

THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist

WYOMING GEO-NOTES
NO. 31



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THE GEOLOGICAL SURVEY OF WYOMING

Gary B. Glass, *State Geologist*

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WYOMING GEO-NOTES

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Cover: A landslide nearly blocks the Greys River in Teton County. See page 43 for details. Photograph by Jim Case, 1991.

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MINERALS UPDATE

OVERVIEW

by Gary B. Glass, State Geologist

By the end of June, the fate of the \$250 million State loan to Kern River Pipeline was no longer in doubt. Governor Sullivan agreed with final recommendations of the Wyoming Natural Gas Pipeline Authority and decided not to make the loan. In the meantime, Kern River started work on the Wyoming portion of the pipeline and Amoco, Pacific Gas and Electric, Union Pacific Resources, and others moved forward with in-fill drilling projects as well as a few wildcat gas wells in anticipation of the new California markets that are opening up for Wyoming.

While there is considerable optimism that the market for Wyoming natural gas is going to substantially increase, there is concern about the weakened price of natural gas. By the end of the second quarter, the spot price at Opal had dipped to \$1.00 and many producers were getting closer to 65 cents per thousand cubic feet (MCF) (Figure 1). In 1990, the average price paid for an MCF of methane was approximately \$1.59 (Table 1). In *Wyoming Geo-notes No. 30*, we incorrectly showed the average price as \$1.38.

We also had an error on Table 2 in *Wyoming Geo-notes No. 30*. Our estimates of methane production should have been 777 billion cubic feet (BCF) for 1990 and 795 BCF for 1991. Table 2 in this issue has been corrected.

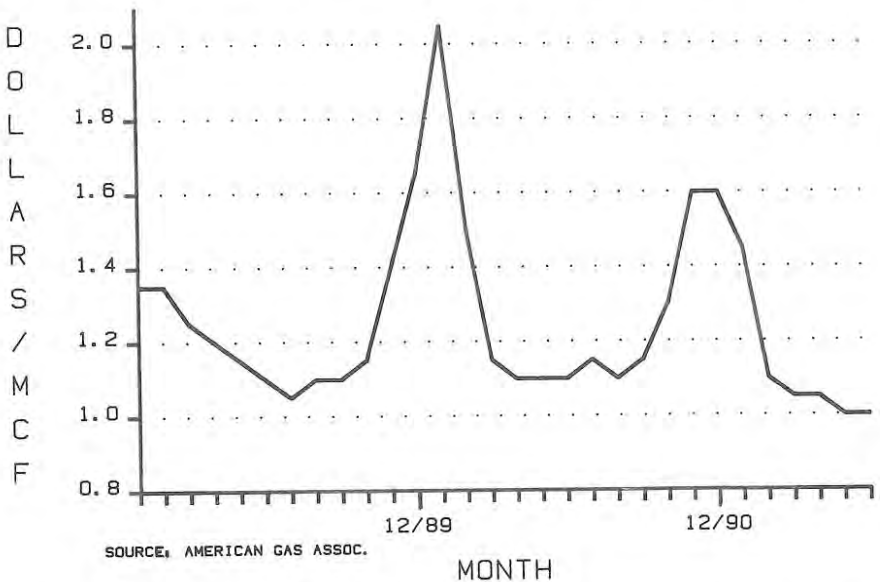


Figure 1. SPOT GAS PRICES AT OPAL, WYOMING, AVERAGED BY MONTH (1989 TO PRESENT).

Table 1. AVERAGE PRICE PAID FOR WYOMING OIL, NATURAL GAS, COAL, TRONA, AND URANIUM, FORECAST TO 1994¹.

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	21.05 ⁷	1.59	8.29	*45.86	19.00
1991	17.00	1.35	7.94	45.00	20.00
1992	17.00	1.48	7.59	46.00	21.00
1993	17.00	1.63	7.24	46.00	21.50
1994	17.00	1.80	6.99	47.00	22.00

* Actual value for comparison.

¹ Modified from Consensus Revenue Estimating Group, Wyoming State Government Revenue Forecast FY91-FY95, October, 1990, 18 p.

² First purchase price in dollars per barrel.

³ Wellhead price in dollars per MCF (includes carbon dioxide).

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 (January, 1991); in dollars per pound of yellowcake (weighted average price for solution-mined and surface-mined uranium).

⁷ Estimated price from Energy Information Administration.

Based on the oil prices for the first six months of 1991, our estimated 1991 oil price of \$17.00 is not looking high (Table 1). While first quarter oil prices started to recover in the second quarter, the recovery was short-lived and posted prices for Wyoming sweet crude never got up to \$20 (Figure 2). First purchase prices for Wyoming sweet have been under \$17.00 a barrel and sour crude is often less than \$14.00.

Perhaps the brightest spot at mid-year was the significant increase in coal production. Production is already far enough ahead of last year that we have revised our forecasts upward for 1991 through 1994 (Table 2). In addition, the COAL UPDATE describes 26 new contracts or test shipments of Wyoming coal.

In regard to other minerals, the bentonite industry has shown some modest gains as new uses for bentonite expand its market. One of the growth areas for bentonite is in the control of pollution. Trona is holding strong, but may not show any significant growth this year. Other mineral commodities showing strength in the second quarter were limestone for the production of lime, granite as railroad ballast, and decorative stone. Table 3 is a production history for many of the other minerals and materials produced in Wyoming.

And a summary of the second quarter would not be complete without mentioning claim staking in the Hartville uplift. Earlier this year, several companies rushed to stake claims for zinc, silver, and gold mineralization in that area of eastern Wyoming.

Table 2. WYOMING MINERAL PRODUCTION, FORECAST TO 1994¹.

Calendar Year	Oil ²	Methane ³	Carbon Dioxide ³	Helium ⁴	Coal ⁵	Trona ⁵	Mined Uranium ⁶	In-situ Uranium ⁷	Sulfur ⁸
*1981	122.1	455.4	—	—	102.8	11.8	4.6	—	0.05
*1982	118.7	465.1	—	—	107.9	10.1	2.1	—	0.07
*1983	120.9	539.7	—	—	112.2	10.5	3.0	—	0.57
*1984	127.8	600.1	—	—	130.7	11.0	1.6	—	0.71
*1985	131.0	597.9	—	—	140.4	10.8	0.6	—	0.80
*1986	122.4	563.2	23.8	0.15	136.3	11.9	0.2	—	0.76
*1987	115.9	619.0	114.2	0.86	146.5	12.4	0.2	0.06	1.19
*1988	114.3	701.6	110.0	0.83	163.6	14.9	0.3	1.40	1.06
*1989	109.1	739.0	126.1	0.94	171.1	16.2	0.1	1.07	1.17
1990	104.0	777.0	127.0	0.95	*184.0	*16.2	*0.1	*1.0	1.17
1991	102.3	795.0	127.0	0.95	193.2	16.0	0.45	1.5	1.17
1992	100.3	894.0	127.0	0.95	202.9	17.5	0.45	4.0	1.17
1993	98.3	1,015.0	127.0	0.95	213.0	18.5	0.45	4.0	1.17
1994	96.3	1,034.0	127.0	0.95	223.7	20.0	0.45	6.0	1.17

*Actual values for comparison; ¹Geological Survey of Wyoming, July, 1991; ²millions of barrels; ³billions of cubic feet (includes vented CO₂); ⁴billions of cubic feet, based on Exxon's estimate that the average helium content in the gas processed at Shute Creek is 0.5 percent; ⁵millions of tons; ⁶millions of tons of uranium ore (not yellowcake); ⁷millions of pounds of yellowcake (U₃O₈), (unknown between 1981-1986 because it was reported only as taxable valuation; estimates for 1989-1994 are based on company information); ⁸millions of tons (prior to 1989, converted from gallons of sulfur produced at gas processing plants as reported to the Wyoming Oil and Gas Conservation Commission).

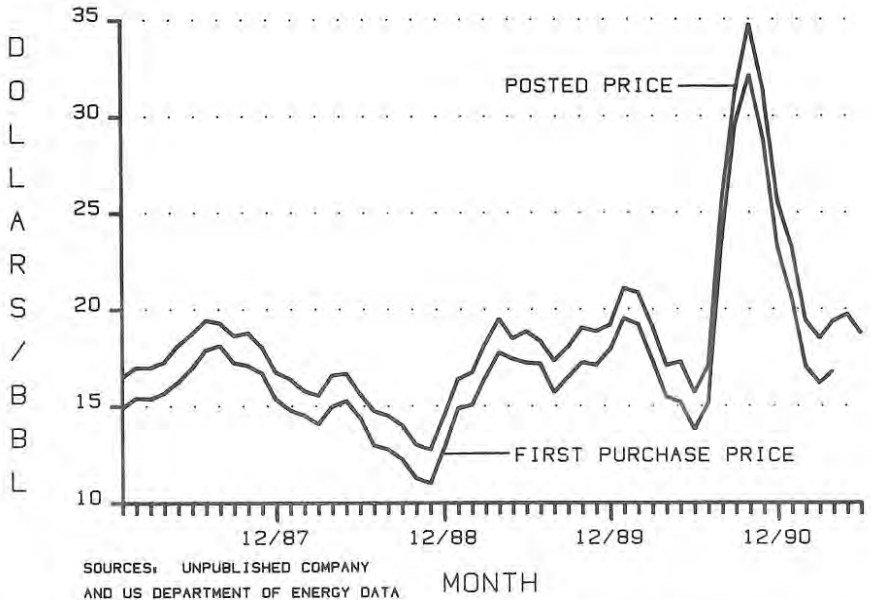


Figure 2. WYOMING CRUDE OIL PRICES AVERAGED BY MONTH (1987 TO PRESENT).

Table 3. PRODUCTION HISTORY OF SELECTED WYOMING MINERAL COMMODITIES¹.

	1982	1983	1984	1985	1986	1987	1988	1989	1990
Bentonite ²	2.35	2.18	3.08	2.59	1.82	2.16	2.32	2.22 ⁶	2.43 ⁶
Clay ⁴	15.7	36.4	59.6	35.9	23.2	1.31	61.1	23.6 ¹	NA
Decorative Stone ²	0.05	0.07	0.08	0.09	0.07	0.06	0.07 ⁷	0.06 ⁶	0.06 ⁶
Dolomite ²	0.61	0.66	0.86	0.87	0.81	0.46	0.19 ⁶	0.15 ⁶	0.21 ⁶
Feldspar ⁴	0.17	----	----	----	----	----	----	2.0 ¹	NA
Gypsum ²	0.26	0.33	0.33	0.35	0.41	0.35	0.40 ⁷	0.20 ⁶	0.44 ⁶
Iron Ore ²	3.28	2.48	----	----	----	----	----	minor ⁸	minor ⁸
Leonardite ⁴	----	----	----	----	----	----	----	----	41.7 ^{1,6}
Limestone ^{2,5}	0.59	0.56	0.65	0.32	0.33	0.32	0.64	0.60 ⁶	1.37 ⁶
Sand and Gravel ^{2,3}	6.24	6.72	8.31	6.40	5.01	4.12	3.15	6.46 ⁶	6.11 ⁶
Shale ⁴	----	----	20.3	14.7	9.88	49.0	50.2 ⁶	1.8 ¹	43.5 ^{1,6}
Sodium Sulfate ⁴	3.17	3.19	3.25	2.71	2.03	----	2.10 ⁶	3.2 ¹	1.9 ^{1,6}

Sources: ¹Ad Valorem Tax Division, unless otherwise noted. ² Millions of short tons. ³ Includes ballast, scoria, and limestone used for aggregate. ⁴ Thousands of short tons. ⁵ Includes 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, July, 1991.

OIL AND GAS UPDATE

by Rodney H. De Bruin, Oil and Gas Division Head, Geological Survey of Wyoming

In late May, Governor Sullivan, on the advice of the Wyoming Natural Gas Pipeline Authority, decided not to make a \$250 million low-interest State loan to Kern River Pipeline. The loan ultimately failed when Kern River rejected some of the State's terms.

The loan negotiations and the efforts of the Wyoming Natural Gas Pipeline Authority, however, focused national attention on Wyoming's very large gas resources and on the competitive price of Wyoming gas. Consequently, gas producers have already signed contracts to transport over 500 million cubic feet of Wyoming gas per day through the Kern River Pipeline. The capacity of the pipeline is 700 million cubic feet of gas per day.

In late June, work began on the 67 miles of the Kern River pipeline that is in Wyoming. Crews began surveying the route, began hauling pipe to storage sites in Uinta County, and began building a compressor station in Lincoln County. Kern River will have an office in Evanston after the pipeline is completed and will employ

six to 12 permanent workers there. The pipeline is scheduled for completion by the end of 1991.

Another pipeline was proposed this quarter as a joint project by KN Energy and Tom Brown Inc. This pipeline will enable several natural gas producers in the Wind River Basin to market their gas through KN Energy's interstate pipeline system. The 80-mile-long pipeline would initially gather up to 30 million cubic feet of gas per day from Fuller Reservoir, Pavillion, Muddy Ridge, and Poison Creek Fields.

In other pipeline news, the U.S. Bureau of Land Management issued Exxon a right-of-way for a pipeline that will transport carbon dioxide from Bairoil to Hartzog Draw Field in the Powder River Basin. The 155-mile pipeline initially will carry 50 million cubic feet per day of carbon dioxide for use in an enhanced oil recovery project at Hartzog Draw Field.

Amoco and Pacific Gas and Electric each announced plans to drill additional natural gas wells in southwestern Wyoming. Amoco plans to drill 72 new wells in Sweetwater and Lincoln Counties while Pacific Gas and Electric plans to drill 59 new natural gas wells in Lincoln County. Both companies have received Federal approvals. FMC Corp., which is a partner in the Pacific Gas and Electric wells, may use some of the gas at their trona mine in the Green River Basin. The new gas from the Pacific Gas and Electric project will be eligible for a tight gas sands tax credit. Natural gas that is produced from these two projects will supply part of the increased demand for Wyoming natural gas when the Kern River Pipeline and the Northwest Pipeline expansion (*Wyoming Geo-notes No. 30*) are completed.

Union Pacific Resources Co. also has plans to increase exploration and development drilling in southwestern Wyoming. The company budgeted \$46 million for nine wildcat wells and 50 development wells for the remainder of this year. These wells, along with the wells planned by Amoco and Pacific Gas and Electric, should increase Wyoming's daily rig count, which has oscillated around 30 for the first six months of 1991 (Figure 3).

The Federal Energy Regulatory Commission (FERC) is reviewing a recommendation made by the Wyoming Oil and Gas Conservation Commission to designate the Blair, Baxter, and Frontier as tight gas formations in portions of southwestern Wyoming. FERC is considering a tight gas designation for the Frontier in parts of T26N, R112-113W; T27N, R112W; and T28N, R113W; for the Baxter in parts of T26N, R112-113W; T27N, R112-113W; T28N, R112-113W; and T29N, R113W; and for the Frontier and Blair in identical areas in parts of T18N, R97-98W; and T19N, R97-98W. If FERC approves these recommendations, gas production from the tight formations in these areas will be eligible for a tax credit.

