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

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THE GEOLOGICAL SURVEY OF WYOMING

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WYOMING GEO-NOTES
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Front cover: View of Medicine Bow Peak in the Medicine Bow Mountains west of Laramie. Photograph by D.L. Blackstone, Jr.

The Geological Survey of Wyoming
P.O. Box 3008, University Station
Laramie, Wyoming 82071

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MINERALS UPDATE

OVERVIEW

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

The last quarter of 1987 provided a few surprises. Oil prices, which had gradually increased over the year, tumbled at the end of the last quarter. And despite price rallies in early 1988, most signs point to a markedly lower average price for the new year. It seems unlikely, however, that OPEC will allow the price to fall as low as it did in 1986. A best guess on the average oil price for 1988 is $15.50. Prices should recover again to the $17 range by 1989. Production of oil, which will meet 1987 expectations, will continue its decline perhaps more precipitously since low prices will hold down drilling. Similarly, the U.S. Bureau of Land Managements (BLM's) decision to suspend competitive oil and gas lease sales in early 1988 will probably have a negative effect on oil activity. Unfortunately, if past actions are any indication, BLM might not resume routine sales for six months to a year while they wrangle with the implementation of new rules.

Production of natural gas has followed predictions for 1987 and increased. Natural gas prices declined again in 1987 as anticipated. There is still every indication that prices will turn around and increase in 1988 and subsequent years. By year-end, the prospects of getting approval for the Kern River Pipeline or another competitive line originating in Wyoming, had improved in view of some companies agreeing to purchase the gas if the pipeline was built. Similarly, there is some indication that the State might provide $250 million in loan guarantees to help any pipeline that originated in Wyoming.

Amoco also remained optimistic about building a new carbon dioxide (CO_2) plant in southwestern Wyoming to use for their planned enhanced recovery operations in other parts of the State. CO_2 from Raptor field would be processed. This CO_2 plant is in addition to Amoco's plans to go ahead with Phase II of their Bairoil enhanced recovery project. Amoco has contracted for CO_2 from Exxon for this latter project.

Last quarter indications are that coal production very likely equaled or topped 140 million tons in 1987, up from 136.3 million tons in 1986. Average coal prices, however, continued downward as predicted. Test shipments of coal from two inactive mines in Carbon County's Hanna Basin raise hopes that one or both of these mines might reopen in 1988.

Tentative plans for a new underground uranium mine suggest that uranium production might increase more in the late 1980s than previously thought. Already two new *in situ* operations have moved forward with their plans.

Increases in trona production look more likely as trade negotiations continue with Japan and the closing of a Montana gypsum wall board plant may mean more demand for gypsum in Wyoming. New interest in limestone deposits and silica deposits in Wyoming left room for cautious optimism about developing these resources in the future.

And last but not least, recent exploration for precious metals continues to suggest that the State may one day see a significant gold mine open. And odds are that if one gold mine opens, there will be others soon after.

Wyoming mineral production forecast to 1991[1].

Calendar Year	Oil Production[2]	Natural Gas Production[3]	Carbon Dioxide Production[3]	Coal Production[4]	Trona Production[4]	Mined Uranium Production[4]
*1981	122.1	455.4	--	102.8	11.8	4.6
*1982	118.7	465.1	--	107.9	10.1	2.1
*1983	120.9	539.7	--	112.2	10.5	3.0
*1984	127.8	600.1	--	130.7	11.0	1.6
*1985	131.0	597.9	--	140.4	10.8	0.6
*1986	122.4	563.2	23.8	136.3	13.3	0.3
1987	115.6	613.0	120.0	140.0	13.4	0.3
1988	111.0	630.0	120.0	143.0	13.6	0.3
1989	117.0	665.0	120.0	146.0	13.7	0.3
1990	108.0	700.0	120.0	149.0	13.8	0.3
1991	100.4	730.0	120.0	152.0	13.9	0.3

*Actual values for comparison; [1] Geological Survey of Wyoming, September, 1987; [2] millions of barrels; [3] billions of cubic feet; [4] millions of tons.

OIL AND GAS UPDATE

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

According to the U.S. Energy Information Agency, the average price paid to Wyoming producers for a barrel of crude oil was $16.51 through the first ten months of 1987. This compares to an average price per barrel of $12.96 for all of 1986. The table below shows the average price Wyoming producers have received for a barrel of crude oil in each of the first ten months of 1987:

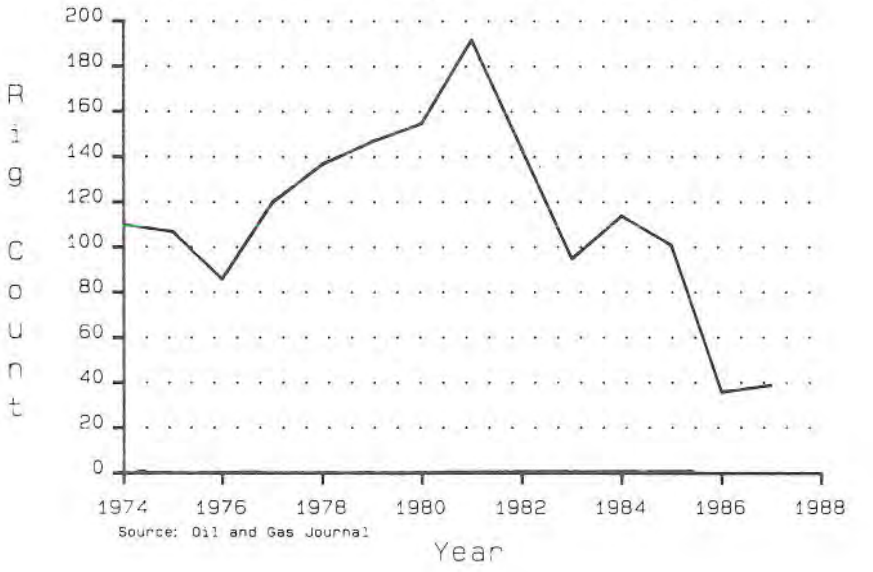
January	$14.91	June	$16.97
February	$15.42	July	$17.93
March	$15.38	August	$18.15
April	$15.69	September	$17.25
May	$16.26	October	$17.10

The average price per barrel showed a fairly steady increase from January until August, but after August there was a decline in both September and October. November will also show a decline in the average price, and the average price for December may well have dropped below $15 per barrel. The main reason for the decline in prices since August is overproduction by OPEC. Iraq is apparently the most flagrant violator of production quotas and is using its oil revenues to fund the war with Iran. The failure by OPEC, at their early December meeting, to deal with the excess production caused a significant price drop in December.

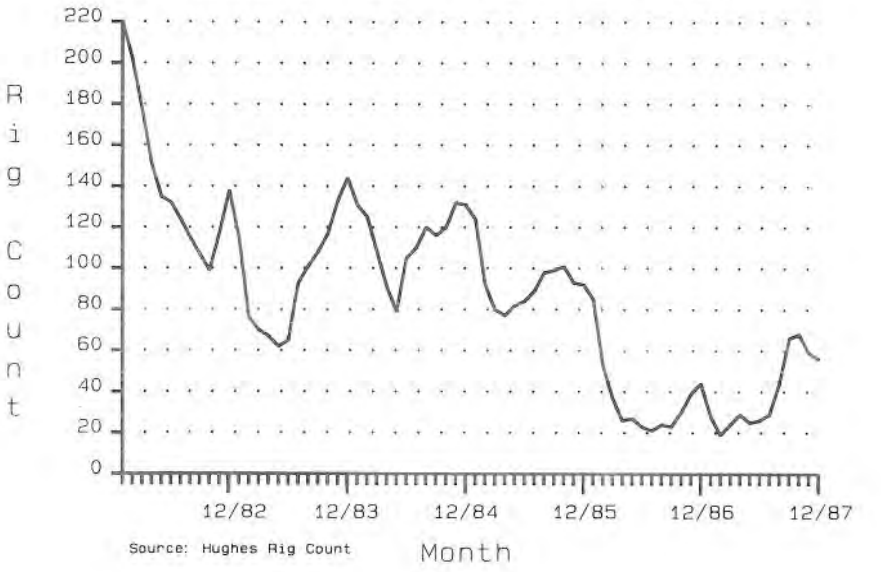
The lower prices have already caused problems for the oil industry in Wyoming. The traditional year-end surge in the rig count failed to materialize in 1987 (see graph on page 4). In fact the count in December was lower than in September, October, and November. The average count in 1987 was 39 compared to an average count of 35 in 1986. As recently as 1984, the count was 114, and in 1981 it averaged an all-time high of 192 (see graph on page 4). It is obvious that although the Wyoming oil and gas industry has recovered slightly from a disastrous 1986, it is still far from being completely healthy again.

