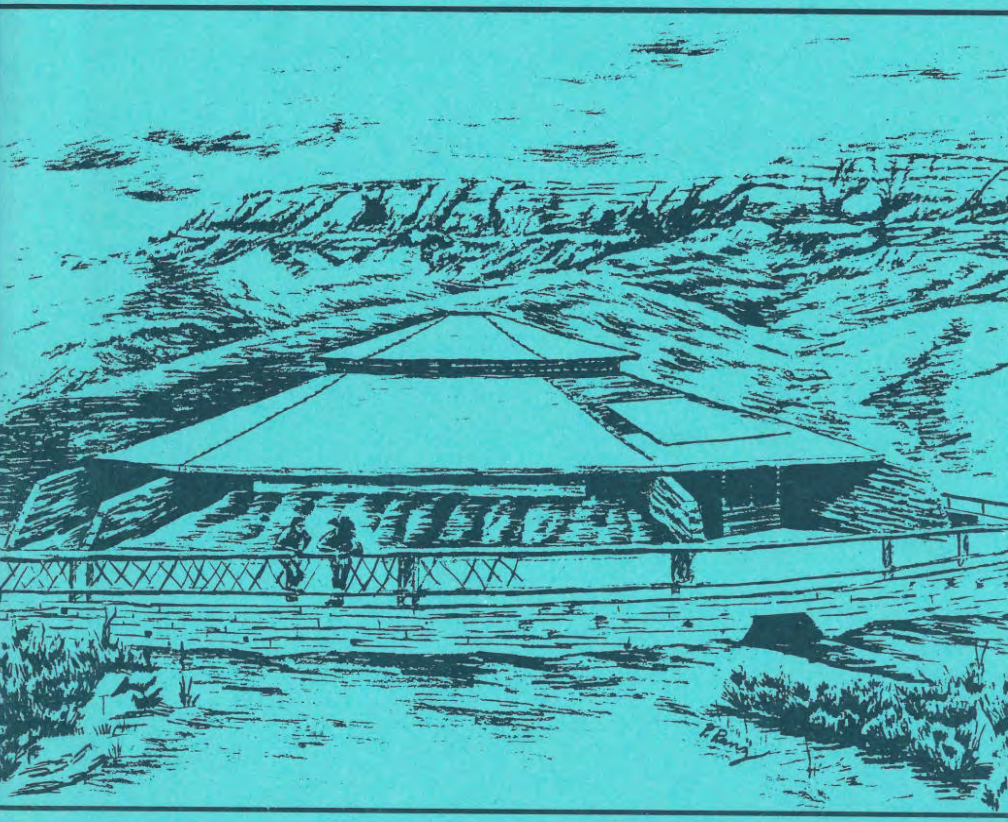
THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist

WYOMING GEO-NOTES
NO. 27



LARAMIE, WYOMING
July, 1990

WYOMING GEO-NOTES

This quarterly digest on the State's geology and mineral resources and activities of the Geological Survey is available by subscription (four issues for $5.00) or as single copies at $1.50 each. Two-year subscriptions are accepted.

Cover: The new visitor's center at Fossil Butte National Monument was dedicated in June. The center's museum depicts the varied plant and animal life that inhabited a 40-60 million-year-old fresh-water lake, deposits of which are now preserved as Fossil Butte. Fossils of fish, crocodiles, turtles, stingrays, birds, frogs, snakes, and even bats are exhibited. This center is a must for both Wyomingites and visitors to the Cowboy State. [Drawing by Phyllis A. Ranz.].

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

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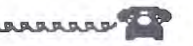

MINERALS UPDATE

OVERVIEW

by Gary B. Glass, State Geologist

The second quarter of 1990 had both its good and its bad points. Let's look at what happened to some of the major commodities. In regard to oil, four new enhanced oil recovery projects were announced at the end of the second quarter (see **Oil and Gas Update**). Collectively, these tertiary recovery projects announced by Amoco, Exxon, Kerr-McGee, and GLG Energy could account for an additional 64.3 million barrels of recoverable oil. Although this incremental production will be spread over quite a few years, it will help to slow the steady decline in annual oil production forecast for the State. In addition, oil production from a newly drilled horizontal hole in southeastern Wyoming may signal a significant new play (see article on **Horizontal Drilling in the Upper Cretaceous Niobrara Formation**).

Unfortunately, oil prices continued a decline that began in the first quarter, dropping to as low as $14.75 in mid-June. Early in the third quarter, however, the price had rebounded and was back up to $17.00 by mid-July.

In regard to natural gas, I must also echo some earlier comments by the Head of our Oil and Gas Division. He noted that it is the gas industry that is poised to give the State's economy a real boost. Wyoming has enough gas reserves to support a large enough increase in gas production to offset value declines related to declining oil production. The proposed Wyoming to California gas pipelines are the beginning of that economic boost. And the increased drilling in the gas fields of southwestern Wyoming shows that the gas industry is preparing itself.

In the meantime, gas prices have not been faring all that well. The spot sale price at Opal ended the second quarter at $1.05, compared to a high of $2.05 in January 1990. Because the higher prices in January were related to some local shortages of gas supplies during a period of high demand, odds are that the price of gas will turn around soon. There was, however, no turnaround in the second quarter of the year.

The 171.1 million tons of coal produced in Wyoming in 1989 was enough for Wyoming to retain its first place among the coal-producing states. Kentucky, however, remained a close second. Because cumulative Wyoming coal production for the first three months of 1990 is already 3.1 million tons more than it was in 1989, it looks like 1990 production will set yet another record.

It has also been pointed out (see **Coal Update**) that Wyoming coal only ranked fifth in total value in 1989, behind Kentucky, West Virginia, Pennsylvania, and Illinois, respectively. While this is probably correct, it certainly does show the bargain that utilities get when they buy **inexpensive, low-sulfur, Wyoming coal.** And Wyoming's compliant coal also reduces any costs related to the control of emissions as well. You might say Wyoming's loss in value is simply the consumer's gain.

While the number of reported new coal sales was notable in the second quarter of 1990 (see **Coal Update**), the price for a ton of Wyoming coal showed no gains in the first two quarters of the year. Perhaps the most serious thing noted in the second quarter was a short newspaper article that said a strike involving the Burlington Northern Railroad had at least temporarily been averted. A crippling strike involving this particular carrier would affect more than 100 million tons of coal produced in Wyoming as well as most of what is produced in Montana. There have been no followup articles regarding a strike.

Turning to trona, production has remained high and 1990 production should meet or exceed the record production that we have forecast (Table 1). It is interesting that an earlier somewhat pessimistic forecast by an industry observer has been proven wrong. Soda ash markets have not faltered as that forecaster predicted. What's more, all of Wyoming's soda ash producers have now announced plant expansions.

Table 1. WYOMING MINERAL PRODUCTION FORECAST TO 1993[1].

Calendar Year	Oil Production[2]	Methane Production[3]	Carbon Dioxide Production[3]	Helium Production[4]	Coal Production[5]	Trona Production[5]	Mined Uranium Production[6]	In situ Uranium Production[7]	Sulfur Production[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	—	0.63
*1985	131.0	597.9	—	—	140.4	10.8	0.6	—	0.80
*1986	122.4	563.2	23.8	0.15	136.3	13.3	0.3	—	0.66
*1987	115.9	619.0	114.2	0.86	146.5	13.6	0.2	0.06	1.19
*1988	114.3	701.6	110.0	0.83	163.6	14.9	0.3	1.4	1.10
1989	108.5	736.7	127.0	0.95	*171.1	*16.2	*0.1	1.2	1.21
1990	103.6	758.6	127.0	0.95	177.1	18.0	0.1	1.0	1.21
1991	98.1	781.1	127.0	0.95	183.8	18.0	0.1	1.5	1.21
1992	92.9	804.4	127.0	0.95	189.2	18.0	0.1	2.5	1.21
1993	88.0	828.3	127.0	0.95	193.1	21.0	0.1	2.5	1.21

*Actual values for comparison; [1]Geological Survey of Wyoming, July 1990; [2]millions of barrels; [3]billions of cubic feet; [4]billions of cubic feet, based on Exxon's estimate that the average helium content in the gas processed at Shute Creek is 0.5 percent; [5]millions of tons; [6]millions of tons of uranium ore (not yellowcake); [7]millions of pounds of yellowcake (U_3O_8), (unknown between 1981-1986 because it was reported only as taxable valuation; estimates for 1989-1993 are based on company information); [8]millions 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).

While it has been hard to find any good news in regard to the uranium industry, it is certainly encouraging that uranium prices increased from $8.80 per pound to $11.00 at the start of the third quarter. It also encouraging that Pathfinder still has onging operations in the Shirley Basin, and that there is a good likelihood that the new owners of Malapai's in-situ operation will reopen it in the not too distant future.

Based on our observations through the first two quarters of 1990, we have increased our 1991 to 1993 forecasts for in-situ uranium production in Table 1. If coal production continues to increase like it has through March, we may be able to increase our 1990 coal forecast by the end of the third quarter. There are currently no reasons to change our forecasts for the other commodities in Table 1.

Table 2 provides production histories for a number of other mineral resources mined in Wyoming. While production of ballast, sand and gravel, and scoria increased between 1988 and 1989, production of bentonite, decorative stone, dolomite, gypsum, and limestone decreased, but only slightly.

Table 2. PRODUCTION HISTORY OF SELECTED WYOMING MINERAL COMMODITIES[1].

	1981	1982	1983	1984	1985	1986	1987	1988	1989
Ballast[2,3]	1.72	0.81	0.99	2.43	0.67	0.61	1.09	0.80[8]	1.28[7]
Bentonite[2]	4.81	2.35	2.18	3.08	2.59	1.82	2.16	2.32	2.22[7]
Clay[4]	23.2	15.7	36.4	59.6	35.9	23.2	1.31	61.1	NA[9]
Decorative Stone[2]	0.05	0.05	0.07	0.08	0.09	0.07	0.06	0.07[8]	0.06[7]
Dolomite[2]	0.87	0.61	0.66	0.86	0.87	0.81	0.46	0.19[7]	0.15[7]
Feldspar[4]	0.03	0.17	----	----	----	----	----	----	----
Gypsum[2]	0.28	0.26	0.33	0.33	0.35	0.41	0.35	0.40[8]	0.20[7]
Iron Ore[2]	4.67	3.28	2.48	----	----	----	----	----	minor[10]
Limestone[2,5]	0.72	0.59	0.56	0.65	0.32	0.34	0.42	0.64	0.60[7]
Sand and Gravel[2]	5.21	4.74	5.00	4.76	4.71	3.53	2.57	2.16	4.62[7]
Scoria[2,6]	0.08	0.08	0.07	0.23	0.13	0.04	----	0.20[7]	0.37[7]
Shale[4]	----	----	----	20.3	14.7	9.88	49.0	50.2[7]	NA[9]
Sodium Sulfate[4]	3.20	3.17	3.19	3.25	2.71	2.03	----	2.10[7]	NA[9]

Sources: [1]Ad Valorem Tax Division. [2] Millions of short tons. [3] Includes granite, scoria and other rock. [4] Thousands of short tons. [5] Includes limestone used for cement rock, sugar beet refining, and other uses. [6] Baked and fused rock, also called clinker. [7] Wyoming State Inspector of Mines. [8] Estimated by Geological Survey of Wyoming. [9] NA = not available. [10] Less than 1,000 tons of iron ore were sold for pigment. Prepared by Geological Survey of Wyoming, July, 1990.

OIL AND GAS UPDATE

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

In January and February 1990, the average posted prices for Wyoming Sweet crude oil were at their highest levels in over three years. Since then (March through June), however, the average posted price has declined (Figure 1). By way of an explanation, refiners across the country bought extra crude oil in January and February to replenish their stocks which had been lowered following the high demand for heating oil and other products during the very cold December of 1989. They were able to rebuild their inventories rather quickly because of the relatively warm weather in early 1990.

OPEC had responded to this increased demand for crude oil in January and February with increased production. Unfortunately, OPEC also continued to produce more crude oil in March and April after most refiners had rebuilt their stocks. Because refiners were no longer willing to pay as much for crude oil once their inventories were rebuilt, prices for crude oil dropped in March and April. OPEC met in early May and agreed to cut production by 1.45 million barrels per day. This agreement stabilized the market somewhat during May (Figure 1). Although several OPEC countries cut back their production in May, several others continued to overproduce. The net effect was a production cut of only 400,000 barrels in May instead of the 1.45-million-barrel cut that was agreed upon.

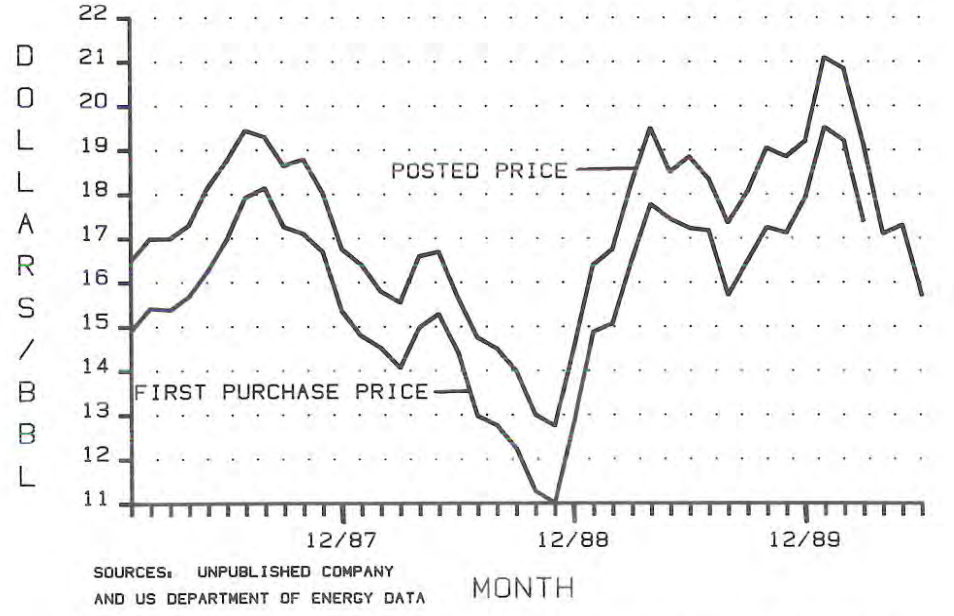

Figure 1. WYOMING CRUDE OIL PRICES AVERAGED BY MONTH (1987-PRESENT).

News of OPEC's overproduction in May sent posted prices for Wyoming Sweet to $14.75 per barrel in mid-June. Posted prices recovered later in June when reports indicated that OPEC had cut production more than expected in June and that some non-OPEC countries were also considering possible production cuts. Price increases in late June were tempered somewhat by reports that showed refiners' stocks at 40 million barrels (11.5 percent) above the levels of one year ago.

Third quarter posted prices for Wyoming Sweet crude could average less than $17 even if OPEC significantly cuts their production. It appears that refiners' inventories are high enough to handle much of the increased demand for products during the summer driving season. If OPEC does not exercise production restraint over the next several months, Wyoming producers may receive even less for their crude oil for the rest of the year.

