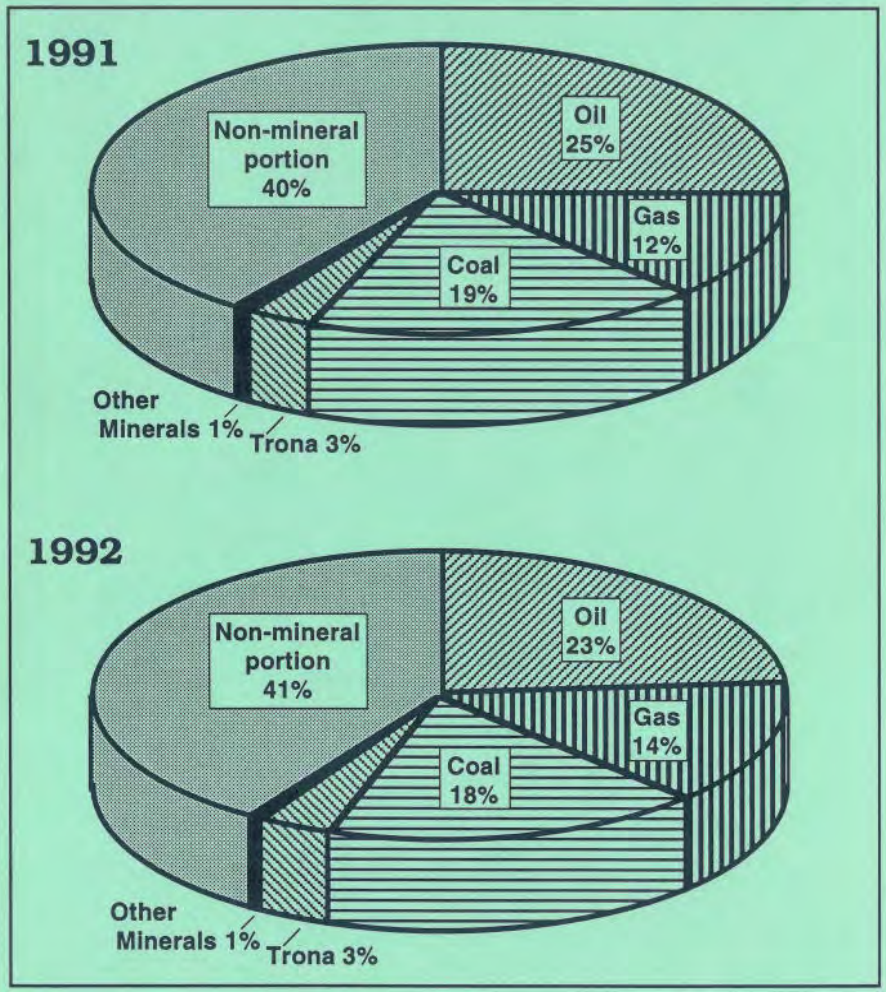
Wyoming Geo-notes

Number 37



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

Laramie, Wyoming
February, 1993

WYOMING GEO-NOTES

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Cover: Diagrams showing a percentage breakdown of Wyoming's total assessed valuation. Minerals accounted for 60% in 1991 and 59% in 1992. Total assessed value for calendar year 1991 was $6.05 billion, compared to an estimated $5.97 billion in 1992. *(Source: Department of Revenue).*

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MINERALS UPDATE

OVERVIEW

by Gary B. Glass
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Some of our forecasts for mineral production and prices have been revised since the last issue of *Wyoming Geo-notes*. In regard to production only our estimates for natural gas were increased (Table 1 and Figure 1). We not only increased our forecast for 1992 by 126 billion cubic feet, but our forecasts for the out years as well. These increases are a result of several factors. First, the Kern River Pipeline has already provided a market for 600 million cubic feet per day of Wyoming gas. Based on a significant show of interest by Wyoming producers, Kern River is now considering an expansion of that capacity. In addition, the prices received for Wyoming gas have been much stronger than in past years and are expected to hold that strength in response to this increase in demand.

Although our production forecasts for oil and coal have been revised downward, the decrease in oil was a million or less barrels in any one of the forecast years (Table 1 and Figure 2). In the case of coal, there is a possibility that production for 1992 might be somewhat higher than forecast, but there is really no way to be sure at this time. Third quarter deliveries of Wyoming coal to power

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

Calendar Year	Oil[2]	Methane[3]	Carbon Dioxide[3]	Helium[4]	Coal[5]	Trona[5]	Mined Uranium[6, 7]	In-situ Uranium[8]	Sulfur[9]
*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	0.91
*1991	99.8	820.0	140.3	1.05	193.9	16.1	0.4	1.1	1.04
1992	97.0	859.0	140.0	1.00	191.0	16.3	0.1	0.8	1.00
1993	93.1	884.0	140.0	1.00	194.3	16.6	—	0.8	1.00
1994	89.4	909.0	140.0	1.00	199.3	17.0	—	0.8	1.00
1995	85.8	934.0	140.0	1.00	204.3	17.2	—	0.8	1.00

*Actual values for comparison; [1]Geological Survey of Wyoming, February, 1993; [2]millions of barrels; [3]billions of cubic feet; [4]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; [5]millions of tons; [6]millions of tons of uranium ore (not yellowcake); [7]although the Shirley Basin mine is closing in 1992, some production of stockpiled ore may be reported in future years; [8]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); [9]millions of tons.

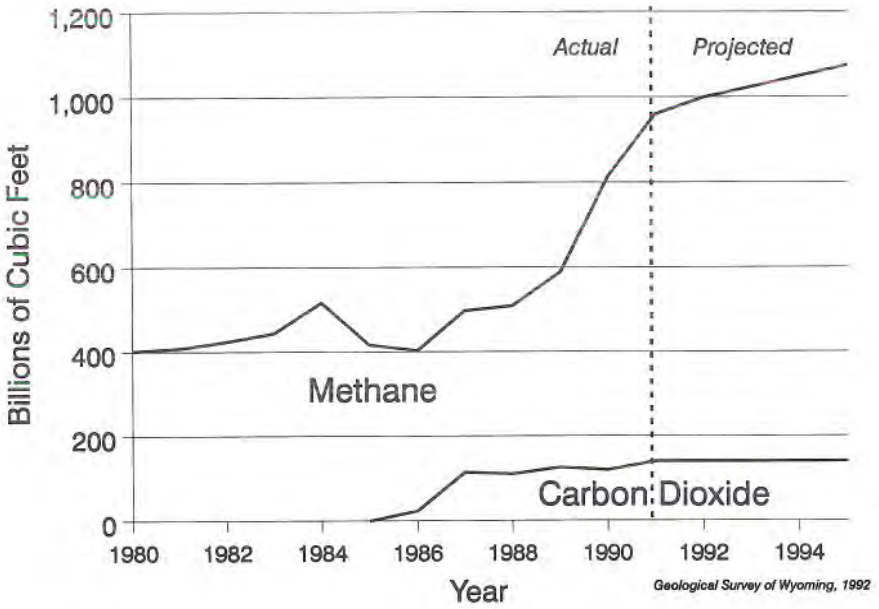

Figure 1. Annual natural gas production from Wyoming (1980 to 1991) with forecast to 1995.

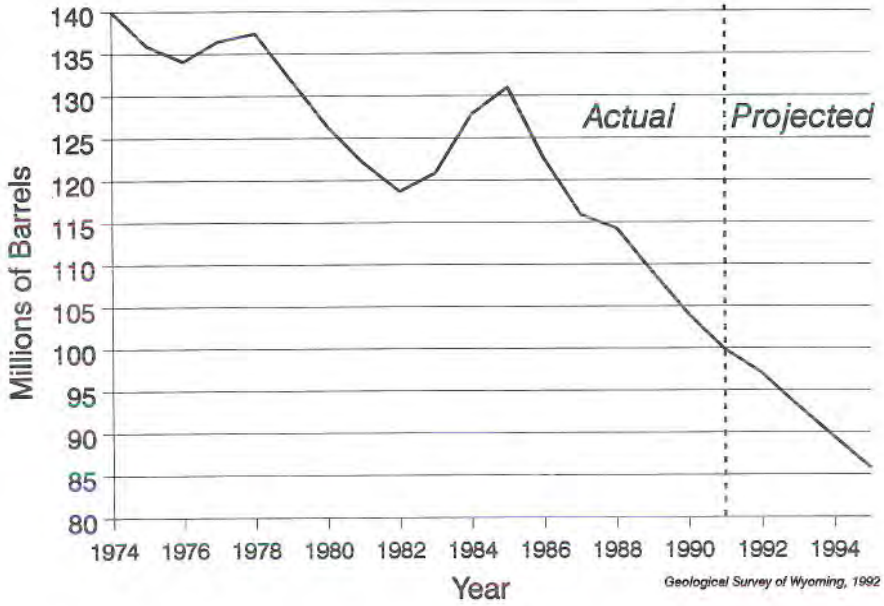

Figure 2. Annual oil production from Wyoming (1974 to 1991) with forecast to 1995.

plants were still 2.2 million tons below deliveries for the same period in 1991. Consequently, there has been no change to our 1992 forecast (Table 1 and Figure 3). Forecast coal production for 1993 through 1995, however, have been lowered slightly.

Although the **Coal Update** section of this issue lists numerous new contracts and sales of coal in the fourth quarter, most are renewing contracts to a current user or were test shipments. Exported tonnages to Spain, however, do look like they may increase. There is still no indication that any new markets have developed as a result of the amendments to the Clean Air Act. Wisconsin Public Service, however, plans to build a new coal-fired power plant for the Rhinelander Paper Co. in Wisconsin. This plant will use Wyoming coal. And Black Hills Power & Light Co. still wants to build a new unit at the Wyodak mine near Gillette. Hearings are being held on this latter plant.

The loss of a significant coal contract in southwestern Wyoming also occurred in the fourth quarter. While at least some of the lost contract was later awarded to a producer in the Wyoming portion of the Powder River Basin, a Montana producer also picked up some of the tonnage.

We lowered our 1992 oil price forecast as a result of prices falling in the fourth quarter (Table 2 and Figures 4 and 5). We are now projecting an oil price of $15.75 between 1993 and 1995, and we reduced coal prices for the same time period (Table 2 and Figures 5 and 6). Forecast natural gas prices were not changed from our third quarter estimate, and spot sale prices remained up through the last

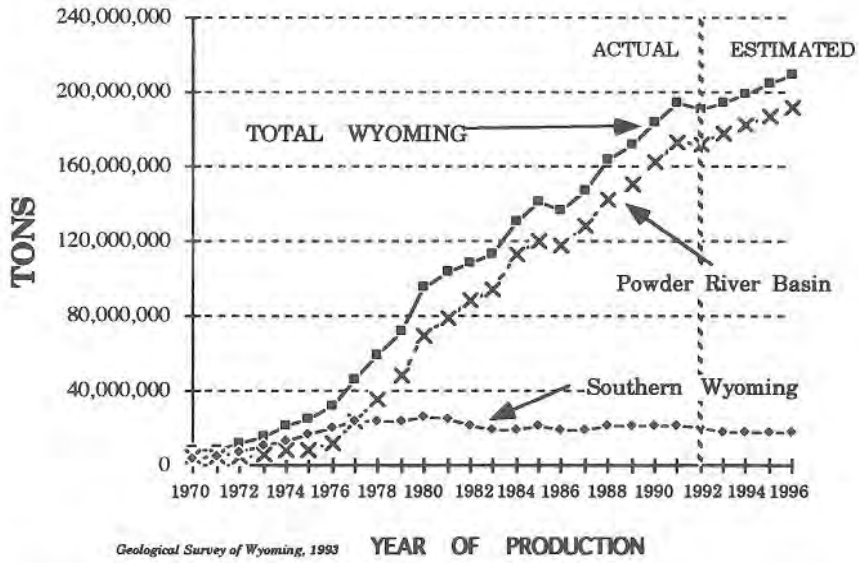

Figure 3. Annual coal production from Wyoming (1970 to 1991) with forecast to 1996.

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

Calendar Year	Oil[2]	Natural Gas[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	15.75	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).

[3] Wellhead price in dollars per MCF (includes carbon dioxide and natural gas liquids).

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

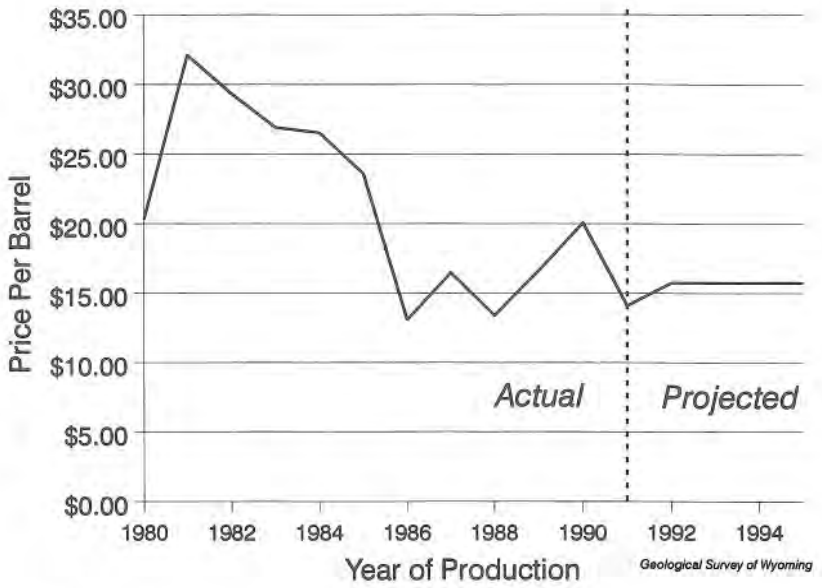

Figure 5. Average prices paid for Wyoming oil (1980 to 1991) with forecast to 1995).

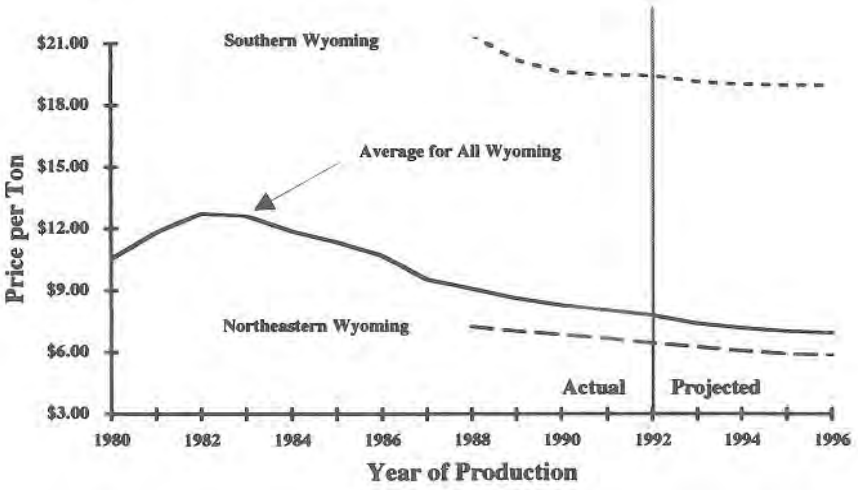

Figure 6. Average prices paid for Wyoming coal (1980-1991) with forecast to 1996 [*Data from U.S. Energy Information Administration (1980-1984)* and *Wyoming Department of Revenue and Consensus Revenue Estimating Group (1985-1996)*].

quarter of 1992 (Table 2 and Figures 7 and 8). Because the coal contract that was lost in southwestern Wyoming was for relatively high-priced coal, its loss resulted in a decrease in the average price paid for a ton of Wyoming coal. Also, a new table has been provided to show the relative prices of Wyoming coal from the northeastern and southern parts of the State (Table 3).

It is obvious from these latest forecasts that production of natural gas, trona, and coal are expected to grow steadily while oil continues its decline. Growth in coal production, however, will be slower than it has been, at least for the next four years. If there are going to be new markets for Wyoming coal related to compliance with the Clean Air Act amendments, they should become notable in 1993, but maybe not until the last half of the year. Actual production increases related to those markets may be longer in coming.

