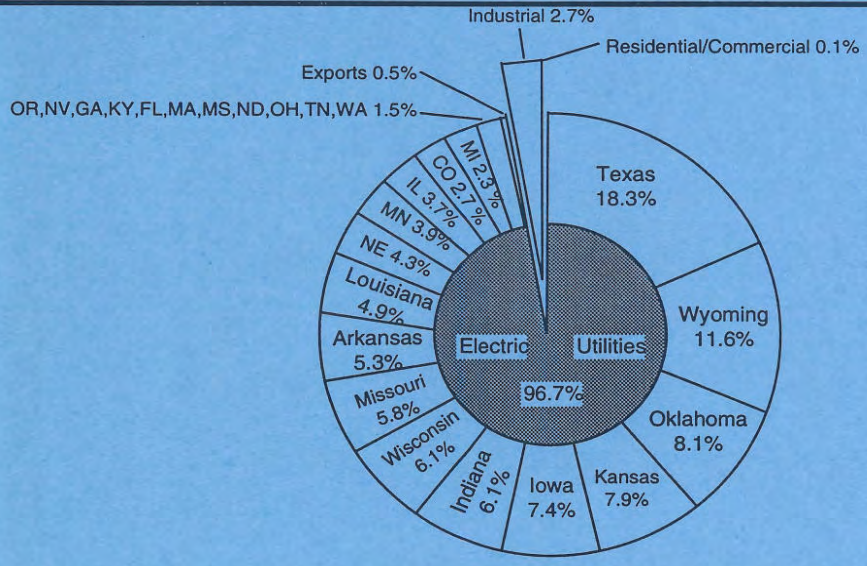
Wyoming Geo-notes

Number 44



Total Coal Mined in 1993 = 209.9 Million Tons

Wyoming State Geological Survey
Gary B. Glass, State Geologist

Laramie, Wyoming
November, 1994

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WYOMING GEO-NOTES
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Cover: Utilization of Wyoming coal in 1993 in percent. (From Energy Information Administration, 1994). Industrial, residential, and commercial usages are not broken down by their destination.

Table of Contents

Minerals Update 1
Overview 1

Oil and Gas Update 8
Exploration and development 13
Wyoming oil and gas exploration summary for 1993 16
Drilling activities and completions 16
Lease sales 17
Powder River Basin 19
Greater Green River Basin 21
Horizontal drilling 21
Reference cited 21

Coal Update 21
Developments in the Powder River Basin 23
Developments in western and southwestern Wyoming 25
Contracts 29
Coalbed methane 29
Reference cited 29

Industrial Minerals Update 32
Bentonite 33
Construction aggregate 33
Decorative stone 34
Limestone (chemical-grade) 35
Trona 36
Uranium 37
Reference cited 38

Metals and Precious Stones Update 39
Diamond 39
South Pass-Atlantic City mining district 39
Silver Crown mining district 40
Encampment mining district 40
Seminoe mining district 41
International mining conference 42
Reference cited 43

Mineral resource and
reserve base estimates for Wyoming 44

Geologic Mapping and Stratigraphy 45
Possible new occurrences of Oligocene rocks 45
Paleontological developments 46
New stratigraphic and paleontologic reports 47

Geologic Hazards in Wyoming 48
Earthquakes in Yellowstone National Park 48

Reports on Seminoe Mountains and organic rocks published 49

Rockhound's corner 50

New Publications of the Wyoming State Geological Survey 51

Wyoming State Geological Survey location maps 53

MINERALS UPDATE

OVERVIEW

by Gary B. Glass
State Geologist, Wyoming State Geological Survey

In October, Wyoming's Consensus Revenue Estimating Group (CREG) made new forecasts of mineral production and prices. As a member of CREG, the Wyoming State Geological Survey assisted in making these revisions. **Tables 1** and **2** and **Figures 1, 3,** and **5-8** reflect the new estimates.

In regard to oil, forecast prices increased slightly (**Figure 1** and **Table 2**). In the previous forecast, oil prices were held at $12.00 a barrel between 1994 and 1997. The new forecast shows them $1.25 to $1.50 higher, or $13.25 to $13.50 a barrel.

One thing contributing to this modest increase in the average purchase price of Wyoming crude relates to the percentage of sour versus sweet crude produced in the State. Data from the U.S. Energy Information Administration indicates that Wyoming's crude oil production is currently about 55% sour crude and 45% sweet. In the recent past, sour crude was closer to 65% of the total oil produced in Wyoming. **Figure 2** shows that the average first purchase price for Wyoming crude between 1989 and mid-1993 was much closer to the Sour Posted Price than it was to the Sweet Posted Price. This was because the lower price received for sour crude was weighted against a greater share of the production in those years. Since mid-1993, however, the average first purchase price for Wyoming crude is closer to halfway between the Sour Posted and the Sweet Posted Prices. The inference is that wells producing lower quality crude oil are not only reaching an economic limit sooner, but are also being plugged or shut in.

The forecast shows oil production continuing to decline (**Table 1**). The rate of decline, however, has been increased to eight percent (**Figure 3**). This compares with a 6% rate of decline previously forecast and an actual 8.8% rate of decline between 1992 and 1993. The accelerating rate of decline is a consequence of low oil prices, which have not only reduced exploration and discoveries, but have also led to the earlier abandonment of wells as well as to fewer new secondary waterfloods and almost no new tertiary recovery projects.

The optimism that natural gas prices were finally going to rise more steadily has disappeared. While it is not likely that the average price will fall to the $1.50 range seen between 1988 and 1992, it does look like prices have again softened, probably to allow demand to catch up with supply. As an indication of this, spot sale prices at Opal, Wyoming, had dropped to pre-1993 levels in the third quarter

Table 1. Wyoming mineral production (1981-1993) with forecasts to 1998[1].

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	81.8	946.4	142.5	1.07	235.0	16.0	—	1.1	1.20
*1995	75.3	985.6	142.5	1.07	245.5	16.4	—	1.1	1.20
*1996	69.3	1,026.3	142.5	1.07	256.5	16.8	—	1.1	1.20
*1997	63.7	1,068.4	142.5	1.07	267.9	17.1	—	1.1	1.20
*1998	58.6	1,112.0	142.5	1.07	279.9	17.1	—	1.1	1.20

*Forecast production by Consensus Revenue Estimating Group (CREG).
[1]Adapted from CREG, Wyoming State Government Revenue Forecast FY95-FY98, October, 1994. [2]Millions of barrels (Source: Wyoming Oil & Gas Conservation Commission, 1981-1993); [3]Billions 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; [5]Billions of cubic feet, based on Exxon's estimate that the average helium content in the gas processed at Shute Creek is 0.5%; [6]Millions of short tons (Source: Wyoming State Inspector of Mines, 1981-1993); [7]Millions of short tons of uranium ore (not yellowcake) (Source: Wyoming Department of Revenue, 1981-1992); [8]Millions of pounds of yellowcake (U_3O_8) (Source: Wyoming Department of Revenue, 1986-1993; unknown between 1981-1985 because it was only reported as taxable valuation); [9]Millions of short tons (Source: Wyoming Oil & Gas Conservation Commission, 1981-1993).

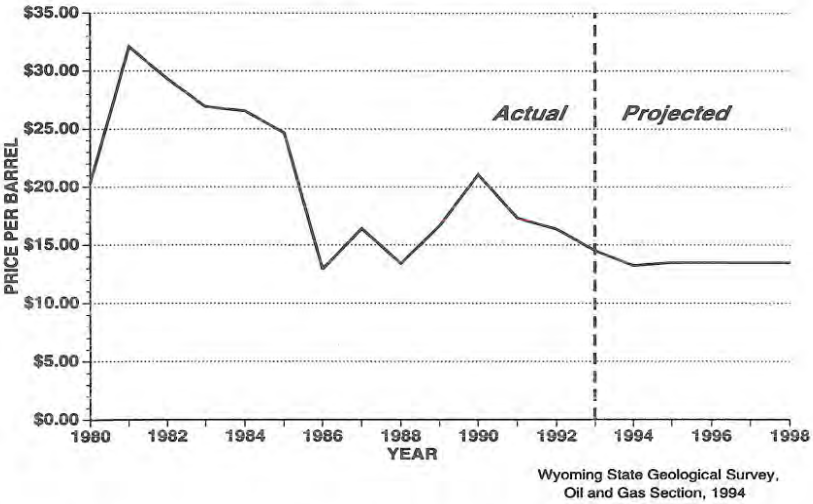
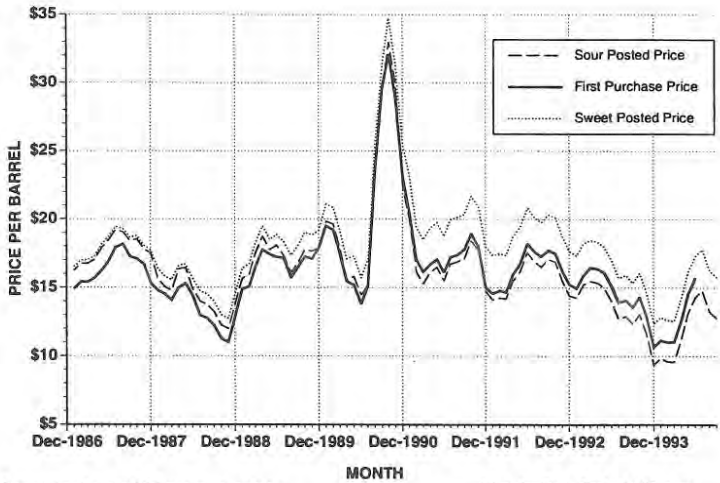


Figure 1. Average prices paid for Wyoming oil (1980 to 1993) with forcasts to 1998.

Table 2. Average prices paid for Wyoming oil, methane, coal, trona, and uranium (1985-1993) with forecasts to 1998[1].

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	7.11	40.08	21.00
*1994	13.25	1.65	6.70	39.00	21.00
*1995	13.50	1.65	6.55	40.00	21.00
*1996	13.50	1.65	6.43	40.00	21.00
*1997	13.50	1.65	6.30	40.00	21.00
*1998	13.50	1.65	6.19	40.00	21.00

* Forecast prices by Consensus Revenue Estimating Group (CREG).
[1] Adapted from CREG, Wyoming State Government Revenue Forecast FY95-FY98, October, 1994.
[2] First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Source: Energy Information Administration, 1985-1993.
[3] Wellhead price in dollars per thousand cubic feet (MCF). Sources: Wyoming State Land and Farm Loan Office, 1989-1993 (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.



Source: Unpublished DOE and company data

Wyoming State Geological Survey, Oil and Gas Section, 1994

Figure 2. Wyoming posted Sweet and Sour crude oil prices and first purchase prices averaged by month (1987 to present).

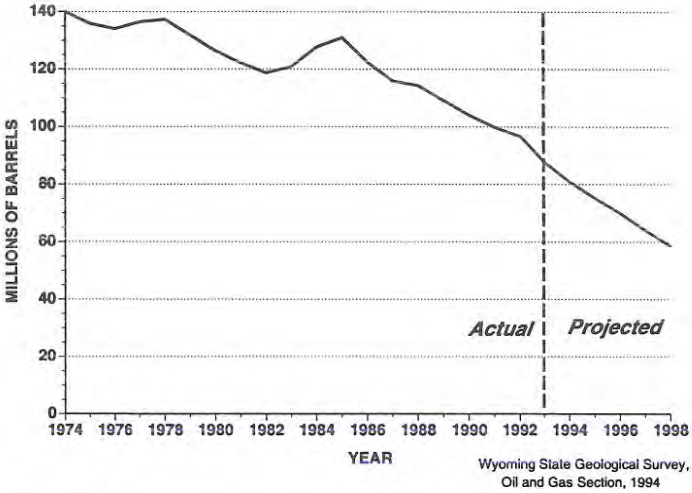


Figure 3. Annual oil production from Wyoming (1974 to 1993) with forecasts to 1998.

(**Figure 4**). The new forecast shows a flat $1.65 per thousand cubic feet between 1994 and 1998 (**Figure 5** and **Table 2**).

The new forecast for natural gas production, which still shows record setting production through 1998, is fairly close to CREG's previous forecast (**Figure 6** and **Table 1**). The annual rate of increase in production, however, is now 3.6%, rather than the 4% previously forecast. This reflects a slightly weaker demand. As in the past, severe winters and(or) very hot summers can noticeably increase production as well as prices in any given year.

The slight increase in carbon dioxide production (**Figure 6** and **Table 1**) comes from Exxon's Shute Creek plant in southwestern Wyoming. Retrofitting at this plant has increased the volume of its throughput. As throughput increases, so does the plant's production of methane, carbon dioxide, and helium since the feedstock contains all three gases.

While the new forecast for coal prices does not project the average price to continue declining by $1.03 as it did in 1993, it does show coal prices declining by 41 cents in 1994, and then leveling off at an 11-cent to 15-cent decline in price each year through 1998 (**Figure 7** and **Tables 2** and **3**). Forty-one cents is still about twice the price decline previously predicted for 1994. The rather significant decreases in price in 1993 and 1994 are a reflection of the 10.7% increase and the projected 12% increase in coal production for those years, respectively. Because the rates of increase in coal production from the Powder River Basin

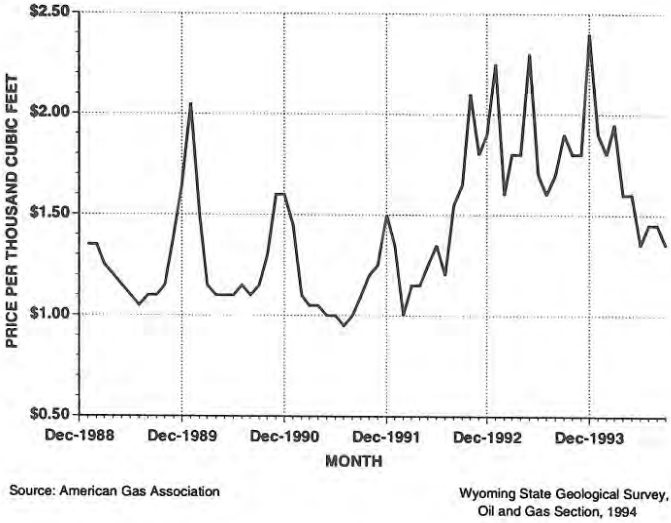


Figure 4. Spot prices for methane at Opal, Wyoming, averaged by month (1989 to present).

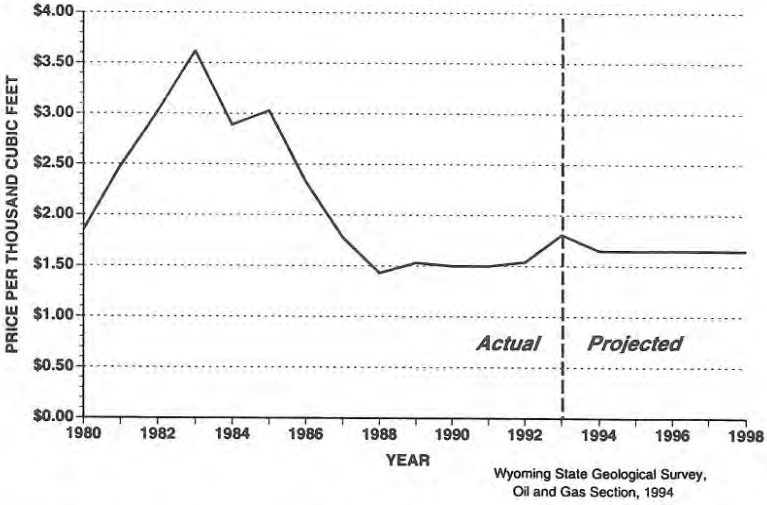


Figure 5. Average prices paid for Wyoming methane (1980 to 1993) with forecasts to 1998.

