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Gary B. Glass, State Geologist

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Cover: The Hole-in-the-Wall, southwest of Kaycee, Wyoming, in Johnson County (photo by A.J. Ver Ploeg). Erosion of the Chugwater Formation accounts for this notorious hole in the Red Wall. This hole provided an escape route for the Wild Bunch and other outlaws. See p. 42 for a discussion of the geologic phenomenon that led to the creation of this feature.

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MINERALS UPDATE

OVERVIEW

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

In October 1993, the State's Consensus Revenue Estimating Group (CREG) released its new forecast of mineral production and prices (as State Geologist, the author is a member of this group) . **Tables 1** and **2** summarize CREG's new price and production forecasts, respectively, for the years 1993 through 1997. On the positive side, CREG's October estimates of natural gas and coal production were both higher than the estimates they made in January (see Tables 1 and 2 in *Wyoming Geo-notes No. 39* for the January forecasts). While CREG's new forecasts for trona production and price were also somewhat lower than their January estimates, growth was still projected. CREG's October forecast of declining oil production, however, was even lower than the January estimate.

In regard to its oil forecasts, CREG reduced its estimate of the average sales price for a barrel of Wyoming crude to $14.50 for 1993 (**Table 1** and

Table 1. Average prices paid for Wyoming oil, methane, coal, trona, and uranium (1985-1992) with forecasts to 1997[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	7.79P	44.50	21.00
*1993	14.50	1.90	7.44	41.00	21.00
*1994	15.75	2.00	7.19	41.00	21.00
*1995	15.75	2.11	6.97	41.00	21.00
*1996	15.75	2.23	6.83	41.00	21.00
*1997	15.75	2.34	6.68	41.00	21.00

* Forecast prices.
[1] Adapted from Consensus Revenue Estimating Group, Wyoming State Government Revenue Forecast FY94-FY98, October, 1993.
[2] First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Source: Energy Information Administration.
[3] Wellhead price in dollars per thousand cubic feet (MCF). Sources: Wyoming State Land and Farm Loan Office, 1989-1992 (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, Coal Production (annual summaries).
[5] Dollars per ton of trona, not soda ash. Source: Wyoming Department of Revenue.
[6] Uranium prices are all estimated by the Geological Survey of Wyoming; in dollars per pound of yellowcake (weighted average price for in-situ and surface-mined uranium)
P = Preliminary.

Table 2. Wyoming mineral production (1981-1992) with forecasts to 1997[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	—	—	102.8	11.8	4.6	—	0.05
1982	118.7	465.1	—	—	107.9	10.1	2.1	—	0.07
1983	120.9	539.8	—	—	112.2	10.5	3.0	—	0.57
1984	127.8	600.1	—	—	130.7	11.0	1.6	—	0.71
1985	131.0	597.9	—	—	140.4	10.8	0.6	—	0.80
1986	122.4	563.2	23.8	0.15	136.3	11.9	0.2	0.04	0.76
1987	115.9	628.2	114.2	0.86	146.5	12.4	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	16.1	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	87.4	899.0	140.0	1.00	202.0	16.2	—	0.8	1.20
*1994	82.2	941.0	140.0	1.00	211.0	16.8	—	0.8	1.25
*1995	77.2	984.0	140.0	1.00	220.4	16.9	—	0.8	1.25
*1996	72.6	1,029.0	140.0	1.00	230.2	17.0	—	0.8	1.25
*1997	68.2	1,076.0	140.0	1.00	240.5	17.1	—	0.8	1.25

*Forecast production

[1]Adapted from Consensus Revenue Estimating Group, Wyoming State Government Revenue Forecast FY94-FY98, October, 1993; [2]Millions of barrels (Source: Wyoming Oil & Gas Conservation Commission, Annual reports for 1981-1992); [3]Billions of cubic feet (primarily methane with some hydrogen sulfide and nitrogen) (Source: Wyoming Oil & Gas Conservation Commission, Annual reports for 1981-1992); [4] Billions of cubic feet. Source: Wyoming Oil & Gas Conservation Commission; [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, Annual reports 1981-1992); [7]Millions of short tons of uranium ore (not yellowcake) (Source: Wyoming Department of Revenue); [8]Millions of pounds of yellowcake (U_3O_8) (unknown between 1981-1985 because it was only reported as taxeble valuation; Estimates for 1993-1997 are based on company information); [9]Millions of short tons (Source: Wyoming Oil & Gas Conservation Commission).

Figures 1 and **2**), which is $1.25 less than it forecast in January. Estimated prices for all remaining years of the forecast were held constant at $15.75 per barrel, the level set in January (**Figure 1**). For 1993, CREG also reduced its oil production estimate to 87.4 million barrels (**Table 2** and **Figure 3**), which is 5.7 million barrels less than its January forecast. Production is expected to decline over the duration of the forecast period, decreasing to 68.2 million barrels by 1997. Since oil prices are expected to remain low throughout the forecast period, little new exploration is anticipated. Similarly, the low prices will make some secondary and most tertiary recovery projects marginal to uneconomical. Consequently, as the existing fields continue to age, production declines will likely accelerate. Although it looks like 1993 production could be 9.7% below that of 1992, CREG is now forecasting a 6% average annual rate of decline between 1993 and 1997 (**Figure 3**), compared to the 4% rate of decline it forecast in January.

As a side note, there are also some individuals and companies concerned that a proposed Alberta to Casper oil pipeline could displace some Wyoming oil

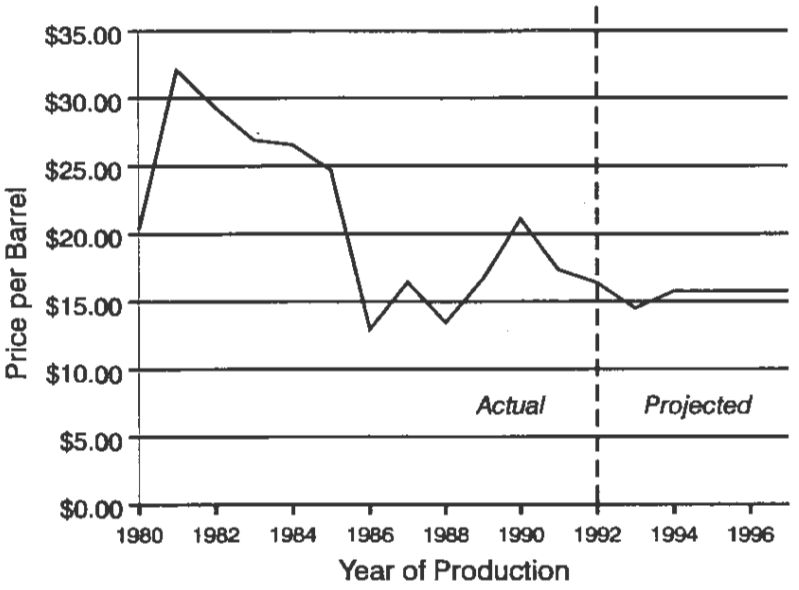

Figure 1. Average prices paid for Wyoming oil (1980 to 1992) with forecasts to 1997.

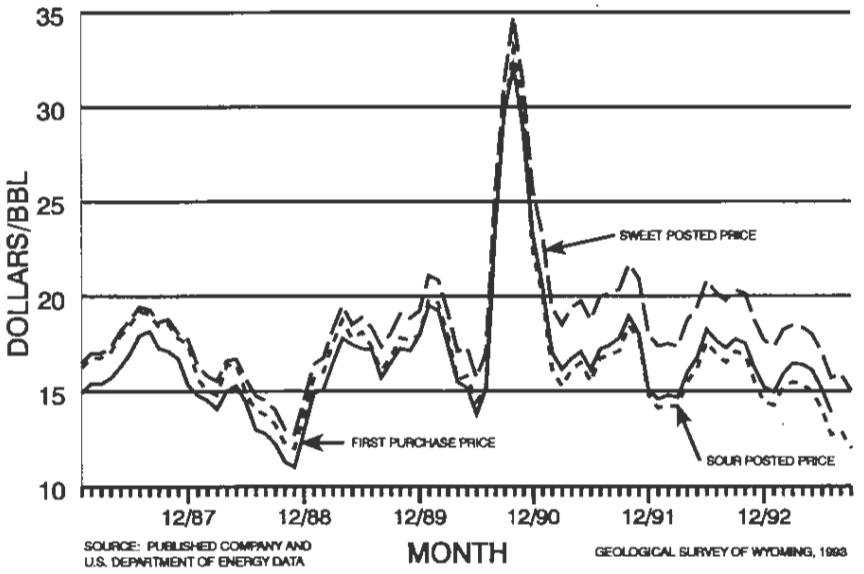

Figure 2. Wyoming posted Sweet and Sour crude prices and first purchase prices averaged by month (1987 to present).

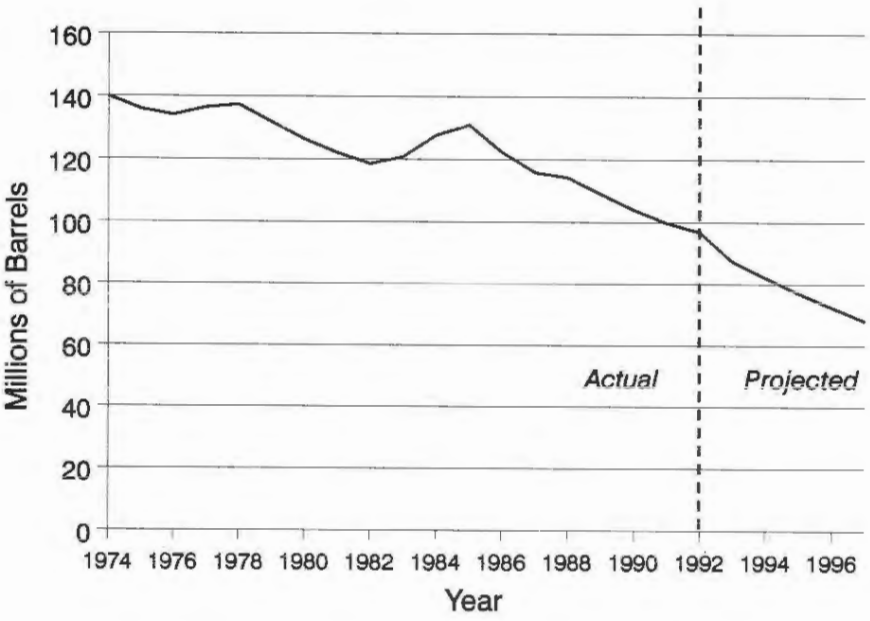

Figure 3. Annual oil production from Wyoming (1974 to 1992) with forecast to 1997.

production in the mid- to late-1990s, possibly accelerating the production decline even more. The U.S. Bureau of Land Management has just begun an environmental assessment of this Express Pipeline project (p. 11).

As mentioned above, CREG has now increased its estimate of the 1993 price of Wyoming methane to $1.90 per thousand cubic feet (MCF)(**Table 1** and **Figure 4**). This is 10 cents higher than their January estimate. Methane prices are expected to rise over the remainder of the forecast period, reaching $2.34 per MCF by 1997. The spot sale prices at Opal, Wyoming, indicate a definite improvement in natural gas prices (**Figure 5**).

The gross production of natural gas (principally methane, carbon dioxide, and helium) is now forecast at 1.04 trillion cubic feet (TCF) for 1993 (**Table 2** and **Figure 6**). This is an increase of 15 billion cubic feet (BCF) over CREG's January forecast. Production is forecast to increase 4% a year throughout the forecast period, reaching 1.217 TCF by 1997. Essentially all the increases in production will be methane, rather than carbon dioxide or helium (**Figure 6**). Production of the latter two gases is primarily a function of available processing capabilities at Exxon's Shute Creek plant in southwestern Wyoming. A new gas processing plant at the Madden Field in northeastern Fremont County is expected to increase production of carbon dioxide somewhat when it comes on line.

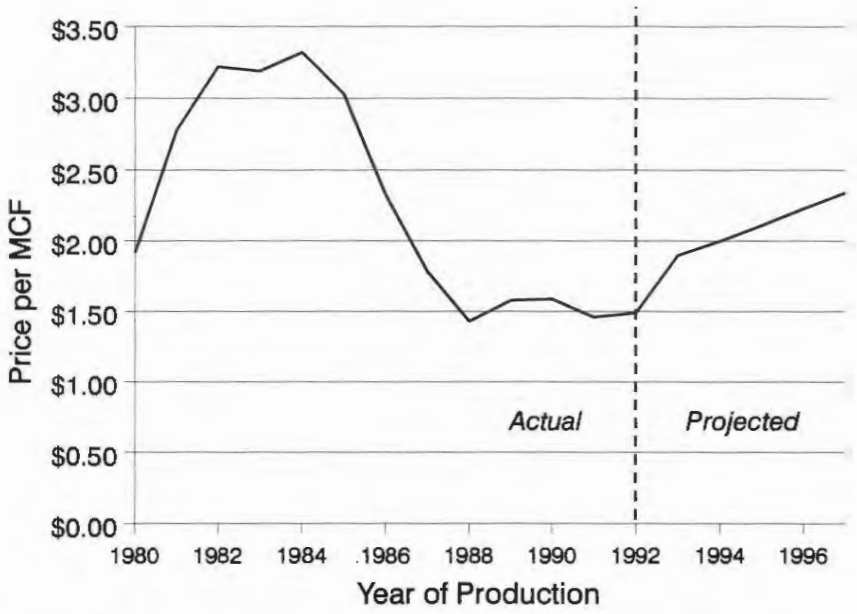

Figure 4. Average prices paid for Wyoming methane (1980 to 1992) with forecasts to 1997.

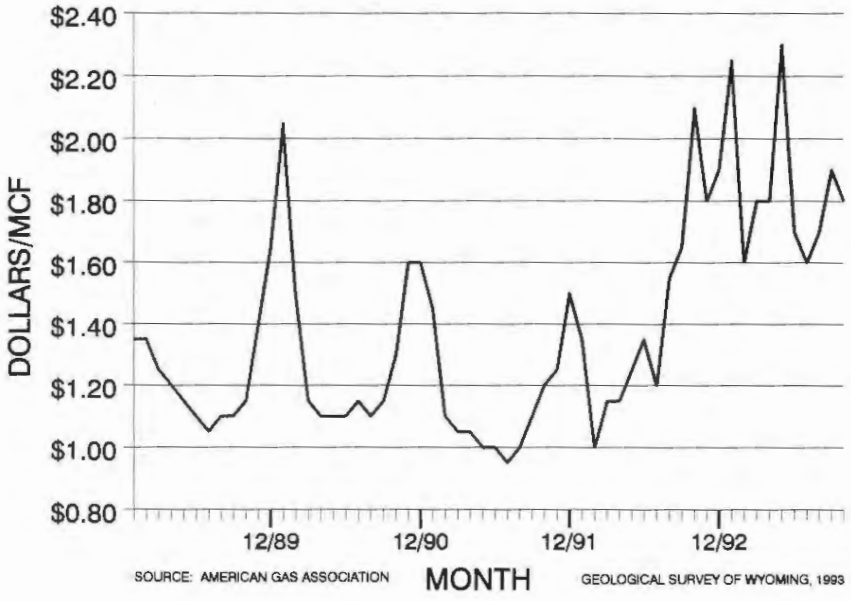

Figure 5. Spot prices for methane at Opal, Wyoming, averaged by month (1989 to present).

