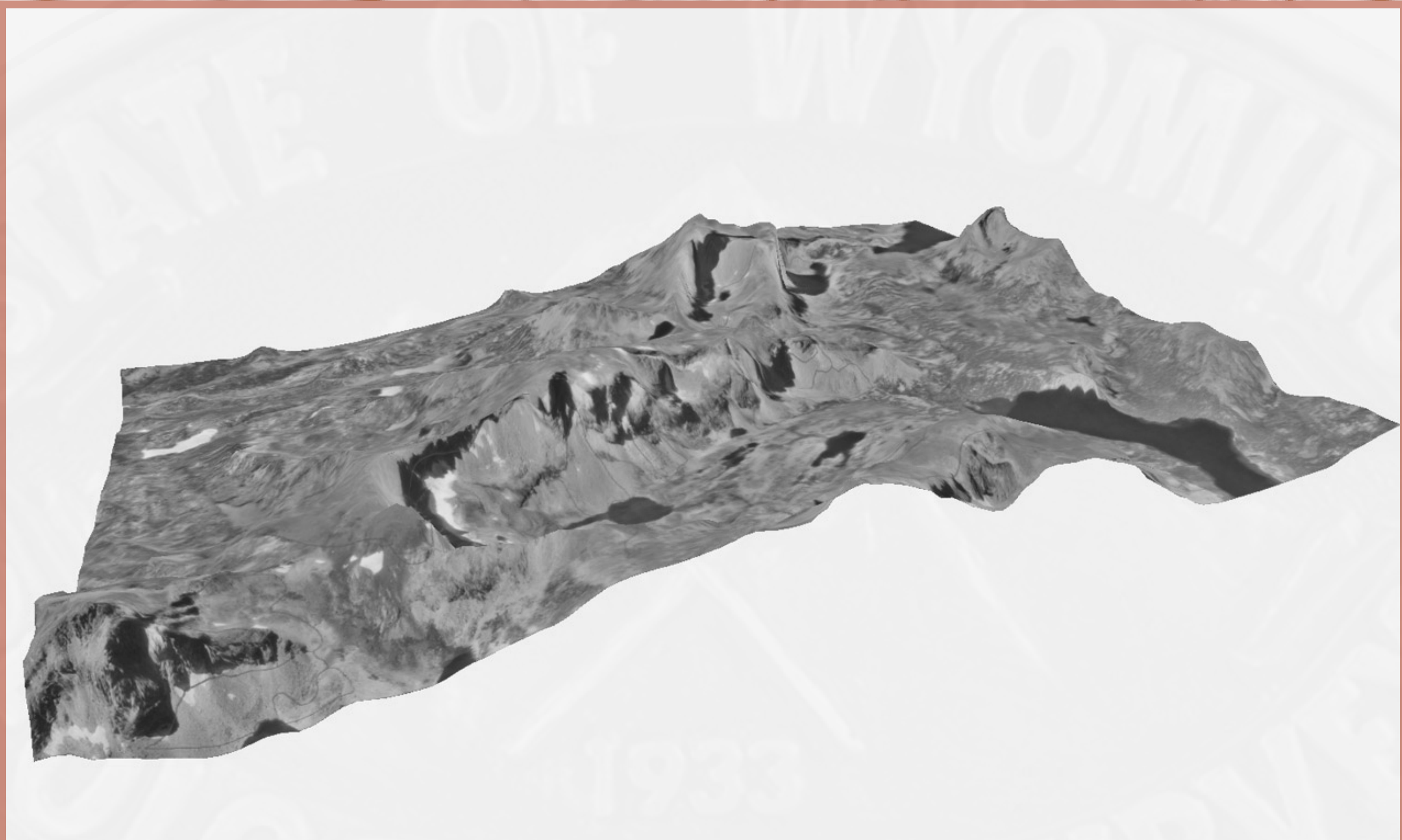
Wyoming Geo-notes

Number 74



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The Blue Trail Slide

Wyoming State Geological Survey
Lance Cook, State Geologist

Laramie, Wyoming
July, 2002

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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Richard W. Jones, Wyoming PG-2972
Editor

Jaime R. Moulton
Layout and design

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Front cover: This is a 3-D view of the northeast quarter of the Mount Bonneville 1:24,000-scale Quadrangle, Sublette and Fremont counties, Wyoming using a web site developed by the Geologic Hazards Section at the Wyoming State Geological Survey (WSGS) (see 3-D interactive images: Landscapes and landslides, p. 28-29). In this northwestward-looking view of the central part of the Wind River Range, Mount Washakie (elevation 12,524 feet) is located in the lower left corner of the image and Mount Hooker (elevation 12,504 feet) in the upper center of the image, connected by the Continental Divide. Note the glaciers (white area along the steep ridges) and glacial lakes (black) dammed by morainal debris. Image courtesy of Tony Bergantino, Wyoming Water Resources Data Systems, and Jim Case, WSGS.

MINERALS UPDATE

Overview

Lance Cook, Wyoming PG-2577

State Geologist, Wyoming State Geological Survey

Mineral production and prices for the first quarter of 2002 appear to be on track with our projections, with coal production ahead of last year's record and natural gas production continuing to increase despite the low prices. The final mineral production numbers for 2001, which were inadvertently omitted from Table 1 of the last issue of *Wyoming Geo-notes* (No. 73, April, 2002), are given in **Table 1**. Sulfur production is only estimated, as it is no longer reported to the Wyoming Oil and Gas Conservation Commission. Final 2001 prices for oil and gas produced in Wyoming, as well as revised forecast coal prices (**Table 2**) were also inadvertently omitted from Table 2 in the last issue of *Wyoming Geo-notes*, although the 2001 prices were given in the individual mineral updates. Final prices for coal and trona produced in 2001 are not yet available.

For production, prices, forecasts, and activities in the first quarter of 2002, refer to the individual mineral update sections.

Also in this issue of *Wyoming Geo-notes* is a discussion of our STATEMAP program, which was recently funded for another year, and two web sites developed by the Geologic Hazards Section. For STATEMAP, we are planning to produce one 1:100,000-scale geologic map and one 1:24,000-scale geologic map along with producing digital geologic map coverages of three more 1:100,000-scale quadrangles in the state. This program will involve at least three sections of the Wyoming State Geological Survey (WSGS). We have also begun a new project to make available 1:250,000-scale digital and hard copy geologic maps of Wyoming. We will emphasize northeastern Wyoming for our initial effort. Information on geologic hazards in Wyoming is becoming more accessible and easier to use as our **Geologic Hazards Update** describes some recent web sites being developed primarily for Wyoming landslides. This issue contains the third installment in our series on the Wyoming Department of Transportation's geotechnical and engineering work on landslides and road reconstruction in Snake River Canyon. This series of articles has been extended to four

Table 1. Wyoming mineral production (1985 through 2001) 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	57.4	1430.6	174.0	1.20	368.8	17.7	2.0	1.20
2002	54.0	1504.8	174.0	1.20	361.0	18.0	2.0	1.20
2003	51.0	1562.8	196.0	1.20	372.0	18.5	2.0	1.20
2004	48.2	1642.8	196.0	1.20	375.7	18.5	2.0	1.20
2005	45.6	1722.8	196.0	1.20	379.5	18.5	2.0	1.20
2006	43.1	1802.8	196.0	1.20	383.3	18.5	2.0	1.20

[1]Modified from CREG's Wyoming State Government Revenue Forecast, October, 2001; [2]Millions of barrels; [3]Wyoming Oil and Gas Conservation Commission, 1985 through 2001; [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 2001); [7]Millions of short tons (Wyoming Department of Revenue, 1985 through 2001; Wyoming State Inspector of Mines, 2001); [8]Millions of pounds of yellowcake (Wyoming Department of Revenue, 1986 through 1999; Wyoming State Inspector of Mines, 2000 and 2001) (not available [N/A] for 1985 and previous years because it was only reported as taxable value; [9]Millions of short tons, estimated.

Table 2. Average prices paid for Wyoming oil, methane, coal, and trona (1985 through 2001) 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	5.78	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	5.45	37.28
2001	21.58	3.66	5.70	38.00
2002	18.00	2.35	5.75	38.00
2003	18.00	2.35	5.86	38.00
2004	18.00	2.35	5.91	38.00
2005	18.00	2.35	6.00	38.00
2006	18.00	2.35	6.07	38.00

[1]Modified 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, 1985-2001; [3]Wellhead price in dollars per thousand cubic feet (MCF), includes coalbed methane. Source: American Association, 1998-2001; Wyoming Office of State Lands and Investments, 1989-2001 (derived from State royalty payments); and 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, 1985-1999.

parts instead of the three we originally planned.

Cross sections of the Wyoming Overthrust Belt

The WSGS is preparing a series of new open file reports, consisting primarily of serial geologic cross sections through the Wyoming part of the Overthrust Belt. The initial group of four cross sections and a discussion of the Hoback Basin and northern-most part of the Overthrust Belt (**Figure 1**) are scheduled for the initial report, followed by another 19 cross sections with discussions in the coming months. These cross sections will be available in color as plot-on-demand documents, along with a brief text.

The structural cross sections were created in 1986 and 1987 by Lance Cook, Wyoming State Geologist, when he was employed by Union Pacific Resources (UPRC) in Denver, Colorado. UPRC graciously gave its permission for the WSGS to publish these sections when Mr. Cook joined the WSGS. The sections were constructed to be true-scale (vertical=horizontal) at 1:48,000. UPRC's extensive well log and seismic data libraries were utilized to provide as much control as possible for the subsurface interpretations and all surface mapping available was compiled and incorporated where possible. All cross sections were constructed to be balanced and palinspastically restorable.

Hoback Basin and northern Overthrust Belt

The first group of cross sections (**Figure 1**) were chosen based on their relevance to current land use and resource issues. The U.S. Forest Service is conducting National Environmental Policy Act (NEPA) analysis for oil and gas activities in several special management areas of the Bridger-Teton National Forest, and these four cross sections reveal important geological aspects of the area that the Forest Service should consider in their decision. Excerpts from the large cross sections were selected to demonstrate important features in the area and the complexity in the subsurface (**Figures 2, 3, 4,** and **5**).

Of particular interest on these cross sections are the back-thrust (Game Hill Thrust Fault on **Figures 2** and **3**) and smaller antithetic thrust structures created by the interaction of the southwest- and west-directed Gros Ventre thrust block and the eastward-directed thrusts of the Overthrust Belt. Although a number of studies have shown the existence of small-scale antithetic back-thrust features along

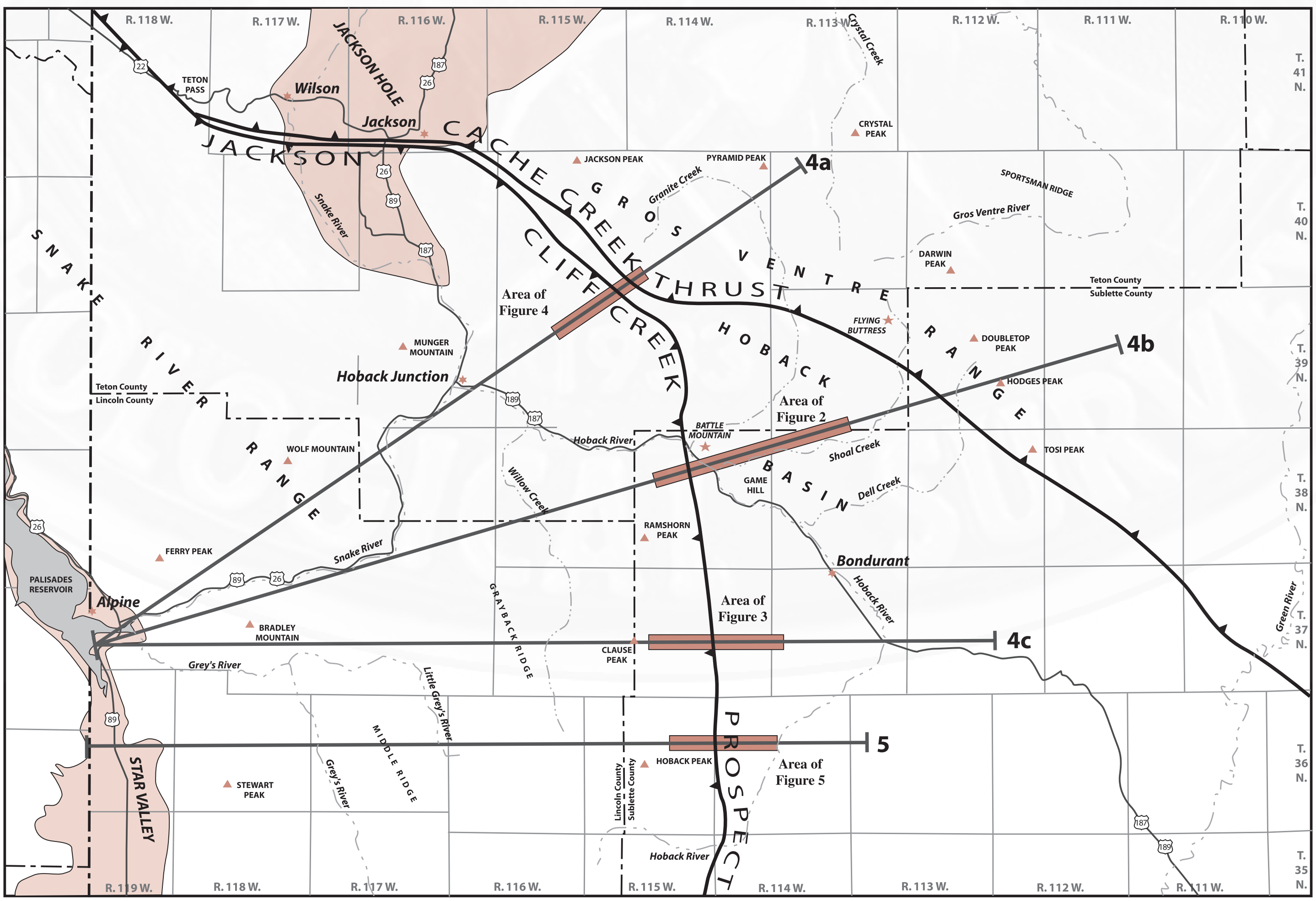

Figure 1. Index map of the northern part of the Overthrust Belt, western Wyoming, showing location of regional cross sections 4a, 4b, 4c, and 5 and selected parts of cross sections discussed in text. Base map from the Driggs 1:250,000-scale (AMS) Quadrangle; geologic features from Lance Cook (unpublished).

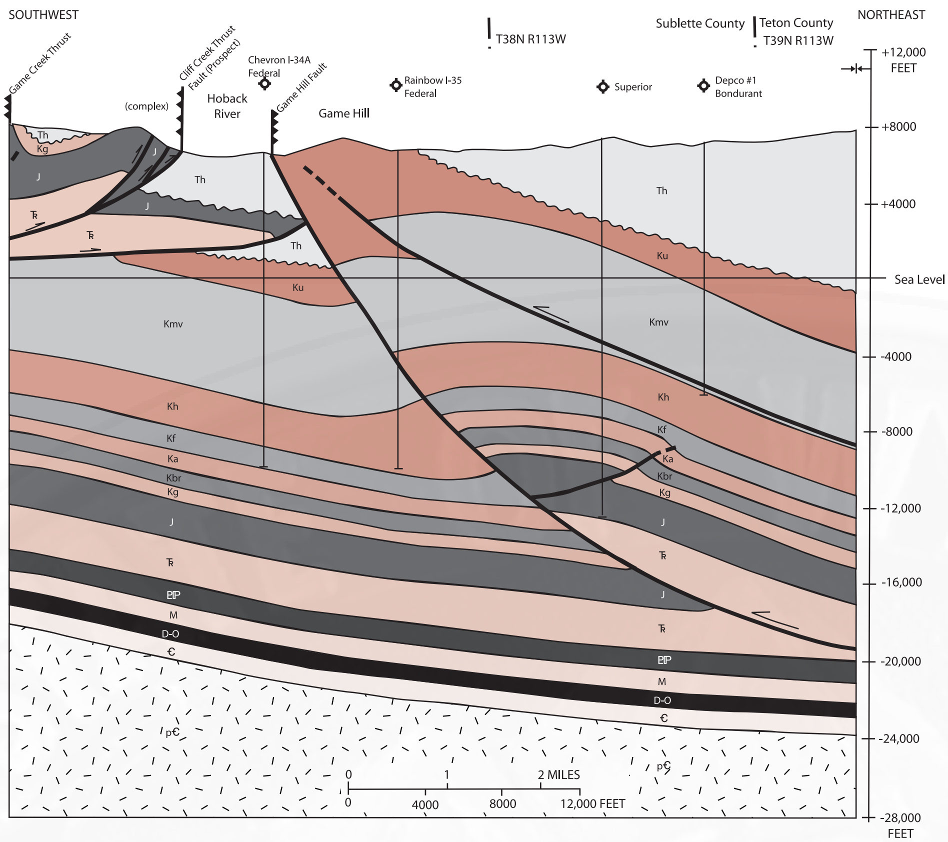

Figure 2. Part of cross section 4b in the northern Hoback Basin showing interaction of the Cliff Creek and Game Hill faults. See Figure 1 for location and Figure 3 for stratigraphic units.

the extent of the eastern edge of the Wyoming Overthrust, the magnitude and intensity of these antithetic thrust structures is much greater in the upper Hoback Basin area. The Cliff Creek thrust represents the easternmost of the Overthrust Belt thrust faults in this area, and is well exposed at the surface at Battle Mountain (**Figure 6**).

The northern-most cross section (**Figure 4**) shows the complexity where these two structural styles (provinces) converge. The complete cross sections shown in the new open-file report also depict observable surface geology, such as the structure of the Gros Ventre Range (**Figure 7**). The southern-most of the four cross sections (**Figure 5**) shows the more typical situation in the Overthrust Belt where the eastward-directed thrusts impinge on the Green River (Hoback) Basin. The structural complexities in this area create opportunities for commercial occurrences of hydrocarbons, particularly gas, given the nature of the potential hydrocarbon source rocks in this area.

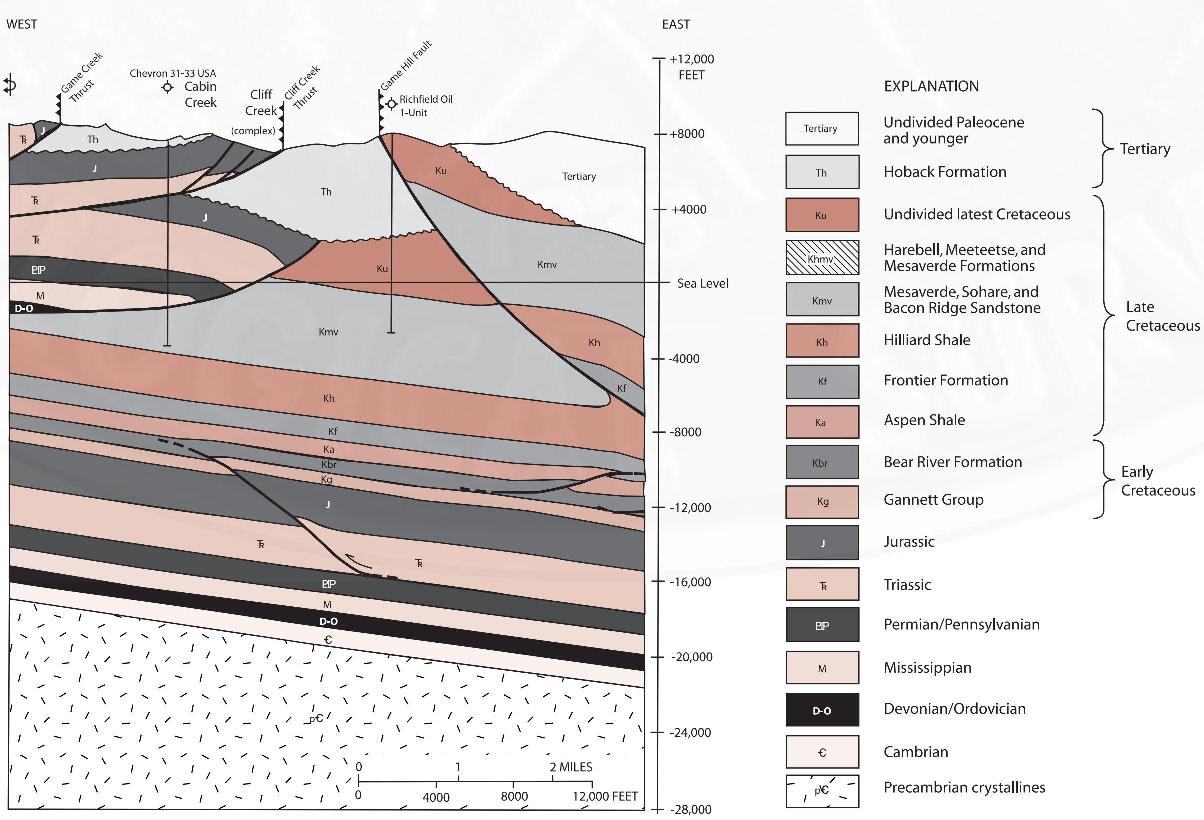

Figure 3. Part of cross section 4c (see Figure 1 for location), central Hoback Basin and northern Overthrust Belt, and key to ages of stratigraphic units used on other cross sections.

