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Cover: Photomicrograph of a piece of fossil plant bark from the Anderson coal bed (Tertiary) in the Powder River Basin. Brightly reflecting material on the left is an oxidized (probably burned during the peat stage) plant component. Scale of photomicrograph is 0.25 mm across the long axis.

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MINERALS UPDATE

OVERVIEW

by Gary B. Glass
State Geologist Geological Survey of Wyoming

This issue provides revised forecasts of production and(or) prices for oil, natural gas, coal, trona, and uranium. In regard to prices, our previous forecasts were increased for oil, natural gas, and coal, but lowered for trona (Table 1). Oil prices are now forecast to rise slowly from an estimated $16.25 a barrel in 1992 to $17.75 in 1995. Since approximately 65 percent of the oil produced in Wyoming is sour or heavy crude, the first purchase price of Wyoming oil is currently averaging about $5.00 per barrel lower than the price paid for West Texas Intermediate. Transportation costs also lower the value received for some Wyoming crude. Figure 1 shows that the first purchase price paid for Wyoming crude has remained slightly above the posted price for Wyoming sour crude since early in 1991. Figure 2 is a graph of the new forecast for Wyoming oil prices.

In regard to natural gas, the estimated price for 1992 was increased from $1.44 to $1.63 per MCF. Spot-sale prices continued to rise in the third quarter, contrary to what usually occurs in this quarter (Figure 3). While this may be in part

Table 1. 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	17.21	1.41	*8.05	*44.18	21.00
1992	16.25	1.63	7.79	44.50	21.00
1993	16.75	1.80	7.57	46.35	21.00
1994	17.25	2.00	7.36	47.42	21.00
1995	17.25	2.20	7.20	49.00	21.00

* Actual value for comparison.

[1] Modified in October, 1992 from Consensus Revenue Estimating Group, Wyoming State Government Revenue Forecast FY93-FY96, October, 1992, 29 p.

[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).

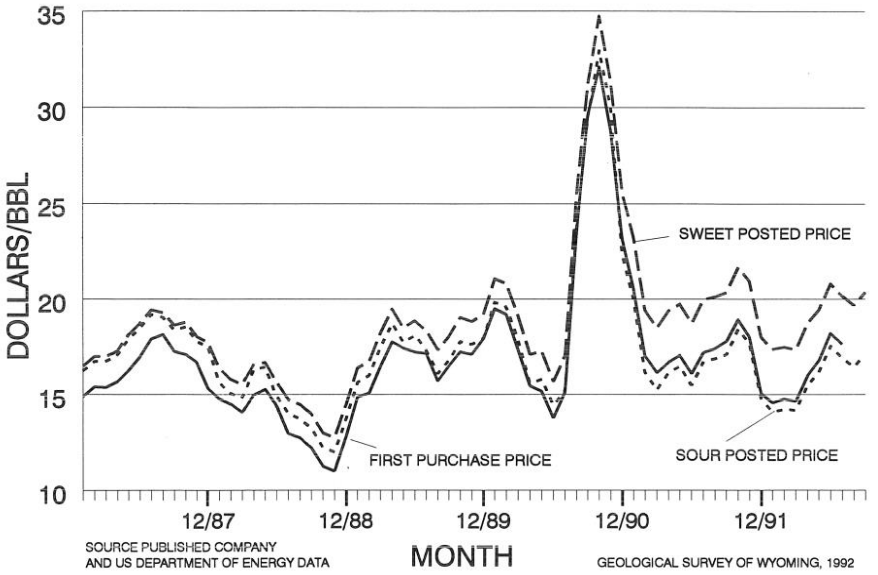

Figure 1. Wyoming posted Sweet and Sour crude prices and first purchase prices averaged by month (1987 to present).

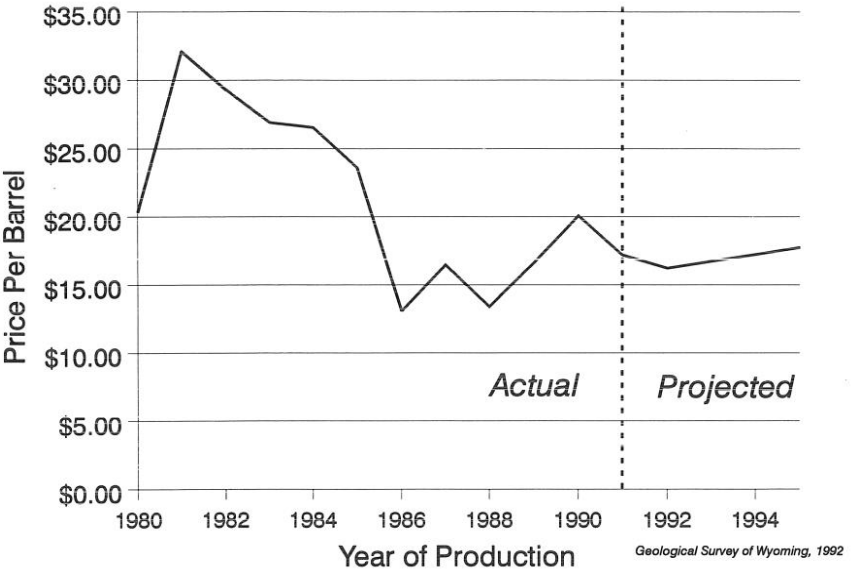

Figure 2. Average prices paid for Wyoming oil (1980 to 1991) with forecast to 1995).

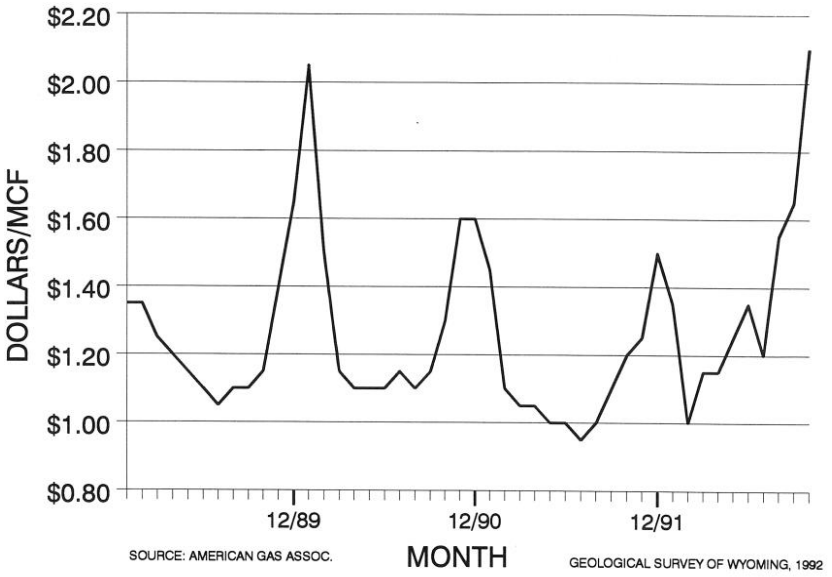

Figure 3. Spot prices for natural gas sales at Opal, Wyoming, averaged by month (1989 to present).

related to the effects of Hurricane Andrew, it is not all related to that because the trend started before the hurricane. Because prices appear to be going up with new demand, natural gas prices are forecast to increase to $2.20 per MCF by 1995 (Table 1 and Figure 4). These prices, incidentally, include the value of natural gas liquids.

The forecast prices for coal were only slightly increased (Table 1 and Figure 5). These increases were necessitated by the lowered production forecasts. By lowering production estimates, the dilution by low-cost coal (coal selling for under $5.00 per ton) was also lessened. Consequently, the average price of coal will not decline as quickly as previously forecast.

Estimates of trona prices for 1992, 1993, and 1994 were lowered somewhat, but the 1995 estimate was left at $49.00 (Table 1).

The production forecasts for oil have been lowered slightly (Table 2 and Figure 6). Production is expected to decline by four percent each year. The possibility of a carbon dioxide pipeline into the Powder River Basin provides some optimism for the future development of some enhanced oil recovery projects. And the U. S. Bureau of Land Management is also hopeful that their new sliding royalties for stripper wells might stimulate some new production on Federal lands.

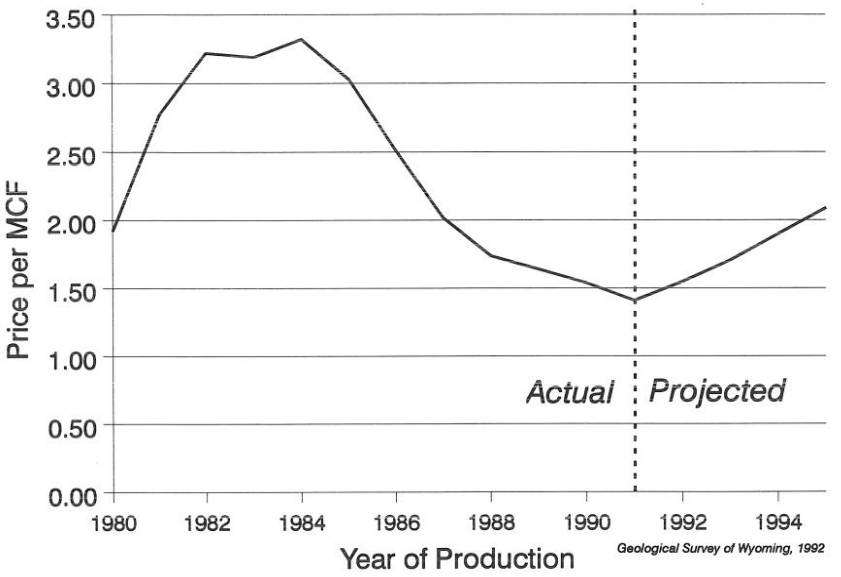

Figure 4. Average prices paid for Wyoming natural gas (1980 to 1991) with forecast to 1995 (includes carbon dioxide and natural gas liquids).

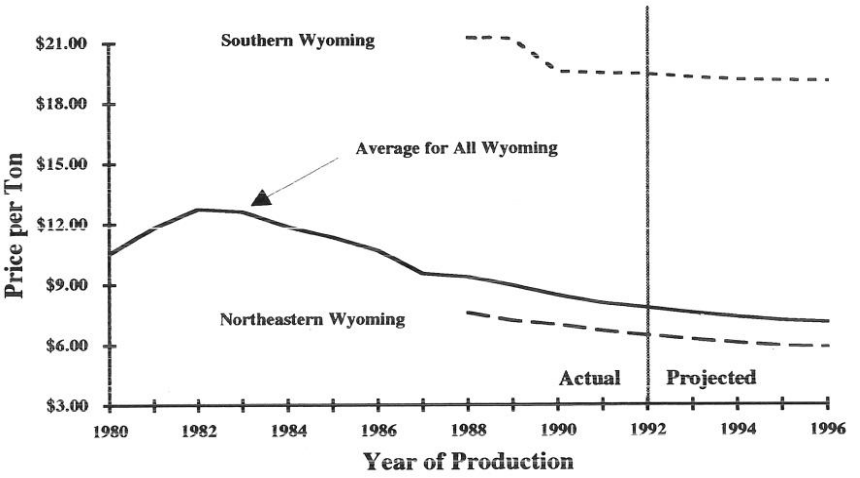

Figure 5. Average prices paid for Wyoming coal (1980-1991) with forecast to 1996 *[Data from U.S. Energy Information Administration (1980-1984) and Wyoming Department of Revenue and Consensus Revenue Estimating Group (1985-1996)].*

Table 2. 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	681.4	131.0	0.98	184.0	16.2	0.2	1.1	0.91
1991	100.0	728.0	131.0	0.98	*193.9	*16.1	0.3	*1.0	1.00
1992	98.0	733.0	131.0	0.98	191.0	16.3	0.1	0.8	1.00
1993	94.0	758.0	131.0	0.98	197.0	16.6	—	0.8	1.00
1994	90.0	783.0	131.0	0.98	202.0	17.0	—	0.8	1.00
1995	86.8	808.0	131.0	0.98	207.0	17.2	—	0.8	1.00

*Actual values for comparison; [1]Geological Survey of Wyoming, October, 1992; [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.

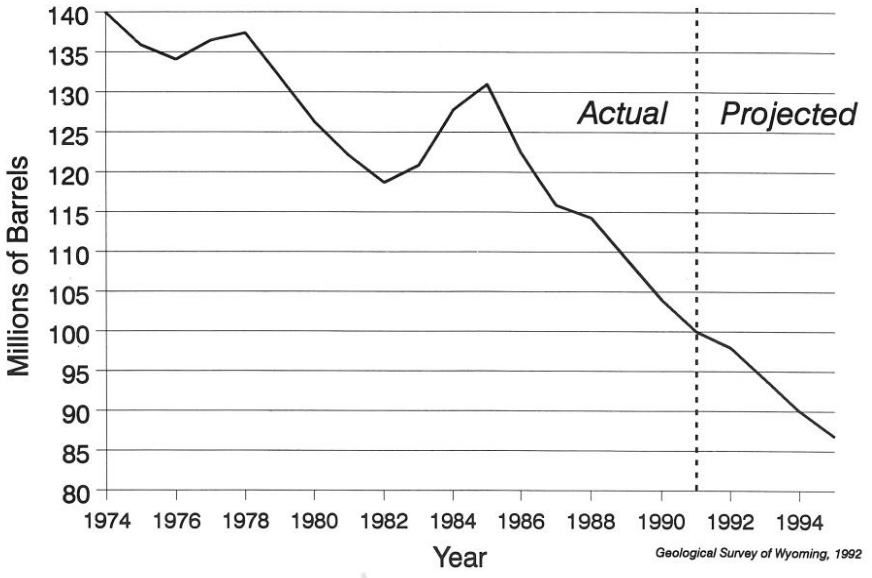

Figure 6. Annual oil production from Wyoming (1974 to 1991) with forecast to 1995.

Although the production of methane is still forecast to increase each year of the forecast, the increases are less than previously estimated (Table 2 and Figure 7). Part of this change simply stems from a better understanding of what percentage of total gas production is methane. Also, with the expiration of the tax credit for tight gas sands, drilling in southern Wyoming is expected to drop off significantly. A similar decline in coalbed methane activities is likely as well.

Monthly coal production from Wyoming for 1992 has not recovered from the first quarter slump, and for the first time since 1986, production is projected to fall below that of the previous year (Table 2 and Figure 8). The reasons for this drop in production are not totally clear, but stockpiling in anticipation of the rail strike, market saturation, and a wait and see attitude in regard to compliance with the 1990 Clean Air Act Amendment are all contributing factors. As a result, the new projection is about a 2.5 percent a year increase, instead of the recent 4-5 percent increases.

Uranium production was lowered 25 percent from our previous estimate (Table 2).

The **Coal Update** in this issue features separate graphs for deliveries of coal sold on contract from those deliveries sold on the spot market (Figures 14A and 14B). These graphs provide a little more insight into the monthly deliveries of coal from Wyoming.