According to a report released by the Interstate Oil Compact Commission, over 19,000 domestic stripper wells (wells that produce less than 10 barrels of oil per day) were abandoned in 1986. Many experts had predicted the abandonment of 40,000 stripper wells. The higher number was not realized because state and Federal agencies relaxed abandonment policies. Wyoming had an estimated 5,200 stripper wells in 1985 which produced nearly 8 million barrels of oil. In 1986 a total of 3,996 stripper wells produced nearly 8 million barrels of oil. These totals show that although there were over 1,200 fewer stripper wells in Wyoming in 1986 than in 1985, they produced nearly the same amount of oil. This means that the poorer producers were abandoned in 1986 while some wells that were producing just over 10 barrels per day in 1985 became stripper producers in 1986. The average stripper well in Wyoming produced 5.47 barrels of oil per day, which is a higher average than any of the other major oil and gas producing states.

WYOMING RIG COUNT
AVERAGED BY YEAR (1974 TO 1986)

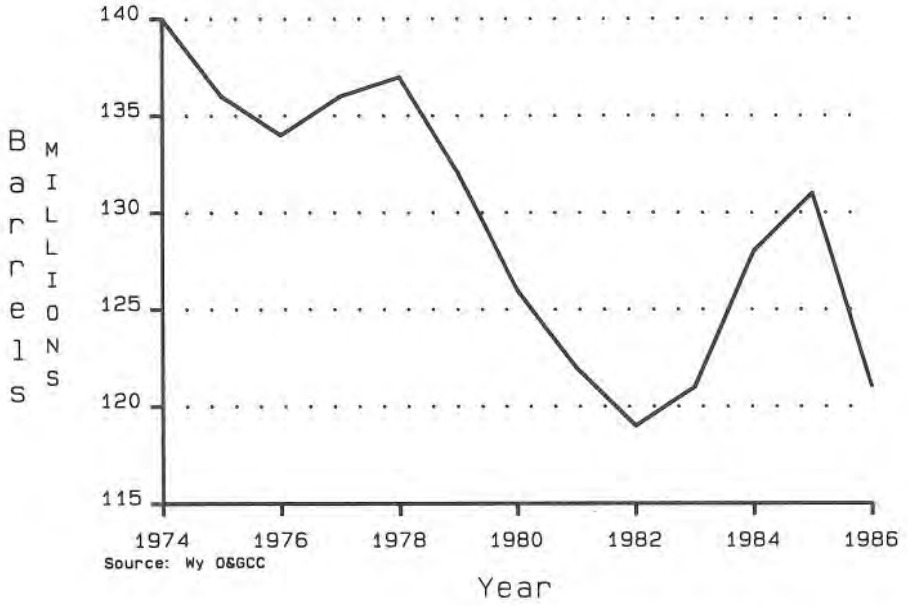


WYOMING RIG COUNT
AVERAGED BY MONTH (1982 TO PRESENT)



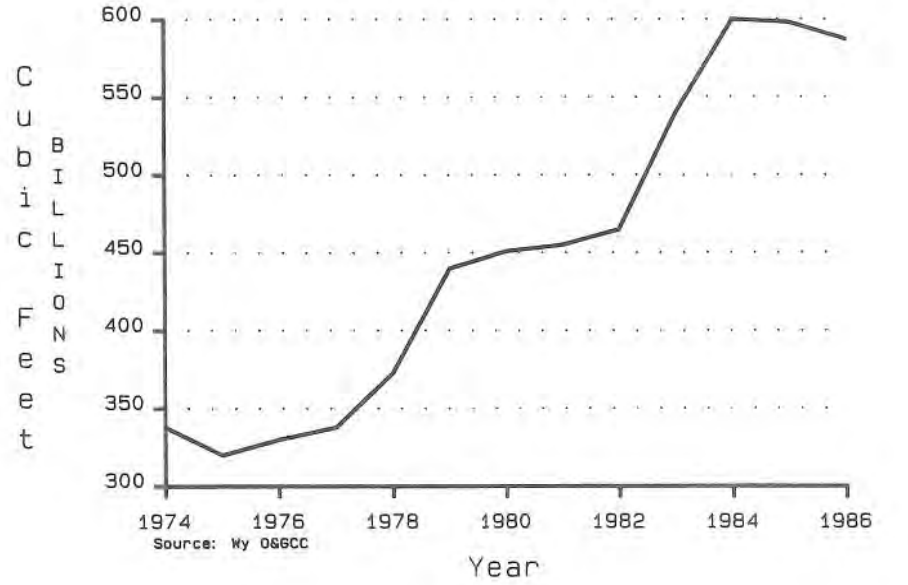
WYOMING OIL PRODUCTION

BY YEAR (1974 TO 1986)



WYOMING NATURAL GAS PRODUCTION

BY YEAR (1974 TO 1986)



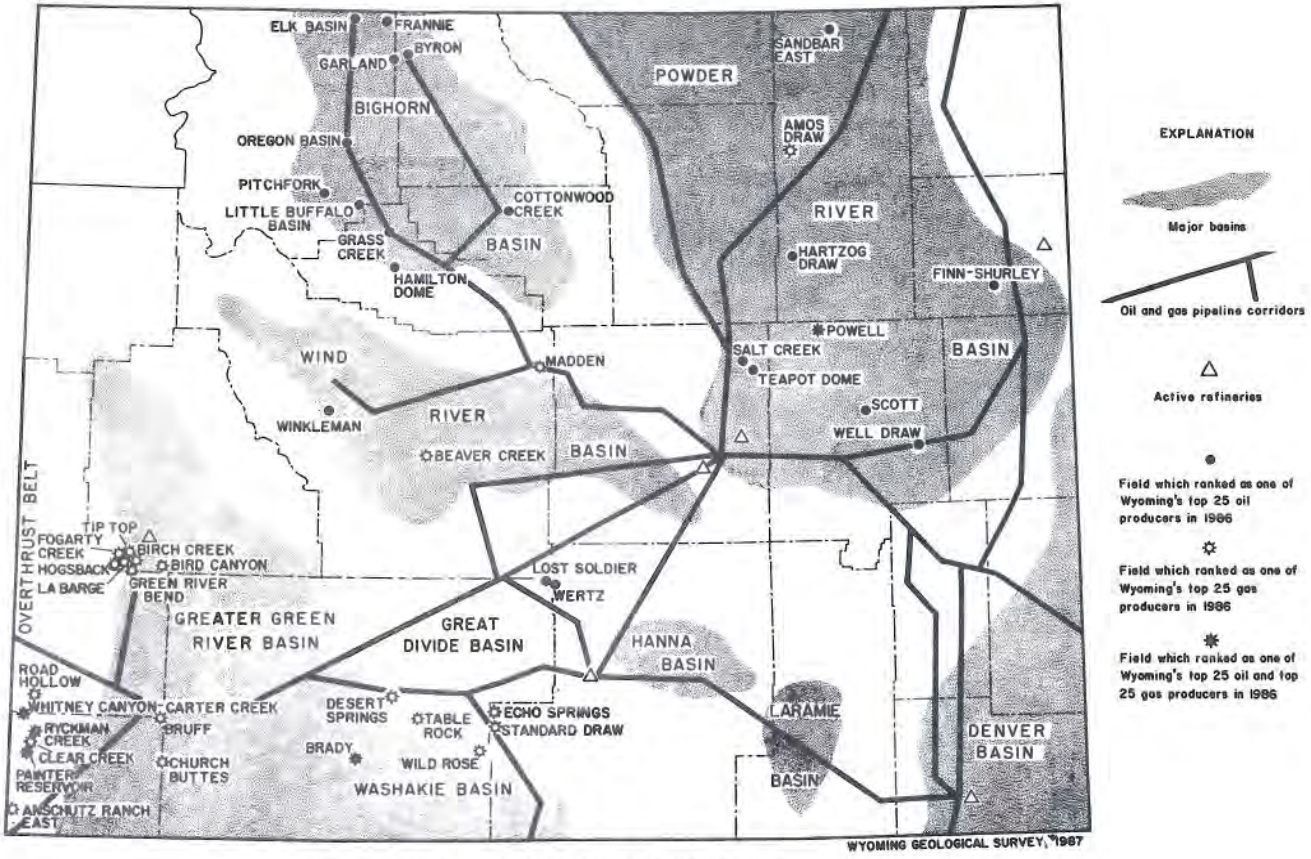
In a related item, a 1987 law passed by the Wyoming Legislature makes all production from Salt Creek field eligible for a two percent severance tax break. The law allows field operators in Salt Creek to include 824 injection wells with 924 producing wells for purposes of calculating stripper production. This means most of the wells and most of the production from Salt Creek will be included in stripper totals for 1987. Severance tax on stripper oil production is four percent compared to six percent for non-stripper production.

Although Amoco has announced plans to continue with Phase II of their Bairoil Project, any further drop in oil prices could jeopardize their planned recovery of an additional 18 million barrels of oil from Lost Soldier field.

In a related item, Amoco announced in November that four new enhanced oil recovery projects in Wyoming are being planned by the company. The new projects would target oil, unrecoverable by conventional techniques, in four old and very large fields. Injection of carbon dioxide into favorable formations in the four fields will add an estimated 115-200 million barrels of oil production over the life of the projects. The company would use carbon dioxide produced from the Raptor field in southwestern Wyoming or from Exxon's Shute Creek plant. Raptor field was discovered in early 1986 by Amoco. The discovery well was drilled in section 12, T.24N., R.112W. and tests of the Madison Limestone yielded production rates of over 13 million cubic feet of gas per day. The gas is 95 percent carbon dioxide. The fields that Amoco has chosen for enhanced recovery are Salt Creek in the Powder River Basin, Beaver Creek in the Wind River Basin, and Elk Basin and Little Buffalo Basin in the Bighorn Basin (see map on page 7). If economic conditions are favorable, construction could start as early as 1989.

