Wyoming Geo-notes

Number 61

Wyoming State Geological Survey
Lance Cook, State Geologist

Laramie, Wyoming
March, 1999

PHONE: (307) 766-2286 Email: wsgs@wsgs.uwyo.edu
FAX: (307) 766-2605 WEB Page: http://www.wsgsweb.uwyo.edu

WYOMING GEO-NOTES
This quarterly digest on the State's geology and mineral resources and activities of the Geological Survey is available by subscription (four issues for $10.00) or as single copies at $3.00 each. Two-year subscriptions are accepted.

Printed on 50% recycled fiber paper. 500 copies printed by Pony X-Press, Cheyenne, Wyoming.

Table of Contents

MINERALS UPDATE

OVERVIEW

Gary B. Glass
State Geologist (retired), Wyoming State Geological Survey

This is the last issue of *Wyoming Geo-notes* that I will officially write and edit. Consequently, I wanted to thank you, the readers, who have encouraged me to persevere through 60 issues over a span of 15 years. In case you are wondering about my math, my count of the issues is correct, as the first issue of *Wyoming Geo-notes* dates back to 1977. While I was pictured in that issue, I was not involved with its writing, editing, or content. There was not another issue until I resurrected *Wyoming Geo-notes* in March of 1984.

And you need to know that without your frequent comments on the value of *Wyoming Geo-notes*, I am not sure how many issues might have been published. At times, I truly needed that encouragement. Overall though, I can honestly say that I have enjoyed writing and editing it.

I also want to thank the staff geologists, who have written the greatest portion of these issues, as well as the support staff, who have actually put the text, tables, and graphs together these many years. Without the help of these individuals, there also would not have been 61 issues. And rather than miss someone's name, I am thanking everyone collectively, because it took all of you to make this work so well for so many years.

Now, here is a very brief **Overview** of the last quarter of 1998. Once more, there are a few changes to our price and production projections, mostly because this issue follows on the heels of the January 1999 meeting of the Consensus Revenue Estimating Group (CREG). In regard to production forecasts, the estimates for oil production have been lowered somewhat for 1999 through 2005 (**Table 1** and **Figure 1**). Natural gas production is unchanged from the last issue (**Table 1** and **Figure 2**). Coal production; however, has been increased significantly for 1998 and all the forecast years (**Table 1** and **Figure 3**).

Also, the coal production estimates in this issue do not agree with CREG's January forecast because the actual 1998 coal production figures were not available until late February. However, the new estimates of coal production in **Table 1** of this issue of *Wyoming Geo-notes* still reflect the same percentage increases as forecast by CREG in January.

According to the Wyoming State Inspector of Mines, annual coal production in 1998 set yet another record at 314,962,091 short tons. This compares with CREG's estimate of 303.3 million tons, which looked like a very good estimate using the production figures that were available to it in January.

No changes were made to the production forecasts for other commodities in **Table 1**.

Table 1. Wyoming mineral production (1985-1997) with forecasts to 2005[1].

Calendar Year	Oil[2,3]	Methane[3,4]	Carbon Dioxide[3,4]	Helium[4,5]	Coal[6]	Trona[7]	In-situ Uranium[7,8]	Sulfur[3,9]
1985	131.0	597.9	—	—	140.4	10.8	N/A	0.80
1986	122.4	563.2	23.8	0.15	135.4	11.9	0.05	0.76
1987	115.9	628.2	114.2	0.86	146.5	12.4	0.00	1.19
1988	114.3	700.8	110.0	0.83	163.6	15.1	0.09	1.06
1989	109.1	739.0	126.1	0.94	171.1	16.2	1.1	1.17
1990	104.0	777.2	119.9	0.90	184.0	16.2	1.0	1.04
1991	99.8	820.0	140.3	1.05	193.9	16.2	1.0	1.18
1992	97.0	871.5	139.2	1.05	189.5	16.4	1.2	1.20
1993	89.0	912.8	140.8	1.06	209.9	16.0	1.2	1.14
1994	80.2	959.2	142.6	1.07	236.9	16.1	1.2	1.10
1995	75.6	987.5	148.8	1.11	263.9	18.4	1.3	1.20
1996	73.9	1,023.4	149.0	1.10	278.4	18.6	1.9	1.22
1997	70.2	1,040.3	151.0	1.10	281.5	19.4	2.2	1.23
1998	63.2	1,052.9	151.0	1.10	*315.0	18.5	2.5	1.20
1999	55.3	1,064.8	151.0	1.10	333.7	18.2	2.5	1.20
2000	52.5	1,089.1	151.0	1.10	353.8	18.2	2.5	1.20
2001	49.9	1,113.9	151.0	1.10	366.0	18.4	2.5	1.20
2002	47.4	1,139.2	151.0	1.10	369.5	18.6	2.5	1.20
2003	45.0	1,165.1	151.0	1.10	373.2	18.8	2.5	1.20
2004	42.8	1,191.4	151.0	1.10	377.0	19.0	2.5	1.20
2005	40.7	1,218.3	151.0	1.10	380.6	19.2	2.5	1.20

[1]Modified from CREG's Wyoming State Government Revenue Forecast, January, 1999; [2]Millions of barrels; [3]Wyoming Oil & Gas Conservation Commission, 1985-1997; [4] Billions of cubic feet; [5]Based on Exxon's estimate that the average helium content in the gas processed at Shute Creek is 0.5%; [6]Millions of short tons (Wyoming State Inspector of Mines, 1985-1997); [7]Wyoming Department of Revenue, 1985-1997; [8]Millions of pounds of yellowcake (not available [N/A] for 1985 and previous years because it was only reported as taxable value); [9]Millions of short tons. *Actual value.

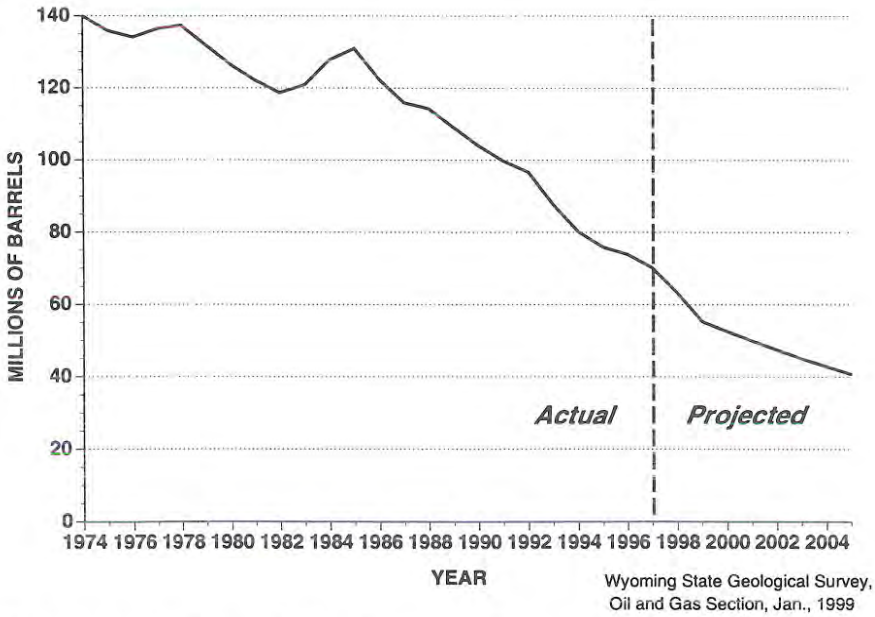


Figure 1. Annual oil production from Wyoming (1974 to 1997) with forecasts to 2005.

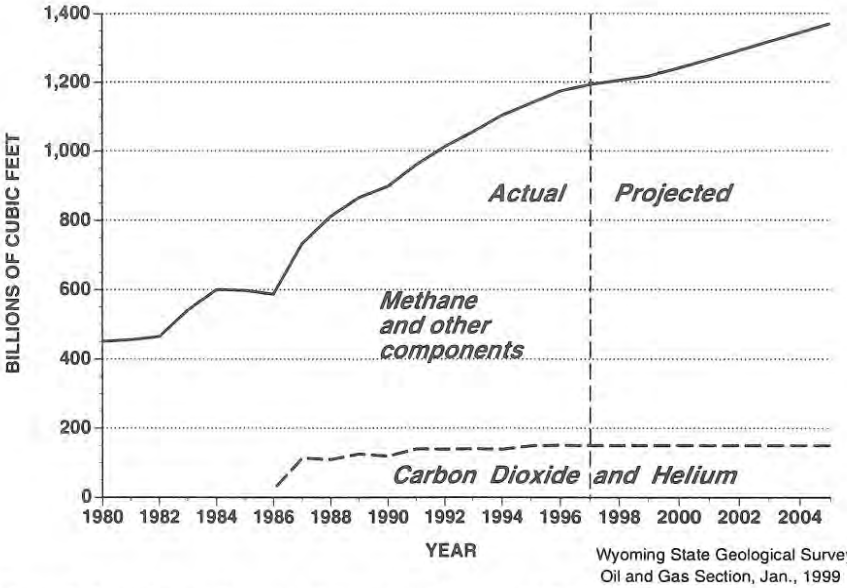


Figure 2. Annual natural gas production from Wyoming (1980 to 1997) with forecasts to 2005.

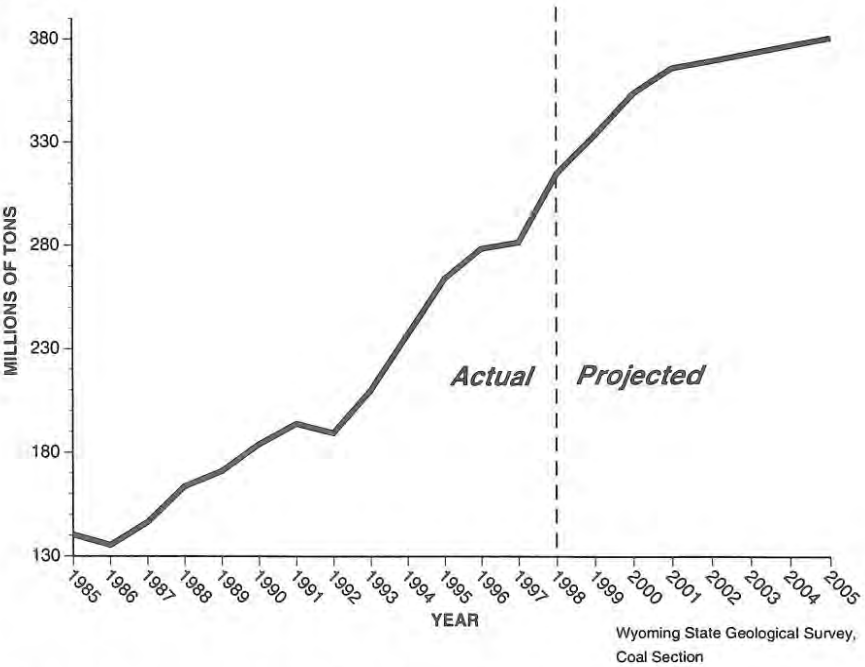


Figure 3. Annual coal production from Wyoming (1985-1998) with forecasts to 2005. Sources: Wyoming State Inspector of Mines (1985-1998) and Wyoming State Geological Survey (1999-2005).

Some price forecasts also changed since the last issue of *Wyoming Geo-notes*. The most significant change was in regard to oil prices. The forecast price was lowered for calendar years 1999, 2000, and 2001 (**Table 2** and **Figure 4**). The lowered price forecasts reflect the continued global oversupply of oil and resultant low prices.

There is one bright spot in this otherwise dreary situation affecting the oil industry. Much of the sour crude from Wyoming is now receiving a bonus of $4.00 or more per barrel. The refiners buying Wyoming oil are paying these bonuses because their supplies have dwindled, as many competing Canadian producers have had to shut in or abandon their production due to low prices. These bonuses; however, only serve to bring the sour crude prices up closer to that of Wyoming sweet crude. To put this bright spot in perspective, the price paid for Wyoming crude in January of 1998 only averaged an estimated $9.20 per barrel. That average included both sweet and sour crude oil prices as well as bonuses.

Another change in the price forecasts was that of natural gas for 1998. CREG lowered its estimate by five cents, to $1.80 (**Table 2** and **Figure 5**).

Table 2. Average prices paid for Wyoming oil, methane, coal, and trona (1985-1997) with forecasts to 2005[1].

Calendar Year	Oil[2]	Methane[3]	Coal[4]	Trona[5]
1985	24.67	3.03	11.36	35.18
1986	12.94	2.33	10.85	34.80
1987	16.42	1.78	9.80	36.56
1988	13.43	1.43	9.16	36.88
1989	16.71	1.58	8.63	40.76
1990	21.08	1.59	8.43	43.70
1991	17.33	1.46	8.06	44.18
1992	16.38	1.49	8.13	43.81
1993	14.50	1.81	7.12	40.08
1994	13.67	1.63	6.62	38.96
1995	15.50	1.13	6.38	40.93
1996	19.56	1.46	6.15	45.86
1997	17.41	1.94	5.68	42.29
1998	10.50	1.80	5.42	41.29
1999	9.50	1.75	5.31	39.91
2000	11.33	1.75	5.17	40.26
2001	13.16	1.75	5.04	41.24
2002	15.00	1.75	5.04	42.04
2003	15.00	1.75	5.04	42.53
2004	15.00	1.75	5.04	42.96
2005	15.00	1.75	5.04	43.15

[1] Modified from CREG, Wyoming State Government Revenue Forecast, January, 1999; [2] First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Source: Energy Information Administration, 1985-1997; [3] Wellhead price in dollars per thousand cubic feet (MCF). Source: Wyoming Office of State Lands and Investments, 1989-1997 (derived from State royalty payments); Minerals Management Service, 1985-1988 (derived from Federal royalty payments); [4] Dollars per short ton (weighted average price for coal mined by surface and underground methods). Source: Energy Information Administration, 1985-1990 and derived from Department of Revenue, 1991-1997; [5] Dollars per ton of trona, not soda ash. Source: Wyoming Department of Revenue, 1985-1997.

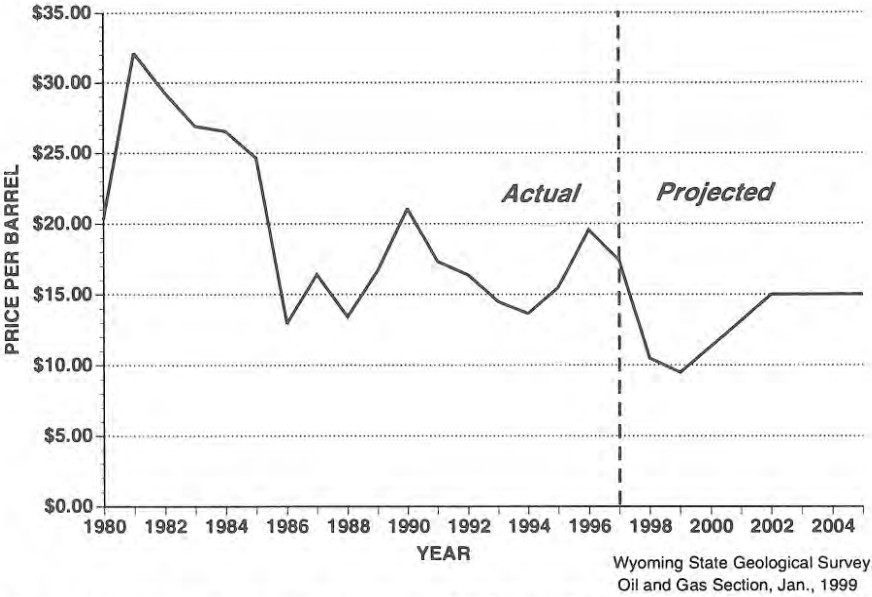


Figure 4. Average prices paid for Wyoming oil (1980 to 1997) with forecasts to 2005.

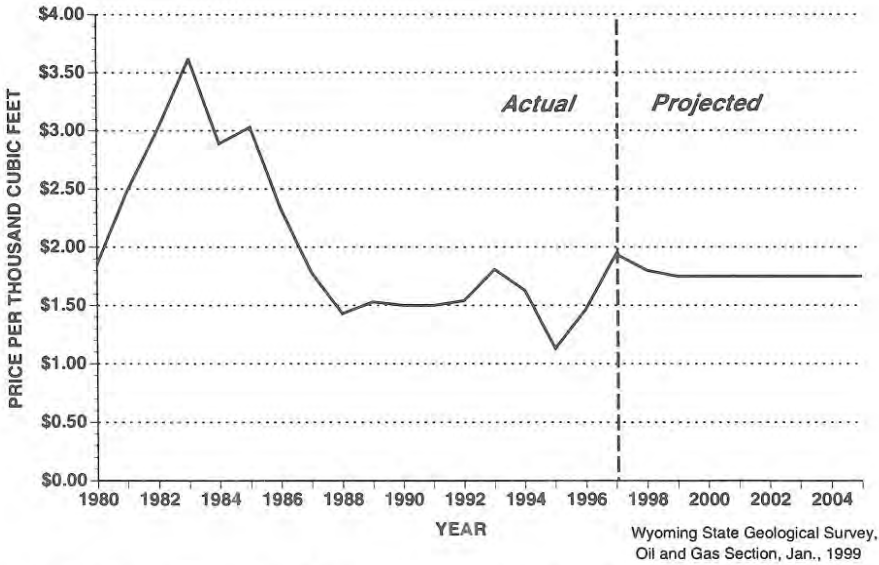


Figure 5. Average prices paid for Wyoming methane (1980 to 1997) with forecasts to 2005.

The forecast for coal prices was left unchanged for now (**Table 2** and **Figure 6**). The changes made to the estimates of coal production are not likely to affect the coal price forecasts by more than a few cents in any given year.

In regard to other items in this issue, the **Industrial Minerals and Uranium Update** features a more in-depth look at construction aggregate. The **Geologic Mapping and Paleontology Update** highlights some of the significant changes to fossil collecting rules on State lands. Jade is the featured mineral in the **Rock Hound's Corner**. There is also a seismological characterization for Natrona County beginning on page 47.

In closing, with my retirement at the end of March, Mr. Lance Cook has ably taken the reins of the Survey. An announcement and short biography for Lance is found in this issue.