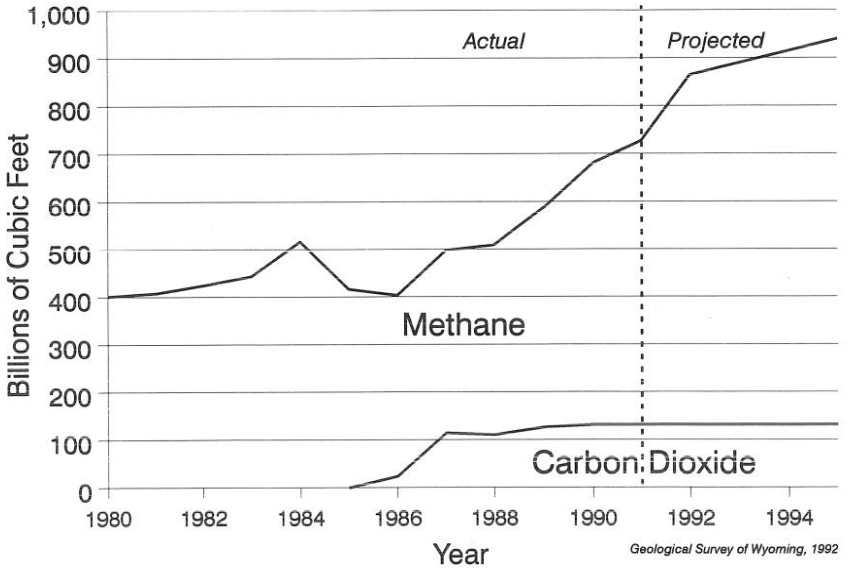

Figure 7. Annual natural gas production from Wyoming (1980 to 1991) with forecast to 1995.

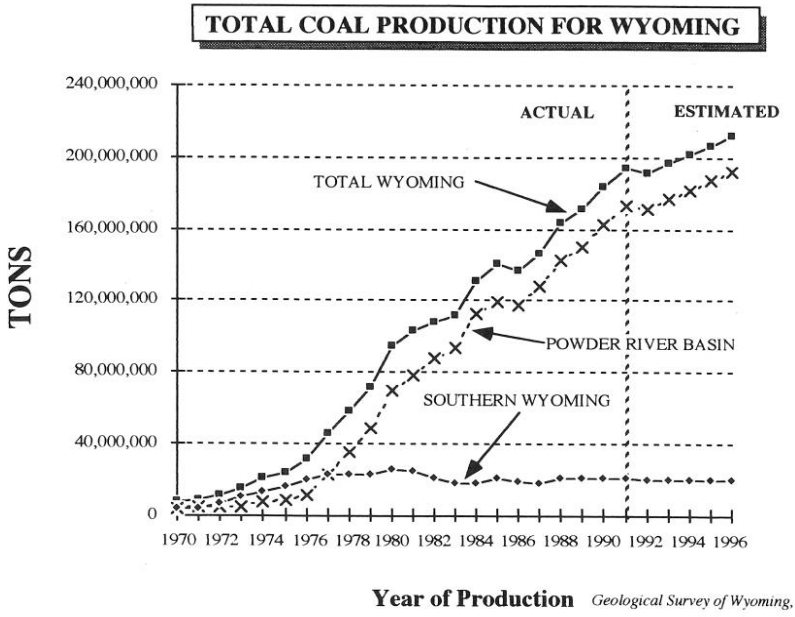

Figure 8. Annual coal production from Wyoming (1970 to 1991) with forecast to 1996.

In other coal-related news, two Federal coal leases netted $158.9 million in bonus bids in the third quarter. Bonus bids are now paid in five annual installments with 50 percent going to the State of Wyoming. Also, another $20 million bonus bid from last year apparently has been removed from litigation.

Another mine was put up for sale in the Powder River Coal Field. Sun Company announced that it wanted to sell the Cordero mine as well as five other coal mines and coke plants in other states. Last year, Mobil Coal Producing's Caballo Rojo mine was sold to Marigold Land Company. Earlier this year, Exxon Coal indicated it might sell Carter Mining Company's Rawhide mine and Shell Oil has offered Triton Coal Company's Buckskin mine and its North Rochelle property for sale.

In non-energy resources, Bentonite Corporation announced a $1 million expansion of its plant in Crook County. U. S. Borax is still apparently interested in the trona deposits of southwestern Wyoming. And some exploration for diamonds resumed in Wyoming as an outgrowth of a recent diamond discovery in Canada.

Table 3 was modified slightly by deleting the line for feldspar production. Production of feldspar is now included in the category of decorative aggregate. Less than 1,000 tons of feldspar were mined in Wyoming in 1991.

Table 3. 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[4]	---	---	---	---	---	---	---	---	---	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
Staff Geologist-Oil and Gas, Geological Survey of Wyoming

The spot market price for natural gas for October at Opal, Wyoming, rose to $2.10 per thousand cubic feet, the highest level since January, 1990, when the spot price reached $2.05 per thousand cubic feet (Figure 3). The October spot price was the highest recorded spot price in at least the last four years. The October spot price was 45 cents higher than the September spot price and 90 cents higher than the October, 1991, spot price. Figure 3 shows that the spot price over the past several years peaked during the winter and was low the rest of the time. This year the spot price began its upward trend in March. It is still uncertain how high the spot price will rise this winter, but it is certain that the average spot price will be higher than the last three years. How long the high spot prices will continue remains speculative.

The increase in natural gas prices, the approval of several infill drilling proposals by the U.S. Bureau of Land Management (BLM), and the anticipated expiration of the tax credit for tight gas sands at the end of 1992, helped to raise the September rig count to its highest average in two years (Figure 9).

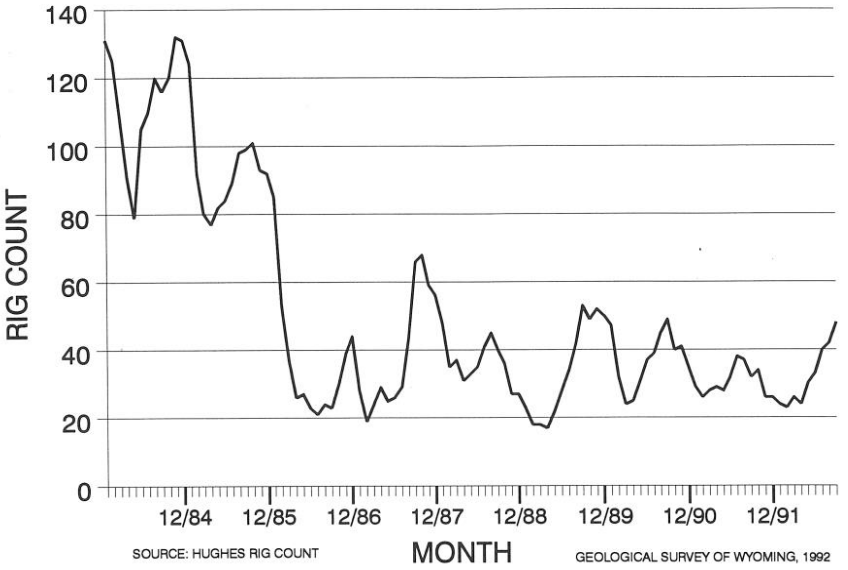

Figure 9. Wyoming daily rig count averaged by month (1984 to present).

During the third quarter of 1992, the BLM approved a request by Washington Energy Resources and Texaco Exploration and Production to drill an additional 30 Frontier gas wells in Fontenelle Field in southwestern Wyoming. The BLM also approved the drilling of up to 70 Almond infill gas wells in the Greater Wamsutter Area. Union Pacific Resources, Barrett Resources, Amoco Production, and Pacific Gas and Electric Co. sought approval for the project, and Union Pacific began drilling the first of 25 wells it scheduled for completion in 1992. The BLM also approved plans for Amoco Production, Union Pacific Resources, Wexpro, and Washington Energy Resources to drill 82 Frontier infill gas wells in the area in and around Church Buttes Field. The 82 wells are scheduled for completion this year and 59 more wells can be drilled later. The final environmental impact statement for the Mulligan Draw Field area was issued by the BLM in late August. In that area, up to 45 wells are planned over the next five to eight years to test the Almond.

The Wyoming Oil and Gas Conservation Commission (WOGCC) submitted recommendations to the Federal Energy Regulatory Commission that four areas be designated as tight gas sands. There were two areas for the Baxter Shale. One covers parts of T27N, R112W, and parts of T26N, R112W. Another covers parts of T25N, R113W; T26N, R112W and R113W; and T27N, R112W. Both areas are in the Green River Basin. The WOGCC also recommended the Dakota Sandstone and the Frontier Formation in a 27,860-acre area in T12N, R100W; T12N, R101W; T13N, R100W; T13N, R101W; and T14N, R100W in the Washakie Basin. The fourth area was for the Frontier Formation in sections 1 and 2, T33N, R95W and sections 26, 35, and 36, T34N, R95W in the Wind River Basin.

The U.S. Bureau of Land Management (BLM) has approved a new rule for stripper wells. The rule defines a stripper well property as "any Federal lease or portion thereof, communitization agreement, or a participating area of a unit agreement operated by the same operator which produces less that 15 barrels of oil per day per eligible well for a one-year qualifying period." The initial qualifying period was defined as August 1, 1990, to July 31, 1991. For properties that were shut in for 12 consecutive months or longer, the qualifying period will be the 12-month production period prior to shut-in. The program will last five years and is subject to review after that. The program may be suspended if the average posted price for West Texas Intermediate crude exceeds $28 per barrel for six consecutive months. The royalty rate for a property's one-year qualifying period is equal to 0.5% + (0.8% x Average Daily Production Rate). Royalty rates can be adjusted downward if the average daily production rate decreases. The BLM and Department of Energy have estimated that the reduced royalty rate will lead to an increase in oil production from Federal stripper wells.

A number of pipelines were in the news during the third quarter. The BLM approved Questar's 20-inch gas pipeline that will run from one mile south of the Wyoming-Utah border to just southwest of Rock Springs. Ashland Oil sold its 447 miles of crude oil pipeline and gathering lines that run from southeastern Montana to Sussex Station in northeast Wyoming. The line was acquired by Belle Fourche Pipeline Co. The Wyoming Public Service Commission approved Northern Gas' planned 12-inch, six-mile-long, gas pipeline from Riverton Dome Field to the Beaver Creek meter station. The BLM granted Northwest Pipeline's request to build a gas pipeline that will run from Canada through six states, including Wyoming. Only nine miles of the line will be built in Wyoming in an area west of Kemmerer. And the State of Wyoming's Natural Gas Pipeline Authority is investigating the possibility of recommending that the State lend $31 million to help build a carbon dioxide pipeline from Bairoil to the Powder River Basin. The carbon dioxide would come from Exxon's Shute Creek plant and would be used to recover additional oil from a number of fields in the basin.

NGL Inc. has contracted with several operators in Silo Field to remove hydrocarbon liquids from the gas associated with their Niobrara oil production. The company installed one gas plant and plans to install two more in the field. The plants will reduce the amount of flared and vented gas in Silo Field.

Washington Energy Exploration plans a gas processing plant to recover natural gas liquids from Henry Field in Uinta County. The company needs a permit from the Wyoming Department of Environmental Quality before construction can begin on the 15 million cubic feet per day plant.

In a $326.8 million deal with Cactus Hydrocarbon 1992-A Limited Partnership, Enron Oil and Gas conveyed an interest in 124 billion cubic feet of natural gas equivalent and other hydrocarbons. The natural gas will be produced from the Big Piney area and delivered over a four-year period. Enron is responsible for production and transportation costs.

KN Energy exchanged natural gas gathering and processing facilities with GPM Gas. KN acquired GPM's Douglas processing plant and gas gathering system in Converse and Campbell counties in exchange for KN facilities in Oklahoma.

Plains Petroleum Operating paid Arco Oil and Gas $10 million for interests in 64 producing wells in 16 fields around Gillette. The wells reportedly have proved developed reserves of two million barrels of oil. Plains' development work will extend into 1993. The acquisition should increase Plains' daily production by about 900 barrels.

The U.S. Bureau of Land Management (BLM) has initiated a Wyoming Liability Action Plan to plug unneeded non-producing wells. The plan charges district offices with, (1) identifying wells on Federal lands which no longer produce and should be plugged and, (2) determining the responsible operator. The BLM will place a demand on the responsible operator to plug the well or the BLM will plug the well if no responsible operator can be found. District offices are also tasked with reviewing existing bond coverage to determine if current coverage is adequate when weighed against the risk for potential Government liability in plugging and reclaiming abandoned wells. The Wyoming Oil and Gas Conservation Commission already adopted new rules to address similar problems on State and fee leases in April of 1992. The State's new rules define "dormant" wells and require their plugging or additional bonding until they are plugged.

Since the State decided to forego the sales scheduled for July and September, there was only one lease sale during the third quarter of 1992. The August sale held by the U.S. Bureau of Land Management (BLM) was the best in terms of total revenue since the October, 1991, sale (Table 4). Because drilling in Wyoming has shifted to gas wells in southwestern Wyoming, it was not surprising that the sale's two highest total revenue bids were for two tracts in the Washakie Basin. Perry R. Bass and others paid $157 per acre ($401,292 total bid) for a 2,555.96-acre lease that covers sections 1, 2, 11, and 12, T13N, R96W. The lease is about three miles west of Lewis gas and condensate production at Triton Field. Perry R. Bass and others also were the high bidders for a lease that covers sections 13,14, and 15, T13N, R96W. They paid $140 per acre ($268,800 total bid) for that lease. These two bids accounted for nearly one half of the sale's total revenue. The high per-acre bid was $230 by Maurice W. Brown for a 318.85-acre tract that covers parts of sections 22, 26, and 27, T47N, R70W. The lease is in an area of abandoned and shut-in Minnelusa oil production.

Exploration and development

Company data and information compiled and published by Petroleum Information indicate the following significant exploration and development events occurred in Wyoming during the third quarter of 1992. Activities related to horizontal drilling and coalbed methane are discussed in separate sections. The letters preceding discussions below refer to locations on Figure 10.

Table 4. 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								

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

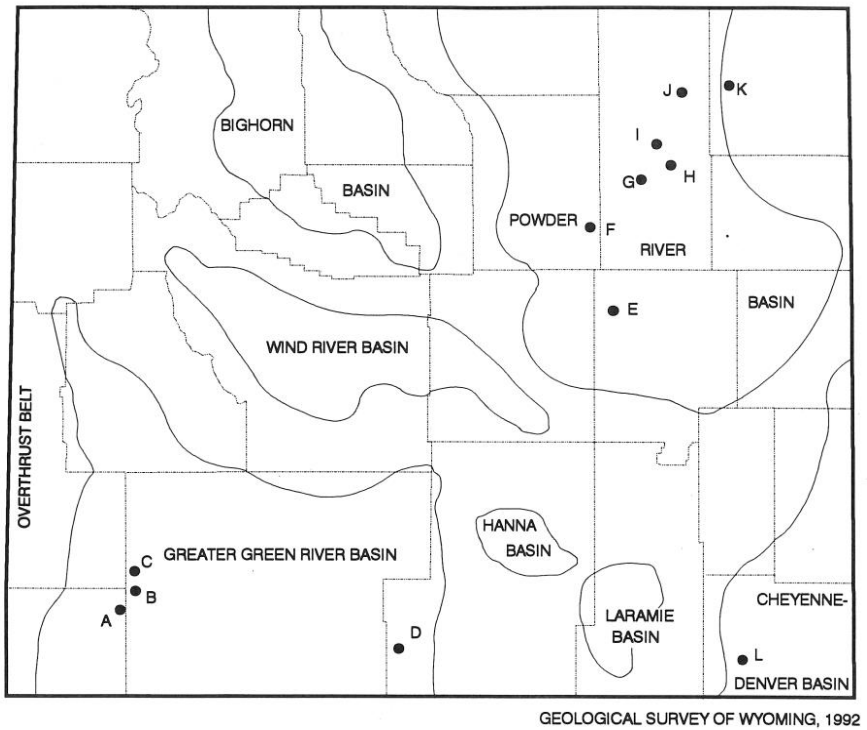

Figure 10. Oil and gas exploration and development activity in Wyoming during the third quarter of 1992 (exclusive of horizontal drilling and coalbed methane activities).