In response to lower prices, the rig count has stayed relatively low in the second quarter after being somewhat higher than 1989 levels at comparable times during the first part of 1990 (Figure 2). Seismic permits and applications for permits to drill (APD's) issued by the Wyoming Oil and Gas Conservation Commission are higher than at the same time in 1989. When projected for all of 1990, however, they are at similar levels to the last four years (Figure 3). It is possible that APD's will end up slightly higher in 1990 than in 1989 because these applications often increase during the latter part of the year.

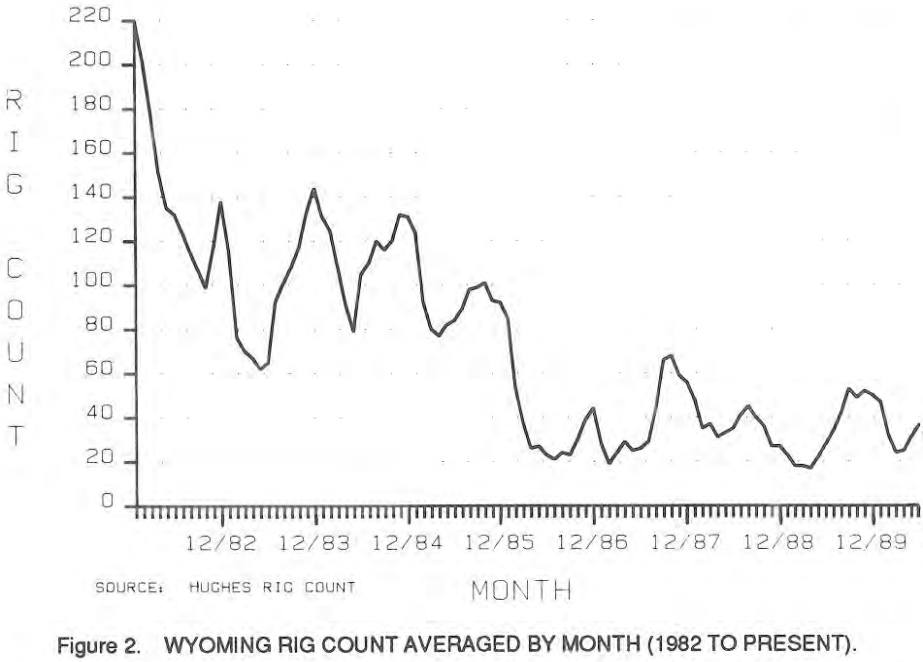

Figure 2. WYOMING RIG COUNT AVERAGED BY MONTH (1982 TO PRESENT).

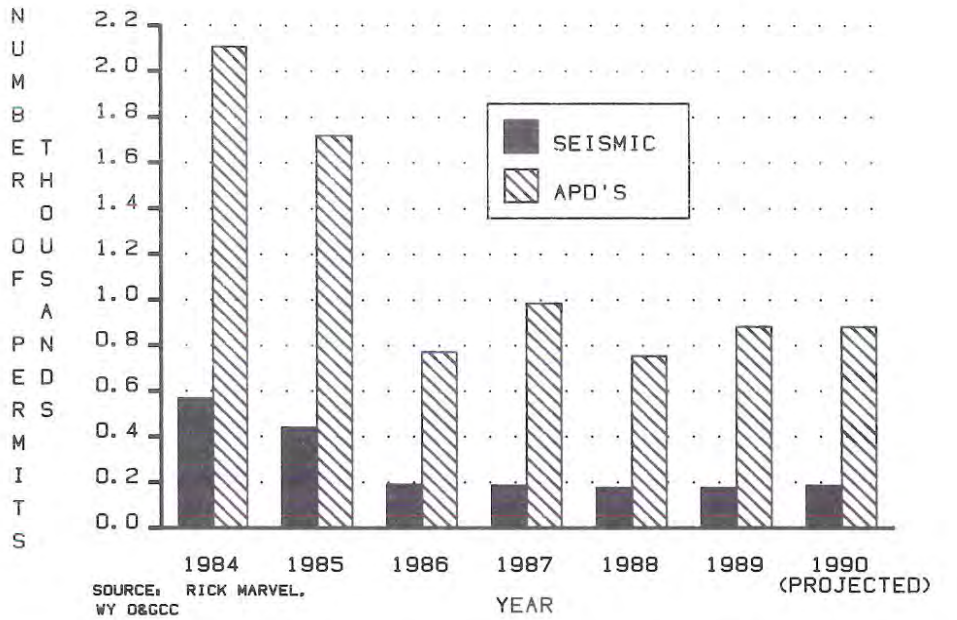

Figure 3. REQUESTS FOR SEISMIC PERMITS AND APPLICATIONS TO DRILL (APDs) MADE TO THE WYOMING OIL AND GAS CONSERVATION COMMISSION (1984 TO PRESENT).

All or portions of several projects were certified as tertiary recovery operations at a special hearing held by the Wyoming Oil and Gas Conservation Commission in late June. Applications were filed by Amoco, Exxon, Kerr-McGee, and GLG Energy. Amoco plans to use the huff n' puff process (single-well, cyclic, carbon dioxide stimulation) on as many as 4,000 wells in Elk Basin, Little Buffalo Basin, Winkleman, Lander, Beaver Creek, Lost Soldier, Wertz, and Salt Creek Fields (Figure 4) over the next ten years. The project will involve injection of carbon dioxide (CO_2) into multiple producing zones within each field. It will take around 10 million cubic feet of CO_2 for each treatment. Amoco estimates that as much as 23.6 million barrels of incremental oil will be recovered if all the planned wells are injected with CO_2.

Exxon plans to inject 160 billion cubic feet of CO_2 into the Shannon Sandstone at Hartzog Draw Field (Figure 4) and estimates that additional oil recovery from this more conventional CO_2 flood will range from 14 to 22 million barrels. The project is due to begin late in 1992. Exxon may supply the CO_2 for this project with a new pipeline from their Shute Creek plant in southwestern Wyoming.

Exxon has awarded a $700,000 contract to Western Wyoming College for archeological studies which will assist them in the determination of a prospective

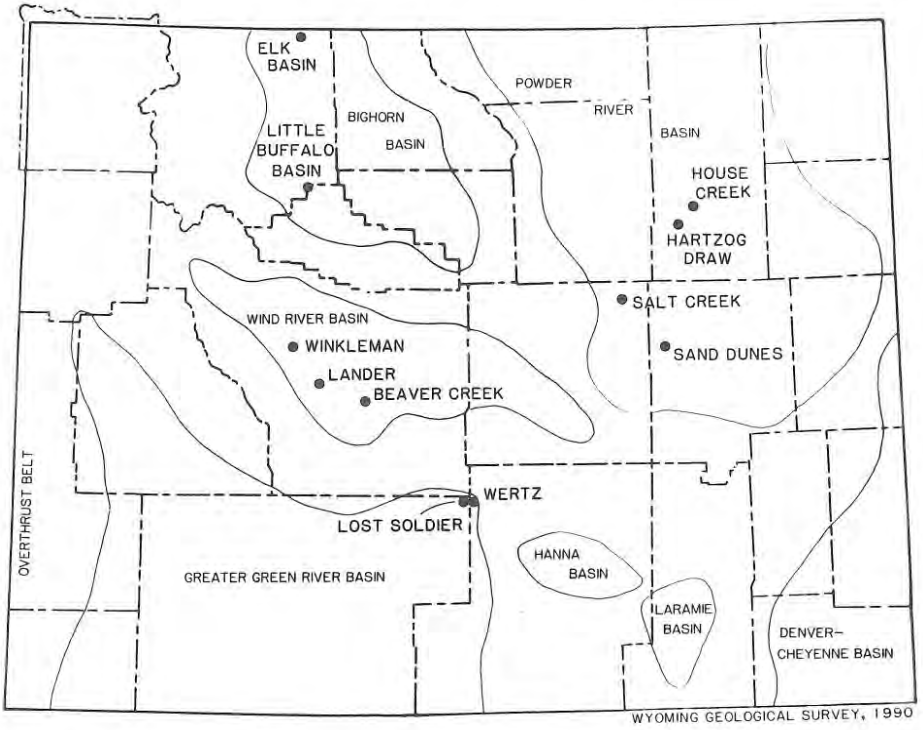

Figure 4. NEW ENHANCED OIL RECOVERY PROJECTS IN WYOMING.

route for a possible 150-mile extension of the pipeline that delivers CO_2 to Wertz and Lost Soldier Fields. Plans for the pipeline are still tentative.

Kerr-McGee plans to proceed with the injection of lean hydrocarbon gas into the Muddy Sandstone at Sand Dunes Field (Figure 4). The project is scheduled to begin early in 1991. Kerr-McGee estimates that an additional 16 to 18 million barrels of oil will be recovered from this project.

GLG Energy will use a polymer-augmented waterflood in the Sussex Sandstone at House Creek Field (Figure 4) to recover an estimated 0.7 million barrels of tertiary oil. If all of these enhanced oil recovery projects go as planned, an additional 64.3 million barrels of tertiary oil could be recovered.

Industry activity in southwestern Wyoming continues to accelerate in anticipation of a pipeline to carry gas from Opal, Wyoming, to southern California and because of increased markets for Wyoming gas in the Pacific Northwest and the Midwest. Kern River Gas Transmission Co. and WyCal Pipeline Co. are apparently both still in the race to build a Wyoming to California pipeline. Both companies placed orders for most of the large-diameter pipe needed for their respective pipelines and

each claims they have signed enough firm transportation contracts to fill their lines. Both companies plan to begin construction later this year and to begin delivery of gas by late 1991.

Altamont Gas Transmission Co. is also moving ahead with plans to move Canadian gas and possibly some Wyoming gas to Opal and then through Kern River's pipeline to southern California beginning in 1993. The company has filed with the Federal Energy Regulatory Commission for an optional certificate to construct and operate the pipeline and has signed precedent agreements to ship 533 million cubic feet per day of the pipeline's 719 million cubic feet per day capacity. Meanwhile, a California Energy Commissioner stated that demand for natural gas in California by the year 2007 will be 2.5 billion cubic feet per day higher than at the present time.

At a meeting with the Wyoming Natural Gas Pipeline Authority and with Governor Mike Sullivan, Union Pacific Resources, Amoco, and Mobil unveiled future drilling plans in southwestern Wyoming. Union Pacific Resources and its partners should complete a 100-well drilling program on the Moxa Arch this year. Another 30 wells are planned on the arch for 1991. The company expects to drill 13 wells in the Church Buttes area and 18 wells in the Bruff area this year. Another 36 wells on the northern end of the Moxa Arch are planned within the next two years. Union Pacific completed 18 gas-producing wells on the Rock Springs uplift in 1989 and plans to drill 22 additional wells there in 1990.

Amoco plans to drill nine development and five wildcat wells this year on the Moxa Arch and in the Wamsutter area. Amoco also plans to drill 10 to 20 wells in these two areas in 1991.

Mobil will drill 15 new wells on the northern end of the Moxa Arch by 1992. Most of Mobil's gas in this area is presently shut in.

In a related item, Coastal Oil and Gas announced plans to drill 20 to 40 wells in the Riley Ridge area on the north end of the Moxa Arch to develop Frontier Formation gas reserves. Enron Oil and Gas drilled 30 Frontier Formation gas wells on the Moxa Arch in 1989 and has plans to drill 30 more Frontier wells each year, through 1993. In addition, Chevron, Texaco, and several independent operators are actively drilling in the Moxa Arch area.

Lease sales did well during the second quarter of 1990. The Wyoming Department of Public Lands' May sale netted the most revenue of any State sale since September, 1988 (Table 3). The high per-acre bid at this sale was $270 by Bruce Evertson for a 400-acre tract that includes S/2 NW and S/2 section 26, T.13N., R.68W. Evertson recently drilled the 26-2 Warren Livestock well in NE NE section 26, T.13N., R.68W. and spudded the 26-3 Warren Livestock well in NW NE section 26, T.13N., R.68W. Both wells are 9,000-foot "J" sand tests in Borie Field. No other details have been disclosed on either well.

Table 3. FEDERAL AND STATE COMPETITIVE OIL AND GAS LEASE SALES IN WYOMING.

BLM SALES

Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
			1987				
TOTAL	$15,724,159	727	646	197,422	177,960	$ 88.36	$6,555.00
			1988				
March	$7,338,210	866	336	1,073,940	315,387	$23.27	$525.00
June	$7,564,135	820	375	755,242	293,050	$25.81	$575.00
August	$5,827,548	847	363	827,471	278,198	$20.95	$1,350.00
October	$3,913,765	820	257	994,618	282,145	$13.87	$6,500.00
December	$3,045,203	766	260	761,242	182,117	$16.72	$330.00
TOTAL	$27,688,861	4,119	1,591	4,412,513	1,350,897	$20.50	$6,500.00
			1989				
February	$2,418,295	800	230	857,475	187,012	$12.93	$1,225.00
April	$2,334,604	732	227	557,643	145,055	$16.09	$390.00
June	$1,673,150	758	163	962,929	138,691	$12.06	$160.00
August	$3,469,570	656	197	577,518	141,841	$24.46	$285.00
October	$3,247,334	788	296	657,918	178,013	$18.24	$3,000.00
December	$2,689,152	552	247	415,266	181,791	$14.79	$340.00
TOTAL	$15,832,105	4,286	1,360	4,028,750	972,403	$16.28	$3,000.00
			1990				
February	$3,301,479	524	259	335,275	141,555	$23.32	$340.00
April	$2,163,988	513	218	399,790	138,909	$15.58	$275.00
June	$3,480,557	511	315	305,550	172,798	$20.14	$240.00

STATE SALES

Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
			1987				
TOTAL	$2,526,567	1,200	579	511,638	244,740	$10.32	$2,300.00
			1988				
January	$826,698	200	142	76,953	56,430	$14.65	$200.00
March	$800,213	200	133	76,304	48,423	$16.53	$465.00
May	$1,649,974	200	182	75,987	69,285	$23.81	$290.00
July	$1,855,646	200	155	77,168	60,519	$30.66	$375.00
September	$751,646	200	142	68,456	55,168	$13.63	$180.00
November	$318,547	200	119	71,085	42,118	$7.56	$130.00
TOTAL	$6,202,724	1,200	873	445,953	331,943	$18.69	$1,640.00
			1989				
January	$331,145	200	112	73,322	39,650	$8.35	$110.00
March	$493,179	200	129	74,512	47,886	$10.30	$140.00
May	$512,736	199	129	76,396	51,919	$9.88	$155.00
July	$684,374	200	154	82,760	65,034	$10.52	$190.00
September	$474,104	200	134	77,889	50,749	$9.34	$540.00
November	$628,446	200	134	76,973	56,036	$11.22	$170.00
TOTAL	$3,123,984	1,199	792	461,852	311,274	$10.04	$540.00
			1990				
January	$190,921	200	100	74,987	38,884	$4.91	$46.00
March	$668,262	200	132	79,405	54,193	$12.33	$85.00
May	$690,310	199	146	79,667	60,986	$11.32	$270.00

Sources: Wyoming Department of Public Lands, Petroleum Information Corporation - Rocky Mountain Region Report, and U.S. Bureau of Land Management.