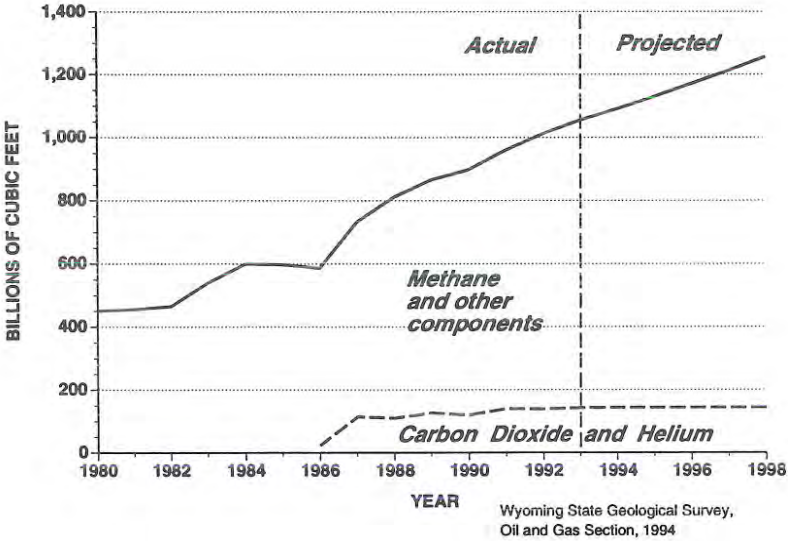


Figure 6. Annual natural gas production from Wyoming (1980 to 1993) with forecasts to 1998.

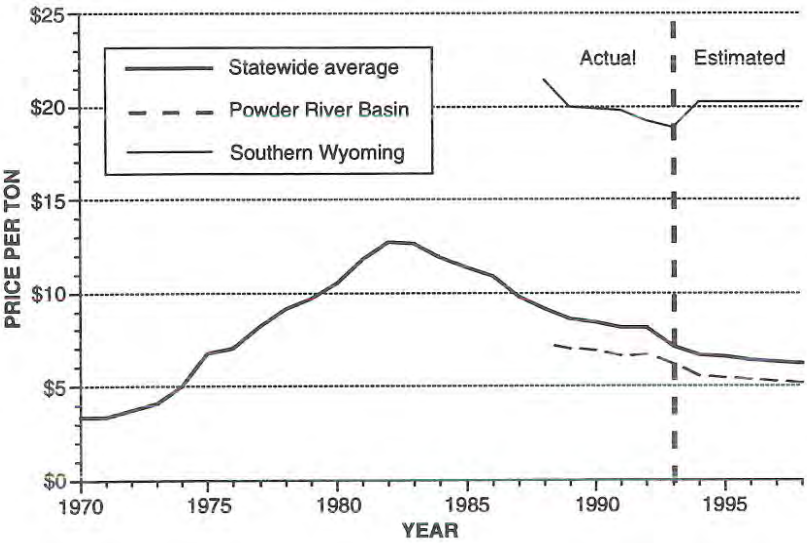


Figure 7. Average prices paid for Wyoming coal (1980 to 1993) with forecasts to 1998. Data from U.S. Energy Information Administration (1980-1993) and the Wyoming Consensus Revenue Estimating Group (1994-1998).

Table 3. Breakdown of average prices paid for coal from northeastern Wyoming, southern Wyoming, and Wyoming as a whole (1988-1993) with forecasts to 1998.

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	$6.24	$18.82	$7.11
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

in 1993 and 1994 are nearly twice what they had been in recent years, considerably more low-priced (prices between $3.50 and $5.00 a ton) spot and contract coal from that basin pulled the average prices down faster than previously anticipated. Smaller annual declines in the average price paid for Wyoming coal are forecast for 1995 through 1998. These smaller declines are predicated on a slowing of the growth rate in production to 4.5% a year. If production increases faster than this, there will be a faster decline in price in those years as well.

There is one thing that may be happening to slow the decline in the average coal price. Supply does not appear to be keeping up with this greater demand. Consequently, spot sale prices show signs of edging higher. "Edging higher" means that the average spot sale price may now exceed $4.15 a ton.

The new forecast still shows coal production setting new records each year through 1998 (**Figure 8** and **Table 1**). Production should increase 12% in 1994, followed by 4.5% annual increases through 1998. A 4.5% increase in production is equivalent to an annual tonnage increase in excess of 10 million tons. There are some indications, however, that bottlenecks in rail transportation may well cap annual growth in production at least on the short term. The Burlington Northern and Union Pacific Railroads both have initiated expansion projects, which are designed to reduce or prevent this kind of problem (p. 21 in the **Coal Update**).

It still remains to be seen how much new production will be needed between now and the next phase of the 1990 Amendments to the Clean Air Act. At least one estimate puts the coal demand from Wyoming at 300 million tons before the end of this decade.

While the new estimates for trona prices have been lowered slightly, the uranium price forecast was left unchanged (**Table 2**).

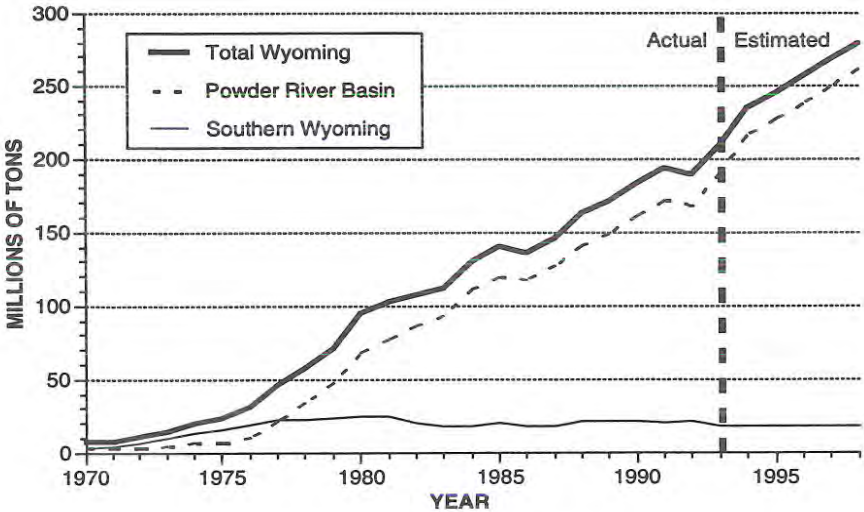


Figure 8. Annual coal production from Wyoming (1970-1993) with forecasts to 1998. Data from the Wyoming State Inspector of Mines (1970-1993) and Wyoming Consensus Revenue Estimating Group (1994-1998).

Similarly, the new forecast shows smaller increases in trona production at least for the next three years than the previous estimate (**Table 1**). The forecast for uranium production stayed the same.

This issue of *Wyoming Geo-notes* also includes a summary of oil and gas exploration activity in 1993 (p. 16-21). The **Industrial Minerals and Uranium Update** provides an historical summary of chemical-grade limestone production in Wyoming. **Table 4** provides historical production for some selected mineral commodities. The **Metals and Precious Stones Update** emphasizes current exploration for diamond, gold, and other metals.

OIL AND GAS UPDATE

by Rodney H. De Bruin
Staff Geologist-Oil and Gas, Wyoming State Geological Survey

The rig count in Wyoming did not increase as much in the third quarter as anticipated, although the September average did increase somewhat (**Figure 9**). The count should improve now that the U.S. Bureau of Land Management (BLM) has approved several large new drilling proposals in southwestern

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

	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	61.1	23.6	---	---	---	---
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]	---	---	---	---	---	---	---	---	0.24[7]	1.00[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[6]	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	52.1[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: [1]Wyoming Department of Revenue, unless otherwise noted; [2]millions of short tons; [3]includes ballast, scoria, and limestone used for aggregate; [4]thousands of short tons; [5]includes chemical grade limestone used for cement rock, sugar beet refining, and other uses; [6]Wyoming State Inspector of Mines; [7]estimated by Wyoming State Geological Survey; [8]short tons of iron ore used for pigment; [9]short tons of iron ore used as weighting additive in cement; [10] short tons. Prepared by Wyoming State Geological Survey, July, 1994.

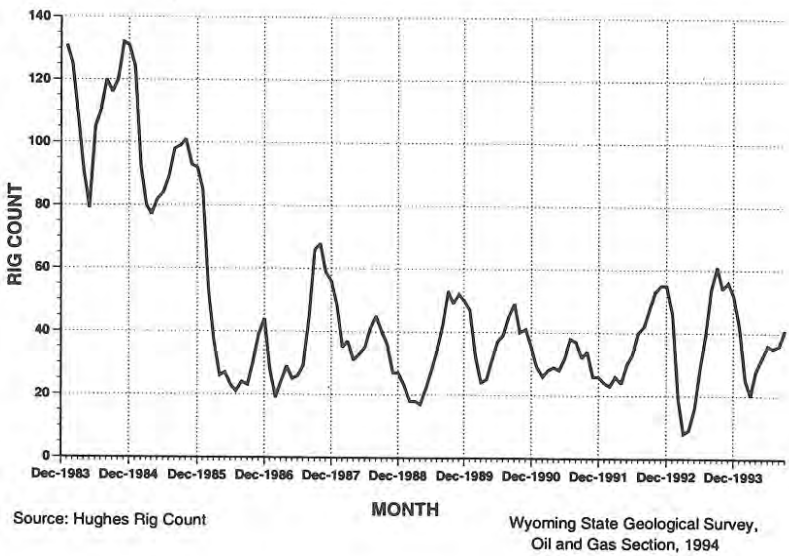


Figure 9. Wyoming daily rig count averaged by month (1984 to present).

Wyoming (see items 4, 6, and 11 in Exploration and Development section starting on page 13). Obviously, demand for Wyoming's natural gas continues to increase.

Alpine Gas Company has submitted an application to the BLM for the creation of the Alpine Tech Unit, a new oil and gas exploratory unit that will extend from Pinedale to 30 miles south on both sides of the Green River. Gas exists in the area, but the technology to extract most of that gas has not been available. Alpine Gas, however, feels it can produce the gas using some new technology and completion techniques.

Oil and gas leasing in Wyoming did well in the third quarter (**Table 5**). Although the total revenue for the September State Land and Farm Loan sale was down from that for the first two sales this year, it was still higher than the total revenue from all but one of the sales in 1992 and 1993. Leasing activity at this sale was about equally divided among southwestern Wyoming, the Powder River Basin, and the Wind River Basin (**Figure 10**). The U.S. Bureau of Land Management's (BLM's) August sale was the best, in terms of total revenue, since 1988 and brought in more money than the total of all BLM sales in 1992. Most of the leasing activity at this sale was either in southwestern Wyoming or in the Powder River Basin (**Figure 11**).

The BLM's August sale had two high per-acre bids of $255. One of the bids was made by Donald B. Anderson for a 40-acre tract that covers NE NE section 12, T23N, R111W. The parcel is about a mile from Frontier gas production at Storm Shelter and Mesa fields. The other high bid was made by Newton Land and Oil Properties for a 480-acre lease that covers S/2 N/2 and S/2 section 26, T22N, R94W. The tract is less than a mile from Almond gas and condensate production at Siberia Ridge Field. David W. Holwegner bid $205 per acre for a 160-acre lease that covers SE NW, NE SW, and S/2 section 25, T33N, R71W. The lease is about two miles east of Frontier oil and gas production at an unnamed one-well field discovered in 1990. Lario Oil and Gas paid $200 per acre for a 208.52-acre tract that covers lots 1 and 2 and SE section 2, T20N, R94W. The lease is about three miles east of Almond gas and condensate production at Wamsutter Field and about four miles west of Almond gas and condensate production at Five Mile Gulch Field. This sale had 30 tracts that sold for $50 or more per acre.

The State Land and Farm Loan sale in September had a high per-acre bid of $190. The bid was made by Rex Randolph for a 40-acre lease that covers NE NW section 21, T53N, R69W. The lease is less than a mile from a shut-in Minnelusa discovery that was completed in 1993. BTA Oil Producers paid $175 per acre for a 640-acre lease that covers section 16, T24N, R99W. The lease is about five miles north of shut-in Lewis gas and condensate production at Sinkhole Field. D. Gundry-White paid $115 per acre for a 320-acre tract that covers W/2 section 16, T50N, R70W, The lease is a mile west of Minnelusa and Muddy production at Rozet Field.

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

FEDERAL SALES (BUREAU OF LAND MANAGEMENT)

Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
1990							
TOTAL	$17,997,133	2,971	1,593	2,169,138	967,293	$18.61	$340.00
1991							
TOTAL	$12,934,277	2,815	1,147	2,191,462	675,777	$19.14	$16,000.00
1992							
February	$940,581	342	126	213,469	67,205	$14.00	$210.00
April	$331,199	355	109	229,407	58,951	$5.62	$112.00
June	$425,183	314	86	168,230	37,701	$11.28	$220.00
August	$1,395,060	335	109	196,800	54,530	$25.58	$230.00
October	$657,029	351	73	259,482	43,843	$14.99	$2,500.00
December	$1,029,888	425	161	366,880	102,248	$10.07	$280.00
TOTAL	$4,778,940	2,122	664	1,434,268	364,478	$13.11	$2,500.00
1993							
February	$1,637,233	464	246	346,357	155,272	$10.54	$220.00
April	$2,116,184	478	259	351,465	177,989	$11.89	$220.00
June	$1,415,793	463	179	351,130	86,435	$16.38	$390.00
August	$1,877,405	462	262	374,274	208,495	$9.00	$400.00
October	$2,636,127	458	247	367,281	186,274	$14.15	$285.00
December	$3,259,266	444	276	275,435	180,879	$18.02	$320.00
TOTAL	$12,942,008	2,769	1,469	2,065,942	995,344	$13.00	$400.00
1994							
February	$3,909,085	442	290	374,969	237,761	$16.44	$160.00
April	$4,248,182	498	278	369,657	201,690	$21.06	$275.00
June	$3,759,282	480	270	417,447	233,664	$16.09	$325.00
August	$5,100,550	439	294	323,410	217,157	$23.49	$255.00

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
1990							
TOTAL	$4,979,094	1,199	732	478,098	380,382	$13.09	$270.00
1991							
TOTAL	$4,457,885	1,295	1,037	479,975	405,910	$10.98	$401.00
1992							
January	$138,165	200	96	72,027	37,840	$3.65	$65.00
March	$200,000	200	114	70,294	41,034	$4.88	103.00
May	$208,166	200	93	60,687	28,605	$7.28	$230.00
November	$200,407	199	116	74,747	43,134	$4.65	$87.00
TOTAL	$745,738	799	419	277,755	150,613	$4.95	$230.00
1993							
March	$601,400	200	137	74,940	54,723	$10.99	$400.00
May	$362,840	200	141	82,388	56,770	$6.39	$90.00
September	$505,587	200	141	80,428	56,845	$8.89	$225.00
November	$510,290	200	143	73,517	53,801	$9.48	$155.00
TOTAL	$1,980,017	800	562	311,273	222,139	$8.91	$400.00
1994							
March	$917,380	200	169	84,571	73,061	$12.56	$170.00
May	$802,688	200	141	75,523	54,199	$14.81	$205.00
September	$586,083	200	149	83,143	61,675	$ 9.50	$190.00

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

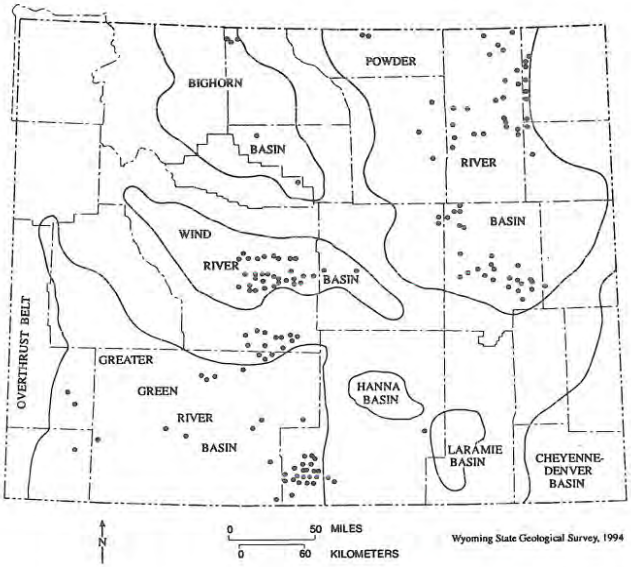


Figure 10. Locations of State oil and gas tracts leased by the State Land and Farm Loan Office during the third quarter of 1994.