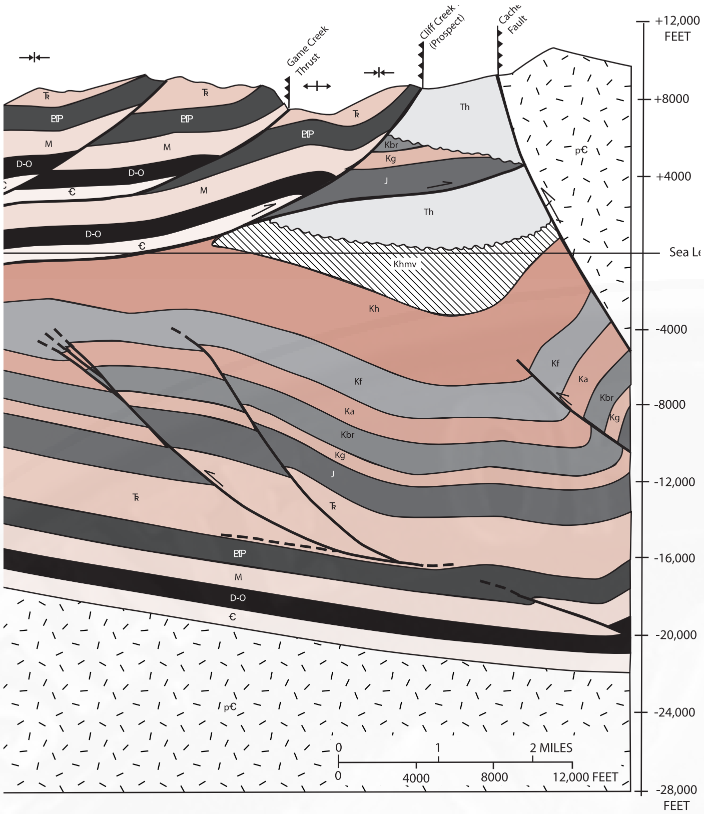

Figure 4. Part of cross section 4a, Hoback Range, northernmost Hoback Basin, and southern Gros Ventre Range. See Figure 1 for location and Figure 3 for stratigraphic units.

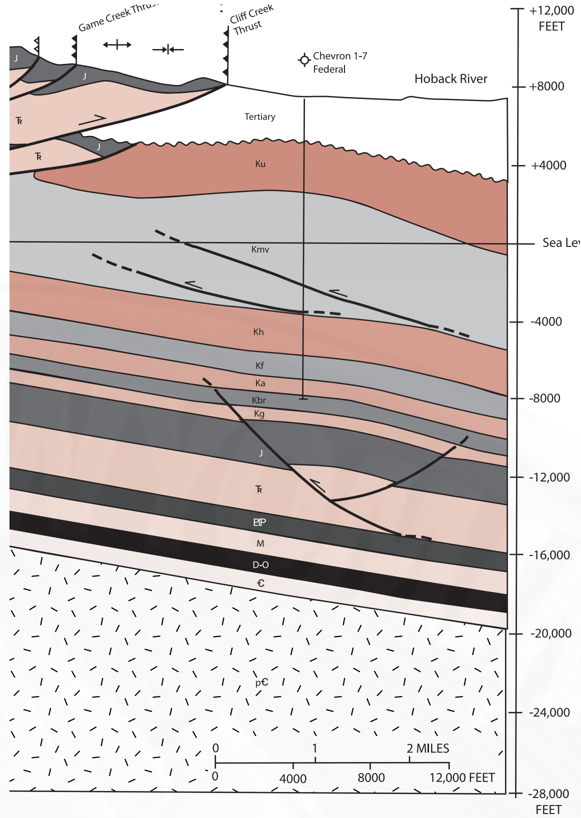

Figure 5. Part of cross section 5 showing leading edge of Overthrust Belt and southern Hoback Basin. See Figure 1 for location and Figure 3 for stratigraphic units.

Figure 6. Battle Mountain, along the Hoback River in Hoback Canyon, contains cliff-forming Nugget Sandstone (Late Triassic-Early Jurassic) and Late Triassic rocks on the hanging wall of the Cliff Creek Thrust overlying Paleocene Hoback Formation (right foreground) on the footwall. Cross section 4b (Figure 2) is a short distance south of this area. View is to the north northwest from U.S. Highway 187/189. Trace of the leading edge of thrust is approximately above the tree tops at base of the cliff. Photograph by Lance Cook.

Figure 7. The Flying Buttress is a prominent and spectacular feature along the southwestern flank of the Gros Ventre Range. View is to the east from above Granite Creek showing Paleozoic rocks on hanging wall of the Cache Creek fault dipping steeply to the southwest. Photograph by Lance Cook.

CALENDAR OF UPCOMING EVENTS

Talks

GOLD PROSPECTING IN WYOMING–*W. Dan Hausel*: Rocky Mountain Prospectors and Treasure Hunters Club, Fort Collins, Colorado, August 7, 2002.

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–*W. Dan Hausel*: public field trip, Atlantic City iron ore mine turnout on State Highway 28, 8:30 am, July 20, 2002.

CHICKEN PARK KIMBERLITES AND DIAMONDS–*W. Dan Hausel*: public field trip, Cherokee Park, Colorado parking lot along U.S. Highway 287, 9:30 am, August 10, 2002.

GOLD AND MINING HISTORY OF THE SOUTH PASS MINING DISTRICT–*W. Dan Hausel*: Rocky Mountain Prospectors and Treasure Hunters Club, Atlantic City iron ore mine turnout on State Highway 28, August 16, 2002.

CHICKEN PARK DIAMONDIFEROUS KIMBERLITES– *W. Dan Hausel*: Rocky Mountain Association of Geologists "On the Rocks" program, Cherokee Park, Colorado parking lot along U.S. Highway 287, 9:30 am, August 24, 2002.

Meetings, conferences, exhibits, etc.

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

DENVER GEM AND MINERAL SHOW–*various WSGS staff*: Denver Merchandise Mart, Denver, Colorado, September 13-15, 2002.

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

WESTERN STATES SEISMIC POLICY COUNCIL (WSPCC) MEETING–*James C. Case, Lance Cook*: Denver, Colorado, September 15-18, 2002.

WYOMING GAS FAIR–*various WSGS staff*: Snow King Resort, Jackson, Wyoming, September 26-27, 2002.

STRATEGIC RESEARCH INSTITUTE COALBED METHANE CONFERENCE–*Lance Cook*: Jackson, Wyoming, September 30-October 1, 2002.

GEOLOGICAL SOCIETY OF AMERICA (GSA) 2002 ANNUAL MEETING–*various WSGS staff*: Colorado Convention Center, Denver, Colorado, October 27-30, 2002.

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS (AAPG) 2003 ANNUAL MEETING–*various WSGS staff*: Salt Palace Convention Center, Salt Lake City, Utah, May 11-14, 2003.

EIGHTH INTERNATIONAL KIMBERLITE CONFERENCE–*W. Dan Hausel*: Vancouver, British Columbia, Canada, June 22-27, 2003.

Oil and Gas Update

Rodney H. De Bruin, Wyoming PG-3045

Staff Geologist–Oil and Gas, Wyoming State Geological Survey

Wyoming oil and gas producers received lower prices for oil and natural gas in the first quarter of 2002 than in the first quarter of 2001. Natural gas production increased 5.1% for the first quarter of 2002, boosted by a large increase in coalbed methane production in the Powder River Basin, which made up 17.8% of Wyoming's total gas production. Oil production declined 6.3% during the same quarter. Compared to the first quarter of 2001, Wyoming's natural gas production in the first quarter of 2002 would have decreased only slightly had coalbed methane production not increased over 20 billion cubic feet (BCF). In the first quarter one Federal lease sale brought in over $5.1 million; the average price per acre was $29.00. The number of applications for permit to drill and the rig counts remained healthy although lower than for the first quarter of last year. Geophysical activity was about the same as for the first quarter of last year.

Prices and production

For our latest price and production forecasts for Wyoming oil and gas, refer to the previous issue of *Wyoming Geo-notes* (No. 73, April, 2002, p. 5-8). Our graphs of production and prices in that issue have not changed but **Tables 1** and **2** include corrected 2001 production and prices.

Prices paid to Wyoming oil producers during the first quarter of 2002 averaged $17.69 per barrel (**Table 3**). The average price for the quarter is $6.36 lower than for the first quarter of 2001, but $1.35 higher than for the fourth quarter. After bottoming out in January of this year, posted sweet and sour crude oil prices and first purchase price rebounded during the remainder of the first quarter (**Figure 8**).

Oil production reported by the Wyoming Oil and Gas Conservation Commission (WOGCC) for the first quarter of 2002 was about 13.6 million barrels (**Table 4**). This production is a drop of 6.3% from production in the first quarter of 2001.

Spot prices for natural gas at Opal, Wyoming averaged $2.03 per thousand cubic feet (MCF) during the first quarter of 2002. This is $4.72 per MCF lower than the average price for the first quarter of 2001, and $0.03 higher than the average price for the fourth quarter (**Table 5** and **Figure 9**).

According to production figures from the WOGCC, natural gas production in Wyoming for the first three months of 2002 was 418.6 BCF, an increase of 5.0% from the first three months of 2001 (**Table 6**). Coalbed methane production from the Powder River Basin accounted for 74.4 BCF of that total or 17.8% of Wyoming's natural gas production for the quarter.

Projects and transactions

A unit of the Williams Companies, Inc. completed the addition of a third cryogenic gas- processing unit at its Echo Springs natural gas processing plant near Wamsutter. The project boosts plant capacity from 250 to 390 million cubic feet (MMCF) of gas per day and liquids extraction from 18,000 to 28,000 barrels per day. The pipeline gathering system that brings natural gas into the plant was also expanded from 330 to 400 MMCF per day. Total cost for the entire upgrade was about $45 million.

Interline Resources Corp. completed reconstruction of its Well Draw plant about 20 miles north of Douglas after the plant sustained severe damage from a fire in August, 2001. Unfortunately, a series of fires and explosions on June 22, 2002 completely destroyed the storage facilities (420,000 gallons of products), along with much of the processing facilities, loading and unloading racks, and other equipment and structures. Luckily, no one was killed or injured. The Well

Table 3. Monthly average price of a barrel of oil produced in Wyoming (1998 through April, 2002).

	1998		1999		2000		2001		2002	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	$12.79	$12.79	$9.30	$9.30	$24.01	$24.01	$24.62	$24.62	$15.70	$15.70
February	$12.16	$12.47	$9.09	$9.20	$26.48	$25.25	$24.82	$24.72	$16.87	$16.29
March	$10.97	$11.97	$11.77	$10.05	$27.24	$25.91	$22.71	$24.05	**$20.50**	**$17.69**
April	$11.54	$11.87	$14.34	$11.12	$22.92	$25.16	$22.85	$23.75	**$22.00**	**$18.77**
May	$11.19	$11.73	$15.16	$11.93	$26.06	$25.34	$23.68	$23.74		
June	$9.63	$11.38	$15.36	$12.50	$28.31	$25.84	$22.99	$23.61		
July	$10.20	$11.21	$17.39	$13.20	$27.12	$26.02	$22.55	$23.46		
August	$9.58	$11.01	$18.43	$13.86	$28.18	$26.29	$23.67	$23.49		
September	$11.19	$11.03	$20.97	$14.65	$30.22	$26.73	$22.02	$23.32		
October	$11.04	$11.03	$20.01	$15.18	$28.75	$26.93	$17.71	$22.76		
November	$9.64	$10.90	$22.20	$15.82	$29.63	$27.17	$16.44	$22.19		
December	$8.05	$10.67	$23.22	$16.44	$23.60	$26.88	$14.86	$21.58		
Average yearly price		**$10.67**		**$16.44**		**$26.88**		**$21.58**		

All averages are derived from published monthly reports by the Energy Information Administration, except that averages in bold print in 2002 are estimated from various unpublished bulletins listing posted prices. *Wyoming State Geological Survey, Oil and Gas Section, July, 2002.*

Table 4. Monthly oil production from Wyoming in barrels (1998 through March, 2002).

	1998		1999		2000		2001		2002	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	5,846,364	5,846,364	5,333,257	5,333,257	5,185,683	5,185,683	5,001,928	5,001,928	4,707,050	4,707,050
February	5,233,502	11,079,866	4,744,527	10,077,784	4,871,733	10,057,416	4,493,565	9,495,493	4,228,696	8,935,746
March	5,759,176	16,839,042	5,297,674	15,375,458	5,202,533	15,259,949	4,969,821	14,465,314	4,618,455	13,554,201
April	5,534,568	22,373,610	5,065,591	20,441,049	5,003,812	20,263,761	4,802,352	19,267,666		
May	5,626,125	27,999,735	5,200,031	25,641,080	5,201,564	25,465,325	4,930,856	24,198,522		
June	5,335,463	33,335,198	5,000,039	30,641,119	5,001,932	30,467,257	4,664,829	28,863,351		
July	5,464,514	38,799,712	5,164,705	35,805,824	5,077,548	35,544,805	4,846,220	33,709,571		
August	5,287,415	44,087,127	5,190,052	40,995,876	5,093,558	40,638,363	4,761,492	38,471,063		
September	5,109,053	49,196,180	5,081,384	46,077,260	4,983,126	45,621,489	4,718,493	43,189,556		
October	5,274,269	54,470,449	5,163,165	51,240,425	5,156,755	50,778,244	4,821,224	48,010,780		
November	5,232,287	59,702,736	5,010,985	56,251,410	4,877,512	55,655,756	4,645,045	52,655,825		
December	5,078,909	64,781,645	5,090,959	61,342,369	4,970,686	60,626,442	4,744,316	57,400,141		
Total Barrels Reported[1]		**64,781,645**		**61,342,369**		**60,626,442**		**57,400,141**		
Total Barrels not Reported[2]		**897,131**								
Total Barrels Produced[3]		**65,678,776**								

[1]Monthly production reports for 1998 from Petroleum Information/Dwights LLC.; 1999 through March, 2002 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, July, 2002.*

Table 5. Monthly average spot sale price for a thousand cubic feet (MCF) of natural gas at Opal, Wyoming (1998 through May, 2002).

	1998		1999		2000		2001		2002	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	$2.05	$2.05	$1.80	$1.80	$2.20	$2.20	$8.75	$8.75	$2.35	$2.35
February	$1.70	$1.88	$1.65	$1.73	$2.40	$2.30	$6.60	$7.68	$1.75	$2.05
March	$1.90	$1.88	$1.50	$1.65	$2.35	$2.32	$4.90	$6.75	$2.00	$2.03
April	$1.90	$1.89	$1.60	$1.64	$2.70	$2.41	$4.55	$6.20	$2.85	$2.24
May	$1.95	$1.90	$2.00	$1.71	$2.70	$2.47	$4.10	$5.78	$2.30	$2.25
June	$1.65	$1.86	$2.00	$1.76	$3.65	$2.67	$2.60	$5.25		
July	$1.60	$1.82	$2.00	$1.79	$3.90	$2.84	$2.05	$4.79		
August	$1.75	$1.81	$2.20	$1.84	$3.10	$2.88	$2.25	$4.48		
September	$1.60	$1.79	$2.60	$1.93	$3.40	$2.93	$2.10	$4.21		
October	$1.65	$1.78	$2.40	$1.98	$4.30	$3.07	$1.25	$3.92		
November	$2.00	$1.80	$2.85	$2.05	$4.35	$3.19	$2.60	$3.80		
December	$2.00	$1.81	$2.10	$2.06	$6.00	$3.42	$2.15	$3.66		
Average yearly price		**$1.81**		**$2.06**		**$3.42**		**$3.66**		

Source: American Gas Association's monthly reports. *Wyoming State Geological Survey, Oil and Gas Section, July, 2002.*

Draw gas plant had a production capacity of 3000 barrels of natural gas liquids per day.

The first phase of a $200 million renovation project at ExxonMobil's Shute Creek gas plant in southwestern Wyoming began in the first quarter of 2002. According to company plans, the present sulfur-producing facility at the plant will be replaced by an acid-gas injection operation and a cogeneration facility, effectively taking the company out of the sulfur business. The gas reinjection project will allow the company to dispose of the sulfur gas stream at the plant, while increasing the reservoir pressure and production capacity of wells that supply the plant. The cogeneration unit will supply steam for the gas reinjection as well as produce enough electricity to power the whole plant. The sulfur recovery facility is near the end of its scheduled life and will be taken out of service in 2003.

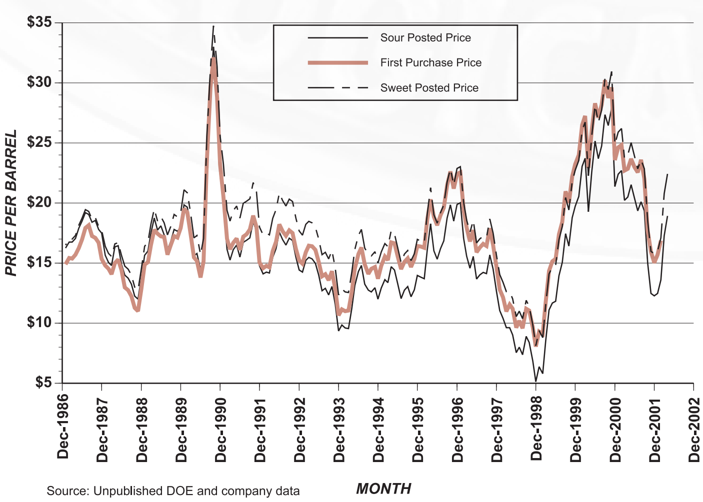

Figure 8. Wyoming posted sweet and sour crude oil prices and first purchase prices, averaged by month (January, 1987 through May, 2002).

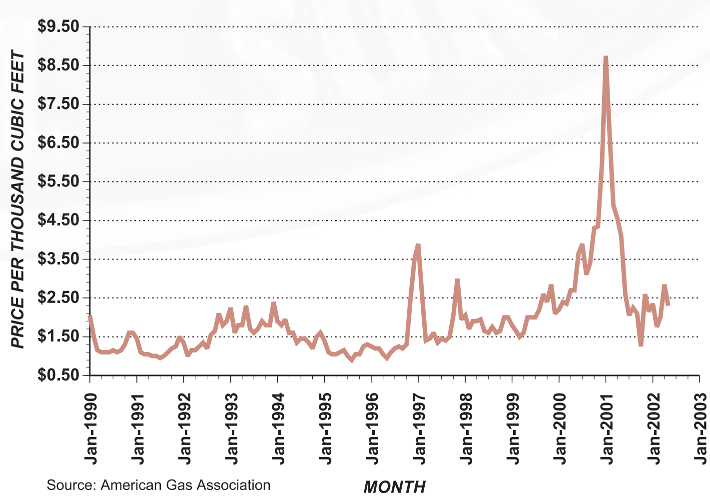

Figure 9. Spot sale prices for methane at Opal, Wyoming, averaged by month (January, 1990 through June, 2002).

Table 6. Monthly natural gas production from Wyoming in thousands of cubic feet (MCF) (1998 through March, 2002).