The high per-acre bid at the U.S. Bureau of Land Management's (BLM's) April sale was $275 by Wacker Oil for a 120-acre lease that includes NE SW and W/2 SE section 10, T.49N., R.72W. The tract is less than a mile southeast of Minnelusa oil production from Einar Field. Revenue from the June BLM sale was the highest since an October, 1988 sale (Table 3). Prenalta Corp. made the high per-acre bid of $240 at this sale for a 188.04-acre parcel covering Lots 9, 10, 11, and 18 of section 4, T.53N., R.69W. The tract is within a mile of Minnelusa oil production at York and Spring Hole Fields. Exxon made the sale's second high per-acre bid of $180 for a 1,600-acre lease that includes S/2 section 2, NE section 20, section 22, NE section 28, and W/2 section 34, T.21N., R.110W. The lease is five to eight miles southeast of the discovery well for Sugarloaf Butte Field, a new Dakota oil and gas field. This area of the Green River Basin has recently seen increased exploration activity for oil and gas in the Frontier and Dakota Formations.

If revenues from State and Federal sales continue on their present course, the revenue from 1990 sales should surpass the revenue generated from sales in 1985, 1986, 1987, and 1989 (Figure 5).

The U.S. Bureau of Land Management (BLM), which has extended a directive, allowing temporary shut in of stripper wells and marginal wells to May 31, 1991, is

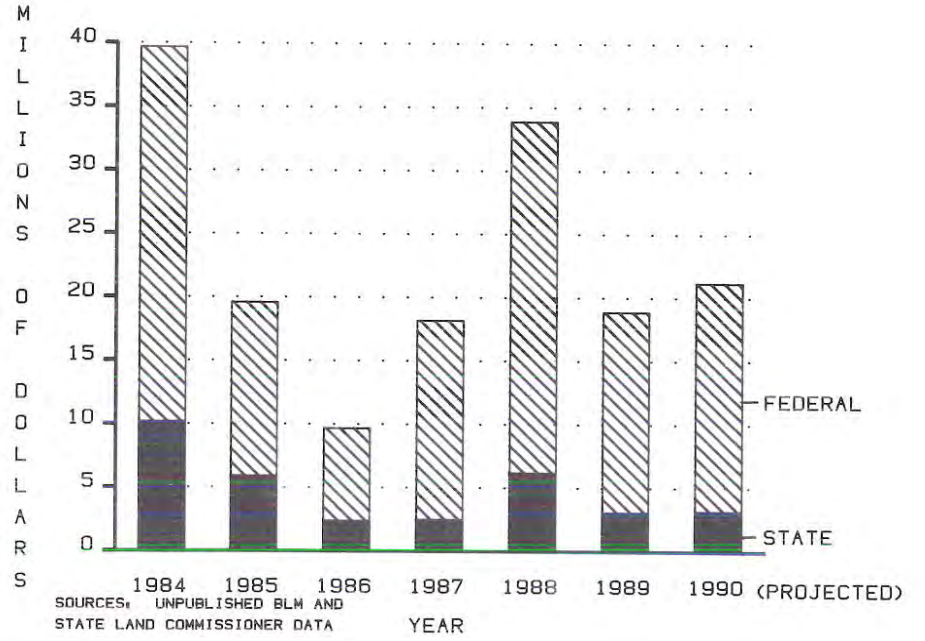

Figure 5. YEARLY REVENUES FROM FEDERAL AND STATE OIL AND GAS LEASE SALES IN WYOMING.

planning hearings on further extensions of this directive. The BLM also will consider what tests or bonding requirements will be required to ensure that the shut-in wells will not pose an environmental risk or put the Federal government at risk in regard to potential liability for unplugged wells.

Based on company data and on information compiled and published by Petroleum Information, the following significant exploration and development events occurred in Wyoming during the second quarter of 1990. The letters preceding the discussions below refer to locations on Figure 6.

A. Mobil Oil set production casing at a Dakota prospect five miles west of Henry Field and five miles north of Taylor Ranch Field. The F22-33G West Flank Unit well was drilled in SE NW Section 33, T.14N., R.114W. No other details are available on this well.

B. Horizontal drilling is picking up momentum in Wyoming. Texaco Inc. plans to drill a shallow well with three horizontal legs at 120-degree angles to each other.

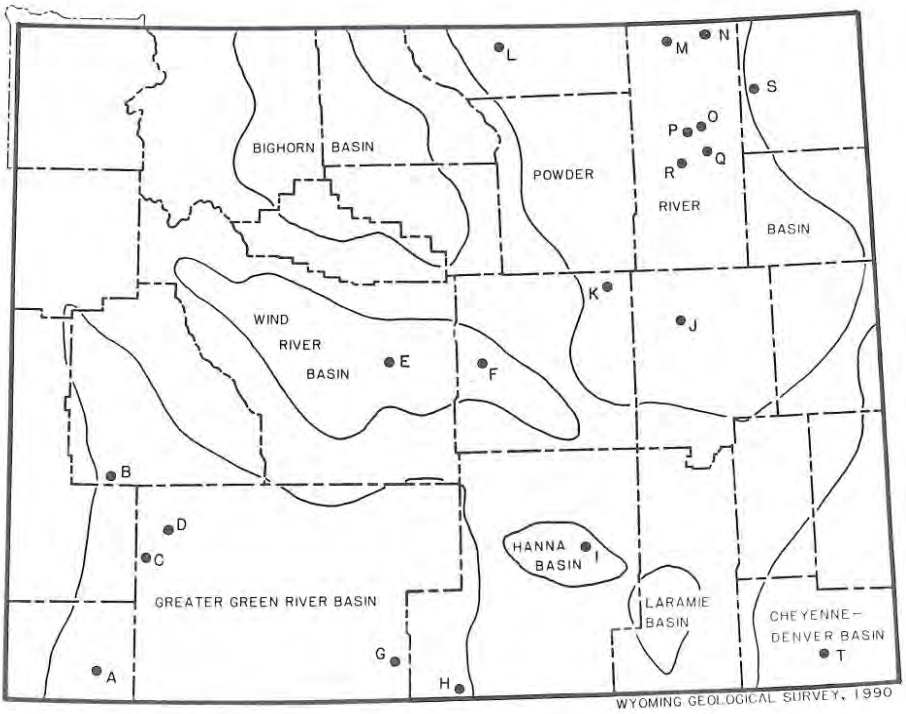

Figure 6. OIL AND GAS EXPLORATION AND DEVELOPMENT ACTIVITY IN WYOMING.

The G634Y LaBarge Unit well will be drilled vertically in NE SW section 34, T.27N., R.113W., to a depth of 460 feet in the Almy sand. Texaco will then drill three 200-foot horizontal radials, one to the southwest, one to the southeast, and one to the north.

C. Amoco Production is reportedly producing gas at a stepout well from the Legacy Field Dakota oil and gas discovery well drilled by General Atlantic in 1988. The Amoco 1 State of Wyoming A well was completed in the Frontier in SW NE section 16, T.22N., R.111W. It flowed gas at the rate of 1.1 million cubic feet per day.

D. Thermal Exploration's 11-14 Palmetto-Federal well in NW NW section 14, T.24N., R.109W., had shows of oil and gas on a drillstem test of the Mesaverde. The prospect is about five miles southeast of Frontier and Dakota production in the Blue Forest Field area.

E. There is increased activity in the Fort Union gas play in the Wind River Basin. TCF completed the Ester Fuller #4 well in NE SE section 26, T.36N., R.94W., in Fuller Reservoir Field. The well flowed 10.7 million cubic feet of gas per day from a total of 257 feet of perforations in ten separate sands. This is the fourth well that TCF has completed in this field since late 1987. Their Ester Fuller #1 well in SW NW section 25, T.36N., R.94W., had produced nearly 1.4 billion cubic feet of gas through March, 1990. Their Ester Fuller #2 well in NE NE section 26, T.36N., R.94W., has produced nearly 700 million cubic feet of gas in just seven months and their Ester Fuller #3 well in NE SW section 26, T.36N., R.94W., produced an average of 905 thousand cubic feet of gas per day during March.

F. Chevron USA also completed a Fort Union gas producer in the Wind River Basin. The 14 Waltman Unit well in NE SE section 13, T.36N., R.87W., flowed 2.04 million cubic feet of gas per day from several Waltman sands.

G. Union Pacific Resources tested their 1 Celsius State 16-1 well in SW NW section 16, T.14N., R.94W., in the Almond Formation for one million cubic feet of gas per day. The well is in Dripping Rock Field which was discovered in 1984. Two other Almond wells in the field had produced a total of 9.7 billion cubic feet of gas through March, 1990, even though both wells are shut in during the summer.

H. Fuel Resources Development Co. has locations staked for nine coalbed methane tests in the Almond Formation near Baggs, Wyoming. The locations are all in T.12-13N., R.90W. These locations are near their A-11-12-90 Russell well in NE NE section 11, T.12N., R.90W., which is reportedly producing gas and water from the Almond.

I. Anderman-Smith Operating staked locations for four coalbed methane tests in the Hanna Basin. The tests are projected to depths that range from 4,500 to 6,000 feet in the Ferris Formation and they are all located in T.23N., R.81W.

J. Hornbuckle Field, discovered in 1984, has a new producing well. The 33-23 State well in NW SE section 23, T.37N., R.73W. M.J. Kennedy Oil completed the well in the Sussex Sandstone flowing 500 barrels of oil per day.

K. In other horizontal drilling activity, Hondo Oil and Gas completed their 1-16H well with a bottom hole location in SW NW section 15, T.40N., R.78W. The well is in East Salt Creek Field and was completed in the Second Wall Creek for an initial pumping potential of 185 barrels of oil, 40,000 cubic feet of gas, and 269 barrels of water per day. Just to the southwest, Amoco plans to drill a horizontal test in the Second Wall Creek in Salt Creek Field. The well will bottom in section 25, T.40N., R.79W.

L. There is fairly active exploration in the Shannon Sandstone play in the Sheridan area of the Powder River Basin. Fields in the Powder River Basin which produce from the Shannon have a predominant northwest-southeast trend, and it is believed that sands in the Shannon were most likely deposited as bars on a mid or outer shelf. To the southeast in Campbell County, Hartzog Draw produced over five million barrels of oil from the Shannon in 1989. Ash Creek and Ash Creek South combined, have produced over 13 million barrels of oil from the Shannon in Sheridan County. In the nearly 80 miles between these two producing areas, there are very few wells that have produced from the Shannon. True Oil is drilling a Shannon test in SE NE section 35, T.55N., R.83W., about 20 miles southeast of Ash Creek South Field. EOG recently completed their 1-6 Bates well in NE NE section 6, T.56N., R.83W., as a dry hole in the Shannon. Both wells are on trend between Hartzog Draw and Ash Creek.

M. Recluse Field has two new Minnelusa producing wells. Hondo Oil and Gas completed their 1 Sutherland-Federal well in NE SW section 11, T.56N., R.74W., for 55 barrels of oil per day. Just to the north in SE NE section 11, Yates Petroleum completed their Yates' 4 Calamity Springs well for 321 barrels of oil per day.

N. Quintana Petroleum completed a stepout from the Hugie Draw Field discovery well. The 1-19 Rocky Butte-Federal in NE NW section 19, T.57N., R.71W., was completed in the Minnelusa pumping 276 barrels of oil per day.

O. CNG Producing discovered oil in the Muddy Sandstone with their 23-20 Federal well in SE NW section 30, T.51N., R.71W. A drillstem test recovered nearly 1,000 feet of highly gas-cut oil. The well is about one mile northwest of Muddy production at Springen Ranch Field. The CNG well produced an average of 127 barrels of oil per day in March.

P. Martens and Peck Operating completed a shallow coalbed methane well in the Fort Union Formation. The 3-Walls-Fee well in SE NE section 30, T.51N., R.72W., flowed 640,000 cubic feet of gas and 330 barrels of water per day. The discovery is a mile southwest of Rawhide Butte Field, which also produces coalbed methane from the Fort Union Formation.

Q. Rainbow Ranch Field has a new Minnelusa producer. Apache Corp.'s 7 Rainbow Ranch Unit well in NE SW section 24, T.49N., R.71W. was completed for 823 barrels of oil per day.

R. DeKalb Energy has an apparent Minnelusa discovery about one mile northwest of Minnelusa production at Doe Field. A drillstem tests at the 32-27 Moser well in SW NE section 27, T.48N., R.73W., recovered 2,140 feet of gas and 525 feet of oil. No other details are currently available.

S. Petroleum Inc. added a new Minnelusa producer to Kiehl Field. The 7 Kiehl in NE SE Section 30, T.53N., R.67W., was completed for 166 barrels of oil and two barrels of water per day. This well extends the boundary of Kiehl Field to the northeast.

T. Cowan Oil Co. completed a horizontal Niobrara test in Silo Field flowing 2,000 barrels of oil and 500,000 cubic feet of gas per day. The 1 Warren well in NW NE section 11, T.15N., R.65W., is the first successful horizontal Niobrara test in the State. More information on this well and the Niobrara play is included in a later article in this issue of Wyoming Geo-notes (see **Horizontal Drilling in the Upper Cretaceous Niobrara Formation**).

COAL UPDATE

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

In 1989, Wyoming retained its ranking as the top coal-producing state in the U.S., but only by a slight margin. The 171,140,004 short tons of coal produced in Wyoming last year was about 0.6 million tons more than the 170,515,184 short tons produced by Kentucky. When Wyoming became the Nation's leading coal producer in 1988, the State produced about 7.1 million short tons more than Kentucky. While Wyoming's 1989 production was a 4.6 percent increase over 1988, Kentucky recorded an 8.8 percent increase for the same period. West Virginia remained the third leading coal-producing state in 1989 with 152,544,262 short tons produced. A summary of the last ten years of coal production for the top five coal-producing states in the U.S. (Figure 7) reveals that Wyoming became the third largest coal-producing state in 1980, the second largest producer in 1985, and the leading producer in 1988.