Wyoming's Natural Gas Pipeline Authority is still examining the possibility of the State assisting in the building of a pipeline to carry carbon dioxide from Bairoil, Wyoming, into the Powder River Basin and possibly other areas as well. They had hoped to make a recommendation in time for this year's Legislative Session, but were unable. Meanwhile, the Pipeline Authority has commissioned an additional study to aid in their deliberations.

Near the end of the year, another potential user of carbon dioxide materialized. A Utah group is looking into using one of the two abandoned refinery sites

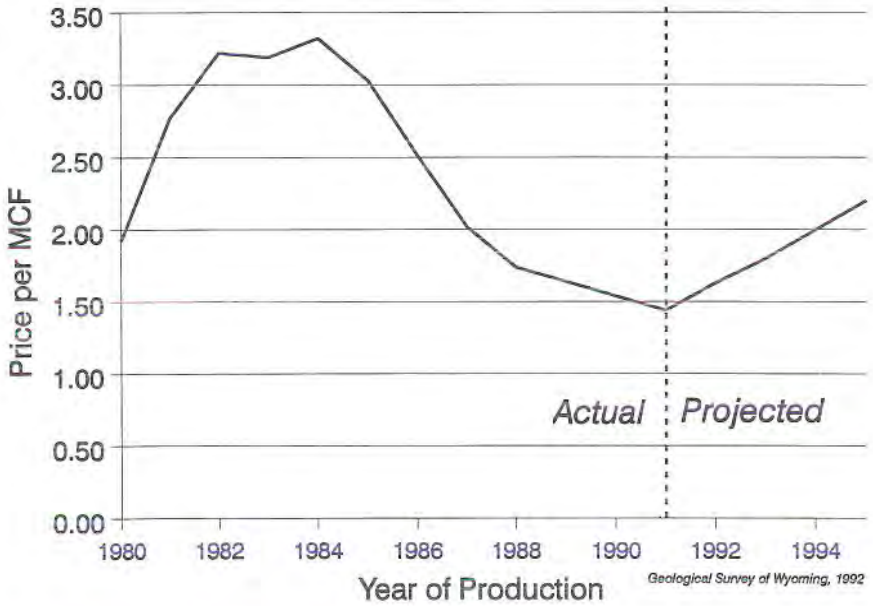

Figure 7. Average prices paid for Wyoming natural gas (1980 to 1991) with forecast to 1995 (includes carbon dioxide and natural gas liquids).

at Casper for the manufacture of two gasoline additives, methanol and MTBE. A pipeline to the Powder River Basin could support the needs of this facility also. This group met with the Natural Gas Pipeline Authority early in 1993 to provide more details about their plans.

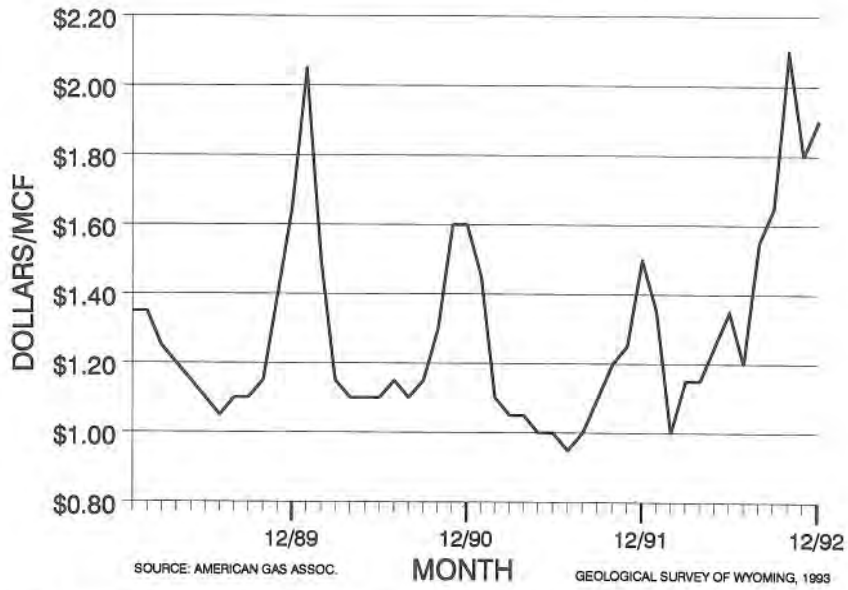

Figure 8. Spot prices for natural gas sales at Opal, Wyoming, averaged by month (1989 to present).

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

The **Industrial Minerals and Uranium Update** in this issue indicates continued expansion and interest in trona. In addition, construction of the Denver Airport has boosted production of cement and construction aggregate in both Colorado and Wyoming. Although production of construction aggregate in Wyoming has been increasing each year since 1988, a projected slowdown in highway work may offset the gains from the airport construction in 1993 (Table 4).

The **Metals and Precious Stones Update** indicates that the diamond rush of Canada has renewed interest in the diamond deposits in Wyoming. There is also renewed interest in the Kirwin Mining District.

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

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Bentonite[2]	2.35	2.18	3.08	2.59	1.82	2.16	2.32	2.22[6]	2.43[6]	2.38[6]
Clay[4]	15.7	36.4	59.6	35.9	23.2	1.31	61.1	23.6	---	---
Decorative Aggregate[2]	0.05	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]
Dolomite[2]	0.61	0.66	0.86	0.87	0.81	0.46	0.19[6]	0.15[6]	0.21[6]	0.23[6]
Gypsum[2]	0.26	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]	3.28	2.48	---	---	---	---	---	minor[8]	minor[8]	---
Leonardite[4]	---	---	---	---	---	---	---	---	22.9[6]	33.3[6]
Limestone[2, 5]	0.59	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]	6.24	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]	3.17	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, October, 1992.

OIL AND GAS UPDATE

by Rodney H. De Bruin
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Because of relatively high gas prices, the pending expiration of the tax credit for tight gas sands, and the increase in demand for Wyoming gas, the rig count in November and December rose to an average of 55. This is the highest average since 1987 (Figure 9). Overall, however, the average rig count for 1992, was only a small improvement over 1991's average (Figure 10).

There is some indication that the December expiration of the tax credit for tight gas may not produce the severe drop in drilling that some analysts anticipate. At least one active Wyoming operator, Enron Oil and Gas, announced plans to reinvest their tax benefits into their drilling program for tight gas sands.

A recent survey by Arthur Anderson & Co. indicated that domestic spending by the oil and gas industry will be greater in 1993 than in 1992. The survey showed the largest increase will probably be in development and property acquisition rather than in exploration.

Perhaps partially as a result of numerous refinery closures in Wyoming over the past 10 years, the Frontier Oil Co. refinery in Cheyenne announced plans to increase its present capacity [35,000 barrels of crude oil per day (BOPD)] to 41,000 BOPD. The refinery will also be able to handle more sour and heavy crude

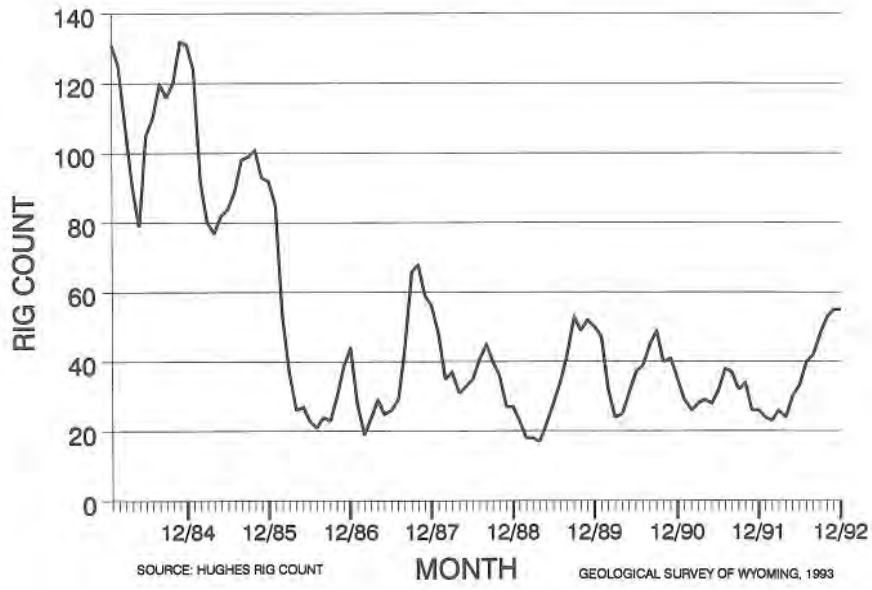


Figure 9. Wyoming daily rig count averaged by month (1984 to present).

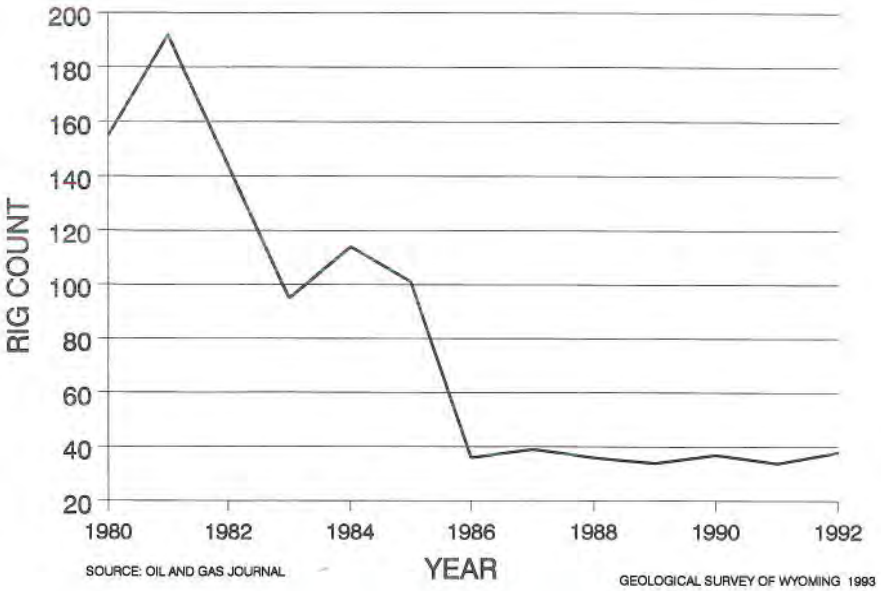


Figure 10. Wyoming daily rig count averaged by year (1980 to 1992).

oil. This is important to Wyoming since a larger share of production from the State falls into the sour and (or) heavy category each year.

A Utah group is considering either the abandoned Texaco or Amoco refinery in Casper as a facility to process methanol and MTBE. Methanol is a gasoline additive that reduces nitrous oxide emissions, while MTBE is a gasoline additive that reduces carbon monoxide emissions. The process would need approximately 40 million cubic feet of carbon dioxide per day.

It is still uncertain if private industry and (or) the State will finance a $31 million pipeline project to bring carbon dioxide into the Powder River Basin. Exxon produces approximately 140 billion cubic feet of carbon dioxide a year at their Shute Creek gas processing plant in southwestern Wyoming. Presently some of this carbon dioxide is vented at the plant because there is no viable market for it. If there were a pipeline capable of bringing carbon dioxide into the Powder River Basin, markets would likely develop for the carbon dioxide since carbon dioxide floods could help recover otherwise unrecoverable oil from some oil fields in the Powder River Basin.

In a related item, the Wyoming Oil and Gas Conservation Commission granted Exxon an extension of a tax break for any oil they produce in the Powder River Basin as a result of carbon dioxide flooding. The tax break, however, may be revoked if a carbon dioxide pipeline is not started by December, 1993.

Union Pacific Resources plans to build a 40-mile pipeline that will connect two Thrust Belt fields to the Whitney Canyon processing plant. The pipeline will carry up to 55 million cubic feet of sour gas and 1,100 barrels of condensate per day. Pipeline construction will start this year and will take six months. Gas and condensate for the system will come from shut-in wells in Yellow Creek Field in Wyoming and Cave Creek Field in Utah. The first well in Yellow Creek Field was reworked and tested for four days at a rate of 10 million cubic feet of gas and 185 barrels of condensate per day commingled from the Phosphoria and Weber. This well, the 1 Urroz in NW NW section 2, T14N, R121W, was originally completed in 1981 by Amoco. When Amoco tested the well, it flowed 25 million cubic feet of gas and 630 barrels of condensate per day from the Phosphoria and 17.8 million cubic feet of gas and 400 barrels of condensate per day from the Weber.

Gas from Wyoming, Colorado, and Utah can now reach more California markets because of a new connecting line between Kern River Gas Transmission and Pacific Gas and Electric. This connection can carry up to 95 million cubic feet of gas per day from Kern River's pipeline to other parts of California.

In a related item, Kern River Gas Transmission apparently will apply for permits to expand the capacity of its pipeline after new agreements with purchasers are completed. The expansion will be gradual with construction on new compressor stations beginning in 1994. The pipeline currently carries 700 million cubic feet of gas per day, but it could carry as much as 1.4 billion cubic feet per day (BCFD) with additional compressors. Canadian gas will provide about 65 percent of the additional gas for the pipeline if the Altamont pipeline from Canada to Opal, Wyoming, is built. The other 35 percent would come from Rocky Mountain producers. If the Altamont pipeline is not built, Rocky Mountain gas producers would have a chance to provide the entire 1.4 BCFD.

The U.S. Department of Energy (DOE) will provide $1.15 million to Sierra Energy Co. toward the $2.3 million cost for a polymer injection project in the Frontier Formation in Badger Basin Field in the Bighorn Basin. The Badger Basin project was one of 14 projects funded in nine states. All 14 projects are designed to demonstrate recovery methods that will prolong the economic life of old fields and slow the decline of domestic oil production.

Kerr-McGee is planning a tertiary recovery project in the Sussex Sandstone at House Creek Field in the Powder River Basin. The project will require 15 new wells. The fluid for the flood will include potassium hydroxide to stabilize the clays and possibly phosphate, which helps water get into tight zones. Peak production of 3,300 barrels of oil per day is expected in 1998. Current production is around 700 barrels of oil per day.

The Interstate Oil and Gas Compact Commission released the results of its national stripper well survey. The survey shows that Wyoming had 3,030 stripper wells in 1991 compared to 2,953 in 1990. There were 171 stripper wells abandoned in Wyoming during 1991. Nationally, there were 462,823 producing stripper wells in 1991. Another 17,584 were abandoned during the year. The average production for a stripper well in Wyoming is higher than for stripper wells

in any of the other major oil-producing States. Daily production in Wyoming was 4.45 barrels compared to the national average of 2.23 barrels.

The Wyoming Oil and Gas Conservation Commission submitted recommendations to the Federal Energy Regulatory Commission that the first Frontier in the Big Piney/La Barge/ Hogsback Field area be designated as a tight gas sand. The area includes parts of T26N-T28N, R113W in southwestern Wyoming.

Basin Exploration purchased 15 development sites and two producing wells in Bird Canyon Field on the Moxa Arch. Basin plans to drill three wells before June, 1993. The primary reservoirs in the field are in the Bear River and Frontier Formations.

Axem Resources paid $3.5 million for the interests of Phillips Petroleum, Hallwood Energy, Enron Oil & Gas, Conoco, Ensearch, and Samedan Oil in the Powell Pressure Maintenance Unit in the Powder River Basin. Axem now has a working interest of 7.7 percent.

Lease sales were disappointing for the fourth quarter of 1992 as well as for the whole year. Total revenue, total acres sold, number of parcels leased, and average price per acre leased in 1992 were all much less than in previous years (Table 5). In the October sale by the U.S. Bureau of Land Management (BLM), Donald B. Anderson Ltd. bid $2,500 per acre ($300,000 total bid) for a 120-acre Moxa Arch lease that covers S/2 NE section 4 and SW SW section 10, T20N, R112W. The lease is near second Frontier production in Whiskey Butte and Seven Mile Gulch Fields and Dakota production in Seven Mile Gulch Field. Lario Oil & Gas Co. made the sale's second highest per-acre bid of $1,125 for a 38.14-acre tract in lot 4 of section 13, T52N, R70W. The lease is near Minnelusa production in Adon Road North Field.

