

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

# WYOMING GEO-NOTES NO. 13



**LARAMIE, WYOMING**

**January, 1987**

## THE GEOLOGICAL SURVEY OF WYOMING

Gary B. Glass, *Executive Director and State Geologist*

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### WYOMING GEO-NOTES

This quarterly newsletter on the geology, mineral resources, and activities of the Geological Survey is available by subscription (four issues for \$5.00) or as single copies at \$1.50 each.

**Front cover:** The "Sinks", west of Lander, Wyoming, where the Popo Agie River disappears into a solution cavern in the Madison Limestone and flows underground for 600 feet. Read pages 62 through 64 of this volume for more information about the Sinks.

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## Minerals Update

### OVERVIEW

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

OPEC's tentative accord at the end of 1986 provides some optimism for 1987. For however long higher prices last, they will not only be welcomed by Wyoming's oil and gas industry, but also by the State's governmental bodies and educational institutes alike because they will help offset the low prices that dominated 1986, and they will help offset declining revenue as annual production from Wyoming's oil fields declines. But \$18 per barrel oil won't stimulate much increase, if any, in oil and gas exploration activity. This means annual oil production will continue its projected decline for the foreseeable future, very possibly at accelerating rates.

Although production estimates for Wyoming's other major revenue-generating minerals (natural gas and coal) are still projected to decrease in 1986, both should show increases in 1987 although estimates for natural gas increases have been scaled down since September of 1986 (compare estimates on page 3 with estimates in *Wyoming Geo-notes No. 12*, page 3).

In regard to other minerals produced in Wyoming, modest increases in production are at least still projected for trona, construction materials and possibly even uranium although the possible increases in uranium production would still leave this industry only a wisp of its past size. In addition, there is a possibility that mining of zeolites, naturally-occurring sulfur, cement materials and even gold could be in the offing in the future although only cement manufacture is almost certain to occur.

Because there were really no significant changes in production estimates for any of the major minerals produced in Wyoming, except natural gas, since our estimates of September, 1986, it may be difficult to fathom the big downward revision of State General Fund revenues projected in December, 1986, for the 1987-1988 Biennium. This revised estimate was after all only slightly more than two months after the one released in October, 1986. As a member of the group that made the projections, let me share the Group's explanations for our major downward revisions for the current Biennium (1987-1988).

The changes primarily stemmed from the availability of additional detailed information not available in late September. Specifically, third quarter severance tax information indicated that the average taxable values for oil, natural gas and coal (the three major sources of mineral revenue) were all substantially below previously predicted and published levels. In addition, for the first time, the Federal government provided monthly information on mineral production from Federal lands and corresponding royalty receipts. In the case of oil, prices indicated by these two sources of information could now be compared with posted field prices for oil.

Compounding the shortfalls in severance taxes related to declining mineral values, sales and use taxes and pooled interest revenue were also lagging behind the October forecasts. Let us look at each of these things more closely, starting with oil. In December, production levels were not changed from the October projections, however, the average taxable value of a barrel of Wyoming crude had shown no evidence of rebounding closer to posted field prices. Prior to 1985, the average taxable value of Wyoming oil had generally been \$1.00 or more above the average price paid for domestic oil. In 1985, the average taxable value fell

to nearly \$1.00 below the national average. Based on all the new information available in December, the average taxable value for Wyoming oil was staying at about 75 percent of the posted field prices. While posted prices were between \$13.50 and \$14.50, Wyoming's average taxable value was only \$10.50 per barrel. Should OPEC's tentative accord in late December actually stabilize oil prices at \$18-\$20 in 1987, projected General Fund revenues from oil for the 1987-1988 Biennium could be \$4-\$8 million higher than forecast in early December. Continued stabilization at these higher oil prices could result in a \$7-\$18 million increase in the projections of severance taxes from oil in the 1989-1990 Biennium.

*Wyoming mineral production forecast to 1991<sup>1</sup>.*

Calendar Year	Oil Production <sup>2</sup>	Natural Gas Production <sup>3,5</sup>	Carbon Dioxide Production <sup>3</sup>	Coal Production <sup>4</sup>	Trona Production <sup>4</sup>	Uranium Production <sup>4</sup>
*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	123.0	558.0	25.0	135.0	11.5	0.3
1987	115.5	605.0	75.0	149.0	11.7	0.3
1988	107.5	629.0	100.0	143.0	12.1	0.4
1989	100.0	664.0	100.0	146.0	12.1	0.5
1990	93.0	699.0	100.0	150.0	12.2	0.5
1991	86.5	730.0	100.0	151.0	12.5	0.6

\*Actual values for comparison, <sup>1</sup> Geological Survey of Wyoming, January, 1987, <sup>2</sup> Millions of barrels, <sup>3</sup> Billions of cubic feet, <sup>4</sup> Millions of tons, <sup>5</sup> Production estimates for natural gas are the only ones changed since September, 1986.

Production history of selected other mineral commodities<sup>1</sup>.

	1980	1981	1982	1983	1984	1985
Ballast <sup>2,3</sup>	1.65	1.72	0.81	0.99	2.43	0.67
Bentonite <sup>2</sup>	3.58	4.81	2.35	2.18	3.08	2.59
Clay <sup>2</sup>	0.04	0.02	0.02	0.04	0.05	0.04
Decorative Stone <sup>2</sup>	0.05	0.05	0.05	0.07	0.08	0.09
Dolomite <sup>2</sup>	1.67	0.87	0.61	0.66	0.86	0.87
Feldspar <sup>4</sup>	200	25	----	----	----	----
Gypsum <sup>2</sup>	0.30	0.28	0.26	0.33	0.33	0.35
Iron Ore <sup>2</sup>	4.88	4.67	3.28	2.48	----	----
Limestone <sup>2,5</sup>	0.50	0.72	0.59	0.56	0.65	0.32
Sand and Gravel <sup>2</sup>	5.06	5.21	4.74	5.00	4.76	4.71
Scoria <sup>2,6</sup>	0.03	0.08	0.08	0.07	0.23	0.13
Shale <sup>2</sup>	----	----	----	----	0.02	0.01
Sodium Sulfate <sup>4</sup>	----	3,201	3,174	3,194	3,250	2,705
Sulfur <sup>2,7</sup>	0.05	0.05	0.08	0.55	0.69	0.77

<sup>1</sup>Source: Ad Valorem Tax Division. <sup>2</sup>Millions of short tons. <sup>3</sup>Includes granite, scoria and other rock. <sup>4</sup>Short tons. <sup>5</sup>Includes limestone used for cement rock, sugar beet refining and other uses. <sup>6</sup>Baked and fused rock, also called clinker. <sup>7</sup>Data from U.S. Bureau of Mines.

In regard to natural gas, both production and price changes were needed between the October and December forecasts. Although the October forecast predicted that production would decline, third quarter severance tax information indicated that production was going to be less than the earlier projection. It was also noted that taxable production for 1986, like 1985, was going to be about 68 to 69 percent of the gross production rather than the 74 percent typical of 1984 and earlier years. Third quarter severance tax collections also indicated that the average taxable value for natural gas had fallen below any amount previously projected, i.e., under \$1.90 per thousand cubic feet (MCF). It was obvious that the gas glut had not yet ended and that lack of demand and low oil prices were holding down natural gas production and prices. Consequently projected production increases had to be moved out about a year from the October projections, and natural gas prices were not forecast to increase until 1988. Persistent higher oil prices (OPEC's \$18-\$20 range) could improve the average projected prices for Wyoming's natural gas. If this should happen, severance tax revenues to the General Fund would increase over the December forecast. But this is not a certainty.

Turning to coal, the production levels forecast in October remained unchanged in December, but third quarter severance tax payments indicated the assessed taxable value had declined to \$8.55 per ton instead of the \$8.65 previously projected. Due to extremely low spot prices paid for Powder River Basin coals, many contracts continue to be renegotiated downward and some contracts have even been bought out early so a utility could benefit from the current low prices. Based on the lowered taxable value for coal in 1986, the estimated average taxable value for a ton of coal were also lowered for 1987 and 1988 in December.



Revenue derived from pooled interest is directly related to the level of the General Fund and Budget Reserve Account cash balances. The General Fund's share of pooled interest has decreased substantially in the last few years with the creation of more earmarked revenue accounts, such as the Water Development Account. For example, the transfer of \$114.6 million from the General Fund to the Water Development Account over the past couple of years is one of the major reasons that the General Fund's share of pooled interest has plunged so sharply and rapidly. Now the General Fund's share of the pooled interest comes almost solely from interest received from the Budget Reserve Account investments. Any decrease in the Budget Reserve Account, which is quite possible with lagging revenues, decreases revenue to the General Fund from this source. Because actual cash balances between October and December were lower than projected, revenues from pooled interest had to be revised downward. Tracking expenditures from a myriad of earmarked accounts all administered by different entities has greatly complicated prediction of this revenue source.

The latest sales tax collections indicated revenue from this source was dropping faster than expected in October. This is consistent with past years, which have shown that sales tax receipts track severance tax collections, particularly on the down side. The outlook for Fiscal Year 1988 is no better due to the current economic conditions, and will probably be compounded by reduced government spending at both the State and local levels.

While more reductions in use tax collections are indicated due to the depressed economy, shortfalls in collections will be tempered by increased revenue stemming from audit collections.

The bottom line at the December revenue forecasting meeting was that the taxable unit value for each of

Summary table of projected taxable production and taxable values.

	Actual	Estimated in mid-December				
	1985	1986	1987	1988	1989	1990
<u>OIL</u>						
GROSS PRODUCTION <sup>1</sup>	131.0	123.0	115.5	107.5	100.0	93.0
TAXABLE PRODUCTION <sup>1</sup>	123.2	115.6	108.6	101.0	94.1	87.7
DIFFERENCE BETWEEN TAXABLE AND GROSS IN PERCENT	92	92	92	92	92	92
AVERAGE POSTED PRICE/BARREL	\$24.08	\$17.33	\$14.67 <sup>4</sup>	\$16.00 <sup>4</sup>	\$18.00	\$18.00
AVERAGE TAXABLE VALUE/BARREL	\$23.33	\$13.00	\$11.00 <sup>4</sup>	\$12.00 <sup>4</sup>	\$13.50	\$13.50
<u>NATURAL GAS</u>						
GROSS PRODUCTION <sup>2</sup>	597.9	558.0	605.0	629.0	664.0	699.0
TAXABLE PRODUCTION <sup>2</sup>	412.0	385.0	418.0	434.0	458.0	482.0
DIFFERENCE BETWEEN TAXABLE AND GROSS IN PERCENT	68	69	69	69	69	69
AVERAGE TAXABLE VALUE/MCF	\$ 3.01	\$ 2.11	\$ 1.92 <sup>4</sup>	\$ 2.10 <sup>4</sup>	\$ 2.25	\$ 2.35
<u>COAL</u>						
GROSS PRODUCTION <sup>3</sup>	140.7	135.0	140.0	143.0	146.0	150.0
TAXABLE PRODUCTION <sup>3</sup>	134.0	128.0	131.0	136.5	141.0	142.0
DIFFERENCE BETWEEN TAXABLE AND GROSS IN PERCENT	96	96	96	96	96	96
AVERAGE TAXABLE VALUE/TON	\$ 9.12	\$ 8.55	\$ 7.00	\$ 6.90	\$ 7.08	\$ 7.21

<sup>1</sup> Millions of barrels; <sup>2</sup> Billions of cubic feet; <sup>3</sup> Millions of short tons; <sup>4</sup> These may be low if OPEC's late December accord succeeds in holding up oil prices.

Wyoming's three major produced minerals (oil, gas and coal) were far below the levels predicted and incorporated in the October forecast. It had not been possible to substantiate that in late September because significant information on tax collections simply had not been available. Once it was apparent that severance tax collections were not tracking the October forecast, it was not surprising that the other revenue sources, particularly sales tax, would also be below earlier expectations. Hopefully, with the advent of new more timely production and pricing information, such radical revisions will be less commonly needed.

It should be remembered, however, that the price of oil is not controlled by Wyoming or the United States for that matter. Until oil prices stabilize, all mineral revenue forecasts will be subject to significant and often abrupt changes.

Unfortunately oil prices in the range of \$18-\$20 will do little to affect the revenue derived from sales and use taxes as these prices are not high enough to really stimulate exploration activity in Wyoming. Renewed exploration and development for both oil and natural gas are paramount to stimulating Wyoming's economy at least in the near term.

#### OIL AND GAS UPDATE

by Rodney H. DeBruin, Petroleum Geologist, Geological Survey of Wyoming

In mid-December the posted price for Wyoming Sweet was raised a dollar to \$14.75 per barrel; however, an analysis of the top 25 oil fields in the State (see table on page 12 and figure on page 13 for the names and locations of the top 25 oil and gas fields) shows that Wyoming is actually getting an average of \$2 less per barrel than the posted price in these top 25 oil fields due in part to reductions for low gravity. These top 25 fields accounted for nearly 56 percent of Wyoming's 1985 production. Spot prices for Wyoming gas have also decreased and are currently around \$1.35 per MCF. This drop has been caused by the excess supply of gas in this country as well as price competition from cheap oil. In addition to the drop in revenues from the low prices for oil and gas, production of Wyoming oil and gas is projected to decline by about six percent in 1986 (see table on page 3).

The only real prospects for reviving the industry, at least in the next year or two, appear to be a signi-

ficant production cut by OPEC or enactment of an import fee. Support for an import fee is gaining momentum, but even its advocates give the fee less than a 40 percent chance of being implemented in the near future. Thus the domestic oil industry is at the mercy of a handful of squabbling oil ministers; the most influential of these represent Middle Eastern countries. A seven percent production cut was agreed upon by OPEC in late December; however, most of the OPEC members have a history of cheating on their quotas. There is also a big surplus of crude on the market as a result of overproduction in 1986. Much of this surplus will have to be used before prices will rise dramatically and stabilize.

On December 2nd a meeting organized by Governor-elect Mike Sullivan was held in Casper to advance the prospects for a fee on all imported oil. Spokesmen favoring the fee included the Governor-elect, a Harvard Economics Professor, the Chief Executive Officer of an oil company and a member of the Texas Railroad Commission. Enactment would have the effect of increasing the price of Wyoming oil by the amount of the fee.

