Wyoming Geo-notes
Number 72

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Highway-affecting landslides of the Snake River Canyon

GIS activities at the Wyoming State Geological Survey

STATE OF WYOMING GEOLOGICAL SURVEY 1933

Wyoming State Geological Survey
Lance Cook, State Geologist

Laramie, Wyoming
December, 2001

Featured Articles

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WYOMING GEO-NOTES: This quarterly digest on the state's geology, mineral resources, and activities of the Wyoming State Geological Survey is available by subscription (four issues for $15.00) or as single copies at $5.00 each. Two-year subscriptions are accepted.

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Front cover: Channel of the Snake River near the Elbow Slide, Snake River Canyon, Wyoming. The river is cutting into a fill bank upon which U.S. Highway 26/89 (dashed line) is built. Vertical distance from river level to the highway is about 65 feet. An article entitled "Highway-affecting landslides of the Snake River Canyon–Part I, Overview and the Elbow Slide" (see page 30 of this issue) describes how the highway was widened and the slopes stabilized without disturbing or affecting a large landslide complex above and adjacent to the project. Photograph by Mark A. Falk, June, 1998.

MINERALS UPDATE

Overview

Lance Cook, P.G.

State Geologist–Wyoming State Geological Survey

Natural gas and coal have been the bright spots for the state's mineral industry so far this year. Increased natural gas production, especially from coalbed methane, and better access to out-of-state gas markets (from increased pipeline capacity) are offsetting much of the decreases in natural gas prices experienced during the year. Coal production is headed for another record year and prices appear to be improving slightly for the first time in many years. Other mineral commodities produced in the state appear to be holding their own, with the exception of declining oil production. A more complete analysis of individual minerals appears in the update articles that follow.

. . . the overall mineral revenue picture for the state is not as rosy as it appeared earlier this year. . .

New features

This issue of *Wyoming Geo-notes* debuts several new features, including a calendar of upcoming meetings and events involving Wyoming State Geological Survey (WSGS) personnel and a section on geographic information systems (GIS) activities at the Survey. This issue also describes a pipeline database/mapping project that was recently funded as well as our new STATEMAP 2002 project proposals that have also been funded. Finally, this issue starts a three-part series describing the geotechnical and engineering work the Wyoming Highway Department has done to mitigate landslide damage along the Snake River Canyon Highway.

Third quarter mineral activity

Prices for Wyoming's three major energy minerals–oil, natural gas, and coal–all decreased in the third quarter, with the largest decrease shown in natural gas prices. Because of the high price "spike" in oil and gas at the end of last year and early this year, we saw those prices drop rapidly in the first quarter and then start to stabilize by the third quarter. Apparently the price fluctuations for energy minerals are not having an impact on the state's natural gas or coal production as both will report new yearly records in 2001 (**Table 1**).

The Consensus Revenue Estimating Group (CREG) for the State of Wyoming published their new mineral production and price estimates in October, and for the most part they agree with what we have predicted in our last few issues of *Wyoming Geo-notes*. Estimated production of natural gas components (including methane, carbon dioxide, helium, and coalbed methane) has been revised upward while oil and trona production estimates have been revised down-

Table 1. Wyoming mineral production (1985 through 2000) with forecasts to 2006[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	1023.4	149.0	1.10	278.4	18.6	1.9	1.22
1997	70.2	1040.7	151.0	1.10	281.5	19.4	2.2	1.23
1998	65.7	1072.6	151.0	1.10	315.0	18.6	2.3	1.20
1999	61.3	1133.1	161.0	1.10	336.5	17.8	2.8	1.20
2000	60.6	1292.9	161.0	1.10	338.9	17.8	2.1	1.20
2001	57.2	1424.8	174.0	1.20	354.5	18.0	2.0	1.20
2002	54.0	1504.8	174.0	1.20	358.0	18.0	2.0	1.20
2003	51.0	1562.8	196.0	1.20	361.6	18.5	2.0	1.20
2004	48.2	1642.8	196.0	1.20	365.3	18.5	2.0	1.20
2005	45.6	1722.8	196.0	1.20	368.9	18.5	2.0	1.20
2006	43.1	1802.8	196.0	1.20	372.6	18.5	2.0	1.20

[1]From CREG's Wyoming State Government Revenue Forecast, October, 2001; [2]Millions of barrels; [3]Wyoming Oil and Gas Conservation Commission, 1985 through 2000; [4]Billions of cubic feet, includes coalbed methane; [5]Based on ExxonMobil's estimate that the average helium content in the gas processed at La Barge is 0.5%; [6]Millions of short tons (Wyoming State Inspector of Mines, 1985 through 2000); [7]Millions of short tons (Wyoming Department of Revenue, 1985 through 2000; Wyoming State Inspector of Mines, 2000); [8]Millions of pounds of yellowcake (Wyoming Department of Revenue, 1986 through 1999; Wyoming State Inspector of Mines, 2000) (not available [N/A] for 1985 and previous years because it was only reported as taxable value; [9]Millions of short tons.

ward (**Table 1**). Coal production estimates are those we forecast earlier while *in situ* uranium and sulfur production have stayed the same. CREG price estimates have been revised upward for coal and trona and downward for natural gas produced in 2001 and 2002 (**Table 2**). Gas and oil prices are forecast to stabilize in the out years. Although the overall mineral revenue picture for the state is not as rosy as it appeared earlier this year, the CREG estimates, while on the conservative side, may be more realistic at least for the next year or two.

Table 2. Average prices paid for Wyoming oil, methane, coal, and trona (1985 through 2000) with forecasts to 2006[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	10.67	1.81	5.41	41.29
1999	16.44	2.06	5.19	38.49
2000	26.87	3.42	5.40	37.28
2001	21.00	3.15	5.70	38.00
2002	18.00	2.35	5.75	38.00
2003	18.00	2.35	5.82	38.00
2004	18.00	2.35	5.85	38.00
2005	18.00	2.35	5.88	38.00
2006	18.00	2.35	5.90	38.00

[1]From CREG's Wyoming State Government Revenue Forecast, October, 2001; [2]First purchase price in dollars per barrel (weighted average price for sweet, sour, heavy, stripper, and tertiary oil). Source: Energy Information Administration, 1985-1999; [3]Wellhead price in dollars per thousand cubic feet (MCF), includes coalbed methane. Source: Wyoming Office of State Lands and Investments, 1989-2000 (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, 1991-2000; [5]Dollars per ton of trona, not soda ash. Source Wyoming Department of Revenue, 1985-2000.

CALENDAR OF UPCOMING EVENTS

Talks

WYOMING GEMSTONES–*W. Dan Hausel*, Southwestern Chapter of SME, Rock Springs, March 14, 2002.

WYOMING'S MINERAL LEGACY–*W. Dan Hausel*, Tate Museum Open House, Casper College, March 23, 2002.

WYOMING GEMSTONES–*W. Dan Hausel*, Torrington Senior Citizen Center, April 10, 2002.

RECENT DEVELOPMENTS IN WYOMING'S INDUSTRIAL MINERALS (POSTER)–*Ray E. Harris*, 38th Annual Forum on the Geology of Industrial Minerals, St. Louis, Missouri, April 28-May 2, 2002.

GEMSTONES AND SEMIPRECIOUS MINERALS AND HOST ROCKS IN THE WESTERN U.S. (THEME SESSION)–*W. Dan Hausel*, 54th Annual Meeting, Rocky Mountain Section, GSA, Cedar City, Utah, May 7-9, 2002.

COLORADO-WYOMING STATE LINE DISTRICT, **WYOMING GEMSTONES**, and **THE GREAT 1872 DIAMOND HOAX**–*W. Dan Hausel*, Colorado Friends of Mineralogy, USGS/Colorado School of Mines Mineral Symposium, September 6-8, 2002.

Field trips

GEOLOGY, GOLD AND MINING HISTORY OF SOUTH PASS–Saturday, July 20, 2002, 8:30 am. Reservations required - contact W. Dan Hausel at dhause@wsgs.uwyo.edu, or (307) 766-2286 x-229. No charge to attend; we recommend participants purchase WSGS Report of Investigations 44 and Reprint 49 (use order form in back).

CHICKEN PARK DIAMONDIFEROUS KIMBERLITES–Saturday, August 10, 2002, starting at 9:30 am (Cherokee Park). Attendees will learn what to look for when searching for diamonds. For reservations contact W. Dan Hausel at dhause@wsgs.uwyo.edu, or (307) 766-2286 x-229. No charge to attend; we recommend participants purchase WSGS Report of Investigations 19 and 53 (use order form in back).

Meetings, conferences, shows, etc.

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS ANNUAL MEETING–Houston, Texas, March 10-13, 2002. WSGS will have a booth.

WYOMING STATE GEM AND MINERAL SHOW–Hitching Post, Cheyenne, Wyoming, May 17-19, 2002. WSGS will have a booth/display.

NATRONA COUNTY GEM AND MINERAL SHOW–Casper, Wyoming, June 22-23, 2002. WSGS will have a booth.

DENVER GEM AND MINERAL SHOW–Denver, Colorado, September 13-15, 2002. WSGS will have a booth.

ASSOCIATION OF EARTH SCIENCE EDITORS (AESE) 2002 ANNUAL MEETING–Halifax, Nova Scotia, Canada, September 14-18, 2002. Richard W. Jones, Past President AESE, will participate.

ROCKY MOUNTAIN SECTION, AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS (AAPG) in conjunction with the **WYOMING GEOLOGICAL ASSOCIATION (WGA) ANNUAL FIELD CONFERENCE**–Laramie, Wyoming, Department of Geology and Geophysics, University of Wyoming and WSGS will host, September 8-11, 2002.

GEOLOGICAL SOCIETY OF AMERICA (GSA) 2002 ANNUAL MEETING–Denver, Colorado, October 27-30, 2002. WSGS will have a sales/information booth, as well as several staff in attendance.

Oil and Gas Update

Rodney H. De Bruin, P.G.

Staff Geologist–Oil and Gas, Wyoming State Geological Survey

Wyoming oil and gas producers received decent prices for oil but low prices for natural gas during the third quarter of 2001. Oil prices were slightly lower and gas prices were considerably lower than for the first quarter of 2001. During the first eight months of 2001, oil production declined 5.8% while gas production increased 10.7%. Natural gas production was boosted by a large increase in coalbed methane production in the Powder River Basin (PRB), which made up 14.6% of Wyoming's total gas production in the first eight months of 2001. In the third quarter, one Federal lease sale brought in over $7.6 million. The number of applications for permit to drill, geophysical activity, and rig counts also remained healthy.

Prices and production

The Consensus Revenue Estimating Group (CREG) for the State of Wyoming released new projections for oil and gas production and prices (**Tables 1** and **2**) in the third quarter. Wyoming's oil production will continue to decrease each year, although the amount and rate has accelerated over that predicted earlier (**Table 1** and **Figure 1**). The decline in production from 1999 to 2000 was only slightly more than 1%, but the decline in production from 2000 to 2001 should return to a more traditional 5.5% despite healthy crude oil prices. This rate of decline is expected to continue through 2006, since exploration and production drilling for oil has been very weak and old oil fields with declining production still produce most of Wyoming's oil. Oil prices for 2001 were lowered slightly (**Table 2**) because of weak demand and a current oversupply on the world markets. Prices should drop again in 2002 to

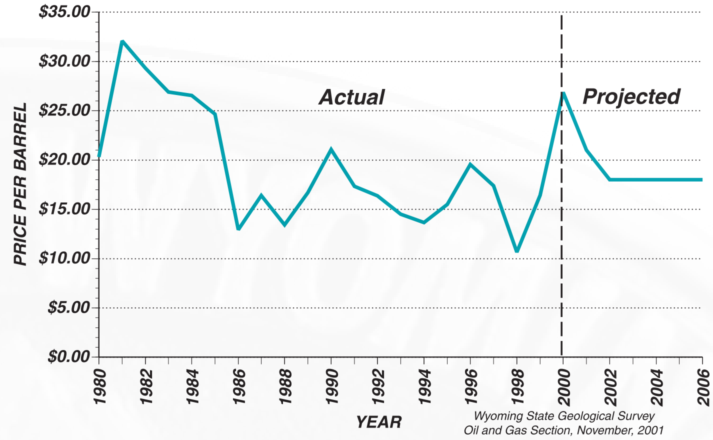

Figure 2. Average prices paid for Wyoming crude oil (1980 through 2000) with forecasts to 2006.

$18.00 a barrel and then stabilize at that value in the out years (**Figure 2**).

Natural gas production has been revised upward from earlier estimates (**Table 1** and **Figure 3**), mainly due to the tremendous growth in coalbed methane production (see **COALBED METHANE UPDATE**); conventional natural gas deposits continue to be discovered and developed. Wyoming has continued to increase annual production of natural gas over the last 15 years even when demand and prices dropped (**Figures 3** and **4**). Prices for natural gas were lowered for 2001 and 2002 (**Table 2**) because of weaker demand and adequate gas in storage for the upcoming heating season. Carbon dioxide and helium production is expected to increase in 2001 because more gas is now processed at ExxonMobil's La Barge plant. Carbon dioxide production will increase further when Burlington Resources

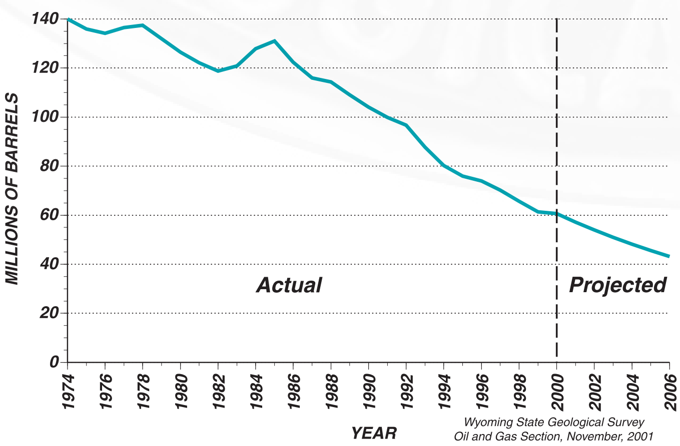

Figure 1. Annual crude oil production from Wyoming (1974 through 2000) with forecasts to 2006.

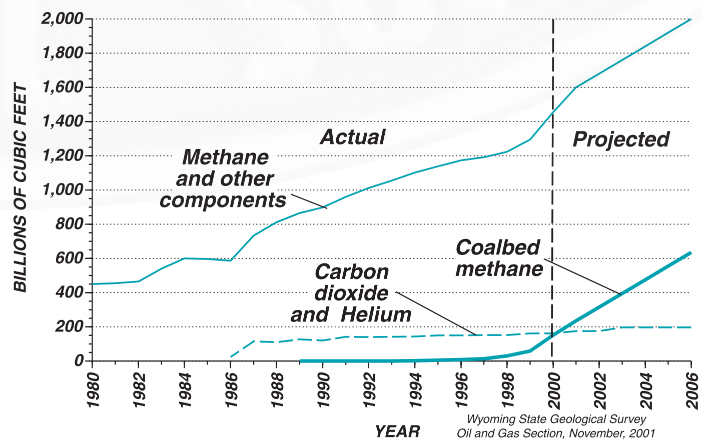

Figure 3. Annual natural gas production from Wyoming (1980 through 2000) with forecasts to 2006.

completes its Lost Cabin plant expansion in the latter part of 2002 (**Table 1** and **Figure 3**).

Prices paid to Wyoming oil producers during the third quarter of 2001 averaged $22.88 per barrel (**Table 3**). The average price for the quarter is $5.63 lower than for the third quarter of 2000, but $3.95 higher than for the third quarter of 1999. Posted sweet and sour crude prices and first purchase price for Wyoming oil averaged by month (**Figure 5**) are still higher that our forecast $21.00 per barrel.

Oil production reported by the Wyoming Oil and Gas Conservation Commission (WOGCC) for the first eight months of 2001 was 38.3 million barrels (**Table 4**). This production is a drop of 5.8% from production in the first eight months of 2000.

Spot prices for natural gas at Opal, Wyoming averaged $2.13 per thousand cubic feet (MCF) during the third quarter of 2001. This is $1.34 per MCF lower than the average price for the third quarter of 2000, and $1.62 lower than for the second quarter of 2001. The average spot price for October of $1.25 is the first time prices have averaged less than $2.00 per MCF since April, 1999, and is the lowest average monthly price in over five years (**Table 5** and **Figure 6**).

Natural gas production in Wyoming for the first eight months of 2001 was 1057.2 billion cubic feet (BCF) according

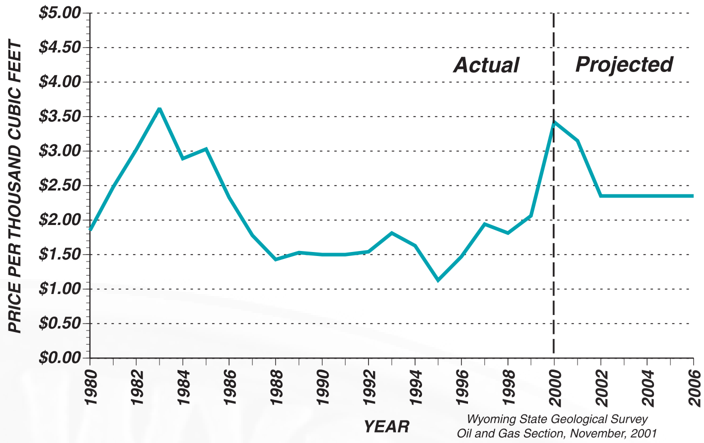

Figure 4. Average prices paid for Wyoming methane (1980 through 2000) with forecasts to 2006.

to production figures from the WOGCC. This production is up 10.7% from the first eight months of 2000 (**Table 6**). Coalbed methane production from the PRB accounted for 154.7 BCF of that total and 14.6% of all Wyoming's natural gas production in the first eight months of 2001. If production stays on its current trend, Wyoming should produce nearly 1.6 trillion cubic feet (TCF) of natural gas in 2001, with about 235 BCF of the total contributed by coalbed methane from the PRB.

Table 3. Monthly average price of a barrel of oil produced in Wyoming (1997 through October, 2001).

	1997		1998		1999		2000		2001	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	$22.56	$22.56	$12.79	$12.79	$9.30	$9.30	$24.01	$24.01	$24.62	$24.62
February	$19.45	$21.01	$12.16	$12.47	$9.09	$9.20	$26.48	$25.25	$24.82	$24.72
March	$17.99	$20.00	$10.97	$11.97	$11.77	$10.05	$27.24	$25.91	$22.71	$24.05
April	$16.81	$19.20	$11.54	$11.87	$14.34	$11.12	$22.92	$25.16	$22.85	$23.75
May	$17.74	$18.91	$11.19	$11.73	$15.16	$11.93	$26.06	$25.34	$23.68	$23.74
June	$15.90	$18.41	$9.63	$11.38	$15.36	$12.50	$28.31	$25.84	$22.99	$23.61
July	$16.29	$18.11	$10.20	$11.21	$17.39	$13.20	$27.12	$26.02	$22.55	$23.46
August	$16.61	$17.92	$9.58	$11.01	$18.43	$13.86	$28.18	$26.29	$23.60	$23.48
September	$16.42	$17.75	$11.19	$11.03	$20.97	$14.65	$30.22	$26.73	**$22.50**	**$23.37**
October	$17.89	$17.77	$11.04	$11.03	$20.01	$15.18	$28.75	$26.93	**$18.00**	**$22.83**
November	$16.51	$17.65	$9.64	$10.90	$22.20	$15.82	$29.63	$27.17		
December	$14.72	$17.41	$8.05	$10.66	$23.22	$16.44	$23.60	$26.88		
Average yearly price		**$17.41**		**$10.66**		**$16.44**		**$26.88**		

All averages are derived from published monthly reports by the Energy Information Administration, except that averages in bold print in 2001 are estimated from various unpublished bulletins listing posted prices. *Wyoming State Geological Survey, Oil and Gas Section, November, 2001.*

Table 4. Monthly oil production from Wyoming in barrels (1997 through August, 2001).

	1997		1998		1999		2000		2001	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	5,964,848	5,964,848	5,846,364	5,846,364	5,333,257	5,333,257	5,185,683	5,185,683	4,995,370	4,995,370
February	5,459,518	11,424,366	5,233,502	11,079,866	4,744,527	10,077,784	4,871,733	10,057,416	4,487,724	9,486,094
March	6,014,780	17,439,146	5,759,176	16,839,042	5,297,674	15,375,458	5,202,533	15,259,949	4,963,991	14,447,085
April	5,729,869	23,169,015	5,534,568	22,373,610	5,065,591	20,441,049	5,003,812	20,263,761	4,730,320	19,177,405
May	6,050,971	29,219,986	5,626,125	27,999,735	5,200,031	25,641,080	5,201,564	25,465,325	4,920,044	24,097,449
June	5,761,549	34,981,535	5,335,463	33,335,198	5,000,039	30,641,119	5,001,932	30,467,257	4,656,240	28,753,689
July	5,964,005	40,945,540	5,464,514	38,799,712	5,164,705	35,805,824	5,077,548	35,544,805	4,828,885	33,582,574
August	5,868,789	46,814,329	5,287,415	44,087,127	5,190,052	40,995,876	5,093,558	40,638,363	4,710,070	38,292,644
September	5,710,557	52,524,886	5,109,053	49,196,180	5,081,384	46,077,260	4,983,126	45,621,489		
October	5,949,974	58,474,860	5,274,269	54,470,449	5,163,165	51,240,425	5,156,755	50,778,244		
November	5,800,811	64,275,671	5,232,287	59,702,736	5,010,985	56,251,410	4,877,512	55,655,756		
December	5,900,791	70,176,462	5,078,909	64,781,645	5,090,959	61,342,369	4,970,686	60,626,442		
Total Barrels Reported[1]		**70,176,462**		**64,781,645**		**61,342,369**		**60,626,442**		
Total Barrels not Reported[2]		**52,364**		**897,131**						
Total Barrels Produced[3]		**70,228,826**		**65,678,776**						

[1]Monthly production reports from Petroleum Information/Dwights LLC., except for 1999, 2000, and 2001 which are from Wyoming Oil and Gas Conservation Commission; [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, November, 2001.*

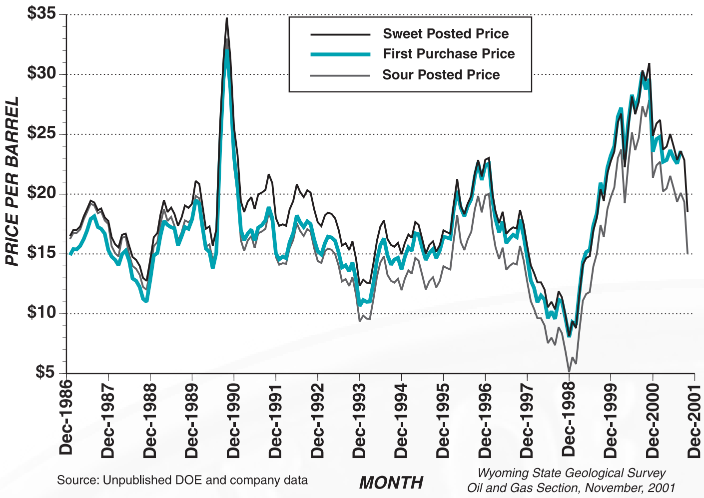

Figure 5. Wyoming posted sweet and sour crude oil prices and first purchase prices, averaged by month (January, 1987 through October, 2001).

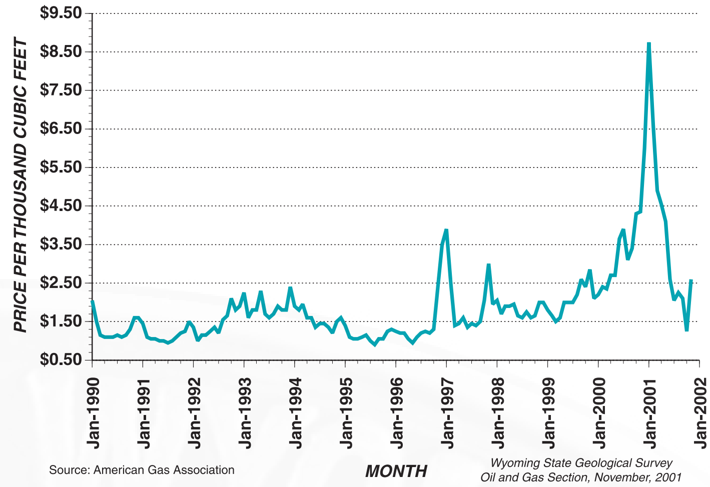

Figure 6. Spot sale prices for methane at Opal, Wyoming, averaged by month (January, 1990 through November, 2001).