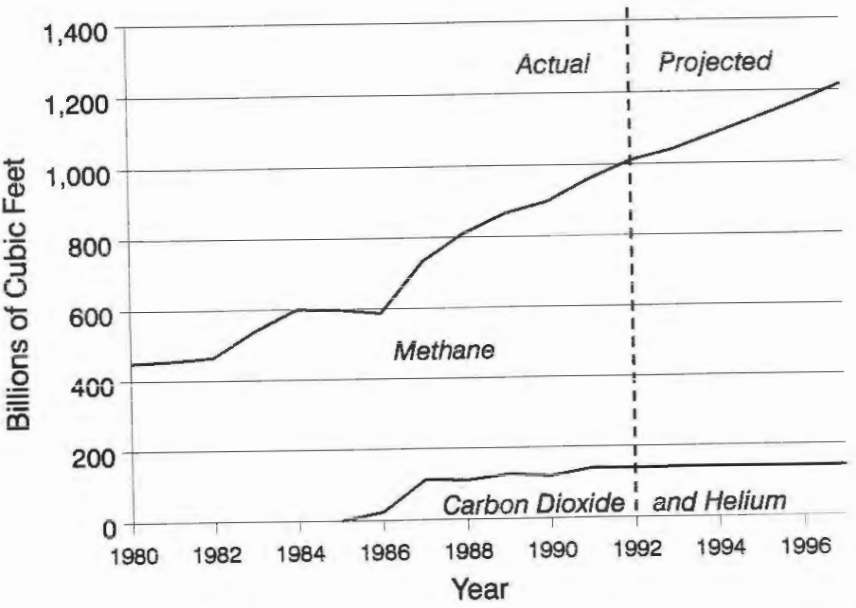

Figure 6. Annual natural gas production from Wyoming (1980 to 1992) with forecasts to 1997.

In regard to coal, the weighted average price for Wyoming coal is now forecast at $7.44 per ton in 1993 (**Table 1** and **Figure 7**). This is 5 cents a ton more than CREG estimated in January, but still 35 cents less than the price of

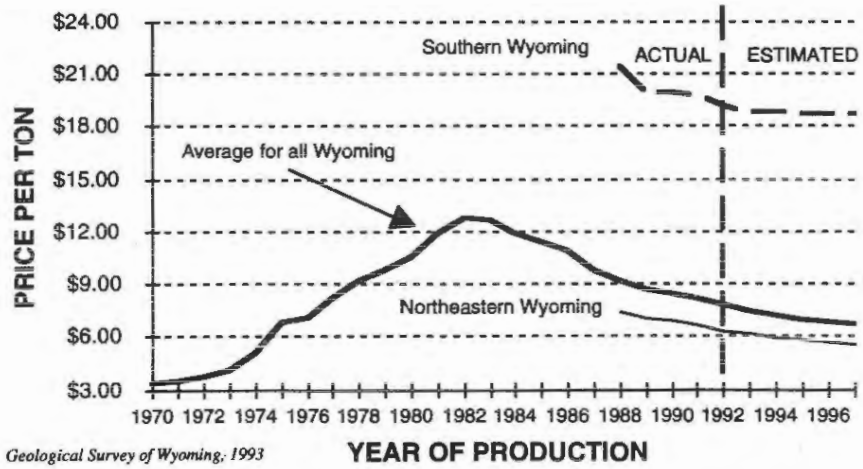

Figure 7. Average prices paid for Wyoming coal (1980 to 1992) with forecasts to 1997. *Data from the U.S. Energy Information Administration (1980-1991) and the Wyoming Consensus Revenue Estimating Group (1992-1997).*

coal in 1992. Throughout the forecast period, the price is expected to continue declining, decreasing to $6.68 per ton by 1997. **Table 3** shows the regional prices paid for Wyoming coal to include forecast prices between 1993 and 1997.

CREG expects 1993 coal production to increase by 5 million tons more than the tonnage it forecast in January. This would bring 1993 coal production to 202 million tons (**Table 2** and **Figure 8**). Coal production is forecast to increase each year of the forecast and to reach 240.5 million tons by 1997.

Table 3. Breakdown of average prices paid for coal from northeastern Wyoming, southern Wyoming, and Wyoming as a whole (1988-1991) with forecasts to 1997.

Year	Northeastern	Southern	Statewide
1988	$7.35	$21.45	$9.16
1989	$7.02	$19.97	$8.63
1990	$6.92	$19.90	$8.43
1991	$6.68	$19.80	$8.09
1992	$6.35	$19.19	$7.79
*1993	$6.18	$18.86	$7.44
*1994	$5.98	$18.75	$7.19
*1995	$5.80	$18.72	$6.97
*1996	$5.70	$18.69	$6.83
*1997	$5.60	$18.67	$6.68

* Forecast prices

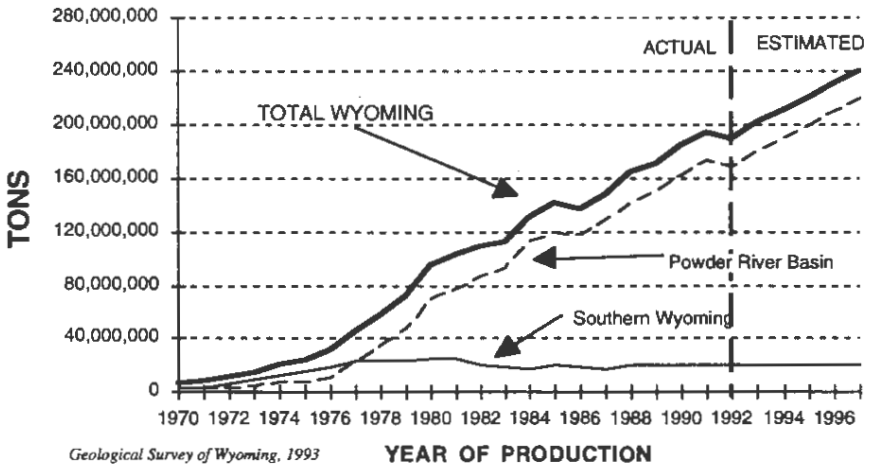

Figure 8. Annual coal production from Wyoming (1970-1992) with forecasts to 1997. *Data from the Wyoming Inspector of Mines (1970-1992) and the Wyoming Consensus Revenue Estimating Group (1993-1997).*

It should be noted that CREG, in January 1993, lowered its October 1992 forecast of coal production because coal production in 1992 decreased from that of 1991. Production so far in 1993, however, has rebounded enough that CREG feels that last year's lower volume was a singular event. Consequently, CREG has adjusted its forecast back to a higher level more consistent to that which had been expected prior to last year's production decline.

Before leaving coal, an interesting sale and test were recently announced. Georgia Power will soon burn Wyoming coal in Units 3 and 4 of the Scherer power plant in Georgia. In this regard, Southern Company Services has purchased a total of four million tons of Powder River Basin coal from two Wyoming mines for delivery in 1994 (see p. 25 and **Table 8**). In addition, New England Power is testing a blend of low-sulfur Wyoming coal and higher sulfur eastern coal at two of their Massachusetts power plants (**Table 8**). The recent sale to Georgia Power and the tests in Massachusetts may signal the beginning of many new sales of Wyoming coal as utility companies approach deadlines for reducing their sulfur emissions pursuant to the Clean Air Act Amendments of 1990.

The State of Wyoming has apparently decided not to join in a suit against an Illinois law designed to protect local Illinois coal producers. Four railroads and two coal companies have filed suit in Federal Court arguing that the Illinois law violates the Interstate Commerce clause of the U.S. Constitution. According to an article in the Casper Star-Tribune (October 22, 1993), Wyoming did, however, present testimony at a Senate Subcommittee on Clean Air and Nuclear Regulation. Wyoming Senior Assistant Attorney General, Mary Guthrie, addressed "protectionist" laws enacted by several Midwestern states. She noted that Western states and their coal producers may have to challenge some or all of these laws in court, and that those challenges would be quite expensive.

Owing in some small measure to a strike at General Chemical Corporation's soda ash plant at Green River, CREG reduced its estimate of trona production for 1993 to 16.2 million tons, a reduction of 200,000 tons (**Table 2**). Between 1993 and 1997, CREG forecasts trona production to increase to 17.1 million tons. CREG also lowered its trona price estimate for 1993 to $41.00 per ton and held that price through 1997 (**Table 1**). In related matters, Wold Trona is still moving forward on its plans for a new trona operation in the Green River area, and the U.S. Bureau of Land Management is gathering information and comments on a proposed sodium (trona) lease sale for late 1994 or early 1995.

Based in no small measure on maps and reports prepared by the Metals and Precious Stones Section of the Geological Survey of Wyoming (GSW), diamond and metal exploration continued in Wyoming. A 12-year GSW study of potentially diamond-bearing rocks in Wyoming has paid off in helping guide exploration by several companies in the Colorado-Wyoming State Line district, the Happy Jack-Pole Mountain area, the Sybille Canyon region, and the Elmers Rock greenstone belt, all in the Laramie Mountains. In addition, work by the GSW in the Green River Basin has also helped promote diamond exploration by

at least three companies. The GSW is, itself, looking for diamonds in some bulk samples from the Leucite Hills. These samples were provided by Union Pacific Resources as part of a $5,000 research project with the GSW.

This summer and fall, there was also exploration for copper in the Sierra Madre, Absaroka Mountains, and Laramie Mountains as well as exploration for gold in the Lewiston district, the South Pass-Atlantic City district, the Rattlesnake Hills, the Seminoe Mountains, and portions of southern Wyoming. Again, geological maps and(or) reports on all these areas were published by the GSW shortly before this current exploration began.

In conclusion, **Table 4** shows the production history for selected other mineral commodities that are or have recently been mined in Wyoming.

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

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Bentonite[2]	2.18	3.08	2.59	1.82	2.16	2.32	2.22[6]	2.43[6]	2.38[6]	2.21[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]
Decorative Stone	---	---	---	---	---	---	---	---	0.24[7]	0.36[7]
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	0.40[7]	0.20[6]	0.44[6]	0.42[6]	0.43[7]
Iron Ore[2]	2.48	---	---	---	---	---	minor[8]	minor[8]	---	---
Leonardite[4]	---	---	---	---	---	---	---	22.9[6]	33.3[6]	37.0[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]
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]
Shale[4]	---	20.3	14.7	9.88	49.0	50.2	1.8	43.5[6]	158.2	113.3[6]
Sodium Sulfate[4]	3.19	3.25	2.71	2.03	---	2.10[6]	3.2	1.9[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 Geological Survey of Wyoming; [8]less than 1,000 tons of iron ore were sold for pigment. Prepared by Geological Survey of Wyoming, July, 1993.

OIL AND GAS UPDATE

by Rodney H. De Bruin
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The rig count in Wyoming continued increasing in the third quarter of 1993. After reaching an all-time low in March of 1993, the daily rig count, averaged by month, has shown steady growth for the last six months (**Figure 9**). The 61-rig average for September, 1993, was the highest average for a month since October, 1987. The higher rig count is primarily related to development drilling for gas in the southwestern part of the State.

There were 389 well completions in Wyoming during the first nine months of 1993, compared to 301 during the first nine months of 1992 (Petroleum Information, 1993). The 213 gas well completions in the first nine months of 1993 compared to 102 gas well completions in the first nine months of 1992. The success rate for all wells in the first nine months of 1993 was 80.5 percent compared to a success rate of 63.8 percent for the first nine months of 1992. The increase in gas drilling in southwestern Wyoming is a result of increased demand and improved prices.

The spot price for natural gas at Opal, Wyoming, dropped slightly in October, 1993 (**Figure 5**). The average spot price for the first ten months of this

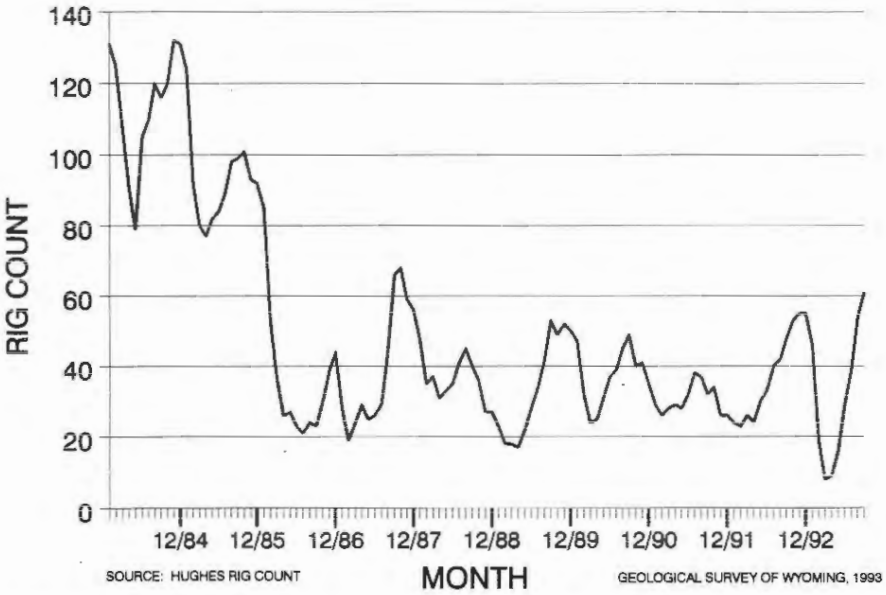


Figure 9. Wyoming daily rig count averaged by month (1984 to present).

year is $1.85 per thousand cubic feet (MCF), compared to an average price of $1.38 per MCF and $1.15 per MCF for the first ten months in 1992 and 1991, respectively.

In a related item, Governor Sullivan and the oil and gas industry have requested that the U.S. Bureau of Land Management (BLM) do more to promote development of natural gas resources in southwestern Wyoming and that BLM accurately describe and adequately consider the natural gas resources in the area. The BLM's draft management plan for southwestern Wyoming assumed that gas production would remain fairly constant in the coming years. The draft document also calls for placing about 337,000 acres of the resource area's 3.5 million Federal acres off-limits to oil and gas leasing.

The situation with oil prices is just the opposite from gas, as prices declined during the third quarter of the year (**Figure 2**). If OPEC adheres to the new production agreements that were approved in late September, prices for crude oil could increase. An increase in crude oil prices would not only benefit the State's crude oil producers, but would also benefit the State's natural gas producers. When crude oil prices are very low, utilities and industries that have the capability to burn both natural gas and fuel oil, switch to fuel oil. Low crude oil prices weaken the demand for and the price of natural gas.

Wyoming's declining crude oil production has created excess capacity in a number of crude oil pipelines that have distributed crude oil from Casper to refineries in other states. A proposed $470 million pipeline (Express Pipeline) would ship 150,000 barrels of oil per day from Alberta, Canada to Casper, where it would connect with other pipelines to refineries in other states. There is some concern that the pipeline could displace some Wyoming crude oil. The pipeline company, however, feels there will be enough excess capacity by 1995 that no Wyoming oil will be displaced. The proposed route of the pipeline follows the route approved for the Altamont Pipeline to Lysite, Wyoming, and then follow other pipeline routes from Lysite to Casper. Completion of the pipeline is planned for 1995.

FD Services, Inc. is reducing its work force at Teapot Dome oil field by 27. Teapot Dome is a Naval Petroleum Reserve owned by the Federal government and operated by FD Services. Low oil prices and declining production were cited as reasons for the reductions.

Amoco Oil Co. has volunteered to clean up an old refinery site at the southeastern edge of Greybull. The clean-up began in August and will cost an estimated $2.5 million. Amoco operated the refinery from 1915 until 1948.