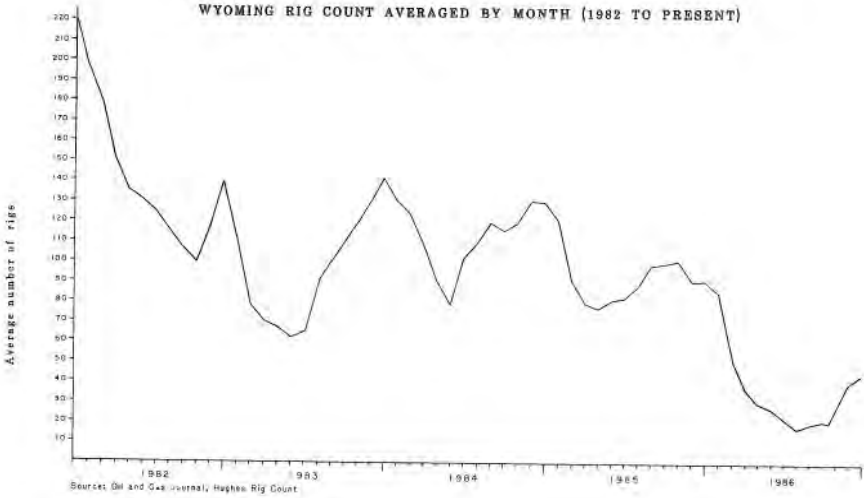
In a related item, the average weekly rig count for 1986 was about 36. Drilling picked up somewhat in December and the rig count averaged over 40 for that month (see figures on page 10 for comparisons with the past).

Well completion statistics for the first eleven months of 1986 are summarized and compared with figures for 1985, 1984, 1983, 1982 and 1981 in the table below:

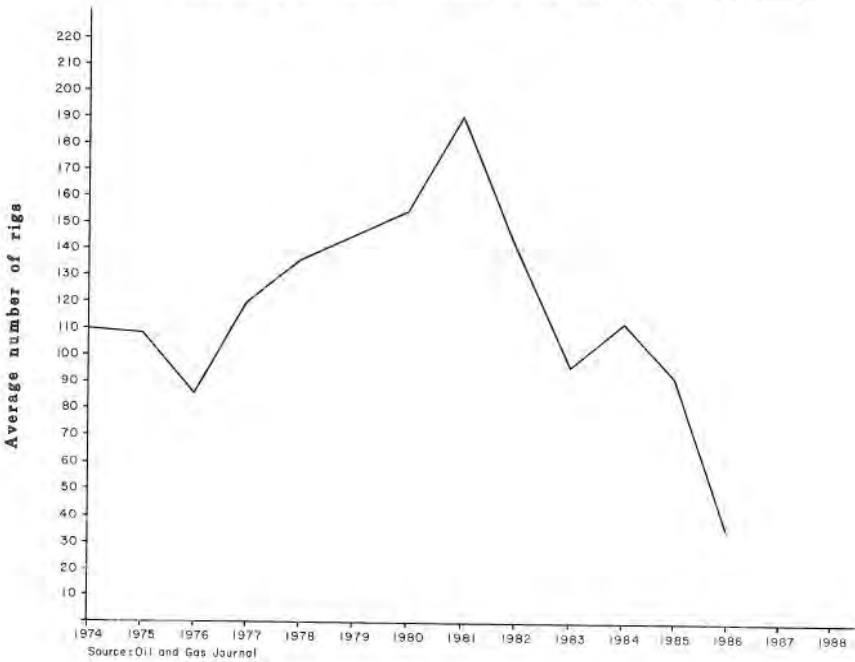
	<u>New field wildcats</u>				<u>All wells</u>			
	<u>Oil</u>	<u>Gas</u>	<u>Dry</u>	<u>Total</u>	<u>Oil</u>	<u>Gas</u>	<u>Dry</u>	<u>Total</u>
1986*	24	2	214	240	282	31	336	649
1985	64	8	469	541	920	109	809	1,738
1984	57	9	440	506	801	142	750	1,693
1983	23	13	305	341	698	152	550	1,400
1982	68	28	404	500	1,029	272	827	2,128
1981	76	43	471	590	756	222	746	1,724

\*11 months. From: Petroleum Information Corporation, Rocky Mountain Region Report, December 17, 1986, p. 7.

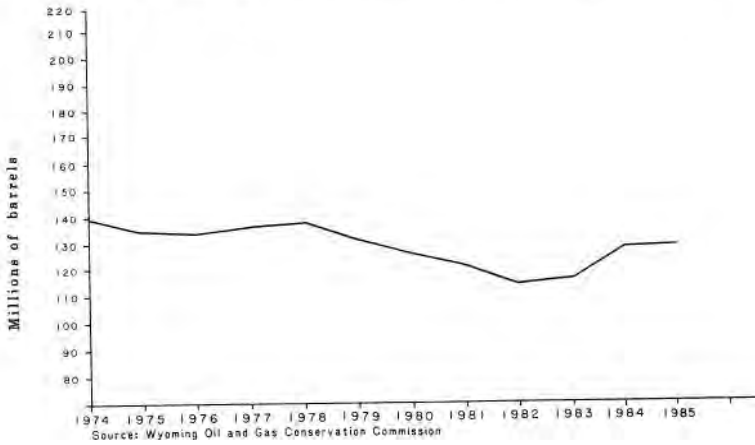
WYOMING RIG COUNT AVERAGED BY MONTH (1982 TO PRESENT)



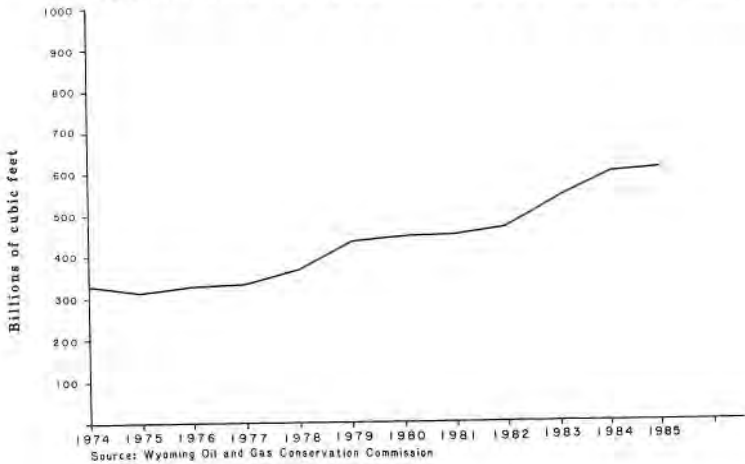
WYOMING RIG COUNT AVERAGED BY YEAR (1974 TO 1986)



### WYOMING OIL PRODUCTION BY YEAR (1974 TO 1985)



### WYOMING NATURAL GAS PRODUCTION BY YEAR (1974 TO 1985)

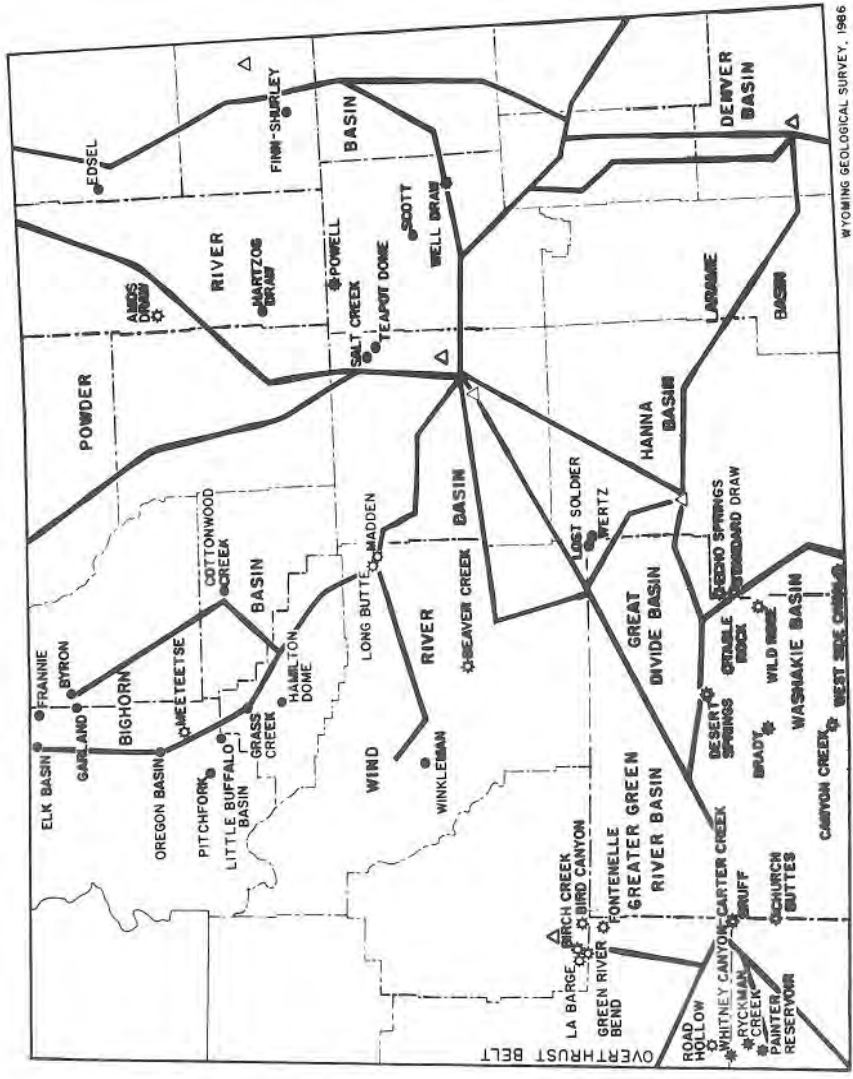


TOP 25 GAS FIELDS IN WYOMING BASED ON 1985 PRODUCTION

Name	Year dis- covered	1985 Production (MCF)	Cumulative Pro- duction through 1985 (MCF)
Whitney Canyon - Carter Creek	1978	109,834,127	304,509,213
Painter Reservoir	1977	71,903,356	272,395,994
Brady	1973	21,350,632	219,310,370
Table Rock	1946	20,451,870	384,260,489
Echo Springs	1976	18,247,865	99,531,473
Ryckman Creek	1976	16,402,064	67,077,892
Powell	1954	14,525,391	44,957,832
Standard Draw	1979	13,032,332	61,867,786
Madden	1969	11,257,510	220,036,657
Bruff	1974	10,833,216	78,713,861
Long Butte	1982	10,319,659	32,707,991
Amos Draw	1982	10,056,546	17,284,308
Beaver Creek	1938	9,083,218	534,722,318
Wild Rose	1975	8,612,453	53,834,294
Church Buttes	1956	8,217,578	336,599,451
Desert Springs	1958	6,515,804	238,213,340
Road Hollow	1981	6,261,810	10,223,515
La Barge	1925	6,193,973	202,329,406
Meeteetse	1954	6,087,908	9,373,618
Birch Creek	1957	5,801,310	153,740,282
West Side Canal	1964	5,211,606	120,160,813
Canyon Creek	1941	4,759,211	233,266,085
Green River Bend	1958	4,579,841	166,550,082
Bird Canyon	1971	4,556,636	26,207,313
Fontenelle	1974	4,296,180	34,701,440
<b>TOTAL</b>		<b>408,392,096</b>	<b>3,922,575,823</b>

TOP 25 OIL FIELDS IN WYOMING BASED ON 1985 PRODUCTION

Name	Year dis- covered	1985 Production (Barrels)	Cumulative Pro- duction through 1985 (Barrels)
Oregon Basin	1912	9,671,706	360,112,778
Painter Reservoir	1977	7,711,152	37,996,305
Salt Creek	1889	6,114,941	610,625,925
Hartzog Draw	1976	5,221,538	46,477,313
Little Buffalo Basin	1914	3,894,253	109,493,484
Elk Basin	1915	3,802,667	423,163,041
Powell	1954	3,511,650	11,494,722
Brady	1973	3,487,542	47,037,899
Hamilton Dome	1918	3,266,556	221,237,338
Lost Soldier	1916	2,891,876	202,639,471
Garland	1906	2,871,820	154,800,791
Grass Creek	1914	2,468,906	177,606,460
Wertz	1921	2,385,066	90,618,339
Byron	1918	2,066,748	116,537,485
Whitney Canyon - Carter Creek	1978	2,005,344	4,053,463
Frannie	1928	1,807,888	108,245,845
Winkleman	1917	1,387,341	82,895,832
Ryckman Creek	1976	1,356,207	13,764,438
Scott	1979	1,277,113	8,801,583
Pitchfork	1930	1,121,636	29,505,530
Teapot Dome Naval Reserve	1922	1,076,595	16,894,643
Edsel	1981	1,046,569	1,850,800
Cottonwood Creek	1953	956,203	50,259,079
Finn-Shurly	1965	912,705	6,121,096
Well Draw	1973	896,280	24,891,927
<b>TOTAL</b>		<b>73,210,302</b>	<b>2,957,125,587</b>



EXPLANATION

Major basins

Oil and gas pipeline corridors

△

Active refineries

●

Field which ranked as one of Wyoming's top 25 oil producers in 1965

☆

Field which ranked as one of Wyoming's top 25 gas producers in 1965

✱

Field which ranked as one of Wyoming's top 25 oil and top 25 gas producers in 1965

WYOMING GEOLOGICAL SURVEY, 1966

GENERALIZED OIL AND GAS INDEX MAP OF WYOMING



Extrapolating the figures for the first eleven months to the end of 1986, leaves Wyoming with approximately 280 fewer wildcat wells and 1,000 fewer total wells than were drilled in 1985. It also indicates approximately 50 fewer oil discoveries and 40 fewer gas discoveries than were made in the boom year of 1981. The figures also show an extreme drop in the drilling of development wells in 1986. If this disturbing trend continues much longer, Wyoming oil production will decline even more sharply.

Revenues from lease sales are also down, reflecting the decline of the oil and gas industry and, in some cases, the lack of high quality lease offerings. The U.S. Bureau of Land Management (BLM) has held two sales since the last issue of *Wyoming Geo-notes*. The October sale drew high bids of \$840,950 for 16,604 acres. There were bids on 68 of the 76 parcels offered with an average bid of \$50.65 per acre. The high per-acre bid of \$516.86 was made by Wessely Energy for a 320-acre tract in section 35, T.48N., R.70W. in Campbell County. The tract is less than one half mile from Pierce Field and one mile from Bishop Ranch South Field, both of which produce oil from the Minnelusa. Bids for the two top tracts in this sale accounted for 25.8 percent of all revenue generated.

