoming previously won a lawsuit which challenged an Oklahoma law requiring utilities in that state to burn at least 10% Oklahoma coal.

Power producers in Wyoming stand to profit from emission allowances. The Environmental Protection Agency (EPA) has granted operators of Wyoming power plants nearly twice as many emission allowances as they need in the new clean air allowance market. Wyoming power plants emitted 78,000 tons of sulfur dioxide in 1991, and the EPA has recently allocated those plants an emission allowance of 140,000 tons of sulfur dioxide. In comparison, power plants in Illinois, which emit as much as six million tons of sulfur dioxide a year, received 400,000 tons in allowances. In late March, the first ever "pollution permits" sold for prices between $122 and $450 per ton of sulfur dioxide emission. It was not clear if Wyoming companies sold very much of their allowances at that first sale.

Table 8. 1991 and 1992 Wyoming coal industry employment and production by coal field and mine.

Company	Mine Name		1991 Employees	1991 Production (short tons)	1992 Employees	1992 Production (short tons)
	POWDER RIVER COAL FIELD					
Amax Coal Co.	Belle Ayr	(surface)	243	14,748,346	234	12,965,204
	Eagle Butte	(surface)	205	13,924,000	214	13,669,205
Antelope Coal Co.	Antelope	(surface)	97	5,448,268	94	5,734,603
Ash Creek Mining Co.	PSO Mine #1	(surface)	1	0	1	0
Big Horn Coal Co.	Big Horn	(surface)	7	158,055	12	105,391
Caballo Rojo, Inc.	Caballo Rojo	(surface)	150	9,383,108	135	7,598,978
Carter Mining Co.	Caballo	(surface)	226	15,267,657	246	15,378,609
	Rawhide	(surface)	194	11,766,870	194	8,629,613
Cordero Mining Co.	Cordero	(surface)	230	13,703,094	229	13,308,010
Dry Fork Coal Co.	Dry Fork	(surface)	47	2,796,061	50	3,440,668
Fort Union Coal Co.	Fort Union	(surface)	5	28,913	4	24,930
Glenrock Coal Co.	Dave Johnston	(surface)	174	2,776,349	175	2,783,077
Kerr-McGee Coal Corp.	Jacobs Ranch	(surface)	367	17,743,542	349	16,444,206
North Antelope Coal Co.	North Antelope	(surface)	134	9,648,953	137	10,149,243
Rochelle Coal Co.	Rochelle	(surface)	162	12,635,888	178	17,050,965
SMC Mining Co.	North Rochelle	(surface)	1	25,765	2	24,085
Thunder Basin Coal Co.	Black Thunder	(surface)	500	30,851,751	513	28,644,138
	Coal Creek	(surface)	7	151,165	27	152,760
Triton Coal Co.	Buckskin	(surface)	143	9,435,021	133	9,121,349
Wyodak Resources	Wyodak	(surface)	57	2,741,809	58	2,957,999
TOTAL			2,950	173,234,615	2,985	168,183,033
	HANNA COAL FIELD					
Arch of Wyoming	Medicine Bow	(surface)	91	2,418,573	93	2,402,009
Arch of Wyoming	Seminoe No.2	(surface)	14	0	5	0
Cyprus Shoshone Coal Co.	Shoshone #1	(deep)	192	2,026,065	179	1,651,966

Rosebud Coal Sales Co.	Rosebud	(surface)	16	11,365	17	2,000
Wyoming & WV, Inc.	Blue Sky No. 1	(deep)	10	247,978	0	0
TOTAL			323	4,703,981	294	4,055,975
	BIGHORN COAL FIELD					
Northwest Resources Co.	Grass Creek	(surface)	14	103,285	14	57,208
TOTAL			14	103,285	14	57,208
	HAMS FORK COAL FIELD					
FMC Wyoming Corp.	Skull Point	(surface)	98	839,454	96	810,020
Pittsburg & Midway	Kemmerer	(surface)	349	3,552,190	326	3,784,041
Wyoming & WV Inc.	Wy & W.V.	(surface)	0	0	6	0
TOTAL			447	4,391,644	428	4,594,061
	GREEN RIVER COAL FIELD					
Arch of Wyoming	Pilot Butte	(deep)	27	261,603	49	453,566
Black Butte Coal Co.	Black Butte	(surface)	439	5,290,400	421	5,889,973
Bridger Coal Co.	Jim Bridger	(surface)	389	5,746,925	395	6,073,832
Lion Coal Co.	Swanson	(deep)	74	131,353	62	162,608
TOTAL			929	11,430,281	927	12,579,979
TOTAL UNDERGROUND			303	2,666,999	290	2,268,140
TOTAL SURFACE			4,360	191,196,807	4,358	187,202,116
GRAND TOTAL			4,663	193,863,806	4,648	189,470,256

Source: Annual report of the Wyoming State Inspector of Mines, 1991 and preliminary data for 1992.

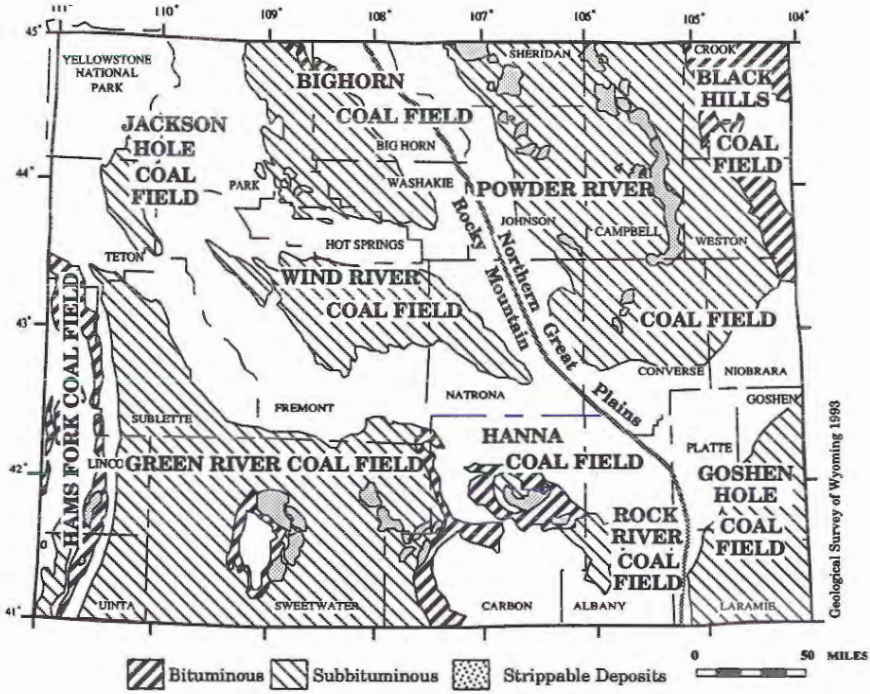


Figure 12. Wyoming coal fields.

Table 9. Coal deliveries by month from Wyoming mines†

	1988 Monthly	1988 Cumulative	1989 Monthly	1989 Cumulative	1990 Monthly
JAN	10,976,860	10,976,860	14,283,020	14,283,020	15,059,530
FEB	11,431,380	22,408,240	11,488,140	25,771,160	13,328,290
MAR	12,871,090	35,279,330	14,124,330	39,895,490	14,535,270
APR	12,694,660	47,973,990	13,489,450	53,384,940	14,155,470
MAY	12,017,500	59,991,490	13,149,170	66,534,110	13,882,590
JUN	12,595,480	72,586,970	12,948,350	79,482,460	13,649,070
JUL	13,905,670	86,492,640	14,043,350	93,525,810	15,368,280
AUG	15,041,090	101,533,730	15,428,210	108,954,020	16,046,910
SEP	13,433,610	114,967,340	13,795,760	122,749,780	15,166,020
OCT	13,696,190	128,663,530	14,523,480	137,273,260	15,244,760
NOV	13,889,890	142,553,420	14,507,130	151,780,390	15,569,280
DEC	14,540,510	157,093,930	13,527,880	165,308,270	14,479,970
Total Tonnage Reported		**157,093,930**		**165,308,270**	
Total Tonnage Not Reported*		**6,494,270**		**5,831,734**	
Total Tonnage		**163,588,200**		**171,140,004**	

† **Source: COALDAT Marketing Reports by Resource Data International, Inc., compiled from FERC Form 423 filed monthly by electric utilities**