A. Wexpro Co. completed a number of significant new Frontier production wells in Church Buttes and Bruff Fields. The 120 Unit well in NE SW section 3, T17N, R112W, flowed 5.0 million cubic feet of gas per day from 12,136 feet to 12,196 feet. The 106 Unit well in SW NE section 3, T17N, R112W, flowed 2.4 million cubic feet of gas per day from perforations between 12,164 feet and 12,206 feet. The 2-9 Champlin well in C SW section 9, T17N, R112W, flowed 3.3 million cubic feet of gas per day from perforations between 12,138 feet and 12,198 feet. The 116 Church Buttes well in SW SW section 10, T17N, R112W, flowed 4.3 million cubic feet of gas per day from between 12,144 feet and 12,178 feet. The 114 Unit well in SE SW section 16, T17N, R112W, flowed 1.8 million cubic feet of gas per day from perforations between 12,216 feet and 12,264 feet. The 111 Unit well in SW NE section 21, T17N, R112W, flowed 3.3 million cubic feet of gas per day from perforations between 12,312 feet and 12,350 feet. The 107 Unit well in SE NW section 26, flowed 1.7 million cubic feet of gas per day from between 12,118 feet and 12,158 feet. The 113 Unit well in NW NE section 33, T17N, R112W, flowed 674,000 cubic feet of gas per day from between 12,116 feet and 12,194 feet. The 108 Unit

well in NW SW section 34, T17N, R112W, flowed 1.1 million cubic feet of gas per day from between 12,066 feet and 12,094 feet. The 119 Church Buttes Unit well in NW NE section 35, T18N, R112W, flowed 1.8 million cubic feet of gas per day from perforations between 12,106 feet and 12,154 feet. Celsius also completed a well in this area. Their 6-2 Matherly-Federal well in N/2 SE section 6, T17N, R112W, flowed 2.1 million cubic feet of gas per day from the Frontier between 12,064 feet and 12,110 feet.

B. Union Pacific Resources completed their D-3 Bruff 206 well in NE NE section 1, T18N, R112W. The well flowed 678,000 cubic feet of gas per day from the Frontier between 11,612 feet and 11,690 feet.

C. Washington Energy Exploration completed their 30-6 Sequoyah-Federal well in NE SE section 6, T19N, R111W. The well flowed 2.5 million cubic feet of gas, five barrels of condensate, and 121 barrels of water per day from Frontier perforations between 11,988 feet and 12,032 feet.

D. Presidio Exploration Inc. completed their 32-20 Big Ridge Unit well in SW NE section 20, T14N, R93W. The well flowed 1.1 million cubic feet of gas, 10 barrels of condensate, and two barrels of water per day from Almond perforations between 10,842 feet and 10,849 feet.

E. Kerr-McGee Corp. completed two new Muddy producers in Sand Dunes Field. The 21-12 Sand Dunes well in NE NW section 12, T36N, R76W, flowed 600 barrels of oil and 441,000 cubic feet of gas per day from perforations between 12,902 feet and 12,913 feet. The 21-13 Sand Dunes well in NE NW section 13, T36N, R76W, flowed 627 barrels of oil and 329,000 cubic feet of gas per day from perforations between 12,701 feet and 12,708 feet.

F. General Atlantic Resources completed a new Frontier discovery at their 25-1-A Bozeman-Federal well in NE NE section 25, T42N, R77W. The well had an initial pumping potential of 62 barrels of oil and 160,000 cubic feet of gas per day from between 12,183 feet and 12,193 feet.

G. Kerr-McGee Corp. announced plans to drill 13 new Sussex development wells in House Creek Field. The wells will be drilled to depths between 8,150 feet and 8,465 feet.

H. Presidio Exploration, Inc. completed a new Minnelusa discovery. The 24-30 Heater well in SE SW section 30, T48N, R71W, produced an average of 135 barrels of oil and 1,000 cubic feet of gas during 18 days in June. Production is from below 10,000 feet.

I. Nicor Exploration completed a new Minnelusa well in Mallard Field. The 23-34A McCreery-Federal well in NE SW section 34, T49N, R72W, pumped 248 barrels of oil per day from between 10,801 feet and 10,805 feet.

J. Lario Oil and Gas has an apparent Minnelusa discovery. A drill stem test at their 1 Jack-Federal well in NE NW section 24, T53N, R70W recovered oil

between 7,453 feet and 7,473 feet. The test recovered 15 feet of oil, 186 feet of oil-cut muddy water, and 537 feet of oil-cut brackish water. The sample chamber contained 400 cubic centimeters of oil and 1,750 cubic centimeters of oil- and mud-cut water.

K. Maxim Drilling and Exploration completed a new Minnelusa well in Lad Field. The 1 Evans well in SW NW section 20, T54N, R67W, pumped 75 barrels of oil per day from perforations between 5,954 feet and 5,957 feet.

L. General Atlantic Resources completed a new well in Borie Field. The 7-3 A.L. King well in SE NE section 11, T13N, R68W, pumped 185 barrels of oil per day from perforations in the Muddy Sandstone between 9,098 feet and 9,121 feet.

Horizontal drilling

During the third quarter of 1992, the following significant activities related to horizontal drilling occurred. The letters preceding the discussions below refer to locations on Figure 11. The discussions are based on company data and information compiled and published by Petroleum Information.

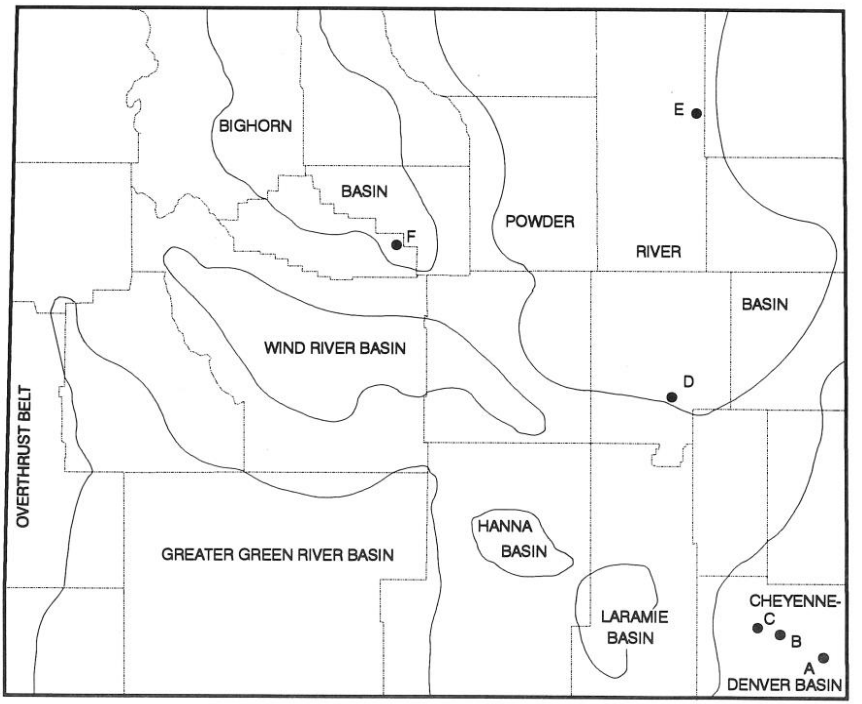

Figure 11. Horizontal drilling activity in Wyoming during the third quarter of 1992.

A. Union Pacific Resources has an apparent Niobrara discovery at their 1-H Pence Ranch 5E-17 well at a surface location in NW NE section 17, T15N, R61W. True vertical depth is 7,042 feet. No other details are available.

B. Drilling in Silo Field is still very active. Gerrity Oil and Gas recovered 1,470 barrels of oil during a 12-hour test of the Niobrara at their 10-1H State well at a surface location in NE NE section 10, T15N, R64W. Total measured depth is 7,857 feet. Gerrity also recovered 1,514 barrels of oil during a 12-hour test of the Niobrara at their 25-13H Epler well at a surface location in SW SW section 25, T16N, R65W. True vertical depth was projected as 8,005 feet. Union Pacific Resources began drilling a Niobrara test at their 1-H Patricia 41-22 well at a surface location in NE NE section 22, T16N, R65W, to a true vertical depth of 8,545 feet. Union Pacific also staked a location for a Niobrara test from a surface location in SW SW section 23, T16N, R65W. Plans call for the 1H Donald 14-23 well to be drilled to a true vertical depth of 8,200 feet. Union Pacific also completed their 1H McConnaughey A1-27 well at a surface location in NE NE section 27, T16N, R65W. The well flowed 318 barrels of oil, 125,000 cubic feet of gas, and 26 barrels of water per day from the Niobrara. True vertical depth is unavailable.

Chesapeake Operating staked a location for their 13H McConnaughey well to be drilled from a surface location in NE SE section 13, T16N, R65W, to a true vertical depth of 8,200 feet in the Niobrara. Wilshire Oil Co. recovered 371 barrels of oil from the Niobrara on a four-hour test. The 1-26H McConnaughey well was drilled from a surface location in NE NE section 26, T16N, R65W, to a true vertical depth of 8,371 feet. Martin Exploration Management staked a location for a Niobrara test. Their 1-24-H Nikoloric is scheduled for a true vertical depth of 8,135 feet from a surface location in NE NE section 24, T16N, R65W. Exxon Corp. completed a Niobrara well from a surface location in NE NE section 30, T16N, R64W. The 1H Epler B was drilled to a true vertical depth of 8,037 feet and flowed 231 barrels of oil and 97,000 cubic feet of gas per day. Exxon also scheduled a test of the Niobrara from a surface location in NE NE section 7, T15N, R64W. The 1 Pace Oil Unit is scheduled for a true vertical depth of 8,100 feet.

C. Union Pacific Resources produced 710 barrels of oil and 107 barrels of water from the Niobrara during 28 days in June at the 1H Berry 41-13 well drilled from a surface location in NE NE section 13, T16N, R66W. True vertical depth is over 8,800 feet.

D. Amoco is preparing for a completion attempt at their 1-25H Morton Ranch well. The well was drilled from a surface location in SW SW section 25, T33N, R72W, to test the Niobrara and Frontier.

E. Consolidated Oil and Gas plans to reenter a vertically-drilled Minnelusa producer and to drill a 400-foot horizontal leg in the Minnelusa. The 3-H Roy-Amoco will be drilled from a surface location in SE NW section 31, T52N, R69W. The well produced over 23,000 barrels of oil from the Minnelusa before it was shut in.

F. Texaco Exploration and Production plans to test the Tensleep at their 61H Black Mountain Unit well. The well will be drilled from a surface location in NW NW section 36, T43N, R91W, to a true vertical depth of about 3,200 feet.

Coalbed Methane

During the third quarter of 1992, the following significant activities related to coalbed methane occurred. The letters preceding the discussion below refer to locations on Figure 12. The discussions are based on company data and on information compiled and published by Petroleum Information.

A. Because environmental assessments took longer than expected, Metfuel only plans to drill four additional wells this year to test coals in the Hanna Formation. Metfuel plans to drill 50 more wells in 1993, 50 wells in 1994, and 26 wells in 1995. Once the wells are drilled and completed, the company plans to employ 17 to 30 people for the 30-year life of the project. According to a spokesman for the U.S. Bureau of Land Management, the wells are expected to generate approximately $108 million in State and local taxes and $90 million in Federal royalties over the life of the project.

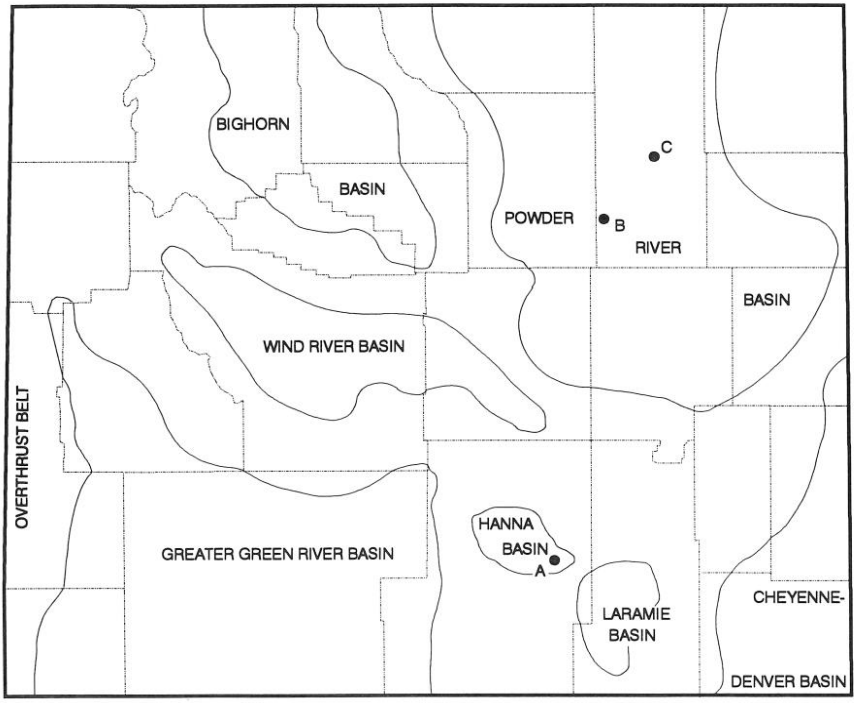

Figure 12. Coalbed methane activity in Wyoming during the third quarter of 1992.

B. Exxon Corp. will drill three wells to test coals in the Fort Union Formation at Hartzog Draw Field. Eighteen nearby wells will be monitored to insure that dewatering the coal in the three Exxon wells will not adversely affect the aquifers.

C. American Oil and Gas plans to drill 30 to 35 wells about 10 miles south of Gillette to test coals in the Fort Union Formation. Approximately 6 to 15 of the wells will be drilled on Federal land and the remainder on private land. An environmental assessment is required since some of the wells are on Federal land.

COAL UPDATE

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

Coal deliveries for the first half of 1992 are down nearly 2% (or 1.5 million tons) as compared to the first 6 months of 1991 (Table 5). This decrease in Wyoming coal production has led to a reassessment of projected production not only for the remainder of 1992, but for the next three years. The current estimate for total coal production for 1992 is 191.0 million tons, which is a projected 1.5% decrease as compared to production in 1991 (Table 6). The major cause for the decrease for the first half of the year (Figure 13) was the lower than expected deliveries of contract sales (Figure 14A). Although spot sales started out higher than they had been in 1991, by the second quarter, they were very close to what they had been in 1991 (Figure 14B).

Other coal producing states such as Kentucky, West Virginia, and Ohio are also reportedly at or just below their 1991 production. Current thought is that a cool summer and mild winter placed less of a burden on power plants, which contributed to a slackened demand for coal nationwide. It is still uncertain when and how the Clear Air Act Amendment will affect Wyoming's coal production, but it will more than likely increase demand in the next three years. A favorable indicator is that a number of eastern utilities are still testing low-sulfur coals from the Powder River Coal Field (Figure 15).