	1998		1999		2000		2001		2002	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	103,640,214	103,640,214	108,524,793	108,524,793	122,078,095	122,078,095	135,968,875	135,968,875	142,975,434	142,975,434
February	94,501,819	198,142,033	94,288,888	202,813,681	114,204,669	236,282,764	123,372,642	259,341,517	132,482,055	275,457,489
March	103,906,999	302,049,032	111,012,987	313,826,668	121,104,908	357,387,672	138,969,778	398,311,295	143,185,727	418,643,216
April	98,201,007	400,250,039	102,363,550	416,190,218	118,775,280	476,162,952	132,559,769	530,871,064		
May	96,741,237	496,991,276	104,746,697	520,936,915	118,462,106	594,623,058	138,100,005	668,971,069		
June	98,413,520	595,404,796	102,717,295	623,654,210	116,887,377	711,512,435	126,733,129	795,704,198		
July	102,055,968	697,460,764	106,733,493	730,387,703	120,690,168	832,202,603	131,151,216	926,855,414		
August	105,378,334	802,839,098	107,536,099	837,923,802	122,412,623	954,615,226	132,329,266	1,059,184,680		
September	98,474,782	901,313,880	108,200,542	946,124,344	119,730,975	1,074,346,201	130,725,850	1,189,910,530		
October	96,470,624	997,784,504	118,545,893	1,064,670,237	127,507,997	1,201,854,198	136,704,129	1,326,614,659		
November	103,445,859	1,101,230,363	110,904,046	1,175,574,283	122,846,630	1,324,700,828	136,260,720	1,462,875,379		
December	99,339,043	1,200,569,406	119,648,215	1,295,222,498	130,711,331	1,455,412,159	142,912,497	1,605,787,876		
Total MCF Reported[1]		**1,200,569,406**		**1,295,222,498**		**1,455,412,159**		**1,605,787,876**		
Total MCF not Reported[2]		**22,955,142**								
Total MCF Produced[3]		**1,223,524,548**								

[1]Monthly production reports for 1998 from Petroleum Information/Dwights LLC.; 1999 through March, 2002 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, July, 2002.*

Shell Exploration & Production Co. acquired Casper-based McMurry Energy Co. and its affiliate, Nerd Energy Co., for an undisclosed amount. Shell acquired primary interest on the Pinedale anticline in southwestern Wyoming where McMurry owned an interest in about 13,000 acres. The majority of the acreage is held by production and McMurry's working interest in the acreage ranged from 19 to 74%.

The Williams Companies, Inc. completed the sale of its Kern River interstate natural gas pipeline to MidAmerica Energy Holdings for $450 million in cash and the assumption of $510 million in debt. The sale also eliminates the need for Williams to fund $1.26 billion in capital expenditure requirements for Kern River over the next year and a half.

The U. S. Bureau of Land Management (BLM) approved Shell Oil's plan to construct a small, temporary pipeline from its Pacific Creek well site to an existing gas pipeline at Buccaneer Field (T26N, R102W). The project will allow Shell to test production from one or more wells drilled on their leases until a permanent pipeline is constructed. The temporary pipeline would not be in place for more than five years.

Pacific Energy LLC. recently purchased about 1600 miles of crude oil pipelines, 500 miles of gathering lines, and oil storage capacity from BP Amoco. Many of the assets are in Wyoming and will be operated under the name Rocky Mountain Pipeline System, LLC. Pacific Energy has plans to expand the system.

Questar Pipeline Co. is acquiring permits and customer contracts for a new natural gas storage facility in salt caverns near Evanston that would store a total of 12.5 BCF of natural gas to help producers and marketers weather poor market prices. The project involves drilling five 3000-foot-deep injection wells into salt beds in the Preuss Sandstone (Middle Jurassic). A dehydration and compression system would be constructed on the surface to serve the caverns. Total cost of the project is estimated between $100 million and $150 million.

Lease sales

Leasing activity at the February, 2002 BLM sale was heaviest in southwestern Wyoming (**Figure 10**). Kerry Hoffman made the high per-acre bid of $345 for a 720-acre lease that covers

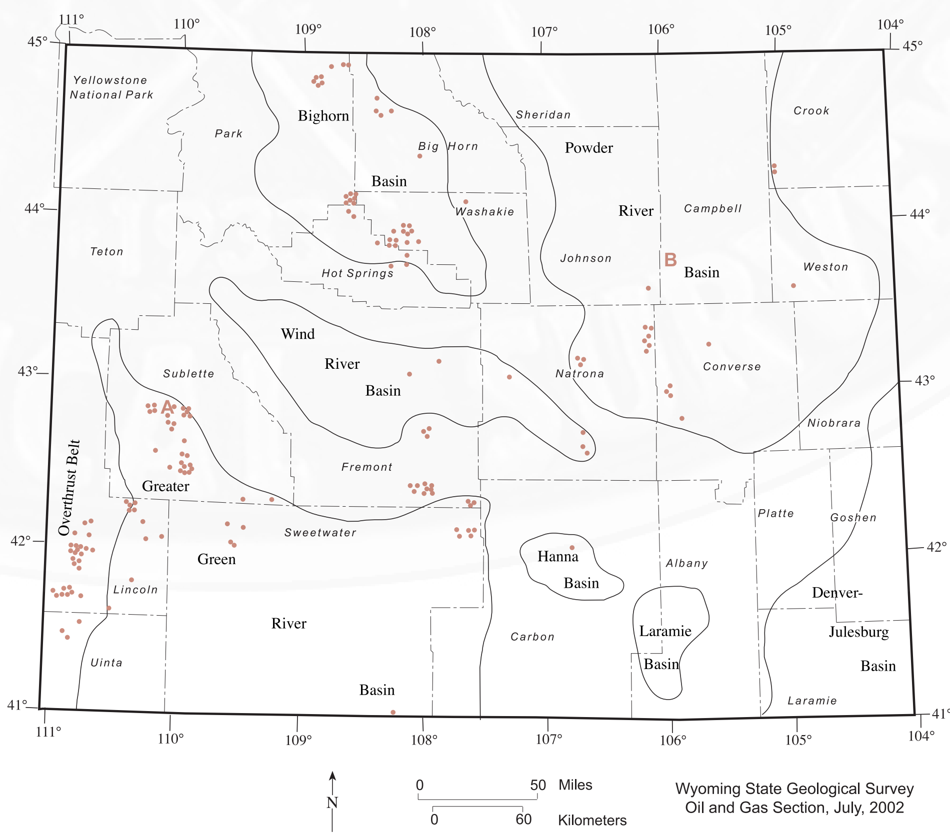

Figure 10. Locations of federal oil and gas tracts leased by the U.S. Bureau of Land Management at its February, 2002 sale. Locations are approximate and may represent more than one tract.

all of section 23 and S/2 SW section 32, T33N, R111W (**location A, Figure 10**). The lease is about 10 miles west of gas production on the Pinedale anticline. Hoffman bought 16 leases in the same area and he alone accounted for bonus payments of over $2.8 million. Black Diamond Energy made the sale's second high per-acre bid of $310 for an 80-acre lease that covers W/2 SW section 27, T44N, R76W (**location B, Figure 10**). The lease is in an area of coalbed methane production from coals in the Fort Union Formation. There were 30 parcels at this sale that received bids of $50 or more per acre. The sale generated revenue of over $5.1 million and the average per-acre bid was $29.00 (**Table 7**).

The number of conventional miles (of seismic exploration) permitted in 456 higher than for the first quarter of 2000...

Permitting and drilling

The WOGCC approved 1619 Applications for Permit to Drill (APDs) in the first quarter of 2002. The total is 276 less than in the first quarter of 2001, but more than for the full years of 1995 and 1996 (**Table 8**). Campbell County again led with 44.5% of the total APDs approved in the first quarter. Sheridan and Johnson counties combined for another 37.2% of the total APDs. Nearly all of the approved APDs in these three counties were for coalbed methane tests.

The WOGCC permitted seven seismic projects in the first quarter of 2002 (**Table 9**). The number of permits is the same as for the first quarter of 2001. The number of conventional miles permitted is 456 higher than for the first quarter of 2001, but the total square miles of 3-D seismic is only slightly more than half that for the first quarter of 2001. Geophysical activity is a good indicator of future exploration and production drilling.

The average daily rig count for the first quarter of 2002 was 43, nine less than for the first quarter of 2001. The rig count does not include rigs drilling for coalbed methane.

Table 7. Federal and State competitive oil and gas lease sales in Wyoming (1996 through February, 2002).

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
October	$998,308	119	105	127,396	107,880	$9.25	$160.00
December	$2,162,599	155	146	125,830	112,159	$9.28	$550.00
TOTAL	$33,991,566	1023	933	1,103,745	973,282	$34.92	$1475.00
2002							
February	$5,137,024	219	164	271,248	177,117	$29.00	$345.00

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
October	$679,343	300	129	112,255	53,396	$12.72	$120.00
TOTAL	$4,684,016	900	533	336,141	203,059	$23.07	$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, July, 2002.*

Table 8. Number of Applications for Permit to Drill (APDs) approved by the Wyoming Oil and Gas Conservation Commission (1996 through March, 2002).

County	1996 APDs	1997 APDs	1998 APDs	1999 APDs	2000 APDs	2001 APDs	2002 APDs
Albany	1	0	0	0	0	1	1
Big Horn	53	59	13	6	11	23	0
Campbell	554	941	1586	4461	5580	6204	752
Carbon	77	84	96	127	174	261	27
Converse	20	16	6	19	70	25	17
Crook	37	26	29	30	47	20	2
Fremont	26	58	76	67	136	149	24
Goshen	0	0	0	0	0	0	1
Hot Springs	24	42	1	8	6	2	4
Johnson	16	6	49	304	769	805	196
Laramie	2	3	2	0	2	3	0
Lincoln	55	122	105	51	70	87	11
Natrona	74	59	36	51	53	45	8
Niobrara	7	8	8	5	18	15	0
Park	30	25	11	12	18	45	5
Platte	0	0	0	0	0	0	0
Sheridan	0	2	35	416	891	1811	433
Sublette	118	179	230	189	338	435	84
Sweetwater	136	210	181	124	335	534	123
Teton	0	0	0	0	0	0	0
Uinta	10	27	26	26	53	35	3
Washakie	30	36	9	0	7	10	0
Weston	10	5	6	4	20	7	0
Totals	**1280**	**1908**	**2505**	**5900**	**8598**	**10,517**	**1691**

Source: All data are from the Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, July, 2002.*

Figure 11 shows the Wyoming daily rig count averaged by month and by year.

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 first quarter of 2002. The numbers correspond to locations on **Figure 12**.

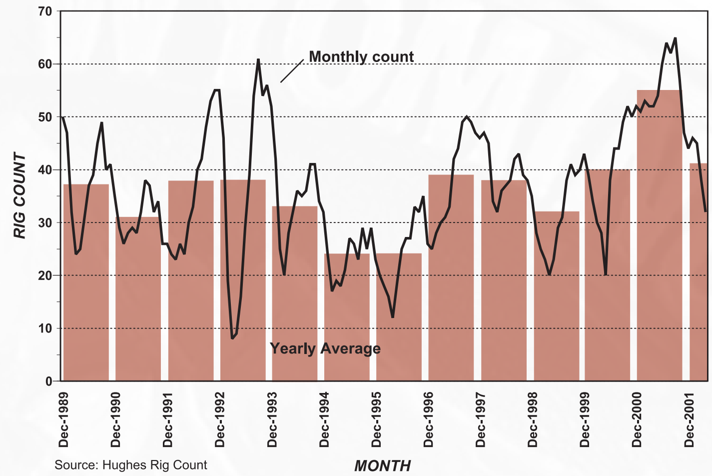

Figure 11. Wyoming daily rig count, exclusive of coalbed methane rigs, averaged by month and year (December, 1989 through March, 2002).

Table 9. Number of seismic projects and miles permitted by the Wyoming Oil and Gas Conservation Commission (1998 through March, 2002).

	1998			1999			2000			2001			2002		
County	Permits	Conventional Miles	3-D Square Miles	Permits	Conventional Miles	3-D Square Miles	Permits	Conventional Miles	3-D Square Miles	Permits	Conventional Miles	3-D Square Miles	Permits	Conventional Miles	3-D Square Miles
Albany	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Horn	1	0	16	0	0	0	1	387	0	1	0	4	0	0	0
Campbell	14	18	182	4	4	10	14	64	132	5	38	3	2	5	0
Carbon	4	0	318	5	77	57	0	0	0	1	500	0	0	0	0
Converse	4	12	239	1	0	50	1	15	0	0	0	0	0	0	0
Crook	2	2	4	1	0	10	7	16	22	4	32	0	0	0	0
Fremont	2	100	0	1	0	88	4	25	116	2	70	15	1	160	0
Goshen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Springs	4	19	0	0	0	0	0	0	0	0	0	0	0	0	0
Johnson	1	4	0	0	0	0	4	35	0	2	4	4	0	0	0
Laramie	0	0	0	0	0	0	0	0	0	0	0	0	1	0	18
Lincoln	1	10	0	1	0	32	0	0	0	1	0	25	0	0	0
Natrona	6	12	214	2	0	230	5	36	135	2	19	63	0	0	0
Niobrara	0	0	0	5	16	31	1	0	25	1	0	16	0	0	0
Park	3	16	132	3	25	32	1	13	0	4	21	20	0	0	0
Platte	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sheridan	1	14	0	0	0	0	0	0	0	2	0	81	0	0	0
Sublette	2	1	115	3	0	308	4	77	44	10	261	374	1	201	0
Sweetwater	6	214	66	9	0	530	13	54	1004	11	129	802	2	205	74
Teton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uinta	2	0	147	1	0	26	0	0	0	1	259	0	0	0	0
Washakie	4	41	35	1	0	8	0	0	0	0	0	0	0	0	0
Weston	1	0	35	1	40	0	0	0	0	0	0	0	0	0	0
Totals	**58**	**463**	**1503**	**38**	**162**	**1412**	**55**	**722**	**1478**	**47**	**1333**	**1407**	**7**	**571**	**92**

Source: All data are from the Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, Oil and Gas Section, July, 2002.*

Table 10. Significant exploration and development wells in Wyoming, first quarter of 2002[1]. Number corresponds to location on Figure 12.

	Company name	Well name/number	Location	Formation tested	Depth(s) interval(s) tested	Tested prod. (per day)	Remarks
1	Anschutz Exploration	14-33ST AL&L	Irregular sec 10, T14N, R121W	Weber Ss.	13,000-13,155	22.5 MMCF 82 BBL cond	Directional redrill in Yellow Creek "Field, surface location is in Utah"
2	Cabot Oil & Gas	12-33 Henry Unit	NW NW sec 33, T14N, R113W	Mowry Sh.	13,080-13,246	364 MCF 157 BBL cond	New reservoir discovery in Henry Field
3	Chevron USA	3-18F Chevron-Federal	SE NE sec 13, T18N, R120W	Mission Canyon Ls.	below 13,000 horizontal producer	2.7 MMCF	Whitney Canyon-Carter Creek Field
	Chevron USA	2-30M ST Chevron-Federal	SE SE sec 30, T19N, R119W	Mission Canyon Ls.	14,744-15,059	4.9 MMCF 20 BBL cond	Directional redrill in Whitney Canyon-Carter Creek Field
4	Questar Expl. & Prod.	8 Verne Valley	SW NW sec 33, T19N, R113W	Frontier Fm.	11,694-11,721	602 MCF 4 BBL H_2O	Discovery well
5	McMurry Oil	5-4 Jonah-Federal	SW SW sec 4, T28N, R108W	Lance Fm.	nine intervals 7897-10,827	6.0 MMCF 155 BBL cond 23 BBL H_2O	New producer in Jonah Field
	McMurry Oil	11-14 Yellow Point	NW SE sec 14, T28N, R109W	Lance Fm.	six intervals 8346-9500	2.9 MMCF 45 BBL cond 46 BBL H_2O	New producer on southwestern flank of Jonah Field
	McMurry Oil	12-13 Yellow Point	NW SW sec 13, T28N, R109W	Lance Fm.	10 intervals 7405-9980	3.1 MMCF 51 BBL cond 13 BBL H_2O	New producer in Jonah Field
	McMurry Oil	4-6 Jonah-Federal	NW NW sec 6, T28N, R108W	Lance Fm.	nine intervals 8234-10,264	3.6 MMCF 42 BBL cond 2 BBL H_2O	New producer in Jonah Field
6	Yates Petroleum	1 Blue Rim-State	NE NE sec 16, T30N, R108W	Lance Fm.	several intervals 11,999-12,149	1.3 MMCF 35 BBL cond 33 BBL H_2O	New producer on Pinedale anticline
	Yates Petroleum	11 Highway-Federal	NE NW sec 3, T29N, R107W	Lance Fm. Mesaverde Fm.	six intervals 11,998-13,541	1.6 MMCF 427 BBL H_2O	Exploratory test on southern end of Pinedale anticline
	Ultra Resources	6-23 Warbonnet	SE NW sec 23, T30N, R108W	Lance Fm. Mesaverde Fm.	five intervals 12,000-13,260	5.4 MMCF 79 BBL cond 98 BBL H_2O	New producer in Warbonnet Field on Pinedale anticline
	Ultra Resources	4-26 Warbonnet	NW NW sec 26, T30N, R108W	Lance Fm. Mesaverde Fm.	13 intervals 8530-12,610	2.7 MMCF 37 BBL cond 656 BBL H_2O	New producer in Warbonnet Field on Pinedale anticline
	Ultra Resources	7-4 Warbonnet	SW NE sec 4, T30N, R108W	Lance Fm.	49 intervals spans 4950 feet	11.3 MMCF restricted rate	Exploratory test near Warbonnet Field
7	Wexpro Co	15-16 Mesa Unit	SW SE sec 16, T32N, R109W	Lance Fm.	11 intervals 9006-13,106	10.7 MMCF 84 BBL cond 48 BBL H_2O	New producer in Mesa Unit
	Petrogulf Corp	36-13 Paradise Ditch	SW SW sec 36, T32N, R109W	Lance Fm.	six intervals 10,913-12,748	1.9 MMCF 13 BBL cond 59 BBL H_2O	Exploratory test near Mesa Unit
	Wexpro Co	8-17 Mesa Unit	SE NE sec 17, T32N, R109W	Lance Fm.	10 intervals 8952-12,888	11.8 MMCF 72 BBL cond 36 BBL H_2O	New producer in Mesa Unit
	Wexpro Co	9-7 Mesa Unit	NE SE sec 7, T32N, R109W	Lance Fm.	six intervals 10,390-13,045	6.4 MMCF 48 BBL cond 48 BBL H_2O	New producer in Mesa Unit
8	EOG Resources	35-29D North Ruger	NW SW sec 29, T15N, R94W	Almond Fm.	12,376-12,406	1.5 MMCF 1 BBL cond	Exploratory well one mile north of Dripping Rock Field
9	Devon SFS Operating	4-32-15-92 Mexican Flats	NW NW sec 32, T15N, R92W	Mesaverde Gp.	three intervals 8753-9540	3.0 MMCF 25 BBL cond 65 BBL H_2O	New producer in Blue Gap Field
10	Yates Petroleum	7 Baldy Butte-Federal	NE SW sec 4, T17N, R92W	Almond Fm.	7854-7928 8026-8196	2.0 MMCF 20 BBL cond 18 BBL H_2O	New producer in Baldy Butte Field
11	Forest Oil	9-4 Forest	NE SE sec 4, T17N, R94W	Almond Fm.	9917-10,039 10,095-10,280	1.6 MMCF 28 BBL cond 78 BBL H_2O	New producer in Wild Rose Field
	Forest Oil	1-4 Forest	NE NE sec 4, T17N, R94W	Almond Fm.	9868-9982 10,024-10,244	1.1 MMCF 25 BBL cond 22 BBL H_2O	New producer in Wild Rose Field
	Forest Oil	9-32 Forest	NE SE sec 32, T18N, R94W	Almond Fm.	9985-10,367	1.1 MMCF 48 BBL cond 70 BBL H_2O	New producer in Wild Rose Field
	Forest Oil	4-32 Forest	NW NW sec 32, T18N, R94W	Almond Fm.	10,096-10,519	1.1 MMCF 10 BBL cond 58 BBL H_2O	New producer in Wild Rose Field

Table 10. Continued. Significant exploration and development wells in Wyoming, first quarter of 2002[1]. Number corresponds to location on Figure 12.