The *Coal Journal* (formerly the *Kentucky Coal Journal*) recently pointed out that although Wyoming was number one in coal production in 1988, it ranked only fifth in the Nation in value (*The Coal Journal*, 1990). Kentucky ranked first with coal valued at $4.14 billion, followed by West Virginia ($4.09 billion), Pennsylvania ($2.11 billion), Illinois ($1.67 billion) and in fifth place, Wyoming ($1.50 billion). The value

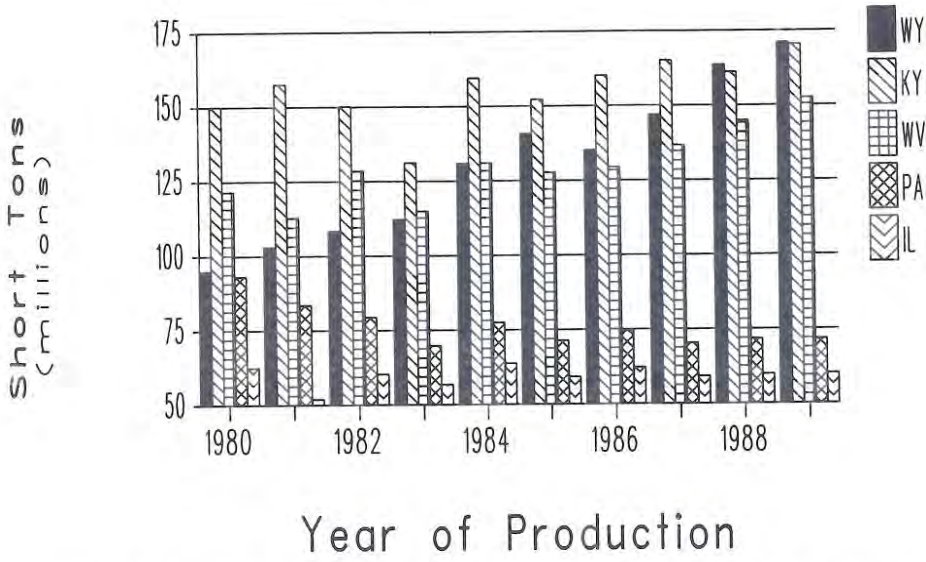

Figure 7. PRODUCTION FROM THE TOP 5 COAL-PRODUCING STATES IN THE U.S. (1980-1989).

for each state was determined by multiplying total coal production by average mine price (in dollars per ton) using figures published by the Energy Information Administration (1989).

National coal production in 1989 is now reported at 980 million short tons, an increase of 27.3 million tons (or nearly 3 percent) over 1988 production. The top five coal-producing states accounted for about 625.9 million short tons (or nearly 64 percent) of the National total; Wyoming alone accounted for over 17 percent of the National total and about 45 percent of the 384 million short tons produced in the western United States.

The first quarter of 1990 saw monthly coal deliveries from Wyoming mines exceed deliveries for the same period in every past year (see Table 4 and Figure 8). By the end of the first quarter, coal deliveries were already three million tons ahead of 1989's record pace. If this trend continues, Wyoming coal production in 1990 is certain to set another new record and could exceed the 177.1 million tons we have projected for this year (see Table 5). Coal production for Wyoming in 1990 will probably increase from three to seven percent over the past year's production. Our current estimate of 177.1 million tons in 1990 only requires a four percent increase in production. While the increase in first quarter production is 7.6 percent, it is still too early to change our current forecast.

Table 4. COAL DELIVERIES BY MONTH FROM WYOMING MINES[1]

	1986 MONTHLY	1986 CUMULATIVE	1987 MONTHLY	1987 CUMULATIVE	1988 MONTHLY	1988 CUMULATIVE	1989 MONTHLY	1989 CUMULATIVE	1990 MONTHLY	1990 CUMULATIVE
JANUARY	11,646,300	11,646,300	12,085,570	12,085,570	10,976,860	10,976,860	14,283,020	14,283,020	15,059,530	15,059,530
FEBRUARY	10,317,700	21,964,000	10,315,680	22,401,250	11,431,380	22,408,240	11,488,140	25,771,160	13,328,290	28,387,820
MARCH	11,401,720	33,365,720	10,436,610	32,837,860	12,871,090	35,279,330	14,124,330	39,895,490	14,535,270	42,923,090
APRIL	9,954,170	43,319,890	10,429,180	43,267,040	12,694,660	47,973,990	13,489,450	53,384,940		
MAY	10,105,320	53,425,210	10,619,470	53,886,510	12,017,500	59,991,490	13,149,170	66,534,110		
JUNE	10,499,280	63,924,490	11,953,650	65,840,160	12,595,480	72,586,970	12,948,350	79,482,460		
JULY	11,497,190	75,421,680	12,850,240	78,690,400	13,905,670	86,492,640	14,043,350	93,525,810		
AUGUST	11,773,510	87,195,190	13,460,470	92,150,870	15,041,090	101,533,730	15,428,210	108,954,020		
SEPTEMBER	11,474,820	98,670,010	12,651,550	104,802,420	13,433,610	114,967,340	13,795,760	122,749,780		
OCTOBER	10,854,670	109,524,680	12,248,080	117,050,500	13,696,190	128,663,530	14,523,480	137,273,260		
NOVEMBER	11,971,990	121,496,670	12,340,720	129,391,220	13,889,890	142,553,420	14,507,130	151,780,390		
DECEMBER	13,025,490	134,522,160	13,008,300	142,399,520	14,540,510	157,093,930	13,527,880	165,308,270		
TOTAL TONNAGE REPORTED	134,522,160		142,399,520		157,093,930		165,308,270			
TOTAL TONNAGE NOT REPORTED	1,782,896		4,089,128		6,494,270		5,831,734			
TOTAL TONNAGE PRODUCED[2]	136,305,056		146,488,648		163,588,200		171,140,004			

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

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

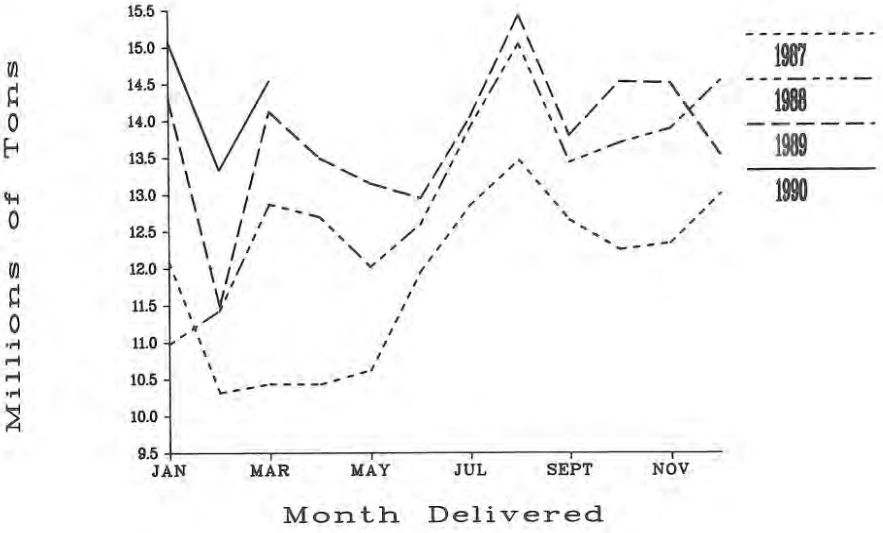

Figure 8. REPORTED DELIVERIES FROM WYOMING COAL MINES. (From COALDAT Marketing Reports by Resource Data International, Inc., compiled from FERC Form 423 filed monthly by electric utilities).

Recently available data on the distribution and utilization of coal produced in 1989 (Energy Information Administration, 1990) indicates that Wyoming coal was used in 29 different states (Figure 9) and overseas. Texas continued as the largest consumer of Wyoming coal in 1989, followed by Wyoming, Kansas, Oklahoma, Iowa, and Arkansas. Of the 20 states that used over 100,000 tons of Wyoming coal in 1988 (see *Wyoming Geo-notes No. 23*, July, 1989, p. 15), ten states used less coal in 1989, seven states used more coal, and three states used about the same amount. An additional two states, Georgia and Ohio, also became consumers of more than 100,000 tons of Wyoming coal in 1989. Five other states that did not use Wyoming coal in 1988 reported coal deliveries in 1989. In total, seven more states used Wyoming coal in 1989 than in 1988 (Georgia, Ohio, New Hampshire, Alabama, Mississippi, Kentucky, and North Dakota).

Significant increases in Wyoming coal usage were recorded in Indiana (an additional 3.0 million tons), Texas (2.9 million tons), and Minnesota (2.2 million tons). Significant decreases in usage were recorded in Illinois (1.3 million tons less), Wyoming (1.1 million tons), and Arkansas (0.8 million tons). Four states consumed almost 50 percent of Wyoming's coal; nine states consumed almost 80 percent of Wyoming's coal.

Table 5. COAL PRODUCTION AND FORECAST TO 1995 (MILLIONS OF TONS).

	1983[1]	1984[1]	1985[1]	1986[1]	1987[1]	1988[1]	1989[1]	1990	1991	1992	1993	1994	1995
Campbell County	88.2	106.8	113.9	111.0	122.3	135.7	143.8	150.9	156.9	161.6	164.8	168.1	171.5
Converse County	2.7	3.3	3.6	4.8	5.1	5.7	6.1	6.0	6.5	7.0	7.5	7.5	7.5
Sheridan County	2.9	2.5	2.4	1.4	1.2	0.9	0.1	M[2]	M	M	M	M	M
Carbon County	4.8	5.1	3.3	1.5	2.2	4.1	4.1	3.0	2.5	2.0	2.0	2.0	2.0
Sweetwater County	9.5	8.9	13.2	12.9	11.8	12.2	12.2	12.0	12.5	13.0	13.0	13.0	13.0
Lincoln County	4.0	4.1	4.3	4.0	3.8	4.9	4.9	5.2	5.4	5.6	5.8	5.8	5.8
Hot Springs County	M	M	M	M	M	M	M	M	M	M	M	M	M
Total Wyoming[3]	112.2	130.7	140.7	135.7	146.5	163.6	171.1	177.1	183.8	189.2	193.1	196.4	199.8
Annual change	4%	16.5%	7.7%	-3.6%	8.0%	11.7%	4.6%	4.0%	3.8%	2.9%	2.1%	1.7%	1.7%

[1] These are actual values for comparison. [2] M means minor tonnage (less than 0.1 million tons). Forecast by Geological Survey of Wyoming, July, 1990.
[3] Totals may not equal sum of components because of independent rounding.

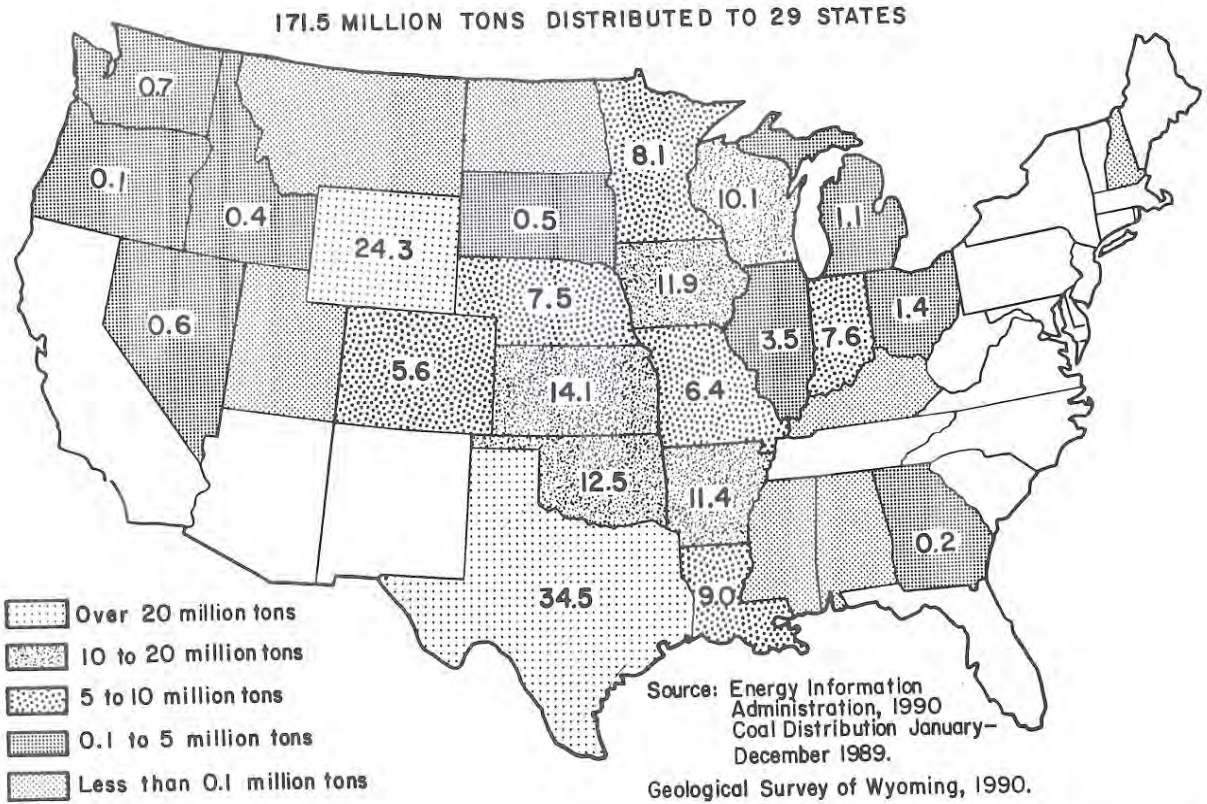

Figure 9. DISTRIBUTION OF WYOMING COAL IN 1989 IN MILLIONS OF TONS (Note: The Energy Information Administration's report shows 0.4 million tons more coal was shipped in 1989 than what the State Inspector of Mines shows as 1989 production. This is a function of

In 1989, electric utility companies located in 23 different states used 97.7 percent of Wyoming's total coal production to fuel steam-electric generating plants (Figure 10). Seventeen different states used Wyoming coal to fuel industrial boilers and 10 states used Wyoming coal for residential/commercial heating. About 1.6 million tons (of the four million tons) in the "other industrial" and the "residential/ commercial" categories went 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 the 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 Corporation's synthetic coke plant in Lincoln County and in a sugar beet processing plant at Torrington.

About 86 percent of Wyoming's coal was shipped out of state in 1989, including 78,000 tons of coal that was exported out of the country. Ironically, about 240,000

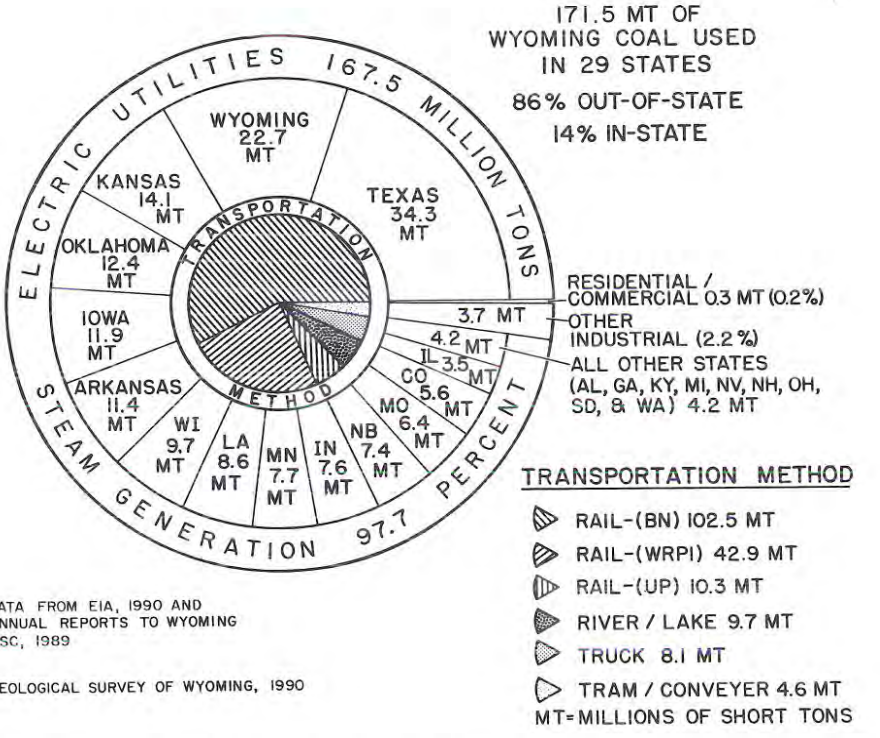

Figure 10. UTILIZATION AND TRANSPORTATION OF WYOMING COAL IN 1989. (Note: The Energy Information Administration's report shows 0.4 million tons more coal was shipped in 1989 than what the State Inspector of Mines shows as 1989 production. This is a function of independent rounding as well as the timing of some shipments).