Projects, transactions, and reports

Jonah Gas Gathering has received approval to build a new 20-inch diameter natural gas pipeline from about 10 miles east of La Barge to Opal, Wyoming. The company also proposes to build an additional 9000 horsepower of compression adjacent to its existing compressor station. The proposed pipeline would parallel the company's existing 20-inch line. The new line would transport 300 to 400 million cubic feet (MMCF) of gas per day produced from Jonah Field and the Pinedale anticline area and deliver it to multiple markets.

In a related development, TEPPCO Partners L.P. recently agreed to acquire Jonah Gas Gathering from Green River Pipeline, LLC. and McMurry Oil Co., both wholly owned subsidiaries of Alberta Energy Co., for approximately $360 million. The assets will be managed and operated by Duke Energy Field Services L.P. under agreements with TEPPCO.

Table 5. Monthly average spot sale price for a thousand cubic feet (MCF) of natural gas at Opal, Wyoming (1997 through November, 2001).

	1997		1998		1999		2000		2001	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	$3.90	$3.90	$2.05	$2.05	$1.80	$1.80	$2.20	$2.20	$8.75	$8.75
February	$2.50	$3.20	$1.70	$1.88	$1.65	$1.73	$2.40	$2.30	$6.60	$7.68
March	$1.40	$2.60	$1.90	$1.88	$1.50	$1.65	$2.35	$2.32	$4.90	$6.75
April	$1.45	$2.31	$1.90	$1.89	$1.60	$1.64	$2.70	$2.41	$4.55	$6.20
May	$1.60	$2.17	$1.95	$1.90	$2.00	$1.71	$2.70	$2.47	$4.10	$5.78
June	$1.35	$2.03	$1.65	$1.86	$2.00	$1.76	$3.65	$2.67	$2.60	$5.25
July	$1.45	$1.95	$1.60	$1.82	$2.00	$1.79	$3.90	$2.84	$2.05	$4.79
August	$1.40	$1.88	$1.75	$1.81	$2.20	$1.84	$3.10	$2.88	$2.25	$4.48
September	$1.50	$1.84	$1.60	$1.79	$2.60	$1.93	$3.40	$2.93	$2.10	$4.21
October	$2.05	$1.86	$1.65	$1.78	$2.40	$1.98	$4.30	$3.07	$1.25	$3.92
November	$3.00	$1.96	$2.00	$1.80	$2.85	$2.05	$4.35	$3.19	$2.60	$3.80
December	$1.95	$1.96	$2.00	$1.81	$2.10	$2.06	$6.00	$3.42		
Average yearly price		**$1.96**		**$1.81**		**$2.06**		**$3.42**		

Source: American Gas Association's monthly reports. *Wyoming State Geological Survey, Oil and Gas Section, November, 2001.*

Table 6. Monthly natural gas production from Wyoming in thousands of cubic feet (MCF) (1996 through August, 2001).

	1997		1998		1999		2000		2001	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	99,579,818	99,579,818	103,640,214	103,640,214	108,524,793	108,524,793	122,078,095	122,078,095	136,051,044	136,051,044
February	91,766,159	191,345,977	94,501,819	198,142,033	94,288,888	202,813,681	114,204,669	236,282,764	123,484,598	259,535,642
March	104,157,578	295,503,555	103,906,999	302,049,032	111,012,987	313,826,668	121,104,908	357,387,672	139,260,769	398,796,411
April	99,459,039	394,962,594	98,201,007	400,250,039	102,363,550	416,190,218	118,775,280	476,162,952	132,553,060	531,349,471
May	101,070,371	496,032,965	96,741,237	496,991,276	104,746,697	520,936,915	118,462,106	594,623,058	138,059,077	669,408,548
June	91,905,308	587,938,273	98,413,520	595,404,796	102,717,295	623,654,210	116,887,377	711,512,435	126,524,923	795,933,471
July	100,129,497	688,067,770	102,055,968	697,460,764	106,733,493	730,387,703	120,690,168	832,202,603	130,742,882	926,676,353
August	97,673,622	785,741,392	105,378,334	802,839,098	107,536,099	837,923,802	122,412,623	954,615,226	130,510,334	1,057,186,687
September	100,028,888	885,770,280	98,474,782	901,313,880	108,200,542	946,124,344	119,730,975	1,074,346,201		
October	102,206,875	987,977,155	96,470,624	997,784,504	118,545,893	1,064,670,237	127,507,997	1,201,854,198		
November	100,752,128	1,088,729,283	103,445,859	1,101,230,363	110,904,046	1,175,574,283	122,846,630	1,324,700,828		
December	103,415,430	1,192,144,713	99,339,043	1,200,569,406	119,648,215	1,295,222,498	130,711,331	1,455,412,159		
Total MCF Reported[1]		**1,192,144,713**		**1,200,569,406**		**1,295,222,498**		**1,455,412,159**		
Total MCF not Reported[2]		**683,432**		**22,955,142**						
Total MCF Produced[3]		**1,192,828,145**		**1,223,524,548**						

[1]Monthly production reports from Petroleum Information/Dwights LLC., except for 1999, 2000, and 2001 which are from Wyoming Oil and Gas Conservation Commission; [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, November, 2001.*

Northwest Pipeline, a unit of the Williams Companies, has filed an application with the Federal Energy Regulatory Commission (FERC) to construct and operate the Rockies Expansion Project in parts of western Wyoming and southeastern Idaho. The proposed $154 million project would increase capacity for transportation of natural gas to markets in Idaho, Oregon, and Washington. The project will add six sections of new pipeline loops that total 91 miles; they will be parallel to or near Northwest's existing system. Construction is scheduled for the spring of 2003, with an in-service date of October, 2003.

The first of several planned expansions to the Kern River pipeline was completed three weeks ahead of schedule. The Kern River pipeline originates in western Wyoming and serves markets in Utah, Nevada, and California. The first expansion boosts capacity from 700 to 835 MMCF per day and may help Wyoming natural gas producers receive higher prices for their gas. Limited out-of-state capacity is a major cause of Wyoming natural gas prices being lower than in other areas of the country. Second, Kern River Gas Transmission, a unit of the Williams Companies, has filed an application with FERC to more than double the amount of natural gas transported on its 922-mile pipeline system. The 2003 Kern River Expansion Project will provide about 900 MMCF per day of additional capacity from Wyoming to Utah, Nevada, and California markets by May, 2003. The project is projected to cost over $1 billion and will loop more than 700 miles of the existing Kern River pipeline. The company also placed an order for more than 700 miles of 36-inch diameter and 42-inch diameter pipe for the project. Third, Kern River Gas Transmission announced that it was dropping transmission rates on Kern River pipeline by as much as 36.5% for original shippers. The reduction went into effect October 1, 2001. The rate reduction and increased capacity of the pipeline is expected to help Wyoming producers become more competitive in the Western gas market.

GIS Database for Wyoming Oil and Gas Pipelines

Abby L. Kirkaldie

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The Wyoming State Geological Survey (WSGS), under contract with the Wyoming State Energy Commission, is developing an interactive oil and gas pipeline database for Wyoming using geographic information systems (GIS) technology. This project will provide a broad base of information on existing and proposed oil and gas pipelines in a single, statewide GIS database. The pipeline database will exist in a standard GIS format (ESRI's ArcGIS® 8.1) with underlying base information and references. This project will allow users to access digital pipeline data for analysis and use for various projects.

The availability of pipeline data in Wyoming is limited and exists in many formats within both the public sector and private industry. This data is uncoordinated, multi-sourced, multi-located, and in many cases, has been generalized at the state level. Thus, it is neither readily accessible nor in a format with standardized information for easy use.

Because a single comprehensive pipeline database for present and future reference and analysis does not exist, there is a need to compile and build such a system. This project will consolidate varying information into a single database that will be better accessible for users. Among the goals of this project is the desire to produce the highest resolution data available with standardized attributing and file structure.

The contract was awarded in September, 2001 and a GIS specialist, Abby L. Kirkaldie, was hired to develop the system. She has worked for the Geologic Hazards Section at the WSGS on a number of GIS-related projects, including STATEMAP, the Love Map Series, and the Earthquake Program. The WSGS is currently in the process of inventorying and obtaining all available oil and gas pipeline and facility GIS and CAD data from both private and public sectors. The WSGS is also inventorying all existing statewide GIS datasets for reference and base map data. The initial completion date of this project is May 30, 2002, but the WSGS will continue to revise and update this database as needed.

The oil and gas industry plays a large role in Wyoming's economy and revenue base. Pipelines are the preferred, principal method to gather, transport, and distribute oil and gas resources produced in the state to their ultimate markets. Oil and gas pipeline data is essential to both the public and private sector for general understanding, specific analysis, and future concerns. The WSGS is anxious to provide this data and is committed to maintain the database and to assist its users.

Ensign Operating Co. has purchased a number of properties in Wyoming from Ocean Energy Inc. The properties are located in Hay Reservoir, Garland, House Creek, Dripping Rock, and Borie fields.

Devon Energy Corp. acquired two more companies thus becoming the largest independent producer of oil, gas, and natural gas liquids in North America. The company purchased Mitchell Energy & Development Corp. for about $3.5 billion in cash and stock, and Anderson Exploration Ltd. for $4.6 billion. Devon's North American gas production, after these purchases, will increase from 1.6 to 2.0 BCF per day and liquids production will increase from 125,000 to about 180,000 barrels per day. Devon acquired Pennz-Energy Co. in 1999 and Santa Fe Snyder Corp. in 2000.

The U.S. Bureau of Land Management (BLM) approved a proposal by Veritas DGC Land to conduct 3-D geophysical operations on an area covering 133 square miles in the checkerboard area (Union Pacific land grant) of southwestern Wyoming. The area is just north of the Adobe Town Wilderness Study Area (WSA), about 18 miles southwest of Wamsutter. The proposal includes hand-placing geophones about a mile inside the WSA boundary to get complete data coverage to the boundary of the study area.

WesternGeco submitted a notice of intent to conduct geophysical operations (Big Piney 2-D project) in the Hoback Basin of west-central Wyoming. The project would include nine vibroseis lines within an area up to 26 miles wide and 40 miles long.

Lease sales

Leasing activity at the August BLM sale was concentrated in the PRB and in southwestern Wyoming (**Figure 7**). Coleman Oil & Gas made the high per-acre bid of $525 for a 164.6-acre lease that covers parts of section 7, T41N, R71W (**location A, Figure 7**). The lease is in an area of shallow coalbed methane that is being developed by the company. Big West Oil & Gas made one of the sale's second high per-acre bids of $290 for a 560-acre tract that covers part of sections 28 and 29, T35N, R87W (**location B, Figure 7**). The lease is about three miles south of Fort Union Formation gas production at Cooper Reservoir Field in the Wind River Basin. Contex Energy made the sale's other second high per-acre bid of $290 for a 480-acre tract that covers parts of sections 13, 24, and 25, T35N, R112W (**location C, Figure 7**). The tract is about four miles south of abandoned Fort Union and Lance Formation gas production at Merna Field in the northern Green River Basin. There were a total of 34 parcels at this sale that received bids of $50 or more per acre. The sale generated revenue of over $7.6 million in bonus bids (of which the state receives half) and the average per-acre bid was $31.11 (**Table 7**).

The WOGCC approved 2763 Applications for Permit to Drill (APDs) in the third quarter of 2001. The total for the third quarter of 2001 is more than the number of APDs approved in all of 1995, 1996, 1997, or 1998 (**Table 8**). Campbell County again led with 61% of the total APDs that were approved in the third quarter. Sheridan and Johnson counties combined for another 22.6% of the total APDs. Nearly all of the approved APDs in these three counties were for coalbed methane tests.

The WOGCC permitted 15 seismic projects in the third quarter of 2001 (**Table 9**). The number of permits is down slightly from the third quarter of 2000; however, the number of conventional miles and square miles permitted is higher. The 709 conventional miles permitted thus far in 2001 is greater than full years in 1997, 1998, and 1999; the number of square miles permitted is higher than for all of 1997. Geophysical activity is a good indicator of future exploration and production drilling.

The average daily rig count for the third quarter of 2001 was 64. This average is 18 more than for the third quarter of 2000. The rig count does not include rigs drilling for coalbed methane. **Figure 8** shows the Wyoming daily rig count averaged by month and by year.

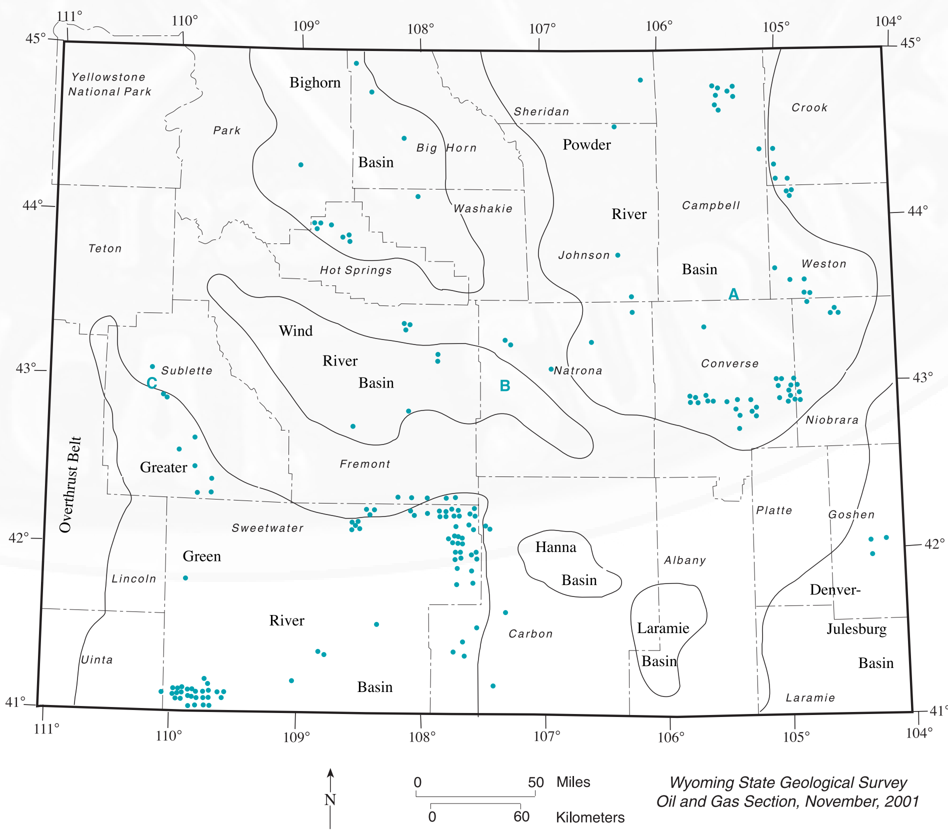

Figure 7. Locations of federal oil and gas tracts leased by the U.S. Bureau of Land Management at its August, 2001 sale. Locations are approximate and may represent more than one tract.

Table 7. Federal and State competitive oil and gas lease sales in Wyoming (1996 through September, 2001).

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
1996							
TOTAL	$11,487,567	1828	1125	1,403,444	739,505	$15.53	$1,450.00
1997							
TOTAL	$31,976,603	1787	1485	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	2247	1710	2,217,975	1,621,637	$39.34	$800.00
1999							
February	$2,734,442	170	138	157,779	124,880	$21.90	$325.00
April	$2,121,220	124	116	129,358	121,421	$17.47	$280.00
June	$8,358,363	179	155	233,599	207,978	$40.19	$32,000.00
August	$3,294,339	206	197	215,631	208,777	$15.78	$290.00
Octoer	$4,395,288	214	175	195,827	142,525	$30.84	$580.00
December	$5,598,020	176	164	128,480	124,093	$28.99	$410.00
TOTAL	$24,197,991	1,069	945	1,060,674	929,674	$26.03	$32,000.00
2000							
February	$5,497,834	192	180	130,289	120,219	$45.73	$525.00
April	$3,057,278	189	161	160,712	128,063	$23.87	$440.00
June	$6,387,887	230	184	260,294	190,306	$33.57	$410.00
August	$5,213,595	240	222	174,040	154,920	$33.65	$475.00
October	$5,028,610	147	129	149,934	124,724	$40.32	$510.00
December	$6,352,525	185	179	182,935	180,380	$35.22	$725.00
TOTAL	$31,537,729	1183	1055	1,058,204	898,612	$35.09	$725.00
2001							
February	$9,138,921	202	159	224,225	148,972	$61.35	$1,475.00
April	$10,976,580	185	184	221,147	221,067	$49.65	$530.00
June	$3,088,796	158	149	144,738	138,088	$22.37	$360.00
August	$7,626,362	204	190	260,409	245,116	$31.11	$525.00

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
1996							
TOTAL	$2,325,497	1049	508	418,111	206,814	$11.24	$206.00
1997							
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
1999							
April	$1,815,526	299	196	123,119	89,194	$20.35	$890.00
June	$1,002,039	300	190	108,310	69,858	$14.34	$400.00
October	$2,369,527	300	216	109,140	77,261	$30.67	$475.00
December	$956,113	291	129	115,502	51,674	$18.50	$500.00
TOTAL	$6,143,205	1,190	731	456,071	287,987	$21.33	$890.00
2000							
April	$1,475,661	299	191	120,319	71,933	$19.54	$525.00
June	$2,119,198	300	197	127,798	79,743	$26.58	$775.00
October	$1,660,315	300	216	117,598	81,603	$20.35	$268.00
December	$1,240,442	300	192	109,375	62,636	$19.80	$210.00
TOTAL	$6,495,616	1199	796	475,090	295,915	$21.95	$775.00
2001							
April	$2,250,353	300	212	112,379	82,834	$27.16	$450.00
June	$1,754,320	300	192	111,507	66,829	$26.25	$650.00

Sources: Wyoming Office of State Lands and Investments, Petroleum Information/Dwights LLC. - Rocky Mountain Region Report, and U.S. Bureau of Land Management. *Wyoming State Geological Survey, Oil and Gas Section, November, 2001.*

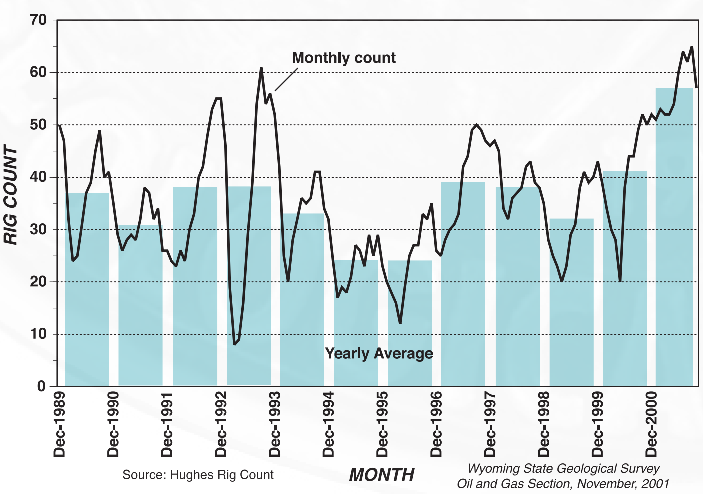

Figure 8. Wyoming daily rig count, exclusive of coalbed methane rigs, averaged by month and year (December, 1989 through September, 2001).

Exploration and development

Company data, news releases, and information compiled and published by Petroleum Information/Dwights LLC. are used to track oil and gas exploration and development activity in Wyoming. **Table 10** reports the most significant activities exclusive of coalbed methane (see the **COALBED METHANE UPDATE** for development in this industry) during the third quarter of 2001. The numbers correspond to locations on **Figure 9**.

Table 8. Number of Applications for Permit to Drill (APDs) approved by the Wyoming Oil and Gas Conservation Commission (1995 through September, 2001).

County	1995 APDs	1996 APDs	1997 APDs	1998 APDs	1999 APDs	2000 APDs	2001 APDs
Albany	1	1	0	0	0	0	0
Big Horn	16	53	59	13	6	11	18
Campbell	151	554	941	1586	4461	5580	4668
Carbon	50	77	84	96	127	174	208
Converse	29	20	16	6	19	70	20
Crook	15	37	26	29	30	47	18
Fremont	30	26	58	76	67	136	118
Goshen	0	0	0	0	0	0	0
Hot Springs	13	24	42	1	8	6	2
Johnson	6	16	6	49	304	769	508
Laramie	10	2	3	2	0	2	3
Lincoln	64	55	122	105	51	70	70
Natrona	80	74	59	36	51	53	34
Niobrara	4	7	8	8	5	18	11
Park	20	30	25	11	12	18	38
Platte	0	0	0	0	0	0	0
Sheridan	0	0	2	35	416	891	1255
Sublette	61	118	179	230	189	338	364
Sweetwater	153	136	210	181	124	335	421
Teton	0	0	0	0	0	0	0
Uinta	11	10	27	26	26	53	27
Washakie	31	30	36	9	0	7	10
Weston	10	10	5	6	4	20	6
Totals	**755**	**1280**	**1908**	**2505**	**5900**	**8598**	**7799**

Source: All data are from the Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, November, 2001.*

Table 9. Number of seismic projects and miles permitted by the Wyoming Oil and Gas Conservation Commission (1997 through September, 2001).

County	1997 Permits	1997 Conventional Miles	1997 3-D Square Miles	1998 Permits	1998 Conventional Miles	1998 3-D Square Miles	1999 Permits	1999 Conventional Miles	1999 3-D Square Miles	2000 Permits	2000 Conventional Miles	2000 3-D Square Miles	2001 Permits	2001 Conventional Miles	2001 3-D Square Miles
Albany	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Horn	2	0	45	1	0	16	0	0	0	1	387	0	1	0	4
Campbell	20	52	79	14	18	182	4	4	10	14	64	132	3	23	0
Carbon	3	7	190	4	0	318	5	77	57	0	0	0	0	0	0
Converse	1	5	0	4	12	239	1	0	50	1	15	0	0	0	0
Crook	7	8	18	2	2	4	1	0	10	7	16	22	2	13	0
Fremont	6	43	126	2	100	0	1	0	88	4	25	116	2	70	15
Goshen	2	227	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Springs	1	8	0	4	19	0	0	0	0	0	0	0	0	0	0
Johnson	2	7	17	1	4	0	0	0	0	4	35	0	2	4	4
Laramie	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lincoln	3	7	116	1	10	0	1	0	32	0	0	0	1	0	25
Natrona	5	14	101	6	12	214	2	0	230	5	36	135	2	19	63
Niobrara	0	0	0	0	0	0	5	16	31	1	0	25	0	0	0
Park	4	56	58	3	16	132	3	25	32	1	13	0	4	21	20
Platte	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sheridan	0	0	0	1	14	0	0	0	0	0	0	0	2	0	81
Sublette	1	0	61	2	1	115	3	0	308	4	77	44	7	221	357
Sweetwater	4	66	296	6	214	66	9	0	530	13	54	1004	9	79	798
Teton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uinta	0	0	0	2	0	147	1	0	26	0	0	0	1	259	0
Washakie	3	36	0	4	41	35	1	0	8	0	0	0	0	0	0
Weston	1	0	17	1	0	35	1	40	0	0	0	0	0	0	0
Totals	**65**	**536**	**1124**	**58**	**463**	**1503**	**38**	**162**	**1412**	**55**	**722**	**1478**	**36**	**709**	**1367**

Source: All data are from the Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, November, 2001.*

Table 10. Significant exploration and development wells in Wyoming, third quarter of 2001[1]. Number corresponds to location on Figure 9.