* **Source: State Mine Inspector's Annual Reports**

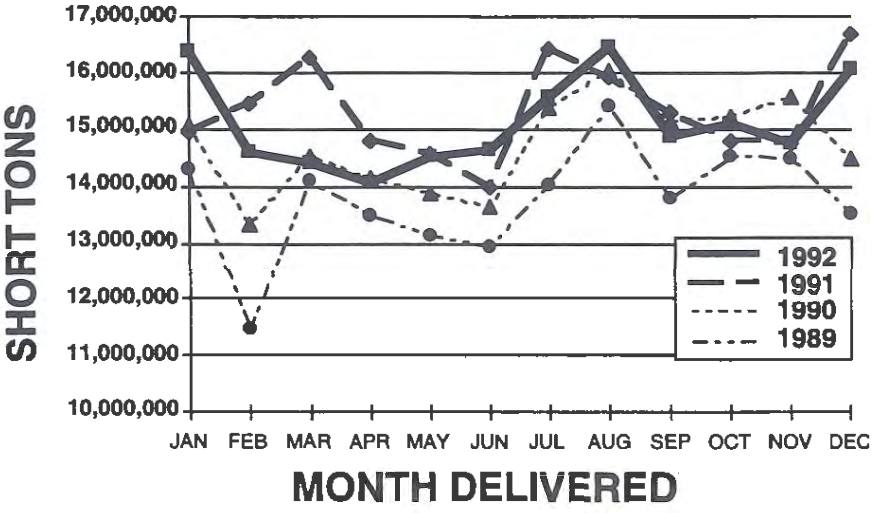
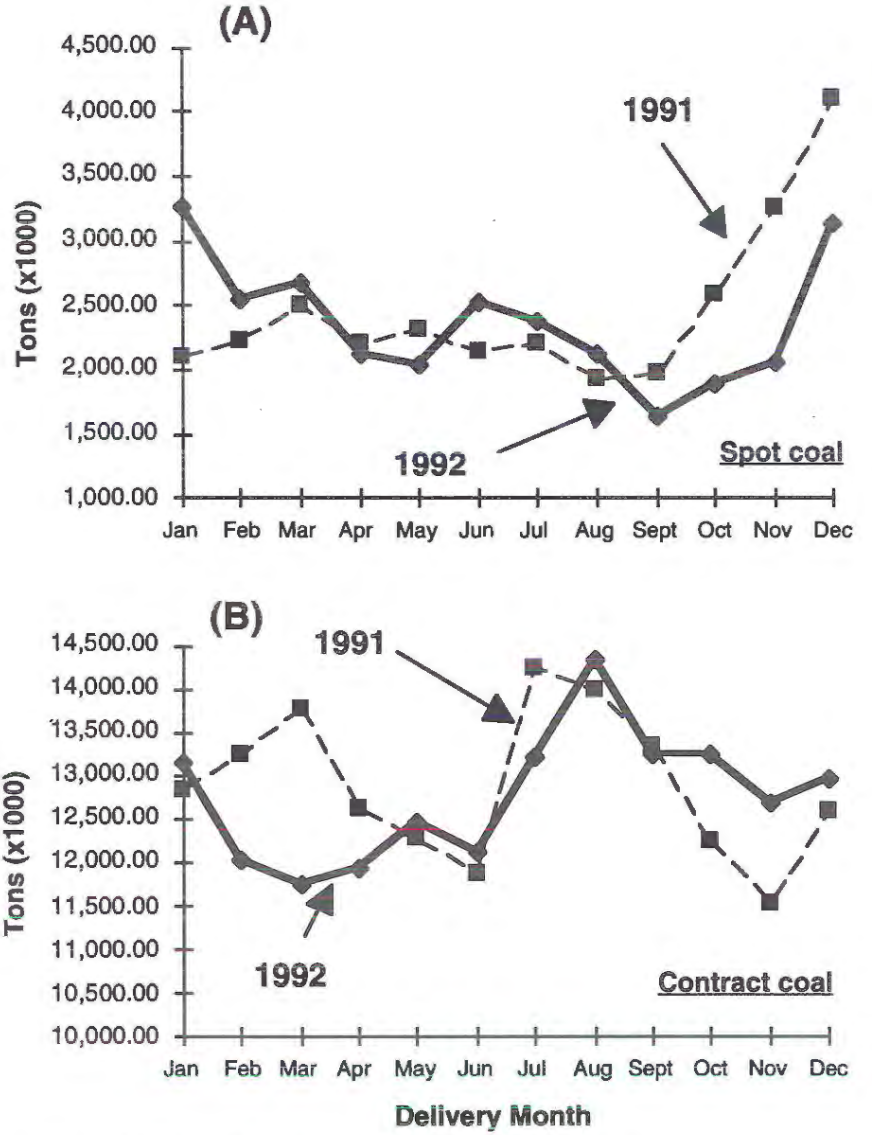


Figure 13. Reported deliveries from Wyoming coal mines. *(from COALDAT Marketing Report by Resource Data International, Inc. compiled from FERC Form 423 filed monthly by electric utilities).*

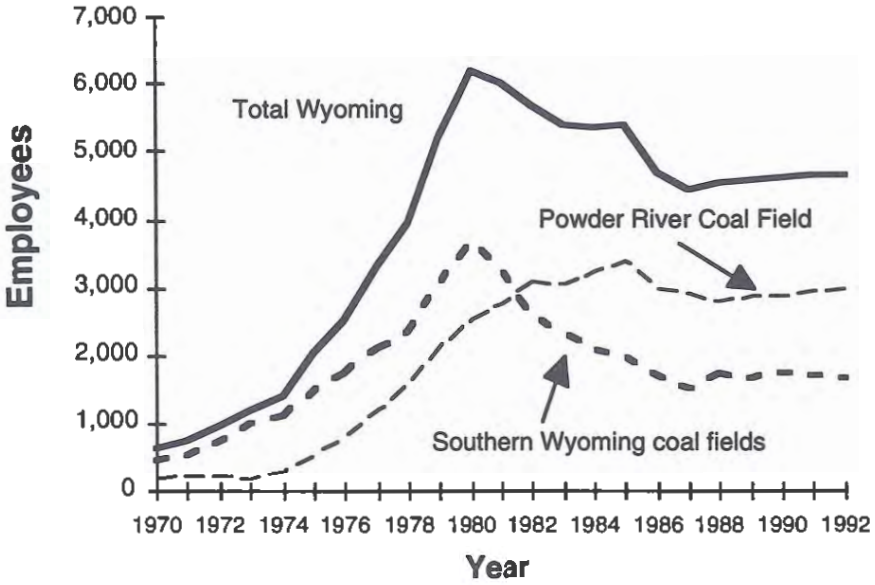
Table 9. *continued*

1990 Cumulative	1991 Monthly	1991 Cumulative	1992 Monthly	1992 Cumulative
15,059,530	14,960,450	14,960,450	16,407,150	16,407,150
28,387,820	15,480,110	30,440,560	14,604,480	31,011,630
42,923,090	16,278,870	46,719,430	14,429,650	45,441,280
57,078,560	14,820,240	61,539,670	14,063,060	59,504,340
70,961,150	14,589,790	76,129,460	14,518,590	74,022,930
84,610,220	14,007,600	90,137,060	14,655,600	88,678,530
99,978,500	16,451,090	106,588,150	15,592,050	104,270,580
116,025,410	15,940,620	122,528,770	16,467,100	120,737,680
131,191,430	15,314,490	137,843,260	14,878,150	135,615,830
146,436,190	14,810,510	152,653,770	15,122,820	150,738,650
162,005,470	14,783,000	167,436,770	14,757,230	165,495,880
176,485,440	16,716,630	184,153,400	16,096,150	181,592,030
176,485,440		**184,153,400**		**181,592,030**
7,521,261		**9,710,406**		**7,878,226**
184,006,701		**193,863,806**		**189,470,256**



Geological Survey of Wyoming 1993

Figure 14. Monthly coal deliveries from Wyoming for 1991 and 1992. (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).*



Geological Survey of Wyoming, 1993

Figure 15. Coal industry employment in Wyoming.

Southwestern Wyoming

Layoffs at the Black Butte mine near Rock Springs have largely been avoided because 175 employees agreed to an early buy-out plan. Of those 175 employees, 142 came from the skilled or craft category and 33 from the salaried or clerical category. Only six full-time employees were furloughed on January 18, 1993.

The Naughton power plant near Kemmerer has begun a multi-phase project which will continue the process of bringing the power facility into compliance with the State's air quality emission standards. The 700,000-kilowatt plant is currently requesting bids for a renovation project that will include modifying its current coal storage and handling facilities. The total cost of the two-year project is an estimated $10 million. The Naughton power plant is owned by Utah Power and Light, a subsidiary of PacifiCorp.

One of the coal suppliers for the Naughton power plant is Pittsburg and Midway Coal Mining Co. (P&M), located just south of Kemmerer, Wyoming. P&M's Kemmerer mine is requesting a permit from the Wyoming Department of Environmental Quality's Air Quality Division to construct a new coal blending and handling system at its mine site.

A fire in an abandoned mine one mile south of Rock Springs has been smoldering for the last 50 years. However, a recent collapse has allowed additional air into the abandoned mine and caused the fire to intensify and to

spread an additional 75 feet. The hole has been filled with dirt, but additional action may be warranted and could cost up to $100,000. The mine fire is considered hazardous because it is near a coking plant.

Developments in the Hanna Coal Field

Several sales of coal from the Hanna Basin were noted in the first quarter of 1993. Cyprus Coal's Shoshone No. 1 mine has shipped over 100,000 tons of spot market coal to Northern Indiana Public Service Co.'s Michigan City and R.M. Schahfer power plants. In addition, both the Shoshone No. 1 and Medicine Bow mines have been awarded part of a 1.2-million-ton-per-year contract to supply Missouri Public Service Co.'s Sibley plant with coal.

A number of researchers at the U.S. Geological Survey (USGS) are interested in coal-bearing rocks in the Hanna Basin. Among Tertiary age basins, Hanna is unique in that it contains over 30,000 feet of rock, much of it interbedded with coal beds. The USGS' Branch of Coal Geology is looking both at the sedimentary depositional setting of the Tertiary in the Hanna Basin as well as some of the petrographic attributes of its coals.

Developments in the Powder River Coal Field

PacifiCorp announced in mid-February that it was selling its 82 percent interest in Nerco, Inc. to Kennecott Corp. Nerco owns and operates the Antelope mine in Wyoming and the Spring Creek mine in Montana. Kennecott is estimated to be paying $470 million for the shares in Nerco. Kennecott has also purchased the Cordero mine in the Powder River Basin from Sun Co. for an estimated $120.5 million. Cordero operates on a 384-million-ton reserve in the eastern Powder River Basin. Some 63 percent of Cordero's production is secured with long-term contracts with midwestern and Texas utilities. Kennecott said that these purchases reflect its high hopes for the market of Wyoming's low-sulfur coal. Kennecott Corporation's parent company is Britain's RTZ Corp., which is one of the largest mining companies in the world.

Black Hills Corp. announced at the end of March that it will build a new power plant near Gillette. The Wyoming Public Service Commission concluded that a new power plant was needed near Gillette. However, the plant will likely result in a 12-17% rate hike for electricity in some Wyoming towns. Black Hills plans to build the $125 million, 80-megawatt power plant at its Wyodak mine. In April, South Dakota regulators also apparently approved the new power plant. Rosebud Energy had been trying to convince South Dakota regulators that a new coal-fired power plant should not be built in Gillette. Rosebud was proposing a 40-megawatt, petroleum-coke-fired plant near Edgemont, SD, which it believed could better serve the community.

The U.S. Bureau of Land Management (BLM) held a hearing in Gillette on March 9, 1993, to consider the Rocky Butte coal mine expansion project proposed by Northwestern Resources Company. According to the BLM, the Rocky Butte lease contains an estimated 575 million tons of coal. The BLM also held a scoping

meeting on Amax Coal West, Inc.'s coal lease by application (LBA) in mid-April at Gillette. The LBA is for approximately 150 million tons of coal under about 915 acres adjacent to Amax's Eagle Butte Mine.

To avoid future declines in production, many Powder River Basin coal producers are trying to acquire leases on additional large coal reserves. For example, Thunder Basin Coal Co. recently acquired another 400 million tons of coal. A spokesman for the company said that most of their current coal reserves were sold; committed to long-term contracts. Therefore, if new reserves had not been secured, production would begin to decline in the late 1990's.

Both Burlington Northern (BN) and Chicago & North Western Transportation Co. (C&NW) ship coal out of the Powder River Basin. However, BN and four other railroads have asked the Interstate Commerce Commission to reject Union Pacific (UP) Railroad's request to gain majority interest in C&NW. At present it is not known how this potential buy out could affect competitiveness of rail service in the basin. UP and C&NW have had a history of business cooperation for hauling coal from the Powder River Basin to UP track. Already UP owns 29.5 percent of C&NW, but it only has non-voting stock.