	Company name	Well name/number	Location	Formation tested	Depth(s) interval(s) tested	Tested prod. (per day)	Remarks
12	Questar Expl. & Prod.	12-10 Red Lakes South	NW SE sec 12, T18N, R94W	Almond Fm.	undisclosed interval	1.0 MMCF	Stepout from Standard Draw Field
13	RME Petroleum	1-19 Fillmore	NE SE sec 19, T19N, R91W	Lewis Sh. Almond Fm.	7774-7814 8504-8712	2.4 MMCF 226 BBL cond	New producer in Fillmore Field
14	Devon SFS Operating	16-22-19-92 East Echo Springs	SE SE sec 22, T19N, R92W	Lewis Sh.	8077-8123	2.1 MMCF 43 BBL cond 35 BBL H_2O	Exploratory test on the Wamsutter arch
	Devon SFS Operating	14-26-19-92 East Echo Springs	SE SW sec 26, T19N, R92W	Lewis Sh.	8008-8012 8031-8035	2.2 MMCF 60 BBL cond 16 BBL H_2O	Exploratory test on the Wamsutter arch
15	RME Petroleum	17-3 Red Desert	SW SE sec 17, T20N, R95W	Lewis Sh. Almond Fm.	7895-8232 9205-9211	1.1 MMCF 37 BBL cond 142 BBL H_2O	New producer on the western flank of Wamsutter Field
	RME Petroleum	17-4 Red Desert	SE SW sec 17, T20N, R95W	Lewis Sh. Almond Fm.	7841-7886 8134-8148 9132-9278	2.2 MMCF 33 BBL cond 83 BBL H_2O	New producer on the western flank of Wamsutter Field
16	Merit Energy	143 Lost Soldier “”A””	SE SW sec 11, T26N, R90W	Muddy Ss.	2026-2090	291 BBL oil 75 BBL H_2O	Workover of a former Lakota producer
17	Patina Oil & Gas	4-1 Pappy Draw-Federal	SE NE sec 4, T26N, R93W	Frontier Fm.	9757-9772 9801-9832	682 MCF 14 BBL H_2O	Wildcat discovery well
18	BreitBurn Energy	6H Lost Dome-Federal	NE NW sec 13, T37N, R83W	Tensleep Ss.	true vertical depth 4895	191 BBL oil 191 BBL H_2O	Horizontal producer in Lost Dome Field
19	Burlington Resources	71 Madden Deep Unit	SW NW sec 12, T38N, R90W	Fort Union Fm.	eight intervals 5912-9350	4.4 MMCF 331 BBL H_2O	New producer in Madden Field
20	Equity Oil Co	59 Torchlight Madison-Tensleep Unit	SW SW sec 19, T51N, R92W	Madison Ls.	3600-3625	300 BBL oil	Infill well in Torchlight Field
21	Ballard Petroleum	1-18 Wildhorse Creek-Federal	NE SW sec 18, T54N, R69W	Minnelusa Fm.	7322-7338	43 BBL oil	Wildcat discovery well
22	Star Resources	19-5 Schuricht-Federal	SW NW sec 19, T52N, R67W	Minnelusa Fm.	5753-5766	90 BBL oil 28 BBL H_2O	Wildcat discovery well
23	True Oil	14-30X Burrows-Federal	SW SW sec 30, T49N, R68W	Minnelusa Fm.	7994-8000	79 BBL oil 15 BBL H_2O	New producer in Slattery Field
24	ExxonMobil Corp	5744H Hartzog Draw Unit	SE NW sec 24, T45N, R76W	Shannon Ss.	below 9000	575 BBL oil 189 MCF 88 BBL H_2O	New horizontal producer in Hartzog Draw Field
25	Timberline Production	1 Pfister-State	SW NW sec 36, T39N, R63W	Morrison Fm.	5880-5890	45 BBL oil	Stepout from Greasewood Field

[1]Abbreviations include: MCF=thousands of cubic feet of natural gas; MMCF=millions 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, July, 2002.*

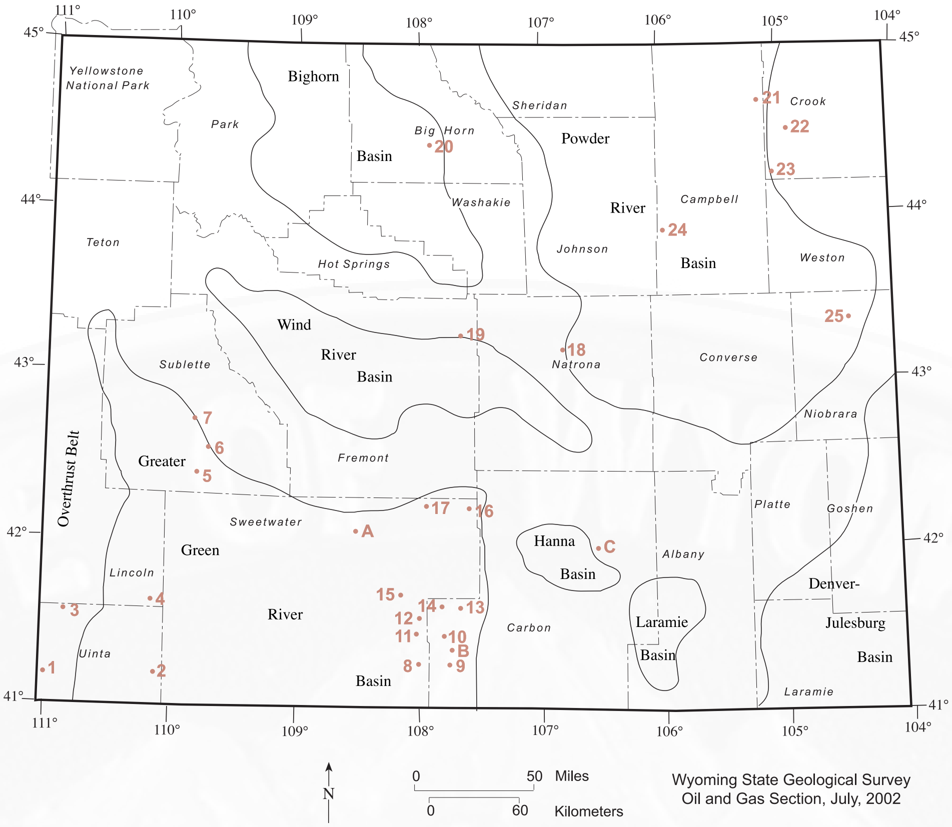

Figure 12. Oil and gas exploration and development activities (numbers) and coalbed methane activities (letters) in Wyoming during the first quarter of 2002. Locations are approximate and may represent more than one well location or project.

Coal Update

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Along with the record-setting 368.7 million short tons of coal produced in 2001, Wyoming mines also attained a milestone of having produced 5 billion tons of coal. Only four other states have ever attained this amount of production. Despite production in the first quarter of 2002 being ahead of last year, the low spot prices will probably adversely affect second and third quarter production and ultimately result in a 2% decrease in 2002 production. Several producers have announced production cutbacks for 2002.

Competition for federal coal leases under the Lease-by-Application (LBA) process resulted in the highest per-ton bonus bid since this form of leasing began. Kennecott Energy bid about $0.74 per recoverable ton of coal, nearly double the previous high per-ton bid. The LBA tract is adjacent to both the Black Thunder and Jacobs Ranch coal mines in the Powder River Basin (PRB). In this issue we have included a corrected map (**Figure 13**) of federal coal leases, proposed lease tracts, and LBAs in the PRB to replace Figure 17 in *Wyoming Geo-notes No. 73* (April, 2002, p. 18). Some lines, labels, and leaders were inadvertently omitted from this map, and we apologize for any inconvenience to our readers.

In southern Wyoming, Black Butte Coal Company will no longer supply coal to the North Valmy power plant in Nevada. Their contract was terminated with final contracted volumes of coal delivered in February. Very little, if any, Wyoming coal is now shipped west of the state, despite the electrical generation problems that appeared in California and other states last year.

The original in-place coal resource base for Wyoming was estimated at 1.5 trillion short tons. This resource base consists of all coal within the state's boundary regardless of depth, thickness, economic value, or feasibility of technical recovery. Demonstrated reserves are those parts of the coal deposits known to exist in the state which are of sufficient thickness and technically mineable using current mining technology. Surface (strippable) demonstrated reserves of 24.4 billion short tons are those under 200 feet or less of overburden

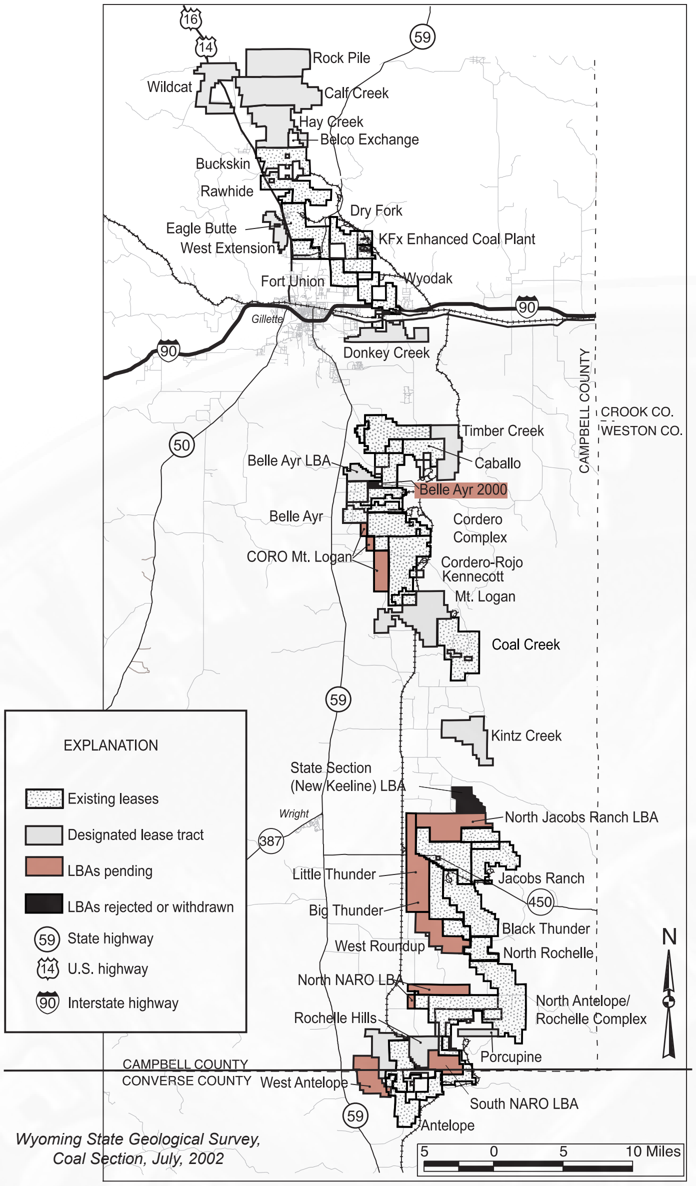

Figure 13. Location of existing federal coal leases, proposed coal lease tracts, exchanges, pending LBAs (brown), and proposed LBAs, eastern Powder River Basin, Wyoming. Sources: U.S. Bureau of Land Management web sites, including http://www.wy.blm.gov/minerals/coal/prb/prb_maps.htm; ftp://ftp.wy.blm.gov/pub/casper/coal/; and http://www.wy.blm.gov/minerals/coal/prb/prb.htm.

while underground reserves of 42.5 billion short tons are those within 3000 feet of the surface.

How long can Wyoming continue to supply the nation with the large amounts of coal it now produces? Since most of Wyoming's coal production is from the Powder River Coal Field and the Wyodak coal zone, **Table 11** can help answer this question. The remaining demonstrated surface reserves for the Wyodak is currently estimated at 15.5 billion short tons of coal. Some 354.2 million short tons of coal were produced from the Wyodak last year, so at this rate, Wyodak reserves will still last nearly 44 years. The mines will then have to move into areas of deeper overburden (over 200 feet). However, demonstrated surface reserves will continue to grow during this time (as different mines encounter their own economic limits) and Wyoming mines will keep working well into the next century, providing Wyoming citizens with jobs, and the nation with energy.

Production and prices

Cumulative Wyoming coal production passed the 5 billion ton milestone in 2001. Since Wyoming's annual coal production began being reported in 1886, over 5.2 billion short tons of Wyoming coal have been mined. Mines in the Hanna and Green River coal fields produced about 7000 short tons in 1886. Last year, production from mines in these two coal fields totaled over 10.0 million short tons. The Hams Fork Coal Field first reported production of about 2000 short tons in 1869; last year 4.5 million short tons were produced. Mines in the Powder River Coal Field produced about 35,000 short tons in 1888; last year they mined 354.2 million short tons.

Despite Wyoming reaching this impressive production milestone, four other states have previously surpassed this mark, with Illinois having produced about 5.9 billion short tons, Kentucky about 8.1 billion short tons, West Virginia about 11.9 billion short tons, and Pennsylvania about 16.8 billion short tons. Of course some of these states have been mining coal since before the Revolutionary War and had at least a hundred-year head start on Wyoming. What is amazing is how Wyoming coal producers accomplished this feat: it took 115 years until the first billion tons of production was reached in 1982. The two-billion-ton milestone was reached in 1989 after only seven years of production; the three-billion-ton mark was reached in five years (1994); the four-billion-ton mark in four years (1998); and the five-billion-ton mark in just three years (2001).

Wyoming's coal production for the first quarter, 2002 was 2.97% more than the first quarter of 2001. During this period, Wyoming mines shipped almost 92 million short tons of coal (**Table 12**). While ahead of last year's record-setting pace (**Figures 14 and 15a**), increased softness in the spot market at the end of March for PRB coals (**Figure 15b**) indicates that overall production should slow during the next two quarters of 2002. Despite this early gain, we estimate that coal production for 2002 will still be about 2% less than in 2001 (**Table 11**).

Spot prices for PRB coal continued a downward trend during the first two months of 2002, but March spot prices for both 8400- and 8800-Btu coal had stabilized and began to turn modestly upward again (**Figure 16**). At the end of the quarter, spot prices were estimated at $4.82 per short ton for 8400-Btu coal and $5.89 per short ton for 8800-Btu coal, FOB the mine.

Because of the soft spot prices, a smaller percentage of Wyoming coal is moving in this arena. From 18 to 20% of the coal shipped out of Wyoming each month is usually sold on the spot market. In the first quarter of 2002, only 14.8% of the shipments were spot sales. Coal producers in the PRB appear to be enjoying increased contract prices negotiated last year

Table 11. Wyoming coal production by county[1,2] (in millions of short tons), 1996 through 2001 with forecasts to 2007.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Powder River Basin												
Campbell County	245.3	246.3	274.1	296.3	299.5	329.5	322.0	330.0	332.7	335.5	338.3	341.1
Converse County	15.8	17.8	23.4	24.0	23.6	24.6	25.0	26.0	27.0	28.0	29.0	30.0
Sheridan County	M	M	M	M	M	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	261.1	264.1	297.5	320.0	323.1	354.1	347.0	356.0	359.7	363.5	367.3	371.1
Southern Wyoming												
Carbon County	4.7	5	3.5	3.5	2.0	0.5	M	2.0	2.0	2.0	2.0	2.0
Sweetwater County	8.2	7.8	9.2	8.0	10.0	9.5	9.0	9.0	9.0	9.0	9.0	9.0
Lincoln County	4.4	4.6	4.7	4.7	3.7	4.5	5.0	5.0	5.0	5.0	5.0	5.0
Subtotal	17.3	17.4	17.4	16.4	15.7	14.5	14.0	16.0	16.0	16.0	16.0	16.0
Total Wyoming[3]	**278.4**	**281.5**	**314.9**	**336.5**	**338.9**	**368.6**	**361.0**	**372.0**	**375.7**	**379.5**	**383.3**	**387.1**
Annual change	**5.5%**	**1.1%**	**11.9%**	**6.9%**	**0.7%**	**8.8%**	**-2.1%**	**3.0%**	**1.0%**	**1.0%**	**1.0%**	**1.0%**

[1]Reported tonnage from the Wyoming State Inspector of Mines (1995 through 2001). [2]County estimates by the Wyoming State Geological Survey, February, 2001 for 2001 through 2006. Totals may not agree because of independent rounding. [3]Estimate modified from CREG's Wyoming State Government Revenue Forecast, October, 2001. M=minor tonnage (less than a million tons). *Wyoming State Geological Survey, Coal Section, July, 2002.*

Table 12. Estimated monthly coal deliveries from Wyoming's mines in short tons (January, 1998 through March, 2002).

	1998		1999		2000		2001		2002	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
January	26,536,217	26,536,217	27,105,791	27,105,791	27,773,610	27,773,610	27,743,000	27,743,000	29,434,938	29,434,938
February	23,196,152	49,732,369	25,803,390	52,909,181	25,594,109	53,367,719	27,827,000	55,570,000	29,550,881	58,985,819
March	23,861,472	73,593,841	28,222,743	81,131,923	28,262,696	81,630,415	33,739,000	89,309,000	32,973,928	91,959,747
April	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	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	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	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	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	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	26,659,121	253,048,372	26,837,295	271,374,045	26,441,615	268,751,646	29,869,000	300,431,000		
November	25,620,216	278,668,588	26,843,021	298,217,066	27,400,245	296,151,892	29,308,000	329,739,000		
December	26,102,620	304,771,208	26,834,927	325,051,993	28,300,773	324,452,665	29,984,000	359,723,000		
Total Utility Tonnage[1]		**304,771,208**		**325,051,993**		**324,452,665**		**359,723,000**		
Total Tonnage Other [2]		**10,190,883**		**11,407,945**		**14,399,483**		**8,955,135**		
Total Tonnage Produced[3]		**314,962,091**		**336,459,938**		**338,852,148**		**368,678,135**		

[1]From Federal Energy Regulatory Commission (FERC) Form 423 for 1998; FERC Form 423 as modified by WSGS for 1999 through March, 2002. [2]Includes estimates of residential, industrial, and exported coal. [3]Wyoming State Mine Inspector's Annual Reports. *Wyoming State Geological Survey, Coal Section, July, 2002.*

(during the high spot prices) while limiting their exposure under current spot market pricing.

Developments in the Powder River Basin

In the U.S. Bureau of Land Management (BLM) coal lease sale in January, 2002, Kennecott Energy submitted the winning bid on the Jacobs Ranch North federal coal tract in Campbell County. Kennecott's bonus bid of $76,159.87 per acre for the LBA was accepted on January 17, 2002. The LBA consists of 4982 acres of minable coal land estimated to hold 515 million short tons of recoverable coal. Kennecott's adjacent Jacobs Ranch mine produced 29.3 million short tons in 2001, so at this rate of production, the life-of-mine reserves at Jacobs Ranch were extended by 17.5 years. Arch Coal bid $65,022.65 per acre, a distant second to the Kennecott bid. The winning bid was approximately $0.74 per recoverable ton; total value of the bonus bid was $379.4 million. The State of Wyoming will receive half the bonus bid payable in equal amounts spread over the next five years or about $75.9 million annually (COAL Daily, 1/18/2002).

Triton Coal, which owns and operates the Buckskin and North Rochelle mines, announced that it would merge with Atlas Pipeline Partners, L.P. (Atlas). Under the merger, Triton Coal will become a public company through a master limited partnership (MLP) under control of Triton's current owner, Vulcan Capital Management. Before the announced merger, Atlas stock was moving at $4 per unit; after the announcement it rapidly rose to $28 per unit. Analysts say that Atlas was worth approximately $100 million before the merger but its value zoomed to roughly $800 million after the merger. This MLP thus sets the market value and the stage for a future merger rumored with Alliance Resource Partners. In 1998, Vulcan and its investors paid only $275 million for the Triton holdings (Coal Outlook, 1/28/2002).

Although they declined to say from where, Arch Coal announced plans to trim 5 million short tons of production from its western mines in 2002. The company cited weak

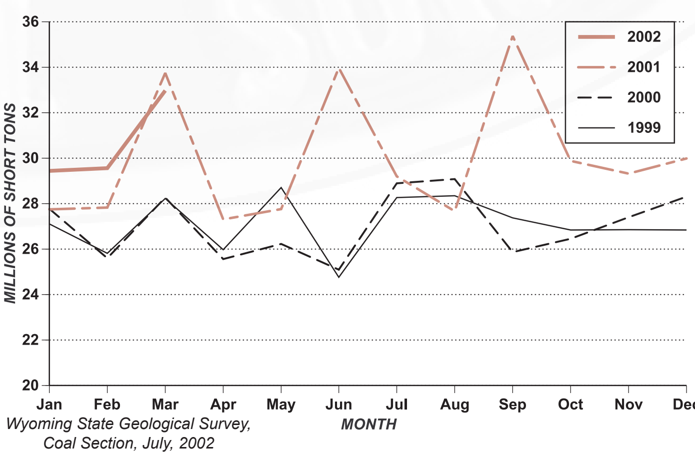

Figure 14. Reported monthly deliveries from Wyoming coal mines (1997 through March, 2002). From Form 423 of the Federal Energy Regulatory Commission (FERC) as modified by the WSGS for 1999 through 2002.