The petroleum and trona industries have been given a three-month extension to work out a policy to resolve conflicts between their operations in the Green River Basin. The extension is the second granted by the BLM this year. The industries' request for a 12-month extension was denied by the BLM. For more details on this policy, see p. 10 in *Wyoming Geo-notes No. 39.*

The BLM issued the final version of an administrative rule that extends the primary term of all new competitive Federal onshore oil and gas leases from five years to 10 years. The rule became effective July 31, 1993, and applies to all future onshore competitive leases. Noncompetitive leases already have a 10-year primary term.

The Minerals Management Service (MMS) has proposed three new rules affecting oil and gas producers. The first rule deals with a payor's/lessee's inability or unwillingness to pay royalties, rents, or other monies owed for certain properties, and would give the MMS the right to disallow credits or refunds due that payor/lessee on other properties. The second rule would prescribe time limits and other limitations on the reporting of credit adjustments made to previous payments for Federal onshore and Indian oil, gas, and other mineral leases. The third rule would add an additional assessment for incorrect reports that are received late. This assessment would be equal to the assessment that is currently applied to incorrect reports received by the due dates. This assessment would apply to incorrect reports received from royalty payors, lease operators, lessees, or other parties.

Although 1993 lease sales are not doing as well as they did in the 1980s, revenue, parcels sold, and acres leased have already exceeded the totals for BLM and State sales for all of 1992 (**Table 5**).

At the BLM's August oil and gas lease sale, the top per-acre bid of $400 was made by Joe Peterson for a 160-acre parcel in NE section 31, T24N, R110W. The lease is near Frontier gas production in Mesa Field. The sale's second highest per-acre bid of $280 was made by Donald B. Anderson, Ltd. for a 280-acre tract that covers N/2 SE and SW SE section 5, and NE section 7, T30N, R113W. The tract is in an area of Almy, Mesaverde, and Frontier production in the Big Piney/La Barge complex.

The State Land and Farm Loan Office is presently holding only four sales a year instead of the six a year that they held prior to 1992. There is a shortage of good parcels and industry interest has remained relatively low. The September sale's high per-acre bid of $225 was made by Kennedy Oil for a 34.65-acre tract in SW SW section 6, T39N, R74W. The tract is a little over a mile from shut-in Frontier production in Spearhead Ranch Field. The sale's second highest per-acre bid of $165 was made by Caddis Resources, Inc. for a 480-acre parcel that includes S/2 S/2 section 12 and N/2 section 24, T15N, R65W. The parcel is on the southwestern edge of Silo Field, where there is horizontal drilling and development of the Niobrara (see **Horizontal drilling** section below).

Exploration and development

Company data and information compiled and published by Petroleum Information indicate the following significant exploration and development events occurred in Wyoming during the third quarter of 1993. Activities related

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

BLM SALES								STATE SALES							
Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre	Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
				1988								**1988**			
TOTAL	$27,688,861	4,119	1,591	4,412,513	1,350,897	$20.50	$6,500.00	TOTAL	$6,202,724	1,200	873	445,953	331,943	$18.69	$465.00
				1989								**1989**			
TOTAL	$15,832,105	4,286	1,360	4,028,750	972,403	$16.28	$3,000.00	TOTAL	$3,123,984	1,199	792	461,852	311,274	$10.04	$540.00
				1990								**1990**			
TOTAL	$17,997,133	2,971	1,593	2,169,138	967,293	$18.61	$340.00	TOTAL	$4,979,094	1,199	732	478,098	380,382	$13.09	$270.00
				1991								**1991**			
February	$4,333,861	370	200	275,600	122,225	$35.46	$16,000.00	January	$2,050,868	300	295	117,677	115,998	$17.68	$401.00
April	$1,880,742	470	217	332,764	132,278	$14.22	$170.00	March	$642,191	197	170	69,652	62,226	$10.32	$110.00
June	$2,002,440	490	176	430,576	120,992	$16.55	$275.00	May	$539,556	199	173	79,156	70,081	$7.70	$77.00
August	$2,005,511	557	211	472,103	120,292	$16.67	$325.00	July	$396,569	200	124	73,179	52,850	$7.50	$70.00
October	$1,616,314	507	175	397,011	94,899	$17.03	$340.00	September	$411,971	200	146	69,025	50,908	$8.09	$260.00
December	$1,095,409	421	168	283,408	85,091	$12.87	$1,600.00	November	$416,730	199	129	71,286	53,847	$7.74	$130.00
TOTAL	$12,934,277	2,815	1,147	2,191,462	675,777	$19.14	$16,000.00	TOTAL	$4,457,885	1,295	1,037	479,975	405,910	$10.98	$401.00
				1992								**1992**			
February	$940,581	342	126	213,469	67,205	$14.00	$210.00	January	$138,165	200	96	72,027	37,840	$3.65	$65.00
April	$331,199	355	109	229,407	58,951	$5.62	$112.00	March	$200,000	200	114	70,294	41,034	$4.88	103.00
June	$425,183	314	86	168,230	37,701	$11.28	$220.00	May	$208,166	200	93	60,687	28,605	$7.28	$230.00
August	$1,395,060	335	109	196,800	54,530	$25.58	$230.00	November	$200,407	199	116	74,747	43,134	$4.65	$87.00
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	TOTAL	$745,738	799	419	277,755	150,613	$4.95	$230.00
				1993								**1993**			
February	$1,637,233	464	246	346,357	155,272	$10.54	$220.00	March	$601,400	200	137	74,940	54,723	$10.99	$400.00
April	$2,116,184	478	259	351,465	177,989	$11.89	$220.00	May	$362,840	200	141	82,388	56,770	$6.39	$90.00
June	$1,415,793	463	179	351,130	86,435	$16.38	$390.00	September	$505,587	200	141	80,428	56,845	$8.89	$225.00
August	$1,877,405	462	262	374,274	208,495	$9.00	$400.00								

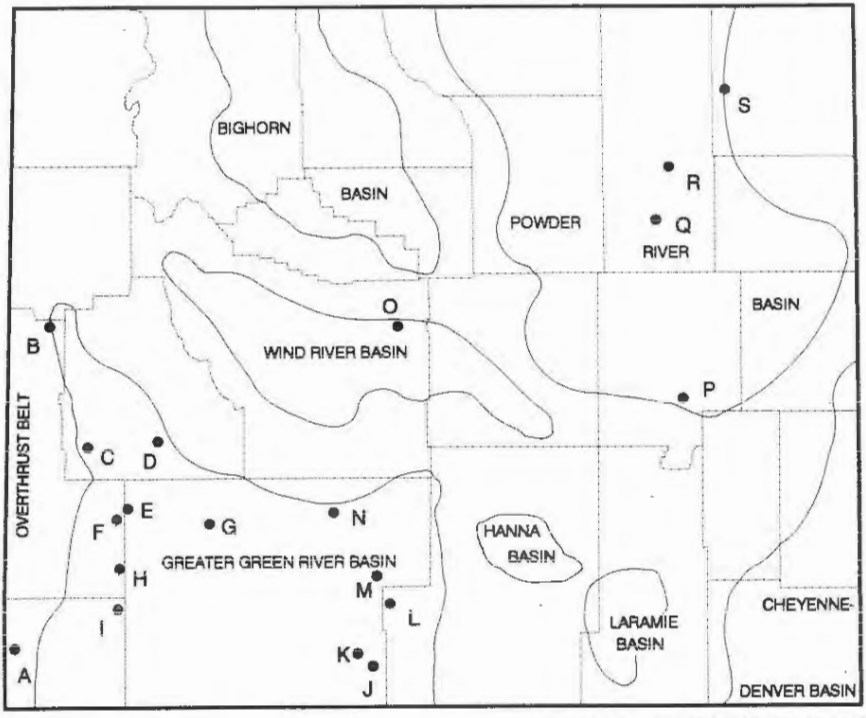
Sources: Wyoming State Land and Farm Loan Office, Petroleum Information Corporation - Rocky Mountain Region Report, and U.S. Bureau of Land Management.

to horizontal drilling are discussed in a separate section. The letters preceding discussions below refer to locations on **Figure 10**.

A. Amoco Production Co. began construction on two 12-inch pipelines between the Anschutz Ranch East Field and the Painter Reservoir complex. One line will transport surplus nitrogen from Painter Reservoir for injection at Anschutz Ranch East Field. The other line will provide the option of transporting Anschutz Ranch East's surplus gas to the gas processing facilities at the Painter Reservoir Complex.

B. Chevron, USA completed its 1-17 Chevron-Hunter Creek well in NE NW section 27, T38N, R115W as a dry hole. While drilling, the well was the only helicopter-supported drilling operation in the U.S. Chevron's plans for additional wells in this area are still unclear.

C. Enron Oil and Gas completed a Mesaverde producer that pumped 338 barrels of oil and 40 barrels of water per day through perforations between 2,704 and 2,760 feet. The 87-22C Federal well in NE SE section 22, T28N,



GEOLOGICAL SURVEY OF WYOMING, 1993

Figure 10. Oil and gas exploration and development activity in Wyoming during the third quarter of 1993 (exclusive of horizontal drilling and coalbed methane activities).

R113W is about three miles from a planned Enron project that would consist of 35 wells that would target the Mesaverde and would be drilled on 20-acre drilling units in a 1,000-acre portion of sections 18,19, 20, and 29, T28N, R113W. Initially five test wells will be drilled to determine the suitability of primary oil recovery. If this part of the project proves successful, the company would drill 30 additional wells over the next seven years. Approximately 15 of the producers would be converted to injection wells for a secondary water-flood recovery project. The BLM has announced its intentions to prepare an Environmental Impact Statement for the project.

D. McMurray Oil completed a deeper pool discovery in the Jonah Field area. The 1-5 Jonah-Federal well in NW NW section 5, T28N, R108W produced an average of nearly 3.9 million cubic feet of gas and 35 barrels of condensate per day from an undisclosed interval in the Mesaverde.

E. Presidio Exploration completed a new Dakota producer in Blue Forest Field. The 30-13 Blue Forest Unit well in NW SW section 13, T24N, R111W flowed 2.6 million cubic feet of gas and 48 barrels of condensate per day from perforations between 10,844 and 10,857 feet. Washington Energy Exploration completed a new Frontier producer in Lincoln Road Field just to the southwest. The 30-35 Farson-Federal well in NE SE section 35, T24N, R111W flowed 5.4 million cubic feet of gas and 48 barrels of condensate per day from perforations between 10,225 and 10,310 feet.

F. The BLM approved an application by Washington Energy Exploration for a Federal exploratory unit on the western flank of the Moxa arch. The Lake Alice Unit encompasses 25,636 acres in T23N, R112W and R113W and T24N, R112W and R113W.

G. Texaco Exploration and Production, Inc. recovered gas on a drillstem test of the Almond Formation (Mesaverde Group) at its 1 Stagecoach Draw Unit well in C NE section 32, T23N, R107W. Pipe recovery included 90 feet of gas-cut mud and the sample chamber contained 1.1 cubic feet of gas. Texaco notified the BLM that the company intends to develop the Stagecoach Draw Unit by drilling up to 30 natural gas wells on the 23,575-acre unit that is located in T22N, T23N, and T24N, R107W and R108W. Texaco plans to drill up to three wells this year.

H. Bannon Energy completed a new Dakota producer in Fabian Ditch Field. The 1 Champlin 288 Amoco D well in SE NE section 9, T20N, R112W produced an average of 3.7 million cubic feet of gas, 12 barrels of condensate, and three barrels of water per day during 21 days of production in June. The operator did not report the producing interval.

I. A number of new producing wells were completed in Bruff Field. The tabulation below summarizes data from these wells.

J. Enron Oil and Gas completed a new Almond Formation gas well in Dripping Rock Field. The 14-33 Ruger Unit well in SW SW section 33, T15N, R94W

has produced 143.1 million cubic feet of gas and 257 barrels of condensate during three months of production. The productive interval was not reported, but the well was drilled to 12,475 feet.

K. Amoco Production has a new Almond Formation gas well in Willow Reservoir Field. The 12 Willow Reservoir Unit well in NW NE section 7, T16N, R 95W flowed 448,000 cubic feet of gas per day from perforations between 13,018 and 13,344 feet.

L. The BLM plans to prepare an Environmental Impact Statement for a development program proposed by Snyder Oil Corp. and other operators in Barrel Springs, Fillmore, Creston, Blue Gap, and Robbers Gulch Fields. The development program could involve the drilling of up to 250 new wells beginning next year. Although the Mesaverde wells in the fields are predominantly spaced at one well per 640 acres, Snyder and the other operators propose drilling one well per 160 acres.

M. Williams Field Services Group and Union Pacific Resources have joined forces to make the Wamsutter Field area a major gas marketing hub. Williams and Union Pacific signed an agreement for joint ownership of 278 miles of gathering lines and a $30 million gas plant now under construction. The plant will have the capacity to process 120 million cubic feet of gas per day and may be expanded to process 200 million cubic feet of gas per day. According to a news release, Questar has expressed an interest in joining the arrangement with Williams and Union Pacific.

N. Presidio Exploration completed three new gas wells in the Lewis Shale at Hay Reservoir Field. The 54 Hay Reservoir Unit well in NE NW section 22, T24N, R97W flowed 4.6 million cubic feet of gas, 50 barrels of condensate, and 11 barrels of water per day from perforations between 10,235 and 10,310 feet. The 5 J.T. Federal well in NW NE section 13, T23N, R97W flowed 4.1 million cubic feet of gas, 236 barrels of condensate, and three barrels of water per day from perforations between 9,342 and 9,421 feet. The 55 Hay Reservoir Unit well in NW SW section 27, T24N, R97W flowed 3.5 million cubic feet of gas, 110 barrels of condensate, and 15 barrels of water per day from perforations between 9,949 and 10,071 feet.

O. After two years of planning, Louisiana Land and Exploration Co. (LL & E) has begun site preparation for a processing plant that will remove hydrogen sulfide from gas produced from the Madison Limestone in Madden Field. Based on a study of natural gas resources at Madden Field, the Madison Limestone contains over 3 trillion cubic feet of gas (methane, carbon dioxide, and hydrogen sulfide) in-place (De Bruin, 1991). LL & E also completed four new wells in Madden Field. The 5-3 Mary-Federal well in NE SE section 3, T38N, R90W flowed 4.5 million cubic feet of gas and 750 barrels of water per day from perforations in the Mesaverde between 15,780 and 15,798 feet. The 15 MDU well in SE SE section 3, T38N, R90W flowed 3.5 million cubic

feet of gas per day from perforations in the Fort Union between 8,084 and 9,006 feet. The 13 MDU well in SE NE section 4, T38N, R90W flowed 3.8 million cubic feet of gas and 102 barrels of water per day from perforations in the Fort Union between 8,875 and 9,396 feet. The 2-6 Arthur-Federal well in SE NE section 6, T38N, R90W flowed 2.5 million cubic feet of gas, 20 barrels of condensate, and 70 barrels of water per day from perforations in the Fort Union between 6,071 and 7,767 feet.

P. Doyle D. Hendrickson reached total depth of 15,200 feet at the 34-19 Scott-Federal well in SW SE section 19, T32N, R70W. The well is currently shut in for evaluation. Original plans called for the well to be drilled through granite to a total depth of 11,500 feet within a mile south of an east-west trending fault (see Blackstone, 1988, for a detailed look at the structure in the area of this well).

Q. Meridian Oil discovered oil in the Turner Sandy Member at the 34-35 Porcupine-Federal well in SW SE section 35, T43N, R72W. The well produced 525 barrels of oil and 1.7 million cubic feet of gas during its first day of production. The depth to the productive interval was not reported.