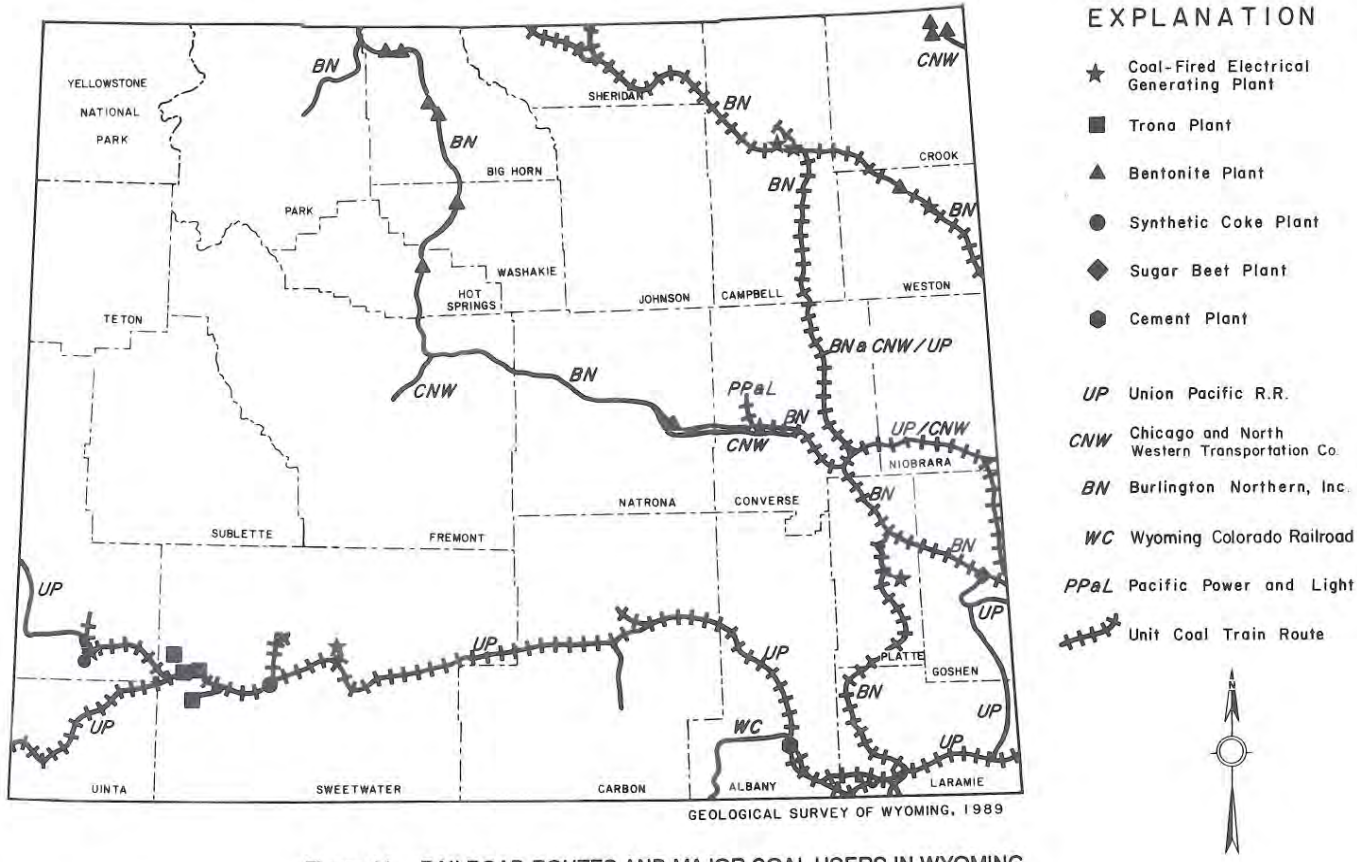

Figure 11. RAILROAD ROUTES AND MAJOR COAL USERS IN WYOMING.

tons of coal used in Wyoming in 1989 were imported from Colorado, Utah, Montana, Pennsylvania, and Coal Production District 8 (which includes parts of Kentucky, Virginia, Tennessee, and Virginia and all of North Carolina). Most of the coal imported into Wyoming is used for "other 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.

Transportation of Wyoming coal in 1989 (Figure 10) was primarily by railroads (92 percent); coal transported by river/lake refers to coal that reached its final destination by barge after originating on a railroad. The 158.3 million tons of coal transported by rail in 1989 represents a 5.5 percent increase (or 8.2 million tons) over 1988.

Burlington Northern Railroad (BN) continues to dominate railroad haulage of coal in Wyoming as the company's 102.5 million tons of coal accounted for nearly 65% of all coal shipped by railroad. 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 (C&NW)/Union Pacific Railroad Company (UP) joint-venture railroad out of the Powder River Coal Field, carried 5.9 million tons (or 16 percent) more coal in 1989 than in 1988. The 42.9 million tons of coal reported by WRPI accounted for 27 percent of the railroad tonnage in Wyoming.

Southern Wyoming coal fields are served by UP; 10.3 million tons of coal or nearly seven percent of the total railroad tonnage in 1989 was hauled by UP. An additional 2.6 million tons of coal (not shown on Figure 10) are hauled on Pacific Power and Light Company's (PP&L) private railroad line between Glenrock Coal Company's mine and the Dave Johnston power plant.

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 12). In contrast, coal tonnages hauled from southern Wyoming mines have decreased slightly since 1983 and reflect a plateau in coal production from this part of Wyoming. A slight yearly increase in the C&NW/UP joint venture's share of the total tonnage (transported out of the Powder River Coal Field) indicates that there is still keen competition between the joint venture and BN. This competition in rail rates and transportation contracts could, in part, be responsible for the increased production occurring at many of the mines in southern Campbell and northern Converse Counties that are served by both railroads.

In other coal transportation news, Santa Fe Pacific Corp. (SFP) has settled an antitrust lawsuit brought against them (and five other western railroad companies)

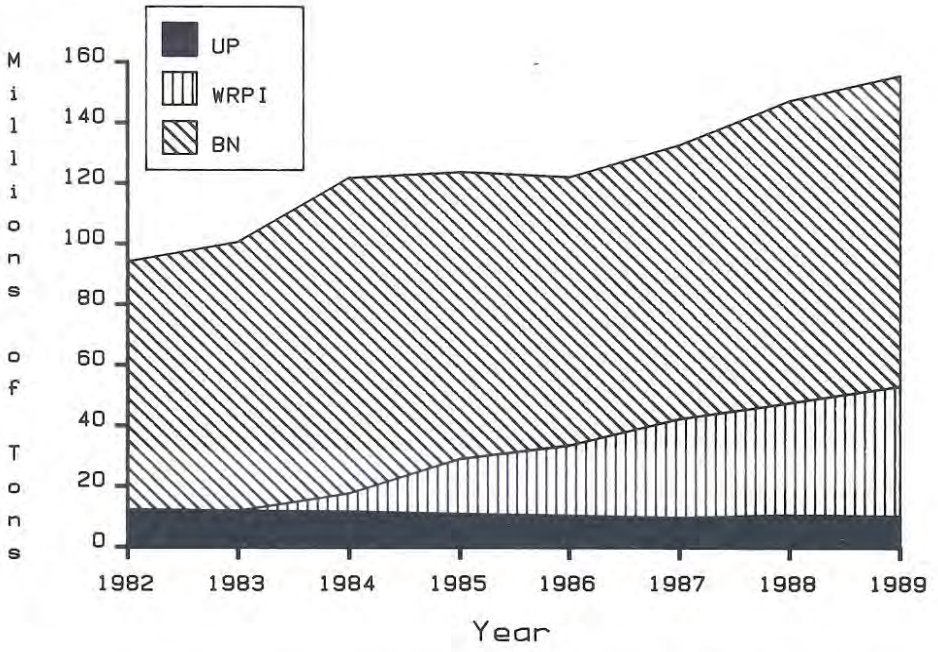

Figure 12. TRANSPORTATION OF WYOMING COAL BY RAILROAD (1982 TO 1989).

by Energy Transportation Systems, Inc. (ETSI). The settlement is apparently the last (in a series) reached by the railroads and ETSI in connection with ETSI's claim that the six railroads conspired to block their proposed coal slurry pipeline from Wyoming to southern Midwest states. At the time of the settlement, SFP was appealing an earlier jury verdict that would have awarded ETSI damages of $750 million. Following this recent settlement, SFP's appeal was dismissed by the 5th Circuit Court of Appeals. Under the settlement, SFP will pay ETSI a total of $350 million over the next eight years. This recent settlement brings the damages awarded to ETSI up to $600 million.

Arch of Wyoming's Pilot Butte underground coal mine north of Rock Springs began producing and selling coal in early 1990. Deliveries to PP&L's Jim Bridger plant east of Rock Springs were noted in March of this year. Also, Pilot Butte apparently provided a test shipment of bituminous coal to either Taiwan or Japan earlier this year. However, plans to test burn coal from this mine at the Intermountain Power Project in Utah (as reported in *Wyoming Geo-notes No. 26*, April 1990, p. 19) are evidently on hold for the time being.

Pacific Power and Light Company (PP&L) can now accept deliveries of coal via unit train at their Jim Bridger power plant east of Rock Springs. Completion of a

railcar unloading facility at the plant in June allowed PP&L to test burn coal from Rochelle Coal Company's Rochelle mine in the Powder River Coal Field, delivered via unit train. PP&L planned to burn additional coal from the Powder River Coal Field during the third quarter of 1990 and coal from the Hanna Coal Field during the fourth quarter. No contracts or other information on these additional coal sales have been announced. Last year, PP&L completed an overland conveyer system at Jim Bridger that carries coal from the Jim Bridger mine to the power plant (see *Wyoming Geo-notes No. 23*, July, 1989, p. 19).

Developments in western and southwestern Wyoming

Builders of the proposed Thousand Springs power plant in northeastern Nevada continue work on permits and an Environmental Impact Statement. The $4 billion project reportedly will be Nevada's largest construction project since Hoover Dam. At least part of the project's coal supply may come from Pittsburg and Midway Coal Mining Company's (P&M) Kemmerer mine in Lincoln County, Wyoming. P&M is one of the owners in the proposed 8-unit, 2,000-megawatt generating facility.

Developments in the Hanna Coal Field

Coal from the Hanna Coal Field was used in several test burns in the first half of 1990 as many utility companies looked closely at low sulfur coals in anticipation that more stringent clean air legislation will be passed by Congress this year. St. Joseph (Missouri) Light and Power tested coal from Rosebud Coal Sales Company's Rosebud mine at their Lake Road power plant; Missouri Public Service Company tested 18,000 tons of coal from Cyprus Shoshone Coal Company's Shoshone No. 1 mine at the Sibley, Missouri, plant; and Illinois Power Company has tested coal from Arch of Wyoming's Medicine Bow or Seminoe II mines. Illinois Power is evidently trying to decide whether to install scrubbers at their plants (to reduce emissions from burning high-sulfur coal) or burn low-sulfur coal. While three of Illinois Power's largest power plants will probably install scrubbers so they can burn coal from the Illinois Basin; the utility's smaller power plant will likely burn low-sulfur coal, hopefully from the Hanna Coal Field. Test shipments of Hanna coal have also reportedly gone to Japan (and possibly Taiwan). Apparently Arch of Wyoming's Medicine Bow mine supplied the coal exported to Japan. It is hoped that these test burns will result in either some new contracts for Hanna coal mines or at least create some significant sales on the spot market.

Another coal sale from the Hanna Coal Field was reported during the second quarter of 1990. Ontario Hydro announced that it was purchasing 300,000 tons of coal from both the Medicine Bow mine and the newly-opened Bull Mountain mine in Montana (operated by Meridian Minerals) for use in Canadian power plants. Actual amounts of coal from each were not announced. The Canadian utility appears to be facing the same problem as its counterparts in the United States, i.e., how to reduce sulfur emissions from its power plants in the most economical way. Unless expensive scrubbers are installed to allow the burning of high-sulfur coal from local sources, the best available option is the purchase of low-sulfur coal.

Developments in the Powder River Coal Field

The controversial JY Ranch exchange (see *Wyoming Geo-notes No. 26*, April, 1990, p. 21), in which Federal coal near Sheridan, Wyoming, was to be exchanged for a scenic easement on some private land surrounded by Grand Teton National Park, was approved by the U.S. Secretary of the Interior in May, 1990. Under the exchange agreement, Sloan-Kettering Memorial Institute received title to a 2,560-acre tract of Federal coal and the Federal government received a scenic easement on 1,106 acres of land on the JY Ranch. The scenic easement insures that the land (along Phelps Lake) will never be developed, even though the land will still be under private ownership. Within hours after the exchange was approved, Sloan-Kettering announced that Consolidation Coal Company had purchased the 207 million tons of coal under the exchanged tract for $5.6 million or about 2.7 cents per ton. Consolidation Coal Company, which also owns interest in the CX Ranch coal property in Montana near the newly acquired coal tract, has not yet announced any specific plans for developing the tract. Shortly after Interior approved the exchange, the State of Wyoming filed a suit to overturn the decision.

The Fort Union mine north of Gillette (Figure 13) has been sold by Total American Mining Corporation, an American subsidiary of the French Total conglomerate, to Fort Union Limited Partners, an anonymous group of investors. Although the investors were not divulged, industry sources indicate that the Drummond Company, Inc., an Alabama-based coal company, may be the new owner. The Fort Union mine produced 42,092 tons of coal last year and employed nine people. Following the sale, five of nine mine employees were laid off. Coal production at the mine has been shipped to Midwestern utilities, used as feedstock in the nearby K-Fuels coal beneficiation plant, and reportedly blended with other coal and exported. The mine contains coal reserves of about 200 million tons.