The Wyoming Board of Land Commissioners' November sale had high bids of $699,027 on 50,540 acres with an average bid of $13.83 per acre. The total revenue generated by this sale makes it the second best sale held in the last two years. The average price per acre was the best since the July, 1986, sale and the number of acres sold was the highest since the September, 1985, sale. Exxon Corporation made the high bid of $290 per acre for a 640-acre tract covering section 36, T.49N., R.72W. The tract is less than a mile from Minnelusa oil production in Wolff and McCreery fields. Powder River Exploration made the second and third highest bids of the sale. They bid $250 per acre for an 80-acre lease in section 16, T.48N., R.71W. The lease is a half mile from Minnelusa oil production at Rabbit Ears field. The third highest bid was $245 per acre for a 320-acre tract in sections 26 and 35, T.49N., R.72W., between Minnelusa oil production at Wolff and McCreery fields. State sale results are summarized in the table on page 8.

The U.S. Bureau of Land Management (BLM) held two very good sales since the last issue of *Wyoming Geo-notes*. The October sale had high bids of $3,274,611 on 33,828 acres with an average bid of $96.80 per acre. The high bid of $6,031.15 per acre at the sale was made by Santa Fe Energy for an 83.18-acre tract in section 33, T.53N., R.69W. The tract is just south and east of the Candy Draw field, a Minnelusa



GENERALIZED OIL AND GAS INDEX MAP OF WYOMING

WYOMING FEDERAL AND STATE COMPETITIVE OIL AND GAS LEASE SALES

BLM SALES

Month	Total Revenue	Number of parcels offered	Number of parcels sold	Total acres	Acres sold	Average price per acre sold	High price per acre
			1985				
February	$ 3,547,273	117	115	34,948	34,028	$ 104.24	$ 1,700.00
April	2,025,793	133	128	25,497	24,056	84.21	2,609.53
June	1,963,897	140	137	40,304	38,904	50.48	2,577.15
August	2,854,821	190	146	75,094	56,906	50.17	1,732.14
October	1,876,105	208	105	81,611	32,052	58.53	1,108.77
December	1,467,265	211	144	73,723	46,908	31.28	1,167.23
TOTAL	$13,735,154	999	772	331,177	232,854	$ 58.99	$ 2,609.53
			1986				
February	$ 1,992,326	211	154	58,507	38,809	$ 51.34	$ 680.00
April	1,795,890	189	116	54,136	29,938	59.99	1,881.88
June	1,332,216	86	75	27,137	24,512	54.35	437.50
August	529,184	104	88	25,686	22,725	23.29	227.63
October	840,950	76	68	17,827	16,604	50.65	516.86
December	774,824	110	82	28,057	19,840	39.05	3,313.13
TOTAL	$ 7,265,390	776	583	211,350	152,428	$ 47.66	$ 3,313.13
			1987				
February	$ 814,653	78	64	18,866	15,537	$ 52.43	$ 1,226.56
April	779,821	95	68	23,338	16,214	48.10	332.00
June	6,436,196	123	121	26,188	25,668	250.75	6,555.00
August	1,327,186	81	74	22,908	21,055	63.03	800.01
October	3,274,611	137	129	34,858	33,828	96.80	6,031.15
December	3,091,692	213	190	71,264	65,658	47.09	521.00
TOTAL	$15,724,159	727	646	197,422	177,960	$ 88.36	$ 6,555.00

STATE SALES

Month	Total Revenue	Number of parcels offered	Number of parcels sold	Total acres	Acres sold	Average price per acre sold	High price per acre
			1985				
January	$ 757,214	200	86	80,019	27,520	$ 26.51	$1,700.00
March	2,077,478	300	172	137,321	69,781	29.77	1,600.00
May	936,374	199	117	73,625	35,273	26.55	350.00
July	636,350	200	113	83,491	43,630	14.59	280.00
September	989,069	200	126	95,052	60,356	16.39	325.00
November	494,739	200	109	70,144	41,399	11.95	320.00
TOTAL	$ 5,891,224	1,299	723	539,652	277,959	$ 21.19	$1,700.00
			1986				
January	$ 630,069	200	123	83,064	49,783	$ 12.66	$ 320.00
March	773,492	199	112	77,237	44,504	17.38	370.00
May	354,941	200	70	74,128	27,543	12.89	140.00
July	418,280	200	63	86,495	25,461	16.43	234.00
September	171,975	200	80	87,017	33,738	5.10	360.00
November	99,403	200	74	75,385	24,728	4.02	120.00
TOTAL	$ 2,448,160	1,199	522	483,326	205,757	$ 11.90	$ 370.00
			1987				
January	$ 300,404	200	74	87,145	32,606	$ 9.21	$2,300.00
March	270,234	200	83	87,034	35,770	7.55	100.00
May	416,108	200	88	81,343	34,111	12.20	260.00
July	477,891	200	107	91,884	47,015	10.16	125.00
September	362,903	200	100	82,367	44,698	8.12	210.00
November	699,027	200	127	81,865	50,540	13.83	290.00
TOTAL	$ 2,526,567	1,200	579	511,638	244,740	$ 10.32	$2,300.00

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

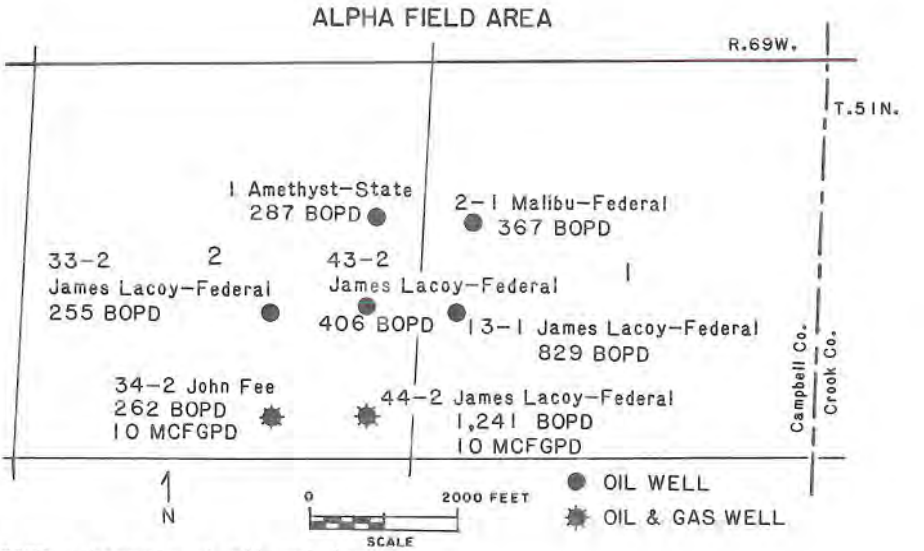
oil field discovered in 1985. Six tracts in this sale received bids of more than $500 per acre, four of these tracts are in the Powder River Basin, one is on the Moxa Arch, and one is in the Wind River Basin.

The BLM's November sale drew high bids of $3,091,692 on 65,658 acres for an average bid of $47.09 per acre. The high bid of $521 per acre was made by Wayne P. Neumiller for a 40.29-acre tract in section 9, T.53N., R.68W. The lease is just north of Minnelusa oil production from Prairie Creek South field. In all, 41 tracts at this sale drew bids greater than $100 per acre; 31 of these tracts are in the Powder River Basin and nine are in southwestern Wyoming. The revenue from BLM's 1987 sales was nearly $8.5 million more than from their 1986 sale and nearly $2 million more than from their 1985 sales. For comparison with past BLM sales, see the table on page 8.

In a late-breaking development, the BLM has suspended its competitive lease sales perhaps for the next six months. The February sale for Wyoming has definitely been cancelled due to the new onshore Federal leasing law just recently signed by President Reagan. The new bill stipulates that all Federal oil and gas leases must be offered initially on a competitive basis. Previously, some leases, which were not considered prospective, had been offered in the simultaneous drawing held by the BLM. The new bill would essentially eliminate these drawings. The cancellation of the February sale as well as the probable cancellation of the April sale and maybe others will not only cost the State money (Wyoming receives 50 percent of the bonus money from these sales), but it comes at a time when competitive bids have swung markedly upward.

One of the best discoveries in Wyoming in 1987 is the Alpha field in eastern Campbell County. The discovery well, the 43-2 James Lacoy-Federal was completed by Maxus Energy in section 2, T.51N., R.69W. in July, pumping 406 barrels of 22° oil per day from the Minnelusa. Since the discovery, six new producing wells have been completed in the new field: The Maxus 33-2 James Lacoy Federal in section 2, T.51N., R.69W. pumping 255 barrels of oil per day; the Maxus 13-1 James Lacoy-Federal in section 1, T.51N., R.69W. pumping 829 barrels of oil per day; the Sun 1 Amethyst-State in section 1, T.51N., R.69W. pumping 287 barrels of oil per day, the 34-2 John Fee in section 2, T.51N., R.69W. pumping 262 barrels of oil per day, the Maxus 44-2 James Lacoy-Federal in section 2, T.51N., R.69W. pumping 1,241 barrels of oil per day, and the Slawson 2-1 Malibu-Federal in section 1, T.51N., R.69W. pumping 367 barrels of oil per day. In addition, Maxus has staked two more locations in section 2 and one more in section 12, T.51N., R.69W., Maxus is waiting on completion tools at an indicated discovery in section 1, T.51N., R.69W. See map on page 10.