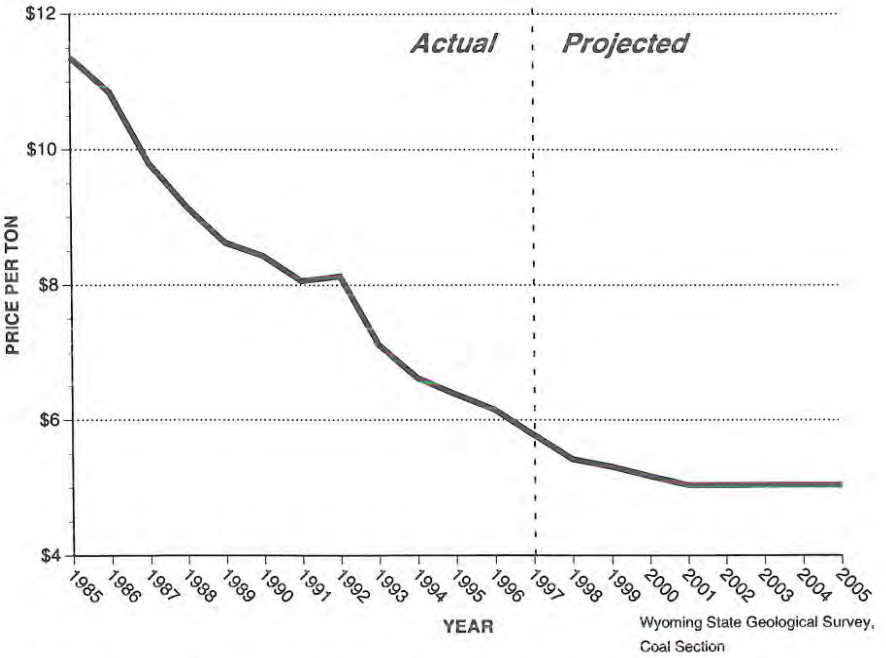


Figure 6. Average prices paid for Wyoming coal (1985 to 1997) with forecasts to 2005. Sources: U.S. Energy Information Administration (1985-1990); Wyoming Department of Revenue (1991-1997); and Wyoming Consensus Revenue Estimating Group (1998-2005).

OIL AND GAS UPDATE

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

Prices paid to Wyoming oil producers during the fourth quarter of 1998 averaged an estimated $8.73 per barrel. This estimated average price for the fourth quarter of 1998 is $7.64 lower than for the fourth quarter of 1997. The estimated average of $7.00 in December would be the lowest average monthly price in many years, but it may be underestimated due to the bonuses that some producers started to get in November (**Table 3**). For calendar year 1998, the average price of Wyoming crude oil is estimated between $10.50 and $10.45 a barrel (**Tables 2** and **3**). This would be the lowest average yearly price since 1978 when the average price was $9.16. **Figure 7** shows the posted Sweet and Sour crude prices and first purchase price for Wyoming oil averaged by month.

Oil production in Wyoming for the first nine months of 1998 was 49.1 million barrels (**Table 4**), according to figures from Petroleum Information/Dwights LLC (PI/D). This production is a drop of about 6.5% from last year's first nine months of oil production, as reported by PI/D. The longer that oil prices remain low, the greater the rate of decline in production will become.

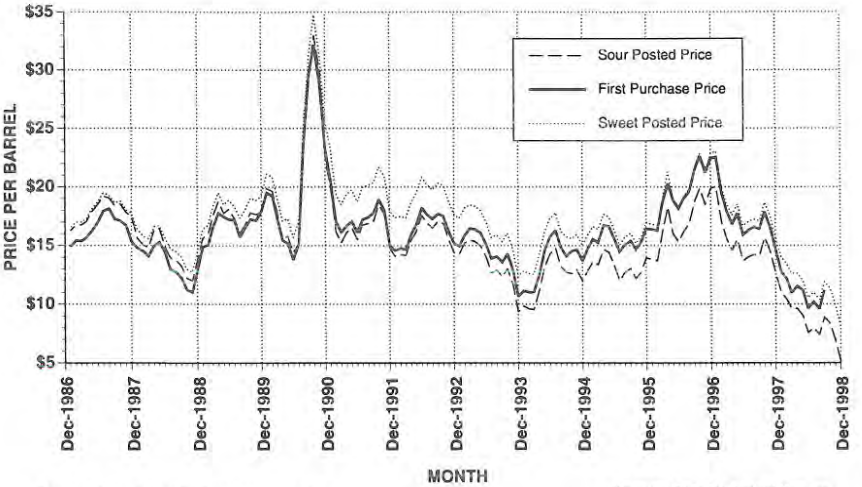
Spot prices for natural gas at Opal, Wyoming, averaged $1.88 during the fourth quarter of 1998. This is 45 cents lower than last year's fourth quarter average price of $2.33. The average price for 1998 is estimated at $1.80 to $1.81 (**Tables 2** and **5**). This compares to last year's average of $1.96 (**Table 2** and **Figure 8**).

Table 3. Monthly average price of a barrel of oil produced in Wyoming (1995 to December, 1998).

	1995		1996		1997		1998	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	$14.77	$14.77	$16.38	$16.38	$22.56	$22.56	$12.79	$12.79
FEB	$15.55	$15.16	$16.28	$16.33	$19.45	$21.01	$12.16	$12.48
MAR	$15.26	$15.19	$18.63	$17.09	$17.99	$20.00	$10.97	$11.97
APR	$16.73	$15.58	$20.29	$17.90	$16.81	$19.20	$11.54	$11.87
MAY	$16.65	$15.79	$18.85	$18.08	$17.74	$18.91	$11.19	$11.73
JUN	$15.52	$15.75	$18.15	$18.10	$15.90	$18.41	$9.63	$11.38
JUL	$14.50	$15.57	$18.98	$18.22	$16.29	$18.11	$10.20	$11.21
AUG	$15.09	$15.51	$19.59	$18.39	$16.61	$17.92	$9.58	$11.01
SEP	$15.41	$15.50	$21.48	$18.74	$16.42	$17.75	$11.19	$11.03
OCT	$14.67	$15.42	$22.63	$19.13	$17.89	$17.77	**$10.40**	**$10.97**
NOV	$15.32	$15.41	$21.19	$19.31	$16.51	$17.65	**$8.80**	**$10.77**
DEC	$16.43	$15.50	$22.42	$19.56	$14.72	$17.41	**$7.00**	**$10.45**
Avg. yearly price		**$15.50**		**$19.56**		**$17.41**		$10.45

Source: All averages are derived from published monthly reports by the Energy Information Administration, except that averages in bold print in 1998 are estimated from various unpublished bulletins listing posted prices.

Wyoming State Geological Survey, Oil and Gas Section, January, 1999.



Source: Unpublished DOE and company data

Wyoming State Geological Survery
Oil and Gas Section, Jan., 1999

Figure 7. Wyoming posted sweet and sour crude oil prices and first purchase prices, averaged by month (January, 1987, to December, 1998).

In 1998, the average monthly spot price for methane at Opal showed less variation than it has for many years. It only varied between $1.60 and $2.05 per thousand cubic feet (**Table 5** and **Figure 8**).

According to production figures from PI/D, natural gas production in Wyoming for the first nine months of 1998 was 897.3 billion cubic feet (**Table 6**). Production in the first nine months of 1998 was up 1.3% from the first nine months of production in 1997, as reported by PI/D.

Public Service of Colorado (PSC) placed its new Front Range pipeline into service on November 1, 1998. The pipeline extends 53 miles from near the Wyoming border just south of Cheyenne to Platteville, Colorado. The 24-inch pipeline, which is capable of transporting 270 million cubic feet of gas per day, can access six interstate pipelines that transport much of the gas that is produced in Wyoming. PSC already has contracts for nearly 80% of the pipeline's capacity.

Wyoming Interstate Co. (WIC) is seeking Federal approval to construct a 143-mile-long pipeline from near Glenrock to west of Cheyenne. The proposed 24-inch pipeline, known as the Medicine Bow Lateral, would initially transport up to 260 million cubic feet of coalbed methane from the Powder River Basin.

WIC recently expanded the capacity of its pipeline between southwestern Wyoming and central Nebraska by 52 million cubic feet per day. This latter line connects to pipelines that deliver gas to the Midwest. The expansion and the Medicine Bow Lateral are designed to provide more transportation capacity for coalbed methane producers in the Powder River Basin.

Table 4. Monthly oil production from Wyoming in barrels (1995 to September, 1998).

	1995		1996		1997		1998	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	6,700,000	6,700,000	6,153,037	6,153,037	5,964,848	5,964,848	5,845,543	5,845,543
FEB	6,100,000	12,800,000	5,693,084	11,846,121	5,459,518	11,424,366	5,232,816	11,078,359
MAR	6,300,000	19,100,000	6,176,805	18,022,926	6,014,780	17,439,146	5,767,159	16,845,518
APR	6,200,000	25,300,000	5,977,362	24,000,288	5,729,869	23,169,015	5,532,958	22,378,476
MAY	6,300,000	31,600,000	6,035,505	30,035,793	6,050,971	29,219,986	5,623,353	28,001,829
JUN	6,200,000	37,800,000	5,916,019	35,951,812	5,761,549	34,981,535	5,333,170	33,334,999
JUL	6,300,000	44,100,000	6,076,992	42,028,804	5,964,005	40,945,540	5,457,560	38,792,559
AUG	6,100,000	50,200,000	6,414,850	48,443,654	5,868,789	46,814,329	5,231,940	44,024,499
SEP	6,100,000	56,300,000	6,180,180	54,623,834	5,710,557	52,524,886	5,085,148	49,109,647
OCT	6,300,000	62,600,000	6,186,019	60,809,853	5,949,974	58,474,860		
NOV	6,100,000	68,700,000	6,221,912	67,031,765	5,800,811	64,275,671		
DEC	6,300,000	75,000,000	6,330,701	73,362,466	5,900,791	70,176,462		
Total Barrels Reported [1]	**75,000,000**		**73,362,466**		**70,176,462**			
Total Barrels Not Reported [2]	**554,113**		**525,957**		**52,364**			
Total Barrels Produced [3]	**75,554,113**		**73,888,423**		**70,228,826**			

[1] Monthly production reports from Petroleum Information/Dwights LLC, except for 1995, which is estimated by the Wyoming State Geological Survey.

[2] (Total barrels produced) minus (total barrels reported by Petroleum Information/Dwights LLC).

[3] Wyoming Oil and Gas Conservation Commission.

Wyoming State Geological Survey, Oil and Gas Section, January, 1999.

Table 5. Monthly average spot sale price for a thousand cubic feet (MCF) of methane at Opal, Wyoming (1995 to December, 1998).

	1995		1996		1997		1998	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	$1.40	$1.40	$1.25	$1.25	$3.90	$3.90	$2.05	$2.05
FEB	$1.10	$1.25	$1.20	$1.23	$2.50	$3.20	$1.70	$1.88
MAR	$1.05	$1.18	$1.20	$1.22	$1.40	$2.60	$1.90	$1.88
APR	$1.05	$1.15	$1.05	$1.18	$1.45	$2.31	$1.90	$1.89
MAY	$1.10	$1.14	$0.95	$1.13	$1.60	$2.17	$1.95	$1.90
JUN	$1.15	$1.14	$1.10	$1.13	$1.35	$2.03	$1.65	$1.86
JUL	$1.00	$1.12	$1.20	$1.14	$1.45	$1.95	$1.60	$1.82
AUG	$0.90	$1.09	$1.25	$1.15	$1.40	$1.88	$1.75	$1.81
SEP	$1.05	$1.09	$1.20	$1.16	$1.50	$1.84	$1.60	$1.79
OCT	$1.05	$1.09	$1.30	$1.17	$2.05	$1.86	$1.65	$1.78
NOV	$1.25	$1.10	$2.45	$1.29	$3.00	$1.96	$2.00	$1.80
DEC	$1.30	$1.12	$3.50	$1.47	$1.95	$1.96	$2.00	$1.81
Avg. yearly price		**$1.12**		**$1.47**		**$1.96**		

Source: American Gas Association's monthly reports, except for the average yearly price, which comes from Wyoming's Office of State Lands and Investments.

Wyoming State Geological Survey, Oil and Gas Section, January, 1999.

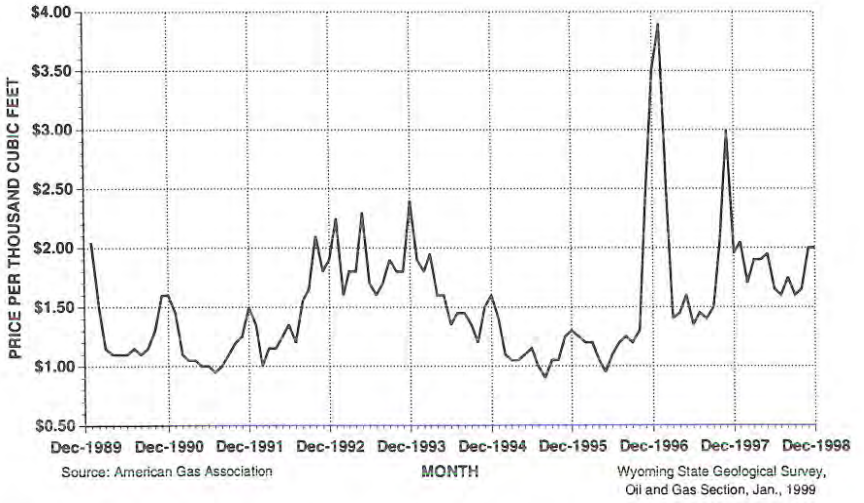


Figure 8. Spot sale prices for methane at Opal, Wyoming, averaged by month (January, 1990, to September, 1998).

Table 6. Monthly natural gas production from Wyoming in thousands of cubic feet (MCF) (1995 to September, 1998).

	1995		1996		1997		1998	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	100,224,249	100,224,249	101,359,648	101,359,648	99,579,818	99,579,818	103,629,444	103,629,444
FEB	86,691,577	186,915,826	96,303,300	197,662,948	91,766,159	191,345,977	94,484,977	198,114,421
MAR	94,344,991	281,260,817	103,541,127	301,204,075	104,157,578	295,503,555	103,892,632	302,007,053
APR	93,929,323	375,190,140	99,479,609	400,683,684	99,459,039	394,962,594	98,169,418	400,176,471
MAY	95,791,327	470,981,467	97,900,863	498,584,547	101,070,371	496,032,965	96,722,294	496,898,765
JUN	92,140,614	563,122,081	87,069,612	585,654,159	91,905,308	587,938,273	98,397,008	595,295,773
JUL	92,796,301	655,918,382	100,219,275	685,873,434	100,129,497	688,067,770	101,999,398	697,295,171
AUG	90,393,416	746,311,798	99,874,019	785,747,453	97,673,622	785,741,392	102,302,878	799,598,049
SEP	92,589,092	838,900,890	93,510,551	879,258,004	100,028,888	885,770,280	97,732,105	897,330,154
OCT	98,386,458	937,287,348	95,441,022	974,699,026	102,206,875	987,977,155		
NOV	94,939,660	1,032,227,008	94,015,007	1,068,714,033	100,752,128	1,088,729,283		
DEC	99,314,617	1,131,541,625	99,141,298	1,167,855,331	103,415,430	1,192,144,713		
Total MCF Reported [1]	**1,131,541,625**		**1,167,855,331**		**1,192,144,713**			
Total MCF Not Reported [2]	**6,448,396**		**5,663,874**		**683,432**			
Total MCF Produced [3]	**1,137,990,021**		**1,173,519,205**		**1,192,828,145**			

[1] Monthly production reports from Petroleum Information/Dwights LLC.

[2] (Total MCF produced) minus (total MCF reported by Petroleum Information/Dwights LLC).

[3] Wyoming Oil and Gas Conservation Commission.

Wyoming State Geological Survey, Oil and Gas Section, January, 1999.

Abraxas Petroleum has sold its natural gas properties in the Wamsutter area of southwestern Wyoming to a partnership that consists of an Abraxas subsidiary and an affiliate of GE Capital Structured Finance Group. Abraxas will continue to operate the properties, which consist of about 11,300 acres and 57 wells. An independent petroleum consultant estimates that the properties have total proven reserves of 76.6 billion cubic feet of gas. The sale was for a reported $60.2 million.

The U.S. Bureau of Land Management (BLM) is seeking comments on a proposed new oil and gas rule. The agency feels the new rule will (1) give operators increased flexibility in meeting agency requirements, (2) reduce overlap among current regulations, (3) ensure appropriate bonding levels to cover such costs as reclamation, and (4) simplify classification of regulatory violations. The comment period for the new rule will end April 2, 1999. Complete details of the rule are available by calling (202) 452-5030. A copy of the rule is also available on the Internet from BLM's website:

<http://www.blm.gov/nhp/news/regul/3100p5.html>

A fact sheet that provides more information on the rule is available online at:

<http://www.blm.gov/nhp/news/oilgasfacts.html>

Leasing activity at the U.S. Bureau of Land Management's (BLM's) October sale was concentrated in the Powder River Basin (**Figure 9**). One of the sale's two high per-acre bids of $430 was made by Devon Energy for a 320-acre lease that covers the W/2 section 15, T51N, R74W (location **A**, **Figure 9**). The lease is nearly three miles west of Muddy production and Fort Union coalbed methane development at Kitty Field. The other high per-acre bid of $430 was made by Coleman Oil & Gas for a 1,740.36-acre lease that covers parts of sections 3, 29, 30, and 31, T48N, R74W (location **B**, **Figure 9**). The lease is several miles west of coalbed methane development in the Fort Union Formation. There were 69 tracts at this sale that received bids of $50 or more per acre.

Similarly, leasing activity at the Wyoming Office of State Lands and Investments' October lease sale centered on the Powder River Basin (**Figure 10**). The sale's high per-acre bid of $590 was made by Coleman Oil & Gas for a 160-acre lease that covers NE section 36, T49N, R72W (location **A**, **Figure 10**). The parcel is about three-quarters of a mile southeast of Minnelusa oil production at Wolff Field, and is just north of several active coalbed methane wells. The sale had 27 parcels that received bids of $50 or more per acre.