The BLM's December sale drew high bids of \$774,824 for 19,840 acres. Bids on 92 of the 110 parcels averaged \$39.05 per acre. Southwestern Energy Production made the sale's high per-acre bid of \$3,313.13 for a 40-acre tract in section 14, T.49N., R.70W. in Campbell County. The tract is in Winter Draw Field, which produces oil from the Minnelusa. Bids for the two top tracts generated 33.6 percent of the total revenue for this sale.

The Wyoming Board of Land Commissioners' November lease sale drew high bids totaling \$99,403 for 24,728 acres. Only 74 of the 200 tracts and less than one third of the offered acreage received bids. Wilbanks

WYOMING FEDERAL AND STATE COMPETITIVE OIL AND GAS LEASE SALES

BLM SALES 1984

Month	Total Revenue	Number of parcels offered	Number of parcels sold	Total acres	Acres sold	Average price per acre sold	High price per acre
February	\$ 7,262,056	21	21	2,304	2,304	\$3,151.31	\$21,239.34
March	615,088	28	28	4,015	4,015	153.20	500.00
April	330,798	29	29	3,977	3,977	83.17	412.51
May	1,571,896	77	75	14,565	14,470	108.63	1,300.00
August	12,465,683	162	162	30,110	30,110	414.00	13,333.33
October	2,521,434	115	115	19,852	19,852	127.01	3,852.00
December	4,761,794	123	123	29,202	29,202	163.07	5,751.50
<b>TOTAL</b>	<b>\$29,528,749</b>	<b>555</b>	<b>553</b>	<b>104,025</b>	<b>103,930</b>	<b>\$ 284.12</b>	<b>\$21,239.34</b>

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
<b>TOTAL</b>	<b>\$13,735,154</b>	<b>999</b>	<b>772</b>	<b>331,177</b>	<b>232,854</b>	<b>\$ 58.99</b>	<b>\$ 2,609.53</b>

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
<b>TOTAL</b>	<b>\$ 7,265,390</b>	<b>776</b>	<b>583</b>	<b>211,350</b>	<b>152,428</b>	<b>\$ 47.66</b>	<b>\$ 3,313.13</b>

STATE SALES 1984

Month	Total Revenue	Number of parcels offered	Number of parcels sold	Total acres	Acres sold	Average price per acre sold	High price per acre
January	\$ 2,316,714	200	165	118,285	92,785	\$ 23.97	\$ 502.04
March	2,173,851	200	166	85,993	66,781	31.49	524.00
May	1,527,903	200	162	87,469	67,579	32.49	390.00
July	2,028,880	200	181	86,387	73,849	26.46	2,100.00
September	1,379,138	200	141	87,095	53,066	24.99	1,020.00
November	739,766	200	135	82,363	51,640	13.33	280.00
<b>TOTAL</b>	<b>\$10,166,252</b>	<b>1,200</b>	<b>950</b>	<b>547,592</b>	<b>405,700</b>	<b>\$ 25.05</b>	<b>\$2,100.00</b>

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
<b>TOTAL</b>	<b>\$ 5,891,224</b>	<b>1,299</b>	<b>723</b>	<b>539,652</b>	<b>277,959</b>	<b>\$ 21.19</b>	<b>\$1,700.00</b>

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
<b>TOTAL</b>	<b>\$ 2,448,160</b>	<b>1,199</b>	<b>522</b>	<b>483,326</b>	<b>205,757</b>	<b>\$ 11.90</b>	<b>\$ 370.00</b>

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

and Associates of Denver made the high per-acre bid of \$120 for a 40-acre lease in section 21, T.42N., R.73W. in Campbell County. The tract is about a mile northeast of Dakota production at Turnercrest Field. Of the 74 tracts which received bids in this sale, 42 drew the minimum bid of \$1 per acre and only eight of the tracts drew bids of more than \$10 per acre. For year-end totals and a comparison with past sales, see the table on page 15. Total revenues from Bureau of Land Management sales and State sales in 1986 were both less than 25 percent of the total revenues from 1984 sales.

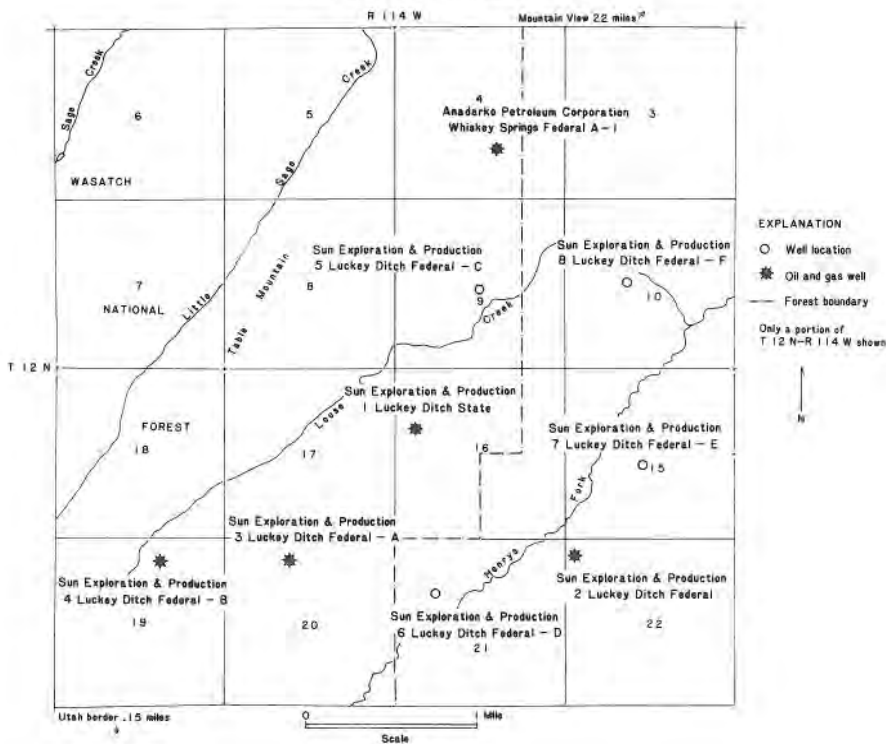
The carbon dioxide (CO<sub>2</sub>) injection project at Rangely Field in Colorado began on October 12. Exxon's Shute Creek plant near La Barge, Wyoming, is supplying the CO<sub>2</sub>. Chevron, the operator for Rangely has agreed to buy 900 billion cubic feet of CO<sub>2</sub> over the next twelve years, which is an average of 205 million cubic feet per day. The initial injection rate, however, is only 75 million cubic feet per day. A spokesman for Chevron said an oil price of about \$20 per barrel is needed to justify the injection of 200 million cubic feet daily.

Colorado Interstate Gas Corporation recently announced that it is studying the possibility of closing its Patrick Draw sour gas plant at Table Rock. A spokesman for the company said a short-term shutdown would probably occur. The plant employs 120 people.

On a more optimistic note, the Luckey Ditch Field in Uinta County continues to expand. Sun Exploration and Production completed the Four Luckey Ditch Federal-B well December 15th in section 19, T.12N., R.114W. flowing 1,085 barrels of 42° oil, 1,076 MCF of gas and 99 barrels of water per day from the Dakota. The well was tested on a 15/64-inch choke through perforations between 15,714 and 15,748 feet. The most recent production figures for September show the discovery well, the One Luckey Ditch State, completed in May of 1985

in section 16, T.12N., R.114W., produced 1,083 barrels of oil and 3,127 MCF of gas per day. The Two Lucky Ditch Federal, completed in April of 1986 in section 22, T.12N., R.114W., produced 988 barrels of oil and 2,675 MCF of gas per day. The Three Lucky Ditch Federal, completed in April of 1986 in section 20, T.12N., R.114W., produced 792 barrels of oil and 1,603 MCF of gas. A fifth well, completed by Anadarko Petroleum Corporation in February of 1986 in section 4, T.12N., R.114W., produced 419 barrels of oil and 4,095 MCF of gas. Sun is currently drilling the Five Lucky Ditch Federal-C in section 9, T.12N., R.114W., and has staked three additional locations in sections 10, 15 and 21 of T.12N., R.114W. (see figure below).

### LUCKY DITCH FIELD AREA



Thermal Exploration recently completed a Dakota discovery on the Moxa Arch in section 10, T.24N., R.111W. The well flowed 6,986 MCF of gas and 323 barrels of condensate per day. This discovery was a deeper pool discovery in Lincoln Road Field which also produces from the Frontier. Thermal Exploration will drill another Dakota test in section 9, T.24N., R.111W., and Texaco has also scheduled a Dakota test in section 3, T.24N., R.111W.

Quarles Drilling of Tulsa will drill a 25,000-foot well for BHP Petroleum in section 3, T.38N., R.90W. The well is scheduled to bottom in Precambrian. This well will be about 2 1/2 miles west of the Rocky Mountain region's deepest producing well, Monsanto Oil's 1-5 Bighorn drilled in section 5, T.38N., R.90W. The 1-5 Bighorn reached 24,877 feet, took 641 days to drill and was completed producing gas from the Madison and Bighorn between 23,758 and 23,902 feet.

The Permian and Pennsylvanian play of western Nebraska has spread into eastern Wyoming. True Oil recently completed a Pennsylvanian wildcat well in section 25, T.22N., R.62W. as a 10,050-foot dry hole. Conoco is nearing its objective of 11,700 feet in the Pennsylvanian in a wildcat it is drilling in section 3, T.19N., R.65W. Both of these wells are in Goshen County.

#### SPECIAL REPORT ON THE OIL AND GAS BUSINESS

by Donald B. Basko, Oil and Gas Supervisor, Wyoming  
Oil and Gas Conservation Commission

*The following paragraphs on Wyoming's oil and gas industry were modified from several recent talks given by Donald B. Basko, Wyoming's Oil and Gas Supervisor.*

In January, 1982, 236 rigs were running in Wyoming. The average rig count for 1983 was 84 per week; during

1984, 115 per week; and in 1985, the figure was 92 per week. Without a doubt, 1986 will be an all-time low because, with the exception of the end of the year, the rig count has barely gotten above the 30 mark, and it hit a low of 19 at one point during the summer.

Applications for Permit to Drill during 1983 totaled 1,856; for 1984, 2,108; for 1985, 1,731; and 773 for 1986. Operators normally drill between 75 to 80 percent of the wells that are permitted. During 1985, there were approximately 1,740 completions compared to 684 for 1986.

The Oil and Gas Conservation Commission's business likewise showed a decrease. For instance, it held 469 hearings in 1983; 466, in 1984; 469 in 1985; and had only 347 in 1986.

During 1985, oil production from Wyoming was 130,984,917 barrels, and gas production was 597.9 billion cubic feet. During 1986, it is anticipated that oil production could be slightly more than 124 million barrels. Natural gas production in 1986 should be about 555 billion cubic feet. Along with the oil and gas production, approximately 1.7 million barrels of water will be produced, or an average of 13 barrels of water for every barrel of oil. Fortunately most of this water is reinjected back into the producing formation to assist in secondary recovery,

A significant amount of the State's gas production is produced from a small area in southwest Wyoming. Thirty-three percent of the State's total comes from fields in Uinta County - primarily Whitney Canyon and Carter Creek Fields - and 21 percent from Sweetwater County from a number of smaller gas fields. The total for the two-county area is almost 55 percent of the State's total.

Under current conditions, holding oil production at 1986's level is not possible when you consider that over 52 percent of the State's total oil production comes from 20 large fields, 12 of which are 57 years old or older. Those older fields with few exceptions are declining four to six percent per year.

There are approximately 5,200 stripper oil wells in the State that average 4.21 barrels per well per day. During 1985, stripper production was 7,983,353 barrels from 210,300 producing acres. Since the turndown in the price of oil, at least 1,400 of those wells have probably been shut-in or plugged. Hopefully, improvement in the price of oil will be an incentive for operators to start producing those marginal wells again.

Seismic exploration activity is also down, along with every other phase of the oil and gas business. During 1984, 526 seismic projects were permitted in Wyoming for a total of 12,345 miles of line. During 1985, the number of projects dropped to 442 for a total of 7,856 miles. It is estimated that during 1986, only 170 projects were permitted for just over 2,940 miles. The drop in seismic exploration activity has been catastrophic.

Twenty-one of Wyoming's 23 counties produce oil or gas. Teton and Platte Counties are the only exceptions. Production comes from 933 fields with 13,965 producing wells. One hundred ninety-two formations or combinations of formations that are commingled produce oil or gas or both. The most prolific oil-producing formation is the Tensleep, which produces slightly less than 20 percent of all oil, followed by the Minnelusa at 15 percent. The largest gas-producing formation is the Nugget, which produces 17.5 percent of all the gas, followed by the Madison, which produces over 13 percent of the gas.

Amoco Production Company is the largest oil producer and accounts for almost 21 percent of all oil production; followed by Marathon at 15 percent; Chevron at 7.3 percent; Cities Service at 4.3 percent and Conoco at four percent. Amoco Production Company is likewise the largest gas producer, accounting for over 25 percent of the gas production, followed by Chevron at 20 percent; Champlin at 5.9 percent; Mountain Fuel Supply at 4.1 percent and Texaco at three percent.

During 1983, there were 30 oil and gas discoveries in Wyoming. During 1984, 59 new fields were found and in 1985, there were 43 discoveries. By November 1986, there had been 36 named discoveries, some of which were actually drilled the previous year or for some other reason had not been named until then.

Insofar as getting Wyoming's production to market, there are 41 operating pipelines in the State that total 9,703 miles of line. There are pipelines in all the counties except Teton. In addition to the pipelines, there are 56 gas plants operating in the State which processed 516.2 billion cubic feet of gas during 1985. The gas plants also produced 777,471,865 gallons of liquid hydrocarbons and 95,793,524 gallons of sulfur.