In a recent article, Chadwick (1992) reported that world coal production for 1991 approached 4.9 billion tons. China, the top producing nation, accounted for nearly a quarter of the world's coal production (1.2 billion tons) while the U.S. produced 983.7 million tons (Figure 16). The Commonwealth of Independent States (CIS), formerly the Soviet Union, produced 625.9 million tons of coal followed by Germany with 380.1 million tons. If the State of Wyoming were an independent country, its production alone would place it within the top eight producing nations of the world.

Table 5. 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		
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		
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		
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.

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	163.1	168.2	172.5	176.8
Converse County	2.7	3.3	3.6	4.8	5.1	5.7	6.1	7.9	8.2	8.0	8.2	8.5	8.7
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	4.6	4.8	4.9
Sweetwater County	9.5	8.9	13.2	12.9	11.8	12.2	12.0	11.9	11.4	11.0	11.3	11.6	11.9
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	197.0	202.0	207.0
Annual change	4.0%	14.2%	7.1%	-3.8%	7.4%	10.5%	4.4%	7.0%	5.2%	-1.5%	3.0%	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, September, 1992. [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).

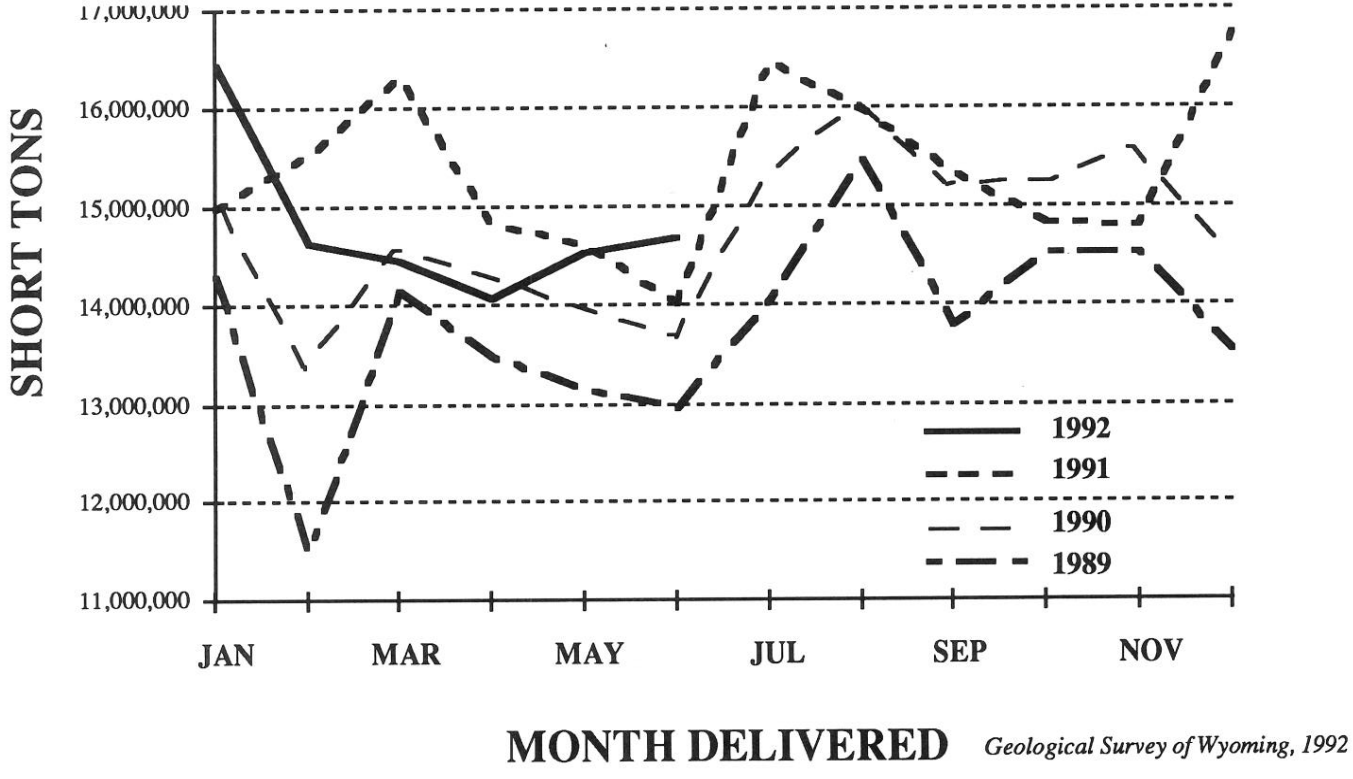

Figure 13. Reported deliveries from Wyoming coal mines *(from COALDAT Marketing Report by Resource Data International, Inc. compiled from FERC Form 423 filed monthly by electric utilities).*

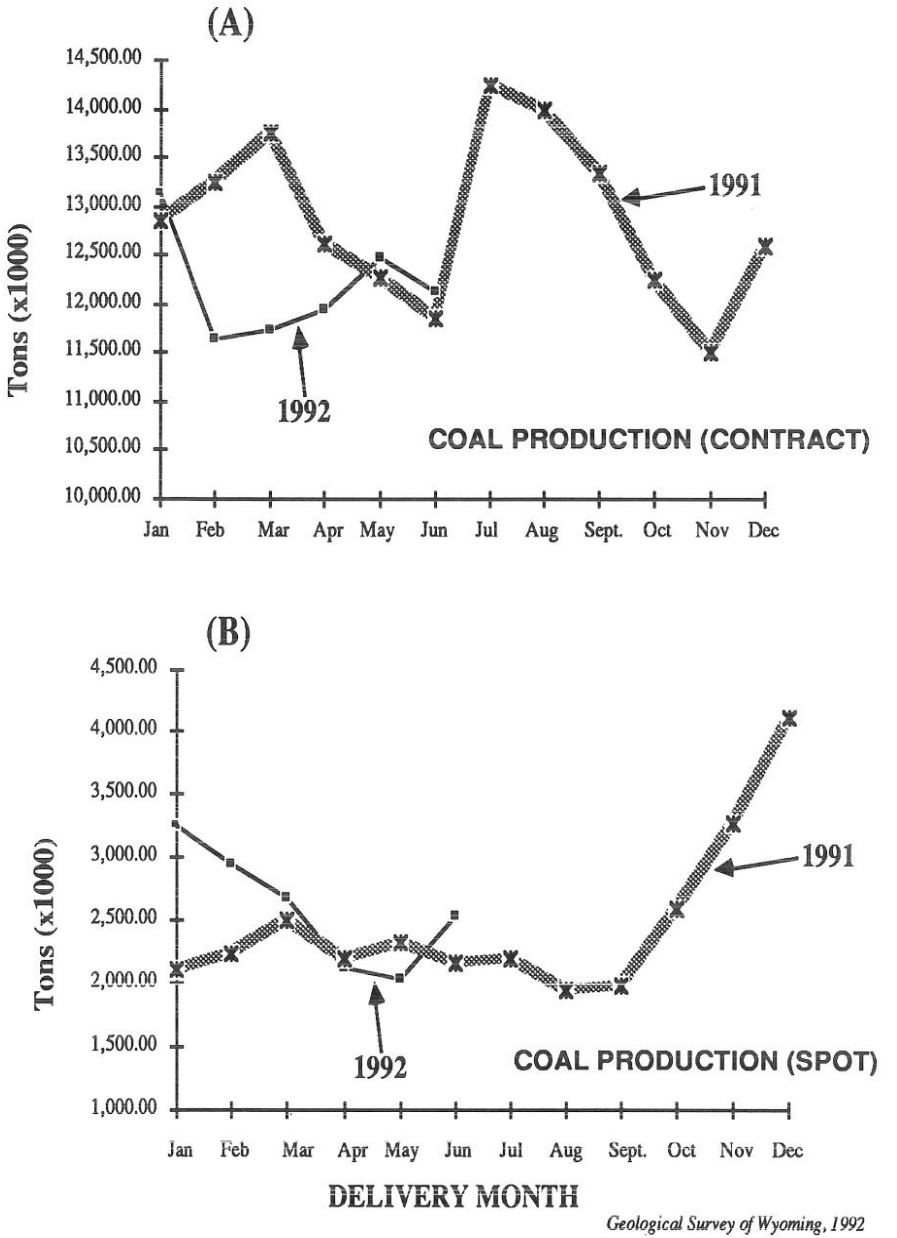

Figure 14. Monthly coal deliveries from Wyoming for 1991 and 1992. (A) Coal sold on contract and (B) coal sold on the spot market. *(Source: COALDAT Marketing Reports by Resource Data International, Inc., compiled form FERC Form 423 filed monthly by electric utilities).*

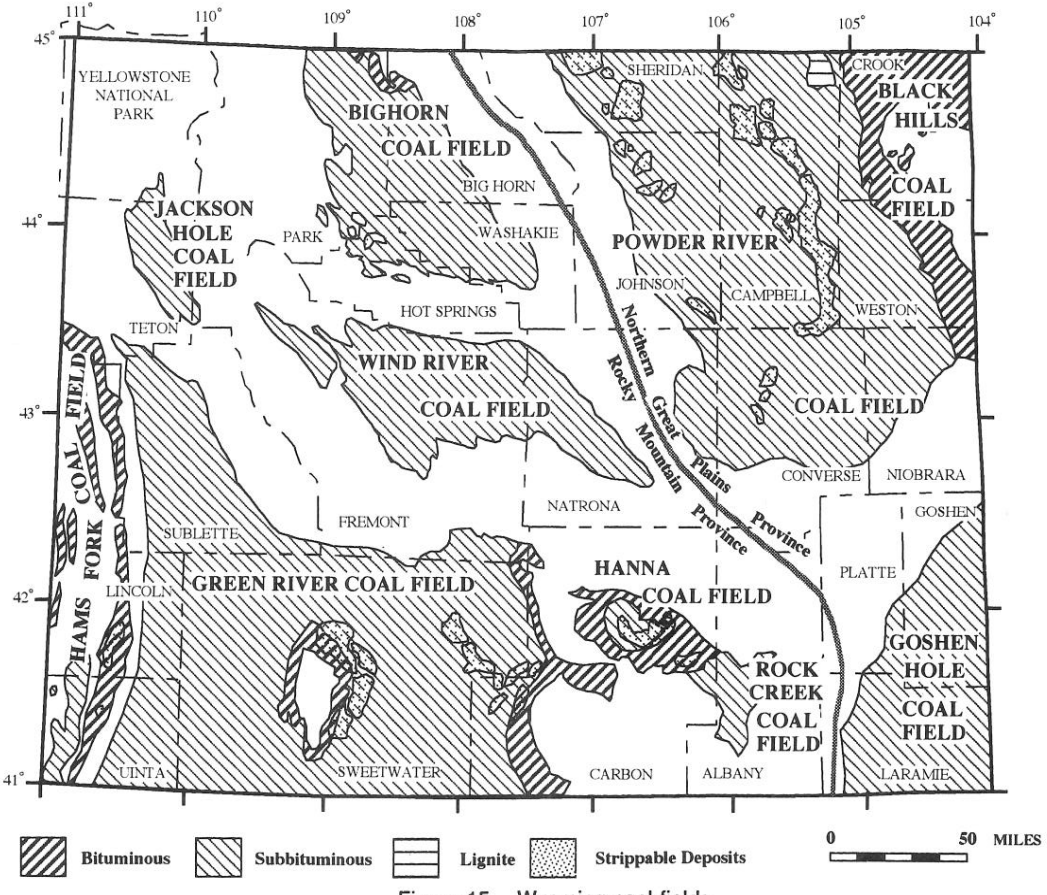

Figure 15. Wyoming coal fields.

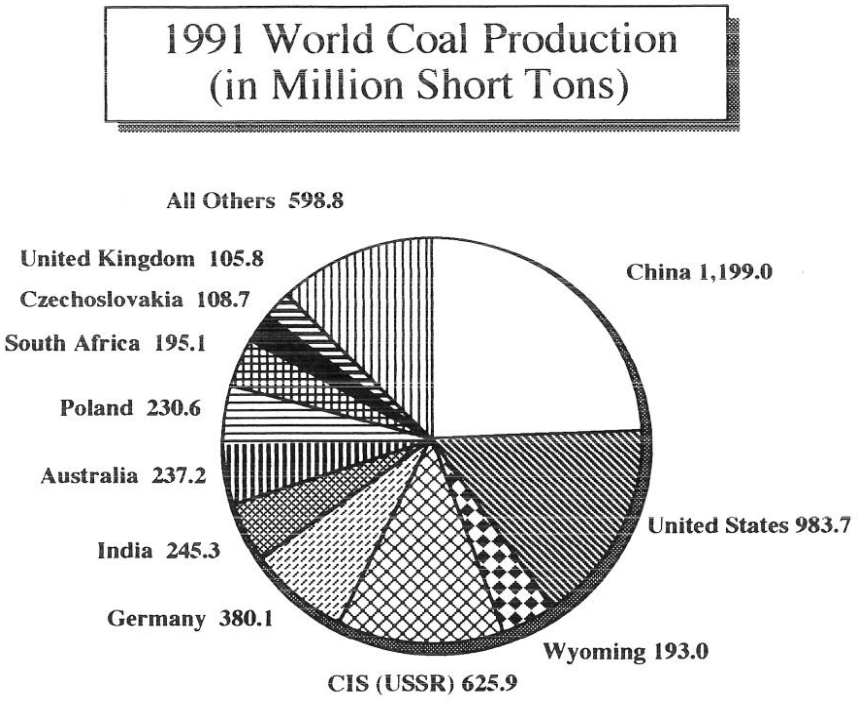

Figure 16. World coal production in 1991 (After Chadwick, 1992).

In 1991, Australia remained the highest coal exporting country in the world. Of the 237.2 million tons of coal Australia mined in 1991, it exported 53% overseas (Figure 17). Although only a small percentage of Wyoming coal is exported overseas (~1 million tons), the U.S. was the second highest exporter in 1991 with 104.5 million tons, or 10% of the total coal mined. Venezuela, which mined only 2.8 million tons in 1991, exported 85% of that (2.3 million tons) to overseas markets (Chadwick, 1992).