Ash field, discovered in September, 1987, has added another producing well. General Atlantic Energy completed the 28-1 Aspen confirmation well in section 28, T.52N., R.69W., pumping 303 barrels of oil per day with no water from the Minnelusa Formation. The discovery well, the 1 Ash-Federal in section 27, R.52N., R.69W., was completed pumping 520 barrels of oil per day with no water from the Minnelusa.



BOPD = barrels of oil per day.
MCFGPD = thousand cubic feet of gas per day.

Two more good gas wells were recently completed in the Swan-Blue Forest-Lincoln Road area on the Moxa Arch. The 44-19 Federal in section 19, T.25N., R.110W. was completed in the Dakota for an initial flowing potential of 4.8 million cubic feet of gas and 146 barrels of condensate per day. The 32-2 Blue Forest Unit-Federal in section 2, T.24N., R.111W. was completed in the Dakota flowing 2.9 million cubic feet of gas and 121 barrels of condensate per day. Both wells were drilled by ITR Petroleum, Houston.

Sun Exploration and Production gauged a flow from the Muddy Sandstone of 252 barrels of oil and 436 MCF (thousand cubic feet) of gas per day on a production test of their 2 Sun Ranch-Federal well in section 15, T.33N., R.86W. The discovery well for the Sun Ranch field, the 1 Sun Ranch-Federal in section 15, T.33N., R.86W., was completed earlier this year flowing 1,048 barrels of oil and 976 MCF of gas per day. At last report, BHP Petroleum was nearing total depth at a southwest offset to the Sun Ranch discovery. Sun has also staked two more locations in the area.

The 23-1 Nicolaysen well, drilled by Combined Oil and Gas of Denver in section 23, T.35N., R.77W., was completed in 2nd Frontier pumping 137 barrels of oil, 55 MCF of gas, and 75 barrels of water per day.

ANR Production recently completed a wildcat in section 26, T.38N., R.74W. The well was completed in the Frontier Formation pumping 351 barrels of oil and 510 MCF of gas per day. The well is a mile southwest of Powell field which produces mostly from the Muddy and Dakota. The nearest Frontier production in the field is over two miles to the northeast.

In some good news for the oil and gas industry, the U.S. Environmental Protection Agency (EPA) reported that it sees no need to classify oil and gas production waste as hazardous and sees no reason to place it under strict Federal regulations. The EPA said such classification would impose extreme costs on the industry and on the economy. The next step in this process is to get the idea past Congress.

Natural gas producers who paid too high Federal royalties would get a refund under a bill passed by the U.S. House of Representatives. The total refund has now been estimated by the Minerals Management Service as no more than $500,000. An earlier estimate by the Service estimated nearly $40 million in overpayments or about $7 million to Wyoming producers.

COAL UPDATE

by Richard W. Jones, Coal Geologist, Geological Survey of Wyoming

Wyoming coal production in 1987 continues to show substantial gains over 1986 and by the end of the year, may even surpass 1985's record coal production. Total coal deliveries for the first three quarters of 1987 were about six million tons more than deliveries made during the same period one year ago and about one million tons more than deliveries made during the same period in 1985 (see table on page 12). If deliveries in the last quarter of 1987 equal those made in 1985 or 1986 (see figure on page 13), coal production from Wyoming for 1987 could be between 140 and 144 million tons.

A follow-up to several items reported in *Wyoming Geo-notes No. 16* (p. 11, 13, and 16) is necessary. The Black Butte coal mine in Sweetwater County did layoff 51 employees in early November as a result of decreases in contracted production. These layoffs (affecting 41 hourly and 10 salaried employees), coupled with earlier voluntary reductions in force, have reduced the work force at the mine from nearly 500 at the end of 1986 to about 350).

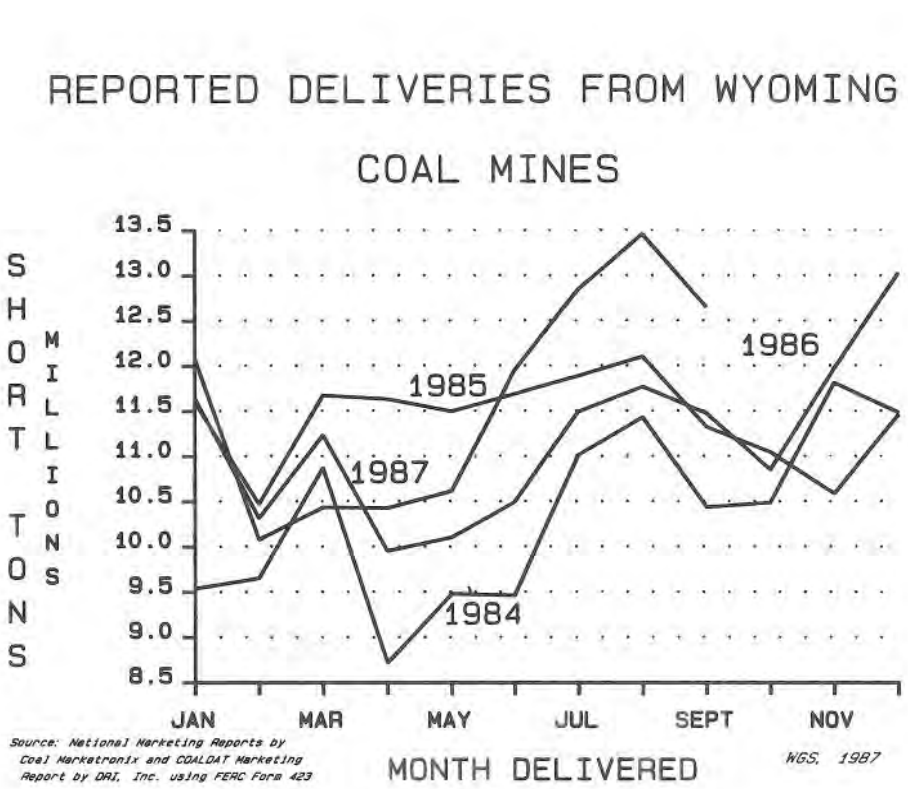
It was also reported in October that Arch Mineral Corporation had laid off the remaining workers at their Medicine Bow mine west of Hanna and that the mine would become inactive. However, in December, Arch announced that the mine would reopen again in early 1988 and that 12 laid off employees would be recalled. Arch will be selling 30,000 tons of coal to Central Power and Light Company in Corpus Christi, Texas. Although the coal sale is only for a test shipment, it is certainly an encouraging development for Carbon County and the Hanna Basin.

Two other positive developments in Carbon County have also occurred recently. First, Cyprus-Shoshone Coal Company, the new owner of the Carbon County No. 1 underground mine north of Hanna, announced in early January, 1988, that they had hired seven more employees and were ready to resume coal production. The company has sold 70,000 tons of coal (primarily for test-burns by interested utility companies and

COAL DELIVERIES BY MONTH FROM WYOMING MINES

	1983 MONTHLY	1983 CUMULATIVE	1984 MONTHLY	1984 CUMULATIVE	1985 MONTHLY	1985 CUMULATIVE	1986 MONTHLY	1986 CUMULATIVE	1987 MONTHLY	1987 CUMULATIVE
JANUARY	10,313,000	10,313,000	9,540,200	9,540,200	11,601,200	11,601,200	11,646,300	11,646,300	12,085,570	12,085,570
FEBRUARY	8,719,700	19,032,700	9,654,600	19,194,800	10,473,900	22,075,100	10,317,700	21,964,000	10,315,680	22,401,250
MARCH	9,051,200	28,083,900	10,875,000	30,069,800	11,674,900	33,750,000	11,401,720	33,365,720	10,436,610	32,837,860
APRIL	8,195,000	36,278,900	8,721,400	38,791,200	11,632,800	45,382,800	9,954,170	43,319,890	10,429,180	43,267,040
MAY	8,364,600	44,643,500	9,481,500	48,272,700	11,497,900	56,880,700	10,105,320	53,425,210	10,619,470	53,886,510
JUNE	8,330,200	52,973,700	9,464,500	57,737,200	11,692,200	68,572,900	10,499,280	63,924,490	11,953,650	65,840,160
JULY	8,734,700	61,708,400	11,019,600	68,756,800	11,893,500	80,466,400	11,497,190	75,421,680	12,850,240	78,690,400
AUGUST	9,669,300	71,377,700	11,433,000	80,189,800	12,107,100	92,573,500	11,773,510	87,195,190	13,460,470	92,150,870
SEPTEMBER	9,189,700	80,567,400	10,440,000	90,629,800	11,325,000	103,898,500	11,474,820	98,670,010	12,651,550	104,802,420
OCTOBER	9,406,300	89,973,700	10,492,500	101,122,300	11,048,500	114,947,000	10,854,670	109,524,680		
NOVEMBER	9,013,600	98,987,300	11,814,200	112,936,500	10,589,700	125,536,700	11,971,990	121,496,670		
DECEMBER	7,680,600	106,667,900	11,486,800	124,423,300	11,459,300	136,996,000	13,025,490	134,522,160		
TOTAL TONNAGE REPORTED	106,667,900		124,423,300		136,996,000		134,522,160			
TOTAL TONNAGE NOT REPORTED	5,519,300		6,322,479		3,784,154		1,782,896			
TOTAL TONNAGE PRODUCED	112,187,200		130,745,779		140,780,154		136,305,056			