Coal Contracts - Powder River Coal Field

Purchasing activities in this coal field were numerous during the second quarter as more and more utility companies purchased coal on the spot market for use in test burns. In addition, some coal was purchased to blend with higher sulfur and higher heat value coals, and some coal was purchased to supplement existing longer-term contracts. In the first quarter, spot coal sales accounted for 8 to 12 percent of the total coal delivered to electric utilities each month from Wyoming mines.

Coal purchased for test burns is summarized below:

1) Tennessee Valley Authority (TVA) purchased 100,000 tons of coal from Mobil Coal Producing, Inc.'s Caballo Rojo mine for use at the utility's Paradise, Kentucky, power plant. The coal will be used in one of the units at Paradise that is not yet equipped with a scrubber.

2) In June, NIPSCO began to test burn 130,000 tons of coal from Peabody Holding Company's Rochelle mine. The burn is at the Schahfer No. 15 unit in Indiana.

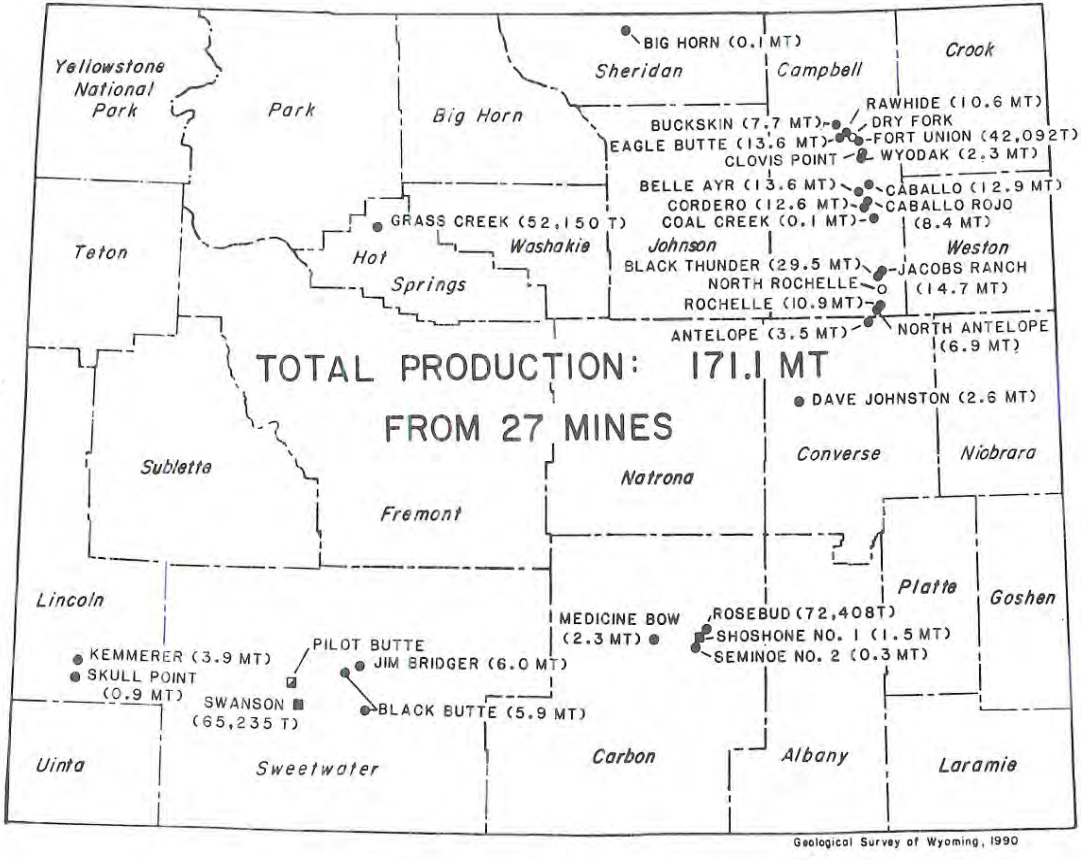

Figure 13. WYOMING COAL MINES AND PRODUCTION IN 1989.

3) Southern Company Services Inc. (SCS), the fuel purchasing agent for Georgia Power Company, is purchasing an additional 1.0 million tons of coal from both Amax Coal Company and Mobil Coal Producing, Inc. for use at Georgia Power's Scherer, Georgia, facility. The coal is an addition to the 492,000 tons purchased for tests conducted during the second quarter of 1990, as reported in *Wyoming Geo-notes No. 26*, (April 1990, p. 23). Most of the Wyoming coal is blended with higher sulfur Eastern coals to reduce sulfur emissions.

4) SCS also purchased an unannounced amount of coal from Thunder Basin Coal Company's Black Thunder mine for its subsidiary, Alabama Power Co., to use in the Miller plant, a generating facility near Birmingham, Alabama.

5) St. Joseph (Missouri) Light and Power Company tested coal from Thunder Basin Coal Company's Black Thunder mine at the Lake Road, Missouri, power plant.

6) Detroit Edison Company test burned coal from Cordero Mining Company's Cordero mine, Mobil Coal Producing, Inc.'s Caballo Rojo mine, and Peabody Holding Company's Rochelle mine at the St. Clair and Monroe, Michigan, generating plants.

7) Fremont (Nebraska) Department of Utilities test burned coal from both NERCO Coal Company's Antelope mine and Amax Coal Company's Belle Ayr mine in May to determine which company would get a 5-year coal supply contract. See item (2) below for details of the new contract.

New coal contracts signed with Wyoming mines are briefly summarized below:

1) Triton Coal Company (a division of Shell Mining Company) is now delivering an undisclosed amount of coal from the Buckskin mine to the Jose Portillo generating plant in Mexico. The Mexican state utility company, Comision Federale de Electricdade, is purchasing the coal to supplement the mine-mouth, high-ash, subbituminous coal currently supplying the plant. The coal is shipped via Burlington Northern Railroad Company (BN) to Fort Worth, Texas, where it is switched to the Southern Pacific Railroad for transport to Eagle Pass, Texas. At Eagle Pass, along the Texas-Mexico border southwest of San Antonio, the coal is switched to the Mexican-owned F&M Railroad and transported the final 10 miles to Portillo.

2) Amax Coal Company's Belle Ayr mine will supply from 125,000 to 150,000 tons of coal per year for five years to Fremont (Nebraska) Department of Utilities. The 8,450 Btu/pound coal sold for $4.05 per ton F.O.B. mine and $13.85 per ton delivered on C&NW. This contract calls for annual price negotiations.

3) Wisconsin Power and Light Company (WPL) purchased 200,000 tons of spot coal from Cordero Mining Company's Cordero mine for use during the second quarter of 1990 at Unit 2 of the Columbia, Wisconsin, power plant. WPL will purchase another 200,000 tons of spot coal from Mobil Coal Producing, Inc.'s Caballo Rojo mine for use during the third quarter of 1990 at the same unit.

4) Cordero Mining Company (a subsidiary of Sun Coal Co.) will supply between 150,000 and 200,000 tons of short-term contract coal to Grand Island Nebraska Electric Department from the Cordero mine south of Gillette. The coal will be delivered to Grand Island via C&NW and UP railroads through October, 1990.

5) Cordero Mining Company supplied 150,000 tons of spot coal from the Cordero mine to Iowa Public Service Company's (IPS) George Neal No. 3 unit near Sioux City, Iowa. This is replacement tonnage for part of the 1.5 million tons of coal that Carter Mining Company was to provide to IPS during 1990 (see *Wyoming Geo-notes No. 26*, April, 1990, p. 22). Evidently, Carter Mining Company was unable to supply some of the coal needed by IPS because they were installing a new conveyor belt system at their Caballo mine.

6) Cordero Mining Company will also supply Iowa Southern Utilities Company with 300,000 to 400,000 tons of spot coal. BN will transport the coal to the Ottumwa, Iowa, plant between April and December, 1990.

7) Mobil Coal Producing, Inc. will supply 220,588 tons of spot coal from the Caballo Rojo mine to Units 1 and 2 of Lower Colorado River Authority's (LCRA) Fayette (Texas) Power Project. This solicitation had bids from $3.30 per ton to $5.15 per ton F.O.B. mine (see *Wyoming Geo-notes No. 26*, April, 1990, p. 22). LCRA accepted and approved Mobil's bid of $3.90 per ton F.O.B. mine. Delivered price of the coal was 118.42 cents per million Btu's, or about $20.13 per ton for 8,500 Btu/pound coal.

8) Thunder Basin Coal Company's Black Thunder mine and Rochelle Coal Company's Rochelle mine in southern Campbell County have both signed long-term coal contracts to supply fuel to boilers operated by Texas Eastman Company at Longview, Texas. No details concerning prices, amounts, or contract lengths were released.

9) Nerco Coal Company's Antelope mine will supply an unspecified tonnage of coal to some of Detroit Edison Company's generating plants in Michigan. Solicitations had been requested for up to one million tons of coal in 100,000-ton increments.

10) Undisclosed coal mines in the Powder River Coal Field will be supplying an unspecified amount of coal to Arch-Daniel-Midland Company's manufacturing plants at Decatur, Illinois, and Cedar Rapids, Iowa, during the second half of 1990. Although no details were available, past solicitations have been on the order of 200,000 to 400,000 tons for this time period.

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INDUSTRIAL MINERALS UPDATE

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

Aggregate (construction)

Construction aggregate is sized rock material (sand and gravel or crushed rock) with specific physical properties and good durability. The production of construction aggregate in Wyoming increased during the second quarter of 1990 as several highway construction projects were initiated.

Meridian Minerals is producing railroad ballast, a kind of construction aggregate, at Granite, west of Cheyenne. While production of ballast at this facility continues, the Burlington Northern and Union Pacific Railroads continue to look for additional ballast sources in Wyoming. One area near Wheatland has been tested for a source of ballast for the Burlington Northern. The rock meets ballast specifications. Lease and access negotiations are currently (July, 1990) underway with the land and mineral owners.

Aggregate (decorative)

Decorative aggregate is sized rock produced for its color or other aesthetic qualities and it must have certain physical qualifications (strength, resistance to acid, etc.). Decorative aggregate is used in colored prestressed concrete, roofing granules, landscape rock, building faces, etc. Georgia Marble produces decorative aggregate from white marble at a plant in Wheatland. This material is available is several sizes down to the rock flour used to color smooth white concrete and white polyvinylchloride (PVC) pipe.

In July, several test samples of various colored aggregates were shipped from Wyoming to a producer of decorative tile. The Geological Survey of Wyoming also has several displays of decorative aggregate. These are available for inspection in the Geological Survey building in Laramie. Interested persons should call Ray E. Harris at (307) 766-2286.

Bentonite

There are still no indications that 1990 production of bentonite in Wyoming will be much different than 1989 production. The primary use of bentonite is in oil and gas well drilling. While other uses, such as pond lining, foundry binders, taconite pelletizing, and cosmetics have increased, these increases have not offset declines in demand related to the drilling of much fewer oil and gas wells. Because of excess capacity, Wyoming's bentonite industry is capable of rapidly increasing production to meet any demand.

Cement

Mountain Cement's plant at Laramie is the only cement plant in Wyoming. The plant is apparently operating at or near capacity and mines its basic raw materials locally.

Dimension and decorative stone

As part of an ongoing project, the Industrial Minerals Division of the Geological Survey of Wyoming has prepared over seventy cut and polished samples of decorative rock from Wyoming, some suitable for dimension stone. These samples are available for inspection in the Geological Survey building in Laramie. Interested persons should call Ray E. Harris at (307) 766-2286. These decorative rocks are suitable for use as facing materials, in floors, in walls, as tile, and as shaped and polished decorative stone.

As an outgrowth of the Industrial Minerals Division's project, several samples of decorative marble, quartzite, limestone, and granite were cut and polished and shown to a variety of users, including experts in the Italian stone industry in Carrara and Verona. A new company, Sunrise Stone, was formed in the second quarter of 1990 and registered with the Wyoming Secretary of State's Office. This company is studying the feasibility of producing decorative stone and dimension stone (blocks, slabs, and tiles) in Wyoming.

Fertilizer, fertilizer ingredients, and related products

Fertilizer is manufactured in Wyoming at the Chevron Chemical Company's plant near Rock Springs. In addition, anhydrous ammonia, nitric acid, ammonium nitrate, carbon dioxide, and urea are produced from natural gas, water, and air at the Coastal Chem, Inc. plant west of Cheyenne. These products are used as ingredients in fertilizer and as industrial chemicals. Coastal also cools carbon dioxide to produce dry ice, which is sold as blocks and pellets in the Rocky Mountain area.

Gypsum

In Wyoming, gypsum is produced at two plants in the Bighorn Basin (near Cody and at Himes, between Lovell and Greybull). Production at these plants is continuing

at levels near capacity. These plants produce wallboard that is marketed regionally and in the Pacific Northwest. Mountain Cement also mines gypsum near Laramie for use in producing cement.

Limestone

Limestone is the preferred crushed rock for use as road surfacing aggregate and base and sub-base material on Wyoming highways (see **Construction Aggregate**). Wyoming limestone is also used to control emissions from the Laramie River Station power plant near Wheatland. A light tan- to buff-colored limestone from the Mississippian Guernsey Formation is currently being tested for use as polished tile (see **Decorative Stone**).

Silica

Development of the silica resource near Cassa, in Platte County has been put on hold due to a labor dispute within the company that has leased the deposit. Over 100 million tons of high-grade silica have been identified at that site. The Geological Survey of Wyoming is continuing to investigate other silica deposits near Lovell, north of Laramie, and east of Glendo. Interest in silica deposits in Wyoming has continued into the second quarter of this year although no additional property has been acquired by private companies.

Wyoming silica may be suitable for the production of several kinds of glass, for high purity silica ($Si0_2$) and glass pellets, for foundry sand, and for hydraulic-fracturing sand. Because soda ash (refined trona) is a major ingredient in the manufacture of glass and since 90 percent of the soda ash produced in the U. S. comes from the trona patch near Green River, Wyoming, the cost of transporting raw materials to glass plants could be saved if glass was manufactured near the raw materials in Wyoming.

Trona

Demand for Wyoming soda ash, which is produced from mined trona, continued at record levels during the second quarter of 1990. This year promises to be even better than the record production of last year. The increase in demand is related to the manufacture of sodium cyanide for use in gold refining, the substitution of soda ash for caustic soda in many industrial processes, and growth in export markets. The best potential for even greater demand still lies in exports.

In the second quarter of 1990, Rhone-Poulenc announced modernization plans for their plant, which will increase its production capacity by 17 percent (the capacity will increase from 1.96 million tons to 2.3 million tons of processed trona per year). Tenneco also announced plans to increase production but through plant expansion. To do this, Tenneco has applied to the Wyoming Industrial Siting Administration for an amendment to their existing permit, rather than seek a new permit. According to

Tenneco, the amendment process would be faster and less costly. The other trona producers, TG, FMC, and General Chemical have previously announced expansion plans.

Zeolites

Zeolites are a group of silicate minerals with unique properties of ion exchange and adsorption. Although most zeolites are currently manufactured synthetically, natural zeolites are already produced in small quantities in several western states (Harris and King, 1990). Recently, however, there has been a concerted move to mine and refine natural zeolites. Because mined zeolites cost less than those produced synthetically, there is the potential that production of natural zeolites could follow the example of the trona industry. Soda ash, produced from mined trona, has replaced all of the synthetically produced soda ash in the U. S., and has also significantly replaced synthetic soda ash in many other areas of the world.