	Company name	Well name/number	Location	Formation tested	Depth(s) interval(s) tested	Tested prod. (per day)	Remarks
1	Chevron USA	3-32M	SE SW sec 32, T19N, R119W	Mission Canyon Ls.	13,962-14,674	87 BBL Cond 11.7 MMCF	New production well in Whitney Canyon-Carter Creek Field
	Amoco Production	3 Champlin 457 Amoco-E	SW NW sec 7, T18N, R119W	Mission Canyon Ls.	14,360-16,760	14.4 MMCF	New production well in Whitney Canyon-Carter Creek Field
2	EOG Resources	152-13 “B”	NW SW sec 13, T29N, R113W	“transition zone”	3303-3348 and 3383-3417	57 MCF 223 BBL Oil 27 BBL H_2O	Big Piney Field area
	EOG Resources	156-24 “B”	NE NW sec 24, T29N, R113W	“transition zone”	3277-3339	115 BBL Oil 99 MCF 40 BBL H_2O	Big Piney Field area
	EOG Resources	153-13 “B”	SW NW sec 13, T29N, R113W	“transition zone”	3288-3340 and 3391-3398	68 BBL Oil 85 MCF 32 BBL H_2O	Big Piney Field area
	EOG Resources	157-24 “B”	NE NW sec 24, T29N, R113W	“transition zone”	3322-3352	31 BBL Oil 72 MCF 86 BBL H_2O	Big Piney Field area
	EOG Resources	167-24 “B”	SE SW sec 24, T29N, R113W	“transition zone”	3316-3365 3369-3414 9769-11,657	221 BBL Oil 297 MCF 51 BBL H_2O	Big Piney Field area
3	Alpine Gas	10-16 Piney	NW SE sec 16, T30N, R111W	Lance Fm.	7366-7380	250 MCF	Wildcat discovery
4	Questar Exp. & Prod.	7-8V Mesa	SW NE sec 8, T32N, R109W	Lance Fm.	8938-13,030 15 intervals	8.5 MMCF 72 BBL Cond 96 BBL H_2O	Pinedale anticline
	Questar Exp.& Prod.	16-29V Stewart Point	SE SE sec 29, T33N, R109W	Lance Fm.	8750-12,595 several intervals	9.9 MMCF 72 BBL Cond 72 BBL H_2O	Pinedale anticline
	McMurry Energy	7-31 Rainbow	SW NE sec 31, T30N, R107W	Lance Fm.	10,879-11,955 five intervals	4.2 MMCF 35 BBL Cond 13 BBL H_2O	Pinedale anticline
	McMurry Energy	11-4 Antelope	NE SW sec 4, T29N, R107W	Lance Fm. Mesaverde Fm.	11,694-12,598 three intervals	3 MMCF 63 BBL Cond 10 BBL H_2O	Pinedale anticline
5	Ultra Resources	5-23 Warbonnet	SW NW sec 23, T30N, R108W	Lance Fm.	9013-12,718 eight intervals	10.5 MMCF 125 BBL Cond	Warbonnet Field stepout
6	Forest Oil	23-12 Elm-Federal	NE NW sec 23, T28N, R109W	Lance Fm.	7737-9577 eight intervals	10.0 MMCF 90 BBL Cond 18 BBL H_2O	Extreme southwestern flank of Jonah Field
	Amoco Production	16-14 Stud Horse Butte	SE SE sec 14, T29N, R108W	Lance Fm.	11,975-12,515	5.9 MMCF 140 BBL Cond 68 BBL H_2O	Northeastern flank of Jonah Field
	McMurry Oil	1-6X Jonah-Federal	NE NE sec 6, T28N, R108W	Lance Fm.	7689-10,678 11 intervals	7.7 MMCF 122 BBL Cond 13 BBL H_2O	Southwestern flank of Jonah Field
	McMurry Oil	8-7 Jonah-Federal	SE NE sec 7, T28N, R108W	Lance Fm.	7636-10,351 11 intervals	6.9 MMCF 60 BBL Cond 36 BBL H_2O	Southwestern flank of Jonah Field

Table 10. Continued.

	Company name	Well name/number	Location	Formation tested	Depth(s) interval(s) tested	Tested prod. (per day)	Remarks
6	McMurry Oil	3-8X Jonah-Federal	NE NEW sec 8, T28N, R108W	Lance Fm.	7824-10,597 11 intervals	6.9 MMCF 102 BBL Cond 27 BBL H_2O	Jonah Field
	McMurry Oil	6-7 Jonah-Federal	SE NW sec 7, T28N, R108W	Lance Fm.	7926-10,428 11 intervals	6.7 MMCF 106 BBL Cond 23 BBL H_2O	Jonah Field
7	Wexpro Co	37 Canyon Creek Unit	NW NW sec 10, T12N, R101W	Mesaverde Fm.	4658-6758 four intervals	4.3 MMCF	Canyon Creek Field
8	Wexpro Co	15 Trail	NE SW sec 10 , T13N, R100W	Mesaverde Fm.	6090-7600 five intervals	4.2 MMCF	Trail Field
9	Amoco Production	21-1 Bitter Creek	SE SE sec 21, T16N, R99W	Lance Fm. Lewis Sh. Mesaverde Fm.	9216-9539 9586-9624 11,237-11,650	2.1 MMCF	Stepout from Bitter Creek Field
	Amoco Production	21-2 Bitter Creek	NW NW sec 21, T16N, R99W	Mesaverde Fm.	11,184-11,389 three intervals	2.1 MMCF	Stepout from Bitter Creek Field
10	Amoco Production	13-4 Wild Rose	SW NW sec 13, T18N, R95W	Mesaverde Fm.	10,110-10,508 several intervals	5.1 MMCF	Wild Rose/Red Lakes Field
11	EnerVest Operating	21-8 Deadman-Federal	NE SW sec 8, T20N, R101W	Frontier Fm.	7968-8032	1.4 MMCF	Stepout from Deadman Wash Field
12	Yates Petroleum	2 Gandy Dancer-Federal	irregular sec 2, T20N, R96W	Lewis Sh.	7222-7375 three intervals	3.2 MMCF 20 BBL Cond 56 BBL H_2O	Exploratory test
13	Yates Petroleum	1 Steamer-State	E/2 SE sec 36, T21N, R96W	Lewis Sh. Almond Fm.	7179-7191 8726-8830	unreported	Exploratory test
14	Tom Brown Inc	19-43 Tribal-Sand Mesa	NE SE sec 19, T4N, R5E	Fort Union Fm.	13,550-13,558 14,130-14,502	1.6 MMCF 46 BBL H_2O	Stepout from Sand Mesa Field
15	Burlington Resources	49 Madden Deep Unit	SW NW sec 12, T38N, R90W	Fort Union Fm.	5778-5972	6.0 MMCF five BBL H_2O	Madden Field
16	Chevron USA	57 Waltman	SW SE sec 1, T36N, R87W	Lance Fm.	7250-7264	7.2 MMCF 40 BBL Cond	Waltman Field
17	BreitBurn Energy	3-BH Lost Dome-Federal	NE NW sec 13, T37N, R83W	Tensleep Ss.	4937-5768	350 BBL Oil 350 BBL H_2O	Horizontal redrill, interval tested is horizontal interval
	BreitBurn Energy	4H Lost Dome-Federal	NE NW sec 13, T37N, R83W	Tensleep Ss.	4944-5959	126 BBL Oil 35 BBL H_2O	Horizontal redrill, interval tested is horizontal interval, true vertical depth is 4850 feet
18	Ballard Petroleum	21-3 WD Unit	NE NW section 3, T48N, R71W	Minnelusa Fm.	9934-9968	342 BBL Oil	WD Field Holdings

[1]Abbreviations include: MMCF=millions of cubic feet of natural gas; MCF=thousands of cubic feet of natural gas; BBL=barrels; Cond=condensate; H_2O=water; Ss.=Sandstone; Ls.=Limestone; Fm.=Formation; Sh.=Shale. *Wyoming State Geological Survey, November, 2001.*

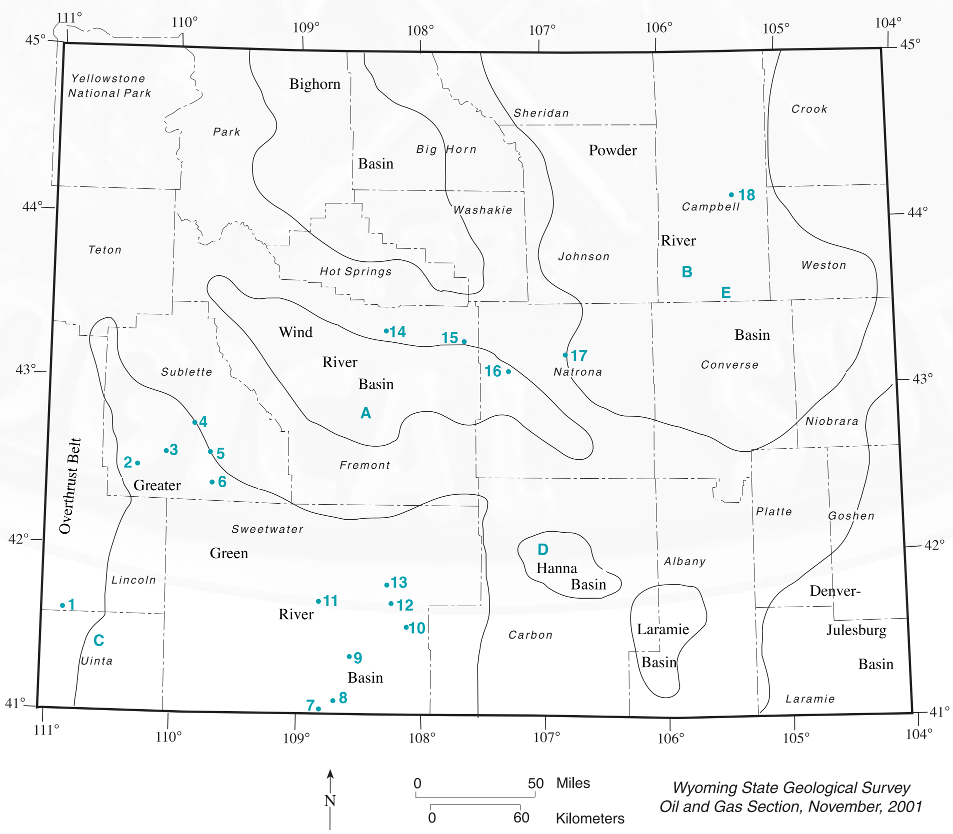

Figure 9. Oil and gas exploration and development activities (numbers) and coalbed methane activities (letters) in Wyoming during the third quarter of 2001. Locations are approximate and may represent more than one well location or project.

Coal Update

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As the nation mourned the September 11 terrorist attacks that resulted in great loss of life in New York, Pennsylvania, and Washington, D.C., Wyoming coal miners joined the nation's war against terrorism by continuing to supply a large part of the fuel that generates the nation's electricity. As we recover from that dark September morning, Wyoming coal will keep the nation's lights shining.

Third-quarter coal production from Wyoming mines is on track to top last year's record production by some 4 to 5%. Year-end and forecast coal prices statewide are now expected to show annual gains instead of losses, the first time this has happened in decades. Although the gains are quite modest, they do reflect the recent upturn in spot market prices, which ultimately affect contracts now being negotiated and signed. Better coal prices have led to an announced restart of Peabody Energy's idled Rawhide mine north of Gillette. Federal coal leasing activities continued in the quarter, as did activities improving transportation of Wyoming coal to markets and expansion of electrical generating capacity at existing facilities.

Production and prices

Wyoming coal deliveries so far this year indicate annual production could possibly reach 360 million short tons, according to U.S. Energy Information Administration (EIA) data. During the third quarter of 2001, Wyoming mines shipped 92,231,000 short tons of coal (**Table 11**). Large spikes in deliveries at the end of each quarter, primarily of contract coal, have accounted for most of the increases over past years (**Figures 10** and **11**). Through the end of September, Wyoming coal deliveries totaled nearly 270.6 million short tons. The Wyoming State Geological Survey's (WSGS's) forecast published earlier (see *Wyoming Geo-notes No. 71*, October, 2001) has been adapted by the Consensus Revenue Estimating Group (CREG) for the State of Wyoming and the new production numbers for 2001 (based on deliveries) support the predicted 4 to 5% increase over 2000 production. After the production surges ahead in 2001 to 354.5 million short tons, modest 1% increases are predicted each year from 2002 through 2006 (**Table 12**). Over 96% of the state's total production is now from Powder River Basin (PRB) mines in Campbell and Converse counties. Note that new production is anticipated from Carbon County starting in 2003, although southern Wyoming production will remain stagnant (**Figure 12**).

Spot prices for PRB coal decreased during the month of July and into the first week of August (**Figure 13**). Spot prices rose slightly, then stabilized between about $8.30 to $6.80 per ton FOB mine in the last six weeks of the third quarter. This is still an amazing $3 to $4 per ton increase over spot prices reported at the end of 2000.

Because the increase in spot prices is expected to have an impact on coal contracts for 2002 and beyond, CREG has revised its estimates of average prices for Wyoming coal (**Tables 2** and **13**). The State Geologist is a member of CREG and provides input into their production and price estimates based on information provided by the head of the Coal Section at the WSGS. Remembering that CREG estimates are usually biased on the conservative side, for the first time since 1992, gains in coal prices are predicted over the next five years. Compare these new forecast prices to those reported in *Wyoming Geo-notes No. 71*, October, 2001, p. 14.

Prices for southern Wyoming coal are somewhat higher than our earlier forecast but are still expected to decrease through 2006. Coal from northeastern Wyoming (e.g. PRB) is expected to increase even more than earlier forecast, and

Table 11. Estimated monthly coal deliveries from Wyoming's mines in short tons (January, 1997 through September, 2001).

	1997		1998		1999		2000		2001	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
January	25,165,405	25,165,405	26,536,217	26,536,217	27,105,791	27,105,791	27,773,610	27,773,610	27,743,000	27,743,000
February	20,743,224	45,908,629	23,196,152	49,732,369	25,803,390	52,909,181	25,594,109	53,367,719	27,827,000	55,570,000
March	22,566,012	68,474,641	23,861,472	73,593,841	28,222,743	81,131,923	28,262,696	81,630,415	33,739,000	89,309,000
April	20,961,008	89,435,649	24,768,989	98,362,830	25,965,867	107,097,791	25,549,039	107,179,454	27,302,000	116,611,000
May	23,102,867	112,538,516	25,278,960	123,641,790	28,698,498	135,796,288	26,222,515	133,401,969	27,752,000	144,363,000
June	20,862,610	133,401,126	24,450,835	148,092,625	24,753,829	160,550,118	25,085,516	158,487,485	33,968,000	178,331,000
July	24,074,929	157,476,055	25,663,577	173,756,202	28,266,458	188,816,576	28,881,862	187,369,347	29,200,000	207,531,000
August	23,002,254	180,478,309	26,591,950	200,348,152	28,346,757	217,163,333	29,075,295	216,444,642	27,662,000	235,193,000
September	22,452,566	202,930,875	26,041,099	226,389,251	27,373,417	244,536,749	25,865,389	242,310,032	35,369,000	270,562,000
October	21,623,057	224,553,932	26,659,121	253,048,372	26,837,295	271,374,045	26,441,615	268,751,646		
November	21,695,072	246,249,004	25,620,216	278,668,588	26,843,021	298,217,066	27,400,245	296,151,892		
December	24,695,740	270,944,744	26,102,620	304,771,208	26,834,927	325,051,993	28,300,773	324,452,665		
Total Utility Tonnage[1]		**270,944,744**		**304,771,208**		**325,051,993**		**324,452,665**		
Total Tonnage Other [2]		**10,536,772**		**10,190,883**		**11,407,945**		**14,399,483**		
Total Tonnage Produced[3]		**281,481,516**		**314,962,091**		**336,459,938**		**338,852,148**		

[1]From Federal Energy Regulatory Commission (FERC) Form 423 1997 through 1998, FERC Form 423 as modified by WSGS for 1999 through 2001. [2]Includes estimates of residential, industrial, and exported coal. [3]Wyoming State Mine Inspector's Annual Reports. *Wyoming State Geological Survey, Coal Section, November, 2001.*

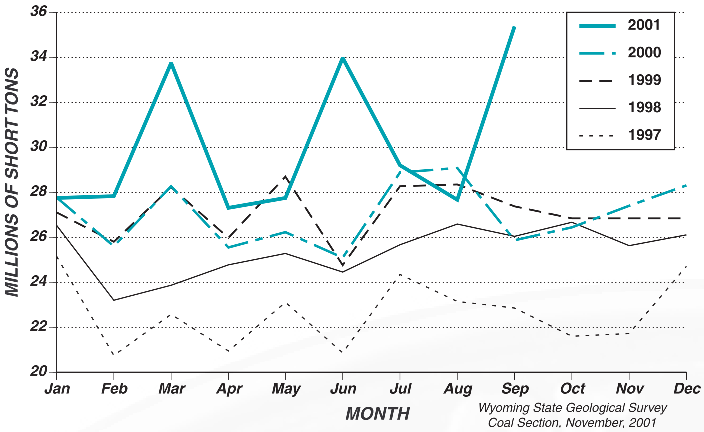

Figure 10. Reported monthly deliveries from Wyoming coal mines (1997 through September, 2001). From Form 423 of the Federal Energy Regulatory Commission (FERC) as modified by the WSGS for 1999 through 2001.

despite decreased prices in southern Wyoming, the overall effect for statewide average prices is still a price increase (**Figure 14**). In 2001, prices for PRB coal are expected to increase 7.7% over 2000 prices; statewide average prices will increase about 4.6% during the same time. The increased coal prices should improve Wyoming's economic outlook from 2002 through 2006.

Developments in the Powder River Basin

On July 10, Peabody Energy announced plans to restart its idled Rawhide mine. The mine was idled in April, 1998 due to weak coal prices in the PRB. With prices rebounding this year, the company said it will start the mine by the end of this year. The targeted production level for the mine is 8 million short tons per year. Prior to mothballing, the mine produced 12 million short tons per year (COAL Daily, 7/11/01). The Rawhide mine produces coal containing approximately 8300 British Thermal Units (Btus) per pound on an as-received basis.

The U.S. Department of Justice (DOJ) in July initiated an investigation of possible anticompetitive practices by the coal industry, mainly at coal operations in the PRB. The DOJ has contacted several producers in the area asking

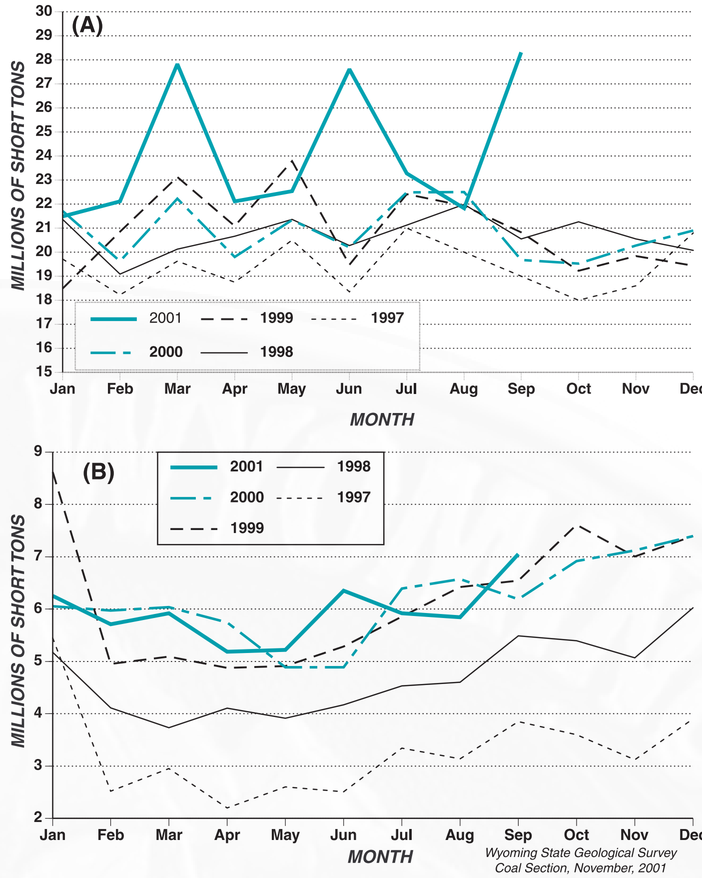

Figure 11. Monthly coal deliveries from Wyoming (1997 through September, 2001). (A) Coal sold on contract and (B) coal sold on the spot market. From Form 423 of the Federal Energy Regulatory Commission (FERC) as modified by the WSGS for 1999 through 2001.

for information on production and pricing dating back to 1998 (COAL Daily, 7/26/01). The DOJ is looking at a period of time in which some producers cut back production at several mines citing depressed market prices. However, annual production levels in the PRB have increased over this same period. The WSGS believes that the PRB is the most competitive coal basin in the world.

Triton Coal Co. has applied to the U.S. Bureau of Land Management (BLM) for a lease modification to acquire a 155-acre tract of coal reserves adjacent to their North

Table 12. Wyoming coal production by county[1,2] (in millions of short tons), 1995 through 2000 with forecasts to 2006.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Powder River Basin												
Campbell County	232.4	245.3	246.3	274.1	296.3	299.5	311.5	315.0	316.6	325.3	328.9	332.6
Converse County	14.1	15.8	17.8	23.4	24.0	23.6	30.0	30.0	30.0	25.0	25.0	25.0
Sheridan County	M	M	M	M	M	M	M	M	M	M	M	M
Subtotal	246.5	261.1	264.1	297.5	320.0	323.1	341.5	345.0	346.6	350.3	353.9	357.6
Southern Wyoming												
Carbon County	3.8	4.7	5	3.5	3.5	2.0	M	M	2.0	2.0	2.0	2.0
Sweetwater County	9.1	8.2	7.8	9.2	8.0	10.0	8.0	8.0	8.0	8.0	8.0	8.0
Lincoln County	4.5	4.4	4.6	4.7	4.7	3.7	5.0	5.0	5.0	5.0	5.0	5.0
Subtotal	17.4	17.3	17.4	17.4	16.4	15.7	13.0	13.0	15.0	15.0	15.0	15.0
Total Wyoming[3]	**263.9**	**278.4**	**281.5**	**314.9**	**336.5**	**338.9**	**354.5**	**358.0**	**361.6**	**365.3**	**368.9**	**372.6**
Annual change	**11.4%**	**5.5%**	**1.1%**	**11.9%**	**6.9%**	**0.7%**	**4.6%**	**1.0%**	**1.0%**	**1.0%**	**1.0%**	**1.0%**
Higher-priced coal[4]	**26%**	**24%**	**22%**	**17%**	**13%**	**9%**	**6%**	**4%**	**4%**	**4%**	**4%**	**4%**

[1]Reported tonnage from the Wyoming State Inspector of Mines (1995 through 2000). [2]County estimates by the Wyoming State Geological Survey, September, 2001 for 2001 through 2006. Totals may not agree because of independent rounding. [3]Estimate is CREG's Wyoming State Government Revenue Forecast, October, 2001. [4]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=minor tonnage (less than a million tons). *Wyoming State Geological Survey, Coal Section, November, 2001.*

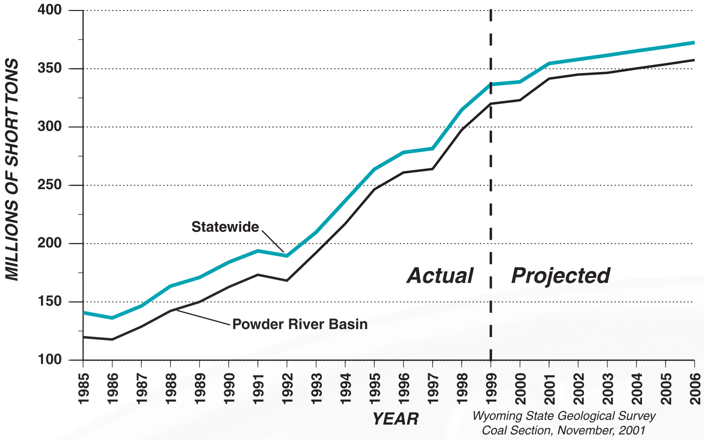

Figure 12. Annual coal production from Wyoming and the Powder River Basin (1985 through 2000) with forecasts to 2006. Sources: Wyoming State Inspector of Mines (1985 through 2000), CREG (2001 through 2006), and the Wyoming State Geological Survey.