Source: National Marketing Reports by Coal Marketronix, compiled from FERC Form 423 filed monthly by electric utilites. Annual Reports of Wyoming State Mine Inspector and Ad Valorem Tax Division.



industrial users) since purchasing the mine, but has not yet announced any definite coal contracts. Second, in late December Energy International (EI) signed an $11.8 million contract with the U.S. Department of Energy (DOE) for an underground coal gasification project located west of Rawlins. The Federal funds will be added to the $65 million EI has received from private sources. The project will burn and gasify a steeply-dipping coal bed and recover, at least initially, urea and ammonia for use in fertilizer plants that EI is purchasing in Georgia and California. The Federal funds are from DOE's Clean Coal Technology Program. EI's application for funds from Wyoming's clean coal technology program was rejected by the State's Investment Fund Committee earlier this year (*Wyoming Geo-notes No. 16*, October, 1987, p. 20).

In the Powder River Basin, six coal mines in Wyoming and one coal mine in Montana were among 1986's top ten coal-producing mines in the United States as recently listed by the National Coal Association. At the top of the list for the fifth year in a row was Thunder Basin Coal Company's Black Thunder mine, with 21.9 million tons produced. Carter Mining Company's Rawhide mine ranked third; Amax Coal Company's Belle

MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING

PETROLEUM

Remaining Resources (January 1, 1987)

Discovered (Includes 10 billion barrels recoverable by enhanced recovery techniques)	13.3 billion barrels[1]
Undiscovered	7.6 billion barrels[1]
Total	20.9 billion barrels

Remaining Reserve Base (January 1, 1987)

Measured reserves (Proved reserves)	0.83 billion barrels[2]
Indicated and inferred reserves	2.8 billion barrels[3]
Total	3.63 billion barrels

NATURAL GAS

Remaining Resources (January 1, 1987)

Discovered	18.6 trillion cubic feet[1]
Undiscovered (there is at least another 115 trillion cubic feet of noncombustible CO_2 gas)[9]	58.0 trillion cubic feet[1]
Total	76.6 trillion cubic feet[1]

Remaining Reserve Base (January 1, 1987)

Measured reserves (Proved reserves)	10.64 trillion cubic feet[2]

COAL

Remaining Resources (January 1, 1987)

Identified (Discovered)	136.0 billion tons[4]
Undiscovered	800.0 billion tons[5]
Total	936.0 billion tons

Remaining Reserve Base (January 1, 1987)

Demonstrated strippable (Measured and indicated reserve base)	27.1 billion tons[4]
Demonstrated underground-minable (Measured and indicated reserve base)	38.4 billion tons[4]
Total	65.6 billion tons

TRONA

Original Resources (1983 estimate)

Trona	81.7 billion tons[6]
Mixed trona and halite	52.7 billion tons[6]
Total	134.4 billion tons

URANIUM

Remaining Resource (December 31, 1985) ..... 1,990,000,000 pounds U_3O_8

Remaining Reserve Base (December 31, 1985)

	U_3O_8
Uranium oxide recoverable at $30.00 per pound	83 million pounds
Uranium oxide recoverable at $50.00 per pound	365 million pounds
Uranium oxide recoverable at $100.00 per pound	632 million pounds

OIL SHALE

Original Resources (January 1, 1983)

Identified (Discovered) ..... 320 billion barrels of shale oil[8]

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[1] Modified from Barlow, J.A., Jr. and Doelger, M.J., 1983, *Wyoming mineral resources:* Barlow and Haun, Inc., Casper, 14 p.

[2] Energy Information Administration, 1986, *U.S. crude oil, natural gas, and natural gas liquids reserves: 1985 Annual Report, October.* (1986 production has been subtracted).

[3] Modified from Barlow and Doelger (1983), footnote 1.

[4] Wyoming Geological Survey, July, 1987. (Modified from Berryhill, H.L., Jr. and others, 1950, *Coal resources of Wyoming*: U.S. Geological Survey Circular 81, 78 p.

[5] Averitt, Paul, 1975, *Coal resources of the United States:* U.S. Geological Survey Bulletin 1412, p. 15.

[6] 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.

[7] U.S. Energy Information Agency, 1985, Uranium Industry Annual, U.S. Department of Energy Report DOE/EIA-0478(85), 142 p.

[8] 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.

[9] Derived from Exxon information.

Ayr and Eagle Butte mines ranked fourth and sixth respectively; Kerr-McGee's Jacobs Ranch mine ranked fifth; Western Energy Company's Rosebud mine at Colstrip, Montana ranked seventh; and Cordero Mining Company's Cordero mine ranked eight. Two Texas lignite mines ranked second and ninth and North American Coal Company's Freedom mine in North Dakota ranked tenth. Each mine produced in excess of nine million tons of coal in 1986.

Coal from the Powder River Basin is apparently priced low enough at some mines to compete with mine-mouth coal used at several of Pacific Power and Light Company's (PP&L) power plants in Wyoming and Washington. It was reported earlier that Mobil Coal Producing, Incorporated's Caballo Rojo mine was delivering 20,000 tons of coal a month to PP&L's Dave Johnston Plant at Glenrock (see *Wyoming Geo-notes 15*, June, 1987, p. 19). In December, PP&L announced that an additional one million tons of coal from eastern Powder River Basin mines would be used at Dave Johnston. Initial shipments of coal under this plan will be from Rochelle Coal Company's Rochelle mine in southern Campbell County via Burlington Northern Railroad Company (BN) unit trains.

PP&L is also considering the purchase of two million tons of Powder River Basin coal in 1989 for the Jim Bridger power plant east of Rock Springs and is also currently testing coal from Thunder Basin Coal Company at the Centralia, Washington, power plant. Coal for Jim Bridger is currently supplied by Bridger Coal Company's (operated by Nerco Coal Corporation, an affiliate of PP&L) Jim Bridger mine and Prospect Point Coal Company's (a subsidiary of Union Pacific Resources, formerly Rocky Mountain Energy Company) Leucite Hills mine. Evidently the two million tons of coal would supplement, rather than replace, the 6.5 million tons used from the Jim Bridger mine and the 151,000 tons used from the Leucite Hills mine in 1986. Similarly, the two owners of the Centralia generating plant, PP&L and Washington Water Power, are purchasing coal to augment that produced by Washington Irrigation and Development Company's Centralia surface mine. However, it remains to be seen whether or not Wyoming coal that must be shipped 900 miles via railroad can compete with either imported or Alaskan coal for this possible market.

In another development involving PP&L, shareholders of Utah Power and Light Company (UP&L) and PP&L recently approved the merger of the two companies into PacifiCorp, the parent company of PP&L. The merger would reportedly lower current electricity rates paid by UP&L customers as well as improve long-term profitability. The merger agreement must be approved by the State Public Service Commissions and the Federal Energy Regulatory Commission before it expires in August, 1988. The proposed merger has drawn heavy criticism from the Utah coal industry and four of Utah's major coal-producing companies have petitioned to intervene in the Utah Public Service Commission's Hearings on the merger. The Utah coal producers are concerned that the merger would decrease the competitiveness of their coal in Utah's electric utility markets and allow coal from other states to be used at the expense of Utah coal. The only coal mine in Wyoming that could be directly affected by this merger would be Pittsburg and Midway Coal Mining Company's Kemmerer mine in Lincoln County, which supplies UP&L's nearby Naughton power plant.

In coal transportation news, the suit brought against several railroad companies by Energy Transportation Systems, Inc. (ETSI) and several utility companies for damages related to the railroads' opposition and successful stopping of ETSI's proposed coal slurry pipeline (see *Wyoming Geo-notes No. 13*, January, 1987, p. 33-36) appears nearly settled. Chicago and North Western Transportation Company (C&NW) recently agreed to pay $15 million to ETSI as a settlement to avoid ETSI's demand for treble damages and injunctive relief against the railroads. In another action, Arkansas Power and Light Company (AP&L) and ETSI recently announced that agreement in the same suit had been reached with Union Pacific (UP) and C&NW. AP&L had been allowed to join ETSI and another utility in their Federal antitrust case on the grounds that the lack of competition for coal transportation to AP&L resulted in rail rates that were too high. Although terms of the settlement were not revealed, future rail rates on AP&L's 30-year contract with UP and Missouri Pacific Railroad are expected to be lower than they were before the settlement.