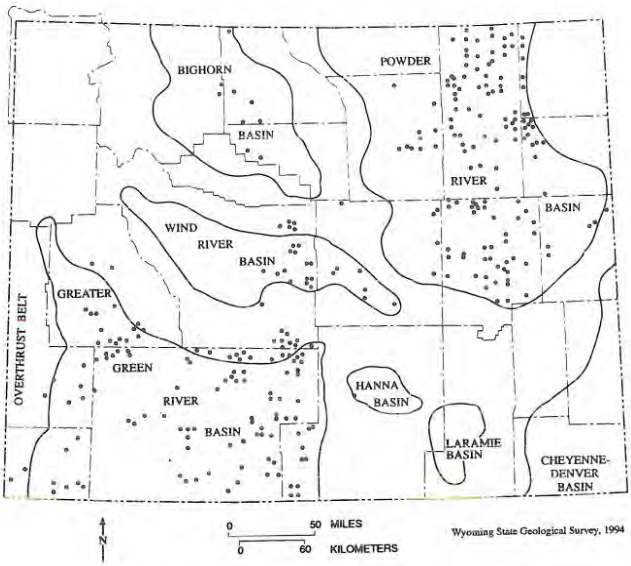


Figure 11. Locations of Federal oil and gas tracts leased by the U.S. Bureau of Land Management during the third quarter of 1994.

Exploration and Development

Company data, news releases, and information compiled and published by Petroleum Information indicate the following significant exploration and development events occurred in Wyoming during the third quarter of 1994. The numbers preceding discussions below refer to locations on **Figure 12**.

1. American Methanol Ltd. let bids for its new $30 million plant located about 15 miles west of Green River. Construction should begin early next year with production beginning in early 1996. The anticipated construction workforce should peak at 200 to 300 next summer. The permanent workforce should be between 25 and 30. A spokesman for the company said the low price of natural gas, access to a cheap supply of carbon dioxide from Exxon's Shute Creek plant, and a local market for methanol were major factors in locating the plant near Green River.

2. Presidio Exploration has scheduled three horizontal Frontier tests on the eastern flank of the Moxa arch. The 13-21H Lodgepole Unit well will be drilled from a surface location in NW SW section 21, T24N, R110W to a true

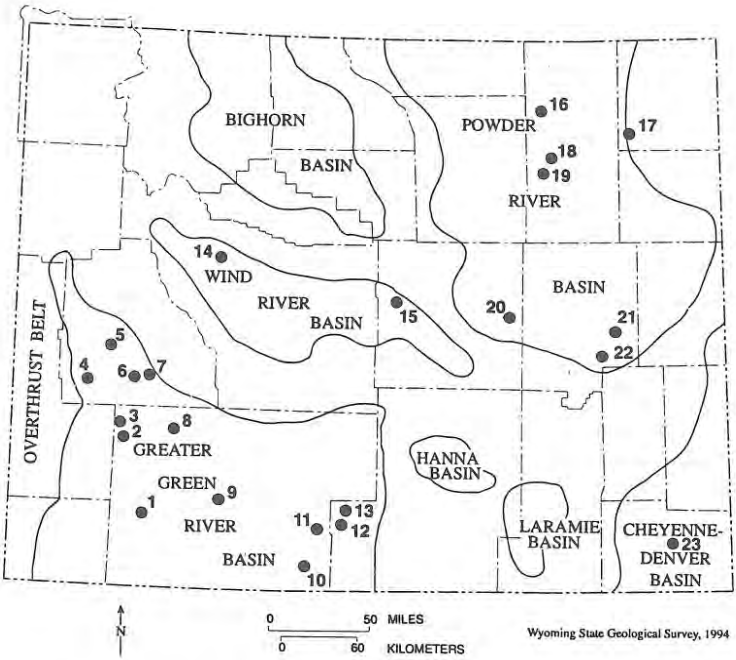


Figure 12. Oil and gas exploration and development activities in Wyoming during the third quarter of 1994 (exclusive of coalbed-methane activities).

vertical depth of 10,900 feet. The 10-29H Lodgepole Unit well will be drilled from a surface location in SE NW section 29, T24N, R110W also to a true vertical depth of 10,900 feet. The 24-15H well will be drilled from a surface location in SE SW section 15, T24N, R110W to a true vertical depth of 11,200 feet.

3. Several oil and gas companies have notified the BLM of their intent to drill 180 to 230 additional wells in the Lincoln Road Field area over the next five years. The area covers all or parts of T22N to T25N and R109W to R112W. The companies estimate that 60 to 70 wells could be drilled each year in 1995 and 1996 and another 20 to 30 wells each year from 1997 to 1999. The main producing reservoirs in this area are in the Frontier and Dakota formations.

4. The BLM approved Mobil Oil's application to drill up to 167 additional gas wells over the next six to eight years within the Tip Top and Hogsback Units in the southwestern corner of Sublette County. Mobil proposes drilling 20 to 30 wells per year.

5. Chevron USA set production casing to 12,355 feet at its 33-16 Billy wildcat well in C SE section 16, T31N, R111W. The well was drilled to test the Lance and Ericson. The well is about 11 miles northeast of Almy and Mesaverde production at Star Corral Field. No other details on the well are available.

6. The BLM approved McMurry Oil Company's proposal to drill up to 40 additional wells in Jonah Field over the next five years. There are already seven wells in the field. The main objective for the additional wells is the Lance Formation at a depth of approximately 10,500 feet. The company has the option of drilling deeper wells to 21,000 feet. The Jonah Field is in southern Sublette County.

7. CNG Producing Co. has moved in a drilling rig to test the Lance at about 12,750 feet. The 4-31 Elk Horn-Federal well will be drilled in SE SE section 31, T28N, R105W. CNG earlier drilled and cased the 3-11 Bull Draw-Federal well in NE SW section 11, T28N, R107W. This well also was drilled to a depth of 12,750 feet to test the Lance.

8. Texaco Exploration and Production will drill a horizontal test of the Almond at its Stagecoach Draw Unit. The 5H Stagecoach Draw Unit well will be drilled from a surface location in SW NE section 31, T23N, R107W to a true vertical depth of 7,950 feet. Stagecoach Draw was discovered last year and has three vertical wells that produce from the Almond Formation.

9. Apache Corp. is acquiring 500,000 acres of undeveloped leases in Sweetwater County from Key Production. Apache intends to start drilling wells before the end of 1994. The acquisition agreement also provides for a joint exploration and development venture by the two companies, primarily in the Powder River Basin.

10. Celsius Energy completed a horizontal development well in Mulligan Draw Field. The 5-H Mulligan Draw Unit well was drilled from a surface location in SE SE section 11, T15N, R95W to a true vertical depth of 12,995 feet. The well flowed 2.4 million cubic feet of gas, 44 barrels of condensate, and 108 barrels of water per day. This well had been declared a vertical dry hole in 1992.

11. In Sweetwater and Carbon Counties, the BLM approved the drilling of up to 275 development wells in and adjacent to Barrel Springs, Blue Gap, Fillmore, Creston, and Robbers Gulch fields. The main reservoirs in these fields are in the Lewis and Almond. The BLM's decision followed its environmental impact statement for the project.

12. Amoco Production reportedly completed its 1 Champlin 278 Amoco E well in SE SE section 13, T18N, R93W. The well was to be drilled to a depth of 18,025 feet to test the Steele and Niobrara. No other details are available.

13. Williams Field Services and Union Pacific Resources dedicated their new Echo Springs gas processing plant in September. The plant began processing gas in April of 1994 and currently processes about 120 million cubic feet of gas per day from over 300 wells in the Wamsutter Field area. Major producers in the area are Union Pacific Resources, Amoco, Pacific Gas & Electric, and Marathon. The design phase to expand the capacity of the new plant is already under way. A decision as to the size and timing of the expansion is expected in 1995.

14. Tom Brown Inc. completed its 24-42 Tribal well in SE NE section 24, T4N, R2E in the Lance between 8,051 and 8,340 feet. The well flowed 1.6 million cubic feet of gas, one barrel of condensate, and one barrel of water per day.

15. Barrett Resources completed an exploratory well in NE NE section 31, T37N, R86W. The 1 Cave Gulch-Federal well initially flowed at rates between 1.2 and 1.7 million cubic feet of gas per day from a subthrust section of Lance between 6,302 and 6,306 feet.

16. Exxon Corp. will drill a horizontal well to test the Mowry Shale at a depth of 13,500 feet. The 1H Wyoming-D-State-Federal-Comm well will be drilled from a surface location in SW SE section 29, T51N, R75W.

17. In southwestern Crook County, Powder River Oil bought Prong Creek Field from Union Pacific Resources. The field has produced 5.4 million barrels of oil from the Minnelusa Formation.

18. True Oil set production casing at its 11-26 Phillips-Federal well in NW NW section 26, T48N, R74W. The well was scheduled to test the Parkman at about 6,800 feet. No other details are available.

19. Apache Corp. completed a new Sussex discovery in NE NE section 33, T47N, R75W. The 41-33 Federal well produced 1,994 barrels of oil from an undisclosed interval during its first month of production.

20. Kachina Exploration completed a new producer in Cole Creek Field. Its 3-14 Federal well in SE SW section 3, T35N, R77W pumped 39 barrels of oil, 15,000 cubic feet of gas, and 18 barrels of water per day from the Dakota between 8,692 and 8,702 feet.

21. In Converse County, Basin Exploration has drilled 11 wells in Well Draw Field to conclude its initial program in the Teapot. The company plans to drill an additional 33 wells in the area by the end of 1994. The combined initial potential for the new wells was 593 barrels of oil and 797,000 cubic feet of gas per day. In addition to the 33 planned wells, the company has identified 30 other possible drilling sites in Well Draw and Scott fields.

22. Vastar Resources has staked its fifth combination slant and horizontal well to test the Frontier and Niobrara in the southern Powder River Basin. The 1-8H Lizard Head well will be drilled from a surface location in NW NW section 8, T33N, R71W to a true vertical depth of 11,770 feet.

23. Exxon Corp. completed a horizontal Niobrara producer in Silo Field. The 1H Wyoming-B-State-Consolidated well pumped 269 barrels of oil and 64 barrels of water per day. The well was drilled from a surface location in SW SW section 16, T16N, R64W to a true vertical depth of 7,891 feet. Union Pacific Resources also completed a new horizontal Niobrara producer in Silo Field. The 1H Yellowstone 14-33 well produced 4,731 barrels of oil, 1.4 million cubic feet of gas, and 642 barrels of water during its first 24 days of production. The well was drilled from a surface location in SW SW section 33, T16N, R65W to a true vertical depth of 8,720 feet. Union Pacific Resources also staked two new horizontal Niobrara tests in Silo Field. The 1H Sweetwater 41-17 well will be drilled from a surface location in NE NE section 17, T16N, R65W to a true vertical depth of 8,633 feet. The 1H Saratoga 41-13 well will be drilled from a surface location in NE NE section 13, T15N, R64W to a true vertical depth of 7,757 feet.

Wyoming Oil and Gas Exploration Summary for 1993

Drilling Activities and Completions

Based on preliminary data available from Petroleum Information (1994), there were 636 well completions in Wyoming in 1993, which is a large increase over 1991 and 1992 completions (**Figure 13**). Of the 636 wells completed in 1993, 138 were exploration wells and 498 were development wells. The success rate for exploration wells was 31.2% compared to a success rate of 23.7% for exploration wells in 1992. In all, 507 wells found oil or gas for a

success rate of 79.7% compared to a success rate for all wells in 1992 of 65.0%. The higher success rate in 1993 is in large part attributable to the larger percentage of development wells drilled in 1993 than in 1992.

Based on data from Hughes Rig Count, the average daily rig count in 1993 was 37, compared to 38 in 1992. The average daily rig count averaged by year has not been above 40 since 1985 (**Figure 14**). Rigs in Wyoming drilled nearly five million feet in 1993, which was more than 1.5 million feet greater than the footage drilled in either 1991 or 1992 (**Figure 15**). The average depth of all wells drilled in Wyoming in 1993 was 7,742 feet, slightly higher than in 1992, (**Figure 16**). The average depth of an exploration well in Wyoming in 1993 was 6,639 feet, which is the lowest average in at least the last 14 years (**Figure 16**).

Lease Sales

Six Federal lease sales held by the U.S. Bureau of Land Management (BLM) in 1993 grossed almost $13 million. The average price per acre was $13.00. Of the 2.07 million acres that were available for lease, 48.2% were leased. For comparison, the six BLM sales held in 1992 grossed only $4.8 million, and only 25.5% of the 1.43 million acres were leased for an average

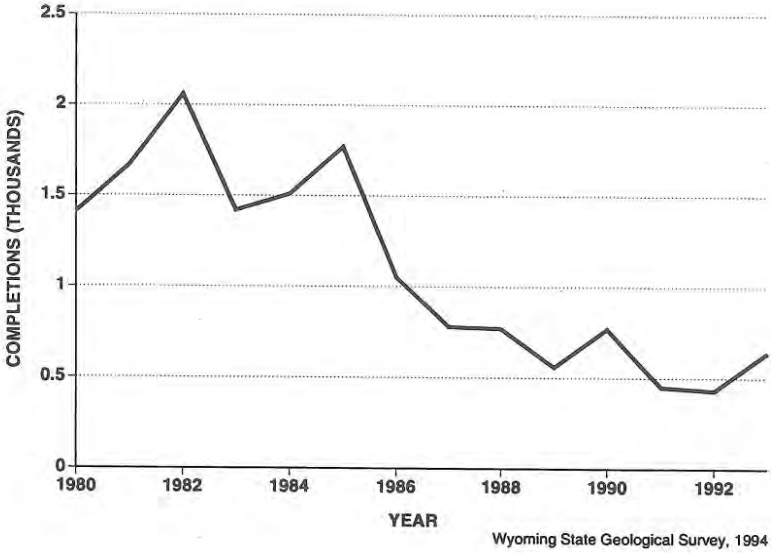


Figure 13. Annual oil and gas well completions in Wyoming [based on data from Petroleum Information (1981-1993)].

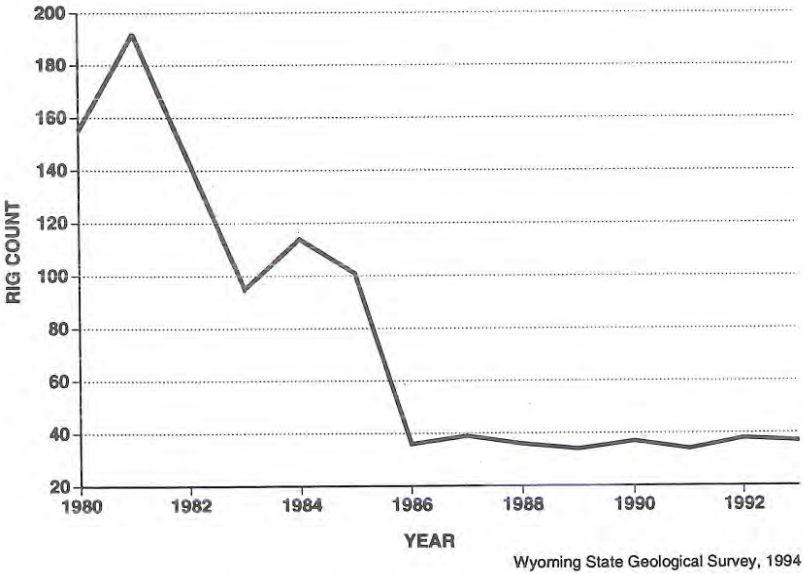


Figure 14. Average daily rig count for Wyoming, averaged by year [based on Hughes Rig County (1980-1993)].