Leasing activity at the BLM's December sale also centered on the Powder River Basin (**Figure 11**). Baseline Minerals made the sale's high per-acre bid of $800 for a 162.96-acre parcel that covers parts of section 20, T49N, R72W (location **A**, **Figure 11**). The tract is about 1.5 miles north of several coalbed methane wells and about the same distance west of Minnelusa production in Dry Gulch Field. The sale's next highest per-acre bid of $675 was made by

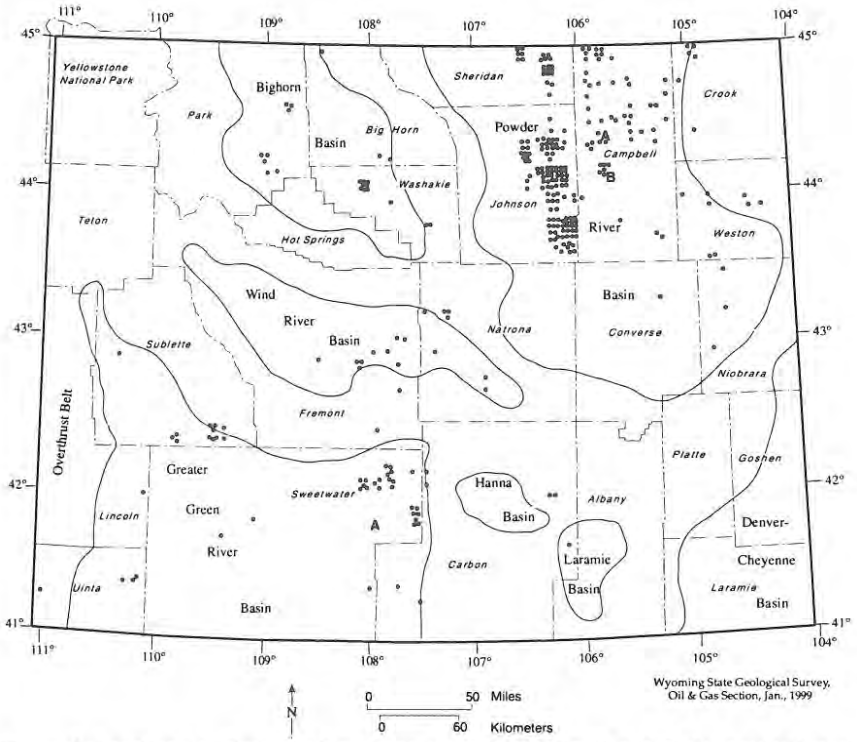


Figure 9. Locations of Federal oil and gas tracts leased by the U.S. Bureau of Land Management at its October, 1998, sale.

Michael Guthrie for a 160.37-acre lease that covers parts of sections 29, 30, and 33, T48N, R72W (location **B**, **Figure 11**). The lease is in an area of coalbed methane development. There were 92 parcels at this sale that received a bid of $50 or more per acre. The six sales held by the BLM in 1998 grossed $63.8 million, which is almost twice the previous record of nearly $32.0 million in 1997 (**Table 7**).

Again, leasing activity at the Wyoming Office of State Lands and Investments' December lease sale was concentrated in the Powder River Basin (**Figure 12**). The sale's high per-acre bid of $215 was made by Sonat Exploration for a 640-acre lease that covers all of section 36, T57N, R84W (location **A**, **Figure 12**). The lease is in an area where Sonat and other companies are carrying out a coalbed methane exploration program that targets Fort Union coals. There were only six parcels at this sale that received bids of $50 or more per acre. The $5.2 million from the four State sales in 1998 was the largest in many years (**Table 7**).

There were 2,505 Applications for Permit to Drill (APDs) in 1998 (**Table 8**). This is the largest number of APDs approved by the Wyoming Oil and Gas

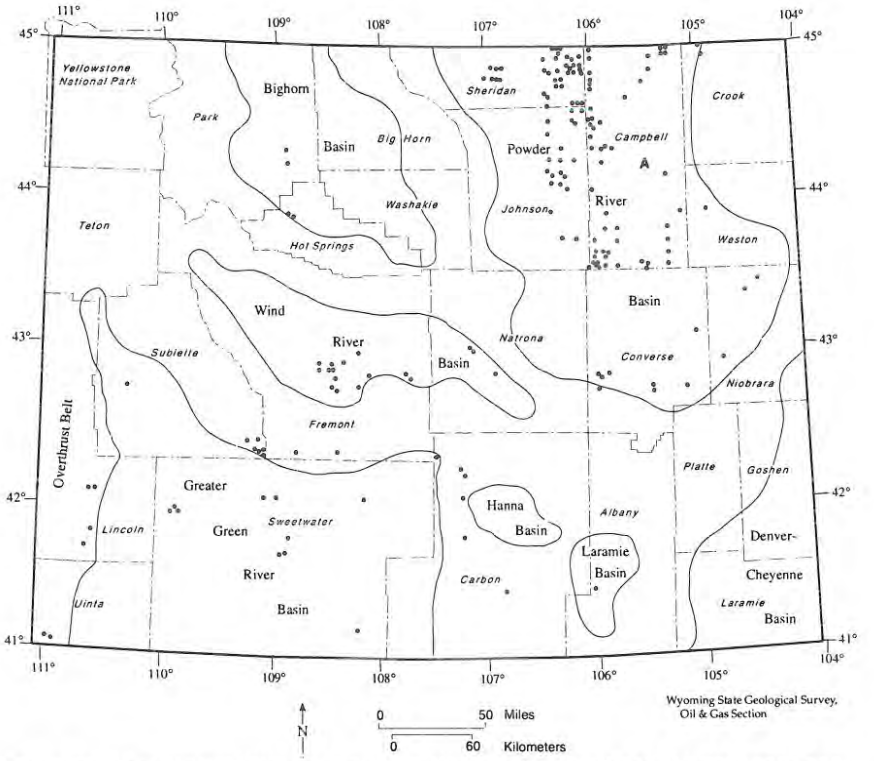


Figure 10. Locations of State oil and gas tracts leased by the Office of State Lands and Investments at its October, 1998, sale.

Conservation Commission (WOGCC) in several years. Campbell County led with over 63% of the total APDs that were approved, and the majority of those were for shallow, coalbed methane wells.

The WOGCC also permitted 58 seismic projects in 1998 (**Table 9**). The 1,503 square miles of 3-D seismic approved in 1998 is larger than in any of the last three years, and the 463 conventional miles are larger than in either 1995 or 1996.

The average daily rig count for the fourth quarter of 1998 was 37. This average is 10 less than in the fourth quarter of 1997, but is still fairly high considering the low prices for Wyoming crude oil. The average daily rig count for 1998 was 39, which is the same as 1997 (**Figure 13**). Most drilling was for natural gas, to include coalbed methane. **Figure 14** shows the Wyoming daily rig count averaged by month.

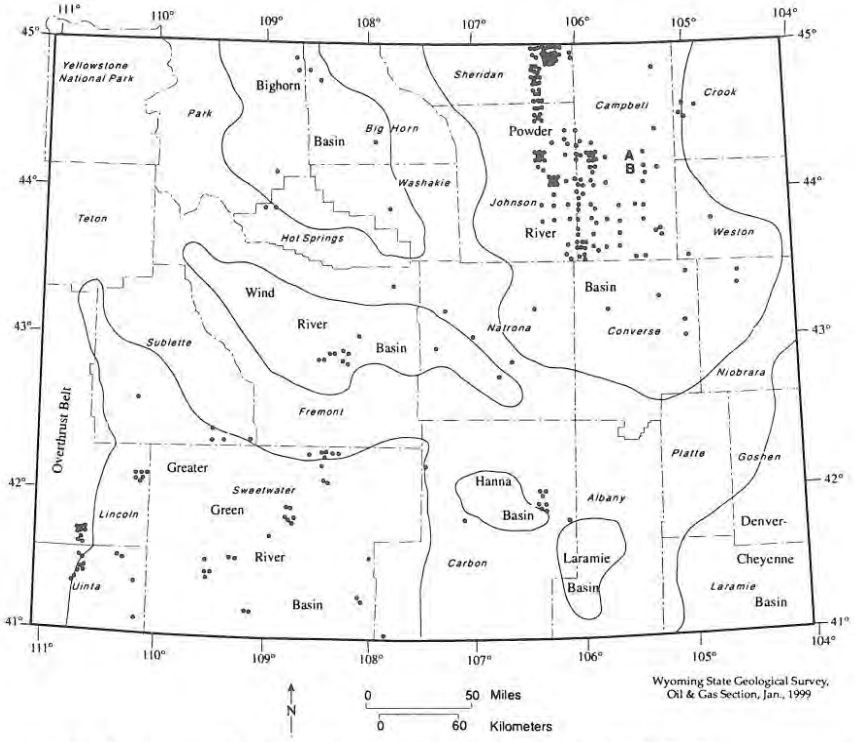


Figure 11. Locations of Federal oil and gas tracts leased by the U.S. Bureau of Land Management at its December, 1998, sale.

Exploration and Development

Company data, news releases, and information compiled and published by Petroleum Information/Dwights LLC indicate the following significant exploration and development events occurred in Wyoming during the fourth quarter of 1998. The numbers preceding discussions refer to locations on **Figure 15**.

1. Amoco Production completed the second well in Session Mountain Field. The discovery was made in 1983 and that well has produced over 9.0 billion cubic feet of gas and 110,000 barrels of condensate from the Bighorn Dolomite and the Madison Limestone. During its first month on line, the new 3-1 Cummings-Federal well in SW NW section 3, T18N, R120W produced an average of 4.3 million cubic feet of gas and 47 barrels of condensate per day from an undisclosed interval in the Bighorn. The well also flowed 2.9 million cubic feet of gas and 31 barrels of condensate per day from an undisclosed interval in the Madison.

Table 7. Federal and State competitive oil and gas lease sales in Wyoming.

FEDERAL SALES (BUREAU OF LAND MANAGEMENT)							
Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
			1995				
TOTAL	$13,047,246	2,649	1,264	2,326,988	1,109,711	$11.76	$1,100.00
			1996				
TOTAL	$11,487,567	1,828	1,125	1,403,444	739,505	$15.53	$1,450.00
			1997				
February	$2,463,137	267	210	222,486	148,148	$16.63	$250.00
April	$2,612,013	145	137	98,865	90,948	$28.72	$400.00
June	$4,642,113	285	249	313,519	262,682	$17.67	$310.00
August	$4,636,555	426	365	430,213	327,172	$14.17	$600.00
October	$12,133,207	286	227	234,561	169,264	$71.68	$400.00
December	$5,489,578	378	297	279,294	208,428	$26.34	$410.00
TOTAL	$31,976,603	1 787	1,485	1,578,938	1,206,642	$26.50	$600.00
			1998				
February	$5,262,908	369	285	366,787	241,654	$21.78	$415.00
April	$10,287,111	247	227	192,561	162,393	$63.35	$395.00
June	$14,737,117	463	367	498,339	368,816	$39.96	$430.00
August	$8,033,029	306	245	349,605	278,095	$28.89	$500.00
October	$10,251,074	455	308	421,900	293,141	$34.97	$430.00
December	$15,229,257	407	278	388,783	277,538	$54.87	$800.00
TOTAL	$63,800,496	2,247	1,710	2,217,975	1,621,637	$39.34	$800.00

STATE SALES (OFFICE OF STATE LANDS AND INVESTMENTS)							
Month	Total Revenue	Number of parcels offered	Number of parcels leased	Total acres	Acres leased	Average price per acre leased	High price per acre
			1995				
TOTAL	$1,656,218	799	492	323,887	202,708	$8.17	$130.00
			1996				
TOTAL	$2,325,497	1049	508	418,111	206,814	$11.24	$206.00
			1997				
April	$719,005	300	189	119,436	80,548	$8.93	$170.00
June	$1,008,470	300	185	108,470	62,447	$16.16	$162.00
October	$627,935	300	165	102,802	63,003	$ 9.97	$115.00
December	$795,610	298	165	107,588	57,202	$13.91	$340.00
TOTAL	$3,151,020	1198	704	438,296	263,230	$11.97	$340.00
			1998				
April	$1,203,792	300	161	115,646	63,848	$18.85	$320.00
June	$1,660,438	300	148	108,654	52,501	$31.63	$600.00
October	$1,313,792	298	178	98,856	65,212	$20.14	$590.00
December	$1,045,447	300	187	121,551	77,852	$13.43	$215.00
TOTAL	$5,223,469	1198	674	444,707	259,413	$20.14	$600.00

Sources: Wyoming Office of State Lands and Investments, Petroleum Information/Dwights LLC - Rocky Mountain Region Report, and U.S. Bureau of Land Management.

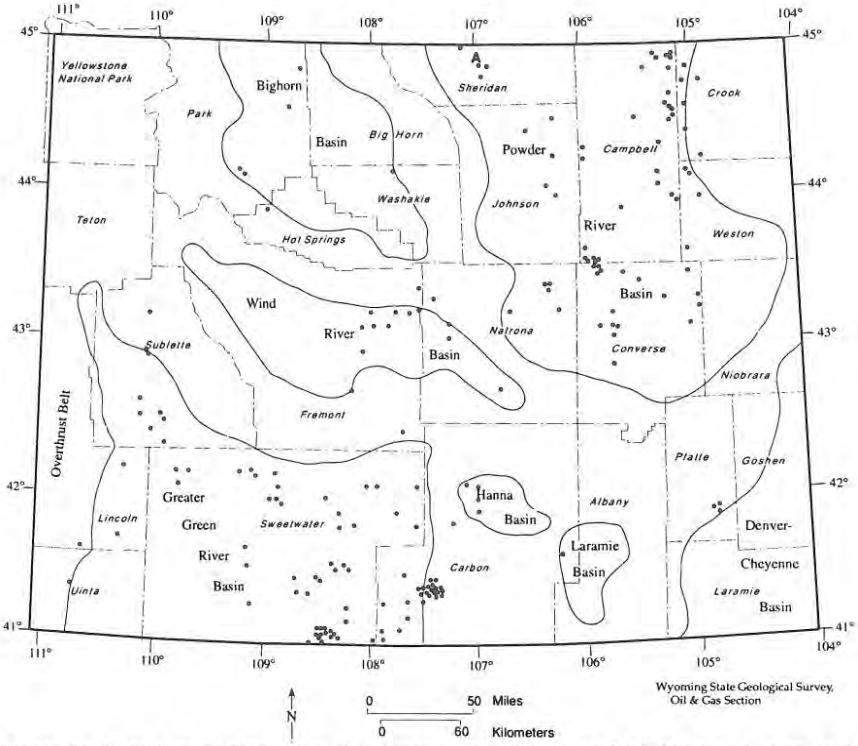


Figure 12. Locations of State oil and gas tracts leased by the Office of State Lands and Investments at its December, 1998, sale.

2. Chevron USA completed a horizontally-drilled well in Painter Reservoir East Field. The 32-5AH-PRU well in SW NE section 5, T15N, R119W flowed 10.0 million cubic feet of gas and 2,500 barrels of oil per day from the Nugget Sandstone. The well was drilled to a true vertical depth of 12,159 feet.

3. Celsius Energy completed an exploration well in SW SE section 11, T20N, R113W. The 3 Reynard unit well flowed 458,000 cubic feet of gas per day from perforations in the second Frontier between 11,304 and 11,312 feet.

4. Texaco Exploration & Production completed three new producers in its Ballerina prospect area. During its first month on line, the 30-3 Ballerina well in SE SW section 3, T21N R113W produced an average of 582,000 cubic feet of gas, seven barrels of condensate, and six barrels of water per day from an undisclosed interval in the Dakota. The 30-2 Ballerina well in NW SW section 2, T21N, R113W produced an average of 2.3 million cubic feet of gas and 14 barrels of condensate per day from an undisclosed interval in the Dakota. The 20-3 Ballerina well in C NE section 3, T21N, R113W flowed 8.1 million cubic feet of gas per day from the Dakota between 12,319 and 12,378 feet.

Table 8. Number of Applications for Permit to Drill (APD) approved by the Wyoming Oil and Gas Conservation Commission (1995 through December, 1998).

County	1995 APDs	1996 APDs	1997 APDs	1998 APDs
Albany	1	1	0	0
Big Horn	16	53	59	13
Campbell	151	554	941	1586
Carbon	50	77	84	96
Converse	29	20	16	6
Crook	15	37	26	29
Fremont	30	26	58	76
Goshen	0	0	0	0
Hot Springs	13	24	42	1
Johnson	6	16	6	49
Laramie	10	2	3	2
Lincoln	64	55	122	105
Natrona	80	74	59	36
Niobrara	4	7	8	8
Park	20	30	25	11
Platte	0	0	0	0
Sheridan	0	0	2	35
Sublette	61	118	179	230
Sweetwater	153	136	210	181
Teton	0	0	0	0
Uinta	11	10	27	26
Washakie	31	30	36	9
Weston	10	10	5	6
Totals	**755**	**1280**	**1908**	**2505**

Source: All data are from the Wyoming Oil and Gas Conservation Commission.
Wyoming State Geological Survey, Oil and Gas Section, January, 1999.

5. Cabot Oil & Gas completed two step-outs from Sugarloaf Butte Field. The 10-30 Sugarloaf well in NE NW section 30, T22N, R110W flowed 452 barrels of condensate and 895,000 cubic feet of gas per day from perforations in the Dakota between 11,654 and 11,710 feet. The 40-19 Sugarloaf well in SE SW section 19, T22N, R110W flowed 461 barrels of condensate and 1.6 million cubic feet of gas per day from the Dakota between 11,596 and 11,612 feet.

6. Marathon Oil completed a step-out from Shute Creek Field. The 21-12 Jackson Creek well in N/2 SW section 12, T23N, R113W flowed an average of 589,000 cubic feet of gas, seven barrels of condensate, and 37 barrels of water per day from an undisclosed interval in the Frontier.

7. Activity continues in Jonah Field. McMurry Oil completed a well on the southwestern flank of the field. The 3-12 Yellow Point well in NE NW section 12, T28N, R109W flowed 2.3 million cubic feet of gas and 76 barrels of condensate per day from an undisclosed interval in the Lance. McMurry also plans to drill a 20,000-foot exploratory test of the Frontier and Dakota at the 8-12 Yellow Point well in SE NE section 12, T28N, R109W. The well may also test the Rock Springs and the Blair Formations. Western Gas Resources' Lance Oil & Gas is offering to sell working interests in Jonah Field. Lance owns working interests

Table 9. Number of seismic projects and miles permitted by the Wyoming Oil and Gas Conservation Commission (1995 through December, 1998).

	1995			1996			1997			1998		
County	Permits	Conventional Miles	3-D Sq Miles	Permits	Conventional Miles	3-D Sq Miles	Permits	Conventional Miles	3-D Sq Miles	Permits	Conventional Miles	3-D Sq Miles
Albany	0	0	0	1	18	0	0	0	0	0	0	0
Big Horn	1	16	0	2	3	66	2	0	45	1	0	16
Campbell	12	24	43	32	56	220	20	52	79	14	18	182
Carbon	1	0	16	2	5	18	3	7	190	4	0	318
Converse	4	39	20	1	4	0	1	5	0	4	12	239
Crook	1	0	5	5	3	20	7	8	18	2	2	4
Fremont	6	32	56	2	5	15	6	43	126	2	100	0
Goshen	0	0	0	0	0	0	2	227	0	0	0	0
Hot Springs	2	70	9	4	17	29	1	8	0	4	19	0
Johnson	1	4	0	0	0	0	2	7	17	1	4	0
Laramie	0	0	0	0	0	0	0	0	0	0	0	0
Lincoln	2	18	110	0	0	0	3	7	116	1	10	0
Natrona	3	27	3	0	0	0	5	14	101	6	12	214
Niobrara	0	0	0	2	0	23	0	0	0	0	0	0
Park	0	0	0	6	20	82	4	56	58	3	16	132
Platte	0	0	0	0	0	0	0	0	0	0	0	0
Sheridan	0	0	0	1	5	0	0	0	0	1	14	0
Sublette	2	0	162	2	21	52	1	0	61	2	1	115
Sweetwater	9	17	497	8	17	670	4	66	296	6	214	66
Teton	0	0	0	0	0	0	0	0	0	0	0	0
Uinta	0	0	0	1	0	40	0	0	0	2	0	147
Washakie	0	0	0	0	0	0	3	36	0	4	41	35
Weston	1	13	0	1	0	16	1	0	17	1	0	35
Totals	**45**	**260**	**921**	**70**	**174**	**1251**	**65**	**536**	**1124**	**58**	**463**	**1503**

Source: All data are from the Wyoming Oil and Gas Conservation Commission.
Wyoming State Geological Survey, Oil and Gas Section, January, 1999.