Effective October 24, 1992, the term for all leases obtained through competitive bidding at BLM lease sales was changed from five to 10 years. The December BLM sale was the first sale under the new terms. Although revenue was higher for the December sale than for the October sale, the longer lease terms did very little to boost interest in BLM leases other than to increase the number of acres leased. The December sale's high per-acre bid was $280 by James H. Borgerding for a 58.16-acre parcel in section 17, T26N, R112W. The lease contains acreage in the bed of the Green River and is within a mile of several Frontier producers in the Big Piney/Stead Canyon area. High Plains Associates made the sale's highest total bid of $121,410 ($95 per acre) for a 1,280-acre lease that covers parts of sections 22, 23, 26, and 27, T51N, R69W. The parcel is within two miles of four Minnelusa oil reservoirs: Wheat Draw, Simpson Ranch, Stewart, and Garner Lake North.

The State Land and Farm Loan Office had their fourth sale of the year after the July and September sales were canceled. The November sale was very poor compared to past years, but it was similar to earlier sales in 1992 (Table 5). The high per-acre bid of $87 was made by Brown Operating for a 240-acre parcel in N/2 N/2, SW NW, and W/2 SW section 16, T47N, R70W. The lease is near shut-in Minnelusa production in Basin Field. The sale's highest bid in terms of total

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

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

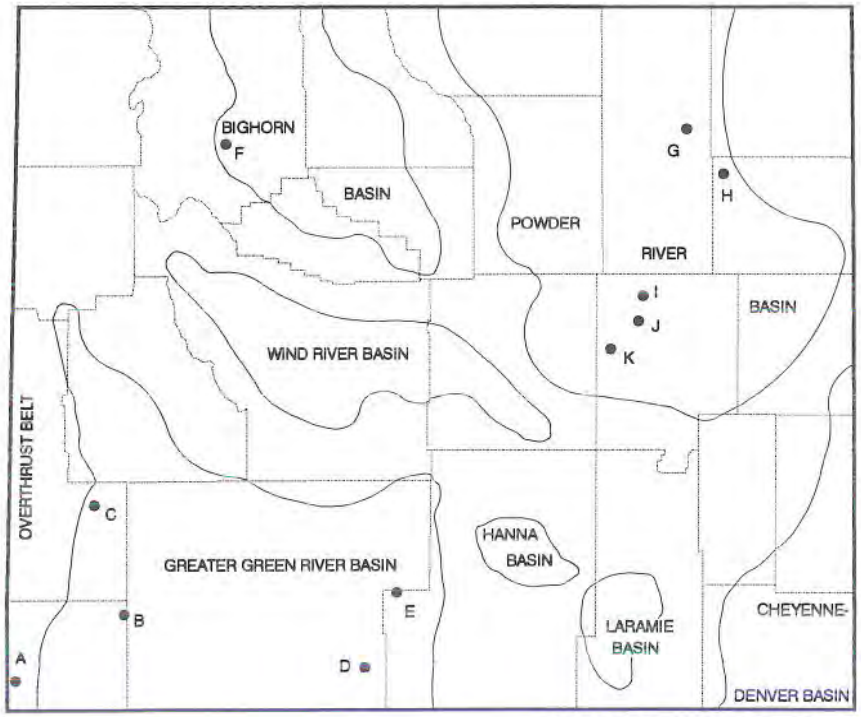
revenue was $44,139.20 ($80 per acre) for 551.74 acres in section 18, T16N, R64W. The lease is on the north flank of Silo Field and includes an inactive horizontal Niobrara well that produced over 2,000 barrels of oil.

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 fourth quarter of 1992. Activities related to horizontal drilling are discussed in a separate section. The letters preceding discussions below refer to locations on Figure 11.

A. Chevron USA has drilled more than 13,400 feet at an exploration test in the Thrust Belt. The 1-14 Chevron-Federal well in SW SW section 14, T14N, R120W is projected as a 17,000-foot test of the Nugget and Twin Creek.

B. Celsius Energy completed two new gas producers in Bruff Field. The 26-3 Bruff-Federal well in NW SW section 26, T18N, R112W flowed 6.3 million cubic feet of gas per day from the Dakota. Total depth was 12,912 feet. The



GEOLOGICAL SURVEY OF WYOMING, 1993

Figure 11. Oil and gas exploration and development activity in Wyoming during the fourth quarter of 1992 (exclusive of horizontal drilling and coalbed methane activities).

30-2 Lawler-Federal well in SE SE section 30, T19N, R112W flowed 5.1 million cubic feet of gas per day from the Frontier. Total depth was 12,208 feet.

C. Yates Petroleum set production casing at their 1 Names Hill Unit well in NW SW section 35, T26N, R113W. The well was scheduled as a Frontier test and was drilled to a total depth of 10,100 feet.

D. Celsius Energy completed two new Almond producers in the Dripping Rock/ Mulligan Draw area. The 7 Dripping Rock Unit well in SE SE section 8, T14N, R94W flowed 7.0 million cubic feet of gas per day. Total depth was 12,646 feet. The 4-1 Celsius-Federal well in SW NW section 4, T14N, R94W flowed 5.9 million cubic feet of gas per day. Total depth was 12,568 feet.

E. Approximately 30 development wells in Echo Springs Field in Carbon and Sweetwater Counties are in various stages of drilling and completion. So far no details have been released on any of the Almond completions. Drilling depths are around 10,000 feet.

F. Marathon Oil plans to drill a 6,020-foot test of the Phosphoria, Tensleep, and Madison on a deeper structural feature on the west flank of Oregon Basin Field. The 1 Sholtz-Federal well will be drilled in NW SW section 16, T51N, R100W.

G. Flying J Oil & Gas recovered 230 barrels of oil from the Minnelusa during a 12-hour test. The 8-29 KM well in SE NE section 29, T50N, R71N was tested between 9,552 and 9,562 feet.

H. Meridian Oil set production casing to about 6,000 feet at their 44-25 Federal well in SE SE section 25, T48N, R68W in order to test the Turner Sandy Member. No other details are available.

I. Kerr-McGee Corp. completed a new well in the Powell Field area. The 15-2 PPMU well in NW NW section 15, T39N, R74W flowed 528 barrels of oil, 2.9 million cubic feet of gas, and 15 barrels of water per day through perforations in the Frontier. The well was drilled to a total depth of 12,326 feet.

J. Klabzuba Operating completed a new Leo producer in Sweede Draw Field. The 1-36 Sweede Draw-State well in SE SE section 36, T37N, R64W produced an average of 69 barrels of oil per day during 16 days of production in September. The well had been projected as a 7,025-foot Leo test.

K. Kerr-McGee Corp. completed a new Muddy producer on the west flank of Sand Dunes Field. The well produced an average of 767 barrels of oil per day during eight days in July but was shut in during August and September. The well was drilled to 12,915 feet and is in NW SW section 24, T36N, R76W.

Horizontal drilling

During the fourth quarter of 1992, the following significant activities related to horizontal drilling occurred. The letters preceding the discussions below refer to

locations on Figure 12. The discussions are based on company data and information compiled and published by Petroleum Information.

A. Samuel Gary Jr. & Associates will reenter an abandoned Almond discovery in the Mulligan Draw Field area and will drill horizontally into the Almond. The 36-10H Mulligan Draw well will be drilled from a surface location in NW SE section 36, T15N, R95W to a true vertical depth of 12,691 feet. This well will mark the first horizontal gas test and the first horizontal test of the Almond in Wyoming.

B. Texaco Exploration & Production completed their 61H Black Mountain Unit well as a Tensleep producer. The well was drilled from a surface location in NW NW section 36, T43N, R91W to a true vertical depth of 3,200 feet. No other details are available.

C. Union Pacific Resources completed the first horizontal well in the Bighorn Basin at their 1H Bass-Federal 33-24. Oil was pumped at the rate of 97 barrels per day with 18 barrels of water per day. The well is producing from the Phosphoria and was drilled from a surface location in NW SE section 24, T48N, R92W to a true vertical depth of 10,502 feet.

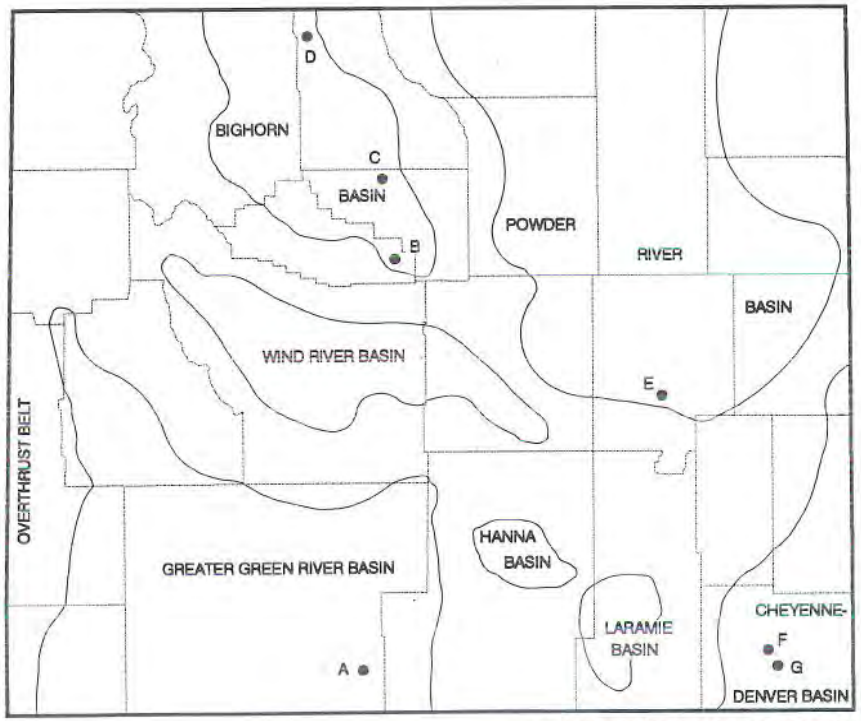


Figure 12. Horizontal drilling activity in Wyoming during the fourth quarter of 1992.

D. Marathon Oil is testing the Tensleep at their 3HI Lindsay well drilled from a surface location in lot 46, T56N, R97W to a true vertical depth of 5,168 feet. The test is in Byron Field.

E. Arco Oil & Gas is completing a Frontier test at their 1-25H Morton Ranch well drilled from a surface location in SW SW section 25, T33N, R72W to a true vertical depth of approximately 12,000 feet. Arco took over the well from Amoco. During the first eight days of tests the well flowed from 490-800 barrels of oil per day, but Arco has not released any other details.

F. Several more Niobrara wells are planned or in progress in Silo Field. Union Pacific Resources reached a true vertical depth of 8,715 feet from a surface location in SW SW section 28, T16N, R65W. The 1-H Earl F. Anderson 14-28 well is on the west flank of Silo Field. Union Pacific Resources also staked locations for two tests in Silo Field. The 1-H Leroy 41-33 will be drilled from a surface location in NE NE section 33, T16N, R64W to a true vertical depth of 7,920 feet. The 14-9 1H Owen will be drilled from a surface location in SW SW section 9, T15N, R64W to a true vertical depth of 7,947 feet. Kachina Exploration plans to drill the 12-13-H State well from a surface location in SW SW section 12, T15N, R64W to a true vertical depth of 7,780 feet.

G. Union Pacific is drilling a Niobrara test in Dale Field. The 1-H Bronco-State 41-16 has a surface location in NE NE section 16, T15N, R63W. True vertical depth is projected at 7,587 feet.

COAL UPDATE

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

Although past years have seen steady increases in coal production, 1992 production is predicted to be 2 - 3 million tons lower than total coal production in 1991 (Table 6). Figure 13 and Table 7 show that 1991 cumulative production on a monthly basis remained above 1990 for 11 of 12 months. In contrast, coal production in 1992 has hovered around 2% less than 1991 for 8 of the 9 months for which there are production statistics. If this trend continues and the predicted decrease in coal production for 1992 occurs, it will be the first such drop since 1986. When compared to 1991, most of the loss seems to be from the so-called contract sales, which were down significantly in the months of February to April and again in July (Figure 14). Spot sales have for the most part paralleled 1991 production.

Table 6. Coal production (1983 to 1991) with forecast to 1995 (millions of tons).

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992[1]	1993[1]	1994[1]	1995[1]
Campbell County	88.2	106.8	113.9	111.0	122.3	135.7	143.8	154.7	164.9	162.6	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	8.5	8.9	9.2
Sheridan County	2.9	2.5	2.4	1.4	1.2	0.9	0.1	0.1	0.2	M	M	M	M
Carbon County	4.8	5.1	3.3	1.5	2.2	4.1	4.3	4.5	4.7	4.5	4.5	4.8	4.9
Sweetwater County	9.5	8.9	13.2	12.9	11.8	12.2	12.0	11.9	11.4	11.0	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	4.4	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	191.0	194.3	499.3	204.3
Annual change	4.0%	14.2%	7.1%	-3.8%	7.4%	10.5%	4.4%	7.0%	5.2%	-1.5%	1.7%	2.5%	2.4%
Low-priced coal[2]			6%	7%	8%	10%	17%	24%	31%	37%	42%	47%	51%

[1] Forecast by Geological Survey of Wyoming, January, 1993. [2] 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).

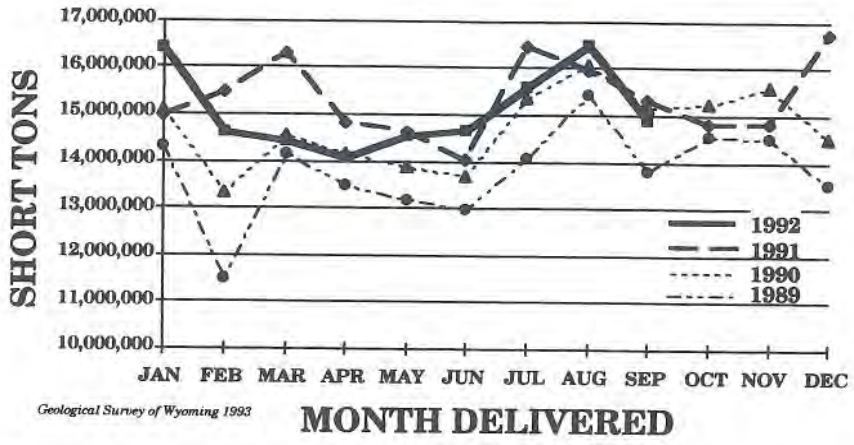


Figure 13. Reported deliveries from Wyoming coal mines *(from COALDAT Marketing Report by Resource Data International, Inc. compiled from FERC Form 423 filed monthly by electric utilities).*

In an effort to protect Wyoming coal sales, Governor Mike Sullivan has been considering a lawsuit against four midwestern and eastern states (Ohio, Indiana, Illinois, and Pennsylvania) that are trying to adopt laws which may hinder sales of low-sulfur Wyoming coal. The State's Attorney General is investigating whether the proposed laws in those states may violate Federal laws regarding interstate commerce. The governor initiated such a lawsuit several years ago against an Oklahoma law that required public utilities to burn at least 10% Oklahoma coal. The U.S. Supreme Court recently upheld that challenge, ruling that the law violated the interstate commerce clause of the U.S. Constitution.

Recent coal leases in the Powder River Basin (Figure 15) stand to generate millions of dollars for both the state of Wyoming and the Federal government. The U.S. Bureau of Land Management (BLM) announced that the State would soon receive $9.2 million, the first of five annual payments, as its share of the bonus bids for leases issued to the Black Thunder and Jacob's Ranch coal mines. In addition, the State will receive half of the $87 million bid by the Powder River Coal Co. for a lease containing nearly 400 million tons of coal reserves in southern Campbell County. This $43 million will also be paid to the State over a 5-year period.

Industry experts are divided on how the new amendments to the Clear Air Act will affect coal production throughout the U.S. *COAL* magazine reports that a structural change is underway and that there may be a regional shift in production. Citing the substantial increase in production of western coal (especially Powder River Basin coals) western coal might quickly dominate eastern markets. The U.S. Bureau of Land Management (BLM) is also projecting a steady rise in coal production especially out of the Powder River Basin of Montana and Wyoming between now and the year 2010. However, Resource Data International (RDI) has taken a different view of the issue. RDI believes that western low-sulfur coal will move eastward, but primarily into midwestern markets where the delivered price is highly competitive.