R. Presidio Exploration completed a new Minnelusa producer. The 21-31 Heater in NE NW section 31, T48N, R71W pumped 358 barrels of oil per day from perforations between 10,348 and 10,370 and between 10,386 and 10,400 feet.

S. Ballard and Associates has purchased Texaco Exploration and Production, Inc's. interest in Donkey Creek and Semlek Fields.

Horizontal drilling

During the third quarter of 1993, the following significant activities related to horizontal drilling occurred. The letters preceding the discussions below refer to locations on **Figure 11**. The discussions are based on company data and on information compiled and published by Petroleum Information.

A. Activity continues in the Niobrara Formation at Silo Field. Kachina Exploration completed the 24-1-H State well drilled from a surface location in NE NE section 24, T15N, R64W. The well flowed 190 barrels of oil per day from an undisclosed interval. Wilshire Oil completed the 1-23H McConnaughey well drilled from a surface location in C NE section 23, T16N, R65W. The well produced an average of 249 barrels of oil, 88,900 cubic feet of gas, and 22 barrels of water per day during its first month of production from an undisclosed interval. Union Pacific Resources completed two wells. The 1H Leroy well, drilled from a surface location in NE NE section 33, T16N, R64W, produced 298 barrels of oil per day from an undisclosed interval during its first month of production. The 1H Wilma 41-7 well flowed 265 barrels of oil and 81,000 cubic feet of gas per day. The well was drilled from a surface

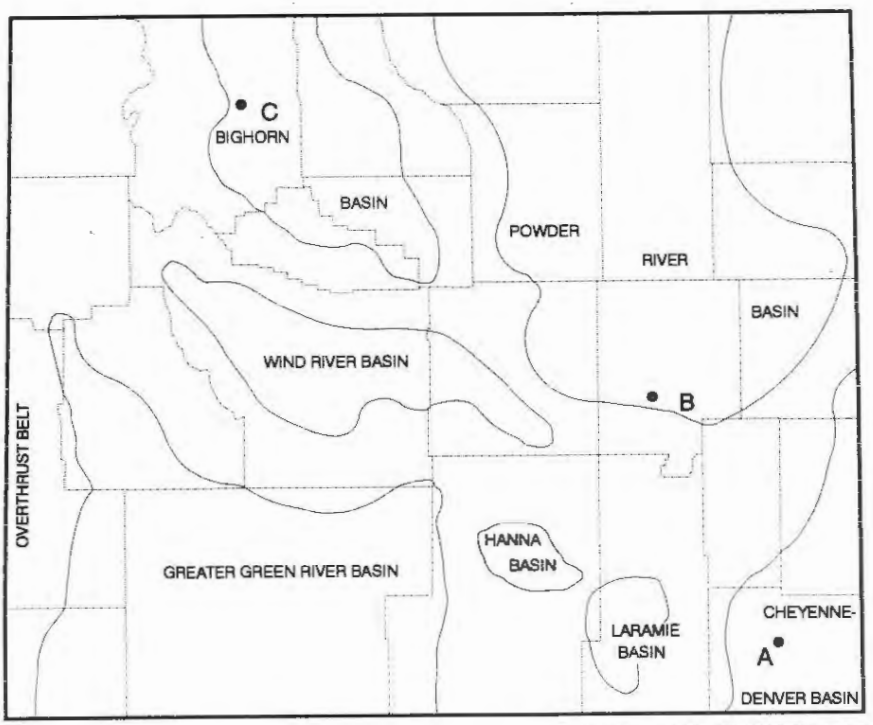


Figure 11. Horizontal drilling activity in Wyoming during the third quarter of 1993.

location in NE NE section 17, T15N, R64W to a true vertical depth of 8,048 feet. In addition to these completions, 11 more horizontal wells in Silo Field were staked by various companies during the third quarter.

B. Arco Oil and Gas will evaluate the Niobrara and Frontier at the 1 H Red Mountain Unit well to be drilled from a surface location in NW NW section 35, T33N, R71W. True vertical depth will be about 11,750 feet in the Frontier.

C. Marathon Oil plans to reenter a Madison producer in Oregon Basin Field to evaluate the potential of the Tensleep Sandstone as a horizontal drilling target. The company will reenter the 3H Sidney well in SW NW section 5, T51N, R100W to determine if drilling a short-radius lateral in the Tensleep is warranted. If Marathon determines that the Tensleep is a good horizontal drilling target, the company will drill a maximum lateral displacement of 800 feet with plans calling for an open-hole completion attempt. True vertical depth will be approximately 3,260 feet.

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COAL UPDATE

by Timothy A. Moore
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In the first six months of this year, coal deliveries from Wyoming mines to utilities were up 8% over the same period for 1992 (**Table 6**). Most of this increase in tonnage occurred during the months of April to June which have been historically low delivery months (**Figure 12**). During the second quarter of 1993 both spot and contract coal sales have been significantly higher than they were in 1992 (**Figure 13**). The higher coal production seen in the first half of this year indicates that production might increase more than 6.5% over that of 1992 (**Table 7**).

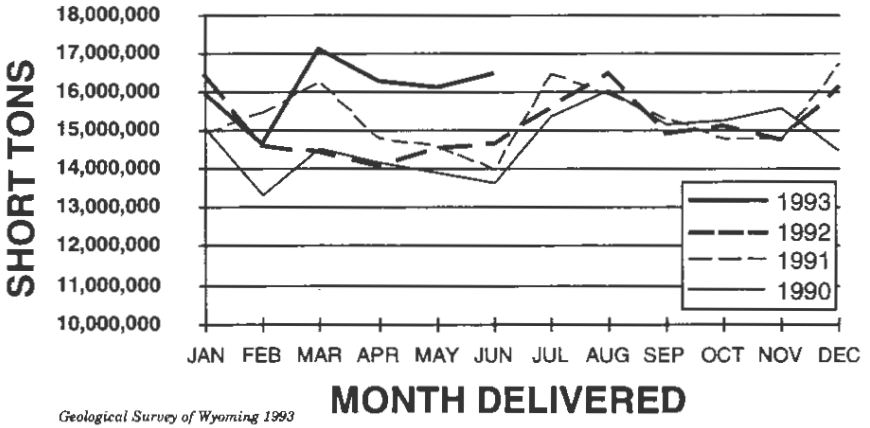

Figure 12. Reported deliveries from Wyoming coal mines. *(From COALDAT Marketing Report by Resource Data International, Inc., compiled from FERC Form 423 filed monthly by electric utilities).*

Table 6. Coal deliveries by month from Wyoming mines[1].

	1989 Monthly	1989 Cumulative	1990 Monthly	1990 Cumulative	1991 Monthly
JAN	14,283,020	14,283,020	15,059,530	15,059,530	14,960,450
FEB	11,488,140	25,771,160	13,328,290	28,387,820	15,480,110
MAR	14,124,330	39,895,490	14,535,270	42,923,090	16,278,870
APR	13,489,450	53,384,940	14,155,470	57,078,560	14,820,240
MAY	13,149,170	66,534,110	13,882,590	70,961,150	14,589,790
JUN	12,948,350	79,482,460	13,649,070	84,610,220	14,007,600
JUL	14,043,350	93,525,810	15,368,280	99,978,500	16,451,090
AUG	15,428,210	108,954,020	16,046,910	116,025,410	15,940,620
SEP	13,795,760	122,749,780	15,166,020	131,191,430	15,314,490
OCT	14,523,480	137,273,260	15,244,760	146,436,190	14,810,510
NOV	14,507,130	151,780,390	15,569,280	162,005,470	14,783,000
DEC	13,527,880	165,308,270	14,479,970	176,485,440	16,716,630
Total Tonnage Reported		**165,308,270**		**176,485,440**	
Total Tonnage Not Reported		**5,831,734**		**7,521,261**	
Total Tonnage Produced[2]		**171,140,004**		**184,006,701**	

[1] Source: COALDAT Marketing Reports by Resource Data International, Inc., compiled from FERC Form 423 filed monthly by electric utilities
[2] Source: State Mine Inspector's Annual Reports

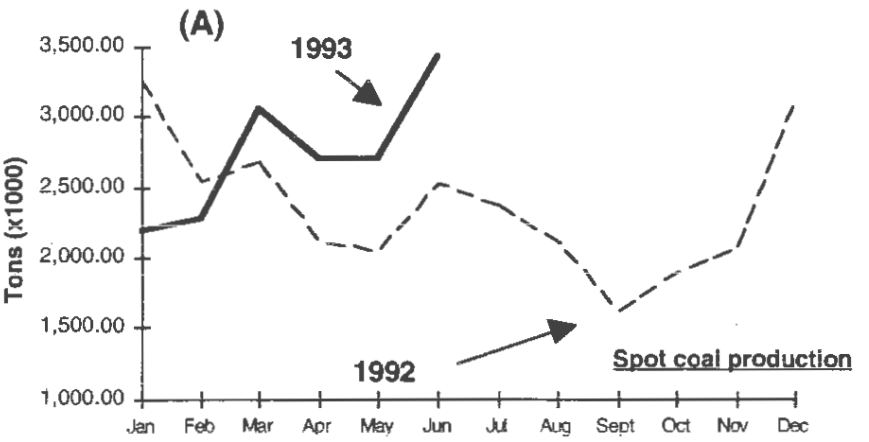

Figure 13. Monthly coal deliveries from Wyoming for 1992 and 1993. (A) Coal sold on the spot market and (B) coal sold on contract. *(From COALDAT Marketing Report by Resource Data International, Inc., compiled from FERC Form 423 filed monthly by electric utilities).*

Table 6. *continued*

1991 Cumulative	1992 Monthly	1992 Cumulative	1993 Monthly	1993 Cumulative
14,960,450	16,407,150	16,407,150	15,931,150	15,931,150
30,440,560	14,604,480	31,011,630	14,646,090	30,577,240
46,719,430	14,429,650	45,441,280	17,112,970	47,690,210
61,539,670	14,063,060	59,504,340	16,259,770	63,949,980
76,129,460	14,518,590	74,022,930	16,085,470	80,035,450
90,137,060	14,655,600	88,678,530	16,473,920	96,509,370
106,588,150	15,592,050	104,270,580		
122,528,770	16,467,100	120,737,680		
137,843,260	14,878,150	135,615,830		
152,653,770	15,122,820	150,738,650		
167,436,770	14,757,230	165,495,880		
184,153,400	16,096,150	181,592,030		
184,153,400		**181,592,030**		**96,509,370**
9,710,406		**7,878,226**		
193,863,806		**189,470,256**		

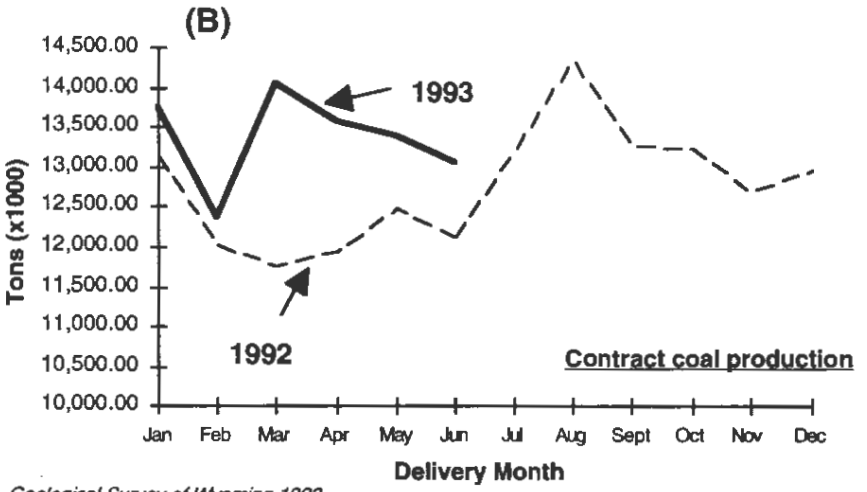

Figure 13. *Continued*

Table 7. Coal production (1984 to 1992) with forecast to 1997 (millions of tons).

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993*	1994*	1995*	1996*	1997*
Campbell County	106.8	113.9	111.0	122.3	135.7	143.8	154.7	164.9	159.6	172.3	180.9	189.9	199.4	209.1
Converse County	3.3	3.6	4.8	5.1	5.7	6.1	7.9	8.2	8.5	9.2	9.7	10.2	10.6	11.0
Sheridan County	2.5	2.4	1.4	1.2	0.9	0.1	0.1	0.2	0.1	M	M	M	M	M
Carbon County	5.1	3.3	1.5	2.2	4.1	4.3	4.5	4.7	4.1	4.3	4.3	4.3	4.3	4.3
Sweetwater County	8.9	13.2	12.9	11.8	12.2	12.0	11.9	11.4	12.6	11.4	11.4	11.4	11.4	11.4
Lincoln County	4.1	4.3	4.0	3.8	4.9	4.8	4.7	4.4	4.6	4.7	4.7	4.7	4.7	4.7
Hot Springs County	M	M	M	M	M	M	0.1	0.1	M	M	M	M	M	M
Total Wyoming	130.7	140.7	135.6	146.4	163.5	171.1	183.9	193.9	189.5	202.0	211.0	220.5	230.4	240.5
Annual Change	14.2%	7.1%	-3.8%	7.4%	10.5%	4.4%	7.0%	5.2%	-2.3%	6.2%	4.3%	4.3%	4.3%	4.2%
Low-priced coal†		6%	7%	8%	10%	17%	24%	31%	37%	42%	47%	51%	57%	62%

* Forecast by Geological Survey of Wyoming, October 1993. † Estimated percentage of total production that is sold on the spot market,through short-term contracts [less than one year duration], or through renegotiated, longer-term contracts all at prices under $5.00. M means minor tonnage (less than 0.1 million tons).

It is not yet clear, however, how much the July and August flooding in the mid-west affected deliveries. For example, Iowa State University curtailed a test burn of Caballo Rojo coal when it only received half of the shipment. However, of the eight states which consume the most Wyoming coal (**Figure 14**), most lie west of the flood-prone Missouri and Mississippi Rivers.