In other news, five coal companies in Wyoming (Exxon, Mobil, Sunedco, Powder River, and Chevron) have signed settlement agreements with the State of Wyoming over back taxes for 1986 and 1987. Wyoming Attorney General Joe Meyer said the settlement with the five companies is for more than $7 million. Two other coal companies (Kerr-McGee and Nerco) have gotten an extension of the June 15th deadline for settlement of back taxes. However, three coal companies

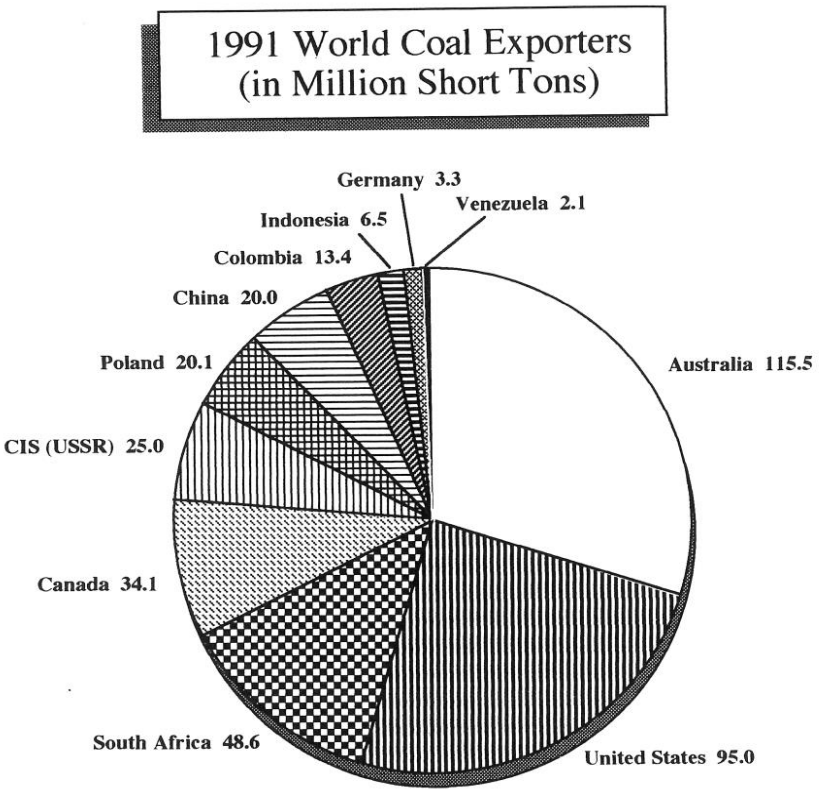

Figure 17. Coal exports in 1991 by country (after Chadwick, 1992).

(Arco, Amax, and Triton [Shell]) have not accepted the State's proposal and will now be issued with formal tax assessments by the Department of Revenue for the years in question.

Developments in western and southwestern Wyoming

PacifiCorp's Naughton power plant and its adjacent coal supplier, the Pittsburg and Midway Coal Co.'s Kemmerer mine in the Hams Fork Coal Field (Figure 15), have reached an agreement on a new long-term contract. The new agreement, which runs through the year 2016, calls for the mine to continue supplying Naughton's three units with two types of coal, some with low-sulfur content and some with higher sulfur content. The agreement also allows PacifiCorp to burn a limited amount of natural gas. Burning coal with natural gas would begin in 1994.

The Black Butte Coal Co. is seeking permission from the Wyoming Department of Environmental Quality (DEQ) to modify its existing source of emissions to increase coal production from 2-2.5 million tons per year at the Leucite Hills mine. This mine is located 25 miles east of Rock Springs.

The DEQ is also seeking public comments on a proposal by Tg Soda Ash, Inc. to burn natural gas instead of coal in two trona ore calciners at the company's soda ash plant near Granger.

Developments in the Hanna Coal Field

Cyprus Shoshone Coal Company's Shoshone No. 1 is the largest underground mine in Wyoming and produced more than 2.0 million tons of coal last year, most of which was sold under a long-term contract to Northern Indiana Public Service Company (NIPSCO). However, production so far this year has been significantly curtailed due to concerns over mine safety and health. No injuries or illnesses, however, have been reported as a result of the mine's condition and the company reports that monthly production is back to normal.

Developments in the Powder River Coal Field

Two Federal coal tracts in the Powder River Basin were leased in the third quarter of 1992. The bid on the first tract was made jointly by Atlantic Richfield Coal Co. (ARCO) and two of its subsidiaries (Thunder Basin Coal Co. and Mountain Coal Co.). This lease (known as the West Black Thunder tract) is adjacent to the existing Black Thunder mine in Campbell Co. The total bid by the ARCO group was $71.9 million for an estimated 429 million tons of in-place coal reserves. The bid on the second tract was made by the Powder River Coal Co. for nearly $87 million on about 396 million tons of Federal coal in southern Campbell County. At 22.1¢/ton, the bid was the highest yet for recent sales. The latter lease, which included the North Antelope and Rochelle tracts, is located adjacent to the existing North Antelope and Rochelle mines. Both these tracts contain the Wyodak coal bed, which averages 71 feet thick on the eastern (Rochelle) portion and 79 feet thick on the western (North Antelope) tract. In this lease offering, the U.S. Bureau of Land Management had consolidated and expanded two maintenance tracts that had been submitted by Peabody's Powder River Coal Co.

After nearly a year in litigation, Kerr-McGee's earlier Federal coal lease has gotten the go ahead. A recent decision by the Interior Board of Land Appeals has allowed Kerr-McGee to take possession of the new coal lease in southern Campbell Co. for which it bid more than $20 million last fall.

In other possible coal lease sales, the Final Environmental Impact Statement for the West Rocky Butte tract (59 million tons) was issued in June 1992. If awarded to the applicant, Northwest Resources, this lease would be combined with the existing, larger Rocky Butte lease (550 million tons) as part of a proposed new mine. The sale date is December 3, 1992. Shell Mining Company has applied

for a maintenance tract next to the existing North Rochelle mine. This tract, called the North Roundup tract, contains an estimated 144 million tons of coal. The proposal is under review. The status of this possible sale is somewhat unclear since Shell sold its Wyoming holdings in the third quarter.

As indicated last quarter, Zeigler Coal Holding Company bought Shell Oil's North Rochelle property as well as its Buckskin mine, which is operated by Triton Coal Company. Carter Mining Company is also considering the sale of its Rawhide mine. In 1991, Mobil sold its Caballo Rojo mine to Marigold Land Company.

In the third quarter, Sun Company announced that its Cordero mine was for sale. The Cordero mine in the Powder River Basin is one of six coal mines and coke plants for sale by Sun, which reportedly wants to focus on its core businesses of petroleum refining and marketing. Cordero is Sun's largest mine and last year produced 13.7 million tons of coal, which is over half of the total tonnage produced from all of Sun Co.'s coal mines. With the sale of the Cordero mine, plans to build a $34.3 million coal drying facility in conjunction with the U.S. Department of Energy (DOE) were also cancelled. Cordero was one of nine projects to win funding from the DOE last year through the Clean Coal Technology Program.

Black Hills Corporation has proposed building an 80-megawatt power plant in Campbell County adjacent to the Wyodak mine. The plant would be called Neil Simpson Station II and would cost about $126 million with construction scheduled to begin in 1993 and finish in January, 1996. The plant would use coal from the Wyodak mine and employ about 40 people. According to Black Hills, the decision to build the plant is still subject to securing the necessary permits and a favorable regulatory treatment.

The Wyoming Department of Transportation denied Wyodak Resources Development Corporation's request to close a portion of State Highway 51 near Gillette in order to mine more than a million tons of coal. Wyodak Resources was asked to draft plans to build an acceptable alternate route that would allow a more normal flow of traffic. The new route could cost an estimated $750,000.

Public hearings on Belco's proposed exchange of coal under I-90 southeast of Buffalo were held in Buffalo on May 6 and in Gillette on May 7. Belco wants to exchange the coal under I-90 for coal north of Gillette. In a similar proposal, Texaco is also seeking to exchange coal from the west side of Lake DeSmet for coal in the eastern Powder River Basin.

The U.S. Department of Energy's (DOE's) approval of the $88 million integrated K-Fuels/ThermoChem clean coal plant near Gillette was given in October. A technical review of the K-Fuels clean coal process has just been completed. The review, which assessed product quality, yield, and thermal efficiency of the process, concluded that it is technically feasible to design and operate a commercial-scale plant. K-Fuels' process subjects Powder River Basin coals to high pressure steam, driving out water and altering the coal to a product

with an increased heating value and a reduced sulfur content. Since the final K-Fuel product is low in sulfur, it is seen as an option for utilities looking to reduce stack emissions so they can meet requirements of the Clean Air Act Amendment of 1990. A commercial plant is expected to cost $85 - $90 million to construct and initial employment would range from 30-50 workers. The new plant could be in production by 1995. The initial output would be 425,000 tons of K-Fuel, which Heartland Fuels would sell to its parent company, Wisconsin Power and Light Co.

Contracts

— Thunder Basin Coal Company's Black Thunder mine has delivered 80,000 tons of coal to Mississippi Power Co. for a test burn. If the test burn is successful, a larger quantity of coal will be further evaluated.

— San Antonio City Public Service Board fired up its new Spruce plant on coal at the beginning of August. The plan is to test the 250-megawatt plant on coal as they bring it to full power by the end of October. The new plant shares a stockpile with San Antonio's Deely plant; a stockpile which has previously included coal from the Powder River Coal Field including the Cordero, Antelope, Belle Ayr, and Buckskin mines. Officials expect to issue a new solicitation in November seeking 1.0-1.5 million tons of spot coal for delivery in 1993. Specifications for the coal are: 8,100-9,100 Btu/lb, 0.6 pounds of sulfur/mmBtu, 7% ash, and 31% moisture.

— Commonwealth Edison is performing a three-plant test burn of Powder River Basin coal in an effort to restructure high-cost western coal supplies. Seven of Edison's coal-fired power plants are supplied under contracts with Black Butte Coal and with Decker Coal Co. in Montana. However, these contracts date back to the 1970s and have escalated until delivered costs are over $50/ton. Therefore Edison has solicited long-term contract offers from coal producers in the Powder River Coal Field of Wyoming. So far Edison has bought 50,000-60,000 tons of test coal from Thunder Basin's Black Thunder mine and has completed a test program of 160,000-180,000 tons of coal from Rochelle Coal Company's Rochelle mine.

— Nebraska Public Power District's (NPPD) Gentleman plant is involved in a test burn of 300,000 tons of Powder River Basin coal. The tests are being conducted in roughly 75,000-ton lots from Rochelle Coal Co.'s Rochelle mine and from North Antelope Coal Co.'s North Antelope mine.

  NPPD will also test coal from Nerco's Antelope mine as well as from Amax Coal Co.'s Belle Ayr mine. These tests will help NPPD decide what to do when its long-term contracts with ARCO Coal (Black Thunder) expire at the end of 1996. These contracts currently supply coal to the Gentleman and Sheldon plants.

— Kansas City Power & Light has solicited 2.37 million tons of Powder River Basin coal for delivery in 1993.

— Wisconsin Power & Light's output has been down because of the mild summer. Therefore its fourth quarter solicitation for the Edgewater No. 4 unit was only 60,000 tons of 8,800 Btu/lb coal from the Powder River Basin.

— Wisconsin Public Service's (WPS's) Pulliam and Weston No.1 and No.2 units have begun receiving shipments of coal from Thunder Basin Coal Co.'s Black Thunder mine. As much as 350,000 tons of Black Thunder coal may be tested in various blends from unit to unit. The blends will include 25-50% Black Thunder coal. The tests are part of a roughly nine-month initial testing of Powder River Basin coal. WPS is testing to assure it can comply with the state's emission standard (0.6 lbs. of sulfur/mmBtu), which goes into effect the first of January.

— Rochelle Coal Co. has signed an amendment to its long-term agreement with Associated Electric Cooperative Inc. to supply low-sulfur coal to the company's Thomas Hill power plant from 1994 to 2010. The new agreement brings total shipments under the contract to about 7 million tons of coal annually for a 16-year period. The new agreement equates to approximately $3 million/year.

— Portland General Electric should be issuing a solicitation seeking 800,000 to 1 million tons of coal for delivery to its Boardman plant during the first half of next year. Boardman which has previously only used coal from the Powder River Basin, made it known that they would entertain coal solicitations from our areas.

— Triton Coal Co. seems to be in contention for a 400,000-ton per year contract with Muscatine Power & Light. If the contract is awarded, deliveries would begin next year and continue through 1998.

— American Electric Power Service Corp. has issued a solicitation for Powder River Basin coals for Indiana Michigan Power's Rockport station. The coal for Rockport must contain a guaranteed minimum of 8,000 Btu/lb and a maximum of 0.6 lbs. sulfur/mmBtu.

— Midwest Power has called for offers on 180,000 tons of Powder River Basin coal for use in the Neal No. 4 unit. Delivery would begin in late November or early December.

— Cordero Mining Company's Cordero mine has renewed its coal supply contract with Grand Island, Nebraska Electric Department through October 1993 at a reported FOB mine price of $3.50/ton. Grand Island needs about 300,000 tons of Cordero coal through the new term.

— Northern Indiana Public Service Co. (NIPSCO) has purchased 29,000 tons of contract coal from Cyprus Shoshone Coal Co.'s Shoshone No. 1 mine; 33,000 tons of spot coal from Amax Coal Co.'s Belle Ayr mine, and 22,000 tons of spot coal from Caballo Rojo, Inc. The coal is for delivery to the Michigan City plant.

— Wisconsin Power and Light has also chosen Amax Coal Co.'s Belle Ayr mine to supply 300,000 tons of spot coal to its Columbia No. 2 unit.

Reference cited

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Industrial Minerals and Uranium Update

by Ray E. Harris
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Aggregate (Construction)

As expected, the production of construction aggregate increased in Wyoming during the third quarter, which is the peak construction season. While production in 1992 should be less than last year, 1992 production should also be greater than in 1993.

Aggregate (Decorative)

Georgia Marble produces various sizes of white marble aggregate at its Wheatland quarry and plant (Figure 18). Sales of white marble continue to increase. In addition to the white product, Georgia Marble is dyeing some of the white marble and selling the dyed product as colored decorative aggregate.

Bentonite

Black Hills Bentonite announced in September that it plans to produce kitty litter at its Worland, Wyoming, bentonite processing plant (Figure 18). Bentonite, a naturally-occurring clay material, has a high cation exchange capacity, a property useful for environmental cleanup operations and deodorizers, including kitty litter.

Bentonite Corporation announced plans to build a new $1 million processing facility at its Colony plant site in Crook County (Figure 18). Company officials said the plant expansion was designed to produce foundry sand binders needed by the metal casting industry.