Lease sales in the State did fairly well during the second quarter of this year although total revenue has dropped off somewhat compared to sales held during the fourth quarter of 1990 and the first quarter of 1991 (Table 4). The U.S. Bureau

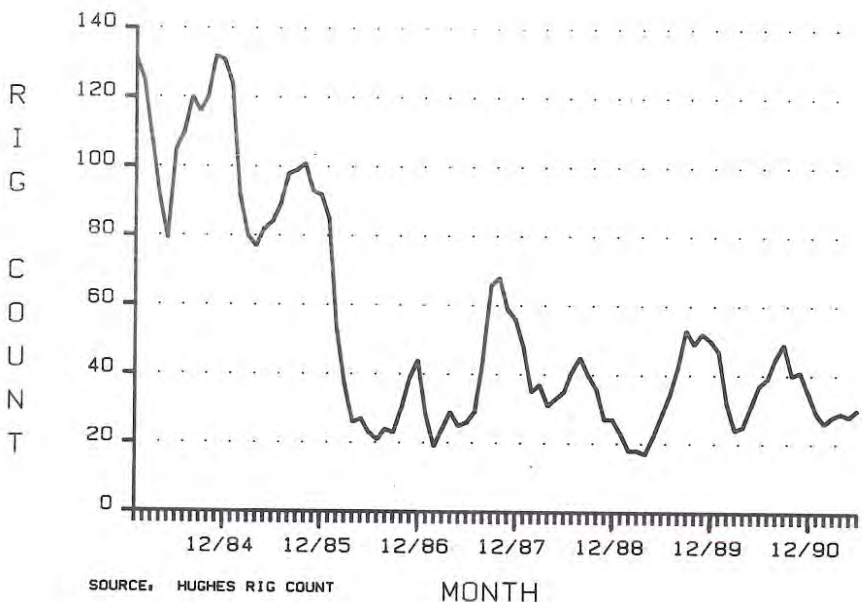


Figure 3. WYOMING DAILY RIG COUNT AVERAGED BY MONTH (1984 TO PRESENT).

of Land Management's (BLM's) April sale had a high per-acre bid of \$170 by Plains Petroleum Operating for a 640-acre tract that covers section 12, T12N, R94W. The parcel is just east of State Line Field.

The high per-acre bid at the BLM's June sale was \$275 made by Samedan Oil Corp. for a 940.7-acre parcel that includes parts of sections 17, 29, 32, and 34, T37N, R75W. The tract is near the north end of Sand Dunes Field. Maurice W. Brown bid \$235 per acre for a 154.68-acre tract that includes lots 5, 6, 7, and 9 of section 7, T53N, R68W, in Prairie Creek Field.

The high per-acre bid at the State Land and Farm Loan Office's May sale was only \$77. Four G Oil Co. made the high bid for a 76.33-acre tract that covers the N/2 NW section 31, T55N, R67W. The tract is a mile southeast of Minnelusa oil production at Carr Creek Field and a mile northwest of Minnelusa oil production at Little Missouri Field.

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 second quarter of 1991. Activities related to

Table 4. FEDERAL AND STATE COMPETITIVE OIL AND GAS LEASE SALES IN WYOMING.

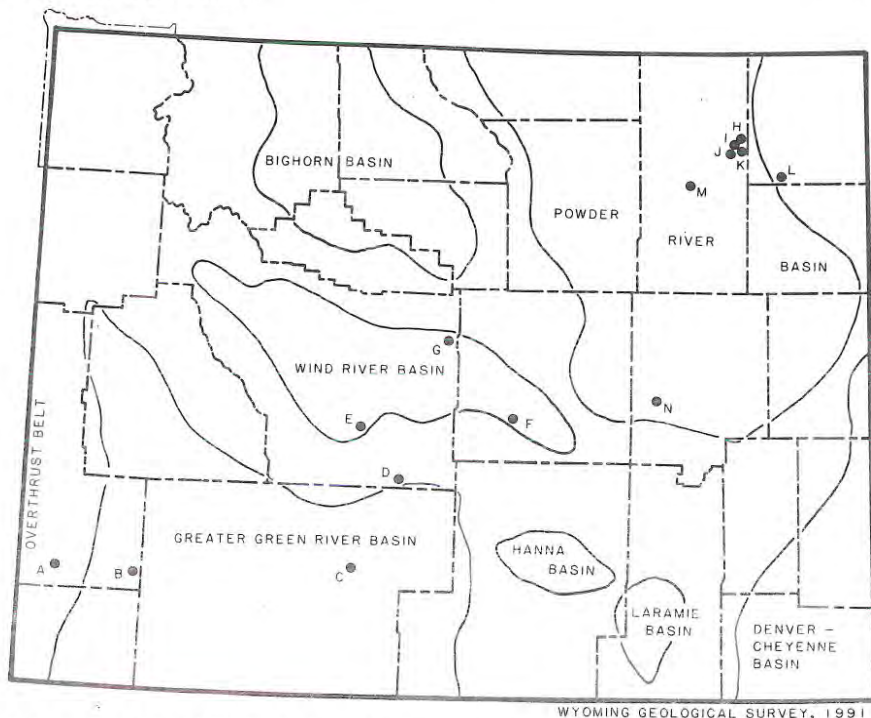
BLM SALES							STATE SALES								
Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre	Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
1987							1987								
TOTAL	\$15,724,159	727	646	197,422	177,960	\$ 88.36	\$6,555.00	TOTAL	\$2,526,567	1,200	579	511,638	244,740	\$10.32	\$2,300.00
1988							1988								
TOTAL	\$27,669,861	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	\$2,163,998	513	218	399,790	138,909	\$15.58	\$275.00	March	\$668,282	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	\$2,590,072	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	69,852	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

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

horizontal drilling and coalbed methane are discussed in separate sections. The letters preceding discussions below refer to locations on Figure 4.

A. Exxon Corp. moved in rigs to drill two 15,000-foot Bighorn Dolomite tests in the Overthrust Belt. The 1 Boxer Jack Unit well is currently drilling in NW SE section 4, T21N, R118W and the 2 Collett Creek Unit well is drilling in NE NW section 30, T21N, R118W. Both wells are in the vicinity of Exxon's Collett Creek Field. Collett Creek Field had produced over 77,000 barrels of oil and nearly 321 million cubic feet of gas through March of 1991. The one-well field produces from the Bighorn and the well has produced for only one year. These two new wells bring the number of active rigs in the Wyoming portion of the Overthrust Belt to three, the highest rig activity in that region for some time.

B. Amoco Production completed two Dakota wells in Bruff Field. The 15 Seven Mile Gulch well in SE NE section 21, T20N, R112W flowed 12.7 million cubic feet of gas, 120 barrels of condensate, and 30 barrels of water per day. The 1 Champlin 122A well in SE NE section 29, T20N, R112W flowed 17.1 million cubic feet of gas and 26 barrels of condensate per day. Just to the south in Bruff Field, Texaco Inc. completed the 2 Government-Donley NCT-2 well in SW SE section 2, T18N, R112W. The Texaco well flowed 4.6 million cubic feet of gas per day from the Frontier.



WYOMING GEOLOGICAL SURVEY, 1991

Figure 4. OIL AND GAS EXPLORATION AND DEVELOPMENT ACTIVITY IN WYOMING DURING THE SECOND QUARTER OF 1991.

C. Presidio Oil Co. completed a wildcat well, the 1-112 Amoco-UPRR, in W/2 NW section 11, T22N, R96W. The well flowed 1.2 million cubic feet of gas and 50 barrels of condensate per day from the Lewis Shale. Presidio may drill up to four additional wells to delineate the productive area and has already staked a location to evaluate the Lance, Lewis, and Almond one mile southeast of the discovery.

D. Wold Oil Properties discovered gas in the Lance with their 2-27 Crooks Creek-Federal well in NW SW section 27, T27N, R92W. The new discovery flowed 887,000 cubic feet of gas per day from an acidized and a nitrogen-fractured, 20-foot zone. The nearest Lance production is nearly 30 miles southwest at Hay Reservoir Field.

E. Pacific Enterprises Oil Co. recovered oil on a drillstem test of the Phosporia at their 12-29 Dishpan-Federal well in SW NW section 29, T31N, R95W. The one-hour test recovered 160 feet of mud-cut-oil and 240 feet of water while the sample chamber held 860 cubic centimeters of oil and 1,290 cubic centimeters of water.

F. Amerada Hess completed an offset to their discovery well at Saddle Rock Field. The new well, the 27-21 Saddle Rock Unit, had a bottom-hole location in NE NW section 27, T33N, R86W, and pumped 452 barrels of oil and 759,000 cubic feet of gas per day from the Muddy. The discovery well, which was completed in NW NE section 27, T33N, R86W, flowed 67 barrels of oil and 289,000 cubic feet of gas per day from the Muddy.

G. The 2 Moneta Hills Unit well in SW SW section 30, T38N, R89W, flowed 157,000 cubic feet of gas and 34 barrels of condensate per day from the Fort Union Formation. This is the second Fort Union producer in Moneta Hills Field that has been completed by Wagner & Brown within the last year.

H. Maxus Exploration completed a new Minnelusa well in Alpha Field. Their 1 Alpha Unit well in SW SW section 1, T51N, R69W, pumped 653 barrels of oil and three barrels of water per day. Alpha Field has produced over two million barrels of oil since its discovery in 1987.

I. Yates Petroleum discovered Minnelusa oil at their offset to the discovery well at Elvira Field. The new well, the 1 East Elvira, in NE NE section 22, T51N, R70W, pumped 120 barrels of oil per day.

J. Pacific Enterprises Oil Co. discovered oil in the Minnelusa at their 24-30 Tanner-Federal wildcat well in SE SW section 30, T51N, R70W. The well pumped 580 barrels of oil per day. The new discovery is about a mile west of Minnelusa oil production at Dutch Field.

K. Flying J Exploration & Production completed two new offset wells to a discovery well that was completed earlier this year. The 9-25 Thompson well in NW SE section 25, T51N, R69W, offsets the discovery well to the east. It pumped

613 barrels of oil per day from the Minnelusa. The 15-25 Thompson well in SW SE Section 25, T51N, R69W, pumped 281 barrels of oil per day from the Minnelusa and offsets the discovery well to the south.

L. L & W Group completed a Fall River discovery, the 1 Federal well, in SW NW section 32, T49N, R66W. The new discovery pumped five barrels of oil and 17,000 cubic feet of gas per day.

M. Nicor Oil & Gas completed the fourth producer in Mallard Field. The 22-34 Merganser-Federal well in SE NW section 34, T49N, R72W, pumped 540 barrels of oil per day from the Minnelusa. The field has produced over 139,000 barrels of oil since the discovery well was completed in July, 1990.

N. W.A. Moncrief Jr. completed the second well in Popskull Field. The new well, the 28-2 Popskull, is in NW NE section 28, T35N, R75W. This well pumped 35 barrels of oil and 2,000 cubic feet of gas per day from the Muddy. In about two years of production, the discovery well has produced nearly 41,000 barrels of oil and 18.6 million cubic feet of gas from the Muddy.

Horizontal Drilling

During the second quarter of 1991, the following significant activities related to horizontal drilling occurred. The letters preceding the discussions below refer to locations on Figure 5. The discussions are based on company data and on information compiled and published by Petroleum Information.

A. Horizontal drilling in the Niobrara continues in and around Silo Field. Exxon tested their 1H Blevins Oil Unit well drilled from a surface location in SE SW section 6, T15N, R64W. The well flowed at a rate of 1,008 barrels of oil and 501,000 cubic feet of gas per day. Exxon also produced nearly 11,000 barrels of oil from the well during drilling. Gerrity Oil and Gas tested their 4-9H State well, which was drilled from a surface location in NE SE section 4, T15N, R64W. Oil flowed at a calculated rate of 2,026 barrels per day during a 12-hour test. Union Pacific's 2H Leroy Goertz 14-3 well, which was drilled from a surface location in SW SW section 3, T15N, R64W, produced an average of 204 barrels of oil and 72,000 cubic feet of gas per day during 22 days of production in March, 1991. Snyder Oil staked a location for a horizontal Niobrara test at a surface location in SW SW Section 19, T16N, R64W. Test results of Snyder's 10-21 Hutton well in SW NW section 21, T16N, R64W, are still unavailable. Silverado Oil staked a location for a horizontal Niobrara test at a surface location in SE SE Section 18, T16N, R64W. Silverado plans to reenter the 1-18-16-H State well and to begin building the angle at 7,635 feet for a horizontal test.

B. Meridian Oil plans to drill a horizontal Niobrara test at a surface location in SE SW Section 29, T14N, R68W. The location is about 23 miles west of Silo Field and is the company's first wildcat in the horizontal Niobrara play.

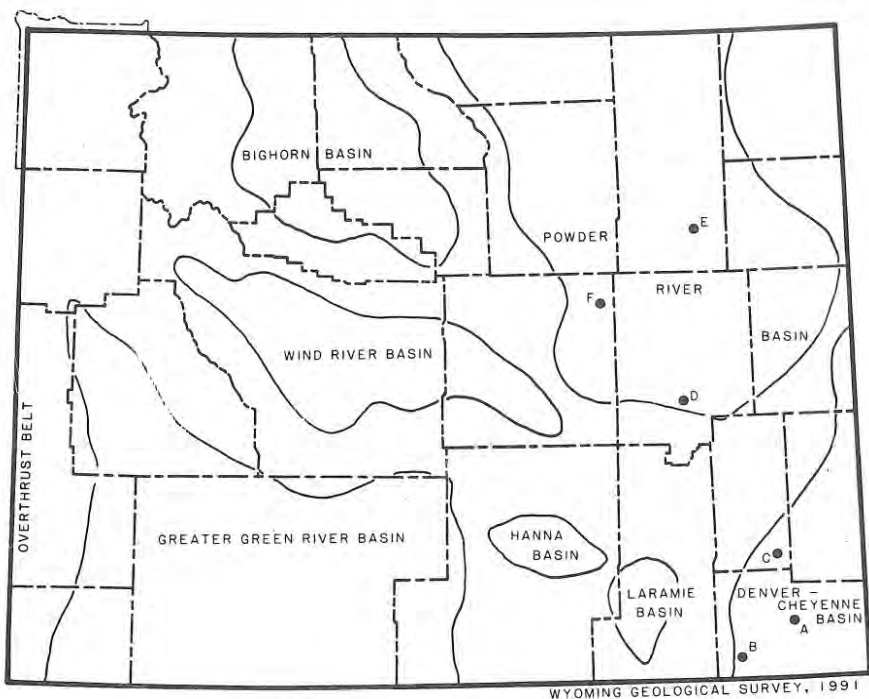


Figure 5. HORIZONTAL-DRILLING ACTIVITY IN WYOMING.

C. Union Pacific Resources completed their 1 H Helbaum 11-11 well as a dry hole. The well was about 12 miles south of Chugsprings Field, an abandoned Niobrara and Codell producer.

