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Number 46



Wyoming State Geological Survey
Gary B. Glass, State Geologist

Laramie, Wyoming
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WYOMING GEO-NOTES

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Cover: Sunrise Stone's granite fabricating plant, located 20 miles southwest of Wheatland. Sunrise quarries two types of stone, 20 miles west of this plant in Albany County. Full-scale operation of this plant began in 1995.

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MINERALS UPDATE

OVERVIEW

Gary B. Glass

State Geologist, Wyoming State Geological Survey

By April 1995, there was some preliminary as well as some final production and price information for the energy minerals produced in Wyoming in 1994. In the case of oil production, it looks like our earlier forecast was about 1.5 million barrels low. Data from Petroleum Information Corp., which is generally very close to the State's official production, shows 1994 production at 79.5 million barrels or 2% higher than the forecast. This equates to a 10.7% rate of decline from 1993. **Table 1** and **Figure 1** reflect the new production estimate. The average price paid for Wyoming oil as reported by the Energy Information Administration is 9 cents higher than our forecast of \$13.58 (**Table 2** and **Figure 2**). In both cases, this is welcome news. The differences are small enough, however, that changes to oil production and price forecasts for 1995 through 1998 are not yet warranted.

Based on near-final data from the State Land and Farm Loan Office, our forecast natural gas price of \$1.56 per MCF for 1994 looks accurate (**Table 2** and **Figure 3**). The \$1.56 is also equivalent to the average 1994 spot sale price at Opal, Wyoming. Preliminary data from Petroleum Information indicate that 1994 production of natural gas will be about 1,096.05 billion cubic feet (**Table 1** and **Figure 4**). This is 26.1 billion cubic feet or 2% more than our forecast. But because of the softened gas market, changes to the current production and price forecasts for natural gas between 1995 and 1998 do not warrant changing at this time.

No changes have been made in coal price forecasts since last October (**Figure 5** and **Tables 2** and **3**). And in the first quarter of 1995, spot sale prices continued to show some signs of edging higher. It is also clear that Powder River Basin mines with coals that have somewhat higher heat values (mostly the more southern of the mines) are getting as much as \$1.00 more per ton than the rest of the producers in that basin.

Based on preliminary statistics from the State Inspector of Mines, coal production in 1994 was 236.9 million tons. This is 1.9 million tons or 0.8% higher than our forecast (**Figure 6** and **Table 1**). This translates into a 12.9% increase over 1993 production. With only one month of coal delivery data available for 1995, it is too soon to know how much to change the 1995 to 1998 forecasts. But since January deliveries came in 10% higher than those in January of 1994, it does look like the 3.9% increase that is forecast for 1995 may be too low. A 10% increase for the year, however, would increase production to a record setting 260 million tons in 1995 and may be too high. The situation in forecasting coal production is further complicated in that it remains to be seen if there are transportation bottlenecks that might affect the ability of Powder River Basin producers to meet growing demand.

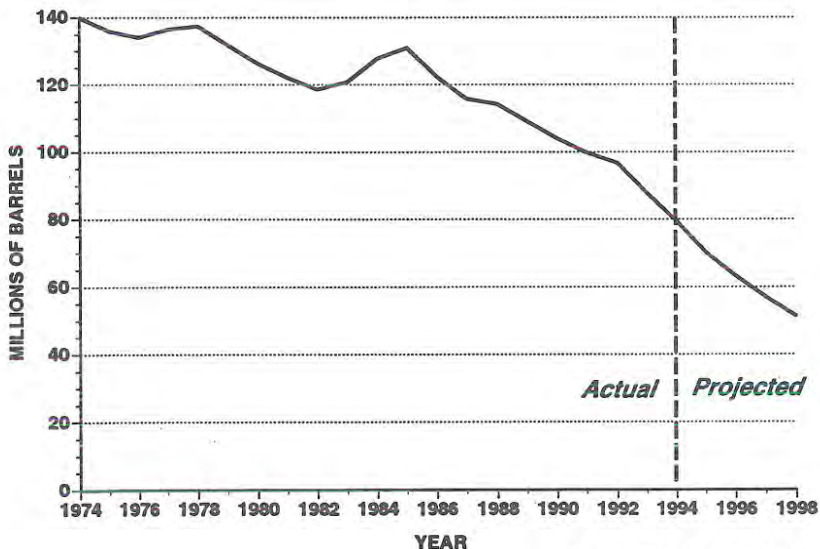
Table 1. Wyoming mineral production (1981-1993) with forecasts to 1998¹.

Calendar Year	Oil ²	Natural Gas ³	Carbon Dioxide ⁴	Helium ⁵	Coal ⁶	Trona ⁶	Mined Uranium ⁷	In-situ Uranium ⁸	Sulfur ⁹
1981	122.1	455.4	—	—	102.7	11.2	4.6	?	0.05
1982	118.7	465.1	—	—	108.0	10.9	2.1	?	0.07
1983	120.9	539.8	—	—	112.2	11.6	3.0	?	0.57
1984	127.8	600.1	—	—	130.7	11.7	1.6	?	0.71
1985	131.0	597.9	—	—	140.4	11.8	0.6	?	0.80
1986	122.4	563.2	23.8	0.15	135.4	13.0	0.2	0.04	0.76
1987	115.9	628.2	114.2	0.86	146.5	13.6	0.2	0.06	1.19
1988	114.3	700.8	110.0	0.83	163.6	14.9	0.3	1.16	1.06
1989	109.1	739.0	126.1	0.94	171.1	16.2	0.1	1.07	1.17
1990	104.0	777.2	119.9	0.90	184.0	16.2	0.2	1.1	1.04
1991	99.8	820.0	140.3	1.05	193.9	16.2	0.4	1.1	1.18
1992	96.8	871.5	139.2	1.05	189.5	16.4	0.1	1.2	1.20
1993	89.0	912.8	140.8	1.06	209.9	16.0	—	1.1	1.14
*1994	79.5	952.5	142.5	1.07	236.9	16.0	—	1.1	1.20
*1995	70.2	947.8	142.5	1.07	245.5	16.4	—	1.1	1.20
*1996	63.2	969.6	142.5	1.07	256.5	16.8	—	1.1	1.20
*1997	56.9	991.9	142.5	1.07	267.9	17.1	—	1.1	1.20
*1998	51.2	1,014.6	142.5	1.07	279.9	17.1	—	1.1	1.20

*Forecast production modified from Consensus Revenue Estimating Group (CREG).

¹Adapted from CREG, Wyoming State Government Revenue Forecast FY95-FY98, January, 1995.

²Millions of barrels (Source: Wyoming Oil & Gas Conservation Commission, 1981-1993); ³Billions of cubic feet (primarily methane with some hydrogen sulfide and nitrogen) (Source: Wyoming Oil & Gas Conservation Commission, 1981-1993); ⁴ Billions of cubic feet. Source: Wyoming Oil & Gas Conservation Commission, 1986-1993; ⁵Billions of cubic feet, based on Exxon's estimate that the average helium content in the gas processed at Shute Creek is 0.5%; ⁶Millions of short tons (Source: Wyoming State Inspector of Mines, 1981-1994); ⁷Millions of short tons of uranium ore (not yellowcake) (Source: Wyoming Department of Revenue, 1981-1992); ⁸Millions of pounds of yellowcake (U₃O₈) (Source: Wyoming Department of Revenue, 1986-1993; unknown between 1981-1985 because it was only reported as taxable valuation); ⁹Millions of short tons (Source: Wyoming Oil & Gas Conservation Commission, 1981-1993).



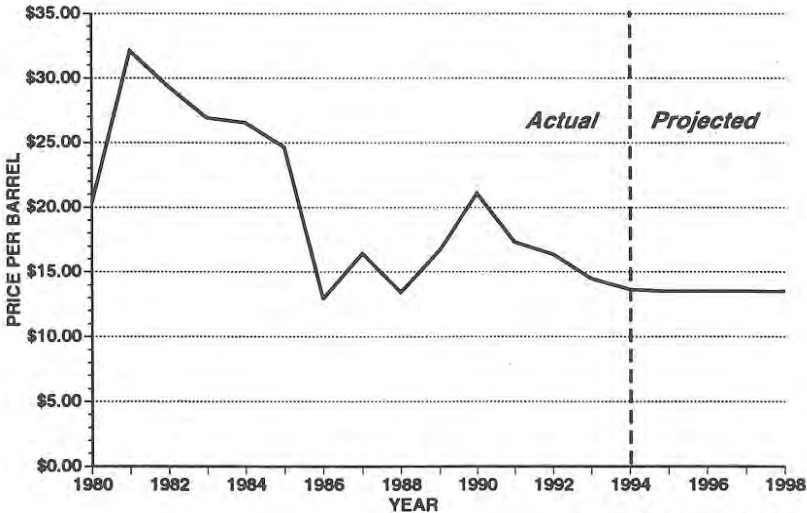
Wyoming State Geological Survey,
Oil and Gas Section, 1995

Figure 1. Annual oil production from Wyoming (1974 to 1993) with forecasts to 1998.

Table 2. Average prices paid for Wyoming oil, methane, coal, trona, and uranium (1985-1993) with forecasts to 1998¹.

Calendar Year	Oil ²	Methane ³	Coal ⁴	Trona ⁵	Uranium ⁶
1985	24.67	3.03	11.36	35.18	36.82
1986	12.94	2.33	10.85	34.80	52.45
1987	16.42	1.78	9.80	36.56	43.55
1988	13.43	1.43	9.16	36.88	25.77
1989	16.71	1.58	8.63	40.76	22.09
1990	21.08	1.59	8.43	41.86	21.16
1991	17.33	1.46	8.09	44.18	21.00
1992	16.38	1.49	8.14	44.50	21.00
1993	14.50	1.81	7.32	40.08	21.00
*1994	13.67	1.56	6.70	39.00	21.00
*1995	13.50	1.56	6.54	40.00	21.00
*1996	13.50	1.65	6.43	40.00	21.00
*1997	13.50	1.65	6.31	40.00	21.00
*1998	13.50	1.65	6.19	40.00	21.00

* Forecast prices modified from Consensus Revenue Estimating Group (CREG).
¹ Adapted from CREG, Wyoming State Government Revenue Forecast FY95-FY98, January, 1995.
² First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Source: Energy Information Administration, 1985-1994.
³ Wellhead price in dollars per thousand cubic feet (MCF). Sources: Wyoming State Land and Farm Loan Office, 1989-1994 (derived from State royalty payments); Minerals Management Service, 1985-1988 (derived from Federal royalty payments).
⁴ Dollars per short ton (weighted average price for coal mined by surface and underground methods). Source: Energy Information Administration, 1985-1993.
⁵ Dollars per ton of trona, not soda ash. Source: Wyoming Department of Revenue, 1985-1993.
⁶ Uranium prices in dollars per pound of yellowcake (weighted average price for in-situ and/or surface-mined uranium). Source: Energy Information Administration, 1985-1990; Wyoming State Geological Survey estimates 1991-1998.



Wyoming State Geological Survey,
Oil and Gas Section, 1995

Figure 2. Average prices paid for Wyoming oil (1980 to 1993) with forecasts to 1998.

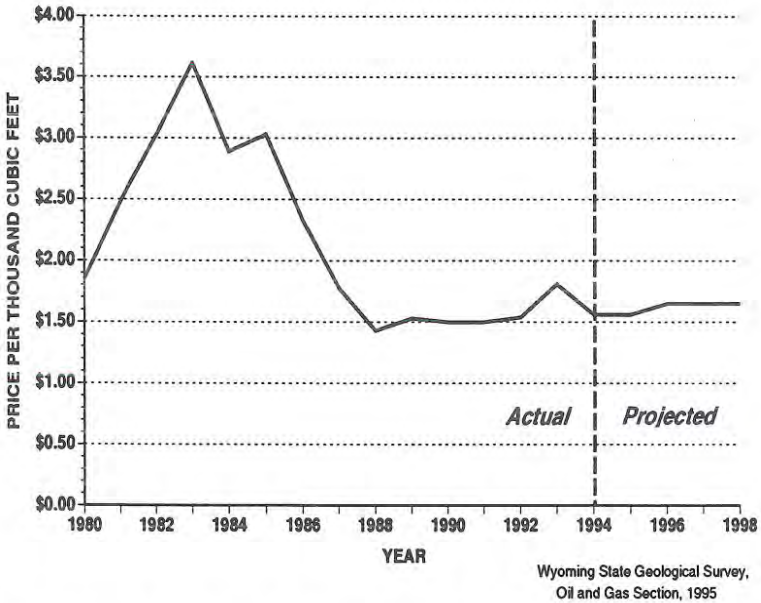


Figure 3. Average prices paid for Wyoming methane (1980 to 1993) with forecasts to 1998.

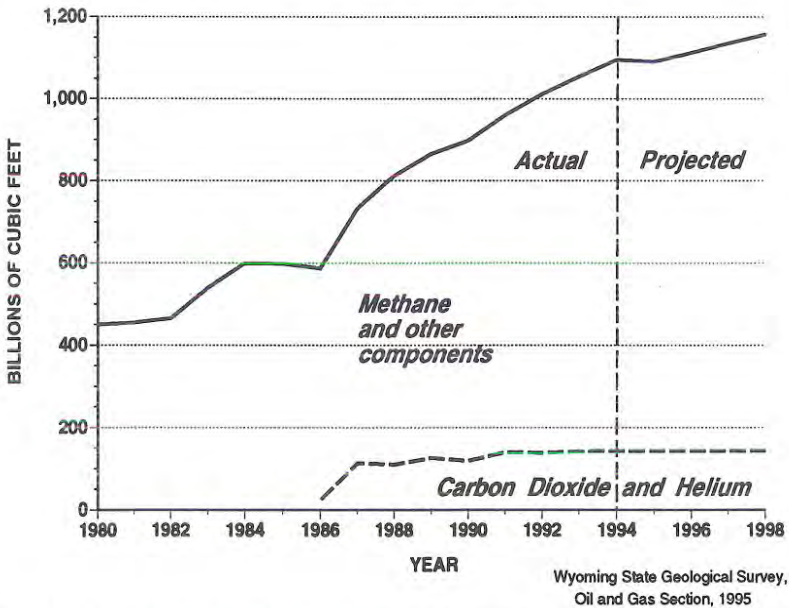


Figure 4. Annual natural gas production from Wyoming (1980 to 1993) with forecasts to 1998.

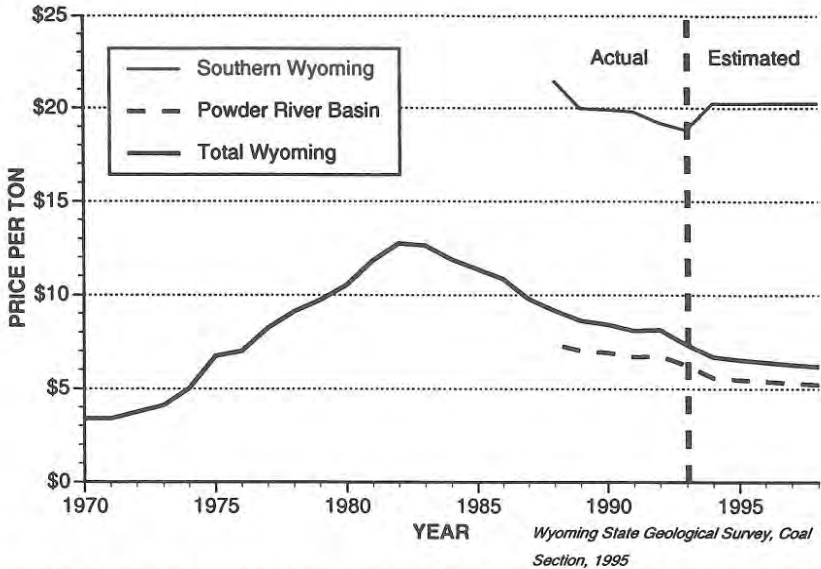


Figure 5. Average prices paid for Wyoming coal (1980 to 1993) with forecasts to 1998. Data from U.S. Energy Information Administration (1980-1993) and the Wyoming Consensus Revenue Estimating Group (1994-1998).

Table 3. Breakdown of average prices paid for coal from northeastern Wyoming, southern Wyoming, and statewide (1988-1993) with forecasts to 1998¹.

YEAR	NORTHEASTERN	SOUTHERN	STATEWIDE
1988	\$7.35	\$21.45	\$9.16
1989	\$7.02	\$19.97	\$8.63
1990	\$6.93	\$19.90	\$8.43
1991	\$6.69	\$19.80	\$8.09
1992	\$6.74	\$19.19	\$8.14
1993	\$6.20	\$19.53	\$7.32
1994	\$5.58	\$20.45	\$6.70
1995	\$5.47	\$20.45	\$6.55
1996	\$5.39	\$20.45	\$6.43
1997	\$5.30	\$20.45	\$6.30
1998	\$5.23	\$20.45	\$6.19

¹Source of statewide data for 1988-1993 is the Energy Information Administration of the U.S. Department of Energy; forecasts for 1994-1998 are from the Wyoming Consensus Revenue Estimating Group. Regional breakdowns are estimated by the Wyoming State Geological Survey.