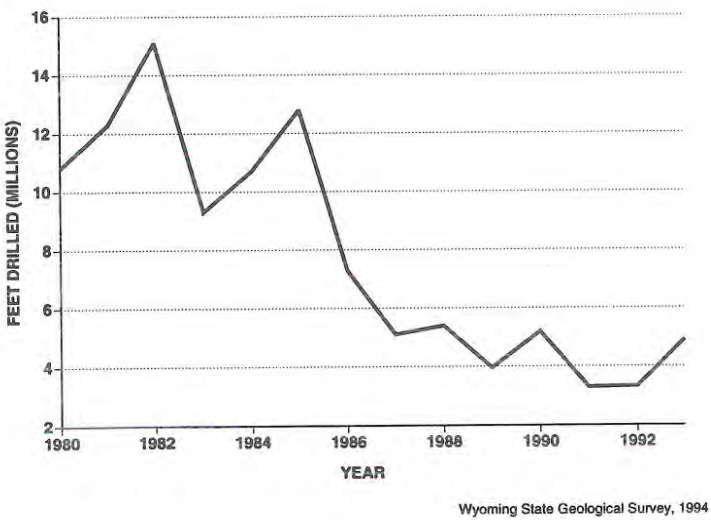


Figure 15. Total feet drilled for oil and gas in Wyoming by year [based on data from Petroleum Information (1981-1993)].

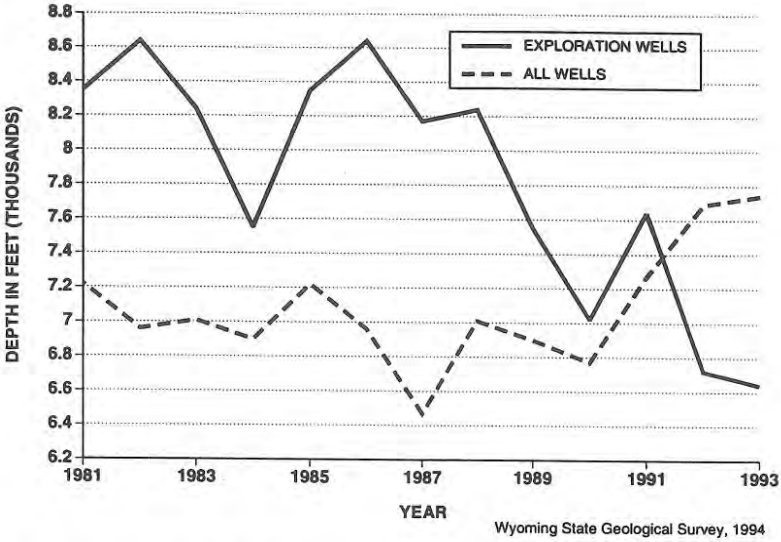


Figure 16. Average depth of oil and gas wells drilled in Wyoming by year [based on data from Petroleum Information (1981-1993)].

price of $13.11. **Figures 17** and **18** show annual revenue and average price per acre leased for recent Federal lease sales, respectively.

The four lease sales held by the State Land and Farm Loan Office in 1993 grossed nearly $2.0 million. The average price per acre was $8.91 and 71.4% of the 311,000 available acres were leased. For comparison, four sales in 1992 grossed only $747,000. Of the 278,000 acres available in 1992, only 54.3% were leased for an average price of $4.95 per acre. **Figures 17** and **18** show annual revenue and average price per acre for State Land and Farm Loan sales in recent years, respectively.

Powder River Basin

In terms of new field wildcats, the Powder River Basin was the fifth leading geologic province in the U.S. with 66 completions in 1993. Nine of these wildcat wells discovered oil or gas (Petroleum Information, 1994). Campbell County was the most heavily explored county in the U.S. with 38 wildcat completions. Of those 38 completions, three found oil and four found gas (Petroleum Information, 1994). In all, the Powder River Basin accounted for 75.9% of all new field wildcat completions in Wyoming.

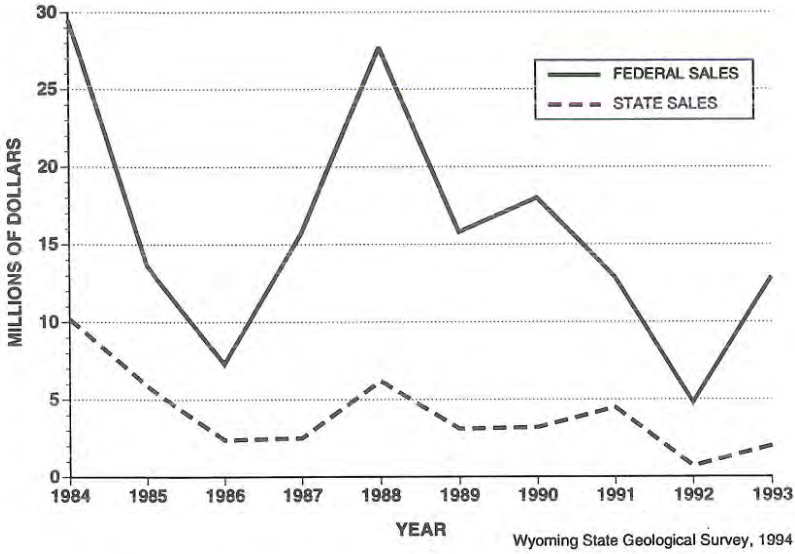


Figure 17. Annual revenue from Federal (Bureau of Land Management) and from State oil and gas lease sales in Wyoming.

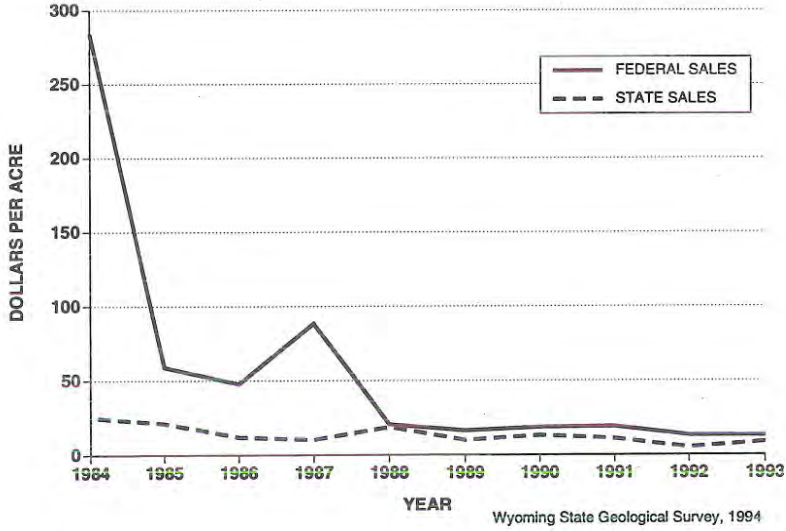


Figure 18. Average price per acre paid for Federal (Bureau of Land Management) and State oil and gas lease sales in Wyoming.

Greater Green River Basin

Five counties in the Greater Green River Basin (Carbon, Sweetwater, Sublette, Lincoln, and Uinta) accounted for 322 well completions in 1993, just over 50% of Wyoming's total completions. Of these wells, 287 found gas and 11 found oil (Petroleum Information, 1994). Sweetwater County had 108 total completions. Drilling in the Greater Green River Basin focused on developing gas reserves in the Almond, Frontier, Muddy, and Dakota formations. Bruff Field was one of the most heavily-drilled fields in the U.S. and had 67 gas well completions.

Horizontal Drilling

There were 20 horizontal wells completed in Wyoming in 1993, compared to 28 horizontal completions in 1992. Almost all of the horizontal completions were in the Niobrara in and around Silo Field in the Denver-Cheyenne Basin.

Reference cited

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COAL UPDATE

by P. Daniel Vogler
Staff Geologist-Coal, Wyoming State Geological Survey

Coal deliveries for the first six months of 1994 were 109.9 million tons, which is a 13.9% increase over the same months in 1993 (**Figure 19** and **Table 6**). This holds true for both spot sales and contract sales (**Figure 20**). However, even though this is record tonnage, there are some utilities that are indicating that shipments to their plants are being delayed by rail congestion in the Powder River Basin. For example, delays in deliveries have reportedly caused two of Nebraska's largest utilities, Nebraska Public Power District and Omaha Public Power District, to dig into their stockpiles. Based on these comments, the demand is apparently even greater than the monthly shipments are indicating.

From the railroads' camp, Union Pacific has announced plans for a $32.5 million project to increase capacity in western Nebraska. This plan involves 13 new bridges and 39 miles of new track. And Burlington Northern has committed $650 million to increase its carrying capacity. Also, Burlington Northern notes that it moved its two billionth ton of coal out of the Powder River Basin in July of this year. For comparison, Burlington Northern only delivered three million tons of coal in 1970. By 1993, it was delivering more than 154 million tons (combined haulage from Wyoming and Montana). While we are projecting that

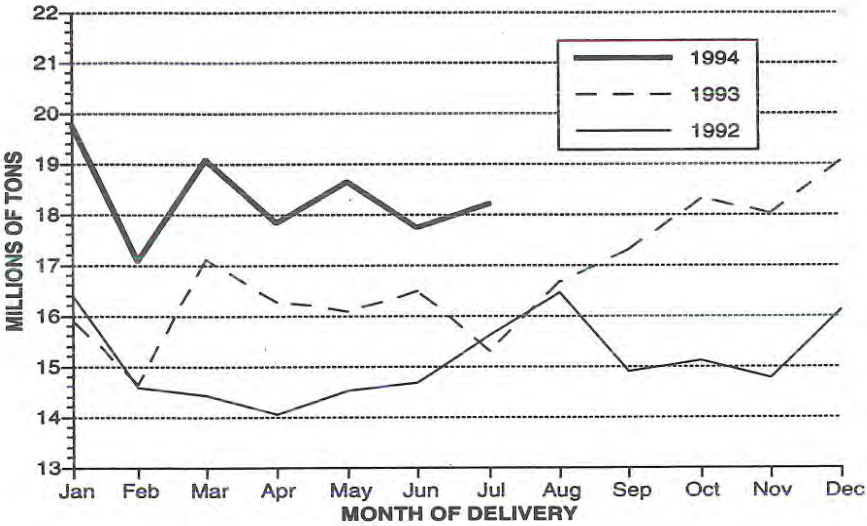


Figure 19. Reported deliveries from Wyoming coal mines (1992 through July 1994). (From COALDAT Marketing Report by Resource Data International, Inc., compiled from FERC Form 423 filed monthly by electric utilities).

Wyoming coal production will reach a record 235 million tons in 1994 (**Tables 1 or 7**), an independent estimate by the Burlington Northern Railroad is even higher at 240 million tons. In addition, the Santa Fe and Burlington are proposing a merger, which would create the nation's largest rail network.

Western Railroad Properties Inc. (WPRI) marked its 10th anniversary on August 16th. WPRI has hauled a total of 490 million tons of coal out of the southern Powder River Basin and expects to haul another 90 million tons in 1994.

The market for Wyoming coal is still expanding. In 1993, Illinois burned 7.5 million tons of Wyoming coal, while Indiana burned 12.4 million tons (**Figure 21**). These two states had traditionally used local coals for their coal-fired power plants. Ten percent increases in consumption of Wyoming coal by seventeen states (IL, IN, IA, MO, KS, NE, OK, TX , AR, LA, WI, MN, MI, GA, OR, ME, and MA) helped production from Wyoming increase 10.8% from 1992 to 1993 (**Table 7**). Compared with past annual growth rates, 4-5% of this increase may reflect compliance strategies related to Phase I of the 1990 Amendments to the Clean Air Act. In 1993, 96.7% of the coal produced in Wyoming fueled electric utility plants (**Figure 22**).

According to statistics recently released by the National Coal Association, coal-fired power plants now provide 57% of domestic electricity. This equates to more than one billion tons of coal delivered to utilities annually.

Peabody Holding Co.'s Powder River Coal has agreed to buy Exxon's (Carter Mining Co.'s) Rawhide and Caballo mines for $360 million dollars. The Rawhide and Caballo mines have more than 1.2 billion tons of coal reserves and collectively produce approximately 25 million tons of coal a year. These two mines are on the Wyodak coal bed. It is not clear how many of Exxon's 450 employees will be retained by Powder River Coal. The sale should be completed in November.

Montana Power has recently put its Grass Creek mine up for sale. The Grass Creek mine, located near Thermopolis in the Bighorn Basin, mines the Mayfield coal bed. Although this mine only produced about 41,000 tons in 1993, it has had much higher production in the recent past.

"Due diligence" may become a cause for concern once again in the Powder River Basin, following allegations by the General Accounting Office (GAO) that the U.S. Bureau of Land Management (BLM) erred in its issuance of some recent Federal coal leases. At issue are some coal leases awarded to Kerr-McGee Coal Corporation's Jacobs Ranch mine. The GAO asserts that these leases were issued while Kerr-McGee's Clovis Point mine was not in compliance with "due diligence" requirements. Under current law, if a company does not comply with "due diligence" requirements on its existing Federal leases, it cannot acquire other leases from the Federal government. The BLM argues that "due diligence" is not an issue since the diligence deadline for the Clovis Point/East Gillette Logical Mining Unit (LMU) does not expire until 1996. There have already been challenges and appeals to these and other recent coal leases on a variety of issues, making GAO's charge the most recent on a long list.

Developments in the Powder River Basin

Kennecott Energy has proposed a $500 million coal enhancement plant, 16 miles south of Gillette at the Cordero mine site. PURON, Kennecott Energy's partner in the venture, states that the coal processing plant will produce 1.5 million tons of enhanced fuel a year by molding the coal into a briquette, which has a higher heating value than the coal it is made from. While the plant may permanently employ as many as 100 people, it will require up to 1,200 workers during its peak construction period. In late September, Kennecott received an air quality permit from the Air Quality Division of the Wyoming Department of Environmental Quality. The plant could be operational by July or August of 1996.

The Encoal coal processing plant located at the Buckskin mine, 12 miles north of Gillette, made its first shipment of Encoal to Western Farmers Electric Cooperative's Hugo plant, where the utility is blending it with unprocessed coal.

Table 6. Coal deliveries by month from Wyoming mines.

	1991 Monthly	1991 Cumulative	1992 Monthly	1992 Cumulative
JAN	14,960,450	14,960,450	16,407,150	16,407,150
FEB	15,480,110	30,440,560	14,604,480	31,011,630
MAR	16,278,870	46,719,430	14,429,650	45,441,280
APR	14,820,240	61,539,670	14,063,060	59,504,340
MAY	14,589,790	76,129,460	14,518,590	74,022,930
JUN	14,007,600	90,137,060	14,655,600	88,678,530
JUL	16,451,090	106,588,150	15,592,050	104,270,580
AUG	15,940,620	122,528,770	16,467,100	120,737,680
SEP	15,314,490	137,843,260	14,878,150	135,615,830
OCT	14,810,510	152,653,770	15,122,820	150,738,650
NOV	14,783,000	167,436,770	14,757,230	165,495,880
DEC	16,716,630	184,153,400	16,096,150	181,592,030
Total Tonnage Reported[1]		**184,153,400**		**181,592,030**
Total Tonnage Not Reported		**9,710,406**		**7,878,226**
Total Tonnage Produced[2]		**193,863,806**		**189,470,256**

[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

Encoal may also send a shipment to Wisconsin Power & Light for a large-scale test burn. The Encoal plant has a 500 ton/day feed rate and is expected to reach 1,000 tons/day after some modifications are made.

In other news, WYGEN Inc. wants to build an 80-megawatt, coal-fired, power plant next to Black Hills Corporation's Neil Simpson No. 2 plant. WYGEN is a subsidiary of Black Hills Corporation.

The September issue of the U.S. Bureau of Land Management's (BLM's) *Wyoming Issues* fact sheet shows three lease by applications (LBAs) pending in the Powder River Basin. BLM issued an Environmental Assessment (EA) on the Eagle Butte LBA in July, but they have not issued a Decision Record. If they approve the sale, it would be in February, 1995. Public review of the EA for the Antelope LBA ends in October. A decision should be made in November, with a sale possible in December, 1995. The schedule for the North Roundup LBA is due in late 1995. BLM notes that an Environmental Impact Statement may be needed for this LBA.