In coal contract news, several short term contracts and several spot sales were announced in the last quarter of 1987. Fort Union Coal Company and Nebraska Public Power District (NPPD) signed a one-year, 200,000-ton minimum coal supply contract for deliveries to the utility's Sheldon, Nebraska, generating plant. NPPD could take as much as 450,000 tons under this contract, which runs through September, 1988. The utility's contract with Rosebud Coal Sales in Hanna expired in 1987; spot coal was also purchased from Fort Union in 1987. Transportation of the coal will be handled by the Burlington Northern and Union Pacific railroads.

Rosebud Coal Sales Company won a Federal contract for delivery of 7,500 tons of coal to Fairchild Air Force Base, Washington. High Btu coal from the Rosebud mine at Hanna will be delivered by Union Pacific and Burlington Northern. Delivered price per ton was listed as $59.95. Another Federal contract was awarded to Big Horn Coal Company for delivery of 5,300 tons of coal to the Veteran's Administration Medical Center at Sheridan. Coal with a heating value of 9,600 Btu/pound (as-received) will be transported by truck from the Big Horn mine north of Sheridan. Delivered price for the coal is $21.10 a ton.

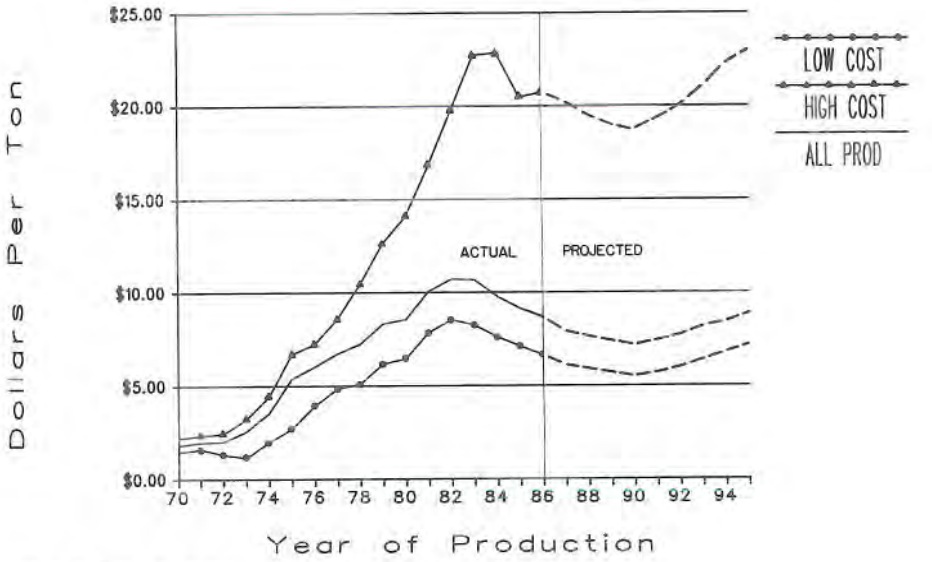
Kansas City Board of Public Utilities recently purchased 200,000 tons of coal on the spot market from Carter Mining Company's Rawhide mine. The coal, which supplements the minimum take of contract coal from other suppliers, reportedly sold for about $15.00 a ton delivered, about $2.50 less than the contracted coal. Subtracting a rail rate of around $12.00 a ton yields an estimated F.O.B. mine price in the $3.00 a ton range.

Omaha Public Power District (OPPD) recently announced several spot coal purchases from Wyoming mines. Amax Coal Company's Eagle Butte mine supplied 200,000 tons of coal to OPPD's Nebraska City, Nebraska, power plant during November and December. All the competitive bids for this coal were reportedly less than $4.00 a ton F.O.B. mine. Carter Mining Company will supply 800,000 tons of coal to OPPD, with 300,000 tons delivered in the first five months of 1988 and 500,000

tons delivered in the last seven months of 1988. The coal will originate at Carter's Rawhide mine and be transported to OPPD by Burlington Northern Railroad. Bids on this spot coal were also reportedly less than $4.00 a ton F.O.B. mine.

A good indication of the overall decreased coal prices and the influence of very low spot coal prices in Wyoming is the valuation of the coal for tax purposes. The recently released 1987 Annual Report of the Wyoming Department of Revenue and Taxation, Ad Valorem Tax Division reveals that the average assessed value per ton of Wyoming coal produced in 1986 was $8.67, a decrease of about five percent from the previous year's $9.12 a ton. Low cost Powder River Basin coal dropped from $7.10 a ton to $6.63 a ton, a decrease of 6.6 percent; high cost coal from southern Wyoming increased slightly in value, from $20.48 a ton in 1985 to $20.74 a ton in 1986 (see figure on page 18). The total value of the coal produced in Wyoming in 1986 was about $1.111 billion, a decrease of $144.9 million from the previous year. Taxable production in 1986 was about seven million tons less than the previous year. Coal accounted for about 18.6 percent of the $5.97 billion total assessed valuation of Wyoming in 1986 and about 31 percent of the total $3.58 billion assessed valuation of minerals in Wyoming.

COAL VALUATION 1970–1990



SOURCE: Wyoming Department of Revenue and Taxation, Ad Valorem Tax Division Annual Reports.

METALS AND PRECIOUS STONES UPDATE

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

Take note! Because of the higher precious metal prices, a few scams or gold frauds have surfaced either as phoney gold mines in Wyoming, or more often as security and stock frauds from operations based outside of Wyoming. To help head off some of these phoney operations, the Secretary of State's Office in Cheyenne will answer questions from potential investors. Call (307) 777-5346 for information. It pays to check before you invest in anything.

Also take note that there are many valid and respectable gold and other precious metal prospects in Wyoming!

Platinum exploration is continuing in the Medicine Bow Mountains of southeastern Wyoming. International Platinum Corporation recently released an interim progress report on their exploration activities for platinum and palladium mineralization in the Medicine Bow Mountains. The company reported that a mineralized pyroxenite in the Mullen Creek mafic complex was identified and continues into the company's property. Vanderbilt Gold Corporation reported that they have delineated at least two geophysical anomalies in the Mullen Creek mafic complex, and plan to test drill the anomalies for platinoids next spring (*The Mining Record*, December 2, 1987). At least four companies are exploring this region for commercial platinum deposits.

In a news release from the *London Mining Journal* (October 30, 1987), it was reported that the Australian company Carr Boyd has developed an interest in the Colorado-Wyoming State Line diamond district in the Laramie Range. Carr Boyd's subsidiary, Diamond Company NL (Dicom), apparently negotiated a mining lease agreement covering five kimberlite intrusives at Kelsey Lake, Colorado. Sources report that Dicom also intends to explore the Wyoming Province for diamonds.

The Geological Survey of Wyoming during the past seven years, has collected stream sediment samples in about two-thirds of the Laramie Range in search of additional kimberlite intrusives. The results of the sampling indicate Wyoming has a very high potential for additional kimberlite intrusives. More than 100 anomalies have been identified by the Survey to date.

For the past five years the Metals Division of the Geological Survey of Wyoming has also been mapping and sampling rocks in the South Pass greenstone belt in western Wyoming. The Division plans to publish geologic maps of all eight 7½-minute quadrangles which cover the 200- to 250-square mile metasedimentary-metavolcanic terrain near the southern tip of the Wind River Mountains. In addition, all accessible underground gold mines will be mapped and sampled.

In late 1986, two 1:24,000 quadrangles were published as open file reports (Hausel, 1986a, b), and now a third quadrangle has been released (Hausel, 1987a). This new map, the Miners Delight Quadrangle, is located along the northern edge of the greenstone belt and

along the northeastern margin of the South Pass-Atlantic City mining district. The map area includes the Atlantic City open pit iron mine, several placer and lode gold mines, and the Miners Delight ghost town, which was abandoned in 1907.

Much of the Miners Delight Quadrangle is underlain by Archean metamorphics that are unconformably overlain by Paleozoic sedimentary rock. The metamorphics include metavolcanics of calc-alkalic, tholeiitic, and komatiitic affinity and a variety of metasediments including banded iron formation, fuchsitic quartzite, metagreywacke, metachert, and graphitic schist.

This quadrangle includes a very important mineralized region that has produced more than 90 million tons of iron ore, thousands of ounces of gold, some silver, copper, and asbestos, and has some identified chromium, nickel, and tungsten anomalies as well as an indication of tin.

Elsewhere in the greenstone belt, gold and silver assays for thirty-one channel and chip samples taken in the Monarch mine (NE/4 sec. 21, T.29N., R.100W.), located west-southwest of the Miners Delight Quadrangle, were completed. The results ranged from 0.13 ppm gold to 8.76 ppm gold. Silver (0.2 ppm) was detected in only one sample.

The Monarch mine was driven into a cross-fault in 2.8 billion year old metagreywackes of the Miners Delight Formation (Hausel and King, 1985). In a crosscut of the lower Monarch adit, a limonite-stained contact between hanging-wall actinolite schist and footwall metagreywacke produced a sample which yielded the highest amount of gold in the mine. For some unknown reason, the early miners followed this contact for only 30 feet even though it may have represented the best target in the mine.

References cited

Hausel, W.D., 1986a, Preliminary geologic map of the Lewiston gold district, Radium Springs Quadrangle, Fremont County, Wyoming: Geological Survey of Wyoming Open File Report 86-25, scale 1:24,000.