D. Amoco still has not started their horizontal well to test the Niobrara and Frontier in NE SW section 25, T33N, R72W.

E. Harvey E. Yates Co. still has not released any test results on their horizontal Niobrara test in SE NW section 19, T44N, R71W.

F. GLG Energy still has not released details on their horizontal Niobrara test in SW NE section 6, T38N, R77W and no activity has occurred at their location in NW NE section 3, T39N, R78W.

Coalbed Methane

During the second quarter of 1991, the following significant activities related to coalbed methane occurred. The letters preceding the discussion below refer to locations on Figure 6. The discussions are based on company data and on information compiled and published by Petroleum Information.

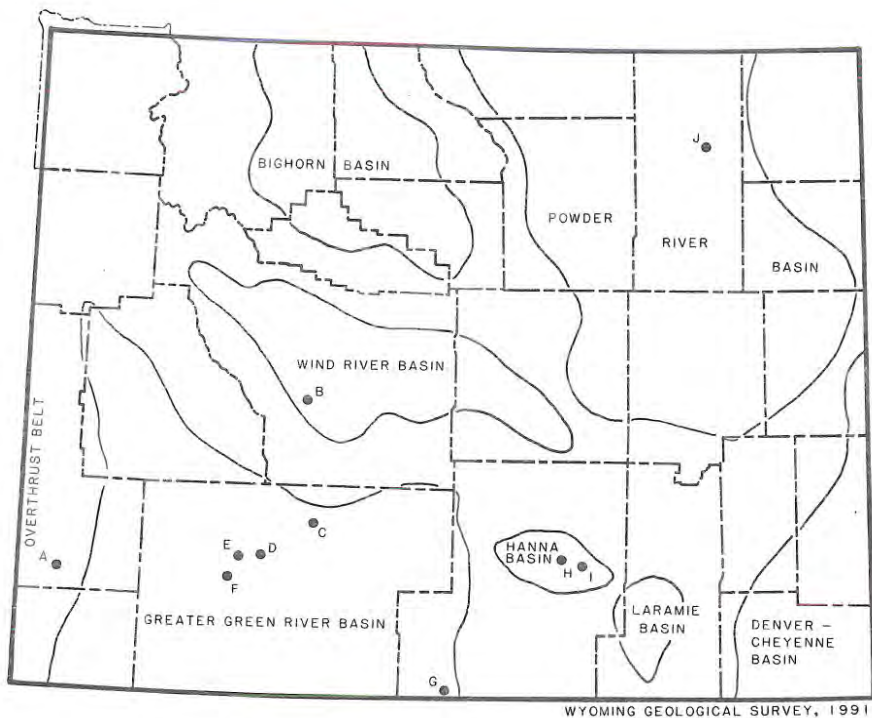


Figure 6. COALBED METHANE ACTIVITY IN WYOMING.

A. DeKalb Energy abandoned their location for a test of coal beds in the Upper Cretaceous Adaville Formation. The location was in SE NW section 36, T22N, R117W.

B. Barker and others (1991) of the U.S. Geological Survey reported a total coalbed methane content of 100 cubic feet per ton from coal beds cored in the Mesaverde Formation from depths of 470 to 590 feet at a well in SE section 32, T2S, R2E. In the area of the well, the aggregate thickness of coal beds reportedly is up to 30 feet. Fifteen miles to the east, the aggregate thickness of coal beds is around 100 feet at about 3,500 feet depth. Barker and others (1991) believe the coalbed methane potential in more deeply buried coals in this area should be good.

C. Cockrell Oil staked a location for a coalbed methane test in the Fort Union Formation in NW NW section 15, T24N, R98W. The test is projected to 5,400 feet in the Lance Formation.

D. Triton Oil and Gas Corp. is still awaiting a decision by the BLM before they can continue with development of methane from Mesaverde coals.

E. No details are available on Buttonwood Petroleum's two Mesaverde coalbed methane wells in sections 19 and 21, T22N, R104W. Both wells were drilled in 1990, but there has been no report of any production from either well.

F. Buttonwood Petroleum ran production casing at their 9-5 UPRC well in C SE section 9, T20N, R105W. The well was drilled to test the coalbed methane potential of Mesaverde coals. Buttonwood has another location staked in the SE SW of the same section.

G. Fuel Resources Development is now producing methane and water from 10 wells in the Wyoming portion of Dixon Field. All of the wells are in sections 1, 2, 11, and 12, T12N, R90W. The wells are producing from Almond Formation coal beds. The company plans to drill additional wells in the area.

H. Conquest Oil's coalbed methane test in the Ferris Formation in section 23, T23N, R83W, was completed as a dry hole and their location in section 30, T24N, R83W, was abandoned.

I. Also in the Hanna Basin, Metfuel is still dewatering their two Hanna Formation coalbed methane wells in sections 3 and 11, T23N, R81W. Metfuel has locations staked for nine additional coalbed methane tests in T23N, R81W.

J. Betop Inc. and Martens and Peck Operating are producing coalbed methane from 10 Fort Union wells in Rawhide Butte Field. A well operated by National Coop Refining and a well operated by Martens and Peck are currently shut-in. Rawhide Butte has produced nearly 500 million cubic feet of gas since it was discovered in 1989.

Huff 'n' Puff Carbon Dioxide Projects

During the 7th Wyoming Enhanced Oil Recovery Symposium in Casper, Wyoming, on May 1-2, 1991, Harry Deans of the University of Wyoming and Robin Passmore of Amoco Production reported the results of a number of carbon dioxide stimulation (huff 'n' puff) projects in Wyoming. The letters preceding the discussions below refer to locations on Figure 7. The discussions are summaries of the results that were reported at the Symposium in Casper.

A. Wold Oil in cooperation with the Enhanced Oil Recovery Institute (EORI) injected the Dakota twice at the Crooks Gap #4 well in Crooks Gap Field. The first cycle of injection produced 3,800 barrels of oil and the second cycle produced an estimated 6,000 barrels of oil so far. The production has stabilized at 22 barrels of oil per day.

B. Amoco cooperated with EORI on a one-well test of the 2nd Cody sand in the Cody #37 well at Beaver Creek Field. The incremental oil that was produced in this well was less than 100 barrels.

C. Marathon cooperated with EORI on a one-well test of the Frontier Formation in the Washakie 11-33 well at Grass Creek Field. There was less than 100 barrels of incremental oil produced in this well.

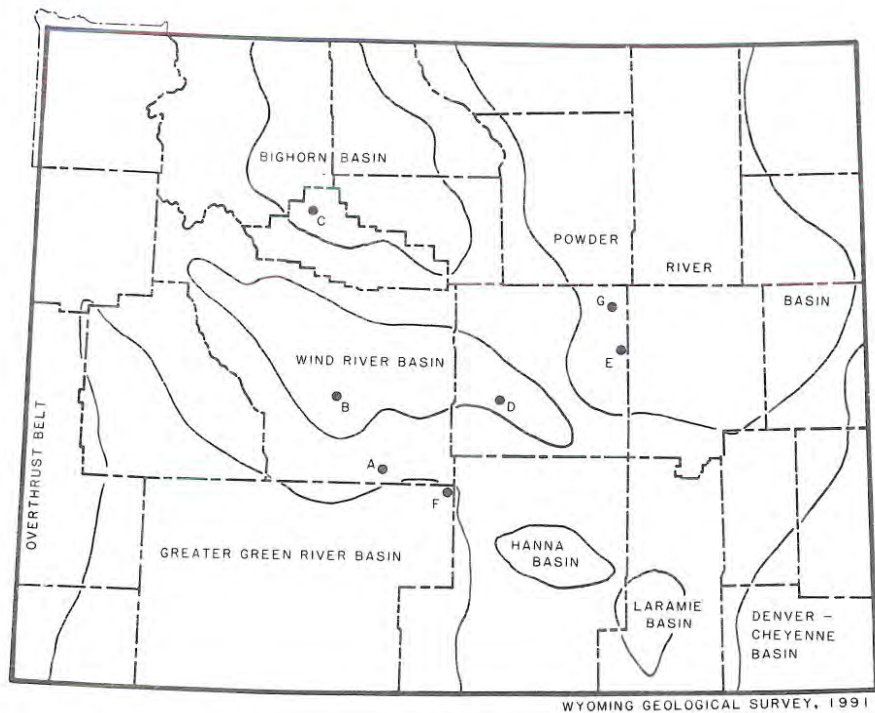


Figure 7. HUFF 'N' PUFF CARBON DIOXIDE PROJECTS.

D. Timberline Production Company cooperated with EORI on a one-well test of the Muddy Sandstone in the Morningstar 1-36 well in Grieve North Field. The well has produced less than 200 barrels of incremental oil.

E. G.G. Nicolaysen cooperated with EORI on a one-well test of the Dakota in the Cole Creek #42X-26G well in Cole Creek Field. There were problems with the pumping system, but the well has produced 1,500 barrels of oil since the stimulation and oil cut has improved substantially.

F. Amoco injected seven wells at Lost Soldier and Wertz Fields. Three tests were in the Darwin Sandstone and Madison Limestone interval, three tests were in the Flathead Sandstone, and one test was in the Tensleep Sandstone. Four of the tests were considered economic, two would have been economic if mechanical failures had not occurred, and one had questionable data because of operational problems. Production of incremental oil at six of the test wells ranged from 925 to 6,600 barrels and totaled 20,635 barrels.

G. Amoco injected three wells in Salt Creek Field. Two tests were in the 2nd Wall Creek Sandstone and one test was in the 1st Wall Creek Sandstone. One of the 2nd Wall Creek Sandstone tests had produced 4,500 barrels of incremental oil through mid-April. The other two tests mobilized tertiary oil, but the volume was

impossible to determine because of severe leakoff of carbon dioxide to other wells. Amoco plans four more tests in Salt Creek Field during 1991.

Reference cited

Barker, C.E., Johnson, R.C., Pawlewicz, M.J., Crysedale, B.L., and Clark, A.C., 1991, Coal-bed methane show within the Wind River Indian Reservation enhances gas prospects in deeper portions of the Wind River Basin, Wyoming (abs.): American Association of Petroleum Geologists Bulletin, v. 75, no. 6, p. 1122-1123.

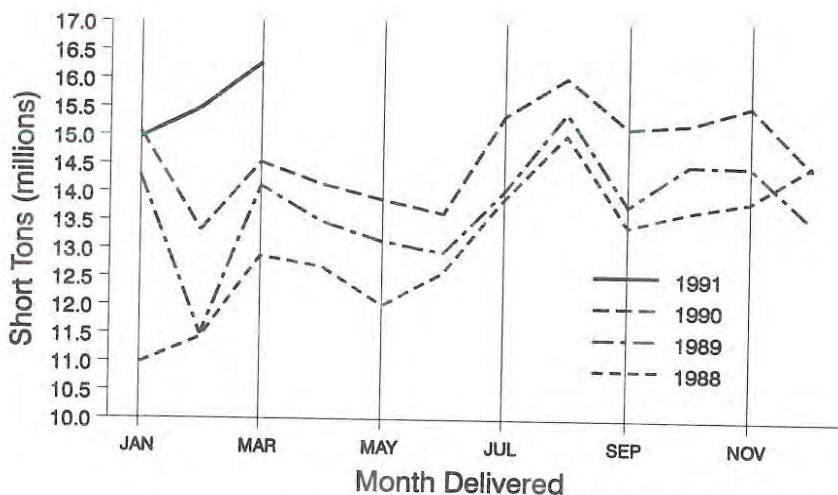
COAL UPDATE

by Richard W. Jones, Coal Division Head, Geological Survey of Wyoming

Wyoming coal production for the first half of 1991 appears to be well ahead of last year's record pace. Based on coal delivery reports from electric utility companies in the first quarter of 1991, about 3.8 million tons more coal were produced during the first three months of this year than for the same period last year (Figure 8 and Table 5). If this trend continues the rest of the year and if unreported tonnage is the same as in 1990, total coal production for 1991 could be 9-10 million tons or about 5 percent greater than last year. Supporting evidence for record production in 1991, mid-year figures from the Energy Information Administration (1991a), based on railcar loadings, indicate that production through June 15, 1991, was about 93.5 million short tons, an increase of about 9.6 million short tons from the 83.9 million tons reported for the same period in 1990. We have increased our earlier projection of 187.6 million tons of production in 1991 (Table 2) to 193.2 million tons. In addition, we have increased our 1992-1994 estimates to show a five percent a year increase in produced tonnage.

Recently available data on the distribution and utilization of coal produced in 1990 (Energy Information Administration, 1991b) indicates that Wyoming coal was used in 30 different states and five other nations (Figure 9). Texas continued as the largest consumer of Wyoming coal in 1990, followed by Wyoming, Kansas, Oklahoma, Iowa, and Indiana. Four states consumed more than half of Wyoming's coal; nine states consumed almost 80 percent of Wyoming's coal.

In 1990, electric utility companies located in 22 different states and five other countries used 97.4 percent of Wyoming's total coal production to fuel steam-electric generating plants (Figure 10) (Energy Information Administration, 1991b). Almost 0.7 million tons of the coal was exported to electric utility companies in Mexico, Canada, Spain, Japan, and Taiwan. Seventeen different states used Wyoming coal to fuel industrial boilers and seven different states used Wyoming coal for residential and commercial heating. About 1.7 million tons of the 4.8 million tons used in the "industrial" and "residential/commercial" categories went



Geological Survey of Wyoming, 1991

Figure 8. 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).

to Wyoming coal users, mostly other mineral-related industries. Four of the five trona plants in southwestern Wyoming used coal to generate steam for use in their refining process and in some cases, to produce electricity (cogeneration); many of the State's bentonite plants used coal in their refining process; and Mountain Cement Company used coal in their Laramie plant (Figure 11). Additional coal was used in FMC Wyoming Corporation's synthetic coke plant in Lincoln County and in a sugar beet processing plant at Torrington.

As in 1989, about 86 percent of Wyoming's coal was shipped out of the State in 1990, including the 0.7 million tons that was exported out of the country. Ironically, 164,500 tons of coal used in Wyoming was imported from Colorado, Illinois, Montana, Pennsylvania, Texas, and Utah. Most of this coal was used for industrial purposes. In many cases, this imported coal is used in Wyoming because it is the closest coal available for the lowest price. In other cases, the imported coal may have specific properties or characteristics not presently available in Wyoming.

According to the Energy Information Administration (1991b) and the Wyoming Department of Transportation, transportation of Wyoming coal in 1990 (Figure 12) was primarily by railroads (87 percent); coal transported by barge on rivers and lakes refers to coal that reached its final destination by barge after originating on a railroad. The 168.7 million tons transported by rail in 1990 is 10.4

Table 5. COAL DELIVERIES BY MONTH FROM WYOMING MINES¹.