In the Montana portion of the basin, Kennecott Energy's Spring Creek mine expects record production in 1994. It produced 7.1 million tons of coal in 1993. Westmoreland Resources' Absaloka mine will supply the Big Stone power plant

Table 6. *continued*

1993 Monthly	1993 Cumulative	1994 Monthly	1994 Cumulative
15,931,150	15,931,150	19,326,770	19,326,770
14,646,090	30,577,240	17,171,910	36,498,680
17,112,970	47,690,210	19,178,990	55,677,670
16,259,770	63,949,980	17,839,110	73,516,780
16,085,470	80,035,450	18,652,290	92,169,070
16,473,920	96,509,370	17,741,480	109,910,550
15,296,480	111,805,850	18,213,540	128,124,090
16,682,090	128,487,940		
17,310,330	145,798,270		
18,300,070	164,098,340		
18,007,907	182,106,310		
19,034,530	201,140,840		
	201,140,840		**128,124,090**
	8,784,986		
	209,925,826		

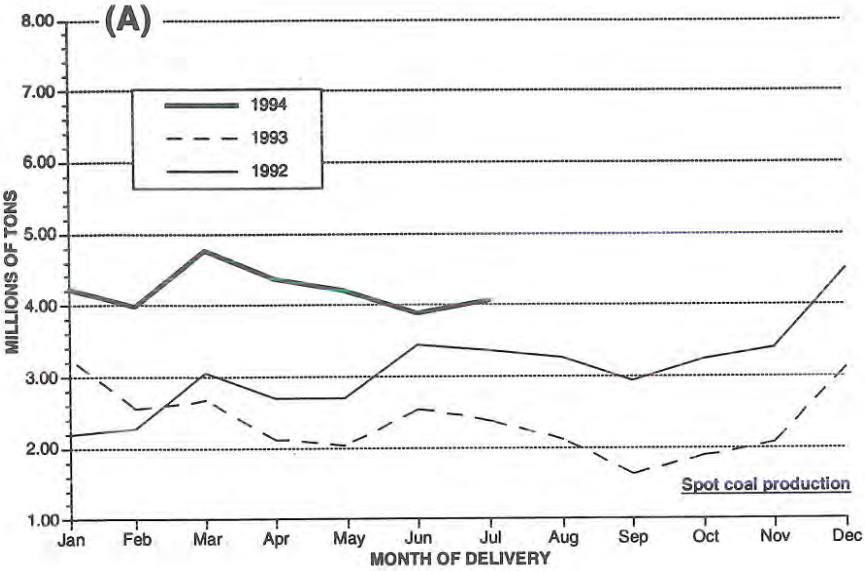
in Milbank, South Dakota, with 1.5 million tons of coal over a 4.5-year period, beginning in June or July, 1995. Otter Tail Power, the managing interest at Big Stone, said that the plant had been using lignite since it was built in 1975.

Also in Montana, miners at Kennecott Energy's Decker mine voted to remain unionized. The Decker mine presently employs 258 people.

Developments in western and southwestern Wyoming

In September, William's Energy Ventures, Inc. and Energy International broke ground for their Carbon County Underground Gasification Project (CCUCG), which is located eight miles west of Rawlins. While the initial demonstration project will run between 18 months and two years, a full-scale facility could be underway as early as December of 1996.

The Wyoming Department of Environmental Quality's Abandoned Mine Lands Division has commissioned an investigation of the subsidence risks associated with the now abandoned coal mines under the towns of Rock Springs, Kemmerer, and Diamondville. The investigation will first determine the potential for mine subsidence. Then a map of potential subsidence areas will be prepared for use in future planning.



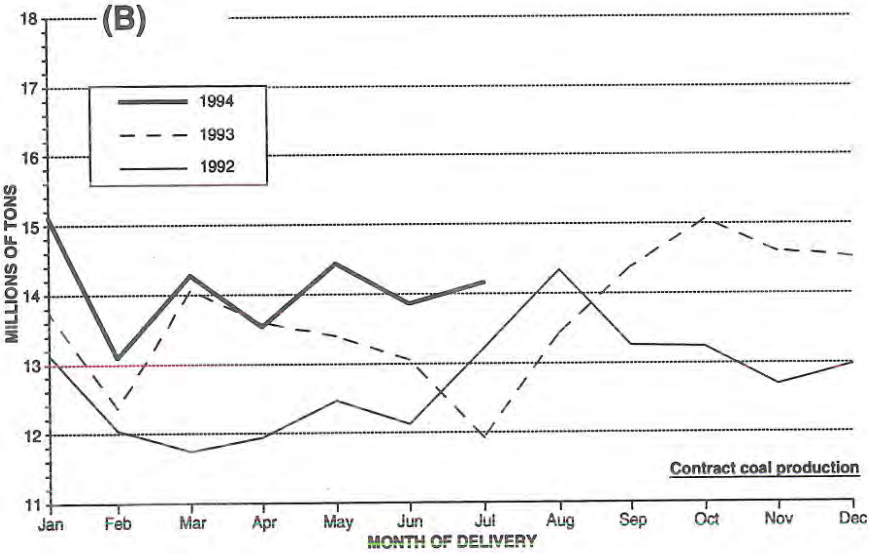
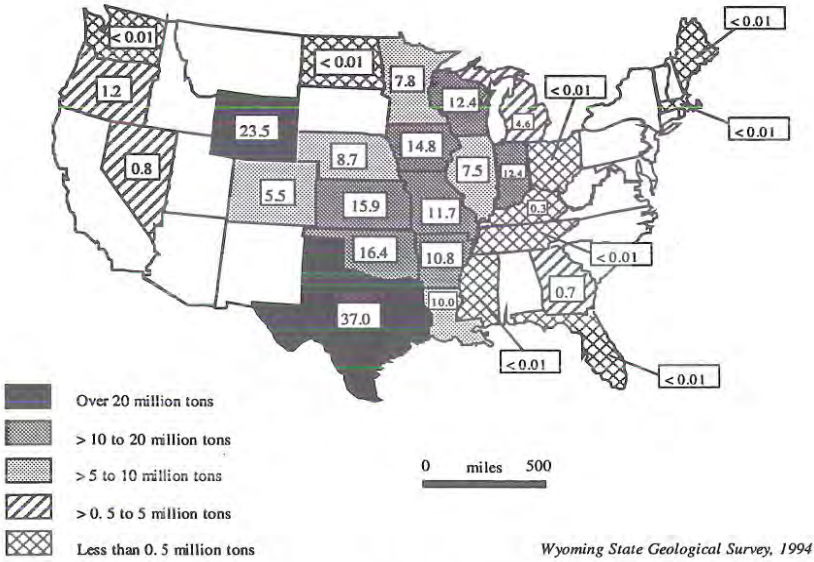


Figure 20. Monthly coal deliveries from Wyoming (1992 through July, 1994). (A) Coal sold on the spot market and (B) coal sold on contract. (From COALDAT Marketing Report by Resource Data International, Inc. compiled from the FERC Form 423 filed monthly by electric utilities).

Table 7. Coal production from Wyoming in millions of tons with forecast to 1998.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994*	1995*	1996*	1997*	1998*
Campbell County	113.9	111.0	122.3	135.7	143.8	154.7	164.9	159.6	181.9	203.7	212.8	222.3	232.2	242.6
Converse County	3.6	4.8	5.1	5.7	6.1	7.9	8.2	8.5	10.2	11.4	11.9	12.5	13.01	13.6
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	0.15	0.2
Carbon County	3.3	1.5	2.2	4.1	4.3	4.5	4.7	4.1	4.4	4.9	5.2	5.4	5.63	5.9
Sweetwater County	13.2	12.9	11.8	12.2	12.0	11.9	11.4	12.6	9.2	10.3	10.7	11.2	11.73	12.3
Lincoln County	4.3	4.0	3.8	4.9	4.8	4.7	4.4	4.6	4.1	4.6	4.8	5.0	5.19	5.4
Hot Springs County	M	M	M	M	M	M	0.1	0.1	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	235.0	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%	12.0%	4.5%	4.5%	4.5%	4.5%
Low-priced coal[1]	6%	7%	8%	10%	20%	25%	33%	35%	47%	54%	58%	60%	62%	65%

*Forecast by Wyoming State Geological Survey, October, 1994. [1]Estimated percentage of total production that was 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).



Figue 21. Distribution of Wyoming coal sales in 1993 in millions of tons. (Data from Energy Information Administration, 1994).

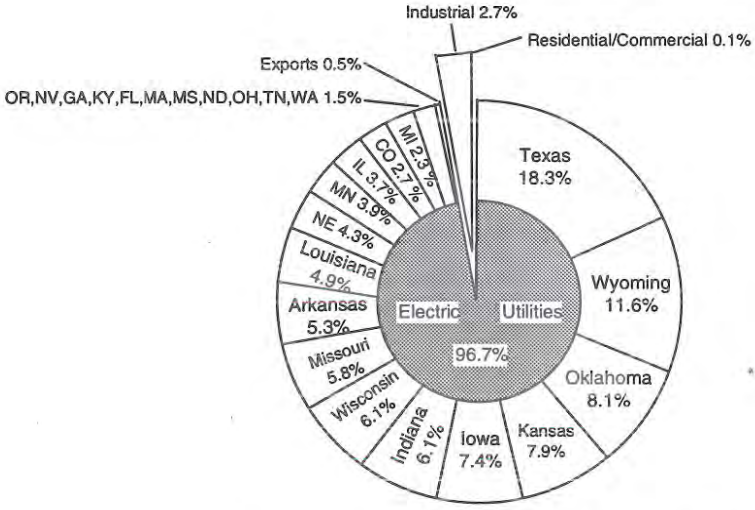


Figure 22. Utilization of Wyoming coal in 1993 in percent. (Data from Energy Information Administration, 1994). Industrial, residential, and commercial usages are not broken down by their destination.

Contracts

New coal contracts, test burns, solicitations, and spot sales for the third quarter of 1994 are summarized in **Table 8** and located on **Figure 23**. Bids on Grand Island [Nebraska] Electric Department's open freight on board (FOB) solicitation suggest that prices may be rising somewhat in the Powder River Basin. The solicitation was for one million tons of contract coal, supplied through 1997. FOB mine offers were:

Exxon Coal USA (Caballo mine):	$4.34/ton
Peabody COALSALES (Rochelle mine):	$5.05/ton
ARCO COAL (Coal Creek mine):	$3.80/ton
Kennecott Energy (Cordero mine):	$4.15/ton
Caballo Rojo, Inc. (Caballo Rojo mine):	$4.05/ton

Grand Island's expiring contract with Cordero is for $3.50/ton ($11.30/ton delivered).

Two contracts of interest both involve a long dormant mine in the Powder River Basin, the North Rochelle mine (**Table 8**). North Rochelle will supply 1.8 million tons to the Dave Johnston power plant and another 1.5 million tons to the Hugo plant over 15 years.

Other significant contracts in the third quarter were the 2.4-million-ton and the 1.8-million-ton contracts signed by the Jacobs Ranch and Belle Ayr mines, respectively. Both contracts will supply the Scherer plant in Georgia and each run through 1997.

Coalbed methane

The U.S. Bureau of Land Management announced it will expedite its Environmental Assessment for American Oil and Gas Corporation's Lighthouse Project. American Oil and Gas Corporation, a Denver based company, plans to drill as many as 200 new coalbed-methane wells into the thick Wyodak coal bed, south of Gillette. The 200-square-mile area of the project is located just north of Reno Junction (All or parts of Ts44-47N, Rs71-73W).

Martens and Peck, a Denver-based operator, has permitted five coalbed-methane wells into the Wyodak coal bed on two different leases, 409 and 650 acres, respectively. The leases are 17-18 miles south of Gillette in sections 14 and 24, T47N, R72W. The holes will be 600-650 feet deep on both leases.

Reference cited

Energy Information Administration, 1994, Quarterly coal report, October-December 1993: U.S. Department of Energy Report DOE/EIA-0121 (93/4Q), Washington, D.C., 154 p.

Table 8. Activities involving coal producers in Wyoming during the third quarter of 1994[1]. [Figure 23 shows locations of the listed power plants].

	Utility	Power Plant	Coal Mine/Region	Activity	Tonnage	Comments
1.	Central & South West Services	various plants[2]	Powder River Basin coal	So	1,500,000 t	N.D.
2.	Detroit Edison	Monroe	Rochelle	C	750,000 t	N.D.
		River Rouge				
		St. Clair				
3.	Georgia Power[3]	Scherer	Jacobs Ranch	C	2,400,000 t	Term through Dec. 31, 1997.
			Belle Ayr	C	1,800,000 t	Term through Dec. 31, 1997.
4.	Grand Island (NE) Electric Dept.	Platte	Powder River Basin coal	So	1,000,000 t	N.D.
5.	IES Industries	Burlington/Ottumwa	Rawhide	C	1,500,000 t	N.D.
		Sutherland	Coal Creek	C	400,000 t	N.D.
		Burlington	Fort Union	C	225,000 t	N.D.
		Ottumwa	Buckskin	C	300,000-400,000 t	N.D.
		Prairie Creek	Caballo Rojo	C	850,000 t	N.D.
6.	Lansing (MI) Board of Water & Light	Eckert	Antelope	T	1,800 t	N.D.
7.	Lower Colorado River Authority	Fayette Power Project Units 1 & 2	Powder River Basin coal	So	1,500,000 t	N.D.
8.	Midwest Powers System	Neal Station Units 1 & 2	Hanna Basin coal	So	600,000 t	N.D.
		Neal North	Jacob's Ranch	C	850,000 t	N.D.

Table 8. Activities involving coal producers in Wyoming during the third quarter of 1994 *(continued)* [1].

	Utility	Power Plant	Coal Mine/Region	Activity	Tonnage	Comments
9.	Montana Power	Colstrip Units 3 & 4	Powder River Basin coal	So	750,000 t	N.D.
10.	Northern Indiana Public Service Co. (NIPSCO)	Michigan City	Belle Ayr	Sp	96,000 t	August & October.
				C	48,000 t	September.
			Shoshone	C	230,000 t	August-October.
		Dean H. Mitchell	Cordero	C	72,000 t	August & October.
				Sp	72,000 t	September.
		Schahfer	Black Thunder	C	444,000 t	August-October.
			Shoshone	C	103,000 t	August-October.
		Bailly	Cordero	C	12,000 t	September.
11.	PacifiCorp	Jim Bridger	Black Butte	Sp	1,000,000 t	Up to one million tons.
		Dave Johnston	North Rochelle	C	1,800,000 t	N.D.
12.	Portland General Electric (PGE)	Boardman		So	650,000 t	First half delivery.
				So	1,200,000 t	Second half delivery.
13.	Southern Indiana Gas & Electric[4]	Warrick	low sulfur coal	So	500,000 t	Part of Phase I compliance program.
14.	Western Farmers Electric Cooperative	Hugo	North Rochelle	C	1,500,000 t	15-year contract.
15.	Wisconsin Public Service Corp. (WIPSCO)	Pulliam and Westin No. 1 & 2	Rochelle/North Antelope	Sp	300,000 t	N.D.

[1] Data obtained from : Coal Week, trade journals, periodicals, FERC database, and personal contacts.
[2] This solicitation is for: West Texas Utilities' Oklaunion plant, Central Power & Light's Coleto Creek plant, Southwestern Electric Power's Flint Creek and Welsh plants, and Public Service of Oklahoma's Northeastern plant.
[3] This power plant is jointly owned by Georgia Power and six other utilities.
[4] This solicitation is for the 50% interest that Alcoa Generating Corp. owns in the Warrick power plant.
N.D. =no other data available; C =contract coal; T =Test burn; Sp =Spot coal; So =solicitation; t =short ton; t/y =short tons per year.