The oil and gas industry was responsible for over 50 percent, or \$301,684,000, of all the property taxes paid in 1985, and 67 percent, or \$272,736,000, of all severance taxes paid. On the whole the industry contributed \$820,000,000 to Wyoming for property taxes, severance taxes, State royalties, Federal royalties, sales tax and use tax during 1985. This outstanding contribution to Wyoming will not be repeated at least in the near term, because of the drastic drop in prices. Oil that peaked in April of 1980 at \$39.50 per barrel and has been as low as \$11.00 per barrel is currently quoted at \$16.25 per barrel. Natural gas



reached \$3.32 per MCF in 1984 and has declined to a spot price of \$1.35/MCF. Employment that once numbered 30,000 people is now estimated at half that figure.

Although most of this recap seems rather bleak, there is some hope, particularly for the natural gas industry. Several years ago, the Interstate Oil Compact Commission (IOCC) conducted a study on gas deliverability. That study showed that during the winter of 1983, a cold snap simultaneously hit Texas and the East Coast and lasted for approximately three weeks. Texas felt sure they had 24 billion cubic feet per day (BCF/D) deliverability, but when all the wells were opened, they had less than 14 BCF/D. The point is that some of the big gas-producing areas do not have the deliverability that they think they have. A further IOCC study pointed out that approximately 30 percent of the Nation's gas comes from offshore wells. These wells, although prolific to start, have a longevity of only six to eight years. These wells have a reserve to production ratio of 6:1, and it is not uncommon for them to decline 40 percent per year. Since very little gas drilling for replacement reserves is going on, a spot gas shortage is very possible this winter, especially if it is a cold winter.

The American Gas Association (AGA) recently related three different scenarios for the long-term gas demand: 1) business as usual, 2) attainable case and 3) potential case. The demand is expected to grow from 17.73 trillion cubic feet (TCF) in 1985 to 19.20 TCF in the year 2000 in the business as usual case; 22.98 TCF in the attainable case and 26.81 TCF in the potential case. This equates to a maximum increase in gas demand of almost 34 percent in the next 14 years. That increase is expected to be utilized in new technologies, such as gas-cooling, compressed natural gas for vehicles, cogeneration and other select uses. The increased demand which is referred to, does not include

presently in-place industrial uses or home heating, etc.

Wyoming has all the right cards to deal with increased gas demand. Gas reservoirs recently discovered in the Madison Formation in the Madden Field (Wind River Basin) as well as other formations encountered in drilling the B.H.P. No. 1-5 Bighorn (section 5, T.38N., R.90W.) yielded spectacular results. Bottomhole pressures exceeded 19,000 pounds per square inch (PSI) with calculated absolute open flows (CAOF) of 80 million cubic feet per day (MMCFD) and fieldwide reserves of five TCF. Some gas wells in the Madison Formation in the Riley Ridge area of western Wyoming have CAOFs in excess of 190 MMCFD. Admittedly, the analysis of the gas from the Riley Ridge Field is 66 percent CO<sub>2</sub>, 22 percent methane, five percent H<sub>2</sub>S, two percent helium and the rest inerts. However, the plant associated with the field will handle 480 MMCFD. That means that 105 MMCFD of methane alone could start coming out of the area.

The shortfall in the deliverability from the big gas-producing states and the anticipated increased demand projected by the AGA make Wyoming a natural for gas exploration and production in the long term, especially since almost two-thirds of Wyoming's gas is now exported to other areas. This prognosis is not meant to imply that drastic shortages of gas will occur in the very near future. However, when mother nature brings on a nationwide cold snap that lasts for any period of time, it has been pretty well documented that the gas industry does not have the deliverability cushion to handle those situations without tapping Wyoming's reserves.

## COAL UPDATE

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

Wyoming coal production for 1986 continues to lag behind 1985's record pace. Coal deliveries for three quarters of 1986 are over five million tons less than they were a year ago, even though deliveries made in the third quarter (July, August and September) of 1986 were only about 0.6 million tons less than deliveries made in the third quarter of 1985. This is slightly encouraging because second quarter deliveries in 1986 were 4.3 million tons less than deliveries in second quarter 1985. Also, deliveries in September, 1986, mark only the second time all year that a single month's coal deliveries have exceeded coal deliveries for the same month in 1985 (see table on page 25 and figure on page 26).

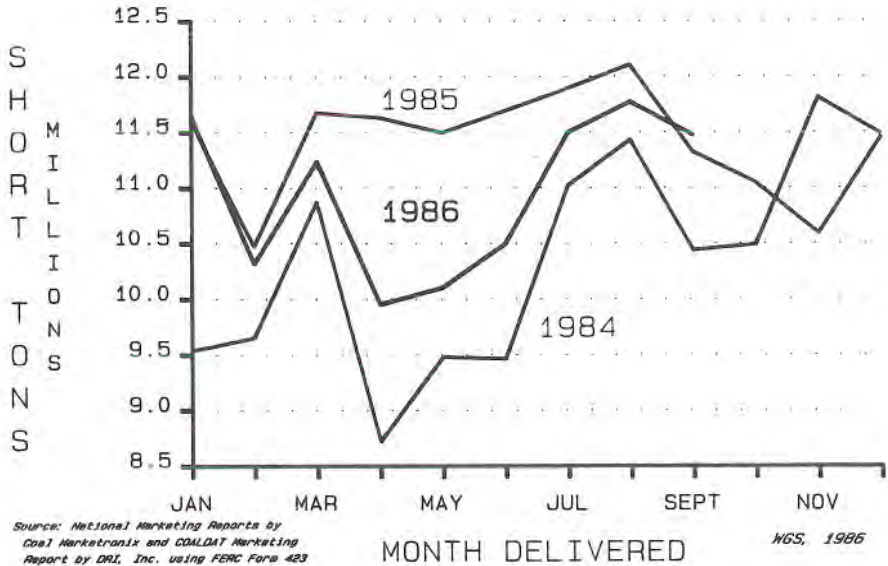
Additional data on Wyoming's 1985 coal production have recently become available (see table on page 27). Production from Federal coal leases increased dramatically from 1984 to 1985, with an increase of over 31 million tons or about 45 percent. The increase in Federal coal production in 1985 was offset by a 2.6-million ton or 14 percent decrease in production from State coal leases and an 18.5-million ton or 44 percent decrease in production of private coal. About 71 percent of the State's total coal production came from Federal coal leases, about 17 percent from private leases and about 12 percent from State coal leases. Coal on State leases was valued at about \$152 million, had an average value of \$9.18/ton (excluding retroactive adjustments) and accounted for over \$14 million in royalties to the State of Wyoming. Coal from Federal leases in Wyoming was valued at over \$1.2 billion and had an average value of \$12.36/ton. Nearly \$28 million in royalties were collected from Federal coal leases in Wyoming in 1985; the State of Wyoming receives 50 percent of these royalties. Wyoming accounted for about

COAL DELIVERIES BY MONTH FROM WYOMING MINES

	1982 MONTHLY	1982 CUMULATIVE	1983 MONTHLY	1983 CUMULATIVE	1984 MONTHLY	1984 CUMULATIVE	1985 MONTHLY	1985 CUMULATIVE	1986 MONTHLY	1986 CUMULATIVE
JANUARY	7,676,600	7,676,600	10,313,000	10,313,000	9,540,200	9,540,200	11,601,200	11,601,200	11,646,300	11,646,300
FEBRUARY	7,301,100	14,977,700	8,719,700	19,032,700	9,654,600	19,194,800	10,473,900	22,075,100	10,317,700	21,964,000
MARCH	8,407,200	23,384,900	9,051,200	28,083,900	10,875,000	30,069,800	11,674,900	33,750,000	11,238,520	33,202,520
APRIL	8,292,000	31,676,900	8,195,000	36,278,900	8,721,400	38,791,200	11,632,800	45,382,800	9,954,170	43,156,690
MAY	8,671,600	40,348,500	8,364,600	44,643,500	9,481,500	48,272,700	11,497,900	56,880,700	10,105,520	53,262,010
JUNE	8,724,700	49,073,200	8,330,200	52,973,700	9,484,500	57,737,200	11,692,200	68,572,900	10,499,280	63,761,290
JULY	8,738,300	57,811,500	8,734,700	61,708,400	11,019,600	68,756,800	11,893,500	80,466,400	11,497,190	75,258,480
AUGUST	9,195,800	67,007,300	9,669,300	71,377,700	11,433,000	80,189,800	12,107,100	92,573,500	11,773,510	87,031,990
SEPTEMBER	8,304,200	75,311,500	9,189,700	80,567,400	10,440,000	90,629,800	11,325,000	103,898,500	11,474,820	98,506,810
OCTOBER	9,390,100	84,701,600	9,406,300	89,973,700	10,492,500	101,122,300	11,048,500	114,947,000		
NOVEMBER	8,757,300	93,458,900	9,013,600	98,987,300	11,814,200	112,936,500	10,589,700	125,536,700		
DECEMBER	9,346,600	102,805,500	7,680,600	106,667,900	11,486,800	124,423,300	11,459,300	136,996,000		
TOTAL TONNAGE REPORTED	102,805,500		106,667,900		124,423,300		136,996,000		98,506,810	
TOTAL TONNAGE NOT REPORTED	5,148,300		5,519,300		6,322,479		3,428,446			
TOTAL TONNAGE PRODUCED	107,953,800		112,187,200		130,745,779		140,424,446			

Source: National Marketing Reports by Coal Markettronic, compiled from FERC Form 423 filed monthly by electric utilities.  
Wyoming State Mine Inspector's Annual Reports.

# REPORTED DELIVERIES FROM WYOMING COAL MINES



60 percent of the 166.4 million tons of coal produced from Federal coal leases in 1985 (U.S. Department of the Interior, Minerals Management Service, 1986).

National coal production figures for 1985 also became available recently (Energy Information Administration, 1986a and 1986b). The total United States coal production in 1985 was 883.6 million tons, a decrease of 1.4 percent over 1984's record-setting 895.9 million tons. The United States dropped to second place among the world's coal-producing countries in 1985. China became the world's leading coal producer in 1985 with 937 million short tons of coal and the U.S.S.R. ranked third in production with 798 million short tons of coal. The top three coal-producing countries accounted for about 55 percent of the world's 4.8 billion short tons of coal produced in 1985.

COAL PRODUCTION STATISTICS FOR WYOMING BY COAL OWNERSHIP

	1981	1982	1983	1984	1985
FEDERAL <sup>1</sup>	59,576,163 (58%)	63,612,335 (59%)	63,536,141 (57%)	69,610,380 (53%)	100,621,788 (71%)
STATE <sup>2</sup>	26,485,275 (26%)	19,872,591 (18%)	18,189,147 (16%)	19,166,425 (15%)	16,541,094 (12%)
PRIVATE <sup>3</sup>	16,721,996 (16%)	24,469,657 (23%)	30,462,615 (27%)	42,035,878 (32%)	23,531,104 (17%)
TOTAL <sup>4</sup>	102,783,434	107,954,583	112,187,903	130,812,683	140,693,986

PRODUCTION ON STATE LEASES BY COUNTY<sup>2</sup>

	1980	1981	1982	1983	1984	1985
CAMPBELL	21,417,481	26,274,778	19,015,683	17,297,232	17,968,567	15,816,484
CARBON	160,584	186,430	384,578	353,974	121,175	79,518
CONVERSE	-	17,953	472,330	537,941	889,710	408,906
LINCOLN	14,107	6,114	-	-	-	-
SWEETWATER	-	-	-	-	186,973	236,186
TOTAL	21,592,172	26,485,275	19,872,591	18,189,147	19,166,425	16,541,094

Reference sources: <sup>1</sup> Minerals Management Service Annual Reports: Royalties, 1981; Mineral Revenues, 1982-1985. <sup>2</sup> Wyoming Department of Public Lands Annual Report, 1980-1984; 1985 (Preliminary). <sup>3</sup> Derived from subtraction of Federal and State production. <sup>4</sup> Annual Reports, Wyoming State Mine Inspector and Wyoming Ad Valorem Tax Division.

Wyoming not only accounted for 16 percent of the Nation's total coal production in 1985 (an increase from its 14.7 percent share of national production in 1984) but it also accounted for about 52 percent of the 268.6 million short tons of coal produced in the Western U.S. Campbell County continued as the Nation's leading coal-producing county: more coal was produced from this county than was produced from each of 25 of the 27 coal-producing states. The State also produced about 26 percent of the Nation's 529.7 million short tons of surface-mined coal, about 52 percent of the Nation's subbituminous coal and lignite, and about 71 percent of the Nation's 192.6 million short tons of subbituminous coal.

Thunder Basin Coal Company's Black Thunder Mine was the leading coal-producing mine in the U.S. for the fourth consecutive year. This mine's production

exceeded the coal production from each of 17 coal-producing states. According to information compiled for the *Keystone Coal Industry Manual* and published in *Coal Age* magazine (McGraw-Hill, Inc., 1986), six of the top ten coal-producing mines in the Nation in 1985 were Wyoming mines: Kerr-McGee's Jacobs Ranch Mine was ranked second; Amax Coal Company's Belle Ayr and Eagle Butte Mines were ranked third and eighth, respectively; Carter Mining Company's Rawhide Mine was sixth and Cordero Mining Company's Cordero Mine was ranked tenth. Two Montana coal mines also were ranked in the top ten: Western Energy's Rosebud Mine was fifth and Decker Coal Company's Decker East and West Mine was ninth. Two Texas lignite mines ranked fourth and seventh, respectively. Ten of the top twenty and fourteen of the top thirty coal mines in the U.S. are Wyoming mines.

The EIA report also presents comparative information on coal mine productivity, recovery rates, utilization rates and productive capacities. The following discussion summarizes some of the national trends in coal mining and production in 1985 and relates statistics on Wyoming's coal industry to these trends.

Coal mine productivity, expressed by short tons per miner per hour, has increased nationally each year since 1978 and in Wyoming each year since 1979. Productivity for Wyoming's only underground mine in 1985 was down about 21 percent since 1984 but was still slightly higher than the national average and about 23 percent less than the average for the Western Region (includes Alaska, Arizona, California, Colorado, Montana, New Mexico, North Dakota, Utah, Washington and Wyoming). In past years, underground mine productivity in Wyoming has been nearly the same as the Western Region average. Surface mine productivity for both Wyoming and the Nation continued to increase in 1985. Wyoming surface mines have the highest productivity in the Nation, about 3.6 times greater than the national

average and about 1.4 times greater than the Western Region average. Overall productivity in Wyoming coal mines was about 14.3 short tons per miner per hour in 1985, compared with the national average of 2.74 short tons per miner per hour (an all-time high) and a Western Region average of 8.55 short tons per miner per hour. Wyoming's overall productivity has increased about 23 percent since 1983 (reflecting increased efficiency at all surface mines and the increasing dominance of the large, highly productive eastern Powder River Basin mines). The State's overall productivity rate is still slightly less than Montana's, however, due primarily to the influence of less productive surface and underground mines in southern Wyoming.