For a similar conversion to the mining of natural zeolites, large, high-grade deposits of natural zeolites must be found and developed. There are several areas in Wyoming that hold promise for such development (Harris and King, 1990).

In Wyoming, Rocky Mountain Zeolites is developing a deposit located near old Fort LaClede, in the Washakie Basin in Sweetwater County. Rocky Mountain Zeolites is planning to market natural clinoptilolite (a specific zeolite mineral, $Na_6[Al_6Si_{30}O_{72}]24H_2O$) for use in removing ammonia from aquaculture, agriculture, and waste-water treatment products. It can also be used to remove unwanted ions from water, radioactive waste, hazardous waste, and air. The clinoptilolite will be producible in several different sizes.

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URANIUM UPDATE

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

The only uranium production in Wyoming in the second quarter of 1990 was at Power Resources (London Central Energy) in-situ, solution mining operation at the Highland mine in Converse County. Malapai Resources in-situ operation west of the Pumpkin Buttes, which was closed by its holding company (Pinnacle West Capital Corp.) in January, was sold to Electricitie de France (EdF). As of early July, the new owners of Malapai had not begun mining.

COGEMA's Pathfinder Mines is continuing to strip overburden and mine and stockpile ore at the Shirley Basin mine. Mill production of yellowcake from Shirley Basin is planned to resume in late July of this year. All active uranium operations in Wyoming are now foreign-owned.

Wyoming was the Nation's fifth largest producer of uranium in 1989 (*Wyoming Geo-notes No. 26*, p. 28). In 1990, Wyoming may become the 4th largest uranium-producing state since the only mine in New Mexico has apparently shut down. Although the production of uranium from Wyoming is expected to diminish in 1990 due to the closure of Malapai and the temporary closure of COGEMA, production should increase again in 1991.

Uranium prices increased a little at the start of the third quarter, going from $8.80 per pound of U_3O_8 to over $11.00 per pound. To put this in perspective, uranium prices in the 1950s were $6.00 to $8.00 per pound. In early 1979, prices reached $42.00 per pound. Currently, purchasers of uranium are finding that stockpiles of mined uranium from the early 1980s are being depleted. As a result, the price of uranium is increasing and, according to one industry official, may reach $16.00 per pound by year's end.

In a promising development, Kennecott Corp., which paid $1 million to U. S. Energy-Crested Corp. (USE-CC) to examine the Green Mountain uranium property south of Jeffrey City, decided to purchase 50 percent of the property for $15 million dollars, and agreed to fund the first $50 million dollars of development work. There are also additional financial arrangements, dependent on production and uranium prices. Kennecott Corp. is owned by RTZ, of Great Britain, which also owns Rio Algom, a company that is conducting evaluations of uranium properties in the Powder River Basin for possible development as in-situ solution mining operations.

METALS AND PRECIOUS STONES UPDATE

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

Several companies conducted preliminary reconnaissance studies in Wyoming (principally for gold and copper) in the spring and several more intended to explore later in the summer. However, the recent decline in gold prices also put a damper on several projects.

Some exploration was reported in the Keystone district of the Medicine Bow Mountains, the Rattlesnake Hills of the Granite Mountains, the South Pass region of the Wind River Range, and the Sunlight district of the Absaroka Mountains. The Geological Survey of Wyoming continued studies of the Seminoe Mountains gold district, and continued searching for evidence of kimberlite deposits in the central Laramie Mountains and Medicine Bow Mountains.

Cody area hot springs

Anyone who has driven along U.S. Highway 16 west of Cody near Buffalo Bill reservoir, is probably aware of the sulfurous hot spring deposits. A large area along the western edge of town is covered by fairly recent hot spring deposits. Several of these were sampled by the Geological Survey of Wyoming last winter to test for evidence of epithermal precious metal mineralization. Of 8 cinder and sulfur samples collected, no anomalous gold or silver was detected.

Kirwin district, Absaroka Mountains

The Kirwin district in the Absaroka volcanic plateau of northwestern Wyoming encloses a major copper-silver porphyry in Tertiary andesites and felsic breccia. The deposit is Wyoming's largest copper ore body. The porphyry was reported by the U.S. Bureau of Mines to host a 70-million-ton ore body averaging 0.75% copper. One informed source suggests that the actual size is 2 to 3 times that reported by the Bureau of Mines.

In the October, 1985, issue of *Rocky Mountain Pay Dirt* (p. 32A), reserve figures reported by AMAX included 1.23 billion pounds of copper, 121,000 ounces of gold, and 5.6 million ounces of silver. The porphyry also carries significant lead, zinc, and molybdenum. Based on these available reserve figures, the Kirwin porphyry hosts metals that are worth more than $1.5 billion based on average 1989 prices.

Currently, the U.S. Forest Service is proposing to purchase the property and ore body for $3.3 million. The Forest Service plans to protect the historic values and animal habitats in the area if it buys the property (Casper Star-Tribune, April 14, 1990, p. B1), which could result in it never being mined and developed.

Precious Stones

Exploration for diamond deposits resumed this summer, with the Geological Survey of Wyoming searching the central Laramie Mountains for indications of diamondiferous kimberlite and lamproite. The project was expanded into the Medicine Bow Mountains in the vicinity of Mullison Park where two diamonds were discovered in 1977. Geophysical surveys are planned in areas where anomalies were identified in previous years.

Seminoe Mountains

The Geological Survey of Wyoming initiated 1990 field studies in the Seminoe Mountains greenstone belt in June. Analyses of most samples collected last field season were reported in *Wyoming Geo-notes No. 25*, p.23-24. Analyses of some other samples, which were collected last field season, are now available (Table 6). The most interesting samples are BP35-89 and BP38-89. Sample BP35-89 was a banded iron formation collected from a mine dump northeast of Bradley Peak, and sample BP38-89 was a carbonate-quartz vein collected near the northeastern flank of Bradley Peak. These two samples contained elevated silver values indicating portions of the iron formation in the district are mineralized.

Sierra Madre

Samples collected last fall from an unnamed mine in NE SW section 11, T.15N., R.87W. of the Sierra Madre contained galena. Assays of these lead-bearing schists produced anomalous gold, copper, zinc, lead, and silver. Sample DEQ17-9/89 contained 3.54% lead and 24 ounces/ton silver (Table 6).

South Pass

Mining companies are showing greater interest in the South Pass gold deposits this year. The gold deposits are principally epigenetic deposits hosted by a variety

Table 6. Assays of some samples from the Seminoe district and from the Sierra Madre.

Sample No.	Description	Au (ppm)	Ag (ppm)	Cu (%)	Zn (%)	Pb (%)	Fe (%)
BP35-89	Banded iron formation from mine dump	nd	5.4	-	-	-	26.1
BP36-89	Quartz from mine dump	nd	1.0	-	-	-	-
BP38-89	Carbonate-quartz vein in banded iron formation	0.06	8.1	-	-	-	-
BP39-89	Gossan in spinifex textured hornfels	nd	nd	-	-	-	2.49
DEQ17-9/89	Galena-bearing chlorite schist	0.09	820	0.22	0.38	3.54	-
DEQ17-9-c	Mineralized schist	0.13	210	0.13	1.04	0.83	-

nd = not detected

of rock types. The most common host rock is metagreywacke followed by amphibolite, meta-andesite, greenschist, actinolite schist, and metatonalite (Hausel, 1990a).

This spring, a few major mining companies conducted brief reconnaissance studies of the greenstone belt and the Geological Survey of Wyoming was asked to lead field trips into the region for several companies as well as for the Geological Society of America (Hausel and Hull, 1990). The GSA field trip was attended by representatives of four major mining companies, as well as consultants and other individuals.

Titanium

A study of the State's titanium resources was recently completed by the Geological Survey of Wyoming (Hausel, 1990b). The report concludes that the State, as a whole, has one of the largest titanium resource bases in North America. Titanium is an important metal with industrial applications (Harris, 1990), and also is an important strategic metal with commercial, military, and aerospace applications.

The known titanium deposits include numerous (Cretaceous) paleobeach placers exposed on the flanks of nearly ever major basin in Wyoming, and also some large (Proterozoic) magmatic deposits such as the anorthosite batholith of the Laramie Mountains and the Lake Owen layered gabbroic complex. These titaniferous deposits also have associated minor minerals and metals of potential economic value. Some accessories include gold, vanadium, chromium, monazite, and zirconium.

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Table 7. MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING.

PETROLEUM

Remaining Resources (January 1, 1989)	
Discovered (Includes 10 billion barrels recoverable by enhanced recovery techniques)	12.9 billion barrels[1]
Undiscovered	7.6 billion barrels[1]
Total	20.5 billion barrels
Remaining Reserve Base (January 1, 1989)	
Measured reserves (Proved reserves) (Includes 0.815 billion barrels of oil and 0.805 billion barrels of gas liquids)	1.62 billion barrels[2]
Indicated and inferred reserves	2.8 billion barrels[1]
Total	4.42 billion barrels

NATURAL GAS

Remaining Resources (January 1, 1989)	
Discovered (Includes 23 trillion cubic feet (TCF) of methane[1] and 12 TCF of CO_2 and He^3)	35.0 trillion cubic feet
Undiscovered (Includes 58 TCF of conventional methane[1]; 7 TCF of coalbed methane[4]; 3,611 TCF of methane in tight gas sands in the Green River Basin[5]; and 103 TCF of CO_2 and He^3)	3,779.0 trillion cubic feet
Total	3,814.0 trillion cubic feet
Remaining Reserve Base (January 1, 1989)	
Measured reserves (Proved reserves) (Includes 10.9 TCF of methane[2] and 11.8 TCF of CO_2 and He^3)	22.7 trillion cubic feet

COAL

Remaining Resources (January 1, 1989)	
Identified and Hypothetical (Discovered)	1,431.4 billion tons[6]
Speculative (Undiscovered)	31.5 billion tons[6]
Total	1,462.9 billion tons
Remaining Reserve Base (January 1, 1989)	
Demonstrated strippable (Measured and indicated reserve base)	26.8 billion tons[7]
Demonstrated underground-minable (Measured and indicated reserve base)	38.3 billion tons[7]
Total	65.1 billion tons

TRONA

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

URANIUM

Remaining Resource (December 31, 1985)	1.99 billion pounds U_3O_8[9]
Remaining Reserve Base (December 31, 1985)	
Uranium oxide recoverable at $30.00 per pound	83 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.

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GEOLOGIC MAPPING AND STRATIGRAPHY

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

TWO NEW GEOLOGIC MAPS TO BE COMPLETED THIS SUMMER

The Stratigraphy Division of the Geological Survey of Wyoming completed photointerpretation on four 1:24,000-scale geologic maps this past winter. Field checking of the Monument Hill and Beartrap Meadows Quadrangles is planned for this summer's field season. These two quadrangles are located southeast of Ten Sleep, Wyoming, near the Big Trails fault system. Rocks ranging in age from Triassic/Permian to Middle Cambrian are present on the quadrangles, along with isolated Tertiary and Quaternary deposits. Portions of the Big Trails fault system cross both quadrangles and an attempt will be made to find more evidence for the nature of movement on the fault.

These two maps and two others (Big Trails NE and Big Trails) were mapped as part of the Nowater Creek 1:100,000-scale color geologic map compilation, which is now completed and ready for drafting. These maps are also a continuation of the Southern Bighorn Mountains mapping project, initially funded by the U. S. Geological Survey under their COGEOMAP Program. Most of the area encompassed by these four quadrangles has not been mapped since N. H. Darton mapped the area near the turn of the century. These first two quadrangles will be completed as Open File Reports late this fall. The third and fourth maps will be field checked and completed during the 1991 field season.

WGA HIGHWAY SIGNING PROJECT IN THE BIGHORN MOUNTAINS

The Survey's Stratigraphy Division will assist Mike Flynn at Sheridan Community College and the Wyoming Geological Association in a geologic signing project along Alternate U. S. Highway 14 on the west flank of the Bighorn Mountains. Formations will be labelled where the highway traverses vertical to overturned Mesozoic and Paleozoic rocks in the hanging wall of the Five Springs reverse fault. The signs will indicate the formation name and its age, similar to the signs placed in the Wind River Canyon by the WGA and the Wyoming Highway Department. Once again the signs will be placed by the Wyoming Highway Department in the locations indicated by this WGA committee.

Mike Flynn and the WGA, assisted by this Division, completed a similar project last fall on the portion of U. S. Highway 14 on the east flank of the Bighorn Mountains above Dayton, Wyoming. Additional projects of this type are planned for the future in other parts of the State.

NEW BIBLIOGRAPHY ON THE GEOLOGY OF WYOMING RELEASED

Students from at least 101 universities and colleges in 38 states (outside of Wyoming) and Canada completed at least 1,062 theses and dissertations relating to the geology of Wyoming through 1987. This information was recently compiled by the Division based on replies to inquiries sent to various colleges and universities. Additional entries were obtained from listings by Dissertations Abstracts International and University Microfilms International. Although there are some 1988 entries included, entries after 1987 are not complete.

Colleges and universities are organized alphabetically by state and entries for each university or college are listed chronologically, beginning with the earliest entry. The listing of theses and dissertations is followed by an author index and a generalized subject index.

This report, *Bibliography of graduate theses and dissertations of the geology of Wyoming (exclusive of the University of Wyoming) 1899 through 1987*, which was compiled by Phillip L. Greer and Alan J. Ver Ploeg, is available from the Geological Survey of Wyoming as Open File Report 90-6. Write the Geological Survey of Wyoming, Box 3008, University Station, Laramie, Wyoming 82071 or call (307) 766-2286 for more information. Cost is $10.00 (prepaid).

RADON UPDATE

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

Back in 1987, a summary article in *Wyoming Geo-notes No. 13* presented what was known about radon in Wyoming. Three maps that have been used by radon researchers to set priorities in sampling for radon in homes in Wyoming were discussed in that article. Two of the maps were based upon background gamma radiation measurements of bedrock and soils in the State. Because gamma radiation is generated in the radon decay process, background gamma radiation measurements have been used across the Nation to roughly delineate areas where radon may occur.

The third map, which was titled *Planning guide map for radon studies in Wyoming*, was published as Geological Survey of Wyoming Open File Report 86-18. This map is composed of two sets of data. The first data set includes limited background gamma measurements derived from exposed geological formations. Those data were extrapolated to cover the entire State. The other data set includes boundaries of uranium mining districts, deposits of clinker which is baked or melted rock overlying burned-out coal beds, and site specific uranium occurrences.

The Wyoming Department of Health and Social Services used the planning guide map to define priorities for placing radon-testing charcoal canisters in a 1987 statewide indoor radon screening program. The radon data that were collected in the screening survey indicated that factors other than the level of background gamma radiation were important in predicting the occurrence of radon. In fact, based upon rough associations that were made between homes with elevated radon and the geological formations or terranes they were located on, it appears that the presence of alluvial deposits with a high background gamma radiation source area is as important an indicator in predicting radon occurrences as are background gamma radiation levels.