Cement

Mountain Cement produces several varieties of portland cement from limestone, gypsum, siliceous shale, and other additives at its plant in Laramie. The company has also been exploring anorthosite deposits near Laramie. Anortho-

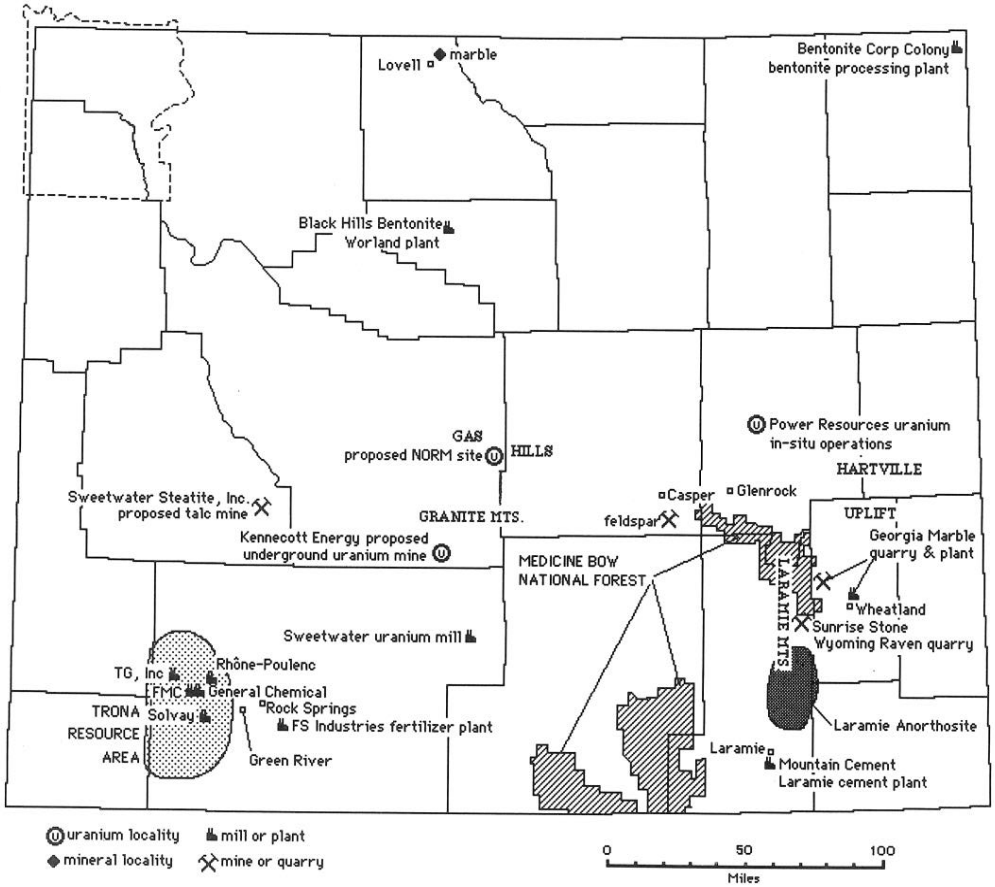

Figure 18. Industrial minerals and uranium activities in the third quarter of 1992.

site, which is a rock composed almost entirely of aluminous feldspar, provides a source of alumina for use as a strengthening additive in cement. Apparently recent tests of the anorthosite within ten miles of Laramie have not located an adequate source of high-grade anorthosite. The company may begin exploring other areas of the anorthosite complex north and east of Laramie (Figure 18).

Decorative Stone

In addition to its production of black granite from the Wyoming Raven quarry west of Wheatland (*Wyoming Geo-notes No. 35*, p. 35), Sunrise Stone also shipped blocks of a pink, granitic migmatite to a facility in Chicago, Illinois, for processing into decorative stone facing and monuments.

In September, representatives of five stone producing companies (from California, Colorado, Georgia, Maryland, and Tennessee) were in Wyoming examining deposits of granite, quartzite, flagstone, and sandstone for potential development. These deposits were located by the Geological Survey of Wyoming (GSW). Most of the interest centered on granite localities in the Granite Mountains of central Wyoming and in the northern Laramie Mountains, and sandstone and orthoquartzite localities in the Hartville uplift (Figure 18). Also, at the end of September, the GSW sent samples of red marble to an individual in North Carolina who may be interested in producing the stone. The samples came from a locality northeast of Lovell.

The Industrial Minerals and Uranium Section of the GSW received an $8,000 grant from the U.S. Forest Service to study and report on the potential for decorative stone in the Medicine Bow National Forest in southern Wyoming (exclusive of the Pole Mountain area east of Laramie) (Figure 18). Several potential quarry sites will be examined during the course of this study.

Feldspar

Small amounts of feldspar were produced from Casper Mountain in the summer of 1992 (Figure 18). This material is used primarily for decorative aggregate, but also may be used for dental products and ceramics.

Fertilizer

In the third quarter of 1992, Chevron Chemical Company finalized the sale of its fertilizer plant to FS Industries. FS Industries is a joint venture between Farmland Industries of Kansas City, Missouri, and J. R. Simplot Co. of Pocatello, Idaho. The plant, which is southeast of Rock Springs, manufactures fertilizer and soil conditioners from phosphate mined in Utah and sulfur recovered from the desulfurization of natural gases produced in Wyoming (Figure 18).

According to the U.S. Bureau of Mines, domestic production of phosphate-based fertilizer in the first half of 1992 is four percent greater than in the first half of 1991. This increase was due in large part to growth in the agricultural sector. However, imports of phosphate, mostly from Morocco, more than doubled during the same period.

Talc

Sweetwater Steatite, Inc. of Rock Springs is preparing a mining permit for a small steatite (massive talc) quarry in southeastern Sublette County (Figure 18). Most of the production from this quarry will be used to produce carved statuary.

Trona

Production, construction, and other expansion-related activities continue to increase 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 18).

A three-year expansion project was completed at the Solvay Minerals, Inc. soda ash plant. It will increase annual production of soda ash at the Solvay plant by 700,000 short tons for a total plant capacity of two million short tons. According to company personnel, ninety new employees have been added to the payroll. Solvay purchased the trona mining and refining operation from Tenneco Minerals earlier this year (*Wyoming Geo-notes No. 35*, p. 36 - 37).

U.S. Borax announced in early September that it was conducting exploratory and feasibility tests towards opening a new trona mine and sodium-compound refining plant. The company also needs to negotiate trona leases with the U.S. Bureau of Land Management and the Union Pacific Railroad. The company may reach a decision on whether or not to proceed with its trona mining plans sometime next year. U.S. Borax is a subsidiary of the British company RTZ, Inc., and is the largest producer of borax and other boron compounds in the U.S.

In late August, the five soda ash producers announced a $5 increase in the price of soda ash. The increase was due to the increasing demand for soda ash worldwide. The list price of soda ash, after the increase, is near $98.00 per short ton. The actual average sales price is usually somewhat less due to contractual sales and other purchasing arrangements.

Uranium

The NUEXCO spot market price for yellowcake remained stable during the third quarter of 1992 at $7.75 per pound. In Wyoming, uranium is now only mined at Power Resources Highland in-situ operation in the southern Powder River Basin north of Glenrock (Figure 18).

The future of the uranium mining industry in the United States remains rather bleak due to an abundance of lower cost foreign sources of uranium. Because of a number of factors including mining costs, government subsidies, and higher grade ore, uranium from Canada and Australia can be produced at about half the cost of uranium mined in the United States. Adding to the industry's woes, in August the Federal government announced a contract to purchase weapons-grade uranium from Russia. This uranium, which contains over 90% of the

fissionable isotope of uranium (U^{235}), will be diluted to 3% U^{235} and sold for nuclear power plant fuel. Weapons-grade uranium from Russia can provide fuel for domestic utilities for many years at a much lower cost than mined uranium.

Despite the worldwide downturn in uranium prices, Kennecott Energy announced that it was continuing with its plans to develop an underground uranium mine beneath Green Mountain south of Jeffrey City (Figure 18). The venture recently acquired the closed Sweetwater uranium mill (Figure 18) from Union Oil of California (*Wyoming Geo-notes No. 35*, p. 39).

On a related issue, American Nuclear announced in August that it may not pursue plans to create a Naturally Occurring Radioactive Materials (NORM) disposal site in the Gas Hills (Figure 18). The company had been investigating the feasibility of using an abandoned uranium mine as a disposal site for this kind of low-level radioactive waste. The site, however, may not be suitable from a ground-water standpoint, and there may not be enough NORM to make the site economic.

METALS AND PRECIOUS STONES UPDATE

by W. Dan Hausel
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The Geological Survey of Wyoming continued its investigations of mineral resources in Wyoming and initiated a study of the Rattlesnake Hills supracrustal belt west of Casper, Wyoming. Company activities were reported for copper, zinc, and gold in several areas of the State. Some activity was also reported in the State Line diamond district following the discovery of diamonds in Canada and one of the greatest land rushes ever reported in that country.

Cooper Hill District, Medicine Bow Mountains

The Cooper Hill district was investigated by the Geological Survey of Wyoming in 1991 (Hausel, 1992; *Wyoming Geo-notes No. 35*, p. 42). In 1992, a mine with 170 feet of tunnels and drifts was located a short distance south of Cooper Hill (section 3, T17N, R78W) and mapped at 1:240-scale. The adit on Cooper Creek was driven on a 5- to 6-foot wide milky quartz vein in chlorite schist. Three samples (CH1-92, CH2-92, and CH5-92, Table 7) collected from the mine were poorly mineralized. Only sample CH5-92 yielded anomalous mineralization (3.65% Cu, and 1.9 ppm Ag). Samples of quartz pebble conglomerate with disseminated limonite after pyrite (?) were collected immediately west of the south end of Cooper Hill (section 34, T18N, R78W) (Samples CH3-92 and CH4-92). Neither sample was anomalous.

Table 1. Assay results from the Cooper Hill district, Medicine Bow Mountains

Sample number	Ag (ppm)	Au (ppb)	Pd (ppb)	Pt (ppb)	Cu (%)	Pb (ppm)	Zn (ppm)
CH41-91	0.6	108	4	11	1.88	14	19
CH42-91	0.1	<5	17	21	—	—	—
CH43-91	<0.1	<5	—	—	—	—	—
CH1-92	<0.1	<5	—	—	—	—	—
CH2-92	<0.1	<5	—	—	—	—	—
CH3-92	<0.1	6	—		—		—
CH4-92	<0.1	5	—	—	—	—	—
CH5-92	1.9	71	—	—	3.65	128	55

A few samples collected from Cooper Hill were assayed in addition to samples previously reported by Hausel (1992) Sample CH41-92 was collected from a skarn near the south end of the hill and yielded 1.88% Cu, 108 ppb (parts per billion) Au, 4 ppb Pd, and 11 ppb Pt (Table 7). Sample CH42-92 was a sample of coarse grained metagabbro and CH43-92 was a sample of quartzite. Sample locations are shown on Plate 1 of Hausel (1992).

Encampment District, Sierra Madre

The U.S. Forest Service has reportedly approved an exploration project by Noranda Exploration in the Big Creek Park area in the Encampment district. The exploration project will include drilling of eight holes to test for copper mineralization. Noranda Exploration also filed 59 claims in the Sunlight Basin area on the south flank of White Mountain in northwestern Wyoming earlier this year (*Pay Dirt*, 1992, no. 148, Jan., p. 12)

At the start of the field season, the Geological Survey of Wyoming (GSW) examined the Broadway mine (S/2 SW section 32, T13N, R83W) in the Encampment district of the southeastern portion of the Sierra Madre. The Broadway mine has had a varied history of exploration and prospecting which has included several individuals, companies (including New Jersey Zinc, Amselco, and Bunker Hill), the U.S. Bureau of Mines, and the GSW, since the Broadway claim was staked in 1907.

According to Osterwald (1947), the Broadway ore zone was exposed at the surface over an area of at least 1,000 feet by 50 feet. Other reports have indicated the mineralized body was traceable for at least 1,400 feet along strike and continued under a thick vegetative cover. Ore samples were reportedly massive, forming 3 - 35 percent of the host rock.

A channel sample taken by the U.S. Bureau of Mines in the 1940s assayed 12.5% Zn, 1.9% Pb, and 0.02% Cu. Another sample from the No. 2 shaft assayed 4.2% Zn and 1.9% Pb. A sample from the No. 3 shaft assayed 1.0% Pb and no detectable Zn. A selected sample from the No. 1 shaft assayed 10.2% Zn and

0.9% Pb. Small amounts of a platinum group metal were also identified by spectrographic analysis (Osterwald, 1947).

The ore was localized along a contact formed of granite with a complex of gneiss, amphibolite, pyroxenite, gabbro, and diorite. Ore replaces amphibolite (Osterwald, 1947) and pyroxenite (DeNault, 1967).

The Broadway property was visited by the GSW on June 3rd of this year. Due to reclamation efforts, there were no outcrops of rock left on the property. Float samples of mineralized rock, however, were collected throughout the area for analysis (Table 8).

The samples collected (Table 8) were highly anomalous in zinc, lead, copper, gold, and silver and included: (1) sample BW1-92, a limonite-stained felsite, which yielded 2 opt (ounces per ton) Ag, 3.28 ppm (parts per million) Au, 0.77% Cu, 0.31% Zn, and 0.30% Pb; (2) sample BW2-92, a bleached granodiorite with disseminated sulfides, containing 1.82% Cu, 1.6 ppm Au, 0.75% Pb, and 12.18 opt Ag; (3) sample BW3-92, a pyroxenite with sphalerite and galena that assayed 4.34% Zn, 5.66% Pb, 0.16 ppm Au, and 47.1 ppm Ag; and (4) samples BW5-92 and BW6-92, which were spessartine-calcite-pyroxene-actinolite hornfels with massive sphalerite that yielded 7.66 and 8.17% Zn with anomalous lead, gold, and silver. Based on the float found on the property, the Broadway deposit was a skarn possibly introduced by granodiorite.

Table 8. Assay results from the Broadway mine, Sierra Madre.

Sample number	Zn (%)	Pb (%)	Cu (%)	Au (ppm)	Ag (ppm)	Pt (ppb)	Pd (ppb)
BW1-92	0.31	0.30	0.77	3.28	(2 opt)	—	—
BW2-92	0.02	0.75	1.82	1.60	(12.18 opt)	—	—
BW3-92	4.34	5.66	0.18	0.16	47.1	—	—
BW5-92	7.66	0.69	0.05	0.10	6.7	<5	2
BW6-92	8.17	0.62	—	0.22	9.9	—	—

Ferris Mountains, Carbon County

In 1871, historic reports of rich deposits of argentiferous galena containing as much as 1,500 opt Ag, led General Bradley's troops to investigate and discover auriferous veins in the nearby Seminoe Mountains (Ferry, 1871). The silver samples most likely were collected from the eastern flank of the Ferris Mountains in the Miners Canyon area rather than in the Seminoe Mountains.

The Ferris Mountains uplift in central Wyoming includes a core of Archean supracrustal crystalline rocks flanked by steeply dipping Phanerozoic sedimentary rock. Much of the supracrustal complex was mapped by Master (1977). However, a smaller block of supracrustal rock along the eastern flank of the range was left unmapped. This Archean block, which surrounds the Miners Canyon area, is currently being mapped by Nancy Bowers as a thesis project at the

University of Wyoming. The Miners Canyon supracrustals are isoclinally folded metavolcanics, pelitic schists, and amphibolites (Nancy Bowers, personal communication, 1992).

Field investigations by the Geological Survey of Wyoming in the Miners Canyon area identified widespread gossans near the Spanish mine (section 6, T26N, R86W). Samples collected (Table 9) included: sample FM1-92, a brecciated, iron-stained, graphitic schist with anomalous silver (5.4 ppm Ag) from a prospect pit in section 6; sample FM2-92 (E/2 E/2 section 6), graphitic schist with limonite boxworks with anomalous silver (1.5 ppm Ag); sample FM3-92 (E/2 E/2 section 6) a piece of quartz-sulfide vein in graphitic schist with anomalous silver (1.5 ppm Ag); sample FM4-92, a nonmineralized chlorite schist from the Spanish mine rib; sample FM5-92, a pyrite-chalcopyrite-arsenopyrite-bearing quartz from a muck pile at the Spanish mine. This sample was weakly anomalous in silver (4.1 ppm Ag).

Table 9. Assay results of samples from the Miners Canyon area of the Ferris Mountains.