Developments in western and southwestern Wyoming

In late September, the FMC coke plant near Kemmerer in the Hams Fork Coal Field (**Figure 15**) tested the viability of drying and briquetting coal. Over the five-day test, nearly 2,000 tons of subbituminous coal from the Skull Point mine, also near Kemmerer, were dried and briquetted. The moisture content was decreased from about 20% to 2%, and the heat content was increased from 10,400 Btu/lb to 13,000 Btu/lb. Coal Drying Technologies, Inc., based in Colorado Springs, Colorado, and FMC Corporation, Philadelphia, Pennsylvania, have entered into an agreement to develop this technology for commercial use. A local Laramie company, MJV Engineering, is also involved in developing

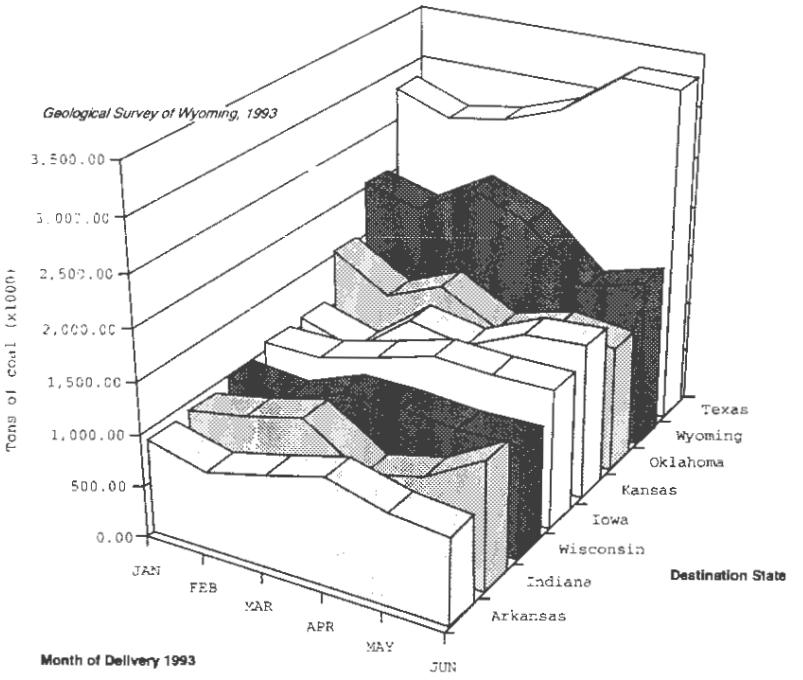

Figure 14. Volume of Wyoming coal delivered to electric utilities in the eight largest consuming states. *(From COALDAT Marketing Report by Resource Data International, Inc., compiled from FERC Form 423 filed monthly by electric utilities).*

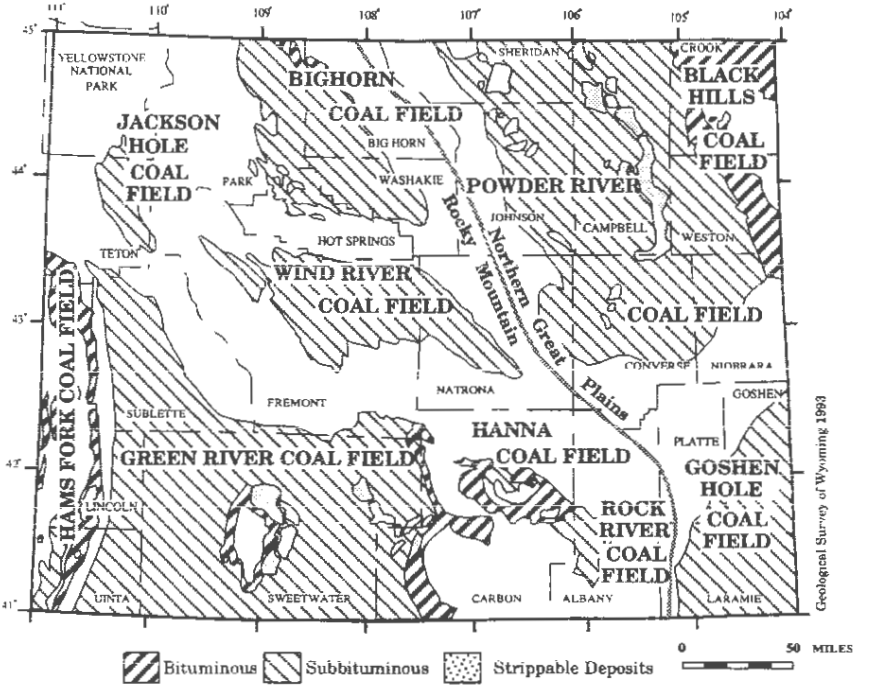

Figure 15. Coal fields of Wyoming.

the drying and briquetting process. In the next few months, two more test runs using Powder River Basin coal are scheduled.

In late August, the U.S. Department of Agriculture's Soil Conservation Service accepted bids on two abandoned mine projects. Both projects are located near Kemmerer in Lincoln County. The first project involves excavation, removal, and backfilling at the Sublet No. 6 mine and is expected to cost from $100,000 to $250,000 to complete. The second project, which includes excavation, filling, and revegetation at the Glencoe mine, is expected to cost less than $100,000.

There is also a reclamation project on an abandoned coal mine in Yellowstone National Park. The work will include filling and sealing the mine entries, disposing of structural debris, and revegetating the area. Last active around 1917, the McMinn coal mine was a small local-use mine that operated in the park during the early years of army occupation.

Arch of Wyoming officials want to revise their Pilot Butte mining permit with the Wyoming Department of Environmental Quality (DEQ). The underground mine is located north of Rock Springs. During the second quarter of this year, Arch furloughed the 27 mining personnel at the Pilot Butte mine. The revision includes a new mine and reclamation plan for the life of the mine. Arch wants the Pilot Butte mining operation to run through the year 2009. The DEQ accepted written objections to the revised mine permit proposal through Oct. 4, but has not yet announced its approval or disapproval.

Developments in the Powder River Coal Field

Another power plant will soon start using up to 4 million tons of Wyoming coal each year. The seven electric utilities that own the Scherer Generating Station in Georgia have signed ownership, operations, and coal transportation agreements, allowing Southern Company Services, to purchase Powder River Basin coal. Units 3 and 4 of the Scherer Station are to be switched to Powder River Basin coal and will most likely come online by January 1, 1994. Amax's Belle Ayr and Drummond's Caballo Rojo mines have received the 4-million-ton spot sale for 1994. It is not clear at this time how the tonnage is divided between the two mines.

In August, work began on Black Hills Power and Light's $124.9 million power plant east of Gillette. The plant is near the Wyodak mine and other power plants owned by the same utility. The 80-megawatt, coal-fired Neil Simpson Unit No. 2 has been in the planning stages since early 1990. Black Hills Power and Light will employ about 350 workers during peak construction. After completion, the plant will need about 35 full-time employees.

The Spring Creek Coal Co. which is owned by Kennecott Energy Co., is laying off about 20 workers. Since January 1992, Spring Creek has laid off about 45 employees. The Spring Creek mine is located just over the border in Montana, near Decker, but most of the employees live in Sheridan, Wyoming. The mine, which employed about 160 people in 1992, is in the process of finding new ways of automating its mining operation so that it can become more efficient. Recently, they installed an overland conveyor for coal-haulage.

On the eastern side of the Powder River Coal Field in Wyoming, Rochelle Coal Co.'s mine suffered a conveyor belt fire sometime in late August or September. The fire may have kept the mine out of normal production for almost a week. In 1992, production at the Rochelle mine, a subsidary of Peabody Holding, topped 17 million tons.

Contracts

New coal contracts, test burns, solicitations, and spot sales for the third quarter of 1993 are summarized in **Table 8.** Of note is Black Butte Coal Company's short term contract to supply coal to the Jim Bridger power plant in Wyoming. The estimated 200,000 to 700,000 tons of coal helps in part to offset

Table 8. Recent activity involving coal producers in Wyoming during the third quarter of 1993.

Utility	Power Plant	Coal Mine or Region	Activity	Tonnage	Comments
Dairyland Electric Power Cooperative	N.D.	Medicine Bow	Sp	N.D.	
Georgia Power	Scherer Units 3 & 4	Belle Ayr Caballo Rojo	Sp	4,000,000	For 1994
Grand Island NB Electric Dept.	N.D.	Cordero	C	300,000-350,000	Contract has been extended through Aug. 1994. FOB mine price is $3.50/t.
Kansas City Board of Public Utilites	N.D.	Caballo Rojo	Sp	200,000	A Western Fuels Assn. purchase.
Lower Colorado River Authority	Unit No. 3	Powder River Basin	So	N.D.	Solicitation is for coal to be delivered over a 5-year period
Midwest Power Systems	Neal No. 1 and No. 2	Hanna Basin Powder River Basin	So So	400,000 700,000	
Muscatine IA Power & Light	N.D.	Buckskin	C	600,000	Expected tonnage for 1994.
New England Electric Power	N.D.	Rochelle	T	7,000-14,000	To be combined in an 18% Rochelle/82% eastern coal, blend Could lead to 0.5 million tons per year.

Table 8. Recent activity involving coal producers in Wyoming during the third quarter of 1993 *(Continued)*.

Utility	Power Plant	Coal Mine or Region	Activity	Tonnage	Comments
Northern Indiana Public Service	Bailly	Caballo Rojo	Sp	20,000	For August spot coal.
	Michigan City	Belle Ayr	Sp	66,000	For August spot coal.
		Belle Ayr	Sp	22,000	
		Black Thunder	Sp	33,000	
		Shoshone	C	60,000	
		Shoshone	C	20,000	
		Shoshone	Sp	40,000	For August spot coal.
	Dean H. Mitchell	Cordero	Sp	33,000	For August spot coal.
		Caballo Rojo	Sp	22,000	
		Caballo Rojo	Sp	33,000	
		Cordero	Sp	55,000	
		Jacobs Ranch	Sp	22,000	
		Shoshone	C	80,000	
	R.M. Schahfer	Shoshone	C	70,000	
Pacific Power	Bridger	Black Butte	C	200,000-700,000	Short-term contract is through the end of this year.
	Centralia	Caballo Rojo	Sp	N.D.	On an as-needed basis.
PSI Energy	Gibson	Powder River Basin	T	N.D.	The test burn will last for 12 months.
Southwestern Electric Co.	Flint Creek	Southern Powder River Basin	So	100,000-200,000	To be issued in the Fall of 1993 or Spring of 1994.
TU Electric	Monticello	Caballo Rojo	Sp	N.D.	
Wisconsin Power & Light	Columbia Nos.1 & 2, Edgewater 3 & 5, Nelson Dewey	Powder River Basin	So	>13,000,000	For 1994 to 1996 contracts
	Edgewater No. 5	Black Thunder	So	500,000	

last January's loss of Black Butte's long-term contract with Commonwealth Edison. The Commonwealth Edison contract accounted for nearly half of Black Butte's production.

Coalbed Methane

Although Metfuels is continuing its coalbed methane project in the Hanna Coal Field, there has been no other significant developments and/or drilling for coalbed methane in Wyoming in the past quarter.

Recent Publications on Coal Geology

International Journal of Coal Geology

Volume 22, 1993

Smyth, M., and Buckley, M. J., 1993, Statistical analysis of the microlithotype sequences in the Bulli Seam, Australia, and relevance to permeability for coal gas: p. 167-187.

Petersen, H. I., 1993, Petrographic facies analysis of Lower and Middle Jurassic coal seams on the island of Bornholm, Denmark: p. 189-216.

Klika, Z., and Kraussová, J., 1993, Properties of altered coals associated with Carboniferous red beds in the Upper Silesian Coal Basin and their tentative classification: p. 217-235.

Kortenski, J., and Bakardjiev, S., 1993, Rare earth and radioactive elements in some coals from the Sofia, Svoge, and Pernik Basins, Bulgaria: p. 237-246.

Wilks, K. R., Mastalerz, M., Bustin, R. M., and Ross, J. V., 1993, The role of shear strain in the graphitization of a high-volatile bituminous and an anthracitic coal: p. 247-277.

Querol, X., Alastuey, A., Chinchon, J. S., Fernandez Turiel, J. L., and Lopez Soler, A., 1993, Determination of pyritic sulphur and organic matter contents in Spanish subbituminous coals by X-ray powder diffraction: p. 279-293.

Riediger, C. L., 1993, Solid bitumen reflectance and Rock-Eval T_{max} as maturation indices: an example from the "Nordegg Member", Western Canada sedimentary basin: p. 295-315.

The Journal of Coal Quality

Volume 12, No. 1, 1993

Fauth, G., 1993, Experiences with on-stream analysis in German coal industry: p. 1-8.

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Cornett, M. S., 1993, Coal gasification: p. 14-18.

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Lloyd, W. G., Riley, J. T., Risen, M. A., Gilleland, S. R., and Tibbits, R. L., 1993, Estimation of ash fusion temperatures: p. 30-36.

Wertz, D. L., Smithhart, C. B., Steele, M. L., and Caston, S., 1993, X-ray characterization of resids from the Wilsonville, Alabama, two-stage direct liquefaction facility. I. XRD and XRF analysis of the Illinois No. 6 resids from run No. 257: p. 36-41.

Selected Publications on Wyoming Coal Geology

Roehler, H., 1993. Eocene climates, depositional environments, and geography, Greater Green River Basin, Wyoming. U.S. Geological Survey Professional Paper 1506-F.

Heffern, E.L., Coates, D.A., Whiteman, J. and Ellis, M.S., 1993, Geologic map showing distribution of clinker in the Tertiary Fort Union and Wasatch Formations, northern Powder River Basin, Montana. U.S. Geological Survey Coal Investigations Map C-142. Scale = 1:175,000.

Watson, W.D., 1992, Opportunity costs of Federal land-use restrictions for U.S. coal markets. Natural Resource Modeling, vol. 6, no. 3, p. 257-284.

INDUSTRIAL MINERALS AND URANIUM UPDATE

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

Aggregate (Construction)

The Wyoming Department of Transportation is testing an experimental aggregate for use as a chip seal on U.S. Highway 85 south of Cheyenne (**Figure 16**). It is a lightweight aggregate produced by Western Aggregates of Boulder, Colorado, not a ceramic material. The aggregate, which is actually a shale, expands upon heating. The material is supposed to reduce the risk of windshield breakage and other vehicle damage caused by loose rock chips. In the past,

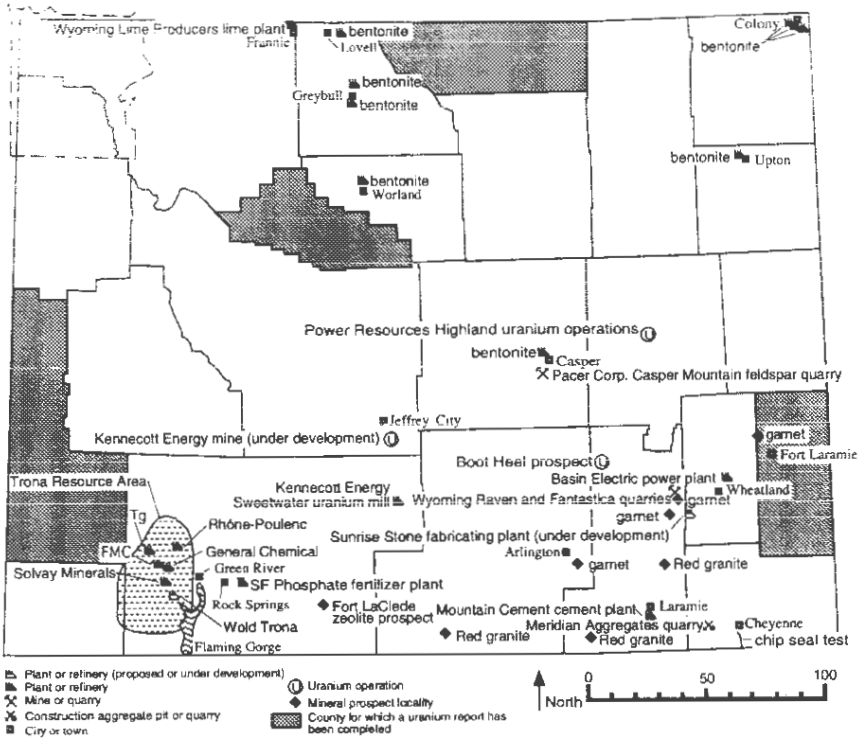

Figure 16. Industrial minerals and uranium activities in Wyoming during the third quarter of 1993.

there was a lightweight aggregate plant in Laramie which produced expanded shale from the Cretaceous Niobrara Formation, and marketed the product under the trade name of "Idealite". If this aggregate is successful, there will be a new market for lightweight aggregate, and a need for additional plants to produce the lightweight chip seal material.

Production of granitic aggregate, known as "Sherman Granite" (technically a quartzofeldspathic gneiss), continues at Meridian Aggregate's quarry west of Cheyenne (**Figure 16**). This is the largest such quarry in the region. Production continues to increase as new contracts are made for granitic aggregate and railroad ballast.