At the present time, our knowledge of the distribution and availability of radon in soils, alluvium, and other geologic units in Wyoming is limited. Making any inferences about the radon potential for a particular geological formation or unit based upon indoor radon readings is difficult if not impossible in many situations. Factors such as home construction, heating systems, and occupant living habits all may affect the indoor radon readings. Measurements of the level of radon in the soils or bedrock outside of homes will result in a much more reliable indication of where site specific, local, or regional problems exist. This type of study is called a soil-gas radon survey.

The Geological Survey of Wyoming recently entered into a cooperative agreement with the Wyoming Department of Health and Social Services and the U.S. Environmental Protection Agency. Under the agreement, the Survey's Geologic Hazards Division will conduct reconnaissance-level soil-gas studies in six areas in or near communities in the State. Within the study areas, the Geologic Hazards Division will test the radon levels in soil gas in different geologic settings, with the expectation of using the data to flag geological formations or units that have the greatest potential for the occurrence of radon.

In order to conduct the study, geologic maps will be compiled for each of the areas. The compiled mapping will be augmented with aerial photo interpretation and limited field mapping. Radon sampling transects will be established for each area in such a manner that soils overlying all dominant geologic units will be sampled. Theoretically, a relationship should exist between soil-gas radon levels and the geologic units that the soils either overlie or are derived from. If the theory is supported by these field studies, useful guidance can be given to future indoor radon sampling programs. For example, if specific geologic units are found to have a higher potential for the occurrence of radon than other units, emphasis can be put on sampling structures located on units with the higher likelihood of containing radon.

For further information, contact James C. Case at the Geological Survey of Wyoming (307/766-2286) or Howard Hutchings at the Wyoming Department of Health and Social Services (307/777-6017).

HORIZONTAL DRILLING IN THE UPPER CRETACEOUS NIOBRARA FORMATION

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

During June, 1990, Cowan Oil Company announced that its horizontal Niobrara Formation test in Silo Field in southeastern Wyoming (Figure 14) initially flowed 2,000 barrels of oil and 500,000 cubic feet of gas per day. Cowan's well, the 1 Warren in NE NW section 11, T.15N., R.65W., at last report was flowing 500 to 600 barrels of oil a day through a 900-foot slotted liner in the horizontal segment of the well. This is one of the first horizontal wells drilled in Wyoming and the first horizontal well drilled in the Niobrara Formation in Wyoming. Snyder Oil Corp., along with Union Pacific Resources and Meridian Oil, supported Cowan's horizontal Niobrara venture and received access to the well data in return for that support. Snyder announced plans to begin drilling two to five horizontal Niobrara tests as a joint venture with unnamed

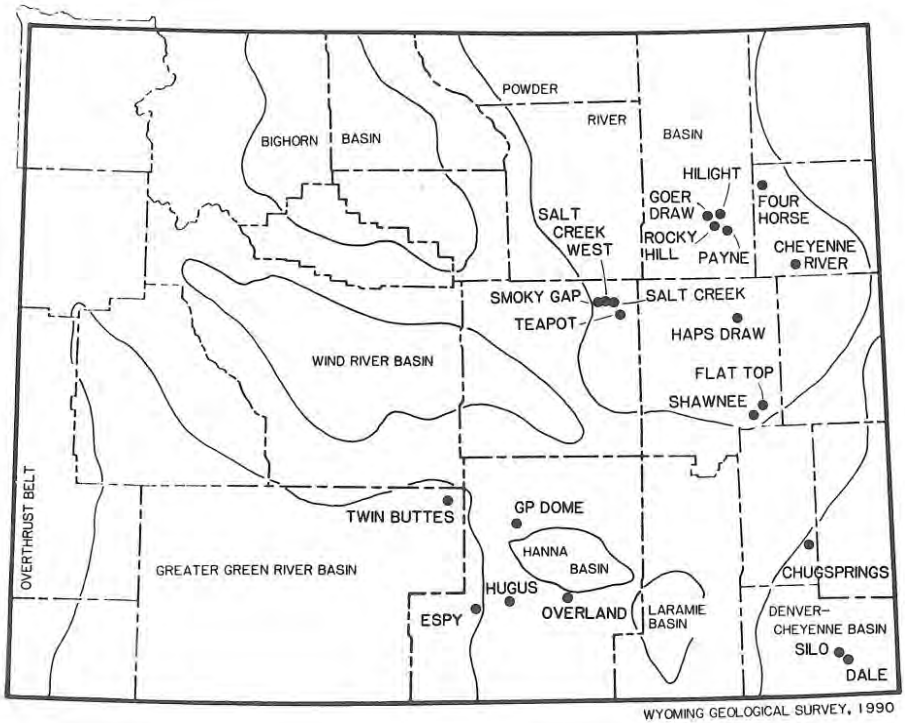

Figure 14. OIL AND GAS FIELDS IN WYOMING WITH PRODUCTION FROM THE NIOBRARA FORMATION.

partners. The tests will be south of Silo Field in Wyoming and in Colorado with drilling scheduled for early next year. Union Pacific Resources also staked a location on the east side of Silo Field about six miles east of Cowan's well. This horizontal Niobrara test will be in section 11, T.15N., R.64W.

It is no accident that the first horizontal drilling activity in the Niobrara Formation in Wyoming is concentrated around Silo Field. The Niobrara in Wyoming has produced an estimated four million barrels of oil and three billion cubic feet of associated gas (Rick Marvel, Wyoming Oil and Gas Conservation Commission, personal communication and Petroleum Information, 1990). Since its discovery in 1981, Silo Field has produced nearly 1.3 million barrels of oil and nearly one billion cubic feet of gas.

Although Silo Field has produced nearly one-third of all oil and gas from the Niobrara in Wyoming, five other fields together have produced a total of two million barrels of oil. These fields are Smoky Gap, Teapot, Cheyenne River, Hilight, and Espy (Figure 14).

The Niobrara Formation in Wyoming is limited to the eastern half of the State. The formation contains two members in the southeastern part of the State; a lower member named the Fort Hays Limestone, and an upper member named the Smoky Hill Member. Only the Smoky Hill Member is present in the Powder River Basin because the Fort Hays Limestone changes into a shale that is included in the Carlile Shale (Weimer and Flexer, 1985).

The Smoky Hill Member of the Niobrara Formation generally contains limestones (chalks) and calcareous shales. Chalks are unlike shallower water carbonate rocks in that chalks generally show only gradual variations in lateral facies. Deeper water settings, like those during deposition of the Smoky Hill Member, have broader areas of uniform conditions with fewer facies changes than shallow water settings. Most Niobrara production in Wyoming comes from the fractured chalks and calcareous shales of the Smoky Hill Member.

Deformation following deposition of the Niobrara has provided the setting for most of the oil and gas production from the Niobrara in Wyoming. Natural fracturing, caused by this deformation, greatly improves reservoir quality in the Niobrara. The development of even minor structures generally enhances production because the chalks and calcareous shales are very brittle and tend to fracture easily (Pollastro and Scholle, 1984). Production from the fractured Niobrara at Silo Field is developed on a very subtle east-west trending structural nose (Spect, 1984 and Sheppy, 1984). The goal for horizontal drilling is to intersect as many natural vertical fractures as possible to maximize production.

While the area around Silo Field is an excellent target area for horizontal drilling in the Niobrara, Niobrara production at the fields shown on Figure 14 indicates that the areas around these fields would be good targets as well. Since it is well-known that natural fracturing normally occurs in the Niobrara in areas of even minor deformation, horizontal drilling should be successful in southeastern Wyoming,

along basin margins, and in deeper portions of basins where structures in the Niobrara can be identified.

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A SIMPLIFIED NOMENCLATURE FOR WYOMING'S COAL-BEARING AREAS

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

Previous nomenclatural schemes for the coal-bearing areas of Wyoming have resulted in a myriad of names and a confusing, sometimes illogical and often meaningless hierarchy of subdivisions. For example, the 10 major coal-bearing areas in the State are variously called regions, basins, and fields (Trumbull, 1960). In turn, each of these areas has been subdivided into subareas referred to variously as basins, fields, deposits, or districts. Each of these categories seems to have a slightly different meaning in each coal-bearing area of the State. To further confuse the issue, 41 separate coal fields have been defined for the 10 coal-bearing areas in Wyoming, using (primarily) the geographic extent of the areas originally mapped by the U.S. Geological Survey 70 to 90 years ago. The boundaries for these coal fields are completely arbitrary from both a geographic and geologic point of view; the 41 coal field names serve no particularly useful purpose, except perhaps as a reference or index to the original area reports, as used by Berryhill, and others (1950).

Because of the inconsistencies, confusion, and incompatibility of the nomenclatural schemes described above, we have adopted a new, simplified nomenclature for Wyoming's coal-bearing areas. First, the two major coal provinces in Wyoming are retained as they were originally defined by the U.S. Geological Survey: the Rocky Mountain Province and the Northern Great Plains Province (Figure 15). The boundary between these two provinces is that used by Campbell (1917): coals fields in the Northern Great Plains are those east of the Front Range of the Rocky Mountains (which in Wyoming is the Laramie Mountains and the Bighorn Mountains).

Secondly, these two provinces in Wyoming are now subdivided into 10 *coal fields* (Figure 15). Some of these coal fields were previously known as coal basins or coal regions; the older terms for these subdivisions are now abandoned and each is now defined as a coal field. A coal field is defined here as an area (delineated by geologic criteria) of coal-bearing rocks that are known to contain minable coal beds or coal deposits. The previous subdivision of these 10 major coal fields into 41 separate "coal fields" on the basis of the geographic extent of early mapping is also abandoned.

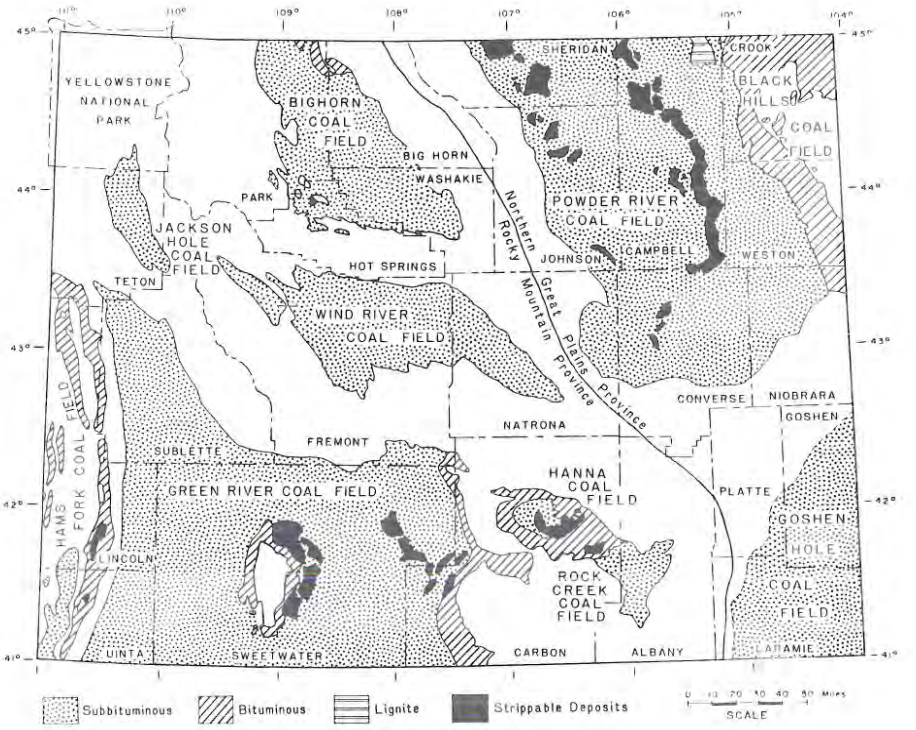

Figure 15. INDEX MAP OF WYOMING COAL FIELDS.

Thirdly, no formal subdivision of the ten new coal fields is recommended. However, an individual coal field can be informally subdivided into specific coal *deposits*, which consist of specific coal beds or coal zones that can be delineated by geologic criteria. An individual coal field can also be informally subdivided into coal mining *districts*, which consist of somewhat loosely defined geographic areas where mining has developed around a definite center. For example, the Powder River Coal Field contains the Wyodak *deposit* and the Felix *deposit*. Similarly, the Powder River Coal Field contains the Sheridan *district* (which could include several deposits) or the Gillette *district* (which includes a portion of the Wyodak *deposit*).

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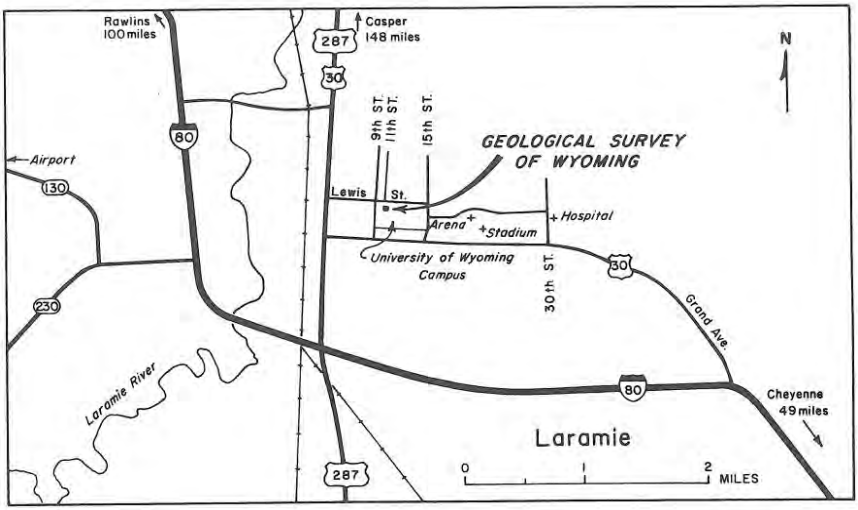
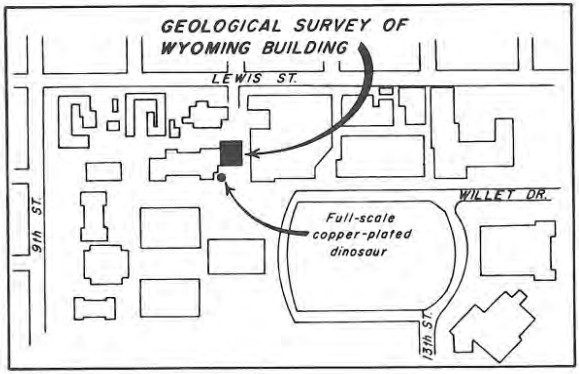
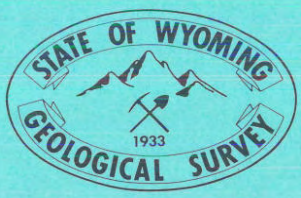
GEOLOGICAL SURVEY OF WYOMING
LOCATION MAPS



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