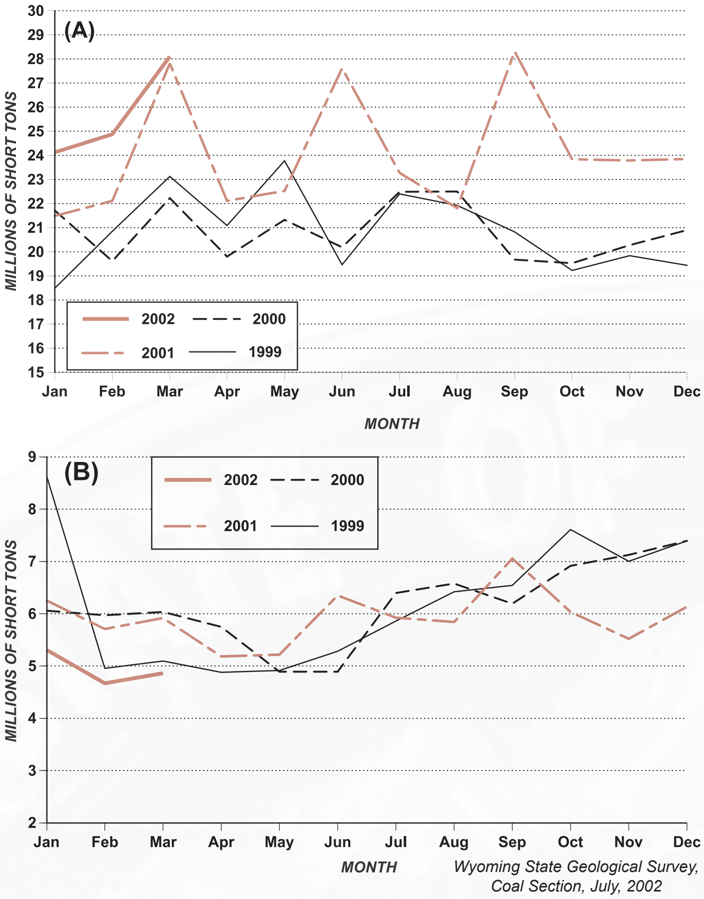

Figure 15. Monthly coal deliveries from Wyoming (1997 through March, 2002). (A) Coal sold on contract and (B) coal sold on the spot market. From Form 423 of the Federal Energy Regulatory Commission (FERC) as modified by the WSGS for 1999 through 2002.

current spot market prices. The producer was believed to have from 2 to 4 million short tons of incremental and uncommitted production in their Black Thunder, Wyoming mine in 2002 (COAL Daily, 3/19/2002).

In late February, Peabody Energy also decided to reduce their 2002 coal production schedule by up to 5 million short tons. Some production (if not the lion's share) most likely will come from the company's PRB mines (U.S. Coal Review, 3/11/2002).

Even though many of the basin's producers are reining in some of their coal production this year, several area mines are looking at projects for expanding their future mining and shipping capacities. Peabody Energy plans to add another dragline this year at their North Antelope/Rochelle mine complex. Kennecott Energy is building a second set of rail tracks into its Antelope mine to increase its loadout capacity (Coal Outlook, 2/25/2002).

RAG Coal West has applied to explore 531.78 acres of federal coal adjacent to its Eagle Butte mine. The company will explore the land to determine the quality and quantity of potential mineable coal resources underlying that acreage (Coal Outlook, 4/3/2002).

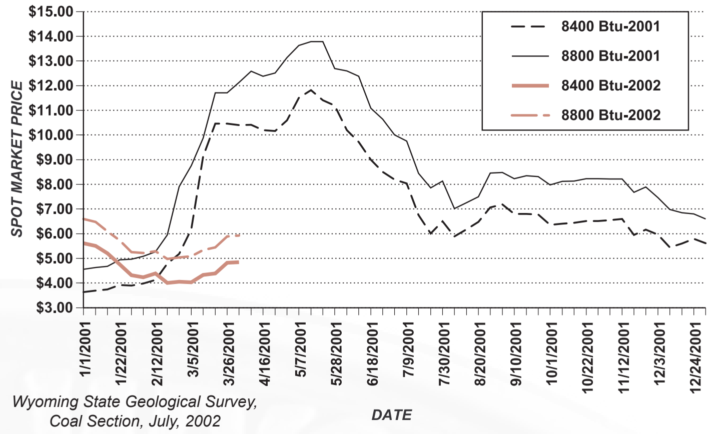

Figure 16. Wyoming PRB coal spot price watch (January 1, 2001 through April 1, 2002). Modified from COAL Daily's spot market index, and Coal Week's short-term spot market price index.

Dust has become a new problem for several PRB mines. The Air Quality Division of the Wyoming Department of Environmental Quality has issued violations for high particulate measurements at the Black Thunder, Jacobs Ranch, and North Rochelle mines. All three mines are in close proximity to each other and are bounded to the west by an area with increased coalbed methane activity. The coal producers contend that they are taking adequate measures to minimize dust, but drought conditions in the basin and road use by the coalbed methane industry may have caused problems at the monitoring locations.

Developments in southern Wyoming

The BLM began revising the Great Divide and the Pinedale Resource Management Plans (RMPs). Changes in the proposed RMPs may lead to more coal properties becoming available for leasing in southern Wyoming. The BLM is calling for submission of coal and other resource information, as well as any other related information, to aid them in identifying issues to be considered in the revised RMPs.

Currently the Great Divide RMP provides federal management guidance for 5 million acres of federal minerals in Albany, Carbon, Laramie, and Sweetwater counties. The Pinedale RMP provides guidance to 1.2 million acres of federal minerals in Fremont, Lincoln, and Sublette counties. Parts of both planning areas fall within the Green River-Hams Fork Coal Production Region, which uses the case-by-case LBA process for coal leasing. The updates for both RMPs are targeted to be completed by the fall of 2004 (COAL Daily, 2/26/2002).

Sierra Pacific Power (SPP) has terminated its long-term coal supply contract with Black Butte Coal Co. in favor of a new contract with Arch Coal to supply coal from their mines in Utah. Black Butte's coal supply contract to SPP's North Valmy, Nevada power plant, was to run through June 30, 2007. However, accelerated purchases and cancellations of minimum volume obligations enabled the power company to fully satisfy the volume requirements of the contract and in February, SPP terminated it early (COAL Daily, 3/22/2002).

Transportation developments

Otter Tail Power filed a rate case with the federal Surface Transportation Board (STB) charging that Burlington Northern Santa Fe (BNSF) common carrier rates for moving coal from the PRB to their Big Stone, South Dakota power station are excessive. The power plant burned approximately 2 million short tons of Wyoming PRB coal in 2001 (Coal Outlook, 1/14/2002).

Since the Dakota, Minnesota & Eastern Railroad (DM&E), received approval from the STB for their PRB expansion project, they have been sued by at least three groups hoping to block the railroad's planned entry into the Wyoming PRB. The Mayo Clinic and the City of Rochester filed briefs with the U.S. Court of Appeals for the D.C. Circuit concerning DM&E's proposed route through their community and near the famous health clinic. A third lawsuit by the Mid-States Coalition for Progress submitted a petition with the U.S. Court of Appeals for the Eighth Circuit on February 7 seeking a review of STB's recent approval. Mid-States claims that DM&E won't be able to secure enough coal hauling business to make the new line viable (COAL Daily, 2/13/2002).

In response to the three lawsuits, the Eighth Circuit Court of Appeals (in St. Louis) said it would hear all three cases. Because the project will impact cities, ranchers, and property owners in the Circuit's judicial area, the Court felt it is the proper place for the legal review (Coal Outlook, 3/4/2002). A fourth petition filed by the City of Winona, Minnesota on February 27 was consolidated with the other three lawsuits and also sent to the Court for hearing.

Despite these lawsuits, DM&E has received support for its project via a group consisting of 20 local governments, 12 chambers of commerce, and nine agricultural organizations that have joined a motion to intervene on the side of the railroad. The local governments represented in this action include the South Dakota towns of Huron, Wall, Philip, Midland, Fort Pierre, Miller, Wolsey, Iroquois, De Smet, and Volga; Beadle County, South Dakota; the Minnesota towns of Lake Benton, Sanborn, Springfield, Tracy, Waseca, and Walnut Grove; and the Wyoming communities of Newcastle and Upton. It has also been reported that Bryon, Lewiston, Owatonna, and Sleepy Eye, Minnesota and Brookings, South Dakota plan to file separate motions in support of the DM&E project (Coal Outlook, 3/11/2002).

Rail Link has again expanded its coal-loading tasks in the PRB, and has opened a new office in Gillette. Rail Link began service at Peabody's Caballo mine on February 14. The company manages train movements into several other Wyoming mines including Peabody's North Antelope/Rochelle mine complex, Kennecott's Antelope mine, and Triton Coal's North Rochelle mine (COAL Daily, 2/20/2002).

...two rules that will require many states, some of which burn Wyoming coal, to reduce NO_x emissions during the summer "ozone season."

Regulatory developments

On February 14, the Bush administration outlined the President's "Clear Skies Initiative," setting forth a goal of reducing power plant emissions by approximately 70% and "greenhouse gases intensity" by 18% over the next ten years. Based on what the White House believes to be a market-based approach, the plan is touted by Bush as a working alternative to the Kyoto Protocol. Targets include a 67% reduction in NO_x (nitrogen oxide) emissions, a 73% reduction in SO_2 (sulfur dioxide) emissions, and a 69% reduction in mercury emissions. For more information on the initiative, the reader may go to www.whitehouse.gov.

The U.S. Environmental Protection Agency (EPA) has postponed until May 31, 2004, the deadlines for two rules that will require many states, some of which burn Wyoming coal, to reduce NO_x emissions during the summer "ozone season." The new deadline will give utilities and industrial users in a number of Midwestern states another year to scrutinize, plan, negotiate, and litigate issues forced by these rules that will seasonally reduce the cap on NO_x emissions (Coal Outlook, 1/21/2002).

Market developments and opportunities

Houston Lighting and Power (HL&P) plans to begin using a 20/80 PRB coal/lignite burn at its Limestone No. 1 Unit in the second half of 2002. HL&P currently uses a 20/80 petroleum coke/lignite blend. The company plans to use 8400-Btu PRB coal and will need approximately 800,000 short tons annually. BNSF currently provides transportation services to the plant (Coal Outlook, 1/14/2002).

Nebraska Public Power District is hoping to test at least three trainloads of PRB coal at its Gentleman, Nebraska power station. Having completed a baghouse retrofit, the utility is seeking PRB coals containing more than 8400 Btus per pound. The test may be a straight PRB burn or a blend of PRB coal with current stocks (Coal Outlook, 1/7/2002).

A bill (HB 2135) put before the Oklahoma State Legislature, known as the Energy Security Act of 2002, includes a new proposal to encourage coal-fired power plants. If the bill were passed, it would enable owners of coal-fired power plants to charge higher rates so that they can recapture new plant costs over a seven-year period instead of the 35-year period currently allowed. The new depreciation schedule would apply to both new coal-fired plants and upgrades at current coal-fired facilities (COAL Daily, 2/11/2002).

Dominion Resources announced plans to purchase Mirant's Indianabased State Line Ventures unit. The reported $182 million deal involves Dominion buying State Line's 197-megawatt (MW) Unit 3 and 318-MW Unit 4 power plants, both of which are currently fired by low-sulfur Wyoming PRB coal (COAL Daily, 2/27/2002).

Table 13 tabulates some of the contract, spot sales, test burns, and solicitations for Wyoming coal, announced during the first quarter of 2002.

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

Stauffenberg, D.G., 2001, Annual report of the State Inspector of Mines of Wyoming, for the year ending December 31, 2001: Wyoming Department of Employment, Office of the State Inspector of Mines, Rock Springs, Wyoming, 81 p.

Table 13. Marketing activities for Wyoming coal producers during the first quarter of 2002*.

Utility	Power Plant	Coal Mine/Region	Activity	Tonnage	Comments
Archer Daniels Midland	System	Peabody/PRB	C	1.2 mt	For 5 plants; delivery in 2002
Cedar Falls Utilities	System	Illinois/PRB	C	30,000 t/y	One to multi-years beginning in 2002
Entergy Services	White Bluff and Independence	PRB	C	1.4 mt	3 years; delivery in 2002
Kentucky Utilities	Ghent	Black Thunder/PRB	C	1 mt/y	4 years beginning in 2002
Muscatine Power & Water	Muscatine	PRB	So	1.1 mt/y	1 to 5 years beginning in 2003
PPL Montan	Corette	Buckskin	T	Single unit train	A successful test of PRB coal
Reliant Energy	Parish	PRB	Sp	700,000 t	Delivery in 2002
Southern Company Services	Scherer	PRB	C	up to 3 mt/y	Up to 3 years beginning in 2003
Tampa Electric	Big Bend, Gannon and Folk	Illinois and PRB	Sp	Minor tonnage	Delivery in 2002
Xcel Energy	System	PRB	C	4 mt/y	Up to 4 years beginning in 2003

*Data obtained from: Coal Outlook, COAL Daily, Coal Age, FERC database, and personal contacts. Note: C = contract; mt = million short tons; mt/y = million short tons per year; PRB = Powder River Basin; Sp = spot coal; So = solicitation; t = short tons; t/y = short tons per year; and T = test burn. *Wyoming State Geological Survey, Coal Section, July, 2002.*

Coalbed Methane Update

Rodney H. De Bruin, Wyoming PG-3045

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Robert M. Lyman, Wyoming PG-656

Staff Geologist–Coal, Wyoming State Geological Survey

Coalbed methane production reported by the Wyoming Oil and Gas Conservation Commission (WOGCC) for the first three months of 2002 was 74.4 billion cubic feet (BCF) (**Table 14**). This was 17.8% of Wyoming's total natural gas production for the first quarter of 2002, and a 37.5% increase over coalbed methane production for the same period in 2001. There were 8672 producing wells and 3670 shut-in wells in March, 2002. The State of Wyoming's Consensus Revenue Estimating Group (CREG) predicts that 315 BCF of coalbed methane will be produced in 2002, an average of 26.25 BCF per month.

An assistant secretary in the U.S. Department of the Interior, Rebecca Watson, believes that the terrorist attack of September 11, 2001 and the Mideast conflict underscore the need to boost U.S. energy production, and coalbed methane development in the Rocky Mountain area will help meet that goal. The U. S. Bureau of Land Management (BLM), overseen by Watson, is expected to release a draft plan this summer, which will include ways to streamline the permitting process for companies operating on BLM-administered land.

Kennedy Oil notified the BLM that it would like to initiate environmental review for a pilot exploratory coalbed methane project on its federal oil and gas leases in T24N and T25N, R98W (**location A, Figure 12**). The area is approximately 35 miles northwest of Wamsutter and just a few miles due east of the Jack Morrow Hills study area described in the last issue of *Wyoming Geo-notes* (No. 73, April, 2002, p. 2-3). The analysis area for the pilot project takes in about 10,240 acres, of which 9090 are federal surface and minerals.

Kennedy plans to explore two coalbed methane areas (pods), apparently in coals of the Fort Union Formation. The northern and southern pods would each contain 10 dewatering wells and one reinjection well. The wells, with the exception of the reinjection wells, would be located on 160-acre spacing. All produced water would be reinjected

Table 14. Monthly Wyoming coalbed methane production in MCF (1998 through March, 2002).

	1998		1999		2000		2001		2002	
	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative	monthly	cumulative
January	1,962,669	1,962,669	3,660,434	3,660,434	8,461,780	8,461,780	17,870,205	17,870,205	25,404,010	25,404,010
February	1,882,421	3,845,090	3,462,685	7,123,119	8,706,458	17,168,238	16,741,272	34,611,477	23,239,610	48,643,620
March	2,134,042	5,979,132	4,110,431	11,233,550	9,872,362	27,040,600	19,271,964	53,883,441	25,793,326	74,436,946
April	2,154,252	8,133,544	4,040,989	15,274,539	10,565,807	37,606,407	19,216,625	73,100,066		
May	2,254,160	10,387,257	4,422,581	19,697,120	11,831,227	49,437,634	20,390,450	93,490,516		
June	2,369,015	12,756,559	4,605,167	24,302,287	12,199,486	61,637,120	20,078,486	113,569,002		
July	2,455,931	15,212,490	4,877,924	29,180,211	13,024,856	74,661,976	20,993,443	134,562,445		
August	2,654,655	17,867,145	4,793,060	33,973,271	14,180,161	88,842,137	21,906,856	156,469,301		
September	2,988,544	20,855,689	5,125,811	39,099,082	14,390,965	103,233,102	21,385,829	177,855,130		
October	3,158,168	24,013,857	5,961,192	45,060,274	15,393,978	118,627,080	23,717,045	201,572,175		
November	3,188,985	27,202,842	5,947,893	51,008,167	15,220,163	133,847,243	23,635,973	225,208,148		
December	3,434,905	30,637,747	7,180,697	58,188,864	16,852,924	150,700,167	25,377,179	250,585,327		
Total Utility Tonnage[1]		**30,637,747**		**58,188,864**		**150,700,167**		**250,585,327**		

[1]Data from the Wyoming Oil and Gas Conservation Commission. *Wyoming State Geological Survey, July, 2002.*

into a water-bearing sandstone containing water of equal or lesser quality. No permanent discharge of produced water is proposed, and all potable water would be protected. Kennedy believes that 10 dewatering wells in each of the pods is necessary to dewater the coal sufficiently to allow the gas to desorb and thus to determine whether gas production is economically viable in the project area.

The BLM has completed three environmental assessments in the Atlantic Rim region approximately 20 miles northeast of Baggs (**location B, Figure 12**). The Sun Dog Pod was proposed by Petroleum Development Corp. (PEDCO) and will include six coalbed methane wells. The Cow Creek Pod was proposed by Double Eagle Petroleum & Mining and will include eight coalbed methane wells. PEDCO also proposed the Blue Sky Pod, which will include up to 23 coalbed methane wells, two reinjection wells, access roads, gathering lines, and a compressor station. Nineteen of the wells would be on federal minerals and the remaining four wells would be on state minerals.

These pods are located in three of nine development areas within the Atlantic Rim region that are proposed for drilling in Mesaverde Group (Almond Formation) coals over the next year. The drilling is expected to provide information for use in an ongoing environmental study of the Atlantic Rim Coalbed Methane Project. An Environmental Impact Statement (EIS) is now underway for the Atlantic Rim Project, which includes proposals by the operators to drill up to 3800 new wells. The BLM will allow the drilling of about 200 test wells in the area to determine the economic and environmental feasibility of such a large-scale project.

Williams Production RMT Co. is proposing to drill up to 16 new exploratory coalbed methane wells in an area about 10 miles northeast of Hanna (**location C, Figure 12**). The proposal calls for seven wells on private land and nine wells on federal land. Nine wells have already been drilled and completed on private land, so the total project would consist of a total of up to 25 wells. Target coal beds are in the Tertiary Hanna Formation. If the pilot project is successful, a pipeline would be built across the Simpson Ridge wind-power project area to connect with major pipelines south of the coalbed methane project area. The area proposed for development is completely within the MetFuel Hanna Basin Coalbed Methane Project Area (now abandoned). An EIS was prepared for that project in 1993.

Industrial Minerals and Uranium Update

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Industrial minerals production remained steady for almost all commodities in the first quarter of 2002, with no major new projects or closures announced. FMC is restructuring their trona operations in Wyoming, and as a result, have announced the layoff of around 90 employees. Construction aggregate producers have seen both seasonal and general increases in demand for their products, due primarily to increased highway construction and reconstruction in Wyoming and neighboring states.

Rio Algom's Smith Ranch uranium *in situ* mine and recovery plant was purchased by CAMECO. As of May, 2002, Wyoming still leads Nebraska in the production of uranium. These two states and their three *in situ* mines are the only producers of uranium in the country other than the production of a few pounds of yellowcake by some uranium mine reclamation operators in Texas.

The Industrial Minerals and Uranium Section's web page was revised in early April to include 2001 trona production. Refer to the web site production table for the latest statewide production figures (http://wsgsweb.uwyo.edu/minerals/1996-01.asp).

Bentonite

Refined bentonite products are produced at 14 mills in Wyoming (**Figure 17**). Bentonite is a special variety of montmorillonite clay characterized by high ion exchange capability, high expansion when water is absorbed, highly controllable viscosity, and low permeability. These properties make it useful for kitty litter, foundry mold binding clay, taconite palletizing, drilling mud, environmental adsorbents, water barriers, and other uses. Bentonite ranks second after mined trona in value of industrial minerals produced in Wyoming.

Bentonite formed when ash, erupted from volcanoes west of what is now Wyoming, fell into clear, saline ocean water. Sodium from the seawater contributed to the formation of high sodium bentonite. Most bentonites in Wyoming are of Upper Cretaceous age (90 to 96 million years ago), although some lower grade bentonitic clay is found in Tertiary rocks. The highest grade bentonites are found in Wyoming south of the Montana border and north of the center of the state (**Figure 17**).