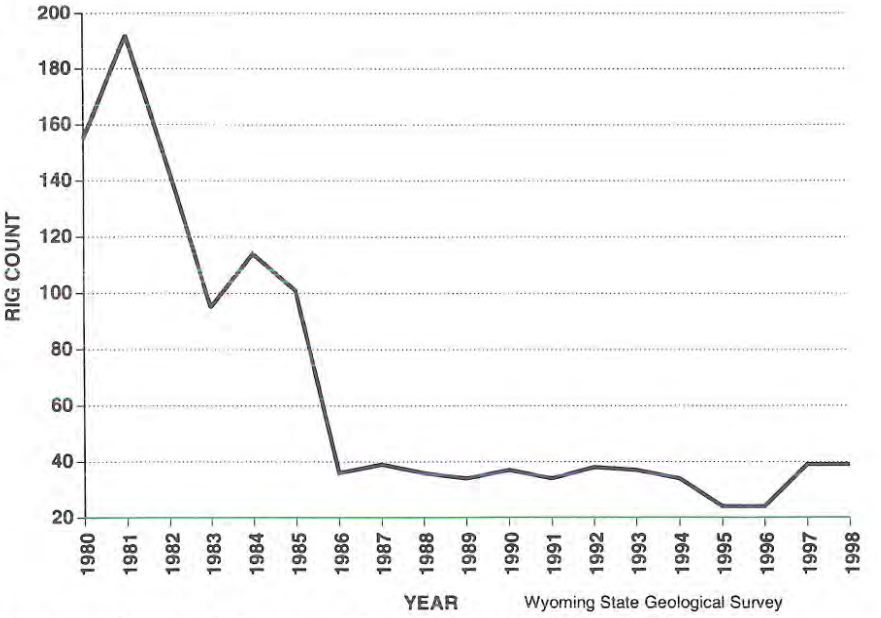


Figure 13. Wyoming daily rig count averaged by year (1980 to 1998).

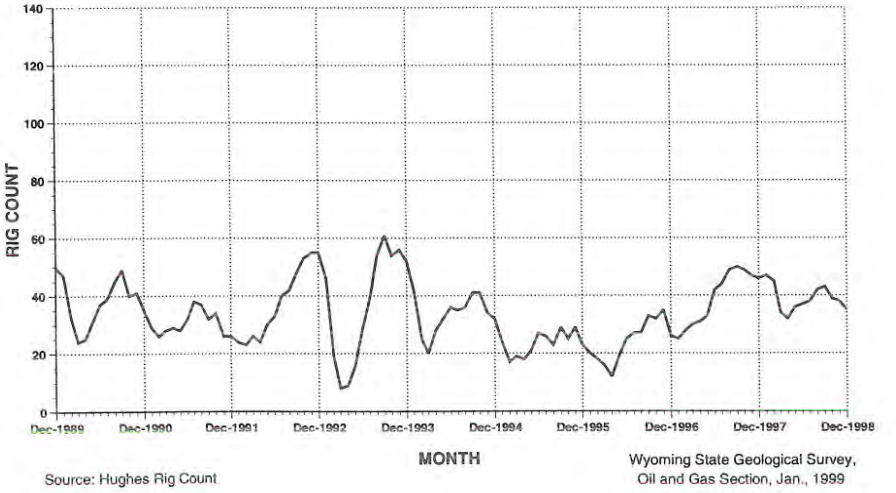


Figure 14. Wyoming daily rig count averaged by month (December, 1989, to December, 1998).

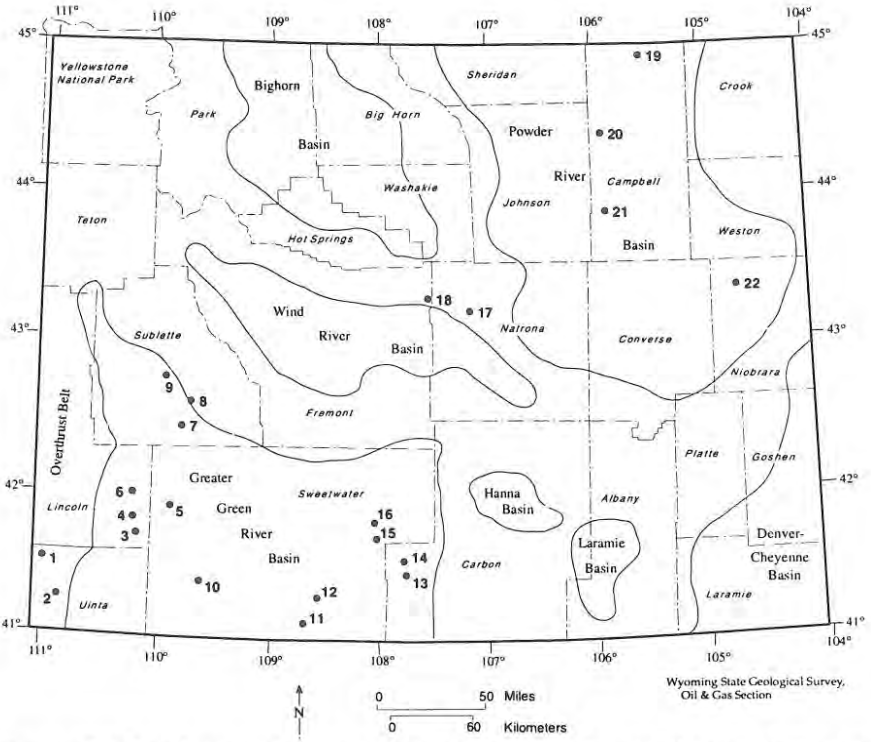


Figure 15. Oil and gas exploration and development activities in Wyoming during the fourth quarter of 1998 (exclusive of coalbed methane activities).

in 19 producing wells with current production of approximately 45 million cubic feet of gas per day.

8. McMurry completed a wildcat four miles north of Jonah Field. The 1-36 Falcon well in NE NE section 36, T30N, R109W flowed 1.7 million cubic feet of gas and 16 barrels of condensate per day from an undisclosed interval in the Lance.

9. Development continues on the Pinedale anticline. Ultra Petroleum connected two Lance discoveries to sales pipelines. The 32-33 Cottonwood-Federal well in SW NE section 33, T32N, R111W initially flowed 1.1 million cubic feet of gas per day from four zones in the Lance at about 9,555 feet. The 15-8 Lovatt Draw well in SW SE section 8, T31N, R109W also began producing an undisclosed amount of gas from several Lance zones. Ultra's 3-22D Mesa well in NE NW section 22, T32N, R109W flowed 5.1 million cubic feet of gas per day from the Lance between 11,750 and 12,043 feet. The 3-28 Stewart Point well in NE NW section 28, T33N, R109W flowed 7.7 million cubic feet of gas per day from five Lance zones above 13,111 feet. Ultra's 13-2A Pinedale-Federal well is flowing gas into a pipeline at the rate of 4.0 million cubic feet per

day. The BLM reported that the Environmental Impact Statement for the Pinedale anticline area would analyze the impacts of 700 well locations in the 197,345-acre natural gas project area.

10. Union Pacific Resources (UPR) is completing a recent exploratory core hole, as a gas well. While drilling a trona test hole, the 1 LB well in C SW section 9, T16N, R108W encountered gas in the Green River Formation at an undisclosed depth. UPR will test the well after completion.

11. Marathon Oil produced an average of 1.0 million cubic feet of gas per day during the first month at its 3 Vermillion Creek Deep well in SW NE section 1, T13N, R100W. Production is from an open-hole interval between 14,716 and 14,774 feet in the Nugget Sandstone.

12. Yates Petroleum discovered gas in the Lance at its 1 Orange Blossom Special well in NE NE section 16, T15N, R99W. The well initially flowed 750,000 cubic feet of gas per day from two Lance intervals between 11,384 and 11,654 feet.

13. Snyder Oil completed two new delineation tests in Baldy Butte Field. After a month of production, the 7-10-17-92 Baldy Butte well in SW NE section 10, T17N, R92W produced an average of 3.3 million cubic feet of gas, 34 barrels of condensate, and one barrel of water per day from an undisclosed interval in the Almond. The 10-10-17-92 Baldy Butte well in NW SE section 10, T17N, R92W averaged 1.2 million cubic feet of gas, seven barrels of condensate, and one barrel of water from an undisclosed interval in the Almond during its first month of production.

14. Amoco Production completed a new well one mile northeast of the nearest producing well in Creston Field. The 12-1 Coal Bank well in SE SW section 12, T18N, R92W flowed 2.6 million cubic feet of gas per day from several Mesaverde sands between 8,167 and 8,988 feet.

15. Amoco also completed a step-out from Tierney North Field. The 11-2 Threemile well in NW SE section 11, T20N, R94W flowed 766,000 cubic feet of gas per day from several intervals in the Mesaverde between 10,416 and 10,823 feet.

16. Amoco completed a new producer in Siberia Ridge Field. The 21-5 C.G. Road Unit well in SE SW section 25, T21N, R94W flowed 3.2 million cubic feet of gas per day from the Lewis between 8,999 and 9,033 feet and from the Mesaverde between 10,345 and 10,563 feet.

17. Barrett Resources 3-29 Mad-Cave Gulch Federal well in NW SW section 29, T37N, R86W was tested in a subthrust Muddy zone at about 18,200 feet. The well flowed 61.0 million cubic feet of gas per day and confirms the subthrust Muddy play discovered by the 1-29 Lak-Cave Gulch-Federal well in NE NW section 29, T37N, R86W. The 1-29 was producing 43.0 million cubic feet of gas per day before it blew out on August 13, 1998. The 1-29 at least partially extinguished itself in early December, shortly before a relief well was completed. After the relief well was completed, Barrett was unable to circulate

into the 1-29, presumably because it had bridged off both above and below where the relief well intersected it. Work to assure control of the 1-29 is continuing, but this work is now at the surface location. Barrett also completed its 1-36 West Cave Gulch-State well in NW NE section 36, T37N, R87W in an undisclosed Lance interval. The well flowed 4.4 million cubic feet of gas, 50 barrels of condensate, and 43 barrels of water per day. W. A. Moncrief, Jr. is preparing to reenter and work over its 16-1 Teepee Flats Unit well in NE SW section 16, T37N, R86W. The well was originally completed in the Frontier between 18,238 and 18,403 feet. Moncrief will reenter the well, drill out cement, and clean out the hole before testing the subthrust Muddy between 19,260 and 19,320 feet.

18. Burlington Resources plans to drill a 25,000-foot Madison test in Madden Field. The 5-6 Bighorn well in SW NW section 6, T38N, R89W is on the east flank of the field, about 2.5 miles east of the closest of three producing Madison gas wells.

19. Bellevue Resources completed an offset to Ute Field. The 1 True Grit (32-18) Federal well in SW NE section 18, T57N, R72W pumped 460 barrels of oil per day from the Minnelusa at about 8,175 feet.

20. Prima Oil & Gas is producing gas and condensate at two new wells in its Cedar Draw project in T51N, R75W. While the names of the wells were not specified, they are probably the 10-44 Cedar Draw Federal well in SW NW section 10 and the 11-23 Cedar Draw Federal well in SW NW section 11. The two wells are producing at a combined rate of 2.9 million cubic feet of gas and 163 barrels of condensate per day from undisclosed intervals in the Muddy Sandstone.

21. Exxon Corp. completed an infill well in Hartzog Draw Field. The 5824 Hartzog Draw Unit well in SW NE section 32, T45N, R75W pumped 412 barrels of oil and 60,000 cubic feet of gas per day from the Shannon between 9,372 and 9,424 feet.

22. Richard Bate plans to horizontally-drill a test of the Newcastle at the 1-H Timber Draw Unit well from a surface location in NE SW section 8, T39N, R65W. The surface location is about 1.5 miles northwest of abandoned Newcastle production at Rankin Field.

COAL UPDATE

Robert M. Lyman
Staff Geologist-Coal, Wyoming State Geological Survey

In late February, coal production figures from the Wyoming State Inspector of Mines showed 1998 was another record setting year. Production in 1998

was 314,962,091 short tons, which is 33.5 million tons or 11.9% greater than production in 1997.

Coal deliveries, as reported on the Federal Energy Regulatory Commission's (FERC's) Form 423, indicate that deliveries from Wyoming coal producers remained at record annual levels through the third quarter of 1998. Deliveries for the last quarter were not yet available. However, through the end of September, deliveries of coal from Wyoming totaled 226,389,251 short tons. This represented an increase of 11.6% over the 202,930,875 tons delivered through the same period in 1997.

Table 10 shows the monthly coal deliveries, as reported on FERC Form 423, for the period 1995 to 1998. **Figure 16** shows monthly coal deliveries over the past three years. **Figure 17** breaks these monthly deliveries into spot sales and contract sales.

Table 11 depicts historic and projected coal production by county. It also provides an estimate of coal from the Powder River Basin, which sells for more than $5.00/ton. The tonnages sold at these higher prices are for the remaining, older, long-term contracts that had escalation clauses built into them. **Table 12** shows a breakdown of the average prices for coal produced in northeastern Wyoming and southern Wyoming over the past ten years.

Developments in the Powder River Basin

In an effort to increase the value of its coal resources in the Powder River Basin (PRB), Black Hills Corporation (BHC) has signed an agreement with Fuels Management, Inc. (FMI) to develop a new coal enhancement technology (*Coal Daily*, 1/6/99). The two companies will build a demonstration plant at BHC's Wyodak mine. The plant will be designed to produce 100 tons/day of enhanced fuel using a patented process developed by FMI. BHC will test the product at their Wyodak power plant. They are also seeking other plants to test the enhanced coal.

The sale of Cyprus-Amax Coal Co. has entered a second phase (*Wyoming Geo-notes No. 60*, p. 28). It is reported that initial non-binding offers for the coal company have been received from 15 groups, and at least six, possibly more, have been placed on a short list. Mine tours and access to confidential company data reportedly began in late January. Final proposals are expected near the end of March (*Coal Outlook*, 1/4/99). The groups on the short list have not been identified.

By the end of 1998, Cyprus-Amax planned to cut its PRB work force by approximately 50 employees. The company cited poor railroad service and reduced production levels as forcing the cut back. In 1999, Cyprus reportedly expects a 10% to 15% drop in production from its PRB mines.

Thunder Basin Coal Co.'s Black Thunder mine now has the largest haul truck in the world (*Casper Star-Tribune*, 11/24/98). The Liebherr T282 coal

Table 10. Monthly coal deliveries from Wyoming's mines in short tons (1995-September,1998)

	1995		1996		1997		1998	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
JAN	21,586,303	21,586,303	21,793,387	21,793,387	25,165,405	25,165,405	26,536,217	26,536,217
FEB	20,839,926	42,426,229	20,374,055	42,167,442	20,743,224	45,908,629	23,196,152	49,732,369
MAR	21,707,422	64,133,651	22,507,800	64,675,242	22,566,012	68,474,641	23,861,472	73,593,841
APR	20,066,616	84,200,267	22,579,959	87,255,201	20,961,008	89,435,649	24,768,989	98,362,830
MAY	21,509,916	105,710,183	22,216,016	109,471,217	23,102,867	112,538,516	25,278,960	123,641,790
JUN	18,602,505	124,312,688	20,698,814	130,170,031	20,862,610	133,401,126	24,450,835	148,092,625
JUL	21,334,608	145,647,296	24,842,971	155,013,002	24,074,929	157,476,055	25,663,577	173,756,202
AUG	21,356,870	167,004,166	24,421,537	179,434,539	23,002,254	180,478,309	26,591,950	200,348,152
SEP	21,355,730	188,359,896	23,339,792	202,774,331	22,452,566	202,930,875	26,041,099	226,389,251
OCT	21,178,610	209,538,506	22,615,721	225,390,052	21,623,057	224,553,932		
NOV	21,042,260	230,580,766	21,421,085	246,811,137	21,695,072	246,249,004		
DEC	22,032,910	252,613,676	22,105,530	268,916,667	24,695,740	270,944,744		
Total Tonnage Reported[1]		**252,613,676**		**268,916,667**		**270,944,744**		
Total Tonnage Not Reported[2]		**11,324,347**		**9,508,289**		**10,536,772**		
Total Tonnage Produced[3]		**263,938,023**		**278,424,956**		**281,481,516**		

[1]COALDAT Marketing Reports by Resource Data International. Inc. (1995); and from Federal Energy Regulatory Commission (FERC) Form 423, 1996-1998.
[2]Includes estimates of residential, industrial, and exported coal, plus tonnage not reported on FERC's Form 423.
[3]Wyoming State Mine Inspector's Annual Reports.
Wyoming State Geological Survey, Coal Section, January, 1999.

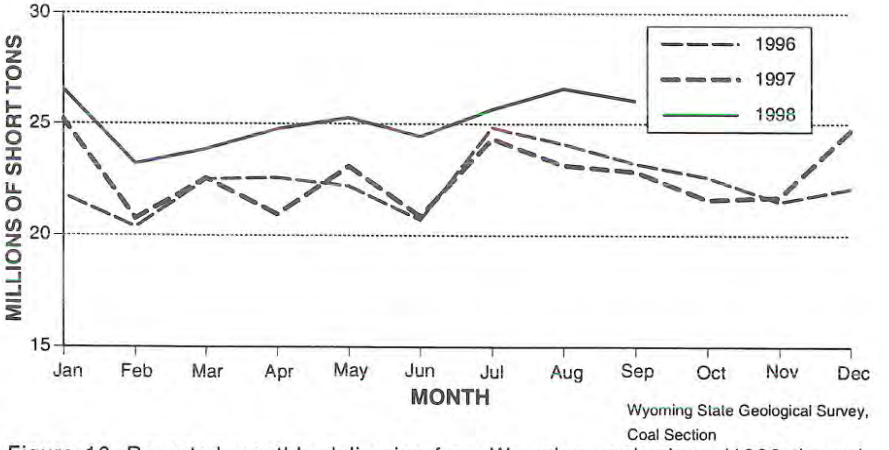


Figure 16. Reported monthly deliveries from Wyoming coal mines (1996 through September, 1998). From the Federal Energy Regulatory Commission's bulletin board.