Burlington Northern Railroad (BN) plans to add 720 more aluminum-body coal cars, primarily to ship low-sulfur coal from the Powder River Basin. BN has made the $25 million investment to transport coal mostly to Northern States Power in Minnesota.

Although the United Mine Workers have struck Peabody Holding Company in the eastern United States, the strikes are not expected to affect Peabody's mines in Wyoming. Powder River Coal Co. is a subsidiary of Peabody Holding Co. and runs two mines in Wyoming, the Rochelle and North Antelope mines. However, these two mines are not unionized and are expected to continue production, which accounts for nearly a quarter of Peabody's total production.

In a move to boost competitiveness, Exxon Corp. is imposing an "employee separation program" that will reduce the number of professional, clerical, and material handling workers by 25 percent (40 employees) at its Carter Coal Co. affiliate in the Powder River Basin. The cut back is not expected to affect Carter's 330 production, maintenance, and technician employees.

Contracts

New coal contracts, test burns, solicitations, and spot sales for the first quarter of 1993 are summarized in **Table 10.** A major and multi-year contract for approximately 1.5 million tons of coal was awarded to Powder River Coal Co.'s Rochelle mine by Commonwealth Edison. The contract partially replaces an old long-term contract, which was terminated in January of 1993. This older contract had been with the Black Butte mine near Rock Springs.

The Tennessee Valley Authority (TVA) has considered converting the Gallatin power plant to burn Power River Basin coals. However, it is doubtful they will

Table 10. Recent activity involving coal producers in Wyoming during the first quarter of 1993.

Utility	Power Plant	Coal Mine or Region	Activity	Tonnage	Comments
Commonwealth Edison	N.D.	Rochelle	C	1.5 million t/y	Contract could last for as long as nine years.
Consumers Power	N.D.	Powder River Basin	Sp	30,000	Anticipated February spot sales.
		Powder River Basin	So	30,000	Spot coal for delivery in March.
Dairyland Electric Power Cooperative	Genoa & Alma	Rochelle	Sp	300,000	Coal originating on Burlington Northern rail lines.
Hastings (NE) Utilities Dept.	N.D.	Exxon Coal	Sp	50,000-150,000	For delivery over the second half of the year.
Iowa Southern Utilities	Burlington & Ottumwa	Buckskin	C (?)	600,000-1.2 million	The contract is currently being finallized and is due to begin this spring.
Iowa-Illinois Gas & Electric	Louisa	Powder River Basin	So	800,000	Took bids in mid-March.
Lansing (MI) Board of Water & Light	Eckert	Powder River Basin	T	5,000	Four to five Powder River Basin producers will be solicited this spring.
Lower Colorado River Authority	N.D.	Caballo Rojo, Cordero, Rochelle, Jacobs Ranch, Caballo	So	200,000	Bids ranged from $3.21/ton (Cordero) to $5.05/ton (Jacobs Ranch).
Midwest Power Systems	Neal No. 4	Powder River Basin	So	N.D.	Solicitation is expected in May or June.
	Neal units 1-3 & Council Bluffs	Powder River Basin	So	800,000	
	Neal south units	Powder River Basin	So	650,000-1 million	For 1993 spot coal.
	Neal north units	Powder River Basin	So	800,000-1.5 million	To be delivered by Western Railroad Properties Inc., Union Pacific & Chicago and North Western Railroad.
	Council Bluffs	Powder River Basin	So	500,000-1 million	Looking for higher sodium PRB coal.
Minnesota Power & Light	N.D.	Belle Ayr, Black Thunder & Cordero	So	N.D.	Considering some Wyoming mines as suppliers for 1993 (current suppliers are Montana's Big Sky and Spring Creek mines).

Table 10. Recent activity involving coal producers in Wyoming during the first quarter of 1993 *(Continued)*.

Utility	Power Plant	Coal Mine or Region	Activity	Tonnage	Comments
Mississippi Power Co.	Daniel	Decker Coal Co.	T	40,000	Part of testing of Powder River Basin and Indonesian low-sulfur, low-cost coals.
Missouri Public Service	Sibley	Rochelle, Shoshone, Medicine Bow	C	1.2 million t/y	Contract is through 1995.
Muscatine Power & Light	No.9	Buckskin	C	300,000-500,000 t/y	Contract is from 1993 through 1998.
Northern Indiana Public Service	Michigan City	Shoshone	Sp	48,000	
	Michigan City	Belle Ayr	Sp	11,000	
	R.M. Schahfer	Shoshone	Sp	58,000	
	Mitchell	Belle Ayr & Antelope	Sp	N.D.	Other lower-Btu Powder River Basin coals may be tested.
	Michigan City	Belle Ayr	Sp	11,000	February spot coal sales.
	Dean H. Mitchell	Belle Ayr	Sp	66,000	February spot coal sales.
Tacoma WA Public Utilities	N.D.	Decker	C	N.D.	
West Texas Utilities	Oklaunion	Belle Ayr & Eagle Butte	Sp	200,000	Supply for its first half spot market coal, other test burns of Powder River Basin expected.
	Oklaunion	Belle Ayr & Eagle Butte	Sp	200,000	The utility may extend its first half agreement with these mines rather than solicit new offers.
Wisconsin Electric Power Co.	Presque Isle (Units 7, 8 & 9)	Arco coal (Black Thunder)	T	38,000	
Wisconsin Public Service Corp.	Pulliam 5-8 units & Westin 1 and 2 units	Rochelle	C	1 million	Contract is for 1 yr and begins in September.

N.D. = no data available; C = contract coal; T = test burn; Sp = spot coal; So = solicitation.

make the switch after estimates were received for the cost of modifying the plant to burn Wyoming coal. In addition, TVA believes that President Clinton's new Btu tax may put further hindrances on converting the Gallatin plant.

Coalbed Methane

During the first quarter of 1993, the following significant activities related to coalbed methane occurred. The letters preceding the discussion below refer to locations on **Figure 16**.

A. The environmental impact statement for Metfuel's coalbed methane project has been released. However, in response to concerns raised by the Wyoming Outdoor Council, the U.S. Bureau of Land Management (BLM) is recommending a scaled-down version of the proposed coalbed methane project. The drilling project, which will be implemented in phases, may ultimately provide 112 to 295 jobs during the several-year construction and drilling phase and 17 to 29 permanent jobs. The proposed project is located about seven miles north of Hanna and involves drilling and development of a maximum of 130 coalbed methane wells. During the first 20 years of operation, the project could produce

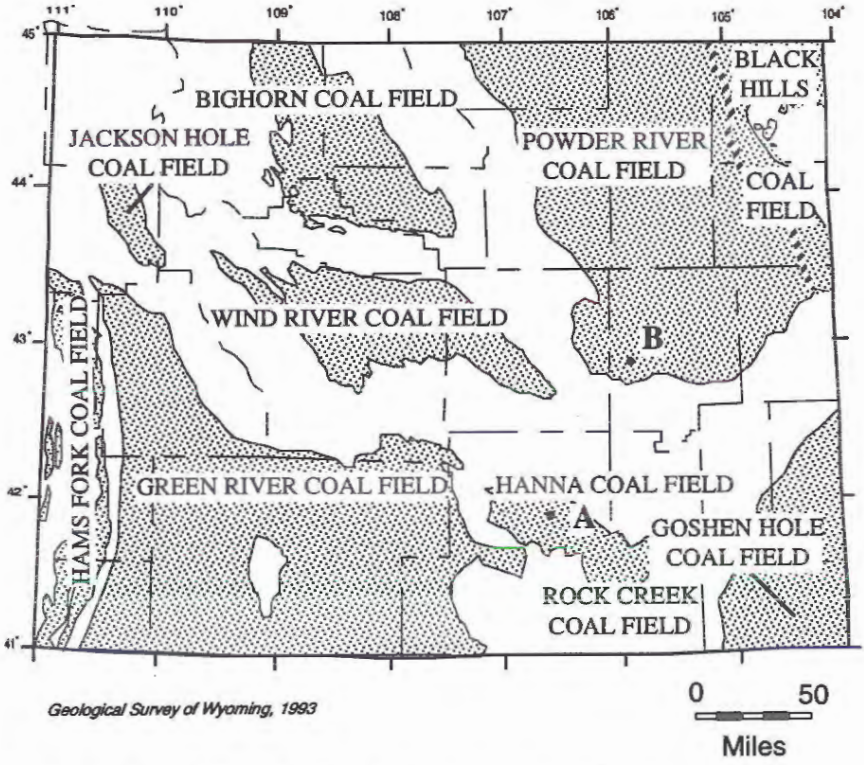


Figure 16. Coalbed methane activity in Wyoming during the first quarter of 1993.

more than 763 billion cubic feet of gas. So far Metfuel has applied to drill 4 holes in the Hanna region.

B. In the first quarter of 1993, Texas-based Tiger Oil Co.'s drilling and testing of coalbed methane holes near the Concho Valley subdivision near Casper were put on hold. Tiger was fined $3,000 in February for drilling too close to residential properties and the Wyoming Oil and Gas Conservation Commission ordered a study of Tiger Oil's operation in and adjacent to the subdivision. In April, as a result of the study, some holes were ordered plugged, but Tiger was also allowed to resume operations with certain stipulations.

INDUSTRIAL MINERALS AND URANIUM UPDATE

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

Aggregate (Construction)

In southeastern Wyoming especially, there is continued interest in limestone for use as construction aggregate. Certain natural gravel deposits in that area of Wyoming, which are used as aggregate, contain unwanted minerals that react with concrete. These minerals, particularly chert and sulfides, cause weakening and premature disintegration of concrete made with them. Consequently, contractors in this area of the State have specified limestone aggregate, which does not react with concrete. Highway construction contracts for certain stretches of Interstate 25 north of Cheyenne, for example, are specifying limestone aggregate for projects this summer. As a result, aggregate suppliers have been exploring limestones along the east slope of the Laramie Mountains from the Wyoming border southwest of Cheyenne to west of Wheatland (**Figure 17**).

Bentonite

Although Wyoming continues to lead the nation in bentonite production, the amount of bentonite produced in Wyoming in 1992, may have decreased somewhat from that produced in 1991. According to the U.S. Bureau of Mines, however, the value of bentonite produced in Wyoming in 1992 increased 20 percent from 1991 (Peterson, 1993).

Decorative stone

The production of black granite at Sunrise Stone Company's Wyoming Raven quarry in Albany County (**Figure 17**) resumed in late March, following the closure of operations during last winter. Because there has recently been an increase in the popularity of patterned decorative stones, Sunrise is also producing blocks of a pink, black, and white granite (geologically a migmatite) from the same quarry. The different colors in this latter rock exhibit a swirled and striped pattern. This stone is marketed under the name "Fantistica".