While production increases, a major coal producer in the Powder River Basin plans to lay off a total of 30 employees at two mines because of declining coal sales (See **Coal Update**). Similarly, another subsidiary of the same parent company has already laid off 50 employees in the Hanna Basin due to

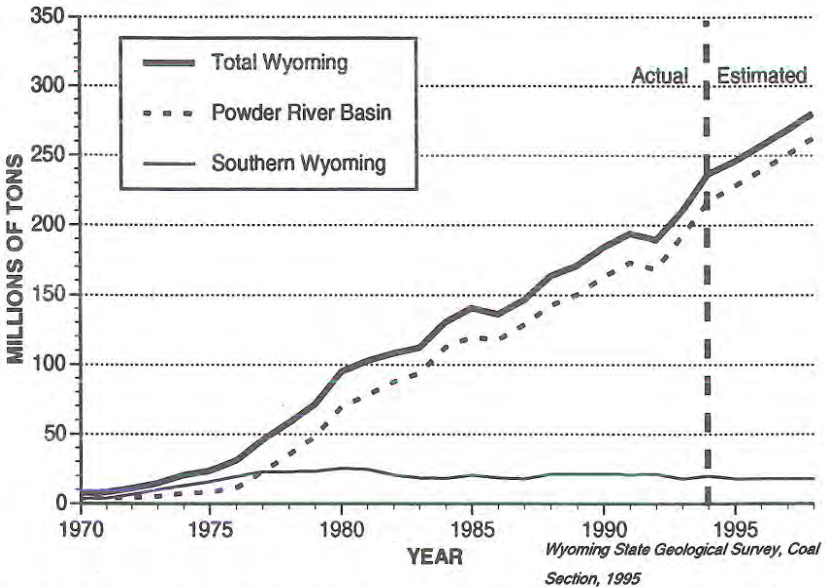


Figure 6. Annual coal production from Wyoming (1970-1994) with forecasts to 1998. Data from the Wyoming State Inspector of Mines (1970-1994) and Wyoming Consensus Revenue Estimating Group (1995-1998).

slackening sales. Both subsidiaries indicated that they needed greater efficiencies if these mines were to remain competitive. In the case of the two mines in the Powder River Basin, any contracts those mines lose will likely be picked up by another Powder River Basin producer. That is not as likely in regard to the mine in the Hanna Basin. Lost contracts there could be picked by producers in other states.

There were no changes made to the October production and price forecasts for trona and uranium (Tables 1 and 2).

Among other things, the **Industrial Minerals and Uranium Update** in this issue provides a discussion of the zeolite resources in Wyoming. Table 4 provides historical production for some selected mineral commodities.

UPDATE ON THE STATUS OF THE USGS AND THE USBM

It does not look like either the U.S. Geological Survey (USGS) or the U.S. Bureau of Mines (USBM) will be abolished as part of the "Contract with America". Both the agencies, however, are slated for substantial budget cuts as well as reductions in staff. Budget cuts of 20-30% are mentioned frequently.

Table 4. Production history of selected Wyoming mineral commodities¹.

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Bentonite ²	2.18	3.08	2.59	1.82	2.16	2.24 ⁶	2.22 ⁶	2.43 ⁶	2.38 ⁶	2.21 ⁶	2.53 ⁶
Clay ⁴	36.4	59.6	35.9	23.2	1.31	---	---	---	---	---	---
Decorative Aggregate ²	0.07	0.08	0.09	0.07	0.06	0.07 ⁷	0.06 ⁶	0.06 ⁶	0.07 ⁶	0.07 ⁶	0.08 ⁶
Decorative Stone ¹⁰	---	---	---	---	---	---	---	---	24 ⁷	100 ⁷	168.0 ⁶
Dolomite ²	0.66	0.86	0.87	0.81	0.46	0.19 ⁶	0.15 ⁶	0.21 ⁶	0.23 ⁶	0.20 ⁶	---
Gypsum ²	0.33	0.33	0.35	0.41	0.35	0.36 ⁶	0.42 ⁶	0.44 ⁶	0.42 ⁶	0.43 ⁷	0.43 ⁷
Iron Ore	2.48 ²	---	---	---	---	---	40 ⁸	40 ⁸	---	---	250 ^{7,9}
Leonardite ⁴	---	---	---	---	---	minor ⁵	38.9 ⁶	41.7 ⁶	22.9 ⁶	37.0 ⁶	39.0 ⁶
Limestone ^{2,5}	0.56	0.65	0.32	0.33	0.32	0.64	0.60 ⁶	0.48 ⁶	0.49 ⁶	0.52 ⁶	0.63 ⁶
Construction Aggregate ^{2,3}	6.72	8.31	6.40	5.01	4.12	3.15	6.46 ⁶	7.73 ⁶	8.62 ⁶	8.11 ⁶	10.6 ⁶
Shale ⁴	---	20.3	14.7	9.88	103.2	52.2 ⁶	15.6 ⁶	43.5 ⁶	158.2 ⁶	113.3 ⁶	---
Sodium Sulfate ⁴	3.19	3.25	2.71	2.03	---	2.10 ⁶	---	1.9 ⁶	1.5 ⁶	1.5 ⁶	1.5 ⁶

Sources: ¹Wyoming Department of Revenue, unless otherwise noted; ²millions of short tons; ³includes ballast, scoria, and limestone used for aggregate; ⁴thousands of short tons; ⁵includes chemical grade limestone used for cement rock, sugar beet refining, and other uses; ⁶Wyoming State Inspector of Mines; ⁷estimated by Wyoming State Geological Survey; ⁸short tons of iron ore used for pigment; ⁹short tons of iron ore used as weighting additive in cement; ¹⁰ short tons. Prepared by Wyoming State Geological Survey, January, 1995.

Individuals and organizations, which use the products and services of these two Federal agencies, should write their Congressional delegations to express support for the products and services they need and use. As a State agency, we have already done that and encourage others to do the same.

DIALWYO AND GET OIL AND GAS DATA

The Wyoming Oil and Gas Conservation Commission has created an oil and gas database that is now accessible to most anyone with a modem connected to an IBM or compatible PC. To access DIALWYO, you need to call or write for a software disk, which is free for the asking. They need to know the kind of disk you desire before they send it. You will receive a users manual with the disk. Their address, phone, and fax numbers are:

Wyoming Oil and Gas Conservation Commission
P.O. Box 2640
Casper, WY 82602-2640
(307) 234-7147
Fax (307) 234-5306

The database provides access to well data and production files, field production, locations of water wells and oil and gas wells (plotted on a section grid), information on hearings, information on spacing and units to include legal

descriptions, as well as the agency's statutes, rules, and regulations. If you have not already browsed this database, you should try it.

COOPERATIVE SCIENTIFIC QUARRY PROPOSED

Fossil Butte National Monument has proposed the development of a scientific/interpretive fossil quarry on State-owned lands south of the monument. This quarry would be opened in partnership with the State of Wyoming so that the scientific community would have a quarry in which they could study the unique, world-class, vertebrate fossil beds of the Green River Formation. These are the beds famous for their abundant fossil fish. But they contain many other vertebrate fossils such as frogs, snakes, crocodiles, turtles, birds, bats, as well as insects and crayfish just to name a few. In addition, to the fossils themselves, these beds hold clues to many unanswered questions about the fossils and the sediments themselves.

The quarry would be opened at an older site not far from a large commercial fossil fish quarry on private lands adjacent to the State land. As a scientific quarry, qualified researchers from around the world could visit and use it as a natural laboratory. All the fossils, would remain the property of the State of Wyoming, and would be catalogued as such. This proposal offers an opportunity for many to benefit from a sharing of resources. As budgets get smaller and research money shrinks, it will take partnerships like this to provide the fiscal as well as the human resources needed to conduct these kinds of scientific investigations. From a personal standpoint, this cooperative effort should help in our agency's preparation of some of the scientifically important specimens found on other State lands in that area. The State Land Board has authorized the State Land and Farm Loan Office to work with Fossil Butte in developing necessary agreements to create a cooperative research quarry.

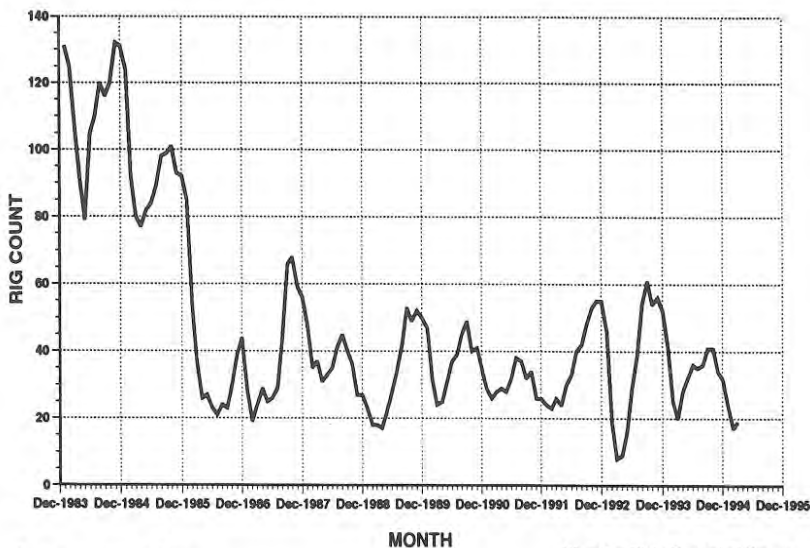
This envisioned research will do much to raise awareness of the rich paleontologic resources found in the Green River fossil beds of Wyoming. That awareness will not only provide more opportunities to enhance our scientific knowledge of the paleontologic resources in those beds, but it should also help tourist and recreational efforts in southwestern Wyoming as well.

OIL AND GAS UPDATE

Rodney H. De Bruin

Staff Geologist-Oil and Gas, Wyoming State Geological Survey

The average rig count for the first quarter of 1995 was 20, compared to last year's first quarter average of 29 (Figure 7). Even though the average rig count



Source: Hughes Rig Count

Wyoming State Geological Survey,
Oil and Gas Section, 1995

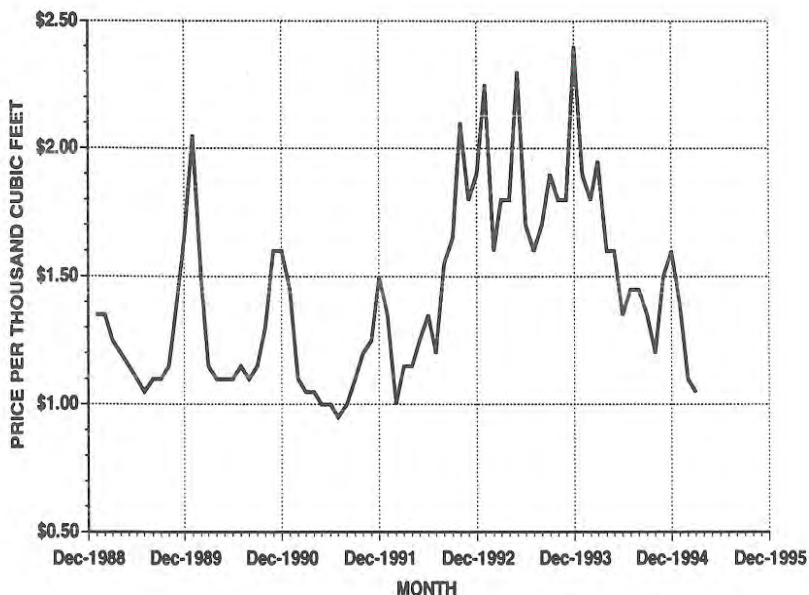
Figure 7. Wyoming daily rig count averaged by month (1984 to present).

was lower this quarter, a total of 38 wells were completed during January and February of 1995. While this is one more well than was completed in January and February of 1994, the average depth of these wells was only 6,600 feet, rather than the 8,500-foot average in 1994.

High storage volumes and a very mild winter have combined to hold down spot prices (Figure 8). The March 1995 spot price at Opal, Wyoming, dropped to \$1.05 per thousand cubic feet, making it the lowest price since February, 1992. The average spot price for southwestern Wyoming during this first quarter of 1995 was \$1.18, compared to an average spot price of \$1.88 for the first quarter of 1994.

Production figures just released by Petroleum Information Corp. (1995), however, show that Wyoming natural gas production was at an all-time high of 1.096 trillion cubic feet in 1994, despite high storage volumes and warmer than normal winter conditions. Production for 1994 was up almost 3.9% over 1993 production even though U.S. consumption was lower in 1994 than in 1993.

A new report just released by the U.S. Geological Survey's National Oil and Gas Resource Assessment Team (1995) shows that Wyoming has remaining resources of approximately 5.7 billion barrels of oil, 4.5 billion barrels of natural gas liquids, and 176.3 trillion cubic feet of natural gas. These resources are divided among proved reserves, reserve growth in conventional fields, undiscovered conventional resources, and continuous-type accumulations in sandstones, shales, chalks, and coal beds. These resources represent 5.1 percent



Source: American Gas Association

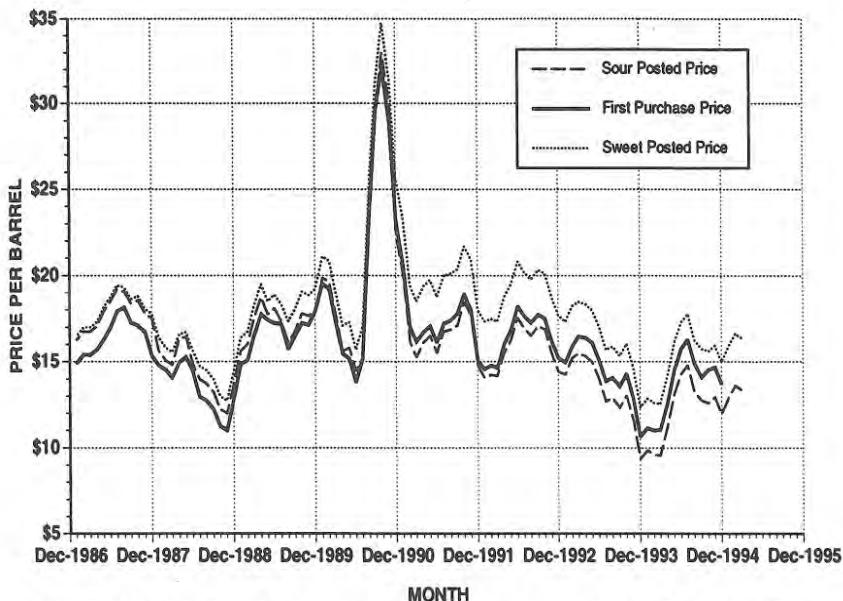
Wyoming State Geological Survey,
Oil and Gas Section, 1995

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

of the remaining oil, 15.4 percent of the remaining natural gas liquids, and 16.4 percent of the remaining natural gas in all onshore areas and State waters of the U.S. Almost 60% of Wyoming's oil resources are located or will be discovered in the Powder River Basin, while about 96% of Wyoming's resources of natural gas liquids and natural gas are located or will be discovered in the Thrust Belt and the Greater Green River Basin. The magnitudes of these resources show that Wyoming will be an important oil- and gas-producing state for many more years.

Even though Wyoming has large crude oil resources, production in Wyoming is declining at a rapid rate. Production figures released by Petroleum Information Corp. (1995) show that Wyoming produced 79.5 million barrels of oil in 1994. This is a drop of 9.5 million barrels from 1993 production, but was 1.5 million barrels higher than earlier projections. It is unlikely that this decline rate in oil production will slow much unless crude oil prices rise and stabilize. There was some improvement in prices for Wyoming crude oil in this quarter compared to the first quarter of 1994 (Figure 9), however, the price needs to increase even more and remain stable longer to stimulate exploration and to provide economic incentives for companies to initiate new enhanced oil recovery projects.

The 1995 Wyoming State Legislature passed a number of bills designed to aid the State's ailing oil industry. House Bill (HB) 17 continues a two percent severance tax reduction on the first five years of incremental production from



Source: Unpublished DOE and company data

Wyoming State Geological Survey,
Oil and Gas Section, 1995

Figure 9. Wyoming posted Sweet and Sour crude oil prices and first purchase prices averaged by month (1987 to present).

new tertiary projects, provided they start before the end of 1996. HB 22 changes the stripper well definition from 10 to 15 barrels of oil per day for production on or after January 1, 1995, providing the price received by the producer is less than \$20 per barrel. The bill also extends the 4.5% severance tax reduction for collection wells through 1999. HB 43 grants a five-year, 4.5% severance tax reduction on renewed oil production from wells that were not producing for at least two consecutive years prior to January 1, 1995. If the price of the oil exceeds \$25 per barrel for six consecutive months, however, the incentive terminates. On qualifying new wells, HB 150 increases the volume of produced oil and gas, which is eligible for a four percent, two-year tax incentive. The limit for oil increases from 40 to 60 barrels per day and the limit for gas increases from 240 to 360 thousand cubic feet per day. If the price equals or exceeds \$22 per barrel of oil or \$2.75 per thousand cubic feet of gas for six consecutive months, the incentive terminates. The incentive is good through March of 1998 for wells drilled on or after January 1, 1995. Wells drilled between July 1, 1993, and January 1, 1995, are subject to the old limits.

The Wyoming State Office of the U.S Bureau of Land Management (BLM) with the cooperation of the BLM's Rawlins and Rock Springs district offices will evaluate energy and mineral development in the Greater Green River Basin. The area covered by this three-year project is about 18.9 million acres in all or parts of Carbon, Sweetwater, Uinta, Lincoln, Sublette, and Fremont counties.

The BLM expects the drilling of 6,000 to 11,000 new wells in this area by the year 2015. In a related item, the BLM is preparing an Environmental Impact Statement for a 1,250-well natural gas exploration and development program proposed by Amoco Production and several other operators. This program covers a 1.3-million-acre area in eastern Sweetwater County. The preferred plan calls for the drilling of 1,250 wells and the construction of associated facilities and pipelines. The project is scheduled to begin in 1996 and continue for 10 years.

Lease sales in Wyoming did fairly well in the first quarter of 1995 (Table 5). The revenues from both the March State Land and Farm Loan sale, and the February BLM sale were lower than at these sales in 1994. In both cases, however, revenues from the two sales were still above average for recent years. The heaviest leasing activity at the sales in the first quarter was about equally divided among southwestern Wyoming and the Powder River Basin. Leases in the Wind River Basin and Bighorn Basin were also in demand, especially at the BLM sale (Figures 10 and 11).

The BLM's February sale had a high per-acre bid of \$425. The bid was made by Marathon Oil Co. for a 1,125.75-acre lease in parts of sections 1, 12, and 13, T23N, R112W. The tract is between Frontier gas and condensate production at Storm Shelter Field to the east and Frontier gas and condensate production at Emigrant Field to the west. The second highest per-acre bid of \$225 was made by Donald B. Anderson for a 49.21-acre parcel in parts of sections 6 and 7, T23N, R111W. This lease is also adjacent to Frontier gas and condensate production at Storm Shelter Field. The third highest per-acre bid was \$170, made by Yates Petroleum for a 240-acre lease that includes S/2 NW and SW section 26, T24N, R112W. There were a total of 13 leases at this sale that drew bids of \$50 or more per acre.