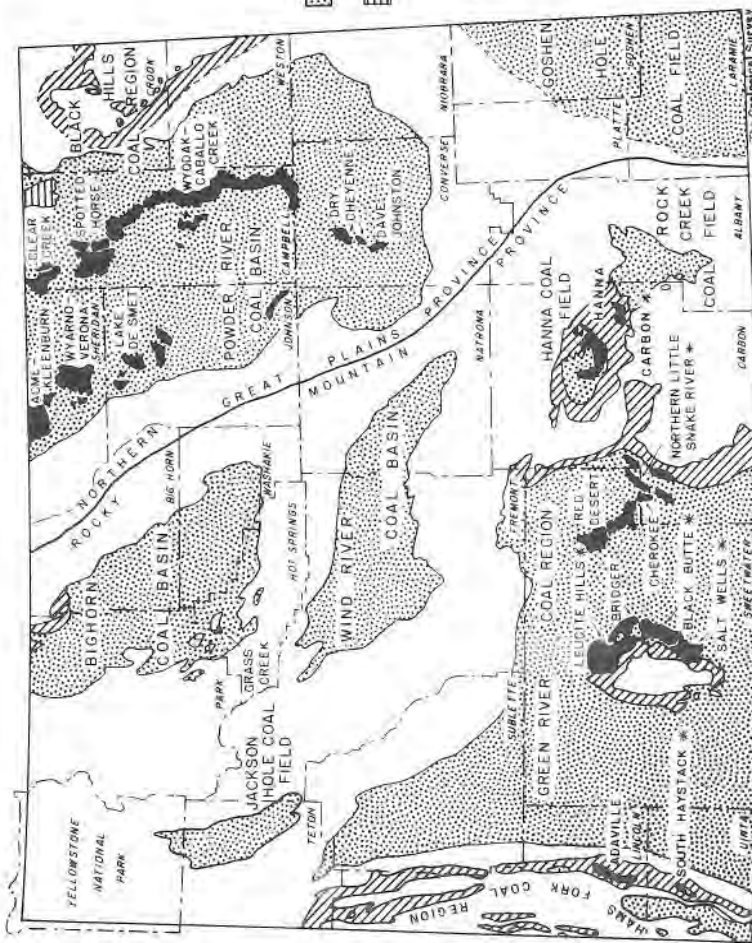
The recovery rate of a coal mine is the percentage of a mine's reserves that can be recovered; this is a measure of the effectiveness of the mining operation. Wyoming mines active in 1985 contained about 6.7 billion tons of recoverable coal reserves; this represents about one-half of the 13.3 billion tons in the Western Region and about one-fourth of the Nation's 25.1 billion tons. Bear in mind that the recoverable coal reserves reported here only represent the coal available in mines that were active in 1985 and are only a small portion of the amount of coal that is available for mining in undeveloped, unleased or inactive areas. Wyoming's overall recovery rate in 1985 was 90.04 percent, down slightly from 1984 and up slightly from 1983. Although this rate is slightly lower than Montana's 91.75 percent (the highest in the Nation) and slightly higher than North Dakota's 89.77 percent, it is significantly higher than the overall recovery rate for both the Western Region (77.63 percent) and the national average (72.61 percent). The overall recovery rate nationally has decreased slightly each of the last five years; both underground and surface mines have experienced these decreases. The overall recovery rates (for both surface and underground



mining methods) in the Western Region have shown slight increases each of the last five years.

The utilization rate of a coal mining operation is the ratio (expressed as a percentage) of the average daily production (total production divided by the number of days worked during the year) to the daily productive capacity (the maximum amount of coal that can be produced on a daily basis). The average daily production in the United States in 1985 was about 3.7 million short tons and the daily productive capacity at the end of 1985 was 4.1 million tons; the utilization rate for the United States was 89.98 percent. This is a decrease from the 91.83 percent utilization rate reported in 1984's record production year and probably reflects the weakened coal market in 1985. In contrast, Wyoming's daily productive capacity in 1985 was 466,000 short tons and the State's daily productive capacity was 495,000 short tons. This yields a utilization rate of 94.16 percent, a four percent increase over 1984's rate of 90.51 percent and an eleven percent increase over 1983's rate of 85.04 percent. If the State's mines had operated at their full productive capacity throughout 1985 (assuming they were able to sell all the coal they produced), they would have been able to produce nearly 150 million tons. Only Montana and Missouri had higher utilization rates than Wyoming in 1985. Compare this to 1984 when thirteen states had utilization rates higher than Wyoming and in 1983 when sixteen states had higher utilization rates. This demonstrates the gaining strength of market demand for the low sulfur, low priced coal from the Powder River Basin in the last few years.

According to the EIA report, the average mine price of all Wyoming coal was \$11.36/ton in 1985, a decrease of \$0.53/ton from 1984's \$11.89/ton and a decrease of \$1.27/ton from 1983. Coal from the Western Region in 1985 had an average price of \$14.53/ton, and the average



**EXPLANATION**

-  Subbituminous
-  Bituminous
-  Lignite
-  Strippable Deposits

\* Preliminary: based on company data

**COAL-BEARING REGIONS OF WYOMING**

The Geological Survey of Wyoming  
1984

price of all coal in the United States was \$25.20/ton. Although the national average price of subbituminous coal increased from \$12.41/ton in 1984 to \$12.57/ton in 1985, Wyoming subbituminous coal decreased in price from \$11.18/ton in 1984 to \$11.00/ton in 1985. Wyoming coal became the second cheapest coal in the United States in 1985. Only North Dakota lignite (at \$9.30/ton), was, on the average, cheaper than Wyoming coal. In previous years, lignite from Texas was somewhat cheaper than Wyoming coal; 1985 is the first year that the average price of Wyoming coal has been less than Texas lignite. Coal from Campbell County in 1985 had an average mine price of \$8.67/ton, compared with \$9.15/ton in 1984 and \$9.64/ton in 1983. On the open market in 1985, Wyoming coal had an average mine price of \$10.81/ton; coal sold as "captive", meaning coal used by the producing company or sold to affiliated or parent companies, had an average mine price of \$17.02/ton.

On a different note, three new coal transportation contracts were signed recently by the Chicago and North Western Transportation Company (C&NW)/Union Pacific Railroad Company (UP) joint venture. In late October, the joint venture signed two contracts with Iowa Public Service Company (IPS): one contract is for haulage of 2.3 million tons of coal from Carter Mining Company's Caballo Mine to the utility's George Neal Unit No. 4 Generating Station near Sergeant Bluff, Iowa; the other contract is for haulage from both the southern Powder River Basin and the Hanna Basin to the utility's George Neal Units No. 1, 2 and 3, also near Sergeant Bluff, Iowa. IPS currently supplies the Neal Units 1, 2 and 3 with coal from Arch Mineral Corporation's Seminoe No. 2 mine near Hanna, but IPS may be using Powder River Basin coal in the near future. Although the contract for coal transportation to the Neal Unit No. 4 is effective January 1, 1987, deliveries will not start until May, 1987, when repairs from last summer's tornado damage to the unit are completed. The Caballo Mine that will supply this contract is located on the

rail line that the joint venture railroad and Burlington Northern (BN) now share. The joint venture had planned their own ten-mile extension line north of Coal Creek junction to serve Caballo and two other mines, but the project was canceled after C&NW/UP and BN agreed to share the existing line.

The third transportation contract signed by the C&NW/UP joint venture is for hauling 0.4 million tons of coal annually from Rochelle Mining Company's Rochelle Mine in southern Campbell County to Consolidated Papers, Incorporated in Wisconsin Rapids, Wisconsin. The coal will be used by Consolidated's three Wisconsin paper plants. C&NW has now signed at least fifteen contracts to haul coal from Wyoming coal mines, including several short-term contracts lasting from six months to one year.

In other coal transportation news, Gulf States Utilities recently announced that new rail rates had been obtained from Burlington Northern and Kansas City Southern railroads on coal haulage contracts from Kerr-McGee's Jacobs Ranch Mine in the eastern Powder River Basin to the utility company's Nelson generating plant near Lake Charles, Louisiana. The rate decrease on the new contract is expected to save the utility about \$3 million a year and will help keep the coal-fired plant competitive with natural gas. The utility purchases about 2.25 million tons of coal per year from Kerr-McGee's mine.

In news related to coal transportation, six railroad companies that haul western coal (including BN, UP and C&NW as well as the Kansas City Southern Railway Company, Missouri Pacific Railroad Company and Atchison, Topeka and Santa Fe Railway Company) have been sued for damages by a Texas utility company and by Energy Transportation Systems, Inc. (ETSI) in two separate legal actions (PenWell Publishing Company, 1986). Houston Lighting and Power Company (HL&P) is seeking damages on the grounds that the six railroads conspired to block

MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING

PETROLEUM

Remaining Resources (January 1, 1986)

Discovered (Includes 10 billion barrels recoverable by enhanced recovery techniques) <sup>1</sup>	13.4 billion barrels <sup>1</sup>
Undiscovered	7.6 billion barrels <sup>1</sup>
Total	21.0 billion barrels
Remaining Reserve Base (January 1, 1986)	
Measured reserves (Proved reserves) <sup>2</sup>	0.82 billion barrels <sup>2</sup>
Indicated and Inferred reserves <sup>3</sup>	2.8 billion barrels <sup>3</sup>
Total	3.62 billion barrels

NATURAL GAS

Remaining Resources (January 1, 1986)

Discovered	19.2 trillion cubic feet <sup>1</sup>
Undiscovered (there is at least another 115 trillion cubic feet of noncombustible CO <sub>2</sub> gas) <sup>9</sup>	58.0 trillion cubic feet <sup>1</sup>
Total	77.2 trillion cubic feet <sup>1</sup>

Remaining Reserve Base (January 1, 1986)

Measured reserves (Proved reserves)	9.88 trillion cubic feet <sup>2</sup>
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COAL

Remaining Resources (January 1, 1986)

Identified (Discovered)	136.2 billion tons <sup>4</sup>
Undiscovered	800.0 billion tons <sup>5</sup>
Total	936.2 billion tons

Remaining Reserve Base (January 1, 1986)

Demonstrated stripable (Measured and indicated reserve base) <sup>4</sup>	27.3 billion tons <sup>4</sup>
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Demonstrated underground-minable (Measured and indicated reserve base) <sup>4</sup>	38.4 billion tons <sup>4</sup>
Total	65.7 billion tons

TRONA

Original Resources (1983 estimate)	
Trona.....	81.7 billion tons <sup>6</sup>
Mixed trona and halite.....	52.7 billion tons <sup>6</sup>
Total.....	134.4 billion tons
Remaining Resource (January 1, 1983).....	995,000 tons <sup>7</sup>

URANIUM

Remaining Reserve Base (January 1, 1983)		<u>ORE</u>	<u>U<sub>3</sub>O<sub>8</sub></u>
Ore recoverable at \$30 or less/ton.....	29.4 million tons.....		39,700 tons <sup>7</sup>
Ore recoverable at \$30.01-\$50.00/ton.....	225.1 million tons.....		151,500 tons <sup>7</sup>
Ore recoverable at \$50 or less/ton.....	254.5 million tons.....		191,200 tons

OIL SHALE

Original Resources (January 1, 1983)	
Identified (Discovered).....	320 billion barrels of shale oil <sup>8</sup>

- 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, 1985, *U.S. crude oil, natural gas, and natural gas liquids reserves: 1984 Annual Report, October*. (1984 and 1985 production has been subtracted).
- 3 Modified from Barlow and Doelger (1983), footnote 1.
- 4 Wyoming Geological Survey, March, 1985. (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. Department of Energy, 1983, *Statistical data of the uranium industry: Open-file Report GJO-100-(83), 77 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.

construction of a 1,400-mile long coal slurry pipeline from Wyoming's Powder River Basin to the Texas and Louisiana area. In the suit, HL&P charge that if construction of the slurry line had taken place, billions of dollars in fuel costs could have been saved by the utility because transportation rates on the coal would have been lower via a slurry line than on a railroad track. ETSI's suit against the railroads alleges conspiracy and violation of antitrust laws and seeks damages of \$940 million. ETSI contends that their coal slurry pipeline project had to be canceled in 1984 because railroad opposition to the project created costly delays to ETSI in securing rights-of-way, permits and other clearances necessary for the project to proceed.

In the last *Wyoming Geo-notes* (No. 12, September, 1986) it was reported that Arch Mineral Corporation had suspended operations at their Seminoe No. 2 Mine. In November, 1986, coal production at this mine resumed after the company reached an agreement with the independent employee's association. The settlement between Arch and the employee's association allowed the 89 miners to go back to work, but at a 37 percent reduction in wages and a total reduction of 51 percent in wages and benefits. During the period of suspended production, supervisory personnel continued operations at the mine to fulfill coal contract obligations.

Also in the Hanna Basin, it appears that the long legal battle between Northern Indiana Public Service Company (NIPSCO) and Carbon County Coal Company (CCCC) is finally over. In early September, NIPSCO agreed to pay CCCC \$181 million in damages for canceling a coal contract after the U.S. Seventh Circuit Court of Appeals upheld an earlier court decision. CCCC had appealed the earlier court decision, asking for specific performance of their contract with NIPSCO instead of a cash settlement. Because NIPSCO was CCCC's only coal customer and the coal company has been unable to secure any new customers, Wyoming's only major under-

ground coal mine appears to be very near permanent closure.

Coal contract activity in Wyoming during the last quarter of 1986 slowed down. Only two short term contracts, one 10-year contract and a single replacement contract were signed with Wyoming coal producers during this quarter. Mobil Coal Producing, Incorporated won a 100,000-ton spot contract to supply coal to one of Oklahoma Gas and Electric's power plants in Oklahoma during the last quarter of 1986.

Amax Coal Company won a one-year, one-million ton contract to supply Wisconsin Power and Light Company's Columbia No. 2 generating unit. Coal for this contract will be mined at Amax's Belle Ayr Mine south of Gillette and will be transported to Portage, Wisconsin via C&NW and the Soo Line.