Rochelle mine. The new tract is believed to contain approximately 13 million short tons of coal. According to BLM, granting the lease modification would be the only way to recover the coal on the tract. By itself, the tract is too narrow to be mined due to the required setback from a county road; the coal can be recovered in conjunction with the current pit sequence for the existing lease. By modifying the current lease, BLM believes the additional coal can be recovered without any additional surface disturbance. BLM held a public hearing on the application and held the comment period open through the end of August (COAL Daily, 8/20/01).

KFx made its final payment of $1.16 million to the State of Wyoming for a loan the company received to develop its clean coal technology. The original amount of the loan was $11.7 million, with the State of Wyoming retaining a 12% interest in the K-fuels patents until the loan was retired.

Table 13. Breakdown of average prices paid for coal from northeastern Wyoming, southern Wyoming, and Wyoming as a whole (1988 through 2000) with forecast to 2006.

	Year	Northeastern	Southern	Statewide
ACTUAL	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	$17.15	$5.41
	1999	$4.57	$16.58	$5.19
	2000	$4.93	$16.19	$5.45
FORECAST	2001	$5.31	$16.00	$5.70
	2002	$5.38	$15.50	$5.75
	2003	$5.44	$15.00	$5.82
	2004	$5.46	$15.00	$5.85
	2005	$5.48	$15.00	$5.88
	2006	$5.51	$15.00	$5.90

Statewide data for 1988 through 1990 are from reports by the U.S. Department of Energy's Energy Information Administration; data for 1991 through 2000 are derived from Wyoming Department of Revenue information; estimates for 2001 through 2006 are from CREG's Wyoming State Government Revenue Forecast, October, 2001; and all regional breakdowns by the *Wyoming State Geological Survey, Coal Section, November, 2001*.

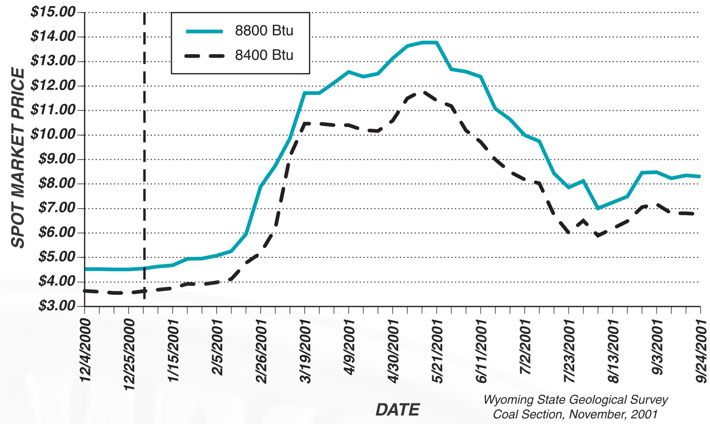

Figure 13. Wyoming PRB coal spot price watch (December 4, 2000 through September 24, 2001). Modified from COAL Daily's spot market index, and Coal Week's short-term spot market price index.

KFx now owns 100% of the patents and is working with Kennecott Energy and two electric utility companies to further develop K-fuel facilities (COAL WEEK, 8/6/01).

BLM scheduled an October 11, 2001 competitive lease sale for the Belle Ayr 2000 Lease by Application (LBA) tract that RAG American Coal is seeking. The tract contains an estimated 31.4 million short tons of recoverable reserves from the Wyodak coal seam, which averages 76 feet thick beneath overburden averaging 192 feet in thickness. The overall as-received coal quality is estimated at 8490 Btus per pound, 30% moisture, 4.75% ash, and 0.35% sulfur (COAL WEEK, 9/17/01).

Transportation developments

Rail Link, Inc. has taken over unit train loading operations at Triton Coal's Buckskin mine and RAG Coal West's Eagle Butte mine. Last year Rail Link began loading operations at Triton's North Rochelle mine. The company also handles the loading of unit trains at the Decker East, Decker West, and Spring Creek mines in the PRB, Montana. Both Decker mines

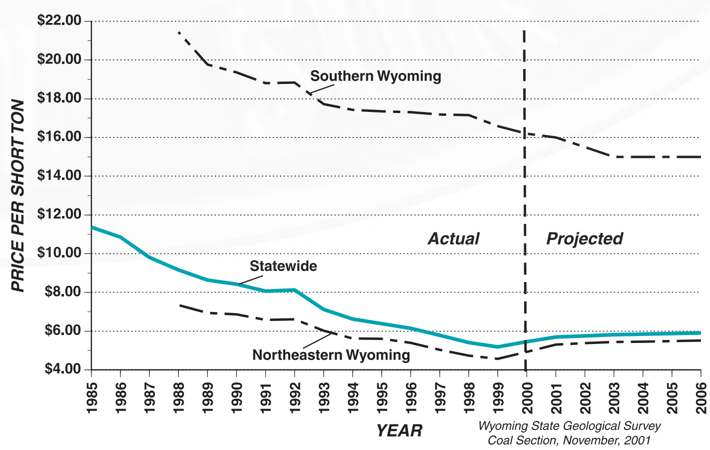

Figure 14. Average prices paid for Wyoming coal by producing area (1985 through 2000) with forecasts to 2006. Sources: U.S. Energy Information Administration (1985 through 1990); Wyoming Department of Revenue (1991 through 2000); and CREG (2001 through 2006).

are a joint venture between Kennecott Energy Co. and Peter Kiewit and Sons, Inc. while Kennecott wholly owns the Spring Creek mine (COAL Daily, 8/7/01).

Plans to construct an alternate rail line from the PRB to consumers in the central U.S. is still moving ahead, albeit slowly. The proposed rail project would be constructed into the PRB, Wyoming by extending the former "Cowboy Line" route that runs through Nebraska. Supporters of the project believe that a Nebraska line will provide certain Midwest utilities with more competitive rail rates than can be offered by the Union Pacific (UP), Burlington Northern-Santa Fe, or the proposed Dakota, Minnesota & Eastern railroads. The group working on the preliminary planning effort is known as the Cowboy Railroad Development Company (COAL Daily, 9/20/01).

Midwest Generation hopes to get permission to construct a rail spur from their Joliet, Illinois power station to the UP line for more direct access to PRB coal. Currently the plant consumes roughly 4.5 million short tons of PRB coal per year, and wants to increase that amount by 1 to 1.5 million short tons. The UP rail lines are now within a half-mile of the plant; the Illinois Central then makes the final delivery. The plant's current haulage contract with the Illinois Central expires in late 2002 (COAL WEEK, 9/3/01).

Regulatory developments

Due to the language common in many coal supply contracts, a change in the way the Bureau of Labor Statistics estimates labor costs in coal mining may have a significant impact on future contract price adjustments. The Bureau's SIC-122 index is often used to escalate labor cost in long-term contacts. The change in methodology for computing the index began in March, 2000, retroactive to rates in April, 1999. While the index now shows lower labor costs, coal operators claim that hourly wages continue to increase at a rate higher than in the last 20 years (COAL WEEK, 8/6/01).

Two Elk Generation Partners, a subsidiary of North American Power Group, has asked the Wyoming Department of Environmental Quality (DEQ) for permission to create a landfill to dispose coal combustion material and scrubber ash from their proposed power plant near Wright, Wyoming. The landfill is designed to hold 9.88 million short tons of combustion waste. As part of the landfill design, the company is proposing that the structure be lined with clay and a plastic membrane (COAL WEEK, 11/24/01).

The U.S. Environmental Protection Agency (EPA) in their newly released *Inventory of U.S. greenhouse gas emissions and sinks: 1990-1999* shows that methane emissions from coal mining have fallen by a third during the past decade. All underground and surface coal mines liberate at least some methane as part of their normal operations. Over the past decade many deep mines implemented degasification in advance of mining. Current coalbed methane production is also reducing the methane released from coal mines and sending more and more methane into the nation's pipeline system. It is interesting to note that the EPA study shows the nation's trash landfills accounting for more than three times the methane released in coal mining (COAL WEEK, 9/25/01).

Market developments and opportunities

Kennecott Energy's KennecottDirect web site, created in January of this year to enable customers to buy coal on a monthly and quarterly basis, is seeing a slowing of sales. The slowdown is related to the limited tonnage available for posting, and in part to customers evaluating the rapid changes the market has seen this year. A company official said that Kennecott was working on upgrades to the site, including online invoicing and access to historical data on shipments (COAL Daily, 7/3/01).

Arch Coal has joined in an agreement with ADA-ES (a specialty chemical company) to help market ADA-249, a product designed to improve combustion of PRB coal in cyclone boilers. Testing at several coal-fired utilities has shown that the chemical additive, when added to a boiler prior to combustion, increases the burning efficiency of subbituminous coal, allowing it to perform more like bituminous coal (COAL Daily, 7/10/01).

Sunflower Electric Power announced plans to expand its Holcomb power plant located near Garden City, Kansas. The company will join with International Energy Partners to develop a 600-megawatt (MW) coal-fired plant adjacent to Holcomb (see other details in *Wyoming Geo-notes No. 71*, October, 2001, p. 16). The new plant will be integrated with Holcomb Unit 1 through common facilities. The two companies, under the newly formed Sand Sage Power joint venture company, will own the new plant on a 50-50 basis. Estimated cost of the project is believed to be \$600 to \$800 million. The plan calls for commercial operations to begin in 2005. Like the present Holcomb plant, the new plant is expected to be fueled by PRB coal (COAL Daily, 8/6/01).

Table 14 tabulates some of the contract, spot sales, test burns, and solicitations for Wyoming coal, announced during the third quarter of 2001.

References cited

Federal Energy Regulatory Commission (FERC) Electric Form 423 (http://www.ferc.fed.us/electric/f423/form423.htm)

Stauffenberg, D.G., 2000, Annual report of the State Inspector of Mines of Wyoming for the year ending December 31, 2000: Office of the State Inspector of Mines, Rock Springs, Wyoming, 81 p.

Table 14. Marketing activities for Wyoming coal producers during the third quarter of 2001*.

Utility	Power Plant	Coal Mine/Region	Activity	Tonnage	Comments
American Electric Power	System	PRB	So	3.5 mt/y	Up to 5 years beginning in 2002
American Electric Power	System	PRB	So	3.5 mt/y	Up to 4 years beginning in 2002
American Electric Power	System	PRB	So	3.5 mt/y	Up to 3 years beginning in 2002
American Electric Power	System	PRB	So	3.5 mt/y	Up to 2 years beginning in 2002
Consumers Energy	System	PRB	So	50 mt	Over seven years; delivery to start in 2003
Hastings Utility Department	Hastings	PRB	So	0.3 to 0.35 mt/y	Delivery to start in 2002, number of years unspecified.
Kentucky Utilities	Ghent	Arch Coal/PRB	Sp	158,887 t	Delivery in second half of 2001
Lansing Board of Water & Light	System	Black Thunder/PRB	C	1.2 to 1.5 mt/y	2002-2003
Lower Colorado River Authority	System	PRB	So	up to 1 mt	Delivery in 2002
MidAmerican Energy	System	PRB	So	2.5 mt/y	Delivery 2003-2007
MidAmerican Energy	System	PRB	So	0.5 mt/y	Delivery 2002-2003
Muscatine Power & water	Muscatine	PRB	So	1.1 mt	Delivery in 2003
Omaha Public Power District	Nebraska City and North Omaha	PRB	So	up to 2.4 mt	Delivery in 2002
PP&L Generation	Corette	Eagle Butte/PRB	C	0.7 mt/y	Contract extension through 2003
Salt River Project	Coronado	PRB	Sp	0.7 mt	Delivery in 2002
TVA	System	PRB	So	up to 0.5 mt	Seeking five to six year contract
Western Fuels Association	Various Association members	PRB	So	4.5 to 8.7 mt	Delivery during or after 2003

*Data obtained from: COAL WEEK, COAL Daily, Coal Age, FERC database, and personal contacts. Note: C = contract; mt = million short tons; PRB = Powder River Basin; Sp = spot coal; So = solicitation; t = short tons; and t/y = short tons per year. *Wyoming State Geological Survey, Coal Section, November, 2001.*

Coalbed Methane Update

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Coalbed methane production in Wyoming through the first eight months of 2001 reached 154.7 billion cubic feet (BCF) (**Table 15**). This was 14.6% of Wyoming's total gas production. There were 7104 producing wells and 2894 shut in wells in August, 2001. The Consensus Revenue Estimating Group (CREG) for the State of Wyoming predicted in October that 235 BCF of coalbed methane will be produced in 2001. This is an average of almost 20 BCF per month (compare this monthly production with past years using **Figure 15**). CREG also projects an annual increase in production of 80 BCF per year through 2006, which results in estimated production for 2006 of 635 BCF. Additional pipeline capacity completed in the third quarter and scheduled for completion in the fourth quarter will allow another 200 million cubic feet (MMCF) of gas per day to flow out of the Powder River Basin (PRB).

Activities of coalbed methane companies

An expansion of the Fort Union Gas Gathering System that extends south of Gillette to Glenrock will increase the line's daily capacity by 200 MMCF to 634 MMCF per day. The Fort Union pipeline feeds three other pipelines near Glenrock, and those lines carry gas out of Wyoming. The largest of the three lines, Wyoming Interstate's Medicine Bow Lateral, carries 427

Table 15. Monthly Wyoming coalbed methane production in MCF (1997 through August, 2001).

	1997		1998		1999		2000			
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	883,090	883,090	1,962,524	1,962,524	3,660,394	3,660,394	8,480,197	8,480,197	18,022,602	18,022,602
February	775,063	1,658,153	1,882,343	3,844,867	3,462,639	7,123,033	8,798,726	17,278,923	16,885,190	34,907,792
March	1,034,623	2,692,776	2,134,019	5,978,886	4,110,819	11,233,852	9,948,250	27,227,173	18,592,019	53,499,811
April	1,033,885	3,726,661	2,154,228	8,133,114	4,042,686	15,276,538	10,598,260	37,825,433	19,263,561	72,763,372
May	1,117,202	4,843,863	2,254,143	10,387,257	4,425,435	19,701,973	11,891,863	49,717,296	20,397,357	93,160,729
June	1,100,462	5,944,325	2,368,974	12,756,231	4,608,771	24,310,744	12,260,550	61,977,846	20,020,624	113,181,353
July	918,571	6,862,896	2,455,849	15,212,080	4,879,316	29,190,060	13,092,297	75,070,143	20,968,648	134,150,001
August	1,324,372	8,187,268	2,654,617	17,866,697	4,793,378	33,983,438	14,269,403	89,339,546	20,528,278	154,678,279
September	1,220,247	9,407,515	2,988,509	20,855,206	5,126,269	39,109,707	14,405,398	103,744,944		
October	1,445,545	10,853,060	3,158,133	24,013,339	5,962,367	45,072,074	15,514,472	119,259,416		
November	1,536,287	12,389,347	3,188,968	27,202,307	5,947,893	51,019,967	15,249,807	134,509,223		
December	1,677,597	14,066,944	3,434,886	30,637,193	7,182,416	58,202,383	16,939,856	151,449,079		
Total Utility Tonnage[1]		**14,066,944**		**30,637,193**		**58,202,383**		**151,449,079**		

[1]Data from the Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, September, 2001.*

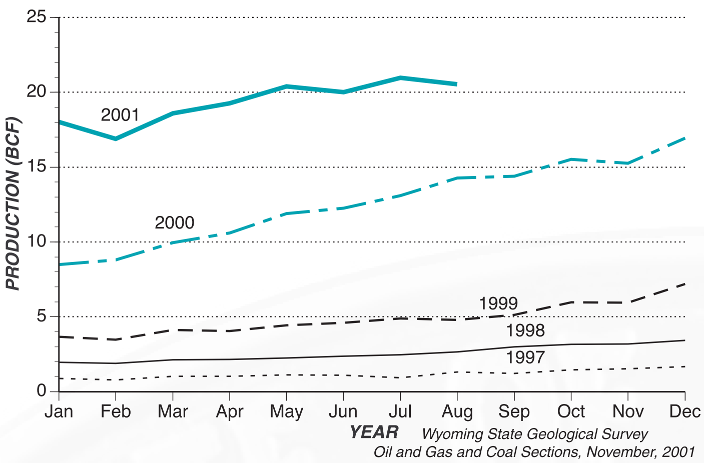

Figure 15. Coalbed methane production in Wyoming by month in BCF (January, 1997 through August, 2001). Data from the Wyoming Oil and Gas Conservation Commission.

MMCF per day from Douglas to other pipelines a few miles south of Cheyenne. The Medicine Bow Lateral expansion project should be completed in December, 2001 (see Figure 17, p. 19 in *Wyoming Geo-notes No. 71*, October, 2001), when the capacity will increase to over 1 BCF per day.

Phillips Petroleum staked two stratigraphic tests in T33N, R97W, to evaluate the coalbed methane potential of Mesaverde coals at a depth of 2150 to 2735 feet. Devon Energy also staked a test in the same township to evaluate Mesaverde coals at a depth of 4874 feet (**location A, Figure 9**).

Western Gas Resources announced that coalbed methane production from its All Night Creek pilot project in the Big George coal bed in T42 and 43N, R73 and 74W (**location B, Figure 9**) began flowing into a sales line at the rate of 2.5 MMCF per day. Fifty-three wells have been drilled and connected to a pipeline, but so far only 39 wells are producing methane. Western and its partner plan to drill an additional 45 wells in the area by June 30, 2002.

Rocky Mountain Gas drilled and completed four wells to test Frontier and Adaville coals in the Hams Fork Coal Field (**location C, Figure 9**) and plans to drill four more wells this year. Production data has not yet been released.

Everest Energy Fund LLC. announced that it has acquired the rights to explore for and produce coalbed methane from an undisclosed area in Johnson and Sheridan counties. The company plans to drill over 600 coalbed methane wells in the next year and projects recoverable methane in excess of 250 BCF.

Allwire Inc., a polyethylene pipe manufacturer, is investing $6.5 million for a 48,000-square-foot manufacturing facility in Gillette. Production should begin in January, 2002. Allwire will produce high density polyethylene pipe for oil and gas, cable conduit, and pump cables.

Regulatory issues

The U.S. Bureau of Land Management (BLM) approved the Seminoe Road Coalbed Methane Pilot Project (**location D, Figure 9**). The project involves the development of six coalbed methane wells and associated facilities on BLM-administered public land. The entire project includes the drilling, completion, and production of 19 wells, with 13 wells on private land. Water produced during the life of the project will be collected and discharged at three points into Pool Table Draw, a drainage that eventually discharges into Seminoe Reservoir.

Phillips Petroleum applied for a permit to create two water reservoirs near the Converse-Campbell county line to store water produced from coalbed methane wells (**location E, Figure 9**). The water would then be diverted using a 115-mile-long pipeline to discharge water into the Cheyenne River via Antelope Creek and on into South Dakota. One reservoir would serve as a collection and settling pond and the other would release water. Phillips believes the reservoirs would reduce erosion, enhance water quality, provide for continued coalbed methane development, augment flows in Antelope Creek, and reduce water discharged into the Tongue and Powder rivers.

The States of Wyoming and Montana signed an 18-month interim agreement on August 15 to monitor water flowing from Wyoming into Montana via the Powder and Little Powder rivers. The agreement will allow water discharge permits to be issued sometime this fall for coalbed methane wells that discharge water into those river drainages. Water that would potentially flow into those drainages is mainly from wells drilled into the Big George coal bed in the western PRB.

Revised activity maps for Powder River Basin

The Oil and Gas and Coal Sections at the Wyoming State Geological Survey (WSGS) have once again revised the coalbed methane activity maps for the PRB, Wyoming. Coalbed methane maps CMM 01-6 and CMM 01-7, of the eastern and western parts of the PRB respectively, contain updated information through September, 2001 and replace maps CMM 01-3 and CMM 01-4, which were updated in June. Updated digital files in ESRI's ArcInfo® format for both these maps are now combined on a single CD-ROM, which also contains CMM 00-3, *Stream classification and drainage systems map of northeast Wyoming coalbed methane development area*. Also updated is CMM 01-5, the reduced version (scale 1:250,000) which combines the larger, more detailed maps of the eastern and western parts of the basin. This map is available as CMM 01-8 and can be ordered in a laminated version. For ordering information and prices, see the **PUBLICATIONS UPDATE** on page 34 of this issue.

Industrial Minerals and Uranium Update

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The economic downturn that began in mid-2000 experienced a partial recovery in late fall. The events of September 11, 2001 have caused some uncertainty in the projections of industrial mineral production in Wyoming. Although 2001 production will probably be less than estimated earlier this year, there seems to be no severe impact on Wyoming industrial mineral commodities in production. Production estimates made by the Consensus Revenue Estimating Group (CREG) of the State of Wyoming in early October did not change for *in situ* uranium and sulfur production; production of trona is expected to be less than previously thought. Forecast prices for mined trona decreased over last year's estimate. Plans to develop dimensional stone quarries in Wyoming have been delayed; however, no developer has indicated curtailing plans. Colorado retailers of landscape rock, ornamental stone, decorative aggregate, fieldstone, and flagstone have detected no reduction in demand. The production of major industrial mineral commodities in Wyoming continues at normal levels and so far, no large-scale reduction in Wyoming seems likely. The continuation of the war on terror may create a greater demand for some industrial minerals.

Field trip

A geologic field trip entitled "Geology, minerals, and soils of Platte County," sponsored by the Platte County Resource District (PCRD), was conducted on October 31, 2001 (**Figure 16**). The field trip leaders were Lance Clark of the PCRD, Ray Harris of the Wyoming State Geological Survey, and Dr. Larry Munn of the College of Agriculture, University of Wyoming. Sites visited included Greyrocks Reservoir, Guernsey Stone's aggregate quarry, Precambrian pillow basalt and historic copper mining sites at Hartville, the Precambrian-Cambrian-Mississippian-Pennsylvanian rock sequence in Guernsey State Park, Imerys Marble Quarry, and the Twin Pine Ranch. Bill Reffalt of Guernsey Stone explained their operation to the participants and Trent Carney of Imerys showed the participants his company's operation, in spite of 120 mile per hour winds at the site at the time. Participants included about 40 residents of Platte and nearby counties and 45 students from Wheatland High School with their science teacher, Wayne Hicks.

Figure 16. Participants on the October 31, 2001 geology, minerals, and soils field trip. Dr. Larry Munn (center, with microphone) is lecturing about soil development at Greyrocks Reservoir. Digital image by Ray Harris, October, 2001.

Bentonite

Refined bentonite products are produced at fifteen mills in Wyoming (**Figure 17**). Bentonite products include, in order by amount of production: foundry mold binding clay, kitty litter, drilling mud, environmental adsorbents, water barriers, and other uses (see *Wyoming Geo-notes No. 70*, July, 2001). The continuation of the war on terror could cause an increase in bentonite production for mineral fillers, foundry clay, and adsorbents. Increased drilling resulting from exploration to secure more domestic sources of oil and gas may affect increased bentonite production for drilling mud.

Construction aggregate

Wyoming's largest producers of construction aggregate are Martin-Marietta Materials (MMM) and Guernsey Stone, a division of Peter Kiewit, Inc. MMM operates a quarry on the Union Pacific Railroad west of Cheyenne in Laramie County (**Figure 17**). The rock quarried there is a granitic gneiss used for railroad ballast and other construction applications. Guernsey Stone also operates a quarry north of Guernsey (**Figures 17** and **18**) that produces dolomitic marble, quartzite, and limestone aggregates used primarily in highway construction but also in a large variety of construction applications in the region. Guernsey Stone also sells their products as decorative aggregate.