Gypsum

Gypsum ($CaSO_4 \cdot 2H_2O$) is produced in Wyoming for wallboard at the Celotex, Inc. plant near Cody and the Georgia-Pacific Corp. plant between Greybull and Lovell in Big Horn County (**Figure 17**). Mountain Cement Co. mines smaller amounts of gypsum south of Laramie for use in manufacturing cement (**Figure 17**). Nationally, the production of gypsum increased about 10% over the corresponding period one year ago.

Limestone and lime

Dakota Coal's construction of a lime plant north of Frannie, Wyoming, continued in the first quarter of 1993 (**Figure 17**). The plant will produce lime for controlling emissions at power plants. Meanwhile, limestone used for emissions control at Missouri Basin Electric's Laramie River power plant near Wheatland (**Figure 17**) are quarried at Dakota Coal's Bass quarry north of Guernsey (**Figure 17**).

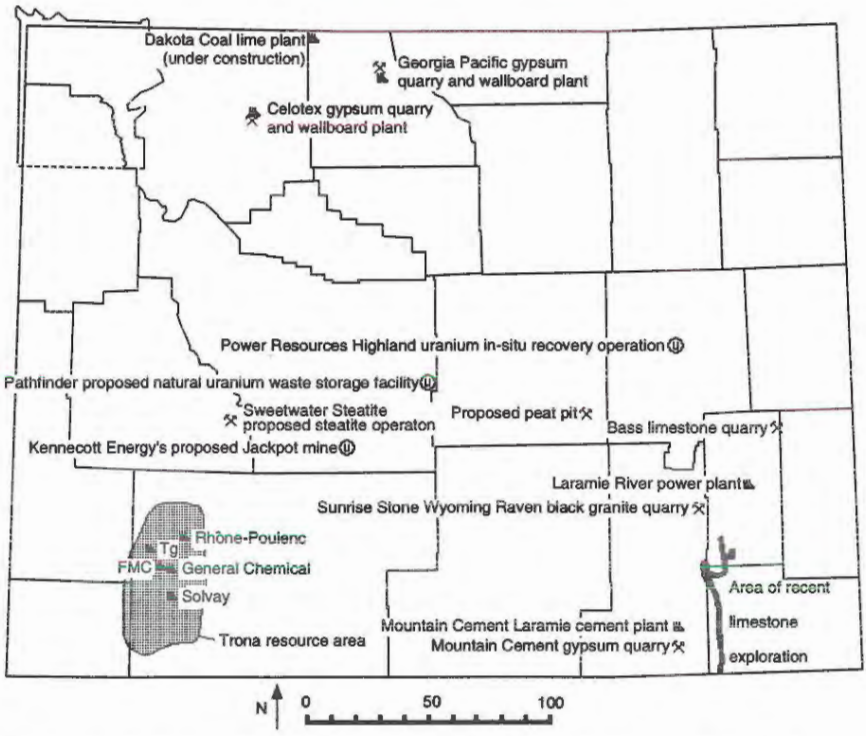


Figure 17. Industrial minerals and uranium activities in Wyoming during the first quarter of 1993.

Peat

Peat is an organic product formed in bogs or swamps. It is used as a soil conditioner, fertilizer, potting soil, nursery soil, and in other specialty applications. Approximately 800,000 short tons of peat are produced annually in the United States. A Wyoming company is testing a peat deposit near Casper for possible production and use in potting soil and as a soil conditioner (**Figure 17**).

Sulfur

In the U.S., sulfur is produced as a by-product from the refining of natural gas (recovered sulfur) or by mining of natural sulfur deposits through a process known as the Frasch method. Wyoming ranked second in the nation in recovered sulfur in 1991 (Ober, 1992). Although state rankings for 1992 are not yet available, last year the nation's production of recovered sulfur increased about six percent over 1991. Sulfur prices, however, have fallen drastically. The current sulfur price (F.O.B. Gulf Coast ports) is around $30.00 per short ton, compared to nearly $60.00 per short ton one year ago (Foster 1993).

Talc (Steatite)

In February, the Wyoming Environmental Quality Council granted Sweetwater Steatite, Inc. of Rock Springs, a permit to mine steatite. The steatite deposit, located in the southern Wind River Range, consists of large boulders of sufficient quality to provide a source of steatite for carving and other artistic uses (**Figure 17**).

Trona

Five plants produce soda ash and other sodium compounds from mined trona in the trona resource area west of Green River. Over 90 percent of the sodium compounds produced in the U.S. come from the Wyoming trona mining area (**Figure 17**).

As reported in *Wyoming Geo-notes No. 37* (p. 39), the U. S. Bureau of Land Management (BLM) proposed increases in the Federal royalty rate for trona. Due to industry opposition, however, the BLM rescinded its recommended increase. In January, officials from the BLM met with industry representatives to discuss possible increases. Following this meeting, the BLM did not make any recommendation, but said that it would continue its study of this issue. The trona mining companies and soda ash producers are objecting to any increase in the royalty rate.

In late 1992, FMC proposed a $120 million expansion project, which would increase production capacity by 20 percent. In February, the Wyoming Industrial Siting Council recommended approval of FMC's proposal. But in April, company officials announced a one year postponement, pending a final decision by the FMC Board of Directors.

Rhône-Poulenc announced in March that it was beginning construction of emission-control devices at its Big Island soda ash refinery. One project includes the modernization of electrostatic precipitators in stacks. Another project will reduce windblown dust from trona stockpiles.

In February, General Chemical's soda ash plant was certified by the International Standards Organization (ISO). Certification by ISO means that the plant's products meet ISO quality specifications. General, a partnership owned by BTR Nylex of Australia and the Tosoh Corporation of Japan, is the first plant in the U.S. to receive ISO certification. This could result in increased sales for General, since many international buyers purchase only from plants certified by ISO.

Uranium

The NUEXCO spot market price for yellowcake declined through the period to a near-record low of $7.60 at the end of February, 1993 (**Table 11**).

Among the factors causing the continuing decline in the price of yellowcake are: 1) In 1991, the former Soviet Union dumped uranium and uranium oxide on the market, resulting in a worldwide oversupply of uranium; 2) There is also additional uranium coming into the marketplace as weapons-grade uranium (>99% ^{235}U) from decommissioned nuclear weapons is converted to fuel-grade uranium (3% ^{235}U); and 3) Actions by Euratom, the European atomic energy cartel, have protected high-priced European nuclear fuel producers, particularly France, from world market conditions (Pool, 1993).

Table 11. NUEXCO spot market price of yellowcake, October 1992, to February 1993.

Month	Price
Oct. 1992	$8.00
Nov. 1992	7.90
Dec. 1992	7.85
Jan. 1993	7.65
Feb. 1993	7.60

In Wyoming, yellowcake is now only produced from uranium ore at Power Resources' Highland in-situ operation in the southern Powder River Basin north of Glenrock. And Kennecott Energy's Green Mountain Mining Venture now has a name, the Jackpot mine. Through May 20, 1993, the U.S. Bureau of Land Management is asking for public comments on this 3,000-ton-per-year underground uranium mine. The proposed mine is located south of Jeffrey City (**Figure 17**). An environmental assessment will follow the comment period.

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METALS AND PRECIOUS STONES UPDATE

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

During the past quarter, the Geological Survey of Wyoming continued to receive numerous inquiries about the State's diamondiferous kimberlites, kimberlitic heavy mineral anomalies, and the Leucite Hills lamproites (*Wyoming Geo-notes No. 37,* p. 43-44). Some interest was also reported in the proposed Crown Butte Mines' New World Gold Project in Cooke City, Montana. And the Carissa gold mine at South Pass-Atlantic City was offered for sale.

The New World Gold Project lies immediately north of the Wyoming border. According to the Casper Star-Tribune (April 4, 1993), mine reserves contain about 1.64 million ounces of gold. In 1982, Geological Survey of Wyoming investigations in this region traced the Irma-Republic vein of the New World mining district to the Wyoming border, where it abruptly ended. Other mineral deposits in this region include the Sunlight Basin and Kirwin copper-silver porphyries, both located in Wyoming (Hausel, 1982).

The Carissa gold mine in the South Pass-Atlantic City area has been put up for sale by a Canadian mining firm. According to production records and estimates, the mine yielded 50,000 to more than 180,000 ounces of gold. The ore reportedly averaged 0.3 ounces per ton. Sampling by the Geological Survey of Wyoming identified a broad shear zone (> 97 feet wide) at the Carissa, containing low-grade gold (Hausel, 1991). Interested individuals and companies can contact Steve Gyorvary or Dave Geible at 307/332-4335.

During the 1992 field season, the Metals and Precious Stones Section of the Geological Survey of Wyoming investigated several mineral deposits. One deposit of potential economic interest was the Broadway property in the Encampment district of the Sierra Madre.

Broadway property

The Broadway property is located on the East Fork Creek in SW section 32, T14N, R83W (see Dudley Creek 7.5-minute Quadrangle). The property is accessible by the Blackhall Mountain forest road running 19 miles south of Encampment. The last 2.5 miles were a rough jeep trail, which was scheduled for closure and reclamation by the Forest Service later in the summer.

Previous reclamation of the mine site has destroyed all field relationships on the property. The old shafts, trenches, and outcrops have been buried, and ore samples are scattered over the mineralized area.

Exploration history

The available records indicate that the Broadway property has had a long period of exploration activity. The property was initially staked by Bill Sodder in 1904. He sank a 20-foot-deep shaft in search of gold. In 1927, B.L. Bensen acquired the property and sunk three additional shafts of about the same depth.

The U.S. Bureau of Mines examined the property in 1942, collecting samples from the mine workings. According to Osterwald (1947), the Bureau of Mines collected five "character" samples and one channel sample. These included: (1) a channel sample along the west side of the No. 1 shaft, about 4 feet from the bottom (Table 12); (2) a sample from the mine dump of the No. 2 shaft; (3) a sample from the No. 3 shaft; (4) rock chips from an outcrop near the No. 3 shaft; (5) a selected sample from the No. 1 shaft; and (6) another selected sample from the No. 1 shaft. The samples contained very small amounts of a platinum group metal identified by spectrograph.

Frank W. Osterwald with the Geological Survey of Wyoming examined the Broadway mine in 1947, and produced a geologic map of the property. Osterwald noted that the property had been examined by geologists with New Jersey Zinc.

Osterwald (1947) reported the ore zone was 1,000 feet long and about 50 feet wide, and continued under a heavily wooded area. The ore mineralogy included massive sphalerite and minor galena with local disseminated chalcopyrite, chalcocite, and covellite. Small amounts of secondary malachite and chrysocolla were observed. The ore content reportedly ranged from 3-35% throughout the property. A grey and white gneissic rock hosting 1-5% disseminated chalcocite, chalcopyrite, and bornite, was described near shaft No. 1.