Under a ten-year contract signed at year's end, Rochelle Coal Company will begin shipping coal to Louisiana Gasification Technology, Inc., a wholly-owned subsidiary of Dow Chemical U.S.A. in 1987. This is a first for Wyoming since the coal will be used in a commercial coal gasification plant at Plaquemine, Louisiana. The coal, which will come from the Rochelle Mine, will be converted into a medium-Btu synthetic gas. The gas will fuel combined cycle gas turbines for cogenerated steam and electricity. Initially the contract calls for 310,000 tons of coal per year. Tonnage requirements will gradually increase to 715,000 tons per year from 1991 through 1996.

The replacement contract is between Nerco Coal Company and the Platte River Power Authority (PRPA) and is the result of negotiation between the two in an effort to reduce the price of coal delivered to the utility's Rawhide plant near Fort Collins, Colorado (see *Wyoming Geo-notes No. 11*, June, 1986, p. 37). The old contract was canceled when PRPA paid Nerco \$29 million; the new contract calls for delivery of a total of 25 million



tons of coal over a period of 30 years. The contract is expected to go into effect in January, 1987, and will be supplied by Nerco's Antelope Mine in northern Converse County.

Federal coal leasing in Wyoming was back in the news in the last quarter of 1986. At a meeting of the Powder River Regional Coal Team (RCT) in early December, 1986, the RCT discussed the future of renewed Federal leasing in the basin and decided to recommend to the Secretary of the Interior that no additional coal leasing be considered until October, 1987. It was decided that if enough interest had been expressed in additional leasing at that time, the RCT would decide on whether or not to proceed with plans for another coal lease sale. Although leasing in the Powder River Basin appeared to be temporarily on hold in 1986, there was a competitive lease sale for a 1,218-acre tract in the Rock Springs area of southern Wyoming in December, 1986. Like the Powder River Basin, the Green River - Hams Fork coal production region had very little coal leasing activity during 1986.

It was reported in *Wyoming Geo-notes* No. 7 (June, 1985) that a Federal Judge had ruled that all the coal leases in Montana issued as a result of the 1982 Powder River Basin coal lease sale were void and the leases were to be canceled. A recent decision by U.S. District Court Judge Battin has modified this ruling: instead of canceling the leases (pending completion of a supplemental environmental impact statement), they are now just suspended. This ruling will enable Western Energy Company to resume mining on three of the leases they had received in the lease sale. The leases could be reinstated if the supplemental environmental impact statement assessing the effects of coal leasing on the Northern Cheyenne Indians is completed and approved. The Northern Cheyenne have appealed Judge Battin's recent decision.

One aspect of Federal leasing is going in reverse: the amount of leased Federal coal in Wyoming seems to be decreasing while the amount of unleased Federal coal in the State seems to be increasing. This situation has been brought about by Section 3 provisions of the Federal Coal Leasing Amendments Act. This section, commonly known as the "diligent development" requirements of Federal coal leasing, provides that if a Federal coal leaseholder (holding a lease issued since 1976) fails to produce commercial quantities of coal from the lease within ten years of the date of lease issuance, the leaseholder would be denied any future Federal mineral leases. Even with the production deadline extended to December 31, 1986, some leaseholders have been forced to relinquish their Federal coal leases. In Wyoming, this has resulted in relinquishment of eighteen Federal leases containing 975 million tons of Federal coal. Twelve of the leases containing about 675 million tons of coal were Powder River Basin leases and six of the leases containing an estimated 300 million tons of coal were in Carbon County and southwestern Wyoming. Texaco, Incorporated relinquished the largest amount of coal from five leases in the Lake De Smet area of the western Powder River Basin. These five leases contained about 584 million tons of coal and were part of Texaco's planned synfuels project. Additional coal lease relinquishments in Wyoming are expected in the future although leaseholders do have several other options besides relinquishment.

It was reported in the last *Wyoming Geo-notes* (No. 12, October, 1986, p. 29-30) that Carbon Fuels Corporation was searching for funding to build an experimental plant that would convert coal to a patented liquid called charfuel. By the end of the last quarter of 1986, the company had secured funding from two sources: a grant from the State of Wyoming's Economic Development and Stabilization (EDS) Board and a grant

and loan from the State's Energy Conservation Program. In mid-November the EDS Board provided a grant of \$18,000 to Albany County to assist Carbon Fuels Corporation in a study of their proposal. At the end of December, the company received a \$2 million grant and a \$2 million loan from the State of Wyoming. The \$4 million came from the \$12.5 million Exxon Restitution Fund, a payment made to the State of Wyoming as part of a Federal court ruling against Exxon that directed the company to repay customers for overcharges on crude oil sales during a period of Federal price controls on U.S. oil. Carbon Fuels Corporation has negotiated an agreement with Pacific Power and Light Company (PP&L) to build a \$25 million charfuels processing plant near PP&L's Dave Johnston powerplant east of Glenrock and to convert a 100-megawatt boiler at the powerplant from coal to charfuel. The demonstration project would convert 500 tons of coal (7,500 Btu/pound) per day (from Glenrock Coal Company's nearby Dave Johnston coal mine) to liquid charfuel having a reported heating value of 13,100 Btu/pound. Evidently the demonstration plant will also test coals from the Hanna area as well as other Powder River Basin coals. Other funds to finance the \$25 million demonstration project are still being sought by Carbon Fuels Corporation.

Also in mid-November, the EDS Board awarded a \$25,000 grant to Coal Brik Factory 1, Ltd. through a Community Development Block Grant sponsored by the city of Rawlins. The company, which is a wholly-owned subsidiary of Centennial Coal Company of Fort Collins, Colorado, will use the grant to conduct feasibility studies for a plant to manufacture coal bricks for home heating. The plant would utilize a relatively high-Btu, low-sulfur coal, recycled paper and petroleum distillate all compressed together to form a solid brick that could be burned in the home in place of wood. The company is looking at a plant site near Rawlins because of the availability of coal in the nearby Hanna Basin and the availability of petroleum

products at the Sinclair Refinery east of Rawlins. Another \$1,000 has been given to the company by the Carbon County Economic Development Corporation for a marketing analysis which will be done by the University of Wyoming's Institute of Business and Management Services.

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## URANIUM AND INDUSTRIAL MINERALS UPDATE

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

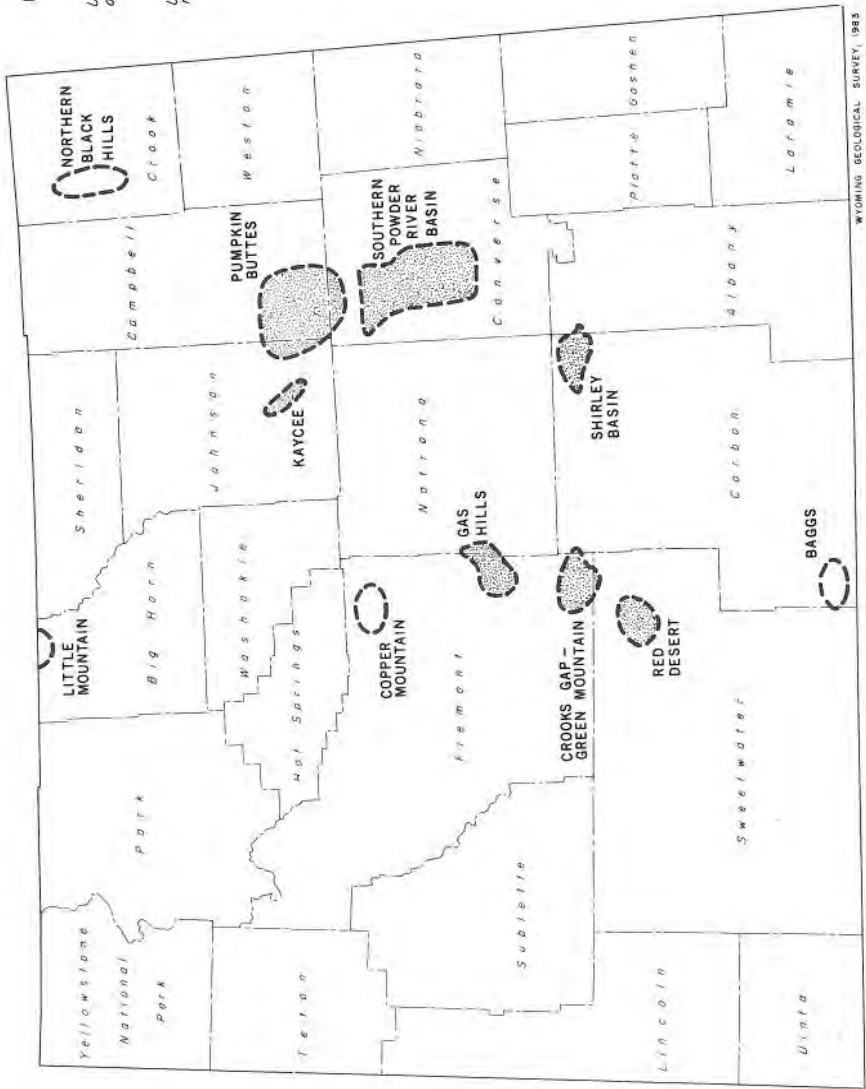
### Uranium

The uranium mining industry in Wyoming is showing signs of a slight recovery. In addition to the two proposed *in situ* uranium recovery operations reported in the last issue of *Wyoming Geo-notes* (No. 12, October, 1986, p. 34), Everest Minerals of Houston, Texas, announced plans for an *in situ* recovery operation at the site of the former Exxon Highland Mine in Converse County. The project, proposed to begin in late 1987, will employ about 40 people. The project has a 15-year design life and will have an annual operating cost estimated at \$10 million. The operation is projected to produce 500,000 pounds of uranium oxide (yellowcake) per year at the beginning, but may expand to 1,000,000 pounds per year, depending upon contracts. Everest has a delivery contract for yellowcake beginning in 1988. Company spokesman John Wold was quoted as saying long-term contract prices for uranium oxide range between \$19.00 and \$22.00 per pound. This compares with the current spot market rate for uranium oxide published by NUEXCO of \$17.00 per pound. (By contrast, the early 1979 spot market rate was \$42.00 per pound). Although Everest received a development permit from Converse County in early December, their permit from the Wyoming Department of Environmental Quality was reportedly rejected.

There have been no new developments regarding the other two proposed solution mining projects, Malapai Resources near Pumpkin Buttes and AGIP in the Poison Basin (Baggs) area.

**E X P L A N A T I O N**

-  Uranium district with active or recent mining
-  Uranium district without recent mining



WYOMING GEOLOGICAL SURVEY, 1985

MAJOR ACTIVE AND INACTIVE URANIUM DISTRICTS

Pathfinder Mines, 80 percent of which is owned by the French Company COGEMA, has expanded its reserves by purchasing uranium claims in the Shirley Basin District from Texaco, Inc. The claims formerly belonged to Getty-Petrotomics, which operated a mine and mill in the Shirley Basin prior to its purchase by Texaco. Pathfinder-COGEMA currently operates a mill and mine complex in the Shirley Basin, the only active uranium mill in the State at the present time.

Pathfinder is also interested in purchasing additional uranium claims in the Gas Hills district. These claims are currently held by the Tennessee Valley Authority, but Pathfinder reportedly is hesitant to make the purchase because of a two-year yet unresolved battle over State reclamation requirements. At issue is whether mining companies can delay reclamation because of economic conditions, and whether a company purchasing new mining property can be required to immediately reclaim preexisting mine pits, particularly when ore still remains in the pits.

On the national level, a bill that would restrict imports of foreign uranium, and provide Federal funds for mill tailings cleanup was introduced in the Senate in September. Utility companies oppose the bill, which would require them to purchase 50 percent of their nuclear fuel from domestic uranium sources. The bill was stalled in joint committee in mid-December, and it appears unlikely to be passed by Congress in the original form.

On a related subject, a U.S. District Court Judge ordered the U.S. Department of Energy (DOE) to schedule 25 percent or less of their total enrichment contracts of imported uranium. This will insure that 75 percent of the uranium enriched in the U.S. comes from domestic sources. This ruling is a factor in the renewed interest in domestic uranium and the letting of contracts for domestic uranium supplies to utilities.

## Trona

Two tracts of land (totaling 3,599 acres) containing trona resources were leased by the U.S. Bureau of Land Management in late September. One tract was leased to Tenneco Minerals (\$245/acre bonus bid) and another to Church and Dwight, Inc. (\$316.33/acre), which operates a soda ash (refined trona) packing facility. A third tract offered by the U.S. Bureau of Land Management received no bids. Wyoming will collect a \$500,000 bonus from the sale. Royalty rates on these tracts are five percent of the sale value while yearly rental rates start at 25 cents/acre for the first year, increase to 50 cents/acre the second to fifth years and \$1.00/acre for subsequent years. The terms of the leases are 20 years with preferential right extensions for ten-year intervals. At the last trona lease sale, which was held in 1967, the bonus bid was \$55/acre.

General Chemical, one of the five trona-producing companies in Sweetwater County (formerly Allied Chemical) sold 49 percent of its assets to ACI International, an Australian-based glass manufacturer. This acquisition may mean an increase in exports to Australia for General Chemical.