Decorative and dimensional stone

Raven Quarries operates a quarry for dimensional stone in northern Albany County (**Figure 17**). Raven produces a red or pink patterned granitic rock named Mirage®, and has produced a black granitic rock called Wyoming Raven®. Raven Quarries is currently producing the black stone (Raven®) for desktops in the Wyoming Senate chamber and the multicolored stone (Mirage®) for the Wyoming

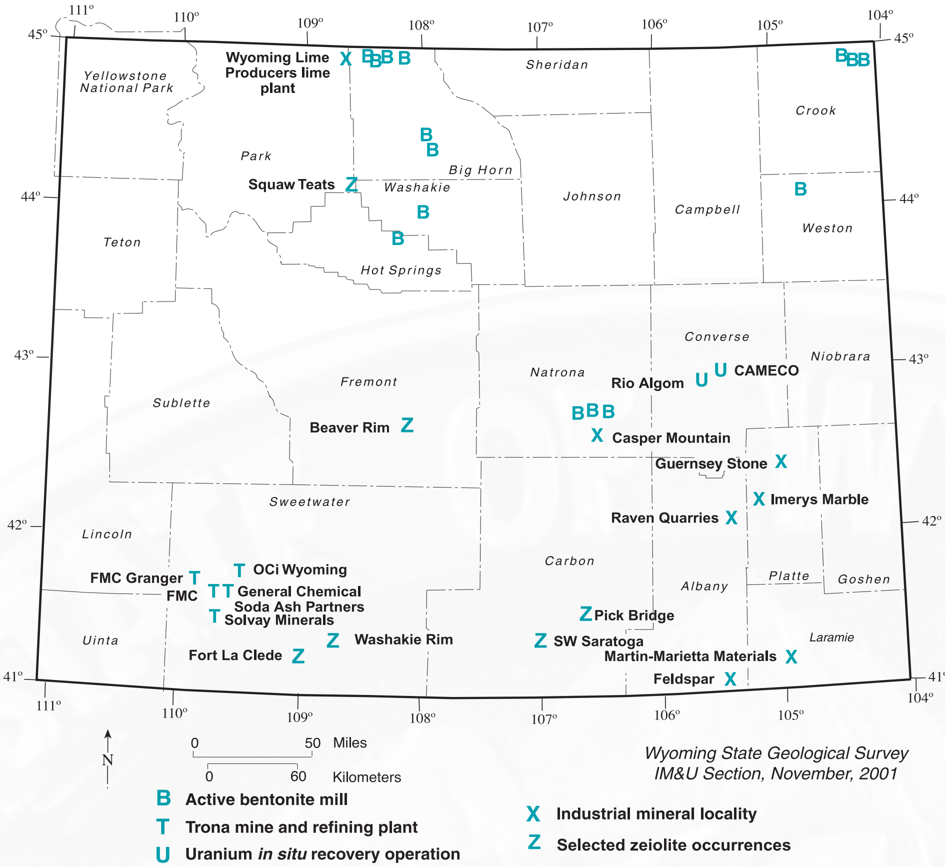

Figure 17. Index map of Wyoming showing the location of industrial mineral and uranium sites mentioned in the text. Locations and areas are approximate and may represent more than one site.

House chamber. Six entities continue to pursue exploration and/or financing to develop additional dimensional stone quarries and large processing plants in Wyoming. Although development plans have slowed due to recent economic uncertainties both related and unrelated to September 11 events, all entities are continuing with development plans.

Decorative aggregate production in Wyoming, however, is increasing. Aggregate used for appearance produced in Wyoming is sold primarily in the growing Colorado Front Range area. The largest producer is Imerys Marble, which produces 180,000 tons of white marble aggregate at its quarry west of Wheatland (**Figure 17**) and plant in Wheatland. Other decorative aggregate is produced at several localities in Wyoming including Guernsey Stone, as noted above (**Figure 17**), which is used in decorative structures in this area (**Figure 19**). In the past, decorative aggregate has been quarried for local and regional markets throughout the state (**Figure 20**).

Feldspar

Feldspar is a common mineral found in many types of rocks. When found in concentrations, it can be produced as an industrial mineral used to manufacture ceramics, as an ingredient in certain grades of glass, for glazes, and as decorative aggregate. Feldspar has recently been quarried on Casper Mountain (**Figure 17**) for the production of ceramic glazes at a plant in Custer, South Dakota. In the past, feldspar has been quarried southeast of Laramie (**Figures 17** and **21**) for the manufacture of false teeth. One of these deposits has been quarried recently for decorative aggregate used primarily for landscape rock.

Limestone

Limestone (calcium carbonate) is quarried in Wyoming for construction aggregate, cement, and emissions control. Limestone quarried in Montana and South Dakota is used as a clarifying agent in the manufacture of sugar from sugar beets in Wyoming refineries. Lime quarried in Montana is manufactured into lime (calcium oxide) at Wyoming Lime Producers north of Frannie, Wyoming (**Figures 17** and **22**).

Trona

Four companies in Wyoming mine trona (sodium sesquicarbonate) by underground methods and solution recovery methods at five locations and produce sodium products at plants near the mines (**Figure 17**). Soda ash, the primary product, is an industrial chemical used to manufacture a variety of products including glass, soap and detergents, soil conditioners, water treatments, and when purified, it is baking soda. Wyoming soda ash production is down from past years due mostly to increased foreign competition from China and some new production from Colorado operations (see *Wyoming Geo-notes No. 70*, July, 2001) for overseas markets. China has increased production by constructing new synthetic process soda ash plants, and their government subsidizes the cost of production. China has some bedded trona deposits as well.

Wyoming soda ash producers anticipate lower production rates in the near future. Trona production is expected to be from 2 to 2.5 million short tons less than previously thought (**Table 1**). The actual price for mined trona was less in 2000 than reported earlier but our forecast prices for 2001 through 2006 are $38.00 per short ton (**Table 2**), $0.25 higher than our last estimate.

Zeolites

Zeolites are a group of minerals with large cation-exchange capacities. They are mined in several western states and sold for a variety of uses including water treatments, toxic element cleaning agents, odor control, and similar uses. Small amounts of clinoptilolite, a zeolite mineral, have been mined in Wyoming near historic Fort LaClede, in Sweetwater County southeast of Rock Springs (**Figure 17**). Zeolites, mostly clinoptilolite, are found in potentially commercial

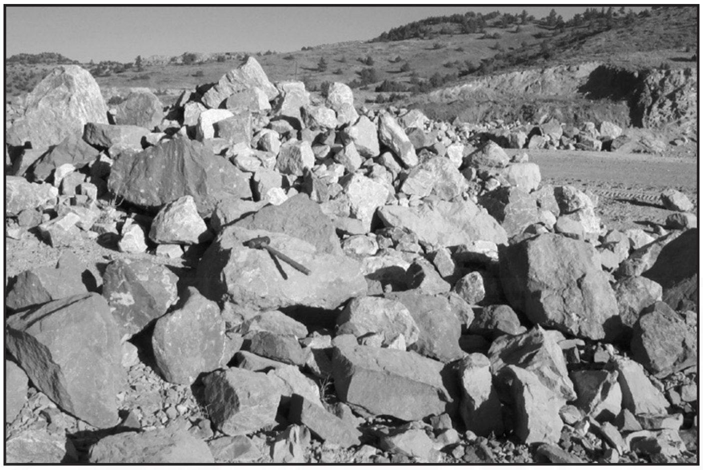

Figure 18. Oversize boulders of Precambrian dolomitic marble of various colors (gray, black, pink, and red) at Guernsey Stone's quarry near Guernsey. These blocks have been used as decorative aggregate boulders at various localities in the region (see Figure 19). Digital image by Ray Harris, November, 2001.

Figure 19. Retaining wall in Fort Laramie constructed of dolomitic marble boulders from Guernsey Stone and cement. Digital image by Ray Harris, November, 2001.

amounts in a few other locations in Wyoming (**Figure 17**). These areas include parts of the Washakie Basin rim in Sweetwater County; Beaver Rim in Fremont County; southwest of Saratoga and at Pick Bridge north of Saratoga in Carbon County; and in the Tatman Formation, especially in the Squaw Buttes area (**Figure 23**) in Park, Washakie, Big Horn, and Hot Springs counties.

Uranium

Uranium is mined by *in situ* methods at two locations in the southern Powder River Basin in Converse County (**Figure 17**). Yellowcake from the two on-site recovery mills is shipped for enrichment and conversion into nuclear power plant fuel. In terms of product value, uranium ranks behind oil, gas, coal, trona, bentonite, and construction aggregate in Wyoming.

The spot market price of yellowcake (the product of uranium mills) increased to $9.45 per pound as of November 19, 2001, according to the Ux Consulting Company, LLC., the Uranium Exchange Company (see http://www.uxc.com/top_review.html), and the Rocky Mountain Minerals Scout.

The Smith Ranch project operated by Rio Algom, one of the existing *in situ* producers, is being sold to an unspecified purchaser. It is unknown at this time if the new owner will change the operation of this project.

Figure 20. Decorative aggregate quarry (foreground). Light brown pumice containing gold-reflecting mica flakes was quarried at this locality east of South Superior in Sweetwater County. The hill in the background is a cinder cone of the Leucite Hills volcanic field. The dark ledge at right center is a lava flow. These rocks are Pleistocene in age, having been dated at less than 1 million years old. Digital image by Ray Harris, August, 2000.

Figure 21. Locality from which feldspar, used to manufacture false teeth, was quarried in the 1950s. This quarry is a pegmatite deposit located 20 miles southeast of Laramie on the Punkin Vine road. Digital image by Ray Harris, October, 2001.

Figure 22. Lime manufacturing plant operated by Wyoming Lime Producers in Park County, north of Frannie, Wyoming. Digital image by Ray Harris, September, 2001.

Figure 23. Zeolite-bearing tuff (light colored layer near center of image) in the Eocene Tatman Formation at Squaw Buttes, on the common boundary of Park and Washakie counties, Bighorn Basin. Digital image by Ray Harris, October, 2001.

Metals and Precious Stones Update

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Palmer Canyon in the Laramie Mountains has become a source for gem and near-gem quality cordierite (iolite) and corundum (sapphires and rubies). This is one of the gemstone localities discovered by the Wyoming State Geological Survey (WSGS) that is now being explored for commercial gems. The STATEMAP 2001 project in the Rattlesnake Hills/Granite Mountains has identified some heretofore undescribed zones of intense alteration in Precambrian rocks; a previously unrecognized igneous event in Precambrian rocks; and what might be an impact crater in Tertiary rocks. Two draft reports were completed, one on the Iron Mountain kimberlite district and another on the Leucite Hills volcanic field.

Cordierite and corundum

A source of gem- and near-gem-quality cordierite and corundum was discovered in 1995 during field reconnaissance in the central Laramie Mountains of southeastern Wyoming (**Figure 24**). The gemstones are hosted by Archean quartzofeldspathic gneiss, chlorite-biotite schist, and mica-kyanite gneiss (**Figure 25**). This cordierite/corundum occurrence, known as the Palmer Canyon deposit, is currently being evaluated as a potential source for gemstones, semi-precious stones, and lapidary stone by the WSGS and a company located in Lyons, Colorado.

Palmer Canyon is located within the Wyoming craton in an area mapped as undifferentiated Archean granite-gneiss (Graff and others, 1982). The region surrounding the Palmer Canyon deposit is relatively unexplored. However, the presence of nearby pelitic schist and vermiculite suggests that further exploration in the region may lead to discoveries of other cordierite and corundum deposits.

A regional stream sediment sampling program in the Laramie Mountains completed by the WSGS in the search for diamondiferous kimberlite also suggests that other gemstone deposits remain to be discovered. Approximately 300 sample sites were considered to be anomalous because they contained kimberlitic indicator minerals (Hausel and others, 1988). Kimberlite is only one of two known rock types that host commercial deposits of diamonds. A few of the sites also contained grains of corundum from unknown sources.

Palmer Canyon was initially investigated for vermiculite prior to 1944 (Hagner, 1944). Vermiculite mica was once used in fireproof insulation. A small vermiculite occurrence was identified in Palmer Canyon and a prospect pit was

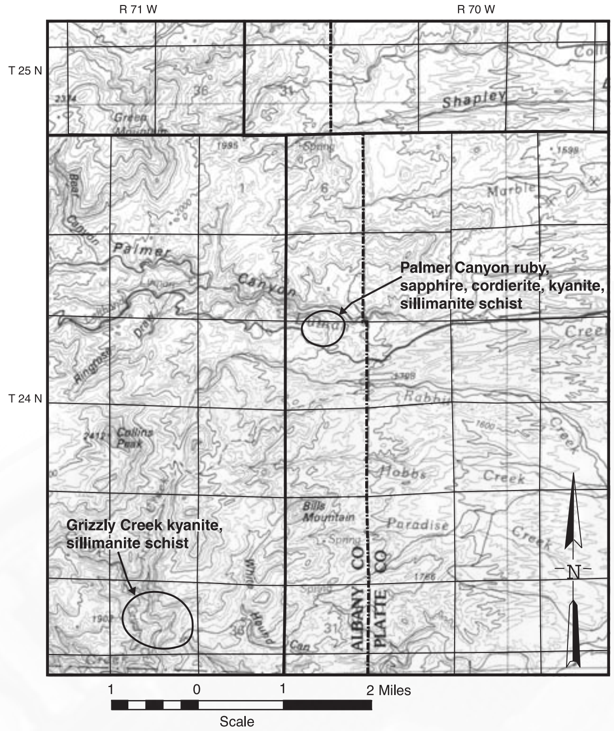

Figure 24. Location map of the Palmer Canyon deposit (from Hausel and Sutherland, 2000).

dug, but the occurrence was too small for commercial vermiculite production. The deposit was not investigated for gemstones. Samples recently collected from the old prospect pit at Palmer Canyon by the WSGS included vermiculite-chlorite-biotite-corundum schist (Hausel and Sutherland, 2000). Some samples of schist contained as much as 20% corundum and as will be discussed later, there may be a correlation between vermiculite and corundum.

During the 1995 investigation by the WSGS, another gemstone, cordierite, was discovered at Palmer Canyon (Hausel, 1998). Samples of sapphire-blue, transparent and translucent cordierite were recovered from gneiss near the corundum schist. The cordierite gneiss and corundum schist were traced on the surface and several samples were collected for microscopic evaluation. The gneiss was traced over a strike length of 200 feet, with a width of about 10 feet. It disappears under soil in every direction from the outcrop, and thus may be more extensive. Detrital cordierite found in soil 300 feet up slope from the outcrop suggests that the deposit may have a minimum strike length of 500 feet. The corundum schist also disappears under cover, and has a minimum strike length of nearly 1000 feet.

Samples of cordierite gneiss were collected from the site during the initial field investigations. In addition, samples of cordierite grains and nodules that weighed 1.5, 6, 11.5, 13.5, 14, 63.5, 109.5, 308.5, 887, 1715, and 2948 carats were recovered. Samples collected more recently included a large nodule of facet-grade, violet-blue, massive, transparent cordierite (>3000 carats) measuring 4.25 x 2.5 x 1.25 inches (**Figure 26**). This is the largest cordierite found in Wyoming to date. The specimen has several fractures, restricting the size of stones that can be cut from the nodule. Some rock

Figure 25. Strongly deformed Archean granite-gneiss exposed at Palmer Canyon (photograph by W.D. Hausel).

samples collected from the site contain as much as 20% transparent cordierite. The cordierite occurs as rounded to disseminated grains and as large nodules. The host gneiss is dark gray to gray cordierite-biotite-sericite-quartz gneiss. Kyanite and sillimanite may also be present, but occur as minor components of the gneiss.

Microscopic analysis of samples from Palmer Canyon shows the presence of five types of minerals that potentially can be used to fashion gemstones and semi-precious gems. These include: (1) violet to blue transparent cordierite (iolite), (2) dark-gray transparent cordierite, (3) red transparent corundum (ruby), (4) white to pink translucent corundum (sapphire), and (5) white, pink, and red translucent to opaque corundum. Low quality, dark-gray, translucent to cloudy cordierite is also present, as is some corundum with prominent rhombohedral parting that tends to crumble (**Figure 27**). These latter minerals have little value as gems. Other material found on the site includes spectacular kyanite schist with large 1- to 3-inch diameter sky-blue kyanite prisms set in a black mica matrix. This rock is very attractive (**Figure 28**).

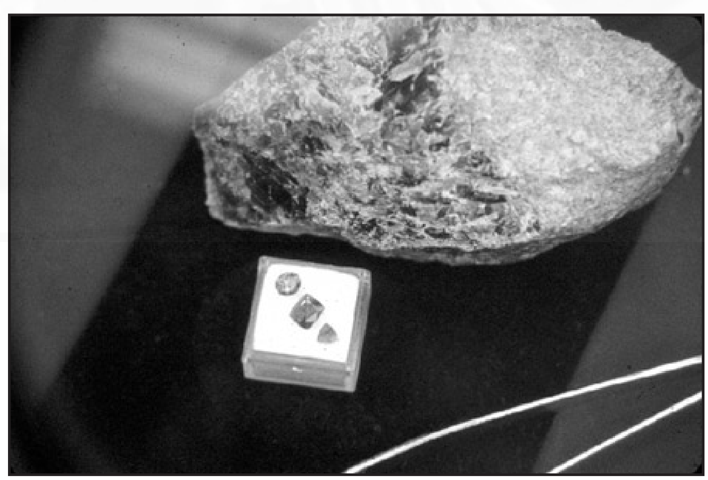

Figure 26. Transparent cordierite nodule shown with three faceted iolite gemstones (photograph by W.D. Hausel).

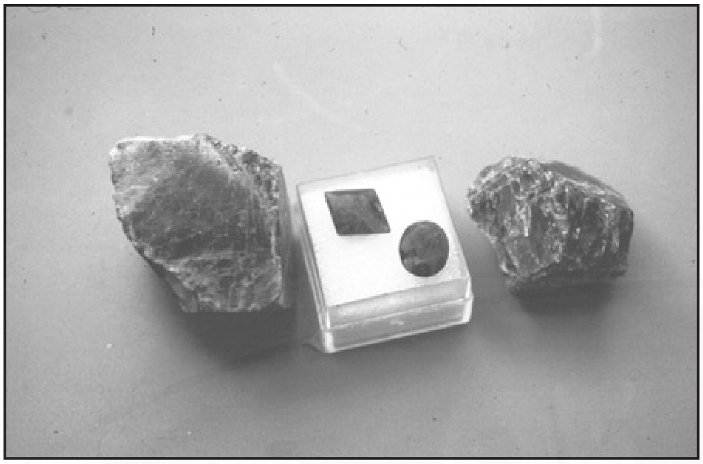

Figure 27. Faceted low-quality (Variety 3) cordierite lying next to uncut cordierite from Palmer Canyon (specimens provided by Vic Norris; photograph by W.D. Hausel).

Figure 28. Hundreds of kyanite prisms found in some mica-corundum schists at Palmer Canyon may produce some unique lapidary material (photograph by W.D. Hausel).

Cordierite, when of gem quality, is termed iolite by the gemologist. Iolite has distinct pleochroism resulting in the gemstone appearing to change color as it is rotated in natural light. Three varieties of natural cordierite were noted at Palmer Canyon: Variety 1 - transparent to translucent, violet to blue cordierite (iolite) with indistinct parting and cleavage; Variety 2 - dark-gray transparent to translucent cordierite with distinct parting and cleavage; and Variety 3 - dark-gray, cloudy, translucent to opaque cordierite with common mineral inclusions and distinct parting and cleavage. Variety 1 is dominant in all the samples collected by the WSGS.

Many specimens of Variety 1 cordierite appear to be suitable for faceting. They range from a pleasing violet to a very light-blue color and exhibit only a hint of cleavage and parting. A few specimens of Variety 1 cordierite were recently faceted, and produced three iolite gems with excellent transparency and pleochroism weighing 0.5, 1.0, and 1.49 carats, respectively, that appear to be of similar quality to many of the highest quality iolites on the gemstone market (**Figure 26**). Microscopic examination of the 0.5-carat iolite triangular brilliant showed a tiny biotite inclusion that is not visible to the naked eye. The 1.0-carat stone was fashioned into a marquise (elliptical-shaped brilliant cut), and under the microscope shows several tiny, unidentified mineral inclusions that are not readily visible to the naked eye. The largest of the three iolites was cut into a modified scissors cut. This stone is clear, but unfortunately has a visible fracture.

. . . most of the described gemstone occurrences [in Wyoming] remain unexploited and unevaluated.

Some gray to dark-gray cordierite (Variety 2) also exhibits excellent transparency. None of this material has yet been faceted, but it is expected to produce a unique and attractive gemstone. Much of this variety has well-developed parting parallel to c{001} and cleavage along b{010}, limiting the size of facetable material, although much of the material can still be fashioned. Many of these gray specimens exhibit rectangular cross sections, and a few exhibit pseudohexagonal habit.

Variety 3 cordierite is not suitable for gems because the faceted material has many flaws. Two samples of Variety 3 cordierite were faceted (**Figure 27**) producing 3.4- and 3.9-carat stones. The larger stone was faceted into a lozenge-cut stone, and the 3.4-carat cordierite was cut with a marquise crown and a step-cut pavilion. Unfortunately, both stones are extensively flawed with fractures, visible cleavage, and some visible mineral inclusions.

Corundum at Palmer Canyon was also investigated. During the initial investigation, several rock specimens were collected within the old Rolf vermiculite prospect pit, as well as from nearby outcrops, and many of these contained some corundum. A few samples contained as much as 15 to 25% corundum; it is locally abundant. Some corundum is translucent to transparent, white, pink, and less commonly, red. The corundum occurs as porphyroblasts in the schist and forms hexagonal prisms and platelets. The largest specimen collected by the WSGS was a 1-inch-long prism, 0.3-inch in diameter. Another broken corundum measured 0.4 inch in diameter. Overall, much of the corundum appears to average about 0.2 inch in diameter.

Microscopic examination of the corundum shows both red ruby and pink to white sapphire. Much of the corundum collected by the WSGS is transparent to translucent, and only one opaque white to pink corundum was seen in the samples collected during this study. This suggests that this deposit could potentially provide a source for commercial ruby and sapphire as well as iolite.

Two specimens of the corundum were fashioned into faceted stones and loaned to the WSGS by Vic Norris for examination (**Figure 29**). One is pink, opaque corundum that was fashioned into a 1.4-carat cabochon. The specimen is pleasing to the eye, but is a near gem of apparently low value. A specimen of red corundum was also faceted into a transparent, 1.1-carat marquise. This stone exhibits a few minor flaws visible to the naked eye, but otherwise is an attractive gem that was appraised for $300 (Vic Norris, personal communication, 2001). Based on this initial sampling, further fashioning of corundums from this deposit will probably produce some very attractive rubies and sapphires.

It is clear that the Palmer Canyon deposit should provide many high-quality gemstones. Reports on this discovery were recently submitted to *Rocks and Minerals Magazine* as well as the Gemological Institute of America.

Deposits similar to the Palmer Canyon occurrence are possible, since much of Wyoming's exposed mountain ranges are cored by amphibolite-grade schists and gneisses and include large areas underlain by metapelitic schists and gneisses. Some of these areas are located only a few miles from the Palmer Canyon occurrence. Curtis (1943), Hausel (1996), Sinkankas (1964), and Spendlove (1989) reported the presence of other gem-quality occurrences of corundum and cordierite in Wyoming and certainly additional occurrences can be located.

Recent field investigations by the author have shown a possible correlation between corundum and vermiculite: about 10 to 20% of the vermiculite deposits investigated in Wyoming to date have some corundum. Further investigations of Wyoming's vermiculite deposits (as well as other pelitic schists) may lead to the discovery of other corundum occurrences.

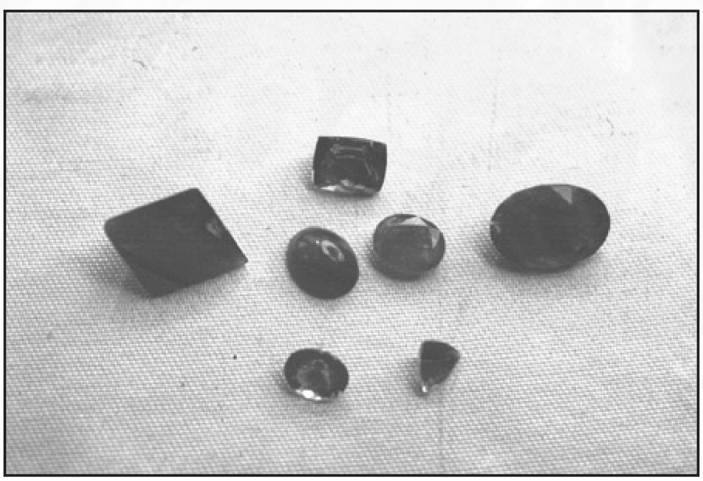

Figure 29. Fashioned gemstones from the Palmer Canyon deposit. In the right center is a transparent red ruby marquise, and in the left center is the dark pink translucent to opaque sapphire cabochon. These are surrounded by the fashioned cordierite gemstones including the two large stones which are low quality cordierite and the three smaller stones which are all iolite (high quality cordierite) gems. (Fashioned stones provided by Vic Norris; photograph by W.D. Hausel.)