Nationally, the production of construction aggregate is about the same as for the same period in 1992. Half (by volume) of all nonfuel mining in the U.S. is construction aggregate, according to the U.S. Bureau of Mines. Road construction and repaving consume about 60% of this product.

Bentonite

Bentonite production continues to expand in Wyoming. The industry is recovering after a ten-year slump, which began with the decline in oil and gas well drilling in 1982. Bentonite is the primary ingredient in drilling mud. However, other uses of bentonite continue to increase, and bentonite production should reach about 75% of the 1982 production levels in the next year or so. Bentonite is mined in Wyoming in numerous pits. It is processed and packaged at nine plants located in the Black Hills, Bighorn Basin, and in the Casper area (**Figure 16**).

Decorative Stone

Sunrise Stone Company continued production of black granite (technically an amphibolite) at its Wyoming Raven quarry and the pink and gray swirled granite (technically a gneiss) at its adjoining Fantastica quarry, both in Albany County (**Figure 16**). Toby SerVoss, owner of Sunrise Stone, recently completed an order for eight truckloads of "Fantastica", which is being used on a Federal building in Chicago. Sunrise is also negotiating with the Federal government for black stone for the proposed Korean War Memorial. Also, there may be a chance that Sunrise's "Wyoming Raven" may replace the Indian "black" rock in the Vietnam War Memorial. The suppliers of the original stone for this memorial apparently used a shoe polish-like coating to make the rock black. Over the past few years, the memorial has lost the coating and has turned brown. There are rumors in Washington that the entire monument may be redone now that there is a stone produced in the U.S. that is black enough to work properly. That stone is "Wyoming Raven".

Sunrise Stone has begun construction of a stone fabricating plant, where stone from the Wyoming Raven and Fantistica quarries will be cut and polished into monuments and possibly into 4' by 8' slabs (see *Wyoming Geo-notes No. 39*, p. 35). This plant is located one-half mile northwest of the junction of Tunnel Road and Wyoming Highway 34 in Platte County (**Figure 16**). Sunrise plans to make the facility available to other quarriers on a contract basis.

Two potential purchasers of red granite were in Wyoming this summer. Gideon Stone, USALA Co., Ltd. from Taiwan plans a return visit and negotiations are underway to supply them with red granite from as many as three separate quarry sites. A Denver-based company, affiliated with Sunrise Stone, is developing plans for one or two new red granite quarries to supply orders for red granite for several large buildings in Saudi Arabia. The red granites are located in Albany and Carbon Counties (**Figure 16**). The initial phases in the permitting process have been submitted to State and Federal agencies.

Feldspar

Pacer Corporation, of Pringle South Dakota, operates a feldspar quarry on Casper Mountain (**Figure 16**). Most of the feldspar produced from this quarry is sold as landscape rock. This quarry was active in the summer of 1993.

Fertilizer

The joint venture, which operates the fertilizer plant southeast of Rock Springs (**Figure 16**), is now known as SF Phosphates Limited Company. It was formerly known as FS Industries. The joint venture is a partnership between J. R. Simplot of Idaho Falls, Idaho, and Farmland Industries of Philadelphia, Pennsylvania. Phosphate-based soil conditioners are manufactured in the plant from phosphate mined north of Vernal, Utah, and sulfur from the desulfurization of Wyoming natural gas. The phosphate is transported to the plant through a slurry-pipeline.

Garnet

Because manufacturers of abrasives have had to shift away from silica (quartz or tripolite), garnet has become an exploration target. Garnet does not come under the new Federal standards for airborne silica. Garnet is found in Wyoming in Precambrian schists and in smaller placer deposits. Three companies conducted exploration projects for industrial garnet in Wyoming this summer. Areas of garnetiferous schists in the Medicine Bow Mountains south of Arlington, in the Laramie Mountains west of Wheatland, and in the Hartville uplift northwest of Fort Laramie were examined (**Figure 16**). There are no immediate plans for the development of these localities.

Lime and Cement

Limestone is used for construction aggregate, as a building stone, as a decorative stone, and as a chemical product. Most chemical grade limestone (95% CaCO3 or greater) is heated and converted into lime (CaO).

Until this year, the only lime converters in Wyoming were associated with the Laramie cement plant, the coal-fired power plants where lime is used as a stack scrubber, or in small portable lime converters associated with highway construction projects. In January of 1993, Wyoming Lime Producers opened its 500-ton per day plant located 1.5 miles north of Frannie, in Park County, Wyoming (**Figure 16**). Wyoming Lime Producers is a subsidiary of Dakota Coal Co., which is a subsidiary of Basin Electric Power Cooperative of Bismarck, North Dakota. The limestone used by the plant comes from the Warren limestone quarry located six miles north of Wyoming in Montana. The Frannie plant is coal-fired, and uses up to 120 tons of coal per day. This coal is purchased from the Big Horn coal mine near Sheridan. Lime from this plant is used in scrubbers at the Antelope Valley power plant near Beulah, North Dakota, and at the Laramie River power plant near Wheatland, Wyoming (**Figure 16**). Both of these coal-fired power plants are operated by Basin Electric.

Trona

Trona is mined in Wyoming from five underground operations west of Green River and refined into soda ash and other sodium compounds at five refineries (**Figure 16**). Worldwide, 30% of all soda ash is produced from mined trona, the

rest is produced from limestone, salt, and other ingredients by the synthetic Solvay process. Synthetic soda ash is more expensive than that refined from trona. Over 95% of the world's soda ash produced from mined trona comes from the U.S., and 90% of all of the trona mined in the U.S. comes from Wyoming.

The primary use of soda ash is in the manufacture of glass. Other uses include the production of caustic soda, an ingredient in soap and detergents, a chemical used in paper treatment, in flue gas desulfurization, and many other uses, including baking soda, which is pure soda ash. All uses of soda ash have been increasing except for the manufacture of glass, which has remained relatively flat, and the production of caustic soda, which has decreased.

Due to expanding overseas markets, the soda ash industry has been expanding in recent years. Construction and upgrading continues at the five existing plants, and Wold Trona is proceeding with its plans for the construction of a sixth trona mine and refinery *(see Wyoming Geo-notes No. 39)* (**Figure 16**). The U.S. Bureau of Land Management (BLM) conducted scoping studies in June and July of this year. As part of its plan, Wold Trona has proposed the exchange of some State land within the Flaming Gorge National Recreation Area for some BLM land in the proposed trona mining area.

The BLM is seeking comments on a proposed sodium (trona) lease sale scheduled for late 1994 or early 1995. The tracts under consideration include approximately 9,800 acres located about 10 miles west of Green River.

On August 1, the United Steelworkers union began a strike against General Chemical, one of the five soda ash producers. As of early November, the plant was operating and shipping soda ash using non-union personnel.

Uranium

The NUEXCO spot market uranium prices in **Table 9** give information about the relative prices of yellowcake and price trends. These prices are not necessarily the figure at which yellowcake is sold. Add-ons and other factors increase the sale price of uranium compounds. And other price indicators are higher than the NUEXCO spot market price.

In Wyoming, yellowcake is commercially produced at Power Resources' Highland in-situ operation in the southern Powder River Basin north of Glenrock (**Figure 16**). Kennecott Energy is continu-

Table 9. NUEXCO spot market price of yellowcake, October, 1992, to April, 1993, (end-of-month price in current dollars).

Month	Price
Oct. 1992	$8.00
Nov. 1992	7.90
Dec. 1992	7.85
Jan. 1993	7.65
Feb. 1993	7.60
Mar. 1993	7.45
Apr. 1993	7.10
May. 1993	7.10
Jun. 1993	7.00
Jul. 1993	6.90

ing development of their Jackpot underground uranium mine south of Jeffrey City (**Figure 16**). The proposed mine output of about 3,000 tons of uranium ore per day will be processed at the Sweetwater mill, 25 miles south of the mine. The BLM is conducting studies and public hearings on the project.

In September, the Secretary of Energy announced the formation of a quasi-independent agency, the U.S. Enrichment Corporation, which will operate uranium enrichment plants for a profit. Yellowcake from uranium mills is sent to enrichment plants, where it is converted into uranium hexafluoride. Due to slight differences in the diffusion rates of ^{235}U, this isotope is concentrated in the enrichment plants, and nuclear fuel, containing around 3% of the fissionable isotope, is produced. This process is expensive, and accounts for most of the price of nuclear fuel.

The U.S. Nuclear Regulatory Commission (NRC) announced earlier this year that it would close its Denver office. Wyoming uranium operators fear that the closure will mean delays in licensing and permitting, because approval for these activities would have to come from the NRC office in Washington D.C.

American Nuclear Corporation, which had planned to create a repository for naturally occurring radioactive materials in Wyoming, dropped plans for such a facility. The company said that it was too costly to proceed with the project.

The U.S. State Department and the U.S. Department of Energy announced in mid-July that the U.S. would resume taking back nuclear weapons-grade uranium from foreign countries. This material had been used for atomic research by several countries around the world. The U.S. is retrieving the material, which it originally supplied to prevent its diversion into atomic weapons.

It is reported that CAMECO, Canada's largest uranium producer, has acquired the Boot Heel property in northern Albany County (**Figure 16**) (Bob Odell, personal communication, Oct. 4, 1993). CAMECO has not announced any plans to develop the property. Negotiations between CAMECO and the owners of several Wyoming uranium properties have been ongoing for the past few years.

The Geological Survey of Wyoming has published three more uranium open file reports as part of a series of county-by-county surveys of all uranium and other radioactive mineral occurrences, past producing mines, and active mines in Wyoming. The new reports, covering Lincoln (OFR 93-2), Hot Springs (OFR 93-3), and Sheridan (OFR 93-4) Counties (**Figure 16**) are the second through fourth in the series. The first report in this series covered Goshen (OFR 93-1) County. (See pp. 49-50 for additional information.)

Zeolites

Several companies are interested in developing the zeolite resources found in the Washakie Formation in the Washakie Basin southeast of Rock Springs. These companies have expressed particular interest in the Fort LaClede prospect (**Figure 16**). However, the development of these resources is on hold because the area is withdrawn from mineral entry due to a preexisting oil shale withdrawal. There have been efforts to encourage the BLM to rescind the withdrawal.

METALS AND PRECIOUS STONES UPDATE

by W. Dan Hausel
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Diamonds

Diamonds dominated exploration activities in Wyoming throughout the summer. Exploration for the gemstone continued in Colorado and Wyoming where Canadian, American, and Australian companies, as well as independent prospectors, continued their acquisition of prospects. More than 100,000 gem and industrial diamonds have been mined from Colorado and Wyoming since the first diamond was discovered in this region in 1975 (McCallum, 1991).

Diamond recovery from a group of kimberlites known as the Kelsey Lake intrusives continued along the state line. In a press release by Redaurum Red Lake Mines Limited (RRLML) of Toronto (August 24, 1993), the company reported that they had entered into an agreement with Diamond Company, N.L., to acquire a working interest in the eight Kelsey Lake diamondiferous kimberlites in the Colorado-Wyoming State Line district. It was reported that RRLML would acquire 25% of the issued capital of Colorado Diamond Corporation Limited, which holds the mineral rights to the Kelsey Lake properties.

It was further reported that a 1,764-ton bulk sample from the two largest of the Kelsey Lake intrusives yielded a total of 58.3 carats of diamond. In weight, the diamonds were 0.4 to 2.23 carats, and the parcel included both gem and industrial quality stones.

Drilling on the Kelsey Lake property identified a potential resource of 11 million tons of diamond ore to a depth of 6,400 feet. The next major phase of the project is the expansion of Diamond Company, N.L.'s diamond recovery pilot plant located in Wyoming. According to the Denver Post (July 25, 1993, p. 14A), Howard Coopersmith, President of Diamond Company, N.L., reported that the company could have a production decision by the end of 1994.

Last Spring, it was reported that Royal Star of Canada had obtained the exploration rights on the Sloan 1 and 2 diamondiferous kimberlite diatremes in the Prairie Divide region of Colorado. Work is continuing on the property and preliminary plans are to drive an exploration adit under the property to evaluate portions of the pipes (Ernie Black, personal communication, 1993). These plans are based on earlier studies that suggested portions of the pipes may be economical to mine (Frank Yaussi, personal communication, 1993).

Fleck Resources of Canada obtained the right to explore properties north of the Kelsey Lake intrusives in the Wyoming portion of the State Line district where the first diamonds were discovered by Dr. M.E. McCallum of Colorado State University in 1975 (McCallum and Mabarak, 1976). The company is currently raising funds to test several known diamondiferous kimberlites in the district and to test several distinct geophysical anomalies (Paterson and MacFadyen, 1984). This portion of the district includes a group of 18 kimberlite intrusives known as the Schaffer group and Aultman 1 and 2 diatremes (Hausel and others, 1981).

North of the State Line district, exploration is also reported in the Happy Jack-Pole Mountain area, Sybille Canyon region, and in the Elmers Rock greenstone belt in the Laramie Mountains to the east and northeast of Laramie. The exploration activities in this region are based on the results of a 12-year study by the Geological Survey of Wyoming (GSW) which identified more than 300 heavy mineral anomalies in the Laramie Mountains, Medicine Bow Mountains, and the Seminoe Mountains (Hausel and others, 1988). The heavy mineral anomalies consist of mineral grains of pyrope garnet, chromian diopside, and/or nonmagnetic ilmenite identified in more than 1,600 stream-sediment samples collected by the GSW.

Diamond exploration is also occurring in the Green River Basin of western Wyoming, where at least three companies have recently acquired properties with diamond potential. Interest in the Green River Basin surrounds several square miles of anthills and road cuts around Cedar Mountain and near Granger. Pyrope garnet and chromian diopside have been found in both areas. There is also some interest in the Leucite Hills. The Leucite Hills, north of Superior, Wyoming, form one of the three largest lamproite fields in the world, and these lamproites are similar to the diamondiferous lamproites found in Australia and other countries.

Diamond Short Course

The author taught a 4-hour short course on diamond exploration and prospecting methods to a full house on September 17th in Casper. The course was co-sponsored by the Wyoming Geological Association and the Geological Survey of Wyoming. Attendees learned about new ideas regarding diamondiferous host rocks, how to recognize some of the common host rocks and related mantle minerals, and methods used to explore and prospect for diamond

deposits. Groups interested in sponsoring or scheduling a similar short course should contact the author at (307) 766-2286 for details.

Copper

Kurtz-Chatterton property, Encampment district: The Geological Survey of Wyoming continued studies at the Kurtz-Chatterton property on Copper Creek in the Sierra Madre of southern Wyoming. Samples collected from the property in 1992 yielded highly anomalous values in copper, gold, and silver. Current studies are focusing on mineralization, wallrock alteration, and geologic mapping at 1:12,000.

So far this year, several companies have expressed interest in the Kirwin copper-silver-gold porphyry located in the southwestern Absaroka Mountains, Wyoming. Amax's exploration of the porphyry in the 1960s and 1970s outlined a minimum reserve of 196 million tons of ore averaging 0.505% copper. Because the drill core is currently stored on the property, parties interested in the property or core should contact the U.S. Forest Service, P.O. Box 2140, Cody, Wyoming, 82414 for information. Their phone number is (307) 527-6241.

Copper King mine, Silver Crown district: Compass Minerals, Ltd., based in Reno, began exploration of the Copper King mine in the Silver Crown district of the Laramie Mountains this fall. The Copper King mine, according to available reports, is a large tonnage, low-grade gold-copper porphyry of Proterozoic age. Based on past drilling results, the Copper King contains at least 35,000,000 tons of 0.22% copper and 0.02 ounce of gold per ton with potential to expand and upgrade the identified reserves.