Table 7. Coal deliveries by month from Wyoming mines[1].

	1988 MONTHLY	1988 CUMULATIVE	1989 MONTHLY	1989 CUMULATIVE	1990 MONTHLY	1990 CUMULATIVE	1991 MONTHLY	1991 CUMULATIVE	1992 MONTHLY	1992 CUMULATIVE
JANUARY	10,976,860	10,976,860	14,283,020	14,283,020	15,059,530	15,059,530	14,960,450	14,960,450	16,407,150	16,407,150
FEBRUARY	11,431,380	22,408,240	11,488,140	25,771,160	13,328,290	28,387,820	15,480,110	30,440,560	14,586,480	30,993,630
MARCH	12,871,090	35,279,330	14,124,330	39,895,490	14,535,270	42,923,090	16,278,870	46,719,430	14,429,650	45,423,280
APRIL	12,694,660	47,973,990	13,489,450	53,384,940	14,155,470	57,078,560	14,820,240	61,539,670	14,063,060	59,486,340
MAY	12,017,500	59,991,490	13,149,170	66,534,110	13,882,590	70,961,150	14,589,790	76,129,460	14,518,590	74,022,930
JUNE	12,595,480	72,586,970	12,948,350	79,482,460	13,649,070	84,610,220	14,007,600	90,137,060	14,655,600	88,678,530
JULY	13,905,670	86,492,640	14,043,350	93,525,810	15,368,280	99,978,500	16,451,090	106,588,150	15,592,050	104,270,580
AUGUST	15,041,090	101,533,730	15,428,210	108,954,020	16,046,910	116,025,410	15,940,620	122,528,770	16,467,100	120,737,680
SEPTEMBER	13,433,610	114,967,340	13,795,760	122,749,780	15,166,020	131,191,430	15,314,490	137,843,260	14,878,150	135,615,830
OCTOBER	13,696,190	128,663,530	14,523,480	137,273,260	15,244,760	146,436,190	14,810,510	152,653,770		
NOVEMBER	13,889,890	142,553,420	14,507,130	151,780,390	15,569,280	162,005,470	14,783,000	167,436,770		
DECEMBER	14,540,510	157,093,930	13,527,880	165,308,270	14,479,970	176,485,440	16,716,630	184,153,400		
TOTAL TONNAGE REPORTED		157,093,930		165,308,270		176,485,440		184,153,400		
TOTAL TONNAGE NOT REPORTED		6,494,270		5,831,734		7,521,261		9,710,406		
TOTAL TONNAGE PRODUCED[2]		163,588,200		171,140,004		184,006,701		193,863,806		

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

[2] Source: Wyoming State Mine Inspector's Annual Reports.

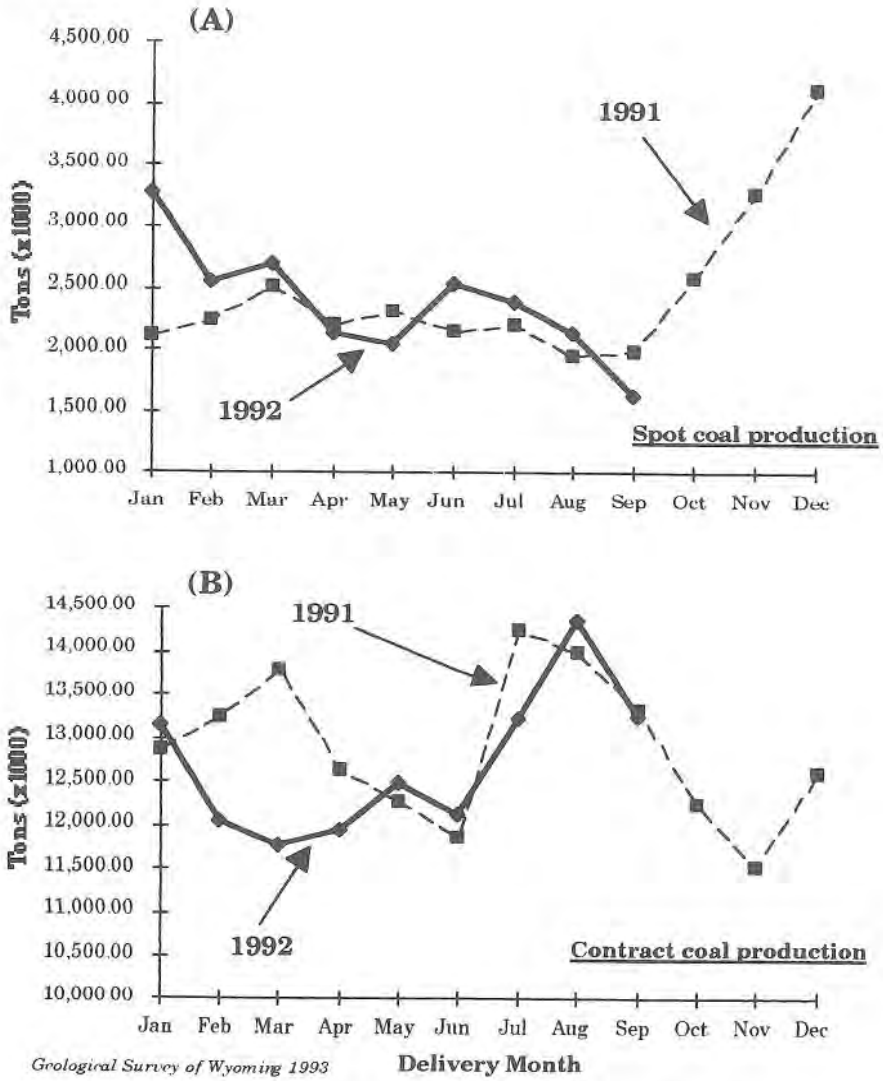


Figure 14. Monthly coal deliveries from Wyoming for 1991 and 1992. (A) Coal sold on contract and (B) coal sold on the spot market. *(Source: COALDAT Marketing Report by Resource Data International, Inc. compiled from FERC Form 423 filed monthly by electric utilities).*

Some eastern companies, however, have already moved west (e.g. Drummond and Zeigler) in order to provide some of their customers with a much lower sulfur product. At a Coal Marketing Strategies conference held in Denver recently, Bill Bales, the Vice President of Norfolk Southern's Coal and Ore Traffic Division, predicted that there will not be a flood of western coals into eastern markets.

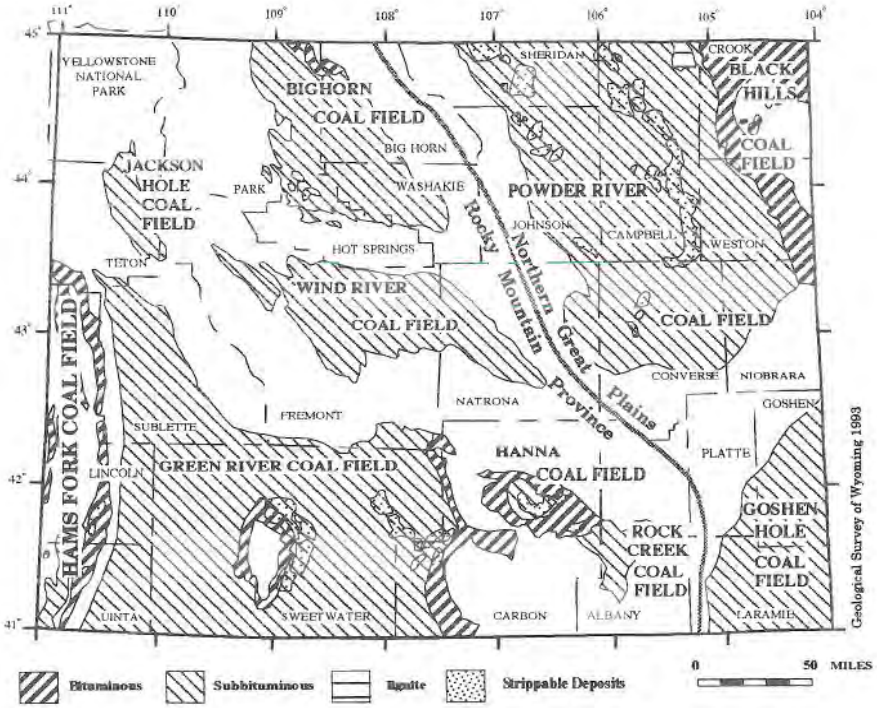


Figure 15. Wyoming coal fields.

Although Georgia Power may decide to burn Powder River Basin coal at its Scherer plant, Bales feels this may be a unique situation. He noted that the Scherer plant was designed to burn either eastern or low-sulfur western coal and that the railroads were eager to establish an "all rail" presence in the Eastern markets.

Char-Fuels Associates Limited Partnership and Amax Coal West, Inc. are each seeking funds for potential Wyoming projects in the final scheduled round of the Federal Clean Coal Technology (CCT) Program. A total of 24 project proposals were submitted in the final round of the U.S. Department of Energy's (DOE's) CCT Program. A total of $2.3 billion in funding requests have been submitted to the DOE, which only has $583 million available in the program.

Ohio Edison, which has been testing low-sulfur coal from the Powder River Basin, has confirmed that it is "considering" the purchase of a test burn of P.T. Adaro Indonesia's "Envirocoal". An Edison fuels official said that no purchase agreement had been signed. Most sources believe that Powder River Basin coals are a more economical alternative to the "Envirocoal" despite the latter's reported quality (10,000 Btu/lb, 0.01% sulfur, and 2% ash). Current prices for the Indonesian product are $29.50/ton at coal piers in the New Orleans area. In

contrast, Powder River Basin coals are delivered to most midwestern power plants at under $20/ton. For more information on Indonesia's "Envirocoal", see the special report later in this **Coal Update**.

Developments in western and southwestern Wyoming

The long-term contract between Black Butte Coal Co. and Commonwealth Edison has been cancelled. The contract was to have lasted until the year 2015. As of January 1, 1993, no more coal will be shipped from the Black Butte mine to Commonwealth Edison, but deliveries will continue from Decker Coal Co.'s mine in Montana just north of Sheridan, Wyoming. Both the Black Butte and Decker mines are owned by Peter Kiewit Mining Group out of Omaha. Sixty percent or about 2.9 million tons of the 5 million tons of coal produced each year at Black Butte were sold to Commonwealth Edison. Part of the other coal production goes to the neighboring Jim Bridger power plant (1.5 million tons annually) and to the Sierra Pacific-Idaho Power and Light power plant in Nevada (500,000 tons/yr). Delivery of Black Butte's coal to five Edison plants in Illinois peaked in 1986 at more than 5.5 million tons. But over the years since then, Kiewit has substituted lower cost coal from the Decker mines for a portion of Black Butte's contract. Edison will now receive a large portion of the former Black Butte contract directly from the Decker coal mines in Montana. More than $1.2 billion of total savings will be achieved under the renegotiated agreements between Edison and Decker. A news release by Edison said residential electricity consumers will see a one percent drop in their electric bills as a result of changes in coal contracts.

With the loss of the Commonwealth Edison contract, the Black Butte mine will lay off about 200 of its 439 employees. The company will be offering severance packages, some including cash payments of more than $35,000 to employees who opt to leave the company voluntarily. The exact package will be related to current salary and length of service. It is expected that supervisory and craft work forces will be cut by the same percentage. The loss of the 200 jobs at the Black Butte mine will be felt in the community of Rock Springs. Lost salaries paid to the miners and the taxes on those salaries will be in the millions of dollars. In addition, the mine will pay some $4 million less in county taxes each year unless new contracts are found. In this regard, Black Butte has signed a new short term contract with the nearby Jim Bridger power plant. Under this contract, Black Butte will sell 50% more coal to the utility for the first six months of 1993.

The Rock Springs District of the U.S. Bureau of Land Management will prepare an Environmental Impact Statement (EIS) on the Deadman Wash coal tract for a competitive sale. The tract is located in lands adjacent to the Bridger coal mine at the Jim Bridger power plant. The tract area includes 2,121 acres of Federal land and about 24 million tons of Federal coal. There is another 2,560 acres of fee lands interspersed with the Federal lands.

The Lion Coal Company which owns and operates the underground Swanson coal mine has filed a permit-renewal application for continued operation. The renewal was filed with the Wyoming Department of Environmental Quality's Land

Quality Division. The permit area encompasses 515 acres located just north of Interstate 80, one mile east of Rock Springs in Sweetwater County. A public hearing will be held prior to any decision on the permit's renewal.

Developments in the Hanna Coal Field

Several sales of Hanna Basin coal were noted in the 4th quarter as well as the confirmation of some 1993 contracts. Cyprus Coal's Shoshone mine shipped over 38,000 tons of coal to the Northern Indiana Public Service Co. in addition to providing coal to Midwest Power System (MPS) for testing with a blend of Powder River Basin coal. The Medicine Bow mine will also deliver up to 800,000 tons of coal to MPS (see section on contracts for further details).

The Wyoming Department of Environmental Quality (DEQ) issued a notice of violation and fined Arch Mineral $22,000. The action was taken because Arch had piled spoils from its Medicine Bow coal mine within a prohibited buffer zone adjacent to Seminoe Reservoir. However, the DEQ is allowing Arch to leave the piles in the area until the company finishes mining in an adjacent pit. Arch expects to complete that mining in 1995 or later. According to state officials, the mine spoils pose no environmental threat to the Seminoe Reservoir. One State official stated that the penalties were assessed as a warning to other coal companies. In the meantime, the Wyoming Outdoor Council may pursue legal action to require the State to issue a cessation order to Arch.

Developments in the Powder River Coal Field

Several tracts of Federal coal were leased in the Powder River Basin in the latter half of 1992. First, the Interior Board of Land Appeals (IBLA) ruled in the U.S. Bureau of Land Management's (BLM's) favor on the 132-million-ton coal lease sale to Kerr-McGee Coal Co. for their Jacob's Ranch mine, east of Wright. A second coal lease sale was held on August 12, 1992, for the West Black Thunder tract adjacent to the Black Thunder mine, which is also east of Wright. Thunder Basin Coal Co. (Arco) won the lease with a nearly $71 million bonus bid. In another lease sale, the North Antelope-Rochelle tract, containing 393.7 million tons of coal, was held on September 28, 1992. This tract is located adjacent to the Rochelle and North Antelope mines operated by Powder River Coal Co. (Peabody), southeast of Wright. With the acquisition of this new property, Peabody Holding Co. has announced a major expansion at the Rochelle and North Antelope coal mines. The increase will be from 25 million tons/yr to 37 million tons/yr.

In a fourth lease sale, however, the BLM rejected an offer of about 26 cents per ton for the 55 million tons of coal in the West Rocky Butte tract. The bid, which was submitted by Northwestern Resources Co., was for $14 million. A new bonus bid for the lease, which contains low-ash, low-sulfur coal of the Wyodak seam, was opened on January 7, 1992. Northwestern's new bid of 30 cents per ton or $16.5 million was accepted.

The BLM has begun preparing for the next lease offering, which is scheduled for 1993. It is the Eagle Butte tract, adjacent to Amax's Eagle Butte mine, north of Gillette. The tract has an estimated 150 million tons of coal.

An agreement has been reached between Thunder Basin Coal Co. (Arco) and the U.S. Environmental Protection Agency (EPA). EPA's inspections of 12 coal mines in the Powder River Basin in the summer of 1992 resulted in six of the mines being cited for hazardous-waste violations. Bob Duprey, director of the EPA's Hazardous-waste Management Division, said Thunder Basin's cooperation was "remarkable", and the coal company has agreed to pay a $152,488 fine and bring the mine into compliance with the Resource Conservation and Recovery Act. The other companies that EPA filed complaints against are: Amax's Eagle Butte and Belle Ayr mines; Powder River Coal's Rochelle mine; Cordero Corp.'s Cordero mine; and Kerr-McGee's Jacobs Ranch mine.