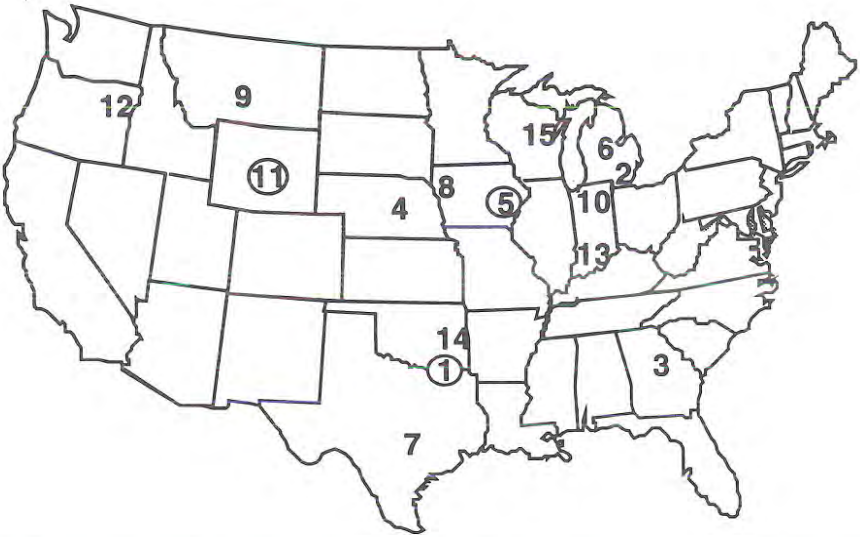


Figure 23. Coal marketing activities related to Wyoming in the third quarter of 1994. [Numbers correspond to those in Table 8; circled numbers denote more than one plant in an area].

INDUSTRIAL MINERALS AND URANIUM UPDATE

by Ray E. Harris
Staff Geologist - Industrial Minerals and Uranium, Wyoming State Geological Survey

The production histories (1920 to the present) of all industrial mineral commodities produced in Wyoming are available in spreadsheet and graphic form from the Industrial Minerals and Uranium Section of the Wyoming State Geological Survey. Also available are recent price histories for selected commodities, in current dollars. Spreadsheets and graphs were prepared from the best available production data, including the former Wyoming State Board of Equalization, the Wyoming Ad Valorem Tax Division of the Wyoming Department of Revenue, the Wyoming State Inspector of Mines, the U.S. Bureau of Mines, the U.S. Atomic Energy Commission (now the U.S. Department of Energy), as well as individual company data. The production history for chemical-grade limestone is included in this issue of *Wyoming Geo-notes*. The production and price histories for bentonite, gypsum, phosphate, sodium sulfate, and trona have already been presented in previous issues of *Wyoming Geo-notes*. The production histories for common clay, shale, cement rock, decorative aggregate, decorative stone, feldspar, graphite, leonardite, silica sand, sulfur, and vermiculite will be included in future issues.

Bentonite

The production of Wyoming bentonite, an expandable and absorbent clay mineral, is increasing. The 1993 production of bentonite was more than 2.5 million short tons, the most since 1985. Although bentonite is also mined in Montana, South Dakota, and Mississippi, Wyoming produces more bentonite than all of these three put together.

In late September, The Bentonite Corporation announced its reopening of a closed plant near Lovell, and a company new to Wyoming, E.T. Ventures, in partnership with Wyo-Ben, will reopen the bentonite plant at Lucerne, north of Thermopolis. These plants will join existing plants in Upton, Casper, Lovell, Greybull, Worland, and three at Colony in northeastern Crook County. Bentonite is mined at several locations in Crook, Weston, Johnson, Natrona, Big Horn, and Washakie Counties. Mined bentonite is dried and blended into specialty products at the plants. The plant at Lucerne will manufacture an absorbent bentonite product for use in cleaning up contaminated sites.

Most bentonite produced before 1991 went into drilling mud, which is used to lubricate and cool the drill bit and to carry broken rock fragments (called cuttings) up and out of a drill hole. The recent increase in production has been due to the wider use of bentonite in other applications, particularly as a binder in foundry castings and as a sealant in containments, such as landfills, waste treatment sites, and equipment maintenance yards. Other current uses of bentonite include kitty litter, mineral fillers, and sealants.

Because of the increasing demand for this unique Wyoming mineral, the Wyoming State Geological Survey is predicting an increase in production in 1994 to 2.75 million tons, the highest since 1984. When the reopened Lovell and Lucerne plants reach full production, the production of bentonite in 1995 could exceed three million tons.

Construction aggregate

The production of construction aggregate in Wyoming is increasing. Chicago North Western Railroad's ballast quarry located at Bald Butte, south of Lusk (**Figure 24**), has been reopened, and the Guernsey Stone Division of Peter Kiewit, Inc. has experienced an increase in demand for their dolomitic aggregate, particularly for highway construction in Nebraska. Guernsey Stone's aggregate is also used in the reconstruction of Wyoming Highway 59 between Douglas and Gillette. Despite this growth, Meridian Aggregates, west of Cheyenne in Laramie County, remains the largest producer of construction aggregate in Wyoming.

In aggregate-rich Teton County, aggregate operators have received a favorable legal decision. The Wyoming Attorney General's Office has ruled that Teton County has no right to deny mining operations once the State has issued

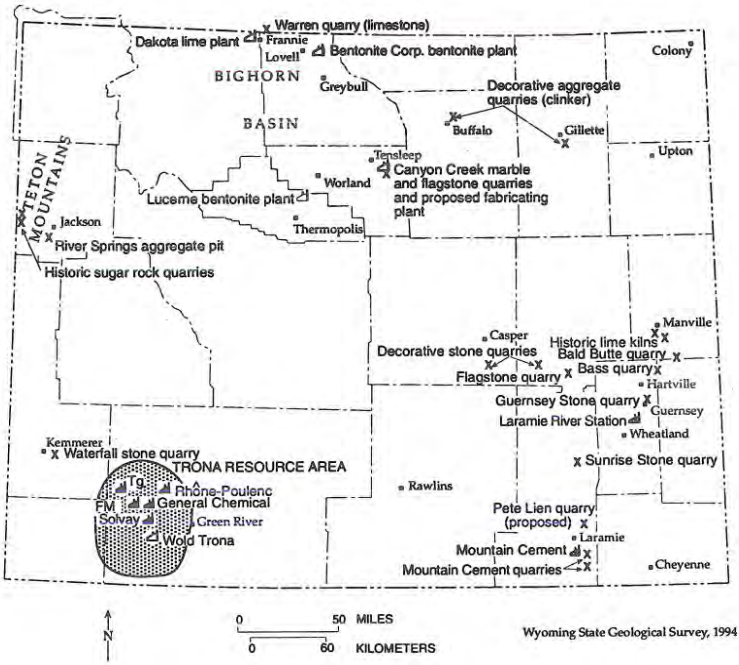


Figure 24. Industrial minerals activities in Wyoming during the thrid quarter of 1994.

a mining permit. Teton County has large resources of construction aggregate, but most of these resources are on land designated by Federal or other governmental administrative rules as off-limits to production.

Decorative aggregate and stone

Decorative aggregate is produced by Colorado Aggregates from a pegmatite on Casper Mountain, in Natrona County; from clinker (baked and fused shale) near Gillette in Campbell County and near Buffalo in Johnson County; from marble by Guernsey Stone in Platte County; and from river rock in Platte and Goshen Counties. Occasionally, decorative green serpentine aggregate is quarried in Converse County. This year, flagstone was quarried south of Douglas in Converse County and southeast of Tensleep in Washakie County. Landscape boulders were obtained from a source in Platte County (see *Wyoming Geo-notes No. 43*, p. 33), and moss rock was obtained from locations in Albany, Converse, Platte, and Washakie Counties. Decorative granite is quarried from the Wyoming Raven-Fantastico quarry in Albany County and manufactured into dimensional stone products at Sunrise Stone's fabricating plant in Platte County.

Although decorative stone is already produced at several different sites in Wyoming, seven companies examined other decorative stone quarry sites in Wyoming during the third quarter of 1994. The examined sites included granites, marbles, sandstones, and limestones as well as some flagstone and landscape rock sources. The primary areas of interest were in Albany, Big Horn, Carbon, Converse, Goshen, Natrona, Niobrara, Platte, and Washakie Counties. Rocky Mountain Stone, which produces dimensional stone products at a fabricating operation near Longmont, Colorado, has expressed interest in locating dimensional limestone in Wyoming to augment or replace its current source of Indiana limestone.

The City Hall in Portland, Oregon, is faced with sandstone blocks. Some of these are weakening due to weathering. The original source of the stone was a small quarry in a Cretaceous sandstone near Waterfall, Wyoming. This quarry was operated by the Union Pacific Railroad around the turn of the last century. There is a possibility that the original quarry, or a nearby source of the same material, could supply the blocks needed to repair the Portland City Hall. Waterfall is a siding on the Oregon Short Line of the Union Pacific Railroad just east of Kemmerer, in Lincoln County.

Canyon Creek Stone has begun the permitting process for a marble fabricating plant southeast of Tensleep. The plant would produce a variety of marble products from nearby quarries including blocks, flagstone, and ashlar. The marble at this site is chocolate brown to pink and varies from uniform color to mottled to wood-grained. Canyon Creek Stone has also located multicolored travertine on its property and is conducting exploratory work on this rock product.

Limestone (chemical-grade)

Limestone is quarried in Wyoming for two unrelated products, construction aggregate and for the production of lime, cement, or other uses. Limestone used for aggregate is selected on the basis of hardness, uniformity, and proximity to the point of use. Chemical-grade limestone on the other hand must meet rigorous chemical tests. Usually, chemical-grade limestone must contain more than 95% calcium carbonate and less than 0.5% silica.

Chemical-grade limestone is used in Wyoming in the manufacture of cement at Laramie, and in the control of power plant emissions at the Laramie River power plant near Wheatland and the Jim Bridger power plant east of Rock Springs. For the cement plant, limestone is quarried just east of the plant site. Limestone for the Jim Bridger power plant is quarried from the Mississippian Madison Limestone north of Rawlins; and limestone from the Mississippian-Devonian Guernsey Limestone is quarried north of Hartville in Platte County for the Laramie River power plant.

In Park County, a plant near Frannie produces lime for the control of emissions. The limestone for this plant is quarried from the Mississippian Madison Limestone at the Warren quarry in Montana. Lime from this plant is shipped to power plants in Wyoming and North Dakota.

Lime was produced in Wyoming before recorded production. Abandoned lime kilns south of Manville, east of Guernsey, and in other locations provide evidence of this early production (**Figure 24**). Beginning in 1920, the State has kept production records (**Figure 25**). These show an increase in use, primarily for sugar beet refining and cement, through the 1920s and even the 1930s. Production declined during WW II, but increased steadily from 1945 to a peak year in 1981. At this time, there were several quarries in Wyoming producing chemical-grade limestone for sugar beet refining, especially in the Hartville uplift, Bighorn Basin, and on the west slope of the Teton Mountains. Beginning in the 1970s and continuing until 1982, some sugar beet refineries in Wyoming closed, and all the limestone used by the remaining plants came from out of state, causing a production decline. Since 1989, the production of chemical-grade limestone has again increased, due to increased production of cement and increased use of lime at the Laramie River and Jim Bridger power plants. Production in 1993 was the second highest on record.

Production of chemical-grade limestone should increase in the future, though probably not steadily. There are plans for a chemical-grade limestone quarry west of Cheyenne to supply cement plants and other construction-related demand in northern Colorado. The lime plant at Frannie has been looking for a source of limestone in Wyoming. The soda ash refineries near Green River use lime in some applications, and have been looking for a Wyoming source. They currently purchase lime from other states, particularly from the Wasatch Front area in Utah. The plans to construct a lime plant north of Laramie are based on this future need, though the plans themselves are currently on hold. Recently, Pete Lien, of Rapid City, South Dakota, acquired the Hartville limestone quarry, once used to supply limestone for sugar beet refining. Sugar beet refineries in western Nebraska, which now get their limestone from Montana, periodically look for a closer source, which could be the Hartville uplift and Laramie Mountains of southeastern Wyoming. The sugar beet refinery in Torrington, which now gets its limestone from Pringle, South Dakota, has also looked for a Wyoming source.

Trona

Natural trona is mined in Wyoming from five underground operations west of Green River, and at an in-situ recovery operation at one of the locations. The trona is refined into soda ash and other sodium compounds at the refinery complexes associated with the mines (**Figure 24**). *Wyoming Geo-notes No. 41* provides a historical summary of trona production and prices.

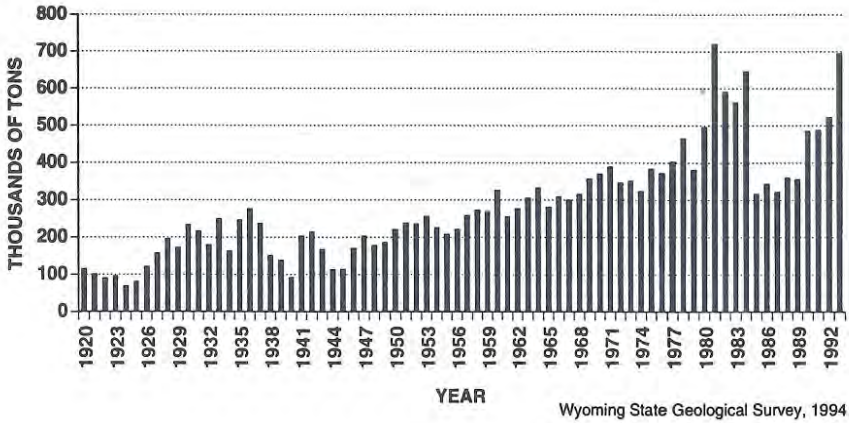


Figure 25. Historical production of chemical-grade limestone in Wyoming (1920-present).

Plans for a sixth trona mine and refining plant continue. Wold Trona can use the "fast track" method of permitting, according to the Wyoming Industrial Siting Council (ISC). This will allow Wold to begin construction, and eventual production, sooner. One of the existing five producers has protested the ISC's ruling, however, noting that the other producers had not been allowed to use the "fast track" process. In August, the U.S. Bureau of Land Management (BLM) approved Wold's mining plan.

The BLM has also announced a competitive lease sale for trona. This would be the first sale since 1986. The BLM has proposed the lease of about 13,000 acres in the trona resource area. The exact reserves of trona have not yet been calculated. The BLM is also studying a possible increase in royalties paid to the BLM from trona extraction.

According to the U.S. Bureau of Mines, exports of soda ash to Pacific Rim countries have increased, while exports to Europe have decreased from about 175,000 short tons during the first quarter of 1991 to 45,000 short tons during the second quarter of 1994 (Kostick and Arguelles, 1994). This significant decrease is a result of exclusionary restrictions imposed by European Union countries. There are no indications that exports from Wyoming to Europe will increase in the future.

Uranium

Uranium is produced in Wyoming at three in-situ recovery operations: Comin's Irigary and Christiansen Ranch locations and Power Resources'

Highland-Morton Ranch properties (**Figure 26**). Additionally, Energy Fuels Nuclear, Cameco, and Kennecott continue active exploration and plans for production (**Figure 26**).

Kennecott has come closer to obtaining a mining permit for its proposed Jackpot mine south of Jeffrey City, in Fremont County (**Figure 26**). The disposal of mine water had been an issue between the company and the Wyoming Department of Environmental Quality (DEQ). This issue has been resolved. Kennecott will use the water, which will be pumped from the mine, to create 20 acres of wetlands. According to the DEQ, mining permits could be issued by the end of 1994.

Reference cited

Kostick, D., and Arguelles, M., 1994, Soda ash and sodium sulfate in June, 1994: U.S. Bureau of Mines Mineral Industry Surveys, 6 p.