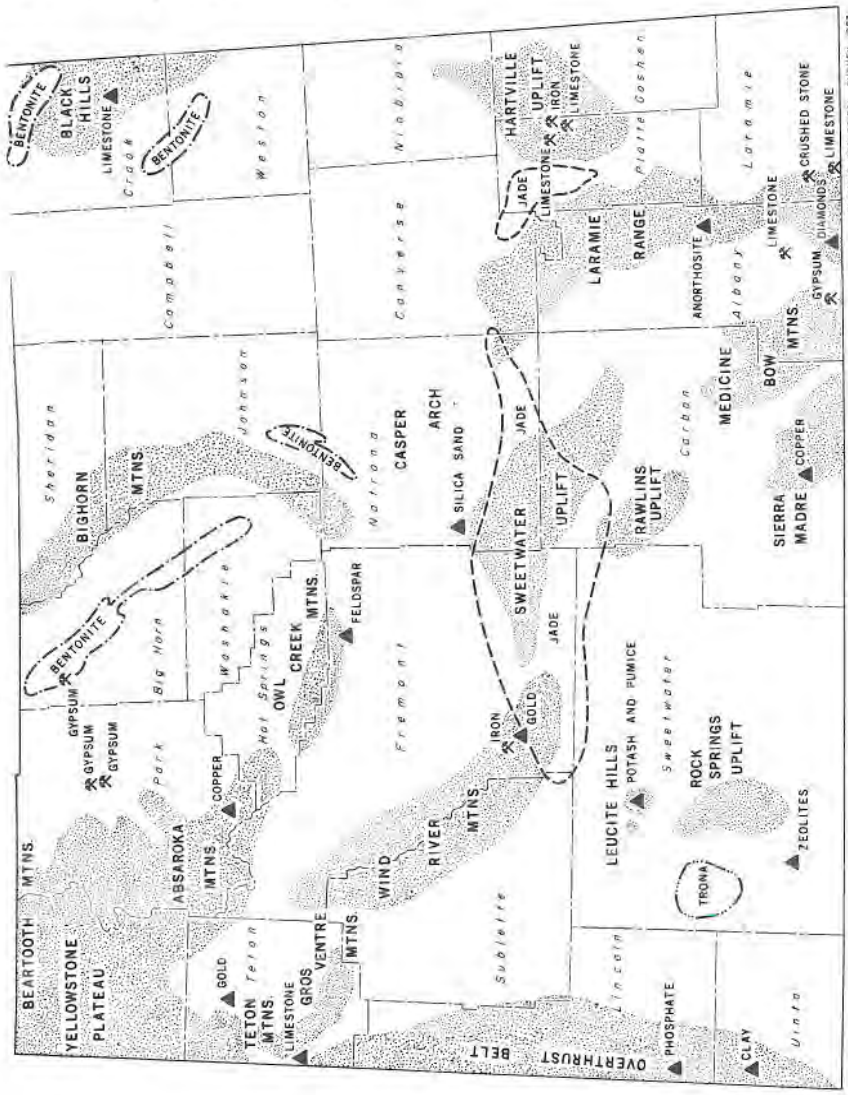
Wyoming Senators Simpson and Wallop are still unsatisfied with Japanese import restrictions on soda ash. Japanese officials responded to U.S. pressure to ease trade barriers, but, according to Simpson and Wallop, did not change any restrictions. Wyoming's Senators said they would bring a solution urging lowered trade barriers before the new Congress in January.

Soda ash production in the U.S. ran two to five percent above 1985 levels according to figures released by the U.S. Bureau of Mines before September. September and October soda ash production, however, dropped 12



**EXPLANATION**

- Mines and quarries
- BENTONITE
- Bentonite mining district
- TRONA
- Trona mining district
- Localities
- JADE
- Jade collecting areas
- Uplift areas



WYOMING GEOLOGICAL SURVEY, 1962

SELECTED MINERAL AND ROCK OCCURRENCES

percent below production during the same months in 1985. This may be due to closings and loss of production in the auto industry. Manufacture of automotive glass is a significant factor in soda ash demand.

### **Bentonite**

The bentonite industry in Wyoming has been hit hard by the decline in oil prices and the resulting decline in oil well drilling. Bentonite is used primarily for drilling mud. The bentonite plant at Lovell, owned by NL Baroid, closed September 24. NL Baroid is one of the chief suppliers of mud to the oil well drilling industry. This is the first bentonite plant in recent times to close in Wyoming. NL Baroid's mill and pits near Colony, in Crook County, continue to operate.

### **Cement**

Mountain Cement Company continues to remodel and upgrade the Laramie cement plant that closed in December, 1985. The plant is being converted from a wet process to a dry process facility. This conversion will lower production costs. The plant is currently producing cement from clinker imported to the plant. Mountain Cement is a subsidiary of Centex Corporation, which produces cement in Texas and owns several construction companies, including Ameriwest Homes of Albuquerque, New Mexico.

### **Sulfur**

Continental Sulfur Company, leaseholders of the natural sulfur deposit west of Thermopolis, announced a proposed test drilling program on the property scheduled for December or January. This will be the first

actual exploration work done on a natural sulfur deposit in Wyoming in recent years. Meanwhile, for the first half of 1986, domestic sulfur consumption decreased eleven percent over the 1985 rate while exports fell by 33 percent.

### Other Industrial Minerals

The Burlington Northern Railroad has begun replacing the wood ties on its lines with concrete ties. Concrete ties manufactured in Canada are being installed on Burlington Northern lines in the Glendo area. Two plants have been proposed to manufacture these ties in the U.S., one in Washington, Idaho or Montana and one in Colorado or Wyoming. To date no site has been selected for either of these plants, which could produce more than one million ties over a four-year period.

In mid-November, Tenneco received a \$40,000 grant from the Wyoming Economic Development and Stabilization Board (EDS Board) for a feasibility study for the development and marketing of a zeolite (clinoptilolite) deposit in the Washakie Basin in Sweetwater County about 20 miles south of Interstate 80 and 50 miles southeast of Rock Springs. The deposit is located on land owned by Upland Company, a subsidiary of Union Pacific Railroad. Tenneco presently mines clinoptilolite in California where most of its production is used for the treatment of water. If Tenneco proceeds with the project after completing its study, it would take an estimated five to six years to bring it on line.

Zeolites are minerals with a high ion-exchange capacity. They can be used as catalysts in petroleum refining, filters, odor absorbents (like kitty litter), water softeners, pollution control agents and for other

uses. Sweetwater County and other areas of the State contain significant zeolite deposits (see Harris, Hausel and Meyer, 1985, for a map depicting known zeolite occurrences in Wyoming).

### Reference

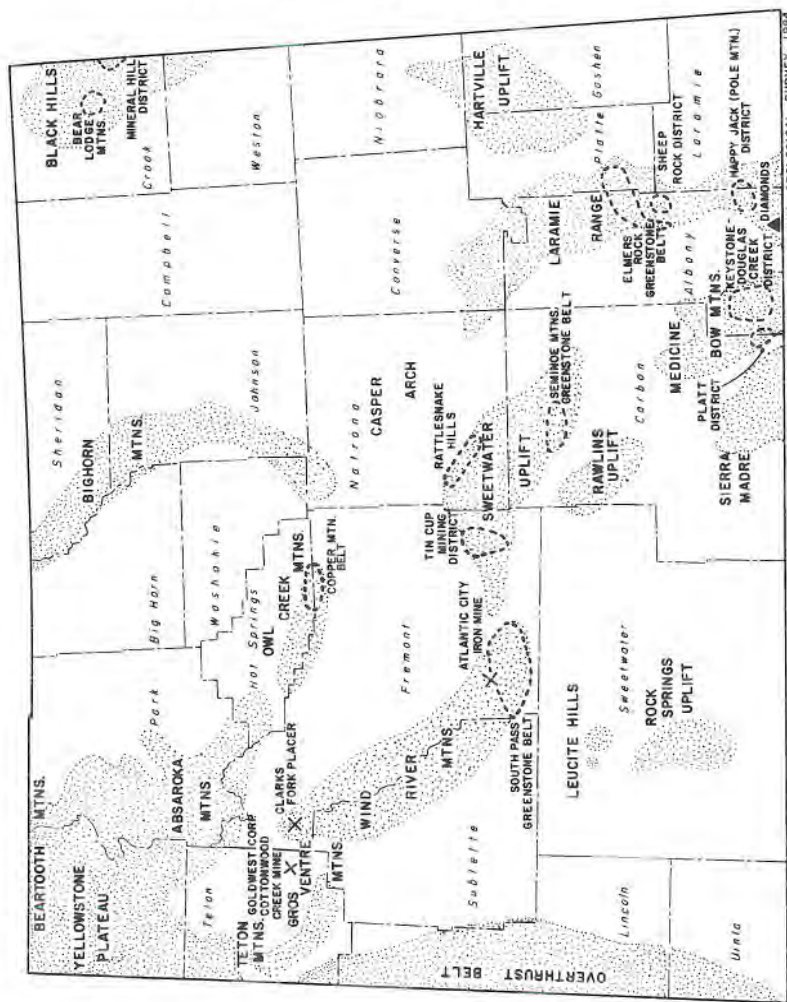
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### METALS AND PRECIOUS STONES

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

The historic Carissa Mine in the South Pass greenstone belt at the southern tip of the Wind River Range was recently purchased in part by Consolidated McKinney Resources of Vancouver, British Columbia. Consolidated McKinney Resources announced that they had begun core drilling on the property and that further tests would be conducted depending on the initial results.

The Carissa Mine was the second largest producer of gold in the greenstone belt. Production estimates indicate that the mine could have produced as much as 53,680 ounces of gold (Hausel, 1980). The mine was developed on a one- to 15-foot wide shear zone in 2.8 billion year old metagreywacke of the Miners Delight Formation. The shear was tested and mined to a depth of 400 feet and along an 800-foot strike length. Five levels were developed in the mine. Armstrong (1948) reported the shear could be traced on the surface for at least 1,000 feet. The ore tenor reportedly averaged 0.32 ounce per ton gold (Hausel, 1980).



WYOMING GEOLOGICAL SURVEY, 1984

REGIONS OF EXPLORATION ACTIVITY FOR STRATEGIC MINERALS

The historic mine operations concentrated on recovering high grade ore in the narrow well-defined shear zone. The adjacent wall rock, however, is highly fractured over a width of 150 to 200 feet and contains numerous quartz stringers and lenses. To test the potential of the wall rock to host commercial mineralization, the Geological Survey of Wyoming collected a 30-foot long composite chip sample in the wall rock north of the shear. Splits of this sample assayed 600 parts per billion (ppb) (0.018 oz/ton) gold and 2.4 parts per million (ppm) (0.07 oz/ton) gold. Further tests need to be conducted, but based on preliminary results, the Carissa could host large tonnages of low-grade ore.

The Geological Survey of Wyoming recently collected another interesting sample in the South Pass district. The sample was from a banded iron formation in the Goldman Meadows Formation (two miles north of the Carissa Mine and two and one half miles southwest of the Atlantic City iron mine in the NW1/4 sec. 9, T.29N., R.100W). More specifically, the sample of magnetite-quartz iron formation came from a shallow shaft on Wyoming Highway Department property. One split of the sample assayed 27.95 percent iron and 1.1 ppm (0.03 oz/ton) gold. A sample of a quartz vein in the iron formation assayed 400 ppb (0.01 oz/ton) gold.

Preliminary geologic maps of the Radium Springs (Hausel, 1986a) and the Anderson Ridge (Hausel, 1986b) 7 1/2-minute Quadrangles in the South Pass greenstone belt were recently published by the Geological Survey of Wyoming. The Radium Springs Quadrangle covers the Lewiston gold district located along the eastern flank of the South Pass greenstone belt. Most of the gold deposits in the Lewiston district are similar to that at the Carissa Mine. Gold occurs in narrow shears in metagreywacke of the Miners Delight Formation. Samples collected in this district by the Survey have assayed

from a trace to over one ounce per ton gold. The Anderson Ridge Quadrangle lies along the western flank of the greenstone belt just west of South Pass City.

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### STRATIGRAPHY UPDATE

by Alan J. VerPloeg, Stratigrapher, Geological Survey of Wyoming.

The Stratigraphy Section of the Geological Survey of Wyoming recently initiated a project to compile a series of maps depicting known surficial structural features in the State of Wyoming. A total of sixteen 1° x 2° quadrangle maps at a scale of 1:250,000 will be compiled. The maps will depict various types of faults

and anticlinal structures with surficial expression as demonstrated by existing mapping in the State. Faults will be identified as normal, thrust/reverse or detachment blocks where existing information allows. Anticlines, domes and monoclines will be plotted where information exists. Faults which are possibly active (Case, 1986) will also be noted. These maps should be completed by March of 1987 and will be initially released as open file reports. Eventually the information will be reduced to a 1:500,000 scale and released as one map for the entire State. The project is partially funded by the Wyoming Department of Health and Social Services. The information on these maps is intended as an aid for designing a radon sampling program for the State of Wyoming.

Work has begun on the yearly update of the listing of ongoing studies on the geology of Wyoming. The report, titled *Ongoing studies on the geology of Wyoming* (Open File Report 86-21) was profiled in the October, 1986, issue of *Wyoming Geo-notes* (No. 12). Questionnaires have been mailed to last year's respondents as well as to new geologic workers identified as working in Wyoming. These questionnaires will allow geologists to identify completed projects, new projects and articles related to these projects. Any readers who are involved in geologic projects in Wyoming and have not received a questionnaire are asked to contact the Geological Survey of Wyoming's Stratigraphy Section.

A fascinating book entitled, *Rising from the plains*, by John McPhee was recently released. This book holds special interest for Wyomingites in that it is centered around the personal history of Wyoming geologist, David Love and his family. The Love's personal history is interwoven with the geological history of the region. The book was originally released in the February 24th, March 3rd and March 10th, 1986, issues of *New Yorker Magazine*. *Rising from the Plains* is published by



Farrar-Staus-Giroux and should be available at most local bookstores.

University of Wyoming Professor, Dr. D.L. Blackstone, Jr., has completed a draft manuscript for a new traveler's guide to Wyoming geology for publication by the Geological Survey of Wyoming in early 1987. Dr. Blackstone prepared a similar publication (Geological Survey of Wyoming Bulletin 55) in 1971 which has been a best seller since its release.

In cooperation with the Oil and Gas Section of the Geological Survey of Wyoming, Dr. Blackstone is also preparing a new tectonic map of the Overthrust Belt in western Wyoming. This new map will be published late in 1987 to complement the Wyoming Geological Association's Annual Field Conference which will revisit the Overthrust Belt. The Oil and Gas Section will spot new wells and fields drilled or developed since 1982, which was the last time this map was updated.

The International Union of Geological Sciences' Subcommittee on Precambrian Stratigraphy has published a proposal for the worldwide subdivision of Precambrian time (Plumb and James, 1986). The proposed subdivisions are the culmination of about 15 years of effort. Quoting from the published article, the subcommittee has made three major recommendations:

(1) Establish two major time units of Eon rank, Proterozoic and Archean, separated by a time boundary at 2,500 Ma (million years ago).

(2) Subdivide the Proterozoic Eon into three units of Era rank, provisionally labeled Proterozoic I, II and III, with time boundaries at 2,500, 1,600, 900 and (about) 570 Ma, respectively.