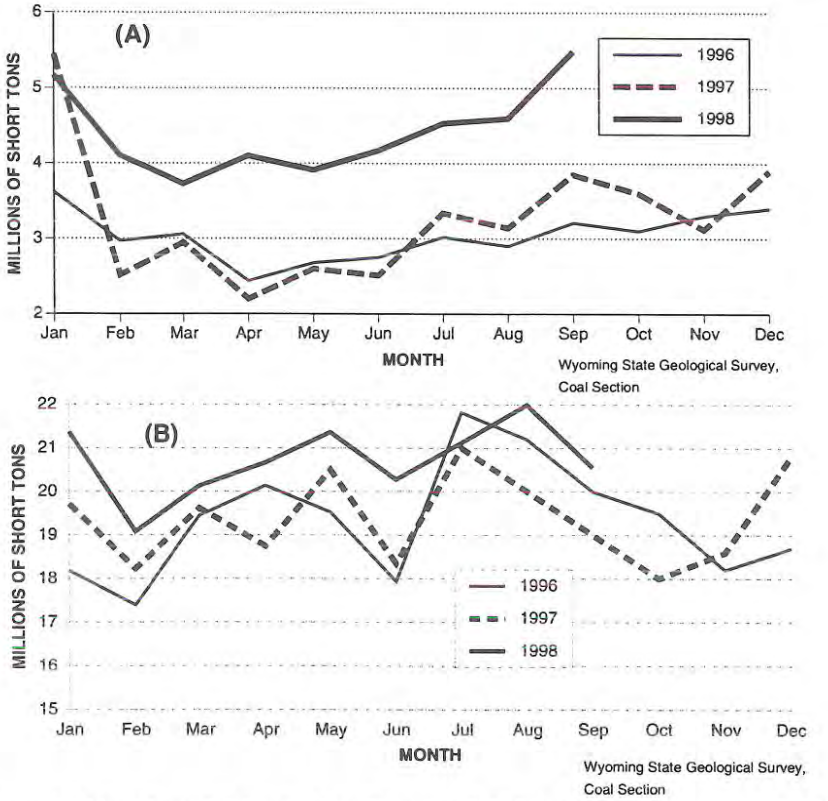


Figure 17. Monthly coal deliveries from Wyoming (1996 through September, 1998). (A) Coal sold on the spot market and (B) coal sold on contract. From the Federal Energy Regulatory Commission's bulletin board.

Table 11. Wyoming coal production by county (in millions of tons), from 1995 to 1997 with forecasts to 2005.

	1995[1]	1996[1]	1997[1]	1998[1]	1999[2]	2000[2]	2001[2]	2002[2]	2003[2]	2004[2]	2005[2]
Campbell County	232.4	245.3	246.3	274.1	292.0	313.0	326.0	329.5	333.2	337.0	340.6
Converse County	14.1	15.8	17.8	23.4	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Sheridan County	M	M	M	M	M	M	M	M	M	M	M
Carbon County	3.8	4.7	5.0	3.5	3.7	2.8	2.0	2.0	2.0	2.0	2.0
Sweetwater County	9.1	8.2	7.8	9.2	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Lincoln County	4.5	4.4	4.6	4.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Total Wyoming	**263.9**	**278.4**	**281.5**	**315.0**	**333.7**	**353.8**	**366.0**	**369.5**	**373.2**	**377.0**	**380.6**
Annual Change	11.4%	5.5%	1.1%	11.9%	6.0%	6.0%	3.4%	1.0%	1.0%	1.0%	1.0%
Higher-priced coal[3]	**26%**	**24%**	**22%**	**17%**	**13%**	**9%**	**6%**	**4%**	**4%**	**4%**	**4%**

[1]Tonnage from the Wyoming State Inspector of Mines. 1995-1998.
[2]County estimates by the Wyoming State Geological Survey, March, 1998.
[3]Estimated percentage of Powder River Basin coal production that is sold at prices above $5.00/ton (older long-term contracts that have not yet expired).
[M means minor tonnage (less than a million tons)].

Table 12. Breakdown of average prices paid for coal from northeastern Wyoming, southern Wyoming, and Wyoming as a whole (1988-1997) with forecasts to 2005.

Year	Northeastern	Southern	Statewide
1988	$7.35	$21.45	$9.16
1989	$6.94	$19.76	$8.63
1990	$6.86	$19.36	$8.43
1991	$6.58	$18.81	$8.06
1992	$6.61	$18.84	$8.13
1993	$6.02	$17.72	$7.12
1994	$5.62	$17.42	$6.62
1995	$5.60	$17.35	$6.38
1996	$5.40	$17.30	$6.15
1997	$5.03	$17.19	$5.78
1998	$4.73	$16.83	$5.42
1999	$4.66	$17.11	$5.31
2000	$4.61	$16.63	$5.17
2001	$4.51	$16.89	$5.04
2002	$4.52	$16.79	$5.04
2003	$4.52	$16.91	$5.04
2004	$4.53	$16.81	$5.04
2005	$4.54	$16.70	$5.04

Statewide data for 1988-1990 are from reports by the U.S. Department of Energy's Energy Information Administration; data for 1991-1997 are derived from Wyoming Department of Revenue information; estimates for 1998-2005 and for all regional breakdowns are by the Wyoming State Geological Survey (January, 1999).

hauling truck has a capacity of 360 tons, stands 25 feet high, and is 28 feet 7 inches wide. It weighs 443,000 pounds empty and over 1.16 million pounds when loaded. Power comes from a Detroit 4000 Series 16-cylinder diesel engine, which generates 2,700 horsepower. It has a 21.5-foot wheelbase and a 53-foot turning radius. The truck runs on a Siemens AC drive system, which is similar to the technology used on the newest railroad locomotives. Each wheel has a 3,000 horsepower AC motor plugged into a gear drive system. Michelin makes the truck's six, 13-foot-diameter tires at an approximate cost of $30,000 each. The tires are expected to have a 15-month running life. The new truck reportedly cost under $3 million.

As part of their mine reclamation, Dry Fork Coal Co. wants to build a water reservoir in the area of its former primary mining pit. Once built, Dry Fork will stock the lake with game fish and offer local residents one of the few places to fish close to home. The lake would cover 53 acres and is designed to hold 1,300 acre-feet of water. Dry Fork hopes the project will save it money as well as benefit the public (*Casper Star-Tribune*, 10/27/98).

AEI Resources expects to close the sale of their Triton Coal Wyoming holdings to Vulcan Capital Management. The purchase includes only the Buckskin and North Rochelle mines in the PRB. *Coal Outlook* (12/14/98) estimates the sale price at $275 million in cash. Vulcan Capital Management is a new equity management firm looking toward its first major venture in the coal industry.

Powder River Coal Co., a subsidiary of Peabody, announced plans to idle their Rawhide mine in March of 1999. Current orders and contracts from this mine will be supplied by the company's other three mines in the PRB.

Powder River Coal Co. is expanding production and improving productivity of its Caballo, North Antelope, and Rochelle mines. At Caballo, the company has gotten a new Model 4100 stripping shovel with a 60-cubic-yard bucket, four new 240-ton haul trucks for overburden removal, and a 270-ton bottom-dump coal hauler. At the North Antelope and Rochelle complex, Powder River has plans to build a $5 million loadout conveyor system. They also plan to add a Model 4100 overburden shovel with a 56-cubic-yard bucket and six, 240-ton overburden trucks.

Coal Outlook (11/23/98) reported that KFx Inc. had sold their idled Fort Union mine to an affiliate in exchange for the affiliate's assumption of all reclamation liabilities related to the mine. The buyer was KFx Fuel Partners, which is the entity that owns the adjacent K-Fuel coal plant.

Developments in Southern Wyoming

Scottish Power Plc, one of the United Kingdom's largest electric utilities, agreed to buy PacifiCorp for an estimated $12.7 billion. Included in the proposed deal is assumption of $4.9 billion in debt, and $7.8 billion in stock for the PacifiCorp holdings. PacifiCorp and Scottish Power officials have met with the U.S. Federal Trade Commission and are confident the deal will go through. In the United Kingdom, government and industry regulating bodies must still approve the sale. The merger should be completed sometime in 1999.

It is believed that the sale to Scottish Power will not impact PacifiCorp's mine-mouth operations at the Jim Bridger power plant. Scottish Power is reportedly interested in maintaining Bridger's status as a low-cost producer of coal-fired electrical generation (*Coal Daily*, 12/8/98).

The U.S. Bureau of Land Management (BLM) has completed the Final Environmental Impact Statement (FEIS) on the proposed Elk Mountain coal mine in Carbon County, Wyoming. The FEIS indicates that the mine's impacts on the environment are manageable. The project is now waiting on the approval of Arch Coal Inc.'s Federal lease application. If the lease is approved, about 5,235 acres of Federal coal reserves will be combined with approximately 15,000 acres of privately owned land, which Arch has already leased for the project (*Coal Daily*, 1/7/99).

Chevron has reportedly received at least three bids for their Pittsburg & Midway coal subsidiary. Details were not confirmed, but one bidder was believed to be a producing coal company while the other two bids came from groups outside the coal industry.

Transportation Developments

On December 10th, the Surface Transportation Board (STB) approved Dakota Minnesota and Eastern (DM&E) railroad's business plan for its expansion into the Powder River Basin. However, a final decision on the expansion project will not be forthcoming until the STB's environmental group completes their Environmental Impact Statement (*Coal Daily*, 12/11/98).

The Burlington Northern Santa Fe (BNSF) railroad has completed construction of new trackage at its South Yard at Alliance, Nebraska. The project included six, new, 7,500-foot-long tracks and two locomotive service tracks. The full length tracks, which run between the BNSF receiving yard and storage tracks, can hold up to six empty sets of unit trains (*Coal Outlook*, 12/7/98). Previously, empty trains often had to sit east of Alliance, tying up trains and crews. The new locomotive service tracks can handle up to 14 engines at a time, giving the locomotive shop more flexibility.

The Union Pacific Southern Pacific (UPSP) railroad has completed restoration of double-track main line in western Iowa. UPSP spent $88 million to restore approximately 32 miles of their Iowa main line. The railroad reports that it now has a 360-mile-long double track crossing the entire state of Iowa. The line currently carries 60 to 70 trains daily. This project expands the carrying capacity to 100 trains a day (*Coal Outlook*, 12/7/98).

Coalbed Methane Developments

Following several widely varying applications for spacing in the coalbed methane play in the Powder River Basin (PRB), the Wyoming Oil and Gas Conservation Commission (WOGCC) has set a docket on its own motion to consider adopting basinwide spacing for coalbed methane wells, at least in the PRB. This docket will be heard on April 12th at the regularly scheduled hearings of the WOGCC.

The Wyoming State Geological Survey has released a map depicting coalbed methane activities in Campbell and Converse Counties in the eastern PRB. The computer-generated map was compiled at a scale of one inch = two miles and shows active wells and permitted locations, gas pipelines and compressor stations, depths to selected coals, selected coal outcrops, and coal mine lease areas. Color plots of Coalbed Methane Map CMM 98-1 can be purchased from the Wyoming State Geological Survey's sales office in Laramie or over-the-counter at the WOGCC offices in Casper. See the section on **New Publications** near the end of this issue for the price as well as ordering instructions.

Denver-based Pennaco started development of a 500,000-acre lease in the PRB in November. Company officials believe that the basin may yield upwards of three trillion cubic feet of the coal-derived gas. Pennaco, which formed only a year ago, plans to spend $20 million to explore and develop its Wyoming holdings (*Casper Star-Tribune*, 11/28/98).

By the end of 1998, Pennaco reportedly drilled 40 wells. Thirty-seven of these wells are located in the South Gillette area, where Pennaco has a 100% interest in the gas. In a January 8th press release, Pennaco stated it would double its rig count to eight. The company plans to drill 600 wells by the end of 1999. Their wells reportedly average 500 to 700 feet deep, and each require about two days to drill.

Sheridan County has made an agreement with Jolen Operating Co., regarding coalbed methane development on lands owned by the county. Sheridan County's lands; however, do not include the mineral estate. Jolen has agreed to pay the county a fee for the use of roads. If gas is found, the operating company will also pay the county $300 a year per well site. If Jolen decides to construct a compressor station at a well head, the charge could go as high as $2,500 per site.

In a January 8th announcement, Western Gas Resources (WGR) indicated its intent to invest approximately $34 million in development of their coalbed methane interests in the PRB. These resources will be used for drilling and well development, as well as for gathering, compression, and pipeline expansion.

In an earlier news release (1/5/99), WGR announced it would participate in Fort Union Gas Gathering LLC's plans to build a 106-mile-long, 24-inch, gathering header for the coalbed methane play in the PRB. WGR will have a 23-1/3 percent interest in the project. Also, WGR will be the construction contractor and field operator for the system.

Regulatory Developments

In the October 5th Federal Register, the Environmental Protection Agency (EPA) issued a revised rule that puts dust from coal preparation plants under New Source Performance Standards (NSPS) for air controls. As a result, Wyoming mines may be impacted by tighter dust restrictions at truck dumps. Prior to this revision, the rule only covered coal crushing, conveying, and screening operations.

The EPA also issued a new rule aimed at cutting nitrogen oxide emissions (*Coal Age*, 12/98, p. 24). The new rule sets a NSPS of 1.5 pounds of nitrogen oxides per mega-watt-hour of gross output. This is the first standard that ties a pollution limit to a unit of produced electricity. The EPA said that its new rule could encourage switching to natural gas, and could have a negative impact on the use of clean coal technology. The EPA feels that coal-fired generators could comply with the new rule by installing emission-controls, such as selective catalytic reduction or selective non-catalytic reduction. Neither of these methods is in widespread use in the U.S. and both are expensive alternatives.

Market Developments and Opportunities

Minnesota Power & Light (MP&L) completed test burns from four sources in the Powder River Basin (PRB). Traditionally, the utility burns PRB coal from Montana, but MP&L is considering switching to a supplier from the Wyoming portion of the basin for at least part of their coal needs. Over the summer and fall of 1998, MP&L tested coal from the Black Thunder mine, the Cordero-Rojo mine complex, the North Rochelle mine, and the North Antelope mine. From these tests, the utility will select a single coal for testing sometime in the first quarter of 1999 (*Coal Daily*, 10/27/98).

In November, Public Service Co. of Colorado was reportedly close to signing an arrangement for PRB coal for its Arapaho plant (*Coal Daily*, 11/4/98). Arapaho started receiving PRB coal in 1997, and by the second quarter of 1998 was burning mostly the PRB product. The utility hopes to structure a contract that will give them access to the spot market when and where they want.

Ontario Hydro released a November solicitation for bids totaling 1.6 million tons. They are seeking PRB coal for use at Nanticoke. Average specifications for the coal included a minimum heat value of 8,800 Btu/lb and a maximum sulfur content of 0.40%.

In November, Illinois Power Co. said it would switch its Baldwin and Hennepin plants to PRB coal (*Coal Daily*, 11/13/98). Phase II of the Clean Air Act of 1990 was cited as their reason for the fuel switch. Switching to the PRB coal at the two plants will back out approximately four million tons of high-sulfur coal from producers in the Illinois Basin.

Mississippi Power Co.'s Daniel plant has been selected to participate in a study that will evaluate ways to increase the efficiency of boilers using low-sulfur PRB coal (*Coal Daily*, 12/8/98). The Electric Power Research Institute (EPRI) selected ADA Environmental Solutions to lead the study. The study will address such items as ash problems associated with PRB coal. Daniel has burned PRB coals from Montana for the past seven years. However, because hundreds of plants burn PRB coal, EPRI fells that the project will have significant value for the utility industry.

Table 13 is a tabulation of some of the contracts, spot sales, tests, and solicitations for Wyoming coal announced during the fourth quarter of 1998.

References Cited

EIA, 1998, Quarterly coal report, October-December 1997: Energy Information Administration Report DOE/EIA-0121 (97/4Q), 144 p.

Stauffenberg, D.G., (1998), Annual report of the State Inspector of Mines of Wyoming for the year ending December 31, 1997: Office of the State Inspector of Mines, Rock Springs, 76 p.

Table 13. Marketing activities for Wyoming coal producers during the fourth quarter of 1998.[1]

	Utility	Power Plant	Region/Coal Mine	Activity	Tonnage	Comments
1.	Alliant Power	Columbia	PRB/Caballo	Sp	3.5 million t	1999 delivery
2.	Alliant Power	System	PRB/Black Thunder	Sp	1.0 million t	1999 delivery
	Alliant Power	System	PRB/Coal Creek	Sp	3.2 million t	1999 delivery
	Alliant Power	System	PRB/Cordero-Rojo	Sp	1.0 million t	1999 delvery
	Alliant Power	System	PRB/Buckskin/North Rochelle	Sp	1.5 million t	1999 delivery
3.	Consumers Energy Corp.	System	PRB	C	2.5 million t/y	2000-2002 delivery
4.	Consumers Energy Corp.	System	PRB	C	4.5 million t/y	2003-2007 delivery
5.	FirstEnergy Corp.	System	PRB	T	Unspecified	1999 test for NOx emmissions
6.	Kansas City Board of Public Utilities	Nearman	PRB/Dry Fork	SP	0.25 million t	1999 delivery, Western Fuels Association
7.	Portland General Electric	Boardman	PRB/Antelope	Sp	1.5 million t	1999 delivery
8.	Southwestern Public Service	Harrington	PRB	So	1.0 million t	1999 delivery, TUCO is agent
9.	St. Joseph Light & Power	Lake Road	PRB	C	0.5-0.25 million t	1999-2001 delivery

[1]Data obtained from: *Coal Week*, *Coal Outlook*, *Coal Daily*, FERC databases, and personal contacts.
Note: C = contract coal; Sp = spot coal; So = solicitation; T = test burn; t =short ton; t/y = short tons per year; and PRB = Powder River Basin.
Wyoming State Geological Survey, January, 1999.

INDUSTRIAL MINERALS AND URANIUM UPDATE

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

Construction Aggregate

Construction aggregate is one of the most abundant natural resources. Aggregates are used in concrete and asphalt, bridges, houses and other buildings, wallboard, roofing, and other structural components. Aggregates range in size from large boulders (rip rap) used as fill in large construction projects to flour-sized particles used in paint, glass, plastic, medicine, agricultural feed and soil conditioners, and many other industrial and household products. Construction aggregates are also used in the purification of water, the control of power plant emissions, and the control of soil erosion.

Aggregates may consist of crushed and sized rock or naturally sized sand and gravel. More than 90% of asphalt pavement and 80% of concrete are construction aggregate. About 60% of all construction aggregate is sand and gravel, while most of the remaining is crushed stone (Tepordei, 1998). A few projects use other aggregate materials such as expanded shale or factory by-products such as mill slag.

Sand and gravel aggregates are dug out of unconsolidated deposits and passed through a series of screens to produce the desired size ranges. Crushed stone aggregates are blasted out of solid rock deposits (limestone, granite, and others), crushed, and then passed through a series of screens. Sand and gravel aggregate is less expensive than crushed stone aggregate, but crushed stone has the advantage of consistency.