Construction aggregate

Construction aggregate includes sand and gravel, crushed stone (granite and limestone), railroad ballast, and crushed naturally baked and fused rock associated with the burning of coal beds. [This material is often but mistakenly called scoria (a type of volcanic rock) or locally, clinker. See the discussion under ***Decorative aggregate***, below.] Construction aggregate is the material, usually sized for use by screening, that is mixed with cement to form concrete, mixed with asphalt or other materials in road paving, or used without a binder as fill, erosional protection, and other construction designations. Near the end of the first quarter of 2002, road construction began to increase and the amount of construction aggregate produced also began to increase. Due to the cost of transportation (around $1.10 per ton per mile) it is necessary to locate aggregate pits near the point of use. Construction aggregate costs around $5.00 per ton, so any haul over five miles results in the cost of transportation to the user being greater than the cost of the material.

Decorative aggregate

Decorative aggregate includes rock produced for decoration or for its appearance, including moss rock, fieldstone or flagstone (which is usually harvested from the surface), or quarried rock which is crushed and sized. Decorative aggregate does not include stone cut to size. Some of the most distinctive decorative aggregate produced in Wyoming is the red rock that typically caps mesas and buttes in the Powder River Basin around Gillette, Sheridan, Buffalo, and other

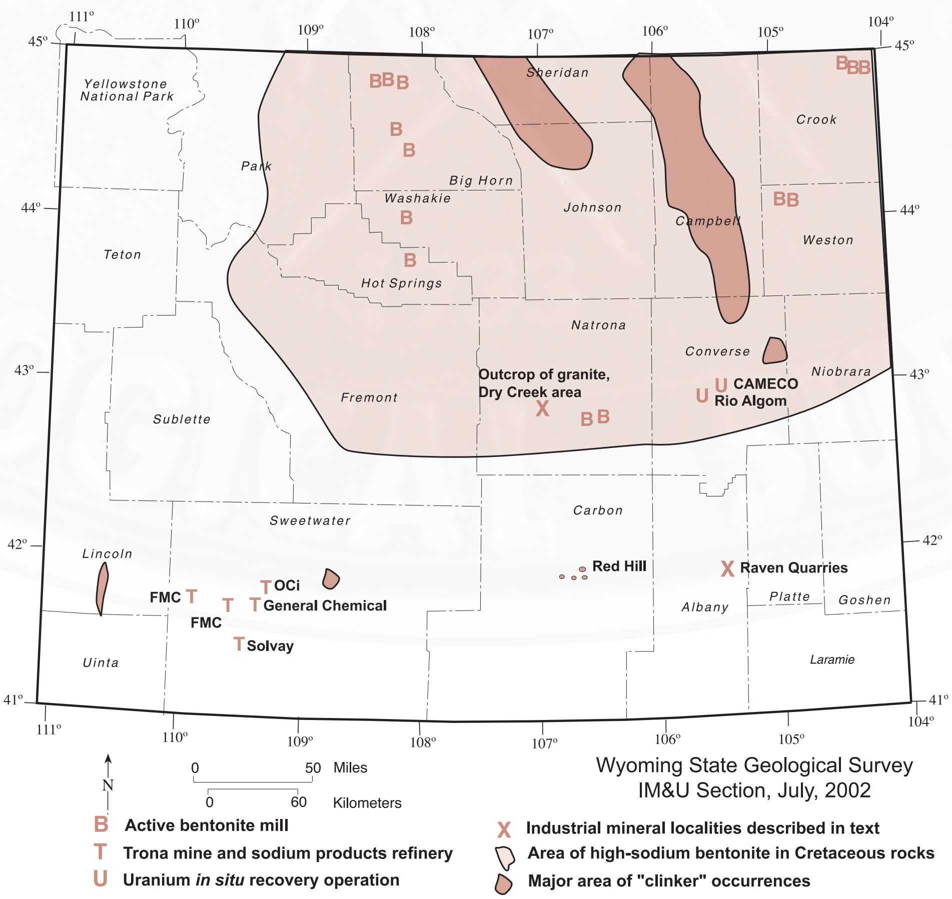

Figure 17. Index map of Wyoming showing the location of industrial mineral and uranium sites mentioned in the text. Locations are approximate and may represent more than one site.

places where coal occurs (**Figure 17**). It is used for decoration primarily as landscaping aggregate. It forms during the baking and fusing of shale and other rock types by the heat from a burning coal bed. It is locally called clinker or scoria, though coal miners refer to it as red dog. However, there are problems with this terminology since clinker is also a material produced when coal is burned and scoria is also vesicular volcanic rock. This baked and fused rock is more correctly classified as "thermally metamorphosed sedimentary rock." This material is often the hardest rock in the area and is locally used for construction aggregate (including road metal). The material is also found in other areas of Wyoming near coal beds, particularly near Kemmerer, Hanna-Elmo (**Figure 18**), and Rock Springs (**Figure 17**).

Dimensional stone

Dimensional stone is quarried by Raven Quarries in northern Albany County (**Figure 17**). Gallegos Stone has leased the quarry from the previous owner, Raven Quarries, LLC., but continues to call the site Raven Quarries and produces both Wyoming Raven® (black granitic rock) and Mirage® (pink variegated stone). Raven Quarries updated its quarrying operations by installing a wire saw to cut blocks from the quarry face. Previously, the quarrying method was to drill closely spaced holes, fill them with black powder, and blast the blocks from the face. The new method is less likely to damage blocks during quarry operations.

Exploration for new dimensional stone quarry sites continued in Wyoming. Six companies planned to visit the state in early summer to examine quarry sites in the field. Granite, limestone, sandstone, and marble sites are all being considered, including the site at Dry Creek (**Figure 19**).

Trona

The amount of trona mined in Wyoming in 2001 by all methods was 17,722,311 short tons, down from the 17,782,153 short tons mined in 2000, according to data released by the Wyoming Mineral Tax office. Four companies in Wyoming mine trona (sodium sesquicarbonate, $Na_2CO_3 \bullet NaHCO_3 \bullet 2H_2O$) by underground and solution recovery methods at five locations and produce sodium products at plants near the mines (**Figure 17**). Soda ash is the primary product. Soda ash 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. Soda ash is also manufactured in the U.S. from sodium sesquicarbonate alkali lake deposits in California and from nahcolite (sodium bicarbonate, $NaHCO_3$) at an *in situ* mine in northwestern Colorado.

FMC Corporation, which operates two trona mines and refining plants (known as Granger and Westvaco), announced the layoff of around 90 workers in order to streamline operations, increase efficiency, and reduce costs. This represents about a tenth of FMC's workforce in the area. FMC also announced in March the sale of its sodium cyanide production to Cyanco, a Nevada partnership. Cyanco will produce the chemical, which is used in refining gold in Nevada, but will purchase soda ash for the process.

A plant at the town of Parachute in northwestern Colorado, produces soda ash from refining the mineral nahcolite, mined by a unique *in situ* process that involves pumping hot water into the nahcolite zone, dissolving the nahcolite, and piping the solution to the plant for processing. The plant has been in operation for about a year and a half. The Williams Companies, the primary owner and investor in the plant, announced in February that its 60% share of the operation was for sale. This action was taken in response to Williams' restructuring related to the bankruptcy of Enron. Williams noted that the plant has been operating at a loss since its completion. The plant annually produces about one million tons of sodium products. Its operation was a factor in Wyoming's trona production declining from 1999 through 2000. The nahcolite substitutes for about 1.8 million short tons of mined trona.

Figure 18. Red Hill, two miles north of Elmo in Carbon County, is capped by red baked and fused shale, the dark, rough-textured outcrops above the lightest layer.

Figure 19. Beige granite outcrop exhibiting few fractures or veins, suitable for a dimensional stone quarry, Dry Creek area, Natrona County.

Uranium

Uranium continued to be mined by *in situ* methods at two locations, CAMECO and Rio Algom, in Converse County, southern Powder River Basin (**Figure 17**). Yellowcake from the two on-site recovery mills is shipped for enrichment and conversion into nuclear power plant fuel in both France and the U.S.

CAMECO, based in Saskatoon, Saskatchewan, Canada, announced their purchase of the Smith Ranch *in situ* uranium mine and recovery plant from Rio Algom. CAMECO also owns the Crow Butte *in situ* uranium mine and recovery plant in Nebraska. These three sites are the only locations where major amounts of uranium are mined and yellowcake recovered in the U.S.

The spot market price of yellowcake (oxidized uranium—the product of Wyoming's uranium mills) increased in late February from $9.80 per pound to $9.90 per pound, where it has remained steady, according to the Ux Consulting Company, LLC., the Uranium Exchange Company (http://www.uxc.com/review/uxc_prices.html; note that this web address has changed since *Wyoming Geo-notes No. 73*, April, 2002), and the Rocky Mountain Minerals Scout.

Metals and Precious Stones Update

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During the first quarter of 2002, the author spoke to several hundred people about the state's mineral resources. The Metals and Precious Stones Section at Wyoming State Geological Survey also responded to an increased number of inquiries about Wyoming's gemstone, diamond, nickel, gold, platinum, and palladium resources.

Talks and field trips

The author presented several talks and a short course in the first quarter and early second quarter of 2002. A talk on *Wyoming Diamonds* was presented to the Casper Rotary Club on March 11. This talk was well-received (with national news coverage) and attracted three companies to examine Wyoming for its diamond potential. Two days later I presented lectures on *Wyoming Gemstones* to the Southwestern Chapter of the Society of Mining Engineers (SME) in Rock Springs on March 14; *Gemstones–Wyoming's Untapped Resource* to the general public at the Tate Museum Open House at Casper College on March 23; *Wyoming Gemstones* to the Rex Young Rock Hounds in Torrington on April 10; and *Diamonds* to the Rawlins Rotary Club on April 23.

I conducted a *Diamond Exploration Short Course* for the Rocky Mountain Prospectors and Treasure Hunters Club at the Daniel N. Miller, Jr. Building (formerly the Wyoming State Geological Survey Building) on the University of Wyoming campus on April 19.

A list of additional talks and field trips scheduled for the near future were listed in the last issue of *Wyoming Geo-notes* (No. 73, April, 2002) and on page 5 of this issue.

Rattlesnake Hills 1:100,000-scale Quadrangle

The Section continued to work on the Rattlesnake Hills 1:100,000-scale Quadrangle which includes much of the Granite Mountains. Both myself and Wayne Sutherland worked towards the completion of the map. During field reconnaisance, we either identified or discovered several interesting mineral occurrences including several jade deposits (as well as two localities that contained jade pseudomorphs after quartz), copper, a significant hydrothermally altered zone that may have potential for copper and gold, jasperoids, banded iron formations, sapphires, and some excellent mineral localities for collectors.

Recent publications

Hausel, W.D., 2002, The Keystone Gold-Copper district, Medicine Bow Mountains, southeastern Wyoming: International California Mining Journal, v. 71, no. 8, p. 15-20.

Hausel, W.D., 2002, The health benefits of carats (abstract): The Contact, Newsletter of the Wyoming Geological Association, vol. 40, no. 4, p. 4.

Publications in press or in preparation

Hausel, W.D., 2002, A new source of gem-quality cordierite and corundum in the Laramie Range of southeastern Wyoming: Rocks & Minerals (in press).

Erlich, E.I., and Hausel, W.D., 2002, Diamond deposits–Origin and Exploration: Society of Mining Engineers (in press).

Hausel, W.D., Gregory, R.W., Motten, R.H., and Sutherland, W.M., Geology of the Iron Mountain Kimberlite district, southeastern Wyoming: Economic Geology (in preparation).

Hausel, W.D., A history of diamond sources in the United States: Gems and Gemology (in preparation).

Rock Hound's Corner: Wyoming Jade boulder

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This issue of *Wyoming Geo-notes* was to carry an article in the Rock Hound's Corner on searching for gold in Wyoming but because of the high interest in gold prospecting, we have decided to produce a separate information pamphlet on this subject. Due for publication this August, the reader can obtain copies of the free pamphlet through the Wyoming State Geological Survey (WSGS).

This Rock Hound's Corner is devoted to one specific gemstone (or should it be a "gem-boulder"). This boulder of Wyoming Jade (**Figure 20**) exemplifies what nearly every prospector and rock hound dreams about: finding a mineral or rock specimen that is too large or too heavy for one person to handle easily. The specimen shown here, which recently was placed on display at the WSGS in Laramie, is a 218-pound boulder of apple-green nephrite jade wind-polished slick found by Ray and Irene Morgan in the 1940s on Crooks Mountain south of Jeffrey City. The boulder is about 2 feet long, 1 foot high, and 1 1/2 feet wide.

The specimen was donated to the State of Wyoming and the WSGS on November 17, 2000 by Jack and Joan Cuthbertson of Lander and J. David and Jane M. Love of Laramie. The conditions for the donation were that the specimen would be on perpetual exhibition and that it would never be cut, sold, loaned out, or stored without approval of the donors.

The Crooks Gap area has been the source for a number of spectacular apple-green nephrite (known as "Wyoming Jade") boulders, some weighing more than a ton (see Hausel and Sutherland, 2000, for a complete description of jade in Wyoming). As described in this reference, jade refers to two distinct and unrelated mineral species, jadeite and nephrite. According to Hausel (2000), "nephrite is an amphibole that is formed of extremely dense and compact fibrous tremolite-actinolite wheras jadeite is a pyroxene of the augite series." Jade in Wyoming is also discussed in the Rock Hound's Corner of *Wyoming Geo-notes No. 66* (June, 2000, p. 56-59).

Although the likelihood of ever finding a boulder of jade like this today is probably very remote, there is always a possibility of more boulders being weathered out and exposed as erosion continues to act on the rocks that contain nephrite boulders. Meanwhile, one can only imagine what kind of excitement a rock hound or prospector must experience when they discover something like this.

References cited

Hausel, W.D., and Sutherland, W.M., 2000, Gemstones and other unique minerals and rocks of Wyoming—A field guide for collectors: Wyoming State Geological Survey Bulletin 71, 268 p.

Hausel, W.D., 2000, Rock Hound's Corner–Jade: Wyoming State Geological Survey, Wyoming Geo-notes No. 66, June, 2000, p. 56-59.

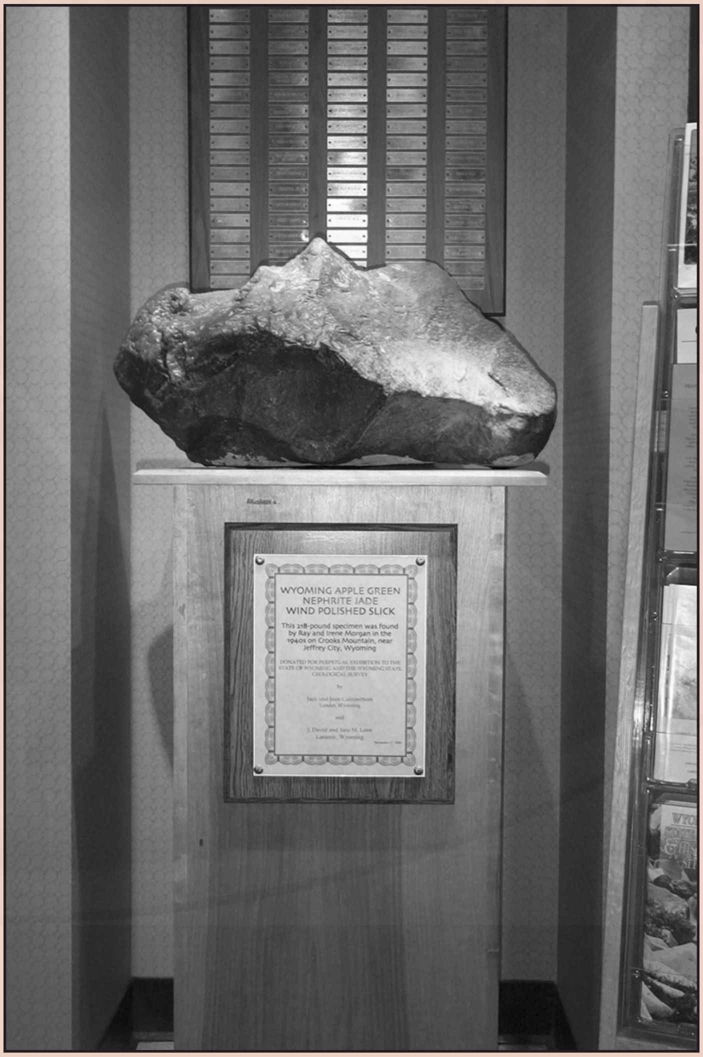

Figure 20. The wind-polished edges of the Wyoming Jade boulder reveal a beautiful apple-green color and the recognizable "slick" while much of the surface exhibits a light greenish-brown weathering rind.

GEOLOGIC MAPPING AND HAZARDS UPDATE

Geologic Mapping, Paleontology, and Stratigraphy Update

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The Wyoming State Geological Survey (WSGS) was recently notified that their STATEMAP 2002 mapping proposal for $70,913 had been funded. The three proposed projects are: 1) map the Kaycee 1:100,000-scale Quadrangle; 2) digitize bedrock geologic maps of the Kaycee, Reno Junction, and Rattlesnake Hills 1:100,000-scale quadrangles; and 3) map the Keystone 1:24,000-scale Quadrangle. This proposal is part of the National Cooperative Geologic Mapping Program (NGCMP), which is profiled in this article.

The Kaycee and Reno Junction maps will support a southward expansion of the Northern Powder River Basin geologic, hydrologic, and water quality database project. The Rattlesnake Hills and Keystone maps are needed to assess a number of highly prospective mineral occurrences and to investigate some heretofore poorly known areas.

The Wyoming Geological Association (WGA) recently awarded grants for field expenses to six students planning field-mapping projects in the Rocky Mountain area. The grants were made from the WGA's J. David Love Field Geology Fellowship in support of field geology projects.

...Congress and the Bush Administration supported doubling funding levels to $64 million by the year 2005.

The National Cooperative Geologic Mapping Program

The National Geologic Mapping Act (Public Law 102-285) was signed into law in 1992 and created the NCGMP. Congress recognized that the U.S. Geological Survey (USGS) and the state geological surveys needed a coordinated program to prioritize geologic mapping requirements of the Nation and to increase production of geologic maps. This law has been reauthorized twice since that time, most recently in 1999. In this latest authorization, Congress and the Bush Administration supported doubling funding levels to $64 million by the year 2005. NCGMP contains three subprograms: 1) FEDMAP–USGS mapping and map related projects, 2) STATEMAP–State geological survey mapping projects, and 3) EDMAP–University student mapping projects.

The FEDMAP subprogram deals with the federal government's role in geologic mapping and related projects. The USGS role includes: 1) addressing issues crossing jurisdictional boundaries between states; 2) developing new applications for the resolution of basic earth science processes; 3) studying federal lands, including our National Parks, providing for the wise management of public lands; and 4) constructing the National Geologic Map Database on the Internet, promoting easier access to available geologic maps for community, government, consulting, and the mineral/energy industry. National priorities are set by a Federal Advisory Committee and a FEDMAP Review Panel made up of federal, state, private industry, and academic members. Current and recent FEDMAP projects are addressing issues such as natural hazards in the California/West Coast area; characterizing and protecting groundwater resources in the southeastern Coastal Plain, the central Great Lakes region, the middle Rio Grande basin, and the Death Valley area; and providing information on published geologic mapping via the Internet-based National Geologic Map Database.

The role of the states in the STATEMAP subprogram is to produce needed geologic maps to support regulatory branches of state and county government, as well as to provide geologic information for planners, the mineral industry, and the general public. Every federal dollar awarded to a state geological survey through an annual competitive grant process is matched by a state dollar. State mapping priorities are set with advice of a broad-based State Mapping Advisory Committee in each participating state. These committees are made up of representatives of private industry, geotechnical consultants, state and county officials, and university faculty. Current mapping projects are addressing needs relating to mineral resource exploration; assessment and protection of water resources; a broad array of environmental concerns ranging from forest health to aquifer contamination by large hog confinement farms; and natural hazards issues including landslides, volcanic eruptions, and earthquakes. Presently, over 150 mapping projects are in progress or have been funded in 46 states.

Universities around the country have the opportunity to train their students to produce high-quality geologic mapping with aid of funding through the EDMAP subprogram. Training students to do quality geologic mapping was on a sharp decline prior to the passage of the National Geologic Mapping Act. Every federal dollar awarded under the

need for quality detailed geologic maps, which most states lacked, has been skyrocketing.

annual competitive grant process for this program is matched by a university dollar. Priorities for these mapping projects are in close consultation with state geological surveys and the USGS. Students soon learn about the issues and needs that must be documented to justify their mapping projects. Since the inception of the program in 1995, highly qualified mentors have trained over 300 students from 94 different universities in mapping techniques.