Gold

Wolf Gold mine, Lewiston district: Barnhart Drilling Company of Riverton, Wyoming, continued exploration of the Wolf gold mine in the Lewiston district of the South Pass greenstone belt along the southern tip of the Wind River Range. The Wolf property was mapped and sampled by the Geological Survey of Wyoming (GSW) in the 1980s (Hausel, 1988, 1991). The GSW identified two shear zones: the principal shear was traced one mile along trend, and a second shear was traced 2,000 feet along strike. A sample collected by the GSW from the primary shear yielded 23 ppm Au (Hausel, 1991, p. 79).

Exploration by Barnhart Drilling resulted in the discovery of two hidden shear zones in addition to the two mapped by the GSW. The presence of four, relatively wide, shear zones, should make the Wolf property an attractive large tonnage gold deposit. According to Ed Finch, company president (personal communication, October 6, 1993), the shear zones have the following approximate widths. Shear number 1 is 200 to 250 feet wide; shear number 2 is 200 to 250 feet wide; shear number 3 is 50 feet wide; and shear number 4 is 200 feet wide. Shears 1 and 3 were mapped by the GSW.

Placer Dome's recent sampling on the property produced a 10-foot channel sample on the number 1 shear that yielded more than 1.0 ounce per ton (opt) gold. This sample was collected from an estimated 150-foot long, plunging, ore shoot in the vicinity of the historic Wolf shaft. Another 16-foot channel sample in the number 1 shear assayed 1 ppm (0.03 opt) gold (Ed Finch, personal communication, 1993). Other samples reported by Barnhart Drilling Company included a 10-foot channel in the number 4 shear that assayed 0.5 ppm (0.015 opt) gold. Two channel samples collected in the number 3 shear assayed 1 ppm (0.03 opt) gold. Barnhart Drilling Company is currently seeking a joint venture partner.

Carissa gold mine, South Pass-Atlantic City district: The principal historic gold producer in the South Pass greenstone belt was the Carissa gold mine in the South Pass-Atlantic City district located about 15 miles northwest of the Wolf mine. The Northern Miner (Sept. 6, 1993) reported that Annabel Gold Mines (AGM) of Vancouver took an option on the Carissa mine from the current owner, Hol Lac Gold Mines (also of Canada), and will earn a 50% interest in the property by funding two years of exploration at $250,000 per year.

The Carissa property consists of 12 patented claims entirely owned by Hol Lac Gold. In 1989, diamond drilling by Consolidated McKinney Resources (another Canadian company), both on the surface and underground, showed that an 80-foot-wide mineralized zone continued to a minimum depth of least 150 feet below the deepest mine workings (the Carissa workings are a maximum of 400 feet deep). Drilling by Anaconda Mining Company in the 1970s intersected the mineralized zone at a depth of about 900 feet below the surface.

The mine was developed by a 350-foot-deep shaft with level four extending from the bottom of the shaft. A 50-foot-deep winze continues below the fourth level to level five. More than 2,300 feet of drifts were developed on a narrow, well-defined, shear. This shear is enclosed by a large envelope of altered, fractured, and rehealed metagreywacke country rock. The envelope enclosing the shear is also mineralized over a minimum width of 97 feet on the surface (Hausel, 1991).

Exploration also continues on some other properties in the district. Much of this exploration is preliminary and no information has been made public.

This fall, a company geologist, accompanied by the author, collected a sample of specimen-grade quartz from the Mint mine located in the Lewiston district. The sample contained several flakes and rods of visible gold.

Rattlesnake Hills

The Geological Survey of Wyoming continued geologic mapping and sampling for gold and other metals in the Rattlesnake Hills supracrustal belt of central Wyoming. Gold has been found in Archean shears and veins and in Tertiary breccias and jasperoids associated with 42-million-year-old alkalic plugs. Two companies are currently exploring the supracrustal belt.

Southern Wyoming

A major mining company continued exploration for Archean and Proterozoic age paleoplacer gold at an undisclosed location in southern Wyoming. Elsewhere, another company initiated plans to explore Tertiary age paleoplacer gold. No results have been made public.

Seminoe Mountains

The Geological Survey of Wyoming published the results of a two-year study of the Seminoe Mountains greenstone belt. The report, which was recently published in the Wyoming Geological Association Jubilee Anniversary Field Conference Guidebook (Hausel, 1993a), included a 1:24,000-scale geologic and sample location map.

The report indicates that the Seminoe Mountains is a folded fragment of an Archean greenstone belt with relatively well-preserved peridotitic and basaltic spinifex metakomatiites, metabasalts, metagreywackes, pelitic schists, banded iron formation, and felsic volcaniclastics. More than 100 million tons of banded iron formation (BIF) have been identified in the district.

Some localized gold, silver, copper, and zinc anomalies have been found associated with the BIF. Values of <0.001 to 42.3 ppm (34.3 ppm = 1.0 ounce per ton) gold, <0.1 to 15.55 ppm silver, 0.003 to 0.045% copper, and 90 ppm and 2,820 ppm (1,000 ppm = 0.1%) zinc were detected in epigenetically altered BIF. Other selected and grab samples of veins, gossans, and altered wallrock yielded from <0.01 to 89.3 ppm gold, <0.5 to 63.8 ppm silver, 0.03 to 4.7% copper, 3 to 9,530 ppm lead, 11 to 43,000 ppm zinc, 27 to 7,600 ppm chromium, and 15 to 2,400 ppm nickel. Possibly the most promising area in the district is a nearly one-half mile diameter, propylitically altered zone, which surrounds the Penn mines on Bradley Peak. Both veins and altered wallrock in this zone have yielded gold anomalies.

Another interesting sample taken from a Tertiary paleoplacer, yielded visible gold, eight purple pyrope garnets, and four chromian diopsides. The paleoplacer contains abundant cobbles and pebbles of BIF suggesting that it originated from the Bradley Peak area. Prior to this sample, this area had not been considered for diamond exploration.

Wyoming Mining History

Another paper published by the Wyoming Geological Association reviewed the State's early mining history for metals and precious stones (Hausel, 1993b). The paper describes early prospecting by the Spanish, elaborates on the historic gold and copper booms of the State, and summarizes some of the notorious mining scandals, including the Great Diamond Hoax and the salting of specimens in the Silver Crown district.

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MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING

PETROLEUM

Remaining Resources (January 1, 1993)		
Discovered (Includes 10 billion barrels recoverable by enhanced recovery techniques)	12.5	billion barrels[1]
Undiscovered	7.6	billion barrels[1]
Total	20.1	billion barrels
Remaining Reserve Base (January 1, 1993)		
Measured reserves (Proved reserves) (Includes oil, gas liquids, and condensate)	1.26	billion barrels[2]
Indicated and inferred reserves	2.80	billion barrels[1]
Total	4.06	billion barrels

NATURAL GAS

Remaining Resources (January 1, 1993)		
Discovered (Includes 20.1 trillion cubic feet (TCF) of methane[1] and 122.0 TCF of CO_2[3])	141.1	trillion cubic feet
Undiscovered (Includes 58 TCF of conventional methane[1]; 7 TCF of coalbed methane[4]; 3,611 TCF of methane in tight gas sands in the Green River Basin[5]; and 31.2 TCF of CO_2[3])	3,707.2	trillion cubic feet
Total	3,848.3	trillion cubic feet
Remaining Reserve Base (January 1, 1993)		
Measured reserves (Proved reserves) (Includes 10.4 TCF of methane[2] and 60.6 TCF of CO_2[3])	70.0	trillion cubic feet

COAL

Remaining Resources (January 1, 1993)		
Identified and Hypothetical (Discovered)	1,428.2	billion tons[6]
Speculative (Undiscovered)	31.5	billion tons[6]
Total	1,459.7	billion tons
Remaining Reserve Base (January 1, 1993)		
Demonstrated strippable (Measured and indicated reserve base)	26.6	billion tons[7]
Demonstrated underground-minable (Measured and indicated reserve base)	42.5	billion tons[7]
Total	69.1	billion tons

TRONA

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

URANIUM

Remaining Resource (December 31, 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, 1992, U.S. crude oil, natural gas, and natural gas liquids reserves: 1991 Annual Report, November, 129 p.
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[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 Januery 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, Geological Survey of Wyoming

Hole-in-the-Wall Location Dictated by Geologic Phenomenon

The Hole-in-the-Wall was made famous by various groups of bank robbers and rustlers who used this erosional feature as a hidden route in and out of the rugged surrounding area which served as their hideouts for many years. Outlaws frequented this general area as early as the 1860s during the Civil War and as late as the turn of the century. Probably the most famous group to use the Hole-in-the-Wall was the Wild Bunch led by the notorious Butch Cassidy.

The Hole-in-the-Wall is a narrow notch eroded in a nearly continuous, vertical cliff called Red Wall, which runs for nearly 25 miles north to south on the east slope of the southern Bighorn Mountains. The only other breaks in the "Wall" occur where the Middle Fork of the Powder River and Beaver Creek cut through the "Wall" 7-10 miles north of the Hole-in-the-Wall. The cliff or Red Wall is made up of the red shales, siltstones, and sandstones of the Chugwater Formation and it towers 400-500 feet above Buffalo Creek which parallels it to the west (**Figure 17**).

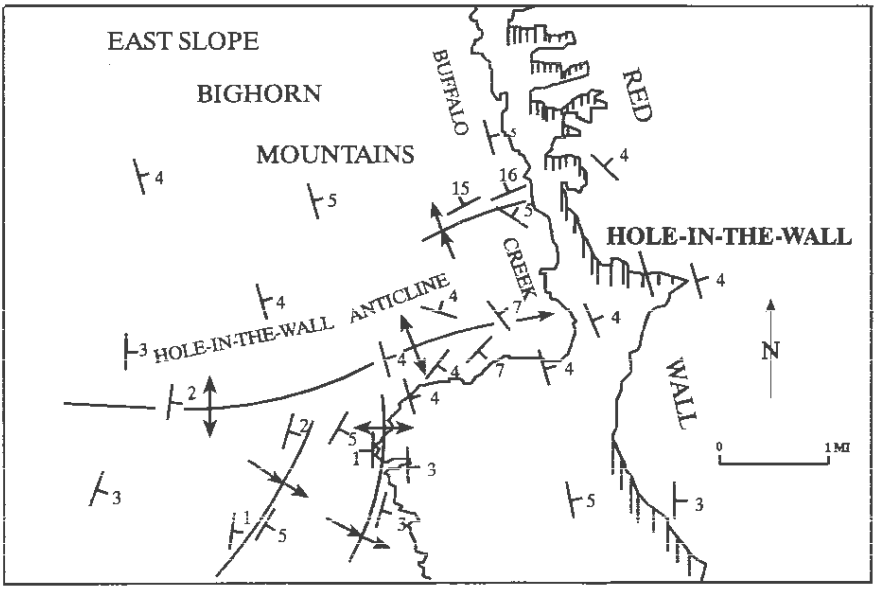


Figure 17. Structural geologic map showing the location of the Hole-in-the-Wall anticline and its effect on the route of Buffalo Creek. The resultant erosional forces led to the creation of the Hole-in-the-Wall. Strike and dip symbols on the map indicate the direction and angle of the rock units exposed in the area.

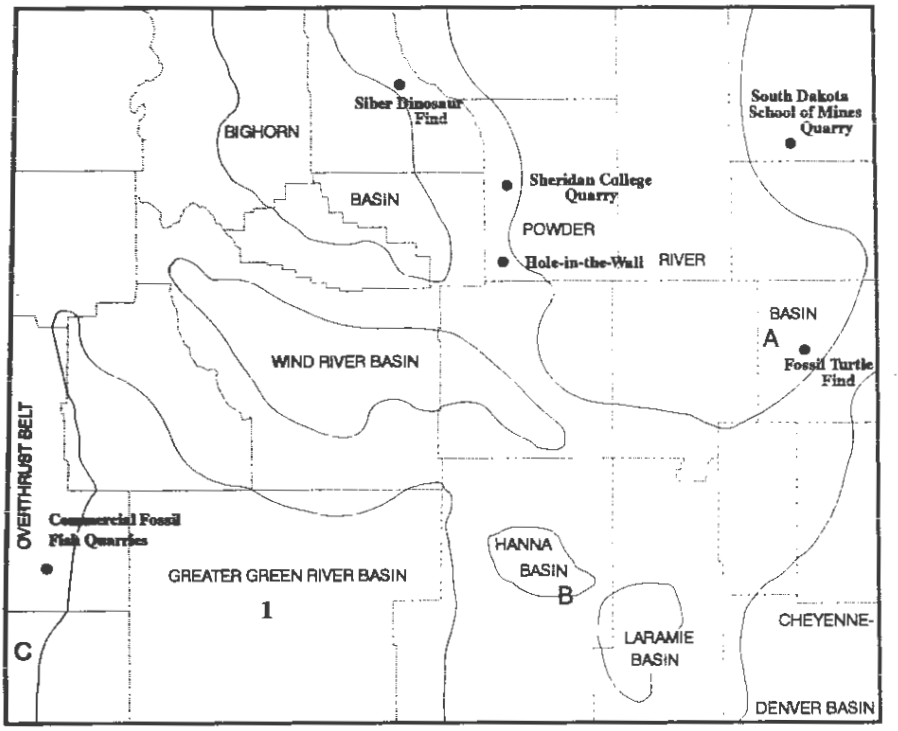
This summer, the Geological Survey of Wyoming completed fieldwork on the Poker Butte and Hole-in-the-Wall Quadrangles and identified some previously unmapped geologic features. These latter features account for the formation and location of the Hole-in-the-Wall. Dip and strike measurements on the bedrock in the area (Triassic Chugwater Formation, Triassic/Permian Goose Egg Formation, and Pennsylvanian Tensleep Sandstone) reveal an east plunging anticline in the area immediately west of the Hole-in-the-Wall (**Figure 17**). Hole-in-the-Wall anticline trends primarily west to east, perpendicular to the regional trend of the rocks, which is mostly north-south along the east flank of the Bighorn Mountains. This anticline also represents a flex-point where the strike of the rocks changes from north-northwest (N15W) to northeast (N25E) as the east flank of the Bighorns begins to wrap around to a more southerly strike and dip into the Wind River Basin (**Figure 17**).

The Hole-in-the-Wall, an erosional feature in the Triassic Chugwater Formation, is at the plunging end of this anticline (**Figure 17**). At this location there is a slight flexure in the Chugwater Formation of the Red Wall accompanied by some fracturing of the bedrock. This fracturing weakened the bedrock making it more susceptible to erosion. However, Buffalo Creek is the primary reason for the occurrence of the Hole-in-the-Wall at this location. Buffalo Creek traditionally flowed toward the north or parallel to regional strike of the rocks in the area, eventually flowing into the Middle Fork of the Powder River. Erosion by this stream formed the Red Wall. Although Buffalo Creek generally flows north, it was deflected to the east when it encountered the Hole-in-the-Wall anticline. Buffalo Creek then made another right-angle bend back to its previous northerly direction of flow around the plunging nose of the anticline (**Figure 17**). When this deflection of Buffalo Creek was initiated, the Hole-in-the-Wall began to form and eventually became the feature we see today.