Construction aggregate accounts for more than one half of the volume of all mining in the U.S. This equated to 2.3 billion tons of aggregate mined in 1996 (Tepordei, 1998). The production from 1996 is the most current data available.

Construction aggregate was produced in all 50 states in 1998. The most populous states naturally mine most of this product. California, Illinois, Ohio, Pennsylvania, and Texas were the leaders in aggregate production in 1996 (Tepordei, 1998).

Only Delaware, Hawaii, North Dakota, and Rhode Island produced less construction aggregate than Wyoming in 1996. However, construction aggregate is the fourth most important mineral product produced in Wyoming, following in order of value: oil and gas, coal, and trona. Aggregate value exceeds that of bentonite, uranium, and gypsum, when all uses of aggregate, including limestone produced for cement production, are included.

Wyoming produced 11,392,231 short tons of construction aggregate in 1997, according to the State Inspector of Mines of Wyoming. This included railroad ballast, rock used for control of power plant emissions, sand and gravel, and crushed stone. Limestone was the primary crushed stone produced in Wyoming, followed by various types of granite, clinker (baked and fused shale), and shale. Construction aggregate pits are located throughout the State (**Figure 18** and Harris, 1997).

Construction aggregates are among the lowest priced of all mined products. Since they are so low priced, transportation costs can become a major part of their cost to the consumer. In Wyoming, material produced for $2.00 per short ton is subject to transportation costs averaging $1.10 per ton-mile. At transportation distances of less than two miles, the transportation cost exceeds the cost of the product at the quarry. To keep costs down, aggregate sources need to be located as close to the point of use as possible. The need to be near population centers often creates conflicts between aggregate producers and nearby home owners.

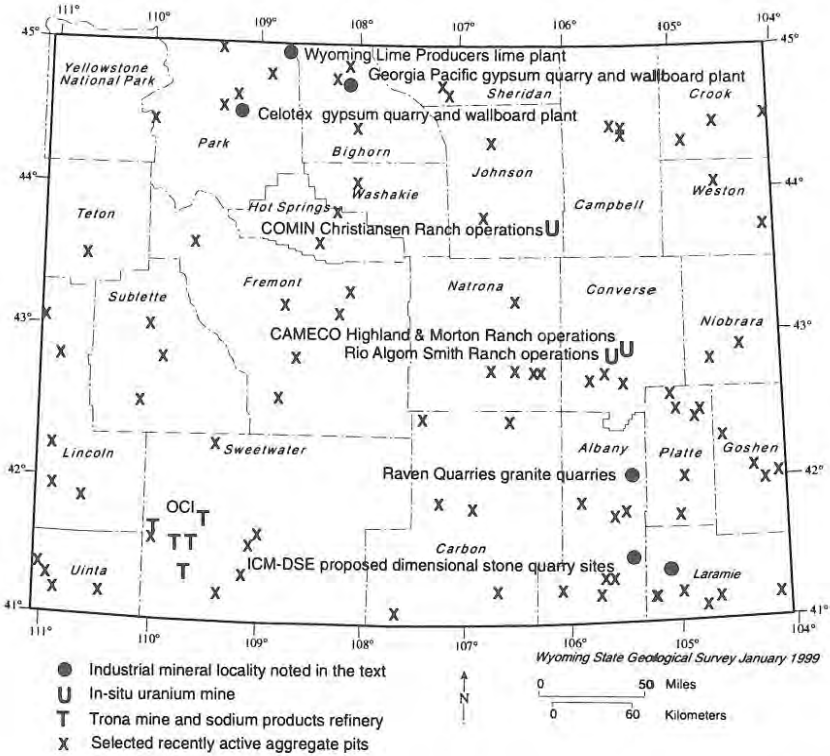


Figure 18. Map of Wyoming's industrial mineral and uranium localities of interest in the fourth quarter of 1998.

These operator and homeowner conflicts are making it more difficult to locate new sources of low-cost construction aggregate. New sources are needed because demand for construction products continues, because the locations of this demand change, and because older sources are being depleted. Typically a construction aggregate source is less than five acres in size.

Wyoming has adequate resources of construction aggregate in most areas of growth, with the notable exception of the Powder River Basin. And continued production is necessary for a sustained economy as well as for economic growth.

Dimensional Stone

Dimensional stone is "any rock that has been removed from its natural place of origin for ultimate use in construction and monuments where the three dimensions of size — width, length, and thickness — together with shape and usually various other elements of appearance, such as color, grain texture and pattern, and surface finish are normal requirements." Durability and strength are other important requirements. (Antonides, 1998).

Raven Quarries is now quarrying pink granite (*Mirage*) at its redesigned quarry in Albany County west of Wheatland (**Figure 18**). Raven is also dismantling its processing facility west of Wheatland and selling the saws and polishing equipment. Production of Raven's black granite (*Wyoming Raven*) and the pink swirled granite (*Fantastico*) may resume as demand warrants.

Dimensional Stone Exploration (DSE) is a Wyoming company owned by International Consulting and Marketing (ICM), an Italian-based manufacturer and distributor of dimensional stone equipment. DSE has applied for permits to quarry limestone and granite at three localities near Laramie and Cheyenne. DSE had been unable to obtain permission to quarry these materials from the holders of grazing leases on lands administered by the U.S. Bureau of Land Management (BLM). However, following discussions between DSE, the BLM, the Wyoming Department of Environmental Quality DEQ), the Wyoming State Geological Survey (WSGS), and the Laramie Economic Development Corporation (LEDC), DSE is proceeding with plans to quarry limestone near Horse Creek in Laramie County. They are also evaluating a newly located limestone site 20 miles northeast of Laramie (**Figure 18**). This potential quarry site was located by the WSGS and shown to DSE in November of 1998.

Gypsum

Two companies mine gypsum in the Bighorn Basin (**Figure 18**). Both companies calcine the gypsum and manufacture wallboard at their plants. These companies mined a combined 459,760 short tons of gypsum in 1997 and are operating at plant capacity.

The Wyoming State Geological Survey is currently assisting in an evaluation of gypsum resources on the Wind River Indian Reservation. This project is a cooperative effort with the Tribal Councils and the Bureau of Indian Affairs.

Lime

Lime is an industrial and environmental chemical used in a variety of ways, including (in order of consumption) steelmaking, desulfurization of flue gas, the manufacture of pulp and paper, construction, purification of water, and the concentration of metallic ore. The term "lime" refers primarily to quicklime (CaO), but also includes hydrated lime ($CaO[OH]_2$), dolomitic quicklime ($CaO \cdot MgO$), type N dolomitic hydrate ($Ca[OH]_2 \cdot MgO$), type S dolomitic hydrate ($Ca[OH]_2 \cdot Mg[OH]_2$), and dead-burned dolomite (a sintered form of dolomite burned with iron to produce a chemically inert refractory product) (Miller, 1998).

Quicklime is produced in Wyoming at the Wyoming Lime Producers' plant in Park County west of Frannie (**Figure 18**). In 1997, this plant used 141,000 short tons of limestone mined in Montana. Their lime production in 1998 reportedly set a new production record.

Trona

Trona is mined at five locations in the Green River Basin west of Green River by underground methods supplemented by solution mining techniques and the recovery of trona from mine water (**Figure 18**). On-site plants refine the trona into soda ash and other sodium-based products.

The production of trona in 1998 is expected to be somewhat less than the record year of 1997 (**Table 1**). This is due primarily to Asian financial difficulties, which have resulted in reduced orders for Wyoming soda ash.

However, Wyoming soda ash producers continue to plan for future expansions. In November, OCI completed an expansion of its production capacity. The processing equipment in the expansion is more efficient than in the older plant, resulting in lower production costs and increased competitiveness in a soft market.

Ninety percent of the soda ash and other sodium chemicals produced in the U.S. are produced from Wyoming's trona deposits. The remaining 10% are produced from surface deposits of trona in California.

In December, American Soda announced plans and applied for permits to mine nahcolite, a sodium mineral similar to trona. They plan to manufacture soda ash at a location in the Piceance Basin near Parachute, Colorado. American Soda's plant is projected to mine 1.4 million short tons of nahcolite and process it into approximately 800,000 short tons of soda ash. This compares with an estimated 18.5 million short tons of trona mined in Wyoming in 1998.

In January of 1999, FMC Corp. announced its intentions to buy Tg Soda Ash. Tg had been on the market for some time. The sale will require some government approvals before it is consummated. With this acquisition, FMC apparently has more Federal sodium lease holdings than allowed by the Federal Mineral Leasing Act of 1920. FMC has been discussing this latter problem with the U.S. Bureau of Land Management.

The Wyoming Oil and Gas Conservation Commission (WOGCC) has proposed new rules for the drilling of deep oil and gas wells in the trona patch of southwestern Wyoming. The rules are designed to help protect miners in the underground trona mines in that region of the State. Comments on the proposed rules will be heard at the WOGCC's hearings in April. Trona operators are also working on some new rules to address the drilling of gas wells completed above the trona mines. Either the WOGCC or the trona operators are expected to propose those rules in the near future.

Uranium

The only uranium produced in Wyoming is by solution mining methods at three localities. These are the Highland-Morton Ranch operation in the southern Powder River Basin (PRB), 100% owned by CAMECO; the Smith Ranch project in the southern PRB, operated by Rio Algom; and the Christiansen Ranch operation in the central PRB, operated by COMIN (**Figure 18**).

According to the Uranium Exchange, the price for uranium decreased in the fourth quarter of 1998, from $9.70 per pound of yellowcake to $8.75 per pound (**Figure 19**). Early this year; however, the U.S. spot market price increased to a January 25th price of $10.50. This price increase may be due to a global firming of demand for nuclear fuel. The Uranium Exchange is on the Internet at: <http://www.uxc.com/top_review.html>

References Cited

Antonides, L.E., 1998, Dimension stone: U.S. Geological Survey Mineral Industry Surveys, 1997 Annual Review, 10 p.

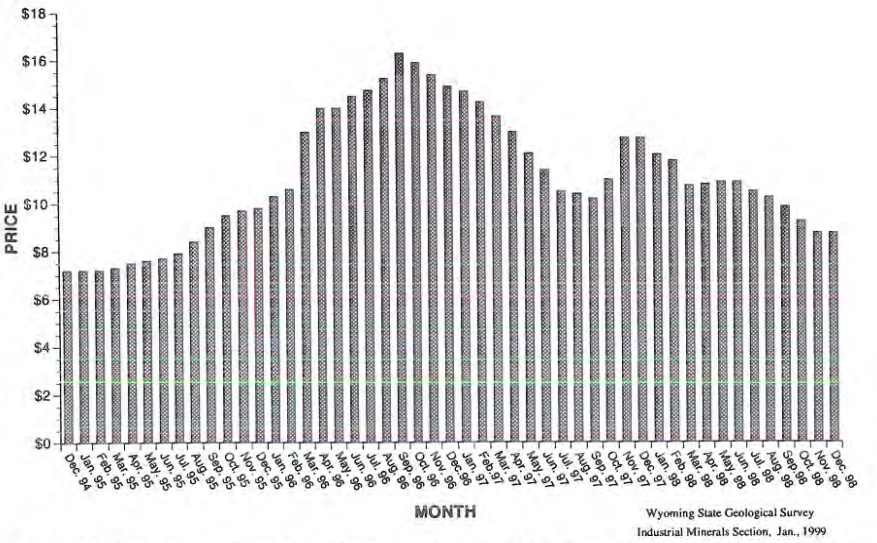


Figure 19. Domestic yellowcake prices, December, 1994, through December, 1998 (from Uranium Exchange).

Harris, R.E., 1997, Industrial minerals and construction materials map of Wyoming: Wyoming State Geological Survey Map Series 47, scale 1:500,000.

Miller, M.M., 1998, Lime: U.S. Geological Survey Mineral Industry Surveys, 1997 Annual Review, 14 p.

Tepordei, V.V., 1998, Natural aggregate — foundation of America's future: U.S. Geological Survey Fact Sheet 144-97 (reprinted September, 1998), 4 p.

METALS AND PRECIOUS STONES UPDATE

W. Dan Hausel, Wayne M. Sutherland, and Robert W. Gregory
Wyoming State Geological Survey

During the past quarter, the Wyoming State Geological Survey (WSGS) published one paper on gold mineralization in the Rattlesnake Hills (Hausel, 1998a), and another on the State's gemstones and related mineral occurrences (Hausel and Sutherland, 1998). The WSGS also responded to numerous inquiries about the State's mineral resources. Many of the inquiries were seeking information on gold, platinum, iron, titanium, diamond, and various gemstone occurrences. One of the more interesting inquiries was from a geophysical and geochemical consulting group that is contracted to develop a new exploration method to find blind (hidden) diamond pipes. They are also looking for new exploration techniques that can differentiate between diamondiferous and barren pipes.

The Head of the Metals and Precious Stones Section of the WSGS, W. Dan Hausel, has been recognized as one of "2,000 outstanding scientists of the century" by the International Biographical Center, Cambridge, England, for contributions to the geological sciences. The Rocky Mountain Prospector's and Treasure Hunter's Club also presented Hausel with an award as the "Prospector's Best Friend".

Gemstones

The WSGS continued to accumulate information on gemstones, as Wyoming has the potential of becoming an important source for raw commercial gemstones, semi-precious stones, ornamental stones, and lapidary material. In past years, the State has been a noted resource for jade and some other lapidary stones. Recent studies by the WSGS indicate that Wyoming is relatively rich in some gems and other ornamental stones.

There is a need to evaluate the economics of developing a gemstone industry in Wyoming. Although the WSGS is identifying and mapping gemstone deposits throughout the State, the economics of gem recovery, cutting, and marketing also need addressed, as these factors are relatively unknown, and outside the expertise of the WSGS.

Some of the more valuable gemstones found in Wyoming include diamond, jade, ruby, sapphire, aquamarine, diamond, peridot, pyrope garnet, chrome diopside, chrome enstatite, cordierite, agate, and jasper.

In the case of diamonds, during the past field season, the WSGS extended its exploration efforts into some less explored portions of the State. These areas include the Bighorn Mountains, Hartville uplift, and the central and northern Laramie Mountains. Exploration for diamonds is considered high-priority by the WSGS, not only because Wyoming has very favorable geology for diamonds, but also because diamond mining could provide a significant new industry for the State.

Australia, Canada, and India have recently developed new diamond industries. In the case of Australia and Canada, their industries were developed through recent exploration of geologically favorable terranes, which are similar to those found in Wyoming.

Prior to 1986, Australia did not have a diamond industry. But following the discovery of a group of diamondiferous olivine lamproites in northwestern Australia, the country now produces 30% of the world's diamonds from one mine.

Until several months ago, Canada did not have a diamond industry. Diamondiferous kimberlites were discovered in the Northwest Territories in the early 1990s, and Canada officially dedicated the Ekati diamond mine in the winter of 1998, following a capitalization of $700 million. More information on the Canadian deposits is available on the following web sites:

<mining-technology.com/projects/ekati/index.html>
<ssimicro.com/~graemeda/diamonds/ index.html>

India's industry was developed to produce cut stones from the Australian mine. India developed a major diamond-cutting center in the early part of this decade, which currently employs 600,000 to 800,000 people (Sevdermish and others, 1998).

In Wyoming, the Iron Mountain kimberlite district, located southwest of Wheatland, continues to be of interest. A large group of kimberlites have been mapped in this district by the WSGS, and many of the kimberlites were sampled to evaluate their geochemistry. Samples collected from the IM7 kimberlite have abundant mantle megacrysts. And a group of pyrope garnets analyzed by electron microprobe have yielded subcalcic 'G10' compositions, suggesting the possibility that this kimberlite may contain diamonds. Many pyropes with G10 chemistry are thought to originate within the diamond-stability field of the Earth's mantle.

The WSGS also continued its mapping, petrographic, and geochemical investigations of the Leucite Hills volcanic rocks. The Leucite Hills lie north of Rock Springs and Superior in southwestern Wyoming. The Leucite Hills include some of the rarest volcanic rocks on the Earth's surface (Hausel and

others, 1995). Besides Wyoming, these ultrapotassic volcanic rocks are found at only a few localities in the world. In the U.S., lamproites have also been reported in Montana, Utah, Kansas, Arkansas, and possibly California (Hausel, 1998b).

Carmicheal (1967) drew comparisons between the Leucite Hills lamproites and kimberlites, suggesting these highly potassic volcanic rocks may have developed by the fractionation of a kimberlitic liquid. According to Carmichael and others (1974), the geochemical similarities between kimberlites and lamproites are related to their source region in the upper mantle. The madupitic lavas, in particular, originated by high-pressure fractional crystallization of a liquid produced by fusion of garnet peridotite. Similar conclusions were drawn by Wade and Prider (1940) for the lamproites in the Kimberley Block of Western Australia, where it was suggested these lavas differentiated from mantle peridotite.

Because of these conclusions, some lamproites are considered favorable sources for diamonds. Diamondiferous lamproites have been known for many years, although these rocks did not attract serious exploration interest until an exploration program was initiated in Western Australia. This interest was based on the concept that lamproites were differentiates of kimberlite (Prider, 1960). This exploration led to the discovery of diamondiferous lamproite in the Ellendale field of the Fitzroy Basin in 1976-1977, and to the discovery of diamondiferous olivine lamproite at the Argyle vent in the East Kimberleys in 1978 (Mitchell and Bergman, 1991).

Gold

The WSGS continued to receive many inquiries about gold. Gold prospecting is fast developing into a significant tourist industry. Each year, prospectors find thousands of dollars in gold in Wyoming. And the many success stories are attracting more and more prospectors to the State. These people spend both tourist and exploration dollars.

Many of the prospectors concentrate on searching for specimen-grade gold samples, including nuggets and quartz specimens with visible gold. Typically, these have high value, and some nuggets will sell for 2 to 3 times the spot price of gold.

The State's most productive gold district is South Pass. This district is located near the southern tip of the Wind River Range in western Wyoming. The available historical records indicate many large nuggets and numerous specimen-grade samples of auriferous quartz have been found in this region (Hausel, 1996).

Some nuggets recently found in the area include a 7.5-ounce nugget found by a prospector searching old tailings with a metal detector, and more than 40 nuggets found by another individual using similar prospecting techniques. Undoubtedly, numerous other unreported nuggets have been found in the area.

References Cited

Carmichael, I.S.E., 1967, The mineralogy and petrology of the volcanic rocks from the Leucite Hills, Wyoming: Contributions to Mineralogy and Petrology, v. 15, p. 24-66.

Carmichael, I.S.E., Turner, F.S., and Verhoogen, J., 1974, Igneous petrology: McGraw-Hill, New York, 739 p.

Hausel, W.D., 1996, Wyoming nuggets: International California Mining Journal, v. 66, no. 4, p. 7-12.