These three subprograms of the NCGMP have provided impetus to a lagging geologic mapping effort around the country. At the same time, need for quality detailed geologic maps, which most states lacked, has been skyrocketing. For more information on these programs and how to participate, refer to this USGS web site: http://ncgmp.usgs.gov/.

STATEMAP 2002 funded

The WSGS recently received notification that their proposal for three mapping projects submitted to the STATEMAP 2002 Program was funded in full for $70,913. Based on consultation with the Wyoming Geologic Mapping Advisory Committee, the three subprojects proposed in October, 2001 were: 1) to map the bedrock geology of the Kaycee 1:100,000-scale Quadrangle; 2) to digitize bedrock geologic maps of the Kaycee, Reno Junction, and Rattlesnake Hills 1:100,000-scale quadrangles; and 3) to map the Keystone 1:24,000-scale Quadrangle (**Figure 21**). For a more detailed discussion of the geologic setting, earlier work, justification, and the techniques and procedures for completing these subprojects, see *Wyoming Geo-notes No. 72* (December, 2001, p. 26-28).

Current mapping priorities established by the WSGS in cooperation with the Wyoming Geologic Mapping Advisory Committee include: 1) producing geologic maps to support coal-bed 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 development of mineral, water, and other resources (**Figure 22**).

The WSGS Mapping Section will map and compile the geology for the Kaycee 1:100,000-scale Quadrangle, with funding of $23,500 from STATEMAP 2002. The completion of this map (SMP 02-1 on **Figure 21**) is needed to augment expansion to the south of the Northern Powder River Basin, Wyoming geologic, hydrologic, and water quality database project (see description in *Wyoming Geo-notes No. 69*, April, 2001). The Reno Junction 1:100,000-scale Quadrangle immediately to the east would also be compiled to augment southward expansion of the database project. However this effort will not be funded through STATEMAP, but will use funds from the Northern Powder River Basin project instead.

The WSGS Publications/GIS Section is funded for $18,437 to convert the Kaycee and Reno Junction bedrock geologic maps (mapped and compiled under subproject 1 above) to digital format (SMP 02-2 on **Figure 21**). The Rattlesnake Hills bedrock geologic map (currently being mapped and compiled by the Metals and Precious Stones Section as part of STATEMAP 2001) will also be converted to digital format with funding from STATEMAP 2002.

The WSGS Metals and Precious Stones Section will complete geologic maps of the Keystone 1:24,000-scale Quadrangle and the Saratoga 1:100,000-scale Quadrangle as a two-year project

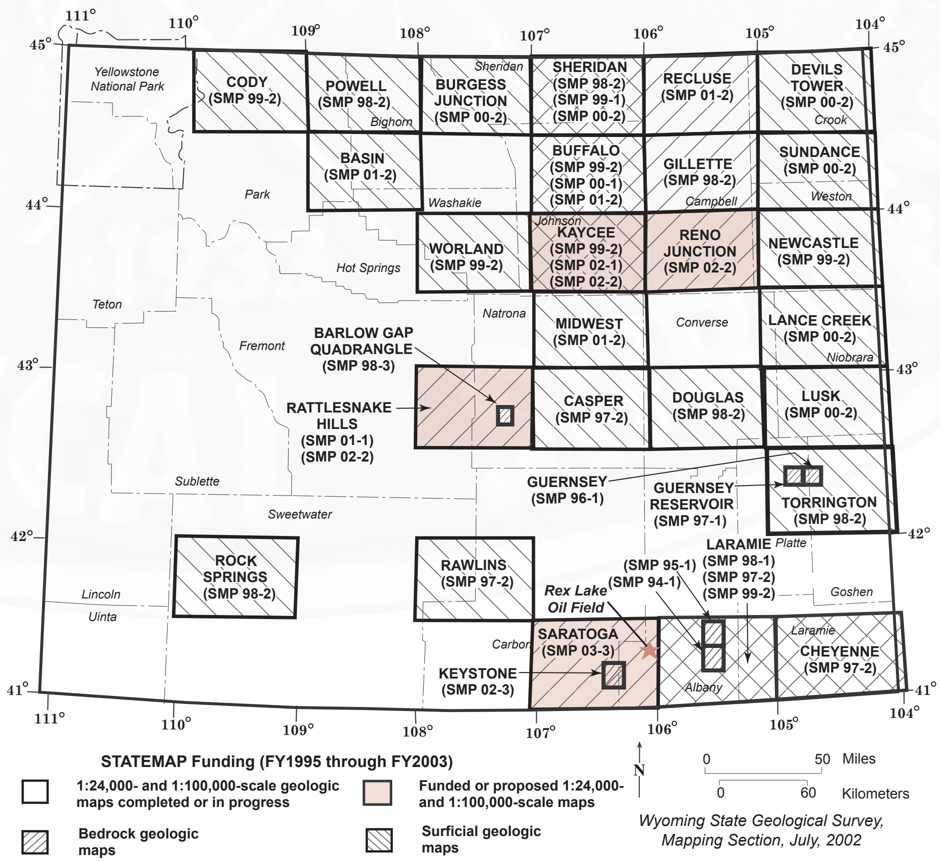

Figure 21. Index map showing status of STATEMAP projects and recently published geologic studies in Wyoming.

Figure 22. Sheridan College's dinosaur quarry southwest of Buffalo is located in the light-colored area to right of truck in lower left foreground. This quarry represents paleontological resources, one of the many resources found on the Buffalo 1:100,000-scale Quadrangle currently being completed as part of the STATEMAP Program. The outcrop on the right is the Jurassic Morrison Formation; the quarry is located in the upper part of the formation. The sandstones to the left and above the quarry are part of the Lower Cretaceous Cloverly Formation.

(SMP 02-3 and SMP 03-3 on **Figure 21**). The first year of this project would entail mapping the Keystone Quadrangle in the Medicine Bow Mountains with $28,976 in funding from STATEMAP 2002. The second year of the project, if funded by STATEMAP 2003, would lead to compiling the geology of the Saratoga Quadrangle.

Completed, funded, and proposed STATEMAP projects are shown in **Figure 21**. The STATEMAP Program, as part of the NCGMP, has significantly expanded and driven the mapping efforts of the WSGS since 1994, contributing $329,491 in funding over the past eight years, including the STATEMAP 2002 funds (**Table 15**). The WSGS completed 30 maps using funding from this program since it began involvement in 1994; an additional 11 maps were completed independent of STATEMAP.

WGA grants awarded

The WGA recently awarded grants for field expenses to six students planning field-mapping projects in the Rocky Mountain area. The grants were made from the WGA's J. David Love Field Geology Fellowship in support of field geology projects and in honor of J. David Love, renowned for his distinguished career as a field geologist in Wyoming with the USGS. Recipients of the grants and their research topics included:

- Diana Strickland, University of Wyoming—meso-Proterozoic deformation in the Medicine Bow Mountains, southeastern Wyoming;
- Sam Teeters, University of Kansas—fluvio-estuarine deposits in the Fort Union Formation, Rock Springs uplift, southwestern Wyoming;
- Scott Hynek, University of Utah—middle Eocene fluvial paleogeography of western Wyoming;
- Aaron Otteman, University of Wyoming—Laramide thrust mechanisms and structures exhibited in the Rawlins uplift and eastern Seminoe Mountains;
- Shane Prochnow, Baylor University—mapping and work on paleosols to determine the subsidence history of the

Table 15. Summary of 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
2003	1-Geologic map of the Kaycee Quadrangle 1:100,000-scale STATEMAP 02-1-funded	$23,500	$23,500	$47,000
	2-Digital geologic maps of the Kaycee, Reno Junction, and Rattlesnake Hills Quadrangles			
	1:100,000-scale STATEMAP 02-2-funded	$18,437	$18,437	$36,874
	3-Geologic map of the Keystone Quadrangle 1:24,000-scale STATEMAP 02-3-funded	$28,976	$28,976	$57,952
	TOTALS	**$329,491**	**$329,491**	**$659,982**

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.

Chinle Formation, Castle Valley, southeastern Utah; and

- Michael Wall, University of Wyoming—modeling the stratigraphy of the Lower Sandy Member of the Blair Formation, Rock Springs uplift, southwestern Wyoming.

New publications on Wyoming geology

Stone (2002) recently completed a comprehensive analysis of the structure of the Rex Lake oil field in the Laramie Basin (**Figure 21**). A million barrels of oil has been produced from the Lower Cretaceous Muddy Sandstone and Cloverly Formation in this northeast-trending anticlinal trap. Seismic control and borehole data combined with surface geologic mapping was used to interpret the structure of the field. Evidence indicates the field developed in the hanging wall of a southeast-verging, detachment thrust emanating from ductile shales in the Permian Goose Egg Formation. This small detachment is antithetic to the regional northeast-trending, basement-involved Rex Lake fault zone. This model is a general analog for the basic structure displayed in many of the Laramie Basin oil fields.

Reference cited

Stone, D.S., 2002, Structure of the Rex Lake oil field, Albany County, Wyoming: The Mountain Geologist, v. 39, no. 2, p. 31-39.

Geologic Hazards Update

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The Geologic Hazards Section at the Wyoming State Geological Survey (WSGS), in cooperation with the Wyoming Water Resources Data System (WRDS) at the University of Wyoming (UW), has developed two interactive web sites, one for accessing and viewing data on landslides in Wyoming, and the other for viewing 3-D interactive images with superimposed landslides. Recently the web sites were discussed with all Wyoming emergency managers to receive additional input on user needs; we invite comments from others that access these sites. The first part of this update article describes these web sites. In late March, 2002, the Section participated in the Wyoming Emergency Management Planning Workshop. Personnel from the Section presented information on: 1) identifying natural hazards, 2) resources for mitigation of natural hazards, and 3) using HAZUS (Hazards U.S.) to estimate losses from natural hazards. The second part of this update summarizes these presentations.

Landslides in Wyoming web site

Landslides are a significant hazard in Wyoming, and are a dominant mapping feature in parts of western Wyoming (**Figure 23**) In the 1980s and early 1990s, the Geologic Hazards Section at the WSGS mapped the entire state for landslides at a scale of 1:24,000. In 2000, the Section, using Earthquake Program Funds supplied by the Wyoming Emergency Management Agency (WEMA) and the Federal Emergency Management Agency (FEMA), subcontracted with WRDS to help generate and to serve a web site on *Landslides in Wyoming*.

This web site can be accessed at: http://www.wrds.uwyo.edu/wrds/wsgs/hazards/landslides/lshome.html. The site provides the user with the ability to view a landslide map with landslides superimposed on a 7.5-minute (1:24,000-scale) quadrangle, or to download a digital map coverage (e00 file) of the landslides in ESRI's ArcGIS®. The site is nearly complete for Teton, Lincoln, Uinta, and Sublette counties in western Wyoming (**Figure 24**). Work is progressing on Fremont and Park counties, and all counties in Wyoming should be completed in the next five to six years. The web site also provides a landslide classification scheme and a list of abbreviations used on the maps.

The landslides can be viewed in two ways. A reduced version of the landslide map (**Figure 25**) can be observed after clicking on the desired quadrangle on the landslide index map. If the user then clicks on the reduced image, a larger scale map can be viewed and navigated. Depending on screen resolution used, the larger-scale map can be viewed at a scale of approximately 1:24,000. The viewer is given basic instructions on how to print a complete map.

The landslide GIS coverage was generated by copying the mapped landslides to mylar, scanning the mylar, converting the scanned image to real world coordinates, and converting the image to a vector coverage. The vector coverage was then attributed using the classification scheme mentioned above. An e00 file can be downloaded at the site for use in ESRI's ARC® products. The Teton County government has already

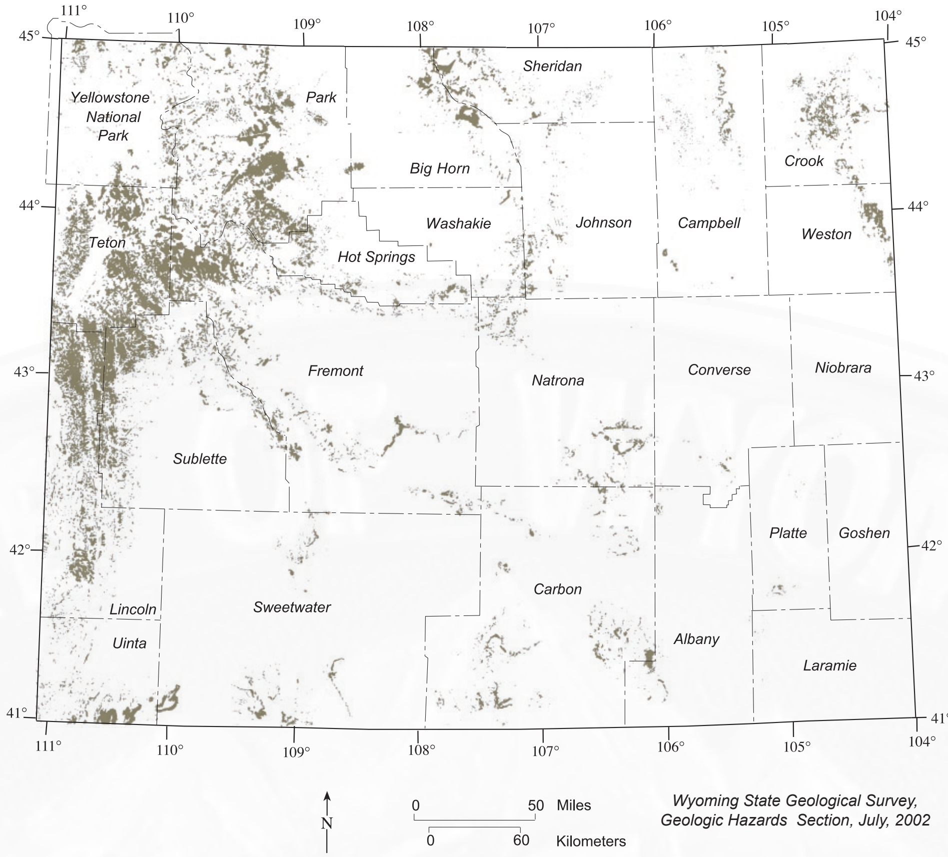

Figure 23. Landslide map of Wyoming. Colored areas indicate extent of mapped active and inactive landslides.

downloaded all coverages for their county, and has generated a detailed county landslide map.

3-D interactive images: Landscapes and landslides

When a disaster occurs, it is necessary for responders to quickly travel to the affected area. The Geologic Hazards Section received input from many cities and counties that indicated a need for 3-D interactive images to assist in planning a disaster response. As a result, the WSGS and WRDS began generating images that could be used for such a purpose. The current images have landslides superimposed, although any feature or map could be placed on the images.

This web site can be accessed at: http://www.wrds.uwyo.edu/wrds/wsgs/hazards/landslides/ls-3d.html. The site allows the user to "fly" through a 3-D image of a quarter 1:24,000-scale quadrangle (referred to as DOQQs or Digital Ortho Quarter Quadrangles). The site is nearly complete for Teton, Lincoln, and Uinta counties, with Sublette County to be completed soon. An example of how an image looks from a distance is shown on the **Front cover** of this issue.

The images are created by superimposing a digital orthophoto over a digital elevation model, using techniques developed by the UW's Department of Geography and Recreation. The landslide coverages mentioned above are then superimposed on the terrain. After downloading

Figure 24. Index to 1:24,000-scale digital landslide maps completed in Teton, northern Lincoln, and northwestern Sublette counties, Wyoming.

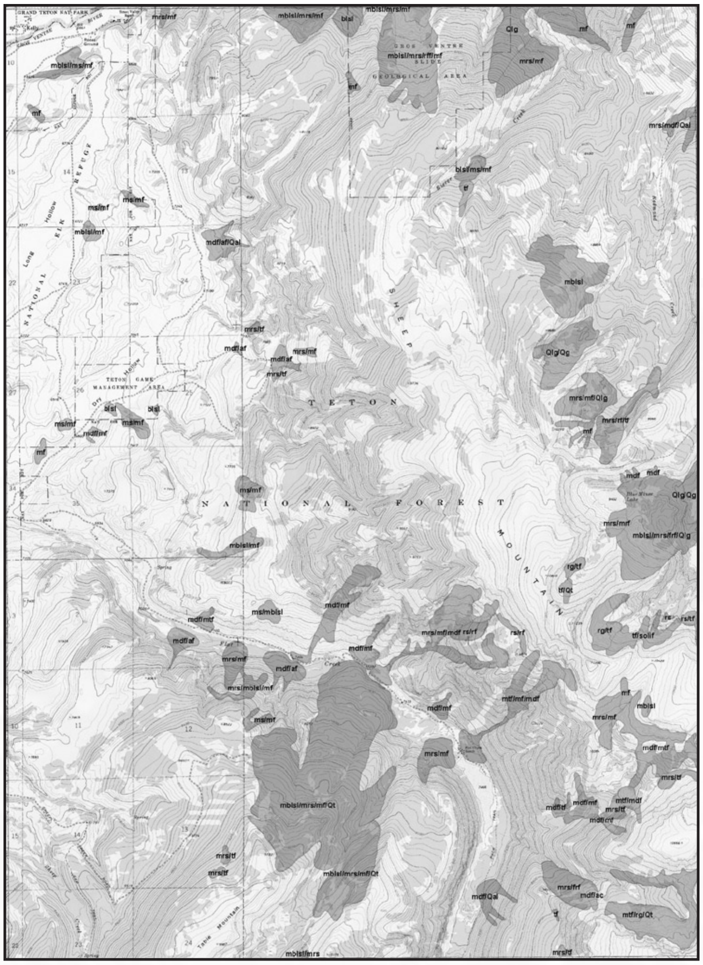

Figure 25. Landslide map of the Blue Miner Lake 1:24,000-scale Quadrangle, Teton County, Wyoming. Darkest shaded areas are landslides with labels indicating landslide type and classification.

free software, the user is able to navigate through fairly realistic-looking terrain. The viewer can "fly," "walk" over, and "study" the image. The "study" function allows the viewer to rotate the image.

As mentioned above, the 3-D product was initially designed to allow the first responders of a disaster to quickly view the terrain and plan an approach. More commonly, it is used by those wishing to "visit" the area at any time. The WSGS will link educational and informational sites to the web site to encourage a greater awareness of Wyoming's terrain and geology.

Wyoming Emergency Management Planning Workshop

The Geologic Hazards Section at the WSGS participated in the Wyoming Emergency Management Planning Workshop in Cheyenne on March 26 to 28, 2002. The workshop, sponsored by WEMA was divided into an anti-terrorist tract and a hazards mitigation tract. A variety of topics were discussed in the mitigation tract, including the Disaster Mitigation Act of 2000, risk management, mitigation planning, natural hazards identification, HAZUS and mitigation planning resources, county mitigation requirements, county projects, continuity of government, and county planning needs assessments. HAZUS is software that has been designed by FEMA to simulate various disaster scenarios and assess damages (see *Wyoming Geo-notes No. 73*, April, 2002, p. 29-33, for a complete description of HAZUS).

To assist county emergency managers in complying with the Disaster Mitigation Act of 2000, the Section presented lectures on natural hazards identification, planning resources for natural hazards mitigation, and HAZUS. The first lecture addressed the first step in mitigation, hazards identification. Topics included landslides, earthquakes, abandoned mine subsidence, windblown deposits, and floods. The audience learned that parts of Wyoming have some of the highest landslide densities in the U.S. All counties in the state have potential for economic damage and possible loss of life from the effects of landslides. Some audience members were surprised to learn that Wyoming is classified as a very high-hazard state for earthquakes, with the possibility of a 6.5-magnitude event anywhere in the state and a 7.5-magnitude event for the western counties. Many areas of the state have had trouble with subsidence from abandoned underground mines, which may damage surface development. Eolian (windblown) deposits were discussed because development can cause the destabilization of these deposits, making them active, which may destroy property. Floods are also possible in many Wyoming communities.

Resources that are available to the county emergency planners for mitigating hazards were discussed next. The WSGS is a comprehensive source for natural hazard information throughout the state. The resources available for landslides include paper landslide maps for the entire state and digital landslide maps for western Wyoming, a 3-D landslide web site (described above), historic files of landslides, current landslide stabilization projects of UW and the Wyoming Department of Transportation (WYDOT), and personal contact with geologists and/or engineers at the WSGS, UW, WYDOT, and private consulting firms.