The State Land and Farm Loan Office's sale in March had two high per-acre bids of \$130. David W. Holwegner bid \$130 for a 640-acre lease that covers all of section 16, T22N, R94W. The lease is in an undrilled section in Siberia Ridge Field. Maurice W. Brown also bid \$130 for a 320-acre lease that covers SE section 33 and SW section 34, T54N, R68W. The lease is within a half mile of Minnelusa oil production at Lily Field. W. Gundry-White bid \$85 per acre for a 581.36-acre lease that covers all of section 36, T39N, R89W. The lease is about a half mile from abandoned Lance and Mesaverde gas production at Badwater Field. A total of five parcels at this sale received bids of \$50 or more per acre.

Exploration and development

Company data, news releases, and information compiled and published by Petroleum Information Corp. indicate the following significant exploration and development events occurred in Wyoming during the first quarter of 1995. The numbers preceding discussions below refer to locations on Figure 12.

1. Union Pacific Resources is planning to drill a horizontal well in Yellow Creek Field from a surface location in SE SW section 30, T15N, R120W. The 30-

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

FEDERAL SALES (BUREAU OF LAND MANAGEMENT)							STATE SALES (STATE LAND AND FARM LOAN OFFICE)								
Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre	Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
TOTAL	\$12,934,277	2,815	1,147	2,191,462	675,777	\$19.14	\$16,000.00	TOTAL	\$4,457,885	1,295	1,037	479,975	405,910	\$10.98	\$401.00
TOTAL	\$4,778,940	2,122	664	1,434,268	364,478	\$13.11	\$2,500.00	TOTAL	\$745,738	799	419	277,755	150,613	\$4.95	\$230.00
February	\$1,637,233	464	246	346,357	155,272	\$10.54	\$220.00	March	\$601,400	200	137	74,940	54,723	\$10.99	\$400.00
April	\$2,116,184	478	259	351,465	177,989	\$11.89	\$220.00	May	\$362,840	200	141	82,388	56,770	\$6.39	\$80.00
June	\$1,415,793	463	179	351,130	86,435	\$16.38	\$390.00	September	\$505,587	200	141	80,428	56,845	\$8.89	\$225.00
August	\$1,877,405	482	262	374,274	208,495	\$9.00	\$400.00	November	\$510,290	200	143	73,517	53,801	\$9.48	\$155.00
October	\$2,636,127	458	247	367,281	186,274	\$14.15	\$285.00	TOTAL	\$1,980,017	800	562	311,273	222,139	\$8.91	\$400.00
December	\$3,259,266	444	276	275,435	180,879	\$18.02	\$320.00	TOTAL	\$917,380	200	169	84,571	73,061	\$12.56	\$170.00
TOTAL	\$12,942,008	2,769	1,469	2,065,942	995,344	\$13.00	\$400.00	March	\$917,380	200	169	84,571	73,061	\$12.56	\$170.00
February	\$3,909,085	442	290	374,969	237,761	\$16.44	\$160.00	May	\$802,688	200	141	75,523	54,199	\$14.81	\$205.00
April	\$4,248,182	498	278	369,657	201,690	\$21.06	\$275.00	September	\$986,083	200	149	83,143	61,675	\$9.50	\$190.00
June	\$3,799,282	480	270	417,447	233,664	\$16.09	\$325.00	November	\$988,001	200	148	86,542	66,217	\$15.07	\$142.00
August	\$5,100,550	439	294	323,410	217,157	\$23.49	\$255.00	TOTAL	\$3,304,152	800	607	331,779	255,152	\$12.95	\$205.00
October	\$4,703,706	492	341	411,117	269,003	\$17.49	\$11,200.00	March	\$524,165	199	131	89,371	57,702	\$9.08	\$130.00
December	\$5,386,789	617	367	479,930	290,384	\$18.55	\$390.00	TOTAL	\$3,304,152	800	607	331,779	255,152	\$12.95	\$205.00
TOTAL	\$27,107,594	2,968	1,840	2,376,530	1,449,659	\$18.70	\$11,200.00	TOTAL	\$524,165	199	131	89,371	57,702	\$9.08	\$130.00
February	\$3,252,668	533	332	473,177	290,046	\$11.21	\$425.00								

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

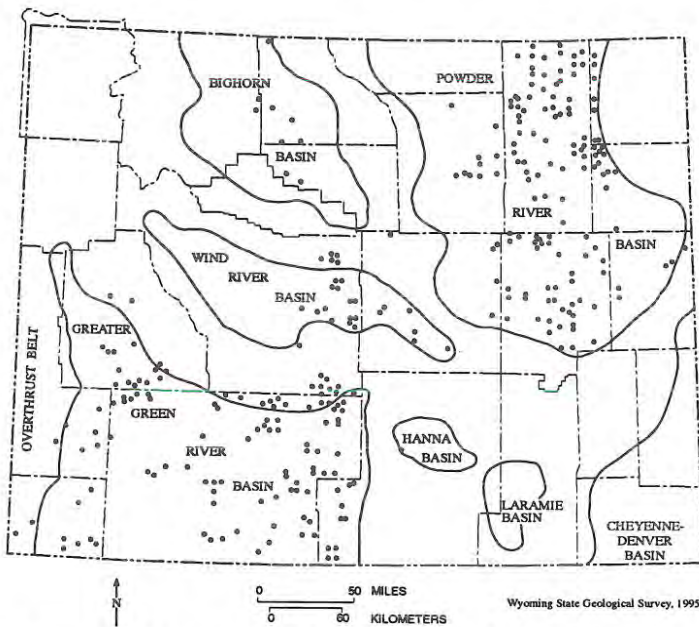


Figure 10. Locations of Federal oil and gas tracts leased by the U.S. Bureau of Land Management at the February, 1995, sale.

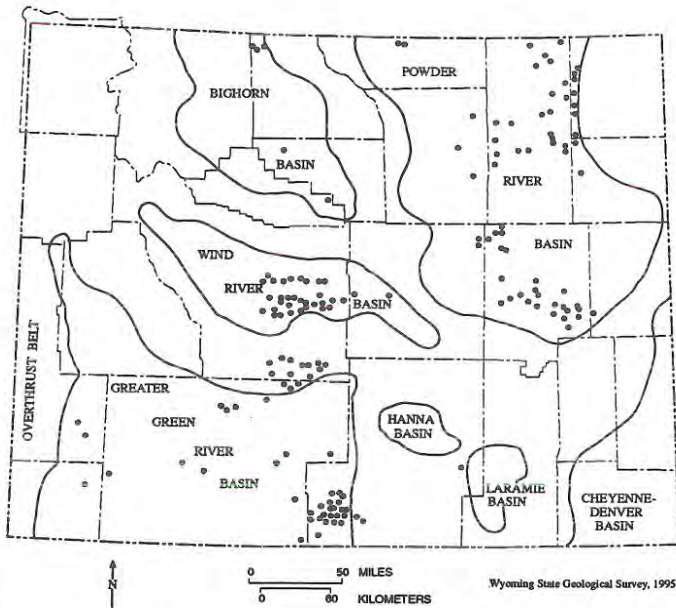


Figure 11. Locations of State oil and gas tracts leased by the State Land and Farm Loan Office at the March, 1995, sale.

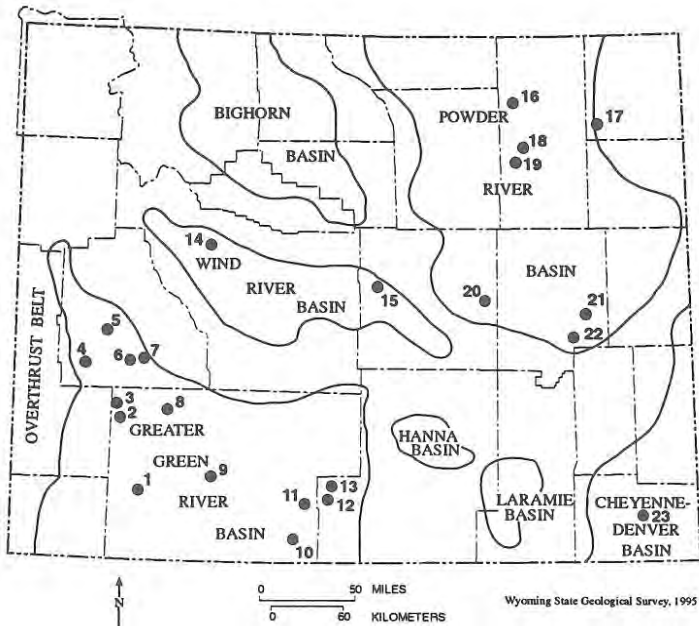


Figure 12. Oil and gas exploration and development activities in Wyoming during the first quarter of 1995 (exclusive of coalbed methane activities).

- 1H Yellow Creek Shallow well will test the Twin Creek Limestone and will be drilled to a true vertical depth of 5,721 feet.
2. Vessels Oil & Gas completed a new producer in Sierra Madre Field. The 5-20 S.M. Nicholson well in NE SW section 20, T13N, R89W had an initial pumping potential of 168 barrels of oil and 147,000 cubic feet of gas per day from the Shannon between 3,464 and 3,678 feet.
 3. Yates Petroleum completed two new producers on the western flank of Crooked Canyon Field. The 2 Depot well in NE NE section 1, T21N, R104W flowed 5.6 million cubic feet of gas and two barrels of water per day from the Morrison Formation between 6,731 and 6,736 feet. The 1 Hunt-Federal well in SE NW section 12, T 21N, R104W flowed 349,000 cubic feet of gas per day from the Dakota between 5,958 and 5,961 feet.
 4. Texaco Exploration & Production completed a horizontal producer in Stagecoach Draw Field. The 5H Stagecoach Draw Unit well was drilled from a surface location in SW NE section 31, T23N, R107W. The well flowed 2.9 million cubic feet of gas and 88 barrels of condensate per day from the Almond. True vertical depth of the well was projected at 7,950 feet. Texaco is also reentering its 4 Stagecoach Draw Unit well to drill a new horizontal

well. The 4H Stagecoach Draw Unit Well is drilling from a surface location in SE SE section 18, T23N, R107W and is projected to a true vertical depth of 7,956 feet in the Almond.

5. HS Resources agreed to purchase Presidio Exploration's 30.3% working interest in the Blue Forest Unit for \$12.8 million in cash. Proved reserves are estimated at 17.8 billion cubic feet of gas and 294,000 barrels of oil.
6. Enron Oil & Gas completed a new well in the Big Piney/La Barge area. The 1-101-26 Big Piney Mesaverde Unit well in SW NE section 26, T29N, R113W flowed 11.2 million cubic feet of gas per day from the Mesaverde between 2,988 and 3,300 feet.
7. McMurray Oil completed a new well in Jonah Field. The 15-28 Steadhorse-Federal well in SW SE section 28, T29N, R108W flowed 3.9 million cubic feet of gas per day from an undisclosed Mesaverde interval.
8. Stovall Oil completed a new well on the northeastern flank of Government Bridge Field. The 14-20 Government well in NE NE section 20, T31N, R82W pumped 130 barrels of oil per day through perforations between 2,784 and 2,828 feet in the Cody Shale.
9. Cenex Inc. completed a new discovery well in NW NW section 28, T33N, R95W. During its first seven days of production, the 4-28 well produced an average of 147 barrels of oil per day from an undisclosed interval in the Tensleep Sandstone.
10. Chevron USA Production discovered gas in a shallower pool in Waltman Field. The 8 Bullfrog Unit well in NE NW section 18, T36N, R86W flowed 2.2 million cubic feet of gas per day from the Wind River Formation between 1,768 and 1,783 feet.
11. Barrett Resources was waiting on completion tools at its 4 Cave Gulch-Federal well in SW SW section 29, T37N, R86W. The well was designed to test the Lance at approximately 8,800 feet. The well is northeast of the company's discovery well, which produced an average of 8.6 million cubic feet of gas and 87 barrels of condensate during its first 29 days of production in December.
12. Marathon Oil will reenter a vertical producing well in Grass Creek Field and drill a horizontal well. The 192H Curtis Unit well will be drilled from a surface location in SW SW section 20, T46N, R98W and will test the Curtis sand at a true vertical depth of about 3,100 feet. The vertical well produced about 103,000 barrels of oil from the Curtis since its original completion in 1984.
13. Marathon Oil also plans to drill another horizontal well by reentering a vertical Tensleep producer in Pitchfork Field. The 85 Pitchfork well will be drilled from a surface location in NW NE section 14, T48N, R102W to a true

vertical depth of about 3,700 feet. The vertical well produced about 72,000 barrels of oil from the Tensleep since its completion in 1986.

14. Texaco Exploration & Production completed a new pay discovery in Whistle Creek Field. The 95-16 Whistle Creek Unit well in NE SW section 16, T56N, R98W flowed 477,000 cubic feet of gas and 91 barrels of water per day from the Cloverly Formation between 4,145 and 4,155 feet.
15. Lario Oil & Gas discovered oil at its 2 Hilda-State well in NE NE section 36, T52N, R69W. The well pumped 171 barrels of oil per day from the Minnelusa between 7,532 and 7,537 feet.
16. Swift Energy discovered oil at its 1 Sinner-Federal 24-15 well in SE SW section 15, T51N, R69W. Oil was swabbed at a rate of 415 barrels per day from the Minnelusa between 7,987 and 8,000 feet.
17. Ampolex completed a new producer north of Donkey Creek Field. The 34-18 Federal well in SW SE section 18, T50N, R68W pumped 53 barrels of oil per day from the Minnelusa between 7,858 and 7,896 feet. The company also is completing its 21-19 Federal well in NE NW section 19, T50N, R68W. The well reportedly hit 44 feet of sand in the Minnelusa; however, no other details are available.
18. Ampolex completed a new discovery well west of Gaither Draw Field. The 23-33 Heiland Trust-Federal well in NE SW section 33, T48N, R73W pumped 43 barrels of oil, 25,000 cubic feet of gas, and eight barrels of water per day from the Sussex between 7,088 and 7,118 feet.
19. Presidio Exploration completed four new wells in Culp Draw/ Heldt Draw Fields. The H-128 Culp Draw Unit well in SE NE section 26, T46N, R77W pumped 220 barrels of oil and 62,000 cubic feet of gas per day from the Shannon between 9,338 and 9,348 feet. The C-125 Culp Draw Unit well in NW NW section 23, T46N, R77W pumped 82 barrels of oil per day from the Shannon between 9,220 and 9,235 feet. The C-130 Culp Draw Unit well in NE SE section 15, T46N, R77W pumped 116 barrels of oil per day from the Shannon between 9,206 and 9,218 feet. The H-127 Culp Draw Unit well in SW SW section 8, T45N, R76W pumped 33 barrels of oil and 18,000 cubic feet of gas per day from the Shannon between 9,376 and 9,384 feet.
20. Crawley Petroleum completed two new producers in Tuit Draw Field. The 2-20 Cosner well in NW NW section 20, T43N, R72W produced an average of 145 barrels of oil and two barrels of water per day from an undisclosed interval in the Turner during its first 10 days of production. The 1-26 Cosner well in SW SW section 26, T43N, R72W produced an average of 19 barrels of oil and 20 barrels of water per day from an undisclosed interval in the Turner.
21. Union Pacific Resources completed a new horizontal producer in Silo Field. The 1H Sweetwater 41-17 well was drilled from a surface location in NE NE section 17, T16N, R65W and produced an average of 224 barrels of oil and

15 barrels of water per day from an undisclosed interval in the Niobrara Formation during its first 18 days of production.

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- Petroleum Information Corporation, 1995, Wyoming production report (December, 1994): Denver, CO, 2087p.
- U.S. Geological Survey, 1995, 1995 National assessment of United States oil and gas resources: prepared by the National Oil and Gas Resource Assessment Team, U.S. Geological Survey Circular 1118, 20 p.

COAL UPDATE

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A monthly record was set in December, with deliveries of 20,866,710 tons of Wyoming coal (Table 6 and Figure 13). December was also a record month for spot deliveries with over 6,101,280 tons delivered (Figure 14A). It was the first time that monthly spot deliveries were above six million tons, further emphasizing a spot coal market that has tripled in Wyoming over the last three years. Monthly deliveries of contract coal finished 1994 at 14,765,430 tons in December. While significant, monthly deliveries of contract sales topped that tonnage twice in 1994 (Figure 14B).

Coal production from Wyoming in 1994 was up 12.9% over 1993 production according to the State Mine Inspector (Table 7). Eleven mines in Wyoming increased production more than 10%, while three mines in the Powder River Basin increased their production by more than 20%. Caballo Rojo had the largest production increase of the year with an 8-million-ton gain over 1993!

While coal mines in Wyoming are producing record tonnages, they are also planning for future production increases as well. The Air Quality Division of the Wyoming Department of Environmental Quality approved a 10-million-ton increase to Caballo Rojo's state air quality permit. Three other mines are also seeking to increase their air quality permits, which if awarded, would result in an additional 25 million tons in production capacity. Currently, the permitted production capacity in Wyoming is an estimated 433.80 million tons of coal per year (Table 8). For comparison purposes, projected annual coal production through 1998 is shown in Table 9.

The Bureau of Land Management's (BLM's) Lease By Application (LBA) sale for the 1,059-acre Eagle Butte tract was held at the BLM office in Cheyenne on April 5. Cyprus-Amox's bid of approximately \$18 million dollars, or about \$0.11/ton (166,400,000 tons) was accepted. The tract was adjacent to the Eagle Butte mine. Half of the proceeds from this sale will be returned to the State over

Table 6. Coal deliveries by month from Wyoming mines.