Hausel, W.D., 1998a, The Rattlesnake Hills - Wyoming's little known gold district: International California Mining Journal, v. 68, no. 4, p. 44-46.

Hausel, W.D., 1998b, Diamonds and mantle source rocks in the Wyoming craton with a discussion of other U.S. occurrences: Wyoming State Geological Survey Report of Investigations 53, 93 p.

Hausel, W.D., and Sutherland, W.M., 1998, Preliminary report on gemstones, semi-precious stones, lapidary materials, ornamental stones, and other unique minerals and rocks of Wyoming - a collector's guide: Wyoming State Geological Survey Mineral Report MR98-3, 170 p.

Hausel, W.D., Sutherland, W.M., and Gregory, R.W., 1995, Lamproites, diamond indicator minerals, and related anomalies in the Green River Basin, Wyoming *in* R.W. Jones (editor), Resources of southwestern Wyoming: Wyoming Geological Association 1995 Field Conference Guidebook, p. 137-151.

Mitchell, R.H., and Bergman, S.C., 1991, Petrology of lamproites: Plenum Press, New York, 447 p.

Prider, R.T., 1960, The leucite lamproites of the Fitzroy Basin, Western Australia: Journal of the Geological Society of Australia, v. 6, p. 71-118.

Sevdermish, M., Miciak, A.R., and Levinson, A.A., 1998, The rise to prominence of the modern diamond cutting industry in India: Gems and Gemology, v. 34, no. 1, p. 4-23.

Wade, A., and Prider, R.T., 1940, The leucite-bearing rocks of the West Kimberley area, Western Australia: Quarterly Journal of the Geological Society of London, v. 96, p. 39-98.

MINERAL RESOURCE AND RESERVE BASE ESTIMATES FOR WYOMING

PETROLEUM

Remaining Technically Recoverable Resources (January 1, 1998)
- Discovered (Includes oil, gas liquids, and condensate) ..... 3.47 billion barrels[1]
- Undiscovered ..... 6.18 billion barrels[1]
- Total ..... 9.65 billion barrels

Remaining Reserve Base (January 1, 1998)
- Measured reserves (Proved reserves) (Includes: 0.627 billion barrels of oil and 0.600 billion barrels of gas liquids and condensate) ..... 1.23 billion barrels[2]
- Indicated and inferred reserves (Reserve growth in conventional fields) ..... 2.41 billion barrels[1]
- Total ..... 3.64 billion barrels

NATURAL GAS

Remaining Technically Recoverable Resources (January 1, 1998)
- Discovered (Includes 35.6 trillion cubic feet (TCF) of methane[1] and 121.5 TCF of CO_2[3]) ..... 157.1 trillion cubic feet
- Undiscovered (Includes 14.72 TCF of conventional methane[1]; 5.43 TCF of coalbed methane; 119.3 TCF of methane in tight gas sands in the Green River Basin; and 31.2 TCF of CO_2[3]) ..... 170.6 trillion cubic feet
- Total ..... 327.7 trillion cubic feet

Remaining Reserve Base (January 1, 1998)
- Measured reserves (Proved reserves) (Includes 13.6 TCF of methane[2] and 59.8 TCF of CO_2[3]) ... 73.4 trillion cubic feet
- Indicated and inferred reserves (Reserve growth in conventional fields) ..... 22.8 trillion cubic feet
- Total ..... 96.2 trillion cubic feet

COAL

Remaining Resources (January 1, 1998)
- Identified and Hypothetical (Discovered) ..... 1,426.6 billion tons[4]
- Speculative (Undiscovered) ..... 31.5 billion tons[4]
- Total ..... 1,458.1 billion tons

Remaining Reserve Base (January 1, 1998)
- Demonstrated strippable (Measured and indicated reserve base) ..... 25.0 billion tons[5]
- Demonstrated underground-minable (Measured and indicated reserve base) ..... 42.5 billion tons[5]
- Total ..... 67.5 billion tons

TRONA

Original Resources
- Trona ..... 76.0 billion tons[6]
- Mixed trona and halite ..... 51.0 billion tons[6]
- Total ..... 127.0 billion tons

URANIUM

Remaining Resource (December 31, 1989) ..... 1.99 billion pounds U_3O_8[9]

Remaining Reserve Base (December 31, 1989)
- Uranium oxide recoverable at $30.00 per pound ..... 66 million pounds[7]

OIL SHALE

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

[1] Modified from U.S. Geological Survey National Oil and Gas Resource Team, 1995, 1995 National Assessment of United States oil and gas resources: U.S. Geological Survey Circular 1118, 20 p.
[2] Modified from Energy Information Administration, 1998, U.S. crude oil, natural gas, and natural gas liquids reserves: Advance Summary, 1997 Annual Report: Washington D.C., 12 p.
[3] De Bruin, R.H., 1991, Geological Survey of Wyoming Open File Report 91-6, 20 p.
[4] Modified from Wood, G.H., Jr. and Bour W.V., III, 1988, Coal map of North America: U.S. Geological Survey Special Geologic Map, 1:5,000,000-scale (color) and 44 p. pamphlet.
[5] Modified from Jones, R.W., and Glass, G.B., 1992, Demonstrated reserve base of coal in Wyoming as of January 1, 1991: Geological Survey of Wyoming, Open File Report 92-4, 26 p.
[6] Wiig, S.V., Grundy, W.D., and Dyni, J.R., 1995, Trona resources in the Green River Basin in southwest Wyoming: U.S. Geological Survey Open File Report 95-476, 88 p.
[7] Energy Information Administration, 1989, Uranium industry annual: U.S. Department of Energy Report DOE/EIA-0478(89), 121 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.

GEOLOGIC MAPPING AND PALEONTOLOGY UPDATE

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

NEW MAPPING AND MAP DIGITIZING FUNDED

The Wyoming State Geological Survey (WSGS) recently received notification that two mapping projects had been funded under the U.S. Geological Survey's STATEMAP 99 Program. The STATEMAP proposals were funded in the amount of $39,500, and include the compilation of a 1:100,000-scale geologic map as well as the digitizing of six, completed, 1:100,000-scale, geologic maps. In this cooperative Federal/State program, each Federal dollar is matched with a State dollar (mostly as salary of the primary researcher).

For the STATEMAP 99 Program, the WSGS' Geologic Mapping Section will compile and map the geology for the 1:100,000-scale Lander Quadrangle. The Lander Quadrangle is located in west-central Wyoming, on the west side of the Wind River Basin (**Figure 20**). Very little in the way of published larger-scale geologic mapping exists for much of the area included in the Lander (1:100,000-scale) Quadrangle, and the majority of the existing maps are old and lack an accurate topographic base.

The $19,500 in funding for this project will purchase aerial photography, base map negatives, and orthophoto sheets; provide the salary for one geologic assistant; rent a field vehicle; and reimburse travel expenses. The Lander geologic map will be completed in 2000.

Since the Wyoming Business Council selected Fremont County and specifically the Lander and Riverton areas for promotion of industrial development, an accurate, up-to-date, geologic map will compliment those efforts. With expanding construction in the Lander area, the geologic map will aid in locating sand, gravel, and limestone resources. It will also assist in identifying potential geologic hazards, in the siting of new industrial and housing developments, and in locating and developing ground water resources in the area.

In addition, the WSGS' Geologic Hazards Section will digitize six, 1:100,000-scale, surficial or bedrock geologic maps. The surficial geology maps, which are currently unpublished, preliminary, in-house maps, are the Cody, Lusk, Newcastle, Sundance, and Worland 1:100,000-scale quadrangles (**Figure 20**). The bedrock geologic map is the 1:100,000-scale Laramie Quadrangle (**Figure 20**), which is currently being compiled and mapped by the Geologic Mapping Section under STATEMAP 98. For each map, the geology layer will be scanned, converted from a raster image to a vector image, and edited for consistency with National Digital Mapping Standards.

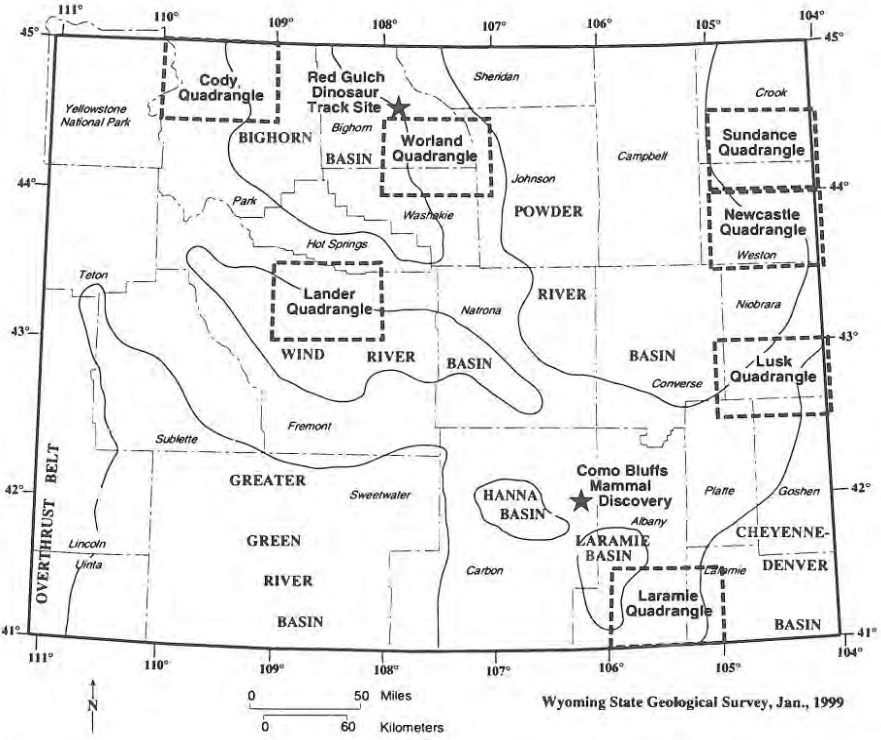


Figure 20. Index to recent paleontologic activities and geologic mapping in Wyoming.

The $20,000 funding for this project will purchase existing, 1:100,000-scale, digital topographic and public land survey data from the EROS Data Center; provide the salary for one geologic assistant; and pay for scanning costs.

Digital geologic maps are now widely used by Federal, State, and local governments, by geologic and geographic researchers, and by private industry. STATEMAP emphasizes the acquisition of new geologic maps and the compilation of existing data at 1:100,000-scale for inclusion in the National Digital Geologic Map Database. This project will provide digital coverages of geologic maps for some of the more populated areas in the State where this type of data is in demand by city and county planners.

This year, the National STATEMAP Review Panel reviewed proposals from 45 State Geological Surveys and competition was quite stiff for available funds. While requests for funding totaled $5,411,123, the available funding was only $3,844,060.

STATEMAP funds have been awarded yearly since passage of the National Geologic Mapping Act in 1992. Funds from this cooperative program

have already helped the WSGS accelerate geologic mapping efforts in Wyoming. Since 1992, the WSGS completed nine maps using funding from this program; an additional eleven maps were completed independent of the STATEMAP funding; and an additional three are in progress with STATEMAP funding.

Nationally, State Geological Surveys have produced 1,907 geologic maps since the program began in 1992; another 699 maps have been completed by state surveys independent of these program funds; and 296 maps are currently in preparation with STATEMAP funding. Efforts have begun to reauthorize the National Geologic Mapping Act of 1992 in order to continue funding of this national mapping initiative.

RED GULCH DINOSAUR TRACKSITE

In the spring of 1998, the Worland District Office of the U.S. Bureau of Land Management (BLM) announced the discovery of fossilized dinosaur footprints on public lands (*Wyoming Geo-notes No. 60*, p. 51-52) near Shell, Wyoming (**Figure 20**). Referred to as the Red Gulch Dinosaur Tracksite, this significant discovery is providing reinterpretations of traditional views of the paleoenvironment of Wyoming during the Middle Jurassic Period (160 to 180 million years ago).

This fall, after the first field season of work, researchers photographed the dinosaur tracks using a radio-controlled airplane supplied by the BLM. The plane has an 8-foot wing span and can fly as slow as 30 miles per hour, which is ideal for taking photos. Repeated passes were made over several acres of the known tracksite, and photos were taken in rapid succession. The photos will be assembled into a high-resolution picture of the site. The photography should aid researchers from the University of Wyoming's Geology Museum in their investigation and mapping of the site.

For those wishing to know more about the Red Gulch tracksite, the BLM has created a web page describing the tracksite and the ongoing research. The web page also provides profiles of the researchers working on the project. The web address is:

<http://www.wy.blm.gov/whatwedo/tracsite/trac.html>

JURASSIC MAMMAL DISCOVERY NAMED

Dr. Robert Bakker recently announced the discovery of a tiny Jurassic plant-eating mammal found in the Morrison Formation near Como Bluff (**Figure 20**). The remnants of a small delicate jaw indicate the creature was no larger than a squirrel. Dr. Bakker, following a 20-year tradition of naming fossil discoveries after a colleague who has helped unearth the story of evolution, named the

new discovery, *Ctenacodon brentaatar*, in honor of Brent Breithaupt, director of the University of Wyoming's Geology Museum. *Ctenacodon brentaatar* joins three other little mammals, a dozen small dinosaurs, five turtles, a lizard-like creature, a pterodactyl, and an *Apatosaurus*, as significant finds from this productive fossil site near Como Bluff.

NEW FOSSIL COLLECTING RULES ON STATE LANDS

The Wyoming Office of State Lands and Investments recently released new rules for commercial and scientific fossil collecting on State lands. Public hearings were held on the proposed rule changes in September of 1997 in Gillette and in Worland. Public comments were received on the rules following these hearings, and a meeting was held with commercial and scientific collectors in May of 1998. The revised rules include new definitions and clarifications, as well as new terms for obtaining and operating commercial and scientific fossil collecting permits.

Some changes of note include: (1) a minimum annual royalty payment of $10,000 for commercial permits, (2) a 10% royalty rate (based on sales price) on all sales above the $10,000 minimum, (3) approval for the sale of gars, stingrays, bowfins, and paddlefish specimens, subject to the above royalties; (4) the right to inspect the books, sales records, and tax returns of a permittee to verify compliance with the required royalty payments; and (5) a provision for the casual collection of fossils on State lands. These new rules are designated Chapter 11 of the rules and regulations of the Office of State Lands and Investments.

SEISMOLOGICAL CHARACTERIZATION FOR NATRONA COUNTY AND SURROUNDING AREAS

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

BACKGROUND

Seismological characterizations of an area can range from an analysis of historic seismicity to a long-term probabilistic seismic hazard assessment. A complete characterization usually includes a summary of historic seismicity, an analysis of the Seismic Zone Map of the Uniform Building Code, deterministic analyses on active faults, "floating earthquake" analyses, and short- or long-

term probabilistic seismic hazard analyses. The Wyoming State Geological Survey has completed a seismological characterization for Natrona County (Case, in preparation). Key points from the report are summarized below.

HISTORIC SEISMICITY

Natrona County has had a number of earthquakes recorded within its borders over the last 104 years, with some causing significant damage. Residents within the county have also felt or have had property damaged by earthquakes originating outside of the County. While the first reported earthquake occurred in 1894, the last earthquake that was felt in the County occurred in 1996. Historically, the region has had a moderate level of seismicity compared to the rest of the State. A detailed map of earthquake epicenters is available at the Wyoming State Geological Survey (Case and others, 1997). A summary of significant earthquakes is presented in *Wyoming Geo-notes No. 51*, and a description of all earthquakes in and around Natrona County is presented in Case (in preparation).

UNIFORM BUILDING CODE

The Uniform Building Code (UBC) is a document prepared by the International Conference of Building Officials. It contains information and guidance on designing buildings and structures to withstand seismic events (*Wyoming Geo-notes No. 47*). Information presented in the UBC and supporting documents generated by the Seismology Committee of the Structural Engineers Association of California (Building Standards, September-October, 1986), indicate non-critical facilities in Natrona County should be designed for effective peak accelerations (90% chance of non-exceedance in 50 years) between 5%-10%g, (average peak acceleration of 7.5%g). Depending on the type of facility, more stringent regulations and criteria may apply.

DETERMINISTIC ANALYSIS OF REGIONAL ACTIVE FAULTS WITH A SURFICIAL EXPRESSION

Natrona County has one suspected active fault system within its borders and a known active fault system just outside of the County. The suspected system is the Cedar Ridge/Dry Fork fault system, which is located along the south flank of the Bridger and Bighorn Mountains. The Dry Fork fault extends into the northwestern part of the County.

The known system is the South Granite Mountain fault system, which trends west-northwest along the northern flanks of the Seminoe Mountains, Ferris Mountains, Green Mountain, and Crooks Mountain. The South Granite Mountain fault system is capable of generating a magnitude 6.75 earthquake, the Dry Fork fault may be capable of generating a magnitude 6.5 earthquake, and the entire Cedar Ridge fault system may be capable of generating a magnitude 7.1 earthquake (Case, in preparation).

If the South Granite Mountain fault system activates, it could generate a peak horizontal acceleration of 3%g in the Casper area and 6.5%g in the Alcova area. These accelerations are roughly equivalent to an intensity V to VI earthquake, and could cause minor damage in those areas.

If the Dry Fork fault system activates as an isolated system, it could potentially generate a peak horizontal acceleration of 7.8%g at Hells Half Acre and 2.5%g at Midwest. These accelerations are roughly equivalent to an intensity VI earthquake at Hells Half Acre and an intensity IV earthquake at Midwest. Minor damage could occur at Hells Half Acre. If the entire Cedar Ridge/Dry Fork fault system activates, it could generate a peak horizontal acceleration of 8.5%g at Hells Half Acre and 2.7%g at Midwest, which are roughly equivalent to an intensity VI to VII earthquake at Hells Half Acre and an intensity IV earthquake at Midwest. Moderate damage could occur at Hells Half Acre.

MAXIMUM TECTONIC PROVINCE EARTHQUAKE - "FLOATING EARTHQUAKE"/SEISMOGENIC SOURCE

Many Federal regulations require an analysis of the earthquake potential in areas where active faults are not exposed, and where earthquakes are tied to buried faults with no surface expression. Regions with a uniform potential for the occurrence of such earthquakes are called tectonic provinces. Within a tectonic province, earthquakes associated with buried faults are assumed to occur randomly, and as a result can theoretically occur anywhere within that area of uniform earthquake potential. In reality, that random distribution may not be the case, as all earthquakes are associated with specific faults. If all buried faults have not been identified; however, the distribution has to be considered random. "Floating earthquakes" or seismogenic sources are earthquakes that are considered to occur randomly in a tectonic province.

Geomatrix (1988b) placed Natrona County in the "Wyoming Foreland Structural Province", and estimated that the largest "floating" earthquake would have a magnitude in the 6.0 – 6.5 range, with an average value of magnitude 6.25. A magnitude 6.25 "floating" earthquake, placed 15 kilometers from any site in Natrona County, would generate horizontal accelerations of approximately 15%g at the site.