	1987		1988		1988		1989		1990		1991	
	MONTHLY	CUMULATIVE	MONTHLY	CUMULATIVE	MONTHLY	CUMULATIVE	MONTHLY	CUMULATIVE	MONTHLY	CUMULATIVE	MONTHLY	CUMULATIVE
JANUARY	12,085,570	12,085,570	10,976,860	10,976,860	14,283,020	14,283,020	15,059,530	15,059,530	14,960,450	14,960,450	14,960,450	14,960,450
FEBRUARY	10,315,680	22,401,250	11,431,380	22,408,240	11,488,140	25,771,160	13,328,290	28,387,820	15,480,110	30,440,560	15,480,110	30,440,560
MARCH	10,436,610	32,837,860	12,871,090	35,279,330	14,124,330	39,895,490	14,535,270	42,923,090	16,278,870	46,719,430	16,278,870	46,719,430
APRIL	10,429,180	43,267,040	12,694,660	47,973,990	13,489,450	53,384,940	14,155,470	57,078,560				
MAY	10,619,470	53,886,510	12,017,500	59,991,490	13,149,170	66,534,110	13,882,590	70,961,150				
JUNE	11,953,650	65,840,160	12,595,480	72,586,970	12,943,350	79,482,460	13,649,070	84,610,220				
JULY	12,850,240	78,690,400	13,905,670	86,492,640	14,043,350	93,525,810	15,368,280	99,978,500				
AUGUST	13,460,470	92,150,870	15,041,090	101,533,730	15,428,210	108,954,020	16,046,910	116,025,410				
SEPTEMBER	12,651,550	104,802,420	13,433,610	114,967,340	13,795,760	122,749,780	15,166,020	131,191,430				
OCTOBER	12,248,080	117,050,500	13,696,190	128,663,530	14,523,480	137,273,260	15,244,760	146,436,190				
NOVEMBER	12,340,720	129,391,220	13,889,890	142,553,420	14,507,130	151,780,390	15,569,280	162,005,470				
DECEMBER	13,008,300	142,399,520	14,540,510	157,093,930	13,527,880	165,308,270	14,479,970	176,485,440				
TOTAL TONNAGE REPORTED		142,399,520		157,093,930		165,308,270		176,485,440				
TOTAL TONNAGE NOT REPORTED		4,089,128		6,494,270		5,831,734		7,521,261				
TOTAL TONNAGE PRODUCED ²		146,488,648		163,588,200		171,140,004		184,006,701				

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

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

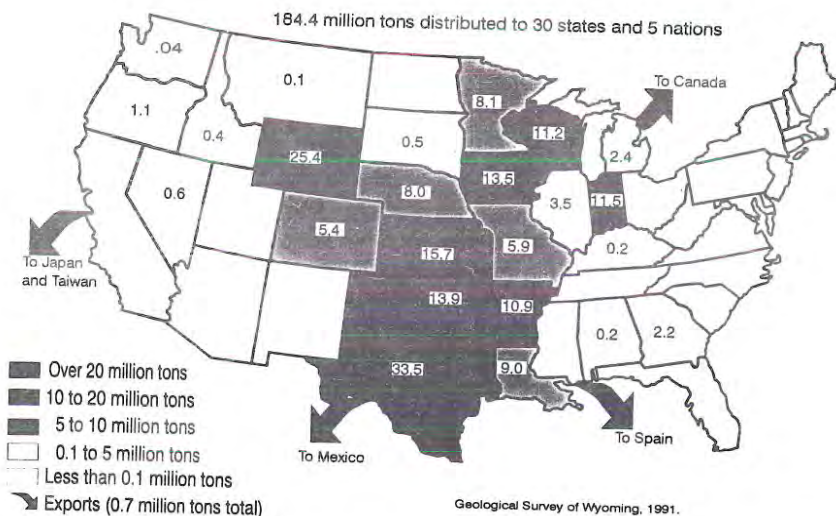
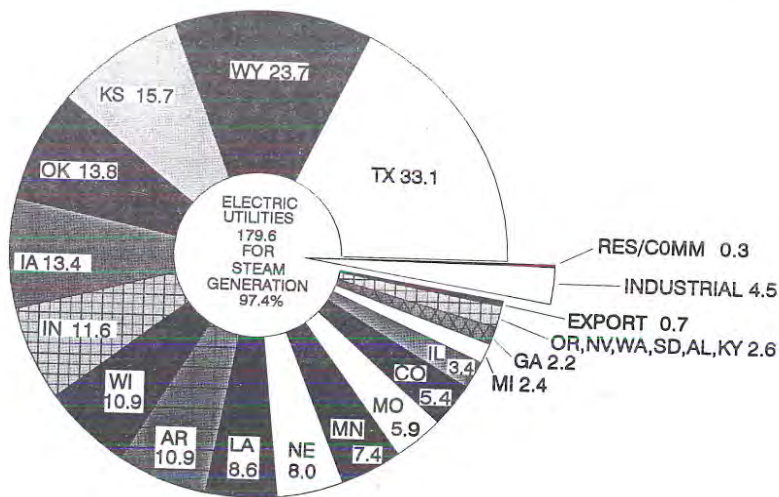


Figure 9. DISTRIBUTION OF WYOMING COAL IN 1990, IN MILLIONS OF TONS (NOTE: THE ENERGY INFORMATION ADMINISTRATION'S (1991b) REPORT SHOWS 0.4 MILLION TONS MORE COAL WAS SHIPPED IN 1990 THAN WHAT THE WYOMING STATE INSPECTOR OF MINES SHOWS AS 1990 PRODUCTION. THIS IS A FUNCTION OF INDEPENDENT ROUNDING AS WELL AS THE TIMING OF SHIPMENTS).



GEOLOGICAL SURVEY OF WYOMING, 1991

Figure 10. UTILIZATION OF WYOMING COAL IN 1990, IN MILLIONS OF TONS (NOTE: THE ENERGY INFORMATION ADMINISTRATION'S (1991b) REPORT SHOWS 0.4 MILLION TONS MORE COAL WAS SHIPPED IN 1990 THAN WHAT THE WYOMING STATE INSPECTOR OF MINES SHOWS AS 1990 PRODUCTION. THIS IS A FUNCTION OF INDEPENDENT ROUNDING AS WELL AS THE TIMING OF SOME SHIPMENTS).

EXPLANATION

- ★ Coal-Fired Electrical Generating Plant
- Trona Plant
- ▲ Bentonite Plant
- Synthetic Coke Plant
- ◆ Sugar Beet Plant
- Cement Plant
- UP Union Pacific R.R.
- CNW Chicago and North Western Transportation Co.
- BN Burlington Northern, Inc.
- WC Wyoming Colorado Railroad
- PP&L Pacific Power and Light
- Unit Coal Train Route

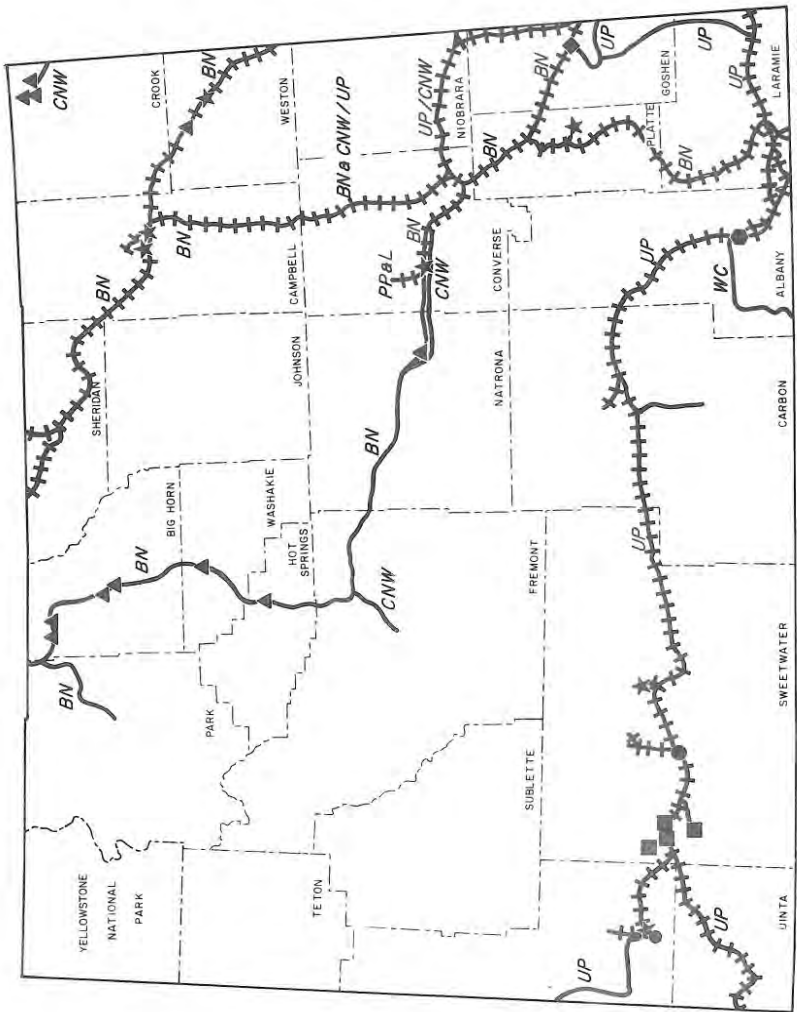
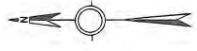


Figure 11. RAILROAD ROUTES AND MAJOR COAL USERS IN WYOMING.

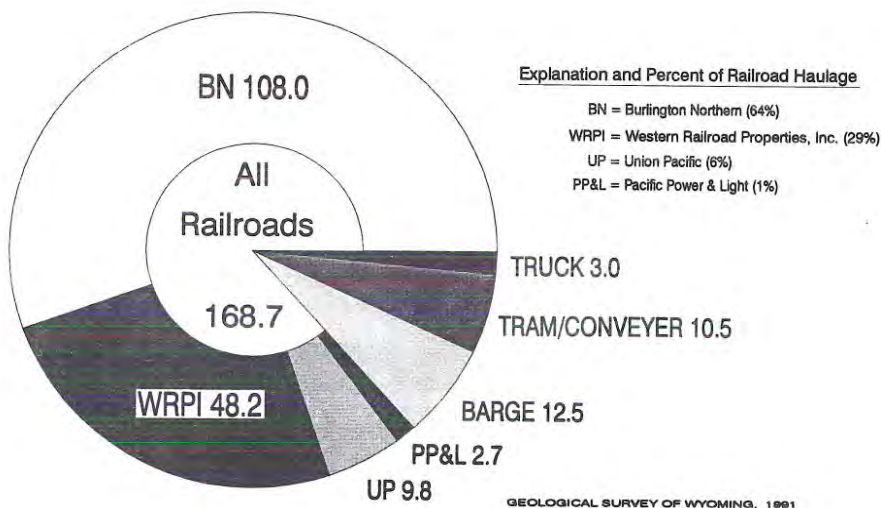


Figure 12. TRANSPORTATION OF WYOMING COAL IN 1990, IN MILLIONS OF TONS (NOTE: COMPILED FROM ENERGY INFORMATION ADMINISTRATION, (1991b) AND ANNUAL REPORTS OF RAILROADS TO THE WYOMING DEPARTMENT OF TRANSPORTATION).

million tons (6.6 percent) greater than the 158.3 million tons transported in 1989. Truck transportation of Wyoming coal in 1990 was 5.1 million tons less than that in 1989 while transportation by tram/conveyer was 5.9 million tons more in 1990 than in 1989.

Burlington Northern Railroad (BN) dominates railroad haulage of Wyoming coal; the company's 108 million tons of coal accounted for about 64 percent of all coal shipped by rail. The amount of coal transported by BN in 1990 was five percent greater (5.5 million tons) than in 1989. Coal shipments on BN are from coal mines in the Powder River Coal Field and exit the field (and the State) to the east, south, and north (Figure 11).

Western Railroad Properties, Inc. (WRPI), which reports tonnages carried by the Chicago and North Western Transportation Company [a C&NW/Union Pacific Railroad Company (UP) joint-venture railroad out of the Powder River Coal Field], carried 5.3 million tons (or 12 percent) more coal in 1990 than in 1989. The 48.2 million tons of coal reported by WRPI accounted for 29 percent of the railroad tonnage in Wyoming.

Southern Wyoming coal fields are served by UP (Figure 11). The 9.8 million tons of coal hauled by UP in 1990 was 0.5 million tons less than that hauled in 1989. UP accounted for about six percent of the railroad tonnage in Wyoming.

Pacific Power and Light Company's (PP&L's) private railroad line between Glenrock Coal Company's mine and the Dave Johnston power plant hauled 2.7 million tons of coal in 1990.

The increased tonnages of coal hauled out of the Powder River Coal Field each year since 1983 have almost been matched by a corresponding increase in the amount of coal transported by the C&NW/UP joint venture (Figure 13), although in recent years BN tonnages have increased at a slightly greater rate than C&NW/UP tonnages. In contrast, coal tonnages hauled from southern Wyoming mines have decreased slightly each year since 1983 and reflect a plateau in coal production from southern Wyoming coal fields.

Of the 182.5 million tons of freight that originated on Wyoming railroads in 1990, about 92 percent of the freight was coal. Over 1.6 million railroad cars were used to haul this coal. Based on the 159 million tons of coal shipped out of Wyoming in 1990 and assuming that the average number of 100-ton coal cars in a coal unit train is about 105, there were approximately 15,143 unit trains of coal that left Wyoming last year. This amounts to about 41 full unit trains leaving the State every day and an equal number of empty unit trains returning.

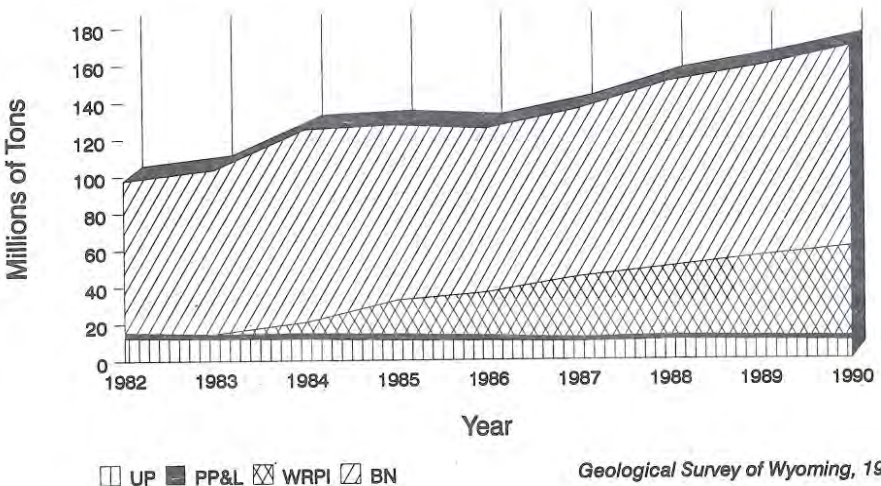


Figure 13. TRANSPORTATION OF WYOMING COAL BY RAILROAD, 1982 TO 1990 (NOTE: COMPILED FROM ANNUAL REPORTS OF RAILROADS TO THE WYOMING DEPARTMENT OF TRANSPORTATION, 1982 THROUGH 1990. SEE FIGURE 12 FOR EXPLANATION OF RAILROAD ABBREVIATIONS).