	1991		1992		1993		1994	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
JAN	14,960,450	14,960,450	16,407,150	16,407,150	15,931,150	15,931,150	19,326,770	19,326,770
FEB	15,480,110	30,440,560	14,604,480	31,011,630	14,646,090	30,577,240	17,171,910	36,498,680
MAR	16,278,870	46,719,430	14,429,650	45,441,280	17,112,970	47,690,210	19,178,990	55,677,670
APR	14,820,240	61,539,670	14,063,060	59,504,340	16,259,770	63,949,980	17,839,110	73,516,780
MAY	14,589,790	76,129,460	14,518,590	74,022,930	16,085,470	80,035,450	18,652,290	92,169,070
JUN	14,007,600	90,137,060	14,655,600	88,678,530	16,473,920	96,509,370	17,741,480	109,910,550
JUL	16,451,090	106,588,150	15,592,050	104,270,580	15,296,480	111,805,850	18,213,540	128,124,090
AUG	15,940,620	122,528,770	16,467,100	120,737,680	16,682,090	128,487,940	20,572,120	148,696,210
SEP	15,314,490	137,843,260	14,878,150	135,615,830	17,310,330	145,798,270	19,129,450	167,825,660
OCT	14,810,510	152,653,770	15,122,820	150,738,650	18,300,070	164,098,340	18,189,260	186,014,920
NOV	14,783,000	167,436,770	14,757,230	165,495,880	18,007,970	182,106,310	18,595,500	204,610,420
DEC	16,716,630	184,153,400	16,096,150	181,592,030	19,034,530	201,140,840	20,866,710	225,477,130
Total Tonnage Reported¹	184,153,400	181,592,030			201,140,840			225,477,130
Total Tonnage Not Reported							8,784,986	11,430,937
Total Tonnage Produced²							209,925,826	236,908,067

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

² Source: State Mine Inspector's Annual Reports

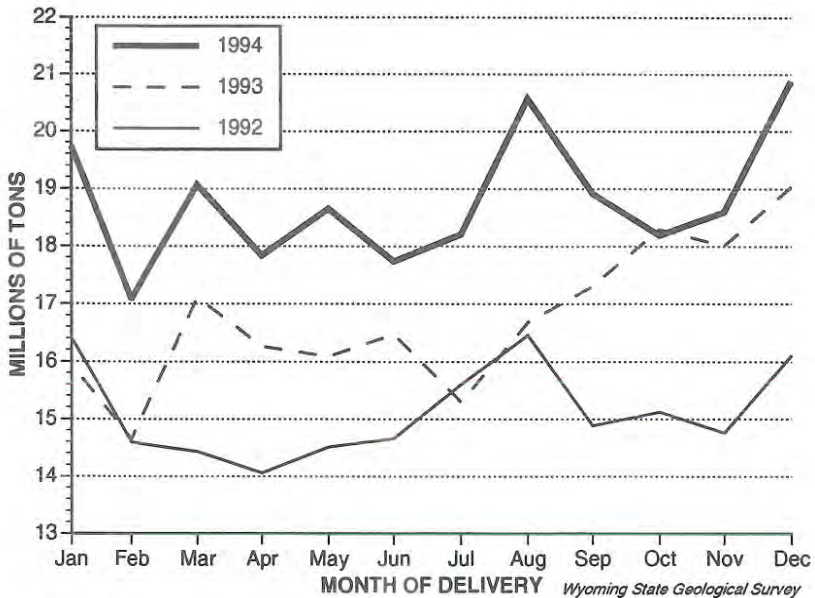


Figure 13. Reported deliveries from Wyoming coal mines (1992 through December, 1994). (From COALDAT Marketing Report by Resource Data International, Inc., compiled from FERC Form 423 filed monthly by electric utilities).

the next five years. Recent LBA sales in the early 1990s generated higher bids (\$0.15-0.21/ton) than the Eagle Butte LBA. These earlier LBA's were on properties in the southern Powder River Basin, where the coals have higher heat values (Btu/pound) and are currently drawing higher Freight on Board (F.O.B.) prices than the mines near or north of Gillette. The lower bid also follows a trend in spot sale prices, which have gradually declined since mid-1991.

Developments in the Powder River Basin

In April, Cyprus-Amax announced that they would be laying off about 30 employees from their Belle Ayr and Eagle Butte mines. Company officials stressed that the layoffs were due to declining coal sales rather than due to reorganization. Cyprus Minerals and Amax merged about two years ago.

As reported in *Wyoming Geo-Notes No. 45* (p. 21), Kennecott Energy had applied for an air quality permit that would allow the company to build a \$400 million coal processing plant at its Cordero mine site. Company officials have now put their plans for the plant on hold, citing lack of Federal tax credits as the main reason. Kennecott officials are assessing the viability of the project without Federal tax credits associated with coal enhancement technology.

Santa Fe shareholders ratified an agreement in February to merge with Burlington Northern Railroad, making Burlington Northern the nation's largest rail network. The agreement was reportedly worth about \$4 billion.

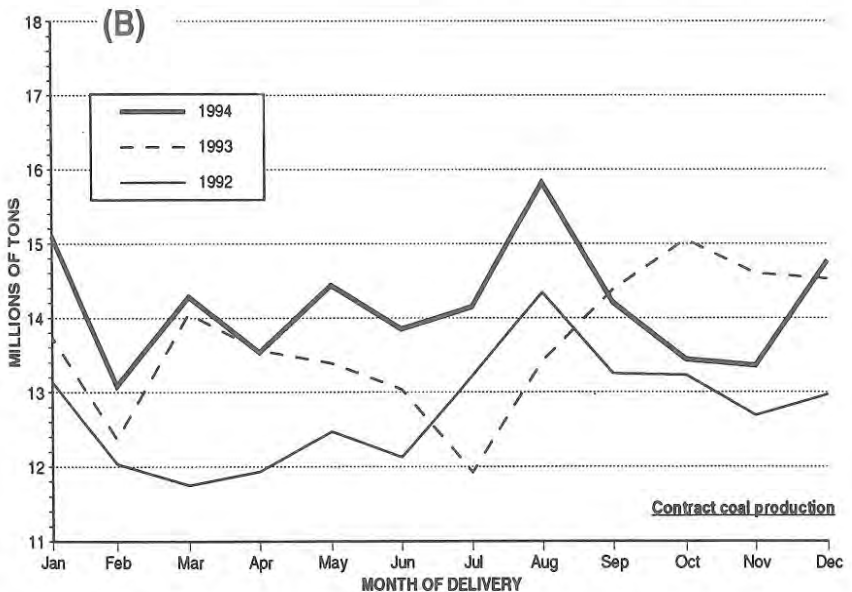
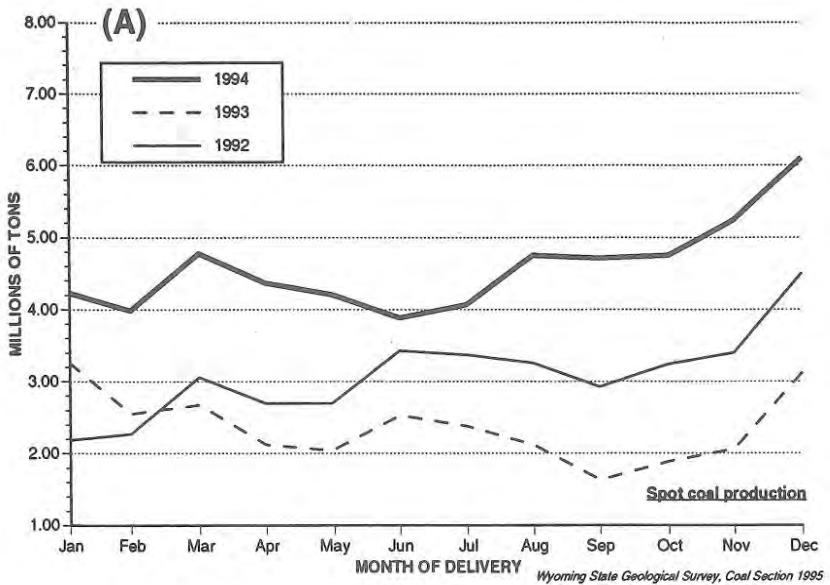


Figure 14. Monthly coal deliveries from Wyoming (1992 through December, 1994). (A) Coal sold on the spot market and (B) coal sold on contract. (From COALDAT Marketing Report by Resource Data International, Inc., compiled from the FERC Form 423 filed monthly by electric utilities).

Table 7. Comparison of coal production and coal industry employment in Wyoming by coal field and mine for 1993 and 1994.

Company	Mine Name	1993			1994			Production Difference 1994-1993	Percentage Increase/Decrease
		Employees	Production(tons)	Employees	Production(tons)	Employees	Production(tons)		
POWDER RIVER COAL FIELD									
Cyprus-Amax Coal Co.	Belle Ayr (surface)	238	15,588,000	239	18,361,865		2,773,865	17.79	
	Eagle Butte (surface)	226	16,700,000	201	17,161,000		461,000	2.76	
Kennecott Energy, Inc.	Antelope (surface)	103	7,286,610	119	8,258,590		971,980	13.34	
Kerr-McGee Coal Corp.	Clovis Point (surface)	1	0	5	202,202		202,202	100.00	
Big Horn Coal Co.	Big Horn (surface)	13	120,000	17	100,733		-19,267	-16.06	
Kerr-McGee Coal Corp.	Caballo Rojo (surface)	225	8,023,000	182	16,611,485		8,588,485	107.05	
Powder River Coal Co.	Caballo (surface)	290	15,418,125	322	14,428,600		-989,525	-6.42	
	Rawhide (surface)	181	9,864,353	176	12,858,787		2,994,434	30.36	
Kennecott Energy, Inc.	Cordero (surface)	187	12,988,628	204	16,413,646		3,425,018	26.37	
Western Fuels/Phillips Coal	Dry Fork (surface)	49	3,277,794	51	3,836,228		558,434	17.04	
Fort Union Coal Co.	Fort Union (surface)	5	58,131	5	84,122		25,991	44.71	
Glenrock Coal Co.	Dave Johnston (surface)	176	2,902,306	182	3,159,725		257,419	8.87	
Kerr-McGee Coal Corp.	Jacobs Ranch (surface)	357	18,387,422	349	20,550,847		2,163,425	11.77	
Powder River Coal Co.	North Antelope (surface)	148	11,761,704	149	14,147,809		2,386,105	20.29	
Powder River Coal Co.	Rochelle (surface)	215	21,184,217	232	22,677,048		1,492,831	7.05	
SMC Mining Co.	North Rochelle (surface)	2	21,775	1	220,909		199,134	914.51	
Thunder Basin Coal Co.	Black Thunder (surface)	493	34,320,470	458	31,616,222		-2,704,248	-7.88	
	Coal Creek (surface)	7	110,488	59	2,532,889		2,422,401	2192.46	
Triton Coal Co.	Buckskin (surface)	138	11,180,379	140	10,955,839		-224,540	-2.01	
Wyodak Resources	Wyodak (surface)	55	3,027,356	52	2,795,942		-231,414	-7.64	
TOTAL		3,109	192,220,758	3,143	216,974,488		24,753,731	12.88	
HANNA COAL FIELD									
Arch of Wyoming	Medicine Bow (surface)	93	2,614,424	76	1,838,300		-776,124	-29.69	
Arch of Wyoming	Seminole No.2 (surface)	5	0	4	Reclamation 0		0	0.00	
Cyprus Shoshone Coal Co.	Shoshone #1 (deep)	179	1,590,696	185	2,543,441		952,745	59.89	
Rosebud Coal Sales Co.	Rosebud (surface)	17	0	17	Reclamation 0		0	0.00	
TOTAL		294	4,205,120	282	4,381,741		176,621	4.20	

Table 7. (continued).

Company	Mine Name	1993			1994			Production Difference 1994-1993	Percentage Increase/Decrease
		Employees	Production(tons)	Employees	Production(tons)	Employees	Production(tons)		
BIGHORN COAL FIELD									
Northwestern Resources	Grass Creek	(surface)	14	41,566	4	5,564	-36,002	0.00	
TOTAL			14	41,566	4	5,564	-36,002	0.00	
HAMS FORK COAL FIELD									
FMC Wyoming Corp.	Skull Point	(surface)	96	803,449	84	670,934	-132,515	-16.49	
Pittsburg & Midway	Kemmerer	(surface)	328	3,261,818	307	3,619,259	357,441	10.96	
TOTAL			422	4,065,267	391	4,290,193	224,926	5.53	
GREEN RIVER COAL FIELD									
Arch of Wyoming	Pilot Butte	(deep)	49	205,579	3	0	-205,579	-100.00	
Black Butte Coal Co.	Black Butte	(surface)	421	2,569,713	274	4,029,060	-1,459,347	56.79	
Bridger Coal Co.	Jim Bridger	(surface)	395	6,417,662	392	7,036,084	618,422	9.64	
Cougar Coal Co.	Swanson	(deep)	62	200,460	82	190,936	-9,524	-4.75	
TOTAL			927	9,393,414	751	11,256,080	1,862,666	19.83	
TOTAL UNDERGROUND									
			290	1,996,735	270	2,734,377	737,642	36.94%	
TOTAL SURFACE									
			4,476	207,929,390	4,301	234,173,690	26,244,300	12.62%	
GRAND TOTAL									
			4,766	209,926,125	4,571	236,908,067	26,981,942	12.85%	

Source: Annual reports of the Wyoming State Inspector of Mines, 1993 and 1994.

Table 8 . Permitted capacity of coal mines in Wyoming and their 1994 production.

Parent Company	Mining Operator	Mine Name	Tonnage ¹	Permitted Capacity ²
Kennecott Minerals	Kennecott Energy	Antelope	8,258,590	12.00 ³
Cyprus-AMAX	Cyprus-AMAX Coal West	Belle Ayr	18,361,866	25.00
Kiewit Mining Group	Big Horn Coal Co.	Big Horn	100,733	4.60
Kiewit Mining Group	Black Butte Coal Co.	Black Butte	4,029,060	9.50 ⁴
ARCO	Thunder Basin Coal Co.	Black Thunder	31,616,222	44.00
Zeigler Coal Co.	Triton Coal Co. (SMC Mining Co.)	Buckskin	10,955,839	24.00
Peabody Holding Co.	Powder River Coal Co.	Caballo	14,428,600	24.00
Drummond, Inc.	Caballo Rojo, Inc.	Caballo Rojo	16,611,485	30.00
ARCO	Thunder Basin Coal Co.	Coal Creek	2,532,889	18.00
Kerr-McGee Corp.	Kerr-McGee Coal Corp.	Clovis Point	202,202	4.00
Kennecott Minerals	Kennecott Energy	Cordero	16,413,646	24.00
Pacific Power and Light	Glenrock Coal Co.	Dave Johnston	3,159,725	4.00
Phillips/Western Fuels	Dry Fork Coal Co.	Dry Fork	3,836,228	15.00
Cyprus-AMAX	Cyprus-AMAX Coal West	Eagle Butte	17,161,000	29.60 ⁵
Fort Union Ltd. Partnership	Fort Union Coal Co.	Fort Union	84,122	9.40
Entech Inc. (Montana Power)	Northwestern Resources (Western Energy Co.)	Grass Creek	5,564	0.35
Kerr-McGee Corp.	Kerr-McGee Coal Corp.	Jacobs Ranch	20,550,847	25.00
PacifiCorp/Idaho Power	Bridger Coal Co. (Glenrock Coal)	Jim Bridger	7,036,084	7.90
Chevron Corp.	Pittsburg & Midway Coal Mining	Kemmerer	3,619,259	4.20
Arch Minerals	Arch of Wyoming, Inc.	Medicine Bow	1,838,300	4.00
Peabody Holding Co.	Powder River Coal Co.	North Antelope	14,147,809	20.00 ⁶
Zeigler Coal Co.	Triton Coal Co. (SMC Mining Co.)	North Rochelle	220,909	8.00
Arch Minerals	Arch of Wyoming, Inc.	Pilot Butte	0	2.00 ⁷
Peabody Holding Co.	Powder River Coal Co.	Rawhide	12,858,787	24.00
Peabody Holding Co.	Powder River Coal Co.	Rochelle	22,677,048	30.00 ⁸
Entech Inc. (Montana Power)	Northwestern Resources (Western Energy Co.)	Rocky Butte	0	16.00 ⁹
Cyprus-AMAX, Inc.	Cyprus-Shoshone Coal Co. (Cyprus-AMAX Coal West)	Shoshone #1	2,543,441	3.50
FMC Corporation	FMC Wyoming Corp.	Skull Point	670,934	1.50
Cougar Coal Co.	Cougar Coal Co.	Swanson	190,936	0.25
Black Hills Corp.	Wyodak Resources	Wyodak	2,795,942	10.00 ¹⁰
Total			236,908,067	433.80 ¹¹

Compiled by Wyoming State Geological Survey, Coal Section, May 1995.

¹Tonnage from State Mine Inspector's office, Box 1094, Rock Springs, WY, 82902.

²Tonnage in millions of tons/year (MMTPY) from Department of Environmental Quality, Division of Air Quality.

³Permitted for 8.5 MMTPY through 2003; 12.0 MMTPY for 2004 and beyond.

⁴Tonnage and capacity figures include Black Butte and Leucite Hills mines.

⁵Permitted for 17.2 to 29.6 MMTPY in various years of the mine's life.

⁶Current Expansion Application (as of 3/14/94) - 16 MMTPY 1994, 18 MMTPY 1995 & 1996, 20 MMTPY 1997 on.

⁷Closed 7/10/93.

⁸Current Expansion Application (as of 3/14/94) - 26 MMTPY 1994, 28 MMTPY 1995, 30 MMTPY 1996 on.

⁹Not constructed yet, permitted for 8 MMTPY for first two years of life; 16 MMTPY each following year

¹⁰On a build up schedule to 10 MMTPY a year.

¹¹This tonnage is based on using the highest possible capacity figures as shown in the footnotes.

Table 9. Coal production from Wyoming (1984 to 1994) with forecast to 1998 (millions of tons).