Few have ever considered that Wyoming had potential for gemstones other than nephrite jade. In the last few decades, the WSGS has shown that there are other gemstone deposits in the state, including ruby, sapphire, peridot, diamond, aquamarine, cordierite/iolite, and several others. Much of the state remains unexplored for gemstones, and most of the described gemstone occurrences remain unexploited and unevaluated.

STATEMAP 2001 project

The Metals and Precious Stones Section of the WSGS is mapping the geology of the Rattlesnake Hills 1:100,000-scale Quadrangle for a STATEMAP project funded by the U.S. Geological Survey. This quadrangle includes much of the Granite Mountains in central Wyoming. The mapping includes the Tin Cup gemstone district, the Gas Hills uranium district, and the Rattlesnake Hills gold district. Much of the work completed to date has been to differentiate the Archean rocks in the Granite Mountains.

A number of interesting discoveries have been made during field reconnaissance in the past few months. For example, a deposit of nephrite (jade) pseudomorphs after quartz was found (**Figure 30**). In the same region, a large zone of intense, pervasive propylitic and potassic alteration was discovered on air photos and verified in the field. Samples of the intensely altered rock were collected for gold analysis, as this altered zone is characteristic of some other gold and copper deposits found in the western U.S. Wayne Sutherland also identified some coarse-grained dikes that cut some Proterozoic mafic dikes in the region. The age of these coarse-grained dikes is unknown, but they could provide evidence for a previously unrecognized igneous event in the Granite Mountains.

Sutherland has identified what is possibly a large impact crater near Black Rock Mountain in the eastern Granite Mountains that is surrounded by at least three gravel-covered "rings" (**Figure 31**). The source of the feature remains a mystery. Field investigations noted a lack of

Figure 30. Nephrite jade pseudomorphing quartz. These specimens of jade have acquired the hexagonal crystal habit of quartz. Samples collected in the northern Granite Mountains (photograph by W.D. Hausel).

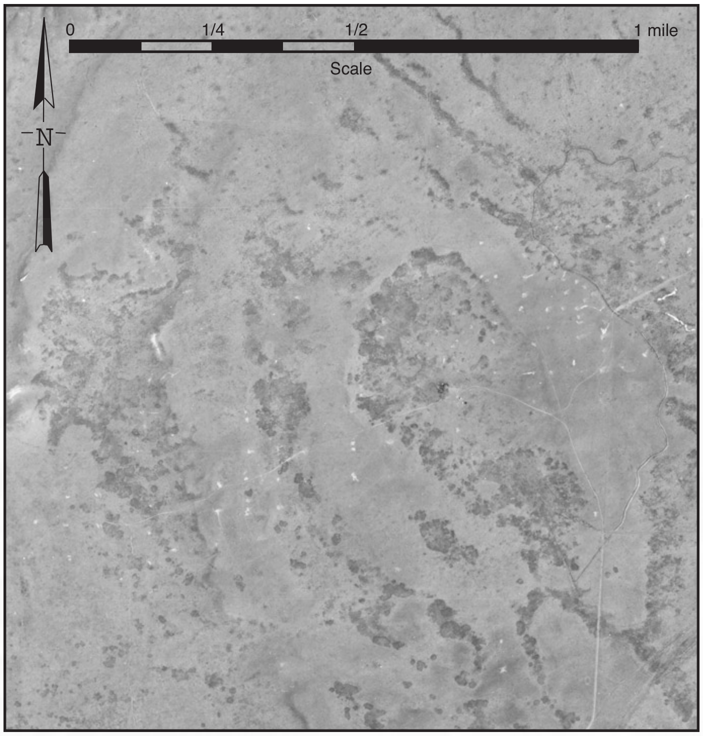

Figure 31. Aerial photograph of a possible impact crater in the Granite Mountains. The crater forms a 100-foot deep, elliptical basin at the right-center of the photograph with three surrounding "rings," primarily to left of crater.

brecciation in the crater, but the presence of vertical to steeply dipping sandstones of the Miocene Split Rock Formation is intriguing. The central part of the area is 100 feet lower than the outermost "ring" and is filled with Recent alluvial and eolian sand, thus rock exposures are poor. It has been suggested that the feature may represent an impact crater, or possibly a deflation basin. No other impact-related evidence (e.g., shattered or shocked quartz grains, debris fans) has been found so far, but the investigation is still ongoing and the authors welcome other investigators.

The Section will begin work on a STATEMAP 2002 grant next fall to map the Keystone 7.5-minute Quadrangle in the Medicine Bow Mountains (see **GEOLOGIC MAPPING, PALEONTOLOGY, AND STRATIGRAPHY UPDATE**). This quadrangle contains the Keystone Quartz Diorite as well as the eastern part of the Mullen Creek layered mafic complex. The mafic complex is interpreted as the source of commercial palladium-copper-gold-platinum mineralization at the historical New Rambler Mine. The Keystone Quartz Diorite is a known source for some narrow high-grade gold veins and shear zones.

Gold, palladium, platinum, tantalum, and diamonds

During the past quarter, the section received requests for information on a number of commodities in the state, and led company field trips to examine some gold and diamond deposits. In addition, some potentially significant palladium, platinum, and tantalum discoveries were reported in the

Rock Hound's Corner: Beryl

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Beryl is one of the more attractive minerals to collect in Wyoming, simply because it forms very distinct, hexagonal (six-sided) crystals that are capped by flat surfaces. The best place to find this mineral is in granite pegmatites in Wyoming's mountain ranges. Granite pegmatites are typically small in area, but they are recognized by the presence of abundant, massive, milky (bull) quartz, with some large feldspar crystals and books of biotite or muscovite mica.

Much of the beryl found in Wyoming has been collector-quality specimens, i.e., distinct hexagonal prisms, that are generally opaque and light-greenish yellow in color. Some transparent varieties of beryl found in Wyoming are gem quality. When of gem quality, few other minerals can match their grandeur. In particular, some gem-quality (transparent) aquamarine has been found in the state (see **Table**). None of the other varieties of gem beryl have been found in Wyoming, with the exception of a few small green transparent beryl crystals that were reportedly found in the Sierra Madre by a prospector.

Beryl is a beryllium-aluminum-silicate with the general chemical formula of Be3Al2(Si6O18). It typically forms simple hexagonal prisms terminated by flat pinacoids. Beryl has perfect basal cleavage, which if too well expressed, may cause the mineral to crumble. Weathered specimens of the mineral tend to have a better developed basal cleavage than fresh specimens. Beryl has a relatively high hardness (7.5 to 8 on Mohs scale) and a relatively average specific gravity (2.66 to 2.83).

Even though opaque varieties of beryl have no intrinsic value except as beryllium ore, many low-quality

Varieties of transparent gemstone beryl.

Color	Terminology
light-blue	aquamarine
green	emerald
yellowish	golden beryl (helidor)
pink	morganite
colorless	goeshenite
red	red emerald

Medicine Bow National Forest by various exploration companies. Other exploration activity in the region was reported by companies searching for diamond and nickel deposits.

Iron Mountain kimberlite district

A manuscript entitled "Geology of the Iron Mountain kimberlite district, with a summary of investigations of nearby kimberlitic indicator mineral anomalies in southeastern Wyoming" was completed and is now being prepared by the Publications Section as a report of investigations. This report summarizes the geochemistry, geophysics, and geology of recent kimberlite-related discoveries made in the Iron Mountain district of the central Laramie Mountains. The WSGS has documented and outlined several new kimberlite occurrences–the district is now considered the second largest kimberlite district in the U.S.

Leucite Hills volcanic field

A draft manuscript entitled "Geology and geochemistry of the Leucite Hills volcanic field, Rock Springs uplift, southwestern Wyoming" was also completed. The Leucite Hills are one of the largest lamproite fields in the world. The unique rock types called lamproites are considered potential hosts for diamonds and may be the rarest rock type on earth.

Diamonds have not yet been found in the field, although a few years ago, the senior author did discover some gem-quality olivine (peridot). During field investigations by the WSGS, several samples were analyzed, some geochemistry was done on diamond indicator minerals (some chromite collected in the field yielded chemical signatures similar to diamond-inclusion chromite), and controlling structures for the individual volcanoes were mapped along with the extent of the field.

Recognition

Jim McGarvey, President of the Wyoming State Gem and Mineral Society, presented W. Dan Hausel with a plaque for Honorary Lifetime Membership to the society. He was recognized for his contributions and achievements to the advancement of mineralogy and rock hounding in Wyoming.

Dan was also highlighted in the September, 2001 issue of *Geotimes*, the November, 2001 issue of *Lapidary Journal*, and in the November, 2001 notes of the *New York Mineralogical Society*. The Wyoming Prospectors Association presented Dan with an honorary membership in August, 2001.

Talks and field trips

A list of talks, field trips, and other events involving the Metals and Precious Stones Section is now included on the WSGS Calendar (see page 2 of this issue) and on the WSGS web site at http://wsgsweb.uwyo.edu.

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crystals provide excellent museum-quality specimens due to their excellent crystal habit. Some beryl crystals are extremely large, as they occur in pegmatites, which are known for large mineral specimens. For instance, some individual specimens found outside of Wyoming have weighed as much as 200 tons (Vanders and Kerr, 1967). The largest specimens of opaque beryl found in Wyoming have come from the Casper Mountain area, where specimens as great as 4 inches in diameter and as much as 3 feet in length have been recovered.

Much of the beryl found in Wyoming has ranged from less than one inch to well-formed crystals more than a foot in length. One large specimen of transparent to translucent aquamarine was found in the Anderson Ridge area of South Pass several years ago (Hausel, 1991). However, most other beryl found in the Anderson Ridge area has been poor quality, yellowish-green, and opaque. Transparent beryl has also been reported from pegmatites along Hoodoo Creek in the southern part of Copper Mountain in the Owl Creek Mountains near Shoshoni, and some aquamarine has been reported in the southeastern Seminoe Mountains. Beryl has also been found in the Hartville uplift of eastern Wyoming, as well as in the Bighorn, Granite, Laramie, Medicine Bow, Owl Creek, and Wind River mountains (Hausel and Sutherland, 2000).

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MAPPING AND HAZARDS UPDATE

Geologic Mapping, Paleontology, and Stratigraphy Update

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The Wyoming State Geological Survey (WSGS) has submitted a proposal to the STATEMAP 2002 Program for three mapping projects. The projects will map the bedrock geology of the Kaycee 1:100,000-scale Quadrangle; digitize the Kaycee, Reno Junction, and Rattlesnake Hills 1:100,000-scale bedrock geologic maps; and map the Keystone 1:24,000-scale Quadrangle. The Kaycee and Reno Junction maps will support efforts to complete geologic maps of the Powder River Basin (PRB) crucial to expanding the Northern PRB geologic, hydrologic, and water quality database project to the south.

Three new articles relating to Wyoming geology were released recently. They characterize fossil resources in the Belle Fourche Shale of the Black Hills area; describe the discovery and development of natural gas in West Side Canal Field on the southern flank of the Washakie Basin; and document the discovery and development of natural gas in Cave Gulch Field on the northeast side of the Wind River Basin.

STATEMAP 2002 proposal submitted

The WSGS recently submitted a proposal for three mapping projects to the STATEMAP 2002 Program of the U.S. Geological Survey (USGS). Based on consultation with the Wyoming Geologic Mapping Advisory Committee (WGMAC), the proposed projects include: compiling and mapping the bedrock geology of the Kaycee 1:100,000-scale Quadrangle; digitizing the Kaycee, Reno Junction, and Rattlesnake Hills 1:100,000-scale bedrock geologic maps; and mapping Precambrian rocks in the Keystone 1:24,000-scale Quadrangle. Current mapping priorities established by the WSGS in cooperation with the WGMAC include producing geologic maps to support coalbed methane exploration/production activities and associated ground and surface water protection needs in the PRB; and mapping the more populated areas of Wyoming to provide assistance to cities and counties in siting and land-use planning, as well as providing information to support mineral and water resource development.

The Mapping Section of the WSGS, under the direction of Alan J. Ver Ploeg, proposes to map and compile the geology for the Kaycee 1:100,000-scale Quadrangle, with funding from STATEMAP 2002. Completion of this map is needed to augment the anticipated southward expansion of the Northern PRB geologic, hydrologic, and water quality database project (described in *Wyoming Geo-notes No. 69*, April, 2001). The adjacent Reno Junction Quadrangle to the east would also be compiled. However, this latter effort would be funded through the Northern PRB project instead of STATEMAP.

The Kaycee Quadrangle is located in northeastern Wyoming (**Figure 32**). The quadrangle includes bedrock ranging in age from Precambrian to Oligocene. The eastern flank of the southern Bighorn Mountains and the adjacent western edge of the PRB are interrupted by a series of northwest-trending anticlines, which are asymmetrical with the steep limbs on the west. These structural features and the Bighorn uplift itself were created by a Laramide-age, northeast-oriented (N40 to 65°E) compressional event. These

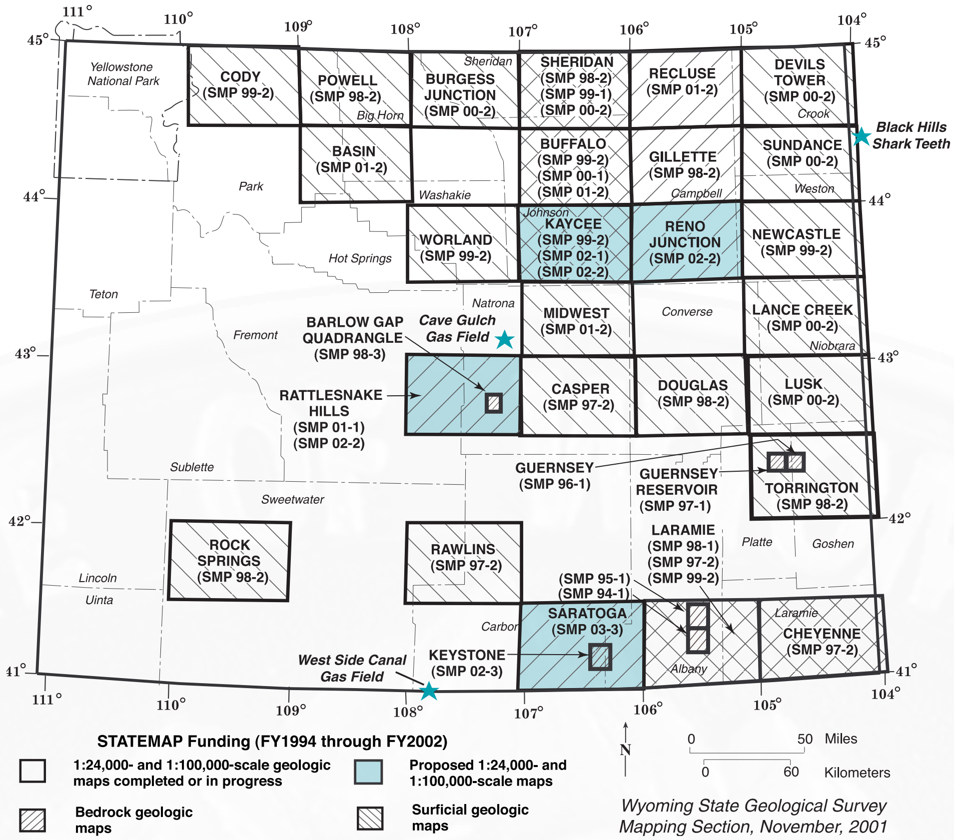

Figure 32. Index map of proposed and completed STATEMAP projects and recently completed geologic studies in Wyoming.

features cover the western one-fourth of the quadrangle. The remainder of the quadrangle includes Cretaceous and Tertiary outcrops dipping toward the east/northeast into the PRB. The axis of the PRB trends northwest to southeast through the northeastern corner of the quadrangle.

The Section has already completed 1:24,000-scale geologic maps of the Packsaddle Canyon, Fraker Mountain, Barnum, Poker Butte, Hole-in-the-Wall, Red Fork Powder River, and Mayoworth quadrangles, funded through the COGEOMAP Program in the 1980s. These maps will help complete the western quarter of the Kaycee Quadrangle. As a spin-off of this effort, The Horn 1:24,000-scale Quadrangle would be completed and published. Requested funding from STATEMAP 2002 will be used to acquire needed aerial photography, negatives, and orthophoto sheets for the 1:24,000 and 1:100,000-scale bases; to furnish salary for one geological assistant; and to pay field vehicle rental and travel expenses.

The Publications Section of the WSGS, under the direction of Richard W. Jones, proposes to digitize the Kaycee and Reno Junction bedrock geologic maps (**Figure 32**), which would be mapped and compiled under the project described above. The Rattlesnake Hills bedrock geologic map (**Figure 32**) is currently being mapped and compiled by the Metals and Precious Stones Section of the WSGS as part of STATEMAP 2001 and will be digitized under STATEMAP 2002.

For each of the proposed maps, the geology layer will be scanned, converted from a raster to a vector image, and edited to be consistent with National Digital Mapping Standards. STATEMAP 2002 funding will be used to acquire existing 1:100,000-scale digital topographic and public land survey data from EROS Data Center, to pay the salary of a GIS assistant, and to cover map scanning costs.

The Metals and Precious Stones Section, under direction of W. Dan Hausel, proposes a two-year mapping project. The first year (STATEMAP 2002) of this project would entail mapping the Keystone 1:24,000-scale Quadrangle (**Figure 32**) in the Medicine Bow Mountains. This quadrangle covers part of the Savage Run Wilderness and includes most of the Mullen Creek layered mafic complex. The objective is to map the Precambrian lithologic units, differentiating the various units within the layered complex (such as troctolites, olivine gabbros, norites, Fe-Ti gabbronorites, anorthosites, sulfide-bearing troctolites, etc). Much of this area is not adequately mapped, and a few mineral companies are exploring for platinum-group metals (PGMs) in this area and have requested the assistance of the Section. Funding from STATEMAP 2002 will be used to acquire needed aerial photography, negatives, and orthophoto sheets for both the 1:24,000- and 1:100,000-scale base maps; to pay the salary of a geological assistant; and to pay field vehicle rental and travel expenses.

The second year of the project (proposed for STATEMAP 2003) would compile the geology of the Saratoga 1:100,000-scale Quadrangle. A large part of the quadrangle has already been compiled (i.e., Sierra Madre and northern Medicine Bow Mountains), but the southern Medicine Bow Mountains and Saratoga Valley need some work.

The STATEMAP Program, part of the USGS National Cooperative Geologic Mapping Program, has significantly expanded and driven the mapping efforts of the WSGS, contributing $258,578 in funding over the past seven years (**Table 16**). The WSGS has completed 30 maps (**Figure 32**) using funding from the STATEMAP program since it began involvement in 1994; an additional 11 maps were completed independently of STATEMAP funding.

New publications on Wyoming geology

Cicimurri (2001) recently published a comprehensive description of the fossil shark assemblage found in the Cretaceous Belle Fourche Shale in the Black Hills region of South Dakota and Wyoming (**Figure 32**). This work results from an M. S. thesis project completed by Cicimurri at Clemson University. Surface collecting and bulk sampling techniques were used to record vertebrate and invertebrate distributions within the Belle Fourche. Results of the study suggest that although the deposition of the Belle Fourche represents a major transgression during the middle Cenomanian (earliest age of the Late Cretaceous), minor regressive events occurred. The majority of the fossils found are limited to thin calcarenites and the shark taxa associated with these rocks indicate a shallow marine, nearshore environment.

Parker and Bortz (2001) recently completed an article characterizing West Side Canal Gas Field in the southeastern part of the Greater Green River Basin (**Figure 32**). The paper outlines the discovery and development of this important structural trap, which has produced over 250 billion cubic feet (BCF) of gas from the Fort Union, Lance, Lewis, Almond, and Amsden formations.

Montgomery and others (2001) recently characterized Cave Gulch Field, an important gas discovery in the Wind River Basin (**Figure 32**). Cave Gulch Field, part of the larger Waltman Field, is a subthrust discovery under the Owl Creek thrust in the northeastern corner of the Wind River Basin. Cave Gulch Field alone contains reserves of 500 BCF to 1 trillion cubic feet of gas. Production is from subthrust Fort Union and Lance reservoirs. This article discusses the use of three-dimensional (3-D) seismic interpretation and subsurface well data in unraveling the complex faulted anticlinal structure. Seismic interpretation is complicated by the effect of thrusted basement rocks at relatively shallow levels, creating strong lateral velocity variations.

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Table 16. Summary of the STATEMAP geologic mapping program in Wyoming.

Fiscal Year	Project Description and Map Scale	State Dollars	Federal Dollars	Total Project Dollars
1995	Geologic map of the Laramie Quadrangle, 1:24,000-scale STATEMAP94	$12,000	$12,000	$24,000
1996	Geologic map of the Howell Quadrangle, 1:24,000-scale STATEMAP95	$10,000	$10,000	$20,000
1997	Geologic map of the Guernsey Quadrangle, 1:24,000-scale STATEMAP96	$8,499	$8,499	$16,998
1998	1-Geologic map of the Guernsey Reservoir Quadrangle, 1:24,000-scale STATEMAP97			
	2-Digital geologic map of the Cheyenne Quadrangle and digital surficial geologic maps	$14,000	$14,000	$28,000
	of the Casper, Cheyenne, Laramie, and Rawlins Quadrangles, 1:100,000-scale STATEMAP97	$17,000	$17,000	$34,000
1999	1-Geologic map of the Laramie Quadrangle, 1:100,000-scale STATEMAP98	$18,500	$18,500	$37,000
	2-Digital geologic map of the Gillette Quadrangle and surficial geologic maps of the Douglas,			
	Powell, Rock Springs, Sheridan, and Torrington Quadrangles, 1:100,000-scale STATEMAP98	$20,000	$20,000	$40,000
	3-Geologic map of the Barlow Gap Quadrangle, 1:24,000-scale STATEMAP98	$18,650	$18,650	$37,300
2000	1-Geologic map of the Sheridan Quadrangle, 1:100,000-scale STATEMAP99	$19,500	$19,500	$39,000
	2-Digital geologic map of the Laramie Quadrangle and digital surficial geologic maps of the			
	Buffalo, Cody, Newcastle, Kaycee, and Worland Quadrangles, 1:100,000-scale STATEMAP99	$20,000	$20,000	$40,000
2001	1-Geologic map of the Buffalo Quadrangle, 1:100,000-scale STATEMAP00	$20,500	$20,500	$41,000
	2-Digital geologic map of the Sheridan Quadrangle and digital surficial geologic maps of the Burgess			
	Junction, Devils Tower, Lance Creek, Lusk, and Sundance Quadrangles, 1:100,000-scale STATEMAP00	$24,500	$24,500	$49,000
2002	1-Geologic map of the Rattlesnake Hills Quadrangle 1:100,000-scale STATEMAP01-in progress	$24,133	$24,133	$48,266
	2-Digital geologic maps of the Buffalo and Casper Quadrangles and digital surficial geologic maps			
	of the Midwest and Basin Quadrangles 1:100,000-scale STATEMAP01-in progress	$24,796	$24,796	$49,592
	3-Entering map data in National Geologic Map Database STATEMAP01-in progress	$6,500	$6,500	$13,000
	TOTALS	**$258,578**	**$258,578**	**$517,156**

The STATEMAP Program, part of the National Cooperative Geologic Mapping Program (NCGMP), has significantly expanded and driven the mapping efforts of the Wyoming State Geological Survey (WSGS) over the past seven years. The WSGS completed 31 maps using funding from this program since it began involvement in 1994; an additional 11 maps were completed independent of the program's funding. Five additional maps are in progress with STATEMAP 2001 funding. Current STATEMAP-supported mapping priorities established by the WSGS in cooperation with Wyoming Geologic Mapping Advisory Committee include: 1) producing geologic maps to support coalbed methane exploration/production activities and associated ground- and surface-water protection needs in the Powder River Basin and 2) mapping the more populated areas of the state to provide assistance to city and county planners in siting and land-use planning, as well as providing information to support mineral- and water-resource development.