Hausel, W.D., 1986b, Preliminary geologic map of the Anderson Ridge Quadrangle, Fremont County, Wyoming: Geological Survey of Wyoming Open File Report 86-26, scale 1:24,000.

Hausel, W.D., 1987a, Revised geologic map of the Miners Delight Quadrangle, Fremont County, Wyoming: Geological Survey of Wyoming Open File Report 87-10, scale 1:24,000.

Hausel, W.D., 1987b, Preliminary report on gold mineralization, petrology, and geochemistry of the South Pass granite-greenstone belt, Wind River Mountains, Wyoming: Wyoming Geological Association 38th Annual Field Conference Guidebook, p. 287-304.

Hausel, W.D. and King, J.K, 1985, Geologic map of the Monarch upper and lower adits: Geological Survey of Wyoming Mineral Report MR 85-5, scale 1:24,000.

INDUSTRIAL MINERALS AND URANIUM UPDATE

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

Uranium

There is some optimism that uranium production from Wyoming will increase in 1988 and future years. An increased demand for uranium for domestic power plant fuel is seen as the reason behind this optimism. In addition to the two new *in situ* operations (Malapai near Pumpkin Buttes and Everest at the Highland Property in the southern Powder River Basin), U.S. Energy, a Riverton, Wyoming, firm has applied for a mining permit for an underground uranium mine beneath the south side of Green Mountain, south of Jeffrey City.

U.S. Energy has announced that it, together with its partially owned subsidiary, Crested Corporation, intends to purchase all of Western Nuclear's property in the Crooks Gap - Green Mountain uranium district. Western Nuclear will keep some royalty rights on any future production. The property includes ten underground and three open pit mines that produced uranium during the 1960s and 1970s.

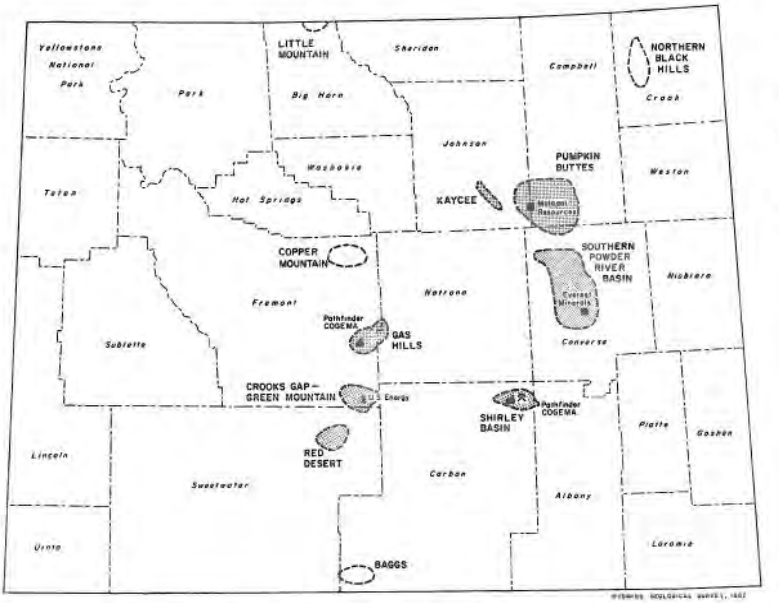
Meanwhile, Pathfinder, continues to mine and mill ore in the Shirley Basin. It also processes small amounts of stockpiled ore at its newly remodeled Lucky Mc mill in the Gas Hills District.

After several court challenges, UMETCO (formerly Union Carbide) was awarded the contract to move uranium mill tailings from the old Susquehanna-Western mill in Riverton to the Gas Hills. UMETCO will begin taking the tailings to abandoned open pit uranium mines when spring comes.

Industrial Minerals

Trona

Trona production in 1987 should exceed the record production of 1986, and 1988 could be better. This increase is due primarily to increased exports, bolstered by an increased demand for domestic glass, particularly flat glass and fiber-optic glass. Soda ash (refined trona) is a primary ingredient in the manufacture of glass.



MAJOR ACTIVE AND INACTIVE URANIUM DISTRICTS

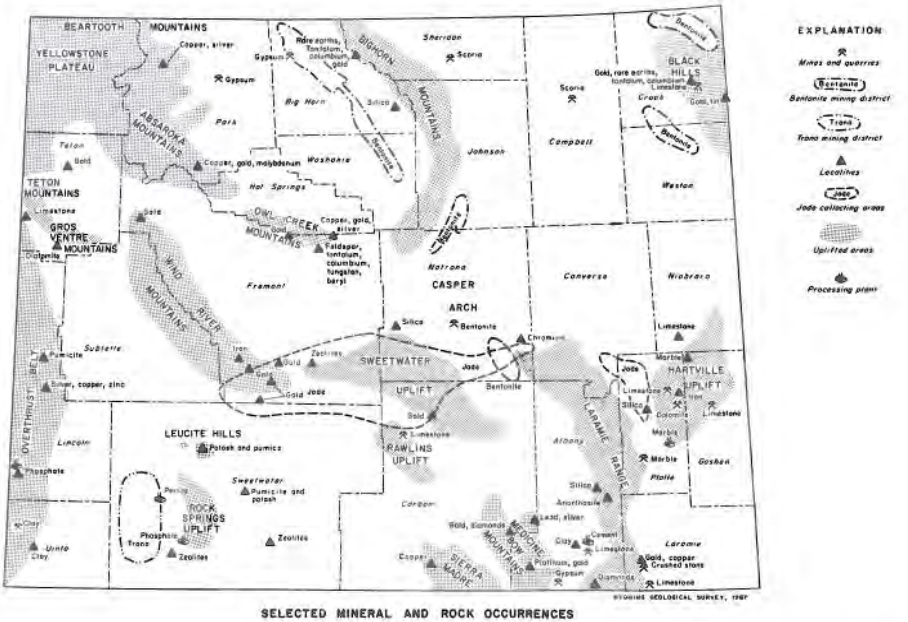
Exports currently account for about one-quarter of soda ash sales from Wyoming. Outside of the U.S., soda ash is synthetically produced from sodium raw materials (halite or sodium sulfate) by the Frasch process. Trona, however, is natural soda ash, needing only limited refining to produce industrial and chemical grade soda ash.

Five producers refine soda ash from mined trona near Green River, Wyoming (figure on page 22). Over ninety percent of U.S. soda ash is produced in Wyoming. FMC produces soda ash by a solution-mining process, in addition to underground mining. The other four producers mine trona exclusively from underground mines.

Bentonite

Wyoming bentonite producers have been suffering through a depression since 1982 when domestic oil and gas well drilling declined sharply. Bentonite, a clay that expands its volume when wet, is used primarily as a well-drilling fluid, though it has many other uses from foundry clay to soap fillers to cosmetic additives. Bentonite production in Wyoming increased slightly in mid-1987 as domestic drilling increased. Wyoming is the Nation's leading bentonite producer.

A new bentonite production company, American Bentonite Corp., based in Billings, Montana, hopes to open two new bentonite mines in Wyoming in 1988. The company, a subsidiary of Davis Mud and Chemical, the largest independent supplier of drilling mud in the U.S., has applied for mining permits in the Kaycee bentonite area west of Kaycee



In Johnson County and from the Bates Creek area 20 miles southwest of Casper in Natrona County. Only small amounts of bentonite may be produced by American Bentonite in 1988. Increased production by this new company, as well as by the other producers, will depend upon an upturn in domestic drilling.

Gypsum

Domestic gypsum production continues to decline. Production in 1987 is five to ten percent below 1986, according to the U.S. Bureau of Mines. In Wyoming, the picture is a little brighter for the two gypsum wall board plants in the Bighorn Basin since a competitor in Montana closed its plant earlier this year.

A couple of firms have expressed an interest in mining gypsum in Wyoming for fertilizer. To date, no mining plans have been announced.

Production of gypsum in southeastern Wyoming by Mountain Cement or its contractor should resume in 1988 as the company reopens its expanded cement plant in Laramie.

Limestone

Limestone production in Wyoming is decreasing as the demand for aggregate for highway construction decreases seasonally. Limestone is

also produced in Wyoming for burn control at power plants. Limestone production in Wyoming for sugar rock (used to refine beet sugar) is a possibility for the future. When Mountain Cement reopens its Laramie cement plant in 1988, limestone production for cement will resume.

The Geological Survey of Wyoming published a report on a limestone deposit south of Manville, in Niobrara County (Harris, 1987). This report, Report of Investigations 39, describes the deposit, including the geology, quantity, and quality of the limestone resource, and suggests uses for the limestone at this location.

Other industrial minerals

The production of other industrial minerals in Wyoming (clay, decorative marble, dolomite aggregate, railroad ballast, sand and gravel, baked and fused rock (clinker or scoria), sodium sulfate, and sulfur continues to increase slightly, although railroad ballast production is highly dependent upon the scheduling of railroad trackage repairs. Phosphate for fertilizer is produced by Chevron near Rock Springs from phosphate rock mined in Utah. All sulfur production coming from Wyoming is produced as a by-product of sour gas and oil refining.