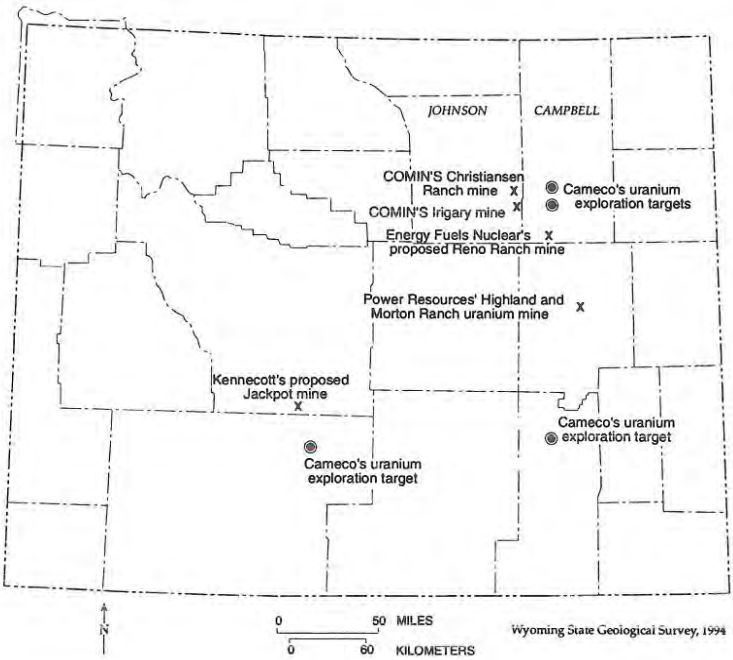


Figure 26. Uranium activities in Wyoming during the third quarter of 1994.

METALS AND PRECIOUS STONES UPDATE

by W. Dan Hausel
Senior Economic Geologist, Wyoming State Geological Survey

Diamond

Exploration for diamond continued at several locations including the Colorado-Wyoming State Line district, the central Laramie Mountains, and the Green River Basin. Some activity was reported in the Colorado-Wyoming State Line district south of Laramie, where approximately 35 kimberlite intrusives are known to occur. Many of these are diamondiferous.

Available production records show that more than 100,000 diamonds have been recovered from the Colorado-Wyoming State Line district. This makes it the principal diamond producing district in the U.S. (Hausel, 1994a).

This production includes: (1) several hundred diamonds that weighed less than 0.1 carat to a 14.2-carat gemstone from the Kelsey Lake kimberlites; (2) 86,000 diamonds from the George Creek intrusives; (3) more than 21,500 diamonds that varied in size from microdiamonds to a 5.51-carat gemstone from the Sloan 1 and 2 kimberlites; (4) several diamonds that varied from microdiamonds to a 2.6-carat industrial-grade stone from the Chicken Park kimberlites; and (5) dozens of diamonds that varied in size from microdiamonds to a 0.86 carat gemstone from the Shaffer and Aultman pipes. Recent activity in the district, according to the Northern Miner (9/26/94) indicates that Royalstar extracted a 3,000-tonne bulk sample from the Sloan 2 pipe. The results are expected shortly.

North of the State Line district, exploration is continuing in search of the source of nearly 300 kimberlitic heavy mineral anomalies identified over a 1,200-square-mile area in the Laramie Mountains (Hausel and others, 1988). Companies are also exploring for the source of hundreds of similar heavy mineral anomalies in the Green River Basin.

South Pass-Atlantic City mining district

Recent drilling activity on the Carissa property near South Pass by Hol-Lac Gold Mines of Canada, was very encouraging (Northern Miner, 9/26/94). Drill hole 94-1 reached a depth of 667 feet and intersected three mineralized zones. One zone averaged 1.09 ounce per ton (opt) Au over 24 feet and included a 4-foot zone that averaged 5.27 opt Au. The other two zones averaged 0.09 opt Au over 6 feet and 0.02 opt Au over 13.8 feet. Hole 94-2 reached a depth below 400 feet and intersected a 15-foot wide zone that average 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.

The Carissa mine was one of Wyoming's principal historic lode gold producers. According to various sources, the property yielded 50,000 to 180,000 ounces of gold (Hausel, 1991). Gold at the mine occurs in a shear zone that is more than 100 feet wide at the surface. The mine workings are located on five levels. The lowest level is 400 feet below the collar of the shaft.

Elsewhere in the district, Groundhog Mining Company from Gillette, Wyoming, reopened the Duncan adit to explore the historic mine workings located two miles northeast of the Carissa mine. Gold in the Duncan mine is shear controlled with high-grade, steeply-plunging, ore shoots localized in fold closures. One two-foot channel sample collected in an ore shoot by the Wyoming State Geological Survey yielded 33.0 parts per million (ppm) or 0.96 opt gold and 6.0 ppm (0.17 opt) silver (Hausel, 1991). Other activity in the district included exploration by a major mining firm. No specifics are available.

Silver Crown mining district

Exploration by Compass Minerals Exploration of Reno, Nevada, continued at the Copper King mine in the Silver Crown district in southeastern Wyoming. The company continued drilling the low-grade disseminated copper-gold deposit to determine the extent of the mineralization as well as the minable reserves. Earlier projects indicated that the Copper King deposit is a large-tonnage, low-grade, porphyry hosted by granodiorite and quartz monzonite (Hausel, 1989).

These earlier projects indicated the deposit contained 35 million tons of ore at an average grade of 0.22% copper and 0.02 opt gold. Spectrographic analyses also show traces of lead, zinc, tungsten, and 0.5 to 3.0% titanium. Later drilling in 1987, by Caledonia Resources Ltd. of Canada, established preliminary reserves which included a small, higher grade zone of 4.5 million tons of ore averaging 0.044 opt gold.

Geochemical and geophysical anomalies also suggest that the known resource may be underestimated. For example, a large magnetic anomaly (1,000 feet wide x 2,000 feet long, with a 450 gamma magnitude) almost identical to that measured over the Copper King deposit, was identified in a gravel covered area 4,500 feet to the southeast. Soil samples over this anomaly yielded anomalous values for the pathfinder elements mercury, zinc, and arsenic. Geological and geophysical evidence also suggests the presence of sulfides down plunge to the southwest and to the east of the main Copper King deposit. An induced polarization survey identified a moderate to shallow metal factor anomaly trending east-northeast of the principal mineralized area.

Encampment mining district

The Wyoming State Geological Survey recently examined a region surrounding the historic Charter Oak mine in the Encampment district of the Sierra

Madre. According to some early reports, the Charter Oak vein contained chalcopyrite, chalcocite, bornite, and azurite in a gangue of quartz, jasperoid, schistose wall rock, calcite, and some chalcedony. Some high-grade gold ore was also reported on the property (Beeler, 1905).

The mineralized rock was reportedly traced 2 miles on the surface and varied in width from 14 feet at the Charter Oak shaft to 100 feet elsewhere. Recent examination of the area shows that the Charter Oak and other mines occur within a layered mafic complex. In addition to the mineralization at the Charter Oak, scattered gossans in the layered complex suggest that the mineralization is widespread, but probably erratic.

Elsewhere in the district, Compass Minerals was exploring some other copper deposits. Exploration was reported at the Kurtz-Chatterton mine. The Kurtz-Chatterton is a moderate size copper-gold-silver deposit.

This mine was one of the three most productive mines in the historic Encampment district. Widespread copper mineralization was found in veins and shears in Sierra Madre granite. The property reportedly contained five distinct veins varying in width from 18 to 44 feet. The ore consisted of chalcocite and chalcopyrite (Spencer, 1904).

Locally, the granite exhibits potassic alteration. Reconnaissance of the property in 1991 by the Wyoming State Geological Survey identified mineralization extending over a strike length of 4,000 feet. The mineralized zone swelled from a relatively narrow zone to possibly 800 feet wide. Samples collected on the property varied from 0.0 to 28.10 ppm Au, 0.0 to 7.24 ppm Ag, 4.0 ppm to 12.55% Cu, 0.0 to 0.8% TiO_2, and trace amounts of lead and zinc.

Seminoe mining district

A report summarizing a two-year study of the Seminoe Mountains north of Sinclair in southeastern Wyoming has been published by the Wyoming State Geological Survey (Hausel, 1994b). This study indicates there are some very unique volcanic rocks there and that they are some of the oldest rocks in the U.S. Many of these volcanic rocks are at least 2.7 billion years old. These old, unique volcanic rocks are komatiites. Komatiites were named after a location along the Komati River in South Africa, only 30 years ago. These rocks exhibit a distinctive rock texture termed spinifex, which looks like blades of *Spinifex* grass found at the type locality along the Komati River. In Australia, these types of rocks have been important sources of commercial nickel deposits.

In addition to mapping the ancient rocks of the Seminoe Mountains, the State Geological Survey also investigated the mineral resources and mining history of this old gold mining district. Gold was discovered in the area in 1871 following an expedition by troops under the command of General Bradley of Fort

Sanders. During the following 20 years, development of the district was greatly hampered by hostilities between the miners and Indians, litigation, and poor mine management. Although production records are nonexistent, production probably amounted to less than 3,000 ounces of gold.

Samples collected during this study included several rocks with anomalous metal contents varying from a trace to 2.6 ounces of gold per ton with some silver, copper, lead, and zinc. One large zone of propylitically altered rock along the western margin of the district yielded several samples containing anomalous gold. This zone is considered a potential target for commercial gold mineralization.

Large deposits of iron also occur in the Seminoe Mountains. These low-grade deposits are similar to the iron ore mined at South Pass in the 1960s and 1970s. One estimate suggests there is at least 100 million tons of iron ore located in the district. Other examined resources included jade and other lapidary stones. The study also identified some minerals commonly found in association with diamond deposits.

International mining conference

At the end of September, the author attended and presented two invited papers at an international conference held at Lake Tahoe, Nevada. The conference, which featured ore deposits, was attended by delegates from 25 different countries.

The first paper, entitled, *Diamonds, kimberlites, lamproites, and related rocks in the United States*, described hundreds of secondary diamond occurrences and their potential host rocks from the Pacific Coast to the East Coast. The paper indicated that dozens of diamonds have been found in the Appalachian Mountains, 600 diamonds have been found in California, more than 90,000 diamonds have been produced in Arkansas, and more than 100,000 diamonds have been produced from the Colorado-Wyoming State Line district. The conclusions presented in the paper support a high potential for the discovery of a commercial diamond deposit in the Colorado-Wyoming region.

The second paper, co-authored with Paul Spry of Iowa State University, was entitled, *Archean greenstone belt mineralization within the Wyoming Province*. This paper described the characteristics of gold mineralization in several of Wyoming's mining districts. In particular, the paper emphasized three areas in the State that have high potential for commercial gold mineralization. These are the South Pass, the Seminoe Mountains, and the Rattlesnake Hills districts.

The conference, *Mineral Exploration '94*, was sponsored by the University of Exeter's Camborne School of Mines, Cornwall, England. Papers presented at the conference will be published in the *International Journal of Exploration and Mining Geology*.

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MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING

PETROLEUM

Remaining Resources (January 1, 1994)		
Discovered (Includes 10 billion barrels recoverable by enhanced recovery techniques)	12.4	billion barrels[1]
Undiscovered	7.6	billion barrels[1]
Total	20.0	billion barrels
Remaining Reserve Base (January 1, 1994)		
Measured reserves (Proved reserves) (Includes oil, gas liquids, and condensate)	1.12	billion barrels[2]
Indicated and inferred reserves	2.80	billion barrels[1]
Total	3.92	billion barrels

NATURAL GAS

Remaining Resources (January 1, 1994)		
Discovered (Includes 20.1 trillion cubic feet (TCF) of methane[1] and 122.0 TCF of CO_2[3])	140.0	trillion cubic feet
Undiscovered (Includes 58 TCF of conventional methane[1]; 7 TCF of coalbed methane[4]; 3,611 TCF of methane in tight gas sands in the Green River Basin[5]; and 31.2 TCF of CO_2[3])	3,707.2	trillion cubic feet
Total	3,847.2	trillion cubic feet
Remaining Reserve Base (January 1, 1994)		
Measured reserves (Proved reserves) (Includes 10.9 TCF of methane[2] and 60.4 TCF of CO_2[3])	71.3	trillion cubic feet

COAL

Remaining Resources (January 1, 1994)		
Identified and Hypothetical (Discovered)	1,428.0	billion tons[6]
Speculative (Undiscovered)	31.5	billion tons[6]
Total	1,459.5	billion tons
Remaining Reserve Base (January 1, 1994)		
Demonstrated strippable (Measured and indicated reserve base)	26.4	billion tons[7]
Demonstrated underground-minable (Measured and indicated reserve base)	42.5	billion tons[7]
Total	68.9	billion tons

TRONA

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

URANIUM

Remaining Resource (December 31, 1989)	1.99	billion pounds U_3O_8[9]
Remaining Reserve Base (December 31, 1989)		
Uranium oxide recoverable at $30.00 per pound	66	million pounds[9]

OIL SHALE

Original Resources (January 1, 1981)		
Identified (Discovered)	320	billion barrels of shale oil[10]

[1] Modified from Barlow, J.A., Jr. and Doelger, M.J., 1983, Wyoming mineral resources: Barlow and Haun, Inc., Casper, 14 p.
[2] Modified from Energy Information Administration, 1994, U.S. crude oil, natural gas, and natural gas liquids reserves: 1993 Annual Report, Advance Summary, August, 11 p.
[3] De Bruin, R.H., 1991, Geological Survey of Wyoming Open File Report 91-6, 20 p.
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[5] Law, B.E., and others, 1989, Estimates of gas resources in overpressured low-permeability Cretaceous and Tertiary sandstone reservoirs, Greater Green River Basin, Wyoming, Colorado, and Utah: Wyoming Geological Association, 40th Annual Field Conference Guidebook, Casper, Wyoming p. 39-61.
[6] Modified from Wood, G.H., Jr. and Bour W.V., III, 1988, Coal map of North America: U.S. Geological Survey Special Geologic Map, 1:5,000,000-scale (color) and 44 p. pamphlet.
[7] Modified from Jones, R.W., and Glass, G.B., 1992, Demonstrated reserve base of coal in Wyoming as of January 1, 1991: Geological Survey of Wyoming, Open File Report 92-4, 26 p.
[8] Modified from Culbertson, W.C., 1983, Genesis and distribution of trona deposits in Wyoming (abstract) in Genesis and exploration of metallic and nonmetallic mineral and ore deposits of Wyoming and adjacent areas: Geological Survey of Wyoming Public Information Circular 19, p. 34.
[9] Energy Information Administration, 1989, Uranium industry annual: U.S. Department of Energy Report DOE/EIA-0478(89), 121 p.
[10] Knutson, C.F., and Dana, G.F., 1982, Developments in oil shale in 1981: American Association of Petroleum Geologists Bulletin, Volume 66, no. 11, p. 2513.

GEOLOGIC MAPPING AND STRATIGRAPHY

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

POSSIBLE NEW OCCURRENCES OF OLIGOCENE ROCKS

The Wyoming State Geological Survey has identified what appears to be outcrops of Oligocene rocks on the southeastern flank of the Laramie Basin. These outcrops were found east of Soldier Spring and in Gilmore, Dry, and Sawmill Gulchs (**Figure 27**). Previously, no Oligocene rocks had been mapped on the east flanks of the basin.