In other coal developments in the second quarter of 1991, it now appears that some states with a large coal-producing industry are enacting legislation designed to control how the electric power-generating companies in those states will meet the Clean Air Act Amendments of 1990. At issue here are the coal-fired power plants that will be required to reduce stack emissions by January 1, 1995, under Phase I of the Act (*Wyoming Geo-notes No. 29*, pages 20-21). Because many of the power plants "targeted" for emission reduction may opt to purchase low-sulfur western coal instead of installing flue gas "scrubbers" and continuing to burn higher sulfur eastern coals, the legislatures in states such as Ohio, Illinois, Indiana, and Kentucky are preparing bills to protect their state's coal industry. Some states are proposing incentives for utility companies to continue burning eastern coal such as the state paying the costs of scrubbers or coal transportation; tax credits, reduction or other relief from state taxes; or state purchase and ownership of rail cars. In some instances, proposed legislation would mandate the use of scrubbers at specific plants or units; in other cases, a utility company would have to calculate the socioeconomic impacts before switching to out-of-state coal. Most of the eastern coal-producing states are encouraging all the utility companies that burn fossil fuels to submit (and eventually have approved) detailed plans on how the utility is going to comply with the requirements of the Act. In nearly all cases, the proposed legislation would enable utility companies to ultimately pass on the costs of compliance to the consumers.

Developments in western and southwestern Wyoming

The compliance problems at Pacificorp's Naughton power plant near Kemmerer (*Wyoming Geo-notes No. 30*, p. 32), which has led to a dispute over a coal supply contract, continued during the second quarter. The last of three mediators for the dispute was named at the end of May by the U.S. District Court in Cheyenne. The article in *Wyoming Geo-notes No. 30* erroneously reported that there are no flue gas scrubbers at the Naughton plant. Only Naughton Units 1 and 2 are unscrubbed; Naughton Unit 3 is already equipped with a wet scrubber.

Utah Power and Light Company (UP&L), the subsidiary of Pacificorp that operates the Naughton plant, is not only seeking to get the power plant back into compliance, but it is also seeking to either rewrite the current coal supply contract with Pittsburg and Midway Coal Mining Company's (P&M) Kemmerer mine or to eventually terminate the contract. UP&L is also seeking compensation from P&M for coal that was sold to other parties from the mine. UP&L claims that coal from the mine is dedicated entirely to the Naughton power plant.

Industry sources indicate that UP&L recently tested coal from the Powder River Coal Field at the Naughton plant. As a related item, Pacificorp is now using coal from sources other than their company-operated coal mines at many of their power plants.

Developments in the Hanna Coal Field

In the second quarter, no new coal contracts or coal sales were reported. Arch of Wyoming's Medicine Bow mine will provide additional coal to Holly Sugar Company's Torrington sugar beet processing plant (no. 2, Figure 14) for next season's campaign (September, 1991 through February, 1992), but that is through an existing contract. An anticipated bid solicitation for additional spot coal for the Torrington plant did not materialize.

Coal from the Hanna Coal Field has been mentioned as a possible candidate for Tampa Electric Company's coal-testing program this fall at the utility's Big Bend plant near Tampa, Florida (no. 26, Figure 14). The testing program is part of Tampa Electric's efforts to determine how to comply with the 1990 Clean Air Act Amendments.

Developments in the Powder River Coal Field

The Whitney Benefits, Inc. lawsuit over unminable coal in an alluvial valley, which could award the corporation \$140 million (*Wyoming Geo-notes No. 30*, p. 30), appears closer to final settlement. The Federal government's request for a rehearing of the case before either a three-judge appeals court panel or the full 12-judge panel was rejected by the U.S. Court of Appeals in May. The last chance the U.S. Government has to appeal the case is before the U.S. Supreme Court on July 1, 1991, or possibly 30 days from that date.

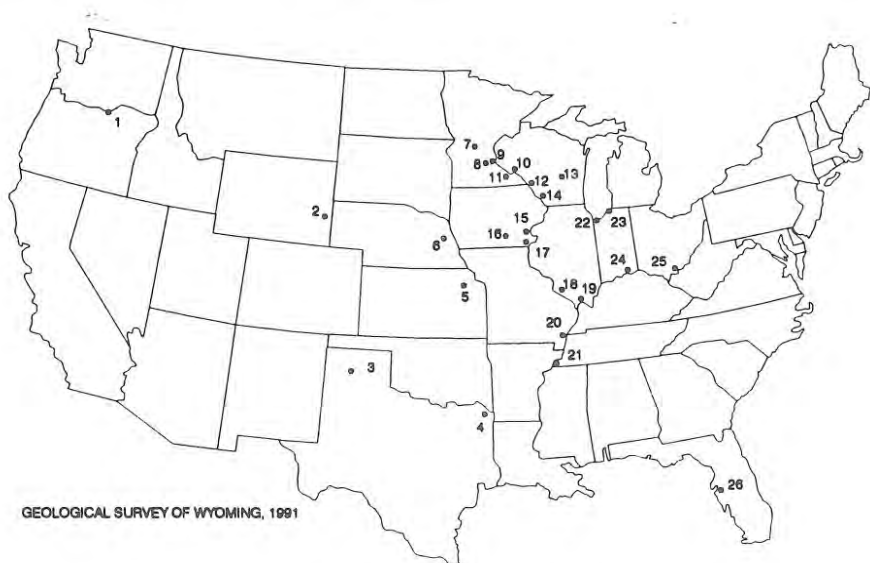


Figure 14. INDEX MAP OF COAL CONTRACTS AND SALES ACTIVITIES INVOLVING WYOMING COAL MINES, NOTED DURING THE SECOND QUARTER OF 1991.

There are apparently no longer plans for construction of a \$50 million polyurethane plant and cogeneration unit north of Sheridan. A joint venture of Perkins Power Company of Sheridan and Petro Oil and Gas, Inc. of California, the plant would have converted the old Acme coal-fired power plant to a 12-megawatt cogeneration unit that combined coal gasification and plastics production. Evidently Perkins Power Company, the owners of the Acme plant, sold its ownership in the plant to American Plastics and Chemicals Company (APAC) of California. APAC announced that they would spend \$5 million to refurbish and renovate the plant this summer. Eventually the coal-fired plant would go back on line as a small electrical generating unit. There is no indication who would supply coal to the plant.

Coal contracts - Powder River Coal Field

Coal purchasing activities during the second quarter of 1991 were numerous, as many spot sales and short term contracts were announced. As in the previous quarter, most of the coal purchased in the second quarter was on the spot market. A large number of coal sales during the second quarter were for either test burns or for blending.

New coal contracts and sales are summarized below:

A) Mobil Coal Producing, Inc.'s Caballo Rojo mine is supplying 850,000 tons of coal to Portland General Electric Company's Boardman, Oregon, power plant (no. 1, Figure 14). Deliveries began in May, 1991, and will continue through December, 1991. Transportation will originate on the Burlington Northern (BN) and terminate on the Union Pacific (UP) railroad.

B) Antelope Coal Company (a subsidiary of Nerco Coal Company) will supply 1.2 million tons of coal from their Antelope coal mine in northern Converse County to Kansas Power and Light Company's Jeffrey, Kansas, energy center (no. 5, Figure 14). Deliveries began in April and will continue until the end of 1991. An additional 0.7 million tons of coal is optional under the sales agreement. The coal will originate on the Chicago North Western Transportation Company (C&NW)/Union Pacific Railroad Company (UP) joint -venture rail line and will terminate on UP lines.

C) Amax Coal Company's Belle Ayr mine supplied an additional 20,000 tons of coal in 1990 and 1991 under an existing five-year, 125,000 ton-per-year contract with Fremont, Nebraska, Department of Utilities (no. 6, Figure 14). The contract, which began in June, 1990, set the base price of the coal at \$4.05/ton F.O.B. the mine. The additional 20,000 tons of coal were purchased throughout the first year of the contract and replaced possible solicitations for additional spot coal.

D) Mobil Coal Producing, Inc.'s Caballo Rojo mine will supply a total of 200,000 tons of spot coal to Dairyland Electric Power Cooperative's Genoa and Alma, Wisconsin, power plants (nos. 12 and 10, respectively, Figure 14). The

tonnage will be split evenly between the two plants and will be delivered by railroad and by barge on the Mississippi River through the rest of 1991.

E) Carter Mining Company, a subsidiary of Exxon Coal USA, Inc., will supply from 250,000 to 1 million tons of spot coal from the Rawhide mine to Iowa-Illinois Gas and Electric Company's Louisa, Iowa, generating station (no. 15, Figure 14). The coal will originate on the BN and terminate on the Soo Line with deliveries slated through the end of 1991.

F) Cordero Mining Company, a subsidiary of Sun Coal Company, will supply Iowa Southern Utility Company's Ottumwa, Iowa, power station (no. 16, Figure 14) with 0.6 million tons of coal from the Cordero mine. Deliveries via the BN began in May, 1991, and will continue until the end of this year.

G) Triton Coal Company, a division of Shell Mining Company, will supply Iowa Southern Utility Company's Burlington, Iowa, power plant (no. 17, Figure 14) with 200,000 tons of spot coal from the Buckskin mine. The coal will be delivered by the BN starting in May, 1991, and continuing through December, 1991.

H) An undisclosed amount of spot coal, probably from Mobil Coal Producing, Inc.'s Caballo Rojo mine and either Thunder Basin Coal Company's Coal Creek or Black Thunder mines, is being supplied to Electric Energy Inc.'s Joppa, Illinois, power plant (no. 19, Figure 14). This coal may only be used in test burns, but it could also be supplemental to high-sulfur Illinois Basin coal currently burned at Joppa.

I) Mobil Coal Producing, Inc.'s Caballo Rojo mine supplied 70,000 tons of spot coal to Northern Indiana Power Company's (NIPSCO's) Dean H. Mitchell power plant in Indiana (no. 22, Figure 14) during June and July, 1991, under an "as-needed, as-available" purchase agreement.

J) Amax Coal Company's Belle Ayr mine also supplied 20,000 tons of spot coal to NIPSCO's Dean H. Mitchell plant in June, 1991, under a similar "as-needed, as-available" purchase agreement (no. 22, Figure 14).

Coal purchased for test burns is summarized below:

K) Coal from Antelope Coal Company's Antelope mine was tested in April at Southwestern Public Service Company's Harrington No. 1 unit in Texas (no. 3, Figure 14).

L) Cordero Mining Company's Cordero mine supplied 40,000 to 50,000 tons of coal for test burns in May at Texas Utilities Generating Company's Monticello, Texas, power plant (no. 4, Figure 14). Some of the coal was burned alone and some was blended with lignite during the tests. The utility company is planning to solicit bids on a 16.5-million-ton, 10-year contract for coal to supplement the lignite it normally burns at the plant. The coal from Cordero originated

on the BN, was transferred to the Kansas City Southern at Kansas City, and delivered via the Louisiana and Arkansas Railroad.

M) The Cordero mine also supplied test coal to Northern States Power Company's (NSP's) Sherco Units 1 and 2 (no. 7, Figure 14), Riverside Unit 8 (no. 8, Figure 14), and the High Bridge plant (no. 9, Figure 14) in Minnesota. So far, NSP has tested about 150,000 tons of coal from a 200,000-ton spot coal contract (*Wyoming Geo-notes No. 28, p. 27*) with Cordero. The coal from Cordero will be tested with other Wyoming and Montana coals as well as burned alone.

N) About 8,000 tons of coal from an unidentified mine in the Powder River Coal Field was blended with 2,000 tons of higher quality coal at Rochester, Minnesota's Public Utility Department (no. 11, Figure 14) and tested in June. Another 10,000 tons of the blended product was probably tested in late June.

O) Rochelle Coal Company, a subsidiary of Peabody Holding Company, will supply test coal from the Rochelle mine in southern Campbell County to Wisconsin Power and Light Company's (WPL's) Columbia Unit No. 2 plant in Wisconsin (no. 13, Figure 14). The coal will be blended with higher quality coal and tested this fall.

P) Rochelle Coal Company's Rochelle mine will also supply test coal to WPL's Nelson Dewey, Wisconsin, plant (no. 14, Figure 14). The coal will be transported by rail to a transfer terminal on the Mississippi River at East Dubuque, Iowa, and then loaded onto a barge for final delivery to the Dewey plant.

Q) Antelope Coal Company will supply coal to WPL's Nelson Dewey plant (no. 14, Figure 14) from the Antelope mine. Some of this coal will be burned both alone and some will be blended with a high-Btu coal in tests that will occur this summer.

R) Some 200,000 tons of coal from the Rochelle mine are being tested at Illinois Power Company's Baldwin, Illinois, Unit No. 3 plant (no. 18, Figure 14). A five-week test of the coal began in late June. The coal will be blended with varying amounts of high-sulfur coal from Peabody Coal Company mines in the Illinois Basin. The Rochelle coal will also be tested alone.

S) Rochelle Coal Company furnished coal from the Rochelle mine to Associated Electric Cooperative Inc.'s power plant at New Madrid, Missouri, (no. 20, Figure 14) for testing that was done in October, 1990. This older test shipment is included now because it was not noted last year.

T) Coal from five mines in the Powder River Coal Field is currently being supplied to Tennessee Valley Authority (TVA) for testing at two power plants in their system (*Wyoming Geo-notes No. 30, p. 38*). Additional testing of Powder River coal at TVA's Allen power station near Memphis, Tennessee, (no. 21, Figure 14) is expected this fall. Most of TVA's test burns have used various blends of low-sulfur, western coal with high-sulfur eastern coal.

U) In April, Amax Coal Company's Belle Ayr mine supplied an additional 20,000 tons of test coal to NIPSCO's Michigan City, Indiana, power station (no. 23, Figure 14). Last quarter the Michigan City power station used 40,000 tons of Belle Ayr coal in test burns (*Wyoming Geo-notes No. 30*, p. 38).

V) Unidentified coal mines in the Powder River Coal Field are expected to provide future test coal for several plants in American Electric Power Cooperative's generating system. Two power plants where test burns may occur are Indiana-Michigan Electric Company's Clifty Creek, Indiana, plant (no. 24, Figure 14) and Ohio Valley Electric Corporation's Kyger Creek, Ohio, plant (no. 25, Figure 14).

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INDUSTRIAL MINERALS AND URANIUM UPDATE

by Ray E. Harris, Industrial Minerals and Uranium Division Head, Geological Survey of Wyoming

Aggregate (Construction)

Because most highway and other outdoor construction projects occur in warmer weather, production of construction aggregate increases in the second quarter of the year. In Wyoming, the production of construction aggregate continues at about the same level as the last two previous years, which means production of construction aggregate should reach 6,000,000 tons again this year. According to the U.S. Bureau of Mines, the production of construction aggregate, nationally, is at its lowest level since 1988.

The railroad ballast quarry at Granite, west of Cheyenne in Laramie County, has been sold to a new owner. The quarry was operated for over 50 years for the Union Pacific Railroad. It was purchased a few years ago by Meridian Minerals, a division of Burlington Northern, Inc. All of Meridian's industrial minerals properties were sold earlier this year. The ballast operation will operate using the name Meridian Industrial Minerals.