The ore was described as being localized along the contact of a granite and a complex of gneiss, amphibolite, gabbro, and diorite. A considerable amount of granite pegmatite was associated with the ore zone. The dip of the ore body varied from 50°SE to 50°NW. The gneisses and amphibolites were fractured and recrystallized near the contact with granite. Ore replaced the amphibolites where

Table 12. Assay results for samples from the Broadway property, collected by the U.S. Bureau of Mines in 1942.

sample #	Zn(%)	Pb(%)	Cu(%)	S(%)
(1)	12.5	1.9	0.02	7.65
(2)	4.2	1.9	--	--
(3)	0.0	1.0	--	--
(4)	0.0	0.5	--	--
(5)	10.2	0.9	--	--
(6)	5.2	1.5	--	--

they had been sheared. Replacement was controlled by a set of northwest trending cross-fractures. The ore deposit was zoned, with copper concentrated near the Sodder shaft and zinc near the No. 1 shaft (Osterwald, 1947).

Bunker Hill Mining Company explored the property during the 1966 and 1967 field seasons. During this period, they mapped, sampled, trenched, and drilled the property. Nine shallow drill holes, totaling 850 feet, were completed. Two intersected significant mineralization. The best drill intercept was near the No. 2 shaft, and it encountered 20.5 feet of 8% Zn. Based on a small amount of data, it was estimated that some of the ore in sight in a small area of 150 feet by 8 feet by 100 feet deep consisted of 12,000 tons of 10% Zn.

DeNault (1967) conducted a thesis project on the Broadway property, mapping the area around the property and collecting stream-sediment samples. At the same time, he completed a small geochemical survey of the soil, which indicated the property was anomalous in lead and zinc. Petrographic work at this time indicated that the pyroxenite host rock typically consisted of diopside with minor enstatite replaced entirely or partially by spessartine. One sample examined by DeNault contained 35% olivine.

Undated analyses of grab sample material were reported by F.K. Root of the Geological Survey of Wyoming (Table 13).

Amselco examined the Broadway property in 1976. In the following year, they drilled the deposit and also completed geochemical soil surveys for zinc, lead, and copper over a relatively large area. The soil surveys identified a 3,000-foot-long copper anomaly; a 2,200-foot-long, 100- to 1,000-foot-wide zinc anomaly; and a 1,500-foot-long lead anomaly. Mineralization was recognized as massive zinc, lead, and copper sulfide associated with a lens of tightly folded pyroxene-garnet rock. The pyroxenite was traced for nearly 1,400 feet on the surface.

On June 3rd, 1992, the Broadway property was briefly examined by the Geological Survey of Wyoming, and a suite of samples was collected for geochemical analysis (Hausel, 1992). Ore sample specimens collected during this investigation consisted of banded massive sphalerite with lesser galena in a matrix of tremolite and spessartine, and granodiorite with disseminated chalcopyrite and chalcocite. The host rock of the massive sulfide is a pyroxene-spessartine hornfels and appears to be typical of skarn.

The five samples collected for assay included: (1) BW1-92, a limonite-stained felsite; (2) BW2-92, a granodiorite with disseminated chalcopyrite and chalcocite;

Table 13. Geochemical analyses of Broadway mine samples, no date or rock descriptions given.

description	Cu(%)	Pb(%)	Zn(%)	Ag(opt)	Au(ppm)
Above shaft 1	0.82	1.0	0.04	9.1	0.5
Blake #1	0.003	1.2	6.9	0.11	0.1
Lower #1	0.44	1.0	0.031	1.5	0.3
Lower #2	0.065	0.52	2.3	0.35	0.4

(3) BW3-92, a sphalerite-galena-bearing pyroxenite hornfels; (4) BW5-92, a spessartine-calcite-quartz-pyroxene-actinolite hornfels with massive sphalerite and minor galena; and (5) BW6-92, a spessartine-calcite-diopside-actinolite hornfels with massive sphalerite and a trace of galena. The samples were highly anomalous in zinc, lead, gold, and silver (**Table 14**).

Table 14. Assay results for samples from the Broadway property, collected by the Geological Survey of Wyoming in 1992.

sample #	Zn(%)	Pb(%)	Cu(%)	Au(ppb)	Ag(opt)	Pt(ppb)	Pd(ppb)
BW1-92	0.31	0.30	0.77	3,278	2.0	--	--
BW2-92	0.02	0.75	1.82	1,604	12.18	--	--
BW3-92	4.34	5.66	0.18	156	1.37	--	--
BW5-92	7.66	0.69	0.05	104	0.2	<5	2
BW6-92	8.17	0.62	--	215	0.29	--	--

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MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING

PETROLEUM

Remaining Resources (January 1, 1993)		
Discovered (Includes 10 billion barrels recoverable by enhanced recovery techniques)	12.5	billion barrels[1]
Undiscovered	7.6	billion barrels[1]
Total	20.1	billion barrels
Remaining Reserve Base (January 1, 1993)		
Measured reserves (Proved reserves) (Includes oil, gas liquids, and condensate)	1.26	billion barrels[2]
Indicated and inferred reserves	2.80	billion barrels[1]
Total	4.06	billion barrels

NATURAL GAS

Remaining Resources (January 1, 1993)		
Discovered (Includes 20.1 trillion cubic feet (TCF) of methane[1] and 122.0 TCF of CO_2[3])	141.1	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	3,848.3	trillion cubic feet
Remaining Reserve Base (January 1, 1993)		
Measured reserves (Proved reserves) (Includes 10.4 TCF of methane[2] and 60.6 TCF of CO_2[3])	70.0	trillion cubic feet

COAL

Remaining Resources (January 1, 1993)		
Identified and Hypothetical (Discovered)	1,428.2	billion tons[6]
Speculative (Undiscovered)	31.5	billion tons[6]
Total	1,459.7	billion tons
Remaining Reserve Base (January 1, 1993)		
Demonstrated strippable (Measured and indicated reserve base)	26.6	billion tons[7]
Demonstrated underground-minable (Measured and indicated reserve base)	42.5	billion tons[7]
Total	69.1	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, 1992, U.S. crude oil, natural gas, and natural gas liquids reserves: 1991 Annual Report, November, 129 p.
[3] De Bruin, R.H., 1991, Geological Survey of Wyoming Open File Report 91-6, 20 p.
[4] Jones, R.W., and De Bruin, R.H., 1990, Coalbed methene in Wyoming: Geological Survey of Wyoming Public Information Circular 30, 15 p.
[5] Law, B.E., and others, 1989, Estimates of gas resources in overpressured low-permeability Cretaceous and Tertiary sandstone reservoirs, Greater Green River Basin, Wyoming, Colorado, and Utah: Wyoming Geological Association, 40th Annual Field Conference Guidebook, Casper, Wyoming p. 39-61.
[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.
[7] Modified from Jones, R.W., and Glass, G.B., 1992, Demonstrated reserve base of coal in Wyoming as of January 1, 1991: Geological Survey of Wyoming, Open File Report 92-4, 26 p.
[8] Modified from Culbertson, W.C., 1983, Genesis and distribution of trona deposits in Wyoming (abstract) in Genesis and exploration of metallic and nonmetallic mineral and ore deposits of Wyoming and adjacent areas: Geological Survey of Wyoming Public Information Circular 19, p. 34.
[9] Energy Information Administration, 1989, Uranium industry annual: U.S. Department of Energy Report DOE/EIA-0478(89), 121 p.
[10] Knutson, C.F., and Dana, G.F., 1982, Developments in oil shale in 1981: American Association of Petroleum Geologists Bulletin, Volume 66, no. 11, p. 2513.

1992 MINERALS AND EXPLORATION SUMMARY FOR WYOMING

by W. Dan Hausel, Ray E. Harris, and Timothy A. Moore
Geological Survey of Wyoming

METALS AND PRECIOUS STONES

Bear Lodge Mountains, Black Hills, northeastern Wyoming

Several companies have expressed interest in the fenitized Tertiary alkalic complex of the Bear Lodge Mountains near Sundance, Wyoming, in past years. Drilling by International Curator and Coca Mines outlined a 8.2-million-ton disseminated gold deposit averaging 0.72 ppm Au. A third party is currently exploring the property.

Encampment district, Sierra Madre, southeastern Wyoming

During 1992, Noranda explored portions of the Encampment district in the Sierra Madre. This district is underlain by Proterozoic metasedimentary rocks and volcanogenic schists that are separated by a major shear zone known as the Cheyenne Belt.

In 1991 and 1992, the Geological Survey of Wyoming examined two deposits in the district. At the Kurtz-Chatterton property southeast of Encampment, selected mineralized samples over a strike length of 4,000 feet yielded 0.7-12.55% Cu, 0.0-28.1 ppm Au, 0.0-7.34 ppm Ag, and 0.0-0.8% TiO_2. Ten samples averaged 4.43% Cu, 5.96 ppm Au, and 2.1 ppm Ag.

The Broadway property south of the Kurtz-Chatterton was also examined. The deposit is a Proterozoic skarn hosted by pyroxenite and amphibolite. Samples included massive sphalerite with galena in pyroxenite, and disseminated chalcopyrite and chalcocite in granodiorite. Six samples ranged from 0.02-8.17% Zn, 0.30-5.66% Pb, 0.05-1.82% Cu, 104 ppb to 3.28 ppm Au, and 0.2-12.18 ppm Ag. One sample was tested for platinoids and yielded <5 ppb Pt and 2 ppb Pd.

Hartville uplift, eastern Wyoming

Several companies continued exploration in the Hartville uplift in eastern Wyoming. The activity was centered around metasedimentary-hosted massive sulfide targets in the Archean eugeoclinal terrane. The uplift is formed of a succession of hematite schist, metadolomite, metabasalt, and pelitic schist unconformably overlain by Paleozoic carbonates. The district has had a past history of copper, silver, uranium, onyx, and iron mining.

Kirwin district, Absaroka Mountains

The Absaroka Mountains in northwestern Wyoming represent a deeply dissected Tertiary volcanic plateau with several mineralized porphyries. In 1992, some exploration activity was reported in the northern Absarokas in the Sunlight Basin area south of Cooke City, Montana. The Kirwin porphyry in the southern Absaroka Mountains was recently donated to the U.S. Forest Service.

The Kirwin porphyry, southwest of Cody, was held by AMAX Exploration for nearly 30 years. According to company reports, AMAX outlined geological 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 study in 1991 indicated the deposit was amenable to in-situ leaching at recovery costs of $0.309 per pound of copper (Ora Rostad, pers. comm., 1992). AMAX sold the property to the Mellon Foundation, which subsequently donated it to the Forest Service. According to the Forest Service, the property is now held in an Acquired Land Status.