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994 ¹	1995 ¹	1996 ¹	1997 ¹	1998 ¹
Campbell County	113.9	111.0	122.3	135.7	143.8	154.7	164.9	159.6	181.9	205.2	212.6	222.2	232.1	242.4
Converse County	3.6	4.8	5.1	5.7	6.1	7.9	8.2	8.5	10.2	11.7	12.1	12.7	13.2	13.8
Sheridan County	2.4	1.4	1.2	0.9	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Carbon County	3.3	1.5	2.2	4.1	4.3	4.5	4.7	4.1	4.4	4.4	4.6	4.8	5.0	5.2
Sweetwater County	13.2	12.9	11.8	12.2	12.0	11.9	11.4	12.6	9.2	11.2	11.6	12.1	12.7	13.2
Lincoln County	4.3	4.0	3.8	4.9	4.8	4.7	4.4	4.6	4.1	4.3	4.5	4.7	4.9	5.1
Hot Springs County	M	M	M	M	M	0.1	0.1	M	M	M	M	M	M	M
Total Wyoming	140.7	135.6	146.4	163.5	171.1	183.9	193.9	189.5	209.9	236.9	245.5	256.5	267.9	279.9
Annual Change	7.7%	-3.6%	8.0%	11.7%	4.6%	7.5%	5.4%	-2.3%	10.8%	12.9%	3.6%	4.5%	4.5%	4.5%
Low-priced coal ²	6%	7%	8%	10%	20%	25%	33%	35%	47%	54%	58%	60%	62%	65%

¹Forecast by the Wyoming State Geological Survey, January, 1995. ²Estimated percentage of total production that is sold on the spot market, through short-term contracts [less than one-year duration], or through renegotiated, longer-term contracts all at prices under \$5.00. M means minor tonnage (less than 0.1 million tons).

In related news, Union Pacific bought the remaining interest in Chicago Northwestern Railways. Union Pacific now has sole ownership of its rail line out of the southern Powder River Basin.

The February issue of the U.S. Bureau of Land Management's (BLM's) *Wyoming Issues* fact sheet listed three lease by applications (LBAs) pending in the Powder River Basin. BLM issued an Environmental Assessment (EA) on the Eagle Butte LBA in July, and a Decision Record in the Spring. As described above, this tract was leased in April of 1995. Public review of the EA for the Antelope LBA ends in October. The draft EA should be released in 1995 with a sale possible in 1996. The schedule for the North Roundup LBA is due in late 1995. BLM notes that an Environmental Impact Statement may be needed for this latter LBA.

Developments in western and southwestern Wyoming

The February issue of the BLM's *Wyoming Issues* fact sheet also shows that no schedule has been set for the LBA requested by the Carbon County Underground Coal Gasification Project. The test site for this project, however, began operation on April 6. This test is designed to provide data for a proposed 30-year, full-scale coal gasification project.

Early in the second quarter of 1995, Cyprus-Shoshone announced the layoff of 50 employees at their Shoshone No. 1 underground mine at Hanna. They cited a reduction in spot sales related to high utility stockpiles as well as a change in their competitiveness caused by deteriorating quality of their coal.

Sweetwater County officials seized the property and assets of Cougar Coal Co. in mid-March, to satisfy delinquent tax payments of over \$1.3 million. The delinquency accrued under previous ownership as Cougar Coal gained ownership just six weeks prior to the seizure. The Swanson underground coal mine outside of Rock Springs was the only producing mine affected by this action.

Contracts

Springfield (MO) City Utilities received numerous bids from its Fall 1994 solicitation for 600,000 tons of coal to be delivered to its Southwest plant. The bids received were:

- 1) Caballo Rojo - \$4.00/ton F.O.B.
- 2) Black Thunder - \$5.09/ton F.O.B.
- 3) Antelope - \$5.10/ton F.O.B.
- 4) Rochelle/North Antelope - \$5.13/ton F.O.B.

At present, a contract has not been issued.

Table 10 and Figure 15 depict contract activity during the first quarter of 1995.

Table 10. Activities involving coal producers in Wyoming during the first quarter of 1995¹.

Utility	Power Plant	Coal Mine/Region	Activity	Tonnage	Comments
1. Consumers Power	Campbell Karr/Wadcock	Powder River Basin coal Powder River Basin coal	So So	250,000 t 150,000 t	Second half delivery.
2. Kansas City Power and Light	LaCygne Station	Powder River Basin coal	So	4,000,000 t	Spot and contract coal.
3. Kansas City (KS) Board of Public Utilities	Kaw/Quindaro	Western subbituminous coal	So	565,000 t	>10,000-Btu coal needed.
4. Sikeston Board of Municipal Utilities	Sikeston	Powder River Basin or Hanna Basin coal	So	700,000 t	
5. Montana Power	Corette	North Antelope	T	100,000 t	
6. IES Industries	Sixth Street/ Burlington	Western Subbituminous	So	80,000-140,000 t	>9000-Btu; <2 lbs of SO ₂ /MMBtu; 2-inch max. coal size.
7. Missouri Public Service Board	Sibley	Rochelle	Sp	as needed	
8. San Antonio City Public Service Board	Deeley No. 1 and No. 2	Shoshone	T	undetermined	
9. Wisconsin Power and Light	Columbia No. 1 and No. 2 Columbia	Caballo and Rawhide Powder River Basin coal	C So So	2,600,000 t 1,000,000 t 2,000,000 t	
	Edgewater No. 3 and No. 4 Edgewater No. 5	North Antelope/Rochelle Black Thunder	C C	900,000 t 500,000 t	

¹Data obtained from: Coal Week, trade journals, periodicals, FERC database, and personal contacts.
N.D. =No other data available; C =Contract coal; T =Test burn; Sp =Spot coal; So =Solicitation; t =short ton; ty =short tons per year.



Figure 15. Coal marketing activities related to Wyoming in the first quarter of 1995 [Numbers correspond to those in Table 10; circled numbers denote more than one plant in an area].

Coalbed methane

According to an Environmental Assessment (EA) released by BLM, Martens and Peck's proposed Lighthouse coalbed methane project, should have minimal impact on the groundwater in the project area. The BLM will, however, require a hydrologic monitoring program to assess any effects that do occur.

INDUSTRIAL MINERALS AND URANIUM UPDATE

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Industrial minerals produced in Wyoming include bentonite, construction aggregate, feldspar (for decorative aggregate), granite (for decorative aggregate, decorative stone, and railroad ballast), gypsum (for cement and wall-board), industrial iron (used in cement), leonardite, limestone (for construction aggregate, cement, and for emissions control at power plants), marble (for decorative aggregate), scoria or clinker (baked and fused shale used for construction and decorative aggregate), siliceous shale (used in cement), sodium sulfate, and trona.

In the following discussions, the locations of most of the mines, quarries, plants, etc. are shown on Figure 16.

Aggregate (Construction)

Rissler-McMurry continues with plans to open a limestone aggregate quarry northeast of Alcova. In January, the company submitted an application for a small mining permit to the U.S. Bureau of Land Management.

Decorative stone

The production of cut and polished pieces of Wyoming Raven, a black granite (actually an amphibolite), and Fantastico (a multicolored gneiss) continues at Sunrise Stone's quarry in Albany County and its fabricating plant in Platte County. In early 1995, Sunrise acquired new polishing and engraving equipment and is now producing finished monuments.

Abbott Construction of Wheatland has begun production of black flagstone and moss rock from the Slate Creek area in southwestern Platte County. This stone is sold in the Colorado Front Range area.

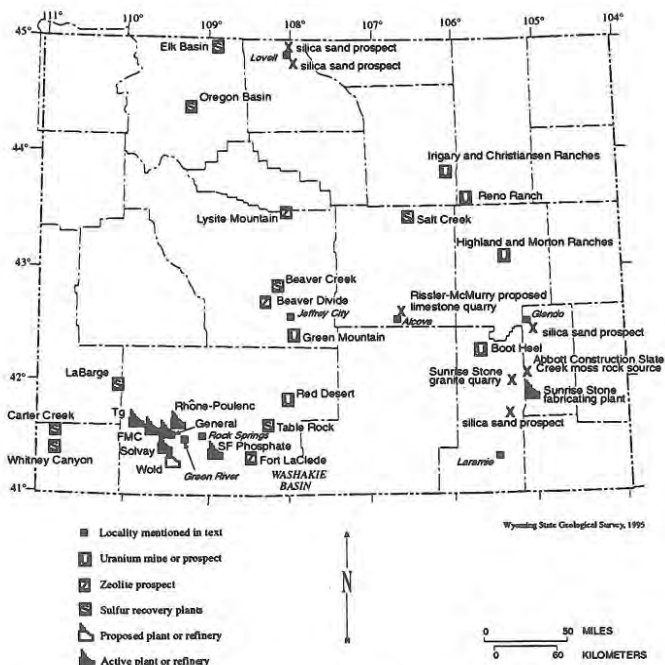


Figure 16. Industrial minerals and uranium activities in Wyoming during the first quarter of 1995.

Exploration for additional quarriable granite sites in Wyoming is continuing. Several companies, including Sunrise Stone, are looking for red granite. Because black and red granite and other colored varieties, such as green or blue shades, bring higher prices, they offer better opportunities for Wyoming producers. More common colors, such as grey and pink, are currently produced in Minnesota, South Dakota, Georgia, North Carolina, Texas, and central and eastern Canada, as well as on other continents. Because these colors of granite are relatively low priced, transportation costs make it harder for Wyoming producers to compete with producers who are closer to the major stone markets.

The Wyoming State Geological Survey has published a full-color brochure on the decorative stones of the Medicine Bow National Forest. This report, which is published as Public Information Circular 34, is available from the Wyoming State Geological Survey (see ordering information at the back of this issue). The report was funded by the U.S. Forest Service (USFS) through a grant from the USFS' Rural Development Program, which is designed to encourage small industries to develop resources on National Forest lands.

Phosphate

SF Phosphates, which operates a plant that manufactures a soil conditioner southeast of Rock Springs, was given approval by the Wyoming Department of Environmental Quality for its \$30 million expansion project. This expansion will double its sulfuric acid production capacity. SF Phosphates manufactures soil conditioners and sulfuric acid from sulfur purchased from the Carter Creek sulfur recovery plant (see also discussion of Sulfur) and phosphate, which is mined north of Vernal, Utah, and shipped to the plant by slurry pipeline. Construction of the expansion project is scheduled to begin in July, 1995.

This expansion is in response to a worldwide increase in the use of phosphate-based soil conditioners and fertilizers. While fertilizers add nutrients to the soil, soil conditioners change soil chemistry. U.S. consumption of agricultural phosphate increased over 10% between December 1993 and December 1994 (Mew, 1995).

Silica sand

In the first quarter, at least two companies were looking at silica sand deposits in Wyoming. Colorado Lien, Inc., thwarted in its efforts to develop a silica sand deposit near Fort Collins, Colorado, was continuing its exploration and sampling programs on silica sand prospects in Albany County. Another company was studying the feasibility of building a glass plant in Wyoming. The plant would need a source of silica sand among other raw materials, all of which occur in Wyoming along with soda ash from trona.

Sulfur

Wyoming ranks second in the nation in the amount of sulfur produced from the refining of natural gas (Table 11).

In the U.S., sulfur is produced by three methods. It is mined from underground deposits by injecting hot water into the deposit through wells and recovering melted sulfur through the wells (Frasch process). It is recovered from the refining of sour natural gas and petroleum, as in Wyoming (recovered sulfur). And recently, sulfuric acid has been recovered by capturing the emissions from the burning of high-sulfur coal.

World sulfur production and prices rose in 1994 for the first time since 1989. Sulfur prices (FOB Tampa, FL) increased from a 20-year low of \$50 per long ton in July, 1993, to about \$70.00 per long ton in January, 1995. Domestic sulfur production (all forms) increased 11% in 1994, over 1993. This increase is related to a worldwide increase in demand for agricultural fertilizers and soil conditioners as well as to a slight increase in the demand for industrial sulfuric acid (Foster, 1995).

Trona

Trona is mined in Wyoming at five locations west of Green River. It is also processed into soda ash and a variety of sodium-based products at refining plants at the mine sites. A sixth facility is under development.

Trona is a mineral composed of sodium carbonate, sodium bicarbonate, and water. Soda ash is refined sodium carbonate and is used primarily in the manufacture of glass. It is also used in products such as baking soda, toothpaste, and paper- and water-treating chemicals.

Table 11. 1993 Production of recovered sulfur from Wyoming¹.

Producer	Plant	County	1993 Production
Exxon Corp.	Shute Creek	Lincoln	427,833
Amoco Prod. Corp.	Whitney Canyon	Uinta	320,239
Chevron, USA	Carter Creek	Uinta	256,836
Amoco Prod. Corp.	Elk Basin	Park	21,514
Amoco Prod. Corp.	Beaver Creek	Fremont	8,363
Colorado Int. Gas	Table Rock	Sweetwater	4,915
Marathon Oil Co.	Oregon Basin	Park	1,765
Amoco Prod. Corp.	Salt Creek	Natrona	350
TOTAL			1,041,816

¹Wyoming Oil and Gas Conservation Commission, 1994

Ninety percent of U.S. soda ash is produced in Wyoming from mined trona; the remaining 10% is produced from surficial trona deposits in California. In the rest of the world, soda ash is produced synthetically by the more expensive Solvay process. Small amounts of soda ash are also produced from mined trona in Turkey.

The demand for Wyoming soda ash is increasing due primarily to increased exports. With the lowering of some trade barriers, soda ash derived from Wyoming trona is replacing soda ash produced by the Solvay process. The domestic consumption of soda ash; however, increased only slightly in 1994, primarily due to an increase in the production of automobiles, which require more window glass. There was also an increase in demand for soda ash used in high-density and low-phosphate detergents. These products use more soda ash than other varieties of detergents. The remaining domestic markets for soda ash remained flat in 1994 (Breunig, 1995).

In response to increased demand and prospects for continued increases in exports, several of the Wyoming manufacturers of soda ash are expanding their operations. In January, FMC announced plans to proceed with a \$45 million expansion project, designed to increase soda ash production by 25%.

The global importance of trona was emphasized once again in this first quarter of 1995. FMC announced that it was selling one-fifth of its interest to two Japanese companies. Once this sale is completed, all of the domestic soda ash producers will be at least partially foreign-owned. Countries with interest in Wyoming's trona mines and refineries are Australia, Belgium, France, Japan, and South Korea. Domestic companies own just under half of the total investments.

Wold Trona is continuing permitting work related to its plans for the construction of a sixth trona mine and refining plant. The construction of access roads began in the first quarter of 1995. Wold plans to produce a product called "refined trona".

Natrona Resources, a Colorado company, announced plans to construct a sodium carbonate refining plant in northwestern Colorado. This plant would produce its sodium product from nahcolite, another sodium evaporite mineral similar to trona. If constructed, this plant is not expected to significantly impact trona operations in Wyoming.

Production of trona ceased for about two weeks at the Solvay mine and plant after a February 3rd roof collapse. One miner died before rescuers got him out of the mine. The cause of the collapse is still under investigation. During the shutdown, experts examined the rest of the mine for damage and restored ventilation and other supply systems damaged by the roof fall. Mining was resumed February 14, and full production was restored by the end of February.

Zeolites

Zeolite is the name for a group of chemical compounds that have a wide variety of uses, from kitty litter to petroleum refining. Natural zeolites are a development opportunity in the State of Wyoming, with a potential similar to that which occurred in the trona industry since the 1950s. In this case, zeolites, like trona, occur naturally in Wyoming and may be mined and processed less expensively than synthetic substitutes.

Natural zeolite minerals and synthetic zeolites are aluminosilicate compounds that have a porous structure that permits small molecules and ions to enter and leave the zeolite. The molecules and ions that enter can be adsorbed into the zeolite, and under proper conditions, some can leave the zeolite through desorption. Zeolites' porous structure and adsorption and desorption properties give rise to the descriptive term "molecular sieve". These properties give economic value to zeolites.

Because of these properties, natural zeolites can remove selected molecules and ions from the environment. Zeolites are already used in many applications, as shown in **Table 12**.

Small amounts of natural zeolites are apparently mined in Arizona, California, Idaho, Nevada, New Mexico, Oregon, and Texas (Virta, 1994). Over the past five years, U.S. zeolite production has increased from an estimated 13,000 short tons to 45,197 short tons (Virta, 1994).

Increased demand for natural zeolites in the U.S. has been for use in sewage treatment, isolation of heavy metal and radioactive elements, and as a filler and whitening agent in paper. The gas purification properties of natural zeolites might have application in coal gasification by providing an oxygen-enriched combustion gas, and then for cleaning the resultant gas. Zeolites might also have a use in cleaning coalbed methane before it is introduced into natural gas pipelines.

In 1994, at least two companies interested in zeolites studied surface outcrops in Wyoming and took samples for testing. The zeolite deposits in the Washakie Basin southeast of Rock Springs received the most interest. Unfortunately developmental work and investment interest in these deposits is thwarted by an existing oil shale withdrawal, which prevents filing of any zeolite claims.

The most promising occurrence is the Fort LaCledde prospect. This prospect is located about 2 miles southeast of historic Fort LaCledde. At this location, the robin's egg blue tuff bed in the Adobe Town Member of the Eocene Washakie Formation contains 65 to 90% clinoptilolite and is several tens of feet thick. Other minerals include quartz, feldspar, mica, calcite, and trace amounts of the

Table 12. Uses of natural zeolites (after Mumpton, 1978; Flanigen, 1980; Minato, 1988; Tsitsishvili, 1988; and Holmes, 1994)

Application	Status
Gas purification	
oxygen separation	used in Japan
nitrogen separation	used in Japan
natural gas purification (acid resistant CO ₂ , SO ₂ , H ₂ O, H ₂ S removal)	used in U.S. and Europe
Pollution abatement	
ammonia removal	used in Japan and U.S.
pet litter	used in U.S.
non-phosphate detergent	used in Japan and Europe
radioactive element isolation	experimental use worldwide
heavy metal scavenging	experimental use worldwide
water softening	experimental use in U.S.
water filtering	experimental use in Europe
flue-stack gas clean-up (SO ₂ , nitrous oxides, hydrocarbons)	experimental use in Japan and Europe
oil spill clean-up	potential use
Agricultural products, including aquaculture	
soil conditioner	number 1 use in Japan
dietary supplement	used worldwide
ammonia abatement	used worldwide
fertilizer enhancer	used in Japan and Europe
fungicide, pesticide and herbicide carrier	experimental use in Japan and Europe
Desiccant and decaking agent	minor use worldwide
Dimension stone	Europe, especially Italy, Germany, Hungary, and Bulgaria; and in Oregon
Filler and extender	
paper	used in Japan, Hungary, U.S., and Canada
rubber	experimental use in Europe
polymers	experimental use in Europe
paint	potential use
Coal gasification	experimental use in U.S.
Construction materials	
dimension stone	used worldwide, but uncommon
pozzolan (high-silica cement)	used in Europe
lightweight aggregate	experimental use in Europe
Energy storage	
methane storage in a solid	experimental
hydration-dehydration of zeolite	experimental
Catalysis	experimental
Feedstock for synthetic zeolite production	experimental
Lightweight aggregate	experimental, especially in Bulgaria

zeolite, erionite (Rocky Mountain Energy, written communication, 1983). A few zones contain some unspecified clay. An exploration program by Rocky Mountain Energy (now Union Pacific Resources) outlined an area of clinoptilolite reserves. Tests of the material were also made to determine the cation exchange capacity of the clinoptilolite, its mineralogy, and expected mining costs and market potential (Rocky Mountain Energy, personal communication, 1986).