The Encoal Mild Coal Gasification project has been given authorization by the U.S. Department of Energy (DOE) to proceed with full-scale operation. The demonstration project was located at Triton Coal's Buckskin mine near Gillette, Wyoming. The technology involves a process called liquids from coal (LFC). The LFC process is a mild gasification process that dries and heats the raw coal under carefully controlled conditions. The resultant products weigh 40% less while retaining 90% of their heating value. The solid and liquid fuels that are produced are both low in sulfur. The products are designed for power plant use. Wisconsin Power and Light has already agreed to buy about 30,000 tons of the solid fuel for use at its coal-fired power plants while Texpar Energy Inc. will buy up to 135,000 barrels per year of the liquid fuel. When fully operational, the plant will produce 180,000 tons of solid, coal-like fuel along with 150,000 barrels of liquids annually. The commercial scale plant will be about 10 times the size of the Encoal demonstration facility. Recently (9/13/92), Encoal completed a seven-day continuous run of its process. Some 2,000 barrels of coal-derived liquid fuel were shipped to Texpar Energy in Waukesha, WI. Several thousand tons of solid fuel from the process were to be shipped at a later date. To date, eight test runs have been completed with a cumulative total of about 600 hours of coal-feed operation.

The DOE has approved a merger between the K-Fuels clean coal project near Gillette and the Thermo-Chem project. This merger will demonstrate a combination of technologies for using clean, low-sulfur, Wyoming coal. The joint project has now been renamed the Thermofuel Clean Coal process. As a result of the merger, Thermofuel will receive $18 million from DOE's Clean Coal IV Program. In addition, the process has received financial backing from Heartland Fuels, a subsidiary of Wisconsin Power and Light, which has promised to purchase the Thermofuel product for commercial use in mid-western power plants. The Thermochem process will gasify Wyoming coal fines - finely crushed coal - and burn the produced gas to produce steam for the K-Fuels plant, thereby achieving greater efficiency and lower operating costs. With the merger, the construction of a demonstration plant near Gillette can move forward. The project will require as many as 200 construction jobs and 40 permanent jobs once the plant is built.

The DOE has also awarded Amax Research and Development Center $15 million for super-clean coal research. The center, located in Golden, Colorado, is working on the development of technology that would reduce sulfur and ash contents from coal significantly enough that the product could be substituted for premium fuel (e.g. oil) in utilities. A second goal is to apply this technology to processing coal fines, which are presently discarded from conventional coal preparation plants. Amax plans to use coal from its western holdings as well as its mines in the east.

The Wyoming Public Service Commission (PSC) will hold at least one public hearing on the Black Hills Corporation's proposal to build a $126 million, 80-megawatt, coal-fired power plant at its Wyodak coal mine, near Gillette. The hearing was held in late January, 1993. The new plant must be approved both by the PSC and the South Dakota Public Utilities Commission. Black Hills says it needs to expand its capacity to meet future demands, to meet peak demand periods, and to serve as a back-up in case one of its other plants is forced to shut down. Rosebud Enterprises of Boise, ID hopes to convince regulators that this new power plant is not needed. Instead, Rosebud wants to build a $75 million, 40-megawatt power plant near Edgemont, SD.

Powder River Coal Co. (a subsidiary of Peabody Coal Co.) has applied to the State for changes in its reclamation plan. The planned revisions would allow the company to leave the overburden piles and depressions rather than returning overburden to the pit. There is concern that such a change could set a precedent for granting similar permit changes at other coal mines. The U.S. Office of Surface Mining is also reportedly watching to see if such approval will render the State's reclamation program in violation of Federal statutes. In response to criticism against the proposed changes, Powder River Coal Co. insists that the plans are not as dramatic as opponents say. The company argues that the plans will make reclamation more efficient and less costly.

Caballo Rojo, Inc. laid off 13 workers due to low sales and a reorganization of its administrative staff. Two of the eliminated positions will come from Caballo Rojo's sales office in Denver, which employs 10 people, while the remaining 11 positions will be come from the Caballo Rojo mine (which employs 135 people). The mine is located just south of Gillette.

Coal contracts

— Nerco, Inc. has signed a contract to supply Commonwealth Edison with 30-40 million tons of coal from its Antelope mine for an undisclosed number of years. Previously, Commonwealth Edison held a relatively high-priced contract with the Black Butte coal mine near Rock Springs. The annual tonnages involved are apparently variable.

— Shell Coal Mining's Triton Coal will be supplying Muscatine Power & Light's No. 9 unit with 300,000-500,000 tons/year of coal from 1993 through 1998. Deliveries from the Buckskin mine begin in the spring of 1993.

— Wisconsin Power & Light (WP&L) has awarded a contract to supply its Columbia No. 2 unit with up to 800,000 tons of 1993-baseload coal. The coal, which will come from the Caballo Rojo mine, will be transported over a Western Railroad Properties/Union Pacific/Chicago and North Western/Soo Line route. WP&L also bought 800,000 base tons of coal from Peabody Holding's North Antelope mine in addition to 300,000 tons from Amax's Belle Ayr mine for fourth quarter delivery to Columbia No. 2. Also, Nerco's Antelope mine was to supply an estimated 77,000 tons to WP&L's Edgewater 3 and 4 plants this last quarter. WP&L mailed out solicitations in November for its first-half, 1993 spot coal requirements at its Edgewater units 3, 4, and 5. Bids were be due in early December. Depending on the outcome of test burns, the utility could purchase about 400,000 tons of spot coal for the Edgewater Nos. 3 and 4 units and 200,000 - 250,000 tons for the Edgewater No. 5.

— Big Sky Coal Co. of Colstrip, Montana, has signed a contract to supply 1.4 - 2.5 million tons of coal annually to Minnesota Power, beginning in January of 1993 and continuing through mid-1997. The Big Sky Coal Co. is owned by the St. Louis-based Peabody Holding Co., Inc.

— West Texas Utilities' (WTUS') second half, 1992 incremental coal suppliers were Amax and Caballo Rojo Inc. with Amax supplying coal from the Belle Ayr mine along with some test coal from its Eagle Butte mine. Test burning was set for early November, according to WTU.

— Northern Indiana Public Service Co. (NIPSCO) has purchased 33,000 tons of spot coal from Caballo Rojo and 33,000 tons from the Belle Ayr mine. NIPSCO will continue taking bids on four grades of coal, including Powder River Basin coal with no more than 1.2 lb of SO_2/mmBtu (compliant coal). Contract coal for NIPSCO's Michigan City plant includes 38,000 tons from Cyprus Coal's Shoshone mine.

— PacifiCorp's requirement for 200,000 - 600,000 tons for the Dave Johnston plant will be supplied by the Cordero and Caballo mines. PacifiCorp's Jim Bridger plant will be supplied with up to 260,000 tons from pit 22 of the Black Butte mine with the utility having an option to purchase up to 600,000 additional tons. Lion Coal Co. will also supply the Bridger plant with 25,000 tons from its Swanson coal mine near Rock Springs.

— In October, Iowa-Illinois Gas & Electric's Louisa plant began receiving second-half 1992 coal shipments from Carter Mining Co.'s Rawhide mine. The utility has also solicited offers from 11 other Wyoming coal mines.

— Omaha Public Power District (OPPD) has chosen Triton Coal Co.'s Buckskin mine to supply its North Omaha plant with 800,000 tons of spot coal in 1993. OPPD also may make use of an option to buy an additional 100,000 tons of coal from the Buckskin mine. The coal will originate on Burlington Northern Railroad with Union Pacific Railroad spotting the coal into the plant. OPPD recently asked Amax Coal's Belle Ayr mine for the 100,000-ton option on its

1992 contract with the mine. With this additional tonnage, the Belle Ayr mine will have supplied OPPD 900,000 tons of coal in 1992.

— In 1993, the Medicine Bow mine in the Hanna Basin will supply 300,000 - 800,000 tons of coal to Midwest Power Systems' Neal Nos. 1 and 2 units. In addition, Midwest may rely on the Caballo mine to supply some 200,000 tons to its Neal No. 4 unit. Solicitations by Midwest were expected in December for its Neal units 1, 2, and 3. Status of a planned test burn of coal from the Shoshone No. 1 mine in the Hanna Basin remains unclear. Apparently, the Shoshone coal was to be blended with coal from the Powder River Coal Field.

— Fremont Nebraska Department of Utilities may have solved a problem it has had in burning dried coal from the Belle Ayr mine. The dusty nature of the product posed a problem until it was mixed with corn cob dust. The utility still has plans to test some of the pelletized coal from the Fort Union Coal Co.

— The Rochelle mine will supply Southwestern Public Service's Harrington plant with 1.2 - 1.3 million tons of coal and the Tolk station with 400,000 tons of coal in 1993.

— Portland General Electric will rely on coal from the Caballo mine in Wyoming and the Decker mine in Montana for its first-half, 1993 spot coal supplies.

— Long-term contract decisions were on hold at Ohio Edison while the utility completed work on its strategy to comply with the Clean Air Act. However, Edison was completing test burns of Powder River Basin coal from Caballo Rojo, Inc.

— Wisconsin Public Service (WPS) will continue it's test burns in anticipation of soliciting contracts in the spring of 1993. In early October, they began blending Powder River Basin coal from the Black Thunder mine with eastern coal. WPS has also agreed to fund construction of a $150 - $200 million high-efficiency, coal-fired power plant in Rhinelander, WI. The new plant will produce both power and 400,000 pounds of industrial steam annually for Rhinelander Paper Co. It is estimated that the 100-megawatt, fluidized-bed combustion unit will burn 400,000 - 500,000 tons of Powder River Basin coal each year.

— Wisconsin Electric Power Co.'s test burn of 26,000 tons of coal from Carter Mining's Caballo mine was described as "very successful". This will probably facilitate tests of other coals from the Powder River Basin.

— Hopefully, the Tennessee Valley Authority (TVA) and Southern Company will open the Gallatin and Scherer plants to Powder River Basin coals. TVA successfully tested 8,800 Btu/lb coals from Arco's Black Thunder mine.

— The Lansing Board of Water & Light may still test burn a Powder River Basin coal at its Otto E. Eckert No. 4 unit. If tested, the coal will be blended with coal from eastern Kentucky (80/20 - eastern/western). The test has apparently been postponed until the Spring of 1993.

— In November, Otter Tail Power called for bids for 200,000 tons of Montana or Wyoming coal. The coal is for their Hoot Lake station over a one year period beginning in January of 1993. Previous coal supplies to Hoot Lake have come from Nerco Coal's Spring Creek mine near Decker, Montana.

— Consumers Power has also completed a couple of small test burns of Powder River Basin coal at the utility's Campbell No. 3 unit.

— Tacoma Public Utility's (TPU's) test burns of Powder River Basin coals from the Decker and Rochelle mines are still under consideration. TPU's test burn of coal from the Rochelle mine in September was apparently successful.

— Utility Fuels Inc.'s spot coal solicitation on behalf of Houston Lighting & Power is for an estimated 1.5 million tons of compliant, low-sulfur, subbituminous coal similar to what is mined in the Gillette, Wyoming area.

— Dairyland Electric Power Cooperative is expected to issue a solicitation in the first of the year for Powder River Basin coals.

— Nebraska Public Power District in a three-month, 300,000-ton test burn of Powder River Basin coals has determined they are viable for their needs at the Gentleman plant. Coal from four mines, Powder River Coal's Rochelle and North Antelope mines, Nerco's Antelope mine, and Amax's Belle Ayr mine were tested.

— Minnesota Power & Light will probably turn to companies on previous short lists rather than issue new coal solicitations for 1993 spot coal sales. These mines include Nerco's Spring Creek mine, Peabody's Big Sky mine, Amax's Belle Ayr mine, Arco's Black Thunder mine, and Sun's Cordero mine.

— Iowa Electric Light & Power is waiting on an assessment of transportation offers before it decides on a 950,000-ton solicitation of Powder River Basin coal.

— This winter Wisconsin Electric Power Co. officials expect to decide on which Powder River Basin coals they will test in the spring. They have already successfully tested coal from Carter Mining's Caballo mine. They will most likely test coals from mines that produce coal with different sodium and sulfur contents than the Caballo mine. The coals are being tested in the Presque Isle-Western units.

— Spain's ENDESA (Empresa Nacional de Electricidad SA), the state-run electrical utility, has closed bidding on up to 1.8 million tons of coal from the Powder River Basin. The contract is significant because it is long-term. Coal producers in the running for parts of the contract are Arco, Peabody affiliate Rochelle Coal, Nerco, and the Kerr-McGee Coal Company. Kerr-McGee has shipped 58,000 tons of coal from its Jacobs Ranch mine to ENDESA.

— Spain's private coal supply agency, Carelec, has requested bids for fourth-quarter coal from the Powder River Basin of Wyoming. Carelec already has bought several trial cargoes of subbituminous coal from the basin for the Meirama power station. The latest two purchases were from Arco's Black Thunder mine. The last shipment from Arco was loaded in mid-October.

Coalbed methane

The U.S. Bureau of Land Management (BLM) has given final approval to an Exxon proposal for a coalbed methane pilot project in Campbell County with drilling to begin by the end of the year (location A on Figure 16). The BLM's environmental assessment found there would be no significant impact to the region from the drilling in the Hartzog Draw Field, thirty-five miles southwest of Gillette. Officials say the three-well project will help determine the viability of tapping the vast natural gas reserves that occur in the coal seams of northeastern Wyoming. An original proposal in 1991 outlined over 1,000 drill holes for the project. The number of drill holes was reduced as a result of an appeal filed last year by the Powder River Basin Resource Council, which claimed the Federal

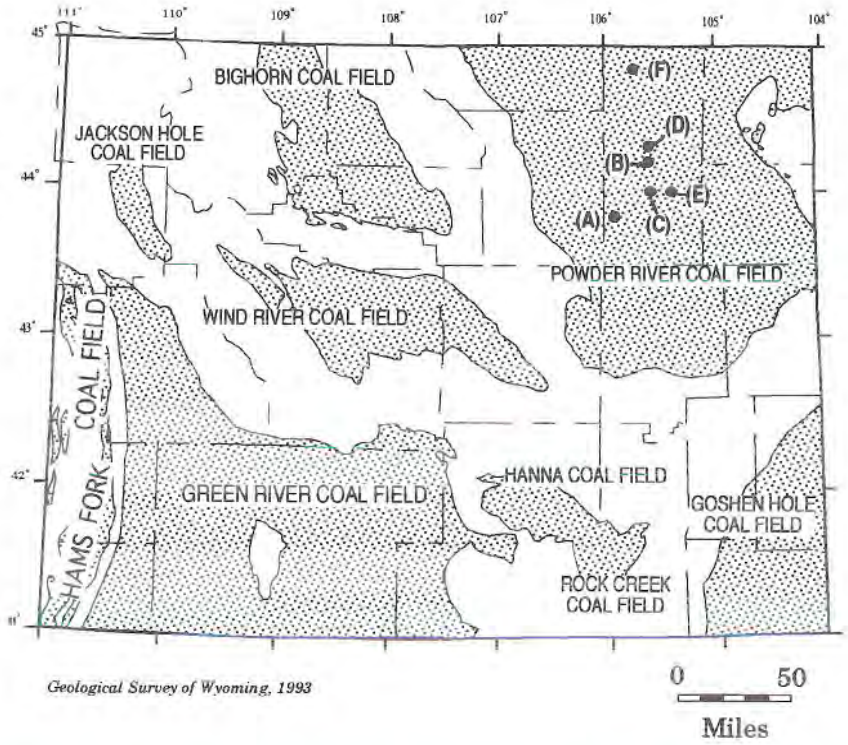


Figure 16. Coalbed methane activity in Wyoming during the fourth quarter of 1992.

government had not considered a staged development when it approved the much more extensive drilling in 1991.

In November, the BLM approved a proposal by a Denver-based company (American Oil and Gas) to drill as many as 45 new coalbed methane wells along U.S. Highway 59 in central Campbell County (location B on Figure 16). The wells are targeted for Tertiary age, Fort Union Formation coals, mainly the thick Wyodak bed in the Tongue River Member. A recent environmental assessment by the BLM estimated that as the project pumps as much as 350,000 gallons of water a day from an underlying ground-water system, nearby water wells could see drawdowns of as much as a hundred feet. In part, this has prompted the Powder River Basin Resource Council to ask BLM to take a second look at American Oil and Gas' proposal.