Sample number	Zn (%)	Pb (%)	Cu (%)	Au (ppb)	Ag (ppm)	As (ppm)
FM1-92	—	—	—	<5	5.4	—
FM2-92	—	—	—	6	1.5	—
FM3-92	—	—	—	<5	1.5	—
FM4-92	—	—	—	<5	<0.1	—
FM5-92	—	—	—	<5	4.1	1330
FM6-92	0.03	0.12	0.87	<5	2.9	—
FM7-92	0.58	7.62	2.72	164	>50.0	—
FM8-92	—	—	—	6	0.9	126
FM9-92	0.02	trace	6.65	390	26.4	—

Other collected samples included: sample FM6-92, a chip sample from a cupriferous shear (S/2 NW section 5) near some old cabin remains that yielded 0.87% Cu, 0.12% Pb, and 2.9 ppm Ag; sample FM7-92, a chip from a cupriferous shear in metavolcanics south of the Spanish mine which yielded 2.72% Cu, 7.62%Pb, 0.58% Zn, 164 ppb Au, and 9.15 opt Ag; sample FM8-92, a pyrrhotite-magnetite chip from a mine dump in the metavolcanics succession in the W/2 SW section 5; and sample FM9-92, (NE section 6) a sample of gossaniferous copper-stained granodiorite from a dump adjacent to an inclined shaft. This sample assayed 6.65% Cu and 26.4 ppm Ag.

Although many of the samples collected in the Miners Canyon area were anomalous in silver, none contained the high values reported by Ferry (1871). But the widespread gossans in this area suggests it is worthy of further investigation.

Rattlesnake Hills, Granite Mountains uplift

The Geological Survey of Wyoming (GSW) began mapping the Rattlesnake Hills Precambrian complex at 1:24,000-scale in late June. The Rattlesnake Hills are part of the Granite Mountains in Natrona County, central Wyoming.

The preliminary study indicates this region is a fragment of an Archean supracrustal belt possibly of similar age as the South Pass granite-greenstone belt in the Wind River Range to the west. Lithologies include a lower (?) supracrustal unit of banded iron formation, metapelite, quartzite, amphibolite, and metarhyolite in contact with pillowed metatholeiites, on the north. Farther north, the metatholeiites lie in contact with a metasedimentary unit of metagreywacke, mica schist, and minor metacherts. The northern contact of the metasedimentary rock is conformable with a succession of amphibolite and metabasalt.

The supracrustal belt has been intruded by more than 42 Tertiary alkalic plugs dated at 43-44 million years old (Pekarek, 1977). Brecciation and iron-staining of the supracrustals is notable along the margins of some quartz latites, but notably absent near phonolites. The GSW collected metachert samples from the Lost Muffler prospect in 1982. These samples yielded anomalous gold (Hausel, 1989, p. 60). This metachert has a minimum strike length of 2,200 feet and contains associated pods and lenses of jasper.

Assay results of some samples collected from the district are reported in Table 10. All of these samples yielded anomalous gold. Sample RH37-92 was especially anomalous and yielded 5 ppm Au. This was from a brecciated iron formation along the southern flank of the supracrustal belt.

Table 10. Assays of samples from the Rattlesnake Hills District.

Sample number	Cu (%)	Au (ppm)	Ag (ppm)
RH29-92	—	0.30	0.20
RH35-92	0.1	0.80	0.56
RH36-92	—	0.30	nd
RH37-92	—	5.00	0.28

State Line District, Laramie Mountains

Following the discovery of diamonds in kimberlite in the Yellowknife region, one of the greatest land rushes in the history of Canada is taking place. Because of the rush, some interest is spilling over into the Colorado-Wyoming kimberlite province.

The Colorado-Wyoming kimberlite province includes more than 100 kimberlite intrusives. In the State Line district south of Laramie, more than a dozen of the ultrabasic intrusives are diamondiferous. To date, more than 100,000 diamonds have been recovered from this area with diamonds up to 2.4 carats. Both gem and industrial diamonds have been found (McCallum and Waldman, 1991). Several geophysical and heavy mineral targets remain unexplored in the region.

Abandoned mine reclamation

During the past few years, the Wyoming Department of Environmental Quality has undertaken a project to locate abandoned and inactive mines for possible reclamation. Samples were collected at many of these sites by the Geological Survey of Wyoming. Analyses of some of these samples are listed in Table 11. Brief descriptions of the sample sites follow.

Sample site DEQ4-1: A 100-foot-long adit was driven into a N81°W, near vertical, shear zone in mafic gneiss located in section 7, T12N, R81W of the Medicine Bow Mountains. The shear is copper-stained and is 2-3 feet wide at the portal. Samples from the shear contained covellite, chalcocite, chalcopyrite, pyrite, and malachite. A chip of the shear assayed 5.34% Cu, 23.4 ppm Ag, and 325 ppb Au (Table 11).

Sample site DEQ4-3 (section 22, T14N, R84W): The Finley shaft in the Sierra Madre, was sunk on a hematite-stained milky quartz vein hosted by diorite, which contained traces of chalcopyrite and malachite. One hematite-stained piece of quartz was assayed yielding no detectable gold or silver.

Sample site DEQ4-11 (NE SE section 2, T13N, R79W): The Lake Creek shaft was sunk on a shear in altered Keystone Quartz Diorite on a ridge between Lake Creek and Muddy Creek in the Medicine Bow Mountains. Based on the size of the mine dump, as much as 500 feet of workings were probably dug in this mine. A sample of copper-stained, potassically altered quartz diorite assayed 0.99% Cu (Table 11).

Table 11. Sample analyses of rock collected from the State's abandoned mine reclamation sites.

Sample number	Cu (%)	Ag (ppm)	Au (ppb)	Pd (ppb)	Pt (ppb)	Pb (ppm)	Zn (ppm)	Ga (ppm)
DEQ4-1	5.34	23.4	325	—	—	3	7	—
DEQ4-3	—	<0.1	<5	—	—	—	—	—
DEQ4-11	0.99	0.9	6	<1	12	19	49	—
DEQ4-15	—	0.1	996	—	—	—	—	—
DEQ4-16	—	<0.1	<5	—	—	—	—	—
DEQ4-24	2.16	1.2	514	—	—	—	—	—
DEQ4-29	0.06	0.5	28	—	—	17	31	—
DEQ4-34	—	0.1	<5	—	—	—	—	—
DEQ4-34A	—	0.2	27	—	—	—	—	—
DP1-92	24.69	0.1	22	5	14	42	57	12
GH1-92	4.89	5.2	18	—	—	12	9	—
HBM2-83	0.22	0.8	217	—	—	33	16	—
RMB1-92	1.70	1.3	169	—	—	25	48	30
RMB2-92	1.19	<0.1	<5	—	—	6	76	—
RMB3-92	—	<0.1	73	—	—	18	182	27
RMB4-92	1.02	0.7	27	—	—	<2	3	—
SS1-84	0.45	0.3	<5	—	—	3	31	—
UB!-92	—	0.1	<5	—	—	—	—	—

Sample site DEQ4-15 (section 1, T13N, R84W): An adit was developed in sheared gneiss in the Encampment district of the Sierra Madre. A sample of the sheared gneiss yielded 996 ppb Au (Table 11).

Sample site DEQ4-16 (section 12, T13N, R84W): A sample from the Cascade mine dump along the Encampment River consisted of limonite-stained metagabbro. The sample was not mineralized (Table 11).

Sample site DEQ4-24 (section 29, T14N, R84W): A sample of cupriferous quartz was collected from the Kurtz-Chatterton property of the Encampment district. The sample assayed 2.16% Cu, 514 ppb Au, and 1.2 ppm Ag. This is the same property recently examined by the Geological Survey of Wyoming, which yielded highly anomalous mineralized samples containing gold, copper, and silver over a relatively large area (*Wyoming Geo-notes No. 34*, p. 40).

Sample site DEQ4-29 (S/2 section 10, T14N, R86W): A shaft was sunk in diorite with the intent of intersecting a sulfide-bearing vein. Development work appeared to have been minimal. A sample of the quartz vein yielded 0.06% Cu (Table 11). The property is located in the Sierra Madre.

Sample site DEQ4-34 (N/2 SW section 27, T15N, R86W): A shaft (an estimated 150 feet of development work) was sunk in amphibolite schist and quartzofeldspathic gneiss in the Sierra Madre. Samples on the dump included quartz-carbonate with minor sulfides. Two samples (DEQ4-34 and DEQ4-34A) collected for analysis were poorly mineralized (Table 11).

Sample DP1-92 was collected from the DePass mine dump (S/2 section 14, T40N, R92W) in the Copper Mountain district of the Owl Creek Mountains (see Hausel and others, 1985). This mine produced copper, gold, and silver in the early 1900s. The sample of cupriferous basalt yielded 24.69% Cu, 22 ppb Au, and 12 ppm Ga, as well as a trace of platinum (Table 11).

Sample GH1-92 was a piece of cupriferous conglomerate from the Greenhope mine in the Hartville uplift (NW section 26, T29N, R65W). The conglomerate lies at the base of the Guernsey Formation (Osterwald and others, 1966, p. 54). The sample assayed 4.89% Cu and 5.2 ppm Ag.

Sample HBM2-83 was collected from the Hub gold mine in the western Sierra Madre (NE section 6, T15N, R87W). The sample was collected from a 1.5-foot-wide quartz vein in amphibolite (Hausel, 1989, p. 155). The quartz assayed 0.22% Cu, 217 ppb Au, and 0.8 ppm Ag (Table 11).

The Doane Rambler mine in the Encampment district of the Sierra Madre was developed in Cascade Quartzite with more than 2,800 feet of drifts (Hausel, 1989, p. 153-154). Four samples of sulfide-bearing quartzite (RMB1-92 to RMB4-92) collected from the mine yielded 1.02% to 1.70% Cu, and none to 169 ppb Au (Table 11).

A sample (SSI-84) from the Sonset mine in the Keystone district of the Medicine Bow Mountains assayed 0.45% Cu (Table 11).

Uraniferous sandstone (UB1-92) was collected from the Uranium Box prospect in the Pumpkin Buttes area of the Powder River Basin. The sample yielded <5 ppb Au and a trace of silver (Table 11).

A sample of titaniferous magnetite from the Iron Mountain mine in the Laramie Mountains (T19N, R71W) was collected for assay. The sample contained less than 5 ppb Au, greater than 10 percent iron, 358 ppm chromium, 8.27% titanium, 0.2 ppm Ag, and 0.31% vanadium.

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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)	1.45	billion barrels[2]
Indicated and inferred reserves	2.80	billion barrels[1]
Total	4.25	billion barrels

NATURAL GAS

Remaining Resources (January 1, 1991)		
Discovered (Includes 21 trillion cubic feet (TCF) of methane[1] and 122.1 TCF of CO_2[3])	143.1	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	3,850.3	trillion cubic feet
Remaining Reserve Base (January 1, 1991)		
Measured reserves (Proved reserves) (Includes 10.4 TCF of methane[2] and 60.7 TCF of CO_2[3])	71.1	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]

[1] Modified from Barlow, J.A., Jr. and Doelger, M.J., 1983, Wyoming mineral resources: Barlow and Haun, Inc., Casper, 14 p.

[2] Modified from Energy Information Administration, 1991, U.S. crude oil, natural gas, and natural gas liquids reserves: 1990 Annual Report, September.

[3] De Bruin, R.H., 1991, Geological Survey of Wyoming Open File Report 91-6, 20 p.

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[5] Law, B.E., and others, 1989, Estimates of gas resources in overpressured low-permeability Cretaceous and Tertiary sandstone reservoirs, Greater Green River Basin, Wyoming, Colorado, and Utah: Wyoming Geological Association, 40th Annual Field Conference Guidebook, Casper, Wyoming p. 39-61.

[6] Modified from Wood, G.H., Jr. and Bour W.V., III, 1988, Coal map of North America: U.S. Geological Survey Special Geologic Map, 1:5,000,000 scale (color) and 44 p. pamphlet.

[7] Modified from Geological Survey of Wyoming, December, 1991, unpublished report for the Energy Information Administration, 29 p.

[8] Modified from Culbertson, W.C., 1983, Genesis and distribution of trona deposits in Wyoming (abstract) in Genesis and exploration of metallic and nonmetallic mineral and ore deposits of Wyoming and adjacent areas: Geological Survey of Wyoming Public Information Circular 19, p. 34.

[9] Energy Information Administration, 1989, Uranium industry annual: U.S. Department of Energy Report DOE/EIA-0478(89), 121 p.

[10] Knutson, C.F., and Dana, G.F., 1982, Developments in oil shale in 1981: American Association of Petroleum Geologists Bulletin, Volume 66, no. 11, p. 2513.

GEOLOGIC MAPPING AND STRATIGRAPHY

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

NEW STRATIGRAPHIC NOMENCLATURE CHART PUBLISHED

The Geological Survey of Wyoming (GSW) recently published the second draft of a stratigraphic nomenclature chart for the State of Wyoming. The chart is black and white on a single sheet and lists the nomenclature in columns corresponding to the major basins and uplifts in Wyoming. Cambrian through Holocene nomenclature is included on the chart along with an extensive list of footnotes and references. The chart was designed to be compatible with the 1:500,000-scale geologic map of Wyoming (Love and Christiansen, 1985). This new chart is titled, *Second draft of a stratigraphic chart showing Phanerozoic nomenclature for the State of Wyoming*, and was released as Open File Report 92-2. The chart was a cooperative effort of J.D. Love and A.C. Christiansen of the U.S. Geological Survey and A.J. Ver Ploeg of the GSW. A version colored the same as Love and Christiansen's map (1985) is planned for publication within approximately one year.

NEW ARTICLES ON WYOMING GEOLOGY PUBLISHED

Two new articles on Wyoming structural geology were recently published in scientific journals. Various workers discussed research done in the Shirley Mountains and Bighorn Mountains (Figure 19).

Steffen G. Bergh (Institute of Giology and Geology, University of Tromsø, Norway) and Arthur W. Snoke (Department of Geology and Geophysics, University of Wyoming) recently published a paper on the Laramide deformation in the Shirley Mountains of southcentral Wyoming (Figure 19). The authors (Bergh and Snoke, 1992) examine three basic structural trends present in the Shirley Mountains. These three trends, as identified by detailed mapping and structural analysis, point toward a polyphase Laramide developmental history for the Shirley Mountains. The earliest identified phase of deformation included N-S basement-involved folds and associated low-angle conjugate reverse faults, some of which were rotated into an E-W orientation during the second phase of deformation. Both the first and second phases were crustal shortening events creating basement cored folds and associated reverse faults. The last phase of Laramide deformation involved the development of conjugate NE-SW oblique-slip faults that lie oblique to and offset earlier features. The authors also discuss the timing of these events and their correlation to overall structural trends in the Wyoming foreland and Colorado Front Range.