Zeolites

A few years ago there was an exploration boom reflecting an interest in developing natural zeolite deposits in Wyoming and other states. Several companies had expressed interest in zeolites in the Beaver Rim and Fort La Clede (map on page 23) areas. Zeolite minerals are natural ion-exchangers used to purify water and remove industrial waste. The zeolite mineral clinoptilolite was especially suited to the purpose. The zeolite boom, however, never materialized in large part because natural zeolites removed larger amounts of toxic elements per quantity of zeolite than previously calculated, thus reducing the anticipated demand (Clifton, 1987). Zeolites now mined in Arizona and Idaho currently supply all of the domestic demand for natural zeolites. Nevertheless, Wyoming's large zeolite resources remain available should new uses or increased demand develop.

Silica

The major ingredient in glass is silica (SiO_2) which occurs in nature as the mineral quartz. Recently, several silica-producing companies have expressed an interest in developing a silica resource and beginning glass production in Wyoming. Two silica deposits in Wyoming were drilled in late 1987 using grant money from the Wyoming Economic Development and Stabilization Board and technical advice and assistance from the Geological Survey of Wyoming. These deposits, one in Albany County and one in Platte County, are located near transportation routes and sources of other glass raw materials (including soda ash). Economic considerations may favor the development of a glass

industry in Wyoming should a deposit of silica sand prove of sufficient quality and quantity to support such a plant.

References cited

Clifton, R.A., 1987, Natural and synthetic zeolites: U.S. Bureau of Mines Information Circular 9140, 21 p.

Harris, R.E., 1987, Geology and economic potential of a high-calcium limestone and dolomitic limestone deposit near Manville, Niobrara County, Wyoming: Geological Survey of Wyoming Report of Investigations 39, 16 p.

STRATIGRAPHY UPDATE

by Alan J. Ver Ploeg, Stratigrapher, Geological Survey of Wyoming

Several comments have been received regarding the new proposed stratigraphic nomenclature chart for Wyoming which was released early in the fall of 1987. These comments are currently under consideration for inclusion in a final version of the nomenclature chart. Reviewers suggested that Triassic/Permian and some Cretaceous nomenclature needs clarification, especially in the Powder River Basin; that Permian/Pennsylvanian nomenclature across northern Wyoming needs revision, and that certain formations need to be split into commonly used members. All of these suggestions will be evaluated with respect to the mapability of any proposed unit at a 1:24,000 scale, one of the prime considerations used in developing this chart. Although the year-end deadline (1987) has passed, any last minute suggestions will be evaluated if possible. If you have significant points to make or note an error in the proposed chart, contact Alan J. Ver Ploeg at the Geological Survey of Wyoming (307-742-2054). This project should be completed by the early part of the summer of 1988.

The Geological Survey of Wyoming just released a new color geologic map entitled *Geologic map of the Newcastle 1° x 2° Quadrangle, northeastern Wyoming and western South Dakota* by J.D. Love, A.C. Christiansen, and L.W. McGrew. This map (Map Series 25-1) is the first in a series of 1° x 2° color geologic maps (scale 1:250,000) which will cover the entire state. These maps will contain some revisions in interpretation from earlier open file maps of the same areas and scale, as well as, from the 1985 state geologic map (1:500,000 scale). See page 29 for price and ordering procedures.

Drafting has been completed on three preliminary geologic quadrangles mapped by the Stratigraphy Division during the past field season. These maps, discussed in the last issue of *Wyoming Geo-notes*, are the Tabletop, Fraker Mountain, and Barnum Quadrangles. They will be released as Open File Reports in early 1988. Photointerpretation is beginning on the Turk Springs and Poker Butte Quadrangles in preparation for field mapping during the 1988 field season. These maps are all part of the Survey's cooperative COGEOMAP Project with the U.S. Geological Survey.

An interesting article recently appeared in the October 1987 issue of *Geology* (p. 896-899). The article entitled, *Dinosaurs, spherules, and the "magic" layer: A new K-T boundary clay site in Wyoming* by B.F. Bohor, D.M. Triplehorn, D.J. Nichols, and H.T. Millard, Jr., discusses a new clay site recently found along Dogie Creek in Wyoming in the drainage of Lance Creek. The clay was discovered in the uppermost part of the Lance Formation. The paleontological significance of this new boundary site is its close association with well studied assemblages of dinosaurs and other vertebrates and flora within the type area of the Lance Formation. According to the authors, this site should aid in resolving both the mechanism of the K-T boundary event and its affect upon life forms, including their extinctions.

SELENIUM IN WYOMING

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

Selenium is a naturally-occurring element that is present in varying concentrations in many geologic formations and soils. In the past, it's use in selenium rectifiers and photovoltaic cells generated commercial interest. Most of the interest in this element, however, has been related to both its function as an essential nutrient as well as its known or potential toxicity to grazing animals.

In order to understand the origin, distribution, and toxicity of selenium, a basic understanding of its chemistry is required. It is similar to sulfur, with which it is often associated and sometimes replaces. Selenium, which is a semi-metal, can be present in many inorganic forms, ranging from metallic to crystalline to gaseous. It is also present in many organic forms, some of which are gaseous. Some forms of selenium are insoluble in water while others are easily dissolved and mobilized.

Selenium has a volcanic origin, and is a constituent of volcanic ash, magma, and volcanic gas. The alteration of volcanic gas and the weathering of volcanic ash and magma converts selenium to forms that can be dissolved in water and transported. As a result, much of this transported selenium has accumulated in marine shales, siltstones, and mudstones. Some has also accumulated in organic deposits such as coal. A few terrestrial deposits have accumulated selenium, primarily those with a volcanic component such as tuffaceous sandstones, siltstones, and claystones. Some limestones have been shown to have a selenium component. Soils that develop on seleniferous geologic formations also have a selenium content. In fact, the weathering process that creates soils in alkaline and arid environments can increase the solubility of selenium in parent rocks.

Vegetation growing on soils or bedrock with a selenium content can also accumulate selenium. It has been known since the 1930s that some vegetation could concentrate selenium to varying degrees. In 1949, Trelease and Beath pointed out that the presence of certain plants

called selenium indicator plants was often associated with seleniferous geologic formations and soils in Wyoming. A discussion of selenium indicator plants is beyond the scope of this text, but there are a few types that are widely distributed in parts of Wyoming. For example, about twenty-four species and varieties of milk vetch (Leguminosae-*Astragalus*), woody aster (Compositae-*Machaeranthera*), goldenweed (Compositea-*Haplopappus*), and princes plume (Cruciferae-*Stanleya*) are all selenium indicators (Rosenfeld and Beath, 1964). Most cases of selenium poisoning in Wyoming have occurred as a result of grazing animals consuming selenium indicator plants.

Much research remains to be done on the occurrence, distribution, and mobilization of selenium in Wyoming. There have been a few areas where detailed sampling and analysis for selenium have occurred. Most areas of the State, however, have had spotty sampling from which broad generalizations have been made about the occurrence and distribution of selenium in geologic formations, soils, water, and vegetation.

Two distinct types of data are presently available. The first set of data relates seleniferous vegetation to geologic formations and soils. In this case, the geochemistry of the bedrock and soils is in large part inferred from chemical analyses of the vegetation growing on the bedrock and soil. The other set of data is based on geochemical analyses of bedrock without any analyses of vegetation. Both sets of data are presently being combined for presentation on a map called, *Guide to potentially seleniferous areas in Wyoming*. The limited data relating selenium to geologic formations and soils will be extrapolated to cover the entire State. When finished, this map will be a form of prospecting map or a map of "the most probable areas of selenium occurrence". The map can then be used to devise sampling schemes and to set priorities for sampling.

Available data have indicated that there are a number of geologic formations in Wyoming that locally have seleniferous vegetation associated with them and that need to be investigated in more detail. There are also some geologic formations in Wyoming, which at least locally, exhibit selenium at concentrations greater than 0.6 parts per million (ppm). A search of available literature revealed that the average concentration of selenium in crustal shale is estimated at 0.6 ppm. Because average concentrations of elements in shale are often used for geochemical comparisons, values above 0.6 ppm selenium are considered significant. These formations and the vegetation growing on them need to be sampled and investigated.

In order to address all pertinent selenium issues and assure coordination among selenium researchers in Wyoming, Governor Sullivan has formed a Selenium Task Force headed up by the Wyoming Department of Environmental Quality. The Geologic Hazards Division of the Geological Survey of Wyoming is an active member of this group. For more information on Task Force activities, contact Mike Carnevale at the Wyoming Department of Environmental Quality (307) 777-7081. Detailed information on the chemistry and geologic distribution of selenium can be obtained from Jim Case at the Geological Survey of Wyoming (307) 742-2054. Because the Task Force is trying to assemble all selenium-

related information from Wyoming, anyone with data on selenium is urged to contact the Task Force or its members.

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First draft of proposed stratigraphic nomenclature chart for the State of Wyoming, J.D. Love, A.C. Christiansen, and A.J. VerPloeg, 1987, ($1.50).

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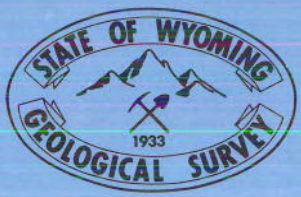
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