Since October, there have been 83 applications for permits to drill for coalbed methane in the Powder River Basin. Of those permits, 39 were requested by Martens & Peck (location C on Figure 16), 19 by Betop, Inc. (location D on Figure 16), 16 by DCD, Inc. (location E on Figure 16), and 9 by Wyatt Petroleum, Inc. (location F on Figure 16).

A special report on Indonesia's "Envirocoal"

There has been several recent news articles about a very low-sulfur (<0.1%), low-ash (<2%) coal from Kalimantan (Borneo), Indonesia (Figure 17). Mined by P.T. Adaro Indonesia, the coal is touted as a major resource for blending with American coals to help reduce sulfur and CO_2 emissions and thereby meet new Federal clean air regulations. A shipment of the coal has already made it to a port at Burnside, Louisiana. This coal will be used in blending tests by utilities. Since the Indonesian coal will likely vie for some of the same markets as Wyoming's low-sulfur and low-ash coals, some background information is warranted.

Figure 17. Location of Borneo and its coal-mining areas.

The "Envirocoal" is mined from a remote part of the island of Borneo near the village of Tanjung (Figure 18). The deposit is located in Miocene age sediments of the Warukin Formation, which consists mostly of terrestrial sandstones, rooted siltstones, and carbonaceous claystones. Miocene age sediments occur throughout most of southeastern Borneo, but are structurally dissected as a result of uplift (from the early to late Tertiary) of the Meratus Mountains. This uplift resulted in the subdivision of the region into the Barito, Kutai, and Pasir Basins (Hamilton, 1979). The three main areas of Miocene coal-bearing outcrops occur (1) west of the Meratus Mountains where P.T. Adaro Indonesia is mining, (2) east of the Meratus Mountains in the Asam Asam and Sarongga areas, and lastly (3) in a slightly folded sequence just west of the Mahakam Delta. Heating values of the coals generally increase northward, with the Sarongga deposit having a heat value of approximately 7,500 Btu/lb whereas the "Envirocoal" has a reported heat value of 10,000 Btu/lb. Even farther northward near the village of Sengata (~50

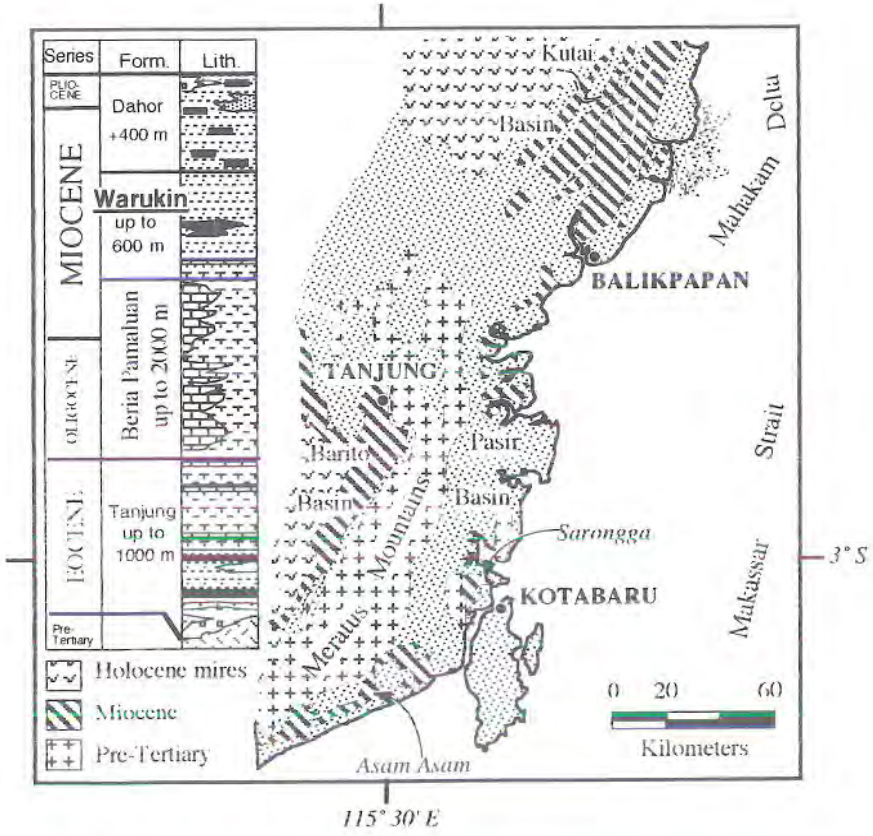


Figure 18. Generalized geologic map of the coal-mining areas of Borneo.

miles north of the Mahakam Delta), P.T. Kaltim Prima is mining a Miocene coal with a heat value of 13,500 Btu/lb (Chairul Nas, University of Wollongong, electronic-mail communication, 1992). At present, only the Miocene deposits near Tanjung and in the region of the Mahakam Delta are mined although P.T. Artumin and P.T. Utah Indonesia (subsidiaries of BHP-Minerals) are mining the Eocene Senakin coal bed east of the Meratus Mountains (Moore and Ferm, 1992).

Although not much is known about the geologic setting or distribution of the Miocene "Envirocoal", there has been some published articles on the Sarongga deposit. This bed is 115 feet or more thick and is distributed in "pods" of approximately 1.5 x 2.5 miles. Lignite in rank, its vitrinite reflectance is 0.35% with as-received moisture values of 31 - 36%. Ash values average 3 - 4% (dry basis) with increases near the top and bottom of the bed to 7%. Sulfur content (mostly organic) is very low, generally averaging 0.10% or less (dry basis). These values compare well with the reported values from the "Envirocoal". Ash and sulfur values from the Powder River Basin of Wyoming generally range from 4 - 6% and 0.20 - 0.35% (dry basis), respectively. However, moisture values of Powder River Basin coals are on average lower, ranging from 20 - 28% (Glass, 1975).

Although 5 - 20 million years old, the Sarongga coal was probably formed much in the same way as the modern domed peat deposits presently accumulating in large areas of Indonesia and Malaysia. Petrographic and pollen analyses show that the same processes of peat accumulation and plant floral assemblages occurred in the Miocene as does presently in the modern mires of Indonesia (Moore and Hilbert, 1992; Demchuk and Moore, 1993). A very specific and characteristic sequence of pollen succession is seen in modern domed mires, and this same sequence is noted in the Sarongga coal.

The unique coal quality seen in both the Sarongga and the "Envirocoal" deposits probably is the result of its formation as a domed mire. Since the organic material is accumulating at such a rapid rate in these mires, the surfaces are actually domed, or elevated, some 20 - 30 feet above the surrounding stream level (Anderson, 1964; Bruenig, 1990). Therefore, this type of mire is especially protected from incursion of sediment-ladened water. It is interesting to note that the "Envirocoal" and the Sarongga deposits have ash and sulfur values no higher than that reported for the domed mires of Indonesia (Esterle *et al.*, 1989; Cameron *et al.*, 1990; Moore and Hilbert, 1992). The slightly higher ash and sulfur values of the Powder River Basin coals may be related to differences under which peat accumulated in those paleo-mires.

Coal course being taught

A coal course titled "Paleobotany and Paleoecology of Coal" is being offered in the Spring semester at the University of Wyoming Laramie Campus. The course will be taught through the Department of Botany (BOT 5690) and will view coal from the perspective of a "fossiliferous sediment". The course will consist of 2-hour, weekly seminars, a field trip in the latter half of the semester, and a few

laboratory sessions examining coal through the optical and scanning electron microscope. Topics will include plant evolution in peat (coal)-forming systems, modern mire environments, geochemical and degradative processes in modern and ancient mires, depositional environments of coal beds, and the effects on coal properties. The course will be co-taught by Drs. J.C. Shearer, T.A. Moore, and J.M. Beiswenger.

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INDUSTRIAL MINERALS AND URANIUM UPDATE

by Ray E. Harris
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In 1992, Wyoming's share of the Nation's nonfuel mineral production decreased to 2.95%, down from 3.05% in 1991 (U.S. Bureau of Mines, 1993). Ranked by states, however, Wyoming moved from 11th place to 10th place. Trona remains the dominant nonfuel mineral produced in Wyoming.

Aggregate (construction)

In the region, production of construction aggregate has increased due to construction at the Denver airport. In Wyoming, this resulted in an increase in production at Meridian Aggregates' granite quarry west of Cheyenne. Aggregate production in Colorado, however, increased enough for it to become the second largest in the U.S., behind California (Teipordei, 1993). For comparison, Colorado only ranked 22nd in aggregate production in 1990. Reduced highway construction in 1993 is likely to offset production gains related to the airport, at least in Wyoming.

Bentonite

Bentonite sales from Wyoming mines and refining plants continue to increase. These increases are primarily for use as foundry sand binders in the metal casting industry and as natural sealants in waste containment. For example, bentonite provides an impervious barrier which can contain the liquid waste in landfills. Before 1991, most bentonite was used for drilling mud by the oil and gas industry. Since then, however, other uses for bentonite have prevailed.

In October, as a result of the expanding market for bentonite, Bentonite Production Corporation, a Denver-headquartered company, announced plans to expand production at its Colony plant in Crook County (Figure 19). The expansion will reportedly enable the company to produce specialty bentonite for the metal casting industry. After expansion, which will cost about $1 million, the plant capacity will be increased by 140,000 short tons per year. Bentonite Corp. produced 325,865 short tons of bentonite from the Colony plant in 1991, according to the Wyoming State Inspector of Mines. They also have a plant at Lovell in Big Horn County (Figure 19).

Cement

Cement production at the Mountain States Cement Co.'s plant in Laramie is close to plant capacity (nearly 400,000 short tons) (Figure 19). Cement from Laramie is being used in the construction of the new Denver airport. Nationally, cement production is averaging about six percent more than in 1991. Cement is produced from chemical-grade limestone, gypsum, and a variety of ingredients used in specialty cements such as siliceous shale, iron ore, aluminous shale or anorthosite, and clay.

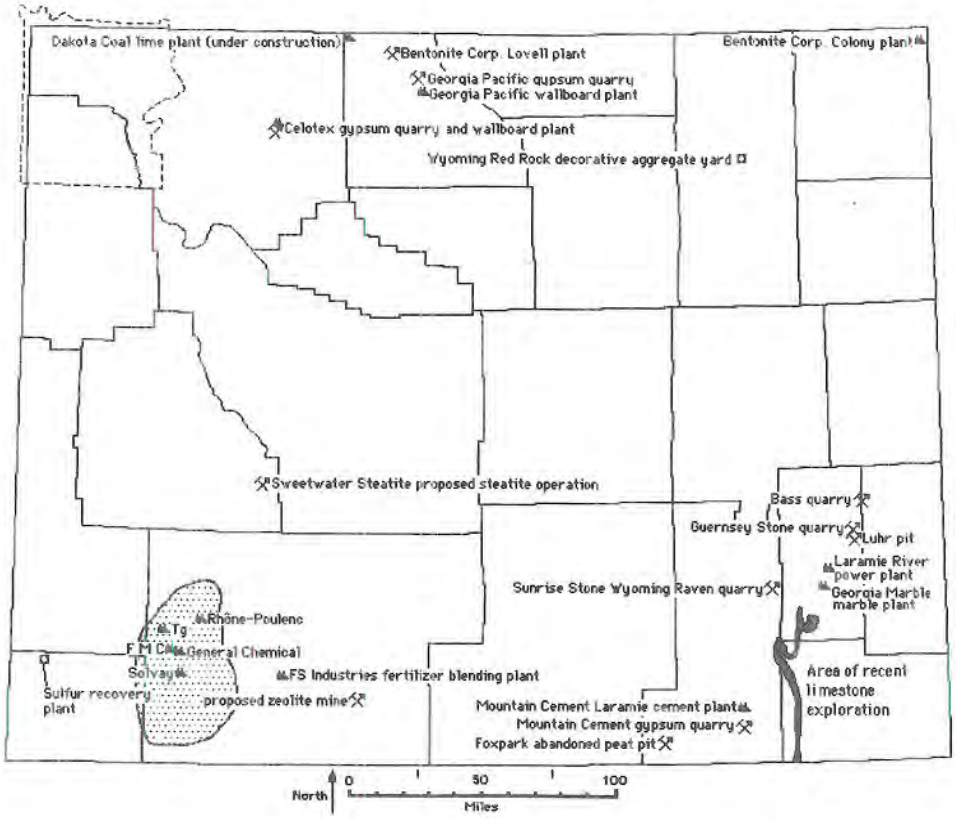

Figure 19. Industrial minerals activities in the fourth quarter of 1992.

Decorative stone

Due to heavy snow and cold weather, production of black granite (mineralogically an amphibolite) has ceased at Sunrise Stone Co.'s Wyoming Raven quarry in northeastern Albany County (Figure 19). Production should resume when the weather improves.

Fertilizer

Simplot Soilbuilders (a division of Simplot Minerals and Chemical), which is a fifty percent partner in the FS Industries fertilizer blending facility southeast of Rock Springs, (Figure 19), purchased retail and wholesale sales operations from Puregro Co. Puregro was a subsidiary of Union Oil of California (Unocal). Puregro's retail stores sold fertilizer and soil conditioners in Colorado and Nebraska. FS Industries recently acquired the Rock Springs facility (*Wyoming Geo-notes No. 36*, page 32), which uses phosphate from Utah and sulfur from sour gas processing plants in Wyoming (Figure 19).

Gypsum

Gypsum ($CaSO_4 \cdot 2H_2O$) is produced in Wyoming for wallboard at the Celotex, Inc. plant near Cody and at the Georgia-Pacific Corp. plant between Greybull and Lovell in Big Horn County (Figure 19). Smaller amounts of gypsum are mined south of Laramie by Mountain Cement Co. for use in manufacturing cement (Figure 19). Production of gypsum in both Wyoming and the Nation was about the same in 1992 as it was in 1991.

Limestone

Limestone, a sedimentary rock composed primarily of the mineral calcite ($CaCO_3$), is produced in Wyoming for construction aggregate, for the manufacture of cement, and for the manufacture of lime for the control of power plant emissions. In the latter case, Dakota Coal, a subsidiary of Missouri Basin Electric, is constructing a lime (CaO) plant north of Frannie, Wyoming, which will use limestone mined in Montana. Meanwhile, lime used for emissions control at Missouri Basin Electric's Laramie River power plant near Wheatland continues to use limestone quarried at the Bass quarry north of Guernsey (Figure 19).

A few companies were exploring for chemical-grade limestone in the Laramie Mountains west of Chugwater and Cheyenne during the fourth quarter of 1992 (Figure 19). Some of this exploration may be in response to the depletion of limestone sources in the Front Range area of Colorado.

Peat

Peat is an organic product formed in wetland areas. 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 U.S.

Michigan is the largest producer of peat in the U.S. Wyoming's neighboring states of Montana and Colorado produce reed-sedge peat from alpine bogs.

Because the demand for peat is increasing, some companies have been inquiring about the possibility of mining peat in Wyoming. Peat was produced in the past from near Foxpark in Albany County (Figure 19). Peat mining opportunities in the U.S. are becoming rarer due to Federal restrictions on wetland development.

Talc (Steatite)

Sweetwater Steatite, Inc. of Rock Springs, applied for a permit to remove surficial boulders of steatite (massive talc) from a site in Sublette County (Figure 19). The steatite would be used for carving stone. The green and gold color of the steatite boulders is unique, and Sweetwater Steatite may have a worldwide market.

Although a Permit to Mine (to remove some boulders) was approved in July by the Wyoming Department of Environmental Quality, a protest was filed in late September by an archaeologist employed by the U.S. Bureau of Land Management (BLM). The archaeologist objected because he claims the boulders have religious significance to the Shoshone and Arapaho Tribes. The Wyoming Environmental Quality Council is reviewing the permit and is scheduled to issue a decision early in 1993.

Trona

Production and construction continues at the five plants that 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 19).

Existing and potential producers have expressed interest in acquiring new trona resources in Wyoming. Because trona is a leasable mineral, applications to lease are filed with and decided by the U.S. Bureau of Land Management (BLM). The following is a summary of leasing interest, as of November, 1992. This information was supplied by the BLM.

1) Approximately 2,560 acres of land containing demonstrated trona reserves were proposed for competitive lease by Tenneco (recently bought out by Solvay Minerals) and General Chemical in 1980. Because the BLM has not completed environmental studies required by the National Environmental Protection Act (NEPA), no action has been taken on this lease. A lease sale is, however, tentatively scheduled for sometime in 1993.