Lamb Construction of Torrington, Wyoming, has reopened the Bald Butte ballast quarry south of Lusk. Chicago North Western Transportation Company needs about 500,000 tons of granite ballast to upgrade a portion of their trackage this year.

Bentonite

Bentonite production in Wyoming continues to increase at a moderate rate. In 1990, Wyoming companies produced over 2.4 million tons, an increase of about 9 percent over 1989. Bentonite is a clay material used in many products, but mostly in drilling mud. Primarily because of a steep decline in domestic drilling, the production of bentonite in Wyoming fell from almost 5 million tons per year in 1981 to less than 2 million tons in 1986. Since 1986, bentonite production has increased slowly due to the development of new uses for the product. Bentonite is now finding more use in barriers to isolate wastes, in containment structures, and as a cleaning and adsorbing agent for industrial chemicals. The Wyoming bentonite industry is operating at about 60 percent capacity according to bentonite producers. Bentonite production should increase again in 1991, and Wyoming will remain the Nation's leading producer.

Decorative Stone and Aggregate

Sunrise Stone cut the first block of black granite (amphibolite) from a quarry in northern Albany County in late June. The 5' x 5' x 8' block will be shipped to a stone-cutting plant in Arkansas. There it will be cut into 1-inch to 3/4-inch thick slabs. These slabs will be polished and sold as decorative facing. Sunrise Stone plans to produce many similarly sized blocks from the quarry this year.

The Geological Survey of Wyoming located the black amphibolite quarry site for Sunrise Stone. The Wyoming Department of Commerce's Division of Economic and Community Development provided a grant to the Town of Guernsey to assist Sunrise Stone in beginning production.

Sunrise Stone and several other companies remain interested in producing decorative stone in Wyoming. Mesa Marble, of Powell, Wyoming, is testing the production of brown, pink, and yellow marble from localities in Washakie County. In June, several samples of buff and white flagstone from Carbon, Niobrara, and Platte Counties were shipped to Colorado for test marketing.

Gypsum

According to the Wyoming State Inspector of Mines, the 1990 production of gypsum in Wyoming was 436,367 short tons. Because the two producers of gypsum wallboard in the Bighorn Basin, Celotex and Georgia-Pacific, are operating at close to plant capacity, future increases in production are unlikely unless the companies expand their plants. Mountain Cement at Laramie mines less than 50,000 tons of gypsum annually for use in portland cement.

Limestone and Lime

Limestone, a rock composed primarily of the mineral calcite (calcium carbonate), is used as construction aggregate, cut stone, and also as the raw material in the production of lime. Lime is used in a variety of products from fluxing agents in steel refining, to emissions control at power plants, to soil conditioning. The mineral-filler industry is another market for lime that could increase greatly in the next few years. Mineral fillers are finely ground rock and mineral substances. They are used in products to give weight, to improve texture or color, or to take the place of more expensive essential materials. Silica is one of the most commonly used mineral fillers. Its use, however, is likely to decline due to health hazards reportedly caused by breathing finely ground silica. Lime could be substituted for silica where it was used as a filler in many products, including plastic, rubber, and paper.

Pete Lien and Sons, Inc. has been testing limestone near Laramie for source material for a lime plant. A quarry site three miles east of Laramie had been proposed, but the location raised protests from nearby residents. The company recently tested limestone at a second site on State land about 11 miles northeast of Laramie. This second site was found to contain sufficient resources of good quality limestone (98 percent calcium carbonate), and Pete Lien and Sons, Inc. has announced that it is now planning to locate the quarry and lime plant at the second site.

It was reported in *Wyoming Geo-notes No. 30* (p. 40) that Dakota Coal was planning to construct a lime plant at the Bass limestone quarry, 25 miles north of Guernsey. Due to recent developments in the markets for lime, several sites for the lime plant, including the Bass site, are now under consideration. According to company officials, the other locations are all in Wyoming.

Leonardite

Leonardite is a substance produced by the oxidation of coal or lignite. It is a sticky, brownish-black organic material used in drilling fluid and wood stain. Black Hills Lignite, an operating division of Black Hills Bentonite, produces and refines leonardite near Glenrock. In 1990, over 41,000 tons of leonardite were mined in Wyoming.

Trona and Soda Ash

The amount of trona mined in 1990 was just under the record set by the trona mines in 1989. According to data from the Wyoming State Inspector of Mines, 16,172,539 tons of trona were mined in 1990, compared to 16,187,732 in 1989. The magazine *Industrial Minerals* reported that dense Wyoming soda ash was selling for \$93 per short ton (FOB plant) in April, 1991, up from about \$80 per short ton in early 1989.

The trona industry continues to expand its product line. In past years, the trona refineries only produced soda ash. Now, the five companies operating in the trona district west of Green River produce soda ash, caustic soda, sodium sulfite, sodium bicarbonate, sodium cyanide, and Tenneco recently announced plans to produce calcined trona.

Calcined trona is trona that is heated to drive off some impurities. Since calcined trona is not fully refined like the other products produced from mined trona, its sale price will be less than other products produced from mined trona. Calcined trona can be substituted for more expensive soda ash in the production of caustic soda, and may be substituted for soda ash in other uses.

Workers at the FMC plant struck over a contract dispute on the first of May. FMC's total output may be a little less than expected in 1991 due to the strike. Despite the strike, FMC mined its one hundred millionth ton of trona in May. The FMC mine has been operating since 1948.

Uranium

According to the Wyoming State Inspector of Mines, Wyoming produced 107,024 short tons of mined uranium ore and 1,047,813 pounds of yellowcake from three solution-mining operations in 1990. Overall production was essentially unchanged from 1989.

The spot market price of uranium continues to drop. At the end of June, the price of U_3O_8 was \$9.10, down from \$9.50 at the end of March.

Pathfinder Mines, a subsidiary of the French Company COGEMA, operates the only active open pit uranium mine and conventional mill in Wyoming. Production from this property in the Shirley Basin of northern Carbon County ceased during a part of 1990 while a new ore body was uncovered. The mine and mill are now fully operational.

Most of the production from solution mining in 1990 was by Power Resources, which is wholly-owned by Nuclear Electric, Ltd., a British company. They produce yellowcake from the Highland mine area in Converse County. Power Resources has been adding to its area of operations. Recently, the company constructed a new solution mining field at the site of the North Morton Ranch deposit, northwest of the Highland deposit. In May, 1991, Power Resources purchased property containing proven uranium resources in the Gas Hills, in southeastern Fremont County. The company noted that it would not develop the Gas Hills property until the demand and price for uranium improves.

The other 1990 producers of yellowcake from solution mining operations were Total Minerals, a French company which purchased Malapai Resources, and Rio Algom, which is owned by RTZ, a British company. Total plans to resume production from its Irigary and Christiansen Ranch properties southwest of the

Pumpkin Buttes in 1992. Rio Algom continues to test and develop a recovery operation at the Bill Smith mine site in Converse County.

Zeolites

U.S. Zeolite, in partnership with Colorado Lien, continues to test their clinoptilolite deposit near Fort LaCledde southeast of Bitter Creek, in Sweetwater County. Zeolites act as molecular sieves and can remove selected ions, including toxic ions from water solutions. The Wyoming Department of Commerce's Division of Economic and Community Development is financially assisting the research and testing of clinoptilolite. The partnership has mined about 200 short tons of clinoptilolite to date.

METALS AND PRECIOUS STONES UPDATE

by W. Dan Hausel, Deputy Director, Geological Survey of Wyoming

Even though the mining industry is suffering through another deep recession, some exploration for metals was reported around the State. Probably, the most notable news during the past quarter was a claim-staking rush in the Hartville uplift in eastern Wyoming. Three, and possibly as many as four, mining companies were competing with one another to acquire as much mineralized land as possible.

The 1991 field season finally began for the Metals and Precious Stones Division of the Geological Survey of Wyoming (GSW), following many Spring thunder storms and a few tornados. In addition to the tornados spotted by Laramie residents along the edges of town, a smaller tornado was also observed on June 5th during field work at Cooper Hill. Runoff from the Spring storms has caused severe flood damage in some areas, making access difficult.

Cooper Hill, Medicine Bow Mountains

The GSW has begun detailed mapping of the historic Cooper Hill mining district. The district was initially mapped by Schoen (1953). Based on Schoen's mapping and recent mapping by the GSW, the district is best described as a faulted and synformal sequence of Proterozoic metasedimentary and metaigneous rocks. According to a regional map by Karlstrom and others (1981), the principal Proterozoic formations underlying the district are the Cascade Quartzite and Vagner Formation. The sequence includes metalimestone, quartzite, thin quartz-pebble metaconglomerate, mica schist, metagabbro, and metabasalt. The district is nearly surrounded by Tertiary conglomerates of the Ferris and Hanna formations.

Mineralization reportedly includes argentiferous galena, some gold, and minor copper (Schoen, 1953). Additionally, one sample of calcite collected from a dump from a prospect pit at the apex of Cooper Hill contained minor disseminated franklinite [(Zn, Mn, Fe)(Fe, Mn)₂O₄]. This mineral was initially identified in hand specimen, then later confirmed by x-ray diffraction. The sample also contains traces of a brownish-green, strongly fluorescent, unidentified mineral (possibly willemite). The calcite fluoresces reddish-orange. Follow-up reconnaissance studies in the area have not found any additional franklinite. The source of the franklinite at this point is unknown.

The GSW is currently remapping the district and examining all historic mines and prospects. Dozens of samples are being collected for assay, whole-rock analysis, and geochemistry. To date, vein and skarn mineralization has been identified.

Hartville uplift

According to local newspapers, three, and possibly as many as four, major mining companies joined in a claim-staking rush for several massive sulfide and unconformity-related targets in the Hartville uplift of eastern Wyoming. Claims were staked over land with potential for zinc-, silver-, and gold-bearing mineralization and also over areas where Woodfill (1987) reported electromagnetic anomalies. The Hartville uplift is interpreted as an Archean eugeoclinal terrane formed of metadolomite, metabasalt, metagreywacke, and hematite schist. The uplift has been mapped in detail by Snyder (1980) with a geological summary by Snyder and others (1989). The mineral resources have been summarized by Woodfill (1987) and Hausel (1989).

In its early history, the Hartville uplift was initially mined for copper and yielded at least 1,568,000 pounds of copper and 2,280 ounces of silver. The district produced iron ore from 1898 until the last iron mine closed in 1981. A minimum of 45 million tons of hematite ore were recovered from the uplift.

Rattlesnake Hills, Granite Mountains

The Rattlesnake Hills in the Granite Mountains include a small Archean supracrustal belt that has been intruded by as many as 42 Tertiary alkalic and calc-alkaline volcanic vents and related intrusives. There were no known reports of gold mineralization in this area prior to 1982 when GSW geologists identified an Archean pyritiferous quartz vein (metachert) in July of that year. The vein was traced along strike for approximately 500 feet. At that time two composite chip samples from the vein were assayed and yielded 0.13 and 0.22 ounce per ton gold (Hausel and Jones, 1982; Hausel, 1989, p. 60).

While it was thought that American Copper and Nickel Company (ACNC) was aware of this 1982 discovery (*Wyoming Geo-notes No. 30*, p. 56), John T. Ray (personal communication, June, 19, 1991) reports that ACNC was unaware of the

earlier discovery when they entered the district in the summer of 1983 and made an independent discovery in the same area, based on mapping by Pekarak (1974). At that time, ACNC noted a sequence of pillowed basalt, felsic volcanoclastics, turbiditic metasediments, chert, and banded iron formation, and "subsequent sampling revealed significant gold values and the property was promptly staked". Gold anomalies were discovered by ACNC in more than one rock type and at more than one locality. Based on ACNC's work, the Rattlesnake Hills appears to be an important Archean and Tertiary terrane with significant (previously unrecognized) gold anomalies.

Seminole Mountains

The GSW resumed mapping in the Seminole Mountains Archean greenstone belt of central Wyoming in June, but access was very difficult this Spring due to erosion of ungraded roads and jeep trails. The GSW is currently mapping east of Sunday Morning Creek in a sequence of serpentinites, cumulate serpentinites, and spinifex-textured basaltic metakomatiites (*Wyoming Geo-notes Nos. 29 and 30*, and Klein, 1981). Some strong carbonate alteration of the metamorphics has been noted in this area including localized limonitic alteration in a portion of one of the cumulates. The GSW expects to complete its mapping by the end of the summer. A final report on the Seminole Mountains gold and iron district should be published sometime next year.

Sheep Mountain, Medicine Bow Mountains

At the request of a Laramie resident, personnel of the GSW visited a previously unreported copper mine along the southeastern edge of Sheep Mountain on the eastern flank of the Medicine Bow Mountains. This mine was possibly part of the historic Jelm Mountain mining district; however, there is no historic or production data on the mine. Preliminary investigations show the mineralization to occur in veins and breccia veins in granite described as Sherman Granite by earlier workers. Mineralization occurs as chalcopryrite, chalcocite, bornite, malachite, molybdenite, ilsemannite (?), and fluorite. While the ilsemannite ($\text{Mo}_3\text{O}_8 \cdot \text{H}_2\text{O}$) is tentatively identified by x-ray diffraction, geochemical analyses are planned to positively identify the mineral. Samples are currently being tested for precious and other trace metals.

South Pass

Steve Gyorvary of the Gyorvary Mining Company received a permit to operate the Mary Ellen gold mine at South Pass early this summer. The Mary Ellen mine was developed as an inclined shaft sunk in a quartz vein in metatonalite porphyry in the South Pass-Atlantic City district. Historic reports indicate the vein averaged 0.4 ounce per ton gold and may have produced 6,250 ounces of gold prior to 1911. There may have been some production after 1911 although no records are available (see Hausel, 1991).

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Table 6. MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING.

PETROLEUM	
Remaining Resources (January 1, 1991)	
Discovered (Includes 10 billion barrels recoverable by enhanced recovery techniques)	12.7 billion barrels ¹
Undiscovered	7.6 billion barrels ¹
Total	20.3 billion barrels
Remaining Reserve Base (January 1, 1991)	
Measured reserves (Proved reserves) (Includes 0.83 billion barrels of oil, 0.67 billion barrels of gas liquids, and 0.10 billion barrels of condensate)	1.50 billion barrels ²
Indicated and inferred reserves	2.80 billion barrels ¹
Total	4.30 billion barrels
NATURAL GAS	
Remaining Resources (January 1, 1991)	
Discovered (Includes 23 trillion cubic feet (TCF) of methane ¹ and 12 TCF of CO ₂ and He ³)	34.1 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 103 TCF of CO ₂ and He ³)	3,779.0 trillion cubic feet
Total	3,813.1 trillion cubic feet
Remaining Reserve Base (January 1, 1991)	
Measured reserves (Proved reserves) (Includes 11.3 TCF of methane ² and 11.7 TCF of CO ₂ and He ³)	22.1 trillion cubic feet
COAL	
Remaining Resources (January 1, 1991)	
Identified and Hypothetical (Discovered)	1,431.0 billion tons ⁶
Speculative (Undiscovered)	31.5 billion tons ⁶
Total	1,462.5 billion tons
Remaining Reserve Base (January 1, 1991)	
Demonstrated stripplable (Measured and indicated reserve base)	26.4 billion tons ⁷
Demonstrated underground-minable (Measured and indicated reserve base)	38.3 billion tons ⁷
Total	64.7 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 ₃ O 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, 1983)	
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, 1989, U.S. crude oil, natural gas, and natural gas liquids reserves: 1989 Annual Report, October.