Donald U. Wise and Curtis M. Obi (Department of Geology and Geography, University of Massachusetts) recently published a paper on the structural geology of the Five Springs area on the west flank of the northern Bighorn Mountains

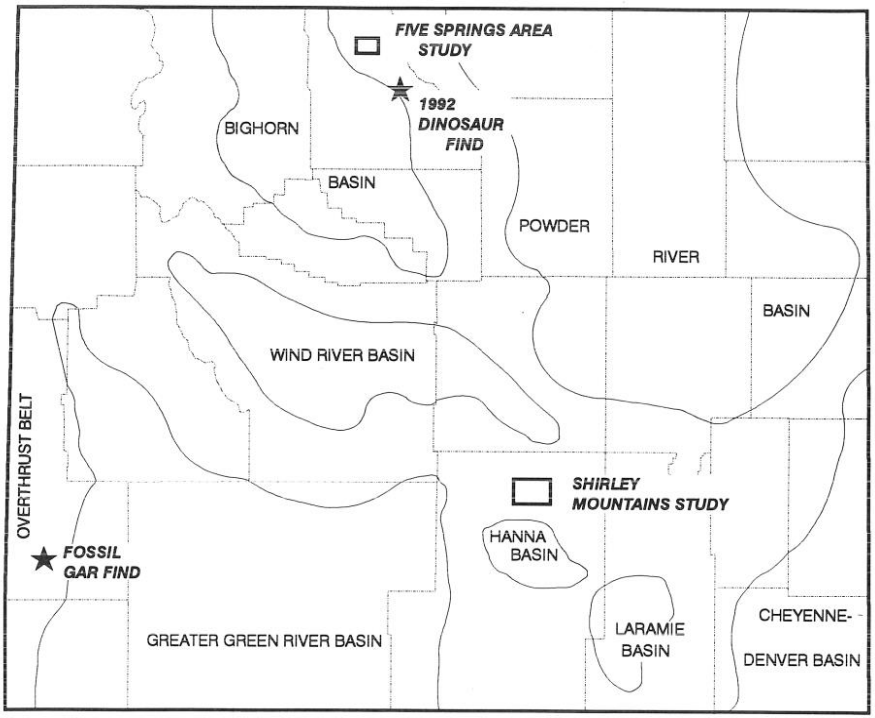

Figure 19. Index to selected geologic studies and fossil finds in Wyoming.

(Figure 19). New road cuts on U.S. Highway 14A exposed almost continuous outcrops through the edge of a Laramide uplift. These exposures provided an opportunity for tracking the changing stress field within rotating basement blocks during Laramide range-front buckling and folding. Stress tensor analysis was performed on three identified fault populations in the exposed granitic rock in the range-front area. The model of deformation developed from the stress analysis indicates basement folding by subhorizontally directed compressional forces. These forces created an early buckle zone that expanded into a small number of rotated blocks with minor reshaping of the rotating blocks by small faults. With respect to the debate of vertical versus horizontally driven tectonics, analysis of the area demonstrates compressionally or subhorizontally driven tectonics. The authors recount the evidence for their proposed model and relate these results to similar Laramide features in the Rocky Mountain area (Wise and Obi, 1992).

ADDITIONAL NEW DINOSAUR FINDS IN THE AREA OF SHELL, WYOMING

Crews from Montana State's Museum of the Rockies and the University of California, Berkeley, have located partial remains of four dinosaurs and parts of others in the Jurassic Morrison Formation (Figure 19). These were found near where the *Allosaurus* was found last fall north of Shell, Wyoming (*Wyoming Geo-notes No. 32*, p. 40-41). Included in the finds from various areas are bones of a flying reptile known as a pterosaur; an armored dinosaur known as an ankylosaur; and a plant-eating sauropod, possibly a *Diplodocus*, which can reach up to 90 feet in length. The large number of dinosaur finds in the vicinity, including those found in very large numbers in the Howe quarry of the 1930's, has raised the question as to why so many fossils have accumulated in this area. One theory is that the Howe quarry may represent an ancient exhumed lake bed where numerous dinosaurs perished when the lake dried up. This summer's finds, however, were more likely buried in an ancient river channel. Work will continue in this area for several years.

LARGE GAR FOUND ON STATE QUARRY

A 6-foot 8-inch gar or *Lepisosteus atrox* was recently recovered from the Mjos quarry on State of Wyoming land west of Kemmerer, Wyoming (Figure 19). This represents the largest gar ever recovered from the fossil fish beds of the Tertiary Eocene Green River Formation in Fossil Basin. The previous largest gar found was a 5-foot 6-inch specimen, which is in a private collection. Gars have long, cylindrical bodies covered with hard diamond-shaped scales. The genus *Lepisosteus* exists today in the Mississippi River drainage, where their diet consists almost exclusively of fish. This recent find is currently being prepared and will reside in the University of Wyoming's Geological Museum.

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GEOLOGIC HAZARDS IN WYOMING

RADON RESEARCH

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

Soil-gas radon samples have been collected on a weekly basis for twenty-seven weeks at twelve sites in the Laramie Basin. *Wyoming Geo-notes Nos. 34* and *35* contained a description of the scope and purpose of the Geological Survey of Wyoming's (GSW's) radon project. *Wyoming Geo-notes No. 35* (p. 58-59) also contained a discussion of the variability of soil-gas radon levels at four sites in the study area.

One site in the study has consistently yielded higher soil-gas radon levels than the other eleven sites. Site 5 has had radon levels that vary from 907 picocuries per liter (pCi/L) to over 2,200 pCi/L. Radon levels have also varied significantly from week to week at site 5 (Figure 20). Obvious soil-gas radon peaks and valleys are present. Soil-gas radon data from site 5 are currently being correlated with soil moisture, soil temperature, barometric pressure, air temperature, wind speed, humidity, and precipitation data that were collected at the site at the same time radon data were collected. Presumably, there should be a relationship between the soil-gas radon and the other environmental factors although the relationship could be so complex that it is hard to recognize.

Hourly soil-gas radon and soil/atmospheric data have also been collected at site 5 in order to determine to what degree changes in soil and atmospheric data affect soil-gas radon levels. Three twelve-hour surveys were completed at the site

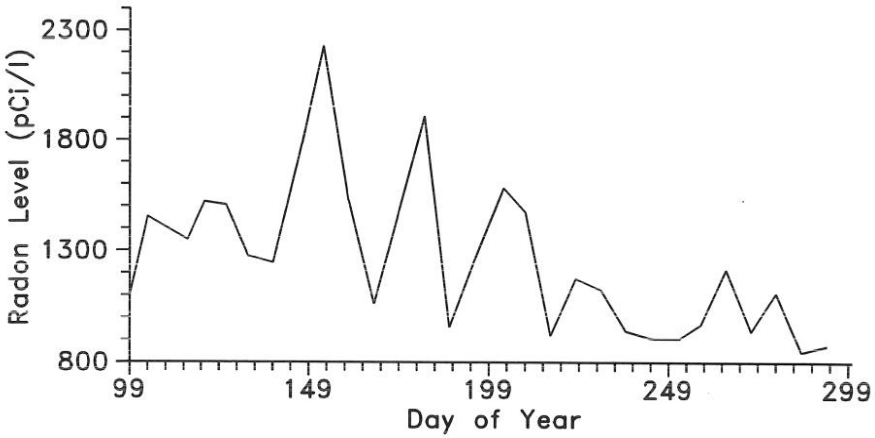

Figure 20. Weekly sampling results for radon at Site 5.

in September, 1992, with the results of the surveys shown in Figure 21. On September 10, 1992, soil-gas radon levels ranged from 1,044 pCi/L (7:00 a.m.) to over 1,265 pCi/L (1:00 p.m.). Radon levels increased from 7:00 a.m. to 10:00 a.m., decreased from 10:00 a.m. to noon, increased from noon to 1:00 p.m., and then decreased from 1:00 p.m. until 5:00 p.m. On September 10, the soil-gas radon samples certainly varied with time. The same observation held for the samples taken on September 17, 1992, when soil-gas radon levels ranged from 1,150 pCi/L (1:00 p.m.) to over 1,308 pCi/L (8:00 a.m.). Radon levels increased from 7:00 a.m. to 8:00 a.m., decreased from 8:00 a.m. to 9:00 a.m., remained at a depressed level from 9:00 a.m. to 1:00 p.m., increased from 1:00 p.m. to 2:00 p.m., and slightly decreased from 2:00 p.m. to 7:00 p.m. On September 23, soil-gas radon levels were at a high of 1,196 pCi/L at 7:00 a.m., and the levels generally decreased throughout the day to a low of 1,097 pCi/L at 7:00 p.m. The patterns observed on September 10 and September 17 were not repeated on September 23. No single factor has yet been found to account for the variance.

Soil-gas radon analyses are currently being conducted on an hourly basis at other sites in the study area. Preliminary data indicate that sites that have a lower average soil-gas radon level on a weekly basis have less variability in the hourly samples. Permeability of the sampled sediments may be a factor in the variance observed in weekly and hourly samples. In any event, caution must be exercised when conducting soil-gas radon surveys. Monthly, weekly, daily, and hourly variance in soil-gas radon levels has been observed. Relationships between sites can also vary. Future articles will discuss the effect of cold temperatures and frozen ground on soil-gas radon levels and variability.

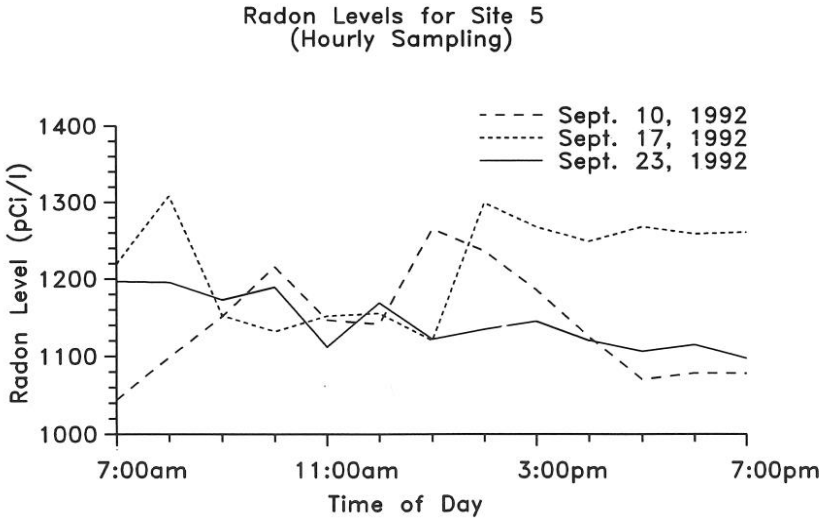

Figure 21. Hourly radon levels measured at Site 5 on three different days in September, 1992.

The variability of the data collected presents significant challenges in the interpretation of the data. Dr. Richard Anderson-Sprecher of the Department of Statistics at the University of Wyoming is cooperating with the Geological Survey of Wyoming in analyzing the radon data. Additional information on the radon research program at the Geological Survey of Wyoming can be obtained from Jim Case or Tracey Ziegler at 307-766-2286.

NEW PUBLICATIONS

Geologic map of the Nowater Creek 30' x 60' Quadrangle, north-central Wyoming, by A.J. Ver Ploeg and P.L. Greer: Map Series 39, 1992, 1:100,000 (color) - $5.00 ($6.50 mailed rolled).

Second draft of a stratigraphic chart showing Phanerozoic nomenclature for the State of Wyoming, by J.D. Love, A.C. Christiansen, and A.J. Ver Ploeg: Open File Report 92-2, 1992 - $3.00 flat ($4.50 mailed rolled).

The John Blue Canyon silica sand deposit, Big Horn County, Wyoming, by R.E. Harris and R.J. Warchola: Open File Report 92-3, 1992 - $4.00.

*Demonstrated reserve base of coal in Wyoming as of January 1, 1991, by R.W. Jones and G.B. Glass: Open File Report 92-4, 1992 - $4.00.

*Preliminary study of metals and precious stones along the Union Pacific right-of-way, southern Wyoming, by W.D. Hausel, G.G. Marlatt, E.L. Nielsen, and R.W. Gregory: Open File Report 92-5, 1992 (supersedes Mineral Report 92-1) - $15.00.

Coal fields and coal beds of Wyoming, by G.B. Glass and R.W. Jones: Reprint 47, 1992 - $4.00.

Field guide to the Seminoe Mountains, by D.L. Blackstone, Jr. and W.D. Hausel: Reprint 48, 1992 - $3.00.

Field guide to the geology and mineralization of the South Pass region, Wind River Range, Wyoming, by W.D. Hausel and J.D. Love: Reprint 49, 1992 - $3.00.

Industrial minerals and construction materials of Wyoming, by R.E. Harris: Reprint 50, 1992 - $3.00.

Form, distribution, and geology of gold, platinum, palladium, and silver in Wyoming, by W.D. Hausel: Reprint 51, 1992 - $3.00.

Geology and mineralization of the Wyoming Province, by W.D. Hausel, B.R. Edwards, and P.J. Graff: Reprint 52, 1992 - $3.00.

Subsurface geology of Upper Cretaceous and Lower Tertiary coal-bearing rocks, Wind River Basin, Wyoming, by D.G. Hogle and R.W. Jones: Reprint 53, 1992 - $6.00.

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

The Geological Survey of Wyoming now sells the Geologic Map of Grand Teton National Park, Teton County, Wyoming by J.D. Love and others, U.S. Geological Survey Miscellaneous Investigations Series Map I-2031 (1992). The full color map and accompanying 17 page pamphlet is available rolled or folded for $4.00. Add $1.50 for rolled maps shipped in a map tube.

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

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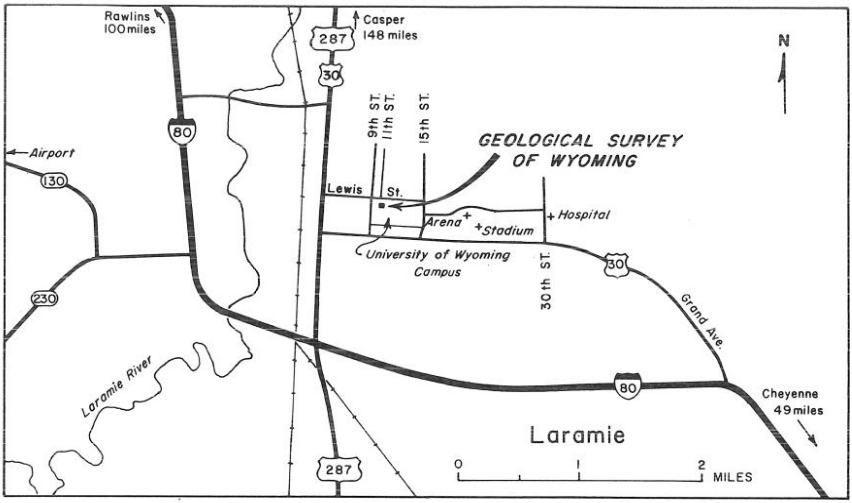
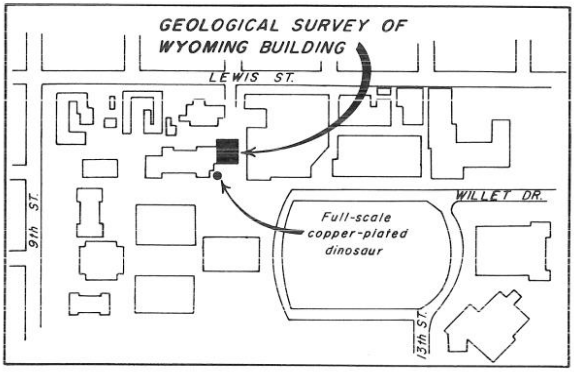
— WYOMING GEOLOGICAL ASSOCIATION —

By special arrangement with the Wyoming Geological Association (WGA), the Geological Survey of Wyoming now sells all of WGA's Annual Field Trip Guidebooks as well as its Symposium Volumes. These publications are available over-the-counter at the Survey's offices on the University campus in Laramie. Although they can be purchased by mail, prepayment is required. Call the Survey for book prices and postage costs. WGA sale prices will be honored also.

GEOLOGICAL SURVEY OF WYOMING
LOCATION MAPS





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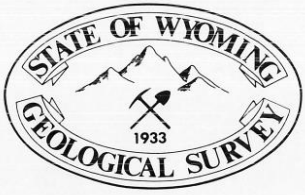
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