2) Church and Dwight (C&D) submitted an expression of interest for a lease sale of trona in April, 1991, for over 3,800 acres of Federal land. Since a NEPA study is required, there are no plans to lease the requested acreage until after

1995. C&D has also acquired trona resources by transfer of lease from General Chemical and the University of Wyoming. C&D is also applying for transfer of leases from Occidental Petroleum. This transfer is subject to BLM review. This lease package reportedly contains more demonstrated trona reserves than those of all present producers combined.

3) U. S. Borax has applied to the BLM for a trona exploration license for 8,624 acres of Federal land. The license was issued in September, 1992, but it has been challenged by C&D.

4) Wold Minerals has asked the State of Wyoming to pursue a land exchange with the Federal government that would involve minable trona acreage. The proposed land exchange involves State lands within the Flaming Gorge National Recreation Area and a block of Federal acreage outside the recreation area. If the exchange occurs, Wold Minerals would seek to lease the State of Wyoming lands. The Wyoming State Land and Farm Loan Office is pursuing the exchange with the BLM.

5) Evergreen Minerals, which applied for a prospecting permit for trona in an area east of the Rhône-Poulenc mine area (*Wyoming Geo-notes No. 33*, p. 34) has cancelled the permit. The company drilled two holes, but did not locate minable trona.

In early December, FMC Wyoming, Inc., announced plans to construct a new plant that would produce soda ash from mined trona. FMC was the largest soda ash producer in 1991. The new construction would expand the capacity of FMC from 2.8 million short tons of soda ash to 3.4 million short tons of soda ash, according to a company spokesman. The plant will cost about $125 million. The construction plans need the approval of the Board of Trustees of FMC, and then the proposal must be submitted to the Wyoming Industrial Siting Council. If approved, construction could take three years.

These exploration, development, and expansion plans are all the result of projected increases in the worldwide demand for soda ash (Kostick, 1992). Outside of the U.S., the only production of soda ash from bedded trona deposits similar to Wyoming's is in Turkey. There is also a large deposit of bedded trona, yet undeveloped, in mainland China. Some soda ash is also produced from natural surficial deposits of trona in California and Africa. The rest of the world's supply of soda ash is manufactured from salt, lime, and other materials by a process known as the Solvay method. This was developed by the Solvay Company of which Solvay Minerals is a subsidiary.

In early December, the BLM announced that it was increasing the royalty on mined trona from 5 percent of its mined value to 8 percent. Five days later, after protests from the soda ash producers and from Wyoming Senator Malcolm Wallop, the BLM postponed the royalty rate increase. Then, two weeks later, the BLM said it was starting over with a study to determine a suitable trona royalty rate.

Zeolites

A South Dakota-based partnership located claims for zeolites in the Washakie Basin, near historic Fort LaClede (Figure 19). The U.S. Bureau of Land Management (BLM) denied the claims because the area is closed to mineral location under the terms of an oil shale withdrawal. The claimant requested that the BLM review the withdrawal since the oil shale development potential is low. Although the BLM has been reviewing the withdrawal for several years, there is no indication when they will complete their review.

Uranium, thorium, and other radioactive materials

The NUEXCO spot market price for yellowcake increased during the early part of the fourth quarter of 1992 from $7.75 per pound of yellowcake to $8.75 per pound. It dropped near the end of the quarter to $8.00 per pound, the current price.

In Wyoming, uranium is now only mined at Power Resources' Highland in-situ operation in the southern Powder River Basin north of Glenrock. Rio Algom and Total Minerals conducted production tests at their in-situ properties in the Powder River Basin, but did not go into production in 1992. Pathfinder Mines is in the permitting process for conducting in-situ production tests on their recently acquired Ruth deposit in southeastern Johnson County. Green Mountain Mining Venture continues to work on the development of an underground uranium mine south of Jeffrey City (Figure 20).

The U. S. Energy Information Agency (EIA) released final statistics on the domestic uranium industry for 1991. These statistics show:

- Domestic uranium production in 1991 declined 11 percent from 1990.
- The average price of delivered uranium (including contract prices) in 1991 declined 13 percent to $13.66 per pound of yellowcake.
- Expenditures for uranium exploration and development increased by four percent.
- Uranium imports reached the third highest level in history. The amount of uranium imported through loans and exchanges (mostly from Russia) more than doubled.
- Uranium exports increased 75 percent over 1990 to 3.5 million pounds of yellowcake.

The recently passed National Energy Bill authorizes the expenditure of $310 million dollars to help pay for the cleanup of abandoned uranium mill tailings sites in the U.S. Five of these sites are in Wyoming. The money for this project has not yet been appropriated.

Thorium is another radioactive element with some uses. One of the largest measured, identified resources of thorium is located in the Bear Lodge Mountains

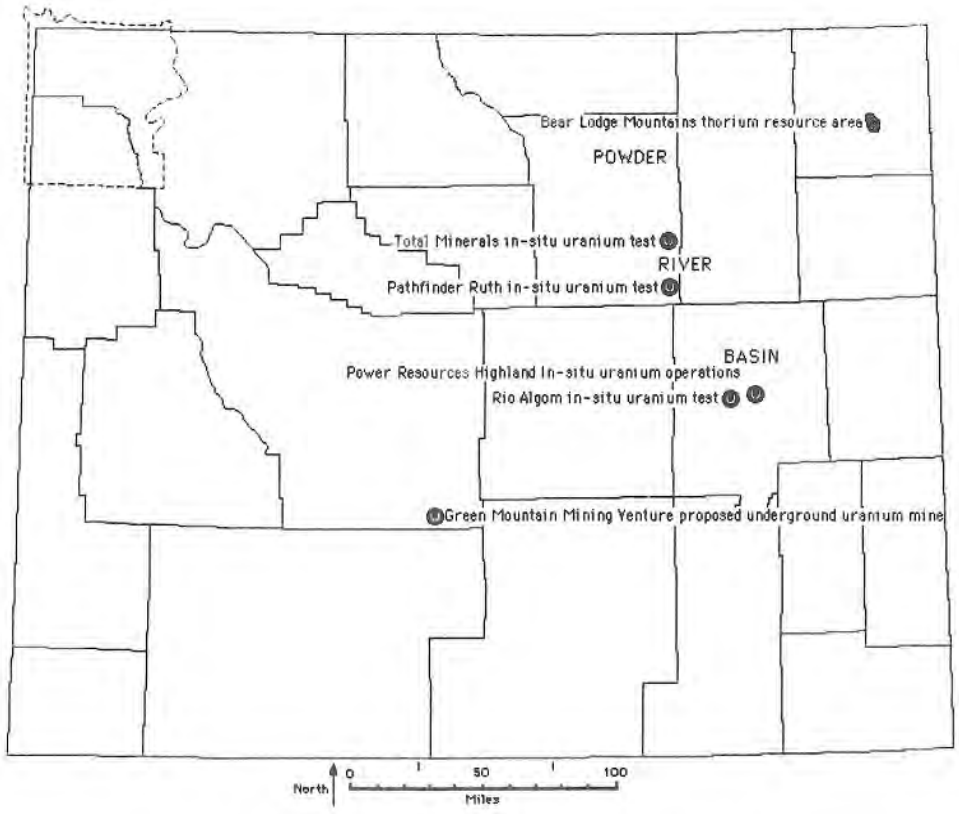

Figure 20. Uranium activities in the fourth quarter of 1992.

of Crook County (U.S. Bureau of Mines and the U.S. Geological Survey, 1980; Staatz, 1983) (Figure 20). Other thorium resources in Wyoming are found in fluvial Cambrian paleoplacers at Bald Mountain in north-central Wyoming (Figure 20), in other Cambrian paleoplacers, and in Cretaceous, marine, beach paleoplacer deposits (black sandstones) in central and western Wyoming.

Thorium is used in refractory materials, in gas lantern mantles , in aerospace alloys, in electronic components, and in chemical catalysts. Molds and crucibles that are used for casting and making high temperature alloys, are made from refractory materials containing thorium oxide (thoria). As an alloying material, thorium is primarily added to magnesium. This gives the magnesium higher strength and resistance to deformation at high temperatures. Thorium nitrate is used to improve tungsten welding rods and to facilitate welding of stainless steel and nickel alloys (Hedrick 1992a, 1992b).

Thorium is also used as fuel in nuclear power plants in a few foreign reactors. Increased development of breeder reactors, which use thorium for fuel, and other experimental applications in conventional reactors would require an increase in thorium production (Hedrick 1992a, 1992b).

In other news regarding radioactive materials, the U.S. Department of Energy signed a contract with the Mayak Production Association of the Russian Ministry of Atomic Energy for the purchase of up to 40 Kg of plutonium-238 (^{238}Pu). ^{238}Pu is used to power U.S. spacecraft.

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METALS AND PRECIOUS STONES UPDATE

by W. Dan Hausel
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The highlight of exploration activity for metals and precious stones in 1992 was a diamond rush which began in the Northwest Territories of Canada and filtered down into the Colorado-Wyoming kimberlite province. Dozens of companies and individuals have been contacting the Geological Survey of Wyoming (GSW) for information on the province, and some companies have been obtaining land packages.

During the fourth quarter, the GSW also received some very interesting data on the Kirwin copper porphyry and completed reports on the Seminoe Mountains mining district (Hausel, 1992a), on the Cooper Hill mining district (Hausel, 1992b), and on a study of metals and precious stones in southern Wyoming (Hausel and others, 1992).

State Line District, Laramie Mountains

What's being called the greatest land rush in the history of North America has been taking place during the past year in the Lac de Gras area of the Northwest Territories of Arctic Canada. The rush followed the processing of a 160-ton bulk sample of a kimberlite discovered in 1991 near Yellowknife. The sample was shipped to Dia Met's diamond extraction plant in the Prairie Divide region of Colorado, and 101 carats of diamonds were recovered from the sample (*Mining Magazine*, 1992, Dec., p. 379-383). Interest in diamond deposits has now spread to the Colorado-Wyoming State Line district. The Geological Survey of Wyoming (GSW) has recently been receiving an average of more than a dozen phone calls per week from individuals and companies seeking information on kimberlites, lamproites, diamonds, and other heavy mineral indicators.

The Colorado-Wyoming kimberlite province includes more than 100 kimberlites intruding Proterozoic crystalline rocks near the southeastern edge of the Wyoming Archean Province. Although no kimberlites have been found within the Archean basement, lamproites of the Leucite Hills intrude the Wyoming Province and numerous indicator minerals have been recovered from the Green River Basin south of the Leucite Hills (Hausel and others, 1985), the Laramie Mountains north of the State Line district (Hausel and others, 1988), and in the Seminoe Mountains district (Hausel, 1992a) within the Wyoming Province.

Diamonds have been recovered from two areas in the Proterozoic terrane. Placer diamonds were recovered from a gold prospect in the Medicine Bow Mountains in 1977, and in-situ diamonds were recovered from several kimberlite diatremes and dikes in the State Line district south of Laramie over the past 18 years. The Colorado-Wyoming State Line district includes more than 40 ultrabasic intrusives, many of which have yielded diamonds. More than 100,000

diamonds (both gem and industrial quality) weighing up to 2.6 carats have been recovered (McCallum, 1991; McCallum and Waldman, 1991).

In past years, several companies have been active in the district, including Cominco American, Superior Minerals, Lac Minerals, Ashton, and Diamond Company, N.L. In addition, three diamond recovery plants have been operated. One by Cominco American, Inc., another by Superior, Lac Minerals, and most recently by Dia Met (Waldman, 1991), and a third by Diamond Company, N.L (Howard Coopersmith, personal communication, 1992). The Cominco American plant at Fort Collins, Colorado, was dismantled a few years ago. The Dia Met Prairie Divide plant is still operational in Colorado, and a second plant operated by Diamond Company, N.L. was recently permitted in Wyoming. Both the GSW and Colorado State University have small research labs for diamond extraction.

Currently, four companies are known to be examining the State Line district. The district has several unexplored targets defined by geophysical (Paterson and MacFadyen, 1984), remote sensing (Marrs and others, 1984), and stream sediment methods (Hausel and others, 1988).

Kirwin Mining District (T45-46N, R103-104W)

According to reports provided by Amax, the Kirwin district in the southern Absaroka Mountains hosts a 196-million-ton copper porphyry ore deposit with associated molybdenum, gold, silver, lead, and zinc. The reports also indicate that there is good potential for expanding the geologic reserves. The property is currently held in Acquired Land Status by the U.S. Forest Service.

Much of the following information on the Kirwin district was obtained from Ora Rostad, former Kirwin project geologist for Amax. The author is indebted to Ora Rostad and Amax for providing the Geological Survey of Wyoming (GSW) with several files and drill logs on the Kirwin property. These files are available for public inspection at the GSW, and any person wishing to see them should contact W. Dan Hausel (307/766-2286) for an appointment.

Kirwin lies 35 miles west of Meeteetse in the southern Absaroka Mountains of northwestern Wyoming. The historic ghost town of Kirwin consists of a few, old, dilapidated buildings and the photogenic headframe of the Wolf mine at the base of Bald Mountain. The district was organized following Will Kirwin's discovery of veins carrying gold, silver, copper, lead, and zinc along the North Fork of the Wood River in 1890. The area was designated the Kirwin mining district in honor of his discovery.

Although the district was explored over the years by a number of companies, Amax's interest in the property goes back to 1960 when an exploration manager for Amax contacted the GSW for information on molybdenum resources in Wyoming, and GSW geologist, William H. Wilson, who had mapped the Kirwin

area, described it as the most promising prospect in the State (Wilson, 1964; 1982). As a result of this discussion, Amax geologists, Ora Rostad and Jon Browne, recommended the district as a potential target for copper-molybdenum mineralization (Rostad, 1983a).

Three years later in 1963, Amax began drilling Bald Mountain and significant secondary-enriched, porphyry-type copper mineralization was intersected. Drilling over the next several years proved the presence of a significant porphyry copper deposit. Based on incomplete data, the U.S. Bureau of Mines reported the porphyry hosted 70 million short tons of ore averaging 0.75% Cu.

Amax drilled 150 holes on 300-foot spacings, totaling 86,861 feet. The drilling program outlined geologic reserves totalling 196 million tons of ore averaging 0.505% Cu and 0.022% MoS_2 at a 0.3% Cu-cutoff grade with by-product credits in silver, gold, lead, and zinc (Rostad, 1983b). However, the full extent of the deposit at depth, was not established.

Reserves suitable for open pit mining were calculated at 160,800,000 short tons with a favorable stripping ratio of 0.57:1 of waste to ore (Rostad, 1983b). Feasibility studies have also indicated that the deposit is amenable to in-situ leaching. In a recent 1991 study on in-situ leaching, it was concluded that recovery costs of $0.309/pound Cu could be anticipated (Ora Rostad, personal communication, 1992).

While Amax apparently gave little consideration to the potential yield of peripheral veins, some of these veins are traceable along trend for more than 2,500 feet. Although the veins are narrow, some have ore grade values. For example, vein material collected from the Oregon mine dump immediately east of the Bald Mountain porphyry produced assays as high as 100 opt Ag and 0.3 opt Au. These specimens typically contain wire silver and acanthite. More importantly, the best assay values obtained in two adits were at or next to the mine faces. In the Oregon mine, a 3-foot-wide sample at the face yielded 17.8 opt Ag and 0.08 opt Au; in the nearby Johnnie mine, a 1.5-foot sample assayed 64.7 opt Ag and 0.12 opt Au (Rostad, 1983b).

Amax drilled one hole to a total depth of 4,000 feet on the nearby Tumlum property. Unfortunately, the hole never exited the igneous complex although the core showed strong pyritic and biotitic alteration plus some copper mineralization (generally under 0.2% Cu) to its bottom. However, Mobil drilled a wildcat oil and gas well on the nearby Johnnie millsite to a total depth of 4,860 feet. Limestone of the Gypsum Springs Formation (a potential host for skarn) was cut at 3,090 feet depth (Rostad, 1982).