The zeolite minerals, erionite and mordenite, are the subject of current research by the U.S. Geological Survey due to a perceived health hazard resulting from their length to circumference ratios (aspect ratios) (R.L. Sheppard, personal communication, 1995). Previous research has shown that their aspect ratios are usually like cleavage fragments of amphiboles. They are therefore not asbestosform. Only wooly erionite, known at only one site in Nevada, has an aspect ratio similar to asbestos (Shedd and others, 1982).

In January, U.S. Zeolite, the owner of the Fort LaCledde occurrence in the Washakie Basin, put the property up for sale. Other potentially commercial zeolite deposits are located in the Beaver Divide area of Fremont County and on Lysite Mountain in Fremont and Hot Springs Counties.

Uranium

Solution mining of uranium in Wyoming continues at Comin's operations at the Irigary and Christiansen Ranch properties in Johnson County and at Power Resources operations at the Highland and Morton Ranch properties in Converse County. Other companies with uranium development operations in Wyoming include Kennecott Uranium, which continues to develop plans for an underground mine on Green Mountain, south of Jeffrey City in Fremont County; Energy Fuels Nuclear, which is investigating production from the Reno Ranch property in southwestern Campbell County; and CAMECO, which is investigating properties in the Red Desert area of Sweetwater County and the Boot Heel area of Albany County.

Internationally, uranium production in 1994 was down almost three percent from 1993, and represented the smallest production since 1957. Prices also declined. Canada remains the world leader in uranium mining, followed by Niger, Russia, Australia, Namibia, the U.S., South Africa, and Uzbekistan. World uranium consumption, which is almost exclusively for nuclear power, is expected to remain flat for the next five years (Pool, 1995).

Power Resource's Highland-Morton Ranch property in Wyoming leads the U.S. in in-situ uranium production; followed by Ferret Resources' Crow Butte mine in Nebraska; Comin's Irigary - Christiansen Ranch operation in Wyoming; the El Mesquite, Texas, in-situ mine; and very small amounts of uranium recovered from mine water at Ambrosia Lake in New Mexico. Uranium is also recovered from Florida phosphate ore processed in Louisiana. Wyoming led the nation in uranium production in 1994, followed by Louisiana, Nebraska, Texas, and New Mexico (Pool, 1995).

The Wyoming legislature continued the severance tax exemption for uranium produced in Wyoming. This bill extends the current exemption two more years. Should prices rise to historic levels, the severance tax would be resumed.

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METALS AND PRECIOUS STONES UPDATE

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Molybdenum and copper

With rising prices, molybdenum is attracting the interest of the mining industry. In just one year, the price of molybdenum increased 340% from under \$5/pound to over \$17/pound (Melman, 1995)! Molybdenum is a metal that is combined with iron in the manufacture of stainless steel. Recently, molybdenum stockpiles have been greatly depleted by increasing demand for the metal coupled with decreasing production.

And copper, which is often associated with molybdenum in many copper porphyry deposits in the western U.S., has risen to a high of \$1.40/pound. The price increases for both these metals has many companies scrambling to find reserves, and to reopen mines that have been closed for many years (Dillard, 1995).

As a result, the Wyoming State Geological Survey has received an increased number of inquiries for information on copper and molybdenum resources in the State. Wyoming has several attractive copper deposits, but the known molybdenum occurrences are relatively minor. The principal copper deposits of interest include several large-tonnage porphyry copper deposits in the Absaroka volcanic field of northwestern Wyoming. One of these, the Kirwin porphyry, was explored and drilled by AMAX in the 1960s, 70s, and 80s. Amax outlined geologic reserves totalling 196 million tons averaging 0.505% Cu and 0.022% MoS₂ with by-product silver and gold. This and other deposits are reviewed in a recent 197-page report available from the Wyoming State Geological Survey (Hausel, 1995).

Diamonds

Diamonds continued to dominate much of the exploration interest in the Colorado-Wyoming region. According to the Rocky Mountain News (3/27/95), Toronto-based Redaurum Ltd. expects to produce about 100,000 carats of diamonds per year from its Kelsey Lake kimberlite intrusives located primarily on the Colorado side of the Colorado-Wyoming State Line district, south of Laramie. To date, the property has produced 60% gemstones, up to 14.2 carats in weight. The company has scheduled the construction of a 250,000-tonne-per-year mill to be built a short distance south of the Wyoming border near U.S. Highway 287.

Royal Gold Inc. from Denver recently joined the diamond rush according to the Coloradoan (3/24/95). Royal Gold originally obtained a concession from Union Pacific Resources to follow-up several gold anomalies discovered by the

Wyoming State Geological Survey. The company decided to expand their exploration program to search for diamonds on Union Pacific's land in Colorado, Utah, and Wyoming. Previous work by the Wyoming State Geological Survey identified nearly 300 heavy mineral anomalies in the Laramie, Medicine Bow, and Seminoe Mountains that may be related to kimberlite intrusives. Additionally, in past years some kimberlites were identified on both State-owned and Union Pacific lands.

Gold

Based on the recommendation of the author, a gold prospector from the Black Hills recently explored a small portion of a drainage in the Lewiston mining district in the South Pass greenstone belt south of Lander. According to the individual, this turned out to be the richest placer he had ever prospected. In a short time, using a hobby dredge, he recovered nearly 27 ounces of gold with nuggets up to a half ounce.

Records suggest that historic production from the South Pass area included about 348,600 ounces of gold and more than 90 million tons of iron ore (Hausel, 1991).

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MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING

PETROLEUM

Remaining Technically Recoverable Resources (January 1, 1995)	
Discovered (Includes oil, gas liquids, and condensate)	3.69 billion barrels ¹
Undiscovered	6.18 billion barrels ¹
Total	9.87 billion barrels

Remaining Reserve Base (January 1, 1995)	
Measured reserves (Proved reserves) (Includes oil, gas liquids, and condensate)	1.05 billion barrels ²
Indicated and inferred reserves (Reserve growth in conventional fields)	2.64 billion barrels ¹
Total	3.69 billion barrels

NATURAL GAS

Remaining Technically Recoverable Resources (January 1, 1995)	
Discovered (Includes 36.2 trillion cubic feet (TCF) of methane ¹ and 121.8 TCF of CO ₂ ³)	158.0 trillion cubic feet
Undiscovered (Includes 15.72 TCF of conventional methane ¹ ; 5.43 TCF of coalbed methane; 119.3 TCF of methane in tight gas sands in the Green River Basin; and 31.2 TCF of CO ₂ ³)	171.6 trillion cubic feet
Total	329.6 trillion cubic feet
Remaining Reserve Base (January 1, 1995)	
Measured reserves (Proved reserves) (Includes 10.2 TCF of methane ² and 60.2 TCF of CO ₂ ³)	70.4 trillion cubic feet
Indicated and inferred reserves (Reserve growth in conventional fields)	26.0 trillion cubic feet
Total	96.4 trillion cubic feet

COAL

Remaining Resources (January 1, 1995)	
Identified and Hypothetical (Discovered)	1,427.8 billion tons ⁴
Speculative (Undiscovered)	31.5 billion tons ⁴
Total	1,459.3 billion tons
Remaining Reserve Base (January 1, 1995)	
Demonstrated strippable (Measured and indicated reserve base)	26.2 billion tons ⁵
Demonstrated underground-minable (Measured and indicated reserve base)	42.5 billion tons ⁵
Total	68.7 billion tons

TRONA

Original Resources (1990 estimate)	
Trona	81.0 billion tons ⁶
Mixed trona and halite	52.7 billion tons ⁶
Total	133.7 billion tons

URANIUM

Remaining Resource (December 31, 1989)	1.99 billion pounds U ₃ O ₈ ⁷
Remaining Reserve Base (December 31, 1989)	
Uranium oxide recoverable at \$30.00 per pound	66 million pounds ⁷

OIL SHALE

Original Resources (January 1, 1981)	
Identified (Discovered)	320 billion barrels of shale oil ⁸

¹ Modified from U.S. Geological Survey National Oil and Gas Resource Team, 1995, 1995 National Assessment of United States oil and gas resources: U.S. Geological Survey Circular 1118, 20 p.

² Modified from Energy Information Administration, 1994, U.S. crude oil, natural gas, and natural gas liquids reserves: 1993 Annual Report, 155 p.

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

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SUMMARY OF MINERAL EXPLORATION IN WYOMING - 1994

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METALS AND PRECIOUS STONES

Diamond, gold, and copper continued to dominate much of the exploration interest for metals and precious stones in Wyoming throughout 1994. Several companies conducted exploration programs for diamonds based on maps of kimberlitic indicator mineral anomalies identified by the Wyoming State Geological Survey (Hausel and others, 1988). Other companies used another report by the Wyoming State Geological Survey to locate exploration targets in Wyoming and elsewhere in the U.S. (Hausel, 1995a).

Exploration for diamonds continued in the Colorado-Wyoming kimberlite province with much of the activity centered in the Colorado-Wyoming State Line district, which is located 25 miles south of Laramie. To date, more than 112,000 diamonds have been produced from this district. The district hosts more than 35 kimberlite diatremes and dikes, nearly all of which are diamondiferous, yielding grades of 0.5 to 135.1 carats/100 tonnes.

According to a press release by Redaurum Red Lake Mines Limited of Toronto (7/24/93), bulk sample tests of kimberlite samples from the Kelsey Lake kimberlites immediately south of the Colorado-Wyoming border have been very encouraging. The recent tests yielded 268 diamonds larger than 2 mm from kimberlite and associated alluvium. Of these, 60% are gem quality and 25% weigh more than one carat. The two largest gemstones were 6.2 carats and 14.2 carats.

Exploration and diamond testing were also reported on the Sloan 1 and 2 kimberlites and the Chicken Park kimberlites in Colorado. These intrusives lie nearly 10 miles south of the Kelsey Lake kimberlites. On the Sloan diatremes, Royalstar drove a 725-foot adit with crosscuts into the Sloan 2 diatreme and processed a 3,000-tonne bulk sample. The sample yielded 9,034 diamonds of a combined total weight of 342.17 carats. The grade of the sample was 12.68 carats/100 tonnes. The largest diamond was a 5.51 carat gemstone. Previous testing of the Sloan 1 and 2 intrusives, in the early 1980s, yielded grades of 6.1 to 25.3 carats/100 tonnes.

Fleck Resources of Vancouver, Canada, currently holds the exploration rights on the Schaffer-Aultman kimberlite intrusives north of the Kelsey Lake

kimberlites, in Wyoming. In the early 1980s, preliminary tests yielded grades of 0.5 to 1.0 carat/100 tonnes with approximately 50% gemstones, the largest a 0.86 carat gemstone. An airborne IMPUT survey over the region in the early 1980s indicated the presence of several buried pipes along the northern edge of the area. None of these anomalies have been investigated.

Southeastern Wyoming has been receiving diamond exploration activity as a follow-up to studies by the Wyoming State Geological Survey (WSGS). The WSGS identified more than 300 kimberlitic heavy mineral anomalies in the Laramie, Medicine Bow, and Seminoe Mountains. Many of the anomalies are located in the Archean craton. Others were detected in the adjacent Proterozoic terrane.

In the Eagle Rock area in the Laramie Mountains, First Choice Industries from Canada followed up on a highly anomalous region identified by the WSGS. According to the Northern Miner (12/26/94), First Choice measured magnetic and resistivity anomalies in this vicinity. Four angle holes were drilled on the targets, but kimberlite was not intersected. The company plans to continue with detailed stream-sediment sampling on all drainages and topographic depressions in an attempt to find the source of the indicator minerals.

Farther north, in the Sybille Canyon area of the Laramie Mountains, a consulting geologist from Colorado reported the discovery of two kimberlite intrusives as a follow-up to the WSGS maps of heavy mineral anomalies. A few years ago, the WSGS identified dozens of kimberlitic heavy mineral anomalies and a nearby kimberlite blow in this region.

Kimberlitic heavy mineral anomalies have also been identified in the southern Green River Basin of southwestern Wyoming. Exploration was recently reported in the basin where chromian diopside and pyrope garnet grains up to 0.25 inch have been recovered from anthills and in roadcuts in the Bishop Conglomerate. The surface extent of these anomalies covers many square miles within the Archean craton. The source of the minerals is unknown.

Four companies obtained property positions in the Leucite Hills of the Green River Basin. The Leucite Hills encompass one of the largest lamproite fields in the world, and is similar to diamondiferous lamproites in Arkansas, Western Australia, and India. The WSGS processed a small bulk sample of olivine-bearing lamproitic agglomerate from Endlich Hill. Endlich Hill is one of 22 lamproite occurrences in the district. No diamonds were recovered.

Royal Gold explored a large silicified zone discovered by the Wyoming State Geological Survey (WSGS) on Quaking Asp Mountain, 10 miles south of Rock Springs (Hausel, 1994b). The silicified zone covers nearly 30 square miles, and continues to a minimum depth of 3,700 feet based on oil and gas drilling logs. The zone includes secondary kaolinite, alunite, travertine, free

sulfur, banded chert, and jasperoid. A seismic profile through Quaking Asp Mountain suggests the presence of a shallow intrusive.

Samples taken from the silicified zone by the WSGS showed enrichment in Ag, Cu, Zn, Pb, Mo, and As comparable to epithermal gold deposits reported elsewhere in the U.S. The Sb, Hg, and Au contents; however, are comparatively low. Gold was detected in 18 of 110 chip samples in very small amounts (trace to 0.110 ppm Au).

The WSGS also received dozens of inquiries about the Seminoe Mountains in central Wyoming. The Seminoe Mountains, which were recently investigated by the WSGS (Hausel, 1994a), form an Archean granite greenstone belt consisting of a refolded succession of metabasalt, amphibolite, peridotitic and basaltic komatiite, metapelite, and banded iron formation (BIF).

Altered BIF samples collected by the WSGS yielded anomalous gold (maximum of 1.36 opt Au) and silver (trace to 0.5 opt Ag), with one zinc anomaly (0.28% Zn). Amphibolites near the western edge of the district are moderately to pervasively propylitized. Vein samples in this altered zone ranged from <0.05 to 89.3 ppm Au, <1.0 to 55.0 ppm Ag, 0.03 to 3.75% Cu, 3.0 ppm to 0.39% Pb, and 22 ppm to 4.3% Zn. Altered wallrock samples yielded a maximum of 9.8 ppm Au, 12.0 ppm Ag, and 0.81 % Cu.

A Tertiary paleoplacer along the northern flank of the Seminoe Mountains also yielded some gold including several pyrope garnets and some chromian diopside. The source of these heavy minerals is probably from the western edge of the district.

In the Laramie Mountains, Compass Minerals Exploration USA/Australia, drilled the Copper King prospect in the Silver Crown district throughout 1994. The property was recommended by the WSGS as a low-grade, Proterozoic-age, Au-Cu porphyry target. Based on previous exploration efforts in the area, the Copper King is mineralized over a minimum 600 by 300 feet area with potential for expansion. A 35,000,000-ton ore body averaging 0.21% Cu and 0.022 opt Au was identified by earlier drilling. Later exploration in 1987, by Caledonia Resources Ltd. of Canada, established preliminary reserves including a small, higher-grade zone with 4.5 million tons averaging 0.044 opt Au. Spectrographic analyses also show traces of Pb, Zn, W, and 0.5 to 3.0% Ti.

In the South Pass greenstone belt in the Wind River Range of western Wyoming, Hol-Lac Gold Mines of Canada's recent drilling on the Carissa shear zone was encouraging (Northern Miner, 9/26/94). Hole 94-1, drilled to 667 feet, intersected three mineralized zones: one zone averaged 1.09 opt Au over 24 feet and included a 4-foot zone that averaged 5.27 opt Au. The two other zones averaged 0.09 opt Au over 6 feet and 0.02 opt Au over 13.8 feet. Hole 94-2 was drilled to a depth of 400 feet and intersected a 15-foot wide zone that averaged

0.05 opt Au. Hole 94-3 reached a depth of 604 feet and intersected two mineralized zones including a 9.5-foot zone that averaged 0.15 opt Au.

Ore reserve calculations in 1993 showed probable reserves of about 100,000 tons grading 0.368 opt Au in the existing mine workings. The 1994 program outlined additional gold mineralization both east and west of the mine and below the present workings (Northern Miner, 1/9/95). The Carissa shear zone was sampled by the WSGS prior to the work by Hol-Lac and a 100-foot-wide mineralized zone was detected and described by Hausel (1991). Elsewhere in the district, Echo Bay conducted reconnaissance exploration.

Several companies showed interest in the Rattlesnake Hills greenstone belt, 50 miles west of Casper. The Rattlesnake Hills belt consists of refolded Archean metamorphic rocks intruded by several Tertiary (42 Ma) alkalic plugs and dikes. The belt consists of metagreywacke, metagabbro, pillow metabasalt, minor ultramafic schist, banded iron formation (BIF), metapelite, and uncommon graphitic schist. One vein in the complex, the Lost Muffler vein, has a strike length of 1.5 miles. The vein consists of quartz, metachert, minor jasperoid, pyrite, and uncommon galena. Assays of vein material range from <0.2 to 2.0 ppm Ag, <5 ppb to 7.55 ppm Au, 38 ppm to 0.04% Cu, 11 ppm to 0.13% Pb, and <0.010 ppm to 0.021 ppm Hg.