³ Derived from Exxon information.

⁴ De Bruin, R.H., and Jones, R.W., 1990, Coalbed methane in Wyoming: Geological Survey of Wyoming, Public Information Circular 30, 15 p.

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

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

⁷ Geological Survey of Wyoming, July, 1991. (Modified from Berryhill, H.L., Jr. and others, 1950), Coal resources of Wyoming: U.S. Geological Survey Circular 81, 78 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.

WYOMING OIL AND GAS EXPLORATION SUMMARY-1990

by Rodney H. De Bruin, Oil and Gas Division Head, Geological Survey of Wyoming

Drilling activities and completions

Based on preliminary data available from Petroleum Information (1991), we estimate that there were close to 700 well completions in Wyoming in 1990, which is an increase over 1989. The final total will approach the number of completions in 1987 and 1988, but will fall short of completion totals for earlier years (TeSelle and others, 1990) (Figure 15). Of the 566 wells drilled in 1990 for which Petroleum Information already has data, 193 were exploration wells. The success rate for exploration wells was 24.9 percent compared to a success rate for exploration wells in 1989 of 20.6 percent. In all, at least 342 wells in 1990 found oil or gas for a success rate of 60.4 percent. In 1989, 315 wells found oil or gas for a success rate of 55.4 percent.

While the average daily rig count in 1990 was 38, the average was 34 in 1989. The daily rig count averaged by year has not been above 40 since 1985 (Figure

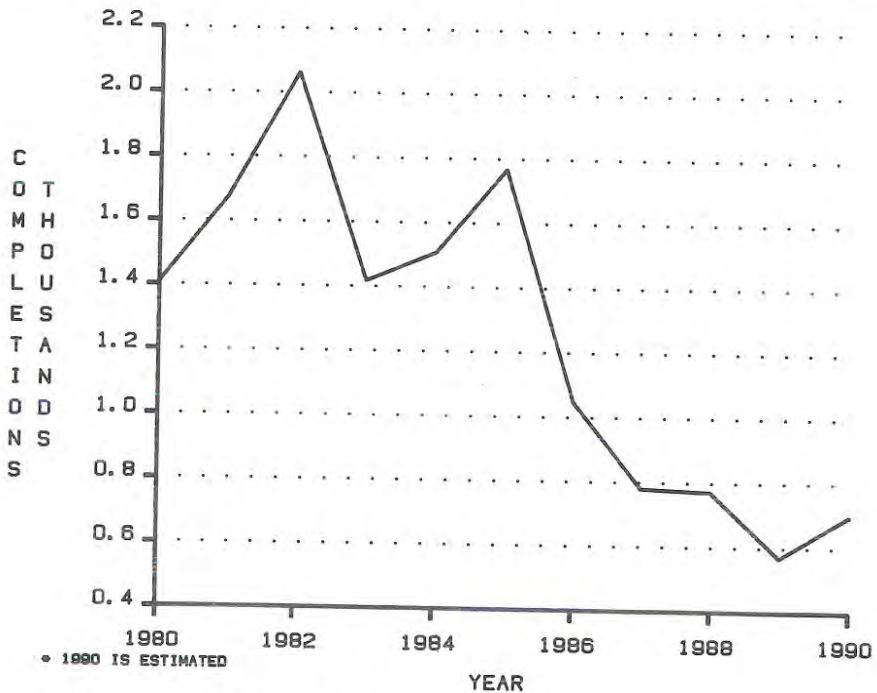


Figure 15. NUMBER OF OIL AND GAS WELL COMPLETIONS IN WYOMING BY YEAR (BASED ON DATA PUBLISHED BY PETROLEUM INFORMATION).

16). Rigs in Wyoming drilled about five million feet in 1990, which was a slight increase over 1989, but a decline from earlier years (Figure 17). The average depth of a well in Wyoming in 1990 was 7,083 feet, the highest average since 1985 (Figure 18). The average depth of an exploration well in Wyoming in 1990 was 7,488 feet. Figure 18 shows that this is a decline from earlier years.

Lease sales

Six lease sales held by the U.S. Bureau of Land Management (BLM) in 1990 grossed nearly \$18 million. Of the 2.17 million acres that were available for lease, 44.6 percent was leased at an average of \$18.61 per acre. The six BLM sales in 1989 grossed less than \$16 million, and only 24.1 percent of the 4.03 million available acres was leased for an average of \$16.28 per acre. Figures 19 and 20 show total revenue and average price per acre leased for recent BLM sales.

Six lease sales held by the State Land and Farm Loan Office in 1990 grossed almost \$5 million. The average price per acre was \$13.09 and 79.5 percent of the 478,000 available acres was leased. The six State sales in 1989 grossed just over \$3 million. Only 67.3 percent of the 462,000 available acres was leased in 1989 at an average of \$10.04 per acre. Figures 19 and 20 show total revenue and average price per acre leased for recent State sales.

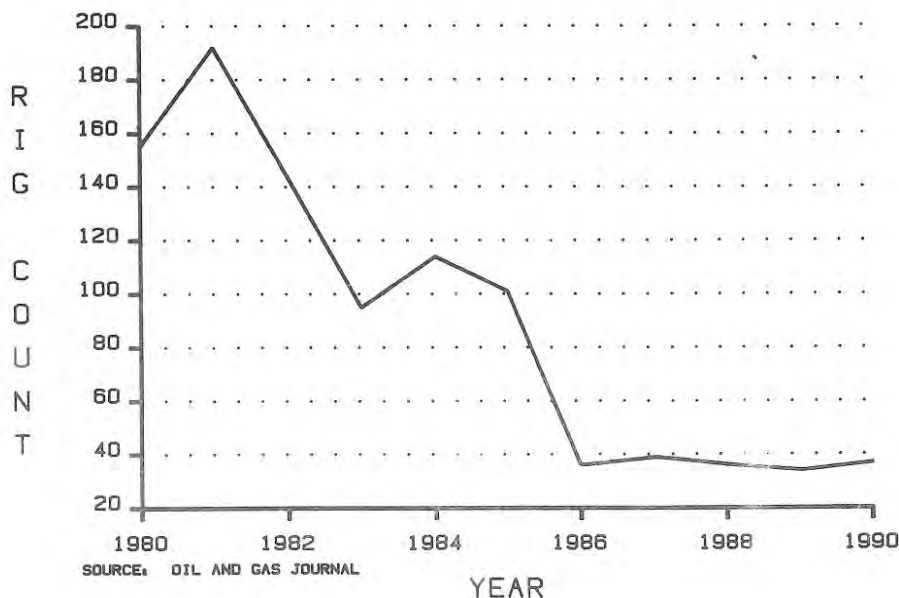


Figure 16. WYOMING DAILY RIG COUNT AVERAGED BY YEAR.

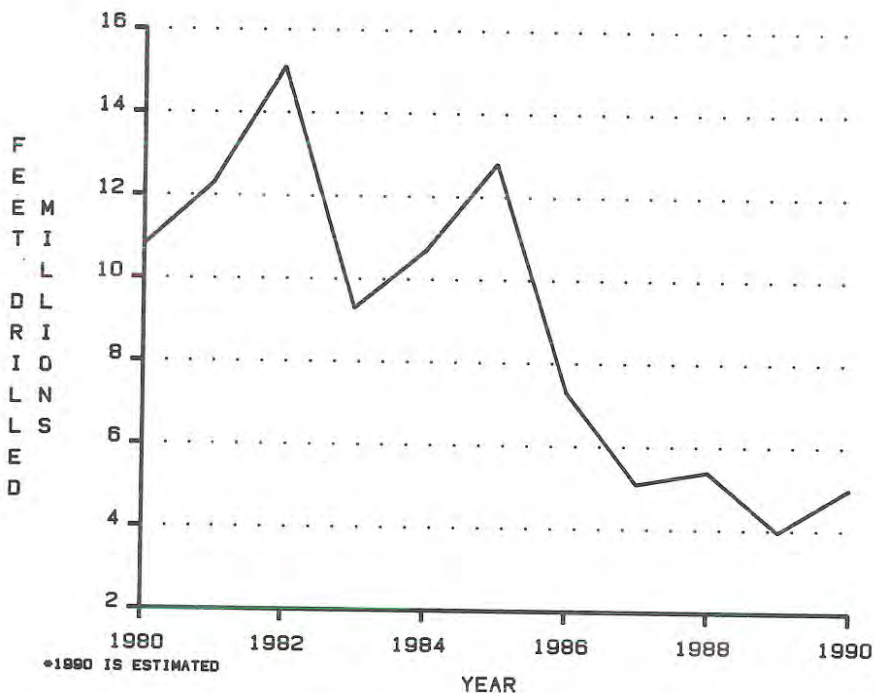


Figure 17. NUMBER OF FEET DRILLED FOR OIL AND GAS IN WYOMING BY YEAR.

Powder River Basin

The Minnelusa play accounted for most of the exploration and development drilling in the Powder River Basin. Campbell County was the most heavily explored county in the United States with 73 wildcat well completions (Petroleum Information, 1991). Of those 73 completions, nine found oil and three found gas. Crook County was the eighth most heavily explored county in the United States with 18 wildcat well completions (Petroleum Information, 1991). Over half of the well completions in Wyoming were in the Powder River Basin and most of these were Minnelusa tests.

Southwestern Wyoming Basins

Drilling, especially for natural gas, increased in southwestern Wyoming in 1990 mainly because several proposed gas pipelines have substantially expanded the potential markets for natural gas from this part of the State. There were 29 exploration tests and 144 production wells drilled in this area in 1990. Most of the exploration and development targeted Cretaceous objectives. Over 30 percent of the well completions in Wyoming were in this area.

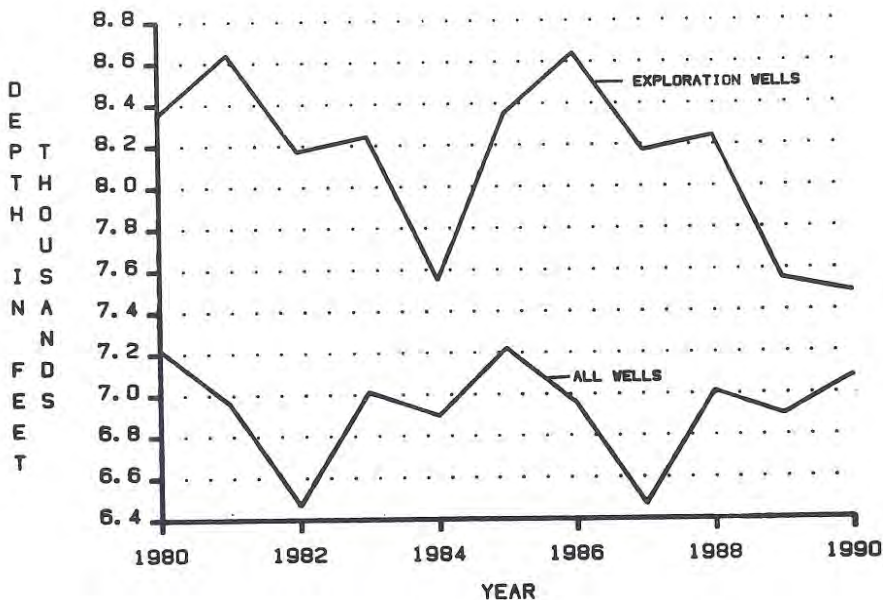


Figure 18. AVERAGE DEPTH OF WYOMING OIL AND GAS WELLS DRILLED BETWEEN 1980 AND 1990 [FROM PETROLEUM INFORMATION (1991) AND TESELLE, AND OTHERS (1990)].

Wind River Basin

The most important activities in this basin involved the multiple completion of two Fort Union gas wells in Fuller Reservoir Field and the W. A. Moncrief Jr. deep Madison Limestone test on the east end of Madden anticline. The Moncrief well, which was spudded as a 24,500-foot test, was completed in early 1991. In addition, Louisiana Land and Exploration Company staked a deep test in late 1990.

Horizontal Drilling

There were 10 horizontal well completions in Wyoming in 1990. The Niobrara Formation at Silo Field in the Denver-Cheyenne Basin had the most horizontal completions. The first well in the play was drilled by Cowan Oil in 1990. Union Pacific Resources completed two wells and Snyder Oil completed one well in this play in 1990. In 1990, several companies also staked locations for additional horizontal Niobrara tests in and around Silo Field.

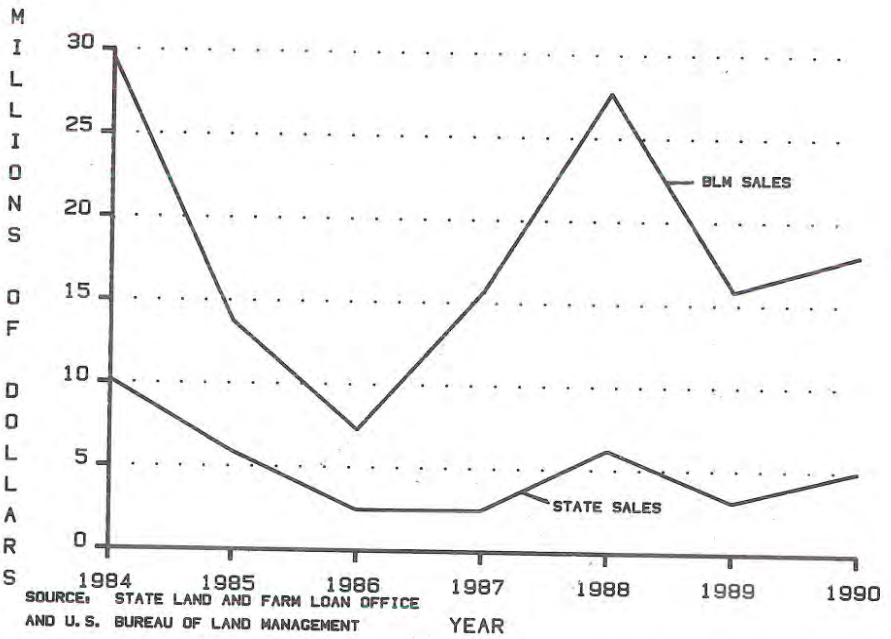


Figure 19. TOTAL REVENUE FROM WYOMING OIL AND GAS LEASE SALES (1984-1990).