The available earthquake resources include a statewide historical epicenter map and report, the WSGS earthquake website, a video entitled *Earthquakes in Wyoming*, two pamphlets entitled *Earthquakes in Wyoming* and *How to make your Wyoming home more earthquake resistant*, extensive files and reports at the WSGS, and personal contact with WSGS and other geologists. The video and pamphlets are available at local libraries in the state and the video can also be checked out at Blockbuster video stores in Wyoming.

Abandoned mine subsidence and eolian deposit resources include historical records, WSGS paper maps of each hazard, data at the Wyoming Department of Environmental Quality's Abandoned Mines Division, and personal contact with WSGS and other geologists. Flood resources include Flood Insurance Rate Maps (FIRM maps), older flood-hazard boundary maps and flood-prone area maps, as well as personal contact with geologists and engineers at the WSGS, the State Engineer's Office, and WEMA.

HAZUS was discussed as a separate topic within mitigation planning resources. For this talk Doug Bausch, the Earthquake Program Manager for FEMA Region VIII, was invited to provide input along with the WSGS Geologic Hazards staff dealing with the use, implication, and limitations of the HAZUS computer program. HAZUS is an (ESRI's) ArcView®-based computer simulation package developed by FEMA to predict losses from an earthquake and landslides associated with an earthquake (see details in *Wyoming Geo-notes No. 73*, April, 2002, p. 29-33). This discussion was based upon a demonstration of HAZUS using Uinta County as a test case. The lecture was designed to inform the emergency managers about the level of expertise and data required for the program to give reliable results. To many emergency managers, it became clear that while the implication of HAZUS is beneficial, running the analysis would be best suited to the WSGS staff with help from the emergency managers in updating the databases used.

Highway-affecting Landslides of the Snake River Canyon—Part III, Blue Trail Slide

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

This was to be the third and final installment of a series of articles detailing work by the Wyoming Department of Transportation (WYDOT) on landslides in Snake River Canyon and WYDOT's efforts to mitigate potential damage and protect the highway and its travelers. The series has been extended to a Part IV in order to more completely cover some innovative technologies used. Part I (see *Wyoming Geo-notes, No. 72*, December, 2001, p. 30-34) gave an overview and background on the canyon highway and discussed the Elbow Slide. Part II (see *Wyoming Geo-notes No. 73*, April, 2002, p. 33-40) emphasized the Wolf Mountain Slide, which blocked access through the canyon for weeks. Part IV, which will appear in the next issue of *Wyoming Geo-notes*, will cover the Deer Creek Slide at the eastern end of Snake River Canyon. We thank the staff at the Wyoming State Geological Survey for helping prepare these articles and we appreciate their interest in our work.

Blue Trail Slide

The Blue Trail Slide is located at milepost 127.3 on U.S. Highway 26/89 (**Figure 26**). Movement on the slide recurs seasonally, resulting in maintenance problems that have continued since the highway was constructed. Generations of patches over the years have totaled up to a thickness of 12.1 feet (3.7 meters) of plant mixed pavement (PMP) across the most active part of the slide (**Figure 27**). The name Blue Trail comes from outcrops of the dark gray shales in the area which look bluish in the daylight.

Significant roadway dislocation has resulted from this landslide over the last 30 years. The slide trends N20°W and extends from the edge of the Snake River, 200 feet (61 meters) below road level, to about 984 feet (300 meters) above the existing roadway (**Figure 28**). The headward zone is active approximately 20 feet (6 meters) up slope of the present roadway, and the mass extends vertically beneath the highway to depths of 33 to 39 feet (10 to 12 meters). The slide debris above the existing highway is currently stable.

The landslide consists of a heterogeneous mixture of detrital sandstone, siltstone, shale, and limestone, with sand, silt, and clay. Slide debris is predominantly brecciated rock that has deteriorated to the consistency of clayey gravel. The slide debris varies in thickness from 11.5 to 49.2 feet (3.5 to 15 meters) with various perched water tables confined to permeable zones. Water levels apparently vary significantly

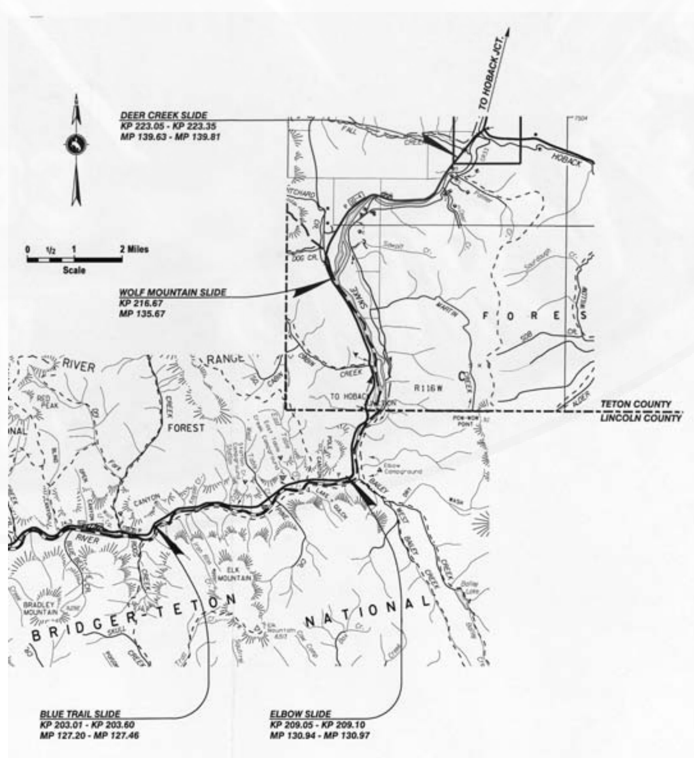

Figure 26. Detailed map of part of the Snake River Canyon showing locations of four major landslide stabilization projects. Map courtesy of Chuck James, WYDOT.

Figure 27. View to southwest across Blue Trail Slide from near roadway level before construction began. Snake River in center left of photograph. Dark area in the road (center of photograph) indicates where the road had been patched repeatedly over the years across the active part of the slide.

with the changing seasons. The landslide debris is underlain by the Lower Cretaceous Bear River Formation. The eastern edge of the slide is very near the contact between the Bear River and underlying Gannett Formation. The Bear River Formation consists of interbedded shale, siltstone, and thin limestone (**Figure 29**). The beds strike N16°E with a 27°W dip. The Lower Cretaceous Gannett Group is made up of siltstone, sandstone, and cross-bedded quartz sandstone.

The sliding mass is a block-type failure with the movement occurring along a relatively weak layer at the soil-rock interface. Observations indicate that movement occurs during wet periods of the year especially when the Snake River is at its highest level. Movement is initiated when the river erodes toe material from the lower part of the slide, reducing support and allowing the upper part of the slide to move downhill, much like a conveyor belt.

In November, 1969, the Blue Trail landslide was first investigated by the WYDOT Geology Program when 11 test holes were drilled. A complete geotechnical investigation and report was completed by the consulting firm of Chen-Northern Inc., (1989) for the purpose of developing recommendations for treating the geologic hazard in conjunction with proposed highway reconstruction. The Report of Geotechnical Investigation for the Blue Trail Slide (1989) recommended "the most positive solution to the problem is a bridge alternative." The proposed structure would extend 366 meters and span **most** of the slide area. After reviewing the proposed bridge layout, this alternative was eliminated when it was determined that all four pier locations were to be founded within the slide debris.

Additional drilling was conducted by WYDOT to identify the slide plane, establish the depth to bedrock, and collect samples for laboratory testing. Using this information, an integrated slope stability analysis was performed using the XSTABL® program for personal computers. Based upon the assumption that the slide is in semi-stable equilibrium (factor of safety ~1.0) a series of stability analyses were run to develop realistic strength parameters for the failure surface. The resulting parameter values for the material along the slide plane are cohesion (c)=0 in kiloPascals (kpa) or in pounds per square foot (psf), and friction angle (N)=14 degrees. Having derived a set of realistic strength parameters, analyses were then conducted to assess various means of remediating the slide.

Various alternatives were analyzed in an attempt to stabilize the landslide and produce a desired factor of safety (FOS) of 1.3, including common methods of lowering the grade and adding lightweight fill to reduce driving forces, building toe berms to increase resisting forces, and shifting highway alignment to avoid the slide. The limits of a narrow canyon and the close proximity of the Snake River restricted the possibility for substantial shift in alignment. Various combinations of the above techniques were analyzed using block and circular methods of analysis (XSTABL®) but resulted in only minimal increases in the FOS.

With the above options considered and determined not effective, other alternatives were researched. A short list of geotechnical construction companies who specialize in ground modifica-

Figure 28. Air-oblique view of Blue Trail Slide looking northward. Dark area in road indicates active part of slide. Nearly all the tree-covered area south of Snake River is also a large landslide mass. Photograph b WYDOT Photogrammetry and Survey

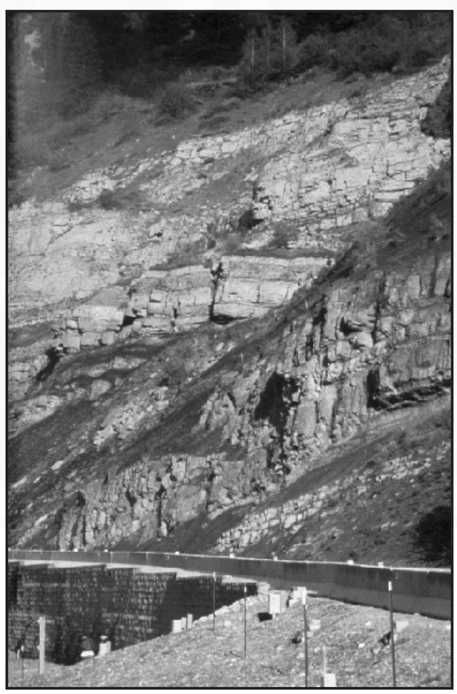

Figure 29. Outcrops of the Bear River Formation at the Blue Trail Slide. The dark-colored areas exposed above the road level are carbonaceous shale beds. Note completed roadway built on an MSE wall.

tion was acquired. Nicholson Construction Company was recommended as the leader, having the most experience in landslide and slope stabilization. Nicholson Construction was presented with our problem and they proposed a Type A INSERT[SM] Wall to correct the slide problem. INSERT [SM] (**IN S**itu **E**arth **R**einforcement **T**echnique) Wall is a Nicholson Construction trademark wall. This type of retaining wall consists of steel reinforcing elements known as Reticulated Minipiles (RMPs) installed and grouted over a regular pattern, acting together with the ground to provide a zone of structurally improved soil (**Figure 30**). The reinforced soil mass can be designed to a FOS=1.3 to provide the stability for the landslide. The advantages of the RMP wall include:

- it can be constructed in any type of ground;
- it can be installed under limited access conditions;
- it causes minimal environmental impact during and after installation (since the constructed system is underground, it does not have a detrimental visual impact);
- it can be utilized where excavation is either necessary or excavation is undesirable;
- it can be permanent or temporary; and
- it is very cost effective.

A preliminary design indicated that the Blue Trail Slide required two INSERT[SM] Walls to stabilize the landslide, due to the long slide geometry. Nicholson's preliminary cost estimate for design and construction of this type of wall was approximately $2,500.00 per lineal foot of wall. Total cost for the walls is $1.45 million. By the time construction started, a third INSERT[SM] Wall was added due to the length of the required mechanically stabilized earth (MSE) wall.

Because it was determined that the slope above the roadway had sufficient natural stability, only the unstable area below the roadway was addressed. Construction began from two temporary benches cut into the slope (**Figure 31**). A heavily reinforced 4000 psi concrete capping beam was constructed with minipile locations split-spaced at 15-inch intervals along the beam length (**Figure 32**). A drill rig suspended at an angle by a walking crane (**Figure 33**) then drilled through the capping beam, the slide debris, and into bedrock. Minipiles consisting of 6-inch-diameter oil field drill pipe were installed in each drill hole and grouted into place (**Figure 30**). In total, the three INSERT[SM] Walls totaling 704 feet in length were constructed, consisting of 483 minipiles with a total cumulative length of 5.3 miles. Additionally, rock (tieback) anchors consisting of 10- or 18-strand cables were placed equidistantly along each cap beam (**Figures 30** and **34**) to provide more resistance and better anchor the minipiles through the failure plane.

After applying tension to the tieback anchors, the cap beams were covered over with fill and an MSE retaining wall containing colored cement blocks (to match the colors of the rocks in the nearby outcrops, **Figure 29**) was constructed on top of the upper RMP wall (**Figures 30** and **35**). The MSE wall enabled the highway to be widened through the landslide area without cutting into the slopes above the roadway.

This project was unusual because it was the first Design/Build project attempted by WYDOT. These projects are totally

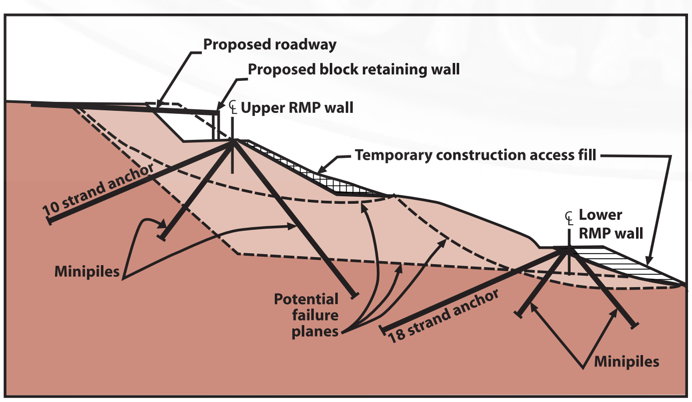

Figure 30. Diagrammatic cross section through Blue Trail Slide showing placement of micropile and tieback reinforced walls to stabilize the slide area. Modified from Turner and others (1998).

Figure 31. Construction of upper and lower RMP walls required temporary cut and fill benches to accommodate equipment. Another RMP wall was installed west of these two walls 39.4 feet (13 meters) below the roadway to stabilize the slope beneath an MSE wall.

Figure 32. Concrete cap beam showing position of battered micropiles. Tieback anchors were then installed at a shallower angle into the bedrock and attached to the cap beam.

Figure 33. Drilling rig suspended on a crane was used to drill holes and install micropiles and tieback anchors.

designed and built by the contractor, with WYDOT only providing project limits, scope, and geotechnical information. The contractor was tasked with presenting a workable engineering solution. Construction started on time and was completed on time and under budget.

The result was a wider and much safer modern highway with shoulders (**Figure 36**) as well as inherently more stable. The project was nominated for several awards, and in 1998, won the Consulting Engineers Council Grand Award for Engineering Design Excellence. For the interested reader, a full technical article on design, construction, instrumentation, etc., refer to Turner, Hasenkamp, and Wolosick (1998).

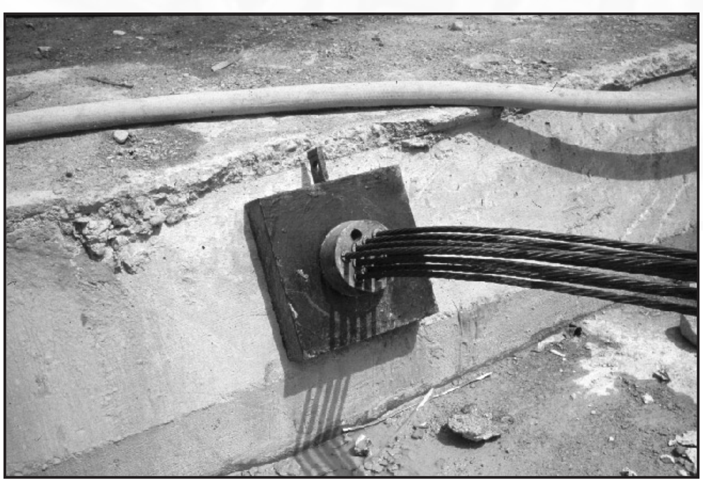

Figure 34. Ten or 18-strand tieback anchors installed on the cap beam were stressed using hydraulic jacks.

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Turner, J., Hasenkamp, R., and Wolosick, J., 1998, Micropile and tieback reinforced walls for landslide stabilization, Snake River Canyon, Wyoming: Proceedings and Field Trip Guide, 49th Highway Geology Symposium, Prescott, Arizona, p. 156-168.

Figure 35. Construction of the MSE wall used geo-grid supported backfill tied into keystone block facing. This wall was built up to the height of the roadway at the base of the concrete barriers.

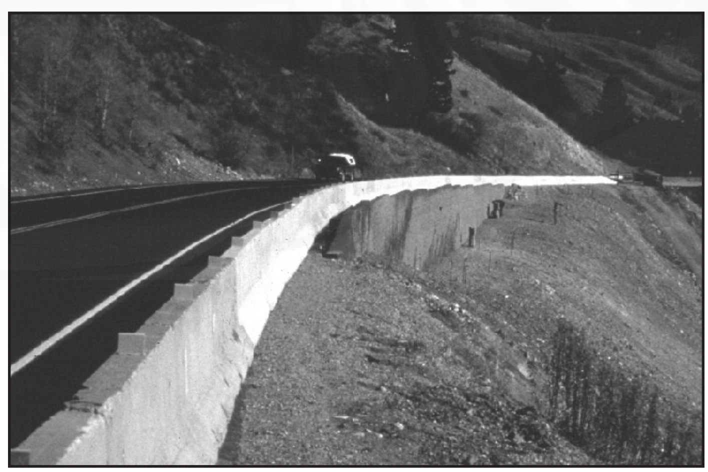

Figure 36. Completed highway reconstruction over Blue Trail Slide viewed to east. Note MSE wall with inclinometers and other instruments to measure and monitor stresses and loads in the slide and on the anchors and micropiles.

PUBLICATIONS UPDATE

New Publications Available from the Wyoming State Geological Survey

Wyoming State Geological Survey publications

2002 Calendar, *Exploring Wyoming's Geology*, by the Wyoming State Geological Survey, 2002: Poster – FREE.

Knightia, Wyoming State Fossil postcard (revised), 2002 – $0.25 each or five for $1.00.

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.

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Oil and gas resource assessment of the Jack Morrow Hills and surrounding areas, southwestern Wyoming, by L. Cook, R.H. De Bruin, C.S., Boyd, and R.W. Jones, 2002: Open File Report 2002-1 – $25.00 (includes 3 oversized sheets) + $3.00 shipping and handling.

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).

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Other publications

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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.

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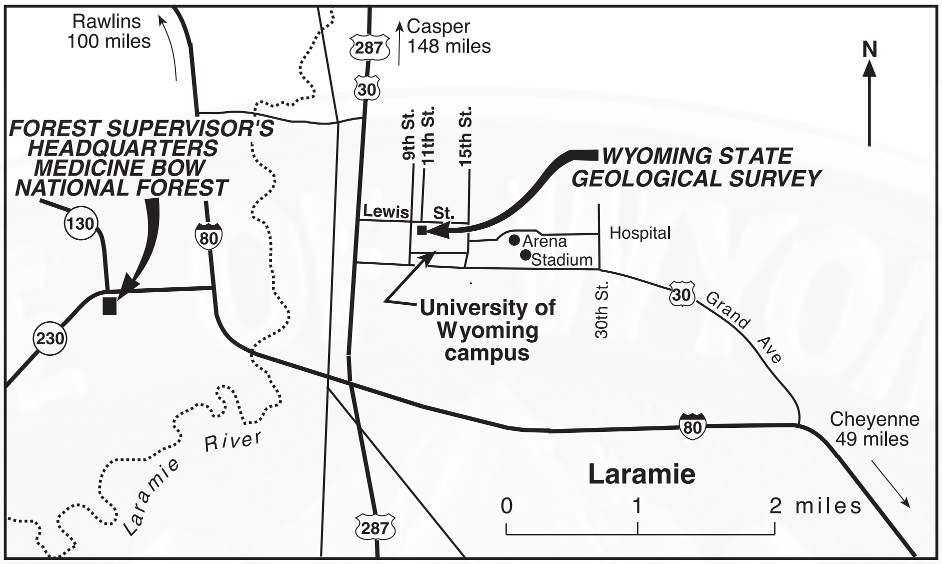

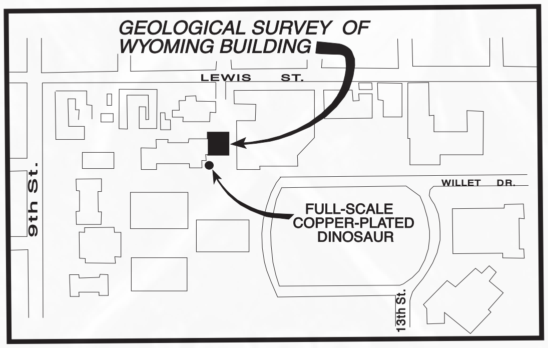

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