In the vicinity of three Tertiary alkalic plugs - Goat Mountain, Sandy Mountain, and an unnamed plug in sections 23, 24, and 25, T32N, R88W, the metatholeiites and metagreywackes have been brecciated and are locally gossaniferous. Samples of the disrupted Precambrian rock collected by the WSGS along the flanks of the Tertiary plugs yielded <5 ppb to 925 ppb Au and 37 ppm to 0.14% Cu. Some samples yielded anomalous arsenic (25 ppm to 1.65% As) and some mercury (0.012 ppm to 0.078 ppm Hg). Breccia vein samples in the disrupted succession yielded 92 ppb to 367 ppb Au. Tertiary volcanics, which disrupted the metamorphics, are also anomalous. Composite chip samples of volcanic rock from the flank of Sandy Mountain yielded 44 ppb and 370 ppb Au.

Samples of BIF yielded <5 ppb to 5.0 ppm Au. Other BIF samples collected for whole rock analysis yielded 15.62% to 64.74% Fe₂O₃ with 23.13% to 79.12% SiO₂.

The Rattlesnake Hills supracrustals lie in contact with granite gneiss along the southwestern flank of the belt. Locally, the gneiss has been fractured and rehealed producing stockwork-like veinlets. A sample of the gneiss yielded 300 ppb Au.

Several companies recently expressed interest in copper in Wyoming. In response, the Wyoming State Geological Survey (WSGS) prepared a 197-page summary report on the metal (Hausel, 1995b). The report describes several

copper deposits in the State including the porphyry copper deposits in the Absaroka Mountains, northwestern Wyoming. The Absaroka Mountains represent a deeply dissected Tertiary volcanic plateau with several mineralized porphyries.

Of principal interest is the Kirwin porphyry southwest of Cody, Wyoming. This property was held by AMAX Exploration for nearly 30 years. According to company reports, AMAX outlined reserves totaling 196 million tons of ore averaging 0.505% Cu and 0.022% Mo at a 0.3% Cu cutoff grade with by-product credits in Au and Ag. A recent study by the company indicated the deposit was amenable to in-situ leaching at recovery costs of \$0.309 per pound of copper. The property was sold to the Mellon Foundation, which subsequently donated it to the U.S. Forest Service.

The WSGS continued evaluating the Encampment district in the Sierra Madre of southeastern Wyoming. Recent reconnaissance of the Puzzler Hill area showed that mineralization was hosted by an ultramafic massif. Mineralized samples from the massif yielded 0.01 to 4.43% Cu, 66 ppm to >2.0% Ni, 14 ppb to 9.86 ppm Au, <5 to 828 ppb Pt, 5 to 4,042 ppb Pd, and <0.1 to 6.6 ppm Ag.

INDUSTRIAL MINERALS

In 1994, exploration for industrial minerals centered on bentonite, construction aggregate, decorative aggregate and decorative stone, limestone, silica sand, and trona. Interest in zeolites continued, especially in the Washakie Basin in the southwestern part of the state, but the development of this resource is hampered by a Federal ban on locating claims in that area.

Most bentonite companies continued exploration for new producible deposits. A joint venture between E. T. Ventures and Wyo-Ben purchased the Lucerne mill and associated pits, and plan to start production in 1995. The Bentonite Corporation announced the opening of a previously closed plant near Lovell.

Exploration and sales of construction aggregate continued. Meridian Aggregates, west of Cheyenne, increased production of their granitic gneiss aggregate, used for railroad ballast and other construction aggregate products. Neosho Construction reopened the Bald Butte ballast quarry south of Lusk. At year's end, a ballast site near Wheatland was being drilled, and rocks near South Superior in western Wyoming and Fort Laramie in eastern Wyoming were being tested for suitability for ballast and other construction aggregate purposes.

Exploration for decorative aggregate and decorative stone increased again, as it has for the past three years. Sunrise Stone, which has produced a black

"granite" (actually an amphibolite) called "Wyoming Raven" since 1991, added a multicolored gneiss, called "Fantastico" to their production line. Sunrise Stone completed and began operating a fabricating plant 20 miles from its quarries. Canyon Creek Stone, formerly Mesa Marble of Powell, Wyoming, began the development of a brown marble and flagstone quarry southeast of Tensleep. Western Aggregates of Boulder, Colorado, produced flagstone from south of Douglas for use at Disney World near Orlando Florida, and quarried and sold black flagstone, white quartz, red moss rock, and several other types of stone. Most of these were marketed in the Colorado Front Range and in southern California. Gideon Stone Co., Ltd., continued exploration for red and black granites for Taiwan markets. Georgia Marble continued quarrying and processing white marble at its Wheatland plant. Wyoming Red Rock developed several decorative aggregate quarries in Wyoming, in green, pink, and white rock. Guernsey Stone, a division of Peter Kiewit, Inc., expanded its production of decorative aggregate and sold several tons of pink marble for landscaping and roofing material in Florida. Colorado Quarries operated a feldspar and quartz quarry on Casper Mountain, and explored for additional sources of colored feldspar in Wyoming.

Two companies conducted research and exploration programs for raw materials used in the manufacture of glass. These raw materials include silica sand, limestone, and feldspar, all of which are found in Wyoming. Because of the presence of these materials and Wyoming's production of soda ash, the Wyoming State Geological Survey is encouraging companies to consider the feasibility of glass production within the State. Low tax rates and energy costs, and innovative transportation methods have the potential to make glass production in Wyoming economically competitive with the rest of the U.S. Of particular interest were silica sand occurrences near Glendo, Laramie, and Lovell. At year's end, several companies were considering feasibility and planning studies.

All five companies that mine bedded trona from the Eocene Green River Formation were constructing or planning plant expansions and improvements. Each of these companies was also considering the proposed Federal trona lease sale, now scheduled for 1995 or 1996. Two other companies (U. S. Borax and Church & Dwight), which are not presently producing trona in Wyoming, have also expressed an interest in the leases. Wold Minerals continued permitting work related to their proposed trona mine and refinery.

There was considerable interest in Wyoming zeolite occurrences in 1994, and a couple companies studied surface occurrences and took samples for testing. The zeolite deposits receiving the most interest are located in the Washakie Basin southeast of Rock Springs, but developmental work and investment interest in these deposits is dampened by an existing oil shale withdrawal, which prevents the location of zeolite claims in that area. Development will apparently have to wait until this withdrawal issue is resolved.

URANIUM

Although there was no exploration for new uranium deposits in Wyoming in 1994, there were several company and property developments. COMIN, a subsidiary of COGEMA, increased production at the Irigary and Christiansen Ranch Properties. CAMECO acquired and explored property in the Red Desert and Shirley Basin areas of Wyoming. Energy Fuels Nuclear continued to consider the construction of an in-situ production facility at its Reno Ranch property. Kennecott Minerals proceeded with the development of the Jackpot underground uranium mine at Green Mountain south of Jeffrey City.

COAL

Coal production from the State of Wyoming rose from 209.9 million tons in 1993 to 236.9 million tons in 1994. This 12.9% increase is the highest annual percentage increase in the last decade.

Three Federal coal lease applications were still pending with the U.S. Bureau of Land Management (BLM) in 1994, all in the Powder River Basin. A fourth lease by application (LBA), the Indian Springs in-situ coal gasification project, was terminated by the applicant, Energy International, Inc. A New application was filed on the same tract near Rawlins by Carbon County UCG, Inc. Adjudication on this tract had not been completed by year's end.

Of the three LBAs pending in the Powder River Basin in 1994, only the Eagle Butte LBA has been completed. An Environmental Assessment (EA) was approved by the BLM in mid-1994. The BLM also signed a decision record in January of 1995, setting the competitive lease sale for April 5, 1995. This LBA added about 150 million tons to Eagle Butte's existing property when it was awarded in an early April sale. An EA for the Antelope LBA, filed by Kennecott in 1992, was started, but its completion is not expected until sometime later in 1995. This LBA will add 60 million tons to the Antelope property. The BLM anticipates needing an Environmental Impact Statement (EIS) for Shell Mining Company's North Roundup LBA. This LBA will add 140 million tons to the existing North Rochelle property.

The U.S. Forest Service granted Antelope Coal Company access to explore Forest Service lands north and west of Antelope's present mine boundaries. Antelope Coal drilled more than 40 coreholes in the Fall of 1994 in section 14 through 33 of T41N, R71W. Also the Wyoming State Geological Survey received several inquiries into a private land offering in the northern Powder River Basin in the Fall of 1994.

Coalbed methane activity is occurring in mainly two areas, the Hanna Basin and the Powder River Basin. In the Hanna Basin, Metfuels Inc. continues to develop their existing property just north of Hanna. Metfuels plans to drill more than 90 wells on 160-acre spacing over the next three years.

In the Powder River Basin, American Oil and Gas Corporation (AOG), a subsidiary of Martens and Peck Operating Company, is planning to drill more than 200 coalbed methane wells over a 115,200-acre area during the next five years. The drilling area, named the Lighthouse project, covers most of T44-46N, R71-73W and is just south of AOG's Marquis project. AOG also drilled five wells in 1994, developing the Marquis project in T47N, R72W. The main target was the thick Wyodak coal zone to the west of Kerr-McGee's Caballo Rojo property.

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GEOLOGIC MAPPING AND STRATIGRAPHY

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STATEMAP FUNDING CONTINUES

The Wyoming State Geological Survey was recently granted \$10,000 to support a second year of geologic field mapping in the Laramie Basin of Albany County (Figure 17). This was \$2,000 less than the previous year's grant. The Geologic Mapping Section applied for funding through the State Geologic Mapping Program (STATEMAP), which is administered by the U. S. Geological Survey (USGS). STATEMAP is a component of the National Geologic Mapping Act of 1992 in which States and the Federal government share equally in the cost of geologic mapping projects. The State must match each Federal dollar with a non-Federal dollar. For the 1995-1996 funding period, there was only \$1,057,000 available to State Geological Surveys for these kinds of proposals.

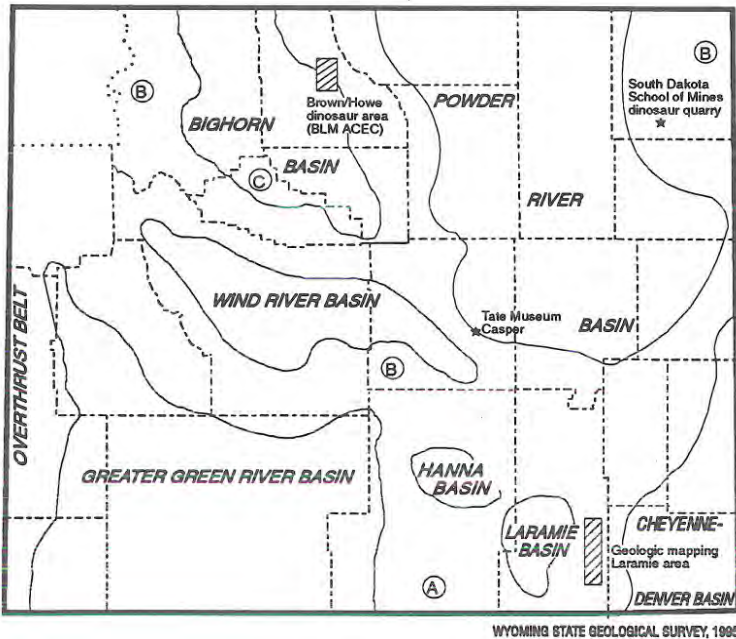


Figure 17. Index to selected geologic activities and recently released maps and reports on Wyoming geology.

The Laramie and Red Buttes Quadrangles (1:24,000-scale) were mapped during the 1994 field season with funds from STATEMAP. Mapping of these quadrangles revealed new structural interpretations which will greatly aid in the location of new water well sites, as many of the water wells around Laramie are tied into the structural geology, specifically the location of faults. In addition the Cenozoic, Mesozoic, and Paleozoic deposits have been more accurately defined and previously unmapped Tertiary deposits have been identified. Field mapping on the Howell Quadrangle will begin in June of 1995. These new maps along with existing mapping will be compiled at the 1:100,000-scale to produce a color version of the Laramie 30' X 60' geologic map. As they are completed, the 1:24,000-scale quadrangles will be released as part of a new Preliminary Geologic Map series. The Laramie and Red Buttes maps are currently being drafted and should be available in May of this year.

Very little in the way of published geologic mapping exists for much of the area included in the Laramie (1:100,000-scale) Quadrangle, and the city of Laramie is the only larger city in Wyoming without a published larger scale geologic map to cover it. Accurate new geologic information enhances the chances of finding good water well sites in the area, aids in the location of needed sand, gravel, limestone, and other construction materials, and helps in land use planning.

UPDATED BIBLIOGRAPHY AND INDEX PUBLISHED

The Wyoming State Geological Survey recently released an updated and revised bibliography and index of theses and dissertations of the University of Wyoming's Department of Geology and Geophysics. This publication updates and revises earlier editions published in 1985 and 1989. There are a total of 784 entries in this updated version, listing theses and dissertations relating to the geology of Wyoming. Each entry includes the author, date, and title of the thesis or dissertation. Entries range from D.C. Abrams' graduate geology thesis completed in 1897 to theses and dissertations completed in 1994. Abrams' thesis described a study of ilmenite beds in southeastern Wyoming. A subject index based on the titles of the theses and dissertations is included in the back of the publication.

This publication, entitled, Bibliography and index of graduate theses and dissertations of the Department of Geology and Geophysics, University of Wyoming, was compiled by Cynthia Boyd and Alan J. Ver Ploeg. The report is available as Information Pamphlet 3 from the Wyoming State Geological Survey. In addition, the Survey previously published a series of index maps for Wyoming that show the location of geologic maps included in University of Wyoming theses and dissertations. These index maps are only updated through 1989.

RECENT PALEONTOLOGICAL DEVELOPMENTS IN WYOMING

Scientists working in the Sundance area (Figure 17) recently found fossilized jaws from three small rodent-like creatures dating back to the age of dinosaurs. James Martin, curator of vertebrate fossils for the Museum of Geology at South Dakota School of Mines and Technology, and John Foster, a doctoral candidate at the University of Colorado, found these relatively rare Jurassic mammal fossils on land administered by the State of Wyoming, west of the town of Sundance. These mammals lived over 150 million years ago and represent some of the oldest mammals found in North America and certainly the oldest documented in the Black Hills area. Some older mammals have been found in Texas, dating back 225 million years. Martin and Foster originally opened this quarry along I-90 in 1991 to remove dinosaur remains found in a Jurassic stream channel. They have removed numerous fossils including plants, clams, turtles, fish, crocodilians, and several meat- and plant-eating dinosaurs. They plan to continue working the quarry for several years, as it has been a rich source of paleontological information.

Robert Bakker, an adjunct curator of the Tate Museum in Casper (Figure 17), recently announced a pledge of \$100,000 to the museum, to aid in turning it into a regional fossil preparation and research center. He will provide these funds from royalties on his next book, *Raptor Red*. He also stated that he would match future donations up to an additional \$100,000. Bakker's pledges are part of a fund raising drive recently begun by the Tate Museum, which has set a goal of raising \$330,000 over the next five years. The funds raised by this effort will go toward staff salaries and supplies and equipment for collecting and preparing specimens that will be returned to the communities where they were found. The museum is currently preparing a *Triceratops* skeleton found near Glenrock, which will be returned to the town when completed.

A 5,457-acre area of Federal lands located north of Shell was recently designated as an Area of Critical Environmental Concern (ACEC) by the Bureau of Land Management (BLM) (Figure 17). This designation will protect the paleontologic resources that the area is so famous for. The ACEC designation will not, however, affect any mining claims filed under the 1872 Mining Law. The area was proposed for this designation over six months ago (*Wyoming Geo-notes No. 44*, page 46). Under this designation, the BLM can enforce stricter management controls on the area, which includes the site of the famous "Big Al" dinosaur find, a nearly complete *Allosaurus* found in 1991. This area, referred to as the Brown-Howe Dinosaur Area, has been the scene of many significant dinosaur finds dating back to the 1930s and as recent as 1993 (*Wyoming Geo-notes No. 41*, p. 45-46). The ACEC will be patrolled regularly; travel can only take place on designated roads within the ACEC; collection and removal of specimens can only occur under a permit issued by the BLM State Director; and regulated grazing on the area is only allowed as long as the scientific value of the area is not disturbed.

NEW MAPS AND CHARTS ON THE GEOLOGY OF WYOMING

The U.S. Geological Survey recently released two new maps and a stratigraphic cross section relating to the geology of Wyoming. Houston and Graff (1995) completed a new color geologic map (1:50,000-scale) of Precambrian rocks in the Sierra Madre mountains of Wyoming and Colorado. This map details the general geology and portrays the structural geology of the southern Sierra Madre. Luedke (1994) presents an overview of Cenozoic volcanic centers in Idaho, Montana, South Dakota, and Wyoming with his new 1:1,000,000-scale map. Latest age date information is also included for these volcanic centers. Roberts and Bossiroy (1995) outline the stratigraphy and coal geology of the Fort Union Formation in the Grass Creek area of the Bighorn Basin. The authors use a cross section and stratigraphic columns to describe the stratigraphy of this significant coal horizon.

Each of these publications is listed below and the study area is located on the accompanying index map (Figure 17).

- A. Houston, R.S., and Graff, P.J., 1995, Geologic map of Precambrian rocks of the Sierra Madre, Carbon County, Wyoming, and Jackson and Routt Counties, Colorado: U.S. Geological Survey Miscellaneous Investigation Series Map I-2452, scale 1:50,000.
 - B. Lueke, R.G., 1994, Map showing distribution, composition, and age of early and middle Cenozoic volcanic centers in Idaho, Montana, west-central South Dakota, and Wyoming: U.S. Geological Survey Miscellaneous Investigations Series Map I-2291-C, scale 1:1,000,000.
 - C. Roberts, S.B., and Bossiroy, Dominique, 1995, Stratigraphy and coal geology of the lower part of the Fort Union Formation in the Grass Creek coal mine area, southwestern Bighorn Basin, Wyoming: U.S. Geological Survey Coal Investigations Map C-146, scale: 1 inch equals 40 feet.
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SEISMIC NETWORKS IN WYOMING

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Seismic networks are composed of a series of seismometers that are strategically placed to provide data that seismologists use to determine the magnitudes, locations, durations, and depths of earthquakes in an area of interest. There are many seismic networks in the U.S. Most are local in extent, and are designed to provide detailed information on small to moderate earth-

quakes. In Wyoming, the University of Utah Seismograph Stations operates a network in Yellowstone National Park, the U.S. Bureau of Reclamation operates a network in the Jackson Lake area, and the U.S. Geological Survey cooperates with the U.S. Air Force on the operation of a network near Boulder, Wyoming (Figure 18).