Federal or state regulations usually specify if a "floating earthquake," seismogenic source, or tectonic province analysis is required for specific types of facilities. Those regulations also generally specify at what distance a "floating earthquake" should be placed from a facility to adequately evaluate its design.

PROBABILISTIC SEISMIC HAZARD ANALYSES

The U.S. Geological Survey (USGS) publishes probabilistic acceleration maps for 500-, 1000-, and 2,500-year time frames. The maps show what accelerations may be met or exceeded in those time frames by expressing the probability that the accelerations will be met or exceeded in a shorter time frame. For example, a 10% probability that acceleration may be met or exceeded in 50 years is roughly equivalent to a 100% probability of exceedance in 500 years. The USGS has recently generated new probabilistic acceleration maps for Wyoming, which include a 500-year map (10% probability of exceedance in 50 years), a 1000-year map (5% probability of exceedance in 50 years), and a 2,500-year map (2% probability of exceedance in 50 years). The 500-year map is often used for planning purposes for average structures, because a 10% chance of meeting or exceeding the accelerations shown on the map in 50 years is considered acceptable in the design of average structures. For more critical structures, the 2,500-year map may be useful for design purposes. The maps reflect current perceptions on seismicity in Wyoming. Copies of the maps can be obtained from the Geologic Hazards Section of the Wyoming State Geological Survey.

Based upon the 500-year map, the estimated peak horizontal accelerations in Natrona County are near 6%g. That acceleration is comparable to an intensity V – VI earthquake, and is similar to the 7.5%g acceleration derived from the Uniform Building Code. An intensity V-VI earthquake can cause minor damage. Based upon the 1000-year map, the estimated peak accelerations in Natrona County are approximately 10%g to 12%g. Those accelerations are comparable to an intensity VI - VII earthquake, which can result in minor to moderate damage. Based upon the 2500-year map, the estimated peak accelerations in Natrona County are approximately 16%g to greater than 20%g. Those accelerations are comparable to an intensity VII-VIII earthquake, which can result in moderate to major damage.

SUMMARY

Damaging earthquakes have occurred and will continue to occur in Natrona County. A maximum credible "random" earthquake of magnitude 6.25 is postulated for the County. In addition, known or suspected active fault systems in or

near the County are capable of generating earthquakes in the magnitude 6.75 – 7.1 range.

Average facilities and homes in Natrona County should be designed to withstand an intensity VI earthquake or an earthquake that would produce a peak horizontal acceleration of 7.5%g. Critical facilities should be designed to a higher standard.

References Cited

Case, J.C., in preparation, Basic seismological characterization for Natrona County and surrounding areas: Wyoming State Geological Survey, Geologic Hazards Section Preliminary Hazards Report 99-1.

Case, J.C., Larsen L.L., Boyd, C.S., and Cannia, J.C., 1997, Earthquake epicenters and suspected active faults with surficial expression in Wyoming: Wyoming State Geological Survey Geologic Hazards Section Preliminary Hazards Report 97-1, scale 1:1,000,000.

Geomatrix Consultants, Inc., 1988, Seismotectonic evaluation of the Wyoming Basin geomorphic province: Report prepared for the U.S. Bureau of Reclamation, Contract No. 6-CS-81-07310, 167 p.

ROCK HOUND'S CORNER

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

JADE

Jade is a gemologist's designation applied to two distinct and unrelated mineral species: nephrite and jadeite. Of the two gemstones, only nephrite has been found in Wyoming. Enough nephrite has been found in the State that nephrite jade is often considered synonymous with *Wyoming jade*, even though nephrite is found elsewhere in the world.

Nephrite is an amphibole that is formed of extremely dense and compact fibrous tremolite-actinolite; whereas jadeite is a pyroxene of the augite series. In hand-specimen, these two minerals closely resemble one another, and are essentially indistinguishable without the aid of physical tests, such as petrographic and (or) x-ray diffraction analysis.

Many similar appearing rocks are often mistaken for nephrite jade such as rounded, stream-worn or wind-polished cobbles of amphibolite, metadiabase, epidotite, quartzite, leucocratic (white) granite, and serpentinite. These rocks are distinguishable from jade by any number of tests including some simple field observations. For example, amphibolite, metadiabase, and leucocratic granite typically have a granular texture that is lacking in jade; the freshly broken surface of quartzite tends to sparkle in sunlight due to the reflection of light off individual quartz grains; epidotite has a distinct pistacio green color and perfect cleavage; and serpentinite is relatively soft and is often easily scratched with a pocket knife. In addition, serpentinite exhibits pockets or zones of weak to moderate magnetism. Jade is not magnetic.

Nephrite jade [$Ca_2(Fe, Mg)_5(Si_4O_{11})_2(OH)_2$] never shows any external structure, unless it occurs as a pseudomorph of another mineral. As an example, in the Granite Mountains of central Wyoming, nephrite has been found as a psuedomorph of quartz. These specimens of jade occur in a pseudohexagonal habit (six-sided prism); but they are uncommon. Typically, nephrite jade occurs in irregular masses and lacks cleavage.

Microscopic examination of nephrite typically shows a mass of matted, intricately interwoven fibers. This unusual form makes nephrite jade extremely tough and resistant to fracturing [toughness can be represented by fracture strength, which is about 30,000 psi for nephrite (Bradt and others, 1973)]. As a result, unless the rock has a schistose fabric, rounded boulders of nephrite are nearly impossible to break with a hammer. Because of its toughness and attractive appearance, nephrite has been termed the *axe stone*. It has been prized since prehistoric times.

Only carbonado, a black granular to compact industrial form of diamond, is tougher than jade. However, gem-quality diamond, which is the hardest known mineral found in nature, lacks the toughness of jade and is easily smashed with a hammer. It is the toughness of jade, combined with its hardness, that makes the gemstone durable and suitable for carving.

Nephrite has a specific gravity of 2.9 to 3.02. Its hardness, as reported by Bauer (1968) and Hurlbut and Switzer (1979), ranges from 6 to 6.5. The mineral occurs as opaque to translucent masses and has a vitreous to almost waxy luster. Nephrite can be black, white, and a variety of green shades.

The green color in nephrite jade is the result of iron within the crystal lattice. When iron is absent, the mineral is practically colorless to cloudy white, resulting in a variety known as *muttonfat jade*. Other varieties of Wyoming jade include translucent, emerald-green *imperial jade*; *apple-green* jade, *olive-green* jade, *leaf-green* jade, *black* jade, and *snowflake* (mottled) jade (Bauer, 1968). The greater commercial values are attached to the lighter green, translucent varieties.

The origin of Wyoming jade was investigated by Sherer (1969), who suggested that nephrite jade developed by metasomatic alteration of amphibole during metamorphism. According to Sherer, blocks of amphibolite were disrupted more than 2.5 billion years ago and trapped in quartzofeldspathic gneiss. Portions of the amphibolite xenoliths were then altered to nephrite by metamorphic fluids derived from regional, amphibolite-grade metamorphism. In other words, amphibole (which is represented by the mineral hornblende, a major consituent of amphibolite) reacted with the hot metamorphic fluids (water) producing actinolite (nephrite jade), clinozoisite, and chlorite. The simplified chemical reaction can be written as:

$$25Ca_2(Mg, Fe)_3Al_4Si_6O_{22}(OH)_2 + 4H_2O = Ca_2(Mg, Fe)_5Al_4Si_8O_{22}(OH)_2 + 24Ca_2Al_{34}Si_3O_{12}(OH) + 14Mg_5Al_2Si_3O_{10}(OH)_8$$

or

amphibole + water = actinolite (nephrite jade) + clinozoisite + chlorite

Along with nephrite, a distinct wallrock alteration assemblage is produced. Typically, the bleached leucocratic granite-gneiss adjacent to jade is often mottled pink and white due to the presence of secondary clinozoisite, pink zoisite, pistacio green epidote, green chlorite, as well as white plagioclase, which is pervasively altered to white mica. For example, rocks displaying this alteration assemblage are often found scattered in the gneiss between known jade deposits in the Tin Cup district in the Granite Mountains of central Wyoming. Because these assemblages suggest the presence of jade, their occurrence is useful as a guide to finding blind (hidden) jade deposits.

Individual pieces of detrital jade can vary in appearance. Some pieces may be covered with a cream to reddish-brown weathered rind that hides the characteristic color of the jade. But where naturally polished to a high-gloss, waxy, surface, known as *slicks*, the detrital jade is recognizable.

Large volumes of jade were recovered from central Wyoming a few decades ago; and small quantities of the gemstone can still be found. Jade has been reported as far west as the Wind River Range (McFall, 1976), and as far east as Guernsey and the Laramie Mountains. To the north, it has been reported in the Wind River Basin. It has also been found at the Rawlins golf course to the south near Interstate 80 (Hagner, 1945) and farther south in the Sage Creek Basin near the Sierra Madre mountains.

Several large boulders have been found in Wyoming. The largest was a 14,000-pound boulder of low-quality black jade reportedly found in the Prospect Mountains (Root, 1980) at the southern end of the Wind River Range (Hemrick, 1975). Some spectacular specimens of green jade have been found in the central part of the State in the Granite Mountains and Crooks Gap regions near Jeffrey City.

References Cited

Bauer, M., 1968, Precious stones, Volume 2: Dover Publications, Inc., New York, p. 261-627.

Bradt, R.C., Newnham, R.E., and Biggers, J.V., 1973, The romance of jade: Earth and Mineral Sciences, Pennsylvania State University, v. 42, no. 4, p. 29-30.

Hagner, A.F., 1945, Diehl-Branham jade: Wyoming State Geological Survey Mineral Report MR45-7, 2 p.

Hemrich, G.I., 1975, The Game Warden's jade: Gems & Minerals, no. 457, p. 8-15.

Hurlbut, C.S., Jr., and Switzer, G.S., 1979, Gemology: John Wiley and Sons, New York, 243 p.

McFall, R.P., 1976, Wyoming jade: Lapidary Journal, v. 30, no. 1, p. 182-194.

Root, F., 1980, Wyoming jade: Geological Survey of Wyoming Information Circular, 8 p.

Sherer, R.L., 1969, Nephrite deposits of the Granite, Seminoe, and Laramie Mountains, Wyoming: PhD dissertation, University of Wyoming, Laramie, 194 p.

LANCE COOK, NEW STATE GEOLOGIST

In January, Governor Geringer named Lance Cook as the new State Geologist of Wyoming. Mr. Cook replaced Gary Glass, who retired at the end of March.

The State Geologist is the chief administrative officer for the Wyoming State Geological Survey, which promotes the beneficial and environmentally sound use of Wyoming's vast geologic, mineral, and energy resources. The State Geologist also serves on the Wyoming Oil and Gas Conservation Commission, the Wyoming Board of Professional Geologists, the Governor's Natural Resources Sub-cabinet, and the Consensus Revenue Estimating Group.

Mr. Cook has been employed by Union Pacific Resources (UPR) in Denver and Fort Worth, Texas, since 1984. Since 1994, he has served as the senior geologist assigned to UPR's Wyoming Overthrust Team.

Governor Geringer said Mr. Cook's experience in and knowledge of Wyoming's oil and gas industry, mining practices, and natural resources will be valuable assets in his new job. "Lance has almost 20 years of professional geological experience, much of it involving the State of Wyoming," he noted. "He has a thorough knowledge of Wyoming geology. He understands the State's Oil and Gas Conservation Commission and is well versed in issues regarding mineral law, Federal and State leasing procedures, state politics, and the personal side of Wyoming."

"This is a dream job for me," Cook said. "I am extremely happy to be here in Wyoming. It is an honor and privilege to serve as a state geologist."

Mr. Cook has moved to Wyoming and set up residence in Laramie. His wife will join him in May of 1999.

NEW PUBLICATIONS BY THE WYOMING STATE GEOLOGICAL SURVEY

Publications available from the Wyoming State Geological Survey, September, 1998 - free.

Proceedings of the First International Soda Ash Conference - Volume II, edited by J.R. Dyni and R.W. Jones, 1998: Public Information Circular 40 - $25.00. ISBN 1-884589-14-6.

Coalbed methane activity in the eastern Powder River Basin, Campbell and Converse Counties, Wyoming, by R.H. De Bruin, R.M. Lyman, and L.L. Hallberg, 1998: Coalbed Methane Map CMM 98-1 - $25.00, rolled only.

A review of Wyoming's coal mines and markets, 1998, by R.M. Lyman and L.L. Hallberg, 1998: Coal Report CR 98-1 - $15.00.

Subsurface correlation of selected Late Cretaceous and older formations along the eastern Powder River Basin, Wyoming (Cross section B-B'), by R.H. De Bruin, 1998: Geophysical Log Cross Section GLCS 98-1 - $5.00, available only as a rolled blueline copy.

Digital geologic map of the Cheyenne 30' x 60' Quadrangle, southeastern Wyoming, western Nebraska, and northern Colorado, by A.J. Ver Ploeg, J.C. Case, and C.A. Jessen, 1998: Geologic Hazards Section Digital Map HSDM 98-2 - $10.00 on CD-ROM for PC-based computers using Windows 95/98 or Windows NT; $25.00 for a plotted color map.

Preliminary digital surficial geologic map of the Casper 30' x 60' Quadrangle, Natrona and Converse Counties, Wyoming, by J.C. Case, L.L. Hallberg, and C.A. Jessen, 1998: Geologic Hazards Section Digital Map HSDM 98-3 - $10.00 on CD-ROM for PC-based computers using Windows 95/98 or Windows NT; $25.00 for a plotted color map.

Preliminary digital surficial geologic map of the Cheyenne 30' x 60' Quadrangle, southeastern Wyoming, western Nebraska, and northern Colorado, by J.C. Case, L.L. Hallberg, and C.A. Jessen, 1998: Geologic Hazards Section Digital Map HSDM 98-4 - $10.00 on CD-ROM for PC-based computers using Windows 95/98 or Windows NT; $25.00 for a plotted color map.

Preliminary digital surficial geologic map of the Laramie 30' x 60' Quadrangle, Albany and Laramie Counties, Wyoming, by J.C. Case, L.L. Hallberg, and C.A. Jessen, 1998: Geologic Hazards Section Digital Map HSDM 98-5 - $10.00 on CD-ROM for PC-based computers using Windows 95/98 or Windows NT; $25.00 for a plotted color map.

Preliminary digital surficial geologic map of the Rawlins 30' x 60' Quadrangle, Carbon and Sweetwater Counties, Wyoming, by J.C. Case, L.L. Hallberg, and C.A. Jessen, 1998: Geologic Hazards Section Digital Map HSDM 98-6 - $10.00 on CD-ROM for PC-based computers using Windows 95/98 or Windows NT; $25.00 for a plotted color map.

[Note: Geologic Hazards Section Digital Maps HSDMs 98-2 through 98-6 are also available on one CD-ROM for $40.00; a set of all five CD-ROMs (purchased at one time) are also $40.00].

*Preliminary report on gemstones, semi-precious stones, lapidary materials, ornamental stones, and other unique minerals and rocks of Wyoming, by W. D. Hausel and W.M. Sutherland, 1998: Mineral Report MR 98-3 - $26.00.

Each geologic section of the Survey now prepares and releases some of its own numbered reports and maps. Please contact the following Staff Geologists for coverage, availability, prices, or further information on specific commodities or topics [Phone:(307) 766-2286; FAX: (307) 766-2605; or use the Email addresses included below]:

James C. Case - Geologic hazards and environmental geology
(Email: jcase@wsgs.uwyo.edu)

Rodney H. De Bruin - Oil and gas
(Email: rdebru@wsgs.uwyo.edu)

Ray E. Harris - Industrial minerals and uranium
(Email: rharri@wsgs.uwyo.edu)

W. Dan Hausel - Metals and precious stones
(Email: dhause@wsgs.uwyo.edu)

Robert M. Lyman- Coal
(Email: blyman@wsgs.uwyo.edu)

Alan J. Ver Ploeg - Geologic mapping, paleontology, and stratigraphy
(Email: averpl@wsgs.uwyo.edu)

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

Order these and other publications from: Wyoming State Geological Survey, P.O. Box 3008, Laramie, Wyoming 82071-3008. Phone: (307) 766-2286; Fax (307) 766-2605; and Email: sales@wsgs.uwyo.edu. An order form is also included at the back of this issue of *Wyoming Geo-notes*. Many of these publications are also available over-the-counter at the Wyoming Oil and Gas Conservation Commission (Basko Building) in Casper, Wyoming. A free list of publications is available on request, and this list as well as an order form is now available on our Web site: http://www.wsgsweb.uwyo.edu

RECREATIONAL MAP PURCHASERS!

Many of the U.S. Geological Survey's (USGS's) new, 1:24,000-scale, topographic maps that cover areas of National Forests now include highlighted Forest boundaries, inholdings of non-Forest lands within the Forest, numbered Forest Service roads and trails, and Forest Service campgrounds and other facilities. All the new maps now being sold also contain a Universal Product Codes bar.

We also carry the U.S. Bureau of Land Management's (BLM's) Surface Management Status maps for the 1:100,000-scale, metric, topographic quadrangles in Wyoming -$6.50 each. Coverage and inventory may be limited for specific areas; please call for map availability.

In addition, we carry the *Recreational map of Wyoming*, published by GTR Mapping. This folded, glove-compartment-style map is available for $3.95. The 1:792,000-scale (1 inch equals about 12.5 miles) map is an ideal companion to the *Wyoming geologic highway map*, which is also available at $7.00. In addition, we have an illustrated discussion of the geology across southern Wyoming titled, *A geological traverse across Wyoming following Interstate 80,* which is published as Public Information Circular 37 - $4.00.

These maps (plus other topographic maps of Wyoming) are available over-the-counter at the Survey offices in Laramie or by mail. We do not offer quantity discounts and can make no exchanges or refunds on the USGS, BLM, or GTR maps. Sales tax of 6% is added to all sales for Wyoming addresses. Postage and additional charges for map tubes for rolled maps are added on when appropriate.

ORDER FORM

Send this order and make checks payable to:

Wyoming State Geological Survey
P.O. Box 3008
Laramie, Wyoming 82071-3008

_____

_____

_____

_____

_____

Phone: (307) 766-2286
Fax: (307) 766-2605
Email: sales@wsgs.uwyo.edu

_____

Quantity	Publication	Publication Title	Price	Total

*No postage charged on prepaid orders unless otherwise specified. If ordering **Memoir 5,** postage for shipping each copy is: $5.00 (Wyoming), $10.00 (other U.S. States), and

Rolled maps ($1.50 each tube)	
WYOMING RESIDENTS ADD 6% SALES TAX	
TOTAL ENCLOSED*	

Wyoming State Geological Survey
P.O. Box 3008
Laramie, Wyoming 82071-3008