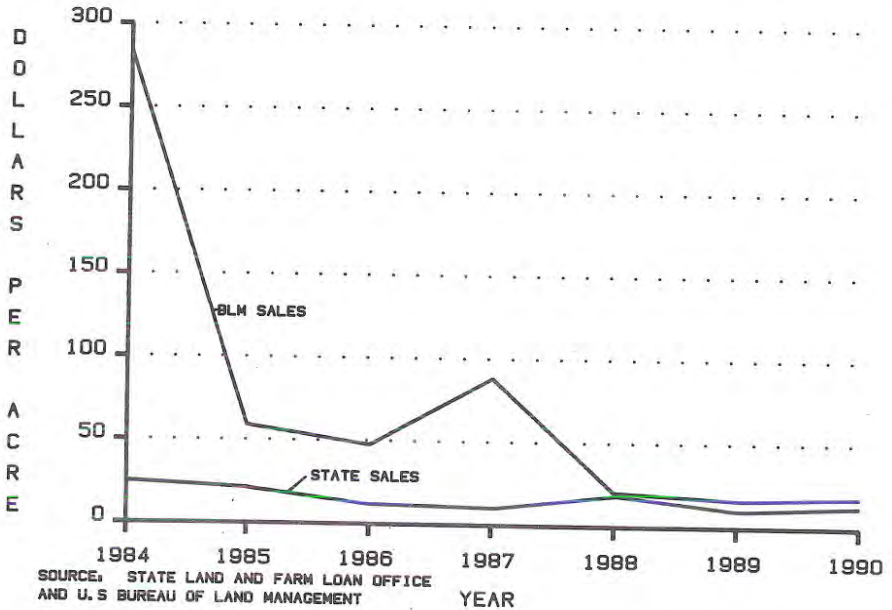


Figure 20. AVERAGE PRICE PER ACRE LEASED IN WYOMING OIL AND GAS LEASE SALES (1984-1990).

Hondo Oil and Gas and Amoco Production each completed a horizontal producer in the Second Wall Creek. Both wells are in the Powder River Basin. Hondo's well was at Salt Creek East Field and Amoco's well was at Salt Creek Field.

Coalbed Methane

There were 32 coalbed methane wells completed in the State in 1990. These 32 wells tested coal beds and sandstone reservoirs adjacent to coal beds. Presently, the most promising areas in the State are in the Powder River Basin around Gillette where there is already production from Fort Union Formation coals; in the Hanna Basin where there is testing of Hanna Formation coals, and in southwestern Wyoming where several companies are testing coals in the Mesaverde Formation.

References cited

- Petroleum Information, 1991, Resume 1990: Petroleum Information, Littleton, Colorado, 413 p.
- TeSelle, R.D., Harris, T.L., and Mitchell, J.R., 1990, Oil and gas development in the northern Rockies, 1989: American Association of Petroleum Geologists Bulletin, v. 74, no. 10B, p. 120-126.

GEOLOGIC MAPPING AND STRATIGRAPHY

by Alan J. Ver Ploeg, Geologic Mapping Division Head, Geological Survey of Wyoming

New bibliographic service available

The Geological Survey of Wyoming (GSW) is now offering a new bibliographic service in cooperation with the University of Wyoming Geology Library. This service includes compilation of short customized bibliographies on specific topics, such as a formation, a structural feature, a geographic area, etc. The GSW will compile these bibliographies from computerized data bases available at the University's Geology Library, and from additional references in the GSW's files, when appropriate. Submitted requests should fall in the realm of general geology, structural geology, stratigraphy, economic geology, and paleontology of Wyoming. In most cases, the GSW will respond to requests within a week to ten days.

A nominal fee may be charged to cover reproduction and postage costs. At least initially, we ask that requests be submitted in writing to:

Geologic Mapping Division
Geological Survey of Wyoming
Box 3008, University Station
Laramie, Wyoming 82071-3008

Out-of-state thesis and dissertation maps

The GSW recently began researching out-of-state theses and dissertations which contain geologic maps of Wyoming. Between fifty and sixty maps have been identified and information from these maps has been added to the files of the GSW during the past four months. The GSW is compiling the locations of these maps on an index of out-of-state thesis and dissertation maps. This index will be published as part of the MS-9 series at a later date. In the interim, the index is updated as new maps are added. Hardcopy maps in the files of the GSW are available for examination in Laramie.

Stratigraphic study of the Wind River Basin published

Diana Gentry Hogle and Richard W. Jones recently published the results of their work on the stratigraphic framework of coal-bearing rocks in the Wind River Basin of Wyoming. The paper is titled, *Subsurface geology of Upper Cretaceous and lower Tertiary coal-bearing rocks in the Wind River Basin, Wyoming* (Hogle and Jones, 1991). The study establishes a refined stratigraphic framework for more than 20,000 feet of Upper Cretaceous and lower Eocene rocks in the Wind River Basin.

Data from 325 electric well logs, 36 wells with palynological age dates, 80 drill hole lithology logs, and some surface exposures were combined with previous work and conclusions in order to redefine the subsurface geology of the basin for this portion of the stratigraphic section. Using this data, eleven cross sections, five isopach maps, and two isopach/isopleth maps were constructed.

The study describes the intertonguing nature of the lower part of the Mesaverde Formation and the underlying Cody Shale; defines an unconformity between the Mesaverde and the overlying Fort Union Formation in the subsurface of the southwestern part of the basin; and defines the amount of deposition and the later erosion patterns of the Lance, Fort Union, and Meeteetse formations. Variations in formation thicknesses appear to be controlled locally, in part by synorogenic structural features forming during the deposition of these sediments. The results of the study should have important implications for coal and hydrocarbon exploration.

Rare dinosaur tracks found in the Teton Wilderness

Kirk Johnson of the Denver Museum of Natural History and Jason Hicks, a visitor from Great Britain, literally stumbled onto significant dinosaur tracks in the Teton Wilderness near Jackson, Wyoming. The tracks, which measured 12 inches long and 9 inches wide, were found in latest Cretaceous rocks (70-72 million years old), and represent one of the last dinosaurs to walk the face of the Earth. The footprints exhibit four toes, with one resembling a sharp claw, indicating the dinosaur was a meat eater. Representatives of the museum feel that the prints may be a new and yet unnamed species of dinosaur. Also, the numerous marine fossil traces found at the locality indicate that the late Cretaceous sea may have extended farther west than previously thought. Johnson indicated that several additional months of work are necessary before they know the true significance of the find.

Reference cited

Hogle, D.G. and Jones, R.W., 1991, Subsurface geology of Upper Cretaceous and lower Tertiary coal-bearing rocks, Wind River Basin, Wyoming: *The Mountain Geologist*, v. 28, no. 2/3, p. 13-36.

GEOLOGIC HAZARDS

by James C. Case, Geologic Hazards Division Head, Geological Survey of Wyoming

Landslide nearly dams the Greys River

The Greys River, in northeastern and northern Lincoln County, flows into the Snake River near Alpine, Wyoming. The Geological Survey of Wyoming (GSW) has mapped numerous landslide complexes along the river, and there is every indication that the river has been dammed by landslides in the past. In early June, 1991, after a period of heavy and prolonged precipitation, a portion of one of the previously mapped landslides (Case, 1990) destabilized and nearly dammed the river.

The landslide constricted the Greys River to a width of only fifteen feet. It is visible from the Greys River road, approximately six miles east of its junction with U.S. Highway 89. The landslide, which is a rockslide/flow complex, extends up the hillside for over 2,200 feet. At its base, it is over 750 feet wide. The U.S. Forest

Service estimated that 200,000 cubic yards of material may have been incorporated into the flowing mass. Most movement occurred in a preexisting landslide that primarily formed in the Jurassic Twin Creek Limestone. Landslides commonly form in that geologic formation in western Wyoming. In the vicinity of the landslide, the Twin Creek Limestone is composed of a shaly limestone that weathers into splintery, finger-sized fragments, sandy limestone, and siltstone, shale, and limestone breccia (Jobin, 1972). The GSW is currently evaluating older aerial photography of the area to determine if there were any subtle clues that the hillside was about to destabilize.

Although the landslide formed in a preexisting landslide mass, the age of the older movement is unknown and can only be roughly estimated. The U.S. Forest Service noted that the ages of the trees that were destroyed in the current landslide range from 100 to 200 years old. The preexisting landslide, therefore, had to be at least that old, and portions of it were probably much older.

Other landslides have also occurred in western Wyoming so far this year. Most notable are debris flows that covered portions of U.S. Highway 14/16/20 east of Yellowstone National Park. Similar occurrences were described in *Wyoming Geo-notes No. 18* (p. 41-42). A slump/flow complex has been a recurrent problem along U.S. Highway 89 between Thayne and Afton. This year the landslide only encroached on the road's shoulder, but in past years, the road has been completely covered.

For further information on landslides in Wyoming, contact Jim Case, Head of the Geologic Hazards Division, Geological Survey of Wyoming.

References cited

- Case, J.C., 1990, Preliminary map of landslides on the Ferry Peak Quadrangle: Geological Survey of Wyoming Preliminary Landslide Map, Scale 1:24,000.
- Jobin, D.A., 1972, Geologic map of the Ferry Peak Quadrangle, Lincoln County, Wyoming: U.S. Geological Survey Geologic Quadrangle Map GQ-1027, scale 1:24,000.

Earth Science Information Center moves

The Geological Survey of Wyoming (GSW) is now housing the Earth Science Information Center (ESIC) for the State of Wyoming. The ESIC, which was previously located at the Wyoming State Engineer's Office, collects, files, and disseminates information on geology, aerial photography, and maps in Wyoming. At the Federal level, the ESIC Program is under the direction of the U.S. Geological Survey.

The ESIC has indices for all Wyoming-related aerial and space photography available from the Federal government. This includes photography generated by

the U.S. Geological Survey, the U.S. Bureau of Land Management, the U.S. Forest Service, the Soil Conservation Service, and NASA. The GSW already had indices available for much of the Federal photography, but the donation completes that coverage. In addition, the GSW has indices available for some non-Federal photography, including that generated by Intrasearch, Inc., Horizon, Inc., and the State of Wyoming.

The GSW has aerial photography available for viewing for much of Wyoming. Coverage is limited in Laramie and Goshen Counties, and portions of northwestern Wyoming. Some of the photography at the GSW, which dates back to the 1940's, is very useful for comparative studies. For additional information, contact Jim Case, Head of Geologic Hazards Division of the GSW.

WYOMING BOARD OF PROFESSIONAL GEOLOGISTS

In July, Governor Sullivan appointed six geologists to the newly created Board of Professional Geologists. These new appointees include geologists: Ronald A. Baugh, an independent geologist in Casper; David S. Gardner of M-I Drilling Fluids Company in Greybull; Roger J. Barton of True Oil Company in Casper; Steven J. Castleberry of Mobil Coal Producing, Inc. in Gillette; Roger W. Miller of Miller & Associates in Casper; and William F. Sherman, a geotechnical consultant in Cheyenne. Gary B. Glass, the State Geologist, is a seventh and ex officio member of the Board.

Wyoming's Legislature authorized this Board to register geologists wishing to use the title "Professional Geologist" in the State of Wyoming (W.S. 33-40-101 through W.S. 33-40-121). Applicants for registration must meet all the following minimum requirements:

1. At least a bachelor's degree in geology or an associated science approved by the Board;
2. A passing score on the Board's examination in the fundamentals of geology;
3. At least four years of active professional experience of a character acceptable to the Board; and
4. A passing score on the Board's professional examination.

During the first year of this act (July 1, 1991 through June 30, 1992), a grandfather clause will allow degreed geologists with at least four years of professional experience to apply for registration without taking any examination. The grandfather clause also allows a degreed geologist, who lacks the required experience, to apply for the status of Geologist-in-training. In this latter case, an applicant need not take the Board's examination in the fundamentals of geology.

Registration will be maintained by payment of an annual renewal fee and may include a continuing education requirement.

Rules governing this act will be ready for public comment by late summer. Additional information about proposed rules, fees, and application forms will be made available as soon as possible. Individuals wishing to receive applications, as they become available, should send their names and mailing addresses to:

Board of Professional Geologists
c/o Geological Survey of Wyoming
Box 3008, University Station
Laramie, WY 82071-3008

NEW PUBLICATIONS

Index of geologic maps of Wyoming included in 1980-1989 graduate theses and dissertations from the University of Wyoming, compiled by J.K. King and A.J. Ver Ploeg: Map Series-9R, 1990, 1:1,000,000 - \$2.50.

Coal map of Wyoming, by R.W. Jones: Map Series 34, 1991, 1:500,000 (color) - \$10.00 folded (\$11.50 mailed rolled).

Oil and gas map of Wyoming, by R.H. De Bruin and C.S. Boyd: Map Series 35, 1991, 1:500,000 (color) - \$10.00 folded (\$11.50 mailed rolled).

*Oil and gas fields map of the greater Green River Basin and overthrust belt, southwestern Wyoming, by Robert W. Gregory and Rodney H. De Bruin: Map Series 36, 1991, 1:316,800 (color) - \$4.00 folded (\$5.50 mailed rolled).

Preliminary landslide maps, by J.C. Case and others: call for the availability of particular 1:24,000- and 1:62,500-scale maps, 1990 - \$3.00.

Landslide map of Wyoming, by J.C. Case, L.L. Larsen, L.A. Coombs, D.R. Gilmer, T.C. Nissen, J.A. Ford, J.C. Cannia, and W.B. Murray: Open File Report 91-1, 1:1,000,000 - \$4.00.

1° x 2° quadrangle landslide maps of Wyoming, by J.C. Case, L.L. Larsen, L.A. Coombs, D.R. Gilmer, T.C. Nissen, J.A. Ford, J.C. Cannia, and W.B. Murray (authorship on individual maps varies): Open File Report 91-2A through 91-2P, (sixteen maps) scale 1:250,000 - \$4.00.

Precambrian geology map of the Seminoe Mountains (iron-gold) mining district, Bradley Peak Quadrangle, Carbon County, Wyoming, by W.D. Hausel: Open File Report 91-3, scale 1:24,000 - \$3.50.

Preliminary geologic map of the Beartrap Meadows Quadrangle, Johnson County, Wyoming, by A.J. Ver Ploeg and P.L. Greer: Open File Report 91-4, scale 1:24,000 - \$3.50.

Preliminary geologic map of the Monument Hill Quadrangle, Washakie and Johnson Counties, Wyoming, by A.J. Ver Ploeg and P.L. Greer: Open File Report 91-5, scale 1:24,000 - \$3.50

Geology and mineralization of the South Pass granite-greenstone belt, southern Wind River Range, Wyoming, by W.D. Hausel: Report of Investigations 44, 1991 - \$20.00 (map is also available separately for \$5.00).

Results of coal drilling projects in the Wind River Coal Field, Wyoming, by R.W. Gregory, R.W. Jones, and Gary B. Glass: Report of Investigations 46, 1991 - \$5.00.

*Tectonic relationships of the southeastern Wind River Range, southwestern Sweetwater uplift, and Rawlins uplift, Wyoming, by D.L. Blackstone, Jr: Report of Investigations 47, 1991 - \$10.00.

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

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.

No first class postage charge for prepaid orders, unless otherwise marked.

— NEW SERVICE AVAILABLE —

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