Lake Owen mafic complex, Medicine Bow Mountains

The Lake Owen mafic complex was recently investigated by Robert Loucks of Purdue University. According to Loucks, the complex is 1.8 billion years old and virtually unaffected by deformation and metamorphism. It forms a 25-square-mile, funnel-shaped intrusion tilted at 75°. In cross-section, at least 16 cyclic units have been identified.

Cumulus sulfides were recognized in at least 12 stratigraphic horizons, with some zones containing elevated Au and Pt ± Pd. Four of the horizons have laterally persistent precious metal anomalies of a few hundred to a few thousand ppb and contain Au-Ag alloys, Pt-arsenides, Pt-Pd tellurides, and sulfides. The mineralized zones are generally lenticular and spotty and include zones up to 15 feet thick with strike lengths of more than 1 mile. Vanadiferous titanomagnetite cumulates are persistent in gabbronorite near the tops of some of the cyclic units.

Medicine Bow Mountains, southeastern Wyoming

The Geological Survey of Wyoming collected 37 stream-sediment samples from drainages along the northern flank of the Medicine Bow Mountains during 1991 and 1992. The samples were panned and the concentrates assayed 0.0-256.0 ppm Au. Only one of 37 sample concentrates did not yield anomalous gold. Twenty samples yielded visible gold as colors and flakes up to 3 mm long.

The results suggest the presence of a widespread source terrane for gold in the Medicine Bow Mountains. But because of the paucity of geochemical analyses of the precious metal, it is not possible to determine if the metal originated from one widespread source, or from several localized sources.

The northern Medicine Bow Mountains are underlain by Proterozoic, miogeoclinal, metasedimentary rocks which include fluvial metaconglomerates

that exhibit similarities to the Witwatersrand of South Africa and the Blind River deposits of Canada. In 1992, a major mining company staked a block of claims in this region.

Quaking Asp Mountain, Rock Springs, southwestern Wyoming

The Geological Survey of Wyoming investigated an enigmatic silicified zone 10 miles south of Rock Springs. The silicified zone covers an area of about 30 square miles and continues to a minimum depth of 3,700 feet based on past oil and gas drilling. Other interesting features include some kaolinitic alteration, alunite, travertine, free sulfur, banded chert, and jasperoid.

Samples taken from the silicified zone show 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. The values were very low (trace to 0.110 ppm Au). To date, no bulk samples have been taken.

Rattlesnake Hills, Granite Mountains, central Wyoming

The Geological Survey of Wyoming investigated the Rattlesnake Hills in 1992. The Rattlesnakes form a supracrustal belt of Archean metasedimentary and metavolcanic rock along the northern edge of the Granite Mountains of central Wyoming. The belt was intruded by more than 40 Tertiary alkalic plugs and dikes. Recent mapping shows that the area consists of a refolded, isoclinally folded greenstone belt fragment with a lower(?) metasedimentary succession of metapelite, quartzite, banded iron formation, and amphibolite overlain(?) by pillowed metatholeiites, which in turn are overlain(?) by metagreywacke with intercalated metacherts. Farther north, the metagreywackes lie in contact with amphibolite and metabasalt.

Targets in the district include quartz breccia veins, metachert, banded iron formation (BIF), jasperoid, breccias, and stockworks. One 2,500-foot-long pyritiferous metachert with minor galena and jasperoid yielded samples with 7.5 and 4.5 ppm Au. Other samples included jasperoid which yielded 52 ppb Au and 2.0 ppm Ag. Another sample of jasperized quartz breccia a few miles west assayed 86 ppb Au, 0.3 ppm Ag, 122 ppm Cu, 239 ppm As, and 5.1 ppm Sb. Scorodite-stained quartz from a more than 5,000-foot-long mineralized zone in metabasalt assayed 925 ppb Au and 1.2 ppm Ag. A sample of brecciated BIF in this same area yielded 5.0 ppm Au and 0.28 ppm Ag. Nearby, a sample of iron-stained stockwork in amphibolite gneiss yielded 0.30 ppm Au.

American Copper and Nickel Company (ACNC) explored the Rattlesnake Hills from 1983 to 1987. ACNC identified several gold anomalies in structurally prepared Archean metamorphics (John Ray, pers. comm., 1991). The area is currently being explored by Canyon Resources.

Seminoe Mountains, central Wyoming

A study of the Seminoe Mountains mining district was completed by the the Geological Survey of Wyoming in 1992. The results show that the belt consists 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. The samples showed uncommon anomalous gold (0.0-1.36 opt Au); more common silver (trace to 0.5 opt Ag); and a zinc anomaly (0.28% Zn). Some amphibolites mapped near the western edge of the district are moderately to pervasively altered to chlorite, carbonate, actinolite, and epidote. Vein samples in this area ranged from <0.05-89.3 ppm Au, <1.0-55.0 ppm Ag, 0.03-3.75% 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.

State Line diamond district, southeastern Wyoming and northern Colorado.

In 1992, some companies and individuals obtained land positions in the State Line district, following the 'Great Diamond Rush' in the Canadian Northwest Territories. Also, Diamond Company, N.L., received a permit to build a diamond-extraction pilot plant in Wyoming.

To date, more than 100,000 diamonds have been recovered from the Colorado-Wyoming State Line district. The diamonds have ranged from microdiamonds to 2.6 carats in weight, and include both gem and industrial stones. Grades of the kimberlites tested to date have ranged from 0.005 carat per tonne to 1.351 carats per tonne (M.E. McCallum, personal communication). Between 35 and 40 kimberlite intrusives occur in the district.

Several untested targets in the district include potential diamond placers, airborne geophysical anomalies, remote sensing anomalies, and some untested diatremes. Additionally, the Geological Survey of Wyoming has identified heavy mineral anomalies (chromian diopside, pyrope garnet, and picroilmenite) at more than 150 localities in the southern and central Laramie Range. Heavy mineral anomalies have also been identified in the Medicine Bow Mountains (including placer diamonds), the Seminoe Mountains, and the Green River Basin. The Green River Basin also encloses one of the largest lamproite fields in the world.

Silver Crown district, Laramie Mountains, southeastern Wyoming

In recent years, several companies have shown interest in a low-grade, Proterozoic, porphyry Cu-Au deposit in the Laramie Mountains between Laramie and Cheyenne. The deposit, known as the Copper King, is mineralized over a 600- by 300-foot area. Drilling has outlined a 35-million-ton deposit with an

average grade of 0.21% Cu and 0.022 opt Au. A higher grade core of 4.5 million tons, averaging 0.044 opt, was also identified by drilling.

INDUSTRIAL MINERALS

In 1992, there was relatively significant exploration for trona, bentonite, construction aggregate, decorative stone, limestone, and zeolites in Wyoming. All the producing soda ash companies and one bentonite company expanded their operations in 1992. Some soda ash companies explored for additional trona resources or new commodities. Limited exploration for peat, leonardite, mica, common clay, and silica sand also occurred.

All five soda ash producers in Wyoming were constructing expanded or new facilities. Solvay Minerals continued its efforts to acquire additional trona resources from the U.S. Bureau of Land Management (BLM) through a lease sale. Three other companies, not in production in Wyoming (Church & Dwight, U.S. Borax, and Wold Minerals), were also applying for trona leases. In addition, U.S. Borax applied to the BLM for an exploration license for more than 8,000 acres of Federal land thought to contain minable trona.

The Bentonite Corporation announced that it was expanding its bentonite production facility in Colony, Wyoming, to increase production of foundry clay. Other bentonite producers in Wyoming continued developmental exploration. 1992 marked the first time since the very earliest days of bentonite production that most bentonite was sold for purposes other than well-drilling fluids. The majority of the bentonite produced in Wyoming is now used for foundry clay and sealants for environmental containment.

There was continued exploration for construction aggregate in Wyoming. Limestone for various construction purposes was sought in southeastern Wyoming, and mining permits were applied for at a couple of sites. The construction of a lime plant continued at Frannie, Wyoming, in the Bighorn Basin. This plant will initially use limestone from the Warren quarry in Montana. Dakota Coal, the operator of the new lime plant, also acquired limestone resources in Wyoming.

Several companies explored selected localities in Wyoming for decorative stone. Star Granite, from Elberton, Georgia, conducted preliminary tests on some potential decorative stone sites in southeastern Wyoming, and companies from Tennessee, California, and Minnesota explored other decorative stone localities in the State. Sunrise Stone, which located a black granite quarry in 1991, expanded production in 1992, and also shipped a pink and grey granite from Wyoming for product marketing tests.

A South Dakota-based company explored for zeolites and planned to begin development in 1992. It was unable, however, to acquire the resources due to the BLM's oil shale mineral withdrawal. Efforts to modify or remove the withdrawal have been unsuccessful.

URANIUM

Little uranium exploration took place in Wyoming in 1992. The only uranium producer is currently Power Resources, which operates a uranium in-situ recovery operation at the Highland mine site in Converse County, northwest of Douglas. Power Resources continued to conduct developmental drilling for the expansion of its production field on the North Morton Ranch ore body, adjacent to the Highland site.

Rio Algom, Total Minerals, and Pathfinder Mines conducted limited developmental drilling tests on ore bodies in the Powder River Basin for potential in-situ production.

In partnership with the Green Mountain Mining Venture (GMMV), Kennecott Energy continued developmental assessment work on the Green Mountain ore body south of Jeffrey City. Work continued on the possible development of an underground mine at this site. The GMMV also purchased the Sweetwater uranium mill from Union Oil in California. The mill was Wyoming's largest producer of yellowcake in 1982. GMMV hopes the mill will be used to produce yellowcake from their proposed Jackpot mine at Green Mountain.

COAL

Coal production in Wyoming fell from 193.9 million short tons in 1992 to 189.5 million short tons in 1992. This 2.3% decrease is the first drop in coal production since 1986 for Wyoming. Still, Wyoming led the nation in coal production for the fifth consecutive year. The decrease in production is believed related to mild winters and cool summers in the south-central and mid-western states, the destination for most coal from Wyoming.

Competition for coal sales among mines continues to be intense, especially in the Powder River Basin. As longer term contracts are replaced by low-cost (<$5.00/short ton) and spot-market coal, mines are having to trim expenses and tighten budgets. A number of coal mining companies have been forced to lay off employees and/or reorganize in an effort to reduce expenditures and cut the overall cost of mining coal.