Western States Seismic Policy Council

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The Western States Seismic Policy Council (WSSPC) is a regional earthquake consortium whose primary mission is to help reduce future earthquake losses. This is done by providing a forum to advance earthquake programs throughout the western region, and by developing and facilitating seismic policies and programs through information exchange, research application, and education. The consortium is composed of directors and representatives of geoscience and emergency management organizations from 13 western states, 3 U.S. territories, a Canadian territory, and a Canadian province.

The Wyoming State Geological Survey (WSGS) has had formal representation at WSSPC meetings since 1988; the Wyoming Emergency Management Agency (WEMA) has participated in WSSPC since the early 1980s. The head of the Geologic Hazards Section at the WSGS was chairman of WSSPC from 1992 to 1993 and also organized WSSPC's first workshop on seismic provisions of building codes in 1992.

2001 WSSPC meeting

The 2001 WSSPC meeting was held in Sacramento, California from October 21 to 24. The theme of the meeting was "Seismic Risk Communication–Creating Greater Public Awareness and Action." The meeting was attended by approximately 150 geologists, emergency managers, and other concerned citizens. Jim Case and Lance Cook from the WSGS and Tony Bergantino from the Wyoming Water Resources Data System attended the meeting.

Primary topics addressed at the meeting included:

- Approaches of leaders who are successful risk communicators;
- Risk communication: Getting an effective response to vulnerability messages;
- Lessons learned: Shared by successful risk communicators;
- The legal ramifications of risk communication;
- Communicating risk to/and within the business community;
- Consensus requirements of successful risk communication; and
- Disseminating risk information after earthquakes.

The center of the exhibit was a series of interactive 3-D aerial views of Teton County, Wyoming. . .

At the WSSPC business meeting, which followed the main conference, a series of policy recommendations were adopted by voting delegates. There were two recommendations important to Wyoming. We report those two recommendations verbatim. For Policy Recommendation 01-3, WSSPC recommends that each state, province, and territory establish a plan for a post-earthquake technical clearinghouse to be activated within 24 hours after each major earthquake within its jurisdiction. Each state should determine the circumstances that would require establishment of a clearinghouse. [Note: this item has already been initiated by WSGS and WEMA.]

For Policy Recommendation 01-4, WSSPC endorses the prompt adoption and enforcement by state and/or local jurisdictions of the seismic provisions in the International Building Code 2000 and the International Residential Code. WSSPC also encourages Code organizations to continue the development and refinement of building codes to include NEHRP provisions with a specific focus on purpose, education, incentives, lifelines and the business/industry and homeowner sectors. [Note: many local jurisdictions in Wyoming have not yet adopted the seismic provisions of any building code.]

WSGS exhibit

The WSGS exhibit of recent products and technologies at the 2001 WSSPC meeting was well-received. The center of the exhibit was a series of interactive 3-D aerial views of Teton County, Wyoming that allowed the user to simulate flying over the county. Landslides in the county that have been mapped by the WSGS were superimposed on the views. This product will be available online at a site to be announced by the end of the year.

Other WSGS items exhibited and distributed to all interested parties included a video and WSGS Information Pamphlet 6 both entitled *Earthquakes in Wyoming*, WSGS Information Pamphlet 5 entitled *How to make your Wyoming home more earthquake resistant*, and handouts on recent digital products of the Geologic Hazards Section. Copies of the video and both information pamphlets can be obtained at the WSGS.

Highway-affecting Landslides of the Snake River Canyon–Part I, Overview and the Elbow Slide

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Mark A. Falk, P.E., P.G.–Project Geologist, WYDOT, Cheyenne, Wyoming

James M. Dahill, P.G.–Project Geologist, WYDOT, Cheyenne, Wyoming

Dr. John P. Turner–Professor of Civil and Architectural Engineering, University of Wyoming

Building and maintaining a modern highway through the Snake River Canyon in northwestern Wyoming has been no easy task for the Wyoming Department of Transportation (WYDOT). A combination of factors including geological features (such as bedrock type, faults, seismic zones), harsh winter climate, poor soils, a river that is constantly changing course, and steep mountainous terrain makes this scenic stretch of roadway particularly vulnerable to landslides and other mass movements.

When WYDOT undertook the task of reconstructing the entire 24-mile section of roadway through the canyon in 1997, numerous landslide areas required stabilization, including a disastrous landslide/debris flow that activated that spring. Rebuilding the canyon highway has been a geotechnical challenge, to say the least. The landslides have forced the Geology Program of WYDOT to consider state-of-the-art mitigation and bidding techniques to build a cost-effective and safe highway that will last for years.

WYDOT geologists and engineers have met the challenges by applying innovative anchored geo-support technologies to several of the most difficult slide areas. Micro-pile walls, soil nailing, and ground anchors are a few of the weapons that WYDOT has employed to make the drive through the canyon a safe and enjoyable experience.

This is the first of a three-part series detailing WYDOT's work on the landslides along Snake River Canyon Highway and what has been done to mitigate potential damage and protect the highway and its travelers. Part I, which appears in this issue of *Wyoming Geo-notes*, contains an overview of the highway and the landslides and discusses the geotechnical measures used in reconstructing the highway where it crosses the Elbow Slide. Part II will discuss the disastrous Wolf Mountain landslide and debris flow of May, 1997, which totally closed the highway for two weeks and severely limited passage for another two weeks. Part III will discuss the Blue Trail and Deer Creek landslides and what has been done to mitigate possible damage and even stabilize them. We thank the staff at the Wyoming State Geological Survey for their interest in our work and for helping prepare these articles.

Four of the largest landslides that have affected the highway system in Wyoming occur within this 24-mile section of highway. . .

Background

Snake River Canyon, often referred to as "The Grand Canyon of the Snake," lies immediately southwest of the geomorphic valley feature known as Jackson Hole. U.S. Highway 26/89 through Snake River Canyon is the principal route providing access to the entire Jackson Hole region and two of the nation's premier national parks, Yellowstone and Grand Teton. The highway closely parallels the Snake River, which flows south out of Jackson Hole then west into Palisades Reservoir and Idaho (**Figure 33**).

The Bureau of Public Roads commenced construction of a road through the canyon from Hoback Junction to Alpine Junction around 1936 using Civilian Conservation Corps (CCC) laborers. Records indicate that the road through the Snake River Canyon was first paved around 1947. The road was upgraded to its current condition between 1955 and 1960. Presently, the entire 24-mile section of roadway through the canyon is scheduled for reconstruction to accommodate increased traffic volumes and bring it up to current design standards. Three out of the five individual projects have been completed and the last two projects will be completed by about 2005. The majority of this route is in a very narrow corridor between the Snake River and steep mountainous terrain.

Traffic counts of 5000 to 6000 vehicles per day on the highway during summer months make this one of the most heavily traveled two-lane primary highways in the state. In addition, there are 400 to 500 year-round commuters who travel from the Star Valley area at the west end of the canyon to work in Jackson. The highway provides year-round access to all recreational activities in the Snake River Canyon, including rafting, fishing, hunting, hiking, and kayaking. This road is truly the economic lifeline of the area.

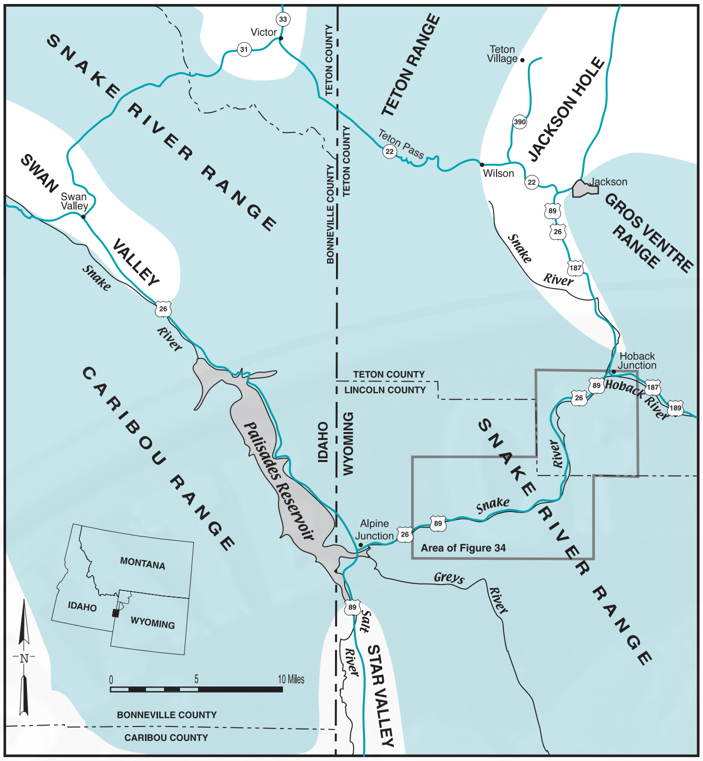


Figure 33. General index map of the Snake River Canyon and surrounding area, northwestern Wyoming and eastern Idaho.

The alternate route into Jackson from the west is a narrow two-lane paved road (Wyoming Highway 22) with grades of 10%, which crosses an 8400-foot-high mountain pass. Due to the steep grades, trucks are not allowed over this mountain pass, and in the winter months there is danger of avalanches. From the Star Valley area, it takes approximately two hours to reach Jackson using the route via Swan Valley and Victor, Idaho over a pass on the Snake River Range and Teton Pass over the Teton Range (**Figure 33**), compared to the 25 to 30 minutes through Snake River Canyon.

Landslides in the canyon

Four of the largest landslides that have affected the highway system in Wyoming occur within this 24-mile section of highway through Snake River Canyon. They are the Blue Trail, Elbow, Wolf Mountain, and Deer Creek slides (**Figure 34**). All are geologically controlled and occur in the Lower Cretaceous Bear River Formation, which consists of interbedded shales, siltstones, and thin limestone units. These rocks weather into very unstable slopes which start moving with the addition of excess moisture. Due to the numerous anticlinal and synclinal folds within the canyon, the Bear River Formation is (unfortunately) crossed many times by the highway. Each crossing provides the potential for a highway-affecting landslide.

The four landslides turned out to be very expensive to fix, but allowed experimentation of new technologies, instrumentation, and research. The benefits of this work can be applied to future landslides. Each slide was unique and had to be mitigated in slightly different ways. Three of the four slides were heavily instrumented, including piezometers, load cells, and vibrating wire extensiometers, which were all wired to data collectors. The data collectors were (and continue to be) downloaded monthly by Dr. Turner's graduate students at the University of Wyoming; the data collected is being used for research projects. These research studies will result in a better understanding of how this new technology works, and its application to future projects.

The Elbow Slide

One of the narrowest parts of the canyon highway is a section approximately 1000 feet long located at milepost 131.8 near a point where the Snake River makes a nearly 90° bend and begins to flow in a westerly direction (**Figure 34**). This large bend is locally termed the "Elbow," thus the name of the project.

The former roadway through this section consisted of two 11-foot wide travel lanes with virtually no shoulders (**Figure 35**). The planned new roadway consisted of two 12-foot wide travel lanes and 8-foot wide shoulders. To widen the template of the road, significant amounts of cutting and filling were required. The Snake River at the "Elbow" has changed course in the past 10 years and began to erode the toe of the highway embankment (**Front Cover**). This erosion created a situation in which the 65-foot high fill slope became marginally stable (**Figure 36**). Cracks in the roadway which indicate this instability appeared

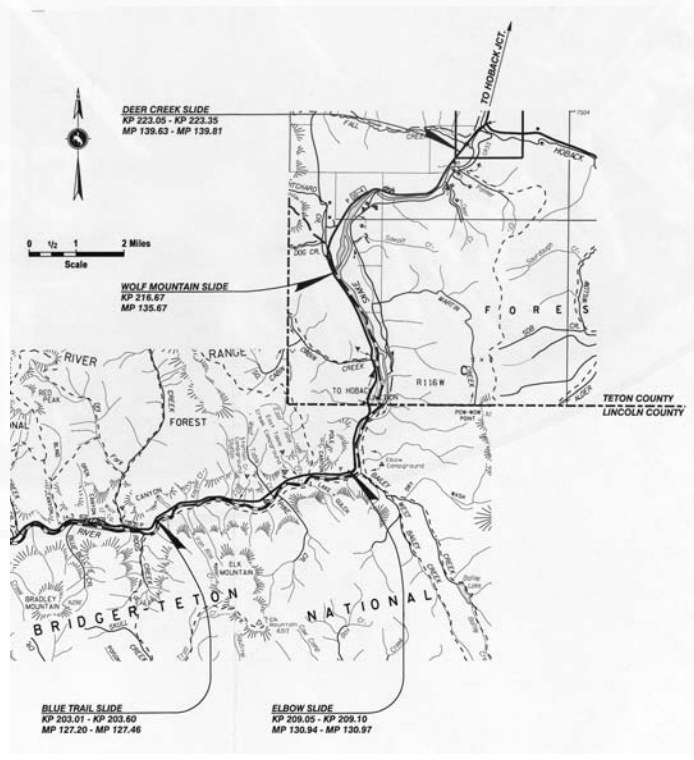


Figure 34. Detailed map of part of Snake River Canyon showing locations of four major landslide stabilization projects. Map courtesy of Chuck James, WYDOT.

Figure 35. View to east of the Elbow Slide area before project began. Note patched and damaged road near sign. The highway and Snake River curve sharply to the left just beyond the slide.

Figure 36. View from the river of Elbow Slide project area before construction showing active erosion of slope (arrow) by Snake River channel. Circled area in left center is a WYDOT carryall with several persons nearby. Note hummocky topography of large landslide area above circle.

in 1996, but no significant displacement ever took place along these cracks.

This fill area lies adjacent to a slowly creeping large landslide which extends approximately 1500 feet above the roadway (**Figure 36**). The first proposal was to cut into the backslope through the "Elbow" to move the roadway away from the migrating river. After a detailed geologic investigation, it was determined that if this backslope were cut, it could cause instability to the large-scale ancient landslide complex present both above and west of the roadway. A highway template was developed instead which avoids all cutting through this area. This template required the installation of some type of wall structure to provide the additional highway width needed.

This project was the first use of the soil nail wall in landslide stabilization for highway applications in the U.S.

A geotechnical foundation investigation for placement of this wall discovered very poor foundation conditions. It was determined that the existing embankment would not support the proposed wall, and building the wall without some type of foundation improvement would result in a slope failure below the wall. The greatest challenge to improving this foundation was the restriction that the road had to remain open to at least single lane traffic during construction. This restriction precluded simply removing all of the poor material and replacing it with a standard reinforced embankment.

At this point, WYDOT put out a request for proposals to do a design/build project to solve this foundation problem. A proposal from the Hayward Baker Company was selected as the preferred alternative (**Figure 37**). This proposal consisted of a system of tiered *soil nail walls*. These are constructed by drilling nearly horizontal holes into an embankment (**Figure 38**), placing long steel rods ("nails") (**Figure 39**) centered in the hole and then filling the holes with grout (**Figure 40**). A "wall" of these soil nails is then constructed (**Figure 41**) and the face further reinforced by steel mesh. The idea behind soil nails is to reinforce the soil, and in some cases, even to attach the reinforced soil mass to bedrock if the nails are long enough. This project was the first use of the soil nail wall in landslide stabilization for highway applications in the U.S.

The lower soil nail wall is 725 feet long and varies in height from 6 to 10 feet with the soil nail members extending 40 feet into the slope (**Figure 42**). The main purpose of this wall was to reinforce the existing embankment and provide a foundation for the mechanically stabilized earth (MSE) wall. The upper soil nail wall is 743 feet long and varies from 13 to 25 feet high with soil nail members extending 33 feet into the slope (**Figure 41**). The main purpose of this wall is to provide support for the existing roadway while the MSE wall is being constructed. The MSE wall is a modular, block-faced wall ranging in height from 13 to 32 feet (**Figure 43**). The wall is reinforced with galvanized metal strips, and provides the additional width needed for the new roadway.

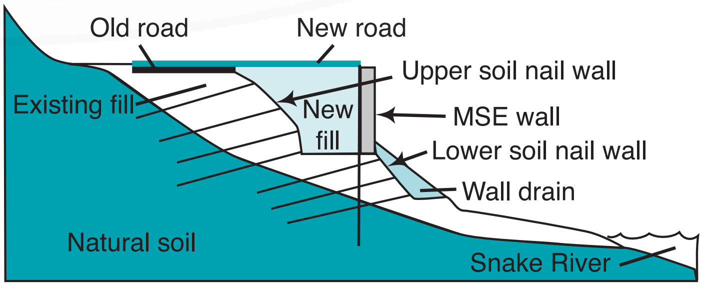


Figure 37. Schematic cross section of construction techniques used at the Elbow Slide, Snake River Canyon, Wyoming. Not to scale.

Figure 38. Construction of upper soil nail wall at Elbow Slide (view to east). Rig is drilling holes for placement of soil nails in wall (arrow shows orientation of soil nails). Grouting and nail placing equipment is just beyond the rig.

Figure 39. Soil nails with centralizers ready for placement in nail wall. These are 30 and 40 feet long, and some were instrumented with strain gauges along their length.

Figure 40. A completed soil nail hole after grouting into place; welded wire fabric is ready for attachment to the nail.

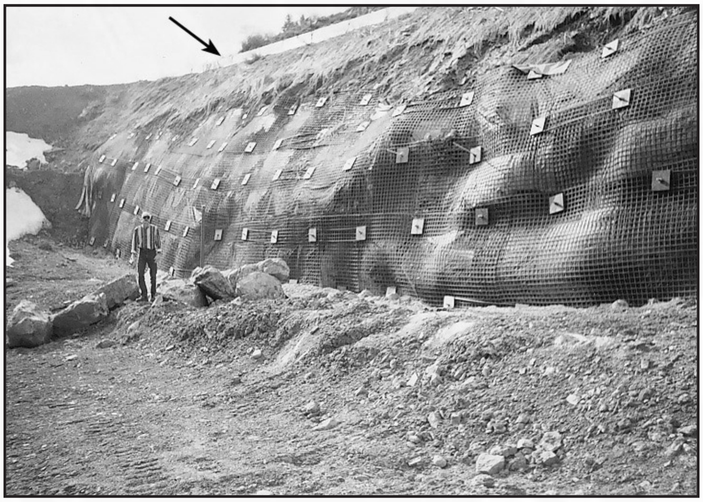


Figure 41. Completed upper soil nail wall at Elbow Slide. This wall stabilized the highway (note temporary highway barriers shown by arrow) during the period when construction was prohibited.

Construction of this project began on August 15, 1998. Construction could not begin sooner because this area is in "designated critical habitat" for bald eagles. No construction is allowed in this part of Snake River Canyon between February 15 and August 15. The construction of the upper and lower soil nail walls was completed in early December, 1998. Due to bad weather and environmental restrictions, it was not possible to begin construction of the MSE wall upon completion of the soil nail walls. Construction of the MSE wall began on August 15, 1999. This wall was part of a 5-mile-long highway reconstruction project which was completed on October 31, 2000 (**Figure 44**).

For more information on this project, including a detailed description of the instrumentation used, refer to the story on the Web site of Slope Indicator (http://www.slopeindicator.com/stories/snakeriver.html). Two technical articles on the Elbow Slide have also been published (Turner, 2001; Turner and others, 1999).

References cited

Turner, J.P., 2001, Performance of soil nail and MSE wall for stabilization of the Elbow fill slide: Federal Highway Administration FHWA-WY-01/01F, Department of Civil and Architectural Engineering, University of Wyoming (July, 2001), 46 p.

Turner, J.P., Jensen, W.G., Wolosick, J.R., and Falk, M.A., 1999, Soil nail and MSE wall for stabilization of the Elbow fill slide, Snake River Canyon, Wyoming: Proceedings of the 50th Annual Highway Geology Symposium, p. 232-246.

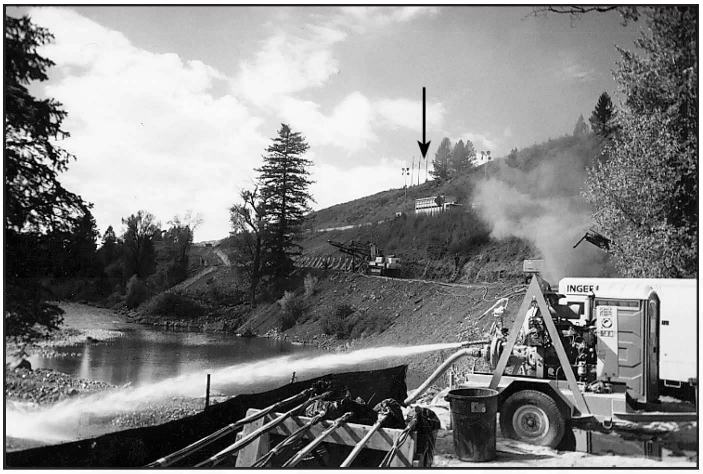


Figure 42. Construction of lower soil nail wall at Elbow Slide. Soil nails in foreground are ready for placement by grouting equipment to right. Note the tour bus on highway (below arrow).

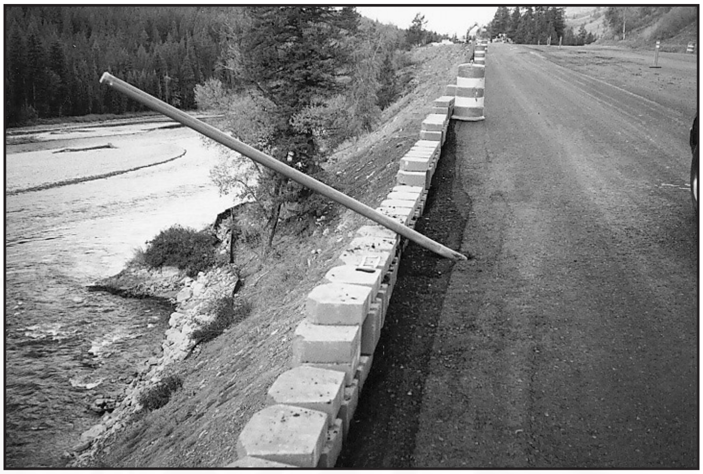


Figure 43. Completed MSE wall after final paving of highway. The pipe (when straightened to vertical) is the casing for an inclinometer which monitors movement behind the lower soil nail wall and the MSE wall.

Figure 44. View of completed Elbow Slide project northward from the Snake River, showing the face of the MSE wall (the blank featureless area behind the trees) and the new highway. Note powerline near skyline which traverses the large landslide mass above roadway.

PUBLICATIONS UPDATE

New Publications Available from the Wyoming State Geological Survey

Wyoming State Geological Survey publications

Carbon dioxide in Wyoming, by R.H. De Bruin, 2001: Information Pamphlet 8 - FREE.

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, 2001: Coalbed Methane Map CMM 01-6 (updated in October, 2001, replaces CMM 01-3), on-demand plotted color map, rolled only - $30.00; digital version (ESRI ArcInfo®/ ESRI ArcView® format) on CD-ROM, including Coalbed Methane Map CMM 01-7 - $100.00.

Coalbed methane activity in the western Powder River Basin, Campbell, Converse, Johnson, Natrona, and Sheridan Counties, Wyoming, by R.H. De Bruin, R.M. Lyman, L.L. Hallberg, and M.M. Harrison, 2001: Coalbed Methane Map CMM 01-7 (updated in October, 2001, replaces CMM 01-4), on-demand plotted color map, rolled only - $30.00.

Coalbed methane activity in the Powder River Basin, Campbell, Converse, Johnson, Natrona, and Sheridan Counties, Wyoming, by R.H. De Bruin, R.M. Lyman, L.L. Hallberg, and M.M. Harrison, 2001: Coalbed Methane Map CMM 01-8 (this is a reduced and combined version of CMM 01-6 and CMM 01-7 at 1:250,000 scale), on-demand plotted and laminated color map, rolled only - $50.00; on-demand plotted color map, rolled only - $40.00.

J. David Love Historical Geologic Map Series, Geology of the Teton-Jackson Hole region, on-demand plotted color map, rolled only - $20.00; CD-ROM of digital map coverages in ESRI ArcInfo® format plus viewable, printable version in MrSid® - $10.00.