(2) Subdivide the Proterozoic into eight time units of Period rank, as yet unnamed, with time boundaries at

2,500, 2,100, 1,800, 1,600, 1,400, 1,200, 900, 700 and (about) 570 Ma, respectively.

According to the article, "Time unit boundaries have been selected so as to enclose or delimit principal cycles of sedimentation, orogeny and magnetism, but the boundaries are defined in years, without specific reference to any bodies of rock." The journal article calls for comment and criticism on both the procedure followed and on the recommendations themselves.

### References

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### GEOLOGIC HAZARDS UPDATE

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

Radon is a colorless, odorless and tasteless gas that results from the radioactive decay of uranium and thorium, both of which are present in some bedrock and soils in Wyoming. There are three isotopes of radon in nature. Radon 222 results from the decay of Uranium 238 and has a half-life (the amount of time in which half of the isotopes decay into other isotopes) of 3.82 days. Radon 220 results from the decay of Thorium 232 and has a half-life of 54.5 seconds. Radon 219 results from the decay of Uranium 235 and has a half-life of 3.92 seconds.

Since radon is a gas, it can easily be drawn into the lungs. The gas is harmless and inert, and is not suspected of causing health problems in humans unless it undergoes further decay (Radon 222  $\rightarrow$  Polonium 218  $\rightarrow$  Lead 214  $\rightarrow$  Bismuth 214  $\rightarrow$  Polonium 214  $\rightarrow$  Lead 210) while in the lungs. The decay products are not gaseous, but rather heavy metals that can also attach themselves to dust particles. If these dust particles are inhaled they can also become lodged in the lung. Particles released by the decay of Polonium 218, Bismuth 214 and Polonium 214 are reportedly especially damaging to lung tissue.

When an atom of Uranium 238 (or Radon 222 for that matter) decays, radiation is generated by the emission of particles from their nuclei. The particles emitted are either alpha particles (two protons and two neutrons) or beta particles (identical to an electron). Gamma rays which are electromagnetic rays similar to light, are emitted at various stages in the decay process also.

Alpha particles are suspected to be responsible for many of the adverse health effects caused by the decay of radon. Beta particles and gamma rays are also generated by the decay of radon, but their health effects are not as obvious or severe. The alpha particles are strongly ionizing and lose energy rapidly. In other words they usually transfer most of their energy to nearby atoms within a very short distance of their origin. This quick dispersal of energy can damage human cells, especially if it is released within the body.

Radon concentrations are expressed as picocuries per liter (pCi/l) of air. A picocurie as applied to radon represents the decay of about 2.2 atoms of radon per minute in one liter of air. The concentrations of radon decay products in air are roughly proportional to a measure of how much alpha particle energy will be

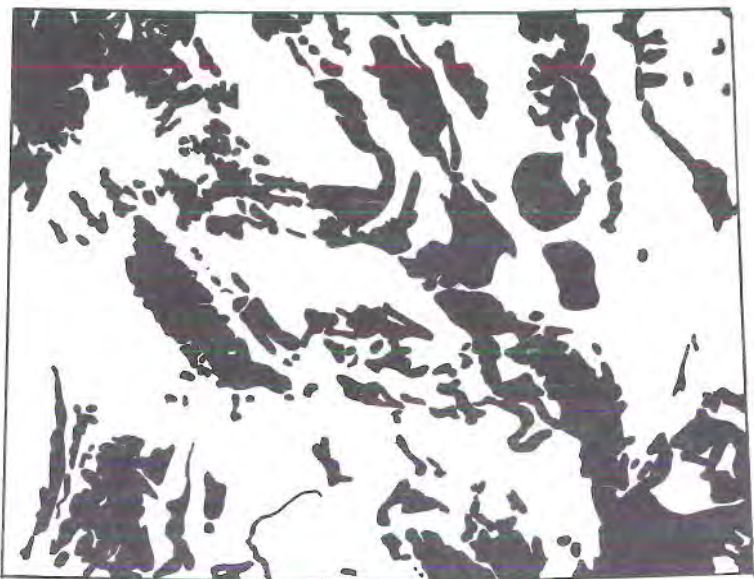
released into the air by the radon decay products. This unit of measurement is a working level (WL). One pCi/l of indoor radon is thought to result in 4.005 WL under average conditions. The U.S. Environmental Protection Agency (EPA) recommends that corrective action for indoor air quality be taken when radon or radon decay product measurements exceed or equal four pCi/l or 0.2 WL, respectively.

Radon is detected in a number of ways, with the most common procedures using alpha track detectors or charcoal canisters. The alpha track detector consists of a piece of film in a plastic container with a filter-covered opening. Alpha particles strike the film, leaving tracks. After the film has been exposed for a predetermined period of time, usually two weeks or more, the film is processed. The number of tracks per unit area is compared to data generated at a calibration facility, and an estimate of the radon concentration in air is derived.

The charcoal canister detector consists of a screened container filled with activated charcoal. When deployed, radon will diffuse into the device, adsorb onto the charcoal and undergo decay. The exposure time is usually less than a week. The gamma radiation generated by the decay of the decay products of radon is then measured in a laboratory and compared to laboratory standards in order to estimate the radon concentration.

The Geological Survey of Wyoming has been working with Julius Haes of the Wyoming Department of Health and Social Services on a radon monitoring program for the State. The study, primarily funded by the EPA, will result in the placement of 3,000 charcoal canisters around the State. Most of the canisters will be placed in homes although a few will be used to monitor hot springs or specific types of bedrock.

The Geologic Hazards and Uranium and Industrial Minerals Sections of the Geological Survey of Wyoming generated a *Planning Guide Map for Radon Studies of Wyoming* (Open File Report 86-18) to assist in the placement of the canisters. A simplified version of the map is shown below (Figure 1). The map primarily represents geological formations with elevated background gamma radiation measurements, as determined by Ray Harris of the Uranium and Industrial Minerals Section. The background gamma radiation indicates where decaying uranium, thorium or potassium-40 may be present. The decay of uranium and thorium will generate radon, while the decay of potassium-40 will not. As a result, anomalous areas shown on the map may actually not present potentially high radon-producing areas.



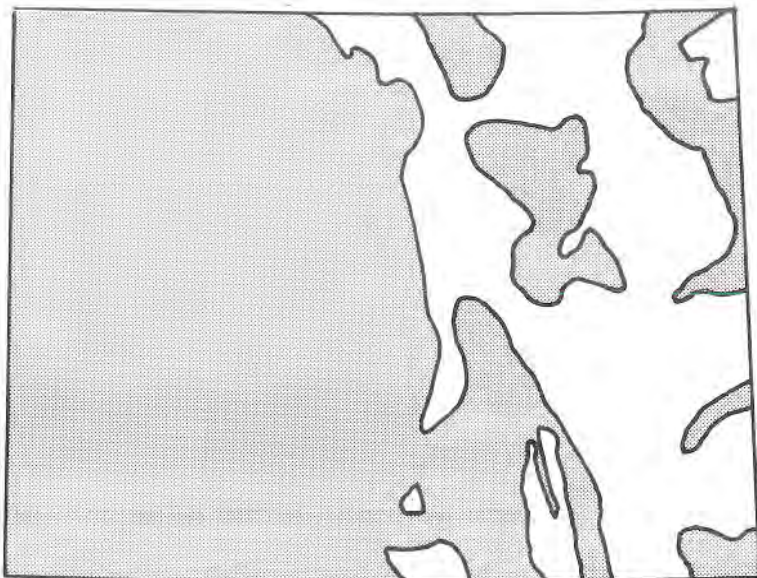
**PLANNING-GUIDE MAP FOR RADON STUDIES IN WYOMING  
MODIFIED FROM GEOLOGICAL SURVEY OF WYOMING  
OPEN FILE REPORT 86-18**

**FIGURE 1**

The background gamma radiation measurements were taken from geological formations and soils derived from the formations. Although measurements to date have not been taken over the entire State, information from the sampled formations was extrapolated to cover the non-sampled areas. As a result, some extrapolated areas shown on the map may not have the elevated background gamma radiation that is indicated. By the same token, there may be areas that have not been measured, but do have potential for generating radon. Uranium mining districts are also shown on the map, whether or not background gamma radiation measurements were made.

Other maps inferring radon potential in Wyoming and the United States have been generated through other agencies or organizations. A *"Where's the radon"* map published in the January 1986 issue of Rodale's *New Shelter* magazine is somewhat misleading. The map was of the whole United States, but a generalized representation of the Wyoming portion is presented below (Figure 2). The map purports to depict four types of radon-bearing minerals or rock types—uranium, granite, phosphate and shale. Granites, phosphates and shales do not necessarily generate significant quantities of radon. In fact, some shales may retard the migration of the gas. The map also does not represent all the shales, granites, phosphates or known uranium-producing areas in the State. This map has had wide distribution in magazines and newspapers.

A map of *"Areas with potentially high radon levels"*, in the United States was recently released by the EPA. A generalized version of the Wyoming portion of the map is presented below (Figure 3). The areas on the map represent information derived from select geological reports on uranium resources and a modification of the National Uranium Resource Evaluation (NURE) data. All granitic areas were to be shown on the map. Although some portions of this map and the one generated by the



**WHERE'S THE RADON**  
**EXCERPTED FROM RODALE'S NEW SHELTER MAGAZINE**  
**JANUARY, 1986**

**FIGURE 2**

Geological Survey of Wyoming are identical, there are some large discrepancies. For example, our measurements indicate that a significant portion of the northwestern corner of the State has potential for generating radon. The EPA map does not flag much of that part of the State. Our map does not use airborne gamma radiation measurements of the State, including those taken as part of the NURE program, while the EPA map relies heavily on that data. All of the background gamma radiation measurements that we are using were taken with a Precision Model II Scintillometer on the ground. These are part of an ongoing study to produce a background gamma radiation map of Wyoming at a scale



**AREAS WITH POTENTIALLY HIGH RADON LEVELS IN WYOMING  
EXCERPTED FROM RADON MAP OF THE UNITED STATES  
E.P.A., AUGUST 19, 1986**

**FIGURE 3**

of 1:500,000. Initially, background gamma radiation maps of the State are being compiled at a scale of 1:125,000 (1° x 2° quadrangles).

It is obvious that with the limited data available to various groups and organizations, different maps of background gamma radiation or potentially high radon levels will be generated. This has caused and will for sometime continue to cause a degree of confusion among the general public. In order to reduce further confusion, The Geological Survey of Wyoming is coordinating with the U.S. Environmental Protection Agency and the U.S. Geological Survey on the existing maps and



those that are in preparation. Through exchange of existing data and cooperative data collection, more accurate maps will eventually define problem areas. In any case, direct measurements of radon are needed at a great many locations throughout the State before any definitive map can be produced. For now, all these maps must be used cautiously, and it must be recognized that none are really accurate. At the least, they are all of limited value in planning a well-thought-out sampling program.

## THE SINKS

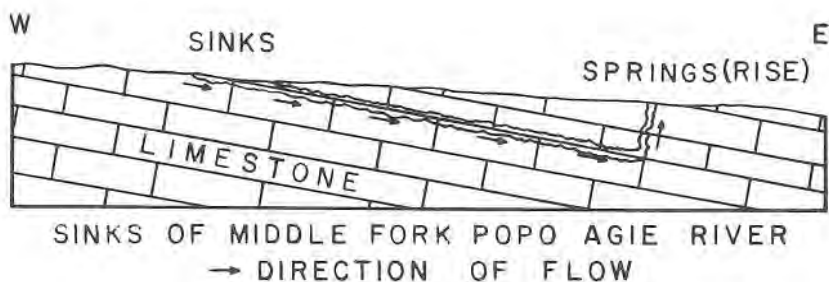
by Sheila Roberts, Editor, Geological Survey of Wyoming.

In the list of geological wonders of Wyoming, the Sinks of the Popo Agie River occupies an instructive position. Geology does not have to be grand scale, difficult to get to or hard to understand to attract awed spectators. At the Sinks, a river disappears into (flows through) an underground cavern and emerges in a single large deep pool.

About six miles southwest of Lander, Wyoming, Highway 131 enters a canyon cut through sedimentary rocks tilted during uplift of the Wind River Range. The rocks dip about 15 degrees to the northeast, so that going southwest up the canyon the road passes older and older strata, starting in Mesozoic and upper Paleozoic rocks and eventually encountering the Precambrian core of the range. The cliffs surrounding Sinks Canyon State Park are mostly Paleozoic limestone, dolomite and sandstone. One of the carbonate units is the Mississippian Madison Limestone a thick, fossiliferous, cliff-forming rock unit about 350 million years old, that is extensively exposed throughout Wyoming and some adjacent states. When the Madison Limestone was deposited, it was in chemical equilibrium with the warm

sea water in which it formed. Later, the sea departed, the rocks were uplifted locally, and the limestone was subjected to several episodes of dissolution by fresh water. In many places the Madison now contains holes, caverns (some very large caves) and zones of broken rock that mark locations of collapsed solution cavities.

The Middle Fork of the Popo Agie River begins in Precambrian terrane about eight miles to the west, at the convergence of several small streams that issue from high mountain lakes near the Continental Divide. At first it behaves like a normal mountain stream, following the course it has incised into the bedrock. The canyon it follows was originally cut by streams and later enlarged by glaciers during the Pleistocene. At the park's Visitors Center, a path leads down to a place where the river, eroding its channel, encountered a cavern in the Madison Limestone and was captured by it. With a roar, the water plunges into a gaping hole in the cliff, flows through a solution cavern for about 600 feet and re-emerges at the Rise, 210 vertical feet below the Sinks:



*Diagram demonstrating how the Sinks is believed to work (modified from Blackstone, 1971, p. 22).*

The "Rise" is a deep circular pool that contains giant trout (protected by a "No Fishing" sign), an indication of the purity of the water.

The main stream passage has not been explored because of the water turbulence and confined space. Exploration of a dry upper cavern disclosed slickensides (polished striated surfaces on the opposite faces of a fractured rock), which indicate that solution developed along a fault (Hill and others, 1976, p. 129).

After its spectacular side trip, the Middle Fork flows unperturbed in its bed out into the basin, through Lander and to the spot just northwest of town where it converges with the North Fork and Squaw and Baldwin Creeks to form Popo Agie River.

In addition to its geological attraction, Sinks Canyon State Park offers an attractive camping and picnicing area. A nature trail provides hands-on experiences with the local flora and fauna and more information on the canyon's geology.

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