Several Federal coal lease sales occurred in Wyoming in 1992, all within the Powder River Basin. First, Kerr-McGee's lease extension to its Jacobs Ranch mine was finally approved by the Interior Board of Land Appeals (ILBA). The Lease-By-Application (LBA) sale was contested by environmental groups, but the ILBA ruled in favor of the U.S. Bureau of Land Management (BLM), which oversees the LBA sales. Kerr-McGee paid approximately $20.1 million as a bonus bid for 132 million short tons of coal. Arco's bid of approximately $71.9 million for a lease adjacent to its Black Thunder mine in the eastern Powder River Basin was accepted. The tract, known as West Black Thunder, consists of 429 million short tons of coal. In another lease sale, the North Antelope-Rochelle tract, containing 393.7 million short tons of coal, was awarded to Peabody Holding Co. for a bonus bid of almost $87 million. Peabody already owns the existing Rochelle

and North Antelope coal mines. Finally, a bid by Northwestern Resources Co. for the West Rocky Butte tract was rejected by the BLM in late December 1992. The bid was for $14 million for 55 million short tons of coal. However, Northwestern Resources' subsequent bonus bid of $16.5 million in early January 1993 was accepted.

GEOLOGIC MAPPING AND STRATIGRAPHY

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

COLOR VERSION OF WYOMING STRATIGRAPHIC NOMENCLATURE CHART PUBLISHED

The Geological Survey of Wyoming recently published the final, colored version of a stratigraphic nomenclature chart for the State of Wyoming. The colors on the new chart are compatible with the 1:500,000-scale geologic map of Wyoming (Love and Christiansen, 1985). The chart is on a single sheet and lists the Phanerozoic nomenclature in columns corresponding to the major basins and uplifts in Wyoming. Cambrian through Pleistocene nomenclature is included for sedimentary and igneous rocks deposited from about 570 million years ago to as recently as 10,000 years ago. Nomenclature is presented for both outcropping and subsurface rocks in each of the basins. Footnotes and references for accepted and alternative interpretations of nomenclature and ages of the rocks are also presented on the chart.

Map Series 41, entitled "Stratigraphic chart showing Phanerozoic Formations for the State of Wyoming", is authored by J.D. Love and A.C. Christiansen of the U.S. Geological Survey and A.J. Ver Ploeg of the Geological Survey of Wyoming. The chart is the culmination of a cooperative effort of the U.S. Geological Survey and the Geological Survey of Wyoming, which began nearly 13 years ago.

LIMITED FUNDS MADE AVAILABLE FOR THE NATIONAL GEOLOGIC MAPPING ACT OF 1992

The U.S. Geological Survey (USGS) is currently soliciting applications for funding from State Geological Surveys under the State Geologic Mapping Program (STATEMAP). STATEMAP is a component of the recently passed National Geologic Mapping Act of 1992 in which States and the USGS equally share in the cost of geologic mapping projects. Each Federal dollar must be matched by the State with a non-Federal dollar. Only $1.3 million will be available for awards in this, the first year of the program. Since the program replaces the previous COGEOMAP program, existing projects from that program will be given priority this first funding year. Some new projects will be funded with the review

panel giving priority to 1:24,000- and 1:100,000-scale mapping in areas requiring resolution of significant socioeconomic issues. The review panel is made up of 5 scientists from State Geological Surveys and 2 scientists from the USGS.

This funding year, the Geological Survey of Wyoming (GSW) submitted one $9,245 proposal for mapping in the Rattlesnake Hills-Barlow Gap supracrustal belts in Natrona County, Wyoming. It is hoped that the program will be funded to a much greater extent in the next funding year, at which time the GSW will submit multiple proposals.

SOME NEW PUBLICATIONS ON WYOMING GEOLOGY

During the last quarter, the following five new reports on Wyoming geology were published. Two papers, dealing with the Powder River Basin, evolved from the U.S. Geological Survey's Evolution of Sedimentary Basins Project. Another deals with the stratigraphic subdivisions in the Late Archean and Early Proterozoic rocks of the Sierra Madre and Medicine Bow Mountains of southern Wyoming. The final two deal with a provenance study on the Fort Union Formation of the Powder River Basin and the Quaternary geology of the Jackson Hole area, respectively. These reports are listed below and located geographically on the accompanying index map (**Figure 18**).

1. Hansley, P.L., and Brown, J.L., 1993, Provenance of the Tullock Member of the Fort Union Formation, Powder River Basin, Wyoming and Montana: Evidence for Early Paleocene Laramide uplift: The Mountain Geologist, Vol. 30, No. 1, p. 25-34.

2. Houston, R.S., Karlstrom, K.E., Graff, P.J., and Flurkey, A.J., 1992, New stratigraphic subdivisions and redefinition of subdivisions of Late Archean and Early Proterozoic metasedimentary and metavolcanic rocks of the Sierra Madre and Medicine Bow Mountains, southern Wyoming: U.S. Geological Survey Professional Paper 1520, 50 p.

3. Naeser, N.D., 1992, Miocene cooling in the southwestern Powder River Basin, Wyoming - Preliminary evidence from apatite fission-track analysis: U.S. Geological Survey Bulletin 1917-O, 17 p.

4. Pierce, K.L., and Good, J.D., 1992, Field guide to the Quaternary geology of Jackson Hole, Wyoming: U.S. Geological Survey Open File Report 92-504, 54 p.

5. Seeland, D., 1992, Depositional systems of a synorogenic continental deposit - The upper Paleocene and lower Eocene Wasatch Formation of the Powder River Basin, northeast Wyoming: U.S. Geological Survey Bulletin 1917-H, 20 p.

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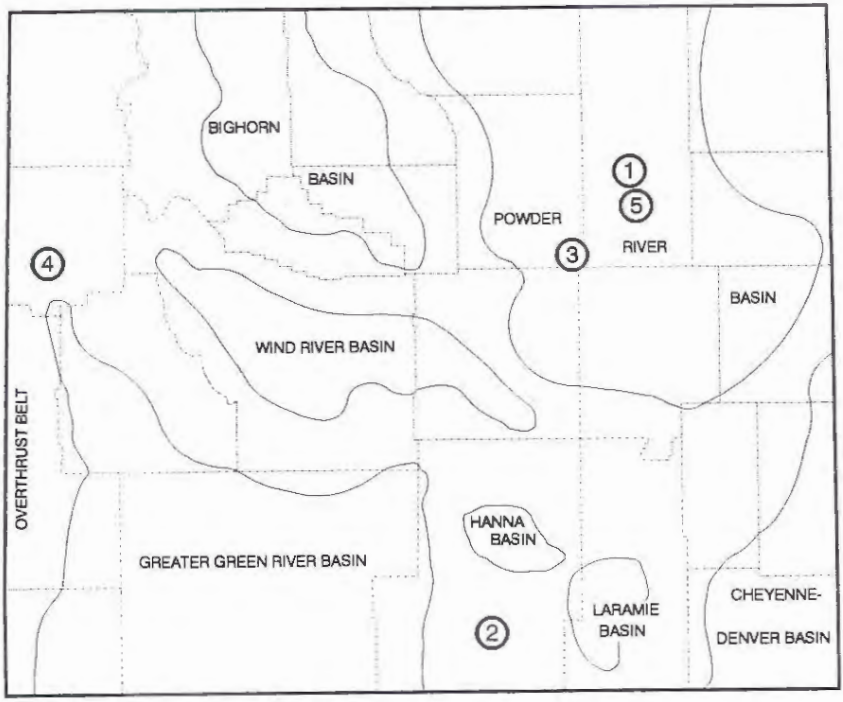

Figure 18. Index to selected geologic studies in Wyoming.

GEOLOGIC HAZARDS IN WYOMING

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

STUDY COMPLETED ON GAMMA RADIATION AND ITS RELATIONSHIPS TO RADON AT FOUR SITES IN WYOMING

Introduction

In 1992, the Geological Survey of Wyoming (GSW) compared aerial and ground-based, background gamma-radiation data with radon data from home sampling at four test sites in Wyoming: central Goshen County, Afton, Sheridan, and Laramie. For the purposes of this study, the central Goshen County area included Lingle, Fort Laramie, and Torrington. In addition, the GSW compared

ground-based, background gamma-radiation data with soil-gas radon data in the Laramie area to test the feasibility of using ground-based, background gamma-radiation data to augument or replace soil-gas radon testing.

Background

In several areas of the U.S., maps of ground-based, background gamma radiation and (or) aerial gamma radiation have been used to identify the potential for the occurrence of radon. Duval, et. al., (1990) found a good correlation between ground-based, background gamma-radiation surveys and soil-gas radon levels in Colorado. Duval (1991) was able to estimate levels of radon in soil-gas in New Jersey by using aerial, gamma-radiation data.

Comparison of background gamma-radiation levels with radon in homes

Radon data from a home sampling survey in 1987 by the Wyoming Department of Health was compared with aerial and ground-based, background gamma-radiation data in central Goshen County, Afton, Sheridan, and Laramie. Afton had the highest mean home-radon level [16.77 picocuries per liter (pCi/L)], followed by central Goshen County (5.96 pCi/L), Sheridan (4.87 pCi/L), and Laramie (3.81 pCi/L).

Table 15 shows a comparison of background gamma-radiation data from ground-based and aerial measurements with home-radon sampling data in the four study areas. The areas are listed under each category from highest to lowest.

Aerial and ground-based, background gamma-radiation data were compared for all four sites. The data were all reported as total gamma radiation, expressed in microroentgens per hour (μR/hr). The ground-based, gamma-radiation data was collected by GSW personnel. Aerial data were derived from the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) reports.

For all sites, the mean values for the ground-based, gamma-radiation levels were higher than for the aerial, gamma-radiation levels. Central Goshen County had a mean, ground-based, gamma-radiation level (18.5 μR/hr) that was 40.2% higher than the associated mean level for the aerial data (13.2μR/hr), (geoMetrics,

Table 15. Ranking of study areas by mean background gamma-radiation levels and by mean home-radon levels. (In each case, the areas are listed from highest to lowest levels).

BACKGROUND GAMMA RADIATION (Ground-Based Measurements)	RADON LEVELS (Home Sampling)	BACKGROUND GAMMA RADIATION (Aerial Measurements)
Central Goshen County	Afton Area	Central Goshen County
Sheridan Area	Central Goshen County	Laramie Area
Afton Area	Sheridan Area	Sheridan Area
Laramie Area	Laramie Area	Afton Area

Inc., 1979). The mean ground-based, gamma-radiation level (10.3 μR/hr) at Afton was 108.9% higher than the associated aerial mean (4.93 μR/hr), (Geodata International, Inc., 1981). Sheridan had a mean, ground-based, gamma-radiation level (14.8 _R/hr) that was 155.6% higher than the associated mean level for the aerial data (5.79μR/hr), (High Life Helicopters, Inc. and QEB, Inc., 1981). Laramie had a mean, ground-based, gamma-radiation level (9.82 μR/hr) that was 38.7% higher than the associated aerial mean (7.08 μR/hr), (geoMetrics, Inc., 1978).