The outcrop east of Soldier Spring is 20-30 feet thick and includes white to light pink tuffaceous claystone, characteristic of the White River Formation of Oligocene age. The outcrops in Gilmore, Dry, and Sawmill Gulchs are up to more than 100 feet in thickness and are composed of unconsolidated silt and sand with gravel and cobble lenses. The gravel and cobbles include limestone and sandstone eroded from nearby Paleozoic rocks, as well as, igneous and

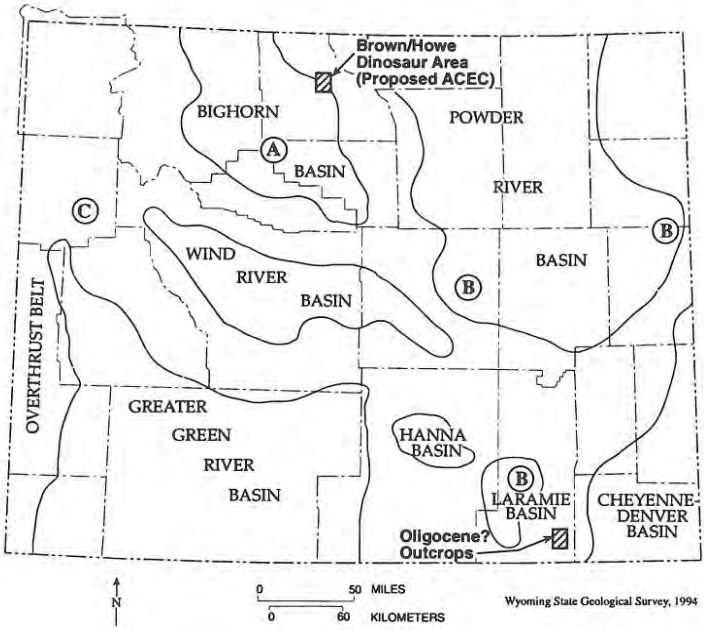

Figure 27. Index to selected geologic activities and recently released maps and reports on Wyoming geology.

metamorphic rocks derived from the Precambrian. During Oligocene time, these latter deposits filled paleo-drainages cut into Paleozoic rocks on the flanks of the Laramie Mountains. The paleo-drainages resulted from the Laramide uplift of the range during the Paleocene and Eocene.

Additional work is needed to definitely establish the age of these deposits and additional deposits may be located as a result of continued mapping in the area. This work is part of a mapping effort in the Laramie area cooperatively funded by the Wyoming State Geological Survey and the U.S. Geological Survey through the STATEMAP program. During the 1995 field season, additional mapping is planned in the southern part of the Laramie Basin.

PALEONTOLOGICAL DEVELOPMENTS

The U.S. Bureau of Land Management (BLM) recently announced its intent to designate a 5,457-acre area of Federal land north of Shell, Wyoming, (**Figure 27**) as an Area of Critical Environmental Concern (ACEC). In addition, 121 acres of the area, known to have the highest fossil concentration, would be withdrawn from mineral and land-law location.

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 (See *Wyoming Geo-notes No. 41*, p. 45-46). This is also the area where the allosaurus "Big Al" was discovered in 1991 (See *Wyoming Geo-notes No. 32*, p. 40-41).

The BLM has issued an Environmental Assessment (EA) describing four alternatives for managing this area, including its preferred alternative outlined above. There is a 30-day public comment period for the document.

In a related note, a Wyoming dinosaur directory has recently been published. The directory, compiled by Brent Breithaupt of the University of Wyoming's Geological Museum and Jerry Nelson of Casper College's Tate Museum, lists museums in the State that have dinosaur exhibits. Museum addresses, phone numbers, hours, and contact persons are included. The directory was dedicated to Brent Breithaupt, who has long been a proponent of the State's paleontological resources.

Copies of the directory can be obtained by writing Brent Breithaupt, UW Geological Museum, P.O. Box 3006, University Station, Laramie, Wyoming 82071 or calling 307-766-2646.

NEW STRATIGRAPHIC AND PALEONTOLOGIC REPORTS

The U.S. Geological Survey recently released three significant new reports on the stratigraphy and paleontology of Wyoming. In one, Love (1994) introduces a new formational name (Leidy Formation) for some Pleistocene rocks in northwestern Wyoming. The other two reports refer to new ammonite descriptions for the Western Interior Upper Cretaceous including the State of Wyoming (Cobban and Kennedy, 1993), and a discussion of Tertiary mammal and plant localities in the southern Bighorn Basin (Bown and others, 1994), respectively.

Each of these reports is listed below and the study area is located on the accompanying index map (**Figure 27**).

A. Bown, T.M., Rose, K.D., Simons, E.L., and Wing, S.L., 1994, Distribution and stratigraphic correlation of Upper Paleocene fossil mammal and plant localities of the Fort Union, Willwood, and Tatman Formations, southern Bighorn Basin, Wyoming: U.S. Geological Survey Professional Paper 1540, 103 p.

B. Cobban, W.A., and Kennedy, W.J., 1993, The Upper Cretaceous dimorphic pachydiscid ammonite *Menuites* in the Western Interior of the United States: U.S. Geological Survey Professional Paper 1533, 14 p.

C. Love, J.D., 1994, Leidy Formation-new name for a Pleistocene glacio-fluviatile-lacustrine sequence in northwestern Wyoming: U.S. Geological Survey Professional Paper 932-D, 13 p.

GEOLOGIC HAZARDS IN WYOMING

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

EARTHQUAKES IN YELLOWSTONE NATIONAL PARK

On September 24, 1994, a magnitude 3.6 earthquake occurred in Yellowstone National Park. The earthquake, which had an epicenter near Canyon Village, was felt throughout the eastern and central portions of the Park. Park visitors at Artists Point fled in panic, according to personnel at the University of Utah's seismograph stations. In early October, Park officials reported that the earthquake changed the eruption schedule of the Fireball Geyser in the Norris Geyser Basin. Similar changes in the Park took place earlier this year, following a magnitude 3.8 earthquake near Norris Geyser Basin on March 26, 1994. Following that earthquake, Ledge Geyser, which had not erupted in fifteen years, erupted two or three times.

The magnitude 3.6 and 3.8 earthquakes are the largest recorded in the Park so far this year. There have been numerous smaller earthquakes, however, that were not felt by anyone in the Park. In fact, these smaller earthquakes occur every week in the Park. Seismic stations operated by the University of Utah, and funded by the U.S. Geological Survey, record nearly all of the earthquakes that occur in the Park. From January 1, 1994, through September 24, 1994, the date of the most recently felt earthquake, the University of Utah recorded approximately 540 earthquakes with magnitudes varying from less than 1.0 to over 3.8. Only a few of those earthquakes were felt, however. Of the 540 earthquakes recorded, most were located near Hebgen Lake-West Yellowstone, Norris Junction, Canyon Junction, Fishing Bridge, West Thumb, between Old Faithful and Madison Junction, and northeast of the south entrance to the Park.

Historically, over 1,000 earthquakes have been reported as being felt in Yellowstone National Park. The first reported earthquake that was felt in the Park occurred in 1871 near Yellowstone Lake. In 1893, a series of earthquakes resulted in some significant changes in geyser activity, especially at the Giant, Giantess, and Great Castle Geysers. Near Norris Geyser Basin, the earthquakes left a huge gap in the earth, about 75 feet wide and several hundred feet long (See *Wyoming Geo-notes No. 40*, p. 48).

In 1959, a magnitude 7.5 earthquake, with an epicenter near Hebgen Lake in Montana, resulted in loss of life and significant damage in the area around Yellowstone National Park. There were aftershocks in the magnitude 6.0-6.5 range that did occur within the Park. More recently, in 1975, a magnitude 6.4 earthquake occurred in the central portions of the Park. Landslides triggered by

that earthquake closed twelve miles of road between Norris Junction and Madison Junction for almost a day.

Earthquakes will continue to occur in Yellowstone National Park as well as the rest of Wyoming. Outside of California, the Park is one of the most seismically active areas in the conterminous U.S.

REPORTS ON SEMINOE MOUNTAINS AND ORGANIC ROCKS PUBLISHED

The Wyoming State Geological Survey announces publication of two new reports, one on the economic geology of the Seminoe Mountains mining district of Carbon County, and the other a field guide to coal and hydrocarbons in northern Wyoming.

Economic geology of the Seminoe Mountains mining district, Carbon County, Wyoming, by W. Dan Hausel, Report of Investigations 50 (ISBN 1-884589-05-7) sells for $8.00. *Organics and the Rockies-field guide*, edited by R.M. Flores, K.I. Mehring, R.W. Jones, and T.L. Beck, Public Information Circular 33 (ISBN 1-884589-06-5) sells for $15.00. Both these publications are available over-the-counter or by mail from: Wyoming State Geological Survey, P.O. Box 3008 University Station, Laramie, Wyoming 82071-3008. (Wyoming addresses include 6% sales tax; orders not prepaid will be billed for first class postage.)

The Seminoe Mountains area of south-central Wyoming is best known for its iron and gold resources and includes narrow high-grade gold veins, banded iron deposits, gold paleoplacers, serpentinite, jade, and lapidary and decorative stones. According to author W. Dan Hausel, a large tonnage gold deposit may be present in zones of altered rock. The report contains two oversized plates, including a 1:24,000-scale color geologic map.

The field guide was prepared for a recent meeting of The Society for Organic Petrology. It contains road logs for field trips through the Wind River, Bighorn, and Powder River Basins as well as eleven topical papers emphasizing the coal- and hydrocarbon-rich rocks and the local and regional geology. Four of the papers summarize recent research on early Tertiary source rocks and coals that are associated with recent discoveries of oil and gas in the Wind River Basin. Other papers discuss the paleogeography of northcentral Wyoming during the Paleocene epoch, correlation of Paleocene rocks using palynostratigraphy, and stratigraphy of a mined coal deposit in the southwestern Bighorn Basin.

ROCKHOUND'S CORNER

by W. Dan Hausel, *Senior Economic Geologist,*

Jade was discovered along the Sweetwater River in southeastern Fremont County about 1936. In the years since, the mineral has attracted great attention as a gemstone.

The name jade is applied to two distinctly different minerals, jadeite and nephrite, both of which have somewhat similar colors and physical features, such as hardness and toughness. Both will take a high polish to produce gemstones or ornamental stones.

Jadeite is a member of the pyroxene group of minerals and is a sodium-aluminum silicate. Nephrite belongs to the amphibole group of minerals, and is a lime-magnesium-aluminum silicate. All the jade found in Wyoming is nephrite.

Wyoming jade (nephrite) varies in color from light green and translucent to dark green, to black, and opaque. In addition to the color variations, there are differences in quality. Not all specimens will take a high polish. Frequently, the jade contains small dark specks which are softer and leave pits in the polished surfaces. A considerable amount of jade found is of inferior quality because of this feature.

Some jade is found in place in Precambrian rocks. Jade also occurs as boulders in recent alluvial deposits. These jade boulders are derived from Precambrian rocks, but have been eroded and transported by streams and then deposited as conglomerates. Jade also occurs as residual boulders on the interstream divides.

A number of jade deposits are known in the Precambrian rocks, from the Wind River Range in the west to the Laramie Mountains in the east. Most of these deposits are dark green or black nephrite. The jade is commonly associated with the contact between granite and dark mafic or ultramafic rocks.

Float boulders of dark green or black jade have been found over a rather large area along the Sweetwater River between Crook's Creek on the east and the Wind River Range on the west. The average size of the boulders is from six inches to a foot in diameter although many larger boulders have been found.

Boulders of the light green, translucent variety of jade have been found in abundance in only two relatively limited areas. The largest boulder of this type of jade, so far reported, weighed about 3,200 pounds. Because the Precam-

brian source of this light green jade may have been buried by later sediments, the source may never be located.

Black jade deposits have been reported in the vicinity of Kortes Dam in Carbon County, and near Daniel in Sublette County. In the 1970s, a 14,000-pound boulder of black jade was uncovered in the Prospect Mountains area of Sublette County. This is the largest known single occurrence of jade in Wyoming.

Gem quality jade occurs south and east of Lander in an area comprising about 700 square miles. This area has been so thoroughly picked over that today the light green jade of Wyoming is largely depleted. In recent years, however, new finds of dark green and black jade have been reported. Even then, polishing tests must be made to determine the quality of the jade, and a considerable part has been inferior in quality.

In addition, there are two other green rocks, serpentine and green quartzite, which commonly occur in this area and which superficially resemble jade. The abundance of these rocks, coupled with the fact that they are so often mistaken for jade, has given rise to exaggerated stories of the abundance of jade in the area. Truckloads of green serpentine have been transported for miles only to prove worthless. A green quartzite is also found in the area and has frequently been confused with jade.

It is possible, of course, that new areas containing gem quality jade will be found, but the jade-bearing regions have been fairly well prospected. None of the jade collectors depend entirely on collecting and selling jade as a livelihood for any length of time. The average jade hunter simply finds it a pleasant way to spend spare time.

Questions on rockhounding? Send them to Rockhound's Corner, %Wyoming State Geological Survey, P.O. Box 3008, University Station, Laramie, WY 82071.

RECENT AND NEW PUBLICATIONS OF THE WYOMING STATE GEOLOGICAL SURVEY

Geology of Wyoming, edited by A.W. Snoke, J.R. Steidtmann, and S.M. Roberts: Memoir 5, 1993.- $75.00 plus postage and handling. Wyoming addresses include 6% sales tax before adding postage. Add first class postage of $5.00 (Wyoming), $10.00 (other states), and $20.00 (International, including Canada).

*Wyoming Geomaps (second printing), by Sheila Roberts: Educational Series 1 (second printing), 1989.-$7.00.

**Knightia* postcard (3rd printing): 1988.-$0.25 each or 5 for $1.00.

**Tyrannosaurus rex* postcard (2nd printing): 1990.-$0.25 each or 5 for $1.00.

*Geologic Map of Wyoming postcard: 1994.-$0.25 each or 5 for $1.00.

Guide to the geology, mining districts, and ghost towns of the Medicine Bow Mountains and Snowy Range Scenic Byway, by W.D. Hausel: Public Information Circular 32, 1993.-$10.00

*Organics and the Rockies—Field Guide, edited by R.M. Flores, K.I. Mehring, R.W. Jones, and T.L. Beck: Public Information Circular 33, 1994.-$15.00.

Geology and mineralization of the Cooper Hill mining district, Medicine Bow Mountains, southeastern Wyoming, by W.D. Hausel: Report of Investigations 49, 1994.-$7.00.

*Economic geology of the Seminoe Mountains mining district, Carbon County, Wyoming, by W.D. Hausel: Report of Investigations 50, 1994.-$8.00.

*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 payable to: New Mexico Bureau of Mines and Mineral Resources or NMBMMR. (Price includes postage and handling.)

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

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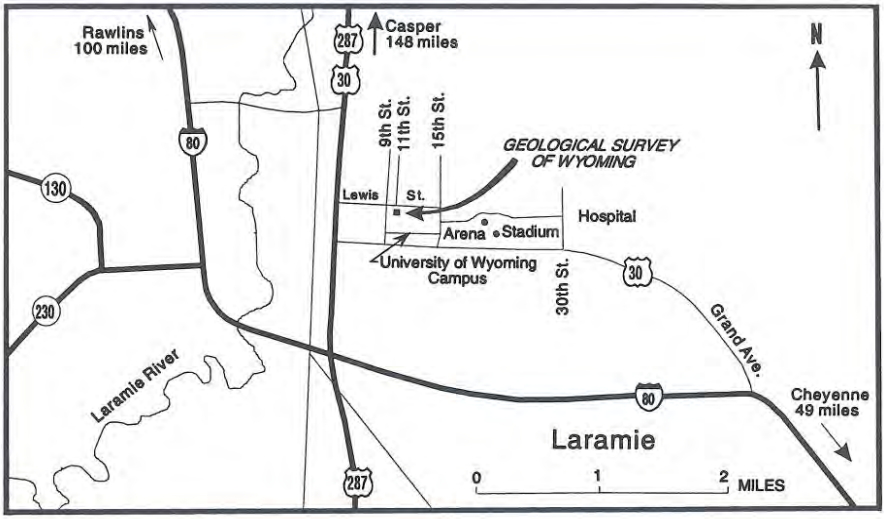

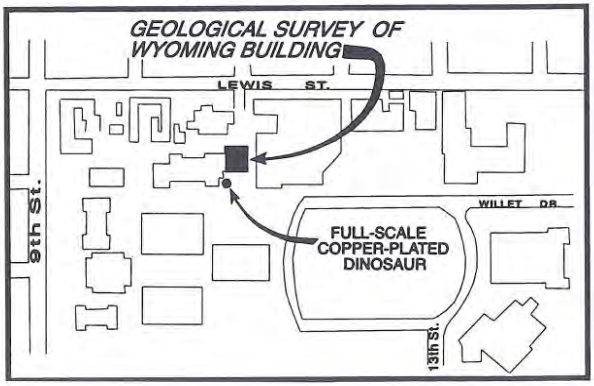

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