New Paleontological Finds in Wyoming

Hans Jacob Siber of the private Swiss paleontological firm Siber & Siber recently announced a new dinosaur discovery on private land north of Shell, Wyoming (**Figure 18**). A team, headed by Siber, located a *Camarasaurus* skeleton which is nearly complete. The *Camarasaurus* was a giant, plant-eating dinosaur, which was quite common to the Jurassic. The find is in the Jurassic Morrison Formation, which is over 138 million years old. Siber indicated the skeleton would be shipped back to Switzerland to become the centerpiece of a museum that Siber opened last year in Aathal. This new find is in the vicinity of the abandoned Howe quarry, which was active in the 1930's, and is the latest in a series of recent finds in the area (see *Wyoming Geo-notes No. 32*, p. 40-41).

This summer, a vertebrate paleontologist from Alabama made an interesting find on a private ranch in Niobrara County (**Figure 18**). Dr. William Garstka from the University of Alabama in Huntsville found a more than 30-million-year-old fossilized turtle in the Oligocene White River Formation. Although it is not unusual to find turtle shells, it is very unusual to find a specimen in which the internal structure and bones are preserved as well as they were in Garstka's find.



GEOLOGICAL SURVEY OF WYOMING, 1993

Figure 18. Index to selected geologic activities and recently released maps and reports on Wyoming geology.

Study of the internal structure of the turtle may reveal a wealth of new information on the habits and habitat of this ancestor of today's pond turtle. Garatka indicated most of what he collected this summer were oreodons, which are 30 to 35-million-year-old precursors of present day pigs.

In a related note, the Geological Survey of Wyoming recently completed its annual inspection of fossil collecting permits on State land. In Wyoming, permits from the State Land and Farm Loan Board are required for both scientific and commercial fossil collecting on State lands. Five commercial permits were examined in the Kemmerer area (**Figure 18**). These quarries are all located in the Eocene Green River Formation in the Fossil Basin where the operators are collecting fossil fish. In addition, two scientific permits were visited. A dinosaur quarry operated by South Dakota School of Mines near Sundance, Wyoming, was examined this fall (**Figure 18**). Crews uncovered an articulated portion of a *Camarasaurus* in the quarry, as well as some additional inarticulated bones from other dinosaurs. This quarry is located in a stream channel in the upper portion of the Jurassic Morrison Formation. Sheridan College, as an agent of the University of Wyoming, operates the other examined scientific permit, which is on the flanks of the Bighorn Mountains, southwest of Buffalo, Wyoming (**Figure**

18). Material discovered at this site during the past field season included inarticulated bones from a *Diplodocus*. This quarry is also located in the upper portion of the Morrison Formation.

New Journal Articles on Wyoming Geology

Three new articles on Wyoming geology were recently published in scientific journals. Landman and Waage (1993) discuss their research on ammonites in the Upper Cretaceous Fox Hills Sandstone of Wyoming and South Dakota. Specimens were collected and described from north-central South Dakota and from the Red Bird-Lance Creek area of Wyoming. Martinsen and others (1993) described their study of the tectonics and stratigraphy of the Upper Cretaceous Mesaverde Group in southeastern Wyoming. Their work specifically addressed the Hanna Basin area where the Mesaverde Group filled the basin in two distinct episodes. West (1993) describes the reactivation of thrust faults and the accompanying Quaternary listric normal or extensional faulting in southwestern Wyoming and northcentral Utah. There is evidence indicating the reactivated movement is in the normal sense or opposite of the original thrust motion.

Each of these articles or reports is listed below and the Wyoming portions of the study areas are shown on the accompanying index map (**Figure 18**).

A. Landman, N.H., and Waage, K.M., 1993, Scaphitid ammonites of the Upper Cretaceous (Maastrichtian) Fox Hills Formation in South Dakota and Wyoming: American Museum of Natural History Bulletin 215, 257 p.

B. Martinsen, O.J., Martinsen, R.S., and Steidtmann, J.R., 1993, Mesaverde Group (Upper Cretaceous), southeastern Wyoming: Allostratigraphy versus sequence stratigraphy in a tectonically active area: American Association of Petoleum Geologists Bulletin, v. 77 no. 8, p. 1351-1373.

C. West, M.W., 1993, Extensional reactivation of thrust faults accompanied by coseismic surface rupture, southwestern Wyoming and northcentral Utah: Geological Society of America Bulletin, v. 105, p. 1137-1150.

New U.S. Geological Survey Publication on Wyoming Geology

The U.S. Geolocial Survey has published a new map on Wyoming geology. The map by Denson, et al. (1993) details the thickness of the Upper Cretaceous Pierre Shale in the north half of the Powder River Basin. The map scale is 1:200,000. This publication is listed below and is shown on the index map in **Figure 18**.

1. Denson, N.M., Gibson, M.L., and Sims, G.L., 1993, Geologic map showing the thickness of the Upper Cretaceous Pierre Shale in the north half of the Powder River Basin, southeastern Montana and northeastern Wyoming: U. S. Geological Survey Miscellaneous Investigations Map I-2380-A, scale 1:200,000.

GEOLOGIC HAZARDS IN WYOMING

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

Western States Seismic Policy Council

The fourteenth annual meeting of the Western States Seismic Policy Council (WSSPC) was held in Jackson, Wyoming, from September 20 - 23, 1993. The meeting was chaired by the author, who is head of the Geologic Hazards Section at the Geological Survey of Wyoming. Participants and delegates from twelve western states in addition to Washington, D.C., Canada, and Guam were in attendance.

The goal of WSSPC is to provide a forum to advance Earthquake Hazard Reduction Programs throughout the western states region, and to develop and recommend seismic policies and programs for the region through information exchange, research, and education. Yearly meetings are held in areas where earthquake-related damages might occur. Jackson was selected as a meeting location as it is near the Teton fault, which is capable of generating magnitude 7.5 earthquakes.

Keynote speakers provided the participants with an update on the reorganization of the Federal Emergency Management Agency, the status of research in the National Earthquake Hazard Reduction Program, and an update on the application of national seismic hazard maps.

The keynote speakers at the meeting were Harvey Ryland, a senior policy advisor to the Director of the Federal Emergency Management Agency in Washington, D.C., Dr. Rob Wesson, Chief of the U.S. Geological Survey's Office of Earthquakes, Volcanoes, and Engineering in Reston, Virginia, and Dr. Ted Algermissen, Deputy Director of the U.S. Geological Survey's Office of International Geology in Reston, Virginia.

Representatives of two other national organizations also gave presentations at the meeting. Dr. Dick Andrews, head of the California Governor's Office of Emergency Services discussed priorities and opportunities for collaboration between WSSPC and the National Emergency Managers Association. Dr. Earl Bennett, the Idaho State Geologist, discussed both the Association of American State Geologists (AASG) National Mapping Program, and the potential for WSSPC collaboration with AASG.

Teton County preparedness initiatives were discussed at the meeting by Jim Stone, the Teton County Emergency Management Coordinator, and Rusty Palmer, the Teton County Fire Marshal. The participants at the meeting also viewed the Mobile Hospital Unit and the Mobile Communications Unit that were developed in Teton County. These mobile units allow the county to rapidly respond to any disaster, including an earthquake. Very few counties in the country have access to such equipment. The mobile units were strongly

supported by the Teton County Commissioners, who were also represented at the meeting. Ms. Sandy Shuptrine, Chairperson of the Teton County Commissioners, provided a welcoming address to the meeting participants.

As part of the WSSPC meeting, a short seminar and a field trip were conducted on how to rapidly assess the earthquake-resistance potential of buildings in a small community. A variety of buildings were visited in Jackson and Teton Village with the group concluding that newer buildings were built somewhat more earthquake resistant than many that were built before the 1980s. The workshop on how to inspect and rate buildings was conducted by Dr. Larry Reaveley, head of the Civil Engineering Department at the University of Utah. The field trip was conducted by Dr. Sherry Oaks, Colorado Earthquake Program Manager, Tim Sullivan, Building Official for the town of Jackson, and Richard Scheerer, a principal in G & S Structural Engineers of Idaho Falls, Idaho.

The next annual Western States Seismic Policy Council meeting is scheduled for Utah in 1994, followed by Arizona in 1995. For additional information on WSSPC, contact Jim Case at (307) 766-2286.

Old Earthquake Records Found

Over the last year, the Geologic Hazards Section at the Geological Survey of Wyoming searched for accounts of pre-1930 earthquakes in or near Wyoming. Wyoming newspapers from 1870-1930 were examined, and a number of events that had not been recognized in recent literature were found.

Mrs. Elnora Frye of Laramie was very helpful with our search. She was searching Laramie papers from the 1870s through 1880s, looking for stories on the Territorial Prison. Fortunately, in the process she also conducted a thorough search for seismic events. A summary of the events discovered by Mrs. Frye or by the Geologic Hazards Section is presented below:

November 7-8, 1882

Denver, CO-Laramie, WY area

In Laramie, a distinct shock was felt at 6:30 p.m., November 7, 1882. The event caused considerable apprehension, and some people ran out into the streets. Clocks were stopped, plaster was cracked, and some glass in windows was broken. The earthquake was quite strong in Denver. Another shock occurred at 5:00 a.m. on November 8, 1882. (Epicenters thought to be located in northern Colorado).

April 28, 1888

Rock Springs, WY area

A severe shock lasting several seconds was felt at 2:30 a.m. A similar event occurred several years ago, and a light shock was felt last spring.

January 22, 1889

Lander, WY area

A distinct earthquake startled many residents on Tuesday afternoon.The trembling lasted but a second or two, but everything shook while it lasted.

October 8, 1889

Manville-Lusk, WY area

Quite an earthquake shock was felt in this area Tuesday night. The event was only slightly felt in Lusk. Manville and Muskrat Canyon were well rocked. The disturbance travelled in a northeasterly direction.

February, 1893

Yellowstone N.P.

(Reported February 21, 1893). Reports state that a series of earthquakes have been felt in Yellowstone N.P. during the last few weeks. The main road south of Norris Geyser Basin caved in for a long distance and to an unknown depth. In one place, there was a huge gap in the earth about 75 feet wide and probably several hundred feet in length. Marks left by the recent earthquake are plainly visible in a number of places.

(Reported March 3, 1893). An Army officer writing to a friend at Cheyenne from Yellowstone N.P. said that earthquake disturbances continue. Ever since the shock of ten days ago, there has been unprecedented and violent activity at the Giant, Giantess, and Great Castle Geysers. The earth opened up in their vicinity, with some of the excavations being acres in extent. The eruptions shook the country for miles around. The few people in the park were greatly alarmed, and the domestic and wild animals were in a nervous condition of fright. An Indian legend states that a village in the park was swallowed up by an earthquake many years ago.

July 1894

Buffalo, WY area

(Reported July 17, 1894). Ranchers in the Bighorn Basin reported that several distinct earthquake shocks were felt in the area a few days ago. Glass in windows was broken and other slight damage was done. The shocks were accompanied by low rumbling sounds.

November 21, 1895

Lander, WY area

A distinct earthquake was felt in Lander at 5:20 a.m. Houses were jarred and dishes rattled. The shock was preceded by a low, rumbling sound. The vibration lasted about three seconds.

March 28, 1896

Rawlins, WY area

An earthquake was felt in Rawlins on Saturday evening. Lamps swayed and dishes were rattled. The wave seemed to originate in the southwest, and was accompanied by a heavy rumbling.

February, 1897

Sundance, WY area

(Reported February 5, 1897). A few days ago, residents of Sundance heard three loud reports resembling the explosion of a boiler or a great blast. The noise was heard by many in town very plainly. It was undoubtedly caused by earthquake shocks. The Shober schoolhouse on Little Houston Creek was severely shaken.

NEW PUBLICATIONS

Traveler's guide to the geology of Wyoming, by D.L. Blackstone, Jr.: Bulletin 67 (Second printing), 1988.-$7.00. [This second printing has a new yellow cover design]

Oil and gas fields map of southeastern Wyoming basins, by R.H. De Bruin and S.D. Hostetler: Map Series 42, 1993.-$5.00 ($6.50 rolled).

* Precambrian basement map of Wyoming: outcrop and structural configuration, by D.L. Blackstone, Jr.: Map Series 43, 1993.- $5.00 (folded only).

* Occurrences of radioactive elements in Lincoln County, Wyoming, by R.E. Harris and J.K. King: Open File Report 93-2, 1993.-$4.00.

* Occurrences of radioactive elements in Hot Springs County, Wyoming, by R.E. Harris and J.K. King: Open File Report 93-3, 1993.-$3.00.

* Occurrences of radioactive elements in Sheridan County, Wyoming, by R.E. Harris and J.K. King: Open File Report 93-4, 1993.-$3.00.

Overview of the Hanna, Carbon, and Cooper Lake Basins, southeastern Wyoming, by D.L. Blackstone, Jr.: Report of Investigations 48, 1993.-$10.00.

R-54. Precious metal, base metal, and gemstone deposits of Wyoming, by W.D. Hausel: Reprint 54, 1993.-$3.00.

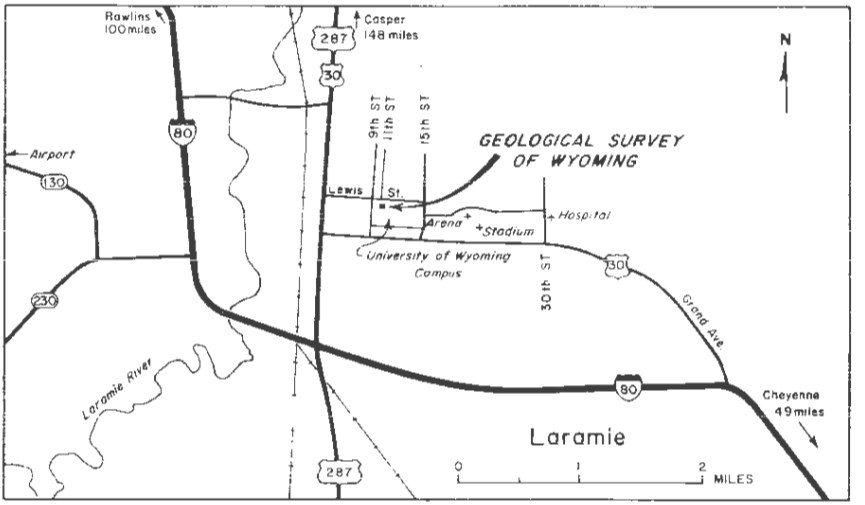
*New releases since the last issue of *Wyoming Geo-notes*.

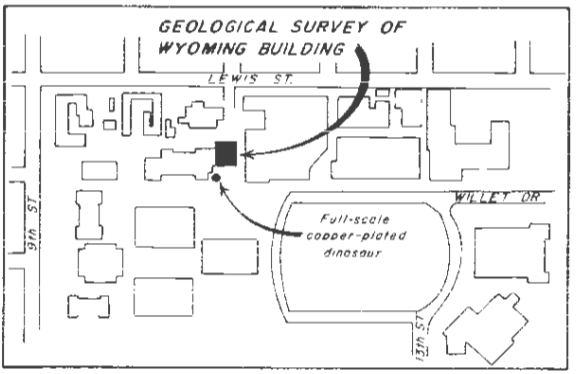
The Geological Survey of Wyoming sells the Geologic map of Grand Teton National Park, Teton County, Wyoming by J.D. Love and others: U.S. Geological Survey Miscellaneous Investigations Series Map I-2031 (1992). The full-color map and accompanying 17-page pamphlet is available rolled or folded for $4.00.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

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

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

GEOLOGICAL SURVEY OF WYOMING
LOCATION MAPS





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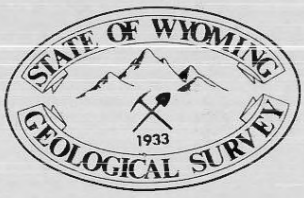
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1933
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