Because the relationship between aerial and ground-based, gamma-radiation data at the various sites was so variable, the relationship was not deemed predictable. Also, previous research indicates that some of the aerial, gamma-radiation surveys done for NURE may have been improperly calibrated or analyzed (Duval, et. al., 1990; Duval, 1991). For these reasons, comparisons with NURE data (especially uncorrected data) must be used very cautiously, if at all.

In regard to comparing ground-based, gamma-radiation levels with home-radon levels, the Afton area is the least consistent. Afton has the next-to-lowest mean, ground-based, background gamma-radiation level, and the highest, mean, home-radon level. If the Afton site were removed from the study, however, all areas would have the same ordering for both ground-based, gamma-radiation and home-radon levels. Assuming that Afton is in some way anomalous for home-radon sampling, this limited study suggests that a ground-based, background gamma-radiation survey may provide a relatively rapid, reasonably priced, alternative to home-radon sampling. The fact that Afton is an apparent anomaly merits further investigation.

Comparison of ground-based, background gamma-radiation levels with soil-gas radon values

In 1992, the GSW conducted a series of soil-gas radon measurements at twelve sites in the Laramie Basin (*Wyoming Geo-notes No. 37*, p. 53-56). Ground-based, background gamma-radiation data were collected at each of the sites on both November 9, 1992, and November 17, 1992.

Results of the soil-gas radon study indicated that the twelve sites could be grouped into three soil-gas radon ranges: low (0-250 pCi/L), moderate (250-750 pCi/L), and high (>750 pCi/L). Ground-based, gamma-radiation data for the twelve sites indicated that three gamma-radiation groupings were also present: low (7.3-8.0 μR/hr), moderate (9.8-11.6 μR/hr), and high (13.2-15.5 μR/hr). The terms low, moderate, and high, as applied to both soil-gas radon and ground-based, gamma-radiation data, are relative and for comparison purposes only. They have no bearing whatsoever on relationships to human health.

With three exceptions, the sites in the ground-based, gamma-radiation groupings correlated fairly well with the sites in the soil-gas radon groupings. Even with the three exceptions, statistical analysis indicated a linear correlation coefficient of 0.715 between the soil-gas radon levels and the ground-based, gamma-radiation levels.

Conclusions

The NURE aerial, gamma-radiation data were the most inconsistent of the compared data. The NURE data, however, did consistently show lower mean gamma-radiation levels than the ground-based data. This study also suggests that corrected NURE data alone may not be a very reliable method to assess the radon potential of an area.

There were reasonably positive correlations when ground-based, gamma-radiation data were compared to home-radon data. Afton was the notable exception. Consequently, to improve the reliability of ground-based, gamma-radiation data, these data should be used in conjunction with other available information.

Ground-based, background gamma-radiation levels correlated well with soil-gas radon levels in the Laramie Basin area. The correlation may be better if gamma-radiation contributions from uranium were used for comparison instead of the total gamma-radiation levels that were used for this study.

Ground-based, background gamma-radiation surveys may be used as one of many reconnaissance tools in determining the potential for radon to occur in an area. The surveys are easily and quickly conducted, and may have less variability than observed in soil-gas radon surveys. Contact Jim Case for additional information on this study at (307) 766-2286.

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SPECTACULAR SLUMP STRUCTURES IN THE BLAIR FORMATION ALONG INTERSTATE-80

by Jane C. Shearer

The cover photograph is of an eye-catching outcrop on Interstate-80, a few miles east of Rock Springs. This outcrop contains a large (15 feet thick by 50 feet long) slump in sandstone beds of the Cretaceous Blair Formation. There are a number of these slumps visible along this part of Interstate-80. Roehler (1988) described similar geological features to the south of the interstate as syndepositional submarine slumps. These slumps formed on the margin of an arcuate delta, which was on the western shore of the interior Cretaceous seaway (**Figure 19**). The slumped sandstone beds are underlain by mudstone (**Figure 20**), suggesting that soft, incompetent mud layers may have failed under the weight of the overlying sandstone. The slumps may have been triggered by such events as rapid sediment influx, severe storms, or earthquakes.

The part of the Blair Formation in which the sandstone slumps occur intertongues to the north and west with the Rock Springs Formation. This formation consists of sandstone, siltstone, carbonaceous shale, and coal and was deposited in the delta plain and delta front. Although coal beds in the Rock Springs Formation are up to 14 feet thick, they are more commonly 4-6 feet thick (Glass, 1976). Some of the more persistent coals have been traced for 30 miles. Coals in the Rock Springs Formation are bituminous rank, have heat values

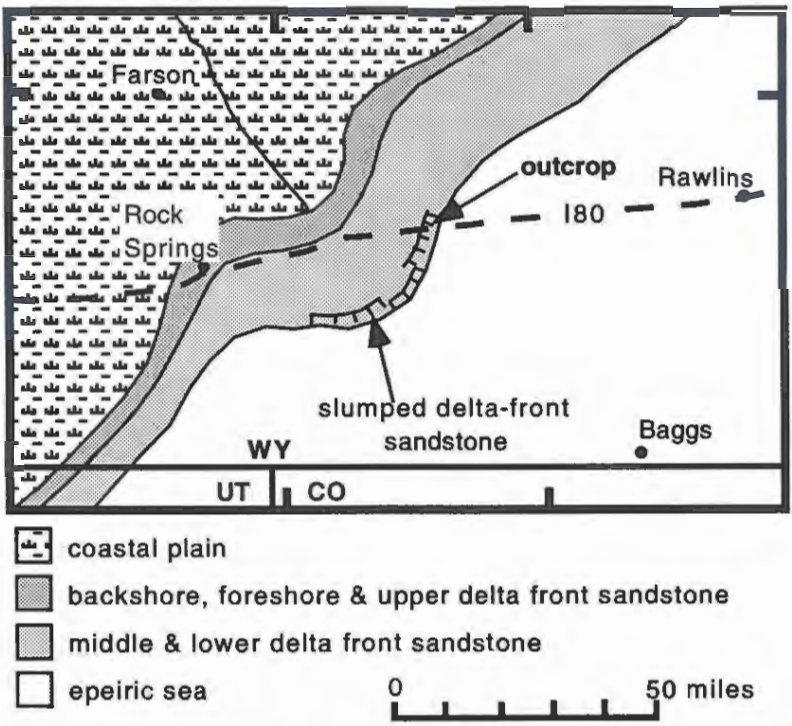

Figure 19. Paleogeographic map of the Rock Springs area of southwestern Wyoming, showing the location of the road cut.

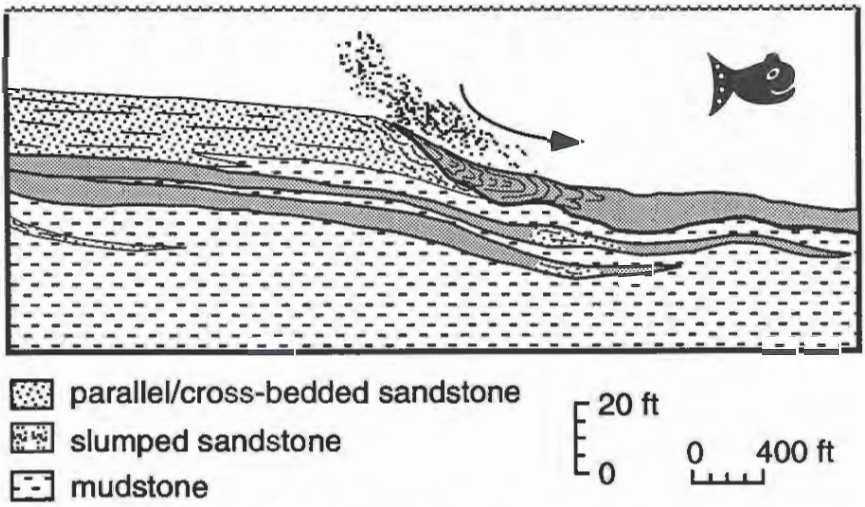

Figure 20. Depositional model for the origin of the slumps

between 9,720-13,110 Btu/pound, ash values from 2.2-10.3%, and sulfur values generally less than 1.4% (Glass and Roberts, 1988; Glass and Jones, 1992).

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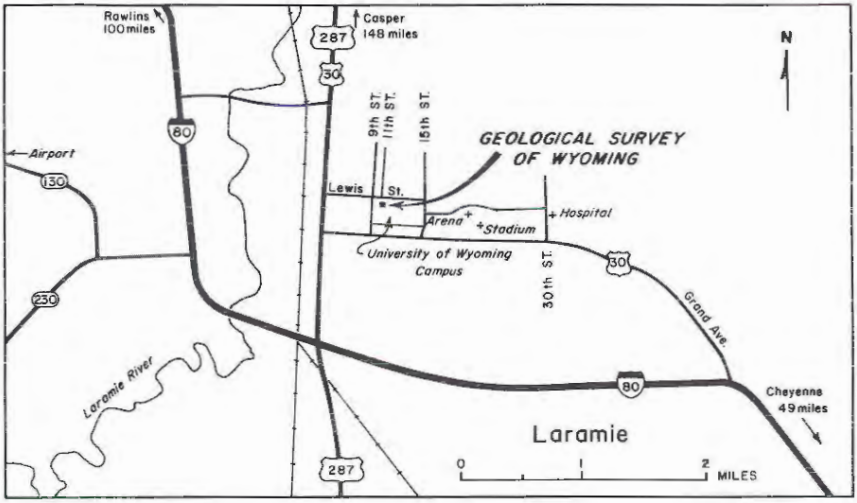

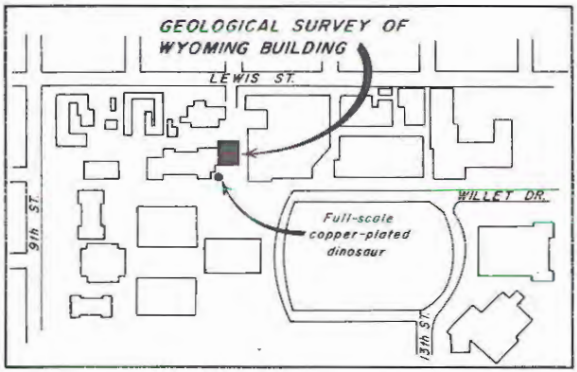

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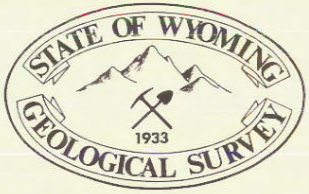
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