- Geologic map of the Cache Creek Quadrangle, Teton County, Wyoming, by J.D. Love and C.M. Love, 2000, scale 1:24,000 (LMS-1).
- Geologic map of the Teton Village Quadrangle, Teton County, Wyoming, by J.D. Love and J.C. Reed, Jr., 2000, scale 1:24,000 (LMS-2).
- Geologic map of the Moose Quadrangle, Teton County, Wyoming, by J.D. Love, 2001, scale 1:24,000 (LMS-3).
- Geologic map of the Gros Ventre Junction Quadrangle, Teton County, Wyoming, by J.D. Love, 2001, scale 1:24,000 (LMS-4).
- Geologic map of the Granite Basin Quadrangle, Teton County, Wyoming, by J.C. Reed, Jr., and J.D. Love, 2001, scale 1:24,000 (LMS-5).
- Geologic map of the Blue Miner Lake Quadrangle, Teton County, Wyoming, by J.D. Love, 2001, scale 1:24,000 (LMS-6).
- Geologic map of the Shadow Mountain Quadrangle, Teton County, Wyoming, by J.D. Love, 2001, scale 1:24,000 (LMS-7).

Each geologic section of the Survey now prepares and releases some of its own numbered reports and maps. Please contact the Staff Geologists for coverage, availability, prices, or further information on specific commodities or topics (see **STAFF DIRECTORY** on back cover).

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

Free USGS hydrology reports available

The Wyoming State Geological Survey (WSGS) has a number of U.S. Geological Survey reports on the hydrology of coal areas in Wyoming. The five reports listed below cover most of Wyoming's coal fields and are free upon request. We do ask the requestor to pay the postage for sending these reports, however. Call our Publications Sales desk for postage charges. They can also be picked up at the Survey office in Laramie at no charge. Quantities are limited and will be distributed on a first-come first-served basis.

Hydrology of Area 48, Northern Great Plains and Rocky Mountain Coal Provinces, Montana and Wyoming, by S.E. Slagle and others, 1986, U.S. Geological Survey Water-Resources Investigations Open File Report 84-141. Includes Yellowstone, Clarks Fork of the Yellowstone, Musselshell River, and Pryor Creek drainages (mostly northern Bighorn Basin).

Hydrology of Area 50, Northern Great Plains and Rocky Mountain Coal Provinces, Wyoming and Montana, by M.E. Lowry, and others, 1986, U.S. Geological Survey Water-Resources Investigations Open File Report 83-545. Includes Powder River, Crazy Woman Creek, Clear Creek, Little Powder, Belle Fourche, and Cheyenne rivers, and Lance Creek (Powder River Basin, Wyoming and Montana) drainages.

Hydrology of Area 51, Northern Great Plains and Rocky Mountain Coal Provinces, Wyoming and Montana, by D.A. Peterson and others, 1987, U.S. Geological Survey Water-Resources Investigations Open File Report 84-734. Includes Shoshone, Bighorn, Greybull, Wind, and Popo Agie rivers (Bighorn and Wind River basins) drainages.

Hydrology of Area 52, Rocky Mountain Coal Province, Wyoming, Colorado, Idaho, and Utah, by H.W. Lowham and others, 1985, U.S. Geological Survey Water-Resources Investigations Open File Report 83-761. Includes Green, New Fork, and Big Sandy rivers, Blacks Fork, Bear River, and Great Divide Basin (Thrust belt, Greater Green River Basin) drainages.

Hydrology of Area 54, Northern Great Plains and Rocky Mountain Coal Provinces, Colorado and Wyoming, by G. Kuhn and others, 1983, U.S. Geological Survey Water-Resources Investigations Open File Report 83-146. Includes North Platte, Laramie, and Medicine Bow rivers (North Park, Saratoga Valley, Hanna, and Laramie basins) drainages.

Other publications

A tapestry of time and terrain: Geologic age of rocks in color, superimposed on the digital shaded relief map of the U.S., U.S. Geological Survey Geologic Investigations Series Map I-2720, 2000, 1 sheet, 55" x 40" (scale 1:3,500,000) plus 24 p. pamphlet - $7.00.

General purpose map of America, U.S. Geological Survey, 2001, scale 1:5,000,000 (42" x 30") - $7.00. This is a detailed, full color reference map that shows International and state boundaries, large and small cities, state capitals, highways, railroads and ferries, rivers and lakes, oceans and bays, natural features, forests, mountain elevations, and terrain.

*Landforms of the conterminous United States–A digital shaded-relief portrayal: U.S. Geological Survey Map I-2206, 1991, 1 sheet, 55" x 38" (scale 1:3,500,000) plus 16 p. pamphlet - $7.00.

This dynamic earth, the story of plate tectonics, U.S. Geological Survey, 1996, 77 p. booklet - $6.00.

Staff Profile: Susan T. McClendon

Richard W. Jones, P.G.

Editor–Publications, Wyoming State Geological Survey

The computer systems administrator at the Wyoming State Geological Survey (WSGS) is Susan T. McClendon. She manages a 25+ user multi-platform networked computer system. Susan is the main Information Technology (IT) person at the Survey and as manager of the computer services unit, is responsible for planning, evaluating, and purchasing hardware and software systems for the agency; assisting and training agency staff on the use of the hardware and software; and helping with entering, revising, and converting and/or manipulating various computer-related data and graphics. She maintains the agency's servers and is responsible for design, implementation, and maintenance of the WSGS Web site, including training and assistance to agency personnel on the use of Web-based applications. She assists the agency's GIS coordinator and other GIS specialists in designing and maintaining geologic computer databases and formulating/implementing database standards for agency data, maps, and records, including GIS-related components. Susan also supervises a part-time student assistant, Jesse Bowen, who is majoring in Computer Science at the University of Wyoming (UW).

Susan serves as a liaison between users of computer and data services and other state agencies and as liaison officer with specified WSGS clients. She represents the WSGS on State of Wyoming computer-related organizational committees. She has represented the WSGS on the Wyoming Geographic Information Advisory Committee (WGIAC) and was appointed

Figure 45. Susan T. McClendon is the computer systems administrator at the Wyoming State Geological Survey.

to the State's Information Architecture Standards Committee in 1997 and 1998. She worked on revising and maintaining the State's Standards document, serving on the Database Standards subcommittee and the Digital Signatures and Electronic Commerce Standards sub-committee.

Susan was born in St. Cloud, Minnesota but has lived in Wyoming and Laramie most of her life. She attended Laramie public schools and graduated from Laramie High School in 1982. Continuing her education at UW in Laramie, she graduated in 1994, earning B.S. degrees in both Computer Science and Management Information Systems. While attending the university, she worked as a Lab Assistant in the Department of Information Technology for 3 1/2 years and as a Grader in the Computer Science Department for a year. As a lab assistant she answered user questions and did trouble-shooting on computer hardware and software; as a grader, she graded exams and homework for three computer classes and did substitute teaching for both COBOL and Computer Organization classes.

Susan joined the WSGS in July, 1995. She has also been an Independent Consultant in Laramie since January, 1996 where she specializes in installing and upgrading networks and computers, as well as devising security policies and operation procedures for small businesses, concentrating on medical offices. Listed amongst her many accomplishments at the WSGS are converting an antiquated Appleshare network to a modern MS Windows NT 4.0 network; implementing network installation of ESRI's ArcInfo® for NT as a client/server based system with stand alone license server and several clients; and developing multimedia CD-ROM project files used to distribute GIS maps and data produced by the WSGS along with making GIS map images available for viewing via a Web browser.

Susan and her husband Bill have two sons, Jack, 10, and Ken, 8. Susan is known around Laramie for her talents in organic gardening, no easy task at Laramie's 7200-foot elevation and extremely short growing season. (She **must** be going to Fort Collins to get those tomatoes and the lettuce!) She also enjoys skiing and bicycling, along with tormenting some staff members at the WSGS.

This dynamic planet, world map of volcanoes, earthquakes, impact craters, and plate tectonics, U.S. Geological Survey, 1994 - $7.00.

*Topo! Wyoming, Seamless USGS topographic maps on CD-ROM, 2000, National Geographic Maps, 6 CD-ROMs. Contains full-state coverage with TOPO! Mapping Software, GPS ready, with 3-D digital shading (toggles off and on) and photo-quality output. Five map scales include general reference map, National atlas series, 1:500,000 map series, 1:100,000 map series, and 1:24,000 map series. Coverages extend outside state boundaries and include all boundary areas contiguous to Wyoming - $99.95.

Attention GPS users

The WSGS is now a dealer for Global Positioning Systems (GPS) accessories offered by Waypoint Enterprises. These are scales for plotting GPS coordinates on maps or for locating GPS coordinates from map locations, "cheat sheets" for operating and initializing the most common GPS units, and a book on GPS. The products listed below are available over the counter at the WSGS sales office in Laramie or by mail. These products do not qualify for our quantity discounts.

Original Waypointer. Used for measuring and plotting latitude and longitude for map scales of 1:24,000; 1:62,500; 1:100,000; 1:126,720; and 1:250,000 - $7.95.

UTM Waypointer. Used for UTM coordinate systems on 7.5-minute, 1:24,000-scale quadrangle maps; includes protractor for determining compass headings - $7.95.

Pocket Waypointer. Used for latitude/longitude (down to seconds or decimal minutes to hundredths of a minute) on 7.5-minute, 1:24,000-scale maps; includes miles for townships and meters for UTM grids -$6.95.

Multiscale UTM Waypointer. Used for UTM coordinate system on seven popular map scales and a protractor for plotting headings - $5.95.

Cheat sheets for quick references to basic functions on various Magellan, Garmin, and Globe GPS units (specify which model or call for availability) - $4.95.

GPS Land Navigation, by Michael Ferguson (1997). Soft cover book that explains principles, uses, and limitations of GPS, coordinate systems, datums, etc. associated with GPS, and other topics - $19.95.

Attention users of All Topo Maps: Wyoming

As a dealer for iGage *All Topo Maps: Wyoming* products, the WSGS is proud to announce a drop in prices and some changes in the configurations of the products:

- *All Topo Maps: Wyoming*, Release 3 now sells for $88.00 and contains over 260 new maps; a uniform color palette for all maps; the ability to search by township, range, and section; the ability to search by National Geodetic Survey (NGS) control points, zip codes, and area codes; and the latest versions of the map seamer, the GPS Tool, and the All Topo Viewer. Those that purchased their Wyoming All Topos before April 11, 2001 can upgrade to Release 3 for $29.00.
- PLS Tool, a $68.00 option ($34.00 when purchased with upgrade), offers users a real-time display of the cursor position to the nearest 1/4 1/4 section (plus township and range) while viewing All Topo Maps. The Public Lands Survey (PLS) tool enables legal descriptions to be read directly from All Topos.
- Big Topo Pro Tool enables creation of unlimited sized maps for those using large format plotters and requiring large seamed maps. Normally a $120 option, this tool is available with the Release 3 upgrade for $90.

GIS Activities at the Wyoming State Geological Survey

Joseph M. Huss

GIS Coordinator–Publications, Wyoming State Geological Survey

The Geographic Information Systems (GIS) component of the Wyoming State Geological Survey (WSGS) has been busy this third quarter with multiple projects and activities. The GIS specialists are currently involved in five projects and are furnishing GIS-related support to several WSGS sections. Outside funding through grants is being used to support contract personnel and cover expenses on four of the projects briefly described below.

The STATEMAP 2001 project involves digitizing and preparation of two bedrock and two surficial geologic maps at 1:100,000 scale. Oil and gas maps of Wyoming are presently being updated and converted to ESRI's ArcGIS® coverages and newly updated map products. Another funded project is to compile a comprehensive GIS database for oil and gas pipelines in Wyoming. A large GIS effort is underway with four WSGS sections to develop an interactive database for the northern Powder River Basin, Wyoming. Finally, the WSGS will receive funding assistance from the U.S. Geological Survey (USGS) to produce additional maps in the Love Map Series.

STATEMAP 2001

The STATEMAP 2001 project is currently underway, consisting of digital surficial and bedrock geologic maps for four 1:100,000 quadrangles in Wyoming (see *Wyoming Geo-notes No. 68*, December, 2000, p. 29-30). This project, funded by the USGS and the WSGS, includes bedrock geologic maps of the Buffalo and Recluse 1:100,000-scale quadrangles, and surficial geologic maps of the Basin and Midwest 1:100,000-scale quadrangles.

> **Updates to maps of Wyoming's oil and gas fields . . . are under development and should be released around March, 2002.**

Jackie Hauptman, a doctoral candidate in the Department of Renewable Resources at the University of Wyoming, is conducting a majority of the GIS effort for the STATEMAP 2001 project. The project is concentrating on the Buffalo and Recluse bedrock geologic maps in support of the Northern Powder River Basin geologic, hydrologic, and water quality database project. Work on the surficial geologic maps of the Basin and Midwest quadrangles will begin this spring.

The Buffalo and Recluse geologic maps were mapped and compiled earlier by Alan J. Ver Ploeg of the Mapping Section at the Survey and were initially digitized by Cindy S. Boyd and Laura L. Hallberg. The maps have undergone multiple quality assurance and quality checks as they approach a finalized cartographic product. The maps will initially be available in a GIS ArcInfo® format and as on-demand maps; ultimately they will be commercially printed for mass distribution.

Wyoming's oil and gas maps

Updates to maps of Wyoming's oil and gas fields, WSGS Map Series MS-48, MS-51, MS-52, MS-53, and MS-54, are under development and should be released around March, 2002. The new maps, now produced using ESRI's ArcInfo®, will allow the WSGS to make annual or biannual updates relatively easily and will give the user flexibility in their choice of map and data products.

Fred Porter and Phyllis Ranz, both long-time cartographers at the WSGS, have become GIS mapping specialists, utilizing their cartographic skills while learning new software techniques. Our first attempt at preparing these maps digitally with ABICAS® software was less than successful, but fortunately most of the digital data could be converted into ESRI's ArcInfo® format. By utilizing mainstream GIS software and techniques, we will now be able to produce a new large format (1:500,000-scale) map of the entire state more often than every five years.

Oil and gas pipeline database

The WSGS, under contract with the Wyoming Energy Commission, is compiling an oil and gas pipeline GIS database using existing data from private industry and other state and federal agencies. Abby Kirkaldie, project GIS specialist, is responsible for obtaining, compiling, and converting a large variety of data for pipeline and facility infrastructure into a single GIS database (see page 6, **GIS DATABASE FOR WYOMING OIL AND GAS PIPELINES**). The database will aid in future pipeline infrastructure planning and development.

Interactive database, northern Powder River Basin

The GIS coordinator is assisting many of the WSGS geologists with the Northern Powder River Basin (PRB) geologic, hydrologic, and water quality database. This project is challenging due to varying GIS techniques and geologic data constraints.

The GIS part of the project includes mapping various geologic and coal units across the northern PRB using Wyoming Oil and Gas Conservation Commission (WOGCC) coalbed methane well information, geophysical well logs, and a coalbed methane well database purchased from industry. Information on geologic formations is extracted from WOGCC and other well information and utilized to interpret the geology across the PRB. This information is then converted into ESRI's ArcInfo® grids to interpolate geologic formation elevations and thicknesses.

> **ESRI ArcInfo® . . . grids of coal beds will also be produced with respect to stratigraphic position.**

The final GIS product will consist of the Lance, Fox Hills, and Lewis geologic formations as complete ESRI ArcInfo® grids covering the northern PRB. Grids of coal beds will also be produced with respect to stratigraphic position. This information will eventually be combined with hydrologic and water quality data to produce an interactive database (see *Wyoming Geo-notes No. 69*, April, 2001, p. 36-38).

Love Map Series

The J. David Love Historical Geologic Map Series is a cooperative project with the USGS to produce and publish J. D. Love's 7.5-minute (1:24,000-scale) quadrangle geologic maps of the Jackson Hole area. This continues a 45-map project that began two years ago, resulting in production of seven maps so far. The next group of maps to be produced will focus on the area immediately adjacent to and within Yellowstone National Park, in support of the USGS mapping efforts centered around the Greater Yellowstone Ecosystem. Funding will primarily support scanning and digitizing the original field maps. The Two Ocean Lakes Quadrangle has been initially digitized and is being reviewed and edited. Upon completion of the review, the map will be released in both digital format and as an on-demand map. After initial release, the geologic map will be combined with digital base map information and made available as a set of digital files as well as a printed map.

Ordering Information

Prepaid orders (preferred)

- We give a discount on large orders of most Wyoming State Geological Survey publications and selected other publications.

  30% discount: 10 of one title or 20 mixed titles
  35% discount: 20 of one title or 30 mixed titles
  40% discount: 30 of one title or 40 mixed titles

- No discounts on U.S. GEOLOGICAL SURVEY TOPOGRAPHIC MAPS and U.S. GEOLOGICAL SURVEY PUBLICATIONS. No discounts on POSTCARDS (PCs), INFORMATION PAMPHLETS (IPs), and some other publications.
- Include postage and handling charges for all prepaid orders (see **ORDER FORM** for chart).

Telephone or Email orders

- Telephone, Fax, or Email orders for maps and publications may be billed to a customer only with pre-approved credit. We may require completion of a credit application to complete your order.
- Payment is due on receipt of merchandise. All orders will be billed for postage charges. Overdue payment may be assessed service fees and/or interest.

Sales tax

- Shipments to addresses within the state of Wyoming must include sales tax of 6%, collected at the point of origin of the sale, which is the City of Laramie in Albany County.
- Sales tax is applied after adding shipping and handling charges, as prescribed by Wyoming statutes.
- All over-the-counter sales are charged 6% sales tax.
- Resellers or entities with tax exempt status should furnish a State of Wyoming Tax ID number or a copy of their State of Wyoming Sales Tax Exemption Certificate.

Mailing (in U.S.A.)

Please allow adequate time for delivery.

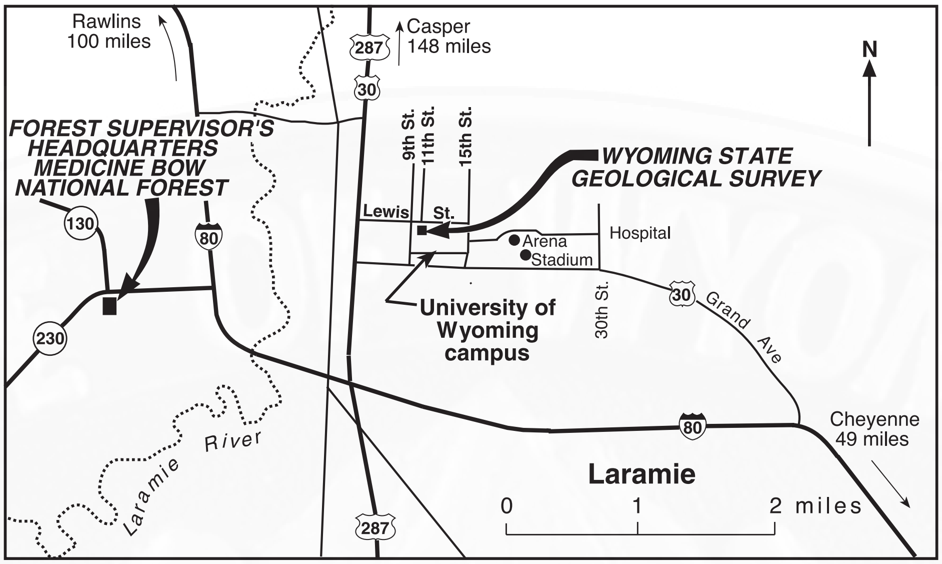
- Regular orders will be mailed FIRST CLASS or PRIORITY. Larger orders will be shipped UPS.
- Expedited mail is permitted if charged to your account number. We cannot guarantee date or time of delivery once your order leaves our building.
- Please allow extra time for handling of products that require plotting or computer processing.

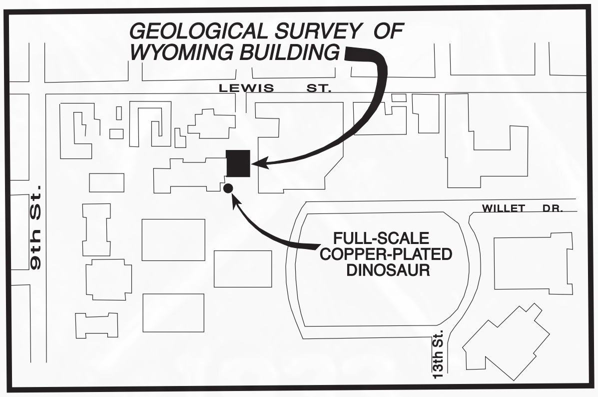
International orders

- International orders must be PREPAID with U.S. dollars through a U.S. Clearing House or with a money order in U.S. currency. Checks or money orders must have a nine-digit U.S. routing number for proper bank clearance.
- Overseas orders will be mailed SURFACE unless otherwise specified.
- PERFORMA information upon request.
- Maps **cannot** be mailed rolled.
- International orders for Memoir 5, *Geology of Wyoming*, must indicate preferred method of shipment (U.S. Postal Service SURFACE, U.S. Postal Service AIR, Federal Express, or United Parcel Service) and must include additional postage for areas outside North America. Memoir 5, which includes a custom shipping box, weighs about 10 pounds (4.6 kg).
- Sorry, we do not accept credit cards for payment at this time.

Many Wyoming State Geological Survey publications are also available for over-the-counter sales at the Wyoming Oil and Gas Conservation Commission office, Basko Building, 777 West First Street, Casper, Wyoming 82601.

Location Maps for the Wyoming State Geological Survey





Improved Telephone System at the Wyoming State Geological Survey

The Wyoming State Geological Survey recently upgraded their telephone system to include voice mail. Persons wishing to contact a specific person or section may now do so directly by dialing the Survey's regular phone number (307-766-2286) and then entering the extension of the person they would like to speak to. An automated phone directory can also be accessed. Messages can be left for a person in a more convenient way. For persons wishing to place an order, or who have sales related questions, simply dial "0" for an operator. For your convenience, the following list may help locate staff members or their sections.

Ext.	Name/section
0	Ordering, sales questions, and general information
223	Lance Cook–State Geologist
225	Jim Case–Geologic Hazards
226	Rod De Bruin–Oil and Gas
228	Ray Harris–Industrial Minerals
229	Dan Hausel–Metals and Precious Stones
230	Alan Ver Ploeg–Geologic Mapping
233	Bob Lyman–Coal
234	Joe Huss–GIS
238	Richard Jones–Publications
242	Susan McClendon–Information Technology

Publications Order Form

Make checks payable to :

Wyoming State Geological Survey
P.O. Box 3008
Laramie, WY 82071
Phone: 307-766-2286
Fax: 307-766-2605
Email: sales-wsgs@uwyo.edu

Please send to:

Name

Mailing Address

City

State Zip

Phone (order cannot be processed without phone #)

Quantity	Item #	Item name	Price	Total Price

Subtotal	
Shipping & handling (see chart below)	
Wyoming addresses add 6% sales tax on subtotal only	
TOTAL ENCLOSED	

Shipping & handling charges

Up to $10.00 .... $2.55
$10.01 to $20.00 .... $5.00
$20.01 to $30.00 .... $6.00
$30.01 to $40.00 .... $7.50
$40.01 to $50.00 .... $8.50
$50.01 to $100.00 .... $10.00
Over $100.00 and international orders (incl. Canada) – Please call for postage and best shipping methods.

Please include shipping and handling charges and 6% Wyoming sales tax (if applicable). Insufficient payment will delay your order. Prices may change without notice. Please allow 2 to 3 weeks for delivery of your order. Some items may not be immediately available, in which case the WSGS will notify you of expected availability.

Publications Order Form

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Survey Directory

WYOMING STATE GEOLOGICAL SURVEY
Lance Cook, *State Geologist*–
Email: lcook@wsgs.uwyo.edu

GEOLOGICAL SURVEY BOARD

Ex Officio
Jim Geringer, *Governor*
Lance Cook, *State Geologist*
Don J. Likwartz, *Oil and Gas Supervisor*
Randi S. Martinsen, *University of Wyoming*

Appointed
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Nancy M. Doelger, *Casper*
Charles M. Love, *Rock Springs*
Stephen L. Payne, *Casper*
John E. Trummel, *Gillette*

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Joseph M. Huss -*GIS Specialist*
Email: jhuss@wsgs.uwyo.edu

Supportive Services Unit
Susanne G. Bruhnke -*Office Manager*
Joan E. Binder -*Administrative Assistant*

Phone: (307) 766-2286
Fax: (307) 766-2605
Email: wsgs@wsgs.uwyo.edu
Web Page: http://wsgsweb.uwyo.edu

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

Change service requested.

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