The possibility of replacement deposits and skarns at depth in the underlying sediments was never fully tested by Amax, even though the company identified a prominent aeromagnetic anomaly between Bald Mountain and Galena Creek to

the east. The anomaly is interpreted to be the result of hydrothermal magnetite at depth (Ora Rostad, personal communication, 1992).

Any future exploration in the district should also consider the possibility of ore-rich breccia pipes. Such pipes could easily have been missed with 300-foot drill spacings.

Another potential target, Spar Mountain, immediately south of Bald Mountain, has a limonitic anomaly covering a large area. Samples of rock collected on the divide between Smuggler Basin and Spar Creek contained some native copper. Spar Mountain is pervasively talus covered and could represent a separate mineralized center with possible secondary enrichment.

The district also has potential for placer gold. Abundant alluvial gravel extends from Kirwin several miles downstream along the Wood River. The gravels are 60-150 feet thick. There is little evidence that the more than 100,000,000 cubic yards of gravel in this area has ever been explored (Rostad, 1982).

Amax recently sold their Kirwin property to the Mellon Foundation, which subsequently donated it to the U.S. Forest Service. It is now in an Acquired Land Status category, meaning the property can either be leased or it can be withdrawn from mineral exploration or surface occupancy at the discretion of the district ranger. The Forest Service notes that an environmental assessment must be completed on the property prior to any decision.

Seminoe Mountains Mining District

The Seminoe Mountains mining district near central Wyoming is restricted to a belt of metamorphic rocks cropping out along the western flank of the Seminoe Mountains. The district was mined for gold in the late 1800s. Additional resources include iron ore, copper, silver, serpentine, asbestos, jasper, jade, and leopard rock. During a recent study by the Geological Survey of Wyoming (GSW), some previously unknown zones of anomalous lead and zinc associated with shears were detected, and some pyrope garnet and chromian diopside were recovered from a nearby gold placer.

The core of the Seminoe Mountains is formed of Archean crystalline rock consisting of an ancient greenstone terrane of metamorphosed volcanic, sedimentary, and plutonic rock intruded by granodiorite. These metamorphic rocks include amphibolite, mica schist, serpentinite, ultramafic schist, metagreywacke, metapelite, and banded iron formation. The flanks of the Precambrian core are unconformably overlain by Phanerozoic sedimentary rock that form a spectacular steeply dipping precipice along the southern flank of the range.

The Metals and Precious Stones Section of the GSW recently completed a report on the Seminoe Mountains mining district, which is available in an

unpublished preliminary format (Hausel, 1992a). Photocopies of the report can be purchased for $12. The report includes text, six tables with assays and whole-rock analyses, a detailed geologic map of the district, and a sample location map.

Southern Wyoming

Over the past two years, the Geological Survey of Wyoming (GSW) has searched over a large area in southern Wyoming for metals and precious stones. The project, which was partially funded by Union Pacific Resources, has led to the discovery of several interesting anomalies. In the first year of the project, anomalous gold was identified in operating sand and gravel pits, stream placers, lodes in the Cooper Hill district, and in the Quaking Asp Mountain silicified zone south of Rock Springs (Hausel and others, 1992).

Results from the second year, which are currently being compiled, show gold anomalies surrounding the northern flank of the Medicine Bow Mountains and precious metal anomalies at several other locations in southern Wyoming. Gold was also recovered from sites immediately adjacent to Interstate 80, as well as from a paleochannel exposed in the Laramie City landfill.

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MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING

PETROLEUM

Remaining Resources (January 1, 1992)		
Discovered (Includes 10 billion barrels recoverable by enhanced recovery techniques)	12.6	billion barrels[1]
Undiscovered	7.6	billion barrels[1]
Total	20.2	billion barrels
Remaining Reserve Base (January 1, 1992)		
Measured reserves (Proved reserves) (Includes oil, gas liquids, and condensate)	1.38	billion barrels[2]
Indicated and inferred reserves	2.80	billion barrels[1]
Total	4.18	billion barrels

NATURAL GAS

Remaining Resources (January 1, 1992)		
Discovered (Includes 20.1 trillion cubic feet (TCF) of methane[1] and 122.0 TCF of CO_2[3])	142.1	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	3,849.3	trillion cubic feet
Remaining Reserve Base (January 1, 1992)		
Measured reserves (Proved reserves) (Includes 10.4 TCF of methane[2] and 60.6 TCF of CO_2[3])	71.0	trillion cubic feet

COAL

Remaining Resources (January 1, 1992)		
Identified and Hypothetical (Discovered)	1,428.4	billion tons[6]
Speculative (Undiscovered)	31.5	billion tons[6]
Total	1,459.9	billion tons
Remaining Reserve Base (January 1, 1992)		
Demonstrated strippable (Measured and indicated reserve base)	26.8	billion tons[7]
Demonstrated underground-minable (Measured and indicated reserve base)	42.5	billion tons[7]
Total	69.3	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]

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GEOLOGIC MAPPING AND STRATIGRAPHY

by Alan J. Ver Ploeg
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NEW DISPLAYS COMPLETED FOR GEOLOGY MUSEUM

UW Geological Museum curator, Brent Breithaupt, recently announced several new displays, renovations, and changes at the Geological Museum on the University of Wyoming campus. Four interactive displays have been set up. They include a *Diplodocus* femur dating back 150 million years that visitors can touch and learn how bones are dug up and transported; and a mosasaur skeleton displayed as it would appear when the fossilized bones were first found, with the bones scattered around. In addition, a 100-million-year-old giant *Inoceramus* clam and a large specimen of selenite gypsum are included in the "touch" displays.

New displays of prehistoric reptile skulls were also added for visual purposes. Among the newly displayed skull casts, are a *Camarasaurus* skull and skulls of a plesiosaur and a phytosaur. The *Camarasaurus* lived in Wyoming 150 million years ago and is a dinosaur contemporaneous with the *Apatosaurus (Brontosaurus*). Until the 1970s, the skull of *Camarasaurus* was mistakenly mounted on the neck of all *Apatosaurus (Brontosaurus)* skeletons. In addition to the skull of the plesiosaur, a skeleton cast of this aquatic reptile has been added to the museum's visual displays. The newest skeleton display is that of *Pteronodon,* a pterosaur, which was a flying reptile dating back to 80 million years ago. This skeleton was found north of Lusk, Wyoming, in the Pierre Shale.

New mineral displays have also been added to the museum. An amethyst geode and a 40-pound jade specimen highlight these new displays. The State Museum in Cheyenne loaned the Geological Museum the jade display along with a small diorama of what Wyoming appeared like during the Jurassic Period, 150 million years ago. An earthquake display prepared by Laramie High School students and several photographs of the Geological Museum in its early days in the late 19th century have also been added. During the Spring semester, Breithaupt will add the interpretive plaques to these new displays, as well as updating many of the older signs in the museum.

NEW U.S. GEOLOGICAL SURVEY PUBLICATIONS ON WYOMING GEOLOGY

Several new reports and maps pertaining to Wyoming geology have been released by the U.S. Geological Survey over the past few months. Six papers evolving out of the Evolution of Sedimentary Basins Project have been published specifically on the Powder River Basin. Also, four more papers by recently retired geologist, Henry Roehler, have been published. These reports and maps along with those of some additional geologists are listed below. To show the geographic area covered by each map or report, they are numbered and located on the accompanying index map (Figure 21).

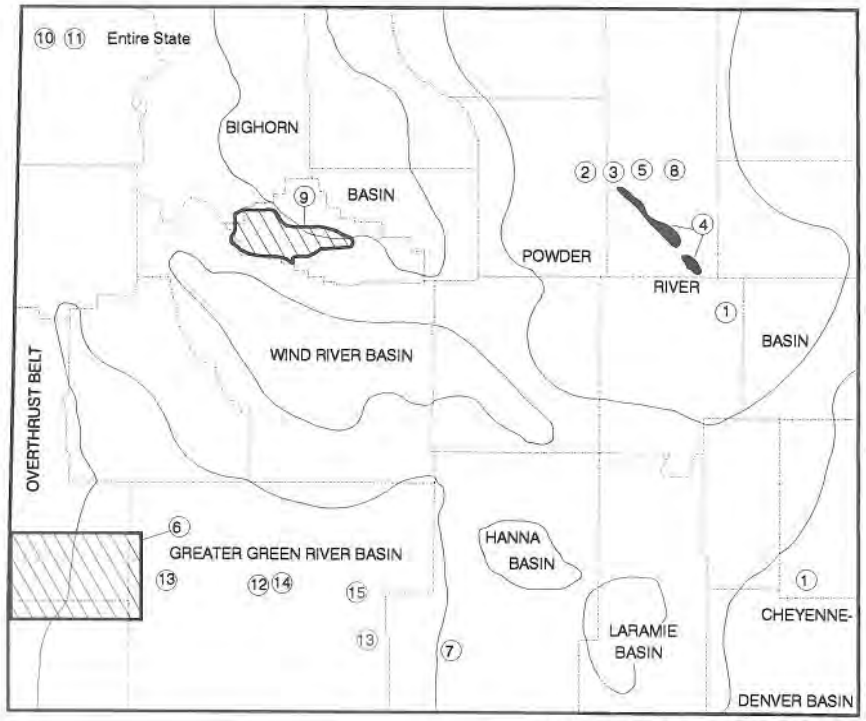

Figure 21. Index to selected geologic studies in Wyoming.

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GEOLOGIC HAZARDS IN WYOMING

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SOIL-GAS RADON STUDY OF LARAMIE BASIN COMPLETED

Background

Radon is present in water, soil, bedrock, and the atmosphere. Over the entire U.S., average radon concentrations in ground water are in the 200-600 picocuries per liter (pCi/L) range although values in public water supplies have ranged from 0-750,000 pCi/L (Milvy and Cothern, 1990). Radon in soils (soil-gas radon) ranges from 20- 100,000 pCi/L with most soils in the 200-2,000 pCi/L range (Otton, 1992). Radon levels in outdoor air average about 0.2 pCi/L, and radon in indoor air ranges from less than 1 pCi/L to over 3,000 pCi/L, but averages between 1-2 pCi/L (Otton, 1992). The U.S. Environmental Protection Agency (EPA) has established an action limit of 4 pCi/L for homes. At 4 pCi/L or greater, the EPA suggests that additional sampling or corrective action be taken.

Since most homes are built on soil, the amount of radon present in soil is of interest. Depending upon the type, quality, and age of home construction, radon can migrate in varying concentrations from soils into a home. If a technique is developed that can reliably predict the radon concentrations for large areas of soils and bedrock, it would be useful in guiding home sampling programs.

In the eastern U.S., soil-gas radon data have been used to generally characterize the potential for radon occurrence in areas underlain by various types of soil or bedrock. Schumann and Owen (1988) conducted 15 distinct soil-gas radon traverses composed of 1,295 sample points in Fairfax County, Virginia, and attempted to rank geologic formations based upon the soil-gas radon levels present in soils developed or present on top of the formations. Reimer (1990) conducted a single, twelve-mile-long, soil-gas radon traverse composed of 48 sample points in Prince Georges County, Maryland, and attempted to rank geologic formations using that data. In both these studies, the sites on the soil-gas radon traverses were only sampled one time.

If soil-gas radon relationships that are observed at one point in time are repeatable over a period of time, the observed data and relationships can be extrapolated regionally. The Geologic Hazards Section of the GSW has been conducting research on soil-gas radon for over a year. The primary purpose of the study was to determine if relative soil-gas radon relationships that were observed from one sampling of a twelve-site traverse were repeatable. A secondary purpose was to investigate the relationships between soil-gas radon and various climatic and soil (moisture and temperature) variables. In addition, soil-gas radon data for all sites were compared to the geomorphic features, surficial deposits, and bedrock that the sites were located on in order to determine if any regional assessments could be made from only twelve sites.

Soil-gas radon relationships

One day each week for thirty-five weeks, the twelve-site traverse was sampled. Each time the traverse was sampled, the sites were ranked from highest soil-gas to lowest soil-gas radon level. No two traverses had the same site rankings. This indicates that repeatability is low when comparing site rankings from one sampling period with another.

Results were somewhat better when sites were grouped into soil-gas radon ranges, and the relationships between the grouped sites were compared. A low range (0-250 pCi/L), a moderate range (250-750 pCi/L), and a high range (> 750 pCi/L) for soil-gas radon were observed in the study. Using the grouping technique, 23% of the sampling periods had identical groupings of sites, without regard to the order of sites within any group.

Obviously, a single sampling of a traverse may not accurately represent soil-gas radon relationships between sites sampled in an area. The Statistics Department at the University of Wyoming determined how many sampling periods were needed to statistically differentiate the twelve sites sampled in this study. In order to distinguish sites where mean radon levels differ by 50%, the twelve sample sites would have to be sampled thirteen different times. If it was necessary to distinguish sites where mean radon levels differ by less than 50%, the sites would have to be sampled an even greater number of times.

Climatic and soil moisture/temperature influences on soil-gas radon

There is a complex relationship between soil-gas radon and climatic and soil (moisture and temperature) variables. Relationships were not consistent from site to site, and at a few sites, relationships varied over time. A few statistically valid correlations, however, are possible when the complete data set is examined.

A significant positive correlation was found between soil-gas radon and precipitation. As precipitation increased, so did soil-gas radon levels. Since these samples were taken from holes bored in the soil, the precipitation may have wetted the surficial layer of the soils to the point where a "cap" was formed. The "cap" would slow the movement of radon to the atmosphere, allowing radon levels to increase within the soil.

There also appeared to be a correlation between soil-gas radon and atmospheric pressure although the correlation was weakly positive. Previous research suggested that the correlation between soil-gas radon and atmospheric pressure should have been negative (Asher-Bolinder, Owen, and Schumann, 1991). The reasons for this apparent conflict are unknown. There also appears to be a weak negative correlation between wind speed and soil-gas radon, which is consistent with most previous research (Asher-Bolinder, Owen, and Schumann, 1991).

Conflicting correlations were found between soil-gas radon and soil temperature or soil moisture. At the sites where soil temperature and moisture samples were only collected 13 times, significant correlations between soil-gas radon and

both variables were negative. At the sites where soil temperature and moisture samples were collected 26 times, significant correlations between the same variables were positive. While it was not determined how many sampling periods would be statistically significant for both climatic and soil variables, it appears that 13 was probably not adequate. No correlations were found between soil-gas radon and air temperature or humidity.

Regional assessment

In this study, it was not clear to what degree the surficial features and deposits versus bedrock were controlling soil-gas radon levels. Most sites with soil-gas radon levels in the low range (0-250 pCi/L) were located along the far eastern margin of the Laramie Basin. The low range sites are generally covered by surficial deposits associated with existing or ancestral streams draining the Laramie Mountains and are underlain by the Chugwater Formation, the Satanka Shale, and the Casper Formation. Most sites with soil-gas radon levels in the moderate (250-750 pCi/L) to high ranges (> 750 pCi/L) were located in the eastern to central portions of the Laramie Basin. The moderate to high range sites were usually covered by surficial deposits associated with existing or ancestral rivers draining the Medicine Bow Mountains and are generally underlain by the Niobrara Formation, Frontier Formation/Mowry Shale, or the Cloverly and Morrison Formations. Meaningful comparisons are not possible because the geologic formations that underlie the low soil-gas radon sites are not the same as those that underlie the moderate to high soil-gas radon sites. Future studies will attempt to determine if it is the surficial deposits themselves or the underlying bedrock that most strongly controls the levels of soil-gas radon in surficial deposits.

Not all soils, features, or deposits in the Laramie area were sampled. Future sampling may find sites with higher soil-gas radon levels. The average soil-gas radon levels for the entire U.S. range from 500-1,500 pCi/L (Mike Reimer, U.S. Geological Survey, personal communication, 1992). The mean soil-gas radon levels for the low and moderate range sites in the Laramie Basin study were below the average U.S. ranges. The mean soil-gas radon level for the high range site in the Laramie Basin study was within the average U.S. range. As mentioned previously, the higher soil-gas radon levels in some areas does not mean that all homes in those areas are elevated in radon. Home construction remains an important factor in how much radon enters any given house.

Conclusions

Soil-gas radon data must be used cautiously. Soil-gas radon relationships between sites and relationships between soil-gas radon and climatic/soil variables may not be entirely repeatable from one sample period to another.

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