The seismic networks in place in Yellowstone National Park and in the Jackson Lake region are considered local networks. Local networks are usually composed of a dense array of short-period, vertical, high-gain seismometers. Short-period seismometers generally are operated at high magnifications to detect very small local events, but the waveform signals are clipped or truncated on larger events, resulting in lost data. The instruments, however, provide very accurate timing of first motions, which helps locate an earthquake. The duration of the signals are used to estimate the magnitude of an event. A well-distributed local network of short-period instruments can provide data to locate rather precisely all magnitude 1.0 or larger events in the vicinity of the network, and can provide data to locate smaller events with less precision.

The U.S. Geological Survey (USGS) has created and is expanding a National Seismograph Network (NSN). The national network is currently composed of 38 standard and cooperating digital stations scattered throughout the U.S. The standard stations are composed of highly reliable, real-time, three-

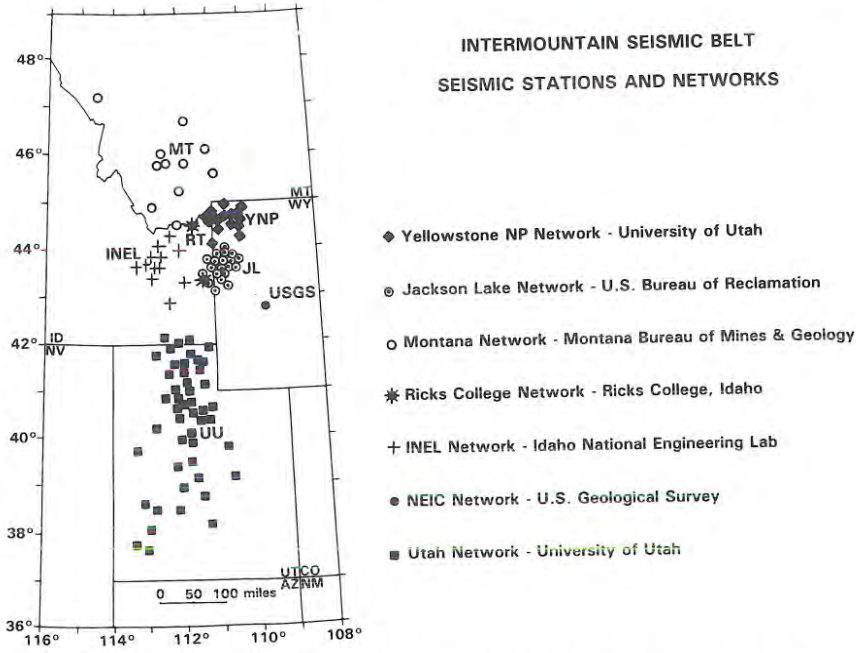


Figure 18. Permanent seismic stations and networks in the Intermountain Seismic Belt.

component, well calibrated, broadband seismometers. Cooperating stations, most of which are operated by universities, provide similar data using instrumentation from other manufacturers. The 24-bit dynamic range of a digital seismograph can record earthquakes with unclipped signals, at local, regional, and continental distances. Compared to short-period seismometers, the broadband stations supply more detail for earthquakes with magnitudes larger than 2.5. Seismologists can use the data supplied by these broadband instruments to generate rather precise waveform models, which are useful when trying to distinguish an underground explosion, rock burst, or a mine collapse from a tectonic event. As with a local network, greater locational accuracy of earthquakes is achieved by increasing the number of stations in the network. Existing NSN broadband stations that are in or near Wyoming are located at Boulder, Wyoming; Rapid City, South Dakota; Dugway, Utah; and Golden, Colorado. A NSN station has been proposed for Yellowstone National Park.

The USGS's National Earthquake Information Center in Golden, Colorado, currently determines earthquake locations and magnitudes using data from more than 100 broadband and short-period seismic stations throughout the country. Many of the short-period stations operate antiquated equipment. Upgrades or modifications are needed at these stations to increase their versatility.

The accuracy of earthquake locations (computed hypocenters) is generally a function of the density of seismic network stations. The velocity models that are used to analyze seismic data also affect the accuracy of the hypocenters. In general, existing local networks have a locational accuracy of ± 1.0 mile (U.S. Bureau of Reclamation, personal communication 1995). In many cases, especially when portable instruments are deployed, much greater accuracy is obtained from local networks. The USGS's existing network of broadband and short-period stations provides a locational accuracy that generally is better than ± 6 miles. As more NSN stations are installed, the locational accuracy of the USGS network should improve significantly. For example, if a NSN station is placed in southwestern Wyoming, regional hypocenter accuracies there should be better than ± 3 miles (U.S. Geological Survey, personal communication 1995).

SEISMIC NETWORK COSTS

There are often significant short-term and long-term cost differences between a local network and a National Seismic Network station. As expected, the size of the local network dictates the cost of the network. The Jackson Lake Network, operated by the U.S. Bureau of Reclamation, is composed of twenty short-period stations. The present day cost for a network of that size is approximately \$250,000 for equipment purchase, installation, and testing.

Approximate yearly costs for data analysis and equipment maintenance for a network of that size are in the \$80,000-\$100,000 range, depending upon personnel, transportation, and repair costs. Using the size of the Jackson Lake Network as a model, it would cost approximately \$12,500 to purchase, install, and test each short-band seismometer station, and approximately \$5,000 per year per station to analyze data and maintain the station. There will be additional costs for data transmission, with those costs dependent upon access to microwave transmitters and telephone lines. These cost estimates are based upon data supplied by the USGS, the U.S. Bureau of Mines, and the University of Utah.

A National Seismic Network broadband station costs considerably more than a typical short-band station. Based upon cost estimates provided by the USGS, it appears that the cost of equipment and installation of a NSN station is approximately \$60,000. Installation costs will increase approximately \$2,500 for each 1000-foot increment over which a power line is installed. Due to recent Federal budget cuts, the USGS requires \$50,000 in outside funds to install a NSN station. The USGS will absorb the station maintenance, data transfer, and data analysis costs for the station.

EARLY WARNING SYSTEMS

Seismic networks provide information on the magnitudes, locations, depths, and durations of earthquakes and are not truly early warning systems. Depending on the accuracy and sensitivity of a network, small earthquakes that may be precursors to a larger event can be detected although not all small earthquakes are precursors. If either an area or a specific fault system, such as the Teton fault, has been seismically inactive, and small scale earthquakes suddenly initiate, a high quality seismic network can help ensure that such events are detected. While the significance of such events may not be known, any abrupt and/or prolonged increase in seismic activity should not be ignored.

Recent seismic events in the trona patch of southwestern Wyoming have raised the question of whether or not a dense local seismic network could serve as an early warning system for future incidents. The answer is no. If there were small magnitude seismic triggers to the recent roof collapses in the trona mines, a local network probably would have detected them. In fact, a single National Seismic Network station in the vicinity of the mines most likely would have detected any small magnitude seismic triggers. The latter kind of station would also be very useful in separating tectonically induced seismic events from mine-related events.

THE FUTURE OF SEISMIC NETWORKS AND STATIONS IN WYOMING

There is a need for more seismic networks and stations in Wyoming. Existing networks also must be maintained. There is also a continuing possibility that the seismic network operated by the U.S. Bureau of Reclamation in the Jackson Hole area will be downsized. Past efforts by citizens in Wyoming have been effective in saving the Jackson Lake Network, but continuing efforts are needed. Letters of concern addressed to Wyoming's Congressional delegation in Washington D.C. may have the most effect in regards to saving the Jackson Lake Network.

Citizens and industries in southwestern Wyoming could benefit from an NSN station in that part of the State. Many industries as well as other entities in southwestern Wyoming have already been contacted about the possibility of forming a funding partnership to support the acquisition and installation of a NSN station in the vicinity of the trona mines. If such a station is installed, the USGS has agreed to do all data interpretation.

An NSN station is needed in the Star Valley (Wyoming) to Draney Peak (Idaho) area. The magnitude 5.9 earthquake in that area in 1994 led to thousands of aftershocks, most of which were detected by portable seismometers set up in the area by the University of Utah Seismograph Stations. Those portable seismometers will be removed on May 7, 1995, due to budget cuts at the USGS. Local funding sources will be sought for an NSN station in the area.

Additional network expansions and NSN stations will also benefit Wyoming's citizenry, but the above two stations are a priority. For a more complete discussion on seismic network needs and possible funding sources, contact Jim Case, Head of the Geologic Hazards Section at (307) 766-2286.

ROCKHOUND'S CORNER

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The Seminoe Mountains, located north of Sinclair in central Wyoming, contain several interesting lapidary materials and gold and copper deposits that make the area exciting for rockhounding. The area is dominated by metamorphic rocks intruded by granites. The flanks of the mountain range are overlain by sedimentary rocks that form a spectacular, steeply dipping precipice along the southern flank of the range. Two roads lead into the Bradley Peak area of the Seminoe Mountains. One road along the southern edge of the range is

maintained by the Miller Estate Company from Rawlins, and requires permission to use. The road on the north flank, however, is a U.S. Bureau of Land Management road.

Some of the more attractive lapidary rock found in the district is the banded tawny and brown jasperized iron formation. Samples of this rock are commonly found as float along Deweese Creek north of Bradley Peak. These rocks have a general appearance of petrified wood.

Leopard rock, a porphyritic diabase containing large, rounded, white, feldspar crystals in a black fine-grained groundmass, produces striking paper weights and book ends, when polished. Outcrops of this material occurs on a ridge adjacent to Wood Creek north of Bradley Peak.

Nephrite jade is also reported in the Seminoe Mountains. The Bishop's jade locality is in serpentinite and reportedly occurs as actinoliferous amphibolite dikes in nephrite-like dikes on the northern flank of the range. The rocks are cut by quartz veins with small mafic inclusions (up to 2 cm) with patches of nephrite jade.

Another jade occurrence, the Sage Creek nephrite, is found in the granite outlier to the north of the Bishop jade. It consists of a pod-like mass of olive-green nephrite in association with quartz in a quartz diorite dike.

Serpentinites in the Bradley Peak area also make attractive paperweights and book ends. The serpentinites on the southeastern flank of Bradley Peak contain some pods of yellow-green serpentine that produces an attractive lapidary stone. Other interesting serpentinites include spinifex komatiites found along the northern flank of the range near the mouth of Sunday Morning Creek. The textures seen in these rocks represent quench textures produced when hot ultramafic magma contacted sea water more than 2.5 billion years ago. The term 'spinifex' is derived from a spiny grass known as spinifex, which is found in the vicinity of the Komati River in southern Africa where komatiite was initially described. The textures consist of radiating prisms of tremolite or serpentine in a groundmass of fine-grained granular chlorite, talc, or fine-grained amphibole.

Bookends have also been produced from some greenish quartzite formed of recrystallized quartz, minor plagioclase, chlorite, and fuchsite mica found north of Bradley Peak. Some schists near the quartzite are highly foliated with kink bands, and locally include 'peanut schists'. These 'peanut schists' contain centimeter and smaller size, rounded, dark-grey to white, peanut-shaped porphyroblasts of cordierite in a matrix of quartz, biotite, and muscovite.

Some quartz vein samples collected around Bradley Peak contain pyrite, chalcopyrite, and visible gold. The best samples are found on the Deserted Treasure and King mine dumps along the northeastern flank of Bradley Peak. Gold has also been panned from dry placers along the northern flank of the range and in the vicinity of the Miracle Mile.

Copper specimens can be collected at the Sunday Morning prospect east of Bradley Peak. The Sunday Morning prospect has specimens of chrysocolla, malachite, and cuprite, in a fractured milky quartz. The Seminoe Mountains are an interesting area to visit and have been described in the following publications:

Hausel, W.D., and Jones, R.W., 1984, Self-guided tour of the geology of a portion of southeastern Wyoming: Wyoming State Geological Survey Public Information Circular 21, 31 p.

Blackstone, D.L., and Hausel, W.D., 1992, Field guide to the Seminoe Mountains: Wyoming State Geological Survey Reprint 48, 10 p.

Hausel, W.D., 1994, Economic geology of the Seminoe Mountains mining district, Carbon County, Wyoming: Wyoming State Geological Survey Report of Investigations 50, 31 p. (includes a detailed map of the area).

NEW PUBLICATIONS OF THE WYOMING STATE GEOLOGICAL SURVEY

Sixty-first Annual Report of the Wyoming State Geological Survey (for Fiscal Year 1994), by Gary B. Glass and Susanne G. Bruhnke: 1995.-free upon request.

*Bibliography and index of graduate theses and dissertations of the Department of Geology and Geophysics, University of Wyoming (revision and update of 1989 version), by C.S. Boyd and A.J. Ver Ploeg: Information Pamphlet 3, 1995.-\$2.00.

*Index to geologic mapping in Wyoming from out-of state theses, compiled by A.J. Ver Ploeg and C.M. Boyd: Map Series 9-S, 1995.-\$2.50 (xerox copies only).

Geologic map of the Monument Hill Quadrangle, Johnson and Washakie Counties, Wyoming, by A.J. Ver Ploeg and P.L. Greer: Map Series 44, 1995.-\$5.00.

Geologic map of the Beartrap Meadows Quadrangle, Johnson County, Wyoming, by A.J. Ver Ploeg and P.T. Greer: Map Series 45, 1995.-\$5.00.

Study of metals and precious stones in southern Wyoming, by W.D. Hausel: Open File Report 94-2, 1994.-\$10.00 (xerox copies only).

*Talc, including steatite, in Wyoming, by R.E. Harris: Open File Report 95-1, 1995.-\$3.00 (xerox copies only).

Decorative stones of the Medicine Bow National Forest, by R.E. Harris: Public Information Circular 34, 1994.-\$2.00.

Phosphate rock resources of the Wind River Indian Reservation, Wyoming, by R.P. Sheldon: Reprint 57, 1982.-\$5.00 (xerox copy only).

Evaluation of bentonite and gold resources on the Wind River Indian Reservation, Wyoming, by C.A. Roberts, J.B. Worthington, and L.G. Nonini: Reprint 58, 1983.-\$12.00 (xerox copy only).

Evaluation of coal resources on the Wind River Indian Reservation, Wyoming, by J. Gersic and E.K. Peterson: Reprint 59, 1983.-\$8.00 (xerox copy only).

Bentonite resources in the Winkleman Dome-Bighorn Ridge, Arapahoe Reservoir, and Blue Ridge areas on the Wind River Indian Reservation, Wyoming, by J. Gersic, and J.B. Worthington: Reprint 60, 1984.-\$10.00 (xerox copy only).

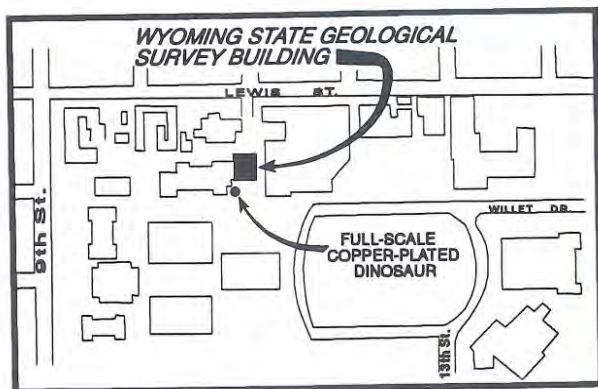
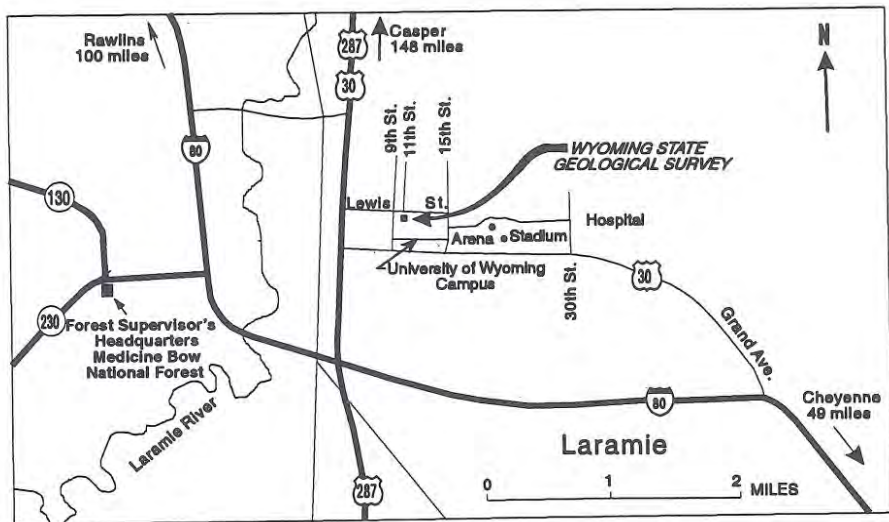
Sand/gravel, gypsum, and iron resources on the Wind River Indian Reservation, Wyoming, by J. Gersic and L.G. Nonini: Reprint 61, 1985.-\$12.00 (xerox copy only).

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

The Wyoming State Geological Survey sells the *Atlas of Major Rocky Mountain Gas Reservoirs*, a publication prepared by the New Mexico Bureau of Mines and Mineral Resources, the Colorado Geological Survey, the Utah Geological Survey, and the Wyoming State Geological Survey -\$99.75. Available over-the-counter or PREPAID, by mail from the Wyoming State Geological Survey in Laramie. Checks, for this publication only, should be made to: New Mexico Bureau of Mines and Mineral Resources or NMBMMR. (Price